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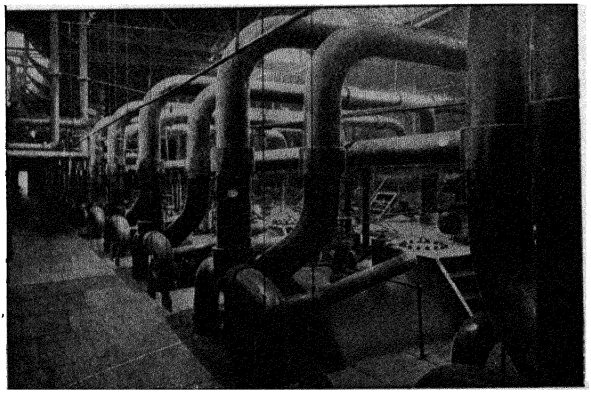

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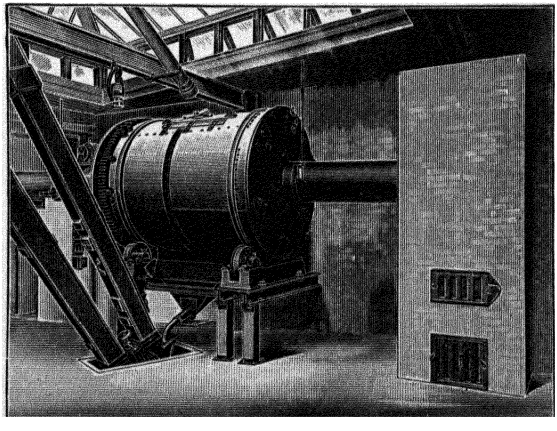

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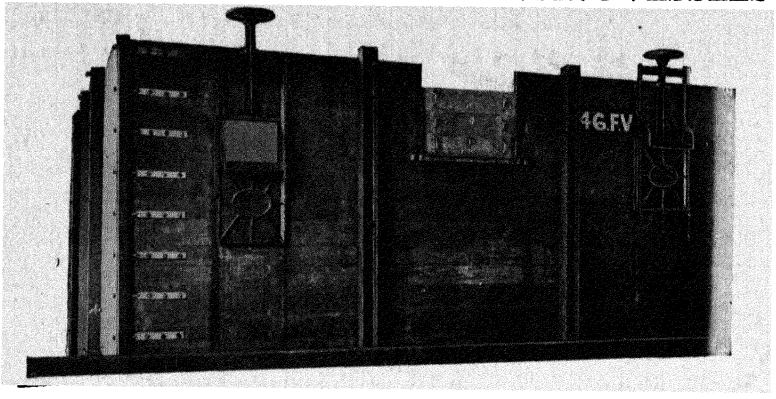

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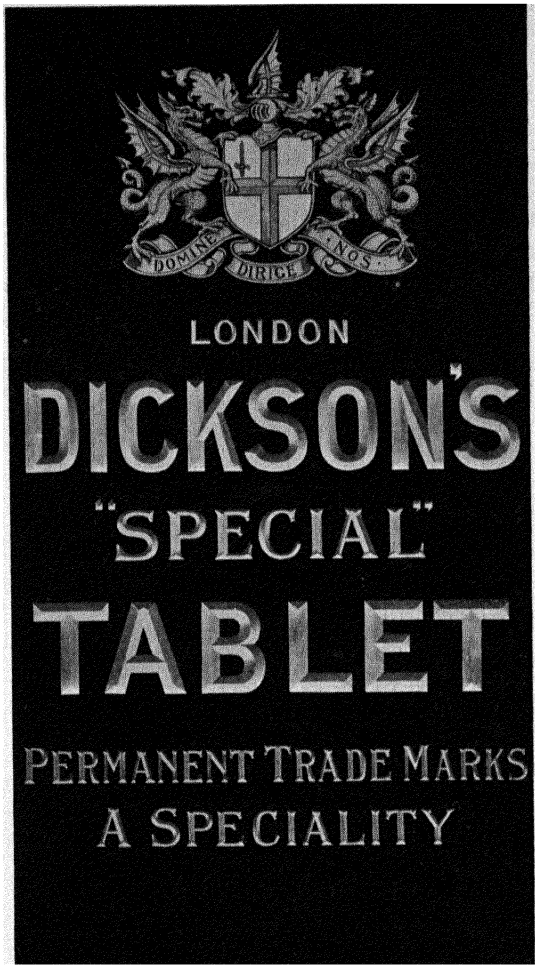

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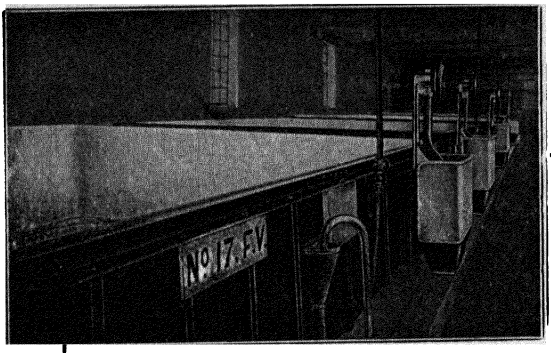

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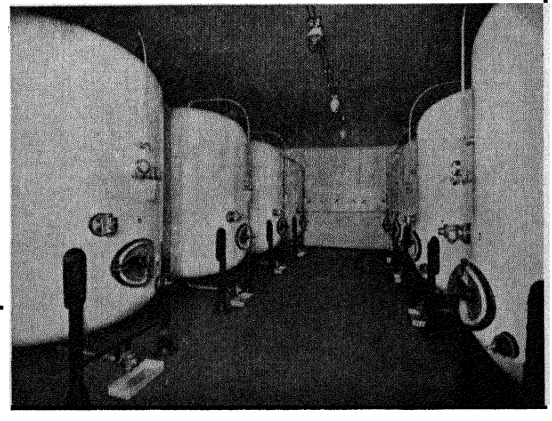

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PREFACE

MR. H. E. WRIGHT, who died in 1907, was a member of that small but intensely enthusiastic band of pioneers who, during the later decades of the nineteenth century, by their strenuous and maintained efforts applied devotedly to the realisation of ideals, albeit not yet fully achieved, raised the brewing industry from the slough of empiricism through which it was then groping to the light shed from a better understanding of the fundamental scientific principles underlying and governing the various chemical and technical processes in connection with the manufacture of malt and beer.

But in the vast amount of scientific research which has identified that period as the most notable epoch in the history of brewing, Wright enjoyed advantages over the majority of his confrères in that, while he possessed a sound and extensive knowledge of contemporary science, he was also a trained brewer and maltster, and was thus in a position to apply upon a large scale his own theories together with those enunciated by eminent men of science of that age who had given the problems of the maltster and brewer their most zealous study and serious consideration.

Wright was a fairly prolific writer, and his contributions to brewing literature continued veritably to the day of his death, which occurred twenty years ago, while the final proofs of his "Handy Book for Brewers" lay ready for correction.

The present author regards it as an honour that he should be privileged to modernise and to augment considerably the work of Wright from the point at which it was discontinued when his labours ceased under the circumstances alluded to.

Every endeavour has been made, and no effort spared or questions of cost considered, to present to brewers and brewing students generally a work of so complete and comprehensive a character as, it is hoped, to justify the all-embracive title adopted. It will be found that each subject is dealt with in a manner commensurate with what is believed to be its scientific and technical importance.

I have to acknowledge with a deep sense of gratitude my indebtedness to the Publishers of the *Brewer and Wine Merchant and Brewers' Guardian* for being permitted to reproduce excerpts from recent articles published in that journal from my pen; to Charles E. Sutcliffe, Esq., of

Mirfield, for his contribution of what I regard as one of the most informative and exhaustive tables so far published on the important subject of Foreign Barley; to F. A. Mason, Esq., Director of the Bureau of Bio-Technology, Leeds, and of Messrs. Murphy & Son, Ltd., for his admirable and lucid explanation of the Hydrogen Ion theory or *p*H values; to Egbert Willshere, A.M.I.Mech.E., of Birmingham, for his clear description of modern milling methods and Malt Mills; to Messrs. John Morris & Son, of Burton-on-Trent, for the valuable information furnished with regard to the rates of pay in the cooperage trade at Burton-on-Trent and other brewing centres of importance; and to The Tintometer, Ltd., for particulars as to the functions and the correct application of the Tintometer in the brewery and maltings.

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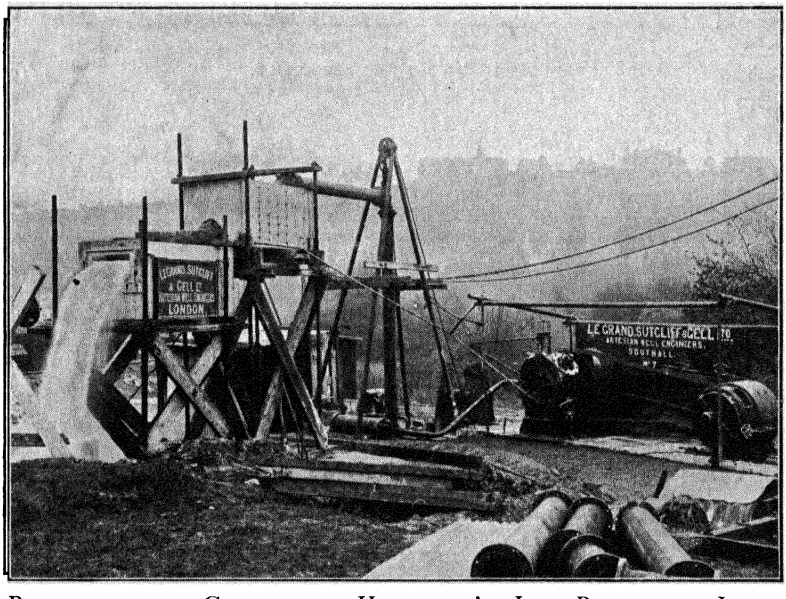

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A STANDARD MANUAL OF BREWING AND MALTING

CHAPTER I

INTRODUCTORY *

NOTES ON CHEMICAL CHANGES—OUTLINE OF PROCESSES OF BREWING—MALTING—MASHING (INFUSION, DECOCTION, AND LIMITED DECOCTION)—FERMENTATION (CLEANSING, SKIMMING, YORKSHIRE STONE SQUARES, ETC.)—RACKING—FINING—STORING—VATTING.

A GRAIN of barley contains, in addition to the husk and germ of the young plant, a considerable quantity of starch and proteins. The chief nitrogenous constituents are complex substances forming a group to which at various times different names have been applied, such as albumens, albuminoids, nitrogenous matters. The class name now generally adopted is "protein," the terms "albumen" and "albuminoids" being employed to designate certain sub-groups. Altogether more than 50 proteins are known, which differ from one another in physical and chemical properties. The starch being mostly insoluble at ordinary mashing temperatures, and the proteins of unmalted grain being also, to a great extent, insoluble, and therefore inactive (in the brewer's sense of the word), one principal object of the malting process is to break up and render soluble at those temperatures as much of the valuable starch as possible, and a sufficient amount of the proteins.

Among the soluble albuminoids is a body—or group of bodies—called, for convenience' sake, **Diastase**, which, upon the malt being mixed in the mash-tun with water of a suitable temperature, attacks its soluble starch, and converts it into a gummy body called **Dextrin, Malto-Dextrins,** and **Maltose,** or malt-sugar. And the longer this infusion is allowed to continue at suitable temperatures the lower, within certain limits, will be in point of fermentability the type of malto-dextrins, and the larger the proportion of maltose will there be contained in the resulting wort.

The maltose afterwards becomes reduced to dextrose by the enzyme "Maltase," after which, by the action of another enzyme, "Zymase," contained within the yeast, the dextrose is reduced to alcohol and carbonic acid gas. [Other transformation products, it is true, are formed concurrently, but these may be neglected till a later stage, the object being

* Occasional references to a Glossary will be found in the text; but after the book was in type it was decided to omit that feature, on account of the size to which the work had attained.

now merely to indicate the broad general principles upon which the maltster's and, after him, the brewer's art reposes.]

It is obvious that the presence of a constituent, undergoing fermentation slowly, and slowly evolving carbonic acid gas concurrently with a production of alcohol, is an important factor in the manufacture of a beer which is required to be in continuously good "condition," and one that will carry a firm and permanent "head."

Malto-Dextrin (or Amylöin) Theory.—According to this theory, malto-dextrins are chemical compounds—not mere *mixtures*—of maltose and dextrin formed in malt-wort in proportions varying with the quality of the malt of the brewing liquor, or with the system of mashing adopted, and it is their abundance or comparative absence which determines the full body (and subsequent "condition") or the thinness of a beer. According to the holders of this theory, the *free* dextrin in wort is an almost uniformly constant quantity; it is only the proportion combined as malto-dextrin which varies. If it be true that this fixed proportion of dextrin alone would not suffice to prevent an excessive "attenuation" of the beer (*i.e.*, the retention of so small a quantity of unfermented matter that the liquid would not be beer at all in the actual sense of the word), and that "free" dextrin is (as the malto-dextrin theorists assert) so stubborn as regards after-fermentation that the quantity present at the time of racking would be found practically unchanged at the end of some months' storage, then the importance of malto-dextrins cannot be overrated. We shall refer to them again at the end of this chapter in connection with the secondary or complementary fermentation in cask, and hope to deal with the subject more fully at a more advanced stage.

Though the terms "Amylöin" and "Malto-dextrin" are fresh instances of the regrettable tendency to enlarge the scientific vocabulary, the existence of such bodies will certainly help to throw light on certain phenomena of fermentation otherwise rather obscure.

Dextrin or the Dextrins.—It is now recognised that there are various dextrins which are colloidal amorphous compounds incapable of forming characteristic derivatives. They are soluble in water and precipitated by alcohol. The dextrin isolated from a starch conversion stopped at a stage which gives a deep brownish-red coloration with iodine is termed **erythro-dextrin.** At a later stage iodine ceases to give a coloration, and the dextrin present is termed **achro-dextrin.** These dextrins have little or no cupric-reducing action, this point being still undecided. Generally speaking, however, dextrins with the higher molecular weights are not so readily attacked by the various yeasts as those with lower. Dextrins are also formed by the action of hot dilute mineral acids, or of heat alone, on starch. The final product in this case is dextrose instead of maltose. These methods are used for the commercial preparation of dextrin.

Peptase.—Another of the soluble ferments (among which diastase ranks), or unorganised ferments, as they are sometimes rather unhappily called, in contradistinction to the organised ferments yeast and its congeners, is peptase, which, though brought into being during the malting process, lies mainly, if not entirely, dormant until suitable conditions, such as those of the mash-tun, stimulate it into activity. To what extent its most favourable sphere of action differs from that of diastase is a question which must be deferred to a later chapter, the only

thing now necessary to be said being that its function is to convert the unaltered protein bodies or albuminoids into peptones, which are apparently—though we do not feel convinced that the action of peptase is so well understood as that of diastase—of the highest importance in nourishing and keeping up the vigour and vitality of the yeast owing to their diffusibility—*i.e.*, their power of passing through the enclosing membrane or cell-wall of the yeast, a power which the unaltered protein bodies, even when soluble, do not possess.

Amides.—These still more advanced products of protein conversion are held to be even more important for yeast nutrition than peptones. The general view is that, in the main, the products of **proteolysis,** a converting action upon the proteins of barley, are during malting *amides*, and during mashing *peptones*. It is held that in "forced malt" (malt driven to grow by the stimuli of abnormal warmth and moisture), amides are produced in excess, while on the other hand the high temperatures of the British mash-tun are unfavourable to peptonisation, for which those of the decoction mash (*v.* p. 18) are more helpful.

Protein bodies were, and still are dreaded in many quarters, but evidence accumulates that if the right type of product be obtained they may be useful. Thus peptones and albumose, a less advanced conversion product, are considered factors in palate-fulness, head-retention, and "condition" of beer. However this may be, the maltster's aim should be to get barleys rich in starch and such as have undergone **maturation,** which, though dependent on ripeness, neither premature nor unduly delayed, is a post-ripening process helped by slight moisture after ripening, combined with air (oxygenation) and other drying influences, and evidenced by "mealiness" of grain.

Given proper access, diastase is capable of converting 2,000 times its weight of starch into maltose and dextrin; some say of transforming 10,000 times its own weight; * and there is even an opinion of authority that the smallest quantity of the said diastase, unchanging itself, is theoretically capable of converting any quantity of starch, if only time be given. We say theoretically, because in practical brewing operations there is always a limit of time which cannot be overpassed; but it may be taken as certain that insufficient conversion of the starch into maltose, the malto-dextrins, and dextrin is never caused by insufficiency of diastase but solely by conditions unfavourable to the activity of that agent—viz., either unsuitable mashing heats—of which more anon; or such a physical arrangement of the starch itself (as in malt made from unkindly barley, badly grown and badly kiln-dried) that the diastase is unable to get at it thoroughly; or, finally, such a high degree of acidity (anything approaching ½%) of the medium, that diastase would be coagulated, and so rendered inert.

It has seemed in accordance with the scope of this book which aims at supplementing rather than supplanting practical teaching in the brewery, to set down at the outset the ABC which really lies at the root of the matter, and which may perhaps be called scientific, to distinguish it from that "rule of thumb" that has done such yeoman's service in its

* Dubrunfaut said 150,000 times; but he was referring to a portion of the nitrogeneous matter which he wished to call "Maltine" (possibly the active part of diastase, but at any rate much less in quantity than diastase would be estimated at).

time, but which is, at this time of day, hardly up to the level of requirements. The beginner, who has perused the foregoing pages carefully, will now, the writers hope, be in a position, whilst running through the summary sketch of malting and brewing that occupies the rest of this chapter, to read a little " between the lines," and see to some extent how this ABC comes in as a guide to practice.

Some Practical Aspects of Modern Malting.—In the successful and economical management of maltings it is absolutely essential that a tabulated record should be maintained of every detail of working, from the steeping stage until the concluding process when the cured malt is unloaded. It is necessary to observe that the floors are fully occupied, but never overcrowded, with " pieces " undergoing various degrees of floor-working, and that directly a kiln is emptied of its load, the next succeeding steep is sufficiently withered to permit of its being loaded to kiln without loss of time. One of the principal attributes of a successful maltster is that he is fully endowed with the faculty of judgment and foresight. Following the principle of leaving undone to-day what can be postponed until to-morrow, always leads to confusion and ultimate disaster when this doctrine is applied to maltings. Unless a maltster continuously surveys what the probable conditions will be days, indeed weeks, ahead in the not unlikely event of a rise in atmospheric temperatures, he may find that the floors are congested, with no unoccupied area upon which to reduce the depth of the pieces. Turning for an outlet to relieve this state of overcrowding, which inevitably results in an increase in the temperature of the grain and forcing conditions, the maltster may find on the one hand, that a kiln may not be available for loading or on the other hand that the withering pieces are not sufficiently advanced in that final floor process. It is true that some maltsters claim that they can follow a " wetting " from steep to kiln and state the age of a piece at any stage of manufacture, and the total quantity of sprinkling liquor which has been added, but with due respect to the unusual ability displayed by such craftsmen we assert that there are too many factors operating to upset all our calculations for preciseness and exactitude in the working of a modern malthouse, and we repeat that the daily recording is an essential equipment to maintain the floors and kiln fully occupied and the labour fully employed. Should a kiln floor, through lack of foresight or omitting to maintain a record, remain empty when it should be in commission, and this occurs at intervals in the course of a season, then fuel costs become unnecessarily high. Of course, in the early autumn and late spring, the higher atmospheric temperatures then prevailing, together with the fact that foreign grain, with its thick husk, which requires a prolonged soaking, is then worked, tends to prolong the intervals between the steeps and to extend the wetting periods, but during the colder months, when working up home grain, the loss in time alluded to is then recovered, and when the season ends—whether it be a short or a long one—the businesslike maltster divides the total number of days occupied by the aggregate quarters of malt manufactured, and thus has the satisfaction or otherwise of learning whether or not the maltings have been worked to their full capacity.

There is another practical point of importance which deserves more than passing reference. We refer to the empirical custom, still in vogue

in some of the largest maltings in the country, of regarding the use of floor thermometers as unnecessary, it being thought that temperatures can be gauged by the physical indications observed from inserting the hand into the piece on floor. Never rely on such uncertain methods, the physical indications of warmth or the reverse being dependent on the health and bodily condition of the individual at the moment, factors which are wholly unconnected with the temperature of the grain. It should be borne in mind that to avoid " forcing " conditions of germination a limit of 59° F. for native-grown barley, and 60° F. for foreign should never be exceeded, with from 1° to 3° higher during the concluding stages of withering. Avoid " sprinkling " as much as possible and rely for the necessary length of acrospire and rootlets and true modification upon lengthy steeping periods, frequent changes of water and abundant aeration of the latter as it runs from perforated pipes into the cistern. There are some maltsters who still adhere to the exploded theory that a long soaking results in diminishing the vitality of the grain. Doubtless this was correct during the days when water remained unchanged until it became stale, but fear of loss of vitality need not be apprehended if the water is changed and the grain thus aerated every twelve to eighteen hours and the steeping is prolonged until the usual well-known modern indications of a thoroughly soaked barley are observed.

Regard the flooring as two distinct processes : (*a*) *germination*, during which period the CO_2 produced should be dissipated and oxygen absorbed by the grain by frequent turning ; (*b*) *withering*, in which reverse conditions should obtain. The CO_2 should be conserved in order to facilitate the asphyxiation of the plant and thus to further withering.

The kilning process should also be treated as consisting of two distinct processes : (*a*) *drying* at low temperatures with all the draught holes fully open. The exercising of the utmost care for nearly a fortnight in maintaining the temperature of the pieces on the floors below forcing limits may be utterly undone in the course of an hour or two by drying off on kiln at opening temperatures below 90° F. But on the other hand, the temperature just named should not be materially exceeded during the first stages of drying, while the bulk of the moisture remains in the load. The object of thus exercising the utmost care in regard to temperatures is to prevent that " setting of the husk " which an increased initial heat would inevitably bring about, with the result that the moisture would be imprisoned within the grain and the finished malt would be vitrified and steely, flavour impaired, colour increased, and extract yield and diastatic power reduced. (*b*) *Curing* requires the reverse conditions to drying. The draught holes should be ultimately completely closed, and only as much air allowed to ingress to the fires to maintain them. The aim here is to permit of the fumes at high temperatures to penetrate into the innermost portions of the malt, thus ensuring the production of a thoroughly cured and stabilised finished article.

In conclusion, it is noticeable how some maltsters cannot employ as high " finishing off " temperatures as others, without gaining an excessive amount of colour, lessening the diastatic power unduly, and impairing aroma and flavour. Apart from the consideration of faulty kilns in this connection, it is mainly a question of noting that the load is as free from moisture as it is possible to render it during the concluding hours of the

drying process. If the latter operation is correctly carried out on the lines suggested, then it is surprising to what heights the final temperature can be increased to, and maintained at, and yet a malt can be produced capable of being employed for pale ales.

Malting.—The first process to be referred to is malting, which is really—albeit many brewers are not maltsters—the earliest and not the least important stage in brewing. It is customary for maltsters working on the original system to " make up " their requirements of foreign malt at the beginning and the end of the season during which periods the warmer temperatures usually prevailing would be less prejudicial to the floor working of foreign-grown grain than to home. Purchases of foreign barley are therefore normally postponed until late in the season in order that delivery may be effected in time to take the place of the English barley, the last steep of which is generally couched not before the end of March. The barley, which is to be operated on, having been obtained, and the light thin corns, and broken grain separated by screening, or, what is still better, the corns of different sizes having been sorted by *grading* (the object of the latter operation being to get bulks of corn which will germinate similarly under similar conditions), it is then steeped—*i.e.*, covered with water—and allowed to soak, in a large fixed vessel called the **Cistern,** for from fifty-five to seventy-five hours for home-grown barley, and up to 100—120 hours for foreign grain.

The water then being drained off, the saturated corn is either thrown or allowed to descend (by opening a valve) into the **Couch** or **Couch-frame.** In malthouses of later construction the cisterns are of iron and conical in shape ; moreover, they are fixed above the couch-frame, so that, on a valve being opened, the whole of the saturated contents is discharged into the receptacle beneath. This arrangement is much more speedy. A good-sized cistern, which it would take two men working with shovels at least thirty minutes to clear, can be emptied in three minutes, while the work superseded is as heavy as any in the malthouse, and the crushing of a good many corns, that fertile source of mould, is prevented. It may be that in extremely cold weather the free conductivity of the metal would render it an unsatisfactory material for cisterns—it is certain that the steep water should never be extremely cold (never below 50°) ; were that the case, such cisterns could be " lagged " with some non-conducting covering.

In the couch the grain rests until the temperature reaches 56° F. The use of the couch merely depends upon the fact that it is found useful to keep the grain at a considerable thickness at first, in order to encourage a slight rise of temperature, and thereby to favour the beginning of germination.

Aeration in steep : Flooring.—Steeping, alternating with aeration, is getting recognised as preferable to continuous steeping, even to the extent of 12-hour periods of each. The grain, thoroughly moistened, without being sodden, seems to have more vitality. It should be sufficient to leave the air, sucked in by the drawn-off steep-water, undisturbed for the desired period by fresh steep-water ; but conical cisterns present some obstacle to due aeration of the lower portions of their charges of grain, which remain considerably wetter than the upper portions.

After the couch the grain occupies a large area on the floors, which

are worked thinner in warm weather than in cold ; so that if 60° F. of temperature be touched, it may never be exceeded.

Malting (continued)—The Floors.—Upon the day that the couch is opened out the grain becomes a " one-day floor " ; upon the following day it is known as a " two-day floor " ; on the succeeding days as a " third-day," " fourth-day," " fifth-day floor," and so on. Every day, generally twice a day, " the piece " or " floor " is turned and moved forward away from the cistern and towards the kiln, which is at the opposite end of the malthouse. The turning is effected with broad, flat wooden shovels, and as each shovelful is thrown forward, a dexterous turn of the wrist scatters it thinly and evenly on the floor in front. The usual practice is to skim the surface with one sweep of the shovel, throw that shovelful forwards, and get up the lower layer, so laid bare, in another sweep. In this way a large percentage of the grains, previously lying at the bottom, will now be thrown for a time on the top, and have their chance of absorbing the oxygen needed for healthy growth.

Mode of turning Floors.—The men, as they turn the floors, work from side to side of the malthouse (or from side to middle, and back again to the same side, if the house is a double one), and sometimes they work forward—*i.e.*, following the shovel, sometimes backward—*i.e.*, in front of the shovel. The latter seems the preferable way, fewer corns being crushed —an important point when it is remembered that every crushed corn is not only liable to turn mouldy itself, but that the mycelia of mould run rapidly from the unsound to apparently healthy corns, given favourable conditions for development. When the men follow the shovel (*i.e.*, work forward), the grains which are unavoidably missed cannot escape being crushed between the workmen's feet and the hard floor, if they be trodden on ; when, on the other hand, they work backward, they tread upon a yielding layer of unturned grain some inches thick, and comparatively little harm, if any, is done. Felt slippers lessen the risk of crushing, but better still from that point of view is the system of working barefoot practised at Newark. Men, however, who have not been brought up to this system naturally object to begin it.

Germination—Rootlets—Acrospire.—Meantime the rootlets have made their appearance ; at first—when the grain begins, as it is said, " to chit " —in a white protrusion at one end of each barley-corn ; then they separate and, if the conditions are favourable to rapidity of growth, this white protrusion soon resolves itself into separate rootlets, three, four, five, six, or even, here and there, seven in number, which grow daily, though they should never grow long and " spindly " (short bushy rootlets are a desideratum), up to the seventh or eighth day from the couch, after which, even though they have from the fourth day been refreshed by judicious sprinkling, the active growth ordinarily slackens, as evidenced by some loss of their pristine brightness of hue.

A less noticeable phenomenon, though some growth is doubtless almost simultaneous with the sprouting of the rootlets, is the development of the **acrospire** or **Plumula.** The acrospire, known to the old malting hand as " the back-spear," starts its growth from the rootlet end on the smooth, not the cleft side of the grain, and grows under the latter's skin to a certain point (about three-quarters the length of the grain), the attainment of which is a sign to the maltster that germination has been carried far

N.B. HANG THIS CARD NEAR "PIECE" ON FLOOR AND KILN.

ROSS-MACKENZIE'S COMPLETE MALTING REGISTER

Steep **No.** 34 Floor **No.** 1

Quality or Type of Barley Yorkshire. Goldthorpe

From whom purchased Smith & Brown

Quantity 60 Qrs. — Bushels

*P = Ploughed
T = Turned
F = Forked

STEEP

Date and hour to steep 14 Mar. 26-e4

Water changed 6 times.

In Water 70 hours.

Date and hour of Final Draining 17 Nov. e2

Sprinkling: M — E 1/4

COUCH

In Couch 15 hours.

	4th Day Gals per Qr.	5th Day Gals per Qr.	6th Day Gals per Qr	7th Day Gals. per Qr.
M		1/4	1/2	
E	1/4	1/2	1/2	

TEMPERATURES OF FLOOR.

	1st Day	2nd Day	3rd Day	4th Day	5th Day	6th Day	7th Day
M 2		48	52	55	58	57	58
M 6		494	52 T	55 T	58 T	57 T	58 T
Noon		49	53	56	58 P	58	58 P
E 5	47	51 T	54 T	57 P.T.	58 T	58 P.T.	58 T
E 10	47	50	54	58	58	58	58 P

	8th Day	9th Day	10th Day	11th Day	12th Day	13th Day	14th Day
M 2	57	59	58	59	62	62	
M 6	58 T	59 P.T.	59 F	60 F	62 F	62.5	
Noon	58	58 P	59	61	62		
E 5	58 P.T.	58 T	59 F	62 F	62 F		
E 10	58	58 P	60	62	62		

KILN TEMPERATURES.

DRYING 1st	DRYING 2nd		CURING 3rd	CURING 4th	CURING 5th
		E 12	110	170	
M 2	96	M 2	108	168	
		M 4	108	166	
M 6	98	M 6	104	164	
		M 8	104	192	
M 10 Loaded 9 a.m.	108	M 10	114	208	
		Noon	122	210	
E 2 82	110	E 2	130	212	
		E 4	140	212	
E 90	112	E 6	148	210	
		E 8	156	212	
E 10 102	114	E 10	172	210	

Date to Kiln 29-3-26

Date from Kiln 2-4-26

Days on Floor 13

Max. Temp on Kiln 210 maintained for 12 hours.

Quality or Type of Finished Malt Pale

Where Stored No. 1. Bin

ANALYSIS.

Diastatic Capacity	30·3
Tintometer Reading	6·5
Extract at 42 lbs.	98·83
Ready-formed Sugars	13·8
Soluble Albuminoids	2·19
Moisture	1·8%

REPORT on Finished Malt:—

Made up from sound barley, fully germinated, well modified & correctly withered prior to loading. Finished malt friable and of good flavour. Suitable material for summer brewing. Analytical results correct except for colour which is excessive.

For further remarks P.T.O.

*When the "piece" is ploughed, turned, or forked, the initial letter P, T, or F is placed after the already noted temperature, i.e., 60 T.

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enough. This acrospire is what, under the natural conditions of growth in the soil, would develop into the green blade with which we are all familiar, but in the artificial process the growth is stopped far short of that; indeed it is, as has been said, rarely allowed to traverse more than three-quarters of the length of the grain (never, on any account, being allowed to protrude), this being all-sufficient to call into being the qualities which differentiate malt from barley. What these are, apart from the physical characteristics of greater friability, flavour, and lower specific gravity (a bushel of good barley weighs about 56 lb., whereas a bushel of malt made from it weighs from 40 to 42 lb.), will be found on pp. 1, 2, and 3.

It may be well, however, before referring to the kiln, to add a fairly representative sketch of the progress of a floor of malt supposed to have been steeped in moderately mild weather in spring, and which, though not showing any exceptional vigour in regard to the average number of rootlets produced, exhibits a satisfactory development of acrospire.

Progress of an average Floor.—After the usual stay, as mentioned in p. 6, under water in the cistern (the water having been changed every twelve hours), and twenty-four to twenty-seven hours in the couch, its career begins as a one-day floor. Suppose the couch "broken" at 7 A.M., it is probable that an inspection of the grains will reveal the rootlets beginning to protrude here and there, and if the floor be reduced in depth, it will be found in the evening, say at 4 P.M., that they are just through in nearly all of them. On the second morning distinct rootlets will have made their appearance in at least half the grains, and varying from one to three in number.

Turning will be resorted to morning and evening—the barley being spread thinner and thinner, and consequently occupying more space until it is a four-day floor, when it may perhaps be advisable slightly to reduce the area over which it is spread. On the morning of the "three-day" floor nearly all the grains will have three well-developed curly rootlets, some of them four. On the evening of the same day all will probably have three rootlets, some four or five, averaging a quarter to a third of an inch in length, and the acrospire will be plainly visible. On the fourth day the rootlets will be fairly well developed, and four or five in number. Perhaps on the evening of the fourth day the rootlets may show a slight loss of brightness, and it may be advisable to begin **sprinkling.** The sprinkling is done with a large can, having a straight spout of exaggerated length, which is freely perforated for a considerable part of its length with fine holes, so that a wide and tolerably fine spray is assured. On the evening of the fifth day the acrospire will be fully halfway up, and in some grains possibly two-thirds. On the sixth day, if the rootlets begin to wither, the acrospire should be two-thirds of the way up, and the grain retain its characteristic fresh, cucumber-like smell.

The development of the acrospire is now slower, but on the evening of the seventh day it will be three parts "up" in many cases, and cautious sprinkling may, if necessary, be resorted to. [N.B.—Sprinkling must be restricted by the necessity of sending the floor to kiln not heavily charged with moisture.] On the eighth day "the mellowing" will probably begin, the acrospire being stationary. It will then certainly be fit for the kiln on the thirteenth morning, but probably before this time mould will have made its appearance, and maybe in such quantity that it will seem ad-

visable to put " the floor " on the kiln a little earlier than its growth otherwise would require. The above details are only given as typical of what occurs in malting a floor of barley when the external temperature is not very low, and where the grain is kept at a moderate temperature, approximating to 60° F., by judicious turning and spreading. In very cold weather the germinating grain may be thirteen full or even fourteen days on the floor.

Malting (continued).—It may be mentioned that as " the floor " nears its next destination, the kiln, on which it will be loaded at an age, generally speaking, varying between eleven and fourteen days, other younger floors will be following it ; and as it is usual to steep about every fourth or fifth day, with certain variations to lighten Sunday labour, it is essential that the malthouse floor should be long enough to hold three separate steepings with a small clear interval between, which must be kept scrupulously clear of scattered corns, the edges of each " piece " too being neatly brushed up.

Withering should be regarded always as a separate operation. It is, in fact, the getting rid of superfluous moisture by the influence of the air, a riddance which is naturally accompanied by the process of asphyxiating the grain due to the action of accumulated CO_2, and by a withering of the rootlets, though the acrospire may still grow slightly ; and it is certainly a point of capital importance not to load the green malt on the kiln in a very moist condition. Some maltsters again like to heap up a " piece " of malt for a time before kilning it, whereby a little more heat is generated, the result, as they hold, being greater mellowness. But in any case, the wisdom of endeavouring to get mellowness and friability by withering or heaping must be decided in connection with the freedom from mould which the piece may or may not exhibit. If mould has begun to run it will be advisable to get the " green malt " upon the kiln at once, and not to incur certain damage for a problematical benefit. **Fitness for the kiln** can be determined by pressing the grain between the thumb-nails, whereupon it should crumble without exuding moisture and without pastiness. Some leading maltsters speak of a withered malt containing an excess of moisture as being of the consistency of butter, instead of possessing, as it should, the lower water content and a certain physical resemblance to cheese. The acrospire should be three-quarters " up," as nearly uniformly as possible. The rootlets, which before should have been short and curly (say half an inch in length at the outside), will now be dry and somewhat shrivelled.

The Control of Malt Kilns.—Modern malthouse foremen may not be academically conversant with the scientific principles underlying the drying and curing of malt, but the majority of these men can apply these principles efficiently in the course of their daily task. They recognise nowadays that the satisfactory kilning of malt really consists of two virtually distinct processes, in which nearly opposite physical conditions should obtain. Some years ago we noted that a well-known malting authority stated in respect to the production of good malt that " If the foreman sees that his fire is guarded from the wind, especially when it is high, and regulates the position of the fuel on the fire-bars according to circumstances, little else is necessary in a good kiln." We do not agree that efficient kiln manipulation is quite so simple a matter. While the

position of the fuel on the fire-bars and the quantity of coal employed are important contributory items of successful stoking, yet the ingress of air during the drying stage in sufficient volume is the main regulating factor. The draught holes leading direct to the fires should extend through a tunnel carried outside the building. There should be no connection whatever between the air that reaches the grates and the air that furnishes the necessary up-draught for the expulsion of the excess moisture from the load of malt undergoing drying on the kiln. In some instances the air employed for the latter purpose is drawn in *above* the fires, but to obviate the ever-present risk of scorching by a sudden blast of cold wind gaining admittance to the load, all the several kiln draught holes should be placed at the lowest point *below* the fires and arranged so that the maximum amount of cold air available will, after due admixture with the hot fuel gases, be distributed equally throughout the load on kiln.

The volume of air secured specifically for this purpose depends upon the condition of the fires. A bright intense fire will continuously evolve large volumes of fuel gases, which is immediately replaced by a corresponding volume of air drawn through the several draught holes situated at the lowest point *below* the fire surface.

To the uninitiated, it appears extraordinary that in a kiln arranged on the principle briefly alluded to, the more intense the fires the greater is the volume and proportion of cold air drawn in and intermixed with the volatile products of the fuel, and, in consequence, the lower are the kiln temperatures ; providing, of course, that the draught holes are maintained fully open. Moreover, under the conditions named the dispersal of the moisture content of the corns occur with greater rapidity. The period occupied for the drying stage varies with atmospheric conditions. *The Times* formerly used to publish regularly information in respect to these conditions from records tabulated three times every twenty-four hours. The temperature of the air, tension of vapour, percentage of humidity, etc., were all registered, and it was only necessary to retain these figures for reference purposes during a short period in any malting season to show the remarkable variability of our British climate.

A written record of all kiln temperatures should form part of a foreman's duties. Reference to these, together with observing the behaviour of the fires, are certainly useful checks, but a regular physical examination of the progress made in drying as indicated by the condition of the corns is so important that such periodic inspection should never be neglected.

The introduction of methods of kilning which showed a decided saving in fuel appealed to the commercial sense of many non-technical directors, and has led to the introduction of this system in quite a number of maltings. The entire kilning of malt cannot be carried on simultaneously except in the hands of an exceptionally skilful fireman. Drying and curing are two distinct and independent processes, as already mentioned, accomplished at a widely differing range of temperatures and under almost totally opposite conditions in respect to draught and similar factors. Apart from labour-saving items of malting plant, legions of devices have been conceived for the purpose of improving the draught and the dissipation of " reek " from the kilns, and for a time each appliance had a certain following. The simple old-time kiln without appendages and constructed on sound lines based on long and wide experience of the

needs of the maltster can be made to serve for the production of thoroughly dried and efficiently cured malts.

Malt, it has been often said, " is made on the kiln." This statement is not quite accurate. While a perfectly germinated and completely withered green malt may be received on a badly constructed kiln or by ignorant management, yet it is obviously not possible to eliminate errors in floor working on any kiln, however faultless or in the hands of any maltster, however skilful.

It is surprising how many craftsmen still contend that it is impossible to " finish off " at extremely high temperatures without incurring the risk of excessive colour, curtailment of diastatic capacity, together with the yielding of an undue amount of fire flavour.

If care is observed to carry the drying process through successfully, curing can be accomplished at astonishingly high temperatures without interfering abnormally with enzymic capacity, or obtaining any of the faults which lower the general quality of a high-quality malt. On the contrary, the higher the maximum curing temperature, providing always that each preceding process has been carried out efficiently, the more enhanced in every attribute is the finished malt. Especially is this the case in the matter of malt flavour. Compare two malts, each of which, " made up " from the same barley, have been thoroughly dried prior to " closing down," but one of which has been subjected for the closing eight to twelve hours to considerably higher temperatures. There can be no question of the improved flavour of the latter product.

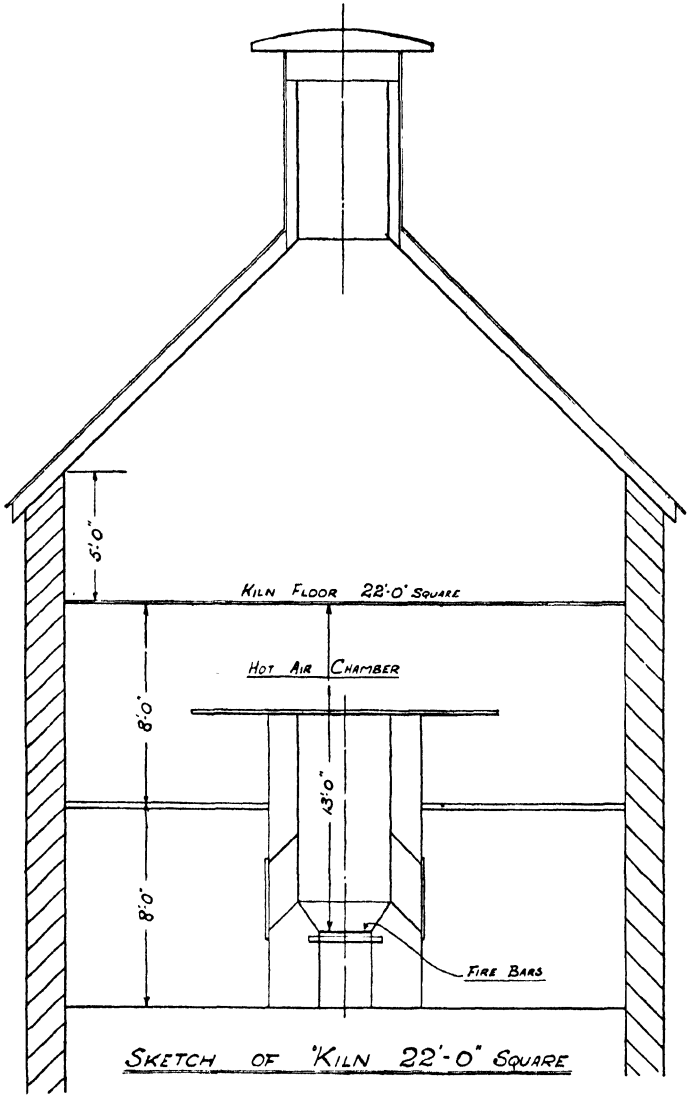
The amount of flavour yielded to the palate by a malt of this type, quite apart from other considerations, is carried forward to the beer and is of inestimable advantage in these days of light ales with a natural tendency for over-attenuation, and, in consequence, lack of palatefulness, especially if large proportions of foreign malts or adjuncts are employed.

Unfortunately the essential element of flavour cannot be detected or estimated by chemical analysis, and doubtless it is for this reason that certain theorists claim that similar results can be obtained by drying and curing malt on practically the " central heating " principle, in which any volume of draught required is obtained mechanically by fans. Malts produced by this method may be similar analytically, but they are utterly devoid of true " malty " flavour as compared with the malts upon which the fuel gases from open fires have been allowed free access to the load on kiln.

The Kiln, of which more anon, consists of a floor either of woven wire or tiles, upon which the green malt has to be loaded, and supported by massive brickwork, within which is the firing-place from twelve to eighteen feet below the floor itself. Rising high above the floor, the upper part of the kiln is generally conical in shape. Stopes says the more closely a kiln resembles a chimney in construction the greater is its effective capacity. Anyhow, large outlet openings, such as are sometimes seen, by leading to over-rapid cooling and consequent super-saturation of the moisture-laden gases, prevent that strong upcast draught which is so essential. But on the other hand the openings must be large enough for getting rid of vapour when the green malt is being dried. Cowls are generally better than fixed openings.

Anthracite Coal (Welsh coal), because of its being comparatively smokeless and virtually arsenic-free, is burnt. It has on the average 6% or 7% more carbon and about ½% less sulphur than ordinary coal.

The important point is to use *moderate heat at first till the malt is*



SKETCH OF KILN 22'-0" SQUARE

Scale ¼" = 1 FOOT

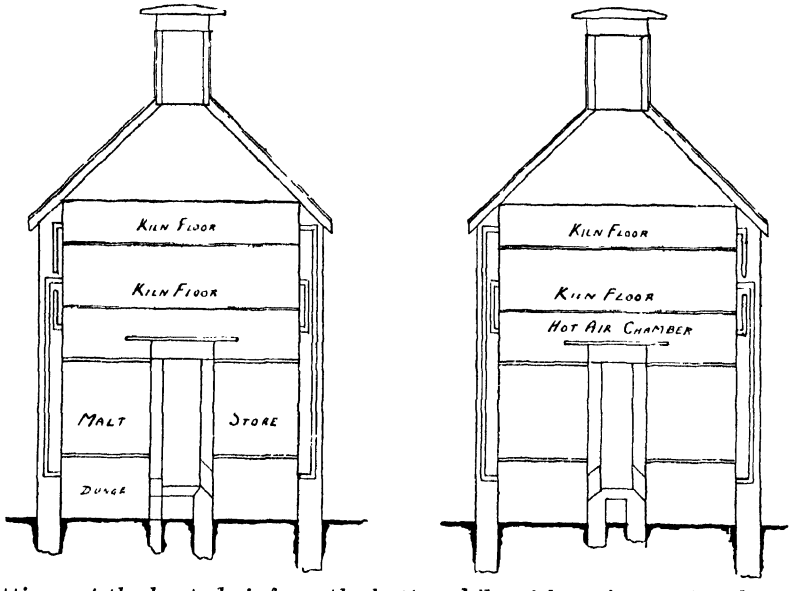
thoroughly dry. Excessive heat applied to the moist green malt imparts a high colour, besides causing other evils, which will be more fully treated of in Chapter II. The malt stays on the kiln (for drying and curing) from eighty-four to eighty-six hours ; and if moderate heat has been used at

first until the malt is "hand-dry," very high temperatures may be employed to finish off without risk.

Double Kilns.—Sometimes an upper kiln is constructed on what is generally known here as the Stopes * principle, but one which has long been appreciated in Germany. The green malt is first loaded on the upper floor, for which woven wire is the best material, as holes are generally cut in it—in fact, have to be cut in it—to enable the men to shovel the charge, when properly dried, down on to the lower kiln floor, for which perforated tiles are as good a material as any. These cut holes are covered with conical wire dissipators or dispersers, which may also be metal cylinders, with one end absent at the part where they fit over the cut openings. In this case they have an arrangement opening and shutting at the top for

DIAGRAM OF UP TO DATE ENGLISH TYPE TWO FLOOR KILN

SCALE 1/16 = 1.0



letting out the heated air from the bottom kiln without its passing through the layer of malt on the upper kiln.

The double kiln is economically the better if only the firing can be so arranged that the temperature of the bottom kiln is high enough for imparting flavour and stability, and the temperature of the upper kiln *at the same time* low enough to dry, without colouring its contents. The only advantage obtained from the employment of double kilns is the commercial one of economy in respect to fuel, which, it is claimed, amounts to from 50 to 70% of the coal required for single kilns. If we were asked to state a preference it would be for the single kilns. The double kilns involve some alteration in steeping, less is wetted at one time, but the

* Other patented improvements will, however, be mentioned in the next chapter. In them the aim has very properly been to meet the defect of the Stopes kiln—*i.e.*, the difficulty of *drying* the upper floor at a low heat, and *curing* the bottom floor at a high heat simultaneously.

steeping is more frequent—say every other day instead of every fourth day.

The mention of Germany recalls that the system of drying and curing practised there differs from the usual English method, in that, in that country, heated air alone is allowed to pass through the malt, whilst here the actual products of combustion pass with the heated air. Indeed, eminent authorities here think this an advantage, holding that the malt, like " a Finnon haddie," keeps all the better for the smoking it receives, and the flavour produced thereby is essential for the brewing of British beers.

After being thoroughly cured the malt is trodden on the kiln or mechanically treated to free it from dried rootlets or " the combes," as they are called. It is then stored, preferably in bins and with " the dust " —*i.e.*, the rootlets—until wanted. Next it is passed over a screen to separate the rootlets, which fall through the mesh of the inclined screen, and is then conveyed to the brewery.

Malt on arriving in the Brewery.—After reaching the brewery the malt is crushed, but not ground, in a malt-mill or malt-mills, whence it is raised, as " grist," while the crushing proceeds, by an elevator or Jacob's ladder, an endless band with cups attached, which as they reach their highest point and begin their descent upside down discharge each its little load of grist into the **Grist-case** or **Hopper,** which commands the mash-tun. Considerably less disintegration of the grist occurs, and consequently a greater degree of buoyancy results in the mash-tun when the crushed malt falls direct to the grist case. This operation takes place, as a rule, on the day before that fixed for the actual brewing. The addition in a semi-dry form of the " hardening " materials rendered necessary to supply the deficiency of saline constituents of a brewing water to any desired standard should be added to the grist, at intervals, as it falls into the grist-case.

The **Liquor,** or " **Plain Liquor,**" as water is always called in a brewery, is also generally heated each evening for the next day's mash. Some brewers prefer to boil it, and allow it to cool down, adding cold liquor if required. The carbonates, or rather bicarbonates (but not the sulphates), of lime and magnesia are thereby precipitated, and with them any iron present in the same form.

Mashing Systems (Infusion, Decoction, and Limited Decoction).—There are three principal systems of mashing, viz., the Infusion Process, which is the usual English method ; the Decoction Process, employed in Germany and elsewhere for the production of lager beer ; and thirdly, a variation of the first with some features of the second, known as Limited Decoction.

In the **Infusion method** the crushed malt and the " liquor " are mixed either in the mash-tun by internal rakes, or they fall into it ready mixed by passage through a mashing-machine, fixed outside the mash-tun, but placed so as to command it. Generally there will be both rakes inside the tun, and one of these external mashers (Steele's, Maitland's, or Riley's, etc.). The mash-tun has a false bottom consisting of perforated or slotted metal plates, which rest on feet so as to be some inches above the real bottom. This interspace and the plates of the false bottom should be covered with the mashing liquor before the grist is started.

The mash-tun should be well heated by steam at a definite pressure previous to mashing—this is especially necessary when the mash-tun is of iron—so that no cooling of the mash may result. The aim is to get the "**initial heat**" most favourable for inducing certain chemical changes which have already been referred to briefly, and will be further dealt with in the chapter on Mashing and Boiling.

The initial heat (by which must be understood the heat of the mash directly all the malt and all the liquor are together in the mash-tun) may range from 150° to 156° F., or even higher, according to the quality of the malt, type of yeast employed, or the character of the beer that one wishes to produce. To attain this, unless Clinch's system of a preliminary heating of the grist be adopted, a "striking heat," *i.e.*, the heat at which the liquor meets the goods, some 10° to 13° F., more or less, above the desired initial, will be requisite. If, on the other hand, the grist be heated, obviously a temperature which approximates to the desired initial will be sufficient.

This "initial" is maintained or slightly raised by the introduction of "**underlet**" or "**Piece Liquor,**" so-called, let under the false bottom; and if there are internal rakes—as there ought to be in all large tuns—it will be the general practice to let them revolve once round the tun, or twice at the most, to mix the underlet and the rest of the mash. Too many revolutions—*i.e.*, too much knocking about of the mash—tend to make the mash "dead," as it is called when the wort drains off badly. Underletting, however, is not the invariable practice, but is often convenient for making up the desired proportion of mashing liquor, which is, as a rule, at about the rate of two and a quarter barrels for each quarter of malt. Underletting is less needed from the point of view of temperature when the bulk of "the goods" is large, or when the mash-tun, especially if it be of iron, is so thoroughly heated that it acts as a reservoir of caloric for the mash to draw upon.

It should be remembered, however, that the more liquid the mash, other things being equal, the higher will the ratio of maltose be to malto-dextrins in the resulting wort, and consequently the tendency of the latter will be towards greater **attenuation**—*i.e.*, towards a beer containing less unfermented matter but more alcohol. Such a beer, skilfully manipulated, may by the pungency attributable to the increased amount of alcohol and of carbonic acid, with which it should be saturated, delude the taster's palate into an impression of even greater body than one less attenuated may succeed in imparting. On the other hand, there being a tendency, when the fermentation is of a very free and rapid character, to the dissipation and consequent loss of too much of the carbonic acid (representing an equal portion with the alcohol of the solid fermentable matter which the wort once contained), considerable care will be necessary to prevent such a beer drinking thin and poor, or, as the expression goes, "below its gravity."

Rest after Mashing—Wort Circulators.—The mash is next allowed to rest or "stand" for a period that varies from an hour and a half, or even less, to two hours; though in the interval some brewers, who have the requisite appliances, find it to their advantage to "circulate" the wort—*i.e.*, to set taps and convey it to the upper part of the mash-tun, *via* some intermediate appliance for raising its temperature. It is then

sparged * over the surface of " the goods " (through sparge-arms of larger aperture than those used for the subsequent liquor sparges), at a temperature considerably above that at which it runs from the mash-tun, the double operation—running-off and sparging-on—being carried on simultaneously.

The advantages of circulating are increased and early brightness of tap, and a shortening of the " rest " or " stand," owing both to the first-named advantage and to the fact that the circulation, provided the temperatures be not excessively raised, stimulates the action of the liquefying and saccharifying diastases; or, on the other hand, if the command of temperature during the process be without limit, the power which the brewer then has of crippling the diastasic action by a very high heat, and of thereby producing a malto-dextrinous rather than a maltose wort, or, in other words, one which will yield a full-drinking beer which will improve by storage.

The **two forms of circulators** in use are **Crockford's** and **Bucknall's.** The former, though no royalty has to be paid, is a somewhat costly arrangement in itself, involving a rotary pump, speeded to at least 1,200 revolutions a minute, considerable lengths of tinned-copper connecting pipe, and a copper vessel with a steam coil in it, which is used for heating the wort as it is pumped up. The opening at the bottom of this vessel (the said opening being connected with its sparge-pipe) is plugged by an overflow pipe, which stands up higher than the coil, so that the latter is always covered while steam is passing through it. At the end of the circulating, which may last fifteen minutes, or considerably more if it be found useful, the vessel is emptied by withdrawing the plug-pipe.

Bucknall's apparatus is simpler. A tube connected with the bottom of the mash-tun, or with the small " back " (vessel) into which the taps flow, is so arranged that a jet of free steam admitted into its lower end drives against the wort which has previously been let into the tube, and by the force of its impact (somewhat after the manner of a Giffard's Injector) carries the latter up with it to a height which commands the upper surface of the mash-tun, raising its heat considerably, of course, at the same time. The objections, if valid objections they be, lie in the use of free or naked steam, connoting the possibility of impurities being introduced, and the fact that its condensation adds to the fluidity of the mash. This increase of fluidity need not, however, be excessive, seeing that the principle of latent heat of steam comes into play. The heating capacity of free steam, accordingly, will be four or five times as great as that of steam conducted through coils, a fact which should theoretically render it easy even to boil the wort, as carried up, with a relatively moderate amount of condensation. And if the said steam inlet be well above the level of the boilers, as it would be in most modern plants, the risk of oily matters and other impurities being introduced, especially if certain chemical boiler-compositions be eschewed, is reduced to a minimum.

* Sparging = sprinkling or distributing water at high temperatures over the surface of " the goods" (as the malt when in the mash-tun is called) through a sparger or sprayer, consisting of specially constructed copper tubing or " arms " perforated with numerous very small holes through which the liquor is sprayed, in the form of a mist, over the goods, the sparger revolving at a high speed.

The remaining steps between mashing and fermentation are roughly and briefly "setting-taps" after the rest in the mash-tun. The major quantity of "liquor" (= water) required to make up "copper lengths" should be sparged on—and this sparging goes on simultaneously with the spending of the taps, while the "liquor" supplied through the arms of the sparger should be so regulated that "the goods" are neither drawn nor beaten down; that is to say, the supply should be copious, and yet the holes in the sparge-arms should be fine enough to prevent the liquor from falling heavily, for a light and sponge-like condition of the goods means good drainage, and good drainage generally means good extract. Modern sparge-arms supply the liquor in the form so thin a spray as to resemble almost a mist, as already mentioned in a footnote to p. 17.

The copper or coppers being "made up"—*i.e.*, filled to the required depth, generally ascertained by taking the dry dip or number of inches from the top which the surface of the wort is to come up to,*—**hops are added.** Some brewers add them while the copper is being made up, before the length is got; some again add the quantities worked out for each copper all together to that copper; others add portions, generally different growths, at intervals, boiling the choicest hops the shortest time, with the object of retaining, if possible, as much of the fine aroma as possible in the wort. When the copper "length" is made up and first boils with the hops it is said to be "through." The coppers may be boiled either by direct fire action or by steam, the relative advantages of which may be referred to later.

The boiling having lasted from one and a half to two hours (longer than this can hardly ever be needed), the copper is "turned out" or "struck" or "cast," the boiling wort, hops and all, rushing out through an opened valve or tap into the **hop-back,** a vessel sometimes rectangular, sometimes circular in shape. The hop-back is fitted with a sparger, or, in the case of a rectangular hop-back, two spargers, similar to that connected with the mash-tun, for extracting any wort remaining in the hops after the last copper has been pumped or run out of it. After a rest of about thirty minutes in the hop-back the wort will be pumped, or proceed by gravitation to the **coolers**—open, shallow vessels of cast-iron or copper—and thence over the **refrigerator** or **refrigerators,** which are, broadly speaking, an arrangement of parallel copper tubes, placed either vertically (of which Lawrence's Vertical Refrigerator is a type) or horizontally (Morton's, etc.), *through* which cold water flows, while the wort flows *over* them in a contrary direction. [To avoid misapprehension on the part of those who have never seen a refrigerator, let me add that the term "vertical" is somewhat of a misnomer; upright would be better. The tubes are in every case—except with certain circular or spiral refrigerators—*at right angles* to the course of the wort.] The object of this passage is to cool the wort from the temperature approaching boiling, say 180°, at which it stands upon the coolers, to a temperature of 60° or 58°, or even lower, which is advisable for the commencement of fermentation.

It will be observed that the wort, which is brilliantly clear at the

* The number of barrels to which these dry inches correspond is ascertained by reference to a Table. Thus suppose 20 dry inches (which is pretty full even for a steam-boiled copper) = 90 barrels, and each inch represents a barrel, then 21 in. = 89 barrels, 22 = 88 barrels, and so on.

higher temperature, becomes more or less dull when cooled down, from the fact that certain bodies, of protein character, soluble in the hot fluid, are thrown out of solution at the lower temperature. It is the business of the yeast, in addition to its vital functions, which result in the phenomena of fermentation (*i.e.*, the production of alcohol and carbonic acid gas from the saccharine matter of the wort), to purge the wort of these factors of turbidity, a purging which is probably effected mechanically, when they are not too plentiful, by the continuous rising of multitudinous yeast-cells to the surface.

Before proceeding further to our description of fermentation, it will be well to refer to certain differences in the method of mashing, as far as they are marked enough to have received special names.

Infusion, Decoction, and "Limited Decoction" Systems of Mashing.—The **Infusion system** is the one described in the foregoing pages, and is the system adopted, with slight modifications, throughout Great Britain. On the other hand, in the great Continental brewing centres the **Decoction system,** so called because portions of the mash are actually boiled or cooked, is preferred. There are, of course, variations, but the usual Viennese system is as follows.

The grist is first mashed with cold water until a homogeneous mixture is obtained, and Thausing says it is considered a sign of good quality in the malt when the mash froths well and has an agreeable smell, and when the water quickly gets a milky appearance. Meantime the water in the copper has been boiled, and enough is now introduced into the mash-tun to raise the heat to a point somewhere between 86° and 100° F.

Next, about one-third of the mash ("goods" and all) is conveyed into a special vessel known as the *maischkessel* (mash-copper) to be boiled, its temperature, however, being brought only by degrees up to 167° F. Its appearance is noted from time to time, and, from being milky at first, it gets gradually transparent as the starch is first liquefied and then saccharified or converted into sugars. Two objects have to be kept in view during this procedure—first, the conversion of the starch during the gradual elevation of the temperature up to 167°, and the more completely this takes place the better; and secondly, to elevate the temperature of the remaining two-thirds of the mash by the return to it of the boiled portion. The boiling of the latter, however, is not begun until the milkiness has all disappeared, the time during which it is boiled varying between a quarter and three-quarters of an hour; and until the ebullition is active, the mass has to be kept in constant movement (by revolving arms, with loops of chain depending, which sweep the bottom of the vessel) to prevent burning.

This portion, the first *dickmaische*, as it is called, having been boiled its due time, enough of it is reintroduced into the mash-tun to raise the temperature of the whole to a point between 110° and 126° F., the mashing apparatus being, of course, still revolving. A few minutes having elapsed, a third part of the mash is again taken (second *dickmaische*), and submitted to treatment similar to that undergone by the first, save that the boiling is generally somewhat prolonged. On this being reintroduced into the mash-tun, the temperature of the whole mash should reach a point which varies between 134° and 149° F.

This second *dickmaische* having been thoroughly incorporated with the residue of the mash, the mashing is stopped so as to allow some of the solid constituents to subside previous to the abstraction of a third portion, which in this instance is more or less clear wort, and is accordingly called the *lautermaische*. This is generally boiled longer than the previous *dickmaischen*, and, at any rate, the boiling is continued until inspection in a glass shows the coagulated proteins being precipitated in large flakes. This having happened, all the *lautermaische* is restored to the mash-tun, the contents of which are thoroughly well mashed once more, so that the final temperature may reach a point between 160° and 167°, this point being, as in the previous operations, higher in the winter than in summer. The " rest " that now ensues is as limited as possible, being, in fact, only continued until the grains are deposited. The mash is, of necessity, much thinner than an infusion mash would be, and the continuous treatment militates against that spongy condition of the goods which is a *sine qua non* in the latter. The wort should then look dark above the grains—a reddish hue is considered a bad sign—and this will happen ordinarily in half an hour, or but little over.

As regards relative stability, most German brewers would pronounce in favour of decoction beers, but then they are thinking of infusion beers fermented on decoction lines, whereas either system has its own special method of fermentation (to be referred to later) exactly adapted to the tastes of its consumers. So that, considering infusion and decoction beers *as they are*, our conclusions will be widely different, and may be summed up as follows : infusion beers are far more alcoholic, while decoction beers contain a much larger percentage, relative to their original gravity, of unfermented, and therefore nutritive, malt extract. The latter, moreover, owing to the extremely low temperature at which they are fermented, are saturated with carbonic acid gas to a degree unusual in the infusion product. On the other hand, the infusion beer may claim much greater stability, being capable, if well brewed, of standing " on ullage " (*i.e.*, on draught) for many weeks, of keeping and improving in bottle for a considerable time, and even of supporting a voyage to India, without precautions other than those implied in attaining as complete an attenuation in cask as is possible.

Decoction beer, on the other hand, is so incapable of supporting " draught," that the smallest cask of it would become undrinkable before an ordinary family could consume it ; and if it be bottled, unless the consumption is to be speedy, " Pasteurisation " (maintaining at a temperature of 140° F. or thereabouts for a time) is an absolute necessity for its preservation. Yet again, no one can deny the refreshing quality possessed by well-iced lager beer (with a temperature so different from that of the lukewarm fluid so often dispensed in summer over English bars), just as no one can deny the superior value, as a digestive stimulant, of light and well-attenuated infusion ale. Bottled decoction beer is simply draught-beer in bottles, which perhaps has lost a trace of its conditioning gas and, if Pasteurised, may have acquired a foreign flavour, the so-called " Bread flavour." Stored for three months, or more, in large barrel-shaped store-casks (of 800—1,500 gallons) in which the complementary fermentation goes on, well-managed beers get super-saturated with gas and there is no need for the conditioning in bottle typical of English

bottled beers of the old style, namely, those which depended on natural ripening, and not on artificial carbonation.

Limited Decoction is the name applied to a process which begins on infusion lines, the mash, however, after a short rest, and after a certain quantity of strong wort has been drawn off, being boiled in the mash-tun itself by means of free steam, let in under the false bottom, the plates of which it is advisable to bolt down to prevent them from shifting. This boiling, especially where "steely" or hard malt is used, dissolves a quantity of starch, unaffected by the previous mashing temperatures. The mash is then cooled down with cold liquor to a temperature at which diastase is able to act (say 160° to 165° F.), and this diastase is got—the potency of that in the mash-tun having been destroyed by the boiling—by the reintroduction into the mash-tun of that portion of strong wort which was run off soon after the completion of the mash, and which will have been maintained at a temperature, in the meantime, not exceeding 160° F. Upon its thorough intermixture with "the goods," the freshly dissolved starch is rapidly converted into dextrin, malto-dextrins, and maltose (malt-sugar).

Those who adopt the method which is described above will perhaps notice a viscid formation of coagulated proteins, approximating to the *Oberteig*, the grey smeary substance which German brewers find on the surface of their "goods." It represents diastasic factors which have done their work, or, at any rate, in the extremely soluble condition of the starch are no longer required; accordingly its retention by the mash will be no disadvantage, rather the contrary, as its tendency in the ordinary infusion system is, after being coagulated at a temperature of 180° or thereabouts, to redissolve or break up upon prolonged boiling, and thus to become, if not eliminated during fermentation, a possible source of trouble to the brewer.* The brilliancy of limited-decoction worts is remarkable; but further working details must be reserved until the chapter on mashing.

Cleansing and Skimming Systems of Fermentation.—Into one of these two divisions all the various methods adopted in this country fall. Even the "stone-square system" of Yorkshire, so famous in that county, is but a specialised kind of "cleansing," and the employment of subsidiary "dropping squares," frequently used in Scotland and elsewhere, will range as a modified and improved form of skimming.

Skimming System.—The simplest and most usual form of this system is that in which the fermentation is begun and ended in the same vessel (known generally as the fermenting vessel or "gyle-tun," or, according to its shape, as a "round" or "square"). The wort is "pitched," *i.e.*, yeast is added and "roused" in, when but a small quantity of the wort, at a temperature o 58° or 60° F., is in the round or square. The yeast is added at a rate varying generally between one pound and three pounds per barrel of the intended total quantity, the variation depending on the quality of the beer (heavily hopped or strong ales will always require more yeast than lightly hopped or low-gravity ales), and the

* Probably because they are unpeptonised. But limited decoction seems to have dropped back in favour, results equal at least in fulness and extract being got by an initial of 115° F. with stiff mash and by raising the same quickly after 45 minutes to 150° F.—(*Cf.* L. Briant in *Journ. Fed. Inst. Brewing*, 1902.)

proved strength of the ferment (yeast) in relation to the type of wort. The **pitching-yeast** should be thoroughly drained of beer, and be knocked up into a homogeneous mass. This facilitates oxygenation or aeration, apparently a great initial stimulus to fermentation. Whitish-coloured yeast is preferred to that of darker hue, as indicative of the greater vigour of the multitudinous component cells in the aggregate, and also indicative of a freedom from resins and amorphous matters. Some brewers, with doubtful policy, use yeast which has been "pressed": some, again, pin their faith upon a preliminary mixture of the yeast with wort at a higher temperature than the usual pitching heat of 58° or 60° F., rousing them up together in a separate vessel—a hogshead with the head out will do for small quantities—in which the wort stands at 75° to 80°, the top being subsequently closely covered up for some twenty minutes. At the end of that time the yeast will have greatly expanded, and the contents of the vessel are added to the wort running into the round or square, and the whole roused together.

When all the worts are "gathered" or "collected," *i.e.*, when the two, three, or four "coppers," as the case may be, have all been run over the refrigerators into the fermenting vessel or vessels, **the Excise officer** comes upon the scene, and by taking "dips" and gravities (previously taken and declared by the brewer) arrives at the number of gallons chargeable for duty.

If two or three distinct varieties of beer are produced at the one operation the brewing is called a **"Parti-gyle."**

When several fermenting vessels have to be filled with the *same* sort of beer, it is sometimes the practice, for convenience in assessing the duty, to have one large **collecting or gathering-square,** the contents of which are subdivided amongst the said fermenting vessels about twelve or fifteen hours later. Nor does the benefit of such a gathering-square stop at mere convenience; a good deal of coagulated, dirty-looking matter, which has risen to the surface of the otherwise silvery-white head, gets eliminated, and the aeration which the transference involves may also be distinctly advantageous.

A **normal fermentation** is one in which skimming-point (coincident with the beginning of formation of a *yeasty,* as distinguished from a frothy head is reached in about forty-eight to sixty hours from the time of pitching. An earlier time would indicate fermentations more or less rapid; a longer period, a somewhat slow type of fermentation. Early stages are the well-known "cauliflower" and "rocky" heads, epithets which, when the heads themselves have once been seen, will require no explanation. The heads rise steadily at first, say until the temperature has risen 5° or 6°, then fall, rising again, as a general rule, if allowed to do so, when the yeast is forming. These early heads are sometimes, though light and frothy in substance, of relatively considerable thickness, especially with medium-strong or strong beers, where the fermentation starts with vigour; thus a head three feet or so in height, the wort beneath it being five feet or so in depth, would be nothing phenomenal. In the case of lightly hopped, light-gravity ales the head will rise much less, but in every case the worts ought to be covered with a coherent head, and must not show any tendency toward what is known as a **Fiery, or Boiling Fermentation.** In the latter case, as the usual yeast-forming point is approached, absolutely no "head" is

to be seen, but a rapid evolution of carbonic acid gas, as in a freshly opened bottle of soda-water, perhaps with the formation of great bladdery bubbles filled with the gas, which burst on the surface. This portent, though it may have no ill effect in the isolated brewing, which *may* even be better than the average of brewings, yet points to faulty conditions of mashing or otherwise, which, if persisted in, must end disastrously.

Medium or rather slow fermentations (the latter being quite distinct from **sluggish fermentations,** in which, owing to feeble yeast or unsuitable preparation of wort, attenuation comes almost to a standstill) generally produce a brighter "racking-sample" than quick fermentations are capable of doing.

The temperature of the wort rises as fermentation progresses, and this rise is, of course, a result of the energetic breaking up of some of the wort constituents by the yeast. The usual rate of rise—unless it be checked by the **attemperator** *—is 1° F. for every brewer's pound of original gravity which, according to saccharometer indications, disappears, broken up into the ultimate products of fermentation.

Skimming-point, which slightly precedes the formation of a yeasty head. The exact point will vary with circumstances and in different breweries, so that experience must decide it. Still more difficult to settle, precisely is the question of **temperature.** If the yeast be vigorous, it may be kept low, but, generally speaking, it is advisable to let it run up—*i.e.*, to leave off attemperating a little before the first "skim." Some, however, advocate a reduction of temperature when the yeast is working off, as tending to the latter's readier separation, an opinion which we do not endorse. A relatively low temperature means not only a yeast less liable to liquefy to nothing in summer, but also a beer more saturated with carbonic acid gas, and therefore more brisk on the palate, with more "bite," as some phrase it, and, in addition, with more hop-flavour; but it must not be lost sight of that the greater vinosity often secured, notably in running beers of rather high gravity, by higher fermenting temperatures, often has a similar, and in *their* case a more marked effect in regard to this briskness on the palate.

So that, though some beers of moderate gravity—for example, those of the now usual AK type—will, if the pitching yeast be good, rack perfectly clean and free from "yeast-bite" (a clinging bitter as distinguished from the aromatic fugitive bitter of the hop), even though the temperature at skimming-point be not over 66°, it yet seems preferable to give beers of high gravity and upwards a range as high as 68° F. Between these two extremes there is of course a happy mean for ordinary running beers of lighter gravity.

But in any case, if low to moderate fermenting temperatures be the rule, the yeast, which, like all other organisms, strives to get into correspondence with its environment (to annex a biological phrase), will soon adapt itself to this procedure; a procedure which is better adapted to

* An attemperator is a copper coil, movable or otherwise, placed beneath the surface of the wort in the fermenting-vessel, and through which cold water can be made to run, whereby the brewer is enabled to control the temperature of his fermentations. Attemperators are either movable or fixed, the former for small tuns, the latter for large. A movable attemperator, even for an 80-barrel tun, is rather unwieldy.

produce yeast of uniform type and consequently of uniform activity, than is the constant employment of high heats.

High fermenting temperatures have a tendency to cause irregular development of yeast-cells, some of which under their influence (though of course we are speaking of extremely minute microscopic objects) are of abnormal size—a tendency which is further to be noticed when yeast from strong worts is microscopically examined.

Skimming is generally effected either through **Parachutes** or **Griffin Sluices.** The former consists of a metal vessel (the parachute) shaped like an inverted shallow cone, with the apex removed, where it fits accurately into a tube that passes down through the bottom of the fermenting-tun. This inverted cone, though in the centre of the tun, is capable of being moved up and down from the outside so as to be on a level with the surface of the wort; it also has a valve at the bottom, likewise capable of being opened from the outside, which being done, the yeast immediately flows, with more or less rapidity, down the copper tube aforesaid to a stage below. In the largest tuns this parachute is replaced by a sort of trough-shaped vessel, which extends from the centre of the fermenting-tun to its edge, and into which the yeast is pushed by skimming-arms made to revolve at will; the trough, like the parachute, is generally connected with a down-tube through which the yeast passes. Such an arrangement is of course only possible with "rounds." "Squares" may have a similar trough-shaped arrangement at one end, into which a skimming board, depending from a rod stretching right across the square and travelling on wheels, pushes the yeast, or small squares may be hand-skimmed.

Sluices are fixed in an opening cut in the side of the fermenting-vessel, and consist of a movable flat plate of metal (with a projecting lip on the upper edge over which the yeast works), which is raised or lowered by a rack and pinion movement actuated by large wheels on either side. At the lower edge of the frame in which the flat plate works is a strip of hard wood (teak), backed by a slice of india-rubber bedded in the frame; this, if the face of the plate has been planed perfectly true, so that no leakage of wort ensues, will last for years. As the sluices are sent out their cogs are undoubtedly too weak. The yeast, as it comes off, is collected in slate "backs" or squares, resting on girders level with those which support the fermenting-tuns themselves; and this, if there be ample space in the fermenting-room for the slate "backs," is a convenient arrangement, enabling the brewer, as it does, to keep his stores of yeast under easy observation.

The first skimming, contaminated by coagulated proteins and hop-resin, which have come out of solution, as the maltose, which retained the latter in that condition, has been gradually decomposed into dextrose, and subsequently into alcohol and carbon dioxide, etc., should always be rejected from the "pitching" or "store" yeast. So should the last head, consisting largely of aged cells of inferior vigour, **the middle skimmings alone being preserved for subsequent pitching purposes.** Skimming is continued—and both with parachutes and sluices manual or mechanical skimming is necessary—until it is judged that the languishing fermentation has just strength enough to throw up one more thin head, of just sufficient thickness to shield it from the germ-laden atmosphere. The decision is arrived at by removing a few square inches of the head and inspecting the

colour of the fluid beneath. If this appears somewhat black the beer has "finished," and the head will be untouched; if, on the other hand, it looks brownish, the head, or a portion of it, will be skimmed off. When there is any doubt, it is better to leave rather too thick a head than to run the risk of skimming too "closely."

Another advantage of the skimming system is the ease with which the beers can be cooled down by means of the attemperator when the fermentation is slackening. They should undoubtedly be racked at a temperature not exceeding 58° F. in summer, and at one more nearly approaching the normal temperature in winter. For cooling down makes the beer, when racked into casks, much less liable to "fret" or "kick-up"—a defect manifested by the ejection from the bungholes of a dirty yeasty froth, and a more or less stubborn turbidity of the fluid. It also minimises the risk of "yeast-bite," that very unpleasant after-bitter taste, already referred to, which is often unfairly attributed to the hops, experience seeming to show that the evil is greatly caused by the action of the alcoholic fluid at high temperatures upon the dead or inactive yeast-cells of the protecting head or those still distributed through the beer. Generally speaking, a very good time for beginning this cooling down would be some twenty-four hours after the first skim, precautions being taken in very cold weather. It is more difficult to approve of the practice which some brewers adopt of keeping attemperators running right up to and during the first twenty-four hours of skimming. In beers so treated there seems a tendency, slight though it may be, to yeastiness of flavour.

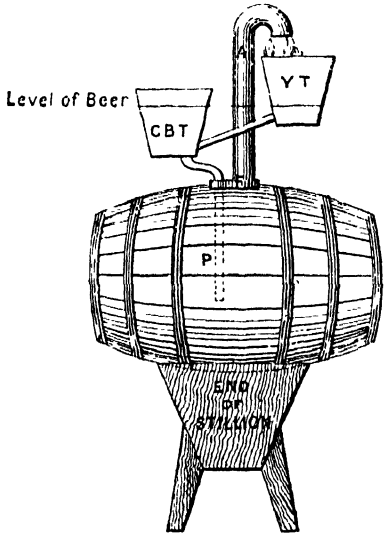
Dropping Squares or Rounds.—When these (which consist of a second series of fermenting vessels, similar in shape to those in which the fermentation is started but placed on a lower floor than they are) are adopted, the point of attenuation at which the wort is discharged from the upper into the lower series is that, or perchance a trifle higher than that, at which skimming would ordinarily begin; and if there are more tuns than one of the same class of beer to be emptied into a similar number of subsidiary or "dropping" vessels, the wort may be so run down as to blend in its passage. The contaminated first head will be left behind in the upper series of tuns; and though in cold weather there is a liability to a check of temperature, this will be amply compensated by the stimulus which the yeast receives from aeration and rousing.

Cleansing System.—This is the system originally mainly associated with Burton-on-Trent and elsewhere; and the essence of it is that the fermentation, though beginning in open fermenting-vessels as in the skimming system, is finished either in (i.) Burton unions, or (ii.) "loose pieces," with or without movable "swan-neck" pipes.

Cleansing in "Loose Pieces," or movable casks, holding generally a little short of three barrels apiece, is conducted on much the same lines as that in the now quite obsolete method of fermenting in carriage casks, except that they are not moved until the beer is racked out of them. And being always, when emptied, rolled out into the yard, they are capable of being thoroughly cleansed without the introduction of steam into the neighbourhood of fermenting beers, where it is objectionable. In this respect they have the advantage over Burton unions, and when fitted with swan-neck delivery pipes with feed-pipe combined, which do away with topping up by hand (often neglected at night), they are quite equal to

them in other respects ; indeed, we think, superior in this, that the swan-necks and feed-trough can be removed and cleaned directly the active ejection of yeast is over, the rest of the topping up, a very trivial matter, being done by hand. Those who are aware how contaminated soft wood (of which material the feed-troughs are made) becomes when in contact with putrescible and yeasty fluids, especially in the summer time, will see how important it is to avoid the risk of passing the later feeds through such a trough which has been in use all the time. Moreover, by moving them at a comparatively early stage, the same trough and swan-necks can be used twice or thrice as often as they could be otherwise.

These loose-piece swan-necks are often so arranged that the same trough serves both as yeast receiver and feed-trough ; but it is much better to have them quite distinct, the only necessary precaution being to have the bottom of the feed-trough some inches above the bunghole, so that the beer level may be well up the swan-neck pipe. The feed-trough (or tank) may be on the same side as, but at a lower level than, the yeast-receiving trough, or upon opposite sides, as in the sketch. The swan-neck pipe, A, has a tapering flange, F, which fits closely into the bunghole of the "Piece." The swan-neck is not fitted centrally in the flange, which it just penetrates, and through the wider part a small tube, P, passes, extending a foot or more below the flange and an inch or two above it —just enough, indeed, for a flexible rubber tube to be slipped over the projection and to connect it with the feed-trough or tank, C B T. There may or may not be a cock between C B T and P, but there should certainly be one between the feed-tank C B T and the yeast-trough B T.



The trough Y T, of necessity, and C B T, if a trough (but if a tank a long pipe from it), will run the whole length of the row of pieces, though for the sake of clearness only an end view, and that of one piece alone, is shown. Parts, however, which would be visible if the sketch were a sectional one are represented by dotted lines.

When the gyle (= the whole brewing) is cleansed, the racking pipe is put into the V T, whence it flows into C B T, which, as has been said, is connected with *all* the "pieces." The outlet cock from the fermenting-vessel on the floor above is then turned on, and the wort flows simultaneously into all the "pieces." Yeast will soon begin to pour out of the swan-necks into the yeast-trough, and beer (wort) will separate from it. The "drawings" (separated beer) can be run straight into the feed-tank, or, what is even better, into a small settling-tank, to precipitate the floating yeast, and thence into the feed-tank. The latter, if the settling-tank command it, can be kept at a constant level by means of a ball-cock arrangement. If the settling-tank (not shown in the sketch)

cannot be arranged to command the feed-tank, then it would mean additional can-work; but the importance of even a relatively bright "feed" is great enough to be worth this.

If the plan, referred to above, of removing the yeast-trough, feed-trough, and swan-necks when the fermentation has slackened (say two days after cleansing) be adopted, the pieces must stand upon a shallow stillion, or one of ordinary depth, which will receive any yeast which is afterwards thrown out.

When swan-necks are not used, or have been removed as suggested, a small protecting cap of yeasty matter will be left covering each bunghole.

Burton Unions.—With Burton unions the principle is the same, but there is a difference in detail. The swan-necks screw into metal bushes fixed in the bungholes, or what correspond to the bungholes; the casks are larger, as a rule, generally holding four barrels, and are enclosed in a wooden frame and supported by trunnions, which rest on bearings fixed on the said frame. The front trunnion has a square head, upon which a handle fits for the purpose of making the casks revolve when they are washed, which is always done *in situ*. The feed-pipes (of 2-inch bore) of Burton unions, instead of passing through the bungholes, as is the case with the "loose-piece" swan-necks, are connected by screw unions, which are permanently fitted in the heads of the casks slightly above the centre.

Burton unions are sometimes fitted with attemperators, which, if fixed, obviously increase the difficulty, already large, of washing them satisfactorily. Of course such attemperators are extremely useful for cooling down the beer when the fermentation has begun to subside, just as they are in the skimming system, but otherwise they are hardly ever necessary. If the temperature be moderate in the larger fermenting-vessel at the time of cleansing, the temperature in the unions can hardly ever rise unduly, taking into consideration the fact that the sub-division of the gyle into the smaller vessels, which are probably cooler than itself, generally induces a reduction of temperature.

Cleansed beers, especially Burton-union beers, are often not racked direct from the cleansing casks or unions, but are run into "settling-backs" or "racking-backs," which are now usually made of large slabs of slate. The uniformity of quality and of attenuation gained thereby are certainly beneficial, but the flattening and risk of contamination by exposure to a germ-laden atmosphere should, in our opinion, be minimised by using the tanks as "racking-backs" only, the beer being got out as quickly as possible. But if the tank be used as a "settling-back"—*i.e.*, as a vessel in which the beer is left for several hours in order that a certain amount of sedimentary matter may be deposited—a floating cover will intercept many of the contaminating organisms; yet, unless its cleanliness be very thoroughly assured, may cause as much harm as it prevents.

Skimmed beers in shallow vessels are sometimes racked on the sixth day from the date of mashing, even when the fermentation is of so slow a type that they have only "come upon the skim" on the third day, but will certainly rack the cleaner for a somewhat longer stay in the round and at temperatures reduced as low as possible; and all bitter ales and medium strong ales, especially in cold weather, should have at least another day.

Preservatives (mainly with a sulphur or a salicylic acid base), if they are,

used, *may* be added in the racking-back (if the preservative is in a fluid form), and thoroughly well roused with its contents—though it is far better to add them, albeit more troublesome, in the casks just before they are ready for shiving up. The use of such preservatives should be unnecessary for well-brewed running beers, but they are unquestionably useful, and largely used for those of a semi-stock character.

Yorkshire Stone-square System.—This system, however interesting in itself, need not detain us long. It is one which is hardly likely to be adopted save in response to local demands, and then only after investigations on the spot. The necessary number and costliness of the vessels are against it. Besides the number of the squares other facts tell against that thorough cleanliness so essential for all brewery vessels—viz., the liability of the stone slabs, of which the squares are constructed, to crack under the influence of boiling water (owing to uneven conductivity), and the readiness with which limestone, of which the slabs consist, is attacked by the sulphurous acid of bisulphite of lime ; so that practically strong solutions of the caustic alkalies are the only purifiers available.

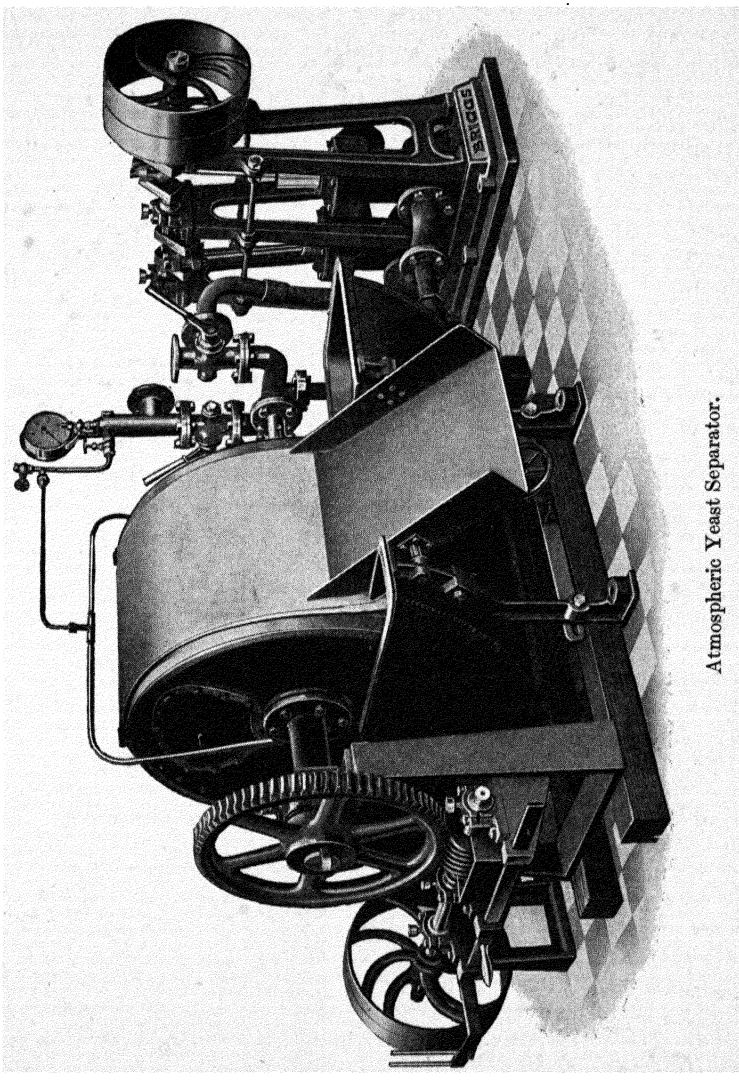
These are freely spread by mopping with *cotton* mops and left on for a considerable time—say two hours—so that a double inspection is really necessary before the brewer can feel sure of a thorough cleansing having been carried out. If this be consistently neglected a scale will form, behind which putrefying organisms will swarm and contaminate the wort. For such a dangerous scale chloride of lime solution, kept in contact for several days, is recommended as the best solvent ; but it is an unsatisfactory material to use where it cannot, from the nature of things, be followed by bisulphite.

The arrangement and method are as follows. The principal squares (which are never large, and are surrounded by another vessel containing water at moderately low temperature) are surmounted by much shallower squares, also of stone, and of the same diameter as that of the lower squares. The large slab which forms the bottom of each upper square also closes in the lower square, and has two apertures, one a " manhole," about eighteen inches in diameter in its centre, the other much smaller, midway between this manhole and the side, and fitted with a pipe which runs downward towards the bottom of the lower square. There is also a valve, which is closed at intervals, so that the feed (the upper square fulfils the part of the feed-tank of the Burton unions) can be made intermittent.

The worts are " pitched " in these vessels (though nowadays one large gathering square for a whole brewing would save an infinity of trouble in the matter of Excise declarations), the yeast being usually mixed with wort in the upper square, and then allowed to run into the lower, which has been filled or nearly filled. Periodical rousing, by means of a pump, the number of strokes given increasing with each repetition, is the corner-stone of the system. It begins between twenty and thirty hours after pitching with the pump-rousing of the contents of the upper square, which has had some inches of wort left in it, now, however, allowed, by opening the valve, to flow into the lower square.

Subsequent pumpings are from the lower square into the upper, whence the wort flows back into the lower again through the open valve ; these pumpings being continued at intervals till the degree of attenuation

is reached at which yeast begins to form. The yeast works out of the manhole into the upper square, and the beer or wort which separates from it flows back into the lower square through the valve. The latter is left open till the fermentation has nearly reached its term, when it is closed for good, any excessive formation of yeast being afterwards skimmed from the manhole. Owing to the enormous degree of aeration and the



Atmospheric Yeast Separator.

mechanical rousing which the fermenting worts undergo, the range of temperature can be very much restricted ; it rarely exceeds 6° as compared with the normal 9°, 10°, or even 12° of ordinary systems. This limitation of temperature has its advantage in the way of securing solid yeast without a tendency to liquefy in summer time ; the separation of yeast from the beer being, moreover, as a rule, facilitated by aeration.

Cleansing in Pontos.—This development of the primitive cleansing idea need not be referred to at length. It is dropping into disuse in London itself, and even for stout and porter, for which it is best suited, so that it is hardly likely to be taken up as a new departure.

Under, or Bottom Fermentation, and Sedimentary, or Low Yeast.—The system of under fermentation (*i.e.*, in which the yeast sinks to the bottom of the gyle-tun instead of rising to the surface) at very low temperatures is the sequel to the decoction system of mashing referred to on an earlier page, and is, perhaps, chiefly of importance to English readers from the fact that the voluminous researches of Continental inquirers, which are so frequently translated for our benefit, have been made mainly, if not entirely, with reference to this method and the type of yeast belonging to it. There is also the further consideration for large exporters that decoction beers, fermented on this plan, are, according to consular reports, gaining ground in many tropical markets, for which their low alcoholic percentage and light character unquestionably fit them, although, as has been pointed out, special " Pasteurisation "—or maintenance for a period at a temperature of 140° F., which for some reason or other has not answered with bottled " infusion-beers "—is required to make the article stable enough for long storage, even in ordinary climates.

Heat is kept down not only by the low temperature of the insulated fermenting-room itself, maintained at 38°—39° F. by overhead series of brine-pipes, but by movable attemperators in which chilled brine or ice-cold water circulates, a cleanlier and simpler means than the old metal vessels, filled with ice, formerly kept floating in the liquid.

The light head is never more than an inch or two thick. It may be that slow fermentations give better results in quality and flavour, but the ideal eleven to twelve days is in practice often shortened to a week, after which the product is let down into store-casks (barrel-shaped vessels of about 25 barrels capacity) lined with " pitch " or melted resin, renewed annually, to minimise leakage of carbonic acid. The pitching, whether the pitch be flared off or sprayed, as the later use is, must be completed out of doors, and the moving of the store-casks is a weighty operation. Before filling, " chips," long strips of hazel, sterilised if previously used, are added to afford attachments for the yeasty matter, and a mercuric pressure-gauge may be inserted for recording the rising pressure. A store-cask once tapped is emptied without delay. The cellar temperature is 32° F. or under.

Yeast Pressing.—Assuming for our purpose that a brewer without recourse to yeast pressing incurs a loss of 3% on the quantity of wort collected and finished beer racked. On the assumption also that by the adoption of yeast pressing he reduces the waste to 2%, the saving is obviously a barrel on every 100 brewed, which quantity the brewer obtains free of duty and without cost for materials. We are not contending that 36 gallons of brilliant filtrate will be secured from the yeast outcrop of a 100-barrel gyle ; we are merely basing our calculation on this favourable factor.

Advocates of the system aver that the barm ale recovered can, and is, sold at the full wholesale price obtaining in any particular area, and that the saving should be regarded as corresponding precisely with that figure, the only deduction from which should be the expenses involved

in working the pressing plant and, of course, the outlay in delivery. The former, as already indicated, is a question of no minor importance where due regard is paid to the numerous items of cost, as particularised. But it is a false theory to base the saving on the selling price of the beer. It is true that the brewer receives the full economic benefit of whatever proportion of the maximum Excise allowance for waste is reduced, but the only other economy is that from the saving secured of the cost of the materials employed in producing the beer recovered as yeast pressings. If a brewing is accidentally lost or spoilt, apart from the question of duty, the loss should not be based on the wholesale selling price on the assumption that the beer was available for sale distribution. In the event of a contingency occurring such as that mentioned, the brewer would at once proceed to make good his loss by replacing the beer wasted with another brewing, at the cost of precisely the additional materials employed to adjust matters. True economy of manufacture, however, cannot be assessed by viewing from the commercial standpoint alone. The technical aspect of the question must be also considered. In the arguments for yeast pressing a consideration of the general character of the filtrate appears to be ignored. It is assumed that the quality of the filtered barm ale is equal to that of the bulk of wort to which the filtrate is returned. The type of ale separated from yeast by means of the machines formerly in vogue had so little to recommend its addition to the ordinary brewery produce that on many occasions an examination of the filtrate prompted a resolution to discard it as the safest policy.

Separating Yeast by Centrifuging.—The mechanical separation of "barm ale" from skimmed yeast has been practised by brewers for generations. Filtration by pumping the yeast through a press upon which cloths attached to a series of plates placed vertically in an iron-ribbed grooved frame, capable of withstanding internal pressure, served its purpose, and the system is still practised in numerous breweries both in this country and abroad. Although a brilliant filtrate invariably results, this, however, is the only redeeming quality in an otherwise disappointing fluid of poor character. The flavour of the ale is harsh, acid, and intensely bitter, due to the pressure generated in the process rupturing the yeast cells, thus yielding their fluid contents, which, moreover, reduces the specific gravity of the filtrate, and it is seldom that the latter reaches to the fermenting-vessel at above 3 brewers' barrels. The filtrate is highly putrescible, and must be added direct from the press to common beers while these are undergoing the course of primary fermentation. It is no wonder, then, that in many instances brewers have discontinued the filtration of yeast by the type of plant briefly described, arguing that the labour required and the efficient maintenance of filter cloths were items of cost which discounted the saving accruing, and that whatever was gained in beer was lost in the lowering of the general character of the gyle to which the filtrate was added. An improvement on the filter in which the yeast, under pressure, is driven through a series of cloths is the Atmospheric Filter, worked on the vacuum principle. In this system the barm ale is separated *in vacuo* from the yeast, which is placed in shallow layers on cloths placed on perforated plates resting horizontally on the upper portion of the filter. The filtrate is less harsh in flavour than that obtained from the pressure plant, but the atmospheric

filter in some instances is not free from the fault of unreliability of results. In a still newer system the skimmed yeast passes direct from the parachutes to a receptacle, where the fluid portion is separated from the solid contents and the former is raised without loss of time by the compressed CO_2 naturally present to the fermenting-vessel, the contents of which are still in the height of fermentation.

The centrifuge principle of filtration has been improved enormously within the past year or two, and the appliance has been applied with complete commercial and technical success in a number of industries for the separation of minute solid particles from liquids, and even liquids from liquids in the case of emulsions, and the centrifuge has now entered the field against filter presses in breweries for the recovery of barm ale. Hitherto the cost of working centrifuges has operated against their more rapid adoption, having regard to the comparatively small quantity of yeast and beer which ordinarily requires to be acted upon in breweries. But in yeast factories dealing regularly every day with large bulks of produce the centrifuge has long been successfully employed, and in consequence details of its capabilities and calculations as to cost of working and maintenance, spread over a number of years, are now available for brewery, technical, and commercial requirements. The advantages of centrifuging is the cleanliness and extreme rapidity of the process, which enables the separation of yeast as skimmed off the fermenting-vessel and the return of the separated beer almost directly to its original-vessel; the brilliant filtrate, fresh and in an environment of carbonic acid gas, with very little of its original flavour impaired, reaches the fermenting-tun at the moment when admixture with the main contents is assured.

A knowledge of the principle upon which the centrifuge is worked is highly interesting. Its action depends upon, in the first place, the differential effect of centrifugal force upon the two states of aggregation, and the final discharge of the clear liquid from the bottom outlet upon the filtering action of the screen under the influence of the impelling centrifugal head. The filtering surface is maintained in a state of unimpaired efficiency by the automatic and instantaneous centrifugal transference of any deposited solid to the periphery of the machine, and requires practically no attention, the various manufacturers—there are several types of new-type machines on the market—claiming that in respect to the advantage just mentioned, and others, a centrifuge is superior to every other type of filter.

The top inflow of the mixture requiring filtration and the bottom liquid discharge set up a transporting current through the machine which results in a definite rate of deposit of particles of the same specific gravity in layers of zones, according to their size. This "grading" of the separated solids is of great utility in many instances, although in the brewing industry it is of less importance, except in that the lighter solid portions of beer and yeast, such as resins and amorphous substances of a colloidal nature, are separated from the heavier substances. The grading is under perfect control, being adjusted for different substances by the speed of rotation of the machine or the rate of input of the mixture. The cycle of operations is as follows. Assuming the centrifuge is empty at rest, the container fixed inside the cage, and the feed-pipe turned

on to the distributing plate, the clutch pulley is brought into engagement and the machine brought up to its working speed—from 1,000 to 1,700 r.p.m. The feed is then turned on and the mixture is allowed to flow in. After a certain time—from five to ten minutes—the catch plates are full of solid, the feed is stopped, and the machine is run for three to five minutes to allow the liquid still in the cage to filter through the screen and to compact the solids. The clutch pulley is then disengaged and the machine brought to rest by applying the brake.

A simple explanation of centrifugal force may be here given. If water be placed in an open can and the can swung in a vertical plane in such a way that the can is upside down in the top position, it is found that at moderate speed the water remains in the can and does not fall out. This is not because the time is too short to allow of such a fall, for if a tap be opened at the bottom of the can, water issues upwards from this when the can is in its highest position. This is a simple example of centrifugal force. It will be readily understood that the quicker the speed of rotation the more quickly does the water come through the tap. All hydro-extractors which expel liquids through openings in a rotating cage or drum apply this simple principle. There are far more hydro-extractors built and used of this form than of all other forms put together.

Racking, Fining, Storing.—Returning to infusion-beers, the temperature at which the beers are let down for racking into casks should not in summer exceed 58°, or lower if possible, and in winter should bear a closer relation to the mean temperature of the season. The contents of casks, when the racking temperature has been high, contract under the influence of cold, so that some flattening ensues ; moreover, the tendency to " kick-up " is (as has been said) greater in beers than have not been cooled, owing to the presence of certain protein bodies, which the higher temperature keeps in solution, and which consequently go out of solution in the cask itself, instead of being left behind in the fermenting or racking vessels, combined with the action of floating yeast, which remains suspended in greater quantity in the warmer fluid, and is stimulated by the inevitable aeration at racking.

Finings are now added before the beer is dispatched, a system that ensures greater regularity, and the brewer saves on every cask the quantity of beer displaced by the finings. A common fault is to add too large a quantity. A quart, irrespective of strength or gelatin content, we fear is the usual amount, and should be the maximum. All carriage casks should be shived with partially bored shives, which permits of the almost instantaneous formation of a spile hole, thus facilitating the injection of finings or ale for " topping up " prior to forwarding. " Finings " depend upon the mechanical action which dissolved isinglass exerts upon the suspended particles, more or less affecting the brightness of the racking sample.

Isinglass, of which the best qualities are simply the swimming-bladder of the sturgeon properly cleaned, is imported from Brazil, Russia, and elsewhere. **Penang** is a good variety. " Leaf 'glass "—as it is called for shortness—is a thin transparent variety, while " Pipe 'glass " has about the shape of a rather small sole, but is two or three times as thick. A fair amount of transparency should be looked for even here.

The isinglass is always dissolved by acids—tartaric, sulphurous, or, more rarely, acetic, as such.

The first-mentioned acids—tartaric and sulphurous—have each of them their defects as "cutting" agents. The former, though yielding an effective finings, encourages the development of mildew; the latter, though protective against mildew, produces a much less efficient finings. Isinglass "cut" with tartaric acid, to which a proportion of sulphurous acid is afterwards added, yields finings the power of which is not much lessened, while its resistance to mildew is sufficient for all practical purposes. Roche alum is sometimes added in the place of sulphurous acid.

Whatever the agent used, a series of tubs—hogsheads with their heads out—will be wanted. Sieves of varying mesh, fitted with revolving brushes, will also be required to rub the swollen isinglass through, the coarsest naturally being used in the passage from the first tub, or hogshead, to the second, and the finer ones in succession. The rubbing through sieves acrates the finings, and may perhaps be a factor in their action. The process should not be hurried, extending from a month or thereabouts to six weeks. In any case, the finings should be distinctly acid; neutral finings, advertised as containing no acids, are not to be recommended. The following are recipes:—

Sulphuric and Tartaric-Acid Finings.—To 7 lb. good isinglass, covered with water, add 1 lb. tartaric acid, dissolved in warm water, and 1 gallon to 1½ gallon of sulphurous acid, the latter added in small portions at intervals. Add fresh water as the isinglass swells. Rub through coarse and fine sieves, with intervals between each rubbing. Make up to 72 gallons.

Acetic-Acid Finings.—To 1 gallon acetic acid add 8 gallons of water; mix well, and add 8 lb. isinglass. Fresh water to be added every morning, and the whole to be well "rummaged" until of the consistency of cream. N.B.—1 lb. isinglass makes 10 gallons of finings.

Both of these finings will mix better if diluted with beer; and if two or three parts of the latter be added to one part of either of the above preparations, a quart of the diluted finings ought to suffice for a barrel of any beer. Any manufacturer of brewers' scientific instruments can supply a simple "viscometer" for checking the viscosity of finings.

Semi-Stock Beers—Storage.—Pale and other bitter and semi-stock ales are generally "hopped down" or "dry-hopped" with 1 lb. or less, per barrel, of hops, which ought to be of really choice quality. It is sufficient just to break them apart; in fact, the less they are rubbed the better, both because of the risk thereon depending of producing "fliers,"—*i e.*, small fragments of hop which draw up with the ale,—and of the danger of introducing more than the normal supply of disease ferments.

The casks of pale ale and other semi-store beers generally have, from exigencies of space, to be "ridden"—*i.e.*, piled some three tiers high. The plan has this disadvantage, that the porous spiles usually inserted cannot readily be removed and replaced by tight spiles—as should be done—directly their function is duly discharged; this function simply being to let off any great excess of carbonic acid gas, which may sometimes be generated in quantities powerful enough to bulge or even to force out the heads of casks. But anything resembling flattening of the beers should be avoided, the presence of the gas, even to the extent of excessive briskness, being preferable to the reverse.

The Burton brewers, as is well known, stack their ales in the open yard; but this plan is only adopted from exigencies of space, an equable temperature of 55° or 56° F. giving probably the most satisfactory results with semi-store or store beers. It goes without saying that their temperature at the time of racking should not exceed and may well be lower than the mean storage temperature; and there are good grounds for supposing that the maintenance of the latter at a fairly uniform point, such as the one indicated, is one of the requisite conditions for confirming the satisfactory flavour of the beer.

Our knowledge of the "**secondary**" or, as it seems preferable to call it, the "**complementary**" fermentation, which takes place after the beers are racked into cask, is as yet inexact; but we are free to suppose that a rise of temperature in the store stimulates the less desirable types of **secondary yeast** into activity, to the prejudice of the preferable types. That there is plenty of range between unsuitable and desirable types may be imagined from the fact that no less than *sixty varieties* of yeast alone have been identified in certain top-fermentation commercial yeasts; and this takes no account of other organisms, the bacteria producing lactic and butyric acids (Pasteur's *ferments de maladie*), which certainly have their influence, so detrimental to the stability of beers, enhanced by an elevated temperature.

And here we may perhaps anticipate what we shall have to say under the head of Fermentation, so far as to remark that whereas there used to be an excessive tendency, when M. Pasteur's epoch-making researches first came before the public, to attribute to the malign influence of bacteria all the ills that beer, and especially bad beer, is heir to, so there is now eagerness to attribute them almost entirely to the so-called **wild-yeasts** first differentiated by the distinguished Danish savant **Hansen.** This differentiation was effected by continued observation of the ways in which various types, carefully isolated, strive to provide for the continuance of their species, when existing in a condition utterly unsuitable for their development in the ordinary way—*e.g.*, by budding as yeast does. This "second string to their bow," as it were, which yeasts, and some bacteria, have as a protection against extermination, consists in the power to sporulate, *i.e.*, form spores, which may be looked upon as analogous to seeds, and which are capable of re-developing into ordinary cells when suitable nutritive conditions recur. In the case of yeast these spores are associated together in a cell, known as an *ascus*, within the yeast-cell itself, and are therefore known as **ascospores.** The production of ascospores, implying, as it does, an absence of nutrition, is accordingly a starvation phenomenon.

By observing the number of days in which ascospores were produced by yeast-colonies **grown from single cells,** and cultivated under artificial conditions (viz., on blocks of sterilised plaster-of-Paris, standing in shallow saucers of water and covered with a bell-glass), and at varying temperatures practically ranging between 37° and 95° F., and, moreover, by noting the periods at which **films,** or **pellicles,** are formed by such colonies on the surface of fermentable fluids within the same range of temperature, Hansen has been able to separate yeast into a number of varieties, one of which (**Saccharomyces Cerevisiæ**) is the alcoholic yeast pure and simple, while the influence of some of the other varieties is markedly unfavourable, either in the direction of producing a bitter flavour (yeast-bite) or turbidity.

Hence the idea of cultivating a " store " of pitching yeast from a single cell (of course of S. Cerevisiæ), which has been practically carried out by Hansen at the **Carlsberg Brewery in Copenhagen,** and adopted in many " under-fermentation " breweries.

For the English top-fermentation system it is alleged to be unsuitable, on account of the difficulty of inducing the essential complementary cask fermentation ; but it is noteworthy, as stated by Hansen, that the same objection was raised in the first instance by M. Jacobsen, the public-spirited owner of Carlsberg, and again, that this system of fermenting with yeast cultivated from a single cell is now in full swing in the top-fermentation breweries of the north of France, respecting which we shall have more to say later on. But the grounds on which its unsuitability is maintained may be briefly stated as follows.

Substances known as **Malto-Dextrins** or **Amylöins,** and alleged to be the final mash-tun products of the hydrolysis of the higher dextrins (*i.e.*, of the changes during which they absorb the elements of water), have been isolated from malt-wort. Further, the said malto-dextrins are apparently unfermentable by absolutely pure yeast (**Saccharomyces Cerevisiæ**), but are fermentable by other types, notably by one (**Saccharomyces Pastorianus II.**), and possibly by **Saccharomyces Ellipsoideus I.**

The elongated cells of S. Pastorianus may be observed in the deposit of really sound bottled ale, but two of its sub-varieties are credited with distinctly noxious influences (yeast-bite and turbidity respectively), and, similarly, a sub-variety of S. Ellipsoideus seems also to be a factor in persistent turbidity. Therefore, however desirable, nay necessary, the fermentation of the malto-dextrins in cask may be, the haphazard employment of all sorts of yeasts, some beneficial, others the reverse, seems but a clumsy way of obtaining it. The better way might be to start the primary fermentation with the type of *pure* yeast best adapted for splitting up maltose by the action of **Maltase** (present in yeast) into dextrose, and the latter into alcohol and carbonic acid gas, and to introduce at racking an equally pure culture of the secondary yeast most favourable to complementary fermentation. Note, however, that a torula isolated by Claussen, and by him named **Brettanomyces** (*v.* p. 329), is by him stated to be the factor in conditioning British store-beers.

Complementary fermentation is stimulated by rolling about the casks into which the ale has been racked, once a day at least, for several days ; and this rolling is of great utility when the beer is required to " come round " quickly for bottling purposes. Indeed, a beer that has not acquired cask condition, is not really fit for bottling, the true criterion of fitness (ripeness) being spontaneous clarification, the ale falling, as is said, " starbright."

The brilliancy noticed at the moment of re-racking of a " racked bright " beer speedily gives place to a perceptible haze, doubtless due to the fact that certain previously dissolved protein constituents are thrown out of solution by the oxidation which has taken place, and which the beer, deprived by the racking, fining, and re-racking of a portion of the carbonic acid gas, its natural protector, was unable to resist. A similar result will supervene in bottle when the brightening has been unduly hurried. Either a copious precipitate will be formed, or the ale, freely oxygenated, will leave much to be desired in respect of brilliancy.

Priming, etc.—It is now the general custom of brewers to prime their ales and black beers, especially the latter—that is, to add a solution of some sort of sugar to the finished beers with the object of imparting body or briskness, or both. Excise regulations will only permit a solution having a specific gravity not exceeding 1·150 (water=1·000), which can be made by diluting a portion of standard syrup, weighing 14 lb. per gallon, with *twice its volume* of water. It is desirable, however, not to get the specific gravity below 1·150°—or, as it is called for brevity, 150°, dropping the 1·000°—which is in itself too low already for the most effective results to be attained. The sugar used may be glucose, if briskness rather than added sweetness is desired; but if it be wished to make the beer more luscious on the palate, then "Invert-sugar" is the material to employ (the lævulose, which forms some 50% of it, being less susceptible than its remaining glucose to speedy fermentative changes).

Vatted Beers.—Though vatting, as a practice, is very considerably on the decrease in all districts and unknown in some, there is still sufficient demand for old vatted beers in the West of England that we cannot altogether pass them over. But there are vatted beers *and* vatted beers. The desire for a more rapid turnover of capital, and the concentration of business in the hands of large firms, has tended to modify the character of vatted beers, which instead of being, as of yore, of very high gravity and supplied to customers unblended, "one way" as it is locally called, are now valued chiefly for the character of age which they impart to the running beers with which they are blended. And as they are blended in proportions often not exceeding 25% of old to 75% of new, it is obvious that the old ethereal vatted character is a secondary consideration; the first requisite being that the vats should come into rapid blending condition, which implies a high degree of acidity, short of sourness however, coupled with absolute brilliancy,—results which are generally secured by fermenting beers of no remarkably high gravity at high temperatures, and supplementing this with rousing and aeration.

But real vatted beers, on the other hand,—*i.e.*, beers brewed to keep in vat—should never show an excess of acidity beyond what the gravity can easily carry. If of high gravity—and high gravity is a *sine qua non*—they become mellow and vinous, and far more exhilarating with age, in spite of the fact that their alcoholic percentage may actually diminish, or, at any rate, not increase after the stage of vat maturity is reached. This stimulating quality has been attributed to the formation of certain aromatic ethers, amongst which that of ethyl acetate—formed by the action of acetic acid upon ethyl alcohol (the ordinary alcohol of fermented beverages) and of ethyl butyrate (which in its pure state is used to flavour "pineapple" rum)—may be mentioned as theoretically possible. Acetic acid, the product of the oxidation of alcohol, is always an increasing quantity in old vatted beers, so that the above-stated view respecting the formation of compound ethers is not necessarily shaken by scientific evidence respecting whisky, in the case of which similar changes were apparently incorrectly thought to take place.* Nor should the possibility

* Dr. Bell, examined before a Parliamentary Committee, stated, in answer to Sir H. Roscoe, that compound ethers and higher alcohols were not increased in whisky by age; that a slight change took place in the acids, but that the increase in value which

of the action of this acid, or of its aldehyde, upon any unfermented residue of maltose, resulting in the formation of ethereal compounds, be altogether overlooked. However this may be, it is certain that by age strong, well-brewed vatted ales and stouts acquire a flavour attainable in no other way; and accordingly a chance may occur for cultivating a trade in this description of ale, or, what is more likely, that it may be wished to keep vats of strong old stout for blending with running black beers.

Stout Vatting—Keeping up Vats.—If the ordinary English system be followed, vatting is perhaps the only way of getting that amalgamation of flavours which characterises a perfect stout, that slight sub-acidity combined with palate fullness and that close and creamy head, or, in the case of English stouts, rather that close *brown* head so admired by connoisseurs. Accordingly a blend of a vatted stout, having a high original gravity (the higher the better), with a sweet running porter of low gravity, will certainly give far better results than a single stout sent out unblended. A few words, then, as to the best method of keeping up the uniform standard of the vatted product.

The best plan for that purpose seems to be that two, three, or more vats, according to the trade, of similar quality should be on hand; that when one of the vats is fit for use, a portion of its contents, not exceeding one-fifth, should be drawn off and used, after which the ullage should be made up as rapidly as is convenient with new beer of the same quality; then the second vat should be drawn upon to the same extent, and filled up likewise; after which comes on the turn of the third vat, or if the trade be small, of the first vat again, and so on. Ultimately, of course, the vats ought to be drawn off completely and thoroughly cleaned; but if "ullages" be carefully avoided, they can be many times refilled.

We have now gone through—cursorily, of course, in most instances—all the usual operations in the malthouse and the brewery; and though we may have possibly turned aside occasionally to give explanations or illustrations a little apart from actual practice, albeit intimately connected therewith, the section in the main deals with manipulative details, and thus clears the way for the consideration of more advanced problems or more exhaustive treatment in later chapters.

takes place in "pot still" (and to a much less extent in patent-still whisky) is due to the disappearance of empyreumatic oils, perhaps as a result of oxidation; though as to the method he could give no opinion.

CHAPTER II

BARLEY, MALTING AND MALT

BARLEY THE PREFERABLE GRAIN—SIX-ROWED, FOUR-ROWED, AND TWO-ROWED BARLEY—"ESCOURGEON" AND CHEVALIER BARLEY—ANATOMY OF THE BARLEY-CORN—CHOICE OF BARLEY—OVER-RIPE GRAINS—TESTS FOR GERMINATIVE POWER—SITUATION OF MALTHOUSE—ITS CONSTRUCTION—PREVENTION OF MOULD—IDLE CORNS—KILNS AND KILN-DRYING—LAST'S PATENT VENTILATORS—CONSTRUCTION OF KILNS—FURNACE AND BAFFLE-PLATE—MR. FREE ON MALTING—KING'S AUTOMATIC REGULATOR—DOUBLE KILNS (STOPES')—CHEMICAL RESULTS OF MALTSTER'S OPERATIONS—SECRETION OF DIASTASE AND OF A CELLULOSE-DISSOLVING ENZYME—PEPTASE—MESSRS. BROWN AND MORRIS'S CONCLUSIONS—MR. J. O'SULLIVAN'S VIEWS—ASPARAGIN—DATA FOR JUDGING GOOD MALT—PNEUMATIC MALTING—ECONOMICS OF MALTING.

BARLEY, owing to the quantity of starch it contains, and the activity of the diastase, is by far the most important grain for the purposes of the maltster and the brewer. It belongs botanically to the family or natural order of the *Graminæ*. The generic name is *Hordeum*.

In some varieties groups of three flower-bearing spikelets are found alternately on either side of the central rachis, each of which is fertile. When this is the case the **six-rowed barley** (represented by two varieties, *Hordeum vulgare* and *Hordeum hexastichum*) is produced. When the two lateral spikelets of each triplet are infertile, then a **two-rowed** barley results. The varieties of the latter used in Great Britain are represented by **Chevalier,*** having a relatively narrow ear with long internodes (*H. distichum*) and **Goldthorpe,** a wide-eared barley with short internodes (var. *H. zeocriton*), developed from the old Fan or Peacock sort. Sundry crosses of these (*e.g.*, **Standwell**) are cultivated. A firm of well-known seed specialists have succeeded in producing a six-rowed Chevalier; it would perhaps, then, be more correct to say that the lateral rows of a two-rowed barley are in a state of dormant fertility rather than actually infertile. Natural cross-fertilisation probably never happens, because the organs of reproduction are enclosed in cuticle until fertilisation has been effected, so that extraneous pollen cannot influence it; but artificial **hybridisation** offers some interesting problems. It was, for instance, found that a "strong reaction," got in crossing widely divergent types, gives richer results than a cross between two closely resembling sorts, albeit a careful watch has to be kept on the many times recultivated progeny so that any plantlets showing defects—*e.g.*, weakness of straw—may be rejected, and permanence of the best type secured. An unfortunate cross, made with the best intentions, may cause reversion to a remote type of an undesirable progenitor.

The so-called **four-rowed barley** is not now supposed to be a distinct

* This barley was originally cultivated by the Rev. John Chevallier. The Trade generally, however, continue upon all occasions to employ the French orthography—"Chevalier."

variety, but *Escourgeon* (winter French) has its clefts curved (and dividing grains unequally) like the seeds from the lateral rows of six-rowed ears. Thus in a sample of *H. vulgare*, free from admixture of any two-rowed sort, the proportion of curved clefts to straight (those of the central row) are about 2 : 1. **Californian and Chilian Chevaliers** often have admixtures of *H. vulgare*, a six-rowed type ; while some oriental barleys, consisting mainly, as do " brewing sorts " generally, of *H. vulgare* or *H. hezastichum* (" brewing " Chilian) have intermixtures of two-rowed. **Ouchac** is a two-rowed sort, supposed to have been first seeded from Chevalier, but not free from admixture. Goldthorpe's may generally be distinguished by a bristly **rachilla** (the spikelet attachment springing from the **rachis** or central axis of the ear), true Chevaliers by a nearly smooth one, but not uniformly.

Awnless barleys are known, but, though long, tough awns tend to lever off the end of the outer palea to which they are attached, they probably serve some useful purpose.

We have pleasure in submitting in the succeeding pages probably the most comprehensive list of Colonial and foreign barleys, with their characteristics, yet published, and supplied by the courtesy of Charles E. Sutcliffe, Junr., of Mirfield, Yorks.

Anatomy of the Barley-Corn.—For a minute description we shall refer our readers elsewhere,* but for a due understanding of the chemical and other changes which are the result of malting, it will be necessary to deal briefly with this part of the subject.

The first thing to notice is the husk, consisting of the **paleæ**—outer and inner palea ; the latter being on the cleft or **ventral** side, the former on the side where the acrospire grows, or **dorsal** side, overlaps the inner palea. Beneath the paleæ are two skins, the very delicate **pericarp,** and beneath this the third skin, the **testa.** Both under the microscope exhibit cellular structure, the elongated cells of the former lying in the direction of the length of the grain, while those of the testa are more or less at right angles to it. The larger portion of the grain beneath these skins consists of the **endosperm,** the white and floury portion containing the bulk of the starch granules, interspersed with nitrogenous matter, packed within compartments, so to speak, of cellulose.

At one end of the grain is the **germ,** consisting of the **acrospire** or **plumula,** with the embryo rootlets. This is separated from the endosperm by the **scutellum,** the membranous lining of which, called the **epithelium,** supports a layer of cells emptied of starch.

It only remains to mention the **aleurone** layer, fairly conterminous with endosperm and germ on the dorsal side, a layer of small irregularly angled cells, having dark-coloured granular contents within thickened cell-walls. The contents seem to consist mainly of proteins and fatty or oily matters, but appear to be insensitive to Millon's reagent, the recognised test for proteins. The purpose served by this aleurone layer was long doubtful, but the researches of Mr. Horace Brown and Dr. G. H. Morris tend to show that it contains a reserve store of nutriment for the *late* use of the young plant.

* Probably no better general guides can be got than Messrs. Matthews and Lott in their book, " The Microscope in the Brewery and Malthouse."

Accordingly, it is not until the endosperm has been nearly exhausted of its starch (at a stage of growth far beyond that allowed in the malt-house, when in fact the young plant has attained a growth of nearly four inches), that the aleurone cells show marked signs of dissolution.

The operations of malting should not be regarded as isolated; they comprise merely the first, though by no means the least important, steps in the wider process of brewing, and the criterion of success is to be found rather in the superiority of the final product, beer, than in the closeness with which the article malt approaches any given standard.

Thus in certain years a large degree of growth may be most desirable; in others, when the malt in the mash-tun undergoes hydration with greater, and in some cases, with almost too great facility, a less degree of growth would suit the circumstances better. This readiness of hydration, or, in other words, this capacity for yielding a wort rich in maltose, and therefore of a highly fermentable character, is doubtless dependent on conditions other than the growth of the acrospire alone, and indeed rests upon vital conditions of the plant itself, which we have, in general, but limited means of gauging. But we may safely conclude that, under certain circumstances, *e.g.*, a favourable seed time, a sunny, genial summer, a sufficiency of rain to keep the plant in vigorous growth, and a dry harvest, the amount of starch stored up in the cells of the grain will exist in a much higher ratio to the nitrogenous constituents than in dull, cold, and rainy seasons.

We know that starch is formed in plants from carbon, derived from the carbonic acid which plants separate from the air; that the chlorophyll of their leaves, under the impulse of sunlight, in some mysterious way forwards this carbon to be combined with fresh oxygen and hydrogen (elements of the water which the plants imbibe) to form starch, which is then stored away in the plant, as the cells which make up its tissues are formed, and it is therefore not hard to see why in dull and wet seasons—moisture in itself being an all-important factor in dissolving matter and thereby making it assimilable by plants—the nitrogenous constituents of the soil should be much more largely represented in the grain than is the case in seasons of ampler sunshine.*

British Malting Barleys.—The points of a good malting barley are: (1) Good condition, by which is meant dry, well-handling grain free from any smell of heating or of mould, and with no trace of growing grains; (2) bright colour; (3) absence of cracked or skinned corns or grains, and of grains of which the germ has been injured or removed in threshing;

* But it has been noted where the chlorophyll-amount, evidenced by deeper green plants, is high, as at edges of plots or in patches where seeds have been destroyed, that the nitrogen percentage of the grain will also be higher than in the rest of the crop. The coincident ranker vegetative growth, with coarser grain, affects the physical condition of the starch granules, perhaps accentuating differences in the "physical texture" of parts of the same granule, which modern research detects (*v.* pp. 43-44), thus rendering the conversion-products more difficult to obtain, and necessitating *forcing* treatment on the floors. Loss of extract is here involved through increased "respiration"; moreover, it is calculated that fully 62% of the nitrogen-bodies, unlike the carbohydrates they replace, are removed by rootlets, held back in "grains," or precipitated on boiling, diminishing the extract by perhaps 2 to 4 brewer's lbs. per quarter, *at the temperature of the British mash-tun.* So, though Prof. Wahl, of Chicago, claims to show that a malt from a barley with over 15% of proteins may, with proper handling, yield a beer sounder and more resistant to chill than one from a barley with 10% (the limit of Windisch and other Germans), the older view will be assumed in the next few pages.

(4) Evenness in size; (5) finely wrinkled or curled skin, which denotes good ripening; (6) the grain, when cut across, should exhibit a white, mealy surface; (7) plump and full grain, inasmuch as the larger the grain the lower the ratio of crude proteins, and the higher the ratio of starch.

Spratt-Archer.—The grain is slightly larger and brighter coloured than Archer; finely wrinkled skin. A hybrid variety obtained by crossing Archer and Spratt; more prolific and of higher malting quality than Archer, and earlier ripening.

Broad-eared Varieties—Goldthorpe.—The grain is large and well coloured. One of the best broad-eared varieties in regard to both yield and malting quality. Earlier ripening than Archer, and slightly earlier than Spratt-Archer.

Plumage-Archer.—Grain large, good colour, and finely wrinkled skin. A hybrid variety raised by crossing Plumage, a broad-eared barley, and Archer. In yield and quality occupies a leading position among present-day varieties.

Archer-Goldthorpe.—Grain is large, good colour, and very finely wrinkled skin. A hybrid variety obtained by crossing Archer and Goldthorpe. In yield not equal to Spratt-Archer, but in quality it equals, or possibly exceeds, that variety.

Maltster.—The grain is large and of good colour. A hybrid obtained by crossing four varieties. The malting quality is good.

Spratt.—This grain is large and coarse, and mainly of feeding quality. Spratt produces heavy crops usually.

1917.—The grain is large and of good colour, but the quality is inclined to coarseness.

Autumn-sown Varieties.—Varieties of this class are distinguished from those sown in the spring by the character of the ear, in which there are six rows of fully-developed grains instead of the usual two. Two well-marked divisions of winter varieties exist, one similar to the broad-eared varieties in the two-rowed classes in so far as the grains are set closely together on the stalk of the ear, and the other similar to narrow-eared varieties in the greater distance between the grains in the ear stalk. Both the divisions are usually known by their botanical names, *Hordeum hexastichum* and *Hordeum vulgare*, but the latter has the addition of the much commoner names of "bere" or "bigg."

Dense Ears (analogous to broad-eared varieties), *Hordeum hexastichum.*—A good winter hardy variety, the grain of which is fairly large. The crops obtained are heavy, and the quality medium to very fair quality.

Lax Ears (analogous to narrow-eared varieties), *Hordeum vulgare*, "bere" or "bigg."—The grain is of fair size, but somewhat uneven in shape, owing to the twist in the four lateral rows of the ear. It is a good winter barley variety, producing heavy crops of grain of from medium to very fair quality. The grain of both classes of winter barley is liable to be thin, and not, as a rule, of particularly good malting quality, but on suitable soils heavy crops are produced which, if not up to malting standard, can be used for feeding. Winter barley resembles the varieties usually sown in spring in its inability to exist in badly-drained soils, and as, naturally, to live through the wettest months of the year, this essential condition of well-drained soil must not be overlooked.

(1) **Factors which contribute to produce Barleys having high Nitrogen Content.**

(*a*) Too rapid or delayed maturation.
(*b*) Hot and dry season.
(*c*) Wide planting, with resulting lack of root competition.
(*d*) Too rich or heavy soil.
(*e*) Excessive use of nitrate manures or nitrogenous fertilisers used alone without admixture of other manures.
(*f*) Large and coarse corns.
(*g*) Original strain or breed (if high in nitrogen).

Some of these factors are avoidable, and others, such as weather, are not.

(2) **Qualities usually associated with Barleys of high Nitrogen Content.**

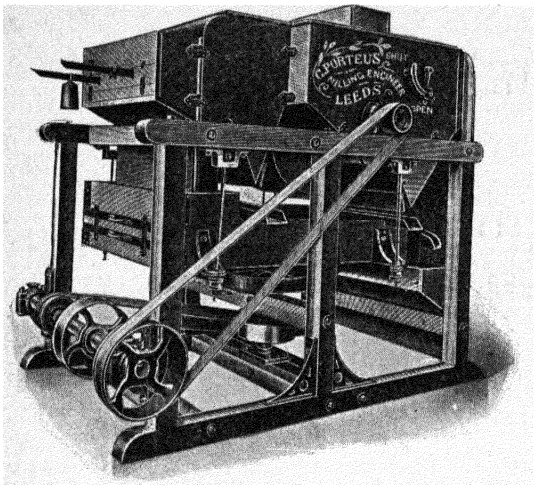
(*a*) High tillering rate when sown.
(*b*) Lower extract in resulting malt.
(*c*) Defective maturation.
(*d*) Steeliness.
(*e*) Lower bushel weight.
(*f*) Larger corns and higher density.
(*g*) Tendency to heat on malting floor.
(*h*) Greater loss by respiration on malting floor.
(*i*) Sluggish modification when malted.
(*j*) Higher nitrogen in finished malt.
(*k*) Higher soluble, uncoagulable proteins in wort.
(*l*) Tendency to fret and haze in finished beer.
(*m*) Tendency to better head retention in finished beer.
(*n*) Lower ratio of grain to straw.

With reference to **the soil** upon which the most suitable barley is grown—and some knowledge on this point often determines a purchase when buyers are well acquainted with their district. We may perhaps quote from one of us what was written thereon in the article referred to in a footnote.

"Barley grown on sandy loams or land with a calcareous subsoil generally answers best in ordinary years. The soil should be moderately cohesive, well drained, though not excessively dry. In hot, dry seasons, however, very heavy barley of good quality may be secured even upon cold and heavy soils." As no cereal perhaps shows more readily than barley the effect of manure in determining a plentiful yield irrespective of quality, so the heaviest crops of barley are got when it is sown after turnips, fed off upon the land. Where, however, the lease allows it, and the land is good enough, it is of far finer quality when a crop of wheat is interposed. The wheat, coming after the turnips, makes good use of the plentiful fertilising matter in the soil, and as it roots deeply, while barley roots comparatively shallow, they derive many of their inorganic constituents from different *strata*. The barley grown after wheat, then, is the brightest in colour; but to raise it successfully requires a good cultivation of the land, as well as liberty to deviate from the ordinary four-course rotation.

The succession of barley to wheat makes it a matter of some difficulty to eradicate weeds. Factors, not unimportant in the production of a good sample of barley, are the **quality and quantity of the seed-corn** employed.

Many farmers are still so unenlightened as to think that the "off-corn" (tail barley) or any rubbish available is good enough for the purpose, while excess in quantity * militates against that free "tillering" which so helps the development of the plant. "On the whole, light lands yield a barley richer in starch, or, what is equally important, whose starch-cells are not so crowded together by the pressure of a thick husk or cell-walls as to be obdurate to the successive influences of the malting and mashing processes.



Barley Dresser.

Heavy lands, or those heavily manured with nitrogenous *excreta*, will produce such unkindly, steely barleys, over-rich in protein bodies. It has been proved, over and over again, that the nitrogen in the grain increases with the quantity of the nitrogenous constituents of the soil; in excess—and this applies still more forcibly to chemical manures, such as nitrate of soda or ammonia salts—nitrogenous manures stimulate an excessive development of straw, whereby the barley easily gets "laid" before it sears have stored up their full supply of starch.

Grading.—A uniform sample generally weighs better than one in which small and large grains are intermixed. Irregularly developed grains, even of the same growth, will germinate irregularly; and it would certainly be preferable to mix growths uniform in size and general character, than to steep barley, just as received, without removing "the tail," by grading or screening.

Over-ripe grains, moreover, will lose germinative power to the extent of 50% in extreme cases, but unfortunately over-ripeness is a defect not very easy to detect. On the other hand, **barley cut before it is ripe** always grows badly, frequently turns mouldy on the floors, and has a strong tendency to heat in store. Such barley, however, may be detected by its shrivelled husk, want of plumpness, and, most of all, by its greenish colour. Sometimes a sample of barley gives evidence of two distinct growths having occurred in the same field, caused probably by uneven sowing. The **skin** should be thin and slightly wrinkled; rough, harsh skins indicate barleys which will be sluggish to work, and will give dissatisfaction in the brewery; a barley with a good skin and in good condition flows easily through the fingers when handled.

Note should be taken of any **admixture of other grain,** such as wheat

* Three bushels of seed per acre (plants 6 to 8 inches apart) give good results as regards "kindliness." Thin seeding, especially on strong soils, is wrong. In an extreme case (plants 15 inches apart) a huge crop of straw with very large coarse grain resulted.

or oats, also of the presence of the seeds of vetches or weeds, which lower the value of the sample, and which there should be machines in every malthouse to remove. Cracked or broken grains, if numerous, ought to influence the rejection of a sample, being great encouragers of mildew. Grains, broken in halves, are most frequent after very hot, dry summers. **Skinned grains** (the husk having been skinned off by setting the threshing machine too close) are worse than broken grains, because no machine yet invented can remove them. **Blackened tips** show that the grain has heated in stack, and become what is termed "mow-burnt."

Reddish* or bluish spots indicate germination on the stalk before harvesting, or, at all events, unfavourable conditions at maturing. Such a growth is likely to occur when a harvest-time of prolonged wet follows weeks of heat, as was the case in 1881 ; but heating in stack is a result of the grain being carried too soon, to which there is indeed great temptation in wet harvest weather, though that is the very time when less hurry and a larger amount of field-room is required to thoroughly kill the increased undergrowth of clover.

Apart from the added difficulty of drying up the undergrowth, a shower of rain does barley no actual harm. Some indeed hold that the grain which has been subjected to a moderate shower is mellowed thereby, and rendered more "kindly" to work on the malting-floors ; others think that the same effect attends the night-dews, which settle so heavily after a warm summer's day, and which, of themselves, deepen the hue even of first-rate barleys towards the end of harvest.

Apart from the indications referred to above it will be necessary after a wet harvest to keep a sharp lookout for **grains which have already germinated,** in which case floor germination may not, and often does not, occur. In extreme cases rootlets may still be perceptible adhering to the grain, or they may have been rubbed off by chance or of malice aforethought. In that case a broken appearance of the germ end, where the rootlets have protruded, and a faint swelling of the acrospire will be the only indications. It is, however, far better to make purchases only of respectable vendors (nor will these cautions even then be thrown away), for rogues will generally endeavour, even when the sample has been satisfactory, to send in the bulk of inferior quality, and the transaction thus occasions positive loss or annoyance, and inconvenience if the bulk be rejected.

The contents of a grain of barley bitten or cut across should be white, floury, and mellow, neither glassy (vitreous) nor of a bluish tinge ; in other words, the barley should be kindly. Glassiness of the interior is an indication of the grain having been grown upon a soil too rich in nitrogen ; or

* Red mould on barley is actually due to *Fusarium hordei*, of which Messrs. Matthews and Lott, in their valuable work, "The Microscope in the Brewery and Malthouse," say : "It is occasionally seen among inferior samples of barley, appearing as a crimson or pink-tinted patch on defective corns, usually at the germinal end ; fortunately it does not spread to healthy corns, but it may be communicated to crushed ones." Its appearance, however, is quite familiar enough on growing floors at times. Jörgensen, referring to Matthews' researches on this mildew, says that probably its spores are of greater weight and adhere more closely to the original mould growth than the spores of other organisms—*e.g.*, penicillium, mucor, and aspergillus, which are very readily disseminated. The student is advised to study it under the microscope, using the one-eighth or one-tenth objective. Its crescent-shaped spores form a capital object, and are not to be mistaken for those of any other mould.

it might be suggestive of excessive artificial drying (sweating), possibly sufficient to injure the germinative power.

Tests for Germinative Power.—The vitality of the germ may be decided, Stopes points out, by removing with a knife the skin over the germ end and then observing it with a weak lens. If alive, the germ has a juicy, fairly firm, yellow appearance, like freshly churned butter, or greenish-yellow, like wax. If it be reddish-brown, dark or black, dried or shrivelled, it is *dead ;* if grey, of *low vitality.*

A correspondent recommends that to facilitate inspection of the germ, a handful of the grain should be put into a glass of boiling water, in which some washing soda has been dissolved. The outer husk will soon split, it is said, and can be removed by careful washing.

The above writer (Mr. Stopes) also gives what he calls a " fire-test," directing it to be carried out as follows. Take from a clear fire a large red cinder, which should be kept by an artificial blast at a uniform heat. Drop the kernels on, one or two at a time. If the corns dance about they may be taken as alive, those that cremate passively are dead. The above manipulation seems a little crude ; an iron pan, heated to redness over a Bunsen burner, would surely answer better.

Of other tests for germinative power, the only one perhaps which does not take too long for the purpose of forming an immediate opinion is that devised by **Haberlandt.** First of all, however, it should be repeated that the embryo (visible to the naked eye if the grain be cut in two endwise) is situated at that end of the grain from which the rootlets protrude. It is the plant in miniature, with dormant stalk and rootlets, ready to start into life under suitable conditions. According to Haberlandt, an inspection of the embryo with the microscope, or even with a hand magnifying-glass, will decide the germinating power of the grain with tolerable accuracy.

When a section is taken, he goes on to say, of any healthy embryo, the rootlets look greenish or pale yellow (sometimes distinctly yellow) the plumula being a fair yellow. If treated with sulphuric acid, the yellow colour becomes very distinct in grains of healthy germinative power after two to five minutes, while if the process be continued five to ten minutes, the embryo assumes a rosy-red hue. In grains, on the other hand, which have had their germinative power weakened or destroyed, the rootlets are of a dull yellow or grey, bluish-grey, or brownish, while the plumula is either of a dirty grey, whitish, or brownish hue. The more completely the germinating power has been destroyed, the darker is the colour, as a rule.

This test, whatever it may be worth, is easily applied. Our experience with it, however, is that the change of colour to something approaching rosy-red occurs much more speedily than in five minutes. One obvious drawback is that it is quite impossible to assure oneself by collateral experiment that the grains which come well out of the test really possess (though it is most probable that they do) the germinative capacity claimed for them. There are also " germinators," obtainable from dealers in brewers' and maltsters' instruments, in which 100 corns can be tested. These, however, are only of service when time for germination is available.

Coldewe's Patent.—A useful apparatus giving as speedy results as possible where the question has to be answered by actual germination, consists of a porcelain tray, having a hundred indentations, into which

as many grains of barley are placed, germ-end downwards. A glass vessel, into which the tray fits resting on a ledge moulded to receive it, is nearly filled with water. A little sand is placed round the barley, a piece of felt put over to prevent too much evaporation, and the whole apparatus is then placed in a moderately warm situation.

The actual routine of malting, with a few simple, practical hints thereon, occupied part of the first chapter ; sundry points, however, require further development.

Situation of the Malthouse in relation to that of the Brewery.—It is nowadays customary and highly convenient to construct a malthouse or malthouses in line with the brewery itself. This not only gives uniformity of façade, but saves labour in more ways than one. A line of rails running into the brewery yard can be used to bring in coal and barley ; power for hoisting barley can be got from the brewery engine or an independent gas-engine, of *ample power* if only a sufficient pressure of gas can *at all times* be relied on, or preferably from electric motors ; and the malt, measured up for each day's "grist," can be conveyed by means of an elevator or screw directly into the "hopper," which feeds the malt-mills.

With regard to the **space required for cistern, couch** (which, though not obligatory, as of old, is still often used), **and working floors,** Mr. Scamell gives for the cistern about 12½ cubic feet per quarter of barley, for the couch 13¼ cubic feet, and for the working floors from 180 to 200 square feet for every quarter. A later authority says that a 15-quarters house should never have less superficial area of combined couch and floor room than 2,600 feet, if in the south of England, or 2,400 in the north of England or Scotland. This is only 173 to 160 feet per quarter, couch space included. In another place, however, he says that 180 feet is probably the safest average ; and that in the construction of the cistern it is not wise to allow less than fourteen cubic feet per quarter.

He would allow a large malthouse a width up to 50 feet, beyond which structural inconveniences occur, as well as the difficulty of keeping the growing floors at a uniform heat, which difficulty is found, the first authority cited holds, in widths of over 40 feet. But this must depend a good deal on the freedom of the ventilation. [The proportions of kiln-floors will be treated later, p. 5.]

Tiles are freely used for working-floors, but, unless most accurately laid, have this drawback, that the jagged edges formed will catch the turning shovel at almost every forward movement, and thereby cause the crushing of many grains, besides harbouring putrescent matter. **Stuart's granolithic flooring,** a sort of hard concrete laid in large slabs, is excellent. **Cement** is held by some to promote a rise of temperature. Nor is iron, as a material for cisterns, theoretically right, it being of great importance to keep the temperatures of the steep liquor from approaching freezing-point. Brick, lined with concrete for economy, or with glazed white tiles for efficiency and cleanliness, is a preferable arrangement. This is as regards rectangular cisterns, but the cone-shaped cisterns referred to in Chapter I. have so much in their favour, that one would think twice before constructing a cistern on the older pattern.

Sweating, Steeping (Bohemian Method), Sprinkling.—Sweating of barley on the kiln, if necessary, should be carried on at a temperature not much exceeding 110° F., the barley under treatment remaining from

eighteen to even thirty-six hours on the kiln ; and it is doubtful whether grain, which has already begun to grow, would be benefited by a sweat ; certainly, in that case, for safety's sake, the heat employed should be extremely moderate. But the value of " sweating " lies in the fact that the moisture content of every corn is reduced to one uniform standard, ensuring more equable absorption of water in the steep. **The temperature of the steep-liquor** is also, as has been said, a point worth attention. In winter it is often far too low, seeing that a temperature approaching freezing-point seriously imperils the vitality of weakly grains, and must delay the germination even of the stronger. A temperature ranging from 50° to 55° F. is a good mean, and the thermometer may be advantageously used at intervals. The **duration of the steep** is, luckily, an open question now (see p. 6). In **Bohemia** a method, involving double steeping, prevails.

Advantages of Barley Sweating.—Some interesting experiments were made as to the increase of germinating power after sweating and storing. An inferior sample of barley was used, but the advantage is clearly demonstrated in the following figures :

Unsweated barley . .	46%	ungerminated corns.
Immediately after sweating .	31%	,, ,,
16 days after sweating . .	12%	,, ,,
30 days after sweating . .	7%	,, ,,

Showing that sweating in itself improves the sample but after a month's storage the effect is very much more marked. This barley contained an average moisture, and therefore it would appear that barley, even in dry seasons, should be sweated before storing. The cheapest and most efficient machine is the well-known barley sweating drum, which used only one quarter of the coal taken by a kiln, and requires labour to fill, turn or empty, and completes the sweating in nine hours.

Malt kilns are used for barley, but they are very expensive, with these very much cheaper working machines available ; also the use of malt kilns delays the commencement of the malting season unduly.

In carrying out the system thus referred to the grain is first steeped for twenty-four hours, then the cistern is emptied, and its contents put in conical heaps about five feet high. These are sprinkled every hour with cold water, and so turned that the moisture may penetrate every part. During this time the cistern is cleansed, and fresh barley steeped, which is also, after twenty-four hours, placed in similar heaps. Then the first charge is thrown back into the cistern and steeped again for six or eight hours, after which it will have swelled enough and absorbed sufficient moisture. There are really no practical difficulties in the way of trying this method, and it appears to us that the combined aeration and moistening which take place have everything to recommend them. Certainly excessive steeping is detrimental, as it extracts valuable substances.

On the other hand, sprinkling, as adapted to the English system of steeping, cannot fully compensate for too short a stay in cistern, it being hardly possible to manage it with regularity enough to promote an even germination under those circumstances.

And as regards the **prevention of mould**— though it may be greatly

limited by thoroughly cleaning and washing the barley before steeping it, preventing by means of curtains or otherwise the access of the dust separated by the screening-machines, and by attention to the temperature of the steep liquor as well as by duly changing the same, and, last but not least by working at temperatures as low as are consistent with free germination—nothing can be more valuable than **bisulphite of lime.** A 10% solution is most useful for washing cisterns whenever emptied, and most destructive of lactic ferments and spores of mould which swarm there. With doubtful barley, a gallon in the steep liquor to every 20 or 40 quarters, according to circumstances, and, even for sprinkling, liquor containing 1% to 2% may be used without danger. It is useful, too, for bins, but there we must own to a liking for a fresh-slaked lime applied hot with a whitewasher's brush.

It is said that **chalk** or **lime** is sometimes used in the steep liquor to reduce acidity and lessen the extractiveness of the liquor. But in view of the fact that the continuous production of lactic acid in the same medium gets more and more restricted by the opposing agency of the lactic acid already produced, and that such production can be renewed by the withdrawal of the latter, which is best effected by causing it to combine with a base to form **lactate of lime,** its benefit in the former case would be more than questionable.

In the latter respect some advantage might accrue if the chalk were freely soluble in water, seeing that, in spite of some opinions to the contrary of leading authorities, of whom Mulder was one, the advantages of hard water for steeping purposes are pretty generally recognised, on the ground that soft water extracts more of the soluble constituents of the barley (over 1% more), of which the loss of the phosphate of potash is the most serious. When hard water is used the phosphoric acid appears to form lime compounds, which remain insoluble until acted upon by the lactic acid, always present, if in minute quantity, in the amsh-tun. In any case, potassic phosphate is of extreme importance in the nourishment of the yeast. Moreover, the extraction of soluble phosphates and their presence in the steep water favour the development of mildew, and that soft water more speedily than hard should give evidence of incipient putrefaction is a necessary consequence, implying more frequent changes of liquor. Such changes, from the point of view of the increased drain upon the soluble constituents of the barley, are so far undesirable.

It is further supposed that the lime and magnesia salts in hard water form insoluble compounds with some of the otherwise soluble albuminoid bodies in the steeped barley, and that the effects of this combination may be traced in the greater readiness with which the worts "break" when boiled in the copper. This, it must be confessed, seems difficult of proof, nor does there seem any reason why such compounds, if they exist, should be more insensible to the influence of the mash-tun lactic acid than the lime phosphates are.

"**Idle corns**" or "**liebacks**" are the grains which do not grow, and include not only those which are really dead, but those of such weak vitality, that anything short of the most favourable conditions prevent their germination.

The capacity for growth of "idlers" of this second class is greatly increased by a moderate kiln-drying of the barley (sweating) before steep-

ing it. Amongst the risks attendant upon an excessive proportion of liebacks are, first, the possible introduction of insoluble starch into the worts, starch which would be rendered soluble by the subsequent boiling in the copper, or even by high sparge-heats when the diastase has become so crippled as to be unable to effect conversion ; although it is true that liebacks which have passed through the malting process without germinating have their insoluble constituents modified into a somewhat more soluble condition. A second risk is their liability to mildew.

It is asserted that " liebacks " of the second class may have their germinating power so much increased by the kiln-drying to which malt is subjected, as to be capable of growing if afterwards planted in the earth. Imperfectly cured malt, which has grown, but not produced, for some reason or other, the normal number of rootlets—seven—is, we have good reason to believe, predisposed to do the same, only producing in the soil, however, the rootlets it failed to produce on the floors. In the case of extreme unsoundness and very faulty undercuring, moisture and warmth may even induce the acrospire to sprout in the air.

The presence of a considerable proportion of idlers may be detected by placing a sample from the floor upon the open palm, held at an angle of 30° to 45° ; the hand being then slightly shaken with an up-and-down jerking movement, the growing grains will drop off first, leaving most of the ungerminated corns behind.

Kilns and Kiln-drying.—Kiln-drying is often very carelessly performed, the malt being loaded on far too thickly. Moisture is a very potent factor in the chemical decomposition of bodies ; so that a high temperature, if dry, is found to be much less energetic in breaking up the various protein and non-protein bodies of the malt than a much lower moist one. By placing the malt thickly on the kiln, especially in a very wet state, the conditions most favourable for this decomposition are maintained ; and in the case of the proteins this breaking-up is attended by a fermentative or putrefactive action, tending to the development of an excess of acid.

The extreme limit of depth should hardly exceed six inches, under ordinary conditions ; beyond this, unless with some special suction arrangements, it is very difficult to dry the malt thoroughly ; and if the floor be turned again and again * with the idea of aiding this result the evil is only intensified, such a plan being, as it would seem, one arranged, of set purpose, to keep the moist vapour circulating continuously from the damp stratum below to the dry one above.

Malt is less coloured by kiln-drying, the drier it is when the curing temperature begins, and *vice versâ*. Thausing says if a pale vinous beer like the Bohemian is required, the moisture of the malt must be got rid of at a low temperature, and thoroughly, before the stronger heat is applied, but that if a dark, sweet, full-mouthed beer, like the Bavarian, is wanted, not only must the green malt be more fully germinated than in the former case, but the curing heat must be applied at an earlier stage—that is, before the malt has become so dry that the aromatic bodies and the substances which help to make the beer " full-mouthed " are no longer

* Green malt, therefore, should not be turned, though it may want lightening to allow the vapour to escape. Moreover, in kilns of ordinary construction the bottom layer is often spoilt, and turning will only intensify the damage. It should, therefore, be freely " forked," but never turned till dry to the touch.

capable of development. But this carried too far may mean formation of empyreumatic products tending to overpower the pleasant flavour of the cured malt.

Besides the increase of colour due to caramelisation the application of high temperatures when the grain is moist may cause a loss of diastasic energy, the proteins which constitute that force being prone to coagulate under the influence of heat when in a semi-dissolved condition. Steeliness is also an effect of such a premature application of heat. But at the same time we know that the hotter the air is the more moisture it will carry away; and it is possible, to some extent, to utilise this property, counterbalancing the higher temperature by freely admitting larger volumes of air. Hence, it is evident that much more air is required during the drying than during the curing stage.

Last's Patent Ventilators.—This useful innovation, though primarily intended for general ventilation, yet, having considerable influence in bringing the green malt, just before loading on, into a suitably dry condition, and being, moreover, dependent on the draught created by the rush of air through the kiln-fires, may be conveniently referred to here. Without in any way limiting or interfering with the usual lateral ventilation through windows, Last's arrangement consists of a series of openings made in the short wall at the kiln-end of each floor (a dozen or more to each floor), which openings have falling doors to close or partly close them—these doors being either actuated singly, which is the best plan, or all together by a rod.

At the opposite end of each floor (the cistern end) are other similar openings, but less numerous, for admitting the air from outside, and obtaining a longitudinal air-current. The former apertures open out into a space surrounding the kiln, the dunge, in fact, but a dunge carried up to a greater elevation than is usual, so that when the kiln-fire is well alight the air rushes down to it through these openings with great velocity.

Construction of Kilns.—Kilns should have a drying surface of at least 25 square feet per quarter. (Mr. Stopes thinks the area should never exceed one-fourth or be less than one-sixth of that of the growing-floors, and in another place says that no pale-malt kiln should have a less area than 33 square feet per quarter of barley steeped.) The writer named also holds that the combined air-inlets should not bear a higher ratio to the air-outlets than as 4 : 5.

The construction of the roof of kilns requires consideration. A *thin* roof condenses the moisture rising from the green malt. Slates, beneath which are felt and boards with air-spaces between, the inside being soundly plastered, form a roof which gives the best results, though it is important to have the plaster made with lime of good holding power.

Existing kilns have been doubled in capacity on the principle advocated by Mr. Stopes (though we believe Mr. Corcoran was the pioneer of double-kiln construction in England), which however differs little from the arrangement which has long obtained in many Continental maltings, except that the products of combustion are allowed to pass through the malt, instead of heated air alone being the drying agent employed. And if the kiln-space was not cramped before, it is obvious that the addition of an upper floor will enable steepings to be made twice as often as before, for an interval of two days, instead of four, between each steeping is enough

to enable the upper kiln to be ready for a fresh floor of green malt. The chief objection to such an arrangement is one which has been referred to in Chapter I., the difficulty of keeping the temperatures at the desired point on *both* floors simultaneously—say 200° to 210° F. on the lower, and 90° to 100° F. on the upper.*

This difficulty seems to be faced with considerable chance of success in M. Hedicke & Co.'s Twin Kiln. The drying floor is in this arrangement also placed above what the patentees call " the roasting floor " ; but as the latter is roofed in (below the drying floor), and has a large tube fitted in the apex of the said roof, which tube passes upward, through the drying floor, direct to the cowl, none of the very hot air passes from this roasting floor into the green malt above to the latter's detriment ; and though in a measure this very heated air may be said to pass away to waste, it yet, in its passage out, helps to create a strong upcast draught, and so increases the volume of more or less warm air sucked through the green malt. The heated air admitted to the green malt passes by comparatively narrow air-channels not through, but beside the roasting floor ; and side by side with these hot-air channels are channels for introducing such supplies of cold air as may seem advisable. Of course the volume of either can be nicely adjusted.

Furnace and Baffle-plate.—The simplest form of furnace consists of a grate formed of heavy bars carried on bearers, and set in firebricks. The whole structure, from about the level of the top of the arched opening through which the fire is fed, arching outwards towards the outer walls of the kiln, and forming the **Dunge,** partly used for the storage of coal, is placed as nearly centrally as possible with regard to the kiln floor. There should be inlets for air besides what passes in through the grate, and a damper at the back of the stove helps regularity of combustion.

Baffle-plates have their advantages. They are large flat surfaces of iron, tiles, etc., suspended a short distance above the fire, and from their function are sometimes known as dispersers. Iron baffle-plates have this disadvantage ; if they get overheated and much kiln-dust falls on them, the latter burns, with a most disagreeable odour, which passes through the malt above. The best baffle-plates are made of tiles supported on thin strips of iron, supported in their turn by transverse iron rods.

It is of importance, as has been indicated when speaking of the necessity of good supplies of air in the early stage upon the kiln, to get rid of the moisture from the green malt rapidly, though at a low heat. For this purpose **cowls** are far better adapted than the open ventilators often seen, but the most effective arrangement of all seems to be the form of suction introduced by Mr. Free. In the large maltings belonging to his firm the kilns are, or can be made, absolutely air-tight chambers, and are each fitted with a Blackman air-propeller placed at the apex of the roof.

These making at first as many as 600 revolutions a minute rapidly draw off the moisture ; and it is further claimed that, in the subsequent curing process and when the revolutions of the propeller (fan) have been reduced to 360 a minute, the malt may lie at more than twice its usual depth, and yet that the temperature will be practically uniform (with a variation of, at the outside, not more than 10° F., a result which, as Mr.

* See pp. 54, 55 for Mr. Stopes's instructions for the management of them.

Free says, can be attained in no other way) ; * that the temperature may be raised even to 230° F. without unduly colouring the malt ; and finally, that the whole process can be effected in half the time taken by the ordinary method.

Now, though the great amount of air (25,000 cubic feet per minute) drawn through by Mr. Free's fan arrangement doubtless removes moisture *mechanically* as well as by absorption, **air-drying ordinarily depends on increased saturation capacity of air at higher temperatures.** Thus air at 32° F. can hold about 2 grains of moisture per cubic foot, but 12 grains at 80° F. If we reckon on a three-fourths saturation, *i.e.*, air going off at 80° with 9 grains water-vapour per cubic foot, and that the incoming air holds 4 grains, it will require 1,400 cubic feet to absorb every pound (7,000 grains) of moisture. Again, with green malt weighing 556 lb. per quarter—*i.e.*, holding 220 lb. or 40% of removable moisture—the theoretical *minimum* required to dry is 308,000 cubic feet per quarter. If half this, + 20% more for safety, be drawn through in 24 hours, so that 110 lb. of moisture per quarter is removed, the malt will have 24% to 25% of moisture left and to be got rid of in the next 24 hours. Then if each quarter occupies 25 square feet the velocity will be 5 to 6 feet per minute. It should be noted, however, that an *exit* heat of 80°, owing to locking-up of heat on conversion of water into vapour, down-draught, and other losses, postulates a *starting* temperature very much higher, say 50° or 60° higher on the under-part of the kiln floor.

Mr. Free's own words on the fan system, as compared with the ordinary method of curing, are valuable and very suggestive. "When malt has been worked with great success from the cistern to the kiln, it is by no means uncommon, where the draught is defective, that more injury occurs on the kiln itself than has taken place during the ten or more days that the malt has remained on the floors. The temperatures used in the early stages of drying are of necessity so low, in order to prevent hardness and colour in the malt, that this point forms the most favourable opportunity for the formation of mould and acidity ; and many brewers who malt for their own requirements will be familiar with the white fungus which spreads itself in large or small patches on the top of a kiln, in which a considerable degree of moisture is still present, together with the mould, which increases with terrible rapidity on the broken and damaged grains until the malt is comparatively dry. This may now be entirely avoided, as under the rapid draught produced by the fan this formation can never take place ; and we can rest assured that from the time the malt is loaded until it is fit for curing no deterioration will take place, even though low temperatures be used throughout. Owing to the rapid draught, the steam arising from the malt is barely perceptible, and the top of the grain, instead of being saturated with moisture, owing to the condensation of the steam, is dry and sweet, although the temperature is lower than dared be used on an ordinary kiln. **When one considers how malt is, for the most part, dried,** it does not seem hard to account for the difficulty of producing good results. An article which has, or which ought to have, received the greatest care and attention, is placed upon a kiln for the purpose of effecting the final stage of drying, which it is important should be carried out with the utmost care, and should be both continuous and progressive.

* That is to say, if three accurate naked-bulb thermometers be placed in the malt on the kiln, one right down on the tiles, the second 4½ inches higher, the third very near the top, say 9 inches above the first, the temperatures will not vary more than 200°, 195° and 190° F.

Yet what happens ? The malt is loaded in the morning, and for the rest of the day is kept at a low temperature. In the evening the fires are banked up, and for the next eight or nine hours not only is the heat not raised, but becomes actually lower. The following morning the fires are made up, and during the rest of the day the malt receives more or less attention ; but in the evening the same process of banking-up is repeated, and for the two following days and nights the same operations are continued. Is it to be wondered at that malt deteriorates more quickly on kiln than it ever did on the floor, when a manufacture is carried out on such principles.

King's Automatic Regulator.—The gloomy picture which Mr. Free has so faithfully painted may be falsified in regard to any particular malting by the use of King's Automatic Regulator. A large iron swing ventilator, accurately balanced on pivots in an iron frame, is placed in a large opening specially cut for it in the brickwork just over the furnace door, and so that it opens or closes at a very slight impulse. Two long brass rods, parallel to each other, are fixed just under the tile floor of the kiln, so that they expand or contract with every rise or fall of the temperature caused by the fire, and so that the expansion of the one rod is *passed on*, through or by the other rod, and added to its expansion to actuate a weighted lever with which the end of the second rod is connected. The lever accordingly, which is in a straight line above the frame of the ventilator, rises or falls as the brass rods expand or contract again, and thus, by means of a slotted rod, opens or closes the easily swinging ventilator. There is an adjusting slide by which the ventilator can be set to open at any temperature, so that the risk of overfiring (*experto crede*) is reduced to a minimum, even when the fires are left for a considerable time. Not only is cold air admitted to the malt directly the temperature reaches the not-to-be-exceeded point, but the draught through the fire from underneath is also checked.

There is another form of regulator consisting of a wheel some 4 feet in diameter, and constructed, as to its outer rim, of a steel tube. The rim of this wheel is about half filled with mercury and a little alcohol. A rise of temperature causes the expansion of the mercury, and so shifts the centre of gravity ; the wheel accordingly begins to rotate, and by means of a wire cord passing from a smaller wheel at the end of the shaft on which the large hollow wheel is fixed, opens the ventilator. There are two scale-pans suspended over the smaller wheel, and it is by the amount of weight hung in these that the temperature is determined at which the ventilator is to open.

Instructions for managing Double Kilns (Stopes's pattern).—Though we have made no secret of the opinion that these kilns are ordinarily not adequate to requirements, the patentee thought otherwise, and gave the following directions (condensed) for managing them.

Green malt to be loaded on the top floor when fit for kiln.

1st day. Temperature not below 80° F. or above 100° F.

2nd ,, Temperature not below 90° F. or above 110° F. At end of second day lower top floor to bottom.

3rd ,, Temperature from 120° F. to 130° F. or 140° F.

4th ,, Temperature from 140° F. to 185° F. or 195° F., *or higher.*

The top floor can be ploughed or forked over lightly, if needed, and

heats can then be raised or lowered, according to the character to be given to the malt. The bottom floor need not be turned or ploughed.

The regulation of heat and air to be effected by due attention to fires, or adjustment of air inlets and dispersers.

When floors are young and green dispersers can be closed and inlets open. Air is required at this stage.

When the bottom floor is to be finished off at a high heat air can be supplied moderately and dispersers * opened. By these means the bottom floor can be 190° F. and the top floor 100° F.

Sweating of barley to be upon the most convenient floor (preferably the bottom one), and the heat of sweating is not to exceed 115° F. when the top floor is loaded.

Heaping-up the Malt after Curing.—To do this for several hours after the kiln-drying and curing is otherwise completed is certainly an advantage from the point of view of flavour; moreover, if the malt, while in an extremely hot condition, be spread out comparatively thin, there is a tendency to absorb an excess of moisture.

To ensure that the highest heat thoroughly *penetrates* the malt, when the maximum has been reached some ten or twelve hours from the end, close all air outlets, especially the large one in the apex of the roof, which can readily be done by a well-fitting door, swinging easily on its centre, and actuated by a cord within reach of the kiln floor. By this means it is easy to maintain the heat within a very few degrees of the maximum, and this with little or no attention to the fires.

Summary of Malting Facts, largely based on Messrs. Brown and Morris's Researches, giving the "Rationale" of the Maltster's Operations.—The two main divisions of the barley-corn, the embryo, and the endosperm (*cf.* p. 40), are never, *as regards the growing part* of the former, in actual contact, being separated by the membranous scutellum and the so-called "palisade" cells (at right angles to the plane of the scutellum) of the absorptive epithelium.† Further, the starch granules, of which, with a fine, net-like intermixture of protein matter, the immediately nutritive portion of the endosperm consists, are enclosed by delicate cellulosic cell walls; and the problem to be understood was, how the diastase, being a "colloid" (*i.e.*, incapable of passing through a membrane, or with such extreme difficulty as to be so practically), could get at the starch, which, being a "colloid" too, is not available for the nutriment of the embryo without some change being brought about. It had previously been known that the "palisade" cells of the epithelium were instrumental in transferring nutriment to the embryo, and that the cells of the endosperm next adjoining the epithelium became depleted of their starch through this channel; but it was not until the epoch-making discovery by the above-named investigators of the existence of *cytase*, an enzyme whose function it is to dissolve *cellulose*, that the key was found. They came to the conclusion, on grounds to be referred to later, that the cytase is secreted, in conjunction with diastase, in the cells of the absorptive epithelium, and

* The dispersers referred to are the iron arrangements, shaped like a chimney-pot, only larger, which cover the holes down which the malt is shovelled from the upper to the lower kiln. They have a number of triangular-shaped openings at the top which can be opened or closed by turning a knob. *Dissipators* are cones of woven wire similarly used for covering these apertures.

† Both epithelium and scutellum are anatomically portions of the embryo.

that obviously the solvent action of the cytase *must* precede any activity of the diastase directed upon the cellulose-protected starch granules of the endosperm.

Cytase Theory Challenged.—Cytase has not been isolated; its existence was assumed from observed phenomena, and six years later Gruss asserted, from his own work with stained sections, that the cell walls enclosing the starch granules are not dissolved, but only acquire transparency, which gives a deceptive appearance of solution, when unstained specimens are observed. Gruss holds that the cell walls within the endosperm consist of two carbohydrates at least, Araban and Xylan, the former of which, less resistant to the solvent diastase than the other, is dissolved, while the Xylan remains intact. This view was confirmed to some extent in 1904 by Ling, who, examining numerous carefully prepared microscopic sections, longitudinal and transverse, found the cell walls to be not only existent but practically continuous. The sections were stained with Congo red. Some action on the cell wall during germination is undoubted, and that this is greater at the germ end and near the periphery of the endosperm than towards the centre or at the distal end. The undetermined carbohydrates are of a gummy nature (*cf.* pp. 142–143, *Galactoxylan*, and Lindet's *Amylan* and *Galactan*); and it has been suggested that the amount in which they are found is a measure of the modification of the malt.

Excessive Readiness to "Modify" not an Unmixed Good.—Be the solvent cytase or diastase and whatever its mode of action, it is certain that the readiness to modify varies considerably in different years. It has been noticed by the writers to have been marked in the barleys of a season not favourable in itself, but following one of unusual sunshine, and in that case seemed attributable to the dryness of the seed-corn and perhaps to some action from the year before upon the seed-bed. Whether the combined conditions resulted in tissues thinner and less resistant to solvent activity, or in greater energy imparted to the latter, may be an open question, but the fact is that a steeping of barley grown in one such year, though frozen by a sudden and severe frost in the heaps into which it was thrown from the cistern, grew to 98% or 99% and modified very fairly. But the very readiness to mellow may demand precautions in the way of restricting acrospire growth (by reduced steep and thinner floors) in the early stages, otherwise it may connote an excessive increase in the "ready-formed sugars" of malt. Excess of these, harmless in itself, indicates waste of carbohydrate matter by respiration and implies increase in the soluble albuminoids too; it is one of the results of "forcing"; but obviously a method which is normal with a grain of average mellowing capacity might be "forcing" in the case of a grain where that capacity was highly developed.

The ready-formed Sugars of Malt.—These may vary from 6 or 7% to 15 or 16%, and it is a noticeable fact that with an increased percentage the ratio of maltose to that of other sugars is considerably increased. Now this maltose occurs entirely in the endosperm, it being, as Brown and Morris discovered, immediately converted into cane-sugar upon its passage into the embryo. At any rate, maltose, as such, is not found in the embryo, though it is conceivable that a saving of energy may be effected by an immediate de-hydrolysis of some limited portion of it into starch

and cellulose, the latter being a necessity for the development of the young newly-formed cells, while starch (which is not diffusible, and therefore cannot pass from the endosperm) is found in the said cells of embryo and rootlets. A portion of the cane-sugar formed from the maltose appears to be inverted by some inverting enzyme (probably invertase, see p. 101) into invert sugars; though here a curious fact occurs, to which Mr. J. O'Sullivan has drawn attention, that, while the ordinary products of inversion (whether by acid or invertase) are *equal* parts of dextrose and lævulose, in the case of germinated barley the former is always greatly in excess of the latter. This fact points to one of two alternatives—either that the lævulose is more rapidly assimilated by the young plantlet, or, which seems more probable, that dextrose is formed from some carbohydrate other than starch.*

An analysis by Mr. J. O'Sullivan of barley before and after germination has the following figures, showing that the maltose in unmalted barley is practically *nil*, or at most a trace.

	Before Germination.	After Germination.
Cane-sugar	1·39	4·50
Maltose	0·62	1·98
Dextrose		1·57
Lævulose		0·72

Relatively low as these figures may seem, the method employed is interesting, and leaves no reasonable doubt as to the existence of cane-sugar in malt. It was as follows:—

Having treated the malt with alcohol, for the purpose of destroying diastatic action, on the completion of which the alcohol was evaporated off, he treated it again with ether to eliminate the fat. Then, taking care that a certain definite volume should represent the sugars in a definite weight of the malt, he determined the specific gravity, opticity,† and cupric-oxide reducing power.† Next, a further measured portion was treated with invertase (see pp. 101 and 266) at 52° to 54° C. (=125½° F. to 129° F.), and on completion of the action, he again determined—

(α) Specific gravity, which showed an *increase*.

(β) Opticity, which showed a *decrease*.

(γ) Copper reducing power, which showed an increase.

All these results point to the fact of cane-sugar existing, and being inverted by the invertase into invert sugar.

(α) Because 100 parts cane become 105 parts of invert (see pp. 101 and 102).

(β) Because the opticity of invert = — 21·3, while that of cane = 66·5.

(γ) Because invert sugar has a copper oxide reducing power which cane-sugar does not possess.

He then proceeded to ferment the inverted solution with yeast *plus* a little diastase; and upon completion of the fermentation, he determined the residual reducing power and opticity with negative results, while the alcohol formed showed an excess over the quantity to be expected if the reducing matter had been only dextrose and lævulose.

* As a possible source α-amylan and β-amylan may be named. These are carbohydrates (see p. 65) which exist in ungerminated barley, but not in germinated. They are known to be transformed into *dextrose* by the catalytic action of sulphuric acid. Phosphoric or organic acids probably have the same influence.

† Reference pp. 167 and 177 and pp. 174 and 188 for explanation of these.

On the other hand, the absence of reducing power which he found is in conflict with results obtained by Dr. Morris in 1895. The latter then held out a hope of continuing his researches, which was not, so far as the writers know, fulfilled up to the death of Dr. Morris; but the process adopted and results obtained pointing to an unfermentable residue, with cupric-oxide reducing power, in malt extract even when made with cold water, were, briefly, as follows:—

Mashes were made, one with cold and two with hot water, and the filtered extracts being boiled (one of the latter with a proportion of hops = 6 lb. per quarter) and cooled, were set to ferment with pressed yeast + 5% of malt extract. When this fermentation was finished, in all three cases the filtrates were boiled to expel the alcohol, their opticity and cupric-oxide reducing power determined, and were then set to ferment a second time with pressed yeast and more malt extract. On the completion of the second fermentations, the solutions were filtered, and their reducing power again determined. It was found in each case—the cold as well as the hot water mashes—that the reducing power was the same, namely, that 3·76 grammes of CuO were precipitated by this unfermentable residue or each 100 grammes of malt, that is to say, an amount equal in reducing power to 1·6 grammes of maltose. This residue is, then, equally soluble in hot or cold water, and is therefore not a product of the mashing operation. The investigator deems it to be the product of the solution of the cellulosic walls of the starch-containing cells which, as has been said, occurs during germination.

Messrs. Moritz and Morris, in a lucid report, state their opinion that the soluble carbohydrates (as they prefer to style the bodies previously grouped as "ready-formed sugars") should in English barley malt not fall below 14% or exceed 15·5%. Other authorities place the minimum at 10%, and the maximum at 14%.

It is supposed that the action of the diastase during germination is simpler and, so to speak, more direct than during the mashing process, maltose being formed at once with no intermediate dextrin stage, and that, similarly, the enzyme, acting upon the proteid bodies, forms, not peptones, but amides and amido-acids.

Further Abstract of Messrs. Brown and Morris's Conclusions.—We may here note—though as a complete statement of them the abstract will be inadequate—some important conclusions of these investigators. Experiment tends to prove the secretion both of the amylo-hydrolyst (diastase) and of the cyto-hydrolyst (cytase) to be to some extent *starvation phenomena*, because when there is a good supply of assimilable carbohydrates—*e.g.*, cane-sugar or maltose—the secretion is checked, or even stopped: in other words, the secretive power of the epithelium is only exerted where the supply of tissue-forming carbon compounds begins to fail.

They have further shown that the **relation of the embryo to the endosperm is that of parasite to host** by the cultivation of "excised" embryos (embryos detached from the endosperm) in various nutrient media. Cane-sugar, invert, dextrose, lævulose, and maltose are all nutritious, but cane-sugar most of all. Lactose, however, does not contribute to the nutriment of the young plant. Even maltose, which at first sight seems to be the natural food, is inferior to cane-sugar; and this is explained by the

ascertained fact that maltose, when absorbed by the growing embryo, is transformed into cane-sugar, so that there is *a saving of energy* effected by supplying cane-sugar already formed. And from this it follows that the seat of the production of the cane-sugar, which the germinated grain contains, is to be sought within the tissues of the embryo itself.

Further experiments made with "excised" embryos, from which the absorptive epithelium had been carefully removed by scraping (from the surface of the scutellum), showed that though such a maimed embryo would grow if placed in a readily assimilable carbo-hydrate (dextrose, cane-sugar, etc.), yet that it had quite lost its power of eroding starch and of dissolving it. On the contrary, embryos retaining their epithelium will liquefy stiff starch paste, embedding themselves in it to an appreciable depth. Rather singularly, the epithelium removed from its embryo seems to retain, to some extent, the power of secreting a starch-dissolving enzyme.

View of Mr. James O'Sullivan.—This investigator, on the other hand, does not consider that diastase is only secreted in the epithelium. Careful experiments, made day by day with germinating barley, have convinced him that it also exists in the endosperm. From a number of grains he cut off one-third of each, the remaining two-thirds, containing the germ, being rejected. From this he scraped the starch (carefully avoiding that near the husk), which, after being mixed with cold water, was gradually heated to 140° to 154° F. Even on the first day (apparently corresponding to a "one-day" floor) some soluble starch was found in the filtrate when cooled: more on the second day, fresh grains corresponding to those of a "two-day" floor having been taken; whilst on the third day, with only three hours' digestion, there was no starch reaction, but only that of α-dextrin.* On the fourth day, although the acrospire had hardly started, there was neither soluble starch nor α-dextrin in the filtrate after twenty minutes' digestion, showing that the conversion was complete.

"An interesting observation," he adds, "in connection with the above facts, is that in no case were there any pitted or eroded starch granules in the portion of the endosperm employed, and even on the eighth day of germination a like portion of the endosperm showed none. It is evident here that Nature makes no mistake; for though the power to dissolve starch is in a position far removed from the place of the consumption of the solution products, yet *solution only takes place where the product of the solution is consumed*, and that is in the vicinity of the growing embryo."

At the date of the above remarks he apparently held the opinion that the diastase of the endosperm end was probably incapable of dissolving the starch granules, but this he subsequently corrected, having found that an aqueous extract of the endosperm end on the fifth day of germination does possess the power of pitting † pure barley-starch granules.

* It will be noticed that this dextrin reaction would be due to the action of diastase on starch during the *digestion*—the action of the enzyme in germinating grain being, as has been said, so energetic that the starch is practically converted at once into maltose, no intermediate malto-dextrin being formed.

† "Pitting" is the action which occurs in the neighbourhood of the acrospire upon the cell-walls (amylo cellulose) of the starch cells, probably preliminary to the diastasic attack upon the more soluble granulose within. Viewed under the microscope with ⅔ to ⅙ objective, it is seen to take the form of cracks in the cell-wall, often roughly radiating from a common centre.

" If we consider the above experiments," he continues, " and believe that the diastase is produced by the embryo, and that it passes out through the scutellum, we must believe two things—that diffusion takes place not only through the scutellum, but also through the endosperm, and that diastase is an easily diffusible body. We know diffusibility is not a property of diastase. The production and presence of naked diastase in the endosperm, no doubt stimulated by the growing embryo, is, to my mind, the most reasonable explanation, and it will carry all the facts, which occur to me, relative to the germination of barley. I say naked diastase, because I believe it is not enclosed in cells, otherwise we could not extract it as easily as we do."

The Maltster's Aim in Actual Practice (supplementing pp. 4 to 12).—Practically, it must matter very little to the maltster, anxious only to make the best malt he can, where the diastase is ; the vital point is, that its activity (and probably that of peptase (?) too) is regulated by acrospire growth. Consequently, excessive growth (" forced " growth) means more " depleted " endospermic cells in the neighbourhood of the embryo ; more waste of valuable starch, converted first into maltose, and then, either direct or through the stages of cane and invert sugar, into cellulose, worthless to the brewer, but all important for the rootlets (unduly stimulated) and embryo ; more carbon-dioxide given off, and therefore more loss in that way, too, of the starch from which it is derived. Malt thoroughly modified up to the very tips he should have ; but the mellowness must be got by stimulating the secretion of *cytase*, the most potent factor, in which appears to be the so-called withering—*i.e.*, a thickening of the piece as they near the kiln, and after the actual wetness from the sprinkling has passed off. In other words, the limited access of air and the previous reduction of moisture restrict the growth of the acrospire and the secretion of the diastase which it denotes, while the secretion of cytase still continues.

Maturation of the barley before steeping (normal to grain grown on suitable soil, well harvested and subjected to slight moisture after ripening, at or about the time of cutting, and followed by drying conditions) is essential for due mellowing of the malt. With such barley it is aided by a natural " sweat " in stack, simulated in other barleys, especially when out of condition, by " sweating " on kiln, *i.e.*, heating to 100° to 110° F. for twenty-four hours, with plenty of air, but emphatically *not a stewing process* at that or higher heats. [It is significant that sweated barley, if afterwards dried to 112° F., shows a larger percentage of weight lost than unsweated barley similarly dried. This points to a liberation, during sweating, of water or its elements *from combination*, resulting in certain physical and even chemical changes quite different from those occurring when the grain is simply dried at 212° F.]

Peptase and Tryptase (Proteolytic Enzymes).—Though the action of an enzyme or enzymes—more than once referred to—and its existence in germinated malt have long been surmised, doubts as to its capacity for surviving kiln heats have been set at rest by Fernbach and Hubert, Windisch and others. The former workers showed that in an aqueous digestion of ground malt prepared in the cold and filtered bright, as much as 45% of the ascertained original coagulable nitrogenous matter was in

some cases rendered uncoagulable when the extract was submitted to "auto-digestion" at 158° F. [Other investigators find this temperature crippling.] Further, it appears that the conversion can be pushed beyond the peptone stage, viz., to amides, seeing that the nitrogenous bodies, whether coagulable or not by heat, but precipitable by phosphotungstic acid (the precipitant for peptones), become unprecipitable by the same reagent when the liquid is "autodigested." Precipitation by alcohol, they assert, gives active substances which can dissolve the proteins obtained from malt extract, even when coagulated by heat, and, more even than this, the N-bodies from barley. The fact that boiling destroys the activity puts the active agency of acids out of the question, as they would not be affected; while undiminished activity after sterilisation by passing the fluid through a Chamberland filter, excludes bacterial action.

The investigators found the proteolytic action strong at 104° F., that its "optimum" was about 140°, and that it was still considerable at 158° under ordinary brewing conditions. Further—and *this is important*—they found, using phosphotungstic acid to distinguish the peptones precipitable by it from amido-compounds, that at 104° F. all the soluble nitrogen belonged to the amido-compounds, unprecipitated by the above reagent; that at 140° F. the latter formed only 50° to 60% of the soluble nitrogen, and at 158° hardly 40%. They compare, in short, the influence of temperature upon the proteolytic enzyme to its known influence upon diastatic action, peptones standing in the former case for the dextrin of the latter and amides for maltose.

Windisch and Schellhorn, however, after many researches, generally with cold-water extract of malt, state that the proteolytic enzyme is destroyed in solution by a temperature of 158° F., that it does not attack coagulated albumen or insoluble albuminoids, though it acts, they say, upon insoluble nitrogenous substances of animal origin and upon gelatine (this best in alkaline solution), peptones which give the Biuret reaction (*see* p. 166) resulting. Further, glycerine extracts an active substance from the malt.

Weiss, supporting the above views, says that the first stage of proteolysis, degradation to albumoses, goes on freely at relatively low temperatures (39¼° to 68° F.), the maximum effect occurring at 124° F., while beyond 158° F. the reaction ceases. Further conversion into products not precipitated by tannic acid proceeds far less rapidly, the optimum temperature lying between 113° and 122° F., and the extremes being about 59° and 158° F. Proteolytic activity is, he says, retarded by presence of free alkali, but stimulated by acidity due to primary phosphates, though excess of free acid has an opposite effect. [The conclusions of Fernbach and Hubert, *sub* "Acidity, etc.," below, should be noted in connection with this and with what follows.]

Windisch and Schellhorn found that the action went on not only in acid and neutral media, but in alkaline, the latter corresponding with the medium favourable to the trypsin of the animal economy (pancreas), and indicating the existence of tryptase, a view also supported by the fact that the degradation of the albumen is so far-reaching. Points noted by them are: (1) At low temperatures the protein degradation is *slow but*

far-reaching. (2) At higher temperatures it is *more rapid but less complete*. (3) The presence of organic acid (lactic, acetic, succinic) increases the enzyme's activity. (4) Development of the enzyme during germination is more readily observed in nitrogenous barleys than in those very poor in albumen.

Their contention that an initial temperature of 140° F. is preferable to the much lower heats adopted for beers of Continental type, because of the far-reaching degradation of the pre-existing soluble albuminoids, which occurs at such lower temperatures, into amido-compounds " which contribute nothing to the viscosity of the beer and may be directly injurious," is traversed by Wahl (Wahl-Hennius Institute of Fermentology, Chicago), some of whose illustrative figures—designed to show not only the benefit of using low starting heats, but also that of having a highly nitrogenous malt (!)—are appended.

Malts were made from Montana Chevalier, with 9·23% proteins, and Minnesota six-rowed, with 15·16%, both calculated on dry substance 91·7% and 89·05% respectively, making 8·4% and 13·5% as usually calculated. The estimated extracts were 71·75% and 64·75% respectively. Obviously the fine Montana, with its low nitrogen content and 34 mealy and 66 half-mealy corns, against the 6 mealy, 72 half-mealy, and 22 steely corns of the Minnesota, was, on the face of it, far and away the best ; but in the result, when malted identically and mashed (of course on American lager lines), it was the beer from " the unsightly small-berried barley of low market value and with a high percentage of albumen " which became brilliant without finings or filtration after about four weeks' storage at 34¼° F., while that from the Montana showed a slight haze after six weeks.

The mashing heats adopted were : Mashing liquor, 110¾° F. ; heat of mash, 99½° F. (maintained 1 hour), mash raised to 153½° F. in 20 min. by free steam and hot water (maintained 15 min.) ; mash raised to 162½° F. in 10 min. (converted in 5 min. ; rest, 40). The worts were boiled for 2 hours, during which the Minnesota malt wort showed the earlier " break," the break itself being in larger flakes.

[Later the beers were stored in bottle at 38¾° to 41° F. for one month, and for a second month (packed in chipped ice) at 33¾° F. Points to be noticed are, that of the amides 0·196% disappeared in fermentation from the Montana wort and 0·167% from the Minnesota, that the peptone albumen *increased*, and that an increase of about 0·1% in maltose was noted after the storage. Strangely enough, while the original gravity of the wort by calculation came out 13·91%, or slightly below the actual for the Montana, it came out 14·38% for the Minnesota, or fully 2° of specific gravity higher than the actual (!).]

During the period of higher temperature the yeast settled down ; during the second, representing the store-cask period (*see* p. 24), separating matter, causing turbidity at first, gradually " clumped down " and the beers became bright above these sediments. Transferred into other bottles, they were pasteurised at 140° F. for 30 min., the heat having been raised from the cold in 45 min. The amount of " albumen " precipitated in the second stage was 0·0024% in each case.

The analytical data are as follow :

	Montana barley wort.	Minnesota barley wort.
Percentage of extract	13·98	13·88
(= brewer's lb.	20·50	20·35)
Crude maltose	10·13	10·72
Sugar : non-sugar	100 : 38	100 : 29·4
Proteins (albumen)	0·010	0·017
Albumose	0·111	0·147
Peptones	0·179	0·333
Amides	0·52	0·723
Total Albumen (N × 6·25)	0·84	1·22
Albumen in % of extract	5·86	8·79

Beer after fermentation :

	Montana barley wort.		Minnesota barley wort.	
	End of primary fermentation.	After two months' storage.	End of primary fermentation.	After two months' storage.
Specific gravity	1·015	—	1·013·5	—
Apparent extract } Balling	3·79	3·78	3·375	3·35
Real extract } Balling	5·74	5·65	5·28	5·38 (!)
Alcohol	—	4·13	—	4·50
Crude maltose	1·44	1·52	1·20	1·35
Volatile acids	0·0036	0·0072	0·0024	0·0084
Non-volatile acids	0·108	0·090	0·108	0·081
Phosphoric acid	0·090	0·090	0·12	0·110
Degree of fermentation	60%	59·40%	62·7%	62·6%
Proteins—Albumen	0·012	0·018	0·026	0·027
Albumoses	0·091	0·109	0·112	0·137
Peptones	0·224	0·201	0·386	0·302
Amides	0·324	0·361	0·556	0·504
Total albumen	0·651	0·68	1·08	0·97

The amount of amides unabsorbed by the yeast is fairly in accord with Stern's observation, hereafter noted, that 0·025 nitrogen in form of asparagin (0·025 × 4·71 = 0·118 asparagin) was the maximum he could get a yeast to absorb in a 10% dextrose solution.

Here we may refer to certain results obtained by Hantke (U.S.A.) in mashing a malt at various temperatures. The several percentages of nitrogenous matter extracted, and the percentages of these precipitated by boiling for one hour, have been quoted by Dr. Sykes, with whose conclusion "that at a mashing temperature of 122° F. the smallest amount of nitrogenous matter coagulable on boiling is extracted ; apparently therefore this temperature is the most favourable one for peptonisation," our own is not in accord.

	Percentage of total N-matter of malt which passed into solution.	Percentage of the dissolved N matter precipitated on boiling for one hour.
16 hours mash at 72° F.	31·78	21·12
1 „ „ 100° F.	52·16	15·24
1 „ „ 122° F.	37·51	14·18
1 „ „ 145° F.	32·75	22·80
1 „ „ 167° F.	32·80	None given

Now if we suppose a malt with 10% nitrogen, then if 52·16% of them

are dissolved in the mash at 100° F., there will be 5·216 lb. in solution for every 100 lb. of malt treated ; similarly from the mash at 122° F. there will be 3·751 lb. in solution. But an hour's boil precipitates 15·24 and 14·18% of these respectively, that is 84·76 and 85·82% of the total nitrogenous extract are unaffected ; or 4·42 lb. in the 100° F. mash and 3·219 lb. in the 122° F. mash remain *uncoagulated*. Now if by peptonisation proteolysis is meant, it seems clear that the "initial" of 100° F. is most favourable to the formation of unprecipitable conversion bodies, among which peptones and amides stand chief, and if we can base any theory on the increased precipitate from the boiled wort of the lower initial it must be that a larger force of enzymes having been brought into action, the extra coagulation may be a measure of their excess.

Acidity and Mineral Matter.—These may be considered together, in view of Dr. Fernbach's researches, until which it was supposed that the acidity in malt was entirely due to lactic acid, increasing appreciably during malting and capable of exceeding the usual limit by 50% if the malt were "forced." But that investigator, using as indicators phenolphthalein, to which malt extract reacts as an acid, and methyl-orange, to which it is alkaline, instead of litmus, condemned as misleading, asserts that *there is no free acid in malts*, the acid reaction of the latter being entirely due to soluble acid salts. The organic acids formed during germination, he says, immediately attack the secondary phosphates (neutral, non-soluble phosphates), and, combining themselves with portions of the base, set free therefrom phosphoric acid previously in combination, and that this phosphoric acid, reacting upon the remaining neutral phosphates, converts them into primary acid phosphates. His later researches, in conjunction with Hubert, on proteolytic action have shown that an addition of acid short of the quantity required to obtain neutrality to methyl-orange helps proteolysis, and may even quintuple the activity of the enzyme, but any excess of acid beyond that which suffices to decompose the salts which are alkaline to methyl-orange (*i.e.*, the secondary phosphates) retards activity. The secondary phosphates, therefore, seem to be the retarding factors, and this independently of the nature of the metallic base. It is pointed out that herein lies an error in the method of isolating enzymes by precipitations with alcohol, the precipitates containing more salts alkaline to methyl-orange than primary phosphates (acid to phenolphthalein), whence comes decreased activity of the purified enzyme (*see* p. 188, Lintner's diastase).

It may be noted that amides (*e.g.*, asparagin), which may be formed to a considerable extent in forced malt, or where the green malt is slowly dried, increase the acidity indication : one grain of asparagin requires 36 c.c. $\frac{N}{20}$ soda (*v.* p. 161) to secure neutrality when phenolphthalein is being used as indicator. The mineral matter of barley averages about 2·6% on the dry substance, and of it about 20·9% is potassium, 8·8% magnesia, and 35·1% phosphoric acid. If the ash of malt be compared with that of barley some loss is shown, about 0·3% on equal weights of substance being taken, but relatively more when it is remembered that 100 lb. of malt represent 131 lb. or more of barley. Though some approve of phosphates as beer constituents, there is evidence that excess of them

has a crippling effect on yeast, and that they favour bacteria. But if reference be made to Professor Wahl's analytical figures, it will be seen that the phosphoric acid in his finished beers is 0·09% and 0·12% respectively, very close, in terms of P_2O_5, to the amount found *before* fermentation in extract from well-managed English malt, say 68 to 69 grains per gallon of wort having the same percentage extract as the Montana wort. In "forced" malts—and the American system is to force—the phosphates may be increased by an amount equivalent to 13 to 14 grains of P_2O_5 per gallon. It is as orthophosphoric acid, H_3PO_4, that the phosphoric acid combines with bases to form primary phosphates, *e.g.*, that with potassium (KH_2PO_4); and a good margin over any yeast requirements seems not inconsistent with good quality. Experiments made some years ago by A. L. Stern went to show that not more than 0·025% of mineral matter (about 1 part per 4,000) in 100 c.c. of a 10% dextrose solution and the same of nitrogen, in form of asparagin, could be assimilated by yeast. It is admitted that the optimum conditions might not have been secured.

Other Constituents of Barley and Malt.—Amongst these are fat, diminished by 20% to 30% by germination, more thoroughly when the latter is slow. The carbohydrates α- and β-amylan and raffinose. The amylans are both converted into dextrose on digestion with sulphuric acid, and if represented in malt at all are only so by their conversion products. The presence of α-amylan is, according to Mr. J. O'Sullivan, probably the reason why unmalted barley cannot be satisfactorily employed in the manufacture of beer. Raffinose—a substance with a + opticity—is supposed to afford nutriment to the embryo.

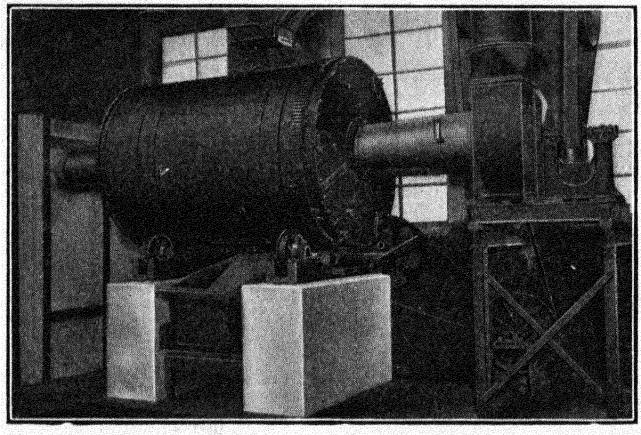
Good Malt, Data for Judging.—The section will be incomplete without a brief catalogue of the physical aspects of the malt best calculated to carry out the chemical programme which the brewer wishes to arrange. Good malt, then, will be free from crushed and mouldy grains and adherent rootlets. It should be of a uniform bright colour, free from dark-tipped grains, and with a thin smooth skin. The skin on either side of the acrospire should never have the "cridled" look of barley which, Ford says, "proves one of two errors—either that it has been forced too much in the young stage of malting, hence the conversion was not perfect, or that the heat upon the kiln was too high before the steam was well off. A rough wrinkled skin may also indicate insufficient ripening of the barley from which the malt was made.

When bitten, malt should be tender, yet crisp, full of flour from end to end, and with no riey tips. Hard or vitrified particles in the flour indicate either excess of nitrogenous matter, or too sudden an application of heat on the kiln; the extract from malt containing them is seldom satisfactory. Partial over-curing—some of the grains having their contents semi-caramelised like those of brown malt—must be guarded against. Such grains are easily detected with a little practice. Their presence indicates very faulty drying conditions, and they may give far too deep a tint to the worts. When the acrospires taken from a few of the grains spring asunder under the knife upon being cut, it is a guarantee against excessive slackness and, to some extent, of proper curing, though the expert empiric determines this by the amount of flavour. Whether the acrospires should be two-thirds or three-quarters up is a matter of taste. We should prefer

three-quarters as a general rule (especially when the barley is not kindly, if they can then be got to grow so far), but uniformity is the main thing. Undergrown stuff, which is virtually almost barley, should never be bought.

In sampling it is no bad plan to count out 100 grains and divide them according to their degree of growth, thus getting the percentage of grains which are three-quarters " up " or more, two-thirds " up," one-half " up," less than half, idlers, etc. Lastly, in buying malt, a lookout should be kept for holes, generally near the acrospire, the work of weevil. These, by the way, should be looked for most carefully when purchases of foreign barley are made. Similar holes may sometimes be observed in samples of African barley, but these may be cases in which the punctures were the work of grubs or caterpillars which have eaten out the greater part of the interior, and assumed the chrysalis form, the slough of which is generally to be found within the husk ; though sometimes the developed, though defunct, moth is in evidence.

Redrying or Retorrifying Malt for running beers, either on kiln or



Drum for Retorrifying Malt.

drum before grinding, is always advantageous in bringing back the biscuity flavour of fresh malt, and friability for good results and high extracts from the mill and ensuring a low percentage of moisture, say, 1% to 5%. To those who retorrify with the object of grinding and mashing at once, there is the added advantage of a low striking heat bringing in fuller enzymic action which a higher strike limits. Generally speaking, hot grist mashing, if properly carried out, gives a greater palate fullness. Optimum results are generally obtained by heating the malt up to 160° F. in five to six hours in a drum for low moisture content, and perhaps four or five hours where the initial moisture is 2% and under. The time required for this temperature on a kiln is of course in the neighbourhood of eight to nine hours.

The drum is the more convenient and efficient machine, since it can generally be erected in the brewery in or near the malt room, using very little fuel, and requires no hand turning or labour for filling and emptying.

Good results are obtained by heating the malt to 160° or 170° F. in the morning, grinding in the afternoon, and mashing the grist next morning. The temperature of the grist will be about 110° F. when mashing.

Pneumatic Malting.—Though there is not space to say much about Pneumatic Malting, which has not hitherto found great favour amongst English maltsters, it cannot be ignored, especially as the modern development of the drum system (Henning's patent) bids fair to obviate previous drawbacks. In the original system of M. Galland the germinating barley was placed in closed vessels provided with a suction-fan, which exhausted the air heated by the vital processes and contaminated by carbonic acid gas, and sucked in air kept cool and moist by being drawn through a bed of coke, on which cold water was continuously sprayed. In spite of the obvious drawback that the grain, incapable of being shifted, grew into a tangled mass, and that the malt had the character of being less tender than that produced in the ordinary way, very good beer was produced by using it.

Certainly some of M. Galland's own beer, brewed at Maxéville near Nancy, was far and away the best of French beers, and not inferior to Viennese brands of repute. The former inconvenience is obviated by the introduction of revolving drums, arranged so as to take a wetting apiece, and capable of being supplied with cooled, moist, and pure air; and it is claimed, moreover, that the erection of a malting on this system results in great economy in prime cost, space, and working expenses.

The Economics of Malting.—Though one man can work a 15-quarter house wetting 45 quarters a fortnight, it takes from ten to twelve men and a foreman in large houses to work an average of 480 or 490 quarters in the same time. Of course, unless the single hand is an exceptional man, the work in the larger houses is better done. This is equally true, assuming the foreman to be efficient, if the men are individually less skilful than the "single-handed" worker. A ton of good anthracite coal is capable of drying and curing from 28 to 35 quarters of malt on a single kiln. Double-kilns, it is claimed, only require approximately half the amount of fuel consumed on single kilns.

Allowance for "increase" varies from 2½% or 3½% in well-managed brewers' malthouses, to anything you please in maltsters'. Of course, too, the season makes a difference. With good dry barley a 5% increase is not unusual, and where foreign barley is malted more may be looked for; at least, where the malt is used in the brewery *by measure*, while the barley itself comes in *by weight*, the increase seems to become something phenomenal. Of course any increase, beyond some 5%, is only apparent.

Nowadays the natural desire of maltsters, who are not brewers, for increase, conflicts with their equally natural desire to get weighty malt by undergrowing it.

It will be clear, therefore, that it would be valueless to attempt to determine a standard charge for malting, generally applicable, per quarter of barley steeped, inasmuch as the various cost items differ considerably from the conditions of working adopted, and vary enormously from season to season from numerous influencing factors, some of which are briefly outlined above.

CHAPTER III

WATER FOR BREWING

PURE WATER—VARYING WAYS OF EXPRESSING RESULTS OF ANALYSIS—RULE FOR HARMONISING—ORGANIC MATTER NOT DIRECTLY DETERMINABLE—ORGANIC CARBON—ORGANIC NITROGEN—TYPICAL ANALYSES—RATIO OF ORGANIC CARBON TO ORGANIC NITROGEN—NITROGEN AS AMMONIA—NITRATES AND NITRITES—AMMONIA PROCESS—MOIST COMBUSTION PROCESS—PHOSPHORIC ACID AND SULPHATES IN POLLUTED WATER—HEISCH (SUGAR) TEST—HANSEN'S METHOD—GENERAL CONDITIONS OF WATER SUPPLY—HARDNESS—SULPHATES—BICARBONATES—SILICA—CHLORIDES—EFFECT OF VARIOUS SALTS ON TYPE OF MALTO-DEXTRIN—KAINIT—ALKALINE SULPHATES—CARBONATES—IRON—TREATMENT OF BREWING WATER—BURTONISING—DOUBLE DECOMPOSITIONS—CLARKE'S PROCESS FOR SOFTENING WATER—EASY QUALITATIVE TEST OF PURITY OF WATER—ANALYSIS.

PURE water may mean one of two things—viz., either the pure water of the analytical chemist, corresponding as closely as possible to the formula H_2O, or, on the other hand, it may mean, and generally does mean, water which, though charged with gases such as carbonic acid and nitrogen, the origin of which (beyond the quantity derived from the air *) may be referred to the oxidation of organic matter, and with a reasonable quantity of dissolved solid or saline constituents, yet shows no evidence of recent contamination to anything like a dangerous extent. Contamination, even in a past not necessarily very remote (of which a high amount of total inorganic nitrogen—*i.e.*, nitrogen existing as ammonia and nitrates—is held to be an index), must be taken into consideration; for though the condition of things which produced it may have ceased for a time, there is a possibility that the stoppage may be only intermittent—*i.e.*, that the aeration, soil-filtration, etc., which have broken up the original organic matter may fail, and the pollution be renewed.

The former type of purity is probably never found uncombined in nature, and even laboratory experiments have failed to eliminate the trace of nitrogen, which prevents the ideal formation of H_2O from being attained. In fact, it has been suggested that it is this inseparable trace of nitrogen which alone renders the boiling of water, in the ordinary sense of the word, a possibility, that, without it, heat would reduce the fluid into its elements. However this may be, the distilled water of the chemist is far from being absolute H_2O, though sufficiently near it for all the purposes of his operations.

Of dissolved saline constituents the brewer tolerates, and indeed desires, a larger quantity than would always be wished for in a drinking water, where the presence—though allegations as to their injuriousness to health have yet to be proved—of salts of lime and magnesia in the form that precipitates on boiling (the bicarbonates, or so-called carbonates) is

* Which in the case of carbonic acid, the principal gaseous product of oxidation seems to be small. Thus lake water contains at most 1 part in 400, whereas *good* well water may have quite 8 gallons CO_2 in 100 gallons of water.

clearly undesirable in view of the deposit produced by them—the too-well-known "fur"—in kettles and domestic boilers.

But for actual brewing operations it seems to be clear, in spite of some revision of views formerly held, that relatively large quantities of sulphate of lime, or gypsum, more moderate quantities of the carbonate, though this is perhaps more questionable, and magnesic salts, or, on the other hand, the chlorides (calcic, magnesic, or sodic) which characterise a different type of water, are all in different ways distinctly useful.

But in any case, freedom from pollution is the question of capital importance, and the proportion of saline constituents is in the second line. We shall therefore deal with the more important point first, and as it appears that considerable mental confusion occurs in consequence of the varying methods of stating the results of analyses, we shall touch upon these several methods at some length, and trust to be able to throw a little light upon what they signify, for the benefit of those who have had little or no experience of operative water analysis.

Results are expressed sometimes in parts per 100,000 (German analyses in parts per 10,000); sometimes in "grains per gallon," which is equivalent to parts per 70,000 (a gallon = 10 lb. of 7,000 grains each), while "free and albuminoid ammonia" is estimated in parts per million—*i.e.*, milligrammes in the litre.

The following rules for converting results into uniform shape may be found useful:—

1. To convert parts per 100,000 into grains per gallon, multiply by ·7.
2. To convert grains per gallon into parts per 100,000 divide by ·7.
3. To convert grammes per litre into grains per gallon (*i.e.*, parts per 1,000, into parts per 70,000) multiply by 70.

(Consequently to convert milligrammes per litre into grains per gallon multiply by 70 and divide by 1,000, or multiply by ·07.)

Organic Matter not directly Determinable.—The actual amount of organic contamination (animal or vegetable) cannot be determined directly by any known method of analysis, but it is supposed that sufficient *data* for forming an opinion can be got by the three methods, which are ordinarily employed, or a combination of them. These are—

1. The combustion process, with which the name of Dr. Frankland is identified.
2. The ammonia process. (Free and albuminoid, otherwise saline and organic ammonia.) Prof. Wanklyn's process.
3. The moist combustion, or permanganate and potash, process.

Some details of the working of the latter two methods, the last in its simplest form, will be given in the chapter on laboratory work. Their practical bearings only will be considered here. The combustion process being too lengthy and difficult for amateur analysts, no attempt to describe the manipulation will be made here, or elsewhere, except in general terms; but an effort will be made to explain the results stated to be obtained by it, premising, however, that in carrying out the process, a small measured volume of water, amounting to a litre if the impurity is likely to be small, is evaporated to dryness, the carbonates having been got rid of previously by treatment with sulphurous acid solution. With the residue (every precaution having been taken to avoid loss or gain) an admixture of pure dry copper oxide is made, and the mixture is then heated in a furnace in

a combustion tube of hard glass. The oxygen thereupon set free from the oxide attacks the organic matter and decomposes it, the resulting carbonic acid and nitrogen being then determined, and the amounts expressed in terms of "**organic carbon**" and "**organic nitrogen.**"

Against this method Professor Wanklyn, championing his own ammonia process, has argued that the ignition of a water residue involves loss of the nitric acid, which exists in considerable quantity in most waters, and its replacement by an equivalent of carbonic acid [HNO_3= 1+14+48=63 replaced by CO_2=12+32=44], this loss of weight being far larger than the organic matter. He also claims to have shown that where solutions of substances containing a known quantity of nitrogen have been tested, the experimental error has been so great as to annihilate the claims of the combustion process to any sort of accuracy.

Again, "previous sewage contamination," which is another feature of Dr. Frankland's method and the Registrar-General's reports, is also objected to by Sutton (Volumetric Analysis) *as introducing a theory*, and as placing a water without a trace of previous sewage contamination upon the same level as one with ·032 part of total inorganic nitrogen per 100,000, owing to the deduction of 320 made as a correction for the average inorganic nitrogen in rain-water. He prefers simply to state the total inorganic nitrogen—*i.e.*, the once organic nitrogen now represented by inorganic compounds, ammonia, nitrates, and nitrites, into which it has been transformed by oxidation. Professor Wanklyn goes further, and disputes the correctness of measuring defilement of water by the presence of nitrates and nitrites, which often come, he thinks, from the geological strata traversed by the water and apart from any possible contamination by organic matter.

Sutton's "Volumetric Analysis," * will serve as a text for a few remarks on the meaning of organic carbon and nitrogen, their ratio to one another, etc. Except the hardness (and even hardness *may* be some indication, seeing that impure waters are generally very hard, owing to the fact that animal *excreta* contain large quantities of lime) and the "total solids," nothing is determined that has not to do with the purity of the water; for chlorine, though generally taken to be combined with sodium in the form of common salt (chloride of sodium), may in conjunction with other *data* have an important bearing on the question of contamination or freedom therefrom.

Chlorine is sometimes calculated as common salt (in the analytical process chlorine is first determined by nitrate of silver solution, the result being multiplied by the factor 1·647).

A word or two more as to the suspicion attachable to the presence of chlorine in somewhat large quantity will not be out of place. Sutton holds that a water containing more than three or four parts of chlorine per 100,000 should be suspected (seeing that human urine contains about 500 parts per 100,000), but Wanklyn, more cautiously, says that five or ten grains of chlorine per gallon are not an absolute bar, even for drinking purposes, but only a reason for suspicion under certain circumstances.

In the particular case in question, if the water containing 5·11 parts

* A book published by Messrs. J. and A. Churchill, to be recommended to those who wish for a systematic handbook of the subject.

of chlorine per 100,000 (=3·57 grains per gallon) showed a high proportion of organic nitrogen, say much above 0·2, it would stand condemned of being unfit for use where a high standard of purity is desirable. A water, however, corresponding exactly to the average of these 157 samples would pass muster. Of course all the conditions would have to be passed in review; and the fact of the water coming from a deep well would tell distinctly in favour of the chlorine *not* being due to recent contamination, and therefore innocuous, if not positively beneficial, which, if combined with calcium or magnesium, it might very well be.

Hardness (temporary and permanent), as well as "total solids," will be referred to later.

Organic Carbon and Organic Nitrogen.—From these the existing condition of the water in respect of organic contamination is to be inferred. In a good water, fit for domestic purposes, the proportions should not under ordinary circumstances exceed ·2 part of organic carbon and ·02 part of organic nitrogen per 100,000. As Sutton, however, points out, the brown, peaty upland waters may contain much more organic carbon, derived from vegetable sources, than this without being condemned, although under usual oxidation influences the proportion, and consequently its ratio to the organic nitrogen, ought to be rapidly reduced. In deep wells, on the other hand, organic carbon, as might be expected, generally falls below the average.

In surface waters from cultivated soil or shallow wells the usual proportions range higher, organic carbon ·25 to ·30, organic nitrogen ·04 to ·05.

Ratio of Organic Carbon to Organic Nitrogen.—The ratio may vary from as much as 10 (or even in extreme cases 20) of carbon : 1 of nitrogen in upland waters and rivers near their source, to equality—viz., 1 of organic carbon : 1 of organic nitrogen—in polluted wells, and accordingly will furnish a useful indication of the origin of the organic matter—for example, thus :—

When the ratio of organic carbon to nitrogen is very high the organic matter is of *vegetable* origin; when the ratio is very low the organic matter is of *animal* origin. The significance, however, of these ratios seems, according to Sutton, to be obscured by the results of oxidation, which in the first case causes a more rapid loss of carbon, so that an originally high ratio of carbon to nitrogen gets considerably reduced; in the second case, on the other hand, the nitrogen disappears more rapidly, so that the ratio, originally low, increases.

Nitrogen as Ammonia (NH_3).—Ammonia in ordinary natural waters seems generally to be due to animal contamination. In upland surface waters, Sutton says, it seldom exceeds ·008 part; in water from cultivated land the average is about ·005. Wanklyn, speaking of "free ammonia," says when it exceeds ·08 part per million (=·008 per 100,000) it almost invariably proceeds from fermentation of urea into carbonate of ammonia, and is a sign that the water consists of diluted urine in very recent condition. This water, he adds, will also be found "loaded with chlorides."

Ammonia being very readily oxidised to nitrates and nitrites, its presence in quantity generally indicates absence of oxidation, and usually coincides with the presence of organic matter. This general statement is

more specifically borne out by Dr. Frankland, who states that he has succeeded in isolating certain microbes, which he calls **nitrifying organisms,** and which make ammonia (itself the product of decomposition) combine with the oxygen of the air, whereby it is converted into nitrous and nitric acids. These microbes are remarkable for the simplicity of their food requirements. They will produce nitric acid from ammonia in liquid practically destitute of organic matter. Indeed, it is only in such starvation media that they establish their supremacy ; in more nutritious media other organisms crowd them out. In sewage, the professor adds, we find *no nitrification but much ammonia.* In such a liquid the nitrifying organisms bide their time till the other organisms have consumed all available nourishment and are perishing from want, then they step in.

Nitrogen as nitrates and nitrites, *i.e.*, combinations of nitric and nitrous acids (derived from oxidation of nitrogenous organic matter, probably as above) respectively with the bases (lime, etc.) existing in the water. The average, though variations are considerable, in deep wells is ·5 part per 100,000, in springs somewhat lower, but in water some from shallow wells, as might be expected, higher.

They are generally considered to be referable to the oxidation of *animal* matter, and, as such, pointing to a defilement (past as far as they themselves are concerned) of the water. Professor Wanklyn, as we have seen, objects even to this, holding them to be often derived from the geological strata which the water passes through. But he points out that vegetation processes in lakes and rivers are calculated to withdraw nitrates from the water.

However innocuous in themselves for potable purposes they may be, some interesting experiments by M. Emile Laurent seem to show that nitrites, at all events, are undesirable in a brewing water. *Harmless as they would probably be in a neutral liquid, the nitrous acid set free from them in a faintly acid medium, such as fermenting wort, apparently exerts a very destructive influence on the growth and fermentative power of yeast.*

Total Inorganic Nitrogen.—The sum of the nitrogen existing as ammonia + that present as nitrates and nitrites, being an indication of *past* contamination (as the organic nitrogen is of *present* contamination), it is therefore, apart from the possible evil influence of nitrites referred to above, mainly of importance as showing only *potential* mischief, which will not become actual as long as the necessary oxidising conditions of aeration and filtration continue. Obviously though, a high proportion of inorganic nitrogen renders the recurrence of actual contamination more probable.

The average quantity yielded by deep wells is ·5 part, by springs about ·4 part per 100,000 ; but though the conditions remain very constant for each well or spring, the range is very wide. As has been said before, "total inorganic nitrogen" corresponds nearly (certain rather arbitrary corrections being made) with Dr. Frankland's "previous sewage contamination."

The Ammonia Process depends upon the more or less brown coloration which water containing ammonia gives on the addition of a definite quantity of "Nessler's solution," and after the free, or as it is sometimes called, the saline ammonia has been determined in this way, the practice is to get at the albuminoid organic ammonia by adding a quantity of

potash and permanganate solution, which, with the aid of heat, converts the existing nitrogenous matter into ammonia, and this is then determined by "Nesslerising" as before. In practice it is usual to take 500 c.c. to distil over 200 c.c., part of which is "Nesslerised" for the free ammonia, then to add the permanganate-potash to the 300 c.c. left. More precise directions will be given in the chapter on laboratory work.

Objection made to Ammonia Process and its Answer.—Fault has been found with this process because there are nitrogenous organic substances which yield no albuminoid ammonia. But this inconsistency, as far as water is concerned, makes the process all the more valuable, seeing that the only one which is likely to occur, viz., urea, is just the one which is provided for. Chance nitro-compounds might, if detected, vitiate the conclusions to be drawn from the analysis.

The General Conclusions to which Professor Wanklyn comes are: Deep spring water is often so pure as not to yield ·01 part of albuminoid ammonia per million, and unless mixed with surface water does not yield as much as ·05 part. Free ammonia exceeding ·08 part per million almost invariably proceeds from fermentation of urea into carbonate of ammonia, and is a sign that the water consists of *diluted urine in very recent condition*. This water will also be found "loaded with chlorides." Much albuminoid ammonia, which generally "comes over" slowly, little free ammonia, and almost entire absence of chlorides, indicate *vegetable contamination*. Any water containing ·02 to ·05 part of albuminoid ammonia per million may be classed as very pure (of course when free ammonia is well under ·08), but there is good ground for suspecting a water containing a considerable quantity of *free* ammonia along with more than ·05 part per million of albuminoid ammonia. In the absence, or nearly so, of free ammonia a water need not be condemned on the score of its albuminoid ammonia unless the latter amounts to something like ·10 part per million.

The Permanganate or Moist-combustion Process, so called because it depends upon a combustion (in a chemical sense) of organic matter by oxygen set free from the permanganate, is, as Professor Wanklyn points out, very useful as an auxiliary to the ammonia process in helping to decide between ammoniacal deep spring water and sewage water. Such a quantity of potassium-permanganate ($KMnO_4$) is taken that 1 cc. of the standard solution = 1 milligramme of oxygen (or $\frac{1}{10}$ milligramme in the simpler process described in the laboratory chapter), and accordingly the number of cubic centimetres of the solution required just to retain a faint trace of the pink tint characteristic of the permanganate, exactly corresponds with the number of milligrammes (or tenths of milligrammes) of oxygen consumed by the organic matter in the quantity (usually one litre) of water dealt with. The results of the process are expressed in reports as "oxygen required to oxidise organic matter."

Professor Wanklyn states that the general conclusions to which his investigations point are that water distinctly of first-class purity does not consume more than ·5 *milligramme* of oxygen per litre (= ·035 grain per gallon), while average drinking water consumes from four to six times as much. Dr. Tidy considers water absorbing not more than ·05 grain of oxygen per gallon to be very pure, and those consuming between ·05 and ·15 grain of medium purity.

Objection made to the Permanganate Test.—Dr. Hassall has stated that though the permanganate readily gives up its oxygen to organic matter and nitrous acid (HNO_2) it fails to do so to nitric acid (HNO_3), the latter being an acid in the highest degree of oxidation of which it is susceptible; and this is the case even when the said acid is present in, very large quantity, and therefore certainly indicating pollution, which though not actively going on, may easily recur. On the other hand, its ready loss of colour in the presence of nitrous acid may lead, as in example No. 1 lower down, to the conclusion that a large quantity of albuminoid organic matter exists; in other words, that the water is undergoing extensive pollution at the time of analysis, whereas there is only evidence of past contamination—a much less serious state of things.

Dr. Hassall also points out that the permanganate is very sensitive to protoxide of iron—as might be expected, seeing that the iron compound always takes up oxygen very readily and passes to a higher oxide. This sensitiveness to the protoxide of iron, however, is apt to be misleading; for however undesirable from a brewer's point of view the presence of an iron salt may be, the reasons are different from those which make fair organic purity an essential. Instructive instances of employment of permanganate, where its indications were misleading, are given below.

	Total Solids.	N as Nitrates and Nitrites.	Equal to Nitric Acid.	Organic Nitrogen from Albuminoid Ammonia.	Equal to Albuminoid Organic Matter.	O required by the Organic Matter, Nitrites, etc.
No. 1.	120·8	2·30	8·87	·011	·14	·52
No. 2.	58·10	3·18	11·55	·006	·07	None.

	Total Solids.	N as Nitrates and Nitrites.	Organic Nitrogen from Albuminoid Ammonia.	Equal to Albuminoid Ammonia.	Protoxide of Iron.	O required by Organic Matter, and Protoxide of Iron.
No. 3.	23·0	None.	·01	·12	·39	·095

Remarks on the above.—In No. 1 a large quantity of the permanganate was decolorised by *nitrous* acid, and therefore the albuminoid organic matter (existing contamination), though really of very small amount, would, if this test alone had been relied on (the oxygen being multiplied by eight as the rule is), have come out 4·16 grains per gallon instead of only 0·14 grain. In No. 2 the absence of any action on the permanganate would lead to the conclusion that this was a very pure water; it had, however, been exposed to such extensive contamination in the past, that it would be hazardous to rely on the conversion of organic nitrogen into the innocuous nitric acid being always so completely and punctually performed. No. 3 shows how the decolorisation of the permanganate by the protoxide of iron may help to condemn a water otherwise extremely pure and suitable for drinking, if not for brewing purposes.

To summarise, as far as we have them, the analytical data which determine the purity of a water.

(i) Organic carbon should not much exceed ·2 part nor organic nitrogen ·02 part per 100,000.

(ii) Free ammonia should not exceed ·05 part, with the same of albuminoid ammonia per million.

(iii) Water consuming ·05 grain or less of oxygen per gallon is very pure; between ·05 and ·15 of medium purity.

Slovenly or Incomplete Statements.—It is perhaps impossible, except by such a comparison as the above, to bring the different systems "into line"; though there is reason to think that some unscrupulous analysts use the easier ammonia process, but state the results in terms of organic nitrogen (N = $\frac{1}{1}\frac{4}{7}$ of the ammonia), a practice which Professor Wanklyn justly deplored.

And though it is anticipating somewhat, this seems a suitable place for referring to his strictures in one mode of stating the results of analysis in regard to mineral solids—namely, that of stating the quantity of each metal and each acid radical in a given quantity of water. Of course, in analysing water, the sulphuric acid, the chlorine, the lime, the magnesia, etc., are determined as such, but it is usual to combine them on certain definite principles—*e.g.*, to combine the sulphuric acid with lime rather than with magnesia, the chlorine with sodium, and to get as much of the latter compound (sodium chloride = common salt) and carbonate of lime as the data will admit of.

On the other hand, it is claimed that a statement of results uncombined does not lend itself "to cookery," but only states ascertained facts. However, it does not readily show whether the water is acid, basic, or neutral; and to ascertain this the puzzled recipient "must divide every quantity of metal or acid radical by its equivalent, then add up the two sets of numbers, and note whether base or acid radical predominate."

Phosphoric Acid, Sulphates, and Hardness (?) as Evidence of Pollution.—Dr. Hassall says, that as phosphoric acid in a combined state as phosphates is a very common constituent of our food, its presence even in minute quantity is an evidence of pollution by sewage, but Wanklyn maintains that except as infinitesimal traces phosphates cannot co-exist with carbonate of lime in a clear water, supporting his contention on the ground that, upon dropping a few drops of a clear solution of phosphate of soda into a beaker of bright, clear water containing carbonate of lime, there will presently occur, upon stirring, a precipitate of phosphate of lime. [But refer next paragraphs on "Sugar (or Heisch) Test" as to phosphorus in an organic form of combination.] Dr. Hassall also suggests that sulphate of lime may, because of the presence of combined sulphuric acid in food, be indicative of sewage contamination; at any rate, as has been pointed out, owing to the large quantity of lime which animal *excreta* contain, polluted water is usually very hard.

Sugar (or Heisch) Test.—The value of this, the so-called Heisch test, has been questioned. The method is as follows. To a large test-tube containing a small quantity of the water to be examined, a little well-boiled (sterilised) sugar-solution is added, the tube then being closed with a sterilised plug of cotton-wool. It is kept for two or three days at forcing tray temperature (say 80° Fahr.), and if no fungoid filmy growth develops, the water is pronounced pure. But Dr. Frankland's experiments tend to show that water known to be contaminated produces no film in the

absence of phosphates, but does produce it directly phosphates are added, in which case its indications would be delusive.

But Messrs. Matthews and Lott ("Microscope in the Brewery and Malthouse," p. 151) have a higher opinion of the test. "It is performed by taking about 250 c.c. of the water to be tested and adding to it 1 to 1·5 grain (? gramme) of pure recrystallised cane-sugar. The bottle containing these is put on the forcing-tank, and the appearance noted at different intervals during several days. Some waters remain quite clear, others become opalescent or milky, while those of the worst class go turbid, and smell strongly of butyric acid. The microscope will show the nature of the bacteria present. The test, according to Professor E. Frankland, indicates phosphorus in the water, and this contention has been sustained by one of us in a series of experiments on a great many samples of water; and as a rider to it the fact has been established *that butyric fermentations occur in the waters containing most phosphates*, other marked signs of contamination being at the same time afforded by chemical analysis." [The italics are the present writer's.]

Further, the former writer, referring to the fact that waters which develop organisms when tried by this test fail to do so after boiling, filtering, and retesting, says (*Brewer's Guardian*, 509), "It is not that the organisms originally present have been killed, but that the main feeding material has departed with the phosphoric acid"—precipitated on expulsion of the carbonic acid gas—"for the addition of mere traces of phosphoric acid to boiled water will suffice to give a fresh growth of organisms."

He adds that he has convinced himself by experiment that phosphorus in the organic form of combination, *e.g.*, in egg albumen, is a richer food for bacteria than inorganic phosphates + sugar, and that waters containing phosphorus in this form may be boiled and filtered and yet give bacterial growths, the phosphorus when in this form not being eliminated by boiling. As a consequence, waters which contain carbonates of lime and magnesia, and which develop organisms with the Heisch test after being boiled and filtered, probably contain organic matter of an albuminous character.

Hansen's Method.—The latest development of research in connection with the fitness of a water supply for brewing tends towards simplicity, and promises results at least as satisfactory as, and far more intelligible than those of the more elaborate processes. In A. Jorgensen's words, "The principle of the method is that it is only necessary to know, for brewing purposes, whether the water contains such organisms as are capable of developing in wort and beer. To this end small quantities of the water in its original or diluted state are added to a series of flasks containing sterilised wort and sterilised beer. An examination of the flasks after incubation in a thermostat at 25° C. (= 77° Fahr.) for fourteen days will then afford information regarding the nature and number of the organisms present in the water in question."

Conditions of Water-supply, Spring and Well Water.—As the careful analyst, having to pronounce upon the qualities of a water, likes to learn as much about its source as he can, so the brewer may very well make himself acquainted with the conditions which determine a plentiful supply or the reverse, conditions, moreover, which stand in some relation to the

quality. We may divide such supplies into spring and well water, the former not necessarily meaning a spring gushing from a rock or hill, but often merely a supply of water which rushes suddenly into a well, which is being sunk, when a porous stratum connected with a more or less distant gathering ground of rain is struck.

Thus clay is impervious to rain, and much money has been spent, where it has run deep, in fruitless efforts to get a sufficient supply of water therefrom; but if in such an attempt a porous stratum (of limestone, chalk, gravel, sand, etc.) were to be struck which ran without a "fault" * to some far-away and extensive gathering ground (*i.e.*, a large extent of porous soil) at a higher level, then a copious supply of water—spring water—would be obtained. And if the level of this distant gathering ground were very high compared with the depth to which the well was sunk, the water would rise up in, or even overflow the top of, the well, and would thus form what is known as an **Artesian well.**

On the other hand, if a well is sunk in a porous water-gathering soil, or even into and through a very shallow basin of clay, overlying such porous strata, which crop out all around the clay and extend for some distance, the water obtained will not be, in the same sense of the word, spring water, but well water. Such a supply of water is not obtained at once even in water-gathering strata; it is only when the water-level—a level varying at different seasons with past rainfall—and which is known as "the plane of saturation," is reached, that any considerable quantity of water can be obtained.

This "plane of saturation" is not uniformly level in the sense that the surface of a lake is level, but, the liquid being sucked up into the pores of the stratified rocks (much as a sponge absorbs water) by capillary attraction, it will vary with the porosity of those rocks, and the narrower the pores the higher the water will mount in them. Obviously, if one of the higher points of "the plane of saturation" be struck, the rate of percolation must be extremely slow.

In any case, the comparative slowness with which a sufficient supply of water percolates from such a saturation area into a well will show the mistake that is sometimes made in sinking deep wells into the chalk. Of course, if a copious stream be struck, well and good; but this is always a chance, and it may be missed merely by a few feet. Consequently the safest and cheapest plan appears to be directly good water (taking the lowest dry-season "plane of saturation") is reached, to leave off sinking downwards, and to drive "headings," at right angles to the shaft, both on the chance of striking a spring and, still more, to form reservoirs in which the water can steadily accumulate. It is quite possible to sink and bore a well 500 or 600 feet deep into chalk without striking a proper spring, and the owner of such a well, sunk without "headings," can never rely, if he should want several hundred barrels of water for refrigerating, etc., on being independent of outside water supplies.

Natural Purification of Water.—The purification of water—that is, the conversion of organic matter, whether animal or vegetable in origin,

* A fault, geologically, is a break in the continuity of a stratum or strata, owing to the forces, which have been at some time or other at work, having first severed and then raised the strata on one side of the cleavage above or away from those on the other. The "throw" of the fault, as the amount of vertical displacement is called, may vary between an inch and several thousand feet.

into harmless constituents—is effected by means of the oxygen dissolved in the water. This process is as much a burning, and as much and no more an oxidation, as when coals are consumed in a grate. The oxygen of the air being much more soluble in water than its nitrogen, the ratio of oxygen to nitrogen is much greater in water than in air, so that the former is obviously in a very active state.

Accordingly, whether it be dissolved by the water directly out of the air, or be found by the latter imprisoned with air in the pores of the soil it traverses, it oxidises the carbon to carbonic acid (CO_2); that is to say, it turns noxious matter into a harmless and even desirable ingredient, which increases as the water gets more and more pure; though of course it is, in itself, no index of purity, as fresh contamination may be going on concurrently, and so the proportion of carbonic acid gas be ever increasing. As has been stated, good spring water may very well contain 8% by measure of carbonic acid. Again, oxygen oxidises the nitrogen of animal origin into nitric acid (HNO_3), which combines with the bases present (lime, etc.) to form nitrates. Nitrites, the salts of nitrous acid (HNO_2), point to partial, and perhaps incomplete, oxidation.

Hardness.—The so-called hardness of water is usually determined by the soap-test—*i.e.*, by shaking up a measured quantity of water with a measured quantity of a standard solution of soap, and observing the point at which the lather formed becomes permanent. The absence of lather at the first addition depends upon the fact that, where lime and magnesia are present in water, the soap forms insoluble compounds with them (oleates and stearates of lime and magnesia), and that only when they are entirely abstracted does the lather begin to form. The readiness with which soap lathers when used with rain or other soft water is a matter of common observation. More details for manipulation will be given in the laboratory chapter.

In England the hardness is calculated on the (most probable) assumption of its being due to carbonate of lime, each grain per gallon shown to be present being called "one degree of hardness." On the Continent the estimation is generally expressed as caustic lime and in parts per 100,000. Obviously any such statement in terms of one salt is only conventional, and may cover a considerable error—*e.g.*, if much magnesia be present: 40 parts of magnesia in its simplest form of combination are theoretically able to precipitate as much soap as 56 parts of lime; and indeed Wanklyn says that one equivalent of magnesia consumes as much soap as one and a half equivalent of lime—hence, he says, 75 degrees of hardness count for 42 grains of carbonate of magnesia.

The hardness considerably decreases, as a rule, after boiling; that is to say, a permanent lather is formed at an earlier stage with boiled water; and it is accordingly useful to determine and state the degrees of hardness before and after boiling. Another name for the degrees of hardness which disappear is "**temporary hardness,**" that which remains after boiling being "**permanent hardness.**" The temporary hardness is due to what are really bicarbonates (though often spoken of as carbonates) of lime or magnesia, though it hardly corresponds exactly, as even after prolonged boiling some two grains of carbonate per gallon remain in solution. Moreover, in some cases, some degrees of hardness are masked by the concurrent presence of carbonate of soda. But the general effect of

boiling, or of a temperature near boiling, is to drive off the carbonic acid, which alone keeps the lime, etc., in solution, and thereby the bicarbonates are converted into carbonates, which precipitate. The permanent hardness is referable to the sulphates of lime and magnesia or to chloride of calcium.

The popular view (once universally held), that a good proportion of the sulphates mentioned, and particularly of that of lime, somewhat limits the solution of nitrogenous matter and of the colouring matters and bitter principles of the hop, is contested as to the former point by later investigators, who assert that the amount of nitrogenous matter extracted by a mash made with distilled water is practically identical with that extracted in a mash made, under precisely similar conditions, with a water treated with sulphate of lime (say twenty grains per gallon of anhydrous salt) ; indeed that, if anything, the distilled water showed the best results, the proportion of the desirable peptones and amides being higher in its case, though the total nitrogen (and *a fortiori* the proportion of the undesirable nitrogenous bodies) was somewhat lower.

The late Mr. Southby, experimenting with a hard water (containing as much as 55·7 grains per gallon of sulphate of lime and 13·8 grains of sulphate of magnesia) against distilled water, was, we believe, the first to prove that the benefit of water containing sulphates of lime and magnesia did not—as far as the malt was concerned—depend upon a diminished solution of nitrogenous matter, which he found to be practically identical with hard or with soft water (varying only by a decimal point), but on the fact that the sulphates appeared to exert some subtle influence which caused the nitrogenous matter, when rendered insoluble by boiling in the copper, to separate in a distinctly flocculent form ; the wort, when filtered and diluted, showing very bright, whereas the distilled-water wort was cloudy throughout, even after filtration.

Obviously then, this suspended matter, which in the latter case is not unlikely to be the cause of a somewhat persistent turbidity, will in the former case be readily separated by drainage through hops in the hop-back, by precipitation on the coolers or by the mechanical action of the yeast. Thausing, recording experiments on decoction lines with waters dosed with sulphate of lime (gypsum) to a considerably larger extent than in Mr. Southby's experiments—viz., with as much as 140 grains per gallon and upwards—notes a similar effect. The wort ran from the mash-tun (the *Lauterbottich*) unusually light and brilliant, and after 1½ hour's boiling " broke " exceptionally well.

Further, Mr. Southby points out that these sulphates of lime and magnesia existing in the mashing liquor exert a slight, but distinct antiseptic influence—in other words, render the wort more capable of resisting the attacks of injurious organisms ; and when it is considered what a relatively long time worts lie in a comparatively unprotected state, even in the best-arranged breweries, this benefit will not appear unimportant.

Second Benefit conferred by Presence of Sulphates.—Another recognised benefit of sulphate of lime in the brewing water is a limitation in the extraction of the rougher bitter flavour of the hop : thus the Burton brewers, using water containing very large quantities of that salt, are able to add probably half as many hops again as users of a water of which the

hardness mainly depends on carbonates.* This is, of course, where high quality and a considerable amount of hop flavour are desired, a matter of great moment, and to it, there is very little doubt, the creamy softness which characterises the best Burton samples, with all their "cleanness" and "finish," is due.

There is an opinion, too, that another point in which water containing sulphate of lime has an advantage over water not containing it, is that **less colouring matter is extracted** by the former from the malt and hops, or, if extracted, that it is precipitated during boiling.

The most desirable proportion of these "permanent-hardness" sulphates (lime and magnesia) seems for general purposes to vary between thirty to fifty grains per gallon, and even the latter amount might give unsatisfactory results in breweries, where it is the custom to derive a substantial portion of the extract from sugar in any shape. For black-beer brewing the presence of lime and magnesia sulphates are not beneficial. These essential sulphates and chlorides for ale production can be added in any proportions deemed necessary to any brewery water in which there is a deficiency.

Bicarbonates.—As has been already mentioned, the lime and magnesia held in solution, when combined with carbonic acid gas in the form of bicarbonates, are precipitated as carbonates when the carbonic acid is driven off by heat. Accordingly, if the brewing water were always submitted to a somewhat prolonged boiling and separation of the precipitate, the action of these salts would be *nil* as regards the mashing and boiling operations; but, as the heating of mashing and sparging liquor is usually conducted, doubtless appreciable quantities find their way, in the shape either of bicarbonates or carbonates, into the mash, where they form, in combination with the lactic acid present in the malt, lactates of lime or magnesia.

We believe that the presence of this normal lactic acid of sound malt (as distinct from the abnormal acidity of unsound malt) is an advantage, and that its abstraction is not only undesirable from the point of view of flavour, to the piquancy of which it almost undoubtedly contributes, of soundness which it helps, being, as far as it goes, a specific poison to the injurious organism known as *Bacterium lactis*, but that just as *in moderate quantity* it aids the action of the diastase, so in ampler measure it assists the action of the peptase (which requires an acid medium) in its important function of peptonising the albuminoid constituents of the wort, or, in other words, rendering them available as yeast nutriment.

Nor should we be surprised if subsequent experiment were to show it to be not without influence upon the extraction of a desirable hop flavour. For each of these reasons, fairly certain or purely conjectural, the retention of the lactic acid may be assumed as a thing to be aimed at, and accordingly the presence of bicarbonates or carbonates *may* explain certain negative, or worse than negative results which sometimes attend the so-called "Burtonising" of brewing water—*i.e.*, adding preparations containing sulphate of lime and other salts.

* An analysis, for example, will be found at the end of this chapter, of a water (B) with which, even when moderately treated with sulphate of lime, it is found impossible to use more than from 2 to 2¼ lbs. per barrel collected of hops, even for pale ales; much lower quantities being obligatory for bitter ales of less gravity.

Not wishing, however, to be accused of overstating the case, we may say that the quantity of carbonate of lime required to neutralise lactic acid would be as 10 : 9. Now taking the normal proportion of free acid (calculated as lactic) = ·2 to ·3 per cent., the former of these being one part in 500 = 140 grains per gallon. But the total carbonates in a water containing 20 grains of them per gallon would, taking the above ratio (10 : 9) and assuming 1·25 gallon to be required to produce 1 gallon of wort, only neutralise (and that, if all the carbonates took part in the reaction) 22·5 grains of lactic acid or barely one-sixth part. However, it may be added that careful experiments by Dr. G. H. Morris have shown the acidity percentage in sound wort from the mash-tun to be not higher than ·073.

Although boiling and filtration (or even decantation) will eliminate carbonates in a laboratory, the same thing is not so easily done in a brewery. Boiling, however, is certainly an advantage, even if the removal of the carbonates be not specially desired, being destructive of any full-grown organisms which may be in the water as well as a stimulant to their spores or germs, invulnerable, as such, even to boiling temperatures, to assume the form of developed organisms, as which they are capable of being destroyed by boiling or even lower temperatures.

On the other hand, the presence of moderate quantities of carbonate of lime and magnesia is circumstantial evidence of the good quality of the water containing those salts. There are occasionally large fissures in the chalk formation, through which polluted water may find its way wholesale ; but as a general rule, owing to the filtration and aeration which the fluid undergoes while passing the pores of masses of chalk, it is usually extremely pure provided it is drawn from fairly deep wells.

Silica is only of importance to the brewer inasmuch as in conjunction with carbonate of lime it forms that rock-like precipitate known as "scale" in boilers, etc., or "fur" in kettles, and which tends to choke the supply-pipes leading from the hot liquor-backs to the mash-tun. This risk of gradual stoppage of the pipes is another reason for a preliminary boiling of the mash-liquor, in a distinct vessel if possible, where the precipitate can be more easily dealt with.

It is impossible to remove this scale by tapping the pipe or expanding it by the sudden application of heat outside because of the envelope of non-conducting composition with which the latter is usually covered ; nor are the copper pipes capable of standing much rough scraping, so that the only alternatives are either to sacrifice the pipes when they get nearly choked, or to treat the separate lengths with strong muriatic (commercial hydrochloric) acid, which, though a dirty and unpleasant job, can be so managed that the scale gets broken and loosened sufficiently for a moderate scraping with a long-handled scraper to remove considerable pieces of the scale, especially after a short soakage with alkaline water and steaming.

This plan has been carried out more than once, and when the scale has been of a very obdurate nature ; but it has been found that contact with the acid must be for a prolonged time, say for twenty-four hours, and that the pipe, with a dummy-flange, cut out of sheet iron and bolted on to each end, must be shifted from time to time (the dummy flanges are better than bungs, which are apt to be blown out owing to the rapid evolution of gas), and that only small quantities of the acid can be put in at a time.

Silica is present in most waters, a thing not to be wondered at when we remember how omnipresent it is in nature. It has been pointed out by J. O'Sullivan that the cellulose fibres of barley husks and of the chaff of wheat are shaped, so to speak, on a skeleton of silica; and in fresh water streams and the depth of ocean are innumerable multitudes of tiny Diatoms reabsorbing and forming their myriads of minute shells from the silica continuously eroded by rain, and carried down to their sphere of operations by streamlets into rivers, and rivers into seas, and reforming anew with their allies the Foraminifera (which construct their shells of carbonate of lime), the sedimentary rocks, just as those which underlie this earth of ours were formed and reformed in countless bygone ages.

Chlorides.—As some brewing centres have gained fame in consequence of the water available there containing sulphates, so others depend for their value mainly on chlorides. Chlorides of calcium and magnesium appear to determine, especially in conjunction with those of sodium and potassium, a full and rich flavour, which those who have tasted certain Scotch ales and compared them with their English rivals will be aware of.

A proportion of chlorides which might be expected to give marked results would be about seven or eight grains of calcic chloride per gallon, six or seven grains of magnesic chloride, ten grains of potassic chloride, and eight of that of sodium per gallon. It may be found advisable to increase the calcic at the expense of the magnesic salt and the sodic at the expense of the potassic, but it will not be overlooked that many waters already contain chloride of sodium (common salt) in some quantity.

The improvement effected by adding this alone is easily put to the proof, and a good deal more than the quantity given can sometimes be used with advantage, especially in the brewing of black beers. The other salts of course will be cautiously added, it being always advisable for the brewer, in this as in other changes, to feel his way before materially altering the character of his beer.

We may perhaps state that we have known common salt to be added at the rate of one pound per quarter of malt, without any restrictive effect upon the subsequent fermentation. This, at the rate of two barrels of mashing liquor per quarter, would actually amount to ninety-seven grains per gallon. This amount would, however, be diluted to at least the half by sparges by the time that the wort was gathered in the copper; but even then the quantity was high, and might easily reach the excess on which prosecutions have from time to time been based.

Effect of various Salts on the Type of Malto-Dextrins.—Dr. Moritz, in a valuable paper on Malto-dextrins (the *compounds* of maltose and dextrin which are stated to impart palate-fulness and condition), gives some interesting parallel mashes of malt (1) **With Distilled Water**; (2) **With Gypsum** equal to 50 grains SO_3 per gallon = 85 grains of the anhydrous salt; (3) **With Calcic Chloride,** 37·5 grains per gallon.

The experiments were made, apparently, not so much to determine the actual amount of malto-dextrin, as whether it was of the higher or lower type (see p. 242)—*i.e.*, one in which dextrin preponderated, or one in which maltose preponderated. As will be seen, the water treated with calcic chloride gave a wort containing a lower type of malto-dextrin,—*i.e.*, one which would ensure rapid condition, and therefore, according to present views, would answer best for short-storage or running beers.

The gypsum liquor, showing higher malto-dextrins, appeared to be suited for long-storage beers. The distilled liquor gave less malto-dextrin altogether, a lower quantity, in fact, than is deemed desirable.

It will not be overlooked, however, that these are laboratory experiments which sometimes show different results—and not least of all when dealing with the types of malto-dextrins—from actual brewery operations. The results were as follows :—

(1)	Maltose	6·29		
	Dextrin	6·88		
		13·17		
(2)	Maltose	6·80		
	Dextrin	9·12		
		15·92		As Malto-dextrin.
(3)	Maltose	9·01		
	Dextrin	6·35		
		15·36		

Kainit.—The addition of Kainit is not now employed owing to its irregularity of composition. Analysis of Kainit carried out by various investigators of eminence prove this. According to Langer ("Lehrbuch der Chemie," u.s.w.) it contains 20% of potassium sulphate, its formula being $K_2SO_4 + MgSO_4 + MgCl_2 + 6\ H_2O$, or potassium sulphate, magnesic sulphate, and magnesic chloride + 6 molecules water of crystallisation. Other authorities differ widely in their analytical results.

Sulphates of Potash and Soda.—Different opinions exist as to the sulphates of potash and soda. Mr. Southby, however, says there is "no doubt that the sulphates of the alkalies have a tendency to cause thinness of palate and a peculiarly poor and, at the same time, harsh flavour in ales. It has been also said that they prevent the ales fining, but I have never been able to find any proof of this assertion."

Carbonates of Soda and Potash.—Whatever the truth about the sulphates there is universal agreement that the carbonates, except for black-beer brewing, are distinctly bad. The extractive nature of the water containing them determines solution of colouring matter from the materials employed, as well as extraction of a rank bitter from the hops ; and the tendency in worts brewed with such water to a less satisfactory "break" seems to point to some modification of coagulated proteins which is, not improbably, detrimental.

Neutralisation by calcic chloride resulting in sodium chloride (common salt) and bicarbonate of lime seems the preferable method, because it can be used *in excess* and is itself in some cases beneficial (*v.* p. 201). We are dealing with very dilute solutions and **mass-action** comes into play, according to which the chemical action of any substance is proportional to its acting mass or concentration. An experiment condensed from Prof. Tilden's "Progress of Scientific Chemistry" (p. 259) will illustrate the effect of mass or relative quantity.

If a dilute solution of ferric chloride in water be mixed with a similar solution of potassium thiocyanate the red coloration due to ferric thiocyanate will appear. Divide the mixture into two, to one portion add more ferric chloride and to the other more thiocyanate ; a deepening of

tint will be observed in both cases involving the apparent contradiction, first that iron was deficient in the original mixture, and secondly that the thiocyanate was so too. It will be found on trial that to produce the maximum effect one or other of the acting materials must be used in very great excess above the quantity indicated by the theoretical equation, which would be used to express the change.

Sulphurous acid has been suggested as a *possible* neutraliser, but one which it would not be well to use in excess of the proportions indicated by the respective atomic weights, 41 parts of acid to 53 of sodic carbonate by weight ($H_2SO_3 = 82 : Na_2CO_3 = 106$). Sulphite of soda would be formed, and from it sulphurous acid might again be liberated by the acid of the mash, exerting a bleaching action on the colouring matters of the wort.

Moderate alkalinity might be neutralised by utilising the free sulphurous acid in bisulphite of lime. Thus, supposing the bisulphite to contain 580 grains of free anhydrous sulphurous acid per gallon, the use of 1 pint per quarter of the mash, which is usually considered safe enough, would neutralise about $1\frac{1}{2}$ to $1\frac{3}{4}$ grain per gallon of sodium carbonate.

The use of calcic chloride is recommended on the assumption that one of the so-called "double decompositions" will take place, resulting in the formation of chloride of sodium and carbonate of lime.

Iron in Water, of which traces are very general, exists usually in the form of bicarbonate of iron ($FeH_2C_2O_6$), which is precipitated on the expulsion of the CO_2 by boiling. It is also found as ferric sulphate or as protoxide of iron. A good deal of mysterious damage is attributed to iron—but certainly iron in solution forms with tannic acid (which, it will be remembered, is an important constituent of hops), tannates of inky hue, thus acting prejudicially in two ways—viz., imparting a bad tint to the product, and diverting part of the tannin from its proper function of precipitating a portion of the proteins (as tannates of albumen).

The development of "fuzzy heads" in fermentation has been supposed to be an outward visible sign of the presence of iron in some form, an opinion I merely state without intending to endorse it. If the water contains carbonate of lime, the latter, being precipitated on boiling, or to some extent as that temperature is approached, will carry down the iron with it; but in the event of there being iron but no carbonate of lime in the water, treatment of the water with carbonate of soda (5 or 6 grains per gallon) has been suggested, the carbonate of soda being afterwards rendered harmless by the addition of calcium chloride in excess, as recommended above. Of course time must be allowed for the precipitate to settle after boiling if such treatment is necessary; and it would be almost imperative to have a distinct hot liquor-back for boiling, whence the purified water could be slowly run into the vessel from which the mashing "liquor" is drawn.

Treatment of Brewing Water—Burtonising—Double Decompositions.—The treatment of brewing wate for special defects has been referred to more than once in the last few pages, but there has, further than this, been so much anxiety to make brewing waters tally with Burton analyses that one cannot ignore it. Still it does not follow, as a matter of course, that the mere addition of sundry salts, and especially of sulphate of lime (gypsum), is going to produce the identical thing. Nor would it be well always to do so.

Brewers, who from the conditions of their trade or the arrangement of their plant find it advisable to use large percentages of sugar (invert or glucose), will certainly not find it to their advantage to use waters highly charged with gypsum. Whatever the cause—and we do not feel called upon to pronounce decidedly, though it may be conjectured, in the light of M. Hansen's discoveries, that the conditions are such as to give the predominance to some undesirable form of secondary (wild) yeast—the conjunction of a water containing much calcic sulphate with the employment of a considerable proportion of sugar, certainly seems to influence the production of beers having what, for want of a better name, may be called a "wiry" character.

Double decompositions are those reactions in which two compounds take part, with the result of a formation of two fresh compounds. Thus in the one mentioned above, where calcium chloride added to water containing carbonate of soda forms calcium carbonate and sodium chloride, the formula $CaCl_2 + Na_2CO_3 = CaCO_3 + 2\,NaCl$ not only emphasises the fact but tells us, because

Ca	= 40	Na_2	= 46	Ca	= 40	*Na	= 23
Cl_2	= 71	C	= 12	C	= 12	Cl	= 35·5
		O_3	= 48	O_3	= 48		
$CaCl_2$	= 111						58·5
		Na_2CO_3	= 106	$CaCO_3$	= 100		× 2
						2 NaCl	= 117

that 111 parts by weight of calcic chloride added to 106 parts of sodium carbonate produce 100 parts of calcic carbonate and 117 of common salt.

A number of years ago Dr. Graham pointed out the probability of a similar double reaction upon the addition of sulphate of lime and chloride of sodium to water, resulting in the formation of sodium sulphate and calcium chloride.

Clarke's Process for Softening Water.—As this process is adopted in at least one very large brewery to my knowledge with useful results, it may be serviceable to set down the *modus operandi* here, as the patent rights have now expired. For each 1,000 gallons of water about 1 oz. of quicklime is required for each degree of hardness (*i.e.*, each grain of hardening matter per gallon reckoned as carbonates of lime). The quicklime being thoroughly slaked in a pailful of water the milk of lime thus obtained is poured into the cistern containing say 100 gallons of the water, which has to be softened, or any multiple thereof according to the quantity dealt with. The remaining 900 gallons (or a corresponding multiple) is then run in and roused to mix.

The whole body of the water will now appear very milky owing to the formation of chalk, the carbonic acid which kept it in solution being abstracted by the caustic lime, this latter combination also resulting in the formation of more chalk, which gradually precipitates, and at the end of about twelve hours leaves the water clear enough for drinking purposes. If greater precision be aimed at, a drop or two of silver-nitrate solution may be added at intervals to a sample withdrawn in a white cup from the cistern. As long as there is lime in excess it will give a yellow or brownish coloration; but as soon as this gets very faint the inflow of hard water should be stopped.

* Na (= Natrium) is the symbol for Sodium.

Professor Wanklyn indicates a way for **accelerating the softening process.** He points out that, on performing the process in a large glass vessel, it will be seen that a layer of quite clear water makes its appearance on the top, and gradually extends downwards. "If we ask how this water has become clear, the only answer that can be made is, that the precipitate has moved down to the layer of water beneath it, and thereby rendered that layer thick; for had the precipitate not descended into it, it would, like the top layer, have become clear. In the same way, this second layer, by its depositing, renders that beneath it turbid. If such a vessel of water took six hours to clear, we should expect that by dividing it into six layers by means of five diaphragms, equidistant from each other and from the top and bottom of the water, that the water would clear in one-sixth the time, or one hour. On making the experiment, this is found to be the case.

"To test this matter more fully, what may be called a 'subsidence filter' was constructed. It consisted of a wooden box 12 inches square and 20 inches deep, containing 24 plates of sheet zinc $\frac{3}{4}$ inch apart. Each plate had 6 holes punched in it, 1 inch in diameter. The holes were near to the side, and had their edges turned up a little. The plates were so arranged that the holes were not opposite each other. A small tap came from just below the lowest plate. Another box like this, but without plates, was also constructed. Both boxes were charged with freshly softened water, containing chalk suspended in it. The water took about eight hours to clear in the box without the plates, and was quite clear in the one with the plates at the end of twenty-five minutes." The lesson learnt from this operation on a small scale might easily be applied on a larger basis, or might be extended to mechanical filtration generally.

Easy Qualitative Test.—If sudden doubt be felt as to the purity of the water supply, certain methods are available, which, though too "rough and ready" to be placed among tests proper, may yet be depended on as far as they go. One of these consists in the addition of a few drops of Condy's Ozonised Fluid to the suspected water, sufficient to give it a faint pinkish tinge. If organic matter be present the pink disappears in a greater or less time, and a brown precipitate (oxide of manganese) is formed, the organic matter being oxidised or burnt up; but if the water be pure, the pink colour remains. This action of the "Condy" may be manifested by putting into some water coloured with it a strip of clear white blotting paper, which consisting, as it does, of cellulose and other organic matter, will have the same effect upon the tinctured water.

Colour and Smell.—If two white glass cylinders (Nessler cylinders) be filled, one with the suspected and one with distilled water, and placed side by side on a porcelain tile, a yellow or brown tint (observed by looking down through the depth) in the former indicates organic matter, but not *necessarily* (unless in water previously pure) of a very objectionable type; for instance, water from a peaty source is often highly coloured.

Again, some of the water may be shaken up in a large wide-mouthed bottle, and the nose applied at once. Any objectionable smell will be more readily detected if the water be slightly warmed.

Organic Matter detected by Ignition of dry solid Residue.—Evaporate some of the water to dryness in a platinum dish, then hold over the flame of a Bunsen burner and observe if it blackens; this will indicate an

appreciable amount of organic matter. A slight charring indicates a small amount of organic matter. As upon further heating the brown colour produced by the charring goes off, the maximum charring must be watched for.

For a sudden pollution of the water supply a temporary remedy may be found in chloride of lime, 10 grains of which boiled with each barrel of the affected water will oxidise the organic matter, any excess chloride being neutralised by adding a corresponding quantity of bisulphite of lime.

This lengthy chapter may conclude with analyses of two sets of water, A and *a* : B. A and *a* are reports by two leading analysts on the same water, taken at the same time and *under identical conditions*. The water came from a 378-foot boring tubed for 230 feet with a 7¼ inch tube, into the old red sandstone formation, the outcrop of which a quarter of a mile away was limited in area ; but the boring was very close to another well with a heading into dolomitic conglomerate, and which gave, as might be expected, a distinctly hard water. B is a chalk water.

ANALYSIS A.

Hardness before boiling	9 degrees.
Hardness after boiling	0·3 ,,
[1 degree = one grain of carbonate of lime per gallon.]	
Free Ammonia	0·049
Albuminoid Ammonia	0·003
Oxygen absorbed in 1 hour	0·059
,, ,, ,, 3 hours	0·066
Nitrogen as Nitrates	none

Acids and Bases.		Probable Combination.	
Chlorine	17·92	Calcium Carbonate	8·0
Sulphuric Anhydride	8·60	Magnesium Carbonate	4·32
Carbonic Anhydride	13·21	Potassium Sulphate	18·70
Lime	4·48	Sodium Carbonate	17·90
Magnesia	2·06	Sodium Chloride	29·03
Potassium	8·38	Silica	0·70
Sodium	18·88		
Oxides of Iron and Aluminium	none		
Silica	0·70	Total mineral matters	78·65

ANALYSIS *a*.

	Grains per gallon.	Probable Combination of the Saline Residue.	
Total Solid Residue	77·28	Chloride of Sodium	28·99
Saline Residue	75·60	Sulphate of Soda	14·87
Organic and Volatile Matters	1·68	Carbonate of Lime	6·12
Lime	3·43	Carbonate of Magnesia	4·45
Magnesia	2·12	Carbonate of Soda	20·03
Soda	27·09	Silica, etc.	1·14
Potash	trace		75·60
Sulphuric Acid	8·35		
Nitric Acid	*nil*		
Nitrous Acid	*nil*		
Chlorine	17·57		
Lead	*nil*		
Iron	trace		
	Parts per million.		
Ammonia free	0·630		
Ammonia Albuminoid	0·020		
	Parts per 100,000.		
Oxygen required to oxidise organic matter	0·015		

[N.B.—Multiply figures "parts per million" by $\frac{7}{100}$ to bring into grains per gallon.]

Results are stated throughout in grains per gallon (*i.e.*, 1 : 70,000). See p. 69.

Discrepancies in these figures are interesting, the Winchester quarts having been filled with every care to ensure uniform samples. In the reports accompanying the figures the analyst of A pronounces the water to be practically identical with the deep-well water of the London basin, and therefore pre-eminently suited for brewing black beer. The analyst of *a* says, "Well adapted for black beer brewing . . . but the amount of carbonate of soda is much above the quantity found in the deep-well waters of the London basin, which, though containing only half the amount found in this sample, are found unsuitable for pale ale brewing." The former advises (for ale brewing) passing the water through a gypsum tank at such speed as will completely decompose the alkaline carbonate, then treatment with calcium chloride to reduce the excess of alkaline sulphate arising from decomposition of the alkaline carbonate. It will then, he says, be fit to produce first-class pale and stock ales. The second analyst advises treatment with calcium chloride (2 pints saturated solution to each 10 barrels of mash and sparge liquor) to decompose the alkaline sulphate-carbonate. There would be, he adds, 50 grains of sodium chloride per gallon altogether, unfitting the water for pale or stock ales. [This advice should be read in the light of the mass-action experiment on p. 201.]

B is a natural water.

The results are stated in grains per imperial gallon of 70,000 grains.

	B
Nitrogen as Nitrates and Nitrites	·1648
,, = Nitric Acid	·74
Oxygen required to oxidise organic matter	·074
The mineral constituents are probably combined as follows :—	
Sulphate of Lime	3·71
Sulphate of Magnesia	—
Carbonate of Lime	16·37
Carbonate of Magnesia	6·61
Sulphate of Soda	—
Sulphate of Potash	—
Carbonate of Soda	—
Chloride of Magnesia	—
Chloride of Sodium	3·80
Nitrate of Potash	1·19
Oxide of Iron	·21
Silica	·84
Organic matter	·59
Total Solids	33·32

The report sent with the above was: "I find this water to be fairly pure; it shows no evidence of recent sewage contamination. The small amount of nitrogen, as nitrates and nitrites, which is present, is in all probability of mineral origin; no alkaline carbonates are present."

CHAPTER IV

HOPS AND SUGARS

HOPS (GOLDINGS, GRAPES, JONES, COLEGATES, ETC.)—THE BEST DISTRICTS—PLANTING—POLING, ETC.—CLIMATIC CONDITIONS—COST OF PRODUCTION— A GOOD SAMPLE OF HOPS—FOREIGN HOPS—SULPHURED HOPS—CONSTITUENTS.

CLASSIFICATION OF SUGARS—FORMULÆ—RAW AND REFINED SUGAR—INVERTING SUGAR IN THE BREWERY—COMMERCIAL GLUCOSE.

HOPS.

HOPS, as known to brewers, are the strobiles, or greenish-yellow cones, of the female plant, consisting of broad and partly overlapping scales. The male plant used at one time to be cultivated—that is to say, a very small percentage of them among the female plants, say 1 in 200 or 300, with the view of securing fecundation—but such a course is now regarded both on the Continent and in England as unnecessary. Botanically the hop (Humulus lupulus) belongs to the Urticæ or nettles.

As is well known, Kent is the hop-growing county *par excellence*. There is something in the soil of its lower greensand belt, and again in the loams and the kindly loamy clays of the so-called Thanet, Woolwich, and Reading beds, which is particularly favourable to the production of a good quality crop ; while, on the other hand, the heavier clays of the district, known as the Weald, are more remarkable for quantity, the crop there often in good years approaching, or even exceeding, a ton per acre. In East and Mid Kent and Farnham the average yield was formerly 6½ to 7 cwt. per acre, but with modern methods of production, the yield in some seasons, under favourable conditions, now reaches that of the Weald.*

A full list of the principal Kentish, Worcestershire and Herefordshire hop-growing parishes will be found as an appendix.

A very capable authority, himself a Mid Kent grower, says : "It is very remarkable that, given the very finest land in Mid Kent, and the most scientific methods of cultivation, with the very same climate, hops cannot be grown equal in quality to those produced in the contiguous East Kent districts barely ten miles distant ; and again, the hops grown in the adjacent Weald of Kent cannot 'hold a candle,' in the matter of quality, to the produce of genuine Mid Kent land. The distinction in the colour, shape, style, and general appearance of the flower-cones is most marked, and discoverable by the veriest tyro (!). The most inexperienced brewer can detect the difference of brewing value in the copper, and the most juvenile merchant can 'spot' the Weald of Kent hops by the coarse and large leaves, the thick strigs, and the comparative want of refinement in the flavour."

* The average growth per acre in cwts. of English hops for 1925 was 13·5, and in 1924, 17·2. The lowest average since 1907 was 6·59 cwts. per acre in 1909.

The different kinds of Hops grown in England comprise—**Early Sorts :** White's Early (delicate and shy cropper), Bramling (good compact cones), Amos' Early Bird (Bramling type, but earlier), Bennett's Early Seedling, Hensham's Jones' Hop, Hobbs' Early, Prolific, and Meophams. The quality probably in the order given, the last two very inferior. **Main crops sorts** comprise **" Goldings," Whitebines, Mercer's** (reputed an earlier variant of the real Goldings), **Cobb's,** an earlier ripening Canterbury Whitebine, and **Fuggles'.** Unfortunately the name Goldings, known to all users of hops, is very loosely applied. Originally a sub-variety of the Canterbury Whitebine, but differentiated from it by larger cones hanging on a more speckled and less luxuriant bine, the name Golding is now given to most first-class sorts. Even the incongruity of **Fuggles' Goldings** is not unknown. The Whitebines (Canterbury and Farnham Whitebines and Mathons of Worcester and Hereford) are so closely related in botanical character that they doubtless are one and the same variety, and, says Prof. Percival of Wye, " they all rank as hops of the very best class on account of the excellence of their flavour and their relatively high lupulin content. Owing to their delicate constitution they can only be grown in the most favoured climates and soils. The Farnham hop is slightly smaller and not quite so round in section as the Canterbury variety, and usually the petals are closer in their arrangement on the strig of the hop. Their colour is also a shade paler and more uniform on both kinds of petals." [These are the seedless and normally darker-coloured " stipular bracts," and the seeded " bracteoles."] All three have pale green bines. " Fuggles'," says Prof. Percival, " belong to the class of large hops, though considerably smaller than the Prolific and Meopham varieties. When fully ripe the hops are squarer in section and pointed, very rich in lupulin but somewhat coarse-flavoured and lacking the uniform golden tint of the best Whitebines. The petals are thick and strong, the basal ones being generally of a darkish green colour. The plant is a heavy cropper, thoroughly hardy and well adapted for growth in the stiff damp land of the Weald and similar districts, where the Whitebine dies out rapidly. The bine is of a sap-green colour." **Late Varieties.—Grape Hops** (cones appearing clustered, narrowish in proportion to length and pointed). **Colegates** (long, narrow cones) are coarse, strong hops yielding heavy crops in the Weald of Kent and Sussex but not very rich in lupulin. **Mayfield Grapes,** Worcester and Hereford, said to be much less coarse than the same-named hop in Kent.

[Prof. Percival's exhaustive paper in the " Journal of the Royal Agricultural Society of England," vol. 62 should be read by all interested in hops.]

North Kents (or the Hill) and **West Kents** are by the trade included in Mid Kent, but experience of Mid Kent brewing goes to show that North Kents are very highly esteemed by brewers there, for a delicacy of flavour rather than potency ; although, as Mr. Whitehead says, Mid Kent growers do not like to confess any inferiority of their own produce. The finest hop land in England, he says, is that from Chatham to Faversham, and from Faversham nearly to Canterbury for some miles, chiefly below the line of railway, upon various clays, loamy clays, and loams of the Thanet, Woolwich, or Reading beds and the Oldhaven beds overlying the chalk. As the chalk appears again, the loam surface decreasing

in thickness, the hop-ground becomes less valuable ; but below Canterbury, in the district from Chilham to Barham Downs east, hops of first-class quality are grown on somewhat sandy loams upon chalk, although the crops are smaller and the poles required are shorter.

Thus far we have only spoken of Kent, but in many breweries, **Farnhams**—*i.e.*, real Farnhams, Farnham Town district hops—are preferred even to East Kents. At one time, when using choice Farnhams frequently, it was generally said that when any gyle of pale ale was of especial merit, this appeared, upon reference, to be concurrent with the fact that a larger percentage of Farnhams than usual had been employed in its production.

On the other hand, in some districts, or it may be in some plants, where copper hopping has to be light, and where the pale ales go very speedily into consumption, Farnhams may give less satisfactory results than the milder and delicate hops of Worcester and Hereford. There seems indeed to be a certain astringency, combined with the great aroma of Farnhams, which makes their position in relation to other hops comparable with that of the highly flavoured astringent, Indian teas, in relation to the milder produce of China.

The hop-districts of Surrey and Hampshire " march together " more or less, the most favourable soil being that referred to by Gilbert White as " the malm, a sort of rotten or rubble stone, which when turned up to the frost and rain moulders to pieces, and becomes manure to itself," a soil found in the neighbourhood of his parish of Selborne, in Hants, and Farnham, in Surrey. These combined districts, where " Farnhams " and " Country Farnhams " grow (marked with the bell, as Kentish hops are with the horse), are confined within comparatively narrow limits, about five or six miles wide by twenty or thereabouts in length. Worcester and Hereford hops grow upon certain formations either of the new or old red sandstone, or the alluvium of certain rivers, " Teme-side " hops perhaps have the preference ; but the most favourable hop-growing soil in both Worcester and Hereford is a red loamy soil on the old red sandstone.

English Hops.

Types and their Characteristics

(from the Journal of the Royal Agricultural Society of England) :—

Worcester Mathon.—A whitebine grown originally in the parish of Mathon, a few miles from Worcester. Of the very highest quality both in flavour and lupulin. A very old and mid-season variety identical with the Canterbury and Farnham whitebines.

Bramlings.—Originally grown at Bramling near Canterbury. One of the best of the early hops. It is of medium size, firm, compact and round in section, with a well-closed tip. Now grown in all the best districts.

Fuggles.—A mid-season or main crop variety, very rich in lupulin, but somewhat coarse flavoured. In shape the hop is large, square in section, and pointed. The petals are thick and strong, and the basal ones of a dark green colour. The plant is hardy, a heavy cropper, and does well on the stiff damp land of the Weald of Kent, where the whitebines die out rapidly.

Canterbury Whitebines.—One of the best main crops of the finest flavour and strong in lupulin. So closely related to the Worcester Mathon and Farnham whitebine that they cannot be distinguished from each other, and are no doubt one and the same hop.

Cooper's White.—One of the best of the Worcester hops and of the whitebine variety, but not equal to the Mathon in flavour. The main points of difference are that the Cooper's White is a more delicate plant, the hops develop earlier and the petals are larger.

Grapes.—So called because the hops grow in thick clusters on short laterals. In shape the hop is long, narrow, square in section, and pointed, and is allied to the Fuggle, but is not such an abundant cropper. The Worcester variety is known as the Mayfield Grape, and has a better flavour than the Kent variety. May be considered the best quality of the late hops.

Colegates.—The latest hop to ripen, and consequently at times difficult to harvest. In shape a long narrow hop, square in section with thin petals, pale in colour. A very hardy variety and a heavy cropper. Has a strong aroma and makes a good yearling hop.

Cobb's East Kent Golding.—A medium sized hop with thin pale yellow petals, good in flavour but somewhat poor in lupulin. Ripens earlier than the whitebine but not so early as the Bramling.

Prolifics.—One of the largest hops grown, but of poor quality, coarse in petal, pointed square in section, and poor in flavour. Grown in districts unsuited to the better kinds of hops. An early variety.

Henhams Jones.—An early variety similar in appearance to Meophams but a better kind. Of oval shape and medium size. Somewhat low in lupulin but of good flavour.

Bennett's Early Seedling.—A medium sized oval hop, rich in lupulin with a moderate flavour. One of the two English hops (the other being the Fuggle), known with certainty to have arisen from seed.

White's Early Hop.—In quality one of the best of the early hops. Of medium size, pale golden colour and excellent flavour, but the plants are delicate and rarely give a satisfactory crop.

Amos' Early Bird.—Of good quality, and ranks high among the best early varieties for cultivation in good districts. Somewhat similar in shape and colour to the Bramling but earlier.

Hobbs' Early Hop.—A long, narrow pointed hop, similar in character to the Prolific, but rather smaller, earlier in ripening, and of a slightly better quality, though it must be classed with the coarse varieties.

Mercer's Rodmersham.—A whitebine hop earlier than the Canterbury, though not so early as the Brambling. A good cropper, and the hop is rich in lupulin, but the aroma is not quite equal to the best.

Planting, Poling, etc.—Two or three sets, as the root-cuttings, from which the young plants grow, are called—two usually giving better results than three—form "a hill," and "the hills" are disposed in a series of parallel straight lines about 6 feet apart, so that each hill is 6 feet from its neighbours in front and behind, as well as to left and right. The cost of poles, of 14 to 18 feet for Goldings, of 12 to 16 feet for Colegates, and 10 to 12 feet for Grapes, has been estimated at £6 to £8 per acre annually. Systems of wire training are now largely adopted.

The **climatic conditions required for a thoroughly good growth of hops,**

are, briefly, weather such that the ground can be kept clear of weeds, and "a good crumb" attained—viz., a thorough disintegration of the soil for the root fibres to run in; further, the absence of prolonged spring frosts, which check the growth of the young plants, a check which, it is supposed, make their juices more grateful to the winged and wingless *aphides* ("the fly," or "lice"); freedom, too, from spring drought, which encourages the attacks of "the flea"; and from very hot and dry summers, which bring "the red spider." After a sudden check caused by cold weather, mildew, the work of a parasitic fungus (*Spærotheca Castagnei*) may manifest itself by white spots upon the leaves, and is perhaps more to be dreaded than the other enemies of the hop plant.

If it (the *Spærotheca Castagnei*) attacks the hops when in burr (*i.e.*, the incipient cone), it prevents the development of the latter, arresting its growth at once; if it attacks the cone it soon takes possession of the delicate internal tissues, a few hops so attacked utterly spoiling the sample.

There is another fungus, too, familiarly known as "**the rust,**" which attacks the leaves of the cones, rapidly turning them from a delicate golden hue to a dull creamy colour. The best remedy for either kind of mildew—though owing to the forward state of the hops when rust appears it is not easy to use it then—is sulphur freely applied by a machine with a revolving fan. For aphis blight soft soap and water, with an infusion of tobacco, squirted over the plants, is the favourite remedy. Against the flea soot and lime are used, but are not considered very effective. A thunderstorm, accompanied by rain, is the only thorough remedy for the attacks of red spider. Ladybirds, on the other hand, are welcome visitors, being destroyers of *aphides*.

The above forms a very cursory sketch of the ills that the hop is heir to, but will be enough to show the difficulty of prognosticating the crop and the truth of the old saw, which looks upon the prospect of the yield as being full of peril up to July 25th at least—

> "Until St. James is come and gone
> There may be hops or there may be none."

And, even then, high winds may prevail just before and during picking, and do incalculable damage to the hops, lessening their condition, and bruising and browning the tender scales of the cones.

Cost of Production.—This is difficult to assess, but it is said to amount on well-managed land to about £40 an acre, of which 20% goes for manure and its application; over 30% for picking, drying, and selling; and 7% for interest on capital. There are other outlays for digging, dressing, poling, tying, earthing, tying top-shoots or "ladder-tying," "nidgetting," etc., which, though individually moderate, make up a considerable aggregate. A Worcestershire witness before a Select Committee put the annual cost there at £30.

Specific Fertilisation.—To test the view that male hops are useless, experiments were made at the Wye Agricultural College in Kent, by definitely impregnating with pollen the stigmas or "brush" appearing when female flowers are "in burr." On the opposite laterals "controls" were left unfertilised and carefully shielded from chance impregnation. The fertilised hops "went away" seven to ten days ahead of the controls, which never caught them up; they were brighter and better grown out than the latter and were found to have more mould-resisting power,

but the oil and alkaloid-containing seeds, as such, are worse than useless. It would have been more conclusive if separate *plants* instead of laterals had been experimented with. It is a known thing, in melon-culture for instance, if one female flower be first fertilised and two others on the same plant later, that one fine fruit will result and two poor ones. The gardener therefore waits till he has three female blooms to fertilise simultaneously.

A good sample of hops should be of a bright greenish-yellow, inclining more to yellow than green, leaving, when rubbed in the hand, yellow traces, with a fragrant and powerful aroma, and a smooth and oily feel. There should be plenty of the yellow powder or lupulin, and that sample which shows stout, thick hops where it has been cut will be *cæteris paribus* the fullest of " condition." The stems should be darker than the corresponding strobiles, which will show that the hops have not been bleached with sulphur.

We may supplement the above, taken from the early edition of this book, by Mr. Whitehead's valuable summary. In a perfect sample the cones as seen on " the face " should be whole, with the strigs completely free from moisture, and the lupulin or gold-dust adhering to the bracts. But very few leaves should be seen, and the cones should be single and not in bunches, and of a brilliant pale gold colour. A pungent aromatic odour should proceed from the sample, without the slightest *soupçon* of the peculiar sweet " gingerbready " smell, as of heated clover hay, indicative of too much heat having been employed in the drying process.

Upon rubbing down some of the sample in the hand there should be no residue of fibrous substance, but the whole should chaff finely, leaving a yellowish resinous deposit upon the fingers, necessitating the use of much soap to remove it. Good judges can determine at a glance, by looking at the sides of a sample, as to the " thickness " or " condition " of the hops and the state of maturity at which they were picked, by the colour, quantity, and general appearance of the seeds, whole, or cut through by the knives. If hops have been scientifically dried and well managed the sample will be most elastic, and may be compressed easily into a small compass, and upon the pressure being removed will spring back to its former size. This is a most valuable index of thorough and judicious desiccation.

The seeds should be firm and dark in appearance, and should " cut hard " before gathering. When hops are, in merchants' parlance, " mashy "—*i.e.*, showing a considerable proportion of small fragments on the face of the sample—they are not fit for " dry-hopping " (hopping down in cask) with, because the small pieces give trouble as " fliers " when the ale is drawn, and because " mashiness " indicates some loss of the most valuable properties, either through over-ripeness or careless curing.

The writer before quoted says that hops are sometimes purposely broken to disclose more of the clean interior of the hop, when more or less weathered and discoloured on the outside. In unbroken cones the lupulin glands (" condition ") are not only far better retained, but rough treatment may even rupture the glands themselves and expose the resinous contents to the air, which converts them into less valuable forms. These lupulin glands, chiefly developed on the bracts with seeds, appear on the seedless bracts of the best hops only. This is not necessarily an argument for fertilisation, though it may be one against *partial* fertilisation, stimulating parts of a plant at the expense of others : let the splendid hops of

Saaz, where the introduction of male plants is penalised, bear witness. The bracts of the best quality hops are broad with rounded tips ; inferior sorts have them long and narrow with somewhat pointed tips.

Of **Continental Hops** the best growths are those of **Saaz** (Bohemia) and of **Spalt** (Bavaria). These, as with us, are divided into a town district (Stadt Saaz and Stadt Spalt) and a " country " district (Spalter Nebengut, Saazer Bezirkshopfen, and Kreishopfen). The Bavarian mark best known in England is Hallertau, ranking as below. Local prices rule so high for the best sorts, especially those " with seal and certificate," that, beyond the Scotch lager brewers, there are probably few in the United Kingdom to use them.

Thausing (5th edit.) gives the following order of values : Saaz (choicest), not necessarily " Saaz Town " growth, but often from the Goldbachthal of Saaz district ; Saaz (choice) ; Spalt (choicest) ; Saaz (" country ") ; Auscha (red-hop district, choice) ; Spalt (choice) and Kinding (a small growth) ; Spalt (country) ; Auscha (red-hop district, second quality) ; Wolnzach and sealed Au hops (Auer Siegelgut) ; Hallertau ; Sandhausen and Schwetzingen (Baden) ; Posen ; Wurtemberg ; with 11 other growths not much known in Great Britain ; Burgundy ranking 19 ; Auscha (green-hop district) 20 ; Altmark 22, and Belgian 23.

In the red hops (Rothhopfen) the desiderata of a good hop are exemplified, bracts tender, " strigs " thin, lupulin aromatic, and seeds very small ; while the green hops, the heavier croppers, have coarser bracts and strigs, with generally larger seeds, and flavour sometimes suggestive of garlic.

American and British Columbian Hops.—America is the factor which our native hop-growers have to reckon with, particularly as the hops sent thence, in spite of a flavour sometimes suggesting that of black-currant leaves,* are preferable to inferior Continental sorts and make excellent " yearlings." All imports of Foreign and Colonial hops have now to pay a duty.

Of United States hops the top prices are usually made by New York States, second and third grades of which make Pacific prices. These, the West Coast hops, usually rank as follows : Sonoma, Oregon, Washington Territory, and, last, Sacramento.

British Columbia has produced magnificent hops, combining size and brightness with the aroma of best East Kents. Cultivation has increased. It is feared that fertilisation experiments with male hops may deteriorate their splendid quality.

Belgian and French Hops.—The best-known Belgian marks are Alost and Poperinghe, but these hops are not usable in high-class beers. Other hop-growing districts are those round Mons, Namur, Asscht, Henzies, and Opwyck.

The best-known French hops come from Burgundy. Those grown in the north of France are absorbed by the local trade, relatively important there.

Sulphured Hops.—Sulphur is used in two ways. (1) It is sprinkled

* As the majority of the hops produced on the Pacific Coast are now grown from English sets, the flavour and aroma mentioned, originally very prominent, are now considerably modified.

on the plant to check blight and mildew (but note that careful growers rarely sulphur after the burr has developed). (2) It is burnt under the hops while on the oast for bleaching purposes and reaches them, not as sulphur, but in the form of sulphurous acid.

Now as regards the first method, unoxidised sulphur is insoluble in ordinary media, and even large quantities mixed with yeast have proved no check to fermentation, though sometimes supposed a factor in developing the disagreeable sulphuretted hydrogen; so that undissolved particles would be chiefly objectionable as indicating unhealthy conditions of growth. Probably sulphurous acid (SO_2) is slowly generated, and this is readily fixed by the lupulinic acid (*see* p. 97), but the combinations are unstable, easily decomposed by water and the risk of injury to quality applies more to the kiln application. (2) As regards this a specialist in hop analysis (Koeberlin) maintains that SO_2 combines chemically with the hop constituents, permanently modifying the bitter principles and antiseptic qualities. He compared the filtrates from 10 cc. of sulphured and 10 cc. of unsulphured hops, each boiled in 200 cc. of water, and found that while the first was agreeably bitter and aromatic, the second had a bad odour and a persistent, unpleasant bitter flavour.

Nor can we ignore the risk (greatly magnified when *malt* is sulphured to get artificial paleness) that sulphur, even the non-arsenical Sicilian kind, may, when thrown upon the fire, exert a temporary reducing effect rendering **arsenic** volatile. Messrs. Baker and Dick (Royal Commission Arsenical Poisoning Report) have often found from $\frac{1}{5}$ to $\frac{1}{100}$ grain of arsenic per lb. of hops.

The most important Constituents of the Hop are :—

1. Essential flavouring oil (0·2% to 0·5%).
2. Lupulinic acids—α- and β-acids, readily changing into α- and β-resins (another γ-acid and corresponding resin also obtained). Perhaps, but not necessarily, corresponding with the "hard" and "soft" resins of Messrs. L. Briant and Meacham.
3. Bitter principles, intimately associated with the α- and β-resins.
4. Tannin (2·5% to 6·0%) and phlobaphen.
5. An alkaloid, narcotic in character, chiefly in seeds.

The first three are contained in and vary with the amount of the lupulinic glands or "Lupulin," the yellow powder or "condition" which, when hops are rubbed, makes the hands sticky with aromatic matter. The essential oil, though it has a boiling point considerably above that of water, volatilises with steam, so that while Hantke, an American expert in brewing, held that 30% of the oil from hops of the highest quality might remain dissolved in the wort, and that the better the hops the more closely would this solution point be reached, A. C. Chapman's researches go to prove that no *unaltered* hop-oil remains.

The α- and β-Acids and Resins.—These bodies, extracted by various solvents (ether, methyl, alcohol), the α-acid being separated by formation of a lead salt of it, are, in the resin form to which oxidation polymerises them, the source of the bittering principles. Though α- and β-acids have many chemical properties in common they differ in melting-point, solubility, crystalline form, etc., the crystals of the former being small rhomboids and those of the latter long prisms or needles. The former is identified with high bittering power, but in hops giving a mild flavour it

is the β-acid which tends to be beyond its normal. Rémy found the total acids ranging from 11·0% to 18·5%, the *a*-acid varying from 3·5% to 6·6% and the β-acid from 7·5% to 12·3%; an extraction of *lupulin* with ether gave, however, only a shade over one-fifth of total resin as α-resin *precipitated with lead salt.*

Lupulinic acid ($C_{25}H_{36}O_4$) exposed to air, whether in the light or dark, was found to become yellow and cheesy, while that in a closed tube filled up with hydrogen remained perfectly white; it also kept well at low temperatures. It is clear, then, that here we have one source, possibly *the* source, of valerianic acid.

Lintner and Schnell (1904) have obtained an acid derivative—the true acid, as they, suppose—from α-acid. The latter, as a pseudo-acid, they propose to call "Humulone," and the derivative "Humulinic Acid," retaining the name "Lupulinic" for the β-acid. The formulæ given are $C_{20}H_{32}O_5$ for humulone and $C_{15}H_{24}O_4$ for humulinic acid.

Whether the α- and β-resins are identical with the hard and soft resins of Briant and Meacham is uncertain, nor is it decisively proved that these, extracted respectively with ether and petroleum ether, are chemical entities or mixtures of resins; one thing appears certain, namely, that the conditions under which hops deteriorate cause a diminution in the so-called "soft" resins and an increase in the "hard," consequently it would appear that the soft resins are, as claimed, **preservatives** and the hard ones practically valueless. Therefore a method which determines the total resins, dividing them into the valuable soft and the comparatively valueless hard resins with relative ease and certainty, even if there be an analytical error of 1%, is one of extreme value; it is carried through as follows: Five grammes of hops placed in a Soxhlet extractor are completely exhausted with petroleum ether. The ether residue is freed from wax (about 0·18% weight of lupulin) by treatment with 90% alcohol, dried again to remove the alcohol, heated for six hours to 90° C., and weighed as "soft resin." The "hard resin" is determined by exhausting the hops a second time with ordinary ether.

Experiments made with hops from which the oil had been removed gave beers of which the soundness, flavour, and brightness were unsatisfactory, even when an equivalent of oil had been replaced. This was attributed to a marked conversion of soft into hard resins, but it points, too, to an intimate connection of oil and resins which may somewhat discount results got by boiling wort with hop-oil alone.

Tannin * ($C_{25}H_{24}O_{13}$) **and Phlobaphen** ($C_{50}H_{46}O_{25}$).—The plenty or scarcity of tannin connotes, according to Mr. Heron, the abundance or scarcity of other desirable constituents. He combats the notion, previously held, that it influences precipitation of albuminous matter as *insoluble tannate of albumen*, maintaining that the precipitate caused by hop-tannin is *tanno-peptone*, which redissolves in the wort. Phlobaphen, found by Etti and Hayduck together with tannin, was said by them to form an *insoluble* compound with the albuminous matter of wort.

* Tannin is precipitated by gelatine from a clear solution, and use is made of this fact in determining the amount present in hops. The difference between the amount of permanganate solution decolourised by the two solutions (before and after the gelatine treatment) gives the oxygen required to oxidise the tannin. The *exact* point is got by added indigo, which is decolourised by O, but only after the tannin has all been dealt with. Gold chloride is a delicate test also.

Hop Extraction in Copper Wort.—The main object to be attained in subjecting hops to a more or less prolonged boil in the copper is to extract their aromatic, flavouring and preservative attributes and to promote coagulation of certain proteins—an essential process in the refinement of wort. The question of determining the correct period of ebullition to which the hops should be submitted has always been a controversial one. Excessive boiling results primarily in an undue disintegration of the hops to an extent that reduces them to a pulp, in which condition they cease to function as a filter bed in the hop back. Further, a prolonged boiling of the hops beyond that necessary for a particular blend will indubitably result in defeating the purpose in view in another important connection. The preservative and bittering principles of the hops are contained within the soft resins, and when these are extracted and yield up their valuable contents to the wort, an additional boiling beyond that stage tends to the conversion of these soft resins into hard resins, which not only possess little if any preservative value, but produce harsh and acrid flavours. The varied and pleasingly aromatic and delicate flavouring properties of the hop are present in the oil, which is extremely volatile at the normal temperatures of boiling wort from 215° F. to 218° F., and this leads to another and very important aspect of the question. With ordinary open coppers or even with those equipped with "domes" and especially where "fountains" are installed, the volatilisation of the flavouring and aromatic principles readily occurs, and it was with a view to obviating their dissipation to the winds that gave rise to the practice of adding a definite proportion of the total hops of those of better quality at half time or later at 30 minutes prior to casting or turning out. Doubtless by adopting this precaution the readily volatile oils are retained in the wort, but experience has proved to us that short boiling periods, while accomplishing the specific object just referred to, are not sufficient to extract the remaining hop principles with the inevitable result that when this theory is adopted the finished beer exhibits a lack of general character in the general direction of being definitely under-hopped. Although probably no "returns" of beer may be received as the outcome of this change of brewing procedure, yet the alteration in palate flavour will be immediately detected by the consumer and complaints will reach the brewery from the retailer on the ground that some form of indefinite alteration in flavour and fullness has occurred to adversely affect his sales. An immediate reversion to former working methods of copper hop manipulation will be rendered necessary to restore the finished brewery produce to its customary position of popularity in the eyes, and especially on the palates, of the customers. If a continuance of this system of retaining a portion of the hops for a brief boiling period is decided upon, then an increase in the total hop rate—with the additional cost involved—is imperative. With a view to solving the difficulty many expedients are adopted to secure the maximum amount of elusive aroma and flavour available.

In one instance where the question of economy was ignored, a further hop rate was employed, and material selected for its especial flavouring qualities was distributed at the moment of casting or turning out the copper equally over the plates of the hop back.

By this means the oils were readily dissolved during the "stand-on"

and remained in solution virtually, no opportunity being thus provided for volatilisation, and the finished beer was unquestionably vastly improved in flavour and aroma. We are not advocating this costly procedure, which merely and obviously secures from the hops partial extraction of their constituents. In France we found that by the Prache and Bouillon process of rapid and intense concentration of the wort the latter only passed through a filter bed of hops as the wort was carried to the refrigerator, and although the finished beer differed in many respects from the British article, yet the aroma and flavour were prominent and pleasing. Owing to the prevailing custom of producing quick running ales in which dry hopping is employed, distinctive aroma is absent, but where time is allowed in the case of semi-stock beers for hops in cask to be employed, then we prefer to rely on these for aroma, adding the entire amount of copper hops to those vessels for the full period determined. The question of the relative periods necessary for the boiling of old or new hops calls for a brief word. With age soft resins are reduced to hard resins, yielding a harsh, bitter flavour, consequently old hops should receive a shorter boiling period than new. The agitation the hops are subjected to when "domes" or "fountains" are installed in coppers permits of a more rapid extraction of the hop constituents in which instances shorter boiling periods can be adopted than in the case of open coppers. "Domes" although they produce over-disintegration, are useful where a copper has a tendency to boil over, but "fountains" introduced when the theory of aeration was popular are now discarded as aeration above 190° F. is not feasible and fountains rapidly disintegrate hops to a pulp with consequent difficulties in hop-back filtration and the re-dissolution of the coagulated wort proteins.

Dry-Hopping.—The hops used for dry-hopping or "hopping down" must be ripe and full of aroma, and in buying them for this purpose a careful search should be made for traces of disease between the "petals" of a reasonable number of the cones. Freedom from sulphur in any form (for which tests are given in the Laboratory Chapter) is specially important here. The existence of diastase in hops, which was pointed out by Brown and Morris, may be noted as probably influencing secondary fermentation, by acting upon dextrin bodies.

Dry-Hopping Rates.—It is customary in many breweries to adopt a "flat" dry-hopping rate of a definite amount calculated per barrel. Not only should the dry-hopping rate be adjusted in accordance with the probable length of time any particular size of cask is expected to be on draught, but, what is of considerably more importance, the comparative superficial area of the timber of different sized casks. No cask, however well cared for, and no matter what treatment it receives prior to passing to the racking room, can be regarded as absolutely sterile, and the comparative wood surface to which the beer is exposed in cask must be taken into account when calculating the dry-hopping rates. In point of fact, the **surface** contents of a pin *per gallon* is virtually twice that of a barrel, and the greater contaminating potentialities of the first-named "vessel for carrying beer" must be recognised accordingly. It is absurd technically to employ a hop rate of one ounce for a pin where eight ounces are added to a barrel in the same gyle. The following are the approximate figures for various sized casks of the area of wood surface

exposed to the action of the beer :—Barrels 68 square inches per gallon ; Kilderkins 86 square inches per gallon ; Firkins 107 square inches ; and Pins 130 square inches.

Storing Hops and Cold Storage.—The general hop-store should be dry, darkish (even light-proof), free from draughts, and cool, as the opposite conditions favour the oxidation which results in a more or less cheesy odour (valerianic acid) being developed. Of late years it has been found that good hops held in thoroughly insulated stores, which can be kept at a temperature under 32°, will come out in 9 or 12 months almost as good as new.* Alternative methods of chilling the stores are by a series of pipes, through which brine several degrees below freezing-point circulates, or by air cooled outside the store and kept in slight but continous circulation. There is a risk that this moving air may have more effect on the hop-constituents than the still air of the pipe system, though minimised by the fact that the same air is used over and over again. Danger of drip from the pipes of the first method may be guarded against by suitable troughs, and indeed will never arise unless the brine-circulation be accidentally stopped. Otherwise the chilled surface of the pipes attracts every possible particle of moisture from the air, retaining it in frozen form and keeping the air practically dry. For a private cold-store there is no better arrangement.

Influence of Drying Temperatures on Soft Resins.—Commenting adversely on some high " oast-house " temperatures recorded in the Wye College experiments (*cf.* p. 137) a Hereford grower, writing to the *Brewers' Journal*, gives three analyses of hops dried with heated air driven by a very powerful fan, in which the recorded heats ranged in 10 hours from 65° to 108° Fahr., the actual heat on hair-cloth being therefore always well below 120° Fahr. There were two kilns, fitted with Hetherington's roller floors and each of 800 feet area. The quantity dried was 1 to 1½ bushels per square foot in 9 to 11 hours. The amount of soft resin is much above normal, the moisture not excessive. (Best moisture limits, at time of pocketing, 8% to 11%. When it is lower than the first, the hops may be brittle, when higher, likely to be slack and keep badly.)

	Soft resin.	Hard resin.	Total.	Moisture %.
1. Bramling . .	14·1	4·1	18·2	12·4
2. " Mathon White " .	14·7	3·4	18·1	12·2
3. Bramling . .	14·0	3·1	17·1	11·1

In earlier editions of this book it was suggested that the fugitive bitter of the new hop—*i.e.*, one which soon leaves the palate clean, unlike the clinging bitter of older hops, may be akin to the glucosides, bodies which break up under the influence of dilute acids of enzymes (*e.g.*, ptyalin in saliva) into sugars or cognate bodies ; and salicin was named as one whose

* It is estimated that the amount of deterioration which hops undergo after five years in cold store is 40%, or an average of 8% per year, against a deterioration of 60% if the hops are stored under ordinary conditions, or an average of 12% per year. A new and extremely important development in this connection is worthy of note. It has been proved that when hops are removed from cold storage and stored under ordinary conditions deterioration proceeds at the same rate as is usual with ordinary stored hops, at any rate so far as the resins are concerned.

bitterness, experienced when a drop or two of its saturated solution is placed on the tongue, soon disappears.

Buying.—In estimating the coming yield, with regard to the question of purchasing or not, it may be well to remember that it is likely to be over-estimated when the summer has been backward, and the crop is accordingly what is called a "top-crop," and that where high winds prevail during picking, the quality and condition of the hops are much decreased; but on the other hand very little faith should be placed in predictions of a total blight, a favourite forecast of those who have hops to sell. Yearlings, the hops of the previous year, though indispensable at the beginning of a season, can never have later the brewing value of new hops. Those of two seasons back are "olds," hops more ancient still are "old-olds," according to the year of growth, and obviously have little or no brewing value.

SUGARS.

The sugars are not the least important of the carbohydrates (so called because in addition to carbon they contain hydrogen and oxygen in the proportion in which these two elements combine to form water—2 : 1).

The sugars specially interesting to brewers are :—

(1) **Glucose, Grape-sugar, or Dextrose (when pure).**—Can be prepared either from separated starch or from a starch-containing grain by boiling with sulphuric acid under pressure, the acidity being afterwards neutralised as in (3).

(2) **Saccharose, Sucrose, or Cane-sugar** (including beet-root sugar), some being "raw," others refined, but neither fermentable without inversion, which however readily takes place under ordinary fermentation conditions by the agency of invertase, (invertin) secreted by healthy yeast. Does not reduce "Fehling." *

(3) **Invert Sugar,** separable into equal parts of dextrose and levulose (fruit-sugar, fructose). Obtained commercially by boiling a solution of cane-sugar, acidified with a small percentage of sulphuric acid. This operation is, as with glucose, effected under pressure to save time, and in both cases the sulphuric acid, which itself undergoes no change (its action being catalytic) has to be subsequently neutralised with whiting. Sulphate of lime is then formed and precipitates on standing, or may be removed by filtration.

(4) **Maltose** not being commercially produced, will be left till the chapter on Mashing. It is the ultimate product of diastatic action upon starch, and it is reduced to Dextrose by the action of **Maltase,** an enzyme contained in yeast.

A process for inverting cane-sugar by invertase (F. W. Tompson's patent) yields a product in which sundry unfermentable, richly flavouring bodies, formed in the acid inversions, are lacking.

* Fehling's solution, which will be more fully treated in the chapter on Laboratory Work, is an alkaline solution of copper sulphate (to which it owes its blue colour). Certain sugars, *e.g.*, glucose, invert, and maltose, have the property, when boiled with the Fehling, of discharging the blue colour and precipitating the copper of the sulphate as a red precipitate of cuprous oxide, reducing the cupric salt to cuprous.

The equations which represent the hydrolysis occurring in the manufacture of brewing-sugars are (the *n* prefixed signifying possible multiplication by some large number):

1. Starch (or grain) boiled with water and acid.

$n(C_6H_{10}O_5) + n(H_2O) = n(C_6H_{12}O_6)$.
[Starch and water yield dextrose.]
Or if the conversion be not pushed to extreme—
$2n(C_6H_{10}O_5) + n(H_2O) = n(C_6H_{10}O_5) + n(C_6H_{12}O_6)$.
[Starch and water yield dextrin and dextrose.]

2. Cane-sugar boiled with water and acid.

$C_{12}H_{22}O_{11} + H_2O = C_6H_{12}O_6 + C_6H_{12}O_6$.
[Can-csugar and water yield dextrose and levulose.]
Invert sugar.

Gallisin and Isomaltose.—Free use of commercial glucose, when containing much dextrose, tends to extreme attenuations; but it is said that the tendency is, or should be, counteracted by the presence of **gallisin**, an unfermentable constituent, of which as much as 15·9% has been determined in maize glucose, and around it and isomaltose a maddening controversy surged. Some derided the supposed importance of gallisin, alleging it at the most to be a crude form of Emil Fischer's **isomaltose** (a disaccharide isolated from glucose in the form of its ozazone,* of which 2% was found in glucose and unfermentable). This same name, "isomaltose," has been used by Dr. Lintner for a product isolated from a diastasic starch conversion. The upholders of the amyloin theory assert Lintner's isomaltose to be merely a mixture of maltose and amylöins; he, however, stoutly stands by it, stating that the main difficulty of proving its individual existence lies in the fact that it does not crystallise. The subject is too thorny to discuss further here.

Commercial Cane-sugar.—Commercial sugar is obtained either from the sugar-cane or beet (*Beta vulgaris*), the latter being far inferior to the former for the brewer's purposes, owing to certain objectionable flavours which, except in the best refined samples, are only too prominent. Maple-sugar is also extensively used in America; the Java palm also yields sugar where it flourishes; and certain grasses, *Sorghum vulgare* and *Sorghum saccharatum*, have been cultivated for the same purpose in the United States, and even tried, but without success, owing to our uncertain summers, in the United Kingdom.

Accordingly, when we speak of cane-sugar apart from chemical surroundings, we mean the produce of the sugar-cane as distinguished from beet-root sugar. In spite, however, of objectionable alkaline flavours due to large proportions of salts of potash, and even a slightly lower degree of sweetness in its finished samples, beet-root sugar is a formidable rival to cane-sugar, not only on account of the bounties paid to foreign exporters by their Governments, but because, owing to the comparatively stable nature of the crop, the factories dealing with the raw material can keep longer at work, and because the beet-root juice contains a smaller proportion of uncrystallisable sugar than that from sugar-cane. It is only, in fact, by adopting the most improved methods (amongst them extraction by the diffusion process instead of by crushing) that the planters of British Guiana have been able to hold their own.

* The ozazones are compounds formed by carbohydrates, except cane-sugar with phenylhydrazine, in acid medium (*e.g.*, maltosazone, glucosazone, etc.).

As it is, Demerara sugar from that colony is perhaps the best and purest in the world.*

The amount of crystallisable sugar in a juice forms its standard of value,—the "refining value,"—and may vary considerably, even in samples which actually contain the same amount of sucrose. Especially in the case of cane-sugar, the natural acid of the juice in a hot climate tends to invert part of the sucrose, and this inverted sugar is not only non-crystallisable itself, but prevents the crystallisation of an equal quantity of uninverted sugar. Ash is also a factor in non-crystallisation, one unit, roughly speaking, rendering five units of sugar uncrystallisable.

But from the invert-sugar maker's point of view this is probably not a question of much moment, although it is supposed that the removal of a portion of the crystals, before inversion, is not an unknown operation.

Cane-sugars are divided into raw and refined. In preparing the former, often only the crudest method is used; for instance, the syrup, whether decomposition has set in or not, is just boiled down to crystallising point over an open fire, and this point being reached, the fluid is run into casks, which are then turned bung downwards for the uncrystallised portion to run out. This, the molasses, is then reboiled in order to get another supply of crystals.

Such being the method employed, it is not surprising that low-class raw sugars, Barbadoes, Jaggery, or Bastards, and indeed ordinary unrefined sugars generally, contain impurities of a revolting character. Among these are fungus spores (probably including that of *Leuconostoc mesenteroides*, supposed to be the cause of the viscous fermentation of sugar refineries, the so-called *Froschlaich*, frog-spawn, or *Gomme de sucrerie* of German or French refiners), bacteria, and bacilli in hosts, not to speak of the *acarus sacchari*, or sugar mite, an insect visible to the naked eye in its adult stage, but existing either in the egg or as a developed organism. This insect is the cause of the complaint known as "grocers' itch" to those who have what is technically known as "the handling,"† but which we may translate by its more sinister synonym, "the manipulation" of sugars. Beside these, fragments of sugar-cane, except as indicating not the most careful manufacture, are unimportant items.

Dr. Hassall, who had had a large experience in the analysis of all sorts of foods, stated that out of 72 samples of brown sugar, purchased at various shops, microscopic fragments of sugar-cane were present in all but one; sporules and filaments of fungus in nearly all; the *acari* were found in 69 of the samples, and often in considerable quantity.

The present writer has detected, amid a horde of disease ferments, what he believes (as firmly as he can without the check of after cultivation) to have been a growing spore of *Leuconostoc mesenteroides;* and the probable connection of this organism with subsequent ropiness should not be lost sight of, especially in view of the facts, that if any beers show a tendency to become ropy, English black beers do so (in bottle if at all),

* It may be interesting to note that the best sugar tends to connote the worst rum, and *vice versâ*. Demerara rum and Jamaica sugar bear witness.

† "Handling" consists largely of mixing various qualities—*e.g.*, coarse dark with light-coloured attractive sugars, with such unholy skill that the fraud (for it is palmed off at the price of the best) shall not be apparent. On account of the difficulty which sugars having a large crystal offer to this sort of "handling," they are somewhat out of favour with the trade.

and that these are the very beers in which crude, unrefined sugars are most largely used.

Were it not for these abominations there would be much to be said in favour of dark-coloured raw sugars for the manufacture of porter and of ales, other than pale or bitter ales, owing to the undoubtedly more pronounced flavour imparted by them than by the higher qualities of refined ; but, as matters stand, they are only fitted, in their crude state, for a " running trade " in a not very high-class article, the producers of which have made up their minds to face the necessity of frequent changes of " pitching " or " store yeast," with all the drawbacks involved therein.

The case might be somewhat different if a previous inversion of this raw cane-sugar were the rule, because the boiling with the acid, which takes place the day before the inverted product is used, when inversion is carried out in the brewery itself, would certainly destroy existing adult bacteria, and what is even more important, because more difficult, it would facilitate the destruction of the spores of those bacteria, which, *as spores*, can survive even a prolonged continuous boil, but which, when the boiling is intermittent, are stimulated into assuming the adult form by the first boiling, and in that phase of their development are ready to be slain by the second.

But for this, it is not very easy to see the advantage of inverting (which some *do* dispute, though the majority consider it a self-evident proposition), because we know that yeast secretes a ferment or enzyme called invertase (invertin), quite apart from its well-known *fermentative* action upon certain saccharine bodies, and that this enzyme, which indeed—as we have seen—can be entirely separated from the yeast (not losing, at any rate, if not gaining, vigour by such separation), has the function of inverting cane-sugar into a mixture of dextrose and levulose—*i.e.*, of converting the non-fermentable into a fermentable sugar.

Thus it will be seen that it really is difficult to say why a perfectly pure cane-sugar, uninverted previously, should not, if boiled with the wort in the usual way, get inverted in the fermenting vessel and give satisfactory results ; unless it could be shown, which, as far as we know has not been done, that the inverting enzyme *must* be separated, or that yeast engaged in vigorous reproduction and fermentation is incapable of secreting it. This may be so to a certain extent. There is analogous evidence in the case of another enzyme, diastase, the secretion of which by the special organ of the grain seems to be " a starvation phenomenon " —*i.e.*, to be at a standstill when there is a plentiful food supply in a very assimilable form.

In the case of common unrefined sugars the facts, first, that the yeast-crop would be severely handicapped in its struggle for existence by the introduction of a horde of bacteria, probably in a very active condition, and again that such sugars contain nitrogenous bodies of uncertain and presumably unstable character, afford good reasons why the neglect of previous inversion, and that too by boiling with acid to minimise one of these evils at least, is not to be thought of.

This, accordingly, will be the place to introduce a description of the method of inverting cane-sugar in the brewery, premising that, in comparing costs, the brewer will remember that he gets the use of a material giving an extract of 84 to 88 brewers' lb., or thereabouts, per

2 cwt. as against 70 or 72 brewers' lb., given by invert [or in other words he puts into his own pocket the profit made by the increase of bulk, and again another profit—for that increase of bulk (19 parts cane, 20 invert) cannot account for the greatly lessened extract—due to fixation of water]. Again, he saves the expense of evaporating his product down to ostensible dryness, or at least down to a concentrated form, which the invert-sugar maker must do to bring his wares into transportable bulk.

So that, evidently, if a good supply of real and unmixed cane-sugar can be depended on, there is a good margin to make the operation of inverting one's own sugar a profitable one.

Against this may be set the fact that the brewer has not time to remove by filtration through animal charcoal, as the invert-sugar maker does, the colour imparted by the boiling with sulphuric acid, so that there would be a difficulty in using sugar home-inverted on the sulphuric-acid system for pale or delicate-coloured ales. For these, then, if previous inversion is a *sine quâ non*, Tompson's patented Yeast Inversion Process must be resorted to, as it imparts no colour. Its manipulation is easier, too ; but, as has been said, unless sugars of the highest class are employed, one safeguard is lost.

The following is the method suggested by Dr. Graham, who did so much to emancipate practical brewing from rule-of-thumb tradition :—

To Invert Cane-sugar.—Fill a kilderkin nearly to the brim with water, then add 10 pints of sulphuric acid (spec. gr. 1840, water = 1000). Then, disregarding the decimal, because exact measurement with the dilution is not necessary, 10 pints of the undiluted acid weigh 22⅔ lb. (1 gallon being taken = 18 lb.) = 360 oz. But the 18 gallons dilute acid = 144 pints—*i.e.*, each pint of it corresponds to 2½ oz. of the original acid. After these preliminaries the next steps are as follows :—

(1) Run into the dissolving tun 22 to 23 gallons of boiling water for each cwt. of sugar to be inverted.

(2) When ready to add the sugar, put in the dilute sulphuric acid in the proportion of 2 pints per cwt. of sugar.

(3) Add the sugar, distributing it carefully ; turn steam on full, and as soon as the sugar is in put on the lid.

(4) When the contents begin to boil the steam may be reduced. Actual hard boiling is unnecessary, though a temperature of 212° must be maintained.

(5) Boil for two hours. When steam is off and lid removed, add whiting, gradually and with great care, otherwise the contents of the vessel will effervesce so much as to boil over.

(6) The whiting being added (say 10 oz. for every 2 pints of the dilute acid), the steam is to be turned on again for half an hour so as to mix the whiting.

(7) The solution should settle before draining off ; also it would be well to run it through a (strong) calico filter.

The designer of this method was content to have this inversion take place on the same day that the sugar was to be used. In another modification of this system, which differs in mere points of detail (*e.g.*, in using 1 lb. of acid and 2 lb. of whiting per cwt. of sugar, and in making up the bulk of the boiling liquid to exactly one barrel inclusive of the sugar), it is recommended to invert the sugar a half-day before using it, say in the

afternoon of the day before the one on which the sugar is to be used. It is essential to test the solution with litmus paper, in order to be sure that the acid is neutralised.

Commercial Glucose is manufactured upon similar lines, that is, by the action of dilute acid, at a temperature of boiling, upon starch. In this country rice, maize, and for one brand sago, are employed, but any source of starch will do. A good deal of the Continental glucose is made from potato starch or "farina." The process is as follows: the rice, maize, or other amylaceous substance is mashed in water containing 1 to 3% of sulphuric acid; after mashing it is run into a receiver, where heat is applied by means of jets of steam; or extracted starch may be either boiled with the dilute acid in an open tank, or heated in a strong cylinder of copper at a high pressure, which greatly expedites conversion.

The conversion may be stopped just when the liquid (cooled down) ceases to give a blue reaction with iodine, in which case the percentage of dextrin in the product will be high.* If the process be pushed further, and especially if it be carried on under pressure, dextrose (with a little maltose) will be the chief product. The acid is neutralised with whiting or limestone, which results in the formation of a precipitate of sulphate of lime. Neubeuer, having made numerous analyses of commercial glucose (probably all of German make), found its average composition to be, fermentable sugar 61·08; dextrin and kindred bodies (non-fermentable 20·54; ash (chiefly gypsum) ·34; water 18·04. And the largest quantity of the latter came out as high as 23·66%!

A good deal of prejudice against the use of sugar exists amongst the public, but its employment can in no sense be stigmatised as adulteration: indeed it would be difficult, if not impossible, to brew the beers which the public taste demands without that valuable adjunct. Glucose tends to determine "dryness," "invert" a more luscious character.

* Modern research speaks of amylöins. But whatever the view about these alleged chemical compounds of maltose and dextrin, there is certainly room for controversy as to the identity of the dextrin-products of the acid process with those of malt-wort. Practice tends to brand the former with less stability.

CHAPTER V

BREWING ROOM CALCULATIONS

GRAVITY—BREWERS' LBS. AND DEGREES OF SPECIFIC GRAVITY—SACCHAROMETERS—CONVERTING DEGREES BALLING INTO BREWERS' LBS.—BAUME INTO SPECIFIC GRAVITY—WORKING OUT THE BREWINGS—ENTRY OF MATERIALS—WORKING OUT SPARGES—COPPER LENGTHS—PARTI-GYLE CALCULATIONS—APPORTIONING HOPS—FORMULA FOR CALCULATING "INITIAL" FROM "STRIKING" HEAT—MAKING UP LENGTHS IN FERMENTING VESSELS (CALCULATIONS FOR)—BOILING DOWN TO A REQUIRED GRAVITY—EXTRACT PER QUARTER—DRY OR SOLID EXTRACT—EXTRACT PER CENT.—EXCISE CHARGES—CONTENTS OF SQUARES OR ROUNDS IN BUSHELS AND GALLONS—COST-PRICE CALCULATION.

The Importance of Recording Percentage Loss at Definite Stages.—That attention to details results in business success is a trite maxim which is more honoured in the breach than in the observance, but a brewer's duties are so multifarious and exacting that unless some system of organisation is applied and maintained, it is no wonder that attention to details is perforce neglected. The importance of mashing cannot be over-estimated. Errors in this initial process can only be partially rectified subsequently. If, as it was formerly contended, malt is made in the kiln, certain it is that beer is made in the mash-tun during and immediately succeeding the mashing. It follows that under no circumstances should the practical working or the actual performing of this primary stage of brewing be delegated to a subordinate who fails to grasp the technical and commercial importance of a satisfactory inter-mixture of grist and water at a definite striking temperature. Uniformity of inter-mixture is more important than the proportion of liquor to grist and to attain a mash of a regular consistency requires constant attention throughout the brief period occupied by the operation. It is true that errors in mashing resulting in "balling" of goods and the consequent heavy loss of extract cannot be wholly overcome by the use of rakes, but their judicious employment minimises these and other faults in mashing, and it is surprising how brewers, even in large establishments, unacquainted with the advantages of rakes exhibit such a decided aversion to install these necessary mash-tun accessories. Hurried running of worts until as complete saccharification of the unmodified starch as possible has been reached must be included in a study of the faults of brewery working. Too much reliance is often placed in the gravity of the "last runnings" as an indication of success or failure in "goods" extraction. The last few barrels carried forward to coppers may be utterly devoid of matters in solution and yet a cursory physical examination of the goods may show that the available extract has by no means been secured, while on the other hand the saccharometer reading of the last runnings may be high and at the same time a glance at the grains shows that they are well spent and virtually exhausted of their contents. In the former case, either through faults in the malt or the adoption of

unsuitable mashing and sparging temperatures, the starch forming the unmodified portion of the grain has not been released from its cellulosic environment and in consequence the sparging liquor added which should gelatinise the refractory starch mentioned, thus preparing it for subsequent enzymic action, has not performed this essential primary function prior to washing out the extract formed. In the latter case a more thorough gelatinisation, liquefaction, and saccharification has accrued, but through some fault in reckoning a supply of sparge liquor insufficient to wash forward the extract thus secured has not been provided.

The faults of copper-house working are mainly irregularity of ebullition and insufficiency of evaporation. When the wort is boiled by steam reduced automatically to the inlet to jacket of pan direct from a high boiler pressure to that necessary to obtain a thorough boil at a high temperature, in accordance with the gravity of wort, then no difficulty is experienced in regard to regularity of ebullition and consequent sufficiency of evaporation, but close and constant supervision is required to ensure efficient stoking and satisfactory results in the respects named in the case of fire boiling. The index which points to a satisfactory or otherwise wort boiling period is the percentage loss between the copper length at collection and that at turning out or casting. This percentage loss varies of course in different breweries, and is dependent on the type of boiling vessel and its setting as well as on the depth of wort and the corresponding surface area exposed for evaporation. The highest loss in successive boilings should be noted, and this percentage should be recorded as a guide for future working. Under ordinary conditions the percentage loss by evaporation calculated on a two hours' boil should show a reduction in volume of 10% in the quantity of wort collected. If this is reached then the boiling operation can be regarded as efficiently performed. As a check on the records of "copper up" and "copper out" lengths and gravities, and also to detect any possible leakage of extract that may occur during the boiling period it is always advisable to ascertain what is the normal percentage loss between gross extract collected in coppers and that existing on the completion of boiling. It will in most breweries be found that this amounts on an average to 2%, and assuming that the spent hops from copper are thoroughly washed in hop-back and exhausted of the wort absorbed the loss of extract from copper to cooler should not exceed a further reduction of 2%. If the percentage loss is found at any time to be in excess of this figure, either the quantity of "splash" employed is too meagre to free the hop-bed from the wort which it would retain if pressing or sparging were not adopted, or the sparging apparatus is faulty. In the case of a rectangular hop-back where two spargers are employed obviously such should distribute an equal quantity of the total sparge liquor, whereas it often occurs that one apparatus disperses a greater or it may be a less volume of splash than its moiety proportion. As a result one half of the hop-bed is over-washed and the remainder under-washed, with a consequent comparatively serious waste of extract which should have been recovered. The percentage loss from coolers and refrigerators to collecting vessel amounts, on an average, to a further 2%, so that the total loss from mash-tun to completion of brewing need not exceed 6%, unless subsidiary vessels such as upper-backs or under-backs are in use, each of which will

retain their due proportion of extract. The loss of extract can be thus readily ascertained at any stage of brewing, and a simple calculation will at once direct attention of those in control of operations to an abnormal loss indicating faulty working. Moreover, with a knowledge of the normal total percentage loss of extract in a given establishment a brewer can, by basing his calculation on the length and gravities of his copper or coppers, estimate, if not determine, the extract per quarter yielded by the malt in use. We have already dealt with the commercial importance of observing the utmost exactitude in securing definite pre-arranged original gravities for each class of beer brewed and in controlling all Excise declarations. Errors in this connection should be included in any discussion of faulty working.

Turning to the subject of fermentation, the practical points to be observed are a complete registration for future reference of the wort temperatures and attenuation from the completion of collecting until the racking stage. A record of the physical indications named should be noted every four to six hours where night men are employed, and at least morning, noon and night in breweries where this labour is not available or considered unnecessary. A glance at these records checked with an actual examination from time to time of the temperatures and gravities and appearance of the contents of the various vessels to which these registers refer will at once apprise the brewer at the earliest moment of faulty working, to overcome which an attempt can be made without loss of time. With regard to waste in fermentation, by careful working the loss at racking can be reduced to a minimum. In considering the possible faults of brewery working, reference should be made to the practice still prevailing in some undertakings of neglecting to make provision for the retention of the bottoms in the skimming and settling backs. Ordinarily the outlet is fitted flush with the bottom of the vessel, and if no movable " thimble " or " bucket " is installed in the aperture of the tap or valve, the whole of the bottoms will pass forward to the racking back, if such is employed, and thence to the casks. If racking takes place direct from skimming and settling tuns, each cask will therefore receive its due proportion of the bottoms, which containing, as all wort deposits do, sedimentary yeast and acid forming and other disease producing bacteria this reduces the stability, impairs the flavour, and interferes with the brilliancy of the beer on draught. By the mere introduction of a movable thimble, so-called bucket, or ordinary short length of piping which will raise the opening of the outlet by from 1½ in. to 2 in. (dependent on the depth of the vessel) clear of the deposit, practically the whole of the contents of the tun will run free from sedimentary matter and the risks which its inclusion involves. When the flow of the racking pipes ceases the thimble, or whatever arrangement is employed, is removed and the " bottoms " is then run into one, or perhaps, two, casks. These are immediately fined and trammed, or gauntried, and owing to the considerable amount of matter in suspension carried forward to these casks the finings will invariably act rapidly and the bright beer can then be at once used without risk for topping-up purposes. If any delay, however, occurs in using off the beer acidity may be developed or a cloud may arise which renders the beer useless for addition to other beers. By observing the precaution to expedite matters in this connection, no

loss of beer ensues. Should the " bottoms " fail to drop bright within 12—18 hours, no improvement can be looked for from a further extended rest, and its condition can be regarded as a reliable indication of faulty working in brewing, especially in respect to the pitching yeast in use.

Gravity.—Probably the first thing the beginner hears of, as soon as he has got some idea of the geography of the brewery, is " Gravity," which may be either expressed for everyday purposes in the so-called **brewers' lbs.**, or in **degrees of specific gravity** (the latter being the scale upon which Excise charges are based), both of them being standards adopted for stating the strength of a particular wort before fermentation, and indeed as a means of classifying it later on, according to its value when a finished product. Thus it is usual to speak of a 14-lb. beer, a 16 or 20-lb. beer, etc.,—even though the specific gravity scale is now commonly and interchangeably used,—and we are wont to say that such and such a beer " drinks " or " does not drink its gravity," the latter verdict being obviously one which the careful brewer endeavours to avoid.

" Lbs. gravity " or " brewers' lbs." then may be defined as those lbs. only by which the weight of a barrel of any wort exceeds the weight of a barrel of water—for instance, a gallon of water weighs 10 lb., therefore a barrel weighs 360 lb.; and a barrel of wort weighing, say 380 lb., would be said to be of the gravity of 20 lb. (strictly brewers' lbs.); and the resulting beer, after fermentation, would be known as a 20-lb. beer, irrespective of the loss of weight, which may show a good deal of variation, but is certain to be considerable, consequent upon the splitting up of the solid constituents of the original wort into carbonic acid, some of which disappears, and alcohol, which is lighter even than water.

This extreme lightness of alcohol accordingly makes the quantity of solid matter removed or split up by fermentation appear to be even greater than it really is; in other words, the alcohol, being so much lighter than water, yet the ordinary saccharometer, which the brewer uses, being incapable of estimating it otherwise than as water, masks a certain portion of really unfermented matter. So that what brewers call the **Final Attenuation,** that is to say, the weight which a barrel of the beer at the close of the primary fermentation would show over the weight of a barrel of water (and which is one-quarter, one-fifth, or sometimes less, of the original gravity), is a purely conventional statement, involving more than one departure from strict accuracy.

Saccharometers.—But it being manifestly inconvenient to be compelled to weigh a barrel, or even a measured part of a barrel, whenever the gravity of a wort has to be ascertained, various saccharometers have been devised, which by a nice adjustment of added weights, increasing with the density of the wort, enable the brewer, as he reads off the numbered mark on the stem to which the instrument sinks in the liquid, to find out the gravity with great ease.

The saccharometers generally used in England are either the old pattern known as " Dring and Fage's," or " Long's," or the specific gravity one known as Bate's, in Germany Balling's saccharometer (graduated to show how many parts by weight of dry, pure, cane-sugar, or parts equal thereto, are present in the solution taken at 14° Réaumur = 63½° F.). In France and elsewhere an instrument on the same principle, known as Baumé's hydrometer or *pese-sirop*, is used; but,

unfortunately, this class does not appear to be constructed on a uniform plan. A formula is given below for converting Baumé into degrees of specific gravity, it being understood that the formula is for an instrument graduated so that a liquid of 1,480° of specific gravity marks 48° on its own scale. Also a similar formula for converting degrees Balling into brewers' lb., with a comparative table, too, of the same equivalents, side by side with one showing the degrees of specific gravity, with their equivalents in brewers' lb.

Balling (Degrees).	Brewers' Lb.	Degrees, S. G.	Brewers' Lb.	Degrees, S. G.	Brewers' Lb.	Degrees, S. G.	Brewers' Lb.	Degrees, S. G.	Brewers' Lb.	Degrees, S. G.	Brewers' Lb.
1 ...	1·5	1001	0·36	1021	7·56	1041	14·76	1061	21·96	1081	29·16
2 ...	2·9	1002	0·72	1022	7·92	1042	15·12	1062	22·32	1082	29·52
3 ...	4·4	1003	1·08	1023	8·28	1043	15·48	1063	22·68	1083	29·88
4 ...	5·8	1004	1·44	1024	8·64	1044	15·84	1064	23·04	1084	30·24
5 ...	7·2	1005	1·80	1025	9·00	1045	16·20	1065	23·40	1085	30·60
6 ...	8·7	1006	2·16	1026	9·36	1046	16·56	1066	23·76	1086	30·96
7 ...	10·1	1007	2·52	1027	9·72	1047	16·92	1067	24·12	1087	31·32
8 ...	11·6	1008	2·88	1028	10·08	1048	17·28	1068	24·48	1088	31·68
9 ...	13·1	1009	3·24	1029	10·44	1049	17·64	1069	24·84	1089	32·04
10 ...	14·6	1010	3·60	1030	10·80	1050	18·00	1070	25·20	1090	32·40
11 ...	16·0	1011	3·96	1031	11·16	1051	18·36	1071	25·56	1091	32·76
12 ...	17·6	1012	4·32	1032	11·52	1052	18·72	1072	25·92	1092	33·12
13 ...	19·1	1013	4·68	1033	11.88	1053	19·08	1073	26·28	1093	33·48
14 ...	20·6	1014	5·04	1034	12·24	1054	19·44	1074	26·64	1094	33·84
15 ...	22·1	1015	5·40	1035	12·60	1055	19·80	1075	27·00	1095	34·20
16 ...	23·6	1016	5·76	1036	12·96	1056	20·16	1076	27·36	1096	34·56
17 ...	25·2	1017	6·12	1037	13·32	1057	20·52	1077	27·72	1097	34·92
18 ...	26·8	1018	6·48	1038	13·68	1058	20·88	1078	28·08	1098	35·28
19 ...	28·4	1019	6·84	1039	14·04	1059	21·24	1079	28·44	1099	35·64
20 ...	30·0	1020	7·20	1040	14·40	1060	21·60	1080	28·80	1100	36·00

The equivalent brewers' or saccharometer lbs. in the first of the above tables are, if anything, a shade high ; **the annexed formula gives closer results.**

Let B = deg. Balling, and s = brewers' (or saccharometer) lbs., then—

$$B = \frac{260\,s}{360 + s}, \text{ and } s = \frac{360\ B}{260 - B}$$

Thus, suppose we want the equivalent of 14° Balling—

$$s = \frac{360 \times 14}{260 - 14} = \frac{5040}{246} = 20{\cdot}5.$$

Formula for converting Baumé into specific gravity—

$$\text{Sp. grav.} = \frac{148{,}000}{148 - \text{deg. Baumé.}}$$

Accordingly, *e.g.*, 9° Baumé

$$= \frac{148{,}000}{139} = 1065° \text{ sp. grav.}$$

But there is a good deal of variation, owing to indefinite standards of adjustment in respect to the latter saccharometer.

It may be added that it matters not what quantity of the wort is taken if only the saccharometer can float in it freely. In practice the

quantity generally taken is that contained in a tall narrow sampling can, wherein the saccharometer can sink down to the topmost mark on its stem without touching bottom.

Degrees of Specific Gravity—Definition.—Each degree of specific gravity is equal to one-thousandth part of the gravity of distilled water at 60° F., water being, as it were, the unit; but instead of unity its value is taken as 1,000, in order to avoid awkward fractions. It will be seen that "a degree of specific gravity," then, means no definite and uniform weight, but is merely the expression of the relation between the gravity of any wort and that of water. A gallon of wort taken from a barrel of 1050 or 1060 sp. gr. will be equally of 1050 or 1060 sp. gr. (bearing the same relation to a gallon of water that the larger quantity does to a barrel), but, according to the definition, each of its degrees will only equal $\frac{10}{1000}$ lb. = ·01 lb., whereas each of those in a barrel would equal $\frac{360}{1000}$ = ·36 lb.

But, inasmuch as specific gravity, equally with brewers' lbs., states the excess of the weight of wort over water (because the 1000 is in general practice dropped and only the degrees in excess quoted), it is plain that there will be a constant uniform ratio between the two, which enables a gravity expressed in one standard to be converted into the other. Thus the ratio between 1 degree of sp. gr. and 1 brewers' lb. is

As 1000 : 360 = as 25 : 9 = as 1 : ·36.

Rule to convert Degrees of Specific Gravity into Brewers' Lbs. and vice versâ.—Multiply the given degrees by ·36, or multiply by 9 and divide by 25.

Ex.—To find the equivalent of 57 degrees in brewers' lb.

$$57 \times \cdot 36 = 20 \cdot 52 \text{ or, } \frac{57 \times 9}{25} = 20 \cdot 52.$$

Rule to convert Brewers' Lbs. to Degrees of Specific Gravity.—Divide by ·36, or multiply by 25 and divide by 9.

$$\text{Ex. } \frac{18 \text{ brewers' lbs.}}{\cdot 36} \text{ or } \frac{1800}{36} = 50, \text{ for 1050 sp. gr.}$$

Sugar Extract.—Why 2 cwt. of Sugar only gives one-third, more or less, of its weight as Extract.—An error in earlier editions of this book, which, taking no account of a contraction that occurs when a strong sugar solution is added to water, understated the extract-yielding power of sugar, was courteously pointed out by Dr. L. T. Thorne. A concrete example was there taken of 1 gallon of sugar weighing 16 lb., and added to 35 gallons of water weighing 350 lb. The resulting 36 gallons, it was stated, would weigh 366 lb., the 6 lb. over the weight of a barrel of water indicating 6 lb. extract per barrel due to 16 lb. of sugar. But with these quantities there is a contraction rather more than equal to 5 fluid oz. (= 0·32 lb.), so that, though the latest determinations give sugar a specific gravity of only 1·58, instead of 1·6, we get the following figures: 1 gallon sugar = 15·8 lb. + 35 gallons water = 350 lb. + 5 oz. (to make measure) = 0·32 lb., or in all 366·12 lb. = 6·12 of extract given by 15·8 lb. of sugar. Consequently,

$$\frac{6 \cdot 12 \times 224}{15 \cdot 8} = 86 \cdot 75 \text{ lb. B.E. per 2 cwt.}$$

whereas without the contraction allowed for, the extract would only work out 82·23 lb. This contraction is not due to escape of admixed air, but to an intermolecular penetration between the sugar and water, similar to that which occurs when absolute alcohol and water are mixed (4% with equal volumes), but less in degree. For optical evidence of contraction, take invert sugar of 1·425 gravity at 60° (14·25 lb. per gallon), which is just fluid enough to pour into a measure without entangling air, and put 50 c.c. into a 100 c.c. measure, making up carefully with water to the 100 c.c. mark. After the sugar has been dissolved by careful shaking it will be found that the volume has shrunk to about 98·7 c.c. The extract from such a sugar would only be 66·8 brewers' lbs. from 2 cwt., if the contraction were disregarded, whereas it really is 72·5 brewers' lbs., a further shrinkage, corresponding with some 2 degrees more extract, occurring when a 50% (*by weight*) solution is diluted to 10% (the adopted standard).

Working out the Brewings and the Maintenance of Stocks.—In a correctly managed brewery the stocks of beer in cellars, together with that of wort undergoing fermentation in F.V.'s., should be recorded on Thursday or Friday of each week in a book maintained for the purpose. The total stocks in the form of fermenting wort and also finished beers should be summarised, from which can be readily ascertained the sales of each class of beer for the current week. The calculation for *each* brand produced is based on the following formula :—Previous week's summary, plus wort in tuns (*i.e.*, present week's brewings), minus present week's summary.

Example.—(1) Previous week's summary of XX. = 227 brls. (2) Wort (XX.), in tuns = 144 brls. ; and (3) present week's summary = 245 brls. ∴ 227 + 144 = 371−245 = 126 brls., present week's sales of XX. Based upon such information obtained for each class of produce, a brewer can calculate his needs for the forthcoming week in order to maintain stocks at any definite standard considered necessary, assuming that the output or sales of XX. for the ensuing week is expected to reach, say, 151 brls., such improved trading conditions warrant augmenting the total stock by 25 brls., thus necessitating a production of 169 brls. of XX. Suppose this class of beer is brewed at 15 " brs. lbs." from 75% of a blend of 3 parts of English malt to 1 of Foreign—the combined grist yielding an extract of 95 brs. lbs. per quarter—and 25% of invert, we work out the materials for the 169 barrels required, as follows :—

Brls.		Brs. lbs.		Total.	Invert.
169	×	15	=	2535	× ·25 = 633·75.

Calculating the extract yield of the invert at 36 " brs. lbs." per cwt., ∴ $\frac{633 \cdot 75}{36}$ = 17·6 cwt., or say 18 cwt., to obviate the waste involved in employing odd amounts. Deducting the extract yield of 18 cwt. (648) from the total required, 2535 — 648 = 1887, and dividing the latter by 95 " brs. lbs.," thus $\frac{1887}{95}$ = 19·86 quarters or, say, 19 quarters 7 bushels composed of 14 quarters 7 bushels English and 5 quarters Foreign.

To calculate the materials necessary for the production of a series of beers of different gravities (parti-gyles) from one brewing, we proceed as in the specific instance just given, ascertaining the materials from the aggregate number of " brs. lbs." required for the several beers.

If the Excise standard = 79·2 lb., covering a month's brewings, is not attained, owing to either material, plant, or system, or two or all of them being faulty, " the charge," instead of being levied on the defective produce is levied upon the material used, although there is no excuse for any brewer obtaining less than 90 lb. per qr. from a mixed grist with normal material.

The hops should be so distributed among the various coppers as to bear a fairly close relation, not only to the number of barrels in each, but to their gravity as well. This point, however, will be more conveniently dealt with when we come to speak of parti-gyles.

Entry of the Malt and Sugar.—The exact quantities of malt, sugar " flakes," hops, and copper finings (if any) which one intends to use have to be entered in the Brewing Book supplied by the officer of Inland Revenue, and this must be done at least two hours before use [the intention to brew having been notified in the same way at least twenty-four hours before]. When the malt weighs less than the standard weight 42 lb. per bushel) it is reduced into the said standard weight for entry. For example, suppose our 32½ quarters of malt, being freely made, weigh only 40 lb. a bushel, *i.e.*, 2 lb. short of the standard, then the working is as follows :—

$32\frac{1}{2} \times 8 = 260$ bushels ; $260 \times 2 = 520$ lb. short, this $\div 42 = 12\frac{8}{21}$, *i.e.*, 12 bushels off 32½ quarters = 31 quarters for entry.

The quantity of sugar is reduced to lbs. for entry.

Sparging for Copper Lengths.—As the conditions vary a good deal it will be impossible to lay down a rule precise enough to meet all cases ; it will therefore perhaps elucidate the matter better if we now proceed to mash our 32½ quarters (on the morning after entry of materials has been made) in imagination.

Formula for calculating Initial Heat from " Striking Heat."—Though not likely to be much used in practice, it may be useful to have such a formula. Of course it is applicable to a mixture of any two bodies whose specific heat is known ; but, as in our own case, it will be used solely for mixtures of malt and water. The lettering used may be arranged with special reference thereto. So when

W. M. = weight of malt (*i.e.*, total weight used),
S. H. M. = specific heat of malt (= ·42),
A. T. M. = actual temperature of malt,
W. W. = weight of water,
S. H. W. = specific heat of water (but as this is taken = 1, it really may be left out of calculation),
A. T. W. = actual temperature of water,

then the general formula will be—

$$\frac{\text{W.M.} \times \text{S.H.M.} \times \text{A.T.M.} + \text{W.W.} \times \text{S.H.W.} \times \text{A.T.W.}}{\text{W.M.} \times \text{S.H.M} + \text{W.W.} \times \text{S.H.W.}} = \text{I.H (ini ial heat).}$$

Supposing, then, we mash each imperial quarter of 336 lb. malt with

2 barrels of water (= 720 lb.) at 165°, and we find, by plunging a mash-tun thermometer into the grist-case, that the A. T. M. = 62°, then our calculation comes out as follows : [We take a single quarter of malt for the calculation and 2 barrels of water to keep the numbers down.]

$$\frac{336 \times \cdot 42 \times 62 + 720 \times 1 \times 165}{336 \times \cdot 42 + 720 \times 1} = \frac{127549 \cdot 44}{861 \cdot 12} = 148 \cdot 1.$$

This approximates pretty closely to the actual *mixing* heat ; but it must not be forgotten that a chemical action, more or less energetic, immediately begins, during which heat is set free. Moreover, the mash ought to fall into a mash-tun so well heated as actually to gain rather than lose heat. Consequently, when the diastasic action is vigorous, and the heating of the mash-tun, especially if an iron one, has been efficiently performed, the mash-tun too being of such a size and so placed that the radiation of heat is inconsiderable, we should expect the temperatures of the mash taken at the finish—*i.e.*, when all the mash is in the mash-tun (and which, though inaccurately, is called the " initial heat ") to show 3° or 4° higher.

The mash being made with 2¼ barrels to the quarter, excluding underlet (if any), the total quantity on " the goods " = 73 barrels. Deducting from this 24½ barrels (because " the goods " imbibe and retain a considerable quantity of the liquor, which may be roughly estimated at 27 gallons per quarter), we get 48½ barrels from the mash-tun, without reckoning sparge. Accordingly, the difference between this and the sum total of the copper lengths will represent the quantity of liquor required as sparge (less any liquor run into coppers direct without being sparged). The total liquor employed for mashing and sparging should not be more than 16¾ brls. or in excess 7¾ brls. per quarter of malt mashed. Any excess should be plain liquor added direct to coppers.

This being a parti-gyle, consisting of two distinct kinds of beer, we shall desire not to mix the coppers in the fermenting vessels ; accordingly the first and second coppers will go for the BA and the third copper for the XX. But this would be impossible if we made up the first copper entirely with wort ; we accordingly run in a considerable portion of plain liquor into both first and second coppers, and moreover keep back a portion of the strong " first runs " in the underback for mixing with and bringing up the gravity of the third copper to XX standard.

A moment's reflection will show that if we get a copper of given length, say of 100 barrels, we are not likely to get 100 barrels from it into the fermenting round ; and for this there are several causes.

(i) The copper dip is taken on boiling wort, whereas in the F. V. it stands at 60° or thereabouts (= a shrinkage of 4%).

(ii) Waste during boiling (amount varies with conditions, atmospheric pressure, and amount of wind, the depth of the copper in relation to surface, etc.).

(iii) Retention of wort by hops (60 lb. hold back about 1 barrel).

(iv) A relatively small amount retained in the intermediate vessels, hop-back and coolers.

We take all these causes in the aggregate, and find that the loss will generally average a known *and constant* amount, within a barrel or thereabouts, at all events, and on that we base our calculations. Suppose

we arrange our three copper lengths at 88, 65, and 80 barrels respectively; experience, say, tells us that we may expect to get in the rounds 76, 56, and 72, the former two totalling up 132 barrels, or exactly the amount required for the BA, the latter being purposely run short, so as to allow of the desired length of 75 barrels being made up by a "splash" over the spent hops.

But this is not all. As before said, a considerable quantity of plain liquor must be run into both first and second coppers to get their blend down to any required gravity. This plan—seeing that the amount of liquor run into coppers has to be deducted from sparge—will have the incidental advantage of preventing an excessive sparging of goods, which is certainly to be avoided (see pp. 224—256). Let us see **how the quantity of liquor which we have to run in is to be calculated.**

The first "runs" from the mash-tun will probably be found to weigh 30 brewers' lb. or thereabouts; but as we intend to keep back 22 barrels in the underback (if any) for the third copper, we shall not be far off the mark if we take the average gravity of the wort which reaches the first copper a little lower—viz., at 26 lb. or 28 lb. As we wish to get the first copper to turn out (*i.e.*, to weigh after boiling) a little, but not much, in excess of the gravity required for the P.A., let us fix the gravity at 17 lb., which, after boiling, will give a wort in the fermenting vessels of 18·5, more or less, according to the duration and vigour of the boil.

Then $88 \times 17 = 1{,}496$ total brewers' lb. required. If we use 12 cwt. of invert, giving an extract calculated in brewers' lbs. as 432, there remain

$(1{,}496 - 432) = 1{,}064$ lb. to get from the wort. Then $\frac{1{,}064}{33} = 32{\cdot}25$,

or, for first copper, $32\frac{1}{4}$ barrels of wort + $55\frac{3}{4}$ barrels of liquor in which 12 cwt. of invert sugar are dissolved.

Then, as we calculate to get from the first copper 76 barrels at $18\frac{1}{2}$ lb., or 1 lb. over the desired gravity, the running-down gravity of the second copper must be $\frac{76}{56} = 1{\cdot}3$ under the desired gravity, viz., 16·2. Perhaps 14·7 might be a sufficient "in-copper" gravity; but if, on the other hand, there is a fairly full copper, such as can be safely boiled by steam, perhaps the loss by boiling, and consequently the increase of the copper's running-down gravity, would be less than if a harder boil was attained by fire. We will accordingly assume 15 lb. to be the required "in-copper" gravity for the second copper.

We will now take the average gravity of the wort making up second copper = 23 lb. (but this must obviously be a question of experience; it will be found sufficiently close under the conditions predicated).

$65 \times 15 = 975$ total brewers' lb. required.

$975 - 108$ (from 3 cwt. sugar) $= 867$.

$867 \div 23 = 37\frac{2}{3}$

Or $37\frac{2}{3}$ barrels of wort to $27\frac{1}{3}$ barrels plain liquor in which 3 cwt. invert sugar are dissolved.

It will be found almost essential in this sort of parti-gyle brewing, or if much sugar is used, to have some kind of **apparatus for dissolving cask-sugar,** such as a copper trough, long enough to hold two casks and fitted

in a stout wooden frame. The trough will have two plug-holes commanding each copper if the latter are side by side, or the contents can be carried some distance by shoots. There are steam nozzles just above where the casks lie, and steam pipes being fitted on them, are forced through holes bored into the sides of the casks exactly opposite the bung-holes. The bungholes are of course downward, and the sugar, as it is melted, flows out of them.

To return to the sparges. The total "in-copper" length required being 88 + 65 + 80 = 233 barrels, out of which 57 barrels are yielded by the mash and 38 barrels are plain liquor, and 138 barrels sparged.

This quantity (138 barrels) should be quite sufficient sparge for 32½ quarters, and if a sample of the last runnings be caught just when the third copper length is made up, it will probably not be found to weigh more than 1·0 brewers' lb., and very possibly less. One needs to be assured then that the sparging apparatus is in good order, and that the sparge-liquor is evenly and lightly distributed; because it may happen that, owing to imperfect sparging, the liquor falling much more copiously in one place than the other may "channel," and then, in very flagrant instances, it would be possible for the "last runs" to be of very low gravity, and yet the major part of "the goods" be unexhausted. With the modern sparger, however, the faults mentioned are in a great measure obviated.

We have purposely taken a rather simple parti-gyle as an illustration. We might, however, fill our pages with an infinite variety, in some of which two mash-tuns might be used, without exactly suiting the requirements of any readers.

Though such a manipulative detail belongs more to another chapter, it may be said here that starting the sparging some 10 or 15 minutes before the taps are set is often a help in "keeping up the goods."

Apportioning the Copper Hops.—Assuming that it is proposed to produce four brewings of say:—

100	Barrels of	Pale Ale of 22 "Brs. lbs.," hopped at 2½ lbs. per barrel collected.
100	,, ,,	Bitter Ale of 17 "Brs. lbs.," hopped at 2 lbs. per barrel collected.
80	,, ,,	Mild Ale of 16 "Brs. lbs.," hopped at 1½ lbs. per barrel collected.
50	,, ,,	Mild Ale of 12 "Brs. lbs.," hopped at 1 lb. per barrel collected.
330		

From a simple calculation it will be seen that the aggregate poundage required is 6025 "Brs. lbs." and the total amount of hops 620 pounds.

Three copper lengths are found to be necessary and when allowance is made for the loss of *extract* between the coppers and F.V.'s—say, 6%—and for the loss of *volume* by evaporation during the boiling and cooling of the wort, replaced in some considerable measure by the liquor for hop sparging or "splash," and if we assume the remainder of the wastage of volume to be 5%, the following, omitting fractions, of gravities will represent the copper lengths and gravities.

Copper No.					
1	105·8	Barrels at	22·0	=	2327
2	125·7	,, ,,	17·0	=	2137
3	111·5	,, ,,	14·0	=	1561
	343·0				6025

Percentage composition of extract :—

Copper No.	
1	$\frac{2327 \times 100}{6025} = 38{\cdot}62\%$
2	$\frac{2137 \times 100}{6025} = 35{\cdot}47\%$
3	$\frac{1561 \times 100}{6025} = \frac{25{\cdot}91}{100{\cdot}00}$

∴ Apportioning of hops :—

Copper No.		Pounds of hops per copper.
1	$\frac{620 \times 38{\cdot}62}{100} =$	239·45
2	$\frac{620 \times 35{\cdot}47}{100} =$	219·91
3	$\frac{620 \times 25{\cdot}91}{100} = \frac{160{\cdot}64}{620{\cdot}00}$	lbs.

Working out Hops at lbs. per Barrel.—In parti-gyle brewing, and especially where beers are being brewed which have to be differently hopped, it is by far the most convenient plan to work by the ascertained proportion per barrel in preference to proportion per quarter. And this is really the best system in every case, because the extract per quarter may easily vary 5 brewers' lb., or more, with varying qualities of malt ; so that if the proportion be calculated per quarter, the smaller quantity of beer yielded by the inferior malt will get the same quantity of hops as the larger quantity of beer yielded by an equal quantity of the better malt.

In practice, if the worts are to be blended, we should probably rather underdo the worked-out proportion for the first copper, and accordingly rather exceed it for the second, seeing that the stability of the extract in the first copper is presumably greater than that of the second. This being so, one would like to support the second copper by adding hops somewhat in excess, where possible, of what its gravity really warrants.

Hop Extraction in Copper Wort.—The main object to be attained in subjecting hops to a more or less prolonged boil in the copper is to extract their aromatic, flavouring and preservative attributes and to promote coagulation of certain proteins, an essential initial process in the refining of wort. The question of determining the correct period of ebullition to which the hops should be submitted has always been a controversial one. Excessive boiling results primarily in an undue disintegration of the hops to an extent that reduces them to a pulp, in which condition they cease to function as a filter bed in the hop-back. Further, a prolonged boiling of the hops beyond that period necessary for a particular blend, will indubitably result in defeating the purpose in view in another important connection. The preservative and bettering principles of the hop are contained within the soft resins, and when these are extracted and yield up their valuable contents to the wort, an additional boiling beyond that stage tends to the conversion of these soft resins into hard resins, which not only possess little, if any, preservative value, but produce harsh and acrid flavours. The varied and pleasingly aromatic and delicate flavour-

ing properties of the hop are present in the oil, which is extremely volatile at the normal temperatures of boiling wort from 215° F. to 218° F., and this leads to another and very important aspect of this question. With ordinary open coppers, or even with those equipped with "domes," and especially where "fountains" are installed the volatilisation of the flavouring and aromatic principles readily occurs, and it is with a view to obviating their dissipation to the winds, that gave rise to the practice of adding a definite proportion of the total hops or those of better quality at half-time, or later at 30 minutes prior to casting or turning out. Doubtless by adopting this precaution the readily volatile oils are retained in the wort, but experience has proved to us that short boiling periods, while accomplishing the specific object just referred to, is not sufficient to extract the remaining hop principles, with the inevitable result that when this theory is adopted the finished beer exhibits a lack of general character, mainly in the direction of being definitely under-hopped. Although probably no "returns" of beer may be received as the outcome of this change in brewing working procedure, yet the alteration in palate flavour will be immediately detected by the consumer, and complaints will reach the brewery from the retailer, on the ground that some form of indefinite alteration in flavour fullness of the beer has occurred to adversely affect his sales. An immediate reversion to former methods of copper hop manipulation will be rendered necessary to restore the brewery finished produce to its customary position of popularity in the eyes, and especially on the palates, of the customers. If a continuance of this system of retaining a portion of the hops for a brief boiling period is decided upon, then an increase in the copper hop rate—with the additional cost involved—is imperative. With a view to solving the difficulty, many expedients are adopted to secure the maximum amount of elusive aroma and flavour available. In one instance, where the question of economy was ignored, a further hop rate was employed and material selected for its especial flavouring attributes, was distributed at the moment of casting or turning out the copper equally over the plates of the hop-back. By this means the oils were readily dissolved during the "stand on," and remained in solution, virtually no opportunity being provided for volatilisation, and the finished beer was unquestionably vastly improved in flavour and aroma. We are not advocating the adoption of this costly procedure, which merely and obviously secures from the hops partial extraction of their constituents. In France we found that by the Prache and Bouillon process of rapid and intense concentration of the wort, the latter only passed through a filter bed of hops as the wort was carried to the refrigerator, although the finished beer differed in many respects from the British article, yet the aroma and flavour was prominent and pleasing. Owing to the prevailing custom of producing quick running ales, in which no dry-hopping is employed, distinctive aroma is absent, but where time is allowed in the case of semi-stock beers, for hops in cask to be employed, then we prefer to rely on these for aroma, adding the entire amount of copper hops to those vessels for the full period determined. The question of the relative periods necessary for the boiling of old or new hops calls for a brief word. With age, soft resins are reduced to hard resins, yielding a harsh bitter flavour, consequently old hops should receive a shorter boiling period than new.

The agitation the hops are subjected to when "domes" and "fountains" are installed in coppers, permits of a more rapid extraction of the hop constituents, in which instances shorter boiling periods can be adopted than in the case of open coppers. "Domes," although they produce over-disintegration, are useful where a copper has a tendency to boil over, but "fountains" introduced when the theory or aeration became popular, are now discarded, as aeration above 190° F. is not feasible, and "fountains" rapidly disintegrate hops to a pulp with consequent difficulties in hop-back filtration, and the re-dissolution of the coagulable wort proteins.

Making up Lengths.—Although we hold with equalising or arranging copper gravities so far that very little calculation will be requisite, it will be desirable to give certain forms to meet cases in which such equalisation is not possible.

For Modern Beers, "Making up Lengths."—

I. To find in what proportion worts of two different gravities must be mixed to obtain a certain bulk at an intermediate gravity.

(α) To find the bulk of stronger wort. **Rule.**—Multiply the given bulk by the degrees (or pounds) of gravity under the gravity required of the weaker of the two worts, and divide by their difference of gravity.

Ex.—How much wort at 50° must be combined with wort at 14° to produce 1,000 gallons at 44° ?

$$\begin{array}{l}\text{Degrees under } (44 - 14) = 30° \\ \text{Difference } . \ (50 - 14) = 36°\end{array}$$

$$\frac{1000 \times 30}{36} = 833{\cdot}34 \text{ galls. at } 50°.$$

[The correctness of which may be proved as follows—

Gallons.		
833·34	× 50	= 41667·0
166·66	× 14	= 2333·24
1000·00		44000·24

$$\frac{44000{\cdot}24}{1000} = 44°.$$

Ex.—How much wort at 30·6 "brs. lbs." must be mixed with wort of 5 lb. gravity to obtain 80 barrels at 21 lb. gravity per barrel ?

$$\begin{array}{l}\text{Lb. under } (21 - 5) = 16 \\ \text{Difference } (30{\cdot}6 - 5) = 25{\cdot}6\end{array}$$

$$\frac{80 \times 16}{25{\cdot}6} = 50 \text{ Barrels at } 30{\cdot}6$$

Proof. $50 \times 30{\cdot}6 = 1530$; $30 \times 5 = 150$; $80 \times 21 = 1680$

(β) To find the bulk of weaker wort. **Rule.**—Multiply the given bulk by the degrees (or pounds) of gravity of the stronger of the two worts over the gravity required. and divide by their difference of gravity.

Ex.—How much wort at 14° must be combined with wort at 50° to produce 1,000 gallons at 44° ?

$$\begin{array}{l}\text{Degrees over } (50 - 44) = 6 \\ \text{Difference } . \ (50 - 14) = 36\end{array}$$

$$\frac{1000 \times 6}{36} = 166{\cdot}66 \text{ galls. at } 14°.$$

Ex.—How much wort at 5 lb. gravity must be mixed with wort at 30·6 to produce 80 barrels at 21 lb. gravity ?

Lbs. over (30·6 − 21) = 9·6
Difference (30·6 − 5) = 25·6

$$80 \times \frac{9{\cdot}6}{25{\cdot}6} = 30$$

Proof. 30 × 5 = 150
50 × 30·6 = 1530
80 × 21 = 1680

II. To ascertain the proportions in which two worts of different gravities must be mixed to get an intermediate gravity.

Rule.—Find the difference of gravity of the two given worts above and below the required gravity. State these differences (inversely) in the form of a fraction, and reduce the fraction to its lowest terms. [The example given is in brewers' lbs., but of course the rule holds equally good for degrees.]

Ex.—In what proportion must worts at 29 lb. and at 8 lb. gravity per barrel be combined to produce a gravity of 20 lb. ?

20 lb. $\begin{cases} 29 \\ 8 \end{cases} \times \begin{matrix} 12 \\ 9 \end{matrix} = \frac{4}{3}$,

i.e., 4 barrels at 29 lb. to each 3 barrels at 8 lb.

III. To ascertain the proportions in which worts of four different gravities may be mixed to produce an intermediate gravity.

Rule (*a*)—State the differences of gravity of all four worts above and below the required gravity, but inversely. This column will give proportions at the gravities in the same line.

Ex.—What proportions of worts at 20°, 37°, 63°, and 80° respectively will give a combined gravity of 57° ?

	Difference reversed		
57°	20	23	(Barrels at 20) × 20 = 460
	37	6	(„ 37) × 37 = 222
	63	20	(„ 63) × 63 = 1260
	80	37	(„ 80) × 80 = 2960
	86		57 = 4902

Obviously, though, other combinations of these gravities might be made which would give the same combined gravity, and in the event of the brewer having to blend four different worts (not a plan to be recommended), he would find it simpler to arrange his coppers so that *equal* quantities of the three weaker worts would be run in, and so that only the proportion of them *taken as a whole*, and the proportion of the strongest wort required to bring the gravity up, must be calculated. And of course the stronger wort, which is naturally the first copper, might easily be the only one whose precise gravity he knows at the beginning of his calculation. If he has worked out the assumed total extract correctly, he may, having got his first copper ready to run down at a gravity of 80°, know that his remaining three coppers will average a gravity of $40° \left(\frac{20+37+63^*}{3}\right)$,

* They can of course only be these gravities with an average of 40°, if they are equal lengths; but if they are at those gravities, though unequal lengths, they will average 40° for any F.V. into which equal lengths are run, though more or less, as the case may be, on the whole.

but he cannot be sure that they will be precisely 63°, 37° and 20°. So that we have

Rule β.—Get the average gravity of the second, third, and fourth coppers, and using that as one term and the gravity of the strong wort as the other, proceed as in Rule II. Assuming the average gravity to be 40°

$$57 \begin{cases} 80 \\ 40 \end{cases} \times \begin{matrix} 17 \\ 23 \end{matrix}$$

Proof. $\begin{cases} 17 \times 80 = 1360 \\ 23 \times 40 = 920 \\ 40 \times 57 = 2280 \end{cases}$

i.e., 17 barrels of first wort and $7\frac{2}{3}$ of each of the others in each 40 barrels.

Boiling down Copper to get a required Gravity.

Ex.—A brewer wants in his gyle-tun wort of a gravity of 45°, but finds in his copper 85 barrels at 38°. How much must he boil away ?

Rule.—Multiply the given bulk by its gravity, and divide by the required gravity. Or multiply by the difference between the two gravities and divide by the required gravity. [The first calculation will give the bulk to which the copper is to be boiled down, the second the amount to be boiled away. And one proves the other.

Ex.—(α) $\frac{85 \times 38}{45} = 85 \times \frac{38}{45} = 71{\cdot}77$ Barrels.

Ex.—(β) $\frac{85 \times 7}{45} = 85 \times \frac{7}{45} = 13{\cdot}23$ „

$85{\cdot}00$ „

N.B.—This, of course, means the amount actually to be boiled away + evaporation on coolers. The usual difference between copper-length and the quantity got in the gyle-tun depends on shrinkage, and retention by hops as well as on these factors.]

Working out Extract per Quarter.—In the paragraph on working out the brewings mention was made of the extract given by a quarter of malt. the so-called extract (which of course differs from the " solid " or " dry extract " to be mentioned shortly) is the apparent extract perceptible by the saccharometer, and generally ranges between 90 and 98 brewers' lbs. per quarter of 336 lb. Forming, as it does, a ready means of classifying malts, from one point of view, the extracts should be worked out on the morning following the brew at latest.

Rule.—Multiply the barrels got by the gravity (or each lot of barrels by their respective gravities, if there are various gravities), deduct the number of brewers' lbs. given by sugar, and divide the remainder by the number of quarters brewed.

Ex.—Suppose we brewed 200 barrels at 18·5 lb. from 31·5 quarters of malt and 20 cwt. of invert sugar. Then 200 × 18·5 = 3,700 lb. ; 3,700 — 720 (lb. from sugar) = 2,980 ; 2,980 ÷ 31·5 = 94·6 extract per quarter.

Dry or Solid Extract may be defined as " the amount of solid matter which a wort contains, whether derived from malt or other material."

It is generally arrived at by multiplying the extract per quarter, as

ordinarily calculated, by 2·597 (2·6 approximately), though a factor as low as 2 538 has been advocated as being more correct.

Let us suppose we have an extract, as ordinarily taken, of 95 per quarter, this × 2·597 = 246·715 dry extract.

Extract per Cent.—We can now make use of the ascertained amount of dry or solid extract to calculate the percentage of extractive matter which the malt yields. This we do by taking the solid extract and dividing it by 3·36 (in other words, multiplying by 100 and dividing by 336, the weight of a standard quarter of malt), and we accordingly find 246·715 ÷ 3·36 = 734·3%.

The necessity of working out the solid extract may be dispensed with by multiplying the ordinary extract by the factor ·7729 (which is 2·597 ÷ 3·36). Thus 95 × ·7729 = 73·43%.

[If, however, the lower factor 2·538 be taken for estimating solid extract, the factor for getting percentage out of ordinary extract will be ·755. The variation is due to a difference of opinion as to the amount of gravity added by any given quantity (say 1 gramme in 100 c.c.) of starch-transformation products. The higher factors depend on the assumption that 1 gramme of malt extract in 100 c.c. raises the density of the infusion by 3·85° (water being 1,000). This is admitted to be true for sugar solutions at 1,050 (though rather too low for those of lower gravity and too high for those of higher), but is alleged not to be high enough for accuracy when starch-transformation products are being dealt with. Mr. O'Sullivan, in fact, considers that 1 gramme of such products in 100 c.c. at 60° F. raises the density 3·95—in other words, that such a solution will have a specific gravity of 1003·95.]*

Excise Charges.—The Excise charges are levied either upon the material used, or upon produce. 84 lb. of malt (= 2 bushels), or 64 lb. of invert sugar or glucose, are expected to yield 1 barrel of wort of the specific gravity of 55° at least, less 4%, and in the event of any lower yield the charge is upon material. Passable material and fair skill ought to ensure in every case a sufficient extract to avoid a "material charge." We will accordingly deal with the charge upon produce first.

The amount levied is £5 per standard barrel, less a rebate of £1 per barrel collected, from which an allowance of 6% is in each case made for waste and loss during fermentation. This deduction, however, is not made daily, but is taken off at the month's end from the total number of gallons chargeable. To enable the charge to be levied, the quantity produced has to be brought into gallons, and these calculated into gallons of the standard gravity of 55°, whereupon their number is entered by the Excise officer in the "specimen book," and the brewer, to avoid chance of mistake, should check the calculation.

* Another way of working out the percentage extract, which will show how the higher solution value affects the extract in an opposite sense, is based on the fact that as 3·85 (or 3·95, as the case may be) shows the density value of 1 gramme of solid extract in 100 c.c., so it shows the value of 1 lb. in 100 lb.—*i.e.*, 10 gallons of water. Accordingly the specific gravity, over 1000 × 3·6 (to bring the 10 gallons up to a barrel) ÷ 3·85, give the amount of solid extract *per barrel.* Hence the percentage extract can be got. Suppose we have 190 barrels at 52° from 40 quarters malt. Then:—

$$\frac{52 \times 3{\cdot}6}{3{\cdot}85} = 48{\cdot}62 \text{ (Solid extract per barrel.)} \quad \text{and} \quad \frac{48{\cdot}62 \times 190}{40 \times 3{\cdot}36} = 68{\cdot}7\%$$

Suppose in one F.V. he has 130 barrels at 1,048, and in another 70 barrels at 1,053, or concisely 48 and 53, then

130 × 36 × 48 = 224,640
70 × 36 × 53 = 133,560
358,200 which ÷ 55 = 6,513 gallons chargeable.

These totals should be entered daily in a small book kept for the purpose, and added up at the end of the month, just as the officer does to get at the amount payable as duty. Any odd standard gallons, less than 36, are carried forward to the following month, except for rebate, which is fully charged each month.

Let us suppose we have 135,021 gross gallons at 55° with 27 " odds " from the preceding month. Then the calculation will be

135,021 (gross gallons at 55).
8,101 (6% deducted).
126,920
27 (" odds " from last month).
36)126,947
3,526 and 11 gallons over (" odds " for next month).

3,526 Barrels at £5	=	£17,630
Total barrels collected 2,000, less 6% = 1880 at £1	=	1,880
Net Duty Payable		£15,750

It has been mentioned that, if the amount and gravity of wort produced do not come up to a certain standard, the charge, instead of being levied upon produce, is levied upon material—*i.e.*, the charge is made, not upon the quantity which the brewer actually gets, but on what he ought to have got. Consequently, he pays a higher duty on what he actually gets than the £5 minus a rebate of £1 which the more competent brewer pays. Although " material charges " ought only to have a theoretical interest, it may be well to give the quantities of materials which are expected to produce one barrel of beer at 1,055. These are malt 84 lb. ; raw cane-sugar 56 lb. ; invert or glucose 64 lb. ; No. 1 syrup (weighing 14 lb. per gallon) 68 lb. ; and No. 2 syrup (weighing 13 lb. 2 oz. per gallon), 82 lb. Flaked rice and maize, 64 lb.

A calculation made on the above basis gives a number of gallons which, less 4%, constitutes the " minimum yield," and on this, if the actual yield fall below it, the charge is made. Both charges are subject to the 6% deduction when the monthly accounts are made up.

It is sometimes necessary for the brewer to work out the contents of a round or square vessel, which is either in position or is intended to be put up ; and to do this he may avail himself of the following divisors or factors.

Contents of Square or Round Vessels in Bushels or Gallons.—Having got the number of cubic inches in his vessel (in the case of rounds, diam. × diam. × depth, all in inches), he has the choice of either dividing by a divisor or multiplying by a factor.

Gives result in	Divisors for		Factors for	
	Squares.	Circles.	Squares.	Circles.
Gallons .	277·274	353·036	·0036065	·0028326
Bushels .	2218·192	2824·29	·00045082	·00035407

Ex.—Suppose we have a rectangular vessel 14 ft. × 15 ft. × 5 ft. = 168 × 180 × 60 inches = 1,814,400 cubic inches.

Then $\frac{1,814,400}{277{\cdot}274}$ = 6,543 gallons = 182 barrels (nearly).

A Speedier way of reckoning the Above.—This, which is correct enough for practical purposes, consists in dividing the *cubic feet* by 6 and adding 4% as correction. This gives the answer in *barrels*, thus—

14 × 15 × 5 = 1,050 cubic feet

$\frac{1050}{6}$ = 175, and 175 + 7 (4% of 175) = 182 barrels.

Cost Price of Beer.—Where a competitive trade is done, it is necessary, and it is never superfluous, to know the cost of each barrel of beer at the moment of production, or rather of delivery. The difficulty is to know precisely what expenses beyond those of actual malt, hops, and sugar used, and of duty chargeable, to divide and apportion strictly to each individual barrel, and which to lump together in a more general manner. On the whole, we should feel inclined to place in the first class those expenses which *do* bear a more or less close relation to the number of barrels produced—viz., those under the headings of coal, wages and salaries, rail (carriage inwards of materials and outwards of finished produce), transport, finings, etc., while those which either would not vary at all, or would vary very little with the number of barrels produced, are such items as interest on capital at 5%, losses on rentals, wear and tear of plant, repairs of plant, etc. The two last are obviously correlated, and where, as large firms generally do, brewers have their own mechanics, repairs are largely included under the head of wages. Accordingly, it seems fairer to divide the sum total of these less elastic items by the average number of brewing days, assigning an amount equivalent to the quotient so obtained to each day ; the result of which, of course, will be that the larger the number of barrels brewed on any particular day the lower will be the debit of each individual barrel in respect to those items. And this is what really occurs. A sudden influx of trade, resulting in an appreciable increase of the output, would not practically increase those items, whereas it would at once increase the other expenses under the heads of coal, railway charges, etc., and, if permanent, would increase those under the head of wages and salaries also, though perhaps not to the same extent. On the other hand, this method of dealing with the elastic (or progressive) expenses and the non-elastic (or unprogressive) expenses has this disadvantage, that, if it is the practice, from some motive of convenience, to brew only a relatively very small gyle on any one day of the week, then the barrels brewed will be unduly overweighted with the latter set of expenses ; but, save for this, it seems far the best working plan.

Legitimate losses on public-house rentals should be fully met by better prices obtainable and the security of a tied trade. Here, indeed, we have nothing to do with the absurdly inflated prices paid for licensed property and the cut-throat competition which spell disaster to the trade.

N.B.—The figures below suffice to show the method proposed.

Cost Price Calculation.

(1) **Debit.**—Aggregate cost of all (*a*) brewing materials employed; (*b*) Duty paid priming; (*c*) Duty levied on brewing (less rebate allowance on bulk barrelage).

(2) **Credit.**—Total amount obtained from (*a*) the sale of the net barrelage yielded by the brewing, together with (*b*) receipts from the disposal of the "grains" and other by-products.

(3) The difference in amount between 2 and 1 constitutes the total gross profits obtained on the brewing.

(4) To ascertain the *percentage* of gross profits multiply the latter by 100, and divide by the credit total (2).

(5) To determine the cost price of the beer per barrel racked, divide the Debit cost (1), less receipts from sale of "grains" and other by-products by the net barrelage racked.

N.B.—The Cost Sheet should, for comparative purposes with similar previous brewings, contain spaces for the entry of such necessary details as (*a*) Original gravity, (*b*) Extract yield per quarter malt mashed and (*c*) loss between collection of worts and the racking of the finished beer.

In the case of ascertaining the Cost Price of "Parti-gyles," the relative debit and credit items should be apportioned in accordance with the percentages of extract, hops, duty, etc.—forming part of each gyle.

The Penalty of Inexactitude in Brewing Mathematics.—Brewing can never be rendered an exact science, as it deals with the employment of organic materials of ever-varying general character, differing in the proportions present of their normal constituents, and, in addition, although every precaution can be observed to standardise the quality of beer, fermentation can never be carried on immune from infection to such a degree that would ensure entire success to even strenuous efforts made in this direction. But a brewer who brings to bear on his work precision and exactitude so far as these factors can be employed throughout every process from the arrangement of the percentage composition of the so-called raw material to the completion of the finished beverage, succeeds in a measure, both in a commercial and technical sense, far above that possible of achievement when "the little things that count" are disregarded in the daily routine. By systematising the methods of working so far as it is humanly possible to control them a brewer not only enjoys the satisfaction gained from the consciousness that he has eliminated elements which would contribute to irregularities in produce, but when unexpected problems arise he can more readily solve them, for the simple reason that he has narrowed down the causes to that due in infection or similar influences which he can to a greater extent mitigate, although not eradicate. It is not our intention to consider the question in its widest aspect, but to confine ourselves to a consideration of the last stages of brewing proper (as apart from fermentation) from the "turning out" or casting of the coppers to the final collection of the worts. In many breweries one is surprised still to find that the sparging or splashing of the hops is made to serve a double purpose, *i.e.*, washing out the extract absorbed by the hops, and breaking down the collecting gravity to approximately that required. We use the term "approxi-

mately " inasmuch as it is impossible to adjust a gravity to that degree of exactitude (which we will discuss later) by the use of splash liquor, the use of which should be limited to the one purpose for which it is employed. Water is necessary to replace the valuable wort present in spent hops, and when the volume of plain liquor is definitely known that affects this, it should remain a fixed rate calculated on a certain number of gallons per lb. of hops used and dependent on the area of the hop-rack. When this rate is decided upon, it should not be departed from, either in the direction of increase or decrease. Copper lengths and strengths can be arranged and the original figures checked by a subsequent calculation at turning out which will leave almost precisely a quantity of hop-splash to correspond with the fixed rate decided on. The volume of water lost by evaporation in the several brewing processes varies, of course, but each brewery provides its own constant. The term just named is not quite accurate inasmuch as evaporation depends on atmospheric conditions, but the percentage figure for loss on this heading is sufficiently correct to secure a rough adjustment of collecting gravities. The fine adjustment should never be carried out with sparge liquor withheld for this purpose. Excess of splash means the washing out of sludge which is rendered more impure if retained for the final breaking down of collecting gravities, as it follows that when copper wort deposit is allowed to remain behind until the temperature is considerably lowered it becomes dangerously unsterile and to add it to a fermenting vessel in this condition is an indefensible proceeding. A deficiency of splash, on the other hand, results in a loss of valuable extract.

The hop-splash should be added to prevent a loss of heat directly the hop-back is emptied and, after a stand of 15—20 minutes carried forward to the cooler wort, while the latter remains at a high and practically sterile temperature.

As we have explained, under normal atmospheric circumstances the fine adjustment of a finished brew is accomplished with a *small* volume of ordinary liquor, not necessarily previously boiled, if the water is of the usual staple brewing quality. But when speaking of a fine and final adjustment we mean to a definite prearranged standard. The gravities of such brand of beer should be purposely finely adjusted prior to declaration in the Excise brewing book in order to secure the utmost monetary advantage accruing from such procedure while complying with the regulations. The use of the original " brewers' lbs. per brl." saccharometer, is essential for the purpose of ascertaining an exactitude in wort gravity readings for Excise declarations. The ordinary specific gravity instrument does not lend itself to precise determinations, even if it were possible to obtain a range of indications divided into $\frac{1}{4}$ degrees. Glass saccharometers are infinitely to be preferred to those supplied in gilt metal. The readings in the former never vary whereas the gilt on the latter is constantly wearing—thus exhibiting incorrect indications. For present-day working in a number of breweries only two saccharometers are required: one showing from 0 to 10 " brs.' lbs.," the other from 10 " brs.' lbs." to 20 " brs.' lbs." By providing these instruments with stems ten inches long, each lb. of gravity is divided into tenths, and thus with clearer reading ready reckonings are facilitated and any difficulty in connection with allowing for capillary attraction is obviated.

These instruments should always be cleaned and dried the moment before they are immersed in the wort. The sample cans must be full to overflowing so that the true gravity may be recorded by placing the eye on a level with, and not above, the surface of the wort. The highest line that the wort reaches is that due to capillarity, and the line actually on the surface is the one that represents the correct measure of density, after, of course, allowance has been made for temperatures above or below 60° F. The question of temperatures has not received the attention it deserves, and unless the factor of expansion or contraction of the volume of liquids is taken into consideration when dealing with exactitude in entering gravities, it may depreciate the value of other precautions. For instance, light beers are invariably collected at 58° F., and when it is remembered that every $2\frac{1}{2}$° F. above or below the recognised standard of 60° F. represents the addition or subtraction of a tenth of a pound from the apparent gravity, it is surprising how few brewers "finishing off" at 58° or $57\frac{1}{2}$° F. deduct a tenth of a pound from their saccharometer indication, and it is the cumulative effect of omission to place any value on these and other seemingly petty details which results in a wort gravity being declared at a degree beyond that upon which duty should have been levied. Formerly the question of loss of revenue from minor sources of error was not attended with serious loss, but at the present rate of beer duty the monetary loss is a heavy penalty on inexactitude.

CHAPTER VI

CHEMISTRY AS APPLIED TO BREWING

ELEMENTS—COMPOUNDS—DALTON, AMPÈRE, AND AVOGADRO—ATOMS, MOLECULES—FORMULÆ (EMPIRIC AND STRUCTURAL)—EQUATIONS (WHAT THEY MEAN)—TABLE OF ELEMENTS—THEIR ATOMICITY—CALCULATION OF PERCENTAGE COMPOSITION FROM FORMULÆ AND VICE VERSÂ—CHOOSING BETWEEN TWO OR MORE POSSIBLE FORMULÆ—ATOMICITY, VALENCE OR QUANTIVALENCE—SATURATION; AUTO-SATURATION—GLYPTIC FORMULA—COMPOUND RADICALS—ISOMERISM—ACIDS, BASES, SALTS—OXIDES—HYDROXIDES (HYDRATES)—BASICITY—TERMINATIONS *-IC* AND *-OUS*; *-ATE* AND *-ITE*—PREFIXES *HYPO-* AND *PER-*. SULPHIDES—CHLORATES, CHLORIDES—ANHYDRIDES—HYDROCARBONS — ALCOHOLS — ALDEHYDES — CARBOHYDRATES—MALTOSE—CELLULOSE—ORGANIC ACIDS—ELEMENTS IN THE NASCENT STATE—ALBUMINOIDS IN BARLEY—AMIDES—PEPTONES—ASPARAGIN—ANALYSES (TYPICAL)—NITROGEN—KJELDHAL'S METHOD OF DETERMINING IT—IODINE REACTION WITH STARCH—VARIOUS QUALITATIVE TESTS—IODOFORM—THE POLARIMETER.

CHEMISTRY, as a science, has for a number of years been separated into two divisions, originating in an apparently fundamental difference now recognised as no longer absolutely existing. This supposed difference, which referred the origin of all the various groups in the second and, from the brewers' point of view, most important division to life-processes or the functions of organisms, was the cause of these divisions receiving respectively the names of inorganic and organic chemistry.

But it having been discovered within the last fifty or sixty years that several of the compounds included in the latter, or so-called organic division, can be produced in the laboratory without the intervention of any animal or vegetable life-functions whatever, it has become evident that the term organic is somewhat of a misnomer, and it is only its convenient conciseness which maintains it against the preferable title of the **Chemistry of the Carbon Compounds,** or (seeing that the carbonates fall within the realm of inorganic chemistry) the still more preferable one of the **Chemistry of the Hydrocarbons and their Derivatives.**

It is beyond the scope of this book, however, to attempt to treat these divisions separately; the most that can be done here is to enunciate a few general principles as introductory to the hints on laboratory work in the next chapter for those who are ignorant of chemistry, and to enable them to approach the consideration of those important carbon-compounds (compounds in which carbon always enters into more or less intricate combination), starch, dextrin, the malto-dextrins, cane-sugar, moist sugar, maltose, dextrose, the alcohols, etc., with a mind capable of appreciating the significance of chemical *formulæ*.

In our study of matter we are confronted with certain substances known as **elements**—over seventy in number, many of them being extremely rare. These elements are so called because they are incapable of being split up into simpler constituents by any known process; they constitute the simplest form of matter known to science.

The discovery of **Radium,** with its enormous output of energy (radio-activity), gives us pause, however, in considering the so-called elements as ultimate constituents of matter. The fact that it slowly disintegrates

into **Helium,** although its definite spectrum, as well as the character of its salts, generally allied with those of calcium, have caused it to be ranked as an element, raises a doubt whether a similar radio-activity, accompanied by disintegration, though infinitely less in degree, may not ultimately be discovered in the elements with lighter atoms (p. 131) as it has in uranium, thorium, and radium with heavy atoms. Therefore in spite of apparently stable compounds formed by " elements," the present view *may* be provisional only.

A Compound may be formed of two or three elements (**binary, ternary** compounds) as H_2O water, H_2SO_4 sulphuric acid. Complex substances may, however, consist of four, five, or more elements (*e.g.*, albumen, consisting of carbon, hydrogen, oxygen, nitrogen, sulphur, and possibly phosphorus). The brilliant hypotheses of Dalton, Ampère, and Avogadro * (though difficult of direct proof) having systematised all known facts, we are justified in taking it for granted that the elements combine in certain definite proportions, and always in the same proportion or in simple multiples of them, unless in the rare cases of an element having a double atomicity, of which more anon. They are assumed to consist of atoms (ἄτομος = indivisible), which may be defined accordingly as " the smallest quantities of elementary matter which can take part in a chemical reaction." Two or more atoms, whether of the same or of different elements, combine together to form a molecule (it is supposed, indeed, that the ultimate particles of most elements, at least in the gaseous state, consist of two or more similar atoms), and a molecule may therefore be defined as " the smallest quantity of elementary matter which can exist in a free state."

Molecular Weight (of O. and H.)—If two volumes of hydrogen and one volume of oxygen be brought together in a suitable apparatus, it can be shown that they can be combined to form two volumes of steam.

Now, on Avogadro's hypothesis, the two volumes of steam will contain the same number of molecules as the two volumes of hydrogen did before the combination ; consequently, if we conceive of volumes so small that they contain single molecules, evidently 2 molecules of H and 1 of O combine to form 2 molecules of steam, which implies that the single molecule of O is divided between the 2 molecules of water, whether gaseous or liquid. In other words, the molecule of O must consist of more than a single atom, and must be at least O_2. Possible O_4, O_6, etc., are not accepted, the O molecule not being found divided into more than two parts. Similarly, the H molecule is found to be H_2, from the fact that one volume hydrogen and one volume chlorine give two volumes hydrogen chloride ; that is to say, one volume H is divided between two volumes of the chloride. Consequently, the molecular weight of these elements is twice their atomic weight.

[Recent experimentshave shown the combining weight of O to be not more than 15·88 (instead of 16) if H be taken as unity. Convenience of getting more whole numbers as atomic values of other elements compensates for the slight error involved in still taking it as 16.]

Empiric and Structural (Constitutional) Formulæ.—An empiric formula —*e.g.*, that of NaCl for sodium chloride (common salt)—simply expresses

* Avogadro's hypothesis summarised is that equal volumes of all gases contain the same number of molecules under the same conditions of pressure and temperature.

the fact that sodium (Na for natrium) enters into combination with chlorine (Cl) atom for atom (*i.e.*, in the proportions of their atomic weights), and should conceivably be written Na_nCl_n, n standing for an unknown and possibly large number. The empiric formula of acetic acid is $C_2H_4O_2$, but its constitutional formula, C_2H_3, O, OH, whilst showing percentage composition, also shows that one atom of oxygen and one of hydrogen are so linked together as to be capable of undergoing substitution by some other atom (thus comporting themselves like a single atom) and again of recombining under suitable conditions. Very **complex molecules** are evidenced by the fact that varying substances, like starch, dextrin, and cellulose, have the same percentage composition, and consequently the same empirical formula, $C_6H_{10}O_5$, which is more correctly written $(C_6H_{10}O_5)n$, the n standing for a probably large multiple. Similarly, cane-sugar and maltose have the same percentage composition, expressible by $C_{12}H_{22}O_{11}$, or, more correctly, $(C_{12}H_{22}O_{11})n$. Fischer's constitutional formula for maltose (some are still more fearsome) is :

$$CH_2OH-CHOH-CH=(CHOH)_2-CH-O-CH_2=(CHOH)_1-CHO.$$
$$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad \diagdown O \diagup$$

An equation, which expresses in concise form the reaction to which it relates, is so called because the weights indicated by the combined symbols, if any, and formulæ, on the one side of the sign = exactly correspond with the weights indicated by the combined symbols and formulæ on the other ; and it may not be superfluous to say that as every element has its symbol, so that symbol represents a definite and constant relative weight of that element. Thus, to take a very simple form $H_2 + O = H_2O$ signifies not only that two atoms (or molecules) of hydrogen combine with one of oxygen to form water, but that exactly 2 lb. of hydrogen combine with 16 lb. of oxygen to form 18 lb. of water ; and the statement obviously stands, if for lb. we read grains or tons or anything between the two, so long as the same value is kept throughout.

The most important Elements, from our technical point of view, are those in the following list. The meaning of the fourth column will be explained in the next paragraph. Those marked (M) are metals. The others are non-metals or metalloids. Those marked (H) are halogens.

Name.	Symbol	Atomic Weight.	Atomicity, Valency, or Quantivalence.
Hydrogen	H	1	Monad, Monatomic, or Univalent.
Chlorine (H) ...	Cl	35·5	,,
Iodine (H)	I	127	,,
Potassium (M)	K	39	,,
Sodium (M) ...	Na	23	,,
Silver (M)	Ag.	108	,,
Oxygen	O	16	Diad, Diatomic, or Bivalent.
Sulphur	S	32	,,
Barium (M) ...	Ba	137	,,
Calcium (M) ...	Ca	40	,,
Magnesium (M)	Mg	24	,,
Copper (M)	Cu	63·5	,,
Nitrogen	N	14	Triad (sometimes Pentad).
Phosphorus ...	P	31	,, ,,
Carbon	C	12	Tetrad, Tetratomic, or Tetravalent.
Silicon	Si	28	,,
Iron (M)	Fe	56	Diad and Tetrad.

Atomicity, Valency, or Quantivalence, are synonyms expressing the varying capacity which an atom of each element has for fixing atoms of other elements. Thus the atom of certain elements such as hydrogen, potassium, sodium, chlorine, silver, etc., have only the capacity of fixing *one* atom of another element, and accordingly those elements are called **monatomic,** or **univalent,** or **monads.** An atom of the diatomic, bivalent, or diad elements, *e.g.*, oxygen, calcium, sulphur, etc., has the capacity of fixing *two* monad atoms or *one* diad. Similarly, each atom of a triatomic (trivalent or triad) element is able to fix three monad atoms or one diad and one monad. One atom of the tetrad carbon can fix four monad atoms or two diads ; a pentad atom can fix five monad atoms or two diad atoms and one monad atom, and so on. To denote atomicity the marks ′ (for monad), ″ (for diad), ‴ (for triad) are sometimes used ; thus Mg'' reminds us that magnesium is diad.

(Later paragraphs on saturation and auto-saturation continue this subject.)

Calculating percentage Composition from Formulæ.—Having now the atomic weights of several of the elements before us, it may be useful to give a rule for calculating the percentage composition of a substance (*i.e.*, the weight of each element in one hundred parts by weight of the compound, all expressed in the same terms) from its formula.

Rule.—The atomic weights of the elements forming the compound are to be added up and a series of rule-of-three sums (corresponding in number to the number of elements composing the compound), of which the first term is the sum of all the atoms ; the second term is always 100 ; the third term being the atomic weight of each element in turn.

Thus, taking acetic acid $C_2H_4O_2$, $C_2 = (12 \times 2) = 24$; $H_4 = (1 \times 4) = 4$; $O_2 = (16 \times 2) = 32$, which together $= 60$.

Then,

(1)	60	:	100	::	24	=	40
(2)	60	:	100	::	4	=	6·66
(3)	60	:	100	::	32	=	53·34

That is to say, the percentage composition is carbon 40, hydrogen 6·66, oxygen 53·34, which added together = 100.

Conversely, **to get the Formula from the percentage Composition** (ascertained, let us suppose, by analysis). We find out, for example, that a compound (and we will take acetic acid again) has the percentage composition of carbon 40 ; hydrogen 6·66 ; oxygen 53·34, and we get at the formula in two steps. First, the amount of each element ascertained must be divided by its atomic weight—thus

$$C = \frac{40}{12} = 3{\cdot}33$$

$$H = \frac{6{\cdot}66}{1} = 6{\cdot}66$$

$$O = \frac{53{\cdot}34}{16} = 3{\cdot}33$$

Next, these amounts are to be divided by the lowest amongst them (in this case 3·33) ; we accordingly get CH_2O, whereas the accepted formula

of acetic acid = $C_2H_4O_2$, which is equally in accordance with the percentage proportions of the elements; it might equally be $C_3H_6O_3$ and so on.

This brings us face to face with the important fact that percentage composition does not necessarily show the correct formula (though it does so in the majority of cases), which has to be decided generally by determining the molecular weight. The molecular weight equals the sum of the atomic weights, corresponding with twice the vapour density compared with that of hydrogen taken as unity.* Exact experiment has shown the vapour density or specific gravity of the vapour of acetic acid (compared with hydrogen = 1) to be 30·07, consequently the molecular weight = 60·14. But if CH_2O were to be taken as the formula of acetic acid, C = 12; H_2 = 2; 0 = 16 = 30 only. It is therefore evident that $C_2H_4O_2$ is the correct formula, the discrepancy of ·14 being due to almost inevitable experimental error.

The molecular weight of a substance, of which the percentage composition is known, may be either expressed M.W. =

$$\frac{100}{\text{lowest product of first step,}}$$

or some simple multiple of it—in the case of the acetic acid M.W. =

$$\frac{100\times 2}{3\cdot 33}$$ 60 (approximately).

The real molecular weight of acetic acid can also be arrived at by considering its only silver salt, **silver acetate,** in which one atom of hydrogen is replaced by one atom of silver. [Silver is *monad, vide* the table of the elements and paragraph succeeding it on Quantivalence.] Experiment shows that 100 parts of silver acetate contain 64·68 parts (nearly) by weight of silver. Then the atomic weight of silver being 108, and one atom of hydrogen being replaced by one atom of silver, either 30 parts acetic acid give 137 parts of silver acetate, or 60 parts acetic acid give 167 parts of the acetate. Let us now multiply the parts by weight (64·68) found in 100 parts of silver acetate by 1·67, and if we find, as we do, that the product corresponds with the atomic weight of silver (108), we conclude that 60 parts of acetic acid, by parting with one atom of hydrogen and taking in its stead one atom of silver, yield 167 parts of

* To avoid the necessity of referring to hydrogen explicitly and continuously as unity when in fact a litre of it weighs ·0896 gramme, the term "krith" is sometimes used in stating the specific weight of *gases*. [On the other hand, solids and liquids have their specific gravity stated as compared with water, 1 c.c. of water = 1 gramme; gold = 19·3; iron 7·8 grammes, etc.] A "krith," then, = ·0896 gramme, the weight of a litre of hydrogen weighed at 0° Centigrade and under a pressure of 760 millimetres of mercury (= 29·92178 inches). Accordingly the specific weight of hydrogen is said to be 1 krith; that of chlorine 35·5 kriths; that of oxygen 16 kriths; and so on. And assuming the number of molecules in one litre of any and every gas to be correctly computed at 6,106,000 *trillions*, the weight of each molecule of hydrogen would be ·0896 gramme ÷ that enormous divisor. Similarly the weight of each molecule of chlorine would be 3·1808 (= ·0896 × 35·5) divided by the same huge number.

We mention this to emphasise the hypothesis (Avogadro's) that under uniform conditions of pressure and temperature the number of molecules in every equal measure of every gas is equal. Not as sometimes stated, that the molecules of different gases are *necessarily* equal *in size*, only that each different molecule occupies an exactly equal space. For aught that is known, each molecule may move freely therein, like, for instance, a pea in a bladder.

silver acetate, or that the correct formula for the acid = $C_2H_4O_2$ and nothing less.

Or it may be put thus :—

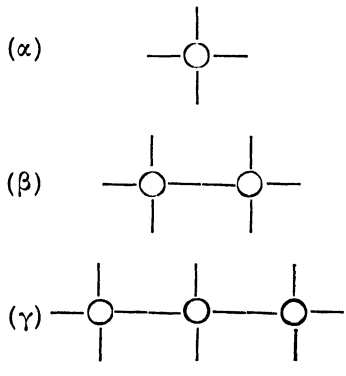
$$\frac{35{\cdot}32 \text{ (got by subtracting } 64{\cdot}68 \text{ from } 100) \times 108}{64{\cdot}68} = 58{\cdot}98$$

the weight of the carbon, hydrogen, and oxygen combined with one atom of silver. But in the acid, instead of the atom of silver, there is an atom of hydrogen ; adding the equivalent of this to 58·98 we get 59·98, which practically = 60, the error of ·02 being an experimental one which one can hardly expect to lessen unless by repeated trial.

We have dealt rather at length with this point, not only because questions bearing upon it are sometimes asked in examination papers, but chiefly because of its intrinsic importance, in view of the complexity of formula exhibited by several of the substances in which we are specially interested.

Saturation of Atoms.—Though an atom may form a compound in which its full power of fixing other atoms is not exercised, such a compound is more or less unstable, the tendency of every atom being to fully saturate itself, that is, to combine with *all* the atoms which it has the power of annexing. That this tendency towards complete saturation is not always very pronounced may be seen from the fact that nitrogen fixes only *three* monad atoms to form the, in one sense, stable compound, ammonia (NH_3), though it is pentatomic, *i.e.*, fixes *five* atoms in ammonium chloride (NH_4Cl). It has been suggested that the term *atomicity* should be reserved for the maximum capacity of saturation, while the capacity of inferior saturation (or combination) should be expressed by *Quanti-valence*. In this sense nitrogen would be *pentatomic* in the ammonium chloride, and *trivalent* in ammonia.

Auto-saturation or Auto-combination.—It is supposed that certain atoms, and we may especially signalise the tetravalent carbon atom, can combine with other atoms of the same element to form a compound-atom of greater atomicity than the original component atoms. Thus two carbon atoms, each of which is capable of fixing four atoms, combine together, each of them in the combination using up one of their valences, so that the combined carbon atom (or molecule) will now have the capacity of fixing *six* monad atoms. This is generally graphically expressed by a sketch (which, it is hardly necessary to say, is purely illustrative, and in no other way purports to represent what occurs), in which the tetravalent atom of carbon is represented with four arms, thus (as *a*) the coming together of two such atoms (as β) with six arms, and the coming together of three atoms (as γ) with eight arms, *i.e.*, forming a combination capable of fixing eight monad atoms. Similarly, four auto-combined carbon atoms will form a compound atom (molecule) capable of fixing ten monad atoms, and so on. The importance of this view lies in the



bearing it may have upon the great complexity of many of the carbon compounds.

Compound Radicals.—There are certain atomic groups (molecules) which appear to play the part of a single atom in regard to combination. They are known as radicals or compound radicals. Like the elements, these radicals have their special atomicity. Thus NO_3, the radical of nitric acid (HNO_3), is monad; SO_4, the radical of sulphuric acid (H_2SO_4), is diad; PO_4, the radical of phosphoric acid (H_3PO_4), is triad. Again, P_2O_7, the radical of a compound of some import in water analysis, pyrophosphate of magnesia ($Mg_2P_2O_7$), is tetrad and fixes two atoms of the diad magnesium.

Asymmetric Carbon Atoms.—It has been found that certain bodies, chemically identical, have opposite opticities (p. 167), and this, and indeed the possession of any "opticity," is attributed to the existence within the molecule of Asymmetric Carbon Atoms, *i.e.*, a carbon atom which is combined with four atoms, either of elements or radicals, but differing each from the other. Thus **tartaric acid,** obtained from the tartar deposit of wine fermentations, has a strong dextro-rotatory action, while **racemic acid,** identical in other properties and chemical composition, got from the tartar of certain districts, is optically inactive. This acid, however, consists of two varieties of tartaric acid, one with a dextro-rotatory, the other with an equally strong lævo-rotatory activity, and crystals obtained in separation of these by concentration of a solution, have facets of two types, the one not fitting on the other if superimposed, but differing as an object does from its reflection in a mirror. Herein is perhaps the clue to the opposite opticities. (*Cf.* text-books, *sub* "Stereo-Chemistry.")

Isomerism, Physical and Chemical.—Such bodies with varying opticities, but otherwise identical, are instances of *physical* isomerism. Chemical isomerism is of two kinds, (*a*) *metameric*, where the substances have the same percentage composition and the same molecular weights, and (*b*) *polymeric*, where the substances have the same percentage composition but different molecular weights, *e.g.*, acetic acid $C_2H_4O_2$, lactic acid $C_3H_6O_3$, and grape-sugar $C_6H_{12}O_6$. Starch, Dextrins, and Cellulose have the same percentage composition $C_6H_{10}O_5$, though plainly, as regards starch and the dextrins split off from it, different molecular weights. *Bacillus ethaceticus* can ferment mannite (mannitol), but not dulcite (dulcitol), though both have the formula $C_6H_8(OH)_6$. Harden has obtained the same selective result with *Bacillus coli communis*, and, writing the formula of glucose as $CH_2OH - (CHOH)_4 - CHO$ and that of mannitol as $CH_2OH - (CHOH)_4 - CH_2OH$, attributes a production of twice as much alcohol from mannitol as from glucose to the compound group $CH_2OH - CHOH$, contained twice in the former and only once in the latter. The action of the organism on glycerol $CH_2OH - CHOH - CH_2OH$ seems to confirm the view that this group is the source of the alcohol formed, the chief products therein being alcohol (C_2H_5OH) and formic acid (CH_2O_2). These are but hints, yet they may show how a multiplicity of possible combinations can account for total difference of qualities in isomeric bodies (isomers).

Acids, Bases, Salts, (Oxides *).—Acids may be either

1. Oxy-acids (oxygen acids) formed by the combination of certain

* **Oxides** are acid, alkaline, or neutral. (1) **The acid oxides** = the oxy-acids, are compounds of O and non-metals or metalloids. (2) **The alkaline oxides** = bases; compounds of O and metals. (3) **Neutral oxides,** which are either exceptions to (1), as water, which when pure is neither acid nor alkaline, or to (2), as oxides of the so-called heavy metals, insoluble in water.

non-metallic elements with oxygen, with addition of water (*e.g.*, sulphuric and phosphoric acids).

[But note that all elements, except fluorine, can combine with oxygen to form *oxides*.]

2. Hydracids = those in formation of which halogens unite with hydrogen, the compound then combining with water (*e.g.*, hydrochloric and hydrofluoric acids, etc.).

Bases are metallic oxides (basic oxides).

Salts are produced by the action of acids upon bases, resulting in a *loss of hydrogen*, which is replaced by an equivalent of a metal; *e.g.*, nitric acid (HNO_3) neutralised with soda yields sodium nitrate $NaNO_3$.

Or in other words, an **acid** is a substance containing hydrogen, which it readily exchanges for a metal when treated either with a metal or with a metallic compound called a base. **A base,** again, is a substance containing a metal, combined with oxygen and hydrogen. It readily exchanges its metal for hydrogen upon being treated with an acid. The products of the action of an acid on a base are, in the first instance, *water*, and next a neutral *salt*.

Familiar bases are caustic potash KOH, caustic soda NaOH, and caustic lime CaO_2H_2, called respectively potassium, sodium, and calcium **hydroxides** or **hydrates.**

Basicity is a term used to express the power that acids possess of parting with their hydrogen and replacing it with a metal. Thus they may be monobasic (hydrochloric, nitric), bibasic (carbonic, sulphuric), or tribasic (phosphoric).

Sometimes, however, a bivalent metal (or base containing such a metal forms a salt with an acid which contains but *one* atom of hydrogen in the molecule (*e.g.*, nitric acid), and it is then believed that one atom of the metal (copper, for example) acts upon the hydrogen atoms of two molecules of the acid thus :—

$$\left.\begin{matrix} Cu + HNO_3 \\ HNO_3 \end{matrix}\right\} = Cu \left\{\begin{matrix} NO_3 + H_2 \text{ or } Cu + 2\ HNO_3 = Cu\ (NO_3)_2 + H_2 \\ NO_3 \end{matrix}\right.$$

But as a rule, the metals combine to form the salts in obvious relation to their atomicity. (*E.g.*, $BaSO_4$, in which one atom of bivalent barium has displaced two atoms of hydrogen from sulphuric acid to form barium sulphate.)

Mineral (Inorganic) and Organic Acids.—Acids are styled mineral (sulphuric, nitric, hydrochloric, phosphoric, etc.); or organic (acetic, lactic, succinic, etc.)—namely, those with C, H, and O in more or less complex combination. Carbonic acid with hypothetical formula H_2CO_3 is represented only by its anhydride CO_2 (carbon dioxide). But its salts, the carbonates, are stable compounds (sodium carbonate, Na_2CO_3, sodium bicarbonate, $HNaCO_3$, and calcium carbonate, $CaCO_3$) containing the diad radical CO_3, in which, so to speak, four out of six arms only of the three diad O atoms have been grasped by the tetrad C atom, leaving two to hold one diad Ca or two monad Na atoms.

Names of Acids.—The usual terminations are *-ic* or *-ous*, which difference signifies that although the elements composing them are identical, yet that the proportion of oxygen is lower in the latter (*e.g.*, sulphuric acid H_2SO_4 and sulphurous acid H_2SO_3). Again the prefixes

hypo- (ὑπὸ = under), and *per-* (short for ὑπερ, very or more) are used in the names of certain acids to signify a proportion of oxygen less than that in the *-ous* acid when the former is prefixed, and greater than that of the *-ic* acid when the *per-* is prefixed. Thus hypobromous (HBrO) or hypochlorous (HClO) and perbromic ($HBrO_4$) and perchloric ($HClO_4$) acids are known.*

Sulphates, Sulphites, Nitrates, Nitrites.—Sulphates are the salts of sulphuric acid, sulphites of sulphurous acid. Similarly nitrates are the salts of nitric acid, nitrites of nitrous acid.

Sulphides are compounds of sulphur with a metallic element.

Chlorates are salts of chloric acid, but **chlorides** are compounds of chlorine, either with metals (metallic chlorides), with which it readily combines, with non-metals, *e.g.*, HCl, which with water forms hydrochloric acid, or with a radical, like ammonium, NH_4, with which it forms ammonium chloride. [When ammonia NH_3 in gas or solution is brought into contact with HCl, ammonium chloride having the composition of NH_4Cl is formed, and therefore, to compare it with metallic chlorides, it is assumed that NH_4 is a radical acting like a metal.]

Anhydrides are binary compounds containing oxygen, and are converted into acids on the addition of water,—*e.g.*, sulphurous anhydride $SO_2 + H_2O = H_2SO_3$ sulphurous acid. CO_2 carbonic acid gas, or carbon dioxide, is carbonic anhydride. So the term *anhydrous* = waterless) is used as an epithet of a salt freed from water.

Hydrocarbons.—The simplest compounds of carbon are those which contain only carbon and hydrogen—the hydrocarbons. All the other more complex carbon compounds (*i.e.*, all the organic acids, the sugars, starch, dextrin, the alcohols, etc.) may be considered as derivatives therefrom. And it may be useful, as an aid to remembering their formulæ, to note two peculiarities.

(1) The number of hydrogen atoms in a molecule is always an *even* number.

(2) The number of hydrogen atoms in a molecule is never greater than twice the number of carbon atoms + 2.

The hydrocarbons which contain this maximum of hydrogen are *complete* or *saturated* hydrocarbons, and may be represented by the general formula C_nH_{2n+2}.

Of these hydrocarbons there is a series increasing regularly by CH_2—viz., methane CH_4, ethane C_2H_6, propane C_3H_8, butane C_4H_{10}, pentane C_5H_{12}, and hexane C_6H_{14}. Space does not permit of any lengthy reference to these and their derivatives, but a linear arrangement of formulæ will show the relation between ethane, its alcohol (ethyl alcohol, which is the alcohol produced in fermentation), its aldehyde, and its acid (acetic), which is characteristic throughout.

C_2H_6	:	C_2H_6O.	:	C_2H_4O.	:	$C_2H_4O_2$.
Ethane.		Ethyl or ordinary alcohol.		Acetic aldehyde.		Acetic acid.

* But *per-*, *-ic*, and *-ous* are also used for certain compounds of iron, chromium and manganese. Thus the proto-salts of these metals are those in which the metal is diad; while in the per-salts two atoms together act as one hexad. The latter are sometimes called *Sesqui-compounds*. The proto-salts of iron are also called ferrous salts, the per-salts are ferric-salts; *e.g.*, ferrous sulphate, $FeSO_4$, and ferric sulphate. $Fe_2(SO_4)_3$ are respectively the protosulphate and the persulphate of iron.

Alcohols may be looked upon as hydrocarbons in which one atom of hydrogen has been replaced by hydroxyl (OH). Thus methyl alcohol (CH_3OH), ethyl alcohol (C_2H_5OH), propyl (normal) alcohol (C_3H_7OH), and amyl alcohol ($C_5H_{11}OH$) all have a molecule differing by one atom of oxygen from that of their corresponding hydrocarbon. Methyl alcohol is obtained in practice by the dry distillation of wood; ethyl is the desirable alcohol; propyl (a colourless liquid with pleasant odour, and amyl alcohol (a burning and extremely acrid-smelling liquid) are both contained, with sundry others, in "**fusel oil.**" The alcohols of fusel oil belong to the "higher alcohols." Amyl alcohol is probably always formed in alcoholic fermentation; it can be got from the last runnings of a still by shaking with hot milk of lime, drying over calcic chloride, and distilling at 132° C. There is evidence to show that amyl alcohol as well as furfurol (of which more on p. 139) are derived from the furfuroids of grain (Lat., *furfur* = bran), both having been got in separate fractions by Windisch from brewers' grains digested with sulphuric acid and distilled; while, on the other hand, fermentation of sugars alone gave no traces, whatever yeasts were used. More recent experiments (1905) lead F. Ehrlich to attribute the non-appearance of amyl alcohol in sugar fermentations to absence of amido acids, proteolytic products from nitrogenous matter. If one of them (leucine) was added to sugar fermentations, amyl alcohol was produced approximately equivalent in amount to the amido acid consumed. Ehrlich therefore connects the amyl alcohols (two modifications in fusel oil) with nitrogenous constituents; and it may be noted, in reference to Windisch's experiment with grains acidified with sulphuric acid, that leucine is produced by action of this acid on *albumen*, muscular tissue, etc., as well as by putrefaction of casein (decomposing cheese). Traces of amyl alcohol, found in sugar fermentations, Ehrlich explains as due probably to leucine, present as a "metabolic" product in the yeast.

Thausing says: "In the mashing process lactic acid acts upon the husk of the grain, and small quantities of xylose (derivative of xylan, a wood-encrusting gum) are formed, and out of this furfurol. Upon opening covered mash-tuns the smell of fusel is distinctly perceptible. The finished beer contains traces of furfurol.

Alcohol by Synthesis.—Although it is to the fermentation of carbohydrates, in the form of fermentable sugars, that we look as *the* source of alcohol, it is interesting, if not reassuring to the distilling interest, to know that the synthetic production of ethyl alcohol is a commercial possibility. It may be produced in two allied ways, in one from the now well-known gas* acetylene (C_2H_2), in the other from ethylene gas (C_2H_4). The initial step in the first process is to make the acetylene combine with two hydrogen equivalents; the resulting ethylene is then passed through strong sulphuric acid, thereby forming sulphovinic acid, which after large dilution and distillation yields alcohol. The sulphuric acid, remaining behind can be used for producing the nascent hydrogen, needed for the first reaction, and iron sulphate. It is said that the output of alcohol does not quite cover the cost of carbide.

But in the second process ethylene gas is produced direct from a special carbide to which the name of *Ethylogène* has been given, but more slowly and therefore more safely than is acetylene. The ethylene, first collected in a gasometer, is pumped thence into sulphuric acid until the latter is saturated, sulphovinic acid being produced as before. But the next step, that of dilution, must be effected slowly to

* Calcium carbide, CaC_2, which gives off acetylene rapidly when water is added, is prepared by heating a mixture of carbon and lime to a high temperature (about 3000° C.) in the electric furnace.

obviate excessive heating, otherwise ethers and, what is worse, acetic acid and perhaps some acetone (C_2H_6O) may be formed.

The reactions are:—

(1) $C_2H_4 + H_2SO_4 = C_2H_5HSO_4$ (sulphovinic acid).

(2) $C_2H_5HSO_4 + H_2O = C_2H_5OH + H_2SO_4$ (sulphuric acid).

The ethylogène is obtained by passing an undisclosed mixture of metallic oxides with carbon (powdered coke) through an electric furnace. The oxides can be used repeatedly and the waste in purifying the sulphuric acid is slight, so that the outlay is represented by fuel consumed in the furnace and for electricity. 440 lb. of coke, it is said, covers the cost of making 22 gallons of alcohol in actual practice on a large scale in Savoy.

Conversely, it may be worth noting, ethylene can be obtained from alcohol (spirit of wine) by gently heating the latter with sulphuric acid (15 c c. H_2SO_4 + 5 c.c. water cooled + 5 c.c. pure alcohol). Further, if to a cylinder one-third full of the gas so obtained, chlorine be added till the cylinder is nearly full and a light then applied, the chlorine will combine with the hydrogen, a dense black smoke be produced, and carbon will be deposited down the sides of the vessel.

But though synthetic alcohol may have a future before it for industrial purposes and as "silent spirit," it would seem that even impurities contribute to the appreciated character of some fermentation alcohols. Amyl Alcohol, under a ban as a fusel-oil constituent, is said to make the effects of alcohol more lasting, but other constituents—**furfurol** (furfurane aldehyde) and **furfurane alcohol**—have distinct effects of their own. Furfurane bodies contain the group C_4H_3O, called "furfur" by Baeyer. Furfurol, or furfurane aldehyde ($C_4H_3OC—O—H$), can be regarded as derived from simple or formic aldehyde, H—C—O—H, the first H having been replaced by the "furfur" C_4H_3O group. The alcohol of this series (furfurane alcohol, furfur alcohol), with the formula $C_4H_3O—CH_2—OH$, may be looked upon as methyl alcohol CH_3OH in which one of the hydrogens of the methyl (CH_3) has been replaced by the C_4H_3O group.

Sir T. Lauder Brunton, from whose interesting "Lectures on the Action of Drugs," given at St. Bartholomew's Hospital, we continue to quote, says, speaking of furfurane (the blend of composite bodies): "Furfurane seems to have the power of acting as an anæsthetic to a greater extent than alcohol has. It lessens the irritability of the sensory part of the nervous system to such an extent that it abolishes voluntary movement and the animal remains motionless, although the power to move is still present, the motor powers at first not appearing at all impaired. Now this very property would greatly enhance the value of an impure alcohol in the eyes of many people, especially of those who want to get rid of their misery, by the stupefaction it would cause.

"The furfurane alcohol has an action something like furfurane, but it is much more stimulating, and appears to cause in dogs that have taken it an amount of beatitude that seems almost indescribable. A dog, after receiving a dose of it, frisks about and seems almost unable to contain himself for joy, just in the same way as one sees a dog frisking about when he is going for a walk on Sunday morning after being confined all the week. After awhile, however, he begins to get uncertain in his legs, he falls down, rises again and frisks about, but he falls down oftener and oftener, and at last he cannot get up at all, and the poor creature seems to get a headache. He beats his head against the floor, and then he lies

quiet for awhile, and by and by gets up again all right. But the exhilaration that the dog has from this alcohol is throughout of a jolly, pleasant kind. The compound Furfur-aldehyde, or furfurol, has an entirely different action. The dog, after receiving a dose of it, seems to become almost like a rabid animal. He crouches in a corner instead of moving about, and bites at anything that is held near him. He seems, as Curci * describes it, to have a certain sullen mania. This is the sort of thing that in a man would lead to crime. The furfur-alcohol is not at all likely to lead to crime, but the furfur-aldehyde might very easily do so."

Furfurol is an oily liquid (*furfur : oleum*) with a smell, though less pleasant, resembling oil of cinnamon and bitter almond oil combined. It can be obtained by distilling bran mixed with an equal part of sulphuric acid and three parts of water. Three parts being distilled over, the distillate, neutralised with carbonate of soda and treated with common salt, is redistilled till half has gone over. In this is the furfurol, which, after purification by additions of dilute sulphuric acid and of small quantities of potassium bichromate at intervals, then drying over calcium chloride, is obtained by redistillation in an amount of about 3% of the bran taken.

We have dwelt at some length on the constituents of the composite fusel oil, not only because the distinct effects of the furfur bodies are intrinsically interesting, but because we believe that the innocuousness of lager beer in quantity, as compared with British top-fermentation beer, is due more to relative freedom from " higher alcohols " than to lower alcoholic strength. That, in fine, low fermentation heats, especially those of " Lager " with its special type of yeast, tend to a minimum, while high heats tend to a maximum of fusel oil. As regards the amyl alcohol at least, the experiments of Ehrlich, already cited, supply a possible reason in that high temperatures, continued over successive crops of yeast, favour that metabolism of which the amido-acid leucine † is a normal or pathological product.

An indictment by Bau ("Wochenschrift f. Braucrei,") of amyl alcohol and secondary octyl alcohol formed during fermentation as possible factors in defective head-retention may be mentioned here. Though their influence is not to be compared with the opposite influence of viscous and colloid matter, they reduce surface tension, Bau says, and that a single drop of either added to a beer with a good head will at once disperse the latter with effervescence. One would like to know how the drop was added by Bau ; if simply on the surface the action might be analogous to that of a fragment of cheese dropped in a foaming glass of stout.

Glycerine, $C_3H_5(OH)_3$, formed to some extent in fermentation, is an alcohol (propenyl alcohol), and there are alcohols of more complex structure, containing 4, 5, 6 or more carbon atoms in the molecule. Of those containing 6 atoms of carbon the hexacid or hexyl alcohols, mannite and dulcite, but with the formula $C_6H_8(OH)_6$, may be mentioned again, for more reasons than one. First, because of their close relation to real sugars, as shown by the fact that nascent hydrogen acting upon glucose or

* Prof. Curci, of Catania, an investigator of these phenomena.

† Leucine—$C_5H_{10}(NH_2)CO_2H$—is not necessarily a product of decay; it has been found in the vegetable world, notably in the white shoots of vetch ; perhaps it is connected with the " budding " of yeast.

upon invert sugar produces mannite, and again acting upon sugar of milk, or galactose, produces dulcite. Secondly, on account of the formation of mannite in the lactic fermentation of sugar, and of its probable importance in connection with mucous fermentation and "ropy" beer. Thirdly, because of the interesting fact (already mentioned) that a certain bacillus is able to "select" between the two. And lastly, because modern chemistry regards glucose and its isomers having the formula $C_6H_{12}O_6$ as aldehydes of these hexyl alcohols; an aldehyde (*alcohol dehydrogenatum*) being an alcohol which has lost hydrogen.

This view is based on the facts that glucose readily takes up oxygen (just as acetic aldehyde does), especially in alkaline media—*e.g.*, reducing copper oxide CuO to cuprous oxide, Cu_2O (in the test with Fehling's solution to be hereafter described), and also that nascent hydrogen converts it into mannite. Taking dextrose as the type of sugar, the simplest equation for ethyl alcohol is:

$$C_6H_{12}O_6 = 2(C_2H_6O) + 2\ CO_2.$$

Dextrose = alcohol and carbon dioxide.

Or,

$$C_{12}H_{22}O_{11} + H_2O = 2(C_6H_{12}O_6).$$

Cane sugar and water. Invert sugar.

$$C_6H_{12}O_6 = 2(C_2H_6O) + 2\ CO_2.$$

Invert sugar. Alcohol. Carbon dioxide.

But, as a matter of fact, these formulæ are only partially true, inasmuch as they do not account for other transformation products, of which the most important are glycerine and succinic acid. More elaborate equations are accordingly necessary to account for these, which will be more properly dealt with under the head of fermentation.

The **aldehydes** are, as has been hinted, to be regarded as alcohol from which hydrogen has been abstracted (*alcohol dehydrogenatum*), although acetic aldehyde—or, as it is sometimes called, ethyl aldehyde—is actually formed in the laboratory, and equally so in the brewer's products by an oxidising agency.

According to the above view the oxidation of alcohol into acetic acid takes place by two reactions, thus:

$$C_2H_6O + O = H_2O + C_2H_4O$$

Alcohol and oxygen = Water and aldehyde

$$C_2H_4O + O = C_2H_4O_2$$

Aldehyde and oxygen = Acetic acid.

Though it may occur perhaps sometimes according to the equation

$$C_2H_6O + O_2 = H_2O + C_2H_4O_2$$

Alcohol and oxygen = Water and acetic acid.

Aldehyde (acetic) is an unstable compound more volatile than alcohol, into which by recombination with H it can revert and readily, under oxidising influences, pass into acetic acid, so that the characteristic flavour it imparts is more or less transitory.*

* A case in point occurred. Some hogsheads of light ale had been bottled, but just before the bottling was completed a fairly good, or at all events a practised, judge, tasted the ale and pronounced it "pricked," and the corks were ordered to be drawn. This verdict was thought to be incorrect, and a few bottles were saved from being emptied.

Oxidation and Reduction are changes referred to in this book from time to time, the former implying that O is added to an element or compound, reduction referring to changes in which O is removed from compounds containing that element. Substances (like copper oxide) which readily give up O are called **oxidisers,** those which are capable of removing it (*e.g.*, hydrogen and carbon monoxide, CO) are **reducers** or **reducing agents.** Thus, if some copper turnings be heated to redness in a hard glass tube and a current of air drawn over them, the copper will be converted into black oxide of copper, CuO (*oxidation*) thus $2\,Cu + O_2 = 2\,CuO$. If now the copper oxide be reheated in a current of H, water vapour will be given off and metallic copper remain in the tube (*a reduction*). Thus $CuO + H_2 = Cu + H_2O$.

Curiously, when two powerful oxidisers interact, both are sometimes reduced. Thus, it is said, if ozone (O_3) be allowed to act on hydrogen peroxide (H_2O_2) or on barium dioxide (BaO_2) that the following reactions occur :

(1) $H_2O_2 + O_3 = H_2O + 2\,O_2$;
(2) $BaO_2 + O_3 = BaO + 2\,O_2$.

Chlorine again acts indirectly as an oxidiser in presence of moisture because of its readiness to combine with H and set free O from H_2O.

The Carbohydrates include all the non-nitrogenous bodies—viz., the starch, dextrins, malto-dextrins, sugars, cellulose, gum, and fat—which are collectively, and some in the highest degree, important to the brewing industry. They are composed of three elements (carbon, oxygen, and hydrogen), and the last two enter into the molecule in the atomic ratio in which they occur in water (2 : 1), whence the name " carbohydrates." They comprise tetroses with 4 carbon atoms to the molecule ($C_4H_8O_4$) ; pentoses ($C_5H_{10}O_5$) with 5 ; hexoses ($C_6H_{12}O_6$) with 6 carbon atoms ; heptoses with 7 ; octoses with 8 ; and nonoses with 9. Only the hexoses and nonoses are capable of undergoing alcoholic fermentation. These bodies are classed in modern chemistry as **Aldoses,** owing to a relation with aldehyde (CH_3 . COH), the latter group of which they contain. To indicate this the pentose formula may be written CH_2OH . 3(CHOH) . COH, and the hexose one CH_2OH . 4(CHOH) . COH, etc. It is to the **Hexoses** that starch, dextrin, cellulose, cane-sugar, maltose, and dextrose belong, because they all contain 6 carbon atoms, or multiples thereof, in the molecule. Next to these, though less important, the **Pentoses** claim mention. They are unfermentable bodies (sugars), *e.g.*, arabinose and xylose, derived from the pentosans of plants, which include gum-like substances—araban, xylan ($C_5H_{10}O_5$), and perhaps others of importance in head-retention. Xylan has been separated from " grains," and galactoxylan ($C_{11}H_{20}O_{10}$), originating perhaps from union of a hexose (galactose ?) and a pentose, with loss of one molecule of H_2O, was found by C. Lintner in Munich beer, where its *rôle* appeared to be that of increasing the permanent foam, although in its separated form, as a loose white powder, it is not really soluble in water, but swells up extra-

These were kept, with the result that the ale was perfectly sound, bright, and in fine condition several months later ; the deposit, which was small, consisting only of normal cells, chiefly of *Sacch. pastorianus*. It transpired that the hogsheads had been given far too much vent, so that oxidising influences were excessive. Probably the aldehyde so formed, which had procured the over-hasty condemnation, soon passed into acetic acid, which the ale, being sound enough, was able to carry.

ordinarily in it. The semi-solution is adhesive and has great viscosity, but is largely kept back in filters, whence the less-consistent foam of filtered beers. These gums are sometimes referred to as **Pectous bodies** (see footnote, p. 146).

The pentosans in barley have been estimated at 8—9%, in malt with its rootlets, on a calculation referred to 100 lb. of dry barley, at nearly 1% more; but calculations based, as usual, on the furfurol obtained by boiling any foodstuff with hydrochloric acid will come out too high, as oxycelluloses also yield furfurol.

Gums of Barley and Malt generally. Besides pentose gums, others to which a hexose formula has been given have been identified, *e.g.* α- and β-amylans ($n C_6H_{10}O_5$) by C. O'Sullivan, who found the former in rye, wheat, oats and barley. Oats and barley contained the larger quantity: in barley it was about 2%, but varied considerably. The β-amylan came to about 0·3%, but the combined totals might vary from 2 to 4%. A 1% solution of α-amylan flows readily, but a 2% one forms a jelly-like fluid, and it is to this gum that the bad drainage of distillers' mashes, consisting partly of oats or raw barley with a high percentage of it, is attributed. Digested with sulphuric acid it is converted directly into dextrose, and presumably some such conversion occurs in germination also. It is lævo-rotatory ($[\alpha]j = -24° \pm 2°$). β-amylan, with an opticity $[\alpha]j = -72°$, increasing on digestion with lime water to $[\alpha]j = -144°$, is supposed to remain in the malted grain.

Lindet, however, alleging that alcoholic precipitants do not destroy enzyme action, has adopted instead chilled water, with 20—25 grammes of added mercurous sulphate per litre, for extraction of the grain with the object of instantly suppressing enzyme action. The filtered extract is treated with barium oxide, neutralised refiltered, and then fractionally precipitated with alcohol, and by this means Lindet obtained two gums, of which he maintains that all gums found by other investigators are mixtures. These gums are a lævo-rotatory **Amylan** $[\alpha]_D = -137·7$, with no reducing action on Fehling, and a dextro-rotatory **Galactan**, with $[\alpha]_D = +78$, and a reducing power of 30—33. The relative proportions vary from 64—88 parts of galactan and 36—12 parts of amylan, the galactan approaching its maximum the more the malt has been forced. Its quantity is increased by germination, though both exist in raw barley.

Lindet thinks amylan to be identical with one of the modifications of O'Sullivan's β-amylan, but the reducing sugar with opticity $[\alpha]_D + 53$ to $+59$, though therein similar to dextrose, was proved to be a pentose (Günther and Tollens' method).

The hexoses (E. Fischer's real carbohydrates) have been subdivided according to the ratio of the carbon atoms of their molecule to 6. Thus dextrose, levulose, galactose, etc., with formula $C_6H_{12}O_6$, are **Monosaccharides**; maltose, lactose, and sucrose or cane-sugar are **Disaccharides**; raffinose, a constituent of barley, and a supposed embryo nutrient, with formula $C_{18}H_{30}O_{15}$, is a **Trisaccharide**; starch, cellulose, and inulin are **Polysaccharides.**

The following classification on different lines (solubility, etc.), condensed from C. O'Sullivan, with one alteration, explained at the end, may be compared :—

Class I.—Saccharans $n(C_6H_{10}O_5)$. Soluble in water, insoluble in alcohol, yielding $n(C_6H_{12}O_6)$ bodies by action of acids, without formation of intermediate bodies.

[**α and β Amylan, Dextran, Levulan, the Galactans, etc.**]

Class II.—Saccharens $n(C_6H_{10}O_5)$. Insoluble in water and in alcohol, yielding $n(C_{12}H_{22}O_{11})$-bodies—*e.g.*, maltose—by action of certain enzymes or certain acids, and finally $n(C_6H_{12}O_6$ bodies by action of acids.

[**Cellulose, Starch, Inulin, etc.**]

Class III.—Saccharins $n(C_6H_{10}O_5)$. Soluble in water, insoluble in alcohol. Converted by certain enzymes into $n(C_{12}H_{22}O_{11})$ bodies, and by acids first into those bodies, afterwards into $n(C_6H_{12}O_6)$ bodies.

[**Malto-dextrins, Dextrin(s), Glycogen, etc.**]

Class IV.—Saccharons (sugars, with sub-groups).

(α) *Saccharoses*, $n(C_{12}H_{22}O_{11})$. Soluble in water and in alcohol below absolute. Converted by acids, and, as to some, by enzymes into $n(C_6H_{12}O_6)$ bodies.

[**Sucrose (cane-sugar), Maltose, Lactose, etc.**]

(β) Glucoses, $n(C_6H_{32}O_6)$. Soluble in water and alcohol.

[**Dextrose, Levulose, Galactose, etc.**]

(γ) Aromatic compounds of no special interest here.

Class V.—Mucilages, Gums, Glucosides, etc.

The alteration made has been to use " Saccharons " for the name of Class IV., and " Saccharoses " for sub-group *a*, instead of the contrary. The writer, with all diffidence, suggests that it is a greater aid to memory, as well as more consistent.

A substance called **Dextran** (isomeric with dextrin), and known as " gum of fermentation," *gahrungsgummi*, so named by Scheibler, who proved its formation during the viscous fermentation of sugar-beet juice, is referred to, and its possible connection with ropiness, later on.

Formation of Carbohydrates, etc., in Plants.—We know that the carbon element, which forms the backbone of starch, is derived from carbon dioxide in the air, that it is absorbed by leaves, and that this CO_2 is broken up, the carbon being retained and the oxygen exhaled. This happens, it is supposed, under the influence of the corpuscles of chlorophyll (green coloration) and sunlight, because starch granules are observed to increase in size only when in contact with the chlorophyll protoplasm ; and further, if certain delicate plants be removed from light, the ready-formed starch granules disappear in a few days, although, if the plants be brought into the light again, they reappear in a few minutes sometimes in sunlight,and more slowly in diffused light. We may have enzyme action here (*cf.* amylase and coagulase, Chapter IX.). All the oxygen contained in the absorbed CO_2 is apparently returned to the atmosphere, but probably the reaction is more complicated than this implies, water undergoing decomposition too. The exact reaction is unknown, but it has been supposed that formaldehyde (CH_2O) may be first produced thus : $CO_2 + H_2O = CH_2O + O_2$, and that glucose might be produced from formaldehyde by condensation thus : $6\,CH_2O = C_6H_{12}O_6$, and starch again similarly from glucose. The young plant is relatively richer in nitrogen and ash constituents ; in other words, the root-conveyed supplies preponderate therein, but as maturity advances the carbon compounds increase with the spread of leaves. While carbon and silica continue increasing as long as the plant is in a green state, it is said that at the time of full bloom a cereal has acquired nearly all the nitrogen and potash found in the mature crop, the assimilation of phosphoric acid lasting somewhat later. But when seed formation begins, an impoverishment of other parts of the plant sets in, so that if the season be favourable to complete development of the seed, the straw of a cereal crop will be fairly exhausted at

harvest-time, whereas in seasons unfavourable to complete maturity the straw is found to contain more of the useful materials.

Starch has now been given the formula $100(C_{12}H_{20}O_{10})$ or $(80\,C_{12}H_{20}O_{10} - 40\,C_6H_{10}O_5)$, signifying that the molecule is made up of 80 *maltan* and 40 *dextran* groups, linked in ring form through oxygen atoms, and that the maltan portion of the chain is hydrolysed by successive changes forming dextrins and ultimately maltose. The weight of its very complex molecule has been fixed at 32,460 by means of Prof. Raoult's method of determining the molecular weight of non-gaseous bodies. This method is based on the fact that substances dissolved in certain solvents (*e.g.*, water, acetic acid, and benzene), with known freezing-points, lower this freezing-point to an extent proportional to the amount of substance taken and *inversely proportional* to the molecular weight of the substance. That is, if weights of substance be taken in proportion to their molecular weights, the varying quantities will all lower the freezing-point equally, with this reservation, that inorganic salts produce about twice the effect per molecule that carbon compounds, such as sugar, do. Taking, then, a carbohydrate simpler than starch, cane-sugar with a molecular weight of 342,* 3·42 grammes of it dissolved in sufficient water to make 100 grammes of solution, froze at 0·185° C. below zero, while one containing half that quantity froze at 0·092° C. below zero. Again, a solution of 1·34 grammes of malic acid ($C_4H_6O_5$), corresponding with its molecular weight 134, and made up with water so that the solution weighed 100 grammes, froze at 0·187° C. below zero, a number almost identical with that of the sugar, the minute variation being explicable perhaps by overlooked intermolecular penetration in the former case as treated of on pp. 237, 238. The greater lowering effect exerted by inorganic salts, especially such as are electrolytes, is attributed to their being, when dissolved, in a state of ionic dissociation (*cf.* pp. 152, 214).

The starch granules consist of *granulose*, enclosed in an envelope of amylo-cellulose, of which two kinds, one soluble in boiling water, the other only in caustic potash with heat, have been differentiated by Brown and Heron. The latter kind on solution gives the blue starch coloration with iodine, the other is only coloured yellow by it in accordance with Naegeli's dictum about amylo-cellulose generally. The starch granules lie closely packed side by side with small granules of proteid matter within a network of thin-walled cells throughout the endosperm. The problem how the granulose is rendered accessible to diastatic influence in malted grain when suitable conditions for the activity occur, is explained alternatively on the one hand by the cytase theory of total solution of the accessible intervening cell-walls, and by a partial solution sufficient for the purpose on the other. The cytase theory, and the objections of Gruss, are set forth on p. 56.

In the development of the starch granule it is now supposed that the cellulosic envelope is first formed, and that the granulose is deposited on the interior in successive layers, the centre of the granule being filled last of all. This is inferred from the fact that, when starch is acted upon by malt extract, minute channels can be observed extending to the centre of the granule, which is *the first part attacked.* It is stated that the case is otherwise with the so-called "transitory starch," formed from sugars at

* $C_{12}H_{22}O_{11} = 144 + 22 + 176 = 342$.

the beginning of germination, and that this is attacked from the outside. Dr. A. Fernbach, noticing the fact that in crystallisation generally the earliest-formed crystals are always the purest, in connection with noteworthy differences in the amount of phosphoric acid found by him in the large and small granules of potato starch, the "nucleus" of the latter especially being comparatively rich in the acid, while the other and presumably earlier deposited layers were free from it, considers that absence of any sort of homogeneity in the contents of the starch granule is indicated. The discovery by him and Wolff of amylo-coagulase (see Ch. IX.), an enzyme capable of throwing down a flocculent deposit of starch from a solution, or even of transforming it into a coagulum, though not perhaps exactly reproducing nature's processes, nevertheless indicates, he thinks, a probability that the successively formed starch layers are a consequence of successive coagulations; and connected with this is a theory of the course of starch transformation in the mash-tun, advanced by Duclaux.

Having in view the fact that nearly all the maltose obtained is produced in relatively short time (20 or 30 minutes from start), its after-production being very slow, Duclaux considers that the first phase is coincident with the attack on the *least resistant* part of the swollen granules, and the slow phase with that on the more highly coagulated parts which gelatinisation does not bring into the same physical condition. This idea of a different physical "texture" (which is, of course, a very different thing from the successive hydrolysation of parts of a complex starch molecule referred to above, and at greater length on p. 237) finds support in an important observation by Musculus that the blue coloration given by starch with iodine in concentrated solution becomes a red one when the solution is sufficiently dilute, an observation which must considerably modify the views generally held (as stated on p. 164) about the reactions of starch and dextrin with iodine.

Artificial Starch.—Dr. E. Roux, having succeeded in getting, by incomplete hydrolysis of amylo-cellulose, "artificial starch granules," with structures seen under the microscope to be similar to those of natural starches, and giving a blue coloration with iodine, but not *gelatinising with hot water*, imagines, in conjunction with Prof. Maquenne, that natural starch consists of two proximate constituents, 80% of one similar to his "artificial" product (unhappily named amylocellulose), and 20% of amylopectin,* to which the gelatinising power of starch paste is attributed. In that view "artificial starch" differs from the natural only in the absence of amylopectin. Further, Dr. Roux considers the so-called "stable dextrin" (see pp. 1, 2, 238) to be a conversion product of amylopectin, which, he says, if acted upon by malt extract at 176° F., is converted into dextrins. Apparently these views are not accepted by Fernbach and Wolff.

The conversion products of starch—dextrin, malto-dextrin, and maltose—are treated with some fullness on pp. 315—329, under Mashing operations.

* Pectin (pectous bodies), a term generally applied to a substance contained in the juice of some fruits (apples, pears, black currants), and in some roots, *e.g.*, beets. When the juice is boiled, albumen separating in flakes, addition of alcohol and hydrochloric acid, even alcohol alone to currant juice, gives rise to a gelatinous precipitate of a pectin body to which formulæ of $C_{16}H_{24}O_{12}$ and $C_{28}H_{42}O_{24}$ have been variously given. Müntz found 0·9% pectates in barley.

with the more convenience in that the quantities of these bodies, and the composition of the first two of them, vary with the methods adopted. But a mode of differentiating various sugars by means of crystalline bodies they can be made to form (osazones), mentioned on p. 102 (footnote), may be amplified.

Osazones.—If phenylhydrazine ($C_6H_5 . HN . NH_2$) be added to a dilute solution of glucose acidified with acetic acid and then warmed to 212° F. for three-quarters of an hour, **Glucosazone** ($C_{18}H_{22}N_4O_4$) crystallises out in yellow needles. The reaction is

$$2(\underset{\text{Phenylhydrazine.}}{C_6H_5 . HN . NH_2}) + \underset{\text{Glucose.}}{C_6H_{12}O_6} = \underset{\text{Glucosazone.}}{C_{18}H_{22}N_4O_4} + 2\,H_2O + H_2.$$

Glucosazone melts at 200°—202° C., while crystals of glucose melt at 86° C. **Fructosazone,** with similar formula and crystallising in yellow needles, melts at 205° C., fructose crystals at 95° C. **Galactosazone** melts at 193° C., while galactose crystals melt at 120° C. Saccharose (cane-sugar) crystals melt at 160° C., but this sugar forms no osazone. **Maltosazone** ($C_{24}H_{30}N_4O_9$) melts at 195°—200° C. **Isomaltosazone** is the name given to an osazone separated by Fischer from glucose, and by C. J. Lintner from beer wort, and from which the much-disputed existence of **Isomaltose** in beer wort has been inferred by some. Lintner's osazone is much more soluble in hot water than maltosazone, and melts at a much lower temperature, namely 150°—153° C. This fact, on the analogy of metallic alloys fusible at points very much lower than those of any of their constituents, and which are lowered still more as the number of those constituents is increased, points to isomaltosazone being an impure osazone, and to "isomaltose" being a mixture. It is prepared by Lintner as follows :—

Five kilogrammes of potato starch and 2 kilogrammes of finely crushed pale-dried malt are kneaded into a thick paste with water, and this is introduced into 17 litres of water at 72° C. (= 152⅖ F.), which temperature is maintained for 4 hours with constant stirring. Then the mash is boiled to destroy diastase, cooled to 30° C. (86° F.), and "set" with 80 grammes of pressed yeast. In two days fermentation is ended, and all the maltose fermented away, as can be proved, so it is said, by an osazone test. The solution is now filtered, the filtrate concentrated and treated with animal charcoal, and again steamed into a thin syrup. After repeated dialysing, fractionation, precipitation, and decolorisation with animal charcoal, about 500 grammes of syrup is obtained, from which by repeated precipitation with absolute alcohol a substance alleged to be pure dextrin-free "isomaltose" is separated in solid form.

The latest researches by Gruters (1904), confirmed by Ost, tend to show that Lintner's isomaltose, prepared as above, is a mixture of maltose and a newly identified malto-dextrin, named by Gruters malto-dextrin-γ. The rotatory power of this malto-dextrin is given as $[\alpha]_D = 160$ and its cupric reducing power *R = 60 (*i.e.* ⅗ that of maltose). Mixtures of it with 20% maltose gave an osazone precisely similar to that of "isomaltose."

Sugars : α, β, γ Modifications (α and β Glucosides).—These variations are rather outside the purview of the operative brewer, but we may just note that glucosides are bodies occurring in nature, which, when treated

* R expresses opticity in terms of maltose ; K in terms of glucose.

with dilute acids, or certain enzymes, break up, yielding dextrose as one of the products. We may cite amygdalin, found in bitter almonds and other kernels, which, when acted on by an enzyme, emulsin, from the same kernels, splits into benzoic aldehyde, prussic acid, and two molecules of dextrose—thus :

$$C_{20}H_{27}NO_{11} + 2\ H_2O = C_6H_5 . CHO + CNH + 2\ C_6H_{12}O_6 ;$$

but when acted on by maltose (from yeast), yields *one* molecule of dextrose and a new glucoside, to which the pleasing name of mandelnitrilglucoside has been given. No prussic acid appears, but if the " artificial " mandelnitrilglucoside be acted upon by emulsin, then prussic acid, benzaldehyde, and dextrose (1 mol.) are formed. Maltose is regarded as an α-glucoside : α and β maltose are isomerides, so are α and β dextrose, but differing in opticity, the α modifications having a higher rotatory power than the β modifications, but with a tendency to approach one another which is much accelerated by addition of an alkali. For instance, Brown and Morris found that the rotatory power of maltose, produced by action of diastase on starch paste in the cold, rose on addition of an alkali, showing that the maltose produced was in β-form : conversely, when maltose is hydrolysed with maltase (an enzyme in yeast), glucose is formed, whose rotatory power diminishes on addition of ammonia ; in other words it is α-glucose.

Unfermentable Sugars—*i.e.*, unfermentable in the limited, or in the brewers' sense of the term. Though, for instance, the milk sugars are obdurate to ordinary yeasts, it was found by Bourquelet in 1888 that galactose, unfermentable in itself by high or low yeasts, becomes so upon being mixed with dextrose or levulose. On the other hand, E. Fischer failed in inducing yeast to attack *l*-mannose, when mixed with dextrose even in the smallest quantity, gradually, and with the greatest caution, though the isomeric *d*-mannose had proved fermentable. This fact is held to support Fischer's " lock and key " illustration of enzyme action, based on the view that stereometric variations, not affecting general character, number of atoms, or percentage composition, interpose obstacles which in rigidity may be compared with the wards of a lock. It would appear that in practice certain **unfermentable by-products** are formed when cane-sugar is inverted by acid, and that these impart to the beer in which such invert is used some permanent fullness, which yeast-inverted cane-sugar does not confer.

Glycogen, a carbohydrate with composition $C_6H_{10}O_5$, though appearing as a varying constituent of yeast, in which, according to Laurent, the amount may reach 32·6% of the dry substance, may be considered here with its kindred bodies. It is given a molecular weight (by freezing-point determination) corresponding with 9,500—10,000, and appears to be a reserve material, whether in the liver where it was first identified and where it is converted into maltose and glucose as required, or in yeast. It is coloured reddish brown by iodine in *very dilute* solution. According to Henneberg, cells containing glycogen and cells without any will be found in the same culture ; the amount during fermentation depends on the quantity of sugar in the liquid : it disappears when the liquid is much impoverished, but reappears when more sugar, cane, glucose, or fructose, is added. Although galactose, with the same percentage formula, $C_6H_{12}O_6$, as glucose, is ineffective in this way, being non-fermentable as

stated above, it is said that glycogen can be formed from lactates and succinates, in which $(C_3H_6O_3)_2$ and $C_4H_6O_4$ are respectively combined with a metal, and even from asparagine $C_2H_3(NH_2)\begin{cases}CO\,.\,NH_2\\CO\,.\,OH\end{cases}$.

Cellulose $(C_6H_{10}O_5)n$ is the substance of most vegetable tissues. It is found perhaps at its hardest in the datestone, at its softest in the delicate membrane of the yeast-cell. It forms the woody fibre of trees (ligno-cellulose), the husk of barley, the framework of the grain's interior, the fibres of cotton, etc. The latter are nearly pure cellulose ; the barley husk, pure cellulose when first formed, is gradually encrusted with foreign matters as the seed approaches maturity. Flax fibre belongs to the pecto-celluloses, a division of the compound celluloses with non-cellulose *pectic* constituents, and with less C and more O.

In analysis of cereals cellulose is ordinarily under-estimated if taken as the "fibre," which remains after boiling with dilute acid and alkali, a treatment likely to convert much of it (say 50—60%) into glucose. **Schweitzer's reagent** (cupric hydrate dissolved in strong ammonia and free from impurities) is the recognised test. It first gelatinises and then dissolves fibre placed in contact with it. Sundry precipitants—*e.g.*, salts of alkali metals—throw down a gelatinous blue compound of copper oxide and cellulose, washing with weak ammonia or dilute acid being adopted to resolve the combination. On dilution of the viscous solution precipitation of the cellulose begins, but requires several days for completion. A more recent method, based on a discovery that cellulose is *not* attacked by caustic potash of 50% strength, has been devised for foodstuffs by Simon and Lorisch, and has the advantage of being speedier. Its features are digestion of a definite weight (*e.g.*, 10 c.c.) of substance, dried at 100° C., with 50% caustic potash for one hour on a boiling water bath, treatment with 3—4 c.c. of hydrogen peroxide which effects precipitation of pectins and lignin, and also decolorisation ; heating for another 15—30 minutes and treatment of the alkaline solution, when cold, with half its bulk of 96% alcohol and 6—7 c.c. of concentrated acetic acid (this to ensure uniform mixture). The precipitate of previously dissolved, cellulose, filtered off by aspiration, is then washed with water and dilute acid to remove phosphates, treated with alcohol and ether, and finally dried and weighed. To facilitate filtration, substances containing starch should be previously acted upon by diastase.

Organic Acids.—The most obviously important of these to the brewer are acetic acid $(C_2H_4O_2)$, lactic $C_3H_6O_3$ [$= CH_3.CH(OH)COOH$], butyric $C_4H_8O_2$ [$= C_3H_7.COOH$], and succinic $C_4H_6O_4$ [$= C_2H_4(COOH)_2$]. Oxalic acid $C_2H_2O_4$ is evidenced as sometimes present in fermenting wort by 8-angled crystals of oxalate of lime occasionally observed in the microscopy of yeast. Lactic acid, and still more butyric acid, are acids looked upon as undesirable constituents of a fermented beer, with the qualification that a limited amount of the former, normally present in the soundest wort, is essential for giving piquancy to the finished beverage, for stimulating peptase action in the mash-tun, and in the copper for checking precipitation by heat or by hop-tannin of the peptones formed. Otherwise, as the products of specific disease ferments, *Bacterium butyricum* (*Bacillus amylobacter*) forming butyric acid, and *Pediococcus acidi lactici*, with the more frequent *Bacterium lactis*, forming

lactic acid, and perhaps *Bacillus subtilis*, sharing in the production of both acids, they are distinct marks of unsoundness. The reactions, taking sucrose as a starting-point, would be:

$$(1)\ \underset{\text{(Cane-sugar)}}{C_{12}H_{22}O_{11}} + H_2O = \underset{\text{(Dextrose and Levulose).}}{2(C_6H_{12}O_6)}.$$

$$(2)\ C_6H_{12}O_6 = 2(C_3H_6O_3).$$

$$(3)\ \underset{\text{(Lactic acid.)}}{2(C_3H_1O_3)} = \underset{\text{(Butyric acid.)}}{C_4H_8O_2} + 2\,CO_2 + 4\,H.$$

It is possible that lactic acid may assume a more important *rôle* in fermentation phenomena, experiments by Buchner and Meisenheimer (1904) with pressed yeast juice leading them to conclude that lactic acid is formed as *an intermediate product* between the splitting up of sugar (the glucose into which maltose is first hydrolysed by maltase) and its conversion into alcohol and carbon dioxide; that two enzymes are concerned in the reaction, one (*zymase*) splitting up the sugar into lactic acid, the other (*lactacidase*) converting the acid into alcohol and CO_2. This view, they say, has escaped notice before, because when the enzymes are constantly replenished (as with living yeast-cells) the acid is consumed almost simultaneously, and the *final products* only are apparent; but the investigators have found that if yeast juice, with which no such renewal is possible, and lactic acid are mixed with sugar the amount of acid is largely increased in four days, whereas in absence of sugar the acid disappears. Juice of low fermentative power, it is said, shows diminished production of the original lactic acid, while a powerful yeast juice stimulates it (*cf.* Ch. IX., "zymase" action).

Such lactic acid, as generally with that produced in fermentation, is optically inactive; but another modification is known, active lactic or paralactic acid (derived from juices of flesh), which turns the plane of polarisation to the right, though its salts are *lævo-rotatory*.

Butyric acid is classed among the fatty acids, and combines the sour flavour of acetic with that of rancid butter. Two modifications are known.

Succinic Acid $C_4H_6O_4$ (or COOH . CH_2 . CH_2. COOH) is formed in the alcoholic fermentation of wort (*v.* pp. 268—298), in other fermentations—notably in a bacterial one of tartaric acid—and is in many ways chemically important. An interesting fact is that it is found in *unripe* grapes, but is replaced by tartaric acid, otherwise dioxysuccinic acid COOH . CHOH . CHOH . COOH; in *ripe* ones, pointing to the probability that, like the amido-body, asparagine COOH . $CH(NH_2)$. CH_2 . $CO(NH_2)$, to which it is closely akin, it is a transition product of immaturity. In beer it and lactic are two of the normal acids, which remain in the residue, when a measured quantity of liquid is being distilled for analysis, and are therefore called "fixed acids," both being calculated as lactic, while the acetic, which goes over, is classed as volatile acid.

Succinic acid is *bibasic*, seeing that it contains two CO . OH ("carboxyl") * atoms, the H of which can be each replaced by an atom of a univalent base, or together by one of a bivalent base, though in certain compounds (acid salts) the H of only one COOH atom may be replaced.

* CO.OH is the carboxyl group, CO is carbonyl, OH hydroxyl.

It will be noticed in the formulæ given in this paragraph that the difference between it and tartaric acid appears in replacement of H of the two methylene or methene radicles (CH_2) by hydroxyl (OH), and between it and asparagine in replacement of the H of one methene atom and OH of a COOH atom by the so-called " amidogen " (NH_2).

Esters (Compound Ethers or Ethereal Salts).—These are formed by interaction of an acid and alcohol, the alcohol radical replacing, wholly or partially, the H of the acid. They include many fragrant bodies—*e.g.*, amylic acetate and ethyl butyrate, used respectively as " pear flavour " and " pineapple essence," some contributing to the bouquet of wines. In beers, especially the old vatted types, the most likely to occur is ethyl acetate :

$$\underset{\text{(Acetic acid.)}}{CH_3 . COOH} + \underset{\text{(Alcohol.)}}{C_2H_5(OH)} = \underset{\text{(Ethyl acetate.)}}{CH_3 . COO(C_2H_5)} + \underset{\text{(Water.)}}{H_2O}.$$

P. Lindner, pursuing an observation, made some years ago, that green malt, kept in a partially filled vessel in presence of air, developed a strong odour of fruit, due to fruit ethers (compound ethers), has recently found a yeast, the cells of which resemble *Sacch. anomalus*, growing voluminously on green malt kept in similar conditions, or on soaked barley placed in tubes 50 cm. × 3 cm. for four to six weeks and freely supplied with air ; yeast which, when sown in wort, produces these ethers in abundance. *Sacch. anomalus* is, he says, easily distinguished from other yeasts by formation of " hat-shaped spores." Rather remarkably the wort, fermented by the ether-producing yeasts, appeared to be protected from bacterial attack, and in the culture process itself, if the grain in the tube is very damp, the yeast develops slowly and the normal smell of butyric acid is suppressed. Other yeasts—and notably *Sacch. apiculatus*—develop an intense ethereal odour in a well-aerated wort, but none in a non-aerated one. " Saaz " yeast (feebly attenuative) was found to produce ethers in considerable quantity, and it may be mentioned that a fragrant ethereal smell may be noticed pervading lager store cellars and emanating from the store casks which have been emptied but not removed. Experiments by Terroine with commercially dry sugars and normal pressed yeast (no dilution) may be just touched on, though the conditions were not such as come into brewery practice. When 66 grammes of saccharose or dextrose were added to 100 grammes of pressed yeast giving a sugar concentration of about 48%, a brisk fermentation, with a strong odour of fruity ether, ensued ; when the sugar was increased to 100 grammes dextrose fermented, but not saccharose, though on dilution fermentation followed with the latter too. It appeared to the investigator that ether production kept pace with alcoholic fermentation, and therefore he attributes the former to zymase action. No ethers were obtained in concentrations below 10% to 20%.

Elements in their nascent state.—In earlier editions of this book it was suggested that hydrogen set free (with carbon) in the formation of asparagine from more complex proteids during the germination of green malt might, in conjunction with free oxygen or oxygen wrested from water, hydrolyse the sucrose of grain into lactic acid ; and also, seeing that elements at the moment of their liberation, *i.e.*, nascent, have more active properties than in a normally free state, the possibility was indicated of

the development of sulphuretted hydrogen H_2S,* producing the so-called " stench " in certain stock beers being connected with butyric fermentation. Its equation shows that hydrogen is set free ; what then is more likely than that in its nascent state it wrests sulphur from one or more of the sulphur compounds present, whether sulphates of the brewing water, bisulphite of lime, sulphurous acid due to hopping, or the sulphur of the albuminoids ? It must not be overlooked, however, that Frew isolated a yeast (*Sacch. fœtidus*) from Burton beer, pure cultures of which, sown in untainted beer (clean " lager," for instance), caused the " stench " to develop therein.

Ionic Dissociation ; Electrons (Corpuscles).—The vigour of nascent elements may be connected with ionisation, that is, on their molecules being represented by **ions** = " things that go " (Faraday). When a solution of a salt (or fused salt), which is an electrolyte, is submitted to the electric current passing between two platinum plates, or carbon and iron plates for chlorine compounds, one the **anode** (positive electrode) connected with the H.P. (high potential or + terminal, the binding screw on the *copper* plate of the battery), the other the **kathode,** or negative electrode connected with the L.P. or — terminal (the binding screw on the *zinc* plate of the battery), evident dissociation occurs. Of the elements composing such salts, the ions of the metals and of hydrogen being, as supposed, positively charged, travel " down the grade " to the kathode, and are called **kations,** while the ions of the acid radical (sulphion SO_4, nitrion NO_3, or chlorine Cl) travel towards the anode, and are called **anions.** SO_4, however, does not appear, as such, at the anode ; it reacts with water and forms sulphuric acid (H_2SO_4), setting oxygen free, and it is this gas which appears at the anode. This is what happens in the so-called electrolysis of water, the sulphuric acid with which it is acidified being the real electrolyte, and undergoing alternate dissociation and recombination, in the first of which its own H is set free, in the second H is taken from the water, the O of which is liberated. Modern chemistry supposes that when salts are dissolved their constituents are more or less completely dissociated into ions, temperature and ample dilution aiding (for NaCl complete ionisation only in dilutions of at least ·000585, or its molecular weight in grammes—58·5—in 10,000 litres), and that these ions are respectively charged positively or negatively, and that the current in electrolysis simply urges them to the opposite electrode. The assumed ' charges " are held to explain marked difference between the ions and elements in a free state ; for instance, sodium (Na) could not exist for more than a moment in the free state. Thus the products of NaCl, when electrolysed, are not Na and Cl, but H at the kathode and Cl at the anode, the separated Na ions at once forming sodium hydroxide (NaOH) and liberating H from the water (electrolytic process of soda-making from brine). It was, however, when electrolysing the fused hydroxides that Sir H. Davy first saw the metals sodium and potassium before they burst into flame instantaneously at the kathode. The ionic theory explains

* However, a specific organism, *Beggiatoa* (the *B. alba* and other sub-varieties), busies itself with decomposing sulphur compounds in water (mostly in hot sulphur springs), setting sulphuretted hydrogen free. In whatever way it proceeds, whether by abstracting oxygen and setting hydrogen free to combine as indicated, or otherwise, such water enclosed in a flask with *Beggiatoa* soon develops H_2S.

why potassium chlorate does not, like the chlorides, give the chlorine reaction with silver nitrate (precipitate of silver chloride), its ions being K and ClO_3; and further, why inorganic salts lower the freezing-point so much more in proportion than sugar does (*cf.* p. 145)—namely, because carbon seems incapable of passing into the ionic state, many of its compounds being non-electrolytes. When its compound, acetic acid, is electrolysed, part only of the H goes to the kathode, while the carbon, taking some H, goes with O to the anode, probably as a passenger *with luggage*.

Interesting circumstantial evidence of dissociation of NaCl is found in the presence of hydrochloric acid in some yeast cells, while sodium chloride, though always present in beer wort in more or less moderate quantity, is detected in none. Now the decomposition of so stable a substance as NaCl by action of any weak acid is not conceivable, but if dissociation does occur in dilute solution, then the passage of Cl ions by **osmosis** through the membranes of the yeast cells is intelligible, without any assumption that it is "vital energy" which makes the salt unstable and more readily decomposable. The formation of the acid, given the chlorine, explains itself.

From some recondite researches on "adsorption," etc.,* we may note that Biltz and two others found that the organic colloids (dextrin and albuminoids) in beer, which are in a state of pseudo-solution, are positively charged with reference to the liquid with which they are surrounded, so that if a current of 113 volts and 0·04 ampere is passed through beer, the colloids migrate to the kathode, in the form of a thick flocculent mass, carrying with them most of the colouring matters, the latter being conveyed by the surface influence of "adsorption." The foam near the kathode is yellow, glutinous, and very permanent; that near the anode white and easily dissipated. Further, they found that if two carbon electrodes were put into a glass of beer and the current passed for about 10 seconds, a fine, copious, and compact head was produced, which lasted for 48 hours.

An important recent discovery in physics is that of **electrons**, better named "**corpuscles**," the term "electron" having been appropriated to signify the charge of electricity carried by an atom to hydrogen. If a sufficient current of electricity be passed by two sealed-in platinum wires through a vacuum tube, in which the nearest possible approach to an absolute vacuum has been attained, it can be shown that a stream of particles, calculated to be $\frac{1}{1000}$ of an atom of H in size, pass *from the kathode* with force sufficient to turn a light mica wheel placed in their path. They are therefore negatively charged, and this is the case *whatever the gas they are split off from*. As similarly charged bodies repel one another, there must be some counteracting positive charge to keep atoms from disruption. Prof. Thomson's electrical model atom consists of a hollow globe, charged with positive electricity, within which bodies representing numbers of corpuscles, negatively charged, revolve, actuated by very complicated forces, in regular orbits. Whether or no this actually represents the atom may be doubtful; or, again, if the atom, as at first supposed, has been really subdivided, seeing that the view gains strength

* Reported at great length in *Zeitschrift für physikalische Chemie.*

that the corpuscles are not *bodies* carrying electricity, but are themselves charges of electricity; and that their separation from the atom of origin leaves the latter equal in mass to what it was before. These advanced physical problems are not for discussion here, but the question suggests itself whether stability or instability of chemical compounds may not be a matter of equality or inequality in the electrical charge and counter-charge; and the only thing to add is Prof. Thomson's latest inference that the number of corpuscles in the atom is proportional to its atomic weight, and is not a very large multiple of it.

Nitrogen and the Albuminoids.—The bodies containing nitrogen are of great importance, but are not yet fully understood. (See Ch. I., p. 1, for latest definition.) The nitrogen bodies in barley or malt, though naturally barley contains a higher proportion of the first and less of the others, have been classified as (α) albuminoids, (β) albumoses, (γ) peptones, (δ) amides and amido acids, (ε) enzymes (which, being active operative agents rather than constituents of wort, will be treated of elsewhere). Analyses, not altogether conclusive, have given the average proportions for barley as 94·3% albuminoids and 5·7% non-albuminoids of total nitrogen-bodies, and those in malt as 79·2% and 20·8%.

The **Albuminoids** contain nitrogen, carbon, hydrogen, oxygen, and sulphur: possibly also phosphorus, but this is more likely combined as tricalcic phosphate, separable as "ash." It may, however, have a direct connection with enzyme action; at least diastase prepared by Lintner's method, drastic as it is, can hardly be separated from the last traces of the salt.

The simplest formula (Lieberkuhn's) assigned to the albuminoids is $C_{72}H_{112}N_{18}O_{22}S$, which, when × 9, is in accordance with a molecular weight of 14,508 found for "egg-albumin" by Raoult's method, and is based on the following percentage analysis:—

		Limits of Variation.
Carbon	53·3	50·0 to 55·0
Hydrogen	7·1	6·9 „ 7·5
Nitrogen	15·7	15·0 „ 18·0
Sulphur	1·8	0·3 „ 2·0
Oxygen	22·1	20·0 „ 24·0

The average percentage of N in albuminoids being arbitrarily taken as 16, 100 divided by that number gives 6·25, the number by which the total N found in a substance (by Kjeldhal's or by soda-lime method) is multiplied to arrive at the percentage of albuminoids therein. This will not be entirely correct in all cases. For instance, if we accept Ritthausen's classification of the proteins, we have among them mucedin with 16·95% nitrogen and fibrin with 15·7%. Again, the nitrogen may be present in the form of peptones or amides, the former relatively poorer, the latter relatively richer in N, than the bodies of which they are the transformation products. In malt the transformation products are usually of the amide type. Further, if we rely upon the "pure diastase" obtained by Lintner's method as typical, the enzymes have a lower nitrogen percentage, that of the diastase in question being only 10·42.

Ritthausen identified the following nitrogenous bodies in barley (10% to 12%, though lower and higher rates are met with); it has, however,

been objected that the casein is really globulin, changed into albuminate by the action of dilute acids or alkalis.

1. **Casein.**—Insoluble, or very slightly soluble either in hot or cold water; soluble in alcohol and dilute potash, and in acetic acid and alcohol.
2. **Fibrin.**—Insoluble in water, but soluble in strong alcohol in the cold (in a 30—70% solution only when boiled), in dilute acids and alkalis.
3. **Mucedin.**—Slightly soluble in cold water, more so in boiling; the water is made foaming by it, and becomes cloudy when cooled. It is soluble in 60—70% alcohol (Tralles) = 0·889 spec. gravity. A hot saturated (alcoholic) solution gets cloudy on cooling, and mucedin is precipitated; on addition of strong 90—95% alcohol a further precipitate, yellowish-white in colour, occurs, which is characteristic of mucedin; soluble in dilute acids and alkalis, but precipitated from the solutions by alkalis and acids (neutralising).
4. **Albumin (vegetable).**—Soluble in cold water, and extractable by that solvent from barley meal. On heating the clear solution it separates in flakes, which are insoluble in dilute acids or alkalis. Partial precipitation at 158—168° F. It can be precipitated from a cold solution by addition of a few drops of nitric acid.

Ritthausen gives to the barley proteins the following composition:

	Casein.	Fibrin.	Mucedin.	Albumin.
Carbon	53·25	54·55	53·97	52·86
Hydrogen	7·13	7·27	7·03	7·23
Nitrogen	16·63	15·70	16·98	15·75
Oxygen	22·49	22·48	21·34	22·98
Sulphur	0·50		0·68	1·18

But Osborne (Connecticut Agricultural Experimental Station), using 10% solution of common salt (NaCl) and 75% alcohol (= sp. grav. 0·8603) as solvents, found:

Albumin (Leucosin)	0·30%
Proteose	1·95
Globulin (Edestin)	
Hordein	4·0
Insoluble Proteids	4·50
	10·75

The hordein in composition and character (carbon 54·29, hydrogen 6·8, nitrogen 17·21, oxygen 20·87, and sulphur 0·83) corresponds fairly with Ritthausen's mucedin.

Analytical method for determining C, H, etc.—Carbon and hydrogen are estimated by combustion of a definite weight of substance in proximity to copper oxide in a glass tube and in a current of oxygen. A platinum trough just sliding in the tube may hold the substance. The heated carbon combines with O to form CO_2, which is absorbed in passing through a bulb filled with caustic potash dissolved in equal weight of water, while the H combines with O to form water, and this is absorbed in a U tube filled with granular calcic chloride. Special precautions must of course be

taken to have the latter anhydrous and any calcic oxide, which might otherwise absorb CO_2, reduced. Further, if the compound contains N, in order to prevent error from decomposition of this element into its oxides, absorbable by the potash, the combustion-tube mouth is to be charged with granular metallic copper, reduced in carbon monoxide, and kept red-hot, when it absorbs O, and liberates free N. The difference in weight of the calcium chloride tube and of the potash bulb (of course properly connected with the combustion-tube), before and after combustion, gives the water and CO_2 respectively absorbed, and the water $\div$ 9 shows the hydrogen and the $CO_2 \div 3{\cdot}6666$ shows the carbon in the given weight of substance ; nitrogen is determined by one of the methods elsewhere described ; sulphur from the barium sulphate formed when the sulphuric acid, into which it can be oxidised, reacts on barium chloride ; oxygen by difference.

In **Osborne's determinations** the first extraction of fine barley meal was made with 10% solution of common salt, which dissolved out albumin, proteose (albumose), and globulin, with a quantity of gum which rendered precipitation of the globulin somewhat difficult. Saturation with ammonium sulphate precipitated *all* the proteins. The residue, after filtration, was again dissolved in 10% salt solution and the filtered solution dialysed * for several days to remove the salt ; and when this was thoroughly done the globulin was precipitated, *because insoluble in non-saline water*. This precipitate, dissolved again twice and twice dialysed, and after that washed with water, alcohol, and ether, and then dried over sulphuric acid, gave the " **Globulin.**"

From the filtrate, heated gradually to 149° F., the **Albumin** coagulated and precipitated, and after separation on a filter was washed with warm water, alcohol, and ether, then dried over sulphuric acid.

The **Hordein** was got after removing the previous bodies from a quantity of ground pearl barley (endosperm) by means of a 10% salt solution, by adding to the still wet mass sufficient alcohol to make a 75% solution. This drawn off, and another extraction being made with 75% alcohol, the combined filtrates were evaporated to one-third of their bulk over a water bath. Subsequent steps were maceration of the plastic mass of protein matter, which separated, in distilled water ; redissolving, after decantation, in 75% alcohol ; pouring of the solution into a large bulk of distilled water ; re-solution of the thereby precipitated protein in 75% alcohol, and the pouring of this last solution into a large quantity of absolute alcohol. Ether was added, but no precipitate occurred before addition of a little sodium chloride sufficient to make up for mineral salts removed by previous treatment. The hordein precipitate *then* obtained was treated with successions of absolute alcohol, in which it is insoluble, and dried over sulphuric acid. The alcohol and ether retained any extracted fat.

The insoluble proteid in the determination was got from the nitrogen, found in the barley *meal*, after its extraction as above with salt solution and alcohol, but multiplied by 5·9, instead of the usual 6·25.

* Using Graham's discovery that parchment or parchment paper is readily permeated by crystalline bodies, but very slowly by colloidal (gum-like) bodies. If the mixture be placed in a drum, floating on water, the sodium and chlorine ions pass through, in equivalent proportions, of course, leaving the colloid behind (**Osmosis**).

Of the "purified" substances obtained, the globulin is insoluble in pure water, but soluble in a 10% salt solution, from which very little is precipitated on boiling, though some turbidity appears at 194° F.; while the hordein is almost insoluble in cold water, but rather more so in hot. No precipitate appears on cooling (unless salt is added), nor is there any coagulation of a solution of it on boiling. Dissolved in strong hydrochloric acid, it gives a crimson solution, a red one in mixed sulphuric acid and water (equal volumes).

Munro and Beaven, using 5% salt solution and 0·9 alcohol, found variations in the mellow and steely corns from the same sample of 1898 barley (with a low total N percentage *as obtained*):

	Per cent. of N.	Per cent. of N soluble in 5% salt solution.	Per cent. of N soluble in 0·9 alcohol.
Mellow Corns .	1·036	0·335	0·257
Steely Corns .	1·456	0·394	0·463

A. J. Murphy, using the same solvents and water, when operating upon a large number of barleys (27 English and 22 foreign), got the figures below. Ground barley was digested in water and in salt solution at 120° F. for two hours; in alcohol at 158° for one hour.

Albuminoids (N × 6·3) calculated on 100 parts *dry* substance.	Minimum.		Maximum.	
	English.	Foreign.	English.	Foreign.
Total . . .	8·43	8·49	10·85	14·56
Soluble (coagulable) . } in	0·5103	0·420	0·359	0·627
Soluble (incoagulable) } water	1·3141	1·119	1·369	1·759
Soluble in 5% salt solution	2·2560	2·099	2·359	2·917
Soluble in 0·9 alcohol .	2·6238	2·024	3·192	3·4129

The figures *generally*, of which only the extremes are given here (leaving out two higher figures 11·38 and 11·54, for which the alcohol-soluble albuminoids are not given), do not seem to support Munro and Beaven's observation that the ratio of alcohol-soluble to salt-soluble albuminoids increases with higher percentages of those bodies, the former being, they suggest, derived from the "reserve proteid"—*i.e.*, "proteid matter related to protoplasmic proteid, as starch is to the sugars." But one notable point is that the ratio of soluble to total decreases as the latter increase, and appears lower in the foreign than in the English, the percentages working out 79·5%, 68·25%, 66·7%, 59·8%.

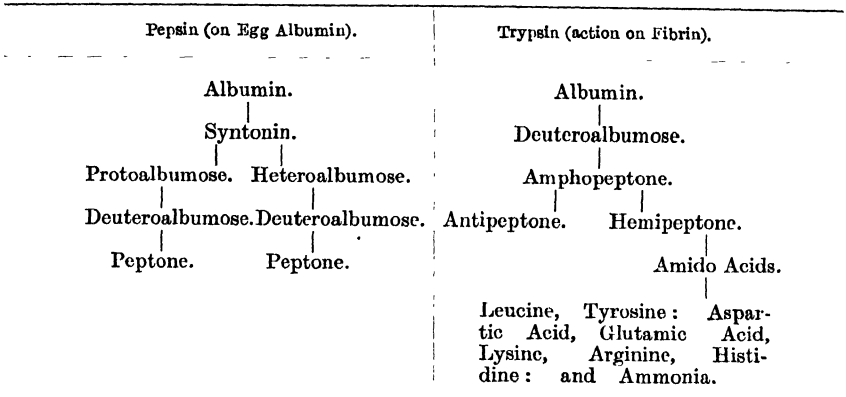
Osborne and another have found that the nitrogen bodies in malt differ from those of barley, in that another globulin (**Bynedestin**), with more carbon and less nitrogen, has replaced that of barley; that the **Albumin**, substantially the same, is increased in quantity, while hordein is replaced by **Bynin** (soluble in dilute alcohol), but in less quantity; and four varieties of **Proteoses** have been differentiated by them. Some scepticism may, however, be permitted as to the bodies precipitated by salt solution or alcohol representing definite entities, and a statement in the Chemical Society's Annual Report for 1904 (though referring to blood proteids) may be quoted. "We must, however, note that the time-

honoured classification of albumin and globulin seems in danger of disappearing. The artificiality of the distinction was first mooted by Starke two or three years ago. Moll now states that by simply warming serum to 56—60° (C.) the globulin is increased at the expense of the albumins, hydroxyl ions being regarded as the cause of the change."

Proteolysed bodies.—With the conversion products of protein bodies we seem, even now, on surer ground, in that we have the amide asparagin, procurable from many plants, and forming crystals, which are stable in the air, and giving very definite results in experimental work. But considerable advances in knowledge may soon be looked for in view of the success achieved by E. Fischer in the synthesis of true peptones from polypeptides, of which asparagin is one.

Some of the newer researches on proteolytic changes in malt extract at various temperatures have been detailed on pp. 60, 61, and the following pages, so that we may now touch briefly on the chemical and physical side of the question, premising once more that **Albumoses** (proteoses) and **Peptones** are held to be important factors in "head retention" and "condition," and that the less complex and crystallisable amido-bodies are specially useful for yeast nutrition. Yet we can hardly suppose that these bodies have sharp lines of demarcation; under ordinary brewing conditions it is more than probable that intermediate bodies are formed, which link them together in no very simple chain. Of the diffusible peptones and still more diffusible amides there can hardly, given a due balance of the two types, be excess in a wort brewed on British infusion lines, but there are other bodies of unstable solubility, that is, bodies which find their way into the fermenting vessel in a state of quasi-solution, which prevents them from being removed mechanically by the yeast, for the nourishment, however, of which their relative want of diffusibility unfits them, as they cannot without extreme difficulty penetrate the yeast membrane. Yet when something occurs to throw them out of solution, a slight alteration of temperature or in the constitution of the wort (*e.g.*, lowering of the specific gravity or acidifying effect of CO_2), they come into evidence as causes of the so-called **albuminoid haze.** There is no reasonable doubt that insufficient modification, or the slackness of malt, increases the proportion of these, under equal conditions. The contention of Wahl (p. 62) is that the temperatures of the British mash-tun extract an undue amount of these albuminoids of the borderland, instead of completely converting them into peptones and amides. This contention may be recorded again without necessarily endorsing it.

Peptone (molecular weight 400 ?), of which, if we may assume the products of pepsin's action upon egg albumin to be paralleled in malt, there may be two types produced in the same conversion, one capable of being further split up into amido-compounds, the other resistant to the action of trypsin (tryptase, in malt). In mash-tun conversions the proteolytic action is duplex, and is favoured by heats below those usual in the British mash-tun, the lower range of these favouring the action of tryptase (the malt analogue of trypsin), the higher (120°—140° F. ?) that of peptase, the analogue of pepsin. Therefore, as we cannot consider any conversion diagrams separately, two, out of many, tentatively showing *peptic* and *tryptic* action, are appended :—



It is supposed that the antipeptone *half* cannot be converted into anything simpler than peptones even by tryptic action, and therefore if the mash-tun conversions, under the most favouring conditions, correspond with the diagrams, it must be to the formation of amides in germinating malt that we have to attribute the preponderance of the latter. Antipeptone, however, can apparently be hydrolysed by other reagents (*e.g.*, nitric acid) into certain amido-bodies. It is said that ammonia is always given off in small quantity when trypsin acts on albumen. Peptones are not precipitated from their solutions by dilute acids, nor by heating, even to the boiling-point.

Synthesis of peptone from simpler polypeptides has been, as already noted, effected by E. Fischer, and attempts have further been made to convert peptones into the more complex proteids, which have so far only attained partial success. On the assumption that peptones are formed by hydrolysis from these complexes, it was hoped that some method of dehydrolysis might be effective, but on this failing it was thought that the condensation of the peptone molecule might occur through fixation of carbon, brought about by concurrent action of formaldehyde (CH_2O). Although treatment of commercial peptone with formalin brought about turbidity, resulting in agglomeration into masses, analysis of these led to no definite conclusion. The filtrate, however, appeared to contain something which gave the reaction of proteids, and similarly when pure peptone was operated on, after albumoses had been salted out, substances were formed with the characteristics of primary and secondary albumoses, and a trace of another resembling albumin. It is noteworthy that no formaldehyde could be separated even by heating, which shows that the bodies formed were, at any rate, not unstable compounds of formaldehyde and peptone.

Acid Amides and Amido Acids.—Though asparagin is not cited amongst the products of tryptic action in the diagram above, there can be little doubt of its playing a prominent part, by means of its diffusibility through cell walls, in the transference of nitrogen from the roots to the seeds of cereals. Found originally in asparagus, and crystallising in rhombic crystals permanent in the air, it can be obtained from many other sources: it exists in malt rootlets (1·96 to 2·66% of the dry substance) and in the young shoots of vetches and other leguminous plants, diminishing as

maturity advances, and being absent from the seed. Its presence in the *leguminosæ* is specially noteworthy, as these are all plants which derive nitrogen from the air in quantity sufficient to cover nutrition (thus clover, though removing 13—14% of its weight in nitrogenous bodies, leaves the ground richer in N than it was before) with the symbiotic assistance of certain bacteroids, which develop tube-like processes that penetrate the root-hairs until they reach the root. To the roots they either transfer nitrogen which they themselves have assimilated, or enable the roots to digest it by stimulating the cells where " hypertrophy " has been set up. It is probable that the latter is what occurs, as there is strong microscopic evidence that the cells at that point are in a state of great metabolic activity. Moreover, the sap in these active cells is *alkaline*, and this has been held to accord with a suggestion by Loew that, in presence of free N and an alkali, living protoplasm can build up ammonium salts (nitrate or other). Tubercles, containing bacteroid colonies observable on the roots at these points, are marks of the transference having occurred.

Whether asparagin be the actual amido-body which exists as the ultimate product of malt proteolysis or no, it has been found capable alone of affording nitrogenous nutriment to yeast, and also of stimulating its *fermentative* action as distinguished from its reproductive function when added to normal wort.

Asparagin ($COOH.CH(NH_2)—CH_2—(CO\ NH_2)$) when boiled with acids or alkalis is converted into aspartic acid ($COOH—CH(NH_2)—CH_2—COOH$) and ammonia, and it may be noted that only the amido group (" amidogen ") of the amide is driven out of the compound thereby : the other amido group, contained in the hydrocarbon portion of the compound, is not disturbed.

Another acid amide found in plants, glutamine, $COOH.CH(NH_2).CH(CH_3)—CO(NH_2)$, is akin to asparagin, from which it differs in having an H atom substituted by " methyl " (CH_3). It is very unstable, being more often indicated by a (probably) decomposition product, glutamic acid, in which one of the amidogen (NH_2) groups is replaced by hydroxyl (OH).

Recent experiments by Ivanhoff bear upon the synthesis of albumin from asparagin during fermentation. In a non-nitrogenous saccharine wort the quantity of albumin in the yeast remained the same after as before fermentation, in spite of the fact that the yeast contained several simpler (non-albuminoid) nitrogenous bodies ; but if asparagin was added a quantity of albumin was produced from it. And in the case of pressed yeast, starved by immersion in water until it became charged with metabolic products, the quantity of albumin reconstructed only reached from 40% to 60% of that originally present in the yeast.

An accelerating influence of asparagin on *Amylase* (the starch solvent) towards starch has been noticed, and has been recently attributed by Effront to the presence of the amino group and not that of the amido group ; * in other words to the group in which amidogen (NH_2) is bound up

* **Amides** are a group of compounds derived from ammonia (NH_3) by replacement of part of the H by an acid radical. They are neutral to litmus, but act as bases towards acids, forming salts with them. Boiled with caustic potash in water they give off NH_3. **Amines** are compounds in which one or more H-atoms of NH_3 are replaced by an alkyl (hydro-carbon-radical or alcohol-radical) ; they are primary, secondary, or tertiary, according as 1, 2, or 3 atoms are replaced.

with the hydrocarbon portion of the compound, because he found that this acceleration was exhibited by aspartic acid, glycine, leucine $C_5H_{10}(NH_2)$--CO . OH, and other substances containing such a group, but not by succinamide (C_2H_4—$CONH_2$—$CONH_2$), acetamide, and others which did not. The definite interest of this lies in the indication that the amino-acids exert a beneficial influence in the germination of starchy seeds, especially in the initial stages, when but little amylase is present.

Differentiation of different N-bodies.—These may be separated as follows from a *solution* (soluble bodies) :—

1. *Coagulable albumen.* Precipitated by boiling ½ hour.
2. *Albumoses.* Precipitated from the filtrate by zinc sulphate.
3. *Peptones.* Precipitated from the filtrate of No. 2 by phospho-tungstic acid.
4. *Amides.* Estimated by boiling a filtrate from No. 1 with hydrochloric acid for 1 hour, and then distilling with caustic soda (*cf.* Kjeldhal's method, p. 164, for reason of the distillation, and note on p. 160). Or if the total soluble albumen be determined, the difference between the figure obtained and the sum of 1, 2, and 3 will give the amides ; but it must not be forgotten that these bodies contain a higher N-percentage than the proteids do (asparagine about 21·21%), so that the correct multiplier for the N obtained is about 4·7 instead of the usual 6·25. But the dissociated ammonia atoms exist in asparagine in the proportion of 34 : 132 ; therefore multiplication of it by 3·882 should give the amides in terms of asparagine. The difference between the sum of 1, 2, 3 and 4, and a total nitrogen determination of a substance equal in bulk to that from which the solution was obtained (or comparable with it), will give the nitrogenous bodies insoluble *within the conditions observed.*

Mr. A. H. Allen, referring to Schulze and Barbiére as recommending that the true *soluble albuminoids* should be distinguished from *peptones*, and these again from the *amido-compounds*, says : "For the qualitative detection of albuminoids the formation of a precipitate on adding acetic acid and potassium ferro-cyanide will suffice. For the precipitation of the *albuminoids* various reagents, such as tannin, ferric acetate, cupric acetate, plumbic hydroxide, etc., should be employed on separate portions of the solution, the precipitate containing least nitrogen being considered that which represents the true albuminoids. The peptones, which in nutritive value are equal, or nearly so, to the albuminoids "—more than equal as far as yeast alone is concerned—" may be precipitated from the filtrate by means of phosphotungstic acid. The *amido compounds* which remain in the solution from which the proteins and peptones have been precipitated are typified by asparagine and glutamine, and may, if desired, be determined by boiling the solution with an acid, and then estimating the ammonia from the amount of gas liberated by sodium hypobromite."

To avoid any change of composition in the nitrogenous bodies during extraction, the same investigator recommends the extraction to be made first with cold and then with hot water, or else with dilute alcohol.

It is hardly to be supposed that these analytical niceties will be within the experimental limits, to which the average brewer must confine himself,

but our hope has been by referring thereto to throw a little light on the difficult and complex, but most important bodies dealt with in the few preceding paragraphs.

Soluble or Coagulable Nitrogenous Bodies.—There is a tendency to lay down arbitrary limits for these, but as we have seen (p. 21), they may vary with the mashing conditions adopted for the same malt. Drinklage (*re* Lager Malt) holds that malt with 9% to 11% of protein content, calculated on the dry substance, should have the following proportions of soluble and coagulable nitrogen :

	Soluble N.		Coagulable soluble N.
Pale to light golden	0·48—0·54%	...	0·11—0·13%
Dark malt	0·39—0·48%	...	0·08—0·11%,

the soluble N as proteins (mean) representing 3·25 and 2·7 respectively. Experiments by Bleisch and Schweitzer showed that the precipitates on boiling worts from the same malt, differently mashed, though with a finishing temperature of 167° Fahr. in both cases, varied as $\frac{1}{12}$th and $\frac{1}{15}$th of the total albuminoids.

It will be instructive to append here two careful analyses by O'Sullivan of pale malt, as indicating the final modifications effected by the malting process. It is stated that every constituent was determined directly, and the closeness with which the totals approximate to a hundred speaks for the accuracy of the methods employed.

			No. 1.			No. 2.
Starch			44·15	...	...	45·13
Other Carbohydrates (of which 60%—70% consists of fermentable sugar), Inulin (?) and a small quantity of other bodies soluble in cold water			21·23	...	...	19·39
Cellular matter			11·57	...	...	10·09
Fat			1·65	...	...	1·96
Albuminoids.						
(α) Soluble in alcohol sp. gr. ·820 and in cold water	·63			·46		
(β) Soluble in cold water and at 68° C.	3·23			3·12		
(γ) Insoluble in cold water but soluble at 68°—70° C.	2·37	}	13·09	1·36	}	13·80
(δ) Insoluble at 68°—70° C. but soluble in cold water (= albumen proper)	·48			·37		
(ϵ) Insoluble in cold water and at 70° C.	6·38			8·49		
Ash			2·60			1·92
Water			5·83			7·47
			100·12			99·76

Typical Analysis of Malts.

1. **Diastatic Capacity.**—Pale ale brewing under present conditions from 32° to 35° on Lintner's standard. Mild ales and stouts 23° to 28° on Lintner's standard. When the same foreign malt is employed in the production of both bitter and mild ales, diastatic capacity should be 26.
2. **Tintometer Reading.**—Under standard conditions, pale ale malts 3·0 to 5·0 in 1 in. cell Lovibond, mild ale malts 7·0 to 9·0 Lovibond—all in 52 series.

3. **Extract.**—This varies considerably and depends on the general quality of the season's barley, etc. The extract yield of mild ale malts, made from medium class barley, ranges from 90 brs.' lbs. to 94 brs.' lbs., and for pale ale malts, made from superior types of barley from 95 to 98 brs.' lbs. Barley of superlative quality is capable of yielding malt from which extracts of 100 brs.' lbs. are obtainable. Foreign malts yield extracts of a much wider range, as low as 84 brs.' lbs. and as high as 92 brs.' lbs.
4. **Soluble Albuminoids.**—2·3% to 2·5%.
5. **Ready formed Soluble Carbohydrates.**—They occur in malt in from 14% to 16%. Excess points to forced growth on the floors and loading to kiln prematurely or insufficiently withered. When the "ready formed sugars" exceed 16% bad brewings result. Under 10% shows that the barley from which the malt was produced was insufficiently germinated.
6. **Moisture.**—In samples direct from the kiln the moisture should not exceed 1%. If when stored some little time, dependent on whether the malt is exposed to the action of the air or has been rendered as air-free as possible, the malt reaches a moisture content of 3%, the material is regarded as having deteriorated, and it should be redried. When the moisture content reaches 5%, the malt is referred to as "slack," in which condition the material is unfit for brewing purposes.
7. **Arsenic.**—Legal limit $\frac{1}{10}$th of a grain per pound (for liquids $\frac{1}{100}$th of a grain per gallon). Malts should not exceed $\frac{1}{30}$th of a grain per lb.
8. **Cold Water Extract.**—19%.
9. **Normal Acidity for Malts.**—1% expressed and calculated as lactic acid.

Nitrogen, the characteristic constituent of all these so-called protein or albuminoid bodies, is a remarkable element. Itself a tasteless, colourless, and inodorous gas, and (under certain circumstances) a singularly inert substance—a species of chemical ballast, as it were—supporting neither combustion nor life, and not readily combining with other bodies, it yet forms compounds of exceedingly powerful properties—viz., with hydrogen, the powerful alkaline base ammonia (NH_3); with oxygen and hydrogen, nitric acid; with excess of chlorine, a dangerous explosive, as it will indeed with many other substances.*

Nitrogen in carbon compounds is estimated in various ways. One, known as the **absolute method,** consists in a combustion of the compound, mixed with copper oxide, in a tube, in which there is also a layer of copper foil, which of course becomes highly heated. All the air must be carefully exhausted before the operation begins, and at the end all the gases (which, if the substance contained nothing beyond carbon, oxygen, hydrogen, and nitrogen, are only three in number, viz., CO_2; vapour of water, H_2O; and free nitrogen) are also exhausted. The water-vapour of course condenses, the CO_2 (carbon dioxide or carbonic acid gas) is absorbed on passing the

* This malign readiness may be amusingly illustrated by soaking a crystal of iodine in strong ammonia. The iodine, getting pasty, combines with the nitrogen of the NH_3 to form nitrogen iodide, which, as soon as it is dry, will explode with a loud report, almost at the lightest touch.

gases through a solution of potassium hydroxide (caustic potash), and the nitrogen, thus separated, can be collected and measured, and its weight easily calculated.

The **Soda-lime Method** and **Dr. Graham's Adaptation of Professor Wanklyn's Ammonia Process** for the determination of nitrogen are both described in the next chapter, with working details.

Kjeldhal's Method, of which there is more than one modification, is based upon the conversion of the organic nitrogen into ammonia by a treatment, which begins with heating a measured quantity of the powdered substance (·5—1 gramme) with a mixture of equal parts of concentrated pure sulphuric acid and Nordhausen (fuming) sulphuric acid, with the addition of one or two grammes of phosphoric anhydride (P_2O_5), which must obviously be free from nitrous or nitric acid. At the end of the whole operation the nitrogen is determined from the ammonia.

The heating (just short of boiling) is kept up for a varying period (*i.e.*, until the mixture loses its dark colour, due to caramelisation of the substance, and turns yellowish or faintly red). Powdered permanganate of potash is then cautiously added in small quantities at a time, because the reaction is very violent—heating being temporarily stopped—till very slightly in excess (shown by a greenish colour of the solution). This completes the oxidation (nitrogen into ammonic sulphate). When cool, concentrated caustic soda (sp. grav. 1·3) is added in excess to decompose the ammonic sulphate, but carefully poured down the side to avoid loss of the ammonia which it liberates. The mixture is now distilled, with special precautions, which include the addition of a few pieces of zinc before the caustic soda, to prevent the violent bumping which would otherwise occur, and the ammonia which comes over is received into standard acid. At the close, when all the ammonia has come over, this mixture, in which the acid is in excess, is "titrated" (as in the soda-lime process), and the ammonia estimated from the difference between the amount of acid before the ammonia was distilled into it, and that which remains after. The ammonia multiplied by $\frac{14}{17}$ gives the amount of nitrogen, which multiplied by 6·25 gives the latter in terms of albuminous matter.

Certain other tests, which are merely qualitative, *i.e.*, which only reveal the presence of such and such an element or compound, but do not give the quantity as a quantitative analysis does, may find a place here, instead of in the next chapter.

Iodine added to a fairly cool solution of starch produces an intense blue colour (iodide of starch, or, more correctly, iodised starch, the formation being apparently not a definite compound), which disappears on heating, it is supposed because the heated water takes up more iodine of which the starch is accordingly deprived, but which reappears on cooling (once). An aqueous solution of iodine is better than a tincture (alcoholic solution), but the iodine is very sparely soluble in water, until a crystal of potassium iodide is added, whereupon immediate solution occurs. With erythro-dextrin iodine gives a reddish-brown colour, which tinges starch-blue more or less violet when both are present. The affinity of iodine being greater for starch than for erythro-dextrin, it is possible by the addition of a very little, and that dilute, iodine solution to cause the starch-blue to develop first and the redder coloration upon a further addition of iodine. It is

further possible, by the cautious addition of very dilute ammonia to such a mixture, to cause the red-brown coloration to disappear while the blue remains. Iodine is a very delicate test for starch, giving a bluish tinge even at such extreme dilution as one drop of starch paste in a quart of water, or putting it otherwise, a liquid containing $\frac{1}{500{,}000}$ its weight of starch-paste strikes a blue colour. With the final, if there be a *final* type of dextrin, known as achroo-dextrin (ἄχροος = uncoloured), no reaction is produced.

But with wort, which is a composite fluid, the first drop or two of iodine solution may be decolourised (it should be added drop by drop if the wort be in a test-tube), therefore the operator must not draw hasty conclusions, but should add sufficient iodine for certainty. If, upon testing the wort some time before the copper lengths are secured, the erythro-dextrin reaction appears, it will be wise to lower the sparging heats, for the reaction may soon be that of soluble starch. And according to Lintner, erythro-dextrins are themselves liable to be thrown out of solution by the alcohol formed in the beer wherein they exist, and consequently a certain degree of haziness may result. Matthews, however, disputes this view of Lintner's, holding that, when dextrins are precipitated by alcohol, they tend to agglomerate without causing any troublesome opalescence.

Nitrites (in Water).—"The best qualitative test for nitrites," says Sutton, "is to acidify the water moderately with pure sulphuric acid, then upon adding potassic iodide and starch liquor, the occurrence of the well-known dark blue colour of starch-iodide reveals the presence of nitrites immediately." [This turns upon the fact that nitrous acid, set free from its compounds, the nitrites, by sulphuric acid, combines with the potassium of the iodide liberating iodine to produce its blue reaction with starch. Note that potassium-iodide, as such, produces no blue colour with starch.]

But a blank experiment with distilled water should be tried, to make sure of the purity of the sulphuric acid.

Nitrates and Nitrites in Water—The Indigo Test.—Colour a little of the water with indigo solution, then add twice the bulk of pure sulphuric acid (which sets nitric or nitrous acid free from their salts). Then, if there are nitrates or nitrites present, the blue colour will be discharged; in the contrary case it will remain. The importance of having pure sulphuric acid, free from nitric acid, is again evident. This test can be made very fairly quantitative by having the indigo solution (made by dissolving pure indigo carmine in distilled water) of such a strength that 10 c.c. are decolourised by 10 c.c. of a standard solution of a nitrate—*e.g.*, 1·011 gramme of potassic nitrate dissolved in a litre, of which 10 c.c. will contain ·0014 gramme of nitrogen. Then if 10 c.c. be run into a measured quantity of the water, and the colour remains after the sulphuric acid is added, the quantity actually decolourised by the nitrates in the water can be ascertained by "titrating back" with the standard potassic nitrate.

The Phenol-Sulphuric Acid Test.—Water, evaporated just to dryness in a platinum or porcelain dish, is treated with a solution (about one drop per c.c. of the water) made in the following manner. To a small quantity of pure crystalline carbolic acid (phenol) is added four times its weight of pure and strong sulphuric acid. The mixture is then heated to boil-

ing for a few minutes, cooled, and diluted with half its bulk of pure water.

The dish is then placed on the water-bath again, whereupon the mixture will acquire a violet-red colour if nitrates are present. With ·5 grain per gallon the colour is intense. [The phenol-sulphuric mixture should be kept in a stoppered bottle.]

Another Qualitative Test, operated upon the " total solids " of water, is given in the next chapter.

Millon's Reagent for Proteins is made by dissolving quicksilver in an equal weight of nitric acid (of density 1·41), then gently warming and diluting the solution with twice its weight of water. There must be a trace of free nitric acid. The liquid is to be decanted from the deposit which separates after standing for some hours. It colours protein bodies red.

The Biuret Reaction for Peptone.—If a solution of peptone be made strongly alkaline with caustic potash or soda, and a few drops of an excessively dilute solution of copper sulphate be added, a beautiful rose-red colour is produced. This reaction was at one time considered characteristic of peptone, but it seems to occur (with somewhat violet shade) with albuminoids. [The employment of a dialyser to separate the diffusible peptone from other non-diffusible albuminoids might make this test of value, but the writer has not tried it.]

Iron, Test for.—Boil about 500 c.c. of the water and collect the deposit, in which all the iron precipitates as a hydrated oxide—ferric oxide—upon a filter-paper, free from iron. Anything adhering to the boiling flask should be washed off with pure hydrochloric acid, which should also be used for washing the filter residue. If the filtrate now contain an iron-salt, there will be, on treatment with potassium-ferro-cyanide (yellow prussiate of potash), a marked precipitate of Prussian blue.

Or add 2 c.c. of nitric acid and 1 c.c. of ferrocyanide of potassium to 100 c.c. of the water; whereupon in the presence of iron the usual blue colour will be produced. It may be advisable to boil the water with the nitric acid to ensure solution of the iron before adding the ferro-cyanide. This test also may be made quantitative by having a standard solution of iron, and comparing the colour given by it at various dilutions on addition of the ferrocyanide of potassium with that given by the water actually under examination. Two Nessler tubes on a white tile should be used.

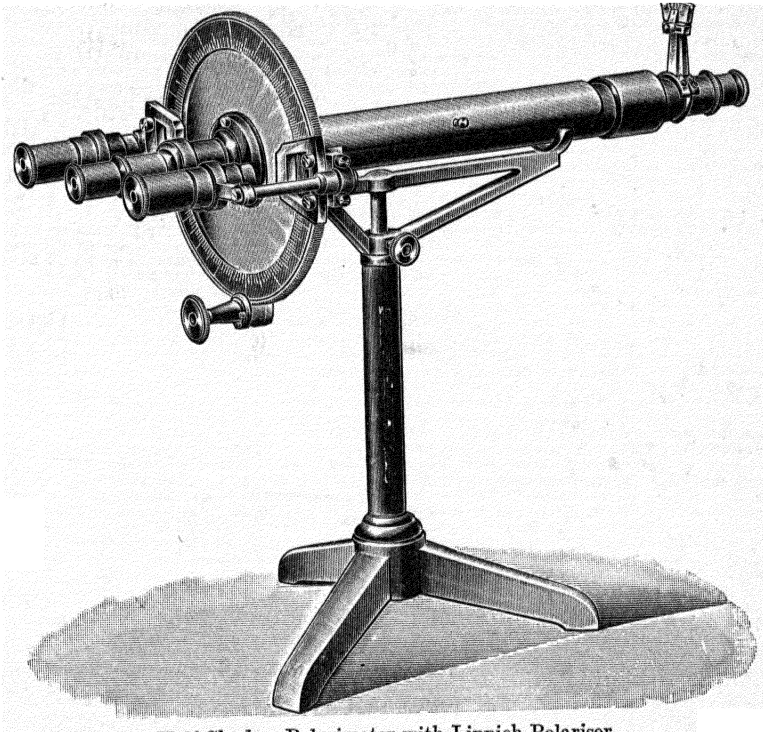
Organic Matter in Water.—Evaporate a portion to dryness in a platinum dish (70 c.c. will do). When dry, hold over the flame of a Bunsen burner. If the residue becomes charred it is a sign of the presence of organic matter, more or less according as the charring is considerable or slight. Watch closely for maximum charring (brown colour), as it goes off on further heating.

Alcohol, Iodoform Test for.—Add to the liquid which is being examined a little iodine solution and a little potash solution ; on warming gently, a yellowish turbidity appears, and crystals frequently separate out on standing. This substance is iodoform, which is insoluble in water. The reaction is so extremely delicate that by it 1 part of alcohol in 300,000 of water can be detected. Concentration of the alcohol by fractional distillation has even enabled a millionth part of alcohol to be detected.

Optical Activity—Polariscope—Polarimeter.—As the expressions

" optical activity," " angle of rotation," etc., may be occasionally used and are frequently to be met with in papers dealing with brewing from a scientific point of view, a brief account of the polariscope or polarimeter may stand here. But we shall have to confine such directions as are given to the " half-shadow " polarimeter, giving an angle easily calculated, as described on p. 168, into the $[a]_D$ opticity; although, for the sake of comparison, both the $[a]_D$ and $[a]_j$ of certain pure substances are placed side by side on p. 168.

The action of the polarimeter is based upon the fact that certain substances, or solutions of them, have the property of causing certain optical alterations in a ray of polarised light passing through them, the correction



Half Shadow Polarimeter with Lippich Polariser.

of which by means of a mechanical adjustment (a milled head actuating a wedge-shaped piece of quartz which is fitted with a scale that moves with it), and then a comparison of the movable scale called the vernier with another fixed scale enables the observer to measure the angle of rotation, and classify it either as a right-handed (+) or left-handed (—) rotation. Albuminoids have a lævo (—) rotatory power.

Without entering too far into detail, it may be said that the polarimeter (of which there are various makes) consists generally of a long telescopic arrangement, capable of being accurately focussed so as to get a sharply defined " field," and placed horizontally with a lighted lamp at the end. In the centre is a movable tube 100 mm. or 200 mm. long (according to the density of the solution) for containing the fluid to be

examined. Two Nicol's prisms, known respectively as the polariser and the analyser (made, in a special way, of the crystal known as Iceland spar), are on either side of the movable tube; also there is a plate of double quartz (*i.e.*, made of two qualities of quartz, having the one a right-handed and the other a left-handed rotation) towards the lamp-end of the apparatus, while, towards the eyepiece end, are first (nearest the movable tube) a plate of left-handed quartz, then, nearly adjoining it, a plate of right-handed quartz, divided diagonally, and so disposed that while one of the divisions is fixed, the other can be moved upwards or downwards by the milled head mentioned in the last paragraph, and thus the thickness of right-handed quartz in the line of vision be increased or decreased. Obviously, if it has to be increased in order to correct the optical disturbance produced by the contents of the tube, then the latter have a left-handed rotation; if the thickness has to be decreased a right-handed one.

The rotatory power of certain pure substances is :—

	Angular reading in 2-decimetre tube given by 1 gramme per 100 c.c.	$[a]_{D\,3\,86}$	$[a]_j$.
Dextrin . .	3·90	195·0	216·0
Maltose . .	2·71	135·4	150·0
Cane-sugar .	1·33	66·5	73·8
Dextrose . .	1·06	52·9	58·6
Levulose . .	−1.91	−95·6	−105·98
Invert sugar .	−0.43	−21·3	− 23·6

N.B.—Prof. Ost, however, considers the rotatory power of maltose to be + 136·5 at least. Brown, Morris, and Millar make it $[a]_D$ + 137·93, and $[a]_j$ + 153·25 for solutions up to 25%. O'Sullivan, using solution factor 3·95, gets $[a]_j$ 154 (and later 155·15). Here the phenomenon of **Birotation** (varying opticity) of certain carbohydrates may be noticed. Thus a freshly prepared maltose solution shows rotatory power much below the normal (though boiling, or the addition of ·1% of alkali—*e.g.*, ammonium hydrate—brings it right at once), whilst that of dextrose decreases.

Briefly, the *modus operandi* is as follows :—The polarising end is placed close to the lighted lamp or electric light; the arrow of the vernier moved exactly to the zero of the graduated scale; the 1- or 2-decimetre tube filled with distilled water and placed in position, and the fact ascertained that the field is equally illuminated all over, or, if not, brought to that state. The tube is then filled (the 1-decimetre for darker coloured, the 2-decimetre for colourless solutions) with the solution, decolourised and clarified, if needful, as below, at 60° Fahr.; replaced, and the field again observed. If the left half-disc appears darker, the vernier arrow must be rotated to the right, and *vice versâ*, until the field is equally illuminated again. The angle indicated by the arrow of the vernier upon the outer scale is noted, and the calculation proceeds. *We will assume that a boiled copper-wort is being inspected, and that the specific gravity = 55°, and

* **Opticity of Brewery Wort.**—About 5 c.c. of wort are taken 30 minutes after tap-setting. This is diluted with ordinary tap water, or distilled water, and made up to about 150 c.c. A small quantity of moist alumina is added and the whole boiled up. Allow to cool and then filter. Take the specific gravity of the filtrate by means of the specific gravity bottle. Take a one dm.-tube and clean both glasses, swill out with water, fill up with filtrate, insert tube in Polarimeter and observe rotation.

the observed angle 15·5°. The specific gravity ÷ 3·86 (= gravity given by 1 gramme sugar in 100 c.c. of water) gives percentage of total solids. Then

$$\frac{55}{3\cdot86} = 14\cdot25 \text{ (grammes of total solids in 100 c c.), and}$$

$$\frac{15\cdot5 \times 100}{14\cdot25} = 108\cdot8, \text{ the opticity or } [a]_{D\ 3\cdot86} \text{ of the wort.}$$

According to Mr. Heron, the $[a]_D$ of a wort should not be less than 105 or exceed 122.

To Decolourise and Clarify.—Add a drop or two of a saturated solution of basic acetate of lead to about 100 c.c. of the wort, and, having gently shaken or stirred the mixture, add twice the quantity of "alumina cream."* to complete clarification and precipitate excess of lead. Filter, and cool.

* **Alumina Cream.**—To prepare this, shake up commercial alum with water at ordinary temperature until a saturated solution is got; set aside a little of this, and to the residue add ammonia, little by little, and stir until the mixture is alkaline to litmus paper; then add drops of the portion set aside until the mixture becomes just *acid* to litmus paper.

CHAPTER VII

THE LABORATORY

ESSENTIALS OF A LABORATORY—THE BREWER-ANALYST'S LIMITATIONS—METRIC SYSTEM OF WEIGHTS AND MEASURES—APPARATUS AND REAGENTS REQUIRED—PREPARATION OF APPARATUS—FEHLING'S SOLUTION—VOLUMETRIC AND GRAVIMETRIC METHODS—TESTING GLUCOSE (INVERT), CANE-SUGAR, MALT—NORMAL OR STANDARD SOLUTIONS—EQUIVALENCE—ALBUMINOIDS BY AMMONIA PROCESS—SODA-LIME PROCESS—DIASTATIC ACTIVITY OF MALT—BEER ANALYSIS—ORIGINAL GRAVITY BY DISTILLATION AND EVAPORATION—DRY EXTRACT, ACIDITY, ETC.—WATER ANALYSIS—COMBINING RESULTS—SOAP TEST—FREE AND ALBUMINOID AMMONIA—OXYGEN PROCESSES—HOPS FOR SULPHUR—CONSTANTS—STANDARD SOLUTIONS.

A ROOM with gas and electric light available, and water laid on, and with ready means of conveying the latter away when running in a continuous stream for cooling; a plain wooden working bench 2 feet 6 inches wide and 3 feet high, with cupboard underneath to hold the larger apparatus and shelves above for the reagents; an earthenware tank (to resist acids) let in flush with the top of the bench, and which may be procured, of Doulton's make, for 10*s.* or 12*s.*; a separate shelf, *free from vibration*, to stand the balance on, is all that will be absolutely necessary beyond apparatus and reagents for the performance of any of the tests or analyses referred to in this chapter.

The gas should be conveyed along a pipe running just above the working bench or table, and below the shelves; and the pipe should have three or four small straight-nozzled taps, on which india-rubber tubing can be slipped and permanently kept to connect them with the Bunsen burners. There should also be a gas-burner of the ordinary type, but with its bracket fixed a good deal lower than is usual—*i.e.*, within each reach of both hands together, for the purpose of bending glass tubing and rounding rough edges.

It is advisable to have good ventilation and a fire; and where experiments with sulphuretted hydrogen or chlorine are likely to be performed there should be a separate chamber (one 2 feet by 1½ feet will do) with glass doors, and connected by a pipe to the flue of the fire. But these are outside the range of the modest experimenter, who limits his inquiries to points practically connected with brewing.

These points will be—

Analysis of sugar (glucose, invert, etc.).

Analysis of malt (determination of extract, diastatic value, acidity, albuminoids, etc.).

Testing hops for sulphur (here the sulphuretted hydrogen evolved requires no special precautions).

Determination of original gravities of beer (either by distillation or by the evaporation process).

Analysis of water (determination of free and albuminoid ammonia by Professor Wanklyn's process; and possibly the amount of oxygen required to neutralise organic matter); determination of total solids;

hardness, before and after boiling; proportions of carbonates and sulphates of lime and magnesia, of chlorine (generally combined as chloride of sodium, or common salt), and, if time allow, of the alkalies.

Further than this the amateur can hardly be expected to go. Indeed, the operative brewer will not easily secure the freedom from interruption which even the comparatively simple water-analysis referred to demands.

The Metric or Decimal System of Weights and Measures offers such obvious advantages in the way of rapidity of calculation and absence of confusion arising from ambiguity of weights of the same denomination,* that it is now generally adopted. Only in expressing the saline constituents of water it is most convenient to express them in grains per gallon; but even here an easy decimal relation enables the metric weights and measures to be used. For instance, Professor Wanklyn recommends 70 c.c. (cubic centimetres) of water to be operated on. This quantity (flasks, marked to measure it, can be obtained) contains 70,000 milligrammes, or exactly the number of grains which a gallon of water contains; so that the result obtained with it *in milligrammes* is exactly equivalent to grains per gallon, and may be expressed as such without alteration. And if this quantity should appear too small for any determination, it is a simple matter to take any multiple of it, dividing the result obtained by that multiple.

Note, that the Greek-derived prefixes *deka-*, *hecto-*, *kilo-*, and *myria-*, are used for the multiples of metres, litres, and grammes, while the prefixes of Latin derivation, *deci-*, *centi-*, and *milli-*, are used for decimal parts of them—*e.g.*, a kilogramme = 1,000 grammes; a milligramme = ·001 gramme.

A litre (= 1·76 pint), a name given to the cubic decimetre, contains 1,000 c.c. One c.c. of distilled water at its greatest density, 4° C. (about 39° Fahr.) = 1 gramme. In practice 1 c.c. at ordinary temperature is taken = 1 gramme; then a litre is reckoned as containing 1,000 grammes or 1,000,000 milligrammes, and use is made of this in determining "free and albuminoid ammonia," which is stated in *parts per million*—*i.e.*, the number of milligrammes found when a litre of water is operated on.

Set of Apparatus and Reagents for Brewing Laboratory.

(*a*) Apparatus.

1 doz. Petrie Dishes.
3 Large Glass Cylinders, 500 c.c. graduated.
3 Mash Flasks, graduated at 515 c.c.
1 Hot Water Oven complete with burner and stand.
3 Hydrometer Tubes.
2 lbs. Assorted Glass Tubing.
1 Revenue Still, Dr. Thorp's.
1 Seed Germination Apparatus for Barley.
1 Government pattern Arsenic Testing Apparatus.
1 doz. Tubes for same.
1 pkt. Filter Papers.
1 Retort Stand with rings and clamp.
1 Filter Stand for two funnels.
1 Hydrometer 1,000 to 1,500.
1 set of 4 Beaume Hydrometers.
1 Glass Syphon with suction tube.
2 Glass Saccharometers.
1 Copper Forcing Tray.
2 doz. Yeast Forcing Flasks for same.
1 Aspirator, 3 Litres with stopcock.
1 Graduated Cylinder 1,000 c.c.
1 Hot Air Drying Oven and stand.

* *E.g.*, the lb. Avoirdupois is heavier than the lb. Troy; but its ounce is lighter than the Troy ounce.

1 Bunsen Burner with rose top.
1 Ordinary Desiccator.
1 Vacuum Desiccator.
1 doz. Evaporating Basins, assorted.
1 piece Platinum Foil 1″ × 1″.
1 doz. Beakers with spouts, assorted.
4 Glass Evaporating Basins.
1 pair Adjusted Watch Glasses.
3 Glass Funnels, small.
1 Large ditto.
2 Stoppered Flasks, graduated 1 Litre.
2 ditto 500 c.c.
1 ditto 250 c.c.
1 ditto 100 c.c.
1 ditto 50 c.c.
1 Burette, 100 c.c. in $\frac{1}{5}$th with stopcock.
1 Burette Stand.
2 each Pipettes 100 c.c., 70 c.c., 50 c.c., 25 c.c., 20 c.c., 10 c.c., and 5 c.c.
1 Pipette 2 c.c. for nesslerizing.
1 Pipette, 10 c.c. graduated in $\frac{1}{10}$th c.c.
2 doz. Test Tubes 6″ × $\frac{5}{8}$″.
1 Test Tube Stand with holes and pegs.
1 Liebig Condenser 45 cm.
1 Stand for ditto.
1 Quire Thick Grey Filter Paper.
100 Swedish Filter Papers.
3 Boiling Flasks, 1,000 c.c.
1 Specific Gravity Bottle and counterpoise 50 Grm.
12 ft. Black I.R. Tubing for gas.
3 Boiling Flasks 500 c.c.
3 ft. Assorted I.R. Tubing for connections, etc.
$\frac{1}{2}$ lb. Glass Rod for stirrers, etc.
1 set of Cork Borers.
1 each File, triangular and rat-tailed.
1 Becker's Balance sensible to 1 milligramme, Agate knives and planes.
1 set Weights for ditto.
2 Nessler Glasses 50 c.c.
1 Retort, 500 c.c. tubulated.
1 Retort Stand with ring for above.
1 White Glazed Tile.
2 Tinned Iron Sand Baths.
1 pair Gunmetal Crucible Tongs.
1 set Wood Blocks for supporting apparatus.
3 Winchester Quart Bottles.
2 Squares Iron Wire Gauze.
2 Water Baths, copper.
2 Tripod Stands.
$\frac{1}{2}$ doz. Assorted Pipeclay Triangles.
1 doz. Assorted Rubber Corks.
4 doz. Assorted Corks.
1 Mortar and Pestle, stoneware.

Additional Apparatus.

Polarimeter, S. & H. $\frac{1}{2}$ shadow, 2 prisms, Lippich model.
1 Microscope and Objectives, $\frac{1}{8}$″ and $\frac{1}{2}$″.
2 Hearson's Incubators 25° C. and 37° C. 12″ × 12″ × 14″.
1 Lovibond Tintometer Set 3*a*.
1 Seck Mill.
1 Platinum Dish 1$\frac{1}{4}$″ diameter, 25 c.c. capacity.

(*b*) REAGENTS.*

Potassium Ferrocyanide, pure.
Acetic Acid, glacial.
Animal Charcoal.
Lead Acetate, tri-basic.
Red and Blue Litmus Papers.
Litmus solution.
Sulphuric Acid, pure for analysis.
Hydrochloric Acid ,, ,, ,,
Nitric Acid ,, ,, ,,
Ammonia ·880 pure.
Decinormal Ammonia.
Sodium Carbonate, recryst.
Caustic Soda, pure sticks.
Caustic Potash ,, ,,
Calcium Chloride, pure.
Cochineal.
Alcohol, absolute.
Methylated Spirit.
Iodine, recryst.
Potassium Iodide.
Indigo Solution.
Copper Sulphate, recryst.
1 lb. Rochell Salt
1 lb. Mercury perchloride.
1 lb. Ammonium Chloride, pure.
1 oz. Silver Nitrate, recryst.
1 lb. Potassium Chromate, pure.
1 lb. ,, Permanganate, pure cryst.
Oxalic Acid, pure
Ammonium Oxalate, pure.
,, Carbonate, pure.
Barium Chloride, pure.
Iron proto sulphate, pure.
Sodium Amalgam.
Zinc, Arsenic free.

The above apparatus and Reagents packed in case complete £41, and can be supplied by Messrs. Townson & Mercer, Ltd., 34, Camomile Street, E.C. 3. Any item included in the above list can be omitted, and others substituted.

* Reagents are of course included in the price given.

Preparation of the Apparatus.—Fit the wash-bottles with corks bored with two holes, through which bent glass tubes are to be passed; one short and bent at a wide angle passes just through the cork, the other bent at a sharper angle has the end of its shorter limb contracted nearly to a point, while the longer straight limb passes through the cork and nearly to the bottom of the flask. [Glass tubing is bent by holding it, a hand on either side of the flame, in the upper part of a gas-jet, and turning it round all the while to get it softened uniformly. Then by *gentle* pressure it can be bent at any required angle. A pointed end is got by softening as before described, and moving the two hands wider apart. A nick with a file where the tube is drawn to a very small bore will enable the operator to break it at the desired place, as it will enable him to divide all other glass tubing of moderate size. Rough edges may be filed, and made smooth in the gas-jet.]

If then the flask is filled with distilled water and the cork with its tubes fitted closely, upon blowing through the shorter tube water is driven out of the pointed tube in a fine spray, just adapted for washing filter residues. Arrange the **drying-oven.** The cheaper japanned sort has three movable legs. Fit a perforated cork into the small opening and fix your thermometer (graduated up to 300° C.) firmly in the cork, so that the quicksilver end is in the interior of the oven.

Slip one end of convenient lengths of vulcanised tubing over the straight-nozzled gas taps, and the other over the inlet pipes of the Bunsen burners. (N.B.—If the tubing be a shade small for slipping over readily, wetting the pipe will facilitate matters.) Get the **desiccator** ready. If you have the cheapest form, which, except the cover, is moulded in one piece, place a few bits of pumice-stone in the lower portion, and pour in sulphuric acid enough to nearly cover them. [The sulphuric acid absorbs moisture greedily, and therefore keeps the desiccator *dry*.] Fit on the perforated zinc on which your glass pan or platinum dish is to stand, and smear a little lard round the finely ground edge on which the cover fits. This will keep the cover from slipping, and make the interior perfectly air-tight.

Put **the balance** on its special shelf. If one of Becker's cheap balances (turning to a milligramme), which are quite good enough for the student-operator, be used, a rectangular glass case, procurable from an operative bird-stuffer for about 15s., will protect it as well as the expensive balances are protected by their specially made cases. The setting-up and adjusting of the balance (by the little screw disc at one arm) must be learnt from some one who knows how to do it, though the task is simple enough.

Before proceeding to actual work, it is necessary to get the weight of, or "to tare," (i) the two or three glass basins which will be used; (ii) the platinum dish, which will be used for igniting residues; (iii) the specific gravity bottle—filled with water at 15·5° C. (= 60° Fahr.), under which conditions its contents are supposed to weigh 50 grammes, but are seldom exact. [The counterpoise = weight of *empty* bottle, is put in scale-pan with the weights.]

The glass basins and platinum dish must be previously dried in the drying-oven at 100° C., and put without loss of time into the desiccator to cool, and the weighing quickly done. Let us assume that glass pan No. 1 (scratch the figure on it with a file) weighs 27·922 grammes (*i.e.*, 27 grammes and 922 milligrammes), that glass pan No. 2 weighs 23·203

grammes, the platinum dish 14·216 grammes, and the water-filling specific gravity bottle 49·983 grammes.

We will now suppose the student with all his apparatus and reagents carefully arranged to hand, in strict attention to Sir H. Roscoe's dictum that "**he who works in a mess will frequently have his mind in a muddle.**"

The first thing to do will be to make the copper-sulphate solution known as **Fehling's Solution** or **Fehling,** which is more satisfactory than buying it ready-made,* though it can be so procured from any dealer in chemical appliances. Decimal weights and measures are used throughout, as more convenient and easy.

Fehling's Solution is the test-reagent for glucose and maltose ; its use depends on the fact that, though it can be boiled alone without undergoing change, yet the addition of a trace of grape-sugar is enough, upon warming, to precipitate from the *blue* solution a portion of the copper as protoxide—Cuprous oxide Cu_2O—and the larger the amount of grape-sugar added, up to a certain point, the greater will be the amount of copper precipitated, till a point is reached when all the blue colour derived from the sulphate is gone, and all the copper lies at the bottom of the vessel as a red precipitate.

It is prepared as follows, the ingredients being :—

34·64	grammes	sulphate of copper
173	,,	Rochelle salt (sodium potass. tartr.)
60	,,	caustic soda.

Crush rather more of the sulphate than is likely to be required, and dry between blotting-paper. Dissolve the salts separately, and mix *after* they are dissolved, adding the caustic soda *last.* Make the whole up to 1 litre. (N.B.—The ring scratched round the neck of the flask a short distance below the stopper is the mark up to which the flask is to be filled. Use distilled water.) [Or where the test is infrequently used the solutions may, to avoid deterioration, be made up separately, the copper solution in one 500 c.c. measure and the Rochelle salt and caustic soda in another, and *carefully mixed in equal quantities* as required. Allen advises, as rendering the solution more permanent, 180 grammes of Rochelle salt and 70 of caustic soda.]

Then 10 c.c. of this solution corresponds to ·05 gramme of glucose ; that is to say, if such a quantity of any saccharine solution as contains ·05 gramme of glucose be run gradually into a porcelain dish, already containing 10 c.c. of Fehling which has been raised to boiling point (over a Bunsen, with or without a sand dish) and be stirred meanwhile with a glass stirring rod, the mixture being still kept boiling, the strong blue colour of the Fehling will disappear, and the liquid become clear as water, or nearly so, but with a red precipitate of cuprous oxide (Cu_2O). A yellowish tinge is a sign that too much of the sugar solution has been run in (the caustic soda gets to work when *all* the copper salt is precipitated), but if the exact point at which the blue disappears be read off (the

* Note that the solution must be kept away from the air and light, otherwise it is liable to undergo a change which makes it untrustworthy. On this account old Fehling should be tested by diluting a small quantity with its own bulk of water and heating to boiling for a few minutes. It ought to remain perfectly clear,

saccharine liquid is run in from a burette * graduated into c.c. and tenths of a c.c.), it is manifest that the percentage quantity can be readily calculated. An example or two will make this clear.

First of all, however, it is advisable to test the correctness of the Fehling itself. This is done by taking some of the purest cane-sugar that can be got (that which is sold, or which used to be sold, as Finzel's crystals), of which 2·5 grammes, dried *moderately* in drying oven, is dissolved in about 200 c.c. of water and boiled for one hour with 2 c.c. of purest hydrochloric or sulphuric acid, which is afterwards nearly neutralised (*i.e.*, so that it will only *very faintly* redden blue litmus paper) with carbonate of soda or with standard potassic hydrate (caustic potash), and finally made up to a litre.

Suppose the burette filled with 100 c.c. of the above now inverted sugar-solution, 10 c.c. of Fehling (it is sucked up into a 10 c.c. pipette, so as just to come up to the mark round the upper stem) is placed in a porcelain dish, which is then heated over a Bunsen burner. A small quantity of the sugar solution (about 2 c.c. at a time to begin with) is then run in and boiled, the mixture being stirred all the while. When the blue colour begins to get faint add the sugar solution drop by drop ; finally when the colour is gone and the deep-red cuprous precipitate lies at the bottom of the dish, read off from the burette the quantity run in. Suppose this to be 19·1 c.c. Then the calculation will be as a Rule of Three sum.

$$19{\cdot}1 : 40{,}000 :: {\cdot}05 = 104{\cdot}712$$

[40,000 = 1,000 (c.c.) × 40 to bring the 2·5 of sugar up to 100 grammes in order to get percentage.]

Then it will be necessary to subtract 5% (= 5·235) from this, because 100 parts cane-sugar = 105 parts glucose.

104·712 — 5·235 = 99·477% of cane-sugar in the sample, a high but very probable percentage. Wherefore the Fehling may be taken as correct.

Volumetric and Gravimetric Methods.—The above, or any analysis of glucose, invert-sugar, etc., conducted on similar lines is known as the volumetric method. Another method, as follows, is known as the gravimetric method.

About 30 c.c. of Fehling is added in a beaker to 50 c.c. well-boiled and boiling water [it is well to have this beaker within another beaker of boiling water]. Then a known volume of the glucose-containing liquid, but not enough to discharge *all* the blue, is added, and the boiling continued for 12 to 15 minutes. Then the precipitated Cu_2O is quickly filtered, washed with well-boiled water, dried and ignited in a porcelain crucible with the filter-paper † for 20 minutes. The ignition should

* A burette is a rather long tube of stout glass, stoppered at the top and with a glass cock at the bottom, capable of letting out the contents drop by drop. It contains 100 c.c. of fluid, and is graduated in front, so that the number of c.c. run out, or any fraction of one, can be easily read off. It is placed in a vertical position on a simple stand in front of the operator. The cock of glass, well ground in, can be treated with a little lard to make it quite watertight, if necessary.

† It is needless to say that the ash of the filter-paper should be taken into account (tared). Half a dozen or so of the kind and size used may be ignited and the ash carefully kept together and weighed. The total divided by 6 may be recorded in the note-book on some page easily referred to, with tares of the other things (*e.g.*, platinum dish, specific gravity bottle, glass evaporating basins) frequently used.

convert the Cu_2O into black cupric oxide CuO, which is then cooled in the desiccator and quickly weighed, as the oxide is very hygroscopic. The CuO found multiplied by ·4535 will give the quantity of glucose in the quantity of the solution which was added.

The factor for *cane-sugar*, after inversion, is ·4308.

But if the ignition is only enough to burn the filter-paper without converting the Cu_2O into CuO the factors employed should be ·5042 for glucose, and ·4790 for sucrose (cane-sugar) after inversion.

Want of space prevents any gravimetric calculations being appended, but the student will be able from the above date to make his own calculations; he will find it instructive to check his results got by volumetry by those that the gravimetric method gives him.

Examination of Commercial Glucose (or Invert-sugar).—Dissolve 2·5 grammes in 500 c.c. water (= 100 grammes in 20,000 c.c., which will be the middle term of the first Rule of Three sum below).

There will be two separate determinations (α) to determine the percentage of existing glucose; (β) to determine the dextrin.

(α) Boil 10 c.c. of Fehling over a Bunsen as before, and run in solution as previously directed from the burette. Then suppose it takes 15·2 c.c. to just precipitate all the copper. The calculation will be—

$$\begin{array}{c} 15{\cdot}2 : 20{,}000 : : {\cdot}05 : x \\ \dfrac{20{,}000 \times {\cdot}05}{15{\cdot}2} = 65{\cdot}78\% \text{ of glucose in sample.} \end{array}$$

Preparatory to determination β 200 c.c. of the above solution is taken, and with addition of 4 c.c. sulphuric acid boiled for 3 hours.

It is then cooled and made up to 250 c.c. at 15·5° C. (= 60° Fahr.). Consequently, in the second solution the glucose will be dissolved in the proportion of 100 grammes in 25,000 c.c., which number will accordingly be the middle term.

As before, 10 c.c. of Fehling is boiled, and the solution run in from the burette. Suppose it takes 16·7 c.c. to neutralise this time. The calculation will be—

$$\begin{array}{c} 16{\cdot}7 : 25{,}000 : : {\cdot}05 \\ \dfrac{25{,}000 \times {\cdot}05}{16{\cdot}7} = 74{\cdot}85. \end{array}$$

74·85 — 65·78 (ascertained glucose) = 9·07, but from this 10% has to be deducted, viz., ·907 (because 9 parts dextrin = 10 glucose), which leaves 8·16.

Consequently the brewing value of the commercial article appears to have been

Glucose	65·78%
Dextrin	8·16%
	73·94%

Examination of Raw or Refined Cane-sugar.—Two grammes of cane-sugar are dissolved in 100 c.c. water, and boiled for 1 hour with 2 c.c. strong sulphuric acid to invert it, and made up to 500 c.c. (the acid should be neutralised).

Suppose it takes 12·5 to precipitate the Cu_2O (10 c.c. of Fehling to be used as before), the calculation will be

12·5 : 25,000 : : ·0475 = 95.
Deduct $\frac{1}{20}$, because 95 parts cane = 100 invert } = 4·75
90·25% of cane-sugar in sample.

Determination by Opticity.—Ten grammes sugar are dissolved in 100 c.c. water, and the solution polarised at 60°. Suppose the observed angle = 6·4 for the 1-decimetre tube; then 6·4 × 100 ÷ 10 = 64 $[a]_D$ of sample, and 64 × 100 ÷ 66·5 ($[a]_D$ of pure cane-sugar) = 96·24% of cane in sample.

[But note that very many samples of raw cane-sugar contain considerable quantities of invert, to determine which a preliminary trial with Fehling, before boiling with acid, is to be recommended. For inverted cane-sugar the third term is ·0475 instead of ·05 as with dextrose.]

Difficulty of deciding if Right Quantity has been run in.—Muddiness, or dull greenish colour, due to impurities, may make it hard to decide if enough saccharine solution has been run in. The usual way of ascertaining if any unaltered *cupric* salt remains is to filter some of the mixed fluid into a beaker (previously washing filter paper or filter with hot water), acidify with a few drops of acetic or hydrochloric acid, and add *one* drop of potassium ferrocyanide. A more or less brown colour will show if any *cupric* salt (insufficient saccharine solution) remains. Ling and Rendle now recommend ferrous thiocyanate as indicator (one drop on a white slab to a drop of *unfiltered* solution), any cupric salt oxidising the ferrous one to ferric, and giving the red colour of ferric thiocyanate. Evident advantages are speed and avoided risk of cuprous oxide in the filtrate being oxidised to cupric, and so giving false indications.

Opticity (ref. *Polarimeter*, pp. 166—169).—Determination of this by a half-shadow instrument, which gives best results with a solution having a gravity of 1040 at 60° Fahr., though the error with higher gravities is said to be slight, affords a close indication of the composition of a sugar, *e.g.*—

Took solution of "invert," having a gravity of 1057.
$\frac{57}{3·86}$ = 14·76 grammes of solid matter in 100 c.c.
Observed rotation (in 1-decimetre tube) = − 2·2.
14·76)−220 (*i.e.*, 2·2 × 100.
14·9 = $[a]_D$ or opticity of sample.
But the [a] of absolute invert = − 21·3; therefore
21·3 − 14·9 = 6·4 deviation due to cane (or residues expressed as cane-sugar).
Then − 21·3 to 66·5 (the $[a]_D$ of cane-sugar) = 87·8.
$\frac{640}{87·8}$ = 7·28 percentage of cane, etc., in sample.

Testing Malt for Maltose and Dextrin.—The method of Dr. Graham, which consisted in expressing all bodies having an immediate reducing action in terms of maltose, and all increase in reducing power consequent upon boiling with acid in terms of dextrin, has been criticised by Messrs. Morris and Moritz on grounds which must be admitted to have weight.

(1) No previous estimate being made of the ready-formed sugars, consisting partly of non-reducing cane-sugar and partly of two different

reducing sugars, it follows that the two latter, although they have distinct reducing powers (maltose ·0807 = 10 c.c. Fehling, dextrose ·05 = 10 c.c. Fehling), are both estimated as maltose.

(2) Upon boiling with acid, the cane-sugar existing in the malt is inverted at the same time as the dextrin is converted into dextrose, so that its product goes to swell the calculated dextrin total; and a further error is introduced by the assumption that the reduction is due to dextrose alone, whereas it is partly due to invert, with, as we have seen, a different reducing power. The total error may be an increase of 4% or 5%.

They further contend that the boiling with acid has other drawbacks. The dextrin, they say, is either not completely converted into dextrose, or, if it be converted thoroughly, then some of the previously existing dextrose gets converted into *non-reducing* bodies; and, further, that some of the albuminoids are converted into bodies which have a reducing action upon Fehling's solution. Much the same objection was made by Mr. Heron nearly nine years earlier.

The accuracy of the method, well thought out as it is, recommended by those authors is open to some doubt, and the following suggested modification is probably not less exact, though may be easier, and depending on the volumetric method alone. That the gravimetric method, in the hands of a skilled operator who is secure from interruption, may be more exact, the present authors will not dispute, but they still maintain that close results may be got volumetrically if care be taken when the point is reached at which all the copper sulphate appears to be precipitated to run in another drop or two of the solution, and then to filter a very small quantity, and test this filtrate with potassium ferrocyanide. The initial steps are :—

(1) **Cold-Water Mash.**—Twenty-five grammes of rather finely crushed malt are thoroughly mixed with 250 c.c. of water, or, better, 50 grammes with 500 c.c. The mixture, stirred at frequent intervals, is allowed to stand for 2 hours, and is then filtered bright. 10 c.c. of the filtrate will contain the cold-water extract of 1 gramme of malt (*i.e.*, the ready-formed sugars, the acid, mineral matter, and albuminoids soluble in cold water).

(2) **Hot-Water Mash.**—Fifty grammes of malt (crushed) in a coffee-mill, or a Seck laboratory mill, kept for the purpose) are stirred into 400 c.c. of water—at a temperature (about 154° to 155° Fahr.) which will give an " initial " of 150° Fahr. An accurate thermometer should be used, and the beaker kept standing on a sand-bath over a gentle flame. Stir frequently for the first half hour, and maintain at 150° for 1 hour; during the next 20 minutes raise gradually to 160°, and then rapidly to boiling. Filter hot into boiling flask, washing the " grains " with nearly 100 c.c. of hot water. Boil for half an hour, cool, filter, and make up to 500 c.c. Then 100 cc. contains the starch-conversion products of 10 grammes malt.

[Though the above approximates, with one exception, to usual mashing conditions, the exception is an important one, which perhaps accounts for the difference between some laboratory extracts and mash-tun results. This is the much higher ratio of the solvent, the proportions in actual mashing being about malt 47 : 100 water, whereas in the laboratory they are 10 : 100.]

We will now take the figures of an actual operation, referring to pp. 168—169 for polarimetric details.

Cold-water mash (filtrate from).

Specific gravity = 1007·45.

$\frac{7\cdot45}{3\cdot86}$ = 1·93 solid matter in 100 c.c. = 10 grammes of malt.

∴ Solid matter in 100 grammes = 19·3% (soluble in *cold* water).

Opticity.—Angle observed in a 2-decimetre tube = 1·6 = 0·8 for a decimetre tube.

Then $\frac{\cdot8 \times 100}{1\cdot93}$ [=a]$_D$=41·45.

Reducing power (α before inversion, β after inversion of 100 c.c. with 25 c.c. yeast-water):—

(α) 7·0 c.c. = 10 c.c. Fehling; then

7·0 : 1000 : : ·064* = 9·14%, *say* { 4·5 Maltose. 3·1 Dextrose. 1·54 Levulose.

(β) 4·5 cc. = 10 c.c. Fehling; then

4·5 : 1250 : : ·0577—16·0%—*i.e.*, 6·86% cane-sugar as invert; and 6·86 × $\frac{95}{100}$ = 6·51.

Therefore r.f.s. = 15·65% (9·14 + 6·51).

Then 19·3% — 15·65%=3·65=min. matter, acid and albuminoids soluble in cold water.

[Albuminoids, etc, will, however, be determined from the hot-water mash.]

Hot-water mash (filtrate from).

Specific gravity = 1027·4.

27·4 ÷ 3·86 = 7·1 solid matter in 100 c.c. = 10 grammes malt.

∴ Solid matter in 100 grammes = 71%.

Reducing power (20 c.c. diluted to 100 c.c., of which 10·9 = 10 c.c. Fehling):—

10·9 : 5000 : : ·0807 = 37% maltose due to starch.

Opticity (observed angle) = 8·6 (for the 1-decimetre tube):—

$\frac{8\cdot6 \times 100}{7\cdot1}$ = 121·1 = [a]$_D$.

Then, subtracting the observed angle of the cold-water extract from that of the hot-water extract (each representing 10 grammes per 100 c.c. under their respective conditions):—

8·6 — 0·8 = 7·8, angle due to starch-conversion products.

And 3·7 (maltose in 10 grammes) × 1·354 (angular deviation caused by 1 gramme maltose per 100 c.c. in 1-decimetre tube) = 5·01 deviation due to maltose (β).

And 7·8 — 5·01 = 2·79 deviation due to dextrin.

2·79 ÷ 1·95 (angular deviation of 1 gramme dextrin) = 1·43 (or 14·3% dextrin.

* The average proportions of the ready-formed sugars are, nearly enough, 4 cane, 3 maltose, 2 dextrose, 1 levulose (the combined dextrose and levulose slightly exceeding the maltose generally). Now their volumetric reducing values are (= 10 c.c. Fehling): Maltose, ·0807 gramme; dextrose, ·05 gramme; and invert (equal parts of dextrose and levulose), ·0475 gramme. So these third terms are got on the following basis:—

(α) $\frac{(\cdot0475 \times 2) + \cdot05 + (3 \times \cdot0807)}{6}$ = ·0645.

(β) $\frac{(\cdot0645 \times 3) + (\cdot0475 \times 2)}{5}$ = ·0577.

The second terms of the proportion sums 1000 and 1250 are used to bring calculation into a percentage at once, 100 c.c. made into 125 c.c. in β equalling 10 grammes malt.

We have now the following figures :—

Ready-formed sugars = 15·65; maltose (from starch conversion) = 37·0; dextrin = 14·3, or 66·95 out of total soluble solids of 71%. [These figures will be carried on to p. 185.]

Amylöin Theory : its Bearings on the above Figures.—It will be well to refer to this point here before proceeding to the acidity and albuminoid determinations ; although, as the theory will be rather fully dealt with farther on (pp. 242—243), and is, moreover, contested, or at most accepted as a working hypothesis by many, the method for determining malto-dextrins (as definite compounds) will not be detailed.

To quote one of the main upholders of the theory : " In the ordinary methods of analysis, the maltose, whether free, or combined as malto-dextrin, will appear entirely as maltose, while the dextrin, whether combined or free, will appear as dextrin. Consequently, in the ordinary analysis, we get our total maltose and our total dextrin, quite irrespective of the amount of each which is free and the amount which is combined. Here are two typical analyses where the percentages of total maltose and total dextrin expressed on 100 parts starch are the same. The figures chosen are integral, so as to make the point as clear as possible.

	A.		B.	
Free Maltose . . .	65	75	73	75
Combined Maltose .	10		2	
Combined Dextrin . .	5	25	5	25
Free (stable) Dextrin .	10		20	

In both these cases the total maltose is 75, and the total dextrin 25, so that had these worts been analysed in the ordinary way, and without regard to malto-dextrins, they would appear the same in constitution ; and they would naturally be regarded as about to yield the same results as regards attenuation, and as regards general character of finished beer. But the recognition of the malto-dextrins indicates that, although identical in respect of total maltose and dextrin percentages, the worts will yield *entirely* different results. For instance, wort A will not attenuate to nearly so low a point as wort B, and the beers yielded by these worts will be entirely different in palate, rate of conditioning, stability, and brightness." *

Let us examine this contention a little. The examples are owned to be hypothetical, and they are indeed so extremely hypothetical as to be at variance with the analytical results given in another part of the same paper. In those examples it appeared that as the quantity of malto-dextrin increased, the type rose also as a general rule ; that is to say, the malto-dextrin compound contained less and less maltose and more and more dextrin. It was only when the quantity of malto-dextrin was low, that its type also was so low as to bear the proportion of maltose 2 : dextrin 1 (as in the hypothetical example A), and this was only in the case of an undercured malt, while those purporting to give the results of mash-tun determinations never showed a lower proportion of maltose to dextrin than maltose 1 : dextrin 1.

Therefore, even if the amylöin theory be proved up to the hilt, it appears that the want of precision lies within much narrower limits than

* " Transactions of the Institute of Brewing," iv., No. 6. Paper by Dr. Moritz.

the above hypothetical example would make it, and that if the dextrin found be worked out as a percentage of actual starch or rather of the carbohydrate portion of the soluble extract, any surplus shown above the 20% of stable dextrin will give a fair indication not only of the amount but of the type of malto-dextrin likely to be formed under the given conditions.*

Of course the indication will not always be very exact, but if the surplus of dextrin is low we may take it that neither quantity nor type is likely to be high; if the surplus of dextrin is high that type, almost certainly, and quantity, most probably, will be high. And it may be added that the dextrin should apparently come out a shade higher than analyses give it, seeing that recent researches have gone far to prove that there is an unfermented residue in beer which is not maltose but which yet has cupric-reducing power; and owing to this amount not requiring correction (for if it were glucose it would ferment away), the correction " maltose into glucose " is somewhat lessened, so that the dextrin amount is fractionally increased.]

Acidity in Malt.—The method of testing for acidity here to be described is based upon chemical equivalence and the use of solutions accurately titrated or standardised.

For example, three distinct kinds of solution will be required; a standard or normal acid solution made with oxalic acid; a corresponding normal alkaline solution of ammonia, or of what is perhaps preferable, sodic hydrate (pure caustic soda); and a solution of litmus, though litmus paper can be made to do. All these can be bought ready prepared, but for the sake of clearness the preparation of the standard acid and alkali solutions will be explained here, the method of making the litmus solution being left to the end of this chapter.

Of the other solutions, not only are standard or normal solutions required, but also one $\frac{1}{10}$ of the strength, and another $\frac{1}{100}$ of the strength, that is to say, 100 c.c. and 10 c.c. respectively of the normal solution diluted to a litre (1,000 c.c.). The decinormal, *i.e.*, the $\frac{1}{10}$ solution, is written shortly $\frac{N}{10}$, the centinormal $\frac{N}{100}$.

It has been said that the preparation of the standard solutions is based upon equivalent values, that is to say, the atomic weights are totalled up in each case, and their sum gives the exact quantity which corresponds to, or neutralises, each of the others. Only it must be noted that in the case of oxalic acid, which is a *bivalent* compound, only half the quantity represented by the total weight will be required. It will be worth while to set forth the calculation at length.

Oxalic Acid—$C_2H_2O_4 + 2\ H_2O$.

$H_2 = 2$; $C_2 = 24$; $O_4 = 64$ . . .	= 90
The two molecules of water of crystallisation .	= 36
	126

* The 20% of stable dextrin is calculated on the *starch* of the malt. This, by referring to Mr. O'Sullivan's analyses in the previous chapter the reader will see averages about 45%. The stable dextrin will accordingly average about 9% on the malt, so that the amount above this, in our analysis 6·94, may be taken as approximating to combined dextrin.

Of which half, as stated above, viz., 63 grammes, is dissolved in a litre to make the normal solution; consequently the $\frac{N}{10}$ solution contains 6·3 grammes and the $\frac{N}{100}$ solution ·63 gramme.

Ammonia NH_3.

$$N = 14 : H_3 = 3 = 17.$$

Accordingly 17 grammes in a litre will make the normal solution.* [63 grammes oxalic acid correspond to 17 grammes ammonia, and 6·3 of the first to 1·7 of the latter.]

Sodic Hydrate NaOH.

$$Na = 23 : O = 16 : H = 1 = 40.$$

Accordingly 40 grammes in a litre will make the normal solution, of which 1 c.c. will neutralise the acid of 1 c.c. of the normal oxalic acid solution. But oxalic acid is not the acid of malt or beer; these are lactic or acetic. We will, therefore, compare their molecular totals with those already taken, to learn what relation those acids bear to the standard alkaline solutions.

Lactic acid ($C_3H_6O_3$).

$$C_3 = 36 : H_6 = 6 : O_3 = 48 = 90.$$

Consequently 90 grammes lactic acid = 17 grammes ammonia, or 40 of sodium hydrate. That is to say, 9 of lactic acid = 1·7 of ammonia or 4 of sodic hydrate, and so on. Conversely a litre of either alkaline solution (normal) will represent (*i.e.*, neutralise) 90 grammes of lactic acid, a litre of the $\frac{N}{10}$ solution will represent 9 grammes, and a litre of either alkaline $\frac{N}{100}$ solution will represent ·9 gramme (this equivalence will be used in the calculations).

Acetic acid ($C_2H_4O_2$).

$$C_2 = 24 : H_4 = 4 : O_2 = 32 = 60.$$

Therefore 6 and ·6 grammes acetic = 9 and ·9 lactic acid in neutralising the alkaline solutions. Accordingly a litre of either normal alkaline solution = 60 grammes acetic, and a litre of the $\frac{N}{10}$ and $\frac{N}{100}$ solutions 6 and ·6 grammes respectively.

Preparing Infusion for Acidity Test-process and Calculation.—Twenty c.c. of the hot-water filtrate is made up to 100 c.c.; 50 c.c. of the above are taken—*i.e.*, 1 *gramme of malt* is dealt with.

The $\frac{N}{100}$ ammonia is used, run in from a burette upon the 50 c.c. in a porcelain dish and tested at intervals with litmus paper. Suppose it takes

* Best got by taking about 19·32 c.c. of *liquor ammoniæ fortior* having a specific gravity of about ·880 and making up to a litre. But in any case it, as well as the sodic hydrate solution, must be standardised against the normal oxalic acid—*i.e.*, when equal bulks are mixed and tested with litmus paper, there must be neither acid nor alkaline reaction.

3·2 c.c. of the $\frac{N}{100}$ ammonia before neutrality is produced. We have seen that 1 litre (*i.e.*, 1,000 c.c.) of $\frac{N}{100}$ ammonia = ·9 lactic acid. So the calculation will be—

1 gramme (the quantity of malt dealt with) took 3·2 c.c. Therefore 100 grammes would take 470 c.c.

$$1000 \quad 320 :: \cdot 9$$
$$= \cdot 288\% \text{ lactic acid.}$$

[Mr. Allen, however (in *Commercial Organic Analysis*), says: "The normal proportion of free acid, calculated as lactic acid, is not more than ·2%, or at most ·3%; ·4% is unusually high, and denotes unsoundness." This is going rather far. Moreover, it must be remembered that though expressed in terms of lactic acid, other acids (*e.g.*, aspartic) probably contribute. Litmus is probably insensitive to the acid of acid-phosphates (*cf.* pp. 64 and 65), which are, besides, estimated in the ash.]

Albuminous Matters.*—Very concordant results, although its trustworthiness has been disputed, can be got by using Professor Wanklyn's ammonia process, albeit specially devised for determining the amount of pollution in water. For this method three standard solutions will be required, instructions for the preparation of which will be found at the end of this chapter. These solutions are (1) Nessler's solution; (2) standard ammonium-chloride solution; (3) solution of potash and permanganate of potash.

More detail will be found when the testing of water for "free and albuminoid ammonia" is described, but it may be said here that the test depends on the fact that a small quantity of Nessler (in practice 2 c.c. are used in each 50 c.c. of water) reveals the presence of even extremely minute traces of ammonia (1 part in 10,000,000) by striking a tint more or less brown, according to the quantity of ammonia present. The tint is compared with that produced by Nesslerising a second 50 c.c. of water to which a known volume of the ammonium-chloride solution has been added, and when an exactly similar tint is produced (which can be matched quite closely by placing the two tubes side by side on a white tile, and looking at them *through their depth*), the amount of ammonium-chloride solution used in the five or six successive Nesslerisings is read off and translated into ammonia.

In water analysis, after the portions containing the free ammonia have been distilled off and tested, the residue is boiled with some of the permanganate-potash solution, in order to convert the organic matter into ammonia, in which form alone it can be estimated by this process. The same method is adopted in estimating the albuminous matters in malt-

* Of course the analytical data obtained are not those of malt as such, but of its extractable matter *at the temperature employed*. Strictly speaking N should be expressed in terms of amides, peptones, albumoses, etc. (*cf.* p. 61). Hantke's table (p. 63) shows that the amounts of extracted and coagulable matter vary greatly with the initial used. One dictum (for Lager beats) gives the quantity of soluble N that a malt with 9 to 11% porticds should contain as 0·48 to 0·54% (= 0·583 to 0·656 NH_3) for pale and golden malt, and 0·39 to 0·48% (= 0·474 to 0·583 NH_3) for dark, of which about one-fourth should be coagulable.

extract. Care must be taken to use " ammonia-free " distilled water for the cylinder (test-tube) to which the ammonium-chloride solution is added for comparison, and that solution must be run in *before* the Nessler. The 2 c.c. pipette used to measure the Nessler, which can be made by the operator out of a piece of glass tubing, will do to stir up the contents of the cylinders.

Let us now proceed to the actual operation. Take a flask of water two-thirds full, to which a little freshly ignited carbonate of soda has been added. Connect the retort by the beak-shaped tube with the condenser (india-rubber stoppers, suitably perforated, make the tightest joints), and bring the naked flame of a Bunsen burner under the retort. [Of course before the contents of the retort begin to boil, cold water must be flowing continuously through the outer tube of the condenser in order to condense the vapour which comes off.] The vapour as it is condensed is to be caught in one of the Nessler cylinders, file-marked, so that 50 c.c. can be accurately caught each time.

Test the first distillate with Nessler to ensure that all the free ammonia is got rid of, which would otherwise vitiate the result, and as soon as no coloration is produced, 10 c.c. of wort (made by making 100 c.c. of the hot-water filtrate up to a litre), representing accordingly ·1 gramme of malt, is added, and the real distillation begins. After the first and second distillates have been tried with Nessler (the second should be nearly colourless), 100 c.c. of the permanganate and potash solution, previously boiled with 200 c.c. of ammonia-free water, is added. [N.B.—A few pieces of pumice-stone, or broken clay pipe put into the flask, will prevent its " bumping," and possibly breaking. The broken pipe should be heated to redness in a platinum dish or crucible till all the darkish colour which it assumes is gone.]

The first 100 c.c. distilled over is taken and made up with " ammonia-free " water to 500 c.c. Five separate distillates—or six if the coloration continue marked—are taken, and should be made up to 500 c.c. like the first, as long as the coloration is considerable. 50 c.c. of each 500 c.c. (or of the 100 c.c. if undiluted) is Nesslerised, and the parallel results got with ammonium-chloride solution noted, and used as a basis of calculation as follows.

[The first two distillates of 100 c.c. each are supposed to be diluted to 500 c.c. ; the others not to require such dilution, but in each case only 50 c.c. is Nesslerised.]

(1)	100 made up to 500.	50 c.c. took 2·25	= 22·5
(2)	100 ,, ,, 500.	50 c.c. ,, 1·25	= 12·5
(3)	100 (undiluted)	50 c.c. ,, 2·25	= 4·5
(4)	100 ,,	50 c.c. ,, 1·5	= 3·0
(5)	100 ,,	50 c.c. ,, ·5	= 1·0
			43·5

i.e , 43·5 c.c. of the ammonium-chloride solution are used to produce a series of tints equal to those produced by the ammonia evolved from 1 gramme of malt.

But each c.c. of the ammonium-chloride solution = ·00001 gramme of ammonia.

I.e., 0·1 gramme = ·000435 of ammonia, and 100 grammes of the malt = ·435 gramme of ammonia.

Rule.—Now multiply the ammonia got by 5·15 * to get the albuminous constituents of the malt.

$$\cdot 435 \times 5 \cdot 15 = 2 \cdot 240 \text{ albuminous matter.}$$

Accordingly we are now able to fill up the gaps which were left in the analysis of the extract from a sample of malt (p. 178). This will now stand—

Ready-formed sugars	15·65
Maltose	37·0
Dextrin	14·3
Albuminoids	2·24
Lactic acid	0·29
Ash, colouring matter, etc.	1·52
	71·0

Estimation of Nitrogen by Soda-Lime Process. (*a*) **Soluble Albuminoids.**—This method consists in heating the substance dissolved in the smallest possible quantity of water—or malt may be mashed, the wort being just evaporated to dryness, and the dry solids carefully scraped up—with a mixture of caustic soda and caustic lime, called soda-lime,† in a combustion tube, which is either of iron and closed at one end, or of hard glass with one end drawn out to a point, which can be broken off when desired. The nitrogen of the albuminoids is thereupon converted into ammonia, which is led into a known quantity of normal hydrochloric, sulphuric, or nitric acid contained in a special bulb apparatus, where it combines with its equivalent quantity of the normal acid. The amount of *acid* remaining unneutralised is then determined by titration, which amount deducted from the known volume in the tube gives the amount neutralised by the ammonia evolved during the combustion. [On the equivalent principle referred to in the paragraph on acidity determination, the normal solutions contain respectively in 1 litre 49 grammes sulphuric acid, H_2SO_4 (half weight of total atoms), 36·5 of hydrochloric acid, HCl; 63 grammes of nitric acid, HNO_3; 40 grammes of sodic hydrate, NaHO, and 17 of ammonia, NH_3.

[Accordingly, as stated before, any measure of one of the normal acid solutions neutralises *exactly the same measure* of the ammonia or sodic hydrate, if the solutions be correctly made.]

The **Combustion-tube,** some 20 inches long, must first have the bottom covered to the depth of about 3 inches with coarsely granulated (not powdery) soda-lime. Then the dissolved substance, with the rinsings as sparingly done as possible, is run in, and after a few minutes' rest the tube is about three parts filled with soda-lime; or, if it be malt, the carefully evaporated extract, care being taken to secure every particle by rubbing

* This factor 5·15 corresponds with the factor 6·25 used for calculating albuminous bodies from total ascertained nitrogen $6 \cdot 25 \times \frac{14}{17} = 5 \cdot 15$ [17 parts ammonia contain 14 nitrogen].

† Can be bought ready for use at Messrs. Townson & Mercer's.

the dish out with a portion of soda-lime after thoroughly scraping out the contents, is put into the tube. We will assume that the amount operated on represents the dried soluble solids from 5 grammes of malt, mashed with cold distilled water in a beaker, the temperature having been gradually raised to 140° and maintained thereat for one hour. [If a concentrated solution, however, is operated on, an asbestos plug, lightly put in, will prevent any soda-lime being carried over when heat is applied and steam generated.]

Five c.c. of normal acid is now run in the special bulb apparatus (Will and Varrentrapp's), which must afterwards be connected with the combustion tube. The connection must fit quite tightly, and precautions must be taken to prevent the cork or stopper, which fits into the combustion tube, from getting burnt. [N.B.—A piece of cotton waste, wetted and hung upon the end of the combustion tube and on the cork in question, and with its two ends dipping into a basin of water underneath, will keep the end of the tube cool.]

The bulb itself must be put in a vessel of cold water as soon as the combustion tube has been placed in the furnace, with its end (that towards the bulb) projecting some three or four inches.

After the combustion tube has got red-hot and vapour has ceased to come off (if the solution was employed), the bulb apparatus is detached, and its contents and subsequent rinsings emptied into a porcelain dish. Alkali solution is now run in from a burette, and when neutrality is just reached (if a few drops of litmus solution have been previously added, the point is just when its red gets a tinge of violet, or red and blue litmus paper may be alternately tried), the quantity is read off, and the calculation is as follows :—

Suppose the quantity of N alkali run in is 3·7 ; then—seeing that 5 c.c. of N acid was run into the bulb—1·3 gramme will have been neutralised by the ammonia given off.

But each c.c. corresponds to ·017 gramme of ammonia (because 1,000 c.c. contain 17 grammes) or to ·014 nitrogen (ammonia contains $\frac{14}{17}$ of nitrogen).

Therefore ·014 × 1·3 = ·0182 gramme of nitrogen from 5 grammes malt, which × 20 (to bring to percentage) = ·364.

·364 × 6·25 (a factor got by dividing 100 by the average percentage of nitrogen which albumen contains) = 2·275 albuminous matter.

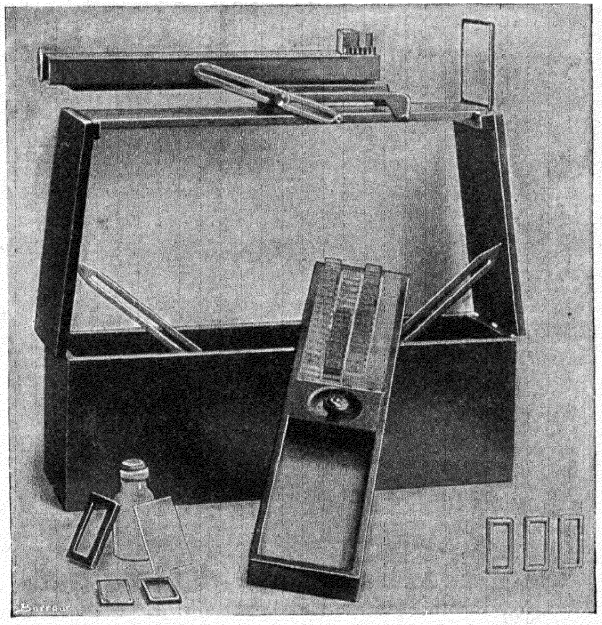
Testing of Malts in Lovibond's Tintometer.—As each brewer desires his own special colour depth in both his pale and his mild ales, he requires his malts to be dried off so that he can obtain from them these special depths of tint.

However the degrees of colour in Lovibond's Tintometer most generally quoted by brewers' chemists for a good bright pale ale malt is 5·0° of Series 52 in a 1-inch cell, and for mild ale malt about 7·0° of Series 52 also in a 1-inch cell.

The 1-inch cell is the standard cell as adopted by the Institute of Brewing. The ½-inch cell is now seldom used, and as each malt has its own specific rate of colour absorption, it is not safe to halve the 1-inch reading to obtain the ½-inch reading, but generally speaking in order to obtain an approximate estimate the 1-inch cell measurement can be halved and then a ·50 glass added to it to equal the ½-inch measurement.

It is recommended that the following formula be followed for laboratory use :—

Extract and Tint.—Fifty grammes of malt are to be weighed out and ground in a Seck mill set at 25, and mashed in a glass beaker of about 500 c.c.s. capacity with 360 c.c.s. of distilled water previously heated to 154—155° F. The beaker is covered with a clock glass, and placed in a water-bath, so that its contents are kept at 150° F. for fifty-five minutes. The mash is stirred at intervals of about ten minutes during this time. The temperature is then raised to 158° F. for five minutes, and the whole mash washed into a flask graduated to 515 c.c., cooled to 60° F., made up



Lovibond's Tintometer.

to the mark with distilled water at the same temperature, well shaken, and filtered.

The above wort, filtered perfectly bright, is to be placed at once in a 1-inch cell, and its tint recorded in colour units of series 52 glasses. Experience has shown that the colour composition of all malts is a combination of orange and yellow and any difference in colour or colour depth is due solely to the varying proportions of these two colours, a correlation of the colours found in malt extracts with the qualities found in the finished beers made from them has demonstrated that those malts which originally contained the greatest proportion of yellow to orange produced beers of a more delicate flavour and of greater brilliancy than those brewed from malts having a lesser proportion.

Total Albuminoids (by Soda-Lime).—The above will give the soluble albuminoids ; if the total albuminoids are required it will be necessary to take the *dry grist*, carefully reweighed after grinding, and to heat the tube

to redness, beginning at the end near the bulb. There should be a portion of soda-lime at the lower end of the *glass* tube, and a portion, likewise unmixed with malt, at the upper end, the grist mixed with the bulk of the soda-lime occupying the space between. The object of having a glass tube and of its being drawn to a point at the bottom is that when the combustion is thoroughly over and the ammonia practically all evolved, the point may be broken off and a gentle current of air blown through, which carries into the bulb any of the ammonia which has been left behind. The calculation will be similar to that already given.

Accuracy of the Soda-Lime Method.—Opinions differ as to this; but it seems that, except in the case of certain compounds, which either do not yield their combined nitrogen as ammonia or not the whole of it, the method may be trusted. With substances very rich in nitrogen the addition of sugar on either side of the substance to be analysed is said to improve the result.

Also a mixture of equal parts of sodium thiosulphate, sodium acetate, and soda-lime, instead of soda-lime alone, appears to give even better results.

Diastatic Activity of Malt.—This may be estimated and classified by Lintner's method. A solution of soluble starch is prepared, of which 10 c.c. represent ·2 gramme, *i.e.*, a 2% solution. It is prepared in the following way. Pure potato starch is covered with hydrochloric acid of 7·5% strength, and allowed to stand for seven days at ordinary temperature or for three days at about 104° Fahr., whereupon it loses its property of forming a paste. It is then repeatedly washed with cold water (by decantation) till litmus paper shows no acid, then drained and dried in the air. The product gives a clear solution with warm water, and of this, as required, 2 grammes are taken and dissolved in 100 c.c. The following is the *original* method of estimating the diastatic power of malt.

In ten test-tubes, containing each 10 c.c. of this solution, are added varying quantities (viz., ·1, ·2, ·3, ·4, ·5, ·6, ·7, ·8, ·9, and 1 c.c.) of a malt extract prepared as given below, in brackets. [An aqueous extract of 25 grammes of finely powdered malt is made, by allowing the mixture to stand for 6 hours at ordinary temperature of the air, filtering and refiltering, if necessary, on the same filter-paper till quite clear. It is then made up to 500 c.c.]

The ten test-tubes after the addition of the malt-extract then stand for one hour—" at ordinary room temperature," Lintner says, but a *uniform* 70° Fahr. is better, after which 5 c.c. of Fehling solution are added to each, and all are placed in boiling water for 10 minutes. [The student who has worked through this chapter will not require the rationale of these steps.]

Then the test-tubes are looked at. If there be one in which the blue colour is exactly discharged that may be taken for classifying, but probably the exact cupric-reducing power will not exactly coincide with the amount of maltose existing in any one of the test-tubes; but there will be one still showing a faint trace of blue, while its neighbour, that had more malt-extract, shows the yellowish tint indicative of its being " over-done." In that case small additions (·02 c.c.) of the malt-extract may be made, successively if necessary, the rest for conversion

of course being allowed; but if rapidity be an object the mean may be taken.

The standard adopted is that when the maltose produced by the action of ·1 c.c. of the malt extract, under the condition prescribed, exactly reduces 5 c.c. of Fehling, the diastatic power = 100.

But suppose ·46 is found to be the exact quantity which precipitates *all* the copper, then $\frac{100}{4 \cdot 6} = 21 \cdot 74$, or correcting for moisture, say 3%, it becomes $\frac{21 \cdot 74 \times 100}{97} = 22 \cdot 41$ for diastatic value of the malt.

This is a low value. A range between 28 and 30 might be looked upon as average. Higher than 35 might imply under-curing, a lower value than 30 might mean insufficient germination. A much over-cured, scorched malt had, in a series of experiments elsewhere referred to, a value of 16·8.

Estimation of Diastatic Power by Titration Method.—Twenty-five grammes of ground malt are to be extracted with 500 c.c. of distilled water for 3 hours at 70° F. and filtered bright, stirring well every half hour. A portion of the filtrate (3 c.c.) is allowed to act on 100 c.c. of a 2% of soluble starch at 70° F. for an hour in a 200 c.c. flask. N/10 caustic alkali (10 c.c.) is then added in order to stop further diastatic action, the liquid cooled to 60° F. made up to 200 c.c. with distilled water at the same temperature, well shaken, and titrated against 5 c.c. portions of Fehling's solution, using thiocyanate as indicator. The titration is carried out as follows:—Five c.c. of Fehling's solution are accurately measured into a 150 c.c. boiling flask and raised to boiling over a small naked Bunsen flame. The converted starch solution is added from a burette, in small quantities, at first about 5 c.c., the mixture being kept rotated and boiled after each addition until reduction of the copper is complete, which is ascertained by rapidly withdrawing a drop of liquid by a glass rod, and bringing it at once in contact with a drop of the indicator on a porcelain or opal glass slab. The results are calculated by the following formula:—

$A = \frac{1000}{X\,Y}$ in which A equals the diastatic activity, X equals the number of cubic centimetres of malt extract contained in 100 c.c. of the fully diluted starch conversion liquid and Y equals the number of cubic centimetres of the same liquid required for the reduction of 5 c.c. of Fehling's solution. The above method (using 3 c.c. of malt to 100 c.c. of 2% solution starch solution) is not accurate for malts having capacity exceeding 50 Lintner; in the case of such malts the relative volume of malt extract must be less, say 2%, or for malts of the highest diastatic capacity such as are frequently used by distillers and vinegar makers (*i.e.*, malts over 80 Lintner), an even smaller volume of extract must be taken (see tables appended, p. 190).

The Detection of Arsenic.

(1) **In Malt.**—Place 50 grammes of malt in a suitable sized flask. Add 100 c.c. water and 15 c.c. pure strong hydrochloric acid. Heat gently to boiling and then drop in a piece of pure copper foil 2 in. × ¼ in., attach a reflex condenser to the neck of the flask, and boil gently for 45 minutes. The reflex condenser returning the

DIASTATIC CAPACITY OR DIASTATIC POWER OF MALTS (" D.P."). (In Degrees Lintner) Standard Method.

(1), 100 c.c. 2% Soluble Starch + 2 c.c. Malt Extract per 200 c.c. (2), 100 c.c. 2% Soluble Starch + 3 c.c. Malt Extract per 200 c.c. (3), 100 c.c. 2% Soluble Starch + 4 c.c. Malt Extract per 200 c.c.

C.C.	1	2	3	C C.	1	2	3	C.C.	1	2	3	C.C.	1	2	3	C.C.	1	2	3
—	D.P.	D.P.	D.P.	—	D.P.	D.P.	D.P.	—	D.P.	D.P.	D.P.	—	D.P.	D.P.	D.P.	—	—	—	—
10	100	66·7	50	16	62·4	41·6	31·2	22	45·4	30·3	22·7	28	35·6	22·7	17·8	34	29·4	19·6	14·7
10·25	97·4	65·0	48·7	16·25	61·4	41·0	30·7	22·25	45·0	30·0	22·5	28·25	35·28	23·5	17·64	34·5	29·0	19·4	14·5
10·50	95·2	63·5	47·6	16·5	60·6	40·3	30·3	22·5	44·4	29·6	22·2	28·5	35·0	23·3	17·0	35	28·6	19·1	14·3
10·75	93·0	62·0	46·5	16·75	59·6	39·7	29·8	22·75	43·8	29·2	21·9	28·75	34·7	23·1	17·35	35·5	28·2	18·8	14·1
11	91·0	60·7	45·5	17	58·8	39·2	29·4	23·	43·4	28·9	21·7	29	34·4	22·9	17·2	36	27·8	18·5	13·9
11·25	88·8	59·2	44·4	17·25	57·8	38·5	29·4	23·25	43·0	28·7	21·5	29·25	34·1	22·7	17·65	36·5	27·4	18·3	13·7
11·50	87·0	58·0	43·5	17·5	57·0	38·0	28·5	23·5	42·6	28·4	21·3	29·5	33·8	22·6	16·9	37	27·0	18·0	13·5
11·75	85·0	56·7	42·7	17·75	56·2	37·5	28·1	23·75	42·0	28·0	21·0	29·75	33·5	22·3	16·75	38	26·2	17·5	13·1
12	83·4	55·6	41·7	18	55·6	37·1	27·8	24	41·6	27·7	21·8	30	33·3	22·2	16·65	39	25·6	17·1	12·8
12·25	81·6	54·4	40·8	18·25	54·8	36·6	27·4	24·25	41·2	27·5	21·6	30·25	33·0	22·0	16·5	40	25·0	16·7	12·5
12·50	80·0	53·4	40·0	18·5	54	36·0	27·0	24·5	40·8	27·2	20·4	30·5	32·8	21·9	16·4	41	24·4	16·3	12·2
12·75	78·4	52·3	39·2	18·75	53·4	35·6	26·7	24·75	40·4	26·9	20·2	30·75	32·5	21·7	16·25	42	23·8	15·9	11·9
13	76·8	51·2	38·4	19	52·6	41·4	26·3	25	40·0	26·7	20·0	31	32·2	21·5	16·1	43	23·2	15·5	11·6
13·25	75·4	50·3	37·7	19·25	51·8	34·5	25·9	25·25	39·6	26·4	19·8	31·25	31·9	21·3	15·95	44	22·6	15·1	11·3
13·5	74·0	49·3	37 0	19·5	51·2	34·2	25·6	25·5	39·2	26·2	19·6	31·5	31·6	21·1	15·8	45	22·2	14·8	11·1
13·75	72·8	48·5	36·4	19·75	50·6	33·7	25·3	25·75	38·8	25·9	19·4	31·75	31·3	20·9	15·65	46	21·6	14·4	10·8
14	71·4	47·6	35·7	20	50·0	33·3	25·0	26	38·4	25·6	19·2	32	31·2	20·8	15·6	47	21·2	14·1	10·6
14·25	70·2	46·8	35·1	20·25	49·4	33·0	24·7	26·25	38·0	25·4	19·0	32·25	31·0	20·7	15·5	48	20·8	13·9	10·4
14·5	69·0	46·0	34·5	20·5	48·8	32·6	24·4	26·5	37·6	25·1	18·8	32·5	30·8	20·6	15·4	49	20·4	13·6	10·2
14·75	67·8	45·2	33·9	20·75	48·2	32·3	24·1	26·75	37·3	24·9	18·6	32·75	30·5	20·4	15·75	50	20·0	13·4	10·0
15	66·6	44·4	33·3	21	47·6	31·8	23·8	27·0	37·0	24·7	18·5	33	30·2	20·2	15·1	—	—	—	—
15·25	65·6	43·7	32·8	21·25	47·0	31·4	23·5	27·25	36·7	24·5	18·3	33·25	29·9	20·0	14·95	—	—	—	—
15·5	64·4	42·9	32·2	21·5	46·4	31·0	23·2	27·5	36 4	24·3	18·2	33·5	29·8	19·9	14·9	—	—	—	—
15·75	63·4	42·3	31·7	21·75	46·0	30·7	23·0	27·75	36·0	24·0	18·0	33·75	29·6	19·7	14·3	—	—	—	—

condensed vapour to the flask prevents any loss of liquid during the process. At the conclusion of the boiling take out the copper foil, wash it well with water, alcohol and ether. Dry it in a water oven and sublime it slowly in a small tube over a small flame. Examine with the microscope any sublimate which may be obtained for the characteristic crystals of As_4O_6. The same process is also applicable to such substances as malt combs, malt dust, hops, etc. In the case of bulky materials use more water and acid in order to maintain sufficient fluidity during the boiling.

(2) **Beer.**—The following is the process recommended by the Manchester Expert Committee. Take 200 c.c. of the beer in a porcelain dish, acidulate with 1 c.c. of pure concentrated hydrochloric acid and evaporate till the volume of the liquid is reduced to one half. Then add a further 15 c.c. of the hydrochloric acid, and insert a piece of pure burnished copper foil $\frac{1}{4}$ in. $\times$ $\frac{1}{2}$ in. in size and maintain the solution gently simmering for 1 hour, replacing the evaporated liquid from time to time by distilled water. If at the end of an hour the copper remains bright and red, the beer is arsenic free. If a deposit is formed on the copper the foil should be removed, washed successively with water, alcohol and ether, dried at a temperature not exceeding 100° C., and subjected to slow sublimation in a thin reduction tube not less than 2 in. long and having an internal diameter of 0·15 in. The upper portion of which should be warmed before the sublimation begins. For the purpose of the sublimation a small spirit lamp flame should be used. If any sublimate is obtained, it must be examined under a magnifying power of about 200 diameters. Any sublimate which does not show well marked octahedral or tetrahedral crystals is not to be considered arsenical. Mere blackening of the copper, or deposit thereon, does not demonstrate the presence of arsenic.

When arsenic is detected by the above test, its quantity is best determined by the

Marsh Test for Arsenic.—This process by Marsh Berzelias should be performed as follows :—The beer—preferably 50 c.c., is acidulated by the addition of 1 c.c. of pure hydrochloric acid and gently boiled in a porcelain evaporating dish for a few minutes until frothing nearly ceases, cooled and gradually introduced into a Marsh apparatus of 200 c.c. capacity, which is already giving off a gentle stream of pure hydrogen gas, evolved from pure zinc and diluted hydrochloric acid. The purity of the evolved gas is first tested by ascertaining that it yields no mirror after 15 minutes, when it has passed through a drying tube charged with successive layers of cotton wool, lead carbonate, and spongy calcium chloride, and then heated to dull redness in a narrow glass tube drawn out to a capillary size just beyond the point of heating. The open point of the tube at which the gas escapes should be turned upwards at right angles, so that the amount of issuing gas can be regulated by seeing that when lighted the flame of the burning gas is just perceptible. The beer is introduced by means of a straight thistle funnel provided with a stopcock so that the admission of

liquid into the apparatus can be regulated without introducing air. From time to time a little pure concentrated hydrochloric acid is also introduced so as to maintain the uniform evolution of gas. The blank experiment having shown no mirror in the heated tube at the end of 15 minutes, the experiment is continued for 30 minutes after the commencement of the introduction of the beer. The arsenical mirror thus obtained is then compared with standard mirrors obtained by treating known quantities of arsenious oxide dissolved in water with the addition of pure hydrochloric acid under precisely similar conditions as to generation of gas, and the quantity of arsenic present is thus judged with great approximate accuracy. The mirror may subsequently be converted into crystals of arsenious oxide by sealing of the portion containing the mirror at each end by means of a blow-pipe, and then gently heating the tube by which means the mirror is volatilised, oxidised, and converted into crystals of the oxide. The mirrors obtained should be small, the comparison of small mirrors yielding more accurate results than where large mirrors are compared.

The Reinsch Test for Arsenic.—This test takes its name from Emil Reinsch, who discovered it about 1842. Its principle is this:—When arsenious oxide As_2O_3, or its salts, is boiled in a solution which also contains hydrochloric acid and metallic copper, the reaction

$$3\ Cu_2 + As_2O_3 + 6\ HCl. = 3\ H_2O + 3\ Cu_2\ Cl_2 + As_2 \text{ takes place.}$$

The arsenic alloys itself with the metallic copper, forming the compound $As_2\ Cu_5$ which forms a discoloration on the surface of the foil, or may drop off in flakes if a large quantity of arsenic is present in the liquid tested. During the sublimation process this alloy is decomposed, and the arsenic is oxidised to As_2O_3, which condenses in the crystalline form on the cold part of the tube.

Fleetmanns Test for Arsenic.—The solution is mixed with excess of caustic potash, a piece of *pure* zinc, or of magnesium, or aluminium foil inserted, and the solution heated. A piece of filter paper moistened with silver nitrate is held over the mouth of the tube. In presence of arsenic, arseniuretted hydrogen is produced and reduces the silver on the paper, forming a greyish or purplish colour. Antimony is not evolved in this test. Fleetmanns test is therefore a ready means of finding arsenic in presence of antimony, although the test is not so delicate as the others given. Or instead of silver nitrate the paper (preferably Michallet's drawing paper) cut into strips may be soaked in a 1% solution of mercuric chloride, and after drying exposed to the gas when the arseniuretted hydrogen produces a stain.

Analysis of Beer—(i) **Original Gravity.**—Take a sample of the beer, and pour from one large beaker to another for a considerable time in order to get rid of the carbonic acid. When the latter has been got rid of, take 250 c.c. and distil (in the Liebig's glass condenser, as arranged by Dr. Graham). Let two-thirds distil over, catch this in another 250 c.c. flask, and make both it (the distillate) and the residue up to 250 c.c. with distilled water.

Then cool both flasks carefully down to 15·5° C., and fill the specific

gravity bottle so that when the stopper is dropped into its place a tiny bead of the liquid just makes its appearance on the small perforation through the stopper. [It must not be a distinct drop, nor must there be any moisture outside the specific gravity bottle.]

With these precautions we weigh successively the specific gravity bottle filled with (1) the beer itself, freed from gas ; (2) the distillate (made up as directed) ; (3) the residue, care of course being taken to rinse out the specific gravity bottle first with the liquid which is being weighed, and to use the counterpoise for bottle, as empty.

Let us suppose that the weights of the bottle filled with the respective liquids are :—

Distillate 49·549 ; residue 51·222 ; and beer 50·793 all in grammes.

It will be remembered that at the outset we weighed our specific gravity bottle filled with distilled water at 15·5° C. and recorded it to hold 49·983 grammes.

Accordingly the calculation will proceed thus :

$$\text{Distillate} = \frac{49{\cdot}549 \times 1000}{49{\cdot}983} = 991{\cdot}3.$$

$$\text{Residue} = \frac{51{\cdot}222 \times 1000}{49{\cdot}983} = 1024{\cdot}78.$$

$$\text{Beer} = \frac{50{\cdot}793 \times 1000}{49{\cdot}983} = 1016{\cdot}2 \text{ (Final attenuation} = 5{\cdot}8 \text{ lb.)}$$

Then we subtract the found specific gravity of the distillate, viz., 991·3, from 1,000, which gives us 8·7, whereupon we refer to a book of tables generally supplied with the specific gravity bottle, and in one of the tables Table I., p. 194) we find that 8·7 = 37·5 degrees of gravity lost.

We then add the 37·5 to the specific gravity of the residue, viz., 1,024·78, which gives us 1,062·28 as the original specific gravity (= 22·42 brewers' lb., with a final attenuation, as stated above, of about 5·8 lb.).

Original Gravity by the Evaporation Process.—This is easier than the distillation process, though, if the other be carefully performed, probably a trifle less exact. It does not, for instance, involve taking any exact quantity of the beer. Any convenient quantity can be partially evaporated (enough to drive off the alcohol) in a beaker, cooled and weighed as before, the difference between the weight of the residue and that of the beer before evaporation providing the required *data*. We can of course use the weights already got for the purpose of illustration, thus :

Deduct gravity of the residue from that of the beer 1,000.

2,016·2 —1,024·78 = 991·42, which in turn deducted from 1,000 = 8·58. Or, what is simpler, deduct the beer gravity from that of the residue, 1,024·78 — 1,016·2 = 8·58.

On referring to the evaporation process table (Table II., p. 194) this will be found to show 37·7 degrees of gravity represented by alcohol, etc. This gives 1,062·48 as the gravity of the wort before fermentation, against 1,062·28 shown by the distillation process.

TABLE I.

Spirit Indication with corresponding Degrees of Gravity lost in Malt Worts by the "Distillation Process."

Degrees of Spirit Indication.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	—	·3	·6	·9	1·2	1·5	1·8	2·1	2·4	2·7
1	3·0	3·3	3·7	4·1	4·4	4·8	5·1	5·5	5·9	6·2
2	6·6	7·0	7·4	7·8	8·2	8·6	9·0	9·4	9·8	10·2
3	10·7	11·1	11·5	12·0	12·4	12·9	13·3	13·8	14·2	14·7
4	15·1	15·5	16·0	16·4	16·8	17·3	17·7	18·2	18·6	19·1
5	19·5	19·9	20·4	20·9	21·3	21·8	22·2	22·7	23·1	23·6
6	24·1	24·6	25·0	25·5	26·0	26·4	26·9	27·4	27·8	28·3
7	28·8	29·2	29·7	30·2	30·7	31·2	31·7	32·2	32·7	33·2
8	33·7	34·3	34·8	35·4	35·9	36·5	37·0	37·5	38·0	38·6
9	39·1	39·7	40·2	40·7	41·2	41·7	42·2	42·7	43·2	43·7
10	44·2	44·7	45·1	45·6	46·0	46·5	47·0	47·5	48·0	48·5
11	49·0	49·6	50·1	50·6	51·2	51·7	52·2	52·7	53·3	53·8
12	54·3	54·9	55·4	55·9	56·4	56·9	57·4	57·9	58·4	58·9
13	59·4	60·0	60·5	61·1	61·6	62·2	62·7	63·3	63·8	64·3
14	64·8	65·4	65·9	66·5	67·1	67·6	68·2	68·7	69·3	69·9

TABLE II.

Spirit Indication with corresponding Degrees of Gravity lost in Malt Worts by the "Evaporation Process."

Degrees of Spirit Indication.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	—	·3	·7	1·0	1·4	1·7	2·1	2·4	2·8	3·1
1	3·5	3·8	4·2	4·6	5·0	5·4	5·8	6·2	6·6	7·0
2	7·4	7·8	8·2	8·7	9·1	9·5	9·9	10·3	10·7	11·1
3	11·5	11·9	12·4	12·8	13·2	13·6	14·0	14·4	14·8	15·3
4	15·8	16·2	16·6	17·0	17·4	17·9	18·4	18·8	19·3	19·8
5	20·3	20·7	21·2	21·6	22·1	22·5	23·0	23·4	23·9	24·3
6	24·8	25·2	25·6	26·1	26·6	27·0	27·5	28·0	28·5	29·0
7	29·5	30·0	30·4	30·9	31·3	31·8	32·3	32·8	33·3	33·8
8	34·3	34·9	35·5	36·0	36·6	37·1	37·7	38·3	38·8	39·4
9	40·0	40·5	41·0	41·5	42·0	42·5	43·0	43·5	44·0	44·4
10	44·9	45·4	46·0	46·5	47·1	47·6	48·2	48·7	49·3	49·8
11	50·3	50·9	51·4	51·9	52·5	53·0	53·5	54·0	54·5	55·0
12	55·6	56·2	56·7	57·3	57·8	58·3	58·9	59·4	59·9	60·5
13	61·0	61·6	62·1	62·7	63·2	63·8	64·3	64·9	65·4	66·0
14	66·5	67·0	67·6	68·1	68·7	69·2	69·8	70·4	70·9	71·4

Method of Using the foregoing Tables.—In our example of the Distillation Process we find the "spirit indication" (*i.e.*, 1,000—specific gravity of distillate) to be 8·7. We then refer to Table I., and taking the first column we find the whole number 8; next we look for the column which has ·7 at the head, and observing the place where these two columns, the one horizontal and the other perpendicular, meet one another, we find 37·5 given as the degrees of gravity lost, or solid extract which has been fermented away. Where the "spirit indication" is in two places of decimals the nearest single decimal is taken; thus for 8·58 take 8·6, which on Table II. gives 37·7 (8·58, however = 37·6, which gives a result very close to that of the Distillation Process).

Improved Alcoholmeter. This ingenious apparatus (now obtainable from Mr. J. Long, of Eastcheap, E.C., Messrs. W. Reeves & Co., 26, Minories, E. 1, and others) may just be referred to here, although its proper sphere is rather the brewing-room than the laboratory. It has been found very useful for the rapid and accurate estimation of "waste" or "returns." It consists of a body or boiler with a spirit-lamp underneath, and a specially graduated thermometer, having a condenser attached, which has to be inserted into the boiler. Advantage is taken of the fact that spirituous liquids boil at lower temperatures than water, consequently the larger the quantity of alcohol in any beer the lower will be its boiling-point. But as there is no exactly constant boiling-point for water, which in fact varies with barometrical pressure, a preliminary operation has to be made by charging the boiler with water, lighting the spirit-lamp, and noting the point at which the water boils, continuing the boiling for some seconds so as to be sure of getting the highest point. Then a movable ivory scale has to be adjusted so that the 0 (zero) exactly faces the highest point of ebullition, which makes the necessary adaptation of the thermometer to the boiling-point of the day.

Then the boiling operation has to be repeated with the beer which is to be tested, and as soon as the liquid is in full boil the highest point which the quicksilver reaches must be carefully noticed, and there, instead of the temperature as in ordinary thermometers, can be read off the "lbs. per barrel," or "degrees of specific gravity," the former on the right hand, the latter on the left of the scale, corresponding to the lbs. or degrees of gravity "lost" during fermentation. This, added to the present gravity as found by a small saccharometer, gives the original gravity of the beer.

Beer showing a Marked Degree of Acidity.*—The beer in question was an actual sample of stout, bottled by a large firm, but palpably sour. Special care being taken to get rid of the carbonic acid, the respective gravities are found to be—

$$\text{Beer before distillation} = \frac{50{\cdot}899 \times 1000}{49{\cdot}983} = 1018{\cdot}32.$$

$$\text{Distillate} = \frac{49{\cdot}484 \times 1000}{49{\cdot}983} = 990{\cdot}0.$$

$$\text{Residue} = \frac{51{\cdot}389 \times 1000}{49{\cdot}983} = 1028{\cdot}12.$$

Then subtract as before the distillate 990 from 1,000 = 10, which it will be seen, on referring to Table I. above, shows 44·2 degrees of gravity lost.

So that, as far as we have got, the strength of the beer appears to have been 1,028·12 + 44·2 = 1,072·3 degrees; but owing to the large quantity of acid, acetic (volatile) and lactic (fixed), present, it will be necessary to determine these, and calculate how much "gravity lost" they represent.

* When much volatile (acetic) acid is present the acidity of the beer should be neutralised, otherwise the "spirit indication" of the distillate may come out too low. Acetic acid has a higher specific gravity than water (1·055 : 1·000), and thus 0·1 of the volatile acid may increase weight of the distillate by ·005, making "the degrees of gravity lost" 1·5 less than the actual.

We avail ourselves of the following table :—

TABLE III.

For ascertaining the Value of the Acetic Acid.

Excess per cent. of Acetic Acid in the beer.	Corresponding degrees of "Spirit Indication."									
	·00	·01	·02	·03	·04	·05	·06	·07	·08	·09
·0	—	·02	·04	·06	·07	·08	·09	·11	·12	·13
·1	·14	·15	·17	·18	·19	·21	·22	·23	·24	·26
·2	·27	·28	·29	·31	·32	·33	·34	·35	·37	·38
·3	·39	·40	·42	·43	·44	·46	·47	·48	·49	·51
·4	·52	·53	·55	·56	·57	·59	·60	·61	·62	·64
·5	·65	·66	·67	·69	·70	·71	·72	·73	·75	·76
·6	·77	·78	·80	·81	·82	·84	·85	·86	·87	·89
·7	·90	·91	·93	·94	·95	·97	·98	·99	1·0	1·02
·8	1·03	1·04	1·05	1·07	1·08	1·09	1·10	1·11	1·13	1·14
·9	1·15	1·16	1·18	1·19	1·21	1·22	1·23	1·25	1·26	1·28
1·0	1·29	1·31	1·33	1·35	1·36	1·37	1·38	1·40	1·41	1·42

N.B.—It will be observed that all the acid is virtually expressed in terms of acetic, which of course involves a slight inaccuracy. One per cent. of acetic acid (or acid equal thereto) is allowed for as being normally present.

The Process.—Take 50 c.c. of the beer freed from carbonic acid (by dashing repeatedly from one large beaker to another), and warm over steam, stirring with a glass stirring-rod. But do not boil, because acetic acid would evaporate. Then cool and put into a porcelain dish, adding $\frac{N}{10}$ ammonia gradually, trying the mixture with litmus papers of both colours, and noting the point at which neutrality is reached. In the case of the acid beer, above mentioned, 27·2 c.c. was required to produce neutrality.

Then 50 c.c. having been taken, 100 c.c. would take 54·4, the *datum* for *total acidity*.

We next proceed to get the fixed acid, and shall then be able to arrive at the volatile acid by difference.

Evaporate 50 c.c. of the beer over a water-bath to dryness, make up to about the original bulk, and test with $\frac{N}{10}$ ammonia. Supposing it takes 20·6 c.c. to neutralise the acidity, this = 41·2 for 100 c.c. (50 c.c. having been taken).

Subtracting 41·2 from 54·4 we get 13·2 (as representing the acidity due to volatile acid), and arrange the following Rule of Three sums :—

1,000 : 41·2 :: 9 = ·370, fixed or lactic acid,
1,000 : 13·2 :: 6 = ·079, volatile or acetic acid,

or ·449, total acid. Upon referring to Table III., taking the nearest index figures given, viz., 45, *i.e.*, looking first *along* the ·4 column and then *down* the ·05 column to the point where they meet, they will be seen to correspond to a "spirit indication" of ·59, which on reference to Table I. (and taking the nearest decimal, viz., ·6) is seen = 1·8 degree of gravity lost.

So that we now have 1072·3 (found by distillation) + 1·8 = 1074·1 degrees, or 26·7 brewers' lb., original gravity.

Analysing the Solid Residue (Dry Extract) of Beer.—We will now go back to the beer first dealt with, and separate the constituents of its solid residue. The first step is to take 25 c.c. of the beer, evaporate it to dryness, cool in desiccator, and weigh. Say we evaporated in glass basin No. 2, the weight of which = 23 203. If we now find the residue + pan = 24·715, the weight of the residue = 1·512. Multiplying this by 4 (to bring to a percentage, 25 c.c. having been taken) we get 6·048% for the solid residue.

Next we proceed to get the maltose and dextrin, for which determination we make use of Fehling's solution, proceeding as before and in two stages.

(α) Before inversion.

Take 50 c.c. and make up with distilled water to 100 c.c. Suppose that 9 c.c. precipitates 10 of Fehling. Then as 50 c.c. were made up to 100, 100 c.c. would be made up to 200, so the Rule of Three sum is—

9 : 200 : : ·05 = 1·11 as glucose = 1·11 + ·55 = 1·66 maltose.

[It will be remembered that maltose has only two-thirds the cupric reducing power or K of glucose, but as it is ·05 of glucose which exactly reduces 10 c.c. of Fehling, the correction into maltose, where the sugar is maltose, has to be made by adding the half.]

(β) After inversion (to determine dextrin).

50 c.c. are taken and 50 c.c. of water added with 3 c.c. of sulphuric acid, and the whole is boiled for 3 hours. After being neutralised, it is warmed and shaken up with animal charcoal to decolorise, filtered, and the filtrate, care being taken to wash the residue carefully, made up to 250 c.c.

Suppose 5 c.c. reduces 10 c.c. of Fehling ; then 50 c.c. having been made up to 250, at the same rate 100 c.c. = 500, and the Rule of Three sum will be—

5 : 500 : : ·05 = 5·0 maltose and dextrin expressed as glucose.

The next step is to multiply 1·66 by $\frac{100}{95}$ = 1·74, which means that the 1·66 of maltose determined is now represented by 1·74 of glucose.

Then 5 — 1·74 = 3·26. From this $\frac{1}{10}$ must be deducted to get the dextrin equivalent ; thus 3·26 — ·32 = 2·94, the percentage of dextrin in the dry extract.

[Owing to there being sometimes a difficulty in reading the exact point of precipitation, the gravimetric process, as before described, may give closer results than the volumetric here used.]

To determine the Albuminous Matter.—10 c.c. of the beer is made up to 100 c.c. with distilled water, and of this 10 c.c. only (= 1 c.c. of the beer) is taken to be "Nesslerised." It is added, as in the case of malt, to a good-sized flask two-thirds full of water, and connected with the condenser. The first distillates are Nesslerised, to ensure that the water is free from ammonia, and then the permanganate-potash solution is added as before. After this addition successive distillates of 100 c.c. are obtained, the first of which we will suppose to be diluted to 500 c.c., the others being Nesslerised undiluted.

In each case 50 c.c. are Nesslerised.

(1)	100 to 500.	50 took	3·5	= 35·0
(2)	100 undiluted	50 ,,	7·0	= 14·0
(3)	100 ,,	50 ,,	3·5	= 7·0
(4)	100 ,,	50 ,,	3·0	= 6·0
(5)	100 ,,	50 ,,	2·5	= 5·0
(6)	100 ,,	50 ,,	1·75	= 3·5
(7)	100 ,,	50 ,,	·50	= 1·0
				71·5

The calculation then proceeds on the basis that as each c.c. of the ammonic-chloride solution = ·00001 gramme of ammonia, and as 71·5 c.c. thereof were required to produce the tints which the distillates from 1 c.c. of the beer gave with Nessler, each c.c. of the beer = ·000715 gramme of ammonia, or 100 c.c. = ·0715 gramme of ammonia, which × 5·2 (the constant factor) = ·371 albuminous matter per cent.

Acidity has also to be taken into account, but as its determination has already been described, we will assume it to stand at ·169 fixed and ·012 volatile.

Then we have—

Maltose	= 1·66
Dextrin	= 2·94
Acidity	= ·181
Albuminous matters .	= ·371
Undetermined (ash, etc.) .	= ·896
	6·048

N.B.—The albuminous matter is higher than normal : ·01 per brewers' lb. or 0·22% has been considered allowable (but *cf.* p. 63 for a much higher rate). The ratio of dextrin to maltose is also higher than usual in the dry extract of finished beer.

Determination of Extract in Flaked Maize.*

(1) Take 100 grammes of ground malt. Digest for 3 hours at 70° F., use 1,000 c.c. tube or ounces measures. Filter bright and bring the specific gravity to about 1,003. This liquid will make the necessary mashing liquor, providing nearly 40 ounces liquid to work with.

(2) Weigh out 50 grammes of Flaked Maize.

(3) Mash the 50 grammes maize with 300 c.c. of your diastatic solution, which has been heated to 150° F. Maintain for one hour at 150° F. Make up to 500 c.c. (*not* 515° c.c., as in the case of malt analysis), with the solution described in (4).

* N.B.—The reason why the multiplying factor for a 10% solution of flaked maize is 3·32 instead of 3·36, as in the case of the analysis of barley-malt, is that the liquid concentration of the former material is lower. The volume occupied by the so-called "grains" in a 10% solution of flaked maize is 2·5. The necessary adjustment to obtain the factor for "flakes" is obtained as follows when the solution is made up to 200 c.c.—

$$\frac{200 - 2{\cdot}5 = 197{\cdot}5 \times 3{\cdot}36}{200} = 3{\cdot}318.$$

To obviate the use of four figures 3·32 is employed. Although strictly speaking the factor is 3·318, it is agreed that 3·32 is sufficiently accurate for the purpose.

(4) Take what remains of your diastatic solution and heat it in a flask to 150° F. Maintain at this temperature for 1 hour, concurrent with the 50 gramme mash. Then cool as usual. Take specific gravity at 60° F., and employ this liquor for making (3) up to the mark.

(5) Calculate as follows :—

Specific Gravity of mash = 1,033·50.

,, ,, of diastatic solution after 1 hour at 150° F. = 1,003. Then 1,033·50 — 1,003 — 1,000 = 30·5,

and "30·5 × 3·36 = 102·48 brs.' lbs." per quarter of 336 lbs., or "30·5 × 3·32 = 101·26 brs.' lbs."

Moisture Determination in Flaked Maize.

Weight of dish = 13·673, 5 grammes maize = 18·673. Weight after 5 hours in oven = 18·16

∴ 18·673 — 18·16 = ·513 × 20 = 10·26% moisture.

Water Analysis.

We can now proceed to the analysis of one average sample of water.

(i) The first step is to get the **Total Solids.**

Take two portions of the water (100 c.c. or 70 c.c. each) and evaporate over a water-bath to dryness (finally drying the residue in drying-oven at 115° to 120° C.).

[70 c.c. is a "miniature gallon" in which milligrammes correspond to grains of the full gallon. If 100 c.c. be taken, then

$$\frac{\text{solids in milligrammes} \times 7}{10} = \text{grains per gallon.}]$$

The water not being very saline we will operate upon 100 c.c., and evaporate *two* portions each of 100 c.c. in our evaporating basins [the best things, however, are platinum dishes, but large ones are costly], which, when empty and properly dried, weigh, let us say, 31·063 and 31·42 respectively.

Then, if the first weighing gives 31·09 ; 31·09 — 31·063 = ·027, and the second shows 31·447, which — 31·42 = ·027, *i.e.*, in each case 27 milligrammes.

Then $\frac{27 \times 7}{10}$ = 18·9 grains of total solids per gallon.

[One residue can now be tried with a drop or two of hydrochloric acid effervescence will indicate **carbonates.**

The other is kept for the **Qualitative test for nitrates and nitrites** Or the first may be kept for "**soluble solids.**"]

(ii) Meantime 4 beakers, each containing 500 c.c., should have bee placed on a sand-bath to partially evaporate. Two of these will be use to determine the sulphuric acid present as **sulphates,** the second pair fc determining the **lime and magnesia.** We will return to these later. [] is recommended to do these operations in duplicate, as they check or another, at all events, till accuracy in manipulation is obtained.]

Nitrates and Nitrites, Qualitative Test for.—Wash the total solids of or dish with distilled water (very little, as they are very soluble), and p into two small test-tubes (about half an inch depth in each).

(α) To one test-tube add sulphuric acid, rather more than the liqu already in the test-tube. (This is done in order to concentrate the minu

quantity of nitric acid, which it does by uniting with the water ; and it must be done under the tap to prevent the nitric acid from being volatilised.)

This being done, add very gradually and carefully, *drop by drop*, ferrous sulphate, so that *it rests upon the surface of the mixture*. Then, if a brownish ring appears at the point of contact, this indicates nitrates. If the nitrates are high, the ring is *blackish*.

(β) To the other test-tube add one drop of ferrous sulphate without sulphuric acid. Similar rings indicate *nitrites*.

We now return to the four beakers, evaporating on the sand bath (step ii.).

(α) The two sulphate beakers are to be acidified with hydrochloric acid, a few drops, until the precipitate of carbonate of lime is dissolved. When reduced to one-fifth, add saturated solution of barium chloride. Go on heating till the precipitate settles. Filter through Swedish filter-paper. Dry precipitate (with the filter-papers) in drying-oven ; ignite over Bunsen in platinum dish ; cool as usual. [N.B.—The baric chloride must be slightly, but only slightly, in excess ; that it is in excess can be ascertained by testing the filtrate with silver nitrate solution, and then, if barium chloride be present, *i.e.*, not converted into barium sulphate, which remains on the filter paper, there will be a curdy precipitate of silver chloride. After this the filtrate may be thrown away. If there is any difficulty in getting a clear filtrate, it is recommended to introduce a minute quantity (half a milligramme) of pure starch immediately after the barium chloride, which conglomerates precipitate, and adds practically no inorganic residue.]

For brevity's sake we only calculate out one beaker here. Suppose the total weight = 14·238, from which we have to deduct 14·216 for platinum dish + ·003 for the filter-paper, then ·019 of barium sulphate remains, *i.e.*, (500 c.c. having been taken) ·019 × 2 = ·038 in litre, which is the same as ·038 grains in 1,000 grains. Seeing that a gallon = 70,000 grains, ·038 × 70 or 2·66 represents the barium sulphate in *grains* per gallon.

We have now to get at the amount of anhydrous sulphuric acid which this sulphate represents, the equivalents being baric sulphate $BaSO_4$ = (137 + 32 + 64) = 233 ; SO_3 = (32 + 48) = 80.

Then the Rule of Three sum will be—

$$233 : 80 :: 2{\cdot}66 : x = {\cdot}913 \text{ grains } SO_3 \text{ per gallon.}$$

(β) The two lime (and magnesia) beakers.

Add a few drops of hydrochloric acid to dissolve the precipitate, then a few drops of strong solution of ammonia, enough to render it just ammoniacal (which will prevent the solution by HCl of the oxalate of lime, which is formed later).

Add a few drops of oxalate of ammonia (saturated solution), and heat gently for half an hour. When the precipitate has settled slope the beaker, and run a drop of oxalate of ammonia down its side ; if a precipitate forms at the point of contact, add more oxalate of ammonia until no such precipitate occurs.

Filter through Swedish paper, but the *filtrate* is *to be kept* to test for magnesia.

The precipitate is to be ignited in the platinum dish (where two beakers have been taken, each filter-paper should be ignited separately and the results averaged) until reduced to whitish ash. The oxalate of lime will now have been converted into carbonate of lime (and some oxide of lime, from loss of carbonic acid). Therefore treat with a few drops of carbonate of ammonia solution to restore the carbonic acid, using gentle heat. Weigh, then again add a little more carbonate of ammonia solution till the weight is constant.

Suppose the first weighing gave 13·241 and the second and third 13·240, we take the last, viz., 13·240 — 13·140 (weight of platinum dish) = ·1 gramme of carbonate of lime in 500 c.c.

·1 × 2 × 70 = 14 grains per gallon *as* carbonate of lime (*i.e.*, total lime in terms of carbonate). But as we do not yet know how much lime is really present as carbonate, the $CaCO_3$ will have to be calculated into calcic oxide CaO, to which end it must be multiplied by 56 and divided by 100, or shortly × ·56, on the equivalent principle. Ca = 40, C = 12, O_3 = 48 = 100, and Ca = 40, O = 16 = 56. Then 14·0 $CaCO_3$ corresponds with 7·84 CaO.

Testing for Magnesia.—The filtrates kept from the lime beakers are first concentrated by boiling, then cooled. About 5 c.c. of a saturated solution of phosphate of soda is now added, and the whole made strongly ammoniacal by the addition of about its own bulk of strong ammonia (if, however, it is made faintly ammoniacal at first the precipitation will be better). Filter again after twelve hours' stand, and wash the precipitate with ammonia solution (made of ⅓ strong ammonia and ⅔ water). It may be a wise precaution to test the filtrate from the washing with a few drops of silver nitrate to show freedom from ammonium chloride ; if there is any white precipitate (of silver chloride) the washing should be continued.

Then the filter-papers containing the residues, after being dried in the drying-oven, are to be burnt in the platinum dish (calcined to whiteness). Very careful weighing is required, as a single milligramme makes an important difference. We will suppose that two precipitates have been ignited, of which we take the average. One weighs 13·148, the other 13·149, which, less 13·140 for the platinum dish and ·002 for the filter-paper, leave ·006 and ·007 respectively. Then ·006 × 2 × 70 = ·84, and ·007 × 2 × 70 = ·980, of which the mean is ·91.

This is pyrophosphate of magnesia, $Mg_2P_2O_7$, or structurally $\left\{\begin{matrix}MgO\\MgO\end{matrix}\right\}P_2O_5$.

$Mg_2 = 48$, $P_2 = 62$, $O_7 = 112 = 222$, and $\left\{\begin{matrix}Mg=24,\ O=16\\Mg=24,\ O=16\end{matrix}\right\}=80$.

Therefore $\frac{·91 \times 80}{222}$ = ·32 grains magnesic oxide (MgO) per gallon.

Chlorine (Chlorides).—This is estimated by using a standard solution * of silver nitrate of such a strength that each c.c. corresponds to one grain of chlorine per gallon of the water under inspection, if 70 c.c. of the latter be operated on.

The presence of chlorine is immediately indicated by a white precipitate of silver chloride, but to ascertain the exact point at which all the

* 4·79 grammes of nitrate of silver (dried in air-bath at 100° C.) dissolved in 1 litre of water.

chlorine has become combined with the silver, use is made of the fact that silver forms a red precipitate with chromic acid (chromate of silver), though less readily than it forms silver chloride, giving a white precipitate, with chlorine.

The process is as follows. 70 c.c. of the water is rendered yellow with a crystal, or a few drops of solution of chromate of potash. Then the nitrate of silver solution is run in from a burette till the red colour just begins to be permanent.

We will suppose 1·2 c.c. is run in before that point is reached, and this = 1·2 grains of chlorine per gallon.

[Care must be taken that neither water nor silver-nitrate solution is acid, as acid dissolves the silver chromate. Acidity should be neutralised or rather more than neutralised with carbonate of soda.]

Soluble Solids.—The determination of "Soluble Solids" and of the "Insoluble Solids" (by difference) affords a valuable clue to the general constitution of the water. The "soluble solids," in fact, comprise generally the alkaline salts, the salts of magnesia and the sulphate of lime (which is far more soluble than the carbonate).

The insoluble solids are almost identical with the carbonate of lime, probably + a little silica.

When the soluble solids are likely to be fairly high, wash with distilled water one of the pans containing "total solids" (evaporated in the first operation), being careful to rub round the pan thoroughly with a glass stirring-rod, which has a short piece of india-rubber tubing fitted to its stirring end. Filter and evaporate filtrate in a tared glass dish, or platinum dish. Dry in a drying-oven, and weigh with the usual precautions (cooling in desiccator, etc.).

When, however, the soluble solids are not likely to be high, it is better to make a fresh evaporation, taking 500 c.c., which we will suppose done in the present case. Otherwise the manipulation as before.

Then suppose the weight deducting that of pan = ·03 gramme (30 milligrammes).

·03 × 2 × 70 = 4·2 grains per gallon.

i.e., Insoluble solids	14·7
Soluble do.	4·2
Total solids	18·9 (found in Operation i.).

Precipitate on Boiling.—Boil 500 cc. for one hour, keeping the beaker filled up to the original level with distilled water. Filter and dry precipitate between watch-glasses at 105° C. [We will assume the weight of the watch-glasses, thoroughly dried, = 12·723, and the weight of the filter-paper, unignited, = ·64.]

Cool in desiccator and weigh.

Then suppose gross weight = .	13·454
Deduct glasses 12·723 } .	13·363
Filter-paper ·640 }	
	·091 (from 500 c.c.)

·091 × 2 × 70 = 12·74 grains per gallon.

(This corresponds with temporary hardness.)

Tabulating the above Results.—Many analysts content themselves with stating results got as above, on the ground that such a method states actual facts and does not lend itself to cookery ; but, on the other hand, it does not enable even the practised chemist to see at a glance what the exact character of the water is, and, of course, is utterly valueless to the inexperienced.

Therefore it seems preferable to combine acids and bases in the form of the most probable combinations, and this we may now proceed to do with the results before us. These results (all in grains per gallon) are—

Total solids	18·9
Soluble	4·2
Precipitate on boiling . . .	12·74
Total lime as CaO.	7·84
Magnesic oxide, MgO. . . .	0·32
Chlorine	1·2
SO_3	·913

Then, as there is too much SO_3 (anhydrous sulphuric acid) for saturating the MgO without overplus (80 parts SO_3 take 40 parts MgO), the acid may be combined with some of the lime. [And note that, speaking generally, the tendency is towards the most insoluble compounds, viz., to a combination of SO_3 with lime rather than magnesia, if both bases are present.]

Then ·913 SO_3 will combine with ·639 CaO (80 : 56 : : ·913) to form sulphate of lime, of which we accordingly have 1·55 grain per gallon.

Then dealing with the rest of the lime ; 7·84 — ·64 (taken as sulphate) = 7·2.

$$\frac{7{\cdot}2 \times 100}{56} = 12{\cdot}86.$$ Lime as carbonate ($CaCO_3$).

CaO. CO_2.

[Or it may be calculated thus, 56 : 44 : : 7·2 = 5·66 CO_2 carbon dioxide to combine with the CaO (to form calcic carbonate $CaCO_3$). 7·2 + 5·66 = 12·86].

The ·32 MgO is to be expressed as carbonate. Then as 40 MgO unites with 44 CO_2, ·32 will unite with ·35 CO_2 = ·67 $MgCO_3$ (carbonate of magnesia).

The chlorine 1·2 is multiplied by the factor 1·647 to bring it into common salt (sodic chloride), its most probable combination, and = 1·97.

[The factor 1·647 is got on the equivalent principle. Chlorine = 35·5. Sodium = 23. NaCl (sodium chloride) = 58·5. Then 58·5 — 35·5 = 1·647.]

So we have—

Sulphate of lime	1·55
Carbonate ,, ...	12·86
Carbonate of magnesia	·67
Chloride of sodium	1·97
Silica and undetermined (water of hydration) .	1·85
	18·90

In the above analysis the silica, etc., is perhaps somewhat high, but as it and the carbonate of lime together agree remarkably closely with the "insoluble solids," while the other constituents total up very closely to the "soluble solids," the analysis may be taken as substantially correct.

In applying the qualitative test for nitrates and nitrites, the water had appeared free from the latter, and with only a trace of the former, so that it hardly seemed necessary to **combine any of the lime with nitric acid.** But if the nitric acid should be considerable (see Indigo process, p. 165), note that it combines more readily with lime and magnesia than with soda, and that the Rule of Three sum (to get the amount of CaO or MgO to be added to the ascertained amount of nitric acid) would be—

108 : ascertained nitric acid : : 56 (or 40 for MgO),

and the result + the ascertained amount of nitric acid = nitrate of lime or magnesia, as the case may be).

Seeing that nitric anhydride N_2O_5, as compared with sulphuric anhydride SO_3, combines in the proportion of 108 : 80, and as compared with carbonic anhydride CO_2 in the proportion of 108 : 44, a given quantity will obviously saturate less lime than either of the other acids ; consequently, if an appreciable quantity of those bases be combined as nitrates, the result will be an increase of the total solids actually determined. In other words, the carbonates of lime and magnesia will not be decreased by nearly the total of the nitrates.

Carbonates of Soda and Potash.—Generally, if determined, they are calculated as the former, though really, if potash be present as carbonate in any quantity, a considerable numerical error is introduced by so doing. This simpler, but hardly correct process, is as follows.

500 c.c. is evaporated to dryness, washed and filtered, though if carefully ignited, the magnesic carbonate, if present, is rendered insoluble, while the carbonate of soda passes through the filter after successive washings.

Then to the filtrate $\frac{N}{10}$ sulphuric acid is added, and the excess titrated back, after rewarming, with $\frac{N}{10}$ ammonia, which gives greater accuracy. Suppose, then, to a filtrate of a considerably alkaline water, prepared as above, 11·5 c.c. of $\frac{N}{10}$ sulphuric acid is added, and after the warming of the mixture, 6 c.c. $\frac{N}{10}$ ammonia is required to produce neutrality.

Then 5·5 c.c. $\frac{N}{10}$ sulphuric acid will have been neutralised.

$5{\cdot}5 \times 2 \times 70 = 770\ \frac{N}{10}$ or 77 c.c. normal acid per gallon. But a litre (1,000 c.c.) of normal acid = 53 grains carbonate of soda (because 53 grains, half the total atomic weights of Na_2CO_3, as in the case of oxalic acid, makes a litre of normal Na_2CO_3). Accordingly the sum is,

1,000 : 77 : : 53 = 4·081 grains per gallon, reckoned as Na_2CO_3.

[Note that cochineal is a much more delicate reagent than litmus,

because carbonic acid does not mask its indication; however, the evaporation to dryness should have got rid of all carbonic acid.]

The Hardness of a Water is generally determined by the "**Soap Test,**" originally devised by Dr. Clark, of Aberdeen, a test which, though sometimes decried because of the instability of the standard solution, is yet capable of giving very useful, and probably accurate results, if the solution be frequently standardised. This is one of the easiest things possible to do.

The test rests upon the basis that salts of lime and magnesia react upon soluble soap to form insoluble oleate, stearite, or palmatite of lime or magnesia, or, in other words, that it is only after those salts have become saturated that a *permanent lather* (one capable of lasting five minutes) is obtainable upon shaking the water in question up with a solution of soap. To make the test quantitative, the soap solution is made of such a strength that each c.c. contains exactly soap enough to be neutralised by 1 milligramme (0·001 gramme) carbonate of lime. The quantity of water used is the miniature gallon, 70 c.c., in which milligrammes correspond to grains in the actual gallon. Thus, by reading off the number of c.c. of soap solution required to produce the permanent lather (less 1 c.c. as a correction for that which even distilled water requires) we arrive at the degrees of hardness—*i.e.*, grains per gallon reckoned as carbonate of lime.

Before making the soap solution it is necessary to have for standardising it a stable solution containing exactly ·001 gramme (1 milligramme) of carbonate of lime in each c.c.

Standardising Solution for Soap Test.—Pure calcic chloride is heated just to redness in a platinum crucible, cooled in the desiccator, and 1·11 gramme taken (= 1 gramme carbonate of lime) and dissolved in a litre of distilled water; or 1 gramme of powdered marble or Iceland spar may be taken and dissolved in slight excess of dilute hydrochloric acid, which is afterwards neutralised with a slight excess of ammonia. Whichever is taken it is to be made exactly up to a litre with distilled water.

The Standard Soap Solution.*—10 grammes purest Castile soap are dissolved in a litre of weak (35%) alcohol (methylated spirit will do). This should make a solution corresponding very nearly with the test solution. To try it, a measured quantity of the lime solution (say 10 c.c.) is put into the "miniature gallon," which is then filled with distilled water to the 70 c.c. mark. This 70 c.c. is then put into a larger flask of say 200 c.c. capacity, and the soap solution added; then the flask is shaken and laid upon its side. If the soap solution is accurate, exactly 11 c.c. (= 10 c.c. for the standardising solution and 1 c.c. for the distilled water) will be required to produce a lather capable of persisting for five minutes. Obviously, it is best to try with less of the soap solution to begin with, as it may require dilution to make it exactly correspond.

The testing of the actual water is performed in the same way (the soap solution having been ascertained to be correct) and similarly the number of c.c. of the water taken, *minus* 1, will represent the degrees of hardness reckoned as carbonate of lime. Note, however, that if 70 c.c. of the water require more than 16 c.c. of soap solution (*i.e.*, with all water more than moderately hard) it will be advisable to dilute the water with exactly

* Another recipe is given at the end of this chapter, one which is said to keep better.

twice, thrice, or four times its bulk, as the case may be, and then to take 70 c.c. of the diluted fluid, of course multiplying the c.c. of soap solution taken by the figure of the dilution.

Hardness after Boiling.—If some of the water be boiled and 70 c.c. of the cooled filtrate be tried with the soap solution, the degrees of hardness after boiling will be ascertained, by deducting which from the total the hardness which disappears on boiling is found by difference. These are otherwise known as the **Permanent and Temporary Hardness,** the former being due to sulphates of lime and magnesia, the latter corresponding fairly closely, though not exactly, to their carbonates.

Objections made to the Soap Test and Precautions—Magnesic Salts.—Apart from the instability of the soap solution itself, objections have been made on the ground of the very different behaviour of salts of lime and magnesia (the two chief factors of hardness) towards the soap solution, as well as because of the obvious fact that expressing one in terms of the other would lead to error. But it is really in the different way in which the salts behave respectively that the chief safeguard is found. Thus lime salts react immediately, magnesia salts only after a lapse of time, so that it is quite possible to produce a persistent lather before all the magnesia salts are decomposed. But on letting the mixture stand a little and shaking it up again, the lather, in the presence of magnesia salts in quantity enough will vanish. [At 70° C. = 158° Fahr. this difference is not apparent.]

Professor Wanklyn gets at the magnesia salts in this way, precipitating the lime salts by adding powdered oxalate of ammonia to the water (about 1 gramme per litre), which is then shaken up for a minute and filtered. He tests the filtrate to ensure the absence of free acid, and likewise with a little of the oxalate to ascertain that all the lime salts have been got rid of (precipitate otherwise of oxalate of lime), and then titrates 70 c.c. with soap solution in the usual way. But owing to the fact that approximately $1\frac{1}{2}$ equivalents of magnesia consume the same quantity of soap as 1 of lime, the result got (number of c.c. of soap solution — 1) has to be multiplied by the fraction $\frac{1}{1\frac{1}{2}}$ to give the actual quantity of magnesia in terms of carbonate of magnesia—*i.e.*, $\frac{2}{3} \times \frac{84\ (MgCO_3)}{100\ (CaCo_3)} = \frac{14.}{25}$

Free and Albuminoid Ammonia in Water.—This process is conducted on somewhat similar lines to that given for determining the albuminous matter in malt, which is indeed only an adaptation of the water process—only, in the case of water, the determination is made in two parts. First, the ammonia already existing in the water in the form of "free ammonia" is ascertained and recorded; then, the residue is boiled with a solution of potassic permanganate and caustic potash (the latter immensely in excess), whereby the organic matter is converted into ammonia, which can then be distilled over and estimated.

It will be remembered that the test depends upon the depth of the tint produced by adding a small quantity of Nessler's solution (very sensitive to ammonia) to the liquid, this tint being matched by Nesslerising side by side with it an equal bulk of water to which a standard ammonia solution has been added. Then the quantity of ammonia added being calculated from the amount of ammonia solution taken to produce the match-tint, this gives the amount in the original liquid. [Note that, as the Nessler

does not react immediately to its full extent, the 50 c.c. cylinders in which the distillate is caught, as well as the comparison cylinder, should stand an appreciable time, say two minutes, and that before the operation begins the apparatus should be copiously washed, seeing that all surfaces long exposed to the air are liable to attract traces of ammonia therefrom ; but ordinary good tap-water will do, though it is recommended to rinse out the retort first with strong hydrochloric or sulphuric acid. Of course the subsequent water-rinsing must then be continued till no trace of acidity remains.]

The Process.—500 c.c. of the water is taken and placed in the retort (carefully poured through a funnel). The retort is then connected with the Liebig's condenser (or Dr. Graham's glass arrangement of it), and when all the connections are properly made, the flame of a Bunsen burner applied to the naked retort, so that it plays upon the surface of the latter up to, but no higher than, the surface of the liquid. The cold water connections are made, and cold water started flowing through the outer tube of the condenser, in order to condense the vapour which comes over. This liquid is now caught in the measured 50 c.c. cylinder, and Professor Wanklyn recommends that this first 50 c.c. should alone be Nesslerised for free ammonia, because although the next 150 c.c. may also contain some and is therefore to be distilled off (to concentrate the liquid as well), the first 50 c.c. invariably, he says, contain 75% of all the free ammonia, the total of which can accordingly be got by adding one-third of that shown by the first Nesslerising to the said result. If the free ammonia is likely to be higher than is consistent with fair purity (above ·08 parts per million is " a sign that the water in question consists of diluted urine in a very recent condition "), yet not in great excess, it may be better to distil over 150 c.c. into a measured flask, Nesslerise 50 c.c. of it, and multiply the result so got by 3. If the free ammonia is in great excess the water must be diluted in carefully ascertained proportions with *ammonia-free* distilled water (distilled water boiled with some carbonate of soda and ferrous sulphate to get rid of the ammonia).

We will, however, suppose that only the first 50 c.c. is Nesslerised, the next 150 c.c. distilled over being thrown away. At this point the flame is removed temporarily, and to the 300 c.c. left in the retort (half a litre was originally taken) 50 cc. of the potash-permanganate solution is carefully added. The flask is now not unlikely to bump violently enough to cause a fracture sometimes, which bumping a few pieces of well-ignited tobacco-pipe (clay) put into it will tend to moderate. At least three successive quantities of 50 c.c. each must be caught and Nesslerised (for albuminoid ammonia) ; in fact, the Nesslerising must be continued as long as the Nessler when added to 50 c.c. distillate strikes a decided tint.

We will suppose, then, that in the first Nesslerising (before the addition of the potash-permanganate) a tint was produced which it required 2 c.c. of ammonia solution in the comparison cylinder to imitate. [Then as 500 c.c. is operated on all results must be multiplied by 2, and it will be remembered that each c.c. of the ammonia solution corresponds with $\frac{1}{100}$ milligramme or ·00001 gramme of ammonia.]

Then 50 c.c. took 2 c.c. and 2 c.c. × 2 = 4 c.c. = ·00004 gramme ammonia, but add one-third. Then ·00004 + ·0000133 = ·0000533 gramme or

·0533 milligramme or parts per million. [N.B.—A litre contains a million milligrammes.]

We will suppose that 3 cylinders (of 50 c.c. each) are Nesslerised after the boiling with potash-permanganate, a fourth giving no coloration, and that

1. 50	took 2·25,	then 2·25 × 2	= 4·5
2. 50	,, ·75,	,, ·75 × 2	= 1·5
3. 50	,, ·5,	,, ·5 × 2	= 1·0
(50 free)			= 7·0 c.c.

= ·00007 gramme ammonia, or ·07 part per million albuminoid ammonia.

The Oxygen Process (Oxygen required to Neutralise Organic Matter) is performed in different ways. Thus the moist combustion process, as Professor Wanklyn calls it, is carried out by means of four solutions—viz., (1) permanganate solution, each c.c. of which contains 1 milligramme of active oxygen (*i.e.*, ten times the strength of the solution subsequently given); (2) protosulphate of iron solution, of which 1 c.c. absorbs 1 milligramme of active oxygen; (3) solution of caustic potash; (4) solution containing sulphuric acid.

The same retort as was used for the ammonia process having been cleaned and mounted, is charged with 1 litre of the water. Before the distillation begins 5 c.c. of the caustic potash solution is dropped into the flask or retort, and then 5 c.c., very carefully measured of the permanganate solution is also dropped. Distillation is then rapidly carried out until about $\frac{9}{10}$ of the water has distilled over. Then 10 c.c. of the sulphuric acid solution is dropped into the retort and shaken up with the remaining 100 c.c. of water therein. Then 5 c.c. of the protosulphate of iron solution is dropped in, and very soon the liquid, which before was pink, will become colourless from absorption of oxygen by the iron solution. Now more of the permanganate solution is dropped from an accurately graduated burette, and the quantity which is *just* sufficient to bring back a permanent pink noted. This quantity 2·6, 3·6, or whatever it may be, represents the quantity consumed by the organic matter in a litre of water, and as each c.c. represents ·001 gramme, 3·6, for instance, would be ·0036, which × 70 = ·025 grains oxygen required per gallon.

A more elaborate plan is the so-called **Forchammer Process,** which necessitates several standard solutions, *e.g.*, potassic iodide, hyposulphite of soda, and starch solutions, the latter two being, especially the hyposulphite, very unstable. Permanganate of potash solution of such a strength that 1 c.c. = ·0001 gramme oxygen (the strength used in the next modification) is also required, and the test turns upon the fact that, after the pink colour has been established in a manner very like that adopted in the first example, it is again discharged by the addition of potassic iodide (2 drops of the solution are first added) in favour of a yellow coloration by free iodine. Just so much iodine is set free as corresponds with the permanganate previously undecomposed, and this is measured by employing the hyposulphite of soda solution, which parts with some of its sodium to form sodic iodide. A comparison is then made between the results got with the actual water and those got with an exactly parallel one made with distilled water, and the quantity of oxygen calculated from the difference. The starch solution mentioned has been used to ensure the

disappearance of the last trace of free iodine, the presence of which it will show by the characteristic blue iodide-of-starch tint, and the hyposulphite is accordingly cautiously added until the exact point is reached at which this tint no longer appears on the addition of starch.

This process being, for an oxygen process, both complicated and lengthy, and being equally, with others, open to the charge of inaccuracy (protosalts of iron and nitrites into the bargain, see pp. 74, 75, affect its determinations), exact working details are not given, and we will proceed to—

The Permanganate and Oxalic Acid Oxygen Process.—Take ·3955 gramme of powdered potassium permanganate, dried at 100° C.; dissolve in distilled water and make up to a litre. Then 1 c.c. of the solution contains ·0001 gramme oxygen.

Test solution for the above. Dry between blotting-paper ·7875 gramme of pure oxalic acid. Dissolve and make up to a litre.

Two burettes should be filled, one with the permanganate, the other with the oxalic acid solution. Into a beaker containing about two teaspoonfuls of distilled water and 12 drops of sulphuric acid run 25 c.c. of the oxalic acid solution and warm on sand-bath. Add about 2 c.c. of the permanganate solution, and warm up again till the colour goes. Then run in gently, drop by drop, more permanganate, of which 25 c.c. ought to produce a faint pink colour. The correctness of the permanganate solution having been thus tried and proved, the water may be tested.

Take 500 c.c. of the water, add 2 c.c. strong sulphuric acid, warm over sand-bath, and run in permanganate gently till the tint becomes permanent. Suppose that 2 c.c. of the permanganate solution produce a permanent pink tint.

We now run in an excess of the permanganate solution (say 5 c.c.) and heat the mixture up to nearly boiling, after which enough oxalic acid solution is added just to destroy the pink. [N.B.—Be careful not to add the oxalic acid solution too fast, otherwise a brownish coloration will be produced.] Suppose it takes 4·9 c.c. of the oxalic acid solution, then ·1 c.c. more of the permanganate has been required by the organic matter, or 2·1 c.c. together.

But 2·1 c.c. = ·00021 gramme oxygen, and ·00021 × 2 × 70 = ·0294 *grains* of oxygen required *per gallon*.

Testing Hops for Sulphur (Sulphurous Acid).—A portion of the suspected hops, mixed with some distilled water, is placed in an ordinary chemical flask, fitted with an india-rubber stopper perforated for a funnel and delivery tube, and a piece of pure zinc is added to the contents of the flask. The stopper is then replaced, and the delivery tube connected with a second flask containing a solution of acetate of lead (sugar of lead). Sufficient hydrochloric acid is now poured down the funnel to react upon the zinc and set hydrogen free, which if sulphurous acid be present takes the form of sulphuretted hydrogen. This, passing into the flask containing the lead acetate solution, causes the formation of a black precipitate of lead sulphide, whereas, of course, if the gas evolved be simple hydrogen no such precipitate occurs.

Alternative method. Owing to the fact that zinc not unfrequently contains traces of sulphur sufficient to vitiate the result with unsulphured hops, the following method has been recommended. 10 grammes of hops

are placed in a 20 oz. flask with 200 c.c. of distilled water and a stick of caustic potash. Boil until the hops are thoroughly mixed, then remove flame, and add half a wineglassful of hydrochloric acid gradually. Replace the flame, and let the steam pass into a flask with a foot, containing 50 c.c. of a solution of lead acetate (made by dissolving 500 grammes lead-acetate in 2 litres of water).

A *third method* adopted by Dr. Griessmayer requires sodium-amalgam and hydrochloric acid. [The sodium-amalgam is prepared as follows.* 100 grammes of mercury are taken, and into them are thrown gradually 4 grammes of well-dried sodium, from which any white crust that forms has been removed. As each particle of sodium combines with the mercury a slight explosion takes place, sometimes sufficient to throw the mercury out of the mortar. When working them together with the pestle it is well to protect the face and hands ; the best plan perhaps is to pass the handle of the pestle through a stiff sheet of paper, which serves to cover the mortar.] The process is as follows.

The hop-liquor (got by steeping a portion of hops for some hours in water) is filtered, and about 100 c.c. of it placed in a flask or test-glass. From ·5 to ·7 gramme (as much as will lie on the point of a knife) of the sodium amalgam is now thrown in, and a strip of paper moistened with an alkaline lead solution suspended in it, after which a few drops of hydrochloric acid are poured in. The flask is now quickly closed, *but not hermetically*. with a cork or glass stopper, and within five minutes, if the least quantity of sulphurous acid be present in the sample of hops, the lead paper will be blackened.

An easy plan of detecting sulphuring, if one possess some long silvered pins, is to thrust one or two up to the head in a pocket of the suspected hops, and to leave them there for some time. If the suspicion was well-grounded the silvered surface of the pins will blacken.

Moisture in Hops.

(1) Weigh 5 grammes hops.
(2) Dry in water oven for 5 hours.
(3) Cool in vacuo.
(4) Weigh.
(5) Calculate to per cent., as in the case of the moisture in malt.

"**Constants**" are factors used to convert one (acid or) salt into terms of another salt (or acid). A few of the more useful for the foregoing tests are annexed.

"Constants."

$CaCO_3$ (Calcic Carbonate)	×	·56	to obtain	CaO (Calcic Monoxide or Lime).
$Mg_2P_2O_7$ (Pyrophosphate of Magnesia)	×	·6396	,,	P_2O_5 (Phosphoric Anhydride).
So_3 (Sulphuric Anhydride).	×	1·7	,,	$SaCO_4$ (Calcic Sulphate).
Cl (Chlorine) . . .	×	1·647	,,	NaCl (Sodic Chloride or Common Salt)
$CaCO_3$ (Calcic Carbonate)	×	1·36	,,	$CaSO_4$ (Calcic Sulphate).
$CaSO_4$ (Calcic Sulphate) .	×	·41176	,,	CaO (Calcic Monoxide).
AgCl (Silver or Argentic Chloride).	×	·4076	,,	NaCl (Sodic Chloride).

* But it can be bought ready prepared.

SO_3 (Sulphuric Anhydride).	× 1·775	to obtain	Na_2SO_4 (Sodium Sulphate, Anhydrous).
$BaSO_4$ (Baric Sulphate) .	× ·343347 (or $\frac{80}{233}$)	,,	SO_3 (Sulphuric Anhydride).
$BaSO_4$,, ,,	× ·58369 (or $\frac{136}{233}$)	,,	$CaSO_4$ (Calcic Sulphate).

Standard Solutions :—

Nitrate of Silver (for Chlorine), 4·79 grammes nitrate of silver (dried in air-bath at 100° C.) dissolved in 1 litre of water.

Nessler's Solution.—35 grammes iodide of potassium, 13 grammes corrosive sublimate (mercury perchloride).

Dissolve separately, with heat (N.B.—The corrosive sublimate dissolves with difficulty), and mix. Add distilled water, but not more than 800 c.c. and 160 grammes caustic potash, or 120 grammes caustic soda, making up to a litre. Before the potash is added, a cold saturated solution of corrosive sublimate in water is to be added till a permanent red precipitate is formed. The " Nessler " should be *yellowish* in colour.

Ammonia Solution (for Nessler Test).—Dissolve first 3·15 grammes ammonium chloride in 1 litre of ammonia-free water. Then take 10 c.c. of the above and make up to 1 litre (*i.e.*, the second litre contains ·0315 gramme, and each c.c. of it = ·01 milligramme of ammonia).

N.B.—This dilution of the stronger solution is likely to be more accurate than making up the solution with ·0315 gramme would be, but that can be done at once if preferred. The weaker solution is the one used.

Potash and Permanganate of Potash.—200 grammes of stick caustic potash, 8 grammes permanganate of potash. (Made up to a litre.)

If dissolved in about 500 c.c. first, and then evaporated almost to dryness in a porcelain dish before dilution to a litre, all ammonia will be expelled.

Soap Solution (see p. 205). 40 parts of dry potassic carbonate rubbed in mortar with 150 parts of emplastrum plumbi (British Pharmacopœia), methylated spirit being afterwards added, and the whole triturated to a cream. Filter, washing residue several times with methylated spirit, and dilute with same to the required standard (to be standardised as before with calcic chloride).

Litmus Solution :—

I. About 10 grammes of the solid material are digested with 500 c.c. of distilled water in a warm place for a few hours. The clear liquid is decanted from the sediment and a few drops of nitric acid added—enough to produce a violet colour. If at any time the colour should partially disappear it may be restored by exposing the fluid to the air in an open dish.

II. " A purer solution," Sutton says, " may be prepared as follows : Boil the litmus, previously reduced to coarse powder, two or three times with alcohol of about 80 per cent., and throw the liquid so obtained away (this treatment removes some colouring matter which is a hindrance to the proper reaction), then digest the litmus repeatedly with cold distilled water till all soluble colour is extracted, let the mixed washings settle clear, decant, and add to them a few drops of concentrated sulphuric acid until quite red, then heat to boiling ;—this will decompose the alkaline carbonates and convert them into sulphates ;—now cautiously add baryta

water until the colour is restored to blue or violet ; let the baric sulphate settle perfectly, and decant into a proper vessel for use.

" Litmus prepared and kept in this way is very sensitive to dilute acids and alkalies. With the slightest excess of oxalic, sulphuric, hydrochloric, or nitric acids it gives a pink red, and with caustic soda or potash, a blue colour ; with ammonia or the bicarbonated alkalies it retains its violet colour."

Barfoed's Solution.—[Though this solution is not indicated for use in the present chapter, its mode of preparation is given below, because it is claimed that it indicates *dextrin* and glucose—the former after a somewhat prolonged boiling but glucose on a short boiling—but that it is not reduced by *maltose* or lactose.]

One part of crystallised neutral acetate of copper is to be dissolved in 15 parts of water, and 200 c.c. of this solution are mixed with 5 c.c. of acetic acid, containing 38% of anhydrous acid. The solution contains about 1% of free acid, and was used by Barfoed in the place of Fehling's solution, the mode of preparing which has been given at the beginning of the chapter.

Moisture Determination.—In lieu of a determination by difference in the weight of a measured quantity of ground-up grain, before and after prolonged drying and then cooling in a desiccator, the following method, whereby the moisture is measured as water and grinding avoided, has been devised by Hoffmann. Into a large metal bulb fitted with a thermometer a funnel with tap and a condenser leading into a graduated cylinder, are placed, first, 200 c.c. of good lubricating oil with 10 c.c. oil of turpentine, and to this are added 100 grammes of *uncrushed* grain. The whole is then well shaken, the condenser and graduated cylinder are attached, and the oil heated to 180° C. within 8 minutes, for a period varying from 3 to 8 minutes with the kind of grain. Then through the funnel 50 c.c. of oil of turpentine containing 5% toluol are added ; this reduces temperature, which is raised to 180° C. again as quickly as possible. It is found that the graduated tube will now contain all the water that was in the grain, except 0·2 c.c. remaining in the oil ; so that the number of c.c. of water in the graduated cylinder + 0·2 will give the percentage of moisture which the grain contained.

CHAPTER VIII

HYDROGEN ION CONCENTRATION

In any industry so old as that of brewing changes in methods and manipulation proceed slowly and almost imperceptibly. A new type of refrigerator may be introduced, the collection and storage of yeast placed upon a higher scientific plane and other modifications of plant or process gradually substituted for the old without these involving any alteration in the basic process of brewing. On the other hand, with regard to our conception of the principles underlying the process, changes may be sudden, and new theories may develop so rapidly that it is difficult to keep pace with them. During the last fifty years brewing history is punctuated by a series of such changing views, ranging from an explanation of mash-tun conversion to yeast metabolism and attenuation, views which necessitate for their adequate appreciation a familiarity with the theories of enzyme action and a knowledge of colloid chemistry. The mash-tun and fermentation vessels which were in use before these theories were evolved still serve their purpose, but the biochemical and biological actions taking place in their contents are much more thoroughly understood and are therefore amenable to more perfect control. The theory of Hydrogen Ion Concentration to be discussed in this chapter has been applied to brewing problems with almost startling suddenness, for the theory itself is a product of the comparatively short while that has elapsed since the publication of the former edition of this book. Not only is it brewing science that is affected by a new outlook upon old processes, but every branch of science and every industry dependent upon biological processes is similarly affected. This is because of its importance to the living cell and its bearing upon all that relates to the welfare of cell-life, be it a cell existing as a separate entity like that of the yeast plant or a blood corpuscle, or a cell forming a unit in a complex multicellular structure like either the barley plant or the human body. As a brewer's wort results from the action of solublising cellular secretions upon insoluble materials, and the attenuation of the wort upon other and living cell secretions, the physical conditions which so profoundly affect the cells themselves must necessarily have intimate bearing upon the whole process of brewing.

It has been known since Pasteur's time that the " reaction " of wort is an influencing factor in the fate of a brew, but it is only since the introduction of methods for measuring hydrogen ion concentration that we have learned how minute are the differences in reaction (as hitherto measured by chemical means) which decide the nature of the wort and even affect the weight of extract obtainable from a given grist. An acid reaction is a normal characteristic of a finished beer, but small differences in the development of substances which give this reaction affect saleability and may become a deciding factor in the balance of profit or loss. Acid bodies, whatever may be their origin, contain hydrogen, but more impor-

tant still is the fact that in solution a part or even the whole of their hydrogen is dissociated from the remainder of the molecule and is present in a free state as shown in the examples given below. All acids are electrolytes, that is, they are decomposable by an electric current, and it is to the theory of electric dissociation, or the **ionic** theory, that we must look for a basis upon which to establish the terms **acidity** and **reaction** mentioned above.

The Ionic Theory.—The assumptions of this theory as elaborated by Arrhenius, are as follows :—

(1) When an electrolyte is dissolved in water, its molecules are immediately more or less completely dissociated into smaller fragments, or ions, of unlike composition : $HCl \rightarrow H + Cl$.

(2) These ions are charged with electricity ; the ions of the one product are charged with positive, the ions of the other with negative electricity, the unit positive charge being equal in quantity, but opposite in kind to the negative charge : $HCl \rightarrow H^+ + Cl^-$.

(3) The dissociation is a reversible action, $HCl \rightleftarrows H^+ + Cl^-$. This equation can be typified as $H\,Ac \rightleftarrows H^+ + Ac^-$, where H is the hydrogen ion and Ac the acidic ion. For example, acetic acid dissolved in water may be represented by $CH_3COOH \rightleftarrows H^+ + CH_3COO$ in which the negative ion is represented by a group of elements. When an electric current is passed through a solution containing ions the positive ion appears at the negative pole or kathode and is termed a kation : the negatively charged ion travels to the positive pole or anode and is known as an anion. Electrolytes are completely ionised at infinite dilution.

Acids of different kinds dissociate to differing extent ; hydrochloric acid and some other mineral acids dissociate very strongly, or, in other words, more completely than organic acids. Acetic and lactic acids which occur in beer dissociate to quite a small extent, and on this account they are termed weak acids ; carbonic acid and boric acid are also weak acids. It should also be observed that " strong " and " weak " are not synonymous with " concentrated " and " dilute " ; the latter terms having reference only to the amount of acid and not their property of ionisation.

Acidity, Alkalinity and Reaction.—It is to the positive hydrogen ion in solution that the property known as acidity is due. A solution of acetic acid contains dissociated H^+, and CH_3COO^- ions, together with undissociated CH_3COOH, but it is the concentration of the H^+ ions which is a measure of the *effective acidity* or *reaction*.

Alkalinity is explained similarly. A base when dissolved in water dissociates into basic hydroxyl ions, the base carrying a positive charge and the hydroxyl ion a negative charge of electricity : $NaOH \rightleftarrows Na^+ + OH^-$. Here again it is to one of these, the hydroxyl ion, that *effective alkalinity* is due. There are strong bases like sodium and potassium hydroxides, and weak bases, of which ammonia is an example.

It is stated in assumption (3) that electrolytes are completely ionised at infinite dilution. Those weak acids which dissociate to only a slight extent continue to undergo dissociation as dilution proceeds, and at any given dilution the concentration of hydrogen ions produced is in accordance with the law of mass action. The ratio of the product of the concentration of the hydrogen ions H^+, and the acidic ions Ac^-, to the concentration of the undissociated HAc is known as the dissociation constant of

that particular acid and is represented by the symbol K; that is $K = \frac{[H^{+}] \times [Ac^{-}]}{[HAc]}$. The same equation may be applied in the case of a base, $K = \frac{[B^{=}] \times [OH^{+}]}{[BOH]}$. Thus there is always a definite relationship between the ionised and the non-ionised molecules in solution.

As examples of the degree of dissociation exhibited by different acids and alkalis, in the case of a decinormal solution of the strong acid HCl, 91 per cent. of the hydrogen is dissociated; of the weak acid CH_3COOH only 1·3 per cent. A decinormal solution of the strong alkali NaOH dissociates to the extent of 84 per cent., whilst a corresponding solution of NH_4OH only to 1·4 per cent. As previously mentioned, it is the concentration of the free H^{+} or the OH^{-} ions which imparts the characteristic properties of acidity or alkalinity; in other words, the degree to which a solution possesses either property is dependent upon the concentration of the free or available hydrogen ions or hydroxyl ions respectively.

Neutrality.—Now our universal solvent water is itself an electrolyte. It dissociates according to the foregoing equation, $HOH \rightleftarrows H^{+} + OH^{-}$, but it does so to an exceedingly small extent. Although there is an almost infinitely large mass of undissociated HOH and an almost infinitesimal proportion of ionised HOH, the H^{+} and OH^{-} ions are not without measurable effect, and it is to these that water owes its behaviour as a conductor of electrical current. Sorensen has determined electrometrically that one litre of pure water at 22° C. contains one ten-millionth gram of hydrogen ions: that is, the concentration of H^{+} ions is $\frac{1}{10{,}000{,}000}$ gram per litre $= \frac{1}{10^{7}} = 10^{-7}$. As the molecules of HOH have been equally dissociated into H^{+} and OH ions, the negative ions OH^{-} must also equal $\frac{1}{10{,}000{,}000}$ gram per litre, $= \frac{1}{10^{7}} = 10^{-7}$. Here we have a solution in which the H^{+} ions giving an acid reaction are perfectly balanced by OH^{-} ions (which would themselves impart an alkaline reaction), with the result that we have a state of *absolute neutrality*.

In all measurements of hydrogen ion concentration pure water is taken as the standard.

The Expression, pH.—At any given temperature the product of the hydrogen ion concentration and the hydroxyl ion concentration is a constant. As the hydrogen ion concentration at 22° C., as determined by Sorensen, is 10^{-7}, and as the hydroxyl ion concentration is equal, the dissociation constant is $10^{-7} \times 10^{-7} = 10^{-14}$. At 18° C. it is $10^{-7\cdot07} \times 10^{-7\cdot07} = 10^{-14\cdot14}$; it will tend towards simplification in what follows if the value 10^{-14} is retained.

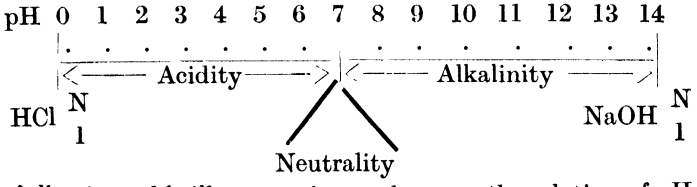
It has been stated that pure water always contains hydrogen and hydroxyl ions in balanced proportion. With so small a H^{+} concentration as $\frac{1}{10{,}000{,}000}$ gramme per litre, which is a readily measurable quantity, it may be easily conceived that it is extraordinarily sensitive to the presence of other dissociable substances, as it is. The absorption of traces of carbonic acid gas from the atmosphere immediately destroys the delicate

balance of positive and negative ions owing to the production of more free H^+ ions, as will be seen from the following equation :—

$$CO_2+H_2O \rightleftarrows H_2CO_3 \rightleftarrows H^+ + HCO_3^-$$

Such a solution would have a hydrogen ion concentration greater than 10^{-7}, say 10^{-6}, and the solution would be no longer neutral. There would still be hydroxyl ions present, and their concentration may be calculated from the dissociation constant 10^{-14} ; $\frac{10^{-14}}{10^{-6}} = 10^{-8}$.

It will be appreciated that whether use is made of the fractions $\frac{1}{10,000,000}$, $\frac{1}{100,000,000}$ *et seq.*, or their logarithmic equivalents 10^{-7}, 10^{-8} *et seq.*, it involves the manipulation of unwieldy figures, which are altogether unmanageable in the production of graphs. Sorensen overcame this difficulty by adopting the symbol pH^+ to denote the " hydrogen ion exponent " or " hydrogen ion concentration." pH^+, or, as it is now more frequently written pH, is the logarithm to the base 10 of H^+ but with the negative sign omitted. Thus 10^{-7} becomes pH 7 ; 10^{-3} = pH 3 ; 10^{-13} = pH 13, the numerical value of pH decreasing with increasing hydrogen ion concentration. A scale illustrating the series of pH values from 0 to 14, *e.g.*, within the limits of the dissociation constant 10^{-14}, may be constructed as follows :—



The following table illustrates in another way the relation of pH values to the strength of hydrochloric acid and sodium hydroxide solutions :—

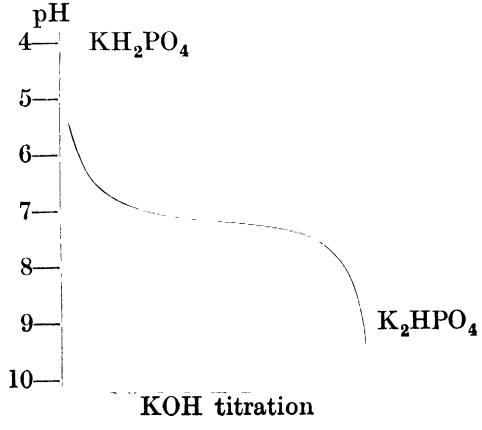
TABLE I.

Strength of solution.	Grammes of hydrogen per litre.	Expressed logarithmically.	PH value.
Normal HCl	1·0	10^{-0}	0·0
1/10 N HCl	0·1	10^{-1}	1·0
1/100 N HCl	0·01	10^{-2}	2·0
1/1000 N HCl	0·001	10^{-3}	3·0
1/10000 N HCl	0·0001	10^{-4}	4·0
1/100000 N HCl	0·00001	10^{-5}	5·0
1/1000000 N HCl	0·000001	10^{-6}	6·0
Pure water	0·0000001	10^{-7}	7·0
1/1000000 N NaOH	0·00000001	10^{-8}	8·0
1/100000 N NaOH	0·000000001	10^{-9}	9·0
1/10000 N NaOH	0·0000000001	10^{-10}	10·0
1/1000 N NaOH	0·00000000001	10^{-11}	11·0
1/100 N NaOH	0·000000000001	10^{-12}	12·0
1/10 N NaOH	0·0000000000001	10^{-13}	13·0
Normal NaOH	0·00000000000001	10^{-14}	14·0

Buffer Action.—So far we have considered only the behaviour of acids dissolved in water in the absence of any substance which might interfere

with the full activity of their dissociated ions. A great many substances have the property of attracting to themselves hydrogen ions which are then, of course, no longer free ; such substances are called " buffers." They are, in point of fact, reaction regulators which prevent rapid changes in the hydrogen ion concentration upon the addition of acids and alkalies. Many salts, particularly acetates, citrates, borates, phthalates and phosphates exhibit this property to a marked degree, whilst amino-acids, peptones, beef extract, malt extract, gelatine and other complex organic substances act in the same way. In contrast with the rapid alteration in pH value which would occur in the case of absorption of CO_2 from the atmosphere by pure water, a buffered solution like a malt wort or beer may remain exposed to air for a considerable time without undergoing any change from this source. Any noticeable alteration in the latter circumstances would be almost certainly traceable to the activity of micro-organisms. Similarly, the addition of acetic acid in small quantities to pure water would have immediate effect on hydrogen ion concentration and the pH value would be considerably lowered. If the same quantity of acid were added to a solution of sodium acetate, the difference in *reaction*, or *available acidity*, before and after addition would be only slight, although the *total acidity* would be the same in each case. R. H. Hopkins has given an interesting example of the buffer effect of a 1 per cent. peptone solution on the reaction of lactic acid. 100 c.c. of pure water is taken, the hydrogen ion concentration of which is $10^{-7\,07}$ (say pH 7). The effect of adding 1 c.c. of lactic acid will be to increase the hydrogen ion concentration to $10^{-3\,42}$ (say pH 3·4), which represents an increase to over 4,000 times the original concentration of hydrogen ions. If, however, the 1 c.c. of N/10 lactic acid be added to 100 c.c. of a 1 per cent. peptone solution of pH 7, the hydrogen ion concentration is merely altered to pH 6·7, an increase to 2·34 times as much. Further, if the same quantity of acid be added to a 5 per cent. solution of peptone, the increase is still smaller, about 1·2 times.

This buffering action has been simply illustrated by G. Hagues, who has summarised the effect of hydrogen ions in brewing. If a solution of a typical buffer substance like potassium dihydrogen phosphate is titrated with a caustic potash solution of about the same strength, the variation of pH value is influenced as in the following diagram.



It will be noted that that portion of the curve at about pH 7 is practically a straight line and that the pH value in this region alters only slightly on the addition of acid or alkali. This constitutes the " buffer " effect of a mixture of the primary and secondary phosphates of potassium and the efficiency of this buffer action depends on the relative amount of the two substances in the mixture. The buffer action of wort may be taken to be analogous to this, but the effect will not be so sharply defined and will extend over a wider range of pH value, since many other buffer substances are present. Quoting further from Hagues, "The effect of saline substances, such as calcium carbonate, in brewing water will be to neutralise a considerable quantity of the more acidic constituents of the buffer mixture, thus lowering the free acidity of the mash. Potassium dihydrogen phosphate may be taken as a typical acid constituent, and the reactions which occur may be represented by the two equations :—

$$4\,KH_2PO_4 + 3\,CaCO_3 = Ca_3(PO_4)_2 + 2\,K_2KPO_4 + 3\,H_2CO_3$$
$$2\,KH_2PO_4 + CaCO_3 = CaHPO_4 + K_2HPO_4 + H_2CO_3$$

Calcium carbonate thus lowers the free acidity by converting some of the primary phosphate into secondary. On the other hand, the presence of gypsum in the mashing water has the reverse effect ; namely of lowering the pH value or increasing the free acidity. In the reaction which takes place calcium phosphate is precipitated, whereby some of the secondary phosphate is changed into primary.

$$4\,K_2HPO_4 + 3\,CaSO_4 = Ca_3(PO_4)_2 + 2\,KH_2PO_4 + 3\,K_2SO_4$$

Similar equations may be written down expressing the reactions taking place with organic buffer substances. Whilst an excess of gypsum is detrimental to the final beer, producing a bitter taste, due to the formation of magnesium sulphate, a small amount is advantageous. It precipitates a certain amount of phosphoric acid as calcium sulphate, which is removed in the hop-back, and which would otherwise exert an excessive restraining influence on the free acidity, preventing the latter from attaining the optimum pH value for the yeast. As a rule, carbonates in brewing water are harmful because they lower the hydrogen-ion concentration of the wort and give rise to conditions favourable to the subsequent formation of the potassium salts of tannin and phlobaphene."

The Determination of pH Values.—There are two practical methods available for the determination of hydrogen ion concentration. The more exact, where applicable, is the electrometric method. This is based upon the method of measuring differences in electromotive force set up by the presence of metallic ions (hydrogen functioning as a metal) in aqueous solution according to the concentration of ions. It involves the use of delicately-constructed and expensive apparatus as well as skilful manipulation. This method and its applications in brewing are lucidly described and discussed by N. M. Parsons in the *Journal of the Institute of Brewing*, 1924, p. 30, in an article which should be consulted by brewers desirous of further information on this subject.

Indicators.—The second or colourmetric method depends upon colour changes produced in certain substances by varying acidity or alkalinity. These substances are called *indicators*, and they are sensitive to changes of reaction within very definite limits. Litmus, although it has been found so useful in the past, is not a definite compound, and its colour reactions

are liable to variations ; its neutral point lies between pH 6·6 and pH 7. Phenolphthalein gives accurate results over its range, which is between pH 8·0 and pH 9·6, and which, as will now be understood, is considerably on the alkaline side of neutrality. Methyl orange has a range from pH3·1 to pH 4·4, this being very considerably on the acid side. Sorensen made a very careful study of the relation of indicators of the sulphon-phthalein series to the pH scale, and Mansfield Clark and others have experimented in the same direction. Some of these substances and their ranges of sensitivity to reaction are shown in the following table :—

TABLE II.

Indicator.	Full Acid Colour.	Full Alkaline Colour.	Sensitive Range.
Thymol blue (acid range)	Red	Yellow	1·2–2·8
Brom phenol blue	Yellow	Blue	3·0–4·6
Brom chlor phenol blue	Yellow	Blue	3·2–4·8
Brom cresol green	Yellow	Blue	3·8–5·4
Methyl red	Red	Yellow	4·4–6·0
Chlor phenol red	Yellow	Red	5·0–6·6
Brom cresol purple	Yellow	Purple	5·2–6·8
Brom phenol red	Yellow	Red	5·4–7·0
Brom thymol blue	Yellow	Blue	6·0–7·6
Phenol red	Yellow	Red	6·8–8·4
Cresol red	Yellow	Red	7·2–8·8
Thymol blue (alkaline range) ...	Yellow	Blue	8·0–9·6
Phenol phthalein	Colourless	Red	8·0–9·6
Cresol phthalein	Colourless	Red	8·2–9·8

The indicators which have proved most useful in the brewing laboratory are Brom thymol blue, Brom cresol purple, Methyl red, Brom phenol blue and Brom cresol green.

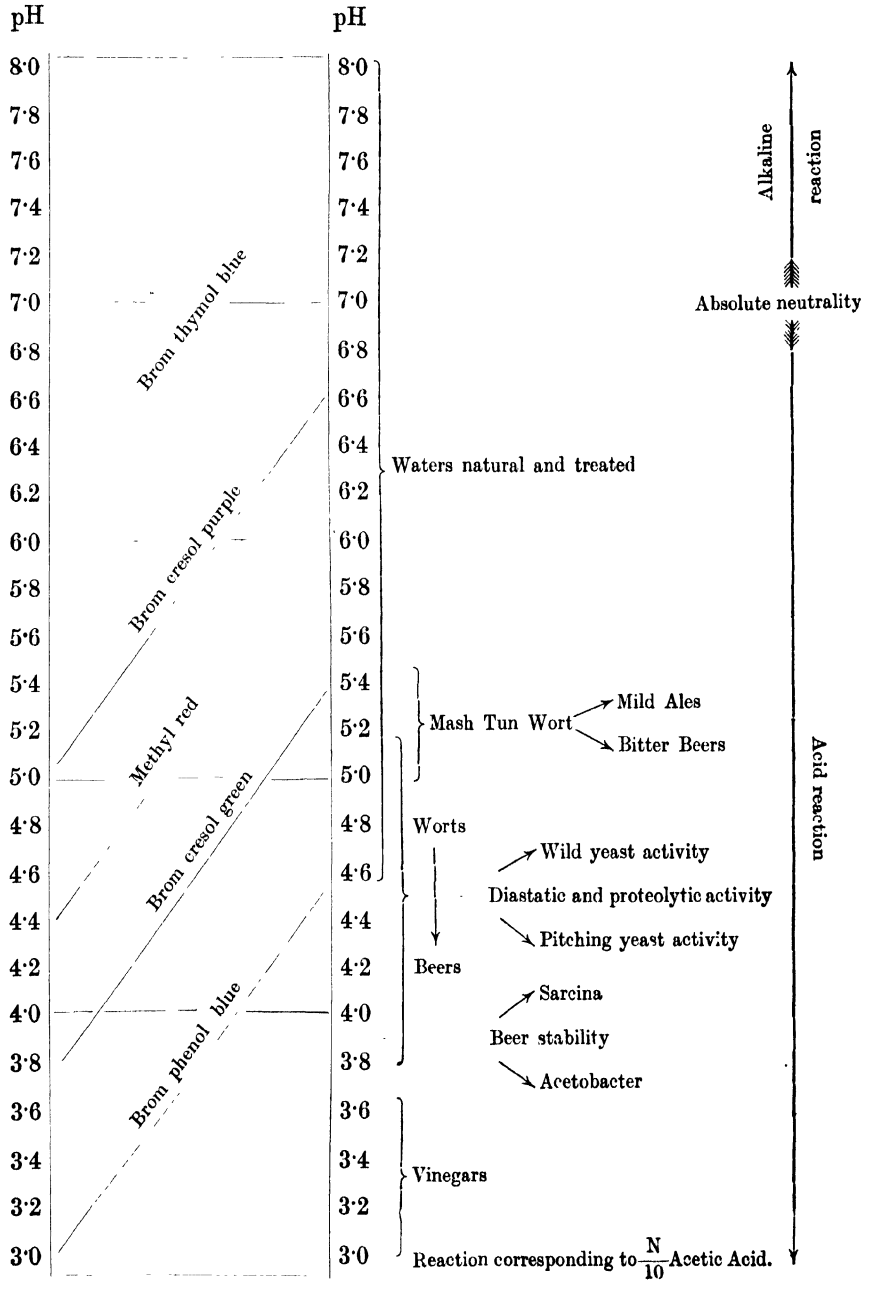
Brom thymol blue is a particularly valuable indicator, as its range of sensitivity from pH 6 to pH 7·6 includes, of course, pH 7, taken as neutrality. At this point it gives a well-defined grass-green coloration. It finds special use in adjusting micro-biological media, and, by using the " Biotec " comparator * a medium or solution of any kind may be adjusted *in situ* alongside a solution of the indicator and its colour compensation tube. Used for testing samples of water or other liquids, this indicator gives instantaneous information with regard to the acid, the absolute neutral, or the alkaline character of the sample ; it does not, of course, give a definite pH value unless the range of deviation from absolute neutrality lies within the range pH 6—pH 7·6.

Brom cresol purple has proved more particularly useful in the examination of natural and treated waters. Methyl red and Brom phenol blue serve for worts and beers, although they are in frequent use for estimating the pH value of acid waters. The pH value of worts fall within the Methyl red range and that of beers within the range of Brom phenol blue. The use of the two last-mentioned indicators is not wholly satisfactory. It will be noted from Table II. that there is an overlap of the less acid end of the range of Brom phenol blue with the more acid end of Methyl red, and with some samples of beer having pH values between 4 and 4·4, the pH indicated by Methyl red is not corroborated by the reaction indicated by Brom phenol blue. Methyl red is known to be unstable because of its tendency

* Bulletin of the Bureau of Bio-Technology, Vol. I., No. 9, 1923.

to undergo reduction. Brom phenol blue is liable to give trouble on account of its property of dichromatism, and Brom cresol green appears to be more serviceable for worts and beer within the range pH 3·8—pH 5·4. The chart given below illustrates the useful ranges of these indicators.

INDICATORS APPLICABLE TO BREWING OPERATIONS



Practical Applications.—A perfect check can be kept upon the reaction of the brewing water by means of the colourmetric method. Well and river supplies are liable to considerable variation, especially those from limestone areas. According to N. M. Parsons, water delivered by the Metropolitan Water Board varies from day to day. With regard to the pH value, waters vary within rather wide limits from pH 8 on the alkaline side to pH 4·5 on the acid side of neutrality. Peaty waters such as are supplied by many Northern Corporations are always acid in reaction, as is also distilled water. When the brewing water is treated, particularly in the case of acid treatment, the method constitutes a valuable check upon the materials used and on the rate of addition. Hagues and Hopkins have published results indicating the relation of hydrogen ion concentration to the mashing process. The optimum reaction for conversion appears to be 5·4. In general practice mash-tun worts varying in hydrogen ion concentration between 5·0 and 5·6 are met with. In the F.V. the wort exhibits a rather rapid increase in hydrogen ion concentration continuing up to racking when usual values lie between 3·8 and 4·2. Parsons has determined what he regards as a "safety-point" for the stability of beers at 4·15 but, as pointed out by Professor Ling, it should be remembered that a satisfactory pH at this stage may be due not altogether to the constitution of the acidity of the wort but to the acids produced by bacteria.

There is little doubt that each brewery will have its own optima of pH values at the various stages of brewing and these must be determined for each individual brewery before real advantage can be taken of the process.

* The writer is indebted to Messrs. Murphy & Son, Ltd., for permission to quote extensively from his paper on this subject which is published in the Bulletin of the Bureau of Bio-Technology, No. 14, 1925.— F.A.M.

CHAPTER IX

MODERN BREWING METHODS

OBJECTS IN MASHING—RESTATEMENT OF GENERAL PRINCIPLES—AXIOMS APPLIED TO PRACTICE—NOTING ACROSPIRE GROWTH OF MALT—MALT OF AVERAGE DIASTATIC CAPACITY—MODE OF INCREASING DEXTRIN RATIO—STARCH—GRANULOSE—AMYLO-CELLULOSE—DEXTRIN—AMYLO-, ACHROO-, AND ERYTHRO-DEXTRINS—MALTOSE—EQUATIONS OF MASH-TUN CHANGES—MALTO-DEXTRIN THEORY—EVIDENCE ON WHICH THE THEORY IS BASED—ISOLATION OF MALTO-DEXTRIN—FORMULA—MODIFICATION OF EQUATION SERIES—PERCENTAGE AND TYPE OF MALTO-DEXTRINS, AND THEIR INFLUENCE—LIMITED DECOCTION—SEMI-PREPARED RAW MATERIAL—HOT GRIST-MASHING—STOUT AND PORTER GRISTS—BROWN AND PATENT MALT—SUBSTITUTE FOR—RAW OR RETURN WORT—DEAD MASHES—SPARGING—UNDERBACK—STEWING—BOILING—ADDING THE HOPS—STEAM-BOILING AND FIRE-BOILING—OPEN OR CLOSED COPPERS—HOT AERATION OF WORT.

Original Brewing Methods.—Modern Mash-Tun Working.—Many years have passed since the system of extraction practised generally was to obtain a series of washings from the mash-tun goods which, for lack of a better term, were spoken of as "mashings." It was usual to drain the goods after standing on for a definite time and between each mash. The number usually ran to three, although some brewers considered that large extracts were obtained at the expense of quality and accordingly limited their so-called "mashes" to two. Even after the introduction of sparging, the method which we have just briefly outlined still obtained, and indeed still survives, we have found, in some districts, and is not, we may add, confined to altogether small breweries. Notwithstanding that in the vast majority of instances it is now customary to sparge and drain off from the "goods" simultaneously we would submit that despite the installation of improved spargers the crude methods of our forefathers in respect to liquor calculations are still adhered to. We will confine ourselves in the present article to discussing this aspect of the question. Assuming the total volume of wort which we decide should reach the copper from the mash-tun amounts to 6½ barrels per quarter of malt mashed, and allowing for absorption by the goods, we must employ 7¼ barrels of liquor for mashing and sparging, of which 2¼ barrels was used in the former operation. Obviously the absorption referred to occurs during the initial mixture of dry grist and water, and the point we wish to direct attention to is the fact that five barrels, or over three times the volume of liquor used in mashing, remains for sparging. And yet this process is considered by many brewers a minor one, and is left in the hands of workmen. We agree that the type of extract is determined at mashing, and is practically unaltered by any course that may be adopted subsequently, but whether the extract is increased and the whole carried forward to the copper depends upon the manner in which sparging is carried out. It will, we think, be granted that in order to exhaust the goods thoroughly and to convert the unmodified starch, which exists to a more or less extent in all malts and is unconverted at ordinary mashing temperatures, it is necessary to work with at least

three separate sparging temperatures. The recognised rule is to draw upon a hot-liquor tank reserved for the purpose certain prearranged volumes of sparging liquor at precise temperatures. Throughout the entire sparging period the bulk of liquor is continually being " broken down " to the temperature required, and as the contents of the vessel is thus constantly being altered, difficulty is experienced in gauging the quantity of liquor necessary to bring up the copper lengths. It is seldom possible to obtain definite temperatures when cold water or steam is added to large bulks of liquor. It is more of the nature of a coarse adjustment, and to finely adjust matters a branch pipe from the cold supply generally runs into the sparging main. This complicates calculations, and as it is impossible to know what portion of the sparge liquor is received from the branch pipe, accuracy of sparging lengths cannot be obtained. The mistake generally errs on the side of excess, which dilutes the available extract, the overplus sparge being carried down the wash out pipe. When the total liquor is correctly gauged by the method which we will presently describe, there is no loss of extract in this respect, the whole reaching the copper.

Breweries where a single hot-liquor vessel serves the double purpose of supplying brewing water together with that required for general washing purposes—and there are many such—have the additional handicap of being compelled to suspend cleaning operations while sparging is proceeding.

The only practical method of ensuring regularity is to ignore the tanks and to confine our calculations to the mash-tun. This is a gauged vessel, a fact which has apparently been generally overlooked. When Steel invented what was then described as an outside masher brewers were advised to use water at the rate of two barrels per quarter of grist, and this was reckoned to occupy the bulk of three barrels in any mash-tun. The same principle is still applied to mashing operations, and it is surprising that it has not been extended to sparging, having regard to the difficulties associated with the latter, which we have already dealt with.

The Inland Revenue base their mash-tun calculations on the number of gallons of liquid which occupy the space of one inch, and this information will be found recorded under the heading of Mash Tun areas in the Excise Specimen book, or the brewer can readily ascertain for himself the quantity of water necessary to cover the depth named, and it is from this factor also that the brewer should form his calculations for sparging. We will assume that it requires on an average 23·81 gallons in one mash-tun and 30·27 gallons in another to cover one inch. If we divide 36 by the above figures we find that a barrel occupies an area of 1·5 inches in the first vessel and practically 1¼ inches in the second. Similarly we can apply this principle to mash-tuns of any dimensions, and the data being a constant is easily borne in mind. For our purpose and to simplify matters if we work out a sparging example based on a mash of ten quarters in the first-named mash-tun, it will be sufficient to illustrate our meaning. After sparging at a high temperature to raise the initial heat to the maximum decided upon, and maintaining the goods at this temperature for half an hour, we then proceed to calculate the quantity of sparging liquor now remaining to complete our copper lengths. At this stage the grains are in a semi-exhausted condition, and measure, apart from the water mixed with them, on an average mixed grist, seven bushels per quarter. We have then 70

bushels, and converting this to gallons, 70 × 8, the grains occupy a total space of 560 gallons, which, divided by 23·81—the factor for our first mash-tun—represents a wet dip of 23·5 inches for grains alone. We have now to ascertain what quantity of water is present in the mash-tun, and it must be clear that, as already explained, every inch and a half in excess of the dip just named relates to a certain definite number of barrels of water.

Towards the close of sparging, by obtaining the total wet dip of the mash and deducting therefrom the depth occupied by the grains alone, we readily ascertain the number of barrels of water present in the tun. We compare this with the length of wort already reached in the copper, and merely continue sparging until the shortage of sparge liquor necessary to complete the copper lengths have been run on to the goods. It is difficult to interpret the full working details of any practical system when they are explained on paper, but with a little practice exact results can always be secured, in any type or size of mash-tun.

The Loss of Extract resulting from Hurried Mash-tun Working.—We have carried out a large number of experiments, extending over a great many years, with mash-tuns of various capacities, and are convinced that deficiency in extracts, while employing normal malts, is mainly attributable to hurried mash-tun working. While the character and composition of the wort is formed in a very great measure during the first half-hour after mashing, due to rapid diastatic action on the fully modified portions of the grist contents, this does not, however, refer to the quantity of extract which will be ultimately secured from the grist. The usual standing on period of two hours is insufficient to gelatinise and saccharify the residue of starch represented by the so-called "hard ends" necessarily present in all malts, for reasons which we need not discuss here, as they were dealt with under "Malting." Higher temperatures are required to break down the cellulosic tissue surrounding the hard ends which has not been reached by the cytase during the malting process. But it must be borne in mind that as the diastase remaining in the goods while sparging is proceeding is weak a rapid increase in temperature to that decided upon would result in starch, or products closely allied, in the tap runnings. First sparging temperatures should therefore never exceed 170°, and if possible five degrees lower is preferable. In order to obviate the risk of unduly crippling still further the residual diastase, the speed of sparge and taps should be arranged that the maximum goods "heat" is reached at not less than two hours from tap-setting, depending, of course, on the range of degrees of temperature that separates this "final" from that registered at the stage just named. Experience has proved that satisfactory results are secured from a final goods heat of 158° for bitters and 160° for milds, if these temperatures are maintained for a further hour. It will be observed that three to three and a-half hours have thus been occupied in rendering soluble those portions of normal grist which resists the influence of the several agencies of change which have been at work during "standing on." In other words, all the residue of starch which accounts for the difference between a high and low extract should, if the conversion has been carried out with some degree of care and skill be now ready at hand, and the remainder of the sparging process is merely one of washing forward the available extract to the coppers with all possible speed, regulated only by the condition of the tap

wort, which should be bright and free from matters in suspension. There are two practical points to be here noted. Until the final washing out stage is reached the goods should always be maintained at the depth registered at the completion of mashing. Care should be observed, too, that the speed of wort running is never under any circumstances accelerated to any extent while gravity is present. A rough but sufficient indicator for our purpose is the colour of the wort at this stage. It should be remembered that the saccharifying medium diastase is in solution in the wort, and if the flow is hastened not only will we suffer in loss of extract, but starch may appear in the last runnings. When the mash shows signs of exhaustion and the gravity begins to wane, there is no necessity for further delay, and, as we have said, washing may proceed with the utmost speed. The time occupied in completing the copper lengths should never be lower than four and a-half hours, and with badly modified malts, or when the diastatic power is low, an additional half-hour is required in order to obtain the extract available. There are breweries where it is impossible to "finish off" under twelve hours from mashing unless the copper lengths are completed within about three hours from tap-setting. But this delay is invariably due to the out-of-date methods of applying the hop-splash. It is still customary in quite a number of establishments to defer "splashing" the hops until the brewing has been collected. The water required for washing out the wort retained by the hops should be run on immediately the hop-rack is empty, and after a stand of 15—20 minutes the splash is carried forward to the coolers without causing loss of time or deferring the refrigerating of the main bulk of wort. This system has other advantages, which we have already fully described in a previous chapter. It would be impossible to lay down definite practical rules to follow in connection with sparging and speed of wort running, as so much depends on plant and class of mash-tun materials employed. The following assumed example will serve to illustrate our meaning, and if applied to a typical plant with normal malts in use, satisfactory results in point of extract increase should be secured. The total barrelage carried forward to coppers in a 20-qr. mash may be taken for our purpose at 130 barrels, or at any rate of 6½ barrels per quarter. The wort from this mashing should be run off as under :—

Rate of speed for 20-qrs. mash.

										Total brls.
½	hour	at	½	brl.	per	qr.	per	hour	. . . .	5
1	,,	,,	¾	,,	,,	,,	,,	,,	. . . .	15
1	,,	,,	1	,,	,,	,,	,,	,,	. . . .	20
1	,,	,,	1½	,,	,,	,,	,,	,,	. . . .	30
1	,,	,,	3	,,	,,	,,	,,	,,	. . . .	60
4½	hours	minimum	time	occupied					. . . .	130

The sparging liquor for washing purposes applied during the last hour should be run on at a less rate that the speed of the wort flow to coppers in order that the sparge may be maintained working until the last copper length nears completion.

The objects that the practical brewer, consciously or unconsciously,

keeps in view when standing by the mash-tun, are to get as large an extract from his malt as is consistent with quality; to secure finished beers to the point of absolute brilliancy, to supply his yeast in the fermentation stage with sufficient suitable food to keep it vigorous, a condition which has a good deal to say on the question of clarification, without over-feeding it; and finally, so to regulate the ratio of maltose to dextrin (or according to the newer lights, the proportion and type of malto-dextrins) in his wort, that the resulting fluid shall be what the taste of his customers demands—viz., either a clean alcoholic (vinous) beer, or one which is "fuller in the mouth," even, it may be, to an extent that makes the product taste somewhat mawkish and cloying to those who are accustomed to a more stimulating alcoholic drink.

And in truth, between the two possible extremes lies the region of safety. A beer brewed so as to develop the maximum proportion of alcohol (on the lines of a distiller's and vinegar brewer's "wash"), far from being stimulating, would taste poor, flat, and thin; while, on the other hand, the retention of a large proportion of unfermented matter does not, as might perhaps be expected, necessarily give the impression of "body,"—often indeed the reverse. The palate, in fact, demands a certain balance of qualities, variable within somewhat restricted limits. There must be "vinosity," *i.e.*, a generous percentage of alcohol, but there must also be body to back it up; there must be, albeit this is a question with which mashing, as such, has nought to do, more or less hop-flavour; and there must be such a degree of saturation with carbonic acid as produces, in conjunction with the other good qualities, what is known as "a bite upon the tongue." Yet all these things are as vanity if the beer will not go bright, either spontaneously or upon the employment of finings; for so close is the connection between eye and palate in estimating the quality of that article, that it is difficult to say which sense takes the lead. Certainly, as far as the general body of consumers is concerned, the eye is gaining the preponderance in the partnership.

We trust we shall not seem ungrateful if we venture to suggest that gentlemen to whose scientific researches the principles which underlie the mash-tun changes owe so much of their development, are too prone to consider malt as being of one unvarying quality. They speak as if malt digested at a certain temperature (or between certain temperatures), and for such and such a space of time, will produce an absolutely unvarying ratio of maltose and malto-dextrins to dextrin, each computed to the second place of decimals. At least—though, stated thus, the absurdity seems evident—this is what they have the air of doing.

However, the operative brewer has grounds for suspecting that although the factors which he, standing by the mash-tun, is able to influence, viz., the heat of the liquor used (the "striking heat"), the degree of liquidity of the mash, and the length of "stand" after mashing, will have considerable influence on the constitution of his wort, yet that those factors, too, which he cannot then influence, viz., the degree of growth of the malt and specially the temperatures it underwent in drying and curing, as well as the character of the original barley, are not less potent. And as practical uniformity of growth, year by year, is the most easily observed, it appears that varying, perhaps widely varying, kiln-temperatures and subtle differences in the character of barley, must be made responsible for

such modifications of the mashing-process as are needed to attain a sufficiently uniform result.

But whatever the modifications, they are modifications which have to be made upon certain lines, and we cannot agree with an assertion, which lately caught our eye in a responsible publication, to the effect that the diastatic power of malt had now become so extreme that it was hopeless to try to limit it by any variations of temperature. This is " throwing up the sponge " with a vengeance ; but fortunately practical experience demonstrates that it *is* possible to do so. Such an assertion is only the crystallised expression of generalisations as to the persistent flatness of beer nowadays ; uncontrolled diastatic energy and extreme flatness standing, as has been said above, in the relation of cause and effect. That such a tendency to persistent flatness is universal we can, of our own knowledge, deny ; that it is even general we find it hard to believe, seeing that it is quite possible for a brewer, using material of no especial quality, to produce beers, even of the lightest gravity, capable, when poured into a glass, of carrying a head which will last for half an hour or more.

But to do this he must be prepared to modify any hard and fast rules which he may have previously formulated, still, however, paying due regard to the general principles on which his earlier system was fashioned.

Restatement of General Principles.—These general principles are based on a series of facts : (1) That an active principle, which is known as diastase, exists in malt, and that it is capable (the malt being ground and mashed, and the heat of the mash kept within a certain range of temperature), firstly, of bringing about the liquefaction of all the starch of the grain (and even of large quantities of added starch in the form of " gelatinised " rice, etc.), with which it comes into contact, and, secondly, of converting this liquefied starch into a type of sugar known as maltose, and another body—or mixture of bodies—of a more gum-like and less fermentable nature, known by the generic name of dextrin.* (2) That this diastase, though more readily extracted in an active condition by water of comparatively low temperature, requires heats higher than those most favourable to its own solution to ensure energetic action upon the starch (for malto-dextrin, see pp. 243—245).

(3) That the ratio of maltose to dextrin may vary between 2 parts of maltose to 1 of dextrin, and 2 parts of dextrin to 1 of maltose—but not beyond these limits (though careful digestion at or below 140° Fahr. may produce maltose in the ratio 4 : 1 of dextrin). (4) That the nearer the initial heat† approaches the lowest permissible limit of 140° Fahr., being subsequently gradually raised, by underlet or other means, some 10° or 12°, the higher will be the ratio of maltose to dextrin, and conversely, the nearer it approaches 160°, the higher will be the ratio of dextrin to maltose with identical malts.

* The two functions of diastase are so far distinct that its maximum liquefying activity (its " optimum ") occurs at about 158° Fahr., and is not destroyed below 200° Fahr., while its saccharifying range is from 122° Fahr. (which, or a few degrees higher, is its " optimum ") to about 170°—or, in the presence of soluble starch, 176°—at which it is destroyed, having long before been markedly restricted. It is almost needless to caution readers that the " optimum " is by no means the best from the brewer's point of view.

† " Initial heat " is the term used to express the heat of the mash directly it is all in the mash-tun.

(5) That the liquidity of the mash affects the ratio in a less degree—*e.g.*, that a stiff mash (one made with less than two barrels of "liquor" to the quarter of malt) lessens the normal proportion of maltose; while a "free" mash (one made with over two barrels to the quarter of malt) increases it. (6) That a wort rich in maltose is one that "attenuates," *i.e.*, which has its solid extract broken up during fermentation readily and rapidly, tending to yield, in consequence, a thin beer, and one in which, when the attenuation is extreme, the unpleasant symptom of "greyness" is apt to appear. That a dextrinous wort, on the other hand, does not attenuate very rapidly, and that a large proportion of its solid extract remains unbroken up during the primary fermentation, remaining as nutriment, gradually yielded, for those types of yeast which carry on the secondary or cask fermentation. Consequently, that dextrinous beers drink "full," and if properly fermented, and if the dextrin proportion be not overdone, have condition with a reasonable amount of pungency and "a bite upon the tongue" (owing to their being saturated with carbonic acid). [This should also be read in the light of the malto-dextrin theory as stated on pp. 243—245.]

(7) That for the subsequent nourishment of the yeast, certain albuminoid (nitrogenous) bodies are required (peptones and amides), differing from ordinary nitrogenous or protein bodies in that they have undergone some alteration of character (*e.g.*, the peptones are such bodies as have undergone hydration, *i.e.*, have taken into combination the elements of water through the agency of peptase), whereby they are rendered diffusible, *i.e.*, capable of passing through the thin but continuous envelope enclosing the yeast-cell, a property which the unaltered albuminoids did not possess. That amides (formed in germination and by proteolysis at relatively low temperatures) are more assimilable by yeast than even peptones are, and that peptones are very slightly, if at all, precipitated by heat or by tannin in a slightly acid medium like wort; but that the coagulum observed after boiling and the precipitated tannate of albumen mainly consist of unpeptonised albuminoids, and that peptones and albumoses are factors in head-retention and palate-fulness.

The subject-matter of the foregoing eight sections being looked upon as axiomatic, the brewer will apply them to practice. Knowing very well what class of beer he wishes to produce, he will consider the quality of the malt he has to deal with (and generally the character of the whole season's make). If he finds that the malt has a good, old, well-developed acrospire, and as a consequence of this and of proper kiln treatment is altogether tender and floury when bitten, he knows that the diastase, and probably the peptase, will be in a pre-eminently active condition, that moreover the starch, being relatively in a very soluble state, will be immediately acted upon and the conversion be very prompt, the maltose—under ordinary conditions—reaching a high proportion.

In such a case he may perhaps have to limit the action of the diastase, and this he does by either a high "striking heat," and consequent high "initial," by making a stiffer mash, by considerably reducing the customary two hours' rest after the mash is finished, or by a combination, maybe, of all three. And if he uses a circulator (see Introductory Chapter) by working it for a short time only, say fifteen minutes, just long enough for the wort to run bright. Circulating, as such, unless very high heats are

reached, distinctly assists diastatic action, consequently its adoption renders some curtailment of the " rest " after mashing essential. [A plan, which has been found to answer, is to circulate for fifteen minutes, starting the circulation ten minutes after the mash—including underlet, if used, and one revolution of the rakes—has been finished, and to set taps one hour after the circulating is over.]

The extreme limit to which the initial heat may be allowed to rise can hardly be stated—so much do circumstances alter cases—but it is limited, first of all, by the paramount necessity of providing the yeast during fermentation with peptonised food, which can be augmented by the use of Malt Extract Syrup (see present page). [156° to 158° Fahr. may be mentioned as very high " initials," in result of which no starvation phenomena appeared, and this with a rather large proportion of invert-sugar used in making up " length," which of course reduced the amount of peptonisable matter.]

This deficiency of peptonised food, it may be mentioned here, will manifest itself by signs (bladdery heads, etc.) during fermentation,which will be further referred to in one of the chapters dealing with that subject ; but such a fact as that the initial heat quoted above was possible, without such manifestations, renders it probable that the activity of peptase increases with the solubility of the albuminoids, just as that of diastase appears to increase with the solubility of the starch. Both, therefore, largely depend upon the friability of the malt, the result of acrospire development.

Dealing with Ill-vegetated Malt, perhaps containing an Appreciable Quantity of Idlers.—With an ill-vegetated malt, on the other hand, a malt in which possibly 50% of the grains have the acrospire only half, or less than half up their length, with an appreciable quantity of totally ungerminated corns, a much more coaxing system will be necessary. A low initial, say 140°, raised gradually by successive underlets to 150° Fahr. or thereabouts, will go some way towards achieving what is desirable—namely, the extraction of the diastase (and peptase) and the gradual solution of the starch, which is in a much less tractable condition than that of well-grown and properly dried malt. The starch of that part of the endosperm to which the acrospire has not reached approximates in fact to the starch of unmalted grain, although more soluble than that (which requires a temperature approaching 212° Fahr. for *its* solution) ; indeed, as has been mentioned, the starchy portion even of " lie backs " or " idlers," although they have not grown at all, has been somewhat modified in the direction of solubility.

The Employment of Prepared Malt Extract in Modern Brewing.—Although diastatic malt syrup, or prepared malt extract, was introduced into breweries, distilleries and vinegar works during the closing years of the nineteenth century, its adoption by brewers as a mash-tun adjunct was, although extremely slow, nevertheless progressive. In these apparently far-off days and up to the close of that epoch of comparatively recent date which marked the passing of beers of heavy to modern original gravity and saw the introduction of malt produce of a strength which bears only a shadowy resemblance to the national beverage of our forefathers, there was no imperative necessity to have recourse to prepared malt syrup as a brewing adjunct. High mash-tun extracts were then

regarded with suspicion, and as the average prime cost of malt seldom exceeded 6*d*. per " brs.' lb." the loss involved in a lessened extract from the grist was not considered a matter of great commercial importance. The original gravities of all the beers brewed were sufficiently high to furnish a sufficiency of yeast nutriment and to maintain the barm in a healthy and vigorous condition. Every brewing text-book of over a decade ago laid emphasis on the extreme technical significance of brewers observing that pitching yeast should be the outcrop of what was then considered a medium heavy gravity beer. Under no circumstances, it was generally conceded, was a brewer justified in employing " store " or yeast for pitching purposes, unless it was obtained from a beer, preferably a mild, of at least eighteen " brs.' lbs."

Circumstances have revolutionised brewing methods, and the theories propounded and the safeguards formerly adhered to so rigidly have had perforce to be abandoned. Except in isolated instances, where is the brewer that can now rely upon obtaining his pitching yeast from an eighteen lbs. beer ? In hundreds of breweries throughout the country the highest original gravity upon which those technically responsible for their products can draw upon for their supplies of pitching yeast does not exceed fifteen brs.' lbs. Craftsmen of a former generation would have without hesitation deemed it impossible to secure true primary fermentation with normal yeast reproduction, as they understood the phrases, or maintain their yeast in a sound and healthy state under such abnormal conditions of working.

The modern operative brewer, as a man of resource, has adapted in a noteworthy manner his methods to the new position, and in overcoming the difficulties inseparably connected with the brewing of unusually light gravity beers, malt extract has played its part.

The employment of this brewing auxiliary must at present be regarded technically as well as commercially as an essential feature of brewhouse practice.

The main functions of malt extract are :—

(1) To furnish *in itself* in a pure concentrated form not only the most stable and high types of uncoagulable proteins but in correctly balanced proportions the mineral constituents naturally present in fully modified malt, thus ensuring for the yeast all the elements organic and inorganic, necessary for its sustenance and propagation.

(2) In addition to the nutrients contributed to wort by malt extract *itself*, the correctly prepared adjunct contains proteolytic enzymes in quantity which act upon the proteins present in the malts in the mash-tun, which, together with the ready formed uncoagulable and assimilable proteins and phosphates, yields not only an ample supply of yeast nutrients to ensure regularity of fermentation, increased reproduction and a healthy, vigorous yeast, but improves the general character of the finished beer by (*a*) conferring an additional roundness and fullness on the palate ; (*b*) enhanced " malty " flavour ; (*c*) augmented stability ; (*d*) freedom from yeast bite or yeastness, a fault especially prevalent in low gravity mild beers ; (*e*) a close tenacious " head " or foam.

(3) Supplies the liquefying and saccharifying diastases for acting, subsequent to gelatinisation, upon the starch present in the ungerminated and unmodified portions of the barley-grain (" hard-ends "), and this

valuable additional extract can be secured in quantity nearer to the maximum amount available from this source, especially with present season's malts, only by the use of a suitable malt extract skilfully prepared and correctly applied.

A brewer who does not use malt extract when employing malts other than those of the highest general quality obtainable, must perforce conserve the enzymic powers originally present in the malts in sufficient force to complete the mash-tun extraction processes satisfactorily and to obtain the exhaustion of his " goods," so far as the limitations of normal mash-tun working methods will accomplish. If he adopts relatively high mashing temperatures he may cripple or inhibit enzymic action to an extent that may adversely and seriously affect starch conversion towards the close of the extraction process, and lessening the amount of yeast nutrient thus affects reproduction and the ultimate vigour and soundness of the ferment. On the other hand, if he employs a relatively low liquid striking temperature in order to encourage and accelerate enzymic activity, and to furnish additional yeast food, he increases the proportion of maltose and low type malto-dextrins in his wort, which is thus rendered more fermentable and therefore additionally attenuative, yielding a thinner and flatter beer, containing, moreover, at racking proteins of a less stable character than is desirable.

The use of malt extract enables a brewer to steer clear of the abnormalities and excesses named and to strike a happy medium, thus reaping many technical and commercial advantages over his unprogressive confrère. It is essential, however, that he applies the adjunct with a true understanding of its functions. In common with every other commodity and preparation the quality and type of malt extract vary. There are brands on the market which, *if correctly applied*, fulfil in the highest degree the claims of this indispensable auxiliary to serve the several purposes to which it owes its introduction into breweries, distilleries and vinegar factories.

The Haze in Mash-Tun Worts.—There are, generally speaking, four main types of haze observable in mash-tun runnings. There is the haze due to some temporary defect in the filter plates which fault, however, can be detected by the traces of portions of grains or husks suspended in the worts, and the matter lends itself readily to adjustment in the succeeding brewing. But there is the persistent protein haze—altogether a different matter—arising from the presence of low class nitrogenous substances mainly from home malts. The advantage of securing an artificial barley ripening, so far as the term applies to the reduction of the moisture to a uniform percentage is concerned by means of " sweating " all home-grown barley on kiln is now regarded as imperative. But although this preliminary treatment of the barley supplemented by slow and efficient germination and withering on floors produces a malt considerably less liable to yield a haze in mash-tun runnings, it does not entirely remove the cause. The danger of collecting hazy worts in copper lies in the fact that no means so far devised can eliminate such dubious constituents. Boiling with the assistance of sulphate of lime in the brewing liquor will not coagulate crude nitrogenous matter, nor will the substances form the necessary " break " by combining with the hop extract.

The use of an astringent in the form of copper finings is distinctly

useful in removing matters in suspension, but the value of this adjunct does not extend to the elimination of protein in a form of extremely fine division. Hot aeration, although employed for the oxidation and subsequent precipitation of resins, may in the process to some extent carry down a portion of the insoluble proteins, and agitation and aeration during refrigeration on a vertical machine serves in a limited sense the same purpose. It is here that the diluting functions of sound foreign malt can be applied with effect, in conjunction with sugar or flaked maize.

The danger of collecting hazy runnings, due to the cause under discussion, is that the proteins survive all the several processes of clarification, and during the primary fermentation, but especially in the finished beer in cask where it serves to directly promote the life action of acid and other disease forming bacteria apart from the fact that the persistent haze renders the beer unsaleable. It follows that all worts should leave the mash-tun taps in an absolutely brilliant condition.

The third cause of hazy runnings is produced by an excess of high-type malto-dextrins. These may be produced by the use of unmodified and vitrified malts, a deficiency of diastase, or the adoption of an excessively high mashing liquor temperature. Deficiency in enzymic power in malts arises from various causes, but mainly from premature loading and excessive initial kiln drying tenperatures. There are maltsters who contend that a shortage in diastatic capacity is due to the restricting effect of unduly severe curing temperatures, but if the drying process has been carried out correctly at low temperatures and the moisture expelled to an extent that has rendered the malt " hand dry " prior to closing down the draught holes the final curing temperatures can be increased to and maintained at a surprisingly high figure without unduly affecting the diastatic capacity of the finished malt.

Formerly with heavy beers the appearance of a dextrinous haze was a serious matter for many reasons and brilliancy of finished beer was not obtained until the dextrinous content was reduced by secondary fermentation, accelerated by continuous rolling of casks in cellars. It is not so much a question of the haze produced by " dextrin," so called, but the fact that the existence in excess of high type malto-dextrins retains in solution resins which are really the direct cause of the haze.

Nowadays with beers of exceptionally light original gravity a dextrinous—or resinous—haze should be seldom met with inasmuch as no difficulty should be experienced with regard to attenuating modern ales. Indeed, much of the present-day brewery produce is over attenuated.

A haze from insoluble starch is liable to make its appearance in the last runnings, but this class of haze can be readily detected by the application of the iodine test. Unless malt extract is employed—and applied at the correct stage—it is certainly unwise to adopt inordinately high sparging temperatures with second grade malts.

Noting Acrospire growth in Proportions per cent.—To notice the quality of the malt systematically is a useful habit, and the following way of recording it may be recommended. Take 100 grains from the sample haphazard, and proceed to separate them into a number of little heaps, representing " grains fully grown," acrospire three-quarters " up," acrospire two-thirds " up," acrospire half " up," acrospire less than half " up," and ungerminated. The numbers in each heap will then give the

number per cent. of the particular degree of growth which the heap represents, and this percentage may be registered in the brewing-book. With very freely grown, in fact overgrown malt, it may be necessary to have one heap containing grains, in which the acrospire is actually through, but this ought not to be ; indeed, a uniform acrospire growth of three-quarters the length of the grain is about the ideal.

Readers of this will probably be familiar with the old-time test, made by throwing a number of the grains on to a surface of cold water, which is then slightly stirred. Those which float are the well-malted grains, those which sink are the ungerminated, while those which float point upwards are imperfectly grown. It is obvious that such a mode of estimating value is very crude, and far inferior in exactness to the count per cent., which moreover has the merit of stimulating a habit of exact observation.

Malt of Average Diastatic Capacity.—Hitherto we have taken as examples either malt of such extreme diastatic capacity that special measures have to be taken to keep that action within bounds, or malt so exactly opposite that equally extreme measures, in the opposite sense, have to be adopted to secure a wort capable of attenuating sufficiently during fermentation ; but it may very well happen that the bulk of any given season's malt will be of medium character, having, perhaps through some climatic conditions which we cannot easily gauge, a normal diastatic capacity with the starch of the endosperm in a sufficiently soluble condition.

Such a malt is of the type most desirable, being the easiest to deal with. The brewer using it will be able to obtain a wort in which either the maltose or the dextrin preponderates, according to the description of beer he may wish to produce, by using in the one case low to medium initials (say 150° to 152°), and then bringing the heat up some five or six degrees, and that not too rapidly, or by a rather high initial (155° to 157°) in the second, an initial which is simply maintained or not raised to any great extent.

Generally speaking, in running beers the maltose ratio will be high as compared with the dextrin, the reverse being the case with stock beers, and to some extent with the light bitter ales which pass rapidly into consumption, and therefore are not entitled to be classed as stock ales, but which may yet be occasionally kept (for bottling or other purposes), or which often remain for some weeks on draught when sold to small private families, and accordingly ought to be brewed somewhat on the lines of a stock beer.

The Functions of Foreign Malt.—Our purpose is to consider the functions, practical and chemical, which foreign malt perform and to what extent this substance can be regarded as an essential constituent of mash-tun grist. Foreign malts if mashed alone yield lower extracts than English, but when mixed with the latter a larger extract is obtained from both materials, due to the buoyancy and consequent better drainage secured from the tougher husks, a characteristic of the grain from certain foreign countries. It must not be supposed that this feature is present in all barleys of foreign origin, the husks of some being of fine texture and similar to that of home-grown grain which disintegrates readily with even careful milling, and both are on a level so far as their drainage qualities are concerned.

Foreign malts of the correct type are of special advantage now when low diastatic values are general. It is not that any deficiency in enzymic activity from home malts is made good from an excess present in foreign. Indeed, the converting power of the finest types of foreign is often low, although, of course, when forcing floor temperatures are employed, as is often the case, and these malts are pale dried, high diastatic values remain. The presence of husky foreign creates buoyancy of the goods, and in this direction assists enzymic action by allowing the diastase greater freedom in liquefying and saccharifying the starch gelatinised by the striking liquor. When flaked maize or rice is employed large percentages of foreign malt are necessary in the mash-tun. These useful and popular brewing adjuncts contain no converting agent, and as they are free from husk, a medium that will overcome this deadness successfully, and at the same time saccharify maize starch is absolutely essential to produce satisfactory results.

But the principal importance attached to the use of foreign malts is the purity and high character of the extract they yield. English malts contain an excess of soluble albuminoids which from their nature are readily dissolved and carried forward to the copper. Now that light gravity ales (hopped meagrely and of low alcoholic content), which are required to be on draught in a brilliant condition on the day of racking, constitutes the main output of the majority of breweries, the stability and brilliancy of this class of produce is specially endangered when nitrogen in the form named is present in excess. Of these nitrogenous substances amides and amino-acids, formed from peptones, during germination of the malt, and also by the action of peptase in the mash-tun readily undergo solution, but are mainly assimilated by the yeast during fermentation. It is the crude albuminoid matter termed glutens, not available as a yeast food, from which the danger arises. High mashing and sparge heats increase their solubility and gluten turbidity may occur with any lowering of the temperature of the finished beer in cask.

There is also the question of cellulose which exists in three forms in malt, two of which are insoluble in water and alcohol, and, therefore, beer, while the third, starch cellulose, undergoes decomposition similar to that of starch. Now crude nitrogenous matter exists in very small amounts in barleys from hot climates compared with that present in British-grown grain, which never receives the ripening influence of the sun to the same extent. In addition, little difficulty is experienced in the germination and modification of foreign barley when these objectionable and dangerous constituents are reduced in floor working to an almost negligible quantity. The total amount of cellulose present in English malt is greater and the fibre cruder in type than that met with in foreign malt. It will be seen, therefore, that the latter serves manifold purposes and secures definite advantages to the brewer, benefits more necessary than ever under modern working conditions. Foreign malt is indispensable as a drainage medium; it acts as a diluent in lowering the percentage of objectionable crude glutens and cellulosic fibre, dissolved to a more or less uncertain extent from the best English malts, which retards brilliancy of beer and lessens its keeping properties, and a blend of foreign malt yields larger extracts than that obtained from home malts mashed alone. The question of milling foreign material deserves greater attention than it generally

receives. It is an established principle that the finer the grinding the greater the extract and the tougher the husk of foreign malts needs breaking up to a degree which ensures that the starch granules in the endosperm of the grain comes under the influence of enzymic action. Unless the ground malt is run direct from mill to grist case the proportion of flour to small nodules should be kept low as elevating the crushed material disintegrates it still further, and there is an inevitable waste of flour and consequent loss of extract. Care should be exercised that the foreign husks are quite free from their contents and cut or stripped as little as possible, otherwise drainage is impeded. Brewers provided with milling machinery on the latest principles are free from the worries connected with operating mills with single rolls, yet the vast majority of the smaller breweries continue to employ this relic of mediæval times, which necessitates separate grinding for each class of malt, with its consequent continuous readjustment of the rolls. When the grist case is of the true cone type, then little difficulty is experienced in obtaining a regular mash, but with a rectangular case the grist will not reach the Steel's machine in the order in which the whole grain was blended in the mill room. Under these circumstances alternate small amounts of from 4 to 8 bushels of foreign and English should be crushed separately, and this is the only practical method of overcoming balling of the goods. Numbers of our best known brewers object to the use of rakes in the mash tun, and we can only conclude that they are supplied with the most efficient milling and mashing plant when the use of rakes may be dispensed with. With single roll mills and rectangular grist cases, the judicious use of rakes are essential to overcome the irregularities of mash consistency inseparably associated with working under the conditions named.

The Employment of New Malt.—Tradition plays an important part in brewing procedure, and the experiences of successive generations form a reliable standard upon which to base our working methods. In the opinion of many practical men, the use of immature malt is a dangerous policy to adopt and to safeguard themselves, care is observed that no grist reaches their mills under six weeks to two months old. The objections raised are that malt under the age named contains an excessive amount of diastase which produces over-hydration of extract. In addition it is claimed that new malt lacks the quality of supplying the correct amount and type of nourishment to yeast. In reply to this contention, we may say that instances have occurred in which the reproduction obtained from the use of new malt has been unusually large, while on the other hand it is true that meagre skimmings also follow the use of fresh malt. It is, however, mainly a question of the percentage of moisture present, which rarely exceeds one per cent. in material only a short time unloaded from kiln. Too little moisture in malt has its dangers like the opposite extreme and accounts for the irregularities in fermentation which follow the use of malt newly off the kiln. Excessively dry malt yields, for any given system of striking temperatures at mashing, a large rise in heat on the intermixture of water and grist, which must necessarily have its effect upon the composition of wort.

When a brewer is compelled to employ new malt there are two remedies, either or both of which can be adopted according to circumstances. If the brewer controls the manufacture of his malt he should hasten the

maturing period by spreading out and frequently turning the load directly after is it stripped from kiln. The hot malt is then in a condition to absorb oxygen with unusual avidity. If malts, on the other hand, are purchased, the brewer, in the absence of analytical data, is at the mercy of the maltsters as regards the age and general brewing characteristics of the material supplied. As a safeguard in this case against the use of new malt, the remedy to be borne in mind during the earlier part of the coming season is to employ striking heats below that customarily used. As a practical guide as to how far striking temperatures may be decreased, an eye should be kept on the character of the fermentations, the extent of attenuations, and the amount of yeast reproduction.

"Slack" Malt.—Malt, when unloaded, should not contain more than 1% of moisture, and when it comes into use some 5 or 6 weeks later the water content present will generally have reached 2 per cent., and if stored under the best conditions the moisture content of malt should not exceed 4 per cent. at four to five months from kiln. Assuming that the average water present in malt deliveries throughout the greater part of the year is 3 per cent., the additional 2 per cent. is a factor of considerable commercial importance. The attention of the consignees should be drawn to the matter in order to provide them with an opportunity of rectifying the water content in future deliveries, and if this is impossible the monetary loss incurred should be deducted from the amount of the invoice. With regard to the loss of extract from the source we are considering, we may say that each 1 per cent. of moisture corresponds to a reduction in extract of three-quarters of a pound per quarter, an item which is worth remembering. Where maltings are worked in conjunction with a brewery, it is best, in order to detect the true source of any irregularity in extract to observe towards the close of the season when it is not practical to redry all the stock on hand, that whatever excess of moisture may be present over the average should be allowed for in weight when delivery is made to the brewery.

Method of increasing Dextrin Ratio, but one requiring a Special Arrangement.—One specific method of increasing the dextrin ratio may be mentioned. It has met with distinct success in the brewing of certain kinds of competition beers, but it needs a special, though simple kind of steam-inlet, and a plentiful supply of uncontaminated free steam for the mash-tun. A metal ring, into which the steam-pipe from the boiler is led, is fitted beneath the false bottom. At its lower curved surface, the one facing the *real* bottom, a number of small holes are drilled, so that when the steam is let in it is to some extent spread abroad by the ring, around which it has to make its way, instead of rushing upwards in jets, as would be the case if the perforations were on the upper surface.

The plan, then, is to mash low, say at 146° to 148°, and almost directly after the mash is finished, to raise the temperature very rapidly by letting in steam till 160°, more or less, is reached. Probably 7° or 8° more would be necessary to reduce diastatic action to a minimum. It is evident that by this method, properly carried out, two important factors in the production of a full "round" beer would be brought into play—namely, a rather high proportion of sufficiently peptonised albuminous matter coupled with a distinctly dextrinous character of wort. As a matter of

fact, the ales brewed in this way were able to compete with fair success against rival beers of higher gravity.*

We will now postpone for a short time the further consideration of purely operative details such as the effect of mixed grists, limited decoction, hot grist mashing, etc., and proceed to consider rather more fully than there has been a chance of doing hitherto, starch, the dextrins and maltose [the albuminoids have been referred to on pp. 183, 185, 188], with the reactions which take place in the mash-tun. Nor must we in this connection overlook the view, which has already been briefly referred to in Chapter I. and elsewhere, that of the formation, in greater or less quantity, of certain compound bodies known as malto-dextrins.

Starch $(C_6H_{10}O_5)_n$ is fairly ubiquitous in the cells of plants, being found everywhere therein except in the tip of a bud, or the ends of rootlets; it consists of a substance called granulose, enclosed in an envelope of amylo-cellulose, or starch-cellulose. This amylo-cellulose is unaffected by the action of diastase, which, moreover, being what is known as a colloid, cannot penetrate the intact membrane composed of the former, and accordingly can only get at the contained granulose upon the said membrane being ruptured, either by heat or by trituration with something rough like sand, in a pestle and mortar.

Upon the application of sufficient heat to a mixture of starch and water, the previously opaque mixture becomes nearly transparent, the starch is gelatinised, or forms a starch-paste. If a dilute starch-paste be filtered, the granulose passes through the filter, as can be observed by applying the iodine test, but the amylo-cellulose remains behind. It is even then doubtful whether real and complete solution of the granulose has taken place; at all events, if a trial can be made of its ability to pass through the walls of plant-cells, only a negative result will be obtained. Hence the necessity of diastase, or of some such factor in germination, to render the starch stored up in the mature seed available for the nourishment of the growing plant.

The prefix amylo- is not a superfluity, seeing that amylo-cellulose does differ from ordinary cellulose in so far that the former is insoluble in Schweitzer's reagent, which first gelatinises and then dissolves the latter. One marked result of the malting process has been to considerably lower the temperature requisite to rupture all the amylo-cellulose envelopes, and to bring it accordingly well below the maximum at which diastase is capable of action. There is no doubt, we think, that the so-called diastase consists of a group of nitrogenous bodies, rather than that it is a distinct individual body, and that of these bodies the most powerful degraders of the starch molecule are those which are the most easily coagulated by heat. Perceptible coagulation occurs at 167° Fahr. or thereabouts, and several degrees below that temperature would be sufficient to greatly restrict diastatic action.†

What precisely the nature of this action is we do not yet know for

* Of course much depends on the type of yeast in use, whether reproductive or attenuative, as to mashing temperatures.

† To be more precise, Messrs. Brown and Heron have shown the proportion of the coagulable albuminoids coagulated in malt-extract to be as follows: At 122° Fahr. = 19%; at 140° Fahr. = 53·5%; at 150° Fahr. = 67·4%; at 169° Fahr. = 80·8%; while at 176° to 178° Fahr. all the coagulable albuminoids are precipitated. This is probably not absolutely true for all malts, but is a useful approximation.

certain, although its results are tolerably clear; but possibly it may be referable to molecular vibration, inducing a break-up of the molecules of starch upon which the enzyme acts. It is generally accepted that heat is an outward and visible sign of intense molecular vibration, and seeing that starch heated with water under a sustained pressure of four or five atmospheres (say at 302° to 320° Fahr.) is ultimately hydrated into some form of fermentable sugar, either maltose or glucose, there is analogy to support that view.

The starch granule varies in size and shape according to its source. Barley-starch granules appear roundish or oval under the $\frac{1}{4}$ to $\frac{1}{10}$ objective, and show no markings unless it be "the pitting" which appears as germination advances. The markings and concentric stratification which some starch granules show more conspicuously than those of barley, are supposed to be due to water not absorbed into the body of the granule. On addition of strong alcohol the water is removed, and the stratification vanishes. On the other hand, chromic acid and dilute alkalies intensify the stratification, the granules swelling up in those liquids. These markings will be noticed surrounding the nucleus or hilum, which is sometimes central as regards the granule itself, but often more or less distant from the centre, especially in the case of potato starch. Potato starch shows the largest granules; the granules of wheat starch, which greatly resemble those of rye and barley in shape, are noticeably smaller.

The micromillimetre or μ, "mu" ($= \frac{1}{25400}$ inch, nearly) is used to designate the diameter of these granules, and accordingly taking the largest and the smallest granules, wheat approximately ranges from 50μ to 2μ; barley from 39μ to 13μ; potato starch from 100μ to 60μ. The size of the wheat and potato starch granules is very variable; in barley-starch there is greater uniformity, but its granules would not be readily distinguishable from those of wheat starch in a mixture of the two. Very conflicting statements, however, are made, both as to the diameter and the relative proportion of large and small granules. The above measurements are from a leading English text-book, but Thausing, quoting Wiesner, states that the smallest granules are found in barley, and that in wheat and rye the number of small and large granules is nearly equal, while in barley the small granules outnumber those of larger size. The subject evidently wants study, but is complicated by the difficulty of getting a microscopic field of unruptured granules.

The average amount of starch and of carbohydrates in the following sources of them are :—

	Starch (determined in the cereals by O'Sullivan with diastase).	Carbohydrates (mean of many analyses).
Potatoes (fresh) .	18%	21%
Barley . . .	39–57%	65–72·8%
Wheat . . .	(white) 55·4%	67·9–71·7%
Maize . . .	(yellow) 54–58%	68·4–70·7%
Rice (cleaned) . .	75–77%	(European) (American) 78·3–79·2

Rice, so rich in starch, has about 7·3 nitrogen-bodies.

The Dextrins—$2(C_6H_{10}O_5)$ or $C_{12}H_{20}O_{10}$—have already been spoken of, as a collective whole, more than once, both in respect of their influence on the beer in which they preponderate, and of the method of securing a sufficient proportion of them in the wort. But as there are several

recognised varieties and sub-varieties of dextrin, it will be useful to set down at a little greater length the indications which serve to distinguish them.

W. Nageli (and others) have identified

Amylo-dextrin I.
Amylo-dextrin II.
Erythro-dextrin.
Achroo-dextrin (α, β, γ, δ, ε, ζ, and η).

Amylo-dextrin I. and II. If starch granules are allowed to stand at an ordinary temperature for two or three weeks in dilute hydrochloric acid (for 1,000 grammes of starch, Nageli used 6 litres made by adding 12 parts of concentrated hydrochloric acid to 88 parts of water, a 12% solution) no external change takes place in the granules but an internal chemical change occurs, which is evidenced by the behaviour of the unswollen residue with regard to iodine. Whilst ordinary starch, if so tried, is coloured blue by the iodine, the starch which has been digested in the above-mentioned way is coloured *yellow*. Moreover, the fluid covering the altered starch contains sugar and a body which is precipitable by iodine and alcohol. That portion which is turned yellow by iodine is Amylo-dextrin I., enclosed in the unaltered envelopes of the starch granules, and that body which is precipitable by iodine and alcohol out of the supernatant fluid is Amylo-dextrin II.

It does not appear, however, that the yellow coloration is a characteristic reaction of Amylo-dextrin I. with iodine, when the former has been obtained in a state of purity. Then a solution of it gives a blue-violet coloration with iodine, while a solution of pure Amylo-dextrin II. gives a red-violet. It appears that neither of these dextrins is one uniform homogeneous substance, but that they consist of two separate substances in varying proportions. These Nageli claims to have isolated, and has found that one constituent is coloured violet and preponderates in Amylo-dextrin I., whilst the other constituent which preponderates in Amylo-dextrin II. is coloured red by iodine. As both are equally precipitated by alcohol, and as their polarimetric dextro-rotation is the same, it is doubtful whether they should be classed as distinct varieties or merely sub-varieties of the same dextrin.*

Amylo-dextrin I. can be got by washing the granules, from which the liquid containing the Amylo-dextrin II. has been filtered, with hot water, whence, upon the solution being cooled down to 32° Fahr., it crystallises out in the form, as the microscope shows, of circular discs—flat circular plates, although at first, unless some movement be imparted to the liquid, the crystals may appear to be of globular form. It has also been obtained in needle-shaped crystals, and there is ground for supposing that the discs are formed by a radiated grouping of these crystalline needles, although the needles are soluble in cold water, but the discs not.

Amylo-dextrin II. falls as a voluminous white precipitate from the

* Amylo-dextrin is considered (by Brown and Morris) to be a member of the same series as malto-dextrin (*q.v.* pp. 243—245), being identical in most respects, *e.g.*, being unfermentable by *S. Cerevisiæ*, though reduced by malt-extract to maltose. Unaltered, *they say*, by fractional precipitation, it has optical and cupric-reducing powers corresponding to a mixture of dextrin and maltose.

fluid which covers the altered starch in the above-described experiment, if a four or five-fold volume of 93% alcohol be added to the filtrate. To purify it further the second precipitate is collected in a filter, washed with alcohol, and afterwards dissolved with water, and the solution brought to freezing-point, whereupon it crystallises out, like Amylo-dextrin I., in flat plates, though occasionally it forms needle-shaped crystals too.

Erythro-dextrin (ἐρυθρός = red) and **Achroo-dextrin** (ἄχροος = colourless) are also distinguished by their behaviour with regard to iodine, the former giving a *red* reaction, the latter *none*. Boiled with dilute acids both dextrins are converted into glucose, the erythro-dextrin passing through the intermediate stage of achroo-dextrin in the process; or, if digested with cold, aqueous malt-extract they are hydrolised into maltose.

If Nageli's experiment be carried on a little further, a time comes when the acid fluid covering the altered starch gives no further reaction with iodine. If the fluid then be neutralised, first with milk of lime and afterwards with calcic carbonate, and then filtered and evaporated to a small bulk, on alcohol being added to the concentrated filtrate, an amorphous precipitate forms, which, upon being filtered and deprived of its water by absolute alcohol, and subsequently dried over concentrated sulphuric acid (in a desiccator), is found to be a white powder, a solution of which gives no colour with iodine, and has accordingly been named achroo-dextrin. It is equally soluble in hot and cold water, and even at freezing-point no turbidity of the solution, *i.e.*, no precipitate, occurs.

Erythro-dextrin, as far as the writers are aware, has not been prepared in a state of purity. It is, however, a constituent of commercial dextrin, which, under the name of "British Gum," is used in calico-printing for thickening colours, and is prepared by heating starch up to a heat ranging between 410° and 520° Fahr., or if it be moistened with very dilute nitric acid, say water containing 2% of the acid, up to one ranging from 230° to 300° Fahr. In practice it is done in two cylinders, one within the other; the inner one having an arrangement for stirring the contents, the interspace between the outer and the inner cylinder being filled with rape-seed oil, which conveys the fire-heat steadily to the contents of the inner cylinder.

The above-named dextrins have this in common, that they show no organised structure, that they are colloids, *i.e.*, unable to diffuse through membranes either vegetable or animal, and that they are more or less soluble in water but not to any extent in alcohol. Erythro-dextrin is, however, less soluble than achroo-dextrin in alcohol, solubility in fact increasing as the scale (*vide* the series of equations on p. 241) is ascended. They differ in their optical power on a ray of polarised light, though all have a right-handed rotation (*dextra* = the right hand), less than that of starch, but exceeding that of maltose, that is to say, as hydrolysis advances the specific rotatory power decreases.

Dextrin, as such, has no reducing action upon Fehling's solution, though there is a possibility of a partial conversion into glucose occurring through the agency of tartaric acid (from the Rochelle salt) if boiling be prolonged (*vide* the test in laboratory chapter), and of a consequent over-estimation of the co-existing maltose. But on the other hand, Barfoed's solution, which is practically normal acetate of copper acidified with acetic acid (the solution contains about 1% of free acid), is said to be reduced by

glucose after a short boiling, but not at all by *maltose*, and by dextrin after a more prolonged boiling.

Maltose ($C_{12}H_{22}O_{11}$), identified by the distinguished French chemist Dubrunfaut in 1847, and rediscovered by C. O'Sullivan in 1874–76, is the final product of diastatic action upon starch. Before the latter's epoch-making communications it was generally supposed that this ultimate product was glucose (Dubrunfaut's view having been completely lost sight of), but from this sugar maltose has now been clearly differentiated, both by its greater rotatory power and its lower reducing action upon Fehling's solution (66·6 parts of glucose, or according to other investigators 61 parts of glucose, precipitate as much cuprous oxide from the solution as 100 parts of maltose are capable of doing). Though the action of diastase, however prolonged, effects no change in maltose, yet boiling with sulphuric acid does bring about an alteration, in the shape of a reducing power corresponding to that of glucose. Hydrolysis summed up in the equation

$$C_{12}H_{22}O_{11} + H_2O = 2(C_6H_{12}O_6)$$

occurs, possibly through H_2SO_4 in ionised state (*cf.* pp. 213 to 221) imparting H_2 and O alternately to the disaccharide carbon compound. Maltose crystallises in hard, white, needle-like crystals, containing a molecule of water of crystallisation, which is lost in an air-bath at 212° Fahr.

Equation dealing with the successive Changes which take place when Diastase acts on Starch.—We may now proceed to consider the equations which indicate the changes taking place when diastase acts upon starch at a jointly favourable temperature (140° Fahr.), although, as will be seen (p. 242), this somewhat elaborate series will require modification, since the malto-dextrin theory is definitely accepted.

It must be observed, too, that the unknown *n* of the formula for the starch molecule—$(C_{12}H_{20}O_{10})_n$—must have the value of 10 *at least* assigned to it, and that the changes appear to take place as the result of successive hydrolyses, maltose and dextrin being formed simultaneously at the first hydrolysis, during which and the succeeding steps one molecule of maltose after another separates, leaving constantly diminishing quantities of dextrin, which, as hydrolysis proceeds, also alters into simpler types.

						*Specific Rotation. 216·0 (for Starch).		Cu_2O (reduced).
(1)	Soluble Starch $10\,(C_{12}H_{20}O_{10})$	+ Water. H_2O	=	Maltose. $C_{12}H_{22}O_{11}$ +	Erythro-dextrin α $9\,(C_{12}H_{20}O_{10})$	209·0	:	6·4
(2)	Erythro-dextrin α $9\,(C_{12}H_{20}O_{10})$	+ H_2O	=	$C_{12}H_{22}O_{11}$ +	Erythro-dextrin β $8\,(C_{12}H_{20}O_{10})$	202·2	:	12·7
(3)	Erythro-dextrin β $8\,(C_{12}H_{20}O_{10})$	+ H_2O	=	$C_{12}H_{22}O_{11}$ +	Achroo-dextrin α $7\,(C_{12}H_{20}O_{10})$	195·4	:	18·9
(4)	Achroo-dextrin α $7\,(C_{12}H_{20}O_{10})$	+ H_2O	=	$C_{12}H_{22}O_{11}$ +	Achroo-dextrin β $6\,(C_{12}H_{20}O_{10})$	188·7	:	25·2
(5)	Achroo-dextrin β $6\,(C_{12}H_{20}O_{10})$	+ H_2O	=	$C_{12}H_{22}O_{11}$ +	Achroo-dextrin γ $5\,(C_{12}H_{20}O_{10})$	182·1	:	31·3
(6)	Achroo-dextrin γ $5\,(C_{12}H_{20}O_{10})$	+ H_2O	=	$C_{12}H_{22}O_{11}$ +	Achroo-dextrin α $4\,(C_{12}H_{20}O_{10})$	175·6	:	37·3
(7)	Achroo-dextrin α $4\,(C_{12}H_{20}O_{10})$	+ H_2O	=	$C_{12}H_{22}O_{11}$ +	Achroo-dextrin α $3\,(C_{12}H_{20}O_{10})$	169·0	:	43·3
(8)	Achroo-dextrin α $3\,(C_{12}H_{20}O_{10})$	+ H_2O	=	$C_{12}H_{22}O_{11}$ +	Achroo-dextrin α $2\,(C_{12}H_{20}O_{10})$	162·6	:	49·3

* It may be well to mention that the optical activity (dextro-rotatory power) stated refers to the actual products of the starch-transformations, not to the wort itself. They are $[a]_j$. The cupric-oxide reducing power is expressed shortly as K.

The same series of changes may be expressed more concisely as follows :—

$$\underset{\text{Starch.}}{10\,(C_{12}H_{20}O_{10})} + \underset{\text{Water.}}{8\,(H_2O)} = \underset{\text{Maltose.}}{8\,(C_{12}H_{22}O_{11})} + \underset{\text{Dextrin.}}{2\,(C_{12}H_{20}O_{10})},$$

which expressed as percentage = 80·8% of maltose and 19·2% of dextrin [worked out as follows : The atomic total of 8 $(C_{12}H_{22}O_{11})$ = 342 × 8 ; that of 2 $(C_{12}H_{20}O_{10})$ = 324 × 2, consequently dividing the 324 by 4 will preserve the ratio = 342 : 81. Then 342 + 81 = 423, and this divided by 100 = 4·23. Then $\frac{342}{4\cdot23}$ = 80·8 (nearly), and $\frac{81}{4\cdot23}$ =19·2 (nearly)].

Dr. Squire, in the course of an admirable paper read before the London section of the Society of Chemical Industry, suggested the following equation for the reaction taking place at 167° Fahr., which he says is tolerably constant :—

$$10\,(C_{12}H_{20}O_{10}) + 3\,(H_2O) = 3\,(C_{12}H_{22}O_{11}) + 7\,(C_{12}H_{20}O_{10}),$$

or expressed in percentage as above = 31·15% of maltose to 68·85% of dextrin.

The dextrin produced at such a temperature is, he says, achroo-dextrin, giving no reaction with iodine ; but if the temperature be raised, or the mixture be rendered slightly alkaline, then the quantity of maltose produced is lowered, and the dextrin would be an erythro-dextrin, giving a red reaction with iodine.

Malto-dextrin Theory.—Since the theory of the formation of certain definite compounds of maltose and dextrin, malto-dextrins or amyloins, appears to be established beyond reasonable doubt, then the equation setting forth the mash-tun reactions will require readjustment, or, at any rate, will have to be taken with the qualification that certain molecules of maltose either effect a fresh combination with free dextrin to form the bodies above-named, or—which is the accepted view—that the converse takes place—viz., that certain complex groups of which the starch molecule is assumed to consist are split up as to four-fifths of the groups, and, if the most favourable conditions exist, are successively hydrolised into maltose *through* a series of amyloins (malto-dextrins). We shall deal a little more generally with these malto-dextrins before giving the formula invented to explain all the ascertained facts, it being a somewhat complicated one.

It will be clearly understood that the theory states these malto-dextrins to be *compounds* and not mere mixtures, having indeed properties varying either from those of their constituents, or from mixtures of them, as is the case with other chemical compounds.

The maltose is readily fermentable in the primary fermentation by ordinary yeast (*Sacch. cerevisiæ*). Dextrin is now alleged to be absolutely unfermented in the primary, and practically unaltered in the secondary fermentation (being found in the beer unchanged, and in the same proportions after some months' storage). Consequently the malto-dextrins, unfermentable in the primary fermentations, alone remain to produce the necessary brisk cask condition by their gradual conversion into alcohol and carbonic acid gas, through the agency of some secondary yeast type or types, *e.g.*, Hansen's *Sacch. Pastorianus* II., or perhaps *Brettanomyces* (*cf.* p. 329).

It is held that there are different types of these malto-dextrins, the higher types (those most suitable for stock-beers) containing more dextrin and less maltose, while the lower types, containing a larger proportion of maltose to dextrin, are less resistant to converting agencies, and therefore, determining more or less rapid condition, are adapted to beers of short storage.

The tenet is that even the lower malto-dextrins are, as such, unfermentable, but that in their case the preliminary stage of the conversion of the whole into fermentable maltose is speedily passed through, when rapid condition follows as a matter of course. A necessary sequence of the unfermentability of malto-dextrin, as such, is that the breaking up must always be effected in successive stages.

(1) Conversion of the higher types into lower types.

(2) Conversion of the lowest type into free maltose.

(3) Splitting up of the maltose molecule into glucose, and thence into alcohol, carbonic acid, etc.

The lowering of type is possibly effected by a diastase-like enzyme secreted by the secondary yeast named above, or some other.

Evidence on which the Malto-dextrin Theory is based.—When it chanced to be found that the higher dextrins, especially up to Conversion No. 7, yielded larger quantities of maltose when degraded with malt extract than the lower dextrins (albeit associated with less free maltose), the conclusion seemed inevitable that it was in some way in *combination* with the maltose. Further, a substance having been prepared (by acting upon starch with malt extract, and subsequent repeated treatment with alcohol) soluble in alcohol of 70 to 80%, and giving the analytical results of maltose 39·8, dextrin 58·1 : inactive matter 2·1%, an aqueous solution of this substance was made by dissolving 12·663 grammes of it in 100 c.c. of water, which thus corresponded to 5·039 maltose (100 : 12·663 : : 39·8). This being set to ferment with a little Burton pressed yeast, the fermentation which ensued stopped at the end of three or four days, with the result that on the ninth day 3·687 grammes of maltose still remained.

Pure crystallised maltose was now added, upon which a brisk fermentation ensued, and after a time ceased, whereupon more maltose was added, and the fermentation started again. Examined when fermentation had finally subsided, the increase of alcoholic strength corresponded very nearly to the added maltose, and the cupric-reducing power of the liquid was but very slightly reduced. In other words, the added maltose had entirely disappeared, but the 3·687 grammes of the original maltose was only reduced to 3·577.

Again, the dextrin, acted upon by malt extract, gave 70% of maltose, just as the dextrin of the liquid before the free maltose was added had done, showing that no degradation of the dextrin had occurred. The question then arose why this 3·577 grammes of maltose had not disappeared, when the brisk fermentation which ensued on the addition of free maltose showed that its survival was in no way due to the defective power of the yeast, or to other unfavourable conditions.

Moreover, if, instead of the free maltose, a few drops of cold-water malt extract were added at the close of the first fermentation, it was also found that fermentation was vigorously renewed, and in the result not only did the apparent maltose (3·687 grammes) practically disappear, but

also some of the dextrin, *the action being accompanied by a degradation of the dextrin.*

Considering these facts, there seem very strong grounds for concluding that the " apparent maltose," as it has been called, is not " free " maltose, but is held in close chemical combination with dextrin in the form of the bodies now called amyloins or malto-dextrins ; and this conclusion is strengthened by what is found to take place when a mechanical mixture of fairly pure dextrin and pure maltose is likewise set to ferment. In the latter case nearly all the free maltose disappears after a rapid and vigorous fermentation.

Isolation of Malto-dextrin.—Messrs. Brown and Morris proceeded to effect it in the following way. Making a starch conversion at 140° to 149° Fahr., with very active diastase, the conversion was stopped at a point very nearly corresponding with Conversion 3 of the series on p. 243. The solution, after boiling, was set to ferment with a little Burton yeast, and after the free maltose was thereby fermented away the liquid was filtered, concentrated to a syrup, and digested for some hours with 90% alcohol to remove the non-volatile products of fermentation. The strength of the alcohol having been reduced to 85%, the alcoholic extract was, after digestion, poured off the residue. The alcoholic extract was distilled, and the residue again treated with 85% alcohol. The extract was again distilled to remove the alcohol, and the residue thus obtained was very nearly pure malto-dextrin (absolutely unfermentable by ordinary *Sacch. cerevisiæ*, though treatment with malt extract converts it completely into maltose), corresponding in optical and cupric-reducing power to a mixture having the percentage composition of maltose 33·9, dextrin 66·1.

Formula for Malto-dextrin.—Accordingly the simplest formula assignable to it is $\begin{cases} C_{12}H_{22}O_{11}. \\ (C_{12}H_{20}O_{10})2, \end{cases}$

i.e., one maltose or amylon group united to two dextrin or amylin groups.

Modification of the Equation Series.—Messrs. Brown and Morris have come to the conclusion that the starch-molecule is not less than five times $(C_{12}H_{20}O_{10})_3$, and, as a matter of fact, they now take it to be 5 $(C_{12}H_{20}O_{10})_{20}$, or as five times the size of the dextrin molecule $(C_{12}H_{20}O_{10})_{20}$. They suppose that four of these amylin groups are arranged round the fifth and similar group ; that the inner group resists hydrolising influences, and constitutes the stable dextrin corresponding to that of Equation 8. This involves the view that the dextrins are not, as previously supposed, a polymetric series, but are uniform in character, the so-called higher dextrins being in no wise different from that found at the conclusion of the mashing operation. The four outer amylin groups, however, are held to be incapable of existing, as such, when hydrolising influences are at work upon them, being, in fact, theoretically capable of undergoing rapid conversion into maltose by a succession of hydrolisations through a series of amyloins, at first, of what are known as the higher types, and afterwards of less and less complexity (in the sense that, as the series advances, the worts containing them, or rather the beers containing them, are less persistently obdurate to the fermentative agencies which determine " condition ").

In an interesting article which appeared in the *Brewing Trade Review*, Dr. Morris writes that " the action may be graphically expressed by the

following equations where n represents the number of amylin groups converted into amylon groups and m the number of unchanged amylin groups " ($n + m$ must = 20, the number of amylin groups in each complex). " In the first instance we may express the very earliest stage of hydrolysis thus :—

$$\left\{\begin{matrix}(C_{12}H_{20}O_{10})_{20}\\(C_{12}H_{20}O_{10})_{20}\\(C_{12}H_{20}O_{10})_{20}\\(C_{12}H_{20}O_{10})_{20}\\(C_{12}H_{20}O_{10})_{20}\end{matrix}\right. + n\ H_2O = \underset{\text{Stable dextrin.}}{(C_{12}H_{20}O_{10})_{20}} + 4\left\{\begin{matrix}(C_{12}H_{22}O_{11})n.\\(C_{12}H_{20}O_{10})m.\end{matrix}\right.$$

Starch Molecule.

At an intermediate point in the hydrolysis the following probably represents the reaction :—

$$\left\{\begin{matrix}(C_{12}H_{20}O_{10})_{20}\\(C_{12}H_{20}O_{10})_{20}\\(C_{12}H_{20}O_{10})_{20}\\(C_{12}H_{20}O_{10})_{20}\\(C_{12}H_{20}O_{10})_{20}\end{matrix}\right. + xn\ H_2O = \underset{\text{Dextrin.}}{(C_{12}H_{20}O_{10})_{20}} + 4 - x\left\{\begin{matrix}(C_{12}H_{22}O_{11})n.\\(C_{12}H_{20}O_{10})m.\end{matrix}\right.$$

Starch. Amylöin Group.

$$+ x(C_{12}H_{22}O_{11}).$$

Maltose.

" This theory," he adds, " appears to embrace and explain all the known facts in connection with starch-transformations ; it enables us to understand why it is impossible to separate the whole of the maltose of a limited conversion either by solution in alcohol or by fermentation ; it also offers a complete explanation of the observed facts in connection with fractional degradation, and other questions of a like nature." The excuse for transporting this paragraph bodily must be the impossibility of putting the theory, as expressed by equations, more concisely, and the general importance of the question.

Evidence for the Opinion that Secondary Yeasts hydrolise Malto-dextrins.—One experiment out of many, devised by the investigators, was to ferment away the free maltose from a conversion made in the usual way. Then after freeing the fermented liquid from alcohol, a solution was made of the residue (containing, be it remembered, no *free* maltose), but still showing on analysis the proportion of

6·986	grammes	Maltose.
16·792	,,	Dextrin.
0·315	,,	Inactive Matter.
24·093	,,	in 100 c.c.

The solution had a specific gravity of 1093 and the dextrin yielded 66·8% of maltose.

Yeast was again added, and the preparation kept at 30° C. (= 86° Fahr.) and closely watched, and the sediment examined daily under the microscope. Gradually the yeast-cells (*Sacch. cerevisiæ*,—primary yeast) finding no free maltose, shrivelled up and apparently died. *At the end of* six *or* seven *days* a few cells of *Sacch. pastorianus* and *ellipticus* began to appear and, concurrently, fermentation started, at first extremely slowly, but by degrees progressed much more rapidly as the newer forms of yeast became more abundant. It was continuing slowly, even at the end of forty days, when the experiment was concluded.

The amount of maltose which had undergone fermentation being

determined (1) from estimation of the alcohol formed and its calculation as maltose, and (2) the decreased specific gravity of the solution (after such distillation), was found to be 14·41 and 14·398, practically 14·4 ; and, as the experimenters say, " when we consider that the original solution only contained maltose = 6·986 grammes per 100 c.c., it is evident that the remaining 7·414 grammes must have been produced at the expense of the dextrin."

Factors determining (1) Percentage and (2) Type of Malto-dextrins.—These factors are three in number—viz., extent of germination, extent of kiln-drying, and mashing heats. As regards (1), the result of under-growing is based upon what has been insisted upon before—viz., that the starch of badly germinated malt approximates to that of the original barley, and may even be to a great extent insoluble at ordinary mashing temperatures. Accordingly it is only as the heat of the mash rises under the influence of hotter sparge temperatures that the starch gets gelatinised, and this only arriving at a time when the power of the diastase is much weakened (both by the withdrawal of the first worts and the higher temperatures), the conversion of such starch is very far from complete, and probably only dextrin and *malto-dextrins of an abnormally high type* are produced in the later runnings. Consequently, though the first copper wort may be of fairly normal constitution, the later worts will contain a high percentage of abnormal malto-dextrins, fermenting with exceeding slowness even in the cask. (In such cases, if anything like early condition is wished for, the use of " priming " or aqueous malt extract is indicated.) (2) High kiln-heats, and (3) High mashing heats, both of which, as compared with lower heats, determine an increase in the amount of malto-dextrin ; although in respect to No. 3, this is more marked when the temperature rises above 150° Fahr. than below it ; and, in fact, as long as it keeps within the usual range, the type of malto-dextrin does not vary much, and indeed is far more influenced by germination and kiln-drying.

And here, in these experimental mashes, a curious discrepancy—as stated by Dr. Moritz—occurs between laboratory experiments and samples taken of actual brewery worts. While the laboratory experiments (at all events, a series on which he relied) showed, with heats rising from 140° to 155°, a very marked increase in the *quantity*, but no alteration in the *type* of the malto-dextrin, which to begin with was rather high (maltose 1 : dextrin 4), the brewery samples, in the preparation of which the heats ranged from 146° to 156° initial, not only showed an increase in the proportions of malto-dextrin, but the type rose also (from M. 1 : D. 1 up to M. 1 : D. 2·9).

Kiln-drying, on the other hand, has a marked influence both on quantity and type. Thus in the case of malts mashed under identical conditions, with one which was undercured, the type was low (2 M. : 1 D.), while the quantity was very small ; but as soundly cured malt was reached, both quantity and type rose, and continued to do so the higher the curing, up to 1 M. : 2 D. When, however, the permissible limit was passed, and overcured scorched malt was used, though the quantity markedly increased, the type somewhat strangely did not (remaining at 1 M. : 2 D.).

Comparing the influence of kiln-drying and mashing heats, Dr. Moritz

states that a pale malt and a high-dried malt, the latter being mashed 9° lower than the former, gave an almost exactly equal quantity of malto-dextrin, but with the high-dried malt the type was lower, and he therefore makes the practical recommendation that for pale (and store) ales, a malt relatively lightly cured and mashing heats relatively high should be employed, while for running beers high-dried malt and relatively low mashing heats should be the aim. [The theory is, it will be remembered, that the high types of malto-dextrins are gradually degraded into lower and lower types, and finally into maltose, as which alone they are fermentable—*i.e.*, amenable to the influence of the yeasts, which bring about *cask condition*.]

"Fretting" explained by the Malto-dextrin Theory.—If we accept the view, also propounded, we believe, by Dr. Moritz, that beer at the time of racking may contain malto-dextrins of such abnormally low type as not to be far removed from free maltose (19 M. : 1 D.), then it is easy to see that such bodies (which might even have been fermented by a young and vigorous yeast during the primary stage in the fermenting vessel, *had such young and vigorous yeast been present*), having escaped fermentation before the racking, may undergo it shortly after, either by the agency of the primary yeast stimulated by aeration, or more probably by secondary yeasts, the germs of which have been absorbed and developed in the interim.

The conclusions of the investigators who have, of necessity, been so often referred to in dealing with the question of malto-dextrins, and whose researches are certainly of the highest importance in a technical sense, and it is gratifying to think that they form a contribution to brewing science, made by this country alone, although the name "malto-dextrin" was proposed by Professor Herzfield of Halle for a substance stated to be intermediate between achroo-dextrin and maltose. This substance, however, was fermentable by primary yeast, and this, as well as its optical and cupric-reducing power, suffice to distinguish it altogether from the malto-dextrins which the English observers claim to have identified.

A few operative details remain to be considered.*

Limited-Decoction Process.—The so-called "Limited-Decoction Process" is an attempt to get some of the results of the German system of mashing, without the expensive and cumbrous plant which that system requires. Something has been said about it already in Chap. I., but the *modus operandi* is as follows. An arrangement for letting free steam into the mash-tun having been provided—a 1½ inch pipe will do for 50 lb. pressure, but should branch into two pipes of the same diameter when just through the bottom of the mash-tun, and the false-bottom plates of the latter must be fastened down securely with bolts and bands, or they will be likely to shift—the mash is made with 2 barrels to the quarter, which may be made first with 1½ barrel at 164° Fahr., the remaining half-barrel at 187° being let in, with steam if necessary, to bring the mash temperature up to 155° or thereabouts for mild ales, and higher for bitter ales. These proportions of liquor may be modified, and probably it would be found generally advisable to use a larger quantity for the actual mash, and less for the underlet.

In 75 minutes from beginning mash, taps may be set, and wort at the

* The formula for ascertaining the striking heat required to attain any given initial, being of the nature of a calculation, will be found in p. 114.

rate of half a barrel per quarter is run off and pumped into a suitable vessel (with steam coil) commanding the mash-tun. The heat of the "goods" is now raised to boiling, gradually up to 170° or 175° at first, then rapidly. After the mash has been kept at 212° or nearly that for ten minutes, it is cooled down to 165° with sparged cold liquor, after which the strong wort previously run off—and which of course has not been allowed to get much over 160° Fahr.—is returned to the mash-tun, the rakes going all the time. The mixture must, on no account, exceed 165°. A short stand of 15 minutes will probably be enough, and then taps can be set and the coppers made up without further delay.

If the iodine test be applied after the boiling of the goods, it will appear that much fresh starch has come into solution. This disappears when the strong wort, which has been held back, is returned to the mash-tun. After this, almost any heat, however high, can be used for sparging, there being no risk of unconverted starch being carried into the copper in solution.

Over-fine crushing of the malt should be specially avoided for limited-decoction mashes, and the use of Conron's patent mashing rakes (those with india-rubber ends, which sweep the false-bottom plates) have been found useful, though for the ordinary system they are scarcely to be recommended. Probably the inrush of free steam somewhat prevents that forcing of fine particles through the apertures of the plates, which brewers, using those rakes in the ordinary infusion process, have found to be their most trying fault. Rakes, at any rate, should revolve while boiling, cooling, and mixing are going on. The extract got from malt, and that factor's malt, in fair years by the limited-decoction method will average 90 or over, but the difference of extract and the benefit is most apparent when dealing with hard and steely malt. The drainage gives no unusual trouble, and it may fairly be claimed that a remarkable brightness of the racking sample usually results. We have seen limited-decoction beers bright in the round at four days.

Limited Decoction with 25% of Unmalted Grain.—The experience of an energetic experimenter in this direction and his mode of applying it was as follows, and without alteration of plant he obtained very bright beers with most brilliant worts. Mashing 25% of whole grist maize, flour, or rice with two-thirds of the malt of which one-fourth was Algerian, to get an initial of 125°, he then gradually raised the heat—taking an hour—to 165°, with the rakes revolving all the time; then he raised the mash rapidly to the boil. After boiling for ten minutes he cooled down to 165° (with cold liquor as before), mashed in the remaining third of the malt, and set taps after 60 to 90 minutes' stand. This time about half the contents of the mash-tun was run off without sparging. Then the boiling being repeated and continued for ten minutes, the mash was again cooled down to 165°, and the large quantity of strong wort last drawn off and held back was returned to the mash-tun, and taps set again after fifteen minutes' stand. The copper lengths were then made up without further delay.

In the narration this seems a troublesome process, but, in any case, if **raw grain material** (*e.g.*, rice grits) be used, the process is a troublesome one, and additional plant—a **Converter,** fitted with rakes briskly revolving—is required. Generally speaking the process, when the latter but no filter-press is used, is to make a free mixture (3 barrels to the quarter) of

grits and water, having previously run in about 1 bushel of ground malt to each quarter of the grits. The converting temperature, at which the mixtures are made, is raised by free steam to boiling-point, and that heat maintained till the starch is fully gelatinised. The mash is now cooled with cold water to about 190°, a quantity of malt similar to the former mashed in, and the temperature raised some 5°. The mixture is then run into the mash-tun simultaneously with a malt-mash of relatively low "initial" (about 130° F.) down an inclined plane, a few inches in depth of the latter being preferably run in first. The whole is now "raked" with a small simultaneous underlet, a "goods" heat of about 150° F. being aimed at.

The Employment of Flaked Maize in Brewing.—Hints on Practical Mash-tun Manipulation.—A knowledge of the correct methods of procedure to be adopted to secure the full advantages accruing from the employment of flaked maize is now easily acquired, although care must, of course, be observed that the unmalted material is added to the mash-tun in such a manner that the maize readily undergoes conversion. This is brought about by diastatic action through the agency of the enzymes present in the malt, and the essentials of success are dependent therefore on the system of maize and malt admixture, which is carried out. In medium-sized and large breweries the difficulties met with occasionally in this connection and also in respect to filtering are removed, or at any rate considerably minimised, by the erection of a supplementary hopper, at the apex of which a feeder is attached, worked by a pulley and belt on the principle of the shaking screen of a malt mill. The hopper is used exclusively for the flakes, and the apparatus is placed in or near the grist case in a position so that it can distribute or spray its contents at any speed desired to meet the incoming grist direct from the mill or elevator. Any inequality that may occur in the mixing of malted and unmalted materials after these precautions are exercised is overcome by the effect of a few turns of the rakes in the mash-tun. We have in mind at the moment, however, an instance of one of the largest breweries, using a high proportion of flakes where the mash-tun is not equipped with rakes, and yet no trouble arises from incomplete conversion or insufficient drainage. While shakers and rakes are of undoubted advantage, there are small breweries successfully employing flaked materials without the aid of the subsidiary plant named. It is to the smaller traders who are not included among the users of maize, and are deterred from adopting this adjunct by a lack of knowledge in regard to its manipulation that these remarks, in the main, are addressed. To produce the best results in the absence of a separate maize mixer and rakes, it is recommended to proceed as follows. Cover the plates of the mash-tun with water to a depth of from two to three inches prior to the commencement of mashing. Then run foreign malt grist into the mash-tun for a few inches in order to secure an efficient filter bed directly above the plates, which should obviate difficulties in connection with subsequent drainage of the wort. This should be succeeded by a mixed grist composed, as far as practical, of equal quantities of malt and flakes, the malt portion being made up mainly of the English used. The mashing is then completed by a top layer of all malt.

Operative brewers are conversant with the difficulty of ensuring that the malts will run forward to the mash-tun in their order, as the result of

special precautions, they are expected to reach the grist case, and no method or pre-arrangement will ensure that the blend of flakes and malt will be mashed in a series of layers which we had previously theoretically calculated upon. The dry maize has a less natural tendency to set in the cone of the grist case than well crushed English malt, and the flakes run towards the slides at a greater speed than we had perhaps bargained for. Then the malt that forms the uppermost layer in the grist case will not when mashed necessarily exchange places and form the corresponding layer in the mash-tun. While mashing is proceeding the uppermost layers of grist are continuously descending the cone of the grist case and arrive at the Steels before the lower portions.

It would be impossible to state what mashing temperatures should be employed to obtain the maximum advantage derived from the employment of flaked maize, as to do so in the absence of knowledge of the system prevailing in any brewery might lead to disastrous results. A brewery having decided to adopt the use of the adjunct we are discussing, should commence with a low percentage, say, 10%, and gradually increasing the percentage until a limit is reached. By this method no appreciable alteration will occur in the general character of the beer produced. What this limitation should be obviously depends upon several factors. A flaked maize may be described as a semi-raw material having regard to the fact that during the course of cleansing and preparation for brewery use the objectionable features present in the original Indian corn are eliminated and the starch content of the cereal are gelatinised. The flavour produced in beer from a proportion of maize correctly cleansed and prepared is similar to that obtained from glucose, the source of which is the same grain, but of course, the character of a beer derived from flaked maize as an ingredient is inferior to that obtained from barley malt, cane, or invert sugar. In rearranging the percentage material composition with a view to including maize, all the considerations mentioned must be duly weighed. Reverting to the question of mashing and sparging temperatures, generally speaking a reduction in the striking heat, normally employed for an all-malt mash should be adopted. What the amount of this reduction of temperature should be depends primarily on the friability and diastatic capacity of the malts in use and if these main materials are satisfactory then very little reduction of temperature will suffice, and no alteration need be made in sparging heats. A rather more fluid mash than when all-malt is used facilitates a speedier conversion of the flaked maize, although care must be observed that this fluidity is not overdone or the initial heat will be raised excessively.

Under all circumstances hurried mash-tun working is fatal to obtaining a large yield of extract, and especially is this the case when maize forms a portion of the goods. When the ordinary precautions we have described are exercised flaked maize can be used regularly as an adjunct without additional plant, or incurring failure in securing the maximum amount of starch conversion.

Semi-prepared Raw Material, or "Flaked Malt."—In preparing these materials the starch is ruptured by steam (superheated steam) and the mass rolled or pressed into flakes, the steam-heated rollers used helping to complete the drying. **"Torrefied Malt"** is barley popped by a sudden blast of heat in its course down an inclined shoot under which is a row of

what are practically powerful Bunsen burners. The grains, even when made from small, thin barley, are larger and of less specific gravity than those of malt itself. It is convenient to use, as it could be ground with the malt.

Composition of Extract from Flakes.—The average composition of flakes, given by Julian Baker, is :—

	Flaked Maize.	Flaked Rice.
Starch . .	79·70 per cent.	81·36 per cent.
Albuminoids .	11·38 ,,	7·21 ,,
Oil . . .	1·12 ,,	0·83 ,,
Water . .	7·28 ,,	8·13 ,,
Cellulose .	0·04 ,,	1·64 ,,
Ash . .	0·48 ,,	0·83 ,,

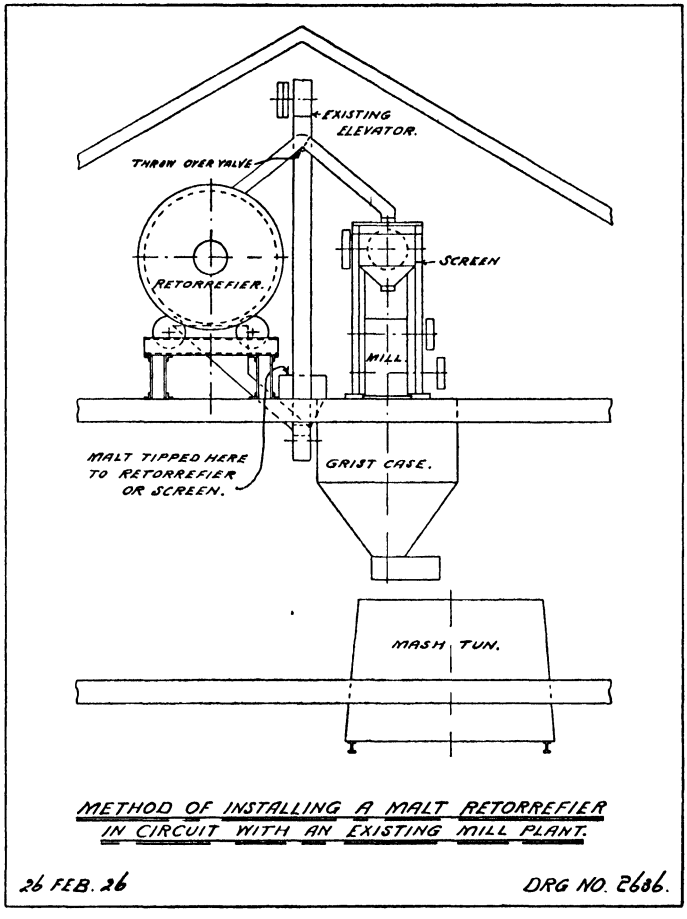
But he has also pointed out elsewhere the effect of the varying diastatic power of the malts mashed with it, as affecting analytical results ; and this applies to operations on a large scale equally with laboratory results—illustrating, too, the necessity of a thorough intermixture insisted on above. Thus when maize flakes were mashed with an equal weight of malt (A), and twice the weight (B), the extract varied as follows. Result in brewers' lbs per 336 lb. of flakes :—

Diast. Power of Malt.	A. (Maize 1 : 1 Malt.)	B. (Maize 1 : 2 Malt.)
40	106·50	106·4
34	102·40	103·2
25	100·25	103·3
12	97·64	97·17

It may be noted that the object in carrying out the laboratory mashes with equal as well as with double quantities of malt grist (the latter being the usual practice for " flakes " determinations) was to minimize the risk of error in allowing for the known extract of the malt. The higher extract shown under column B, when malt with 34 diastatic power, and still more when malt of 25 was used, may be due to such an experimental error ; but it is explicable on the assumption that, when malt below a certain diastatic standard is mashed with flakes, a preponderance of the diastase-container is essential for the best conversion results. Unluckily, the conjecture is spoiled by the figures which the lowest diastatic value presents. The employment of " Flakes " yields infinitely superior brewing results to glucose which is mainly obtained from maize. Glucose, as such, is wholly fermentable in the primary fermentation, while the ratio of fermentable to unfermentable carbohydrates yielded by " Flakes " can be adjusted by the mashing striking temperature adopted.

The Filter Press Process (Meura's).—This process has survived the experimental stage, and its advocates claim that it brings about an increase of extract averaging 4½% (say 6 lb. per qr.) ; but others put this at the more moderate figure of 1·2%. Probably it will be even lower with well-modified malts (those which in laboratory determinations of extract show less than 1% of difference between their " fine grist " and " coarse grist " mashes), because in the wet grains from such malts the average carbohydrate residue is 1·3%, while that found in a sample of filter grains submitted by a well-known company was 0·5%, the difference being possibly augmented by a small amount of cellular matter (digestible fibre) rendered soluble. With the exception of fine grinding, to the extent of pulverisation, the alterations are purely mechanical : the very different temperatures traditionally used for Infusion and for Decoction beers are still retained. The changes are to use a steam-jacketed convertor instead of a mash-tun, its rounded bottom allowing a better discharge into the filter than a flat one possibly could. The discharge is through a pipe 6 in.

in diameter and without bends. It is found that a fall of 8 ft. gives a velocity which carries the mash into every chamber of the filter, and though it is desirable that the mash should be fairly liquid (3 barrels to the quarter), any additional liquor beyond the normal can be added just before the discharge. The effective part of the filter consists of grooved metal plates with filter cloths stretched over and set on frames, the varying widths of which—*e.g.*, 2—2½ in. (Belgium), about 1⅛ in. with 34



chambers (U.S.A.) up to 3 in. (England)—control the depth of each of the chambers and the thickness of the ultimate cakes of compressed grains.

The wort is first drawn off by gravitation ; afterwards pressure of half an atmosphere may be used to squeeze out the strong wort and lessen the amount of liquor required to wash the goods. This liquor enters the grooves, covered by the filter cloth, at one side of each layer of " goods," through which it passes, escaping at the other side. Time is saved because fine grinding quickens the conversion ; and, contrary to experience with sparges, it has been found that the finer the grist the better is the filtration

—a fact probably explained by the absence of imperfectly converted starch, tending to block filter-ways in mash-tuns by "adsorption." This may commend the system for black beers, the worts of which often drain badly, as conversion can be crippled before filtration.

Hot Grist Mashing.—Uniform heat within a variation of a few degrees is imparted to a bulk of malt grist by passing heated air into it for some hours (Clinch's patent). The benefits claimed for this system are that a distinctly malty aroma is brought out in the grist and remains in the beer (some analogous results may be observed on toasting, or even warming, a slack biscuit before the fire); that defects in kilning, notably undercuring, are made good; and that the heated air coming into contact with the crushed particles of malt does this very effectively and without imparting the slightest increase of colour; and that the employment of relatively low "striking heats" (no higher, in fact, than the initial heat desired) instead of heats 12° or 15° higher, with perhaps an underlet besides at a much more considerable temperature, not only results in speedier conversion owing to the non-coagulation of diastase, but secures the attainment of a large proportion of dextrin (or malto-dextrin if the view as to the absolutely uniform quantity of dextrin resulting from a starch-transformation be correct), with much greater yeast-feeding property than such highly dextrinous worts, obtained on ordinary lines, as a rule exhibit. A great tendency to fobbing, necessitating careful boiling of the worts, is evidence of the presence of much dextrin, whether free or combined, while the possibility of reducing the pitching-yeast by some 20%, which is said indeed to be advisable, will show the yeast-feeding character that the wort possesses.

Stout and Porter Grists.—A proposition advanced in some treatises dealing with the practical side of brewing, namely, that the initial heat for black beers should be low, needs qualification. It has been stated that palate-fulness is thereby brought about, but the tendency will be exactly the reverse, unless lines similar to those suggested on the next page be followed. One might even go so far as to say that in some cases, those for instance where black beers are brewed in comparatively small quantity by country brewers having no large local demand for that class of product, an initial even higher than that used for running ales is required.

More than in any other beer is a good firm persistent head a desideratum in black beers, and from what has been said before it will be understood that this is attainable solely by ensuring the presence of a good proportion of dextrin, whether it be combined as malto-dextrin, or free, as was at one time supposed.

And although there is no diastatic capacity in the black or roasted malt, which forms part of the grist, and very little, if any, in the brown and other coloured malts, there is equally no starch in the former, and very little in the latter to undergo hydrolysis, so that the question of the wort's relative poverty in diastase does not come into play, and indeed has no foundation in fact.

There is no doubt that the extraction of a large proportion of albuminous matters, especially in the form of peptones, also tend to give softness and body, if their presence can be secured without the extreme degree of conversion into maltose, which, unless special precautions be taken, they will determine. This might be done by working on lines laid down in an

earlier part of this chapter, *i.e.*, by getting a low initial heat and rapidly and considerably raising it (to diastase-crippling point) by free steam, or by some specific modification of the limited-decoction system, or by the employment of the hot-grist process. But failing facilities for these, our own experience makes for higher heats than those used for ales. Similarly, we hold that the " rest " or " stand " after mashing should, if anything, be curtailed.

Black beers are brewed from a mixture of pale, brown, or amber, crystal or chocolate as preferred, and patent, or black, malts, though in Dublin, and we believe in Cork, the brown is omitted. The Irish brewers' patent malt, however, is not the over-roasted *black* stuff (giving a rough and burnt flavour) which so often does duty for that material in England. It is rather of a rich chocolate brown, and being used in large quantities easily escapes the extreme slackness which samples taken from the country breweries here would often exhibit. Also, as we are given to understand, the brewers in Ireland depend largely, if not solely, upon malt, while in England sugar is considerably used, and that often of very inferior quality, under the questionable idea that anything will do for stout, as the colour covers a multitude of sins.*

Brown or Blown Malt is made by subjecting well-vegetated barley—after the moisture has been duly got rid of—to a sudden blast of intense heat generated by heaping up the kiln fire with oak or beechen faggots or billets. The result is an increase of bulk averaging 25%, if all the conditions are favourable. Owing to the risk and the high rates of insurance demanded in consequence, this malt is generally made at certain centres by maltsters, the large London breweries being alone able to profitably make for themselves.

Amber Malt is manufactured from ordinary malt which, however, is subjected on the kiln to the colouring and flavouring influences obtained from high temperatures maintained for a relatively long period *in the presence of a fairly heavy moisture content.* These temperatures range from 160° to 180° or even higher, and with careful preparation the diastase should not be completely destroyed, leaving a D.P. of from 8 to 10 Lintner. Amber malt is valuable in the direction of contributing a " malty " flavour and aroma to stouts, but its employment has been found useful for the same reasons in beer production when using large proportions of maize and rice flakes. Amber malt yields an extract of exceptional brilliancy, and it assists the clarification of other worts by increasing coagulation or " break " due to the degree of caramelisation the malt receives in the special kiln treatment to which it is submitted on the kiln.

Crystal Malt is prepared as follows : after undergoing normal germination on the floors the grain is soaked in a somewhat dilute sugar solution, or any weak solution of saccharine substances. The malt is then cured in the ordinary manner on the kiln and its manufacture completed by methods similar to that adopted—although in a modified form—for

* Also it may be added that another characteristic of the Irish system is attenuation pushed to an extreme that the English brewer, who rather aims at keeping a high proportion of unattenuated matter in beer of this class, never dreams of, body and condition being afterwards secured by " worting," *i.e.*, by adding strong wort in incipient fermentation (what the German brewers know as Kräusen, *anglice Kreising*) instead of priming with dissolved sugar, as is general in England.

roasted or so-called patent malt. Crystal malt yields an intensely malty flavour and aroma peculiar to itself. It is valuable for colouring mild ale, to which it confers improved flavour, an enhanced palatefulness and an attractive rich colour.

Patent, Roasted, or Black Malt.—The first name was given because a "patent," or licence, was required for its manufacture when the malt-duty was in force. It should be plump and not too black; the malt exhibiting a brownish fracture is the best. It is roasted in a large revolving cylinder.

Owing to the necessity of buying these malts in larger quantities than are required for one operation, they are generally used in far too slack a condition for perfect success. A large part of the aroma certainly gets lost, and accordingly, the late Mr. Stopes pointed out the advisability of using patent malt fresh, giving the following detailed method of producing it on a small scale.

The apparatus consists of a perforated cylinder, turning easily on bearings, and fitted above a fireplace enclosed in sheet iron, which is extended upwards, so as to form a chimney to carry away smoke, steam, or fumes. The cylinder holds one or two bushels of corn, and should be kept revolving steadily. There should be a low coke fire at first, and afterwards, as the steam passes away, a brighter one. In thirty minutes a fine aroma steals from the malt, which should be inspected five minutes later, by which time a good chocolate tinge ought to have been acquired. In forty minutes the operation will be completed, and the charge may be turned out to mellow. Mr. Stopes also pointed out that slack pale malt may be more advantageously used in this way than by redrying it for ordinary use.

This plan certainly involves trouble, but the advantage of using the roasted malt fresh is very great. Manual labour for turning would perhaps prove somewhat expensive, but moderate hydraulic power would perhaps do better than power got from the ordinary shafting.

The Manufacture of Black Malt.—Black malt is manufactured by placing ordinary malt directly into roasting drums and scorching it to the desired type of colour, without any previous moistening. According to practical experience it is advisable to have the black malt drums of such dimensions that about 2½ cwts. of malt may be scorched in one operation. The drums may be heated by open fire, and for carrying off the gases generated by the roasting process small apertures in the jacket of the drum are sufficient. In the interior of the drum iron rods issue from the wall which serve to mix the malt properly when the drum revolves so as to produce uniform scorching. A particularly uniform malt is obtained by the following proceeding: The malt is roasted in two combined drums. A lower drum is heated by direct fire, and another above by the fire gases of the lower one. The material is first heated in the upper drum, revolving about 9 to 10 times a minute. When the malt begins to show the first tints of scorching, the process is continued and finished in the lower drum over the direct fire until the desired depth of colour is reached. The lower drum makes 11 to 12 revolutions per minute.

In black malts roasted dry in this manner the husk is strongly overheated, which causes a profound modification of the husks. These black malts thus often acquire a burnt or empyreumatic odour and taste.

To avoid these faults it is considered expedient to prepare black malt

not from dry but from moistened malt. Instead of moistening malt it is just as good to use half finished kiln malt. In fact, black malts prepared from malts with a higher moisture content show a more uniform browning of the mealy body. The taste also remains milder, the husks being modified to a less degree and hence less quantity of bitter substances formed.

Substitute for Patent Malt.—A very effective substitute for patent malt—at least in part—is "specially prepared caramel" as supplied by various manufacturers, and it not only gives colour (about 14 lb. to 16 lb. = a bushel of patent in colour-giving power) but also adds to the non-fermentable extract, and thus helps the production of a full-bodied article. Its tendency, too, is to increase the permanence and brownness of the head.

The following grist of 30 quarters has been recommended for porter—

Pale Malt (and equivalent in sugar) . . .	24
Brown Malt	4
Patent Malt	2
	30

And for stout 4 bushels less of patent and 4 more of pale malt, the required length being shorter.

For some districts, *e.g.*, where blending with ale is done, this stout might be too pale. In a case where deep colour is required, the following proportions answer for stout.

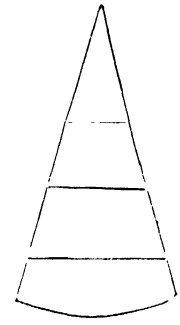
25 quarters pale, 4 quarters brown, $2\frac{3}{4}$ quarters patent (in mash); 8 cwt. (approximately) of cane-sugar, and 140 lb. of stout caramel. These quantities, of course, to be adjusted in accordance with the quantity and gravity of the wort required. Much larger proportions of caramel are employed by some brewers, and there are cases in which it has entirely replaced black malt.

We hold that the mashing liquor should, if possible, be boiled for stout, and that common salt should be added to the maximum extent formulated in the chapter on water.

Dead Mashes (and flooding of Goods).—Factors which determine deadness of mash are over-fine grinding of the malt, the separation of the heavy flour from the lighter husk, which otherwise tends to keep it buoyant, perhaps intensified by jarring in the elevator cups, and an excessive fall into the grist-case, steely malt, or the use of too much huskless malt substitute. Knocking about of the mash with the rakes has also some influence in the same direction. In the first two, and probably in the last two cases, a layer of pudding-like starchy matter will, when the grains are thrown out of the mash-tun, be found to have formed midway between the top and the bottom, or lower. This layer, obdurate at first, may partially, if not entirely disappear, owing to the solvent action of the diastase, and thus, as is generally found to be the case when the taps make a bad start, drainage gradually improves. At higher temperatures, be it noted, the liquefying action of diastase is even more rapid than its saccharifying action.

Sparging formerly produced deadness of mash and consequent flooding

of the goods. The sparge-liquor should flow on evenly and lightly, a three-armed sparger being better than a two-armed for a large mash-tun. Messrs. Wilson & Co., of Frome, arranged a simple but ingenious appliance for testing the evenness with which spargers work. It is, in effect, a shallow vessel made of copper or tinned iron, the bottom forming a sector of the mash-tun circle—*i.e.*, occupying an angle enclosed by two radii, and the arc they cut off. This vessel is then divided by partitions, as shown in the annexed outline, and placed upon a level corresponding to the surface of the goods. The sparger being then made to revolve with liquor in the usual way, if its action is correct, obviously all the divisions of the test-vessel will be filled simultaneously. Flooded mashes are now, however, seldom due to faulty sparge arms. The liquor falls from the modern spargers in the form of an exceptionally light and fine spray, which does not adversely affect the original buoyancy of the "goods" at mashing.



The heat of the sparge-liquor should be so regulated that the temperature of the "goods" shall not, at any time, exceed 160°, and an even lower temperature may sometimes cause the extraction of starch. Not that the unconverted starch, as such, is specially injurious, but its non-conversion does signify waste; moreover, a heat high enough to liquefy starch and destroy even a weakened diastase probably involves extraction of certain nitrogenous bodies in a state of semi-solubility (see p. 158), that is to say which are soluble at high temperatures and in a saccharine wort, but which, in the absence of these influences, may determine a serious and persistent turbidity. Moreover, towards the end of the sparges the "goods" temperature should show a decided drop. As a general rule, sparges beginning at 170° to 175°, and finishing at 160° or 155° F. or even lower, would be within the limits of safety. The collection of the mash-tun wort should be regarded as two processes: (1) extraction and (2) "washing off." During the extraction the goods should be maintained, or even slightly exceed, the original depth. At that point when it is known that starch conversion is completed, "washing off" should then be proceeded with, the wort being collected at a considerably accelerated speed. The depth of the goods meanwhile being allowed to gradually diminish until the final coppers lengths are collected. By careful and skilled working sparging can be continued almost until the stage just named has been reached.

The Underback.—In some of the newer plants attempts have been made to dispense with the underback, the mash-tun taps running directly into the coppers. Although it is convenient to be able to run straight into either copper, without the wort passing through the underback, yet the latter should not be suppressed. It should be adjoining the coppers and like them of copper, and at a level higher by a few inches than the rim of the copper, so that the wort can flow easily into those vessels. The underback should certainly have a steam coil; and a convenient size, having regard to the necessity of sometimes keeping back strong wort for the purpose of bringing up the gravity of later coppers (especially in the case of parti-gyles), would be one capable of holding fully one-third of the

maximum amount which can be boiled in the largest copper. We may say from experience that one holding only one-fourth is sometimes found inconveniently small.

For example, a brewer is, let us say, in the habit of brewing 200 barrels at a time, of which 130 barrels are pale ale and 70 barrels XX. We need not enter far into his reasons for arranging his brewing thus, which may be complex; the arrangement may be dictated by some consideration of convenience in racking, while, owing to the pale ale being more or less of a running character, or certainly not stock in the full sense of the word, the mashing conditions which suit the one kind of ale will not be unsuitable for the other. Well, in brewing the above quantity, he finds perhaps that it does not do to habitually get *more* than 25% of his XX extract from sugar, within which limit an underback holding 20 to 24 barrels of strong wort (of 30 to 35 lb. gravity) will enable him to keep; but supposing that, owing to some extra pressure, he wants to brew 80 barrels, which his larger copper is quite capable of turning out at one boiling, then he will find, having only an underback of the above size, that he must exceed the percentage of sugar which he finds most satisfactory.

Our own experience is dead against exceeding a certain limit, which of course may vary with circumstances and in different plants. Once in a way an excess of sugar beyond the usual maximum may do no harm, but persisted in it will tend to yeast-weakness. Special measures, such as the employment of some form of peptonised or mineral yeast food, or a good brand of manufactured malt extract syrup, may facilitate the use of even larger percentages of sugar; an instance is even within our knowledge where beers of considerable repute have been brewed with as much as 50% of sugar, the yeast being at the same time of rather exceptional purity and vigour.

Stewing the Wort in Underback or Copper.—This practice, which consisted in keeping the worts while gathering, or for part of the time, at a uniform (and converting) temperature of 170°, or somewhat under, was at one time advocated, either with the idea of securing the conversion of any soluble starch, or from some misty notion of peptonisation. Brewers, however, I think, came to the conclusion that whatever the benefits of the system might be, and they were not very apparent, they were heavily discounted by a thinness of palate developed thereby. Upholders of the amyloin theory maintain that diastase in the underback has no power of degrading to a type lower than that of the malto-dextrins already co-existing in the wort, and they would stew (if they did it at all) the later runnings, in which both percentage and type of malto-dextrin are generally very much higher, with some of the diastatic first wort kept back at a suitable temperature.

Boiling.—The objects of boiling are fourfold:—

1. Sterilisation of wort in regard to therein-existing organisms.
2. Coagulation or precipitation of certain albuminoids.
3. The extraction of as much of the hop-aroma as possible.*
4. To obtain the full effect of any directly antiseptic influence which the hops (probably in their resins) possess.

As to 1, some very interesting researches by Dr. G. H. Morris have shown that absolute sterilisation is secured—almost universally—by 15 minutes' boiling with hops in the copper. In one case only out of several,

* Methods of working out proportions are given in Chapter V., "The Brewing Room."

and that when the malt was apparently a very bad specimen, did a sample of wort, taken after a 15 minutes' boil in the copper, and then submitted to the ordeal of the forcing tray for 7 days, show a few short *bacilli*; others showed none after 21 days of the same treatment.

Dr. Morris thinks that the temperature of the boiling wort, which he fixes at about 215° Fahr. for the lower part of the copper, is greatly aided by the acidity of the medium, due partly to the lactic acid incidental to the malt and partly to acid (tannic) derived from the hops. (Acid liquids are much more easily sterilised than alkaline, as Pasteur showed long ago.) Also it is aided, he thinks, by an antiseptic property which the hops possess, and which is supposed to reside in some of the resins. He quotes Hayduck's experiment as showing that the extract of 1 gramme of hops in 500 c.c. would be sufficient to entirely stop the action of the lactic ferment, and to restrict, more or less, that of the other disease-ferments except *Bacterium aceti*. Hayduck's extraction, though the fact is not stated, was probably an aqueous one, so that the conditions are not quite on all fours with those which obtain in the brewer's copper; but, on the other hand, seeing that the proportion 1 : 500 only means about ¾ lb. of hops per barrel, the brewer's position is in respect of quantity more favourable.

As to 2, the albuminous matters affected by the boiling divide themselves into two groups, those coagulable by boiling (or, indeed, by a temperature of 180° Fahr.), and those precipitated by the action of the hop-tannin, which combines with them, forming insoluble tannate of albumen. The former separate as a flocculent coagulum in very minute flakes, and though partially redissolved in the boiling wort help to form the cooler sediment. They are easily precipitated, so much so that a sample of first-copper wort, taken almost directly after the length has been made up (we refer to one which has been at, or near, boiling-point when gathering), will often filter bright and remain bright, and even if boiled in a beaker will give little or sometimes no further precipitate.

The case is different with the tannate of albumen. This is only formed after somewhat prolonged boiling (necessary, of course, to extract the hop-tannin), whereupon it shows as a somewhat coarsely flaked coagulation, forming the portion of the wort-constituents which separates when the so-called "break" occurs.

An apparatus was on sale to remove the albuminous matter which is coagulable by heat, before its re-solution in the boiling wort. The wort in its passage to the copper is first heated, then cooled, and then passed through a cellulose-filter, which removes the albuminous coagulum, and it was claimed that thereby a good deal of potentially harmful matter is removed, matter which, it was alleged, does come out of solution again slowly both in cask and bottle, and forms a considerable part of the sediment in both.

No. 3, is to add the hops, which have been apportioned for each copper, entirely while the copper length is being made up, *i.e.*, to have them all in just before the copper boils.

Hops, when added to a boiling copper, should be roused in to prevent the volatilisation of their essential oil before they get submerged. Volatile as this oil is, there seems reason to suppose it less readily driven off when diffused through the wort.

As to No. 4, although it has been suggested that any antiseptic pro-

perties possessed by the hop reside in the resins, this is by no means certain. At any rate, a good boil is necessary to dissolve these resins, and as they seem somewhat intimately bound up with a portion of the essential oil, it is probable that a strong boil, by dissolving more of the latter out, will retain as much in the nett result as a slack boil which causes less volatilisation. It is remarkable, however, that no apparatus has been devised for general use to secure the retention of *all* the essential oil (so much of which now scents the air for furlongs' distance when coppers are boiling) without losing the advantage of vigorous ebullition.

Steam-boiling *v.* **Fire-boiling—Closed** *v.* **Open Coppers.**—In spite of the increasing use of steam-jacketed coppers, there is still a feeling in many quarters that they are only a convenient makeshift, far inferior to fire-coppers for producing a keeping and brilliant beer. One who has seen ales quite up to the average in the former respect and inferior to none in the latter, produced in a brewery where the only boiling vessel was an iron square back, with a coil, which only succeeded in keeping up the semblance of a boil for the greater part of the time that the wort was supposed to be boiling (sometimes not more than 80 minutes), may well feel somewhat sceptical about this.

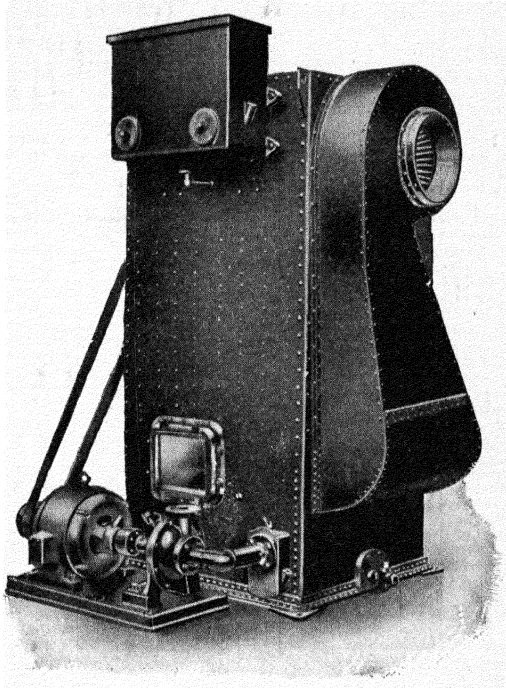
The notion appears to be that as the heat of steam is not more than 212°, or, say, not more than 240° when at considerable pressure, whereas the heat of a furnace will be several times this, the heat from the latter must be much more searching and effective, it being forgotten that if this were so, if in fact the wort were not protected from such extreme temperatures by an impalpable cushion of vapour between itself and the inner surface of the copper, and which probably absorbs all the heat above 212°, or, say, 215° (for the temperature will vary with the depth of the liquid, being higher at the bottom of the copper where the pressure is greater), the brewing of a pale beer in a fire-copper would be impossible, owing to the caramelisation which must ensue. That a fire-copper, closed at the manhole, and in which boiling takes place under some amount of pressure, will be the best for black beers, may be readily believed.

Open coppers are held to colour worts less than closed coppers do, pressure on the latter causing some caramelisation and extracting colouring matter from the hops. In a dome-and-pan copper pale beers can certainly be brewed.

Hot Aeration of Wort.—The value attached to this rests on the view that at high temperatures, and at high temperatures alone, atmospheric oxygen enters into *chemical* combination (as distinct from the free oxygen entangled at lower temperatures) with certain constituents, resinous or nitrogenous, which it eliminates in the form of cooler sediment, thereby lessening the risk of a later incomplete cask precipitation. Whether worts on a cooler with a layer of vapour above them are in surface contact with atmospheric oxygen is open to question. Precipitation of suspended matter is mechanically more rapid from thin layers of wort on large cooler areas than from bulks of great depth, but the coolers certainly afford scope for the infection of the wort by microbes. (See " Pure Air Installations.") The numbers of these organisms, neutral or hurtful, have been estimated by tens of millions, and were it not for the great preponderance of the yeast cells (reckoned by a modest computation at about 900,000 *millions* per lb. of dry pressed yeast) they would soon be masters of the situation.

It may be worth noting and for the student to visualise the figures, that this number of cells would have collectively a surface capacity estimated at 2,303 sq. feet, and that in each barrel of fermenting wort pitched with 1 lb. of liquid yeast, the initial area of the yeast-like cell surface may be taken as half this, viz., 1,152 sq. feet.

The Standardisation of Brewery Produce.—The Successful Application of a New Scientific Principle in Purifying, Heating or Cooling the Air of Breweries.—The maintenance of regularity and precision in the general character of any manufactured article is the keystone to success and continuous progress in business and the enhancement, to an incalculable extent, of commercial prestige. The effect of the moral influence due to achievements in manufacture is, it will be readily conceded, of a more far-reaching character in the brewing industry than in any other trade.



THE HEENAN AIR PURIFIER AND COOLER.

Irregularity in the quality of output and the consequent uncertainty engendered in the public mind in the matter of supplies, are adverse factors of so damaging and insurmountable a nature, that brewers are finding it increasingly difficult to overcome the prevailing competition.

Hitherto, up to a certain point, the application of scientific principles has assisted in the standardisation and stabilisation of brewery produce. For example, the biological changes which occur in the conversion of barley into malt are now better understood, and the brewing and market values of malt and other extract-yielding materials are now assessed on definite analytical standards. The power of enzymic action in the hydration of starch is now known and the proportions of fermentable to unfermentable carbohydrates can be, in some measure, adjusted and regulated by the aid of the polarimeter, as through the medium of the tintometer beer colours can be standardised. Equally so in other and minor directions. Yet with all the knowledge the modern scientifically trained maltster and brewer possesses, with the observance of every care in the selection of materials and in ensuring exactitude in his methods of working, and despite the undoubted advantages gained from the numerous appliances he can call to his assistance in his endeavour to produce beers of

uniform quality and stability, there has always operated hitherto a series of supremely dominating agents which sooner or later foiled the brewer's untiring efforts to achieve success in deservedly enjoying the professional satisfaction owing to him, in return for the care and skill applied.

This unsatisfactory state of affairs is due to *infection* in more or less degree by air-borne disease producing and acid-forming micro-organisms which primarily contaminate the worts, and in consequence the yeast, with the inevitable result that the beers lack stability, their flavour is impaired, and their brilliancy obscured, the latter fault in itself rendering modern brewery produce absolutely unsaleable.

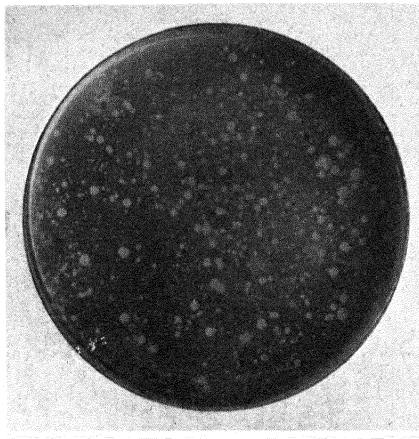
Formerly, with pre-war beers of higher original gravity, the contaminating effects of infection were somewhat minimised by the added preservative power conferred by the heavier hop rates then obtaining, and the increased alcohol and CO_2 content of beers in general. In addition, the pitching yeast from the worts of that period was not only more powerful and vigorous in action, and thus more capable of checking the development of alien micro-organisms, but the yeast then reproduced was sufficiently greater in amount, to permit the brewer to select his yeast for subsequent pitching purposes from the purer middle skims.

Post-war beers are brewed under conditions that present difficulties of a character which brewers of a past generation would regard as insuperable. Lower original gravities, decreased hop-rates, and reduced alcohol content, all render modern malt beverages incapable of combating the destructive effects produced by infection from bacteria, moulds and wild yeasts. Moreover, by reason of the lack of soluble mineral and organic yeast nutrients in present-day worts, yeast production is reduced to a point, the paucity of which deprives the brewer of the valued advantage he formerly possessed of rejecting unsuitable heads for future use, and by being then in the happy position of making his choice from a plenitude of material, he was obviously assisted in maintaining his strain of yeast in a state of greater purity and power than it is possible to attain nowadays.

Having regard to the altered and adverse conditions of working which has now for some years obtained in every brewery an earnest attempt was made to solve the problem by attacking it at its foundation, or in other words, removing the fundamental cause of most of the ills the modern brewer is heir to. We refer, of course, to the purification of air in breweries carried out under systems which on the evidence of users themselves are not sufficiently effective to ensure regularity of results.

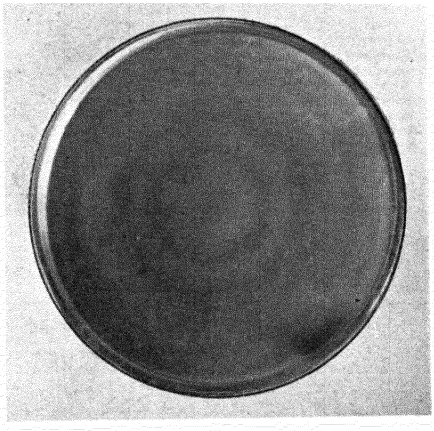
Messrs. Heenan and Froude, the well-known engineers, of Worcester and Manchester, have for many years manufactured plants for the cooling, purifying, filtering and heating of air, which machines, with the necessary auxiliaries, are now to be found in nearly every country. Their success led them to consider the question of air purification for breweries in all its bearings, and the advice of leading bacteriologists were sought, with a view to the evolution of a plant that would, in the matter of efficiency and economy of working, supersede all others. The present writer, it may be added, represented in a humble way in the exhaustive investigations which proceeded for some time, the point of view and requirements of the brewer.

Bacteriological research has furnished proof beyond all possibility of doubt that bacteria are, in brief, incapable of passing through water, and it is in the application to the full of this hitherto unapplied scientific



No. 1.

Micro-photo of air at point of ingress to the "Heenan" machine in the neighbourhood of a busy city thoroughfare 880 colonies of micro-organisms



No. 2.

Micro-photo (taken at the same period) of air as it emerges from the "Heenan" Air Purifier and Cooler Sterile.

principle that the complete success of the new "Heenan" plant is due.

The "Heenan" Air Purifier is of the stationary type, the outer casing being rectangular in shape, made of stout mild steel plates. The base of this casing forms a tank into which the cooling water falls previous to re-circulation by the pump.

The cooling and purifying medium consists of a series of screens arranged horizontally, and built up of phosphor bronze metallic wool. These screens are fitted into the upper portion of the purifier casing, and the cooling water is distributed over them through special perforated brass water troughs.

The air to be purified is drawn from the atmosphere by means of a centrifugal fan bolted to the side of the purifier casing, and distributes the contaminated air to the underside of the lowest screen; the air is forced through the purifying trays, and leaves the purifier at the top in a perfectly pure condition. A series of eliminator blades are fixed in the path of the purified air to arrest any loose particles of water that may be entrained in the air.

The air after leaving the purifier is in a highly saturated condition at a temperature closely approaching that of the cooling water, and with re-circulated water the temperature of the purified air is only some 2° or 3° Fahr. above the wet bulb temperature. This ensures a supply of purified and cool air, but should it be desired to heat the air, a heater is fixed in the duct from the purifier outlet so that any degree of heat can be given.

The usual method is to re-circulate the water by means of a small centrifugal pump mounted alongside the purifier. This pump is generally motor driven, and a further drive taken up to the fan shaft, but if convenient a drive can be taken from any counter-shafting.

The advantages accruing from this cooling or, on the other hand, the heating of the purified air, lies in the direction of a considerable economy in the total period of time occupied in the refrigeration of the copper worts due, it will be seen, to accelerated evaporation or intensified condensation.

The "Heenan" Air Purifier can be installed in any department of the brewery premises, but from the experience gained by the present writer from an extended working of the plant, full efficiency is best secured when the machine is placed to command the hopback, wort-receiver, or coolers, and the refrigerators. The wort as it reaches the hopback is sterile, a condition that is transitory. It is essential that all worts should receive efficient hot aeration—one of the most vital processes to successful brewing—and the necessary deposition of the "grounds" which results therefrom cannot be obtained without an attendant rapid and considerable diminution of temperature to a limit that is too low to destroy the causes of infection inseparably connected, to a more or less extent, according to the season of the year and the situation of the brewery, with all cooling and refrigerating rooms.

From the exhaustive bacteriological determinations obtained by the County Analyst of Worcestershire, the air as it emerges from the "Heenan" Purifier *shows the unexampled standard efficiency of* 100%, even when atmospheres of abnormal impurity are under treatment, and it follows that when the "Heenan" plant is installed, the wort remains sterile at collecting in the fermenting vessels, providing, of course, ordinary precautions are observed to prevent the ingress of impurified air from outside sources.

In brewing processes, by far the most vulnerable or susceptible to the devastating effects of infection, are those of wort cooling and refrigerating. It may be argued that, to a minor extent, it would be desirable to extend the purification methods so well begun, to the fermenting, skimming, racking, and yeast rooms of a brewery. If it is a question of rendering security doubly secure, then this subsidiary installation can most readily be carried out, the additional outlay merely involving the expenditure incurred in the purchase and erection of auxiliary air-ducts to any desired department of the brewery.

For our part, speaking from an extended experience of the value of the "Heenan" Air Purifier the efficiency of the main installation already described in full will, in the majority of instances, prove sufficient.

The adoption of a "Heenan" Air Purifier solves the problem that has harassed the brewing industry for generations, namely, that of securing precision and exactitude of results in that the beer reaches the consumer improved in flavour, of increased stability, and in brilliant condition. Such beers maintained in the forcing tray at high temperatures do not develop wild yeasts, bacteria or moulds.

It is acknowledged that beer successfully bottled on the natural system is the acme of the bottler's art, and yet the system is being superseded by recourse to chilling, filtering and carbonation. The faults hitherto of the natural system of bottling are the irregularity of produce, due to the development principally of wild yeast haze, premature acidity, "floaters," and excessive deposit. By reason of the complete elimination, at the source, of contamination by disease-producing micro-organisms from beers brewed under the "Heenan" Pure Air system, are when bottled naturally, free from the disadvantages enumerated above.

It may be asked in what manner is the pitching yeast affected. The yeast is improved in such a measure that the necessity for "changes" is wholly obviated.

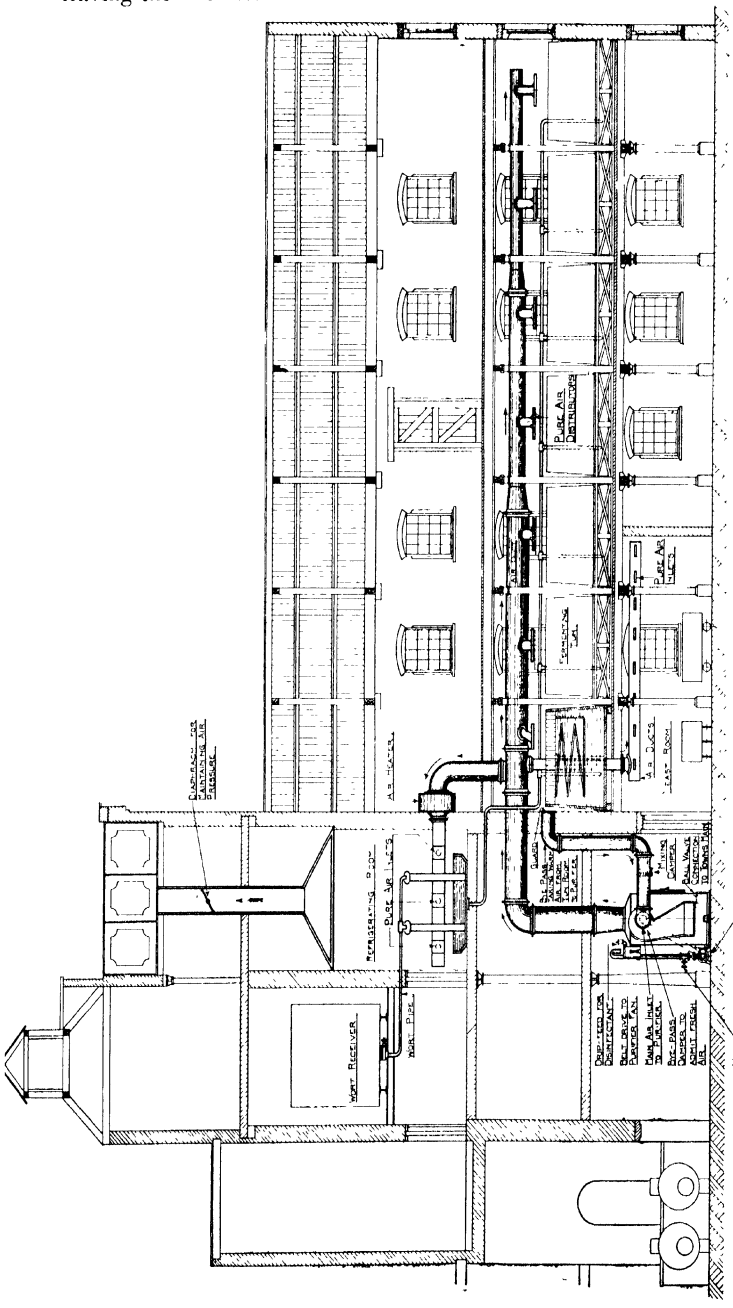
Examined microscopically, the yeast skimmed from worts collected in a sterile condition by the aid of the "Heenan" Air Purifier exhibit fields uniformly free from "rods" and other micro-organisms which adversely affect the general quality of the finished beer.

As already mentioned the wort is more susceptible to infection, and its subsequent intensely adverse effects upon the finished beer, during the cooling and refrigerating stages, and although by the application of the Pure Air System described the wort reaches the F. V. sterile where it obtains the protective influences of the yeast when the latter is in the full vigour of a normal fermentation, yet there are instances where the purifying and the sterilising of the air may with considerable technical advantage be extended to other departments of the brewery.

The fermenting or skimming rooms can be, so to speak, swept clean of air-born micro-organisms and other atmospheric impurities prior to the commencement of wort collection in fermenting vessels and throughout the rousing periods. In breweries where the dropping system obtains the "Heenan" plant can be employed with considerable advantage while the partially attenuated wort is in the course of transference from one vessel to another and also throughout the skimming stages on this particular system.

The interior of the various rooms are maintained under the con-

tinuous pressure of purified air, so that external draughts cannot introduce dust—contaminated as it is with disease producing micro-organisms—and unfiltered air into the building. The air is cooled to a low temperature or, on the other hand, if desired, it can be heated before leaving the Purifier.



"V" TYPE HEENAN COOLER

ARRANGEMENT OF BREWERY PURIFYING PLANT.

CHAPTER X

FERMENTS IN GENERAL

ORGANISED AND UNORGANISED FERMENTS—SO-CALLED INORGANIC FERMENTS—ENZYMES—TABLE OF ENZYMES WITH FUNCTIONS—DEFINITION OF FERMENTATION—GERM THEORY *v.* SPONTANEOUS GENERATION—PROFESSOR TYNDALL'S DEDUCTION—FUNGI—WHY FERMENT-ORGANISMS MUST BE CLASSED AS VEGETABLE ORGANISMS—PASTEUR'S SOLUTION—*Aspergillus Niger* AS AN EXAMPLE—RAULIN'S LIQUID—PROTOPLASM—HYPHA—MYCELIUM—SEPTATION—CORRELATION OF GROWTH—ABORTIVE MYCELIA—MODES OF REPRODUCTION—POLYMORPHISM AND PLEOMORPHY—SCHIZOMYCETES—HYPHOMYCETES AND SACCHAROMYCETES—THE MICROSCOPE—HINTS ON SELECTION AND MANAGEMENT OF MICROSCOPE—ANGLE OF APERTURE—ITS PARTS—MAGNIFYING COMBINATIONS—EXAMINATION OF YEAST.

IT was at one time customary to class together as Ferments all the agencies taking direct part either in alcoholic or acid fermentations, or in those hydrolytic processes which result in the breaking up of complex into simpler bodies, and which are, in the main, so far as they directly affect the brewer, preliminary to fermentation in its former and more restricted sense. That is to say, the term Ferments included organised structures like yeast* and bacteria, with a definite shape and mode of propagation of which the microscope informs us, and equally those unorganised active products formed during metabolic processes in living cells, *e.g.*, invertase in yeast, or by plants during germination of their seeds, *e.g.*, diastase and peptase, including, too, those found in the animal economy, (ptyalin, pepsin, trypsin, etc.), which are analogues of similarly acting vegetable secretions. These are now better distinguished as **Enzymes,** an alternative term " Zymase " having now been allocated to one enzyme, obtained from yeast-juice, as the enzyme or zymase *par excellence*.

Some writers have even included under the name of **Inorganic Ferments** those mineral acids which are able under suitable conditions (dilution, intermixture with a solution of the complex body to be operated on, and temperature) to determine changes like those of starch into dextrin and dextrose, or of cane-sugar into invert, without themselves undergoing change or loss in the operation, that is, by catalysis, but this seems to be stretching the term unduly, as the catalysts, though bringing about hydrolysis like most of the enzymes, have no connection, as the latter have, with the living organisms inseparable from fermentation.

What exactly the enzymes are, what their composition, and how they function, is not yet very clear. Many of them have been extracted and kept in a more or less pure state for some considerable time : some in the dry state can be heated to 100° C. without being weakened, but in the liquid state, in which they function, temperatures which appear to show a vital relation, still existing, to the organisms wherein they originate, are fatal : at the same time the fact that, below these fatal temperatures, the " optimum " temperature (*i.e.*, that of the greatest functional activity) is relatively high points to their action being dependent on molecular vibrations, which we know are accelerated by heat.

* Over 500 true yeasts are known. Three names (Pasteur, Hausen and Buckner) remain intimately associated with the study of yeast.

The hydrolytic enzymes (**hydrolysts,** the body acted upon being a **hydrolyte**) have the power of bringing about changes which bear no relation to their own mass. They are highly complex bodies, of albuminoid character, unorganised, that is, without biological structure or independent life, though always, as has been said, of organic origin. The secretion, at least of one of them, diastase, appears to be a starvation phenomenon, seeing that the development of it, though normal in germinating barley, *does not occur* if the embryo be supplied with sufficient sugar for its nutrition. It is possible that this limitation of secretion may apply generally; also that a condition precedent to the action may be a combination of the enzyme with the body acted upon, definitely shown by Wurtz to occur in the case of Papain, the vegetable pepsin of the papaw tree. In this case a compound of papain with the albuminoid being acted on can be isolated by washing with water, which upon digestion in water at 104° F. surrenders the latter *as peptones*, while regenerated papain is available to act upon another portion of albuminoid. In this case alternate combination and separation would be the keynote of the action, and would go far to explain independence of mass. Similarly, O'Sullivan and Tompson have pointed out that a solution of invertase and cane-sugar can support a higher temperature than one of invertase alone, which indicates a probable combination between the enzyme and the cane-sugar acted on. It has been stated that enzyme activity is catalytic, like that of mineral acids, but less energetic; recent researches, however (Armstrong and Caldwell), appear to show that enzymes are really more active than acids in promoting hydrolysis, but "that this apparent activity is due to the greater affinity the enzyme has for the sugar, and that in reality the acid has the greater hydrolytic activity" (*Ann. Rep. Progress Chemistry, Chem. Soc.*, 1904).

The term Enzymes, indeed, as now employed, not only includes the hydrolysts which bring about simpler molecular arrangement, such as the transformation of starch into sugar, but agencies which bring about an opposite or *synthetic* result, helping to form complex bodies out of the simpler ones, which alone are capable of passing in solution through cell walls; and there is ground for supposing that these enzymes of opposite tendencies often exist side by side, the one controlling and acting as a brake upon the other, as exemplified by the starch-solvent amylase and the co-existing amylocoagulase, which precipitates dissolved starch out of solution.

Of the manifold additions to the growing list of enzymes that of Buchner's **Zymase,** the supposed enzyme separable from the juice of yeast cells which have been killed, at least so far as any possibility of cell-reproduction goes, and which has the power of breaking up sugar into alcohol and CO_2 much as perfect yeast cells have, is the most important. Its claims to modify vitalistic conceptions of fermentation (Pasteur's contention that alcoholic fermentation depends entirely on the presence of *living* yeast cells) will be touched on later; meantime, in spite of the contention that its fermentative power is not enzymic, but is due to particles of living protoplasm (bioblasts) not destroyed by a treatment which kills, *as cells*, the cells containing it, the balance of evidence is in favour of its being an enzyme. Thus it can be dried, and, after being kept for a short time, still excite fermentation: it is diffusible, soluble in water, passes through filters, and is active in the presence of chloroform. On the

other hand, dilution, to any extent usually favourable to enzymes, has been found to inhibit its action.

Important, in an explanatory sense, as a cellular fermentation is, in practice we identify fermentation with microscopic forms of organised ferments, always found in fluids undergoing change. That these forms are the causes, and not the effects of these changes, has been proved beyond a doubt, and equally that their functions are specific—viz., that one, a rounded organism (yeast), produces alcohol, carbonic acid, etc., at the expense of the sugar; that others, either short and rounded, or elongated rods, produce acid, lactic or butyric; and that a third form of bacterium, constricted in the middle, is associated with putrefaction. Certain organisms take up the work where others leave it, and act upon their residues, bringing the originally complex bodies nearer and nearer to an elemental condition. Let us now define fermentation in this sense.

Fermentation (from *fermentum*, a ferment, short for *fervi-mentum*, from *fervere*, to boil), so called from the internal movement moderately resembling that of ebullition which wine-must and beer-wort undergo, is the name applied to all those processes wherein certain micro-organisms, as a result of their nutrition and multiplication, effect the degradation of complex matter into simpler forms. And though we are accustomed to look upon wine or beer as the ultimate aim of fermentation, it will not be overlooked that those products really only represent a stage of arrested degradation. Whether they enter into consumption at that stage or not, their inevitable lot is to be converted into the simplest derivatives, of which water and carbonic acid form the major part.

That these fermentations—from the highest to the lowest in the scale—were the work of distinct micro-organisms, Pasteur's experiments some score of years ago conclusively proved, but the opinion which he felt justified in publishing, that, under no circumstances, could such or such a fermentation take place without the introduction, designed or accidental, of some member or members of the specific ferment, did not meet with such ready acceptance.

Against this opinion "*omne vivum ex vivo*," or **Germ Theory,** as it was called, certain learned pundits rose up and propounded the "**Spontaneous Generation**" **Theory,** to the effect that the introduction of an actual predecessor was not necessary to secure a crop of micro-organisms, seeing that decomposing organic matter developed within itself (spontaneously, so to speak) yeast, bacteria, bacilli, etc., according to circumstances.

They were fortified by the fact that on several occasions flasks of fermentable matter sterilised (*i.e.*, boiled for a certain time) and hermetically sealed in accordance with Pasteur's suggestions had undoubtedly undergone fermentation, whereas Pasteur had said they would not; and it was not until Professor Tyndall took the matter up that the spontaneous generation theory practically collapsed. Himself observing that certain liquids, apparently sterilised and closed with due precautions, showed fermentative changes, and especially in proximity to a store for hay (infusions of which soon teem with bacteria, or rather bacilli), he made the brilliant deduction * that "indurated germs," as he then called them," spores,"

* This deduction was later on confirmed inductively by microscopic observation, the sporulation of bacteria, and the tenacious vitality of their spores, being now ascertained facts.

as they are now styled, must exist capable of withstanding much more adverse conditions than the fully developed organisms to which they belonged, and which Pasteur had studied and classified.

And he found experimentally that intermittent boiling, *i.e.*, short periods of boiling with an interval, say, of one day between, was quite destructive of spores, as well as of the fully developed organisms, whereas a continuous boil of even greater extent had only destroyed the latter. Accordingly, it is now found to be a simple matter to sterilise infusions so that no fermentative changes shall take place within any measurable time, nor is it necessary to seal the flasks hermetically. If only they are closely plugged with previously sterilised cotton wool (which filters the air and arrests the spores), and subsequently sterilised in the manner described, the absence of any fermentative change, in the vast majority of cases, almost conclusively disproves spontaneous generation, the very few exceptions being referable to imperfect sterilisation and manipulation.

All ferments—limiting the term to those organic forms which can be handled or, at all events, seen in the mass with the unassisted eye or individually with the microscope (yeasts, moulds, or bacteria)—belong botanically to the group of **Fungi.**

That they are to be assigned to the vegetable rather than placed low down in the animal realm is made clear by the fact that they are able to draw all the nutriment required for their growth from a suitable mixture of mineral matters. This is typical of vegetable life. The most lowly organised animal must have its food prepared for it in some way or other, must have the mineral or elementary constituents, into which that food could be resolved by analysis, got ready for it by some previous agency, and this is necessarily the agency of some vegetable organism or organisms.

On the other hand, all plants—except those which deliberately elect to live a parasitic existence on the juices of other plants (amongst which parasites the dodders may be instanced)—can and do draw all their nutriment from the mineral constituents of the soil, or extract the carbon which they require to build up starch or its kindred carbohydrates from the carbonic acid gas which the air contains. Plant-life, in short, using the term in its widest sense, is the agency which bridges the great gulf fixed between the inorganic and organic realms.

It must be added that the fungi, and notably the bacteria and moulds, co-operate in this destructively rather than constructively ; although they may be capable of building up organic structures (their own) out of mineral matter, their most important function is the breaking down of complex organic substances into simpler and simpler forms, in which they are again available for plant nutrition. In fact, it is not too much to say that it is these minutest organisms, formidable only in their numbers—a bacterium reproducing itself once in an hour is theoretically capable, and given suitable conditions may be really capable of developing into over 16,000,000 individuals at the end of twenty-four hours—which alone render the earth habitable. Were it not for them, dead plants and animals would lie where they fell, and in no long time the surface soil would be cumbered with *débris*.

Again, were it not for the fact, of the utmost importance to brewers, that each separate kind of organism, such as we are speaking of, secretes, while performing its special functions, matter which acts as a **specific**

poison to itself, there would be practically no limit to their reproduction, and all creation would become their prey.

To come to particulars—yeast is capable of converting into alcohol carbonic acid, etc., sugar which is in a sufficient degree of solution, but as sugar contains no nitrogen which (as well as phosphoric acid and potash) is essential for the growth of the ferment, there would come a time when yeast sown in such a solution of pure sugar would cease to act as a ferment—long before all the sugar became converted—simply because the necessary food for its development was absent. But add to the sugar and water ammonic tartrate, potassium phosphate, calcic phosphate, and magnesic sulphate in the following proportions (**Pasteur's Solution**)—

Potassic phosphate	20	parts
Calcic phosphate	2	,,
Magnesic sulphate	2	,,
Ammonic tartrate	100	,,
Cane-sugar	1,500	,,
Water	8,376	,,
	10,000	

the growth and development of the yeast goes on *pari passu* with the splitting up of the sugar into the usual products of fermentation, just as readily and thoroughly as it would in the most perfectly prepared malt-wort. Nor is the presence of the organic sugar in the solution even necessary to the growth of the yeast, apart from the exercise of its fermentative functions. That is to say, the yeast can split up the salts, getting its needed phosphoric acid from the phosphates, its nitrogen from the ammonic tartrate, the hardly less necessary potash from the potassic phosphate, and so on.

Aspergillus Niger—Raulin's Solution.—A still more minute study has been made of the requirements of a certain mould, known as Aspergillus Niger, by M. Raulin, a disciple of M. Pasteur.

Although this mould grows readily enough on bread moistened with vinegar, on slices of lemon or other acid fruits, M. Raulin has found that the medium which in the shortest space of time produces the largest weight of the plant (in which, in fact, it chokes all rival growth) is composed as follows :—

	Grammes.	
Water	1,500	The culture to take place in shallow porcelain basins, open to the air, the liquid being an inch or less in depth. The temperature required is about 95° Fahr.
Sugar Candy	70	
Tartaric Acid	4	
Nitrate of Ammonia	4	
Phosphate of Ammonia	0·6	
Carbonate of Potassium	0·6	
Carbonate of Magnesia	0·4	
Sulphate of Ammonia	0·25	
,, ,, Zinc	0·07	
,, ,, Iron	0·07	
Silicate of Potassium	0·07	

Complex as this solution may appear, it has been found that even trifling deviations produce most marked diminution of the crop. Thus, the phosphate being omitted, instead of each gramme produced with the

full solution, only ·005 gramme is found, and the omission of the ammonium nitrate causes almost as great a fall-off ; the withdrawal of the potassium salts brings each gramme down to ·04 gramme, and, what is perhaps the most remarkable of all, the mere traces of zinc and iron contained in their compounds also have a most potent influence.

Again, in the case of yeast, every cell under the microscope is observed to be bounded by **a continuous cell-wall or membrane,** without any orifice either for the absorption of food or the excretion of waste products, and this involves the necessity of its food supply being in such a state of thorough solution as to be capable of passing into the cell by **Osmosis** or **Diffusion.**

This is a distinctly vegetable characteristic, considering which, in conjunction with their power of assimilating mineral food and the total absence—except perhaps in sundry bacteria—of chlorophyll, and the consequent inability of yeast and its kindred organisms to utilise the atmospheric carbon as nutriment, we can see why botanists have placed these organisms firstly among the great division of the **Cryptogamia,** then amongst one of its subdivisions the **Thallophytes** (see Glossary), and finally amongst a subdivision of the latter—viz., the **Fungi.** To the most commonly known species of the latter a considerable resemblance is shown indeed by yeasts in the rapid multiplication of their cells ; and the fact that the cells of yeast rapidly separate, as a rule, while those of a mushroom adhere together is only a distinction and not an essential difference. Indeed, in one species of yeast, the caseous yeast of Pasteur, a certain amount of coherence may be observed, and the mushroom, as we know it, is a complex form of what will be mentioned later, **a Sporophore.**

It does not appear of vital consequence to consider whether these fungi are plants which have degenerated from plants of higher organisation, that is to say, plants in which, consequent upon some lapse of the ability to secrete chlorophyll, there has been that degeneration of structure which is observed to take place on disuse of functions in other organisms, or whether they are plants whose race has never known aught but development of cell on to cell by some sort of gemmation or budding process.

The fact, however, that the same cell is capable of two methods of reproduction, fairly analogous to those, for instance, of a potato, viz., by shoot (bud) and by seeds (spores), points to a merging of root and stem into a single cell—*i.e.*, a degeneration. These may be interesting problems in evolution or its converse, but to consider them in full would take us too far afield.

All the fungi with which we have to do, whether they be yeasts, moulds, or bacteria, may be referred, as regards their first appearance, to separate **hyphæ.**

A hypha is a tube-shaped membrane of cellulose, charged with the mysterious nitrogenised-carbon substance known as **Protoplasm.*** The

* Protoplasm is so called because it is the primary substance found generally in all organic structures, though itself appearing to be a clear and structureless jelly-like substance, except under the highest microscopic powers, under which it assumes the aspect of a very fine network of delicate fibres, whose interspaces are filled with minute particles and fluid, yet even then no trustworthy evidence of structure is obtained. As Professor Huxley says, " Protoplasm, simple or nucleated, is the formal basis of all life. It is the clay of the potter."

Some scientists regard it as a form of proteid + water. A late writer says, not con-

protoplasmic contents are sometimes watery in appearance, sometimes finely granular. When certain moulds, where hyphal growth has its most extended development, are observed under the microscope (though so exceedingly delicate are they that to get a fairly perfect specimen is no easy matter), the hypha is seen to be a tube of relatively considerable length, which at intervals branches out just below thin transverse divisions of cellular matter (**transverse septa**), which form at right angles to the direction of the tube's growth. These branches branch out again in their turn, so that before long a much-branched tree-like organism (though of course of microscopic dimensions) appears—especially with the mould styled *Mucor Mucedo*—which is known as a **Mycelium.**

Very rapid growth is rendered possible by the action of the protoplasm, which plasters on to the inner surface of the enclosing membrane fresh layers of cellular matter, whereby the membrane, continuously expanded as it is, is kept from becoming too attenuated. Although layers of cellular matter are spoken of it will not be forgotten that we are referring to an organism so minute that a single mycelium under a less magnification than 300 diameters would scarcely be discernible ; it is only indeed the enormous aggregate of the mycelia which renders the mildews, with which we are familiar, visible to the unassisted eye.

Harking back again to hyphæ, we shall see that in the case of other fungi—for instance, yeasts and bacteria—the initial stage of growth is similar to that of moulds, though this growth stops short of the development of mycelia.

In the case of yeast, for example, which in an ordinary nutritive medium like wort develops by budding, that is to say, by small cells growing out of the parent-cells, and which, having reached a sufficient stage of growth, separate, and soon proceed to put forth cell-buds of their own, or may even do so before the separation occurs—the cell is, in effect, a hypha,* the new cell is the hyphal branch, which instead of forming part of a mycelium, growing on to the original hypha, separates as soon as it is sufficiently developed, the septation, if such it can be called in the case of yeast, showing the greatest variation from the original type, seeing that instead of occurring above the branching-point and preceding such branching or budding as with mildews, in the case of yeast it occurs at the point where the bud is formed and subsequently thereto.

In the mildews the formation of a transverse septum appears to be the cause of branching, impelling, as it does, the ever-growing protoplasm to seek a new outlet ; in the yeasts it is—if a true septation at all—a consequence of it.

Nor need this variation be any obstacle to considering these two methods of growth as simple developments of one original scheme. What is known as " **correlation of growth** " is an accepted principle in respect of

tradictorily, " Now protoplasm is one of these carbon compounds, and perhaps the most complex of them all. In fact, it seems to have reached the utmost limit possible in this respect, and the chemical equilibrium is so unstable that it is ready to break down at the least touch. We can regard protoplasm as occupying the summit of chemical changes : the elements of food are by their mutual affinities gradually built up into more and more complex structures, until they reach the form of protoplasm, when they can go no further, but begin to break up under certain conditions into less and less complex forms, until they reach the final stage of CO_2, H_2O, etc., which all organic matter comes to."

* This is most obvious to anyone looking at the illustrations of film formation of *S. Cerevisiæ*, given by Hansen, as to which see Chapter XI.

organic nature ; one which means that all the parts of an organism are so intimately connected and bound together that when one part is made to change, some other parts are not unlikely to undergo modification as a consequence of the first change.* The artificial conditions, then, under which the yeast-fungus has been cultivated for centuries has most probably brought about enough variation from the original type to account for the divergences of the two methods of growth.

The bacteria, schizomycetes, or "splitting fungi," also increase in a similar way "with a difference." This difference is that, instead of budding as yeast does, they multiply by repeated transverse subdivision, following the formation of a fine diagonal membrane at the place of fission. As soon as this membrane has thickened sufficiently, separation of the one organism into two occurs.

Abortive Mycelia.—And the view that these methods of reproduction, both in yeasts and bacteria, may be looked upon as an abortive tendency to form mycelia, is strengthened by a converse tendency which has been observed in organisms, which normally develop a mycelial growth. For instance, in the case of *Mucor Mucedo*, a mould of common occurrence, forming a white mass on bread, fruit, etc., and in that of *Mucor Racemosus*, it has been observed that the filamentary tubes of the mycelia sometimes get divided by relatively close transverse partitions, and that these divisions then bud, the buds and the divisions themselves thereupon becoming so rounded that there is actually a difficulty in distinguishing them from yeast cells.

We do not mean to say that these mucors take entirely to the formation of what I have styled "abortive mycelia"—indeed, the phenomenon appears to be due to unfavourable conditions, principally a limitation of the needful amount of air, which being corrected, the bud again develops mycelial threads, or erect hyphæ, which eventually terminate in the usual spore-bearing heads.

The fact, however, that budding is occasionally substituted for branching, even to such a limited extent, is a connecting link between the two vegetative modes, as they may be called to distinguish them from the mode of propagation by special reproductive arrangements.

The Two Distinct Modes of Reproduction.—As has been hinted above, the fungi, with which we have been dealing, have two distinct modes of reproduction, both analogous to those double methods met with in some more highly organised plants. Just as the potato can be propagated either from tubers or from seed, or strawberries either from runners or seed, and other plants from bulbs, which grow on to the original bulb, or from cuttings, and as a rule likewise from seed, so these lower organisms have their double method of reproduction, the one distinctly vegetative, the other by special reproductive arrangements.

The vegetative mode occurs by the formation of cell on to cell, which either separate rapidly, as in the case of yeast, or remain connected, albeit parted by septation, as in the case of moulds, and is one in which the

* This question of correlation of growth may have a closer interest for us than that stated in the text, which indeed is somewhat academic. When yeast strives, as it will and as other organisms do, to get into correspondence with its environment, which may vary much within the limits offered by actual malt-wort and other fermentation conditions, it is conceivable that other physical changes may occur not obviously connected with that attempt at self-adaptation.

analogy even gets closer to the vital conditions of higher organisms (*e.g.*, the potato) in that, nutritive conditions being suspended—as, for instance, when the yeast is skimmed from the wort, or the potato removed from the soil—the cell (yeast) or agglomeration of cells (potato) passes into a quiescent condition, wherein the potential vitality of the single cell, with its cell-wall thickened by protoplasm, does not yield in permanence to that of the tuber.*

The second mode, viz., that by special reproductive apparatus (organs one cannot well say without limiting the ground too much, though the process is analogous in one of its aspects to the reproductive one of higher organisms, and in the other has its counterpart in the parthenogenic births known to occur with certain lowly animal forms), manifests itself by the formation of **spores,** which are generally **asexual,** *i.e.*, produced without the co-operation of any external protoplasm, but which may also be, as in the case of some of the moulds, of apparently **sexual** origin, where two mycelial threads join together, the conjunction resulting in the formation of a so-called **zygospore.**

The asexual spores of moulds are known as **gonidia** or conidia, and are borne upon short branching finger-like joints known as **sterigmata,** the branching being sometimes simple, sometimes complex, but (when a microscopic specimen can be secured, which, however, is difficult) forming a tassel-like head—the **sporophore**—to the hyphal ends of the mycelium.

The spores of yeast, which are endogenous and asexual, are called **ascospores,** but these will be more fully referred to in Chapter XI.

But whether the spores be sexual or asexual, they are obviously a resource for the maintenance of the species under extremely adverse conditions, being, as they are, much more resistant to hostile influences (heat, drought, etc.) than the vegetative cell ever is, and yet when favourable conditions recur, readily originating a new growth—the ascospore budding, and the gonidium or zygospore sending out a hypha in the usual way.

Polymorphism and Pleomorphy.—Before touching on the classification of the fungi, incidental to our industry, let us understand the meaning of these two terms, which, though sometimes confused, may well be kept distinct. In the classification which follows, and looking at Division I., the schizomycetes, *i.e.*, the bacteria, in the widest and popular sense of the term, we shall find that very considerable variations of shape are mentioned (*e.g.*, micrococcus, bacterium, bacillus, leptothrix, spirillum, etc.), and though these differences of shape often indicate organisms, which are far from being identical in function, and which may therefore be looked upon as individually distinct, yet it has been shown (by Zopf) that the same organism can, under certain circumstances, assume either of these forms. This variation, known as **polymorphism,** or **alternation of generation,** naturally detracts somewhat from the value of any classification on morphological lines, which, however, is the only basis open to us at present.

* Some readers may remember that some old bottled beer, brewed in the eighteenth century, was found at Messrs. Worthington's Brewery, of which it was stated that the yeast cells in its deposit still showed signs of vitality. And it is not an unknown practice in country places, where a store of yeast is not easily got, to dip a quantity of twigs into yeast, which being carefully dried, are competent to start a fresh fermentation many months after.

Polymorphism should, however, be distinguished from what de Bary calls the **Pleomorphic craze,** in which view, according to A. G. Salamon, an organism might begin as a yeast, then, if it chanced to be swallowed by a fly, would develop into a totally different organism, pathogenic to the fly. And again, if the fly chanced to fall into water, that the organism, totally changed once more, would become a mucor, which on being wafted into a fermentable fluid, would become a yeast again, and so on in a continuous circle.

The fungi, with which the brewer is mostly concerned, may be marshalled in three divisions—

1. The **Schizomycetes** (fission-fungi, or bacteria).
2. The **Hyphomycetes** (or moulds).
3. The **Saccharomycetes** (sprouting-fungi or yeasts).

The **Schizomycetes** multiply in two ways—viz., (1) By subdivision, which sometimes occurs in three dimensions of space, the parts which separate developing each into a fresh schizomycete; or (2) By spores formed endogenously.

[The schizomycetes are the smallest fungi known. Some are **Chromogenic,** *colour producing,* others **Pathogenic,** *disease producing,* and others **Zymogenic,** *producing fermentation.* Many of these organisms are motile forms, *i.e.*, showing a spontaneous movement, actuated, as very high microscopic powers show, by one or more hair-like appendages at either end known as a **cilium** or **flagellum.** Their interior is charged with a pasty mass of protoplasm differing in no way, as far as the present means at command enable us to judge, from that of **yeast.**

That this active, but apparently identical, protoplasm should in one case produce lactic acid, in another butyric, in others putrefactive ferments, and yet again, alcohol and carbonic acid, is a mystery as yet unfathomable.

Bacteria perish in pure water from lack of nutriment, which fact differentiates them from *algæ,* with which they are often confounded. Though frequently isolated, they sometimes exude a gelatinous matter which causes a number of them to adhere together in a mass. Such a colony is called a **Zoogloea,** or resting-stage.

The importance of the *rôle* they fill in breaking up complex matter into simpler forms has been dwelt on before. Many forms appear to have a **peptonising** influence; indeed, the liquefaction produced by bacterial colonies on gelatine-stiffened wort is a peptonisation.]

Various forms found amongst the schizomycetes are—

(i) **Coccus forms.** Micro- and macro-coccus, simple or compound.

[Spherical bodies, some of which, the **micrococci,** are extremely minute, even for microscopic objects, as small as 0·5 μ, though *Micrococcus crepusculus,* the one associated with all sorts of putrefaction, is 2 μ. The macrococci are, of course, the larger spherical forms. Among compound cocci is **Tetracoccus** (four cells joined together, but in pairs), supposed to be a **Sarcina,** but hardly showing the characteristic package-like shape of other Sarcinæ. A long chain of micrococci is called a **Streptococcus.**]

(ii) Bacteria (in limited sense).

[Short rods. Amongst them are **Bacterium termo,** *the* ferment of decay; **B. lactis,** a ferment which forms lactic acid in milk and beer;

B. aceti, which oxidises alcohol into acetic acid. The latter collectively, *i.e.*, when forming a wrinkled film, is known as **Mycoderma aceti,** and the individual organisms assume various forms, appearing both as bacteria and bacilli, in irregularly swollen forms and in curved forms. **Bacterium xylinum,** myriads of which organism constitute the gelatinous membrane known as the vinegar plant, its action being similar to that of *B. aceti, plus* the production of an appreciable quantity of cellulose.]

(iii) Bacilli.

[Longer rods, which grow till twice their original length, then split into two transversely, although even then the separation is not always apparent without staining ; * the latter, however, makes the articulations visible.

Among the bacilli which affect the brewer injuriously are **B. subtilis,** or bacillus of hay-infusion, causing a butyric fermentation, and said to be the agent concerned in the ripening of cheese. Length 6 μ.

B. amylo-bacter, an anaerobic ferment causing butyric fermentation too, is morphologically very like *B. subtilis*, but may sometimes be distinguished from it, when it contains starch in its cell, by staining with iodine. Its size, too, is greater, length 10 μ width 2 μ. The two bacilli are also said to sporulate differently, *B. subtilis* forming its spore at the end of the rod, while *B. amylobacter* forms it at the centre.

B. ulna.—Also morphologically very like *B. subtilis* (unless it be that the cells are broader), found in putrefying white of egg infusion, and is therefore an indicator of *uncleanliness*, though apparently itself unhurtful in beer. A magnification of 3,000 diameters by Dr. Dallinger showed it to have a flagellum at each end. The plasma within appears dense and fine grained.

B. panificans.—Supposed by Laurent to act as the " leaven " of rye-bread, just as ordinary yeast (or, according to Engel, *Sacch. minor*) does for wheaten bread.]

(iv) **Clostridium forms.**

[A bacillus enlarged in the middle or near it and drawn out towards the ends.

Bacillus Amylobacter is sometimes called **Clostridium butyricum.**]

(v) **Leptothrix forms.**

[Unbranched thread-like forms which are frequently parasitic. Very similar to them (though the freely oscillating threads enveloped in a gelatinous envelope are somewhat thicker) the **Beggiatoæ,** which certainly set free sulphuretted hydrogen in sulphur-containing water, and have solid granules of sulphur within their structure.

Another noteworthy example is Leptothrix, or more generally **Crenothrix kuhniana,** a tough, slimy fungus which partially clogs water-pipes (noticeable in attemperator outlets), and which, under the microscope, appears to consist of unbranched hyphal tubes, straightish or curved, visibly articulated at the base, but primed towards the apex with spores ready to escape. The spores seem to take the *coccus* shape, passing into *diplococci*, before developing into a fresh tube-like process, or some-

* Staining is done in various ways (methods of Koch, Ehrlich, Prideaux, etc.). Koch, for instance, treats fluid from diseased tissues (tuberculosis) with strong tincture of methylene blue and potash, afterwards adding vesuvin, which discharges the blue from everything except the special bacilli (even other micrococci), which remain blue on a brown field. It has been objected that such violent treatment alters the proportions (length and breadth) of bacteria.

times they cluster together, forming a *Zooglœa;* and sometimes the spores develop new threads before leaving their original hyphal home, the threads making their way through the gelatinous sheath of the latter.]

(vi) **Cladothrix forms.**

[Quasi-branched forms, very similar to Leptothrix. High magnifying power shows the apparently ramified structure to be what is known as "false branching."]

(vii) **Spirillum (Vibrio, Spirochæta, Spirulina) forms.**

[Curved spiral. Probably an alternative form of otherwise-shaped schizomycetes. There is especially ground for supposing that **spirillum amyliferum** is only a phase of *bacillus amylobacter*, it being found in the latter's company, and apparently storing up starch (its contents, except where a spore afterwards develops, are coloured blue by iodine, *but only when growth has ceased*) within its cell-wall.

Further than this spirilla do not appear to be of particular interest to us, the *habitat* of this form of schizomycete being generally brackish or putrefying water.

(viii) **Involution forms.**

[Irregular shapes difficult to classify. *Bacterium aceti* assumes one such form, thus differentiating itself from *B. xylinum*, the organism of vinegar plant, which does not.]

Hyphomycetes, or Moulds.

These form a growth with which all are familiar; but the patches of them, visible to the naked eye, consist of innumerable mycelial tubes, of microscopic dimensions, intertwined in every possible way, the mass being sprinkled, as it were, with spore-bearing heads formed at the terminals of the branches.

Although, when compared with bacteria, they may be looked upon as only being in the second line of attack, they are yet of great import, not alone on account of the ill effects which they undoubtedly bring about, but also because a definite growth of mildew is generally a cover for a horde of bacteria.

The greatest field for mischief which they have in connection with brewing is that afforded by the malting floor, where, given a number of broken, "tipped," or cracked corns, mould is certain to appear, infecting a proportion even of the sound grain.

Here the degradation of nitrogen-compounds by these powerful oxidising and putrefactive agents, not to speak of that of the carbohydrates affecting profit, is greatly conducive to unsoundness of product. An indirect, but no less certain, evil is that the enormous number of spores and mycelia, however thoroughly they may be themselves destroyed during the brewing process, nevertheless afford a suitable nutriment to similar organisms finding their way into the fluid after sterilisation-influence has ceased.

A few of the more important moulds, classified as Saprophytes or Parasites, are :—

(*a*) **Saprophytic Moulds.**

(i) **Penicillium Glaucum.**—The commonest mould of all, forming masses, whitish at first but afterwards greenish-grey, upon the green malt, or in empty casks and neglected brewing vessels, and consisting of innumerable mycelia tangled together. The hyphal branches of the

mycelia terminate in a number of short irregularly branched tubes which end in the so-called **sterigmata,** elongations of the tube which bear the conidia, the whole spreading out in a somewhat fan-like way. The conidia, however, do not hang on alternate sides of each sterigma, but are formed by a globular swelling-out of the sterigma at short intervals, so that the actual tube appears to pass through the centre of each conidium. One conidium forms at the tip of each sterigma, and this is actually the first to appear, the one nearest to it being next oldest, and so on.

This mould, like *Aspergillus niger*, grows well in Raulin's liquid, but better with addition of a little gypsum. It, with *Aspergillus* and with *Oidium lactis*, is classified as Ascomycetes.

(ii) **Aspergillus Glaucus (Eurotium Aspergillus Glaucus)** is perhaps the next most frequent mould ; it grows freely on green malt,* where it feeds on the latter's saccharine constituents, and forms a felt-like greyish mass (white, however, when young), the greyness of which is due to conidia separated and settling down as a dust of that colour.

Its conidia are borne on numerous sterigmata, shorter and spreading out more radially than those of *P. glaucum*, and forming on a hyphal tube in which elongation has extended further than usual without septation.

Also, it develops a somewhat circular-shaped ball fruit, the **sporocarp,** supposed to be sexual (see Glossary), and interesting because of its ascospore formation, not unlike that of yeast.

(iii) **Aspergillus Niger.**—The mould referred to on p. 270 as the one studied by Raulin. As the name implies, the colour of the mildew in mass is black. It may sometimes be found on broken, damp rice, even when the latter has been subjected to heat, if sterilisation-influence has been imperfect, as when it has balled into lumps during careless gelatinisation.

(iv) **Mucor Mucedo.**—Found on decaying fruits, bread, meat, also on yeast, grains of corn and malt, but growing most freely on horse excreta. When the oval spores are placed in nutritive fluid they rapidly swell, their homogeneous protoplasm becomes granular, and crowds up to the cell-wall, leaving a large vacuole. Shoots, developing from one or more points, form a much-branched mycelium (branching without septation), from the midst of which arises a thick branch (sporophore) with a sort of elongated knob-shaped head. With the length of this knob as a radius, a round, yellow-coloured sporangium forms, and within the latter a large number of the oval spores develop. This mould also forms zygospores (p. 274).

One of its functions appears to be the secretion of calcic oxalate, but the importance of the mucors to us is that under some conditions they can act as alcoholic ferments, though to a less extent than yeast.

(v) **Mucor Racemosus.**—Found on stale food, fruits, etc., and *fæces*. It resembles *M. mucedo*, but is altogether on a smaller scale. Its sporophores throw out side branches, each terminable by a sporangium, which then appear to cluster together, whence the name (*racemosus*=clustering, *racemus*=a bunch of grapes). Its chief interest consists in a habit peculiar to itself of forming propagative buds (as well as sporangia and zygospores) within the mycelial tube (cell-wall forms and separates them

* According to Hansen however, though *A. glaucus* was the most often found in trial flasks infected by the *air* of malting floors, it was comparatively rare on the floors themselves, where *Penicillium glaucum* was most frequent.

off), which can bud like yeast-cells, although formed on a larger scale than the latter.

(vi) **Mucor stolonifer.**—Found in warm seasons of the year on sourish soft fruits, where it forms a woolly white growth with black-stalked heads.

(vii) **Mucor erectus.**—Habitat on decaying potatoes; said to be capable of forming 8% alcohol in beer wort.

(viii) **Fusarium hordei.**—Forming the red mildew seen on germinating barley of low quality, but apparently does not spread rapidly. Develops crescent-shaped spores, very characteristic under microscope.

(ix) **Oidium lactis.**—A mould fungus producing lactic acid, and whose hyphæ form a thick white felt, somewhat resembling that of *Mycoderma vini*, but whiter and thicker. The hyphæ, generally in their upper portion, are transversely septated at brief intervals, so that short pieces, resembling conical cells and with granular contents, freely separate off (a connecting link between yeasts and moulds ?) Sometimes found in beers of low alcoholic strength, but growing more freely on the surface of yeast or stale milk. The terminal cells (conidia) are colourless. It is suspected of being pathogenic (certain forms of skin disease). [Another oidium, *O. albicans*, is associated with the infantile disease called "thrush." *Oidium vini*, or *Tuckeri*, is the too-well-known scourge of vineyard proprietors.]

(x) **Monilia Candida.**—A mould occurring on ripe juicy fruits, etc., which at certain stages forms cells, closely resembling those of yeast, especially when added to wort, in which it can excite alcoholic fermentation. It also appears to have the faculty of fermenting saccharose *as saccharose—i.e.*, without previous inversion, it being unable to secrete invertase.

(xi) **Dematium Pullulans.**—A mould developing yeast-like cells in freely septated divisions of hyphæ. The cells show budding processes but otherwise are not of much importance, seeing that they incite no alcoholic fermentation, unless Lintner's idea that it is a factor in ropy fermentation were established.

(xii) **Aspergillus or Eurotium oryzæ.**—See "Koji" in Glossary.

(xiii) **Botrytis cinerea** (see Glossary), also a facultative parasite (*e.g.*, on nowdrop).

β. **Parasitic Moulds.**

(xiv) **Ustilago Carbo** or **Segetum.**—The "smut" on barley, oats, etc., where it forms black patches. Dark coloured hyphal growth, somewhat like *O. lactis* in form.

(xv) **Tilletia caries** and **lœvis.**—On wheat.

(xvi) **Fumago salicina.**—On hops.

(xvii) **Sphærotheca castagnei.**—On hops.

Saccharomycetes.—[Fungi which propagate by budding, and also, under less favourable conditions, forming spores. They generally act as degraders of saccharine bodies into alcohol, etc., or affect the alcoholic product favourably or unfavourably. Amongst them are—

(i) **Sacch. Cerevisiæ.**—The real alcoholic ferment; now supposed incapable of acting except as a primary ferment—*i.e.*, to be unable to effect degradation of malto-dextrins, on which cask conditioning depends. Average diameter 8 μ.

Three sub-types at least have been isolated. See p. 301.

(ii) **Sacch. Pastorianus** [Reess].—Cells of elongated form, some very

much so. Found in bottle deposits of even sound ale. Suggested as the ferment which breaks up malto-dextrins, reducing them first into lower and lower types, and finally into maltose, in which form *Sacch. cerevisiæ* can deal with them.

Three sub-types isolated, one of which causes a strong, harsh bitter, another turbidity. See pp. 322, 323.

(iii) **Sacch. Ellipsoideus** (Reess].—Otherwise *Sacch. ellipticus*. The yeast of wine. Cells about 6 μ long and elliptic in shape. A sub-variety, *Sacch. ellipsoideus II.*, is supposed to cause turbidity.

(iv) **Caseous Yeast.**—A form described by Pasteur, resembling ordinary high yeast, except in its tendency to agglomerate in a curdy mass. In water, he says, it falls at once to the bottom like a curdy precipitate, and the supernatant water is scarcely dimmed by the few suspended globules. He thinks it can survive a heating (in bottle) of 122° Fahr., which suffices to kill the pure high yeast left in the alcoholic fluid. Length of long axis about 10 μ.

(v) **Sacch. Coagulatus,** otherwise **Caseous Yeast No. 2** (Matthews).—Apparently an agglomerating variety, distinct from (iv.), observed and named by Mr. C. G. Matthews, and said to have an activity hardly inferior to that of *Sacch. Cerevisiæ*, at 60° to 70° Fahr. and greater above 70 Fahr. Further it is said to take up little or no resin from the worts, and consequently to produce a beer with a marked resin bitter. The beer has also a high ratio of acidity, and is stubborn in brightening. The average diameter of cells is given as 5 to 6 μ.

(vi) **Sacch. Conglomeratus** [Reess].—Cells united in clusters, produced by budding from one or more parent cells. In wine-must and decaying grapes. Diameter 5 to 6 μ.

(vii) **Sacch. Exiguus** [Reess].—In after fermentation of beer and said to cause turbidity, floating, as it does, on account of its low specific gravity. According to Hansen it cannot ferment maltose, and therefore only yields about 1% alcohol in beer wort, but excites vigorous fermentation in solutions containing saccharose (which it inverts) and dextrose. Cells about 5 μ × 2·5 μ.

(viii) **Sacch. Minor** [Engel].—Said to be the active factor in the fermentation of bread. Diameter 6 μ; of another kind, according to Matthews and Lott, 3 to 4 μ.

(ix) **Sacch. Apiculatus.**—A ferment occurring freely in wine-yeast, on succulent fruits and sometimes in spontaneously fermented (Belgian) beer. The cells are lemon-shaped as a rule, but decidedly smaller than *Sacch. Cerevisiæ* (4·5 to 7 μ long × 2 to 3 μ wide). As it secretes no inverting enzyme it does not attack disaccharides (saccharose or maltose), but vigorously ferments dextrose and levulose. (Hence it has been used analytically to ferment away dextrose from mixed solutions.) Its chief interest to us lies in the fact that it became the object early employed in Hansen's brilliant inductions, for which its typical shape adapted it, and again, which may seem contradictory but is not, in the great variety of forms it can assume (oval, sausage-shaped, bacterium-like ?) in addition to its typical one.

(x) **Sacch. Mycoderma** or **Mycoderma vini** (or *M. Cerevisiæ*).—The organism whose cells densely crowded together form the greyish, wrinkled, greasy-looking film on exposed beer or wort. The cells are sometimes like

those of *Sacch. Pastorianus* (elongated with one or two large vacuoles), but more translucent, and by close observation minute granular bodies may usually be seen moving about, apparently in the fluid contents of the vacuole. It has been classed among the Saccharomycetes, because, according to Pasteur, although naturally aerobian, it is capable, when submerged, of acting as a somewhat feeble alcoholic ferment. According to Hansen, however, this is not so. This is the organism which may sometimes be seen in bottled ales of light gravity, forming a filmy growth just at and above the level of the liquid. [Those troubled in this way should note Pasteur's advice, p. 350.] Almost all brewery yeast contains some, and experiments by H. van Laer tend to prove that it acts as a drag or *retarder* upon yeast. These will be referred to in the paragraph under heading of Saaz, Frohberg, and Logos yeasts.

Sacch. Pastorianus arborescens.—This species, often found in pitching yeast, and easily mistaken for *Mycoderma cerevisiæ*, though its films are paler and more delicate and do not form thick folds as the latter does, has been studied by H. van Laer. Its cells are formed in rolls disposed in fine tree-like forms. Without its being specially formidable it was found that beers infected with it were "piecy," after finding in the usual way, the "pieces" being formed either by the yeast in its arborescent form or by particles of gelatine enclosing it. It is found at the bungholes of cleansing casks in the crust formed after the primary fermentation, and there seems reason to connect with it some of the elongated cells of Pastorianus shape found in bottle deposits, because in comparative fermentations made with pure yeasts the cells were all round or elliptical, while with those fermented with an admixture many elongated cells were found.

Selective Yeasts.—Under this head brief reference may be made to certain yeasts with more limited range than that of the usual brewery type. **Saccharomyces Marxianus** (found by Marx on grapes), with oval, rounded, or kidney-shaped cells, can invert and ferment cane-sugar but not maltose. **Sacch. Ludwigii,** found by Ludwig in the mucilaginous juice of acorns, can invert saccharose and ferment the resulting invert, but not maltose. In shape extremely variable at different stages, its most characteristic phase is one where its spores roughly resemble an ace of hearts in shape, the upper part remaining, more or less, when the lower has become distorted. These limited capacities have led to these yeasts being used with the idea of fermenting away dextrose and levulose from inter-mixtures with maltose, but the accuracy of results so obtained is questionable. This incapacity to ferment maltose is shared with *Sacch. Exiguus* and *Sacch. Apiculatus*. **Sacch. Anomalus,** isolated by Hansen from Bavarian yeast, has been already referred to (p. 151) as forming fruity ethers. It is said to be not infrequent in English top fermentations, where it is said to induce cloudiness, but to be less usual in bottom fermentations. Its curious spores resemble a bowler hat in shape, or a basin with a distinct rim.

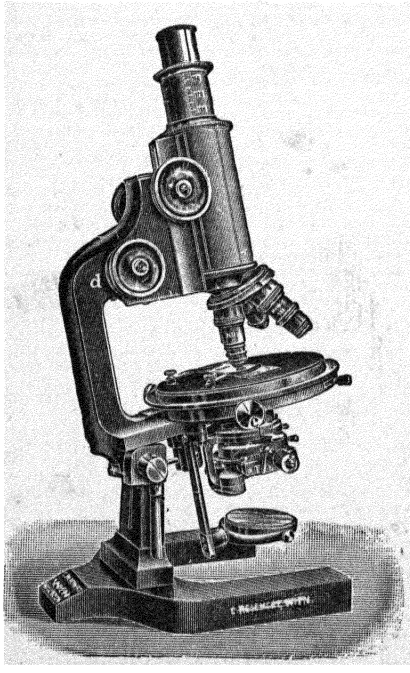
Schizo-Saccharomycetes.—Under this head comes **(Schizo) Saccharomyces Pombe,** obtained from millet beer of Central Africa. It does not propagate by budding, but the cells form division walls at right angles to their length and split apart there. It is a very rapid and far-reaching yeast, which ferments dextrin and may easily bring about an attenuation of over 80%, with more acid than normal yeasts produce.

Saaz, Frohberg, and Logos Yeasts.—These terms imply fermentative characteristics belonging to certain types of both top and bottom yeasts. Thus in a normal wort Saaz (first obtained from a brewery there) only ferments maltose, Frohberg (first from a brewer of that name) can ferment malto-dextrin also, while Logos can ferment dextrin (also inulin) with relatively much acid formed. The approximate degrees of apparent attenuation produced by these several types in a wort of 1·060 O.G. would be one-third for Saaz (to 1·020), one-fourth for Frohberg (to 1·015), and one-sixth for Logos (to 1·010).

Interesting experiments, in which yeasts of each of these three types were used, were made by H. van Laer showing that *M. Cerevisiæ* acts, perhaps beneficially, as a drag on yeast. Separate fermentations of 200 c.c. of wort in 250 c.c. Pasteur flasks, both without any and with a trace of mycoderma added, care of course being taken to avoid infection, were made with the following result :—

		Extract left (actual)	Alcohol % by vol.
I. (*a*)	Saaz yeast alone . . .	4·925	3·9
(*b*)	,, ,, + Mycoderma .	5·15	3·85
II. (*a*)	Frohberg yeast alone . . .	3·175	5·2
(*b*)	,, ,, + Mycoderma .	3·4	4·7
III. (*a*)	Logos yeast alone . . .	1·55	5·8
(*b*)	,, ,, + Mycoderma .	2·8	4·8

The beers were decanted into sterilised bottles directly signs of fermentation had ceased. All were brilliant in three to four weeks later, but except III. (*b*), which showed an active secondary fermentation, were rather flat. (The retarding influence, it will be noticed, of the mycoderma had been relatively greater in this case, *i.e.*, with the most attenuative yeast.) The mycoderma beers were paler than the controls, their deposits greater but more compact.



Symbiosis. — Many organisms thus working together in double harness, as it were, produce results differing from their single action. Thus a crude " Chinese yeast " contains a starch-converting mould, *Amylomyces Rouxii*, which produces dextrin and fermentable sugars and is further capable of fermenting these, but not so rapidly or well as the yeast associated with it can.

The Microscope. — The good qualities of a microscope are partly mechanical, partly optical.

The mechanical qualities consist in stability and smooth movement of the working parts, with just that amount of rigidity which ensures the maintenance of a focus once obtained.

The optical good qualities are (1) Freedom from chromatic and

spherical aberration. (2) A fairly large and well-illuminated "field." (3) Good definition. (4) Good penetration. (5) Resolving power. (6) Flatness of field.

The mechanical qualities explain themselves. As to the optical, **Chromatic aberration** means the tendency to split up a compound ray of white light into its component coloured rays, so that the object under observation appears fringed with colour. The correction of this tendency in objectives and eyepieces will be referred to again, but it may be mentioned incidentally that perfect achromatism, *i.e.*, the avoidance of any coloration with every object and when used with *oblique* light, is sometimes attained at the expense of definition.

Spherical aberration, also due to imperfect correction, or to the lenses not being ground in true spherical form, is evidenced by putting under the objective a glass slide on which are drawn a number of fine lines, crossing one another at right-angles, whereupon the lines, especially at the edges of the "field," will appear curved, either towards one another at top and bottom or the reverse (in the former case like the lines of longitude on the map of a hemisphere).

Fair size of the field (other things being equal) and **good illumination** of every part are obvious advantages, and only need be insisted on because some makers endeavour, by reducing the diameter of the optical tube, or by fixing in the objective with a rim of metal (a continental practice, as opposed to the English maker's method of fixing with Canada balsam), to give a factitious quality to their objectives, which the contraction of the field (the outer portion, which is generally most defective, being cut off) enables them to do. [The size of the field should however not be so great as to fatigue the eye, *i.e.*, the eye must be able to take in every part of it at one time.]

Good definition is perhaps the most important point of all; it means clearness of detail, in other words, absence of mistiness.

Penetration is the power of giving a good idea of an object (or a fluid) possessing appreciable depth, without alteration of the focussing adjustment; thus a microscope giving at the same time a *clear* view of yeast and bacteria (which, extremely thin as is the pressed-out droplet of liquid in which a mixture of them would be examined, float, generally speaking, at different levels) would have a penetrative power not easily obtained.

Resolving power.—This is the power of resolving or separating the component parts of minute objects, striations, close lines, etc., instead of fusing them into an apparently entire surface, and accordingly is akin to good definition, except that it largely depends on a wide angular aperture (and is thus a somewhat antagonistic property to penetration, which is characteristic of medium angular aperture), whereas definition seems to depend on a proper balance of constructive precautions.

Flatness of field is, practically, absence of spherical aberration; and though absolute flatness is rarely to be got in objectives over $\frac{1}{4}$ inch, the more closely they approximate thereto the better.

The angle of aperture is strictly that angle formed with the focus as one point and the two opposite extremes of that part of the objective which is used in the magnification * as the other two points—*i.e.*, the angle

*Therefore if the outer defective portion of the field be cut off, as has been stated to be the case sometimes, the angular aperture is reduced.

within which rays of light can pass from any part of the object, which is in focus, into the objective ; but practically it is measured in the following manner.

A semicircle of wood, marked at the circumference with the angular degrees (180°), and technically known as a Protractor, is used. On it is a flat, narrowish piece of wood moving freely on a pivot fixed in the centre of the straight side of the semicircle. This piece of wood has two uprights, deeply grooved at top to receive the tube of the microscope placed horizontally, and the end furthest away from the pivot, in its circular movement, just touches the line outside of which the angles are marked off. The microscope tube, detached from its stand, is then placed in position, lying down upon these grooved uprights, and exactly in a line with it (at a distance of some 8 feet from the objective end) is a lighted candle.

On looking now through the tube, the field of course appears perfectly illuminated, but if the wooden support be now rotated on its pivot, either to right or left, the illumination will gradually vanish. This is accordingly what is done. The eyepiece end of the tube is rotated, say first to the right, until a thin *crescent* of light alone remains, and then similarly to the left.

The number of angles passed over from right to left is then noted and taken as the angular aperture, though in reality the angle through which image-forming rays pass is often not more than two-thirds of the tabulated angle, especially when the aperture is high. This can be got as high as 170°, and when it is remembered that 180° equals two right angles (so that two rays proceeding from a common point and 180° from each other would be in the same straight line, and therefore could not possibly pass through the same lens) the difficulty of getting beyond this will be seen.

But, as has been said before, penetration, with which wide angular aperture is inconsistent, is of importance in a brewer's microscope.

Magnifying power depends primarily upon the **Objective,** which is a combination of lenses, forming one whole, which is screwed into the bottom of the tube (closest to the object), " the nose " of the microscope ; and secondarily, upon the **Eyepiece,** used in conjunction with it, the A eyepiece giving less magnification but a wider field than the B eyepiece, with the same objective, while the C is more powerful than B.

A and B are the eyepieces most frequently used, " deeper " eyepieces, except with objectives of very wide angular aperture, losing in illumination and definition more than they gain by amplification. Hence it is a good, though severe test of the excellence of a microscope to look at some test object (*e.g.*, the Podura scale *) with an objective and a shallow eyepiece, and then again after replacing the latter by a " deeper " eyepiece. If there is no appreciable loss of definition, the instrument has come triumphantly through the ordeal.

Objectives, or object-glasses, are classified according to their powers, and the names $\frac{1}{8}$, $\frac{1}{10}$ (inch), etc., approximate to their focal distance ; and the shorter the latter is, the greater the magnifying power. Thus—

* The scale of an insect found in timber-stacks. But the slide should be procured from one of the few *practical* microscope makers.

Low powers are: The inch, the two-thirds inch, and any of greater focal distance.
Medium powers are: The half-inch, four-tenths, quarter-inch, and fifth.
High powers are: All of shorter focal distance than one-fifth, *e.g.*, $\frac{1}{6}$th, $\frac{1}{8}$th, $\frac{1}{10}$th, $\frac{1}{12}$th inch, etc.

Approximate magnifying power of certain combinations—

$\frac{2}{3}$ inch	about	60	diameters	with	A and	90	with B	eyepiece.
$\frac{1}{5}$	,,	250	,,	,,	A ,,	400	,, B	,,
$\frac{1}{10}$	,,	400	,,	,,	A ,,	600	,, B	,,

Magnifications of 1,000 and 1,200 (expressed × 1,000, × 1,200 when the magnified object is sketched) and even more are obtainable, but necessitate very high-class instruments.

[The **Immersion Principle** is adopted with some of the highest powers—*i.e*, a drop of water is interposed between the lower lens of the objective and the object or its cover-glass. Less light is lost thereby because some of the oblique rays of light, instead of passing onwards in the same line of obliquity, are, in accordance with a well-known optical principle (because passing from a rarer medium, air, into a denser medium, water), deflected from their course, and travel upwards in a more or less parallel direction. This system is not, however, adopted to any extent, if at all, by English makers, who rely upon superior methods of illumination.]

High power objectives have their definition much affected, according to the thickness of the cover-glass usually interposed between them and the object, and accordingly most of them have a screw-collar, by rotating which the necessary correction can be made; but Mr. Crouch gets over this necessity in his brewer's cheap microscope by adjusting his objective (a $\frac{1}{10}$th) to one particular thickness of cover-glass, which he supplies in small squares.

Each objective consists of three pairs of lenses, each formed of a double convex of crown-glass and a plano-concave of flint-glass (sometimes even of eight lenses), this arrangement being necessary to cure chromatic aberration, and the eyepieces, also corrected, consist of two plano-convex lenses with their convexity downwards.

The eyepieces should further be inspected for **scratches** on the surface of either lens, or for minute **air-bubbles,** technically known as "seeds," imprisoned in joining the lenses.

To detect these, screw on a medium or moderately high power objective, and let subdued light through from the mirror. If this be properly done, these and adventitious specks may be located by turning the eyepiece round, then by unscrewing the top lens and turning it round alone first, and afterwards the bottom part. The specks, etc., will of course move with the part on which they are.

Compound microscopes are either **Monocular** or **Binocular** (with two eyepieces), the latter, although the most comfortable for general work, not being adapted for use with the high powers which the study of yeast and bacteria requires, and which, for even moderate ambition, should reach a combination × 600, though undoubtedly for yeast alone a distinct magnification of 200 to 300 diameters is better to work with than a hazy one of 600.

Other parts of the microscope include **the Stand,** with its base in tripod

form, the two front feet having a good wide spread, and the hinder one (near the observer) being U shaped and with a broad bearing, widely curved, at bottom, to secure steadiness, if the tube is to be pulled down into a horizontal position. There are variations in form, some microscopes having, for instance, a wooden stand, but the above arrangement in iron is as workmanlike as any.

The Tube is that portion of the instrument into which the objective is screwed below, and the eyepiece slipped above. The extreme length between these points should not exceed 8½ inches, and for brewer's work one of less length, but with a draw-tube (like that of a telescope) enabling it to be lengthened if desired—this increasing magnification—is useful.

The tube is connected with the tripod part of the stand by " a limb," which works upon pivots or trunnions at the apex of the tripod, and can be moved through an angle of 90°, or more, and so stand vertically or horizontally.

Beneath the tube is the **stage,** on which the object to be examined is placed, and there is generally, as part of it, a smoothly moving object-holder, which can be made to slide either by two small projecting brass handles, or, as in the more highly finished microscopes, is made in two parts and fitted with two milled heads, one of which moves the upper portion (of the object-holder) from right to left and back again, the other moving the whole object-holder, virtually the greater part of the stage, at right angles thereto.

Underneath the stage is sometimes a **substage** in which the **Diaphragm** is placed. The important part of this is a round blackened plate pierced with circles of different diameter for regulating the admission of light to the object, but better for high powers is the **Achromatic Condenser,** which in its simplest expression is a plano-convex lens, with the convexity uppermost, rimmed with brass to enable it to be fitted to the stage or substage and covered with a removable cap pierced with a small round hole. This arrangement not only concentrates upon the object the rays of light thrown upwards by the **Mirror** beneath (which should be of at least two inches diameter, and moving on trunnions, as well as on a crank-arm fixed to " the limb "), but cuts off peripheral rays of the pencil.

The focus is got by means of the **coarse** and **fine adjustments,** both milled heads (the former generally actuating a rack and pinion, though a draw-up arrangement instead is practicable and cheaper), the coarse adjustment serving to get the approximate focus, the fine adjustment (one *turn* of which only moves the objective upon which it acts $\frac{1}{100}$ inch) being finally used to get a sharp definition.

It is more convenient to have the light, especially when a lamp is used, on the observer's left hand than upon his right, as his right hand will be wanted, more or less, for moving the slide and the adjustments and so might intercept some of the illumination.

It is impossible to lay down any short general rule for the position of the mirror with reference to the object, the path of the reflected rays depending not only on the direction whence they come before impinging on the mirror, but also upon the concavity of the latter or its absence. The mirror will accordingly be moved about until ample light to view the object is obtained.

Direct sunlight, falling on the mirror, is not to be recommended, for it

often causes the object to appear fringed with a prismatic ring of colour. Sunlight reflected from a white wall or from a white cloud is the best natural illuminant. Microscopists, however, generally prefer artificial light, and to fulfil their requirements special lamps, burning mineral oil (which must be of the best), are constructed, the wick portion of which is easily raised or lowered, and which have a chimney for cutting off all light except in the required direction.

Great cleanliness is necessary, and the microscope must be kept out of the damp. It is more convenient to have one which can be taken out of its box ready for use, without screwing the parts together; if, however, the microscope is one which must be taken apart before it will go into the case, it is better not to use the latter habitually, but to have the instrument ready for action and protected by a glass shade. Be careful to wipe off all dust, and to use the cleanest and softest (old) handkerchief that can be got for finishing the wiping of lenses, cover-glasses, etc.

To protect it from the vibrations of the brewery, Messrs. Matthews and Lott recommend that the feet of the table on which it is wont to stand should rest on four thick india-rubber pads.

The most perfect way of keeping a supply of clean glass slides and covers, especially the latter, is to wash them after use in dilute nitric acid, rinsing two or three times afterwards with fresh distilled water, and then to drop them into a stoppered wide-mouthed bottle of alcohol. From this they can be removed as required by aid of a clean pair of forceps, and carefully wiped.

Or they may be put away, ready wiped, in a receptacle made of wash-leather and having divisions, each of which takes one glass. But practically it is generally enough to wash with some friction under a hot water tap, letting the moderately hot water run on long enough to rinse the glass thoroughly.

To examine yeast, etc., it should be diluted freely with water (tap water of good quality will do) till the fluid has a milky, or rather "sky-blue," appearance, because the details of crowded fields cannot be well observed. Put the smallest possible drop upon a clean glass slide, and for this the best thing is a short bit of platinum wire fixed into a handle of glass tubing (this is done by causing the end of the tube to contract upon the wire by the heat of a gas flame), and with its (the wire's) end bent into a fine hook. The platinum hook can be thoroughly rinsed in a stream of hot water before use, without causing any tendency to rust, or may be sterilised by heating to redness in the flame of a Bunsen. Over the droplet so placed upon the glass slide one of the clean thin glass covers is gently put, so that the liquid spreads evenly, without intermixture of air-bubbles, nearly to the edge of the glass cover. For moulds, alcohol is a better medium than water.

The only thing remaining to caution the novice about is to be careful not to ram down the objective on to the object, which might result in a breakage of the slide and even injury to the objective. The best plan is to get the objective down *within* the focal distance, first, by means of the coarse adjustment, looking while doing so, not through the tube, but at the objective and object themselves, and then focussing upwards—*i.e.*, away from the object.

Possibly, however, he may be puzzled by a sort of to-and-fro movement

of apparent particles ; but this is merely optical, and will cease to trouble him with practice.

There is also the so-called **Brownian movement**—that is, an apparent vibratory or dancing movement of inanimate, but real particles, which might lead to a hasty inference of the presence of vibriones. The movement is, however, different, and the simplest way of getting an idea of it is to rub a trace of the water-colour pigment, known as gamboge, upon a slide, diluting slightly with water, and after putting on the glass cover, inspecting in the usual way.

Without making invidious distinctions, it is right to name two makers who have successfully endeavoured to satisfy the demand for a trustworthy microscope at a moderate cost. These (naming them in order of acquaintance) are Mr. Crouch of the Barbican, several of whose microscopes have come under the writers' observation, and Messrs. James Swift & Son, at whose establishment (81, Tottenham Court Road) visitors are not only certain to have all their questions courteously answered, but may have the opportunity of seeing the various lenses in process of manufacture before purchasing.

The Detection of Wild Yeast in Pitching Sample.—In the strict sense of the term the presence of cells of wild yeast cannot be ascertained by ordinary microscopic examination with any degree of certainty. It is true that when a sample of composite yeast is examined under a correct light and with a high power lens the several varieties of saccharomycetes present may probably be distinguished but not with certitude morphologically. S. Cerevisiæ ordinarily exhibits cells of a round or slightly oval form, while S. Pastorianus cells are of a sausage shape. Unfortunately the value of a microscopical examination as a guide to the detection of wild yeast contamination is nullified by the power that saccharomycetes possess of assuming the forms of other varieties. Hansen's test for the detection of wild yeasts has been subjected of late to considerable criticism in respect to its reliability. He noted that spore formation in different classes of yeast occurred at different temperatures, and when the whole of the six varieties, which formed the subject of his investigation, were cultivated at a definite temperature, they were all able to produce spores, and the important point was revealed that the various types of yeast showed a very wide range of differing periods of time which elapsed before spore formation commenced, and it is upon this factor that Hansen bases his method of detection.

Although of highly scientific importance the test is of little practical value to the operative brewer who needs must, in the majority of occasions, decide quickly the purity and general suitability of his barm for pitching purposes.

The busy modern brewer has not the time to devote to the correct cultivation of samples of yeast in an endeavour to ascertain the presence of wild forms. Blocks of plaster of Paris are used and the samples maintained at 52° Fahr. for 10 days. If no spores are formed at the conclusion of that period, then it can be assumed that the samples are immune from contamination within wild yeasts. We have employed the term " assumed " inasmuch as the cultivation and ultimate detection of true ascospore formation is no easy matter in a 'prentice's hand, and it requires the analytical mind and the skill and precision created by

a training in mycological methods to obtain conclusive and reliable results.

There is a test, however, which can be readily applied and yields valuable information as to the presence of wild yeasts in beer. Examine a fine sample of beer which subsequently developed a distinct haze or cloudiness, and also a sample of beer in the rough about four days from racking. Apply the following tests to them : Analyse the carbohydrates present, " force " them at high temperatures and note the reduction in gravities that occur. Under no circumstances should beer exhibiting the tendency named be mixed off with beer that is satisfactory, even although the infected beer has become brilliant. But the latter can be used off in smaller quantities if sterilised, especially during the winter months.

The bacteria met with in brewing practice, and fermentology in general, are exceedingly small bodies, a fact that should be amplified to emphasise its importance. On an average bacteria or " rods " are not more than one-twenty-fifth-thousandth of an inch in diameter. It requires twenty-five thousand of the average sized bacteria to reach an inch, and twenty-five thousand such lines would only cover a square inch just one layer deep. Moreover, it would take twenty-five thousand more layers to give a cubic inch. Briefly, then, the average bacteria occupies a volume of not more than one-fifteenth trillionth of a cubic inch.

It is difficult for the lay mind to comprehend how objects so exceedingly minute can be of any particular economic importance or significance. But these micro-organisms make up for their minuteness by the enormous powers for reproduction which they possess. They multiply thus : Bacterium, when fully developed, splits in the middle forming two bacteria. Observed under the microscope a bacterium will develop to the full, divide, and form two separate organisms in the course of 20 minutes if the medium and temperature are favourable to bacterial reproduction. Assuming, therefore, satisfactory cultural conditions such as moisture, nutriment, and the correct high temperatures, one bacterium will reproduce itself to an almost incredible extent in the course of a few days. Bacteria, of course, never develop spontaneously in nature. They must have ancestors just as the higher plants and animals have. The ability of various bacteria to withstand unfavourable conditions differ, but in the case of spores (which correspond to the seeds of higher plants) these have the power of adapting themselves in some measure to unfavourable conditions. Heat, however, will generally kill bacteria, and it is upon this fact that Pasteur based his sterilisation method now known as " Pasteurisation."

The production of a cloud in beer may be due (apart from considerations of materials or faults of brewing) either to bacteria or to yeast. If the former, then there may be the cumulative effect of the presence of millions of bacteria to a cubic centimetre (20 drops) to bring about the haze in beer. Should the lack of brilliancy be due to yeast, then as the yeast cells are considerably larger, a smaller number will produce the same objectionable result.

Apart from developing a haze in beer and the production of lactic acetic and other acids which render beer unfit for consumption, especially during summer temperatures, certain bacteria produce undesirable flavours. The yeasts are from twenty-five to a hundred times larger than

bacteria, which accounts for the extreme difficulty in discerning the latter in an ordinary microscopic field of diluted yeasts. Yeasts differ in their method of multiplication; instead of developing to normal size and splitting in the centre as is the method of bacterial growth the yeast cells throw out buds which develop and finally break away from the parent cell, to enter into a career of propagation and general life functioning on its own. In turn it throws out buds and so on.

Moulds are still larger than even bacteria or yeasts; indeed, so large are some of the moulds that some of their constituents can be observed physically without recourse to microscopic examination. Moulds are, however, more complex than either yeasts or bacteria. They are surface growths which require free oxygen for their development, and if the film is permitted to subside in beer an unpleasant flavour will be produced.

Most of the TORULA (see p. 329) are easily recognised by their almost perfectly round shape, their content of fat, their peculiar manner of propagation which causes them to give off simultaneously many small round buds, and finally by their membrane, almost always surrounded by a layer of a mucilaginous substance. Many of the moulds and bacteria, under certain conditions are able to ferment the sugars, although this fermentation is not active and is prolonged. Indeed, all cells which contain sugar are able in the absence of oxygen to function as yeast cells and produce alcoholic fermentation. Fischer and Theirfelder have established that only these sugars are fermentable, in which the carbon atoms are in multiples of three.

CHAPTER XI

FERMENTATION WITH COMMERCIAL YEAST—ITS SCIENCE AND PRACTICE

LIEBIG AND PASTEUR—CONFLICTING THEORIES—PROFESSOR HUXLEY'S SIMILE—TRAUBE'S HYPOTHESIS—BREFELD'S RESEARCHES—ADOLF MAYER'S—YEAST REACTING ON ITS OWN TISSUES—NÄGELI'S THEORY—DUMAS—BOURQUELOT AND "SELECTIVE FERMENTATION"—BY-PRODUCTS (GLYCERINE AND SUCCINIC ACID)—INEVITABLE CONTAMINATION OF INDUSTRIAL YEAST—NUMBER OF AERIAL SPORES VARIES—HIGH AND LOW YEAST—THREE VARIETIES OF THE FORMER—MICROSCOPIC APPEARANCE OF THE CELLS—ORDEALS WHICH YEAST CAN SURVIVE—ANALYSIS OF HIGH YEAST—EFFECT OF AËRATION—ALCOHOL PERCENTAGE AND MAXIMUM DENSITY OF WORT—HEAT GENERATED—CONCURRENT ACTION OF DISEASE FERMENTS—ATTENUATION—HEADS—FOXY SMELL—SLUGGISH FERMENTATIONS—FIERY FERMENTATIONS—BAKER'S YEAST.

WE shall not attempt to peer into the mists of antiquity in the hope of discerning the birth of the primitive yeast-cell, or even do more than mention the respected names of Leuwenhoek, Willis, Stahl, and Schulze. Their researches, important as they were, have now merely an historical interest.

Nearly fifty years ago, **Pasteur** began his epoch-making publications, and proved that certain forgotten discoveries (particularly those of Cagniard-Latour and Schwann) were based on facts, and that yeast is not a dead mass, as Liebig (to select a great name) supposed, but that it consists of living and multiplying organisms, that yeast germs (spores, as such, were of course unknown till later) occur in the air, and that fermentation is bound up with the presence, the reproduction, and the nutrition of these organisms.

Then the battle raged. **Liebig** had enunciated as early as 1839, with all the weight of his authority, his theory that yeast was a lifeless albuminous body, the molecules of which, being altered in composition by oxidation, imparted a similar disturbance of equilibrium to the adjoining sugar molecule, causing it, in consequence, to break up into alcohol and carbonic acid.

Pasteur, on the other hand, maintained that yeast, like all living things, takes oxygen from the air, giving out a corresponding quantity of carbon dioxide, and that accordingly no fermentation is induced in the presence of *free* oxygen. But if access of free oxygen were prevented, the yeast, he said, would take the required oxygen from the oxygen-containing compounds (*e.g.*, sugar), whereupon equilibrium being destroyed, the sugar splits up into alcohol and carbonic acid, by-products being formed in the shape of succinic acid and glycerine. He accordingly constructed the definition **"Fermentation is life without air."**

Professor Huxley illustrated the difference of these opinions by the simile of a card-house, to which he likens the sugar, comparing the yeast to a child coming near the card-house. "Liebig's hypothesis is," he says, "that the child comes by, shakes the table and tumbles the house down,"

while that of Pasteur is that " the child pulls out the bottom card, and thus tumbles the house down."

Liebig would never entirely give up his mechanical theory, though forced to own that yeast is no lifeless mass ; the most he would do in the way of concession was to suggest that an enzyme (like invertase) was secreted, or perhaps excreted, from the yeast capable of splitting up glucose into the products of fermentation.

The chemical hypothesis was supported by **Traube,** whose views deserve to be cited as an example of perverted ingenuity in its main contention, though in details there may be fact to support them. He contended, first of all, that the ferment itself is a chemical compound, which cannot be separated from the yeast-organism without loss of activity (consequently not an enzyme), and that its action was as follows : Sugar consists, he said, of two complex atoms, a reducible (A) and an oxidisable (B). The ferment in the yeast takes oxygen from the group A, and conveys it to group B, whence arises on one side alcohol, on the other carbonic acid. And seeing that the oxygen-conveyer (the ferment) never became saturated, but by surrender of the oxygen taken up was constantly qualified again for fresh reduction, so it was clear that a small quantity of ferment could split up a very large quantity of sugar.

Traube later on modified this view so far as to assign to the water of the fermenting fluid a part in the fermentation, contending that by the affinity of the ferment for oxygen on the one hand, and of the atom-group A for hydrogen on the other, the water was first of all decomposed, then that its hydrogen was taken up by the atom-group A, while its oxygen was taken up by the ferment and conveyed to the atom-group B. The atom-group A was thereupon transformed into alcohol, the atom-group B into carbonic acid.

This extremely fanciful view is ingenious but further removed from demonstration than when enunciated. It takes no account of the by-products formed in every alcoholic fermentation, in greater or less quantity. Nevertheless, we, who have seen the resuscitation of many ideas once consigned to the limbo of neglect, may hesitate before branding this as nonsense.

Traube traversed Pasteur's view that the sugar serves as a source of oxygen for the yeast, maintaining as the result of experiments so late as 1874, that the albuminous bodies of the fermenting fluid have to supply that requirement, when air is excluded.

Brefeld was the next, whose investigations claim notice, with his experiments aimed at Pasteur's statement that yeast can grow even without free oxygen. He hermetically sealed up a fermenting fluid sown with two or three yeast cells (say a droplet of fermenting beer-wort) in small lenticular-shaped glass chambers, with almost air-free carbonic acid gas, and then followed the growth of the yeast-cells microscopically. He found that growth of the cells only lasted for two days with the temperature at 13° to 14° C. (= 55·4° — 57·2° Fahr.), their appearance at the end of fourteen days being completely that of dead cells.

Relying upon his experiments, Brefeld thought himself (1874) justified in concluding, in opposition to Pasteur and Traube, that yeast cannot grow without free oxygen, and that Pasteur's theory (that yeast, unlike all living organisms, can live and grow without other oxygen than the

combined oxygen of the sugar) was completely without foundation in fact.

Brefeld further asserts, on the strength of other experiments, that the yeast growing in a fermentable fluid and having a constant supply of free oxygen, cannot cause fermentation. In this he is in practical agreement with Pasteur, as will appear later on; he differs, however, in holding fermentation of sugar by yeast to be the expression of incomplete co-operation of all the conditions necessary to maintain the growth of the cells—in other words, that "Fermentation is a pathological phenomenon, which begins at the moment when the yeast in the unexhausted nutritive fluid can grow no longer, and which stops with the death of the yeast-cell."

Brefeld's standpoint, accordingly, was that the growth of yeast and fermentation are two separate processes. In breweries, according to his position then, both stages go on side by side in different parts of the fermenting wort. On the surface, where the oxygen of the air has access, the yeast grows without being able to cause fermentation; in the lower depths, on the contrary, where all quasi-free oxygen has been consumed by the yeast, *fermentation* occurs. Then the yeast absorbs sugar (maltose or glucose) out of proportion to other nutritive bodies, and splits it up into alcohol, carbonic acid, and other products. This abnormal life-process, Brefeld said, will last for weeks, the vitality of the yeast getting less and less, and finally the fermentation dies away, even though the supply of sugar outlasts the vitality of the yeast.*

The practical outcome of Brefeld's conclusions, supposing them to be accepted, is that air must be allowed access to promote the multiplication of the yeast, while exclusion of the air and consumption of such oxygen as has been already admitted, seems necessary for fermentation, as such, to start. The aeration of the wort should then take place once and thoroughly for the yeast to gain strength and multiply, whereby it is eventually able to decompose a larger quantity of sugar; but a further introduction of air would be not only undesirable, but even injurious.

A natural corollary of Brefeld's views as to fermentation being the expression of an arrested development is that he inclines to Liebig's opinion, holding that the nitrogenous substances exuding from the yeast-cells during fermentation (an emission whereby, he says, the yeast becomes poorer in nitrogen as fermentation is prolonged †) are, in all probability, the actual exciters of fermentation, and that fermentation is therefore a purely *chemical process*.

Adolf Mayer now turned his attention to the matter, and repeated Brefeld's experiments in the glass chambers, at one time enclosing carbonic acid, at another hydrogen, in order to determine the possibility of an injurious influence due to carbonic acid, so poisonous to some other forms of life; he worked, however, with larger quantities of fermentable fluid (4 litres of beer-wort), and with most careful exclusion of air. He found no marked difference of appearance, whether carbonic acid or hydrogen had

* Such a residue of undegraded sugar in a malt-wort would be explained by the advocates of the malto-dextrin (amylöin) theory, with great probability, as being due to the fact that it originally existed, and still exists, not as free maltose, but as the definite compound (though the type may vary) malto-dextrin, which is, until degraded by some other agent, obdurate to the attack of primary yeast (see pp. 243—245).

† This statement is hardly borne out by Hayduck's experiments, to be mentioned later.

been introduced before the closure of the vessel. It further appeared that in the majority of cases, budding of the yeast-cells occurred in spite of the most careful exclusion of atmospheric oxygen, but that the growth died away always on the second or third day, before the sugar of the nutritive solution was exhausted.

Further, the majority of the samples, totally freed from oxygen as they were, showed cloudiness and yeast deposit, a fact which pointed to growth and multiplication of the yeast.

Mayer accordingly confirmed Brefeld's experimental results to the extent of allowing that the growth of yeast is hindered by exclusion of oxygen, but did not think himself justified in concluding that absolutely no growth of the cell occurs when oxygen is excluded.

He also draws attention to the discovery made during his researches that the lactic bacteria entering in very small quantity (in company with the yeast) into fermentable fluids, multiply very vigorously in spite of the exclusion of oxygen; therefore Brefeld's strongly enunciated law that "*all* organisms must breathe free oxygen" cannot claim to be universal.

Brefeld's second assertion, that growing yeast, with an ample supply of air, causes no fermentation, was tested by Mayer, and this investigator found that very considerable quantities of air can be introduced into fluids containing budding yeast without stopping the yeast-fungus from acting as a ferment. "This much," he says, "is at any rate established, that under certain conditions of oxygen-introduction simultaneous fermentation and growth *can* occur, and that, not in the intermittent way imagined by Brefeld (viz., that here one cell which finds itself favourably situated with regard to oxygen will grow, and that there another, lying at the bottom, will act as a ferment), but that the selfsame cell will simultaneously grow and excite fermentation. He considers that the existence of a stage, intermediate between the two states, which Brefeld hypothetically argued for, is demonstrated, and that this stage, in which yeast simultaneously grows and ferments, appears to be a very wide one.

Pasteur again returned to the charge, and by use of a large flask, containing a fermentable fluid, and from which oxygen was rigorously excluded (entire absence of free oxygen was shown by there being not the faintest blue coloration of indigo carmine, reduced with sodic bisulphite), proved, on very slightly impregnating the contents of the flask with yeast, that fermentation can occur in the absence of free (*i.e.*, not combined in sugar) oxygen, the extraordinarily small quantity of the ferment developing immediately, and the fermentation continuing to completion, although somewhat more slowly than when air was admitted.

And, finally, Brefeld renewing his experiments with yeast (from wine) and with the *gonidia* of *Mucor Racemosus*, in a solution prepared from the purest inverted sugar-candy, ammonia salts, and mineral constituents derived from cigar ash, air being rigorously excluded, satisfied himself that his former contention was incorrect, and that Pasteur's statement, that the growth of yeast cells in a medium free from oxygen was due to the oxygen of the sugar, had been verified. The results also, as far as they went, knocked the bottom out of Traube's theory (that the oxygen demanded by the yeast in a medium where no atmospheric oxygen was present would be wrested from albuminoids and not from sugar), seeing that there were no albuminoids admitted into Brefeld's solution.

Brefeld was still disinclined to acknowledge absolute uniformity; he still distinguishes between (1) Fermentation with growth; (2) Fermentation without growth or loss of substance; and (3) Fermentation with loss of substance to the point of extinction. And many will admit the possibility of these processes going on contemporaneously.

A curious fermentation-phenomenon, observed by M. Pasteur, throws some light upon the way in which the latter process may occur, though of course his experiment—equally with all the others—was not on actual brewing lines.

·424 gramme of pure sugar-candy was set to ferment with an amount of damp yeast = 10 grammes of dry yeast, and this mixture furnished by the end of two days 300 c.c. of CO_2, whereas the sugar alone would only be capable of yielding 110 c.c. of the gas. The liquid then, being carefully distilled, gave rather over ·6 gramme of absolute alcohol, or a weight of alcohol greater than the total weight of the sugar employed and proportionate to the volume CO_2 formed. Whence came this?

This experiment shows that very large excess of yeast mixed with sugar will first decompose the latter, and then go on reacting energetically on its own tissues and carbonated constituents. And it was found upon stopping the fermentation, at a moment when the CO_2 formed corresponded to, or was but little in excess of that corresponding to the amount of sugar employed, that *all the sugar had disappeared.* This is a point of some importance, as tending to show that as long as a fermentable sugar-body is present, the ferment will not begin to consume its own tissues, although there is reason to suppose that the soluble nitrogenous matter,* of which yeast contains considerable quantities, is utilised to form fresh protoplasm for new cells, otherwise how could cell-multiplication in a pure sugar solution be possible?

What is the reason why yeast, mixed with a feeble proportion of sugar after it has decomposed the latter, proceeds to act with such energy upon its own tissues when, as far as we know, no such action takes place with the brewer's "store-yeast," which is generally kept—often in considerable bulk—for three or four days after collection? Can it be that in the former case a molecular vibration is set up, which does not immediately subside at the point when the sugar is all decomposed? If this could be proved it would furnish an argument for the last general theory of fermentation—apart from that which is, in the main, Pasteur's—to be mentioned in this chapter.

Nageli's Fermentation Theory.—As Liebig's was the **chemical theory,** and Pasteur's is the **vitalistic theory,** so Nageli's may be called the **molecular** or perhaps the **catalytic theory.** According to his view, the action of the yeast-cell is due to the molecular vibration of the protoplasm which it contains: further, in consequence of this molecular action, the decomposition of the sugar takes place outside the cell, and not inside, as Pasteur's theory requires. The action is supposed to extend to a minute

* Fresh yeast, dried at 212° Fahr., shows a loss upon being washed, which may be estimated at about 23%, calculated on its weight when dried. Yeast, which has been softened by being kept in a warm place, say at 80° Fahr., for two days, will show a loss of weight= over 50% calculated similarly. [100 grammes fresh yeast dried at 212° then weighs 30 grammes, after the washing 23 grammes: the softened yeast weighs after washing 14 grammes. Schützenberger.]

but (having regard to the extreme smallness of the objects we are speaking of) sensible distance from the cell.

Dr. Squire, in a lecture referred to in another chapter, pointed out that the formation of acetic ether, which contributes to the scent of fermenting wort, and which occurs, as far as we can see, by the combined action of the alcoholic and acetic ferments, tells strongly for Nageli's view, because we know that "acetic ether is produced when alcohol and acetic acid are brought together in the nascent state. Now if acetic acid be formed *inside* the acetic-ferment cell, and the alcohol produced *inside* the yeast cell, no acetic ether could be produced, but if a zone of molecular vibration, in which the work is done, surrounds each cell, it is clear that, whenever these zones cut one another, acetic ether would be produced.

Further, Nageli's theory also explains—what is not easily explicable otherwise—the suppression of one ferment, present in small quantity, by another ferment, present in large quantity. More powerful vibrations tend to suppress less powerful vibrations, which are not in unison with them; and if we suppose each ferment to have a peculiar vibration of its own, by which it sets up a specific decomposition in the surrounding medium, we can easily understand how the predominating vibrations tend to suppress the rest."

However, the following facts demonstrated by Dumas, though prior, we believe, to the publication of Nageli's hypothesis, especially the first, rather militate against that view. The third aims at the chemical theory.

(1) That saccharine liquids are not influenced by a ferment, even through the shortest columns of liquid or *the thinnest membranes*. (2) That sonorous vibrations have no influence on the movements of fermentation. (3) That no chemical action amongst the great number of those which have been tried has been able to effect decomposition of sugar into alcohol and carbon dioxide.

Again, Bourquelot's experiments on **"Selective Fermentation,"** if their results could be shown to be constant for every species of yeast, would go far to prove that the decomposition of the sugar takes place within the yeast-cell, as Pasteur said, and not outside of it, as Nageli maintained. For he claims to have established that the rate with which any fermentable sugar is decomposed stands in a close ration to its diffusibility through membranes (*i.e.*, by dialysis), *i.e.*, that dextrose is more rapidly fermented away than levulose, and levulose than maltose, their diffusibility standing in the same order.

With regard, however, to the above-quoted results of Dumas, it has been found by Duclaux and Buchner that dextrose can be split up into alcohol and CO_2 when exposed to sunlight in presence of caustic potash.

Buchner's Zymase.—In 1897 E. Buchner alleged that Pasteur's vitalistic view of fermentation could no longer be maintained, and that Liebig's was shown to be nearer the truth by the fact that yeast juice, derived from cells that were actually *dead*, could exert fermentative functions by means of an enzyme it contained, to which he gave the name of Zymase. It was originally got by grinding up yeast with quartz sand and then subjecting the mass of disintegrated cells so obtained to strong pressure, finally passing the resultant liquor through a porous porcelain filter. The yellowish and slightly opalescent liquid, from which CO_2 began to escape at 40° C. (= 104° F.), became a practically solid mass on further

heating, owing to the presence of coagulable proteids, yet upon evaporating at low temperature the zymase, with other enzymes, could be obtained in a solid form, in which it can be retained for a fair time without losing its property of causing fermentation; on the other hand, a rapid loss of this power by the juice itself when kept, not to speak of the variable action of different juices, rather points to still inherent vitality, against which it is argued that its passage with unaltered efficiency through a Berkfeld filter and activity in the presence of chloroform indicates enzyme activity. The rapid deterioration of the juice can be delayed by saturating it with a fermentable sugar, a case which with other enzymes is, says Abeles, without parellel, and he argues that Buchner's assumption that this occurs because the sugar restricts destruction of the zymase by peptonising enzymes is not tenable, in view of the fact that only fermentable sugars are protective. In any case the juice contains several enzymic bodies, oxidase, maltase, invertase, a glycogen ferment, and an active proteolytic one acting upon the protein constituents autodigestively. It is plain that, whatever view be taken, the agency of yeast-cells is indispensable for producing the zymase-containing juice, nor, even if it were desirable on other grounds, could juice be substituted for yeast-cells in pitching, the ready-formed zymase in each litre of yeast (= 0·22 gallon) having been calculated (J. J. van Hest, 1903) to be an amount capable of decomposing 87 grammes (3 oz.) of sugar, obviously a very small portion of the work, in a fermentation sense alone, that the yeast has to perform.

Important work by Macfadyen, Morris, and Rowland on fermentation by yeast juice gave results varying from Buchner's. Thus one of their experiences was that very moderate dilution (1 : 2) completely stopped fermentative action, whereas Buchner used water without detriment in its extraction, and Harden and Young found that dilution with a 6-fold vol. of water did not affect autodigestion, but that when the juice contained glucose a 3-vol. dilution reduced fermentation to 0·5 or 0·7 of its original force. The three investigators named found that large quantities of gas (CO_2) were given off on **autofermentation of the juice,** even when maintained at a temperature low enough to keep it solid, as against Buchner's temperature of 40° C., and *sometimes even more than when sugar was added:* this last applied specially to sugar concentrations over 10%, whereas Buchner finds the juice fermentation in higher concentrations (40%) more energetic, and even goes so far in his criticism of the English work as to say that results with lower solutions are vitiated by absence of proof of their sterility, being in themselves insufficient to keep organisms in check. Macfadyen, Morris and Rowland's method of winning the juice is as follows (the quantity obtained being extremely variable, but averaging 30 to 35 c.c. of juice, with gravity 1050—1060, per 100 c.c. of dry yeast), the operation lasting 3½ hours.

Brewers' yeast was mixed with equal quantities of water, centrifugalised and the supernatant liquid drained off. This was repeated till the water came off clear and colourless. The pasty mass, wrapped in a double thickness of hydraulic chain cloth, is subjected to pressure of 70—100 atmospheres, and the resulting yeast is in a white powder. Next the cells are disintegrated by a contrivance which keeps the yeast in violent agitation with added silver sand, the rapidly succeeding mutual impacts rupturing the cell-walls and expelling contents (material is kept cool by

circulating brine of 5° C., as otherwise the temperature rises nearly to boiling point). The juice is separated by adding Kieselguhr and pressing as before, but under 200—350 atmospheres.

They found that only with strong juices does the ratio of alcohol to CO_2 approximate with that given by Pasteur ; with a weaker juice the alcohol is generally higher, but an amount of sugar disappears in excess of that represented by alcohol and CO_2, the amount so disappearing being less the nearer the alcohol and CO_2 formed approach the ordinary fermentation ratio. The sugar apparently disappears *as such* (it being proved that no juice constituent can counteract cupric reducing power, and that *no hydrolysable sugar has been formed*) ; it is therefore assumed to form a sugar-x compound with an x (unknown) constituent of protoplasm, and that it is decomposition of this sugar, locked up as sugar-x, which yields the gas in auto-fermentation. With strong juice, decomposition goes on till all the sugar-x is broken down, but with weak juice not. From this and correlated facts the induction has been made that the consumption of sugar by normal yeast, in its conversion into alcohol and CO_2, occurs in two stages (1) building up of the sugar molecules into the living protoplasm of the yeast ; (2) a breaking down of the complex into alcohol and CO_2. Harden and Young agree *generally* with the previous workers in the case of top-fermentation juice, but they think the disappearing sugar preferable to a non-reducing substance, convertible into reducing sugar by acid-hydrolysis. In acellular fermentations the maximum of sugar convertible into CO_2 and alcohol is 85% of the sugar disappearing.

The By-products of Fermentation (Glycerin and Succinic Acid).—Gay-Lussac's equation to explain the fermentation of cane sugar as reconstructed by Dumas and Boully stood—

$C_{12}H_{22}O_{11}$	+	H_2O	=	$4(C_2H_6O)$	+	$4(CO_2)$
Cane-sugar.		Water.		Alcohol.		Carbon Dioxide.

According to which alcohol and CO_2 are formed in the proportion of 184 parts—4 (24 + 6 + 16)—of the former to 176—4 (12 + 32)—of the latter, or in percentage 51·11 of alcohol to 48·89 of CO_2.

According, however, to Lindet and Marsais (recent work), the ratio of alcohol to CO_2 diminishes continuously during fermentation, more alcohol being formed at the outset, but the CO_2 gradually overtaking it, so that at the close the two are in equal quantities, the ratio not being apparently influenced by temperature or acidity at any stage.

However this may be, Dubrunfaut, soon after the above equation was issued, stated the impossibility of making the equation of fermentation with alcohol and carbonic acid alone ; but it was left for Pasteur to prove that a proportion, which he estimated as averaging about 5% of the fermentable matter, was diverted into the formation of by-products and of tissue for the newly formed yeast (approximately 4% for the by-products and 1% for the yeast).

His conclusions, summarised by Schutzenberger, and a further development of them, are as follows :

Pasteur endeavours to represent by an equation the decomposition of the four parts of sugar which yield succinic acid and glycerine. The expression is very complex.

$$\left.\begin{matrix}49(C_{12}H_{22}O_{11}+H_2O)\\ \text{or } 49(C_{12}H_{24}O_{12})\end{matrix}\right\} + 60H_2O = 24\,(C_4H_6O_4)+144(C_3H_8O_3) + 60CO_2$$

According to Pasteur 105·65 grams of glucose yielded: ethyl alcohol 51·11, carbon dioxide 49·42, succinic 0·673, glycerol 3·40 = total 104·603.

This equation can only be considered, as Pasteur himself says, as a very approximate expression of the numerical results of the analysis, and not as a mathematical expression of the reaction.

A much simpler equation was proposed by Monoyer (*Thèse de la Faculté de Médecine de Strasbourg*) to represent the results of Pasteur's analysis.

$$\left.\begin{matrix}4\,(C_{12}H_{22}O_{11} + H_2O)\\ \textit{or}\ 4\,(C_{12}H_{24}O_{12})\end{matrix}\right\} + 6H_2O = 2(C_4H_6O_4) + 12(C_3H_8O_3) + 4CO_2 + O_2$$

He supposes, at the same time, that the excess of oxygen serves for the respiration of the globules of the ferment, a possible, if not a very convincing conjecture.*

It is to be understood, of course, that the proportions of these two by-products are never absolutely constant for a given weight of sugar. Where the fermentation is slow, in the sense of being really sluggish, or where the yeast is weak or vegetating under unfavourable conditions, the proportion of alcohol produced seems to decrease, and that of the glycerine and succinic acid to increase in proportion. On the other hand, a good store of assimilable nitrogenous food and of suitable mineral matter *in organic combination* increases the amount of alcohol and lessens that of the by-products. This has probably a bearing upon the apparent anomaly involved in the undoubted benefit which many brewers have experienced from judiciously added yeast foods, while all the time their wort contains nitrogen far in excess of what any conceivable growth of yeast cells could absorb, if only it were in the highly peptonised condition of the added material. A slight acidity of the medium is also regarded as somewhat unfavourable to by-products, the reverse being noticed if the medium be neutral.

Now, however, the fact that in acellular (zymatic) fermentation the quantities of glycerine and succinic acid are less than where living cells are employed points to the fact of their being **metabolic** products of yeast, which vary with the factors influencing the yeast's fermentative vigour. If we accept Brefeld's conclusion that these by-products are mainly formed at close of fermentation, or when exhausted yeast is used, and generally when conditions are unfavourable to its activity, it would seem that fermentative vigour is less resistent to adverse influences than metabolism is. But recently Seiffert and Reisch have come to the opposite conclusion that most glycerine is produced in the early stages when yeast production is strongest, hardly any at the close. This may be true for vigorous fermentations and Brefeld's view for those with feeble or impure yeast; at any rate, with pure yeast (Hansen's No. 1) the ratio of alcohol to glycerine has been found as low as 100 : 2·63, while

* The probability of this conjecture is questioned, because, as far as the writers know, the elimination of free oxygen has not been observed in normal fermentation. There is practically no doubt that oxygen plays an important part in the decomposition of the glucose molecule, but that it is oxygen which is a product of the electrolytic decomposition of the water necessary to the hydrolysis, during which the action is so rhythmic that neither oxygen nor hydrogen are liberated, as such. As we have seen, hydrogen is evolved in a butyric fermentation (p. 149), and this implies the setting free of a corresponding amount of oxygen; but the immediate result is the formation of products more highly oxidised than alcohols, namely acids.

Modern science certainly tries to explain the different actions of enzymes by the accumulation of O. atoms at non-contiguous carbon atoms, producing asymmetry or otherwise with a given enzyme, and fully thirty years since Baeyer's still-quoted series of formulæ was drawn up to illustrate the hypothesis that an accumulation of oxygen at certain points of the glucose molecule, consequent on alternate separation and addition in different order, caused weakness at those points and that there disruption might occur.

with a very large number of lagers the ratio ranged from 100 : 5·457 to 100 : 4·140. In view of the formation being metabolic, and not directly fermentative, the Gay-Lussac equation may still be taken to express the fermentative result.

In the present chapter, be it understood, we have been and are discussing **Commercial or Industrial Yeast,** which though nominally consisting of the cells of *Sacch. cerevisiæ* (the true alcoholic ferment), really consists of an admixture of yeast-types, infected, however slightly, with a few of the other organisms, known as bacteria or bacilli, and classed by Pasteur under the name of *ferments de maladie.*

But in any fairly good yeast there is an immense preponderance of the cells of *Sacch. cerevisiæ*, and under conditions favourable to its growth it will develop so much more rapidly than the undesirable organisms, that the mischief wrought by the latter is much restricted, and except when ales are being brewed for long storage is hardly of practical significance. Whether there is any " crowding-out " of " wild yeasts," with a restriction of the evil influence of some of them (for which see next chapter) by conditions favouring a vigorous growth of *Sacch. cerevisiæ*, is less clear, but assuredly, if absolutely pure yeast could be employed to excite fermentation and all access of bacteria prevented, there need be no limit to the keeping quality of the product.

But this ideal state of things is impossible with the ordinary arrangements of a brewery plant. The prolonged exposure of worts, on the coolers and in other vessels, gives ample chance for spores of bacteria and mildews to fall into the fluid, and these spores or germs are capable of resisting the heat of the wort, after it has left the copper, whatever it may be, a heat which would be often sufficient to destroy the fully developed organisms.

So it is here that the question of sound material and good manipulation becomes important ; if the ideal state of things—absolutely pure yeast and exclusion of bacteria—could be secured, the soundness of the material would be a minor matter ; but in the actual state of casual contamination unsound malt and hops tend to give bacteria the upper hand ; with badly contaminated yeast, no malt, however sound, and no manipulation, however skilful, will suffice to produce a stable beer ; it is only when malt and hops of first-rate quality are skilfully manipulated, and the wort produced from them is set to ferment with yeast free from visible contamination, that the casual bacterial contaminations, numerous as they are, get so pressed in the background, that the final product can be relied upon to withstand the forcing-tray test, or support the ordeal of consignment to the tropics.

Undoubtedly the number of aerial spores varies greatly.—Prolonged rain, as Miquel showed, greatly purifies the air from bacteria, and so long as the earth keeps moist their number continually diminishes. As the air dries their number proportionally increases. The contrary holds good with the spores of mildews.

Such being the enemies to whose attacks beer-wort lies exposed, an important thing to do is to assist, as far as possible, the survival and predominance of what is fittest from the brewer's point of view—viz., the alcoholic ferment, *Sacch. cerevisiæ*. What the most favourable conditions are we shall in a short time consider.

High and Low Yeast.—Of the ordinary alcoholic yeast, *Sacch.*

cerevisiæ, there are two distinct varieties (without counting sub-varieties of which two at least, *Sacch. cerevisiæ I.* and *Sacch. cerevisiæ II.*, have been isolated), viz., high yeast, and low yeast. The high yeast (surface or top-fermentation yeast) is used to ferment infusion beers, and is the variety known to English brewers ; low yeast is the variety which brewers of Lager beer employ in the fermentation of decoction-worts.

That they are simply deviations from a common stock, started and made stable by the persistently different conditions under which their vital activity is exerted [amongst which need only be cited the frequent aeration which high yeast undergoes and the very much higher temperature at which it works], few will be disposed to doubt, though it is more questionable whether either variety could, by suitable treatment, be changed into the other in the course of a few fermentations.

An authority of great weight, Jorgensen, says : " In spite of many assertions to the contrary, it has hitherto been impossible to bring about an actual conversion of top yeast into bottom yeast, and *vice versa;* according to the investigations of Hansen and Kuhle, it is easily possible to produce transitory top fermentation phenomena with a bottom fermentation yeast ; these, however, quickly disappear with the progressive development of the yeast. Therefore, when it is stated that bottom yeast, for instance, can be converted into top yeast by continued cultivation at an elevated temperature, we must first assume that the bottom yeast employed was impure, and had contained admixed top yeast, which slowly developed by cultivation at an elevated temperature at the expense of the bottom yeast, until it finally constituted the chief portion of the yeast."

It was stated above that at least two varieties of *Sacch. cerevisiæ* had been isolated. To be strictly correct, according to Jorgensen, there appear to be at least three distinct races of bottom-fermentation and the same number of races of top-fermentation yeasts, which have been prepared in a pure state. Dealing with the latter class only, their characteristics are—

No. 1. Slight attenuation, quick clarification. The beer has a sweet taste.

No. 2. Great attenuation, quick clarification. The beer has a more pronounced taste.

No. 3. Slow clarification, but *giving normal after-fermentation.* Flavour more wine-like. The beer resistant to yeast turbidity.

The importance of the words in italics will be seen in connection with the subject-matter of the next chapter, and with the latest view of " cask-conditioning," dealt with elsewhere (pp. 319).

Neither of the above sub-varieties are wild-yeasts, and consequently may be expected to co-exist in the very purest specimen of commercial yeast ; if then the results produced by pure cultures of them *in identical worts* are so markedly different, this may help us to see why the beer from one brewery will have a flavour and *cachet* quite distinct from that produced in another, however much the materials and systems employed may be alike, and to attribute the fact to one or the other of the sub-varieties having gained the preponderance.

It may also help to explain why a modification of mashing-heats designed to bring about a change in the character of the product (say in the direction of more or of less attenuation) does not always bring about that

change at once with mathematical certainty, because maybe, in the pitching yeast used, the sub-variety, unfavourable to the desired alteration, preponderates.

It will of course be understood that it is impossible to differentiate these sub-varieties by aid of the microscope, and in many cases even the cells of wild-yeasts are only distinguishable by the Hansen method of analysis (ascospore and film formation) to be touched upon in the next chapter. With this reservation we will proceed to describe

The Appearance of the Cells under the Microscope.—In outward shape the cells of the top fermentation or high yeast are rather larger and more globular than those of low yeast, but in any microscopic "field" some of the cells will appear oval, others round, according as they are observed sideways or "end-on."

In the very young cells, such as may be found in a drop of wort taken from a tun in incipient fermentation, a portion of which is examined under the microscope, the contents have a clear appearance almost like water—*i.e.*, they contain clear and homogeneous plasma; in the more developed cells careful observation may detect a finely granulated condition of the contents, while in the cells which are germinating there will be distinctly visible in the protoplasm one large **vacuole**, or two (or more) smaller ones, which appear to consist of clear liquid isolated in the form of drops.

These are the most vigorous cells, which, probably on account of the great abundance of nitrogen in their protoplasm, are the heaviest and the best fitted to effect reproduction. Later still the internal plasma may contract still more, and one abnormally large vacuole be discerned, but generally the contents of the old cells will be darker and more coarsely granulated and without vacuoles. They are then enclosed by a *thickened* membrane, which occasionally is compressed in such a way as to give the cells an irregular shape. [N.B.—A slight alteration of the fine adjustment causes these vacuoles to look lighter or darker than the surrounding part of the cell, and the cell itself than the surrounding medium according to the focal distance.]

Nuclei (in the Cells) and Rejuvenation of Old Cells.—Further cell-nuclei are observable on staining with certain reagents,—*e.g.*, osmic or picric acids,—and there are sometimes spherical bodies within the vacuole, occasionally moving with some activity in the clear plasmic fluid; this, however, we have most clearly noticed in a "field" of *Mycoderma vini*. If mature cells, in which the protoplasm has shrunk towards the cell-wall or membrane, be placed in a fermentable liquid, they present, says Jorgensen, "a highly characteristic picture during the short period which precedes the phenomena of fermentation. The granulations disappear, and numerous fine threads of plasma occur in the clear cell-sap and gradually mark out rounded vacuoles; finally these disappear, and the cell is again filled with a clear homogeneous plasma."

Detection of Old and Effete Cells.—The best way for those who are not as yet very expert in observing yeast, if not for all, to enable them to detect old and effete cells in a sample of pitching yeast, is to add a little aniline blue to the water with which the yeast is diluted in preparing it for the microscopic slide. The colouring matter very soon penetrates into the interior of the aged cells and stains them, but the young and vigorous cells,

being able to resist it, remain uncoloured. A weak solution of iodine has a similar effect, the worn-out cells being stained brown.

Regularity of Size is also a desirable feature, so that, other things being equal, a yeast in which the cells appear uniform, though only of moderate size, might be expected to give better fermentation results than one in which a portion of the cells are larger and a portion smaller.

As a rule, high fermenting temperatures, if continuous, tend to determine irregularity of size, and so will cultivation in strong worts, as compared with those of medium gravity, when they serve as the fermentation medium, the abnormally large cells consisting of over-fed, gorged specimens, which are on the point of losing their special functions. Hayduck's researches —to be referred to again in the chapter containing the section on yeast-turbidity—showed pretty conclusively that fermentative vigour increases with the amount of nitrogen present *up to a certain point*, after which a loss of assimilative power in respect to the nitrogenous constituents of the wort rapidly occurred ; a discovery which furnishes one reason why **store-yeast, taken from fermentations of wort whose original gravity was only medium, say 15 to 18 lb., gives better results than that taken from worts of much greater density,** though the latter would, at first sight, be expected to show greater fermentative and reproductive vigour.

Pitching Yeast Selection from Microscopic Examination.—In the choice of a pitching yeast based on a microscopical examination, regard should also be paid more to the type and nature of the disease-forming micro-organism than the number present detected. There are acid-forming bacteria, of which perhaps only a trace may appear in a microscopic field, yet they possess nevertheless such a tremendous power for development at the expense of the beer and the prestige of the brewery that their presence in yeast cannot be ignored. During the height of fermentation the vigour of the primary yeast, which is then at its reproductive maximum, compels alien micro-organisms to remain inert, but when skimming point is reached and the beer is cleansed of its yeast the bacteria has a clear field for its depradations which, if favoured with temperatures at this stage of above 68° F. or 70° F., together with the advantage of a diminished volume of CO_2 and the absorption of oxygen, may produce incipient acidity in beer. Apart from the regular examination of pitching yeast by a practised hand, or rather eye, and the rejection of all skims exhibiting evidence of contamination, the last heads should, as an additional precaution, be always discarded. Since the introduction of weaker beers greater care has to be exercised to ensure cleanliness of plant and premises, and while formerly an occasional dose of an artificially prepared yeast food was sufficient to maintain yeast vigorous and healthy, now the addition of nutrients have to be resorted to in many instances almost with regularity, without which addition the yeast would fail to find in present-day wort the necessary nutriment for its normal reproduction, weakness would inevitably follow and both the beer and the yeast would be at the mercy of the disease-forming micro-organisms which are less affected by such conditions. It falls to the lot of the modern brewer to successfully produce an article under difficulties which would have been regarded as insurmountable by craftsmen of a former generation.

We say one reason because repletion of the cells is not the only one why yeast taken from high-gravity worts tends to weakness instead of strength. In such worts the fermentation itself loses much of its original vigour as attenuation advances, the yeast being, as it were (and as happens to other ferment-organisms), hampered, if not poisoned, by its own excretion-products, notably the alcohol, and as a consequence, only producing a relatively degenerate offspring.

Severe Ordeals which Yeast can survive.—Although an alteration in the constitution of a wort, which is relatively very slight, will destroy that delicate equilibrium of reproduction and fermentation which is essential for the brewer, yet yeast will retain its vitality under conditions, the rigour of which would kill higher organisms instantaneously. According to well-known observations by Melsens—

(1) Fermentation *can* proceed in melting ice, *i.e.*, at a temperature too low for grain to germinate in.

(2) Its vitality is not destroyed by a temperature of — 100° C., say, or 148° Fahr. *below zero.*

(3) Yeast immersed in water and enclosed in strong vessels can resist the pressure caused by the water being frozen, even when the pressure is of the intensity of 8,000 atmospheres.

[If this be so, it is by no means wonderful that yeast can resist the pressure applied by an ordinary yeast press, without any rupture of its elastic cell-walls.]

Further, it is stated, that yeast, when carefully dried, will withstand heating up to 212° Fahr., although a much lower temperature will destroy the activity of ordinary moist yeast.

Its Limitations.—On the other hand, all alcoholic fermentation, even the feeblest, is stopped when the temperature is maintained for some time at 120° Fahr.; indeed the maximum temperature for genuine alcoholic fermentation may be looked upon as about 92° Fahr.

Similarly, fermentation only reaches a point short of the normal, in a closed vessel; and when the pressure of the evolved carbonic acid exceeds 25 atmospheres, the yeast perishes.

Analysis of High Yeast.—Concordant analyses of yeast are hardly to be expected. The following are given by Thausing, as the results determined from high yeast, apart from its ash.

	Dumas.	Mitscherlich.	Mulder.	Wagner.
Carbon	50·6	47·0	50·80	45·5
Hydrogen	7·3	6·6	7·16	6·2
Nitrogen	15·0	10·0	11·08	9·4
Oxygen (and Sulphur) . .	27·1	36·4	30·98	38·9
	100·0	100·0	100·02	100·0

The sulphur according to Mitscherlich being ·6%,

The Nitrogen is of course in various Combination.—Von Nageli made the proteids (separable into (i) those in the form of ordinary albumen, and (ii) those in the form of phosphated compounds, analogous to casein) 36 and 9 respectively, and peptones (precipitable by lead acetate), 2%, or 47% in all, which, taking the usual divisor of 6·37, gives a lower percentage of nitrogen than any of the high-yeast analyses show.

The Ash (representing the Mineral Constituents) varies from 2·5%

(Schlossberger) to 8·9% or more. It is supposed that Schlossberger's low percentage was due to his having experimented with freely washed yeast, which had accordingly parted with an appreciable quantity of its mineral constituents. And the mineral constituents, or ash, may be taken upon the average to be made up as follows :—

50 to 59% of phosphoric acid, 29 to 39% of potash, 4% of magnesia, and 2% of lime.

Consequently we see **the necessity of mineral constituents,** chiefly phosphoric acid and potash, in any medium intended to nourish or be fermented by yeast. And hence, as well as owing to the absence of nitrogenous food, yeast cannot carry on a prolonged fermentation in a pure solution of sugar.

For a short time fermentation—given a suitable temperature—can progress, the adult yeast giving up some of its own nitrogenous matter to supply the young cells, but this is a process of impoverishment which can be only temporary. The overlooking of this has probably been the cause of apparently contradictory experimental results.

Of each of the two groups (mineral matter and nitrogenous food) fairly prepared malt wort contains more than a sufficiency, but the replacement of a large proportion of the malt-extract by saccharine substitutes—and the more so perhaps, the purer the latter are—tends to reduce them below the quantity desirable. In such a case, accordingly, the desirability of the utmost possible " peptonisation " of the existing nitrogenous matter, in order to make it available for yeast nutrition, is obvious.

Some brewers, where the wort shows a deficiency in those constituents, advocate continuous rousing as a stimulant to the yeast, but this is a treatment which cuts both ways.* Indubitably both the resultant aeration and the elimination of some carbonic acid are measures calculated to give a decided fillip to the yeast, but in reality one stimulating its propagative rather than its fermentative faculty.

In the majority of cases the course indicated is to use a larger initial proportion of pitching yeast when the medium is likely to be below the proper nutritive value—*i.e.*, to depend for the due attenuation rather upon the mature cells of the pitching yeast than upon the cells which they may give birth to. If such a course be adopted without excessive aeration the yeast will assert its presence rather in the fermentative than the propagative sense.

Effect of extreme Aeration.—This was investigated in connection with M. Pasteur's dicta upon **Aerobic** and **Anaerobic** ferments, *i.e.*, ferments which require air in order to perform their function and those which only act as a ferment when air is excluded, and as far as the writers know, the conclusions come to by Pasteur and his school have not in one respect been controverted, namely, in regard to the influence exercised by the oxygen upon the increased crop of yeast on the one hand, and the decrease of alcohol, etc., on the other.

* In one large brewery within our knowledge the early " heads " are systematically knocked in every hour or two, often enough, at any rate, to prevent the necessity of boarding up the tuns. Another has a costly apparatus of shafting and permanent rousers. Dr. Graham, too, a good many years ago, designed an apparatus for pumping in filtered air, and thus combining aeration and rousing. He claimed that by its use very strong beers intended for vatting, which in the usual way would not attenuate below say 8 or 9 lbs., could, if desired, be attenuated to a third of that.

These conclusions may be formulated thus.—Yeast, though it *can* exist and act as a ferment without air (deriving its necessary oxygen from the sugar which it breaks up), does not like to do so; and it is, in fact, less able to support the absence of free oxygen, or more correctly atmospheric oxygen, than many disease organisms are—*e.g.*, the butyric ferment, which was once supposed to be quite anaerobic. Therefore, though yeast is capable of fermenting sugar in the absence of air, such fermentation goes on with dangerous slowness, but in one sense very profitably, seeing that only 1% of the sugar is abstracted for the necessities of the growing ferment, the other 99% being available for the production of alcohol, carbonic acid, etc.

But if, on the other hand, the operation were to be conducted with thin layers of wort and in such very shallow vessels that any gas evolved, which might otherwise prevent the readiest access of air, easily passes off, then not only will yeast, amounting in weight to some 25% of the sugar and probably representing that weight of it, be formed (instead of a weight approximating to 1%), but the remaining 75%, or thereabouts, of the sugar will be burnt up by the atmospheric oxygen and resolved into water and carbonic anhydride (CO_2), giving almost absolutely no alcohol at all.*

This being so, we may doubt the wisdom of excessive and indiscriminate aeration of worts after the fermentation is well established. More yeast will be clearly produced, but it will be at the expense of the matters which were intended to yield exhilarating and palatable products.

These facts have their analogues amongst plants more highly organised. To name one instance only, beetroot, which is capable (after being lifted from the ground and given free access of atmospheric oxygen) of forming fresh leaves, *i.e.*, fresh cells at the expense of the sugar stored up in its root tissues, will, on the other hand, says Duclaux, produce alcohol from the same store if placed in carbonic acid gas so that air is excluded.

Alcohol percentage.—Highest Allowable Density of Saccharine Wort.—Probably in no case can any yeast, however pure or vigorous, raise the proportion of alcohol beyond 14 to 15%, nor is fermentation likely to progress in a solution containing more than 20% by weight of fermentable matter (water 4 : sugar 1)—say in a gravity of over 51 brewers' lb.—perhaps owing to the reason assigned by Helmholtz, viz., that in solutions of greater density the excess of alcohol formed, by precipitating nitrogenous matter hindered the fermentative vigour of the yeast, but quite as probably to the fact that the alcohol and carbonic acid produced act as specific poisons. Moreover, in solutions of great concentration the excess of sugar tends to diminish the amount of water within the yeast cell to a point below that essential for its vitality.

Heat generated during Fermentation.—The reader knows that fermentation is always marked by a rise in temperature, which is fairly close to a rise of 1° Fahr. for each brewers' lb. of gravity disappearing from the ken of the saccharometer. What is the source of this heat ?

* This hypothetical case of the unprofitable combustion of all the saccharine matter is, of course, an extreme one, unless as regards a very small proportion of the constituents of any given wort; but it may indicate an explanation of the unpleasant experience of most exporters of beer—viz., that occasionally the samples taken at the shipment port are affirmed to show, on analysis at Somerset House, a gravity lower than that which was declared for drawback. It is of course annoying for the shipper, who knows he was charged upon the higher scale, to be mulcted perhaps in two or three degrees, but his first impulse to condemn the analyst of inaccuracy is probably unjust.

We know that in chemical decompositions and combinations generally heat is evolved, and a German scientist, Fitz, explains the greater part of the heat which becomes free in fermentation to be due to the difference of expansive force between the sugar on the one hand and the bodies into which it is broken up on the other. Some again refer it to a combustion process, and make it dependent on the amount of carbon oxidised into carbon dioxide. Further, Thausing says, no inconsiderable amount of heat—nearly one-fourth of the whole—is set free by the mixture of the alcohol formed with water.* But on the other hand, part of the warmth set free is absorbed by the multiplication of the yeast-cells and part is translated into work, whereby the resulting carbonic acid gas is enabled to overcome the pressure of the atmosphere.

But the heat actually generated in a normal fermentation is estimated at only one-tenth part of that which the combustion of the sugar, with free access of air, would yield (Bertholet says one-fifteenth part only), and this limitation is explained, on a simple combustion theory, first, by the fact that only one-third of the total carbon is consumed instead of the whole, and secondly, because the alcohol, which is formed in the case where air is excluded, is itself combustible, through the agency of certain ferment-organisms other than yeast, and therefore—until these other organisms come into play—that it locks up a not inconsiderable amount of heat.

Concurrent Action of Acetic and Lactic Ferments.—In pre-scientific times brewers used to find it gravely stated in their text-books that acetous fermentation began at a certain temperature—77° if we remember rightly, neither more nor less. There is, however, reason to suppose that no definitely fatal temperature exists, but that the action of the acetic as well as of the lactic ferment is generally to some extent concurrent. The formation of acetic ether (ethyl acetate), which contributes to the pungent smell of tuns in strong fermentation, not only points to some activity of an acetic ferment, but, as has been said, supports Nageli's view that the fermentative influence is exercised outside the cell, but within zones of molecular vibration.

It is true that the formation of acetic acid chemically by oxidation of alcohol is a possibility (though in a laboratory only effected when platinum black is added), and it is perhaps conceivable that such acetic acid, at the moment of its formation, might penetrate the cell-membrane of the nearest yeast-cell (yeast is not averse to moderate acidity, indeed is stimulated by it), and there combine with its equivalent of *nascent* alcohol to form acetic ether.

We believe the range of fermentative power to be fairly covered by the following table :—

	Action Begins.	Maximum Activity.	Action Destroyed.	
Yeast ... a little over	32° F.	92° F.	122° F.	Vitality destroyed as well.
Acetic Ferment .	54° F.	97° F.	122° F.	
Lactic Ferment .	50° F.	112° F.	122° F.	But vitality can support a much higher temp.

* It is well known that on mixing absolute alcohol with water a very considerable rise of temperature occurs, though the combined quantity shrinks below those of its component parts. This may account, too, for part of the loss of bulk which occurs between that of the gathered wort and that of the racked beer.

Fortunately, however, the lactic ferment develops with difficulty in the presence of even 1% lactic acid, while 2% kills it; yeast, on the other hand, *prefers* a degree of acidity approaching 1%.

Growth of Moulds.—If a mixture of yeast, bacteria, and moulds were to be introduced (and they always are introduced, though the former enormously preponderates) in anything like even quantity into—

(α) A neutral wort. Bacteria would gain the upper hand.

(β) Wort with 1% acid. Yeast would gain the upper hand.

(γ) Wort with 5% organic acids. Mouldiness would gain the upper hand.

(DR. SQUIRE.)

Other Fermentation Phenomena.—Attenuation.—At first sight it might be supposed that the lowering of gravity indicated by the saccharometer as any fermentation proceeds, would show the actual amount of saccharine matter converted into alcohol, carbonic acid, etc., + the 1% of sugar and albuminous matter abstracted for the food of the growing yeast plant. But this is not so.

The apparent degradation of solid matter is greater than the real one, owing to the fact that the great specific lightness of the alcohol formed (displacing an equal quantity of heavier water) masks a certain amount of unaltered matter. Let us assume a case.

A beer whose final attenuation = 1,016·2 (say 5·8 lb.), might, if a measured quantity were distilled and the distillate and residue then made up to the original bulk in the way described on p. 193, have a residue (*i.e.*, when all the alcohol was away) = 1,024·7 and a distillate of 991·4 (= 10·9% of proof spirit, or over 5·3% of absolute alcohol ? *

Obviously, then, the alcohol present hid 8·5 degrees of specific gravity, or a percentage of solid extractive matter which may be got approximately by dividing the excess of degrees over 1,000 (viz., 24·7 and 8·5 respectively) by 3·95. [3·85 is sometimes recommended, but 3·95 is considered the more correct divisor for starch transformation products in solutions of low density.] Then $\frac{24{\cdot}7}{3{\cdot}95} = 6{\cdot}25\%$ of solid extract and $\frac{8{\cdot}5}{3{\cdot}95} = 2{\cdot}15$ of the same covered or hidden by the alcohol present.

Nor is the alcohol, though by far the most influential, the only factor in what we call attenuation. Caramelised sugar bodies are formed, having only the gravity 5 : 6 compared with that of the maltose which yielded them. They are, however, not produced beyond the limit of 5%, and generally less than that of the total sugar, but remain in the residue, and thus affect final gravity. Glycerine and succinic acid also have a lighter specific gravity than the sugar which yielded them, and the farther fermentation is pushed, the higher will be the proportion of these by-products at the expense of the alcohol.

Proteins are, moreover, eliminated to the extent of at least one degree of gravity.

* The spirit indication 8·6 (1,000—991·4) shows 37 degrees of gravity lost; 37 + 1,024·7 = 1,061·7 (= 22·2 brewers' lb.). So that this beer attenuated to nearly an (apparent) fourth, has nearly ½% proof spirit per lb. of original gravity, and seeing that proof spirit contains 49·24% absolute alcohol *by weight* (or at least alcohol containing not more than 1% water), there will be nearly half the quantity of absolute alcohol that there is of proof spirit. Although the example here given applies to what is now termed a heavy beer, the argument is equally applicable to light ales.

The latter considerations can hardly be taken account of; they are at most mentally averaged by the practical operator. The hiding effect of alcohol is more important, but only requires to be stated for its significance to be grasped.

Perhaps a more important point is **the influence exerted by hops in preventing the loss of gravity in a wort.** Nettleton (p. 22 of his very detailed "Original Gravity") says: "It appears that hops tend to prevent the loss of gravity in a wort, *although the same amount of alcohol may be produced.* To do this, some compensating action must be going on in the wort during fermentation, say by the building up of some heavier body; by the prevention of the formation of some lighter body, which would, if hops were absent, be formed, and consequently give lightness to the beer; or the action of hops in retarding the loss of gravity may be by their preventing the precipitation of some otherwise insoluble body.

"The mixing together of pale and brown malts to form a wort has a similar effect to that of hops, in partially preventing the loss of gravity."

[This action is distinct from and more recondite than that exerted by hop-extract, derived from heavy hopping, and especially from the introduction of a large proportion of new hops, upon the rate and extent of fermentation. In this latter case it seems probable that the resinous and oily matter of the hop either coats the membranes of the yeast-cells, rendering them less permeable, or makes the wort too viscous for the easy separation of the maltose.

Whatever the explanation may be, the fact is within the experience of most brewers that heavy hopping—and the rule applies in some measure to the use of new hops also—retards the fermentation and tends to check attenuation. The course indicated, then, is naturally the employment of a larger quantity of pitching-yeast].

Influence of Cane-sugar on Attenuation.—Some brewers, though not many in this country, use uninverted sugar in quantity, and the author of "Original Gravity" points out an interesting fact in connection therewith—viz., that if it were practicable to prepare a wort entirely from cane-sugar, it would be found two or three hours after the wort had been pitched, that the gravity had become higher, instead of lower, owing to the change of cane-sugar into invert-sugar [$C_{12}H_{22}O_{11} + H_2O = 2\ (C_6H_{12}O_6)$—*i.e.*, 19 parts, or say lb. into 20 parts or lb.], and he says that a cane-sugar wort might even rise from 1,055 to 1,058 under these circumstances.* Or to put it in another form. Suppose a wort containing 7·5% of cane-sugar—*i.e.*, 3·158% of carbon with a gravity of 1,030·2. This, by inversion, will rise to 1,031·3—*i.e.*, there would be an increase of 1·1 degree of gravity, albeit the same quantity of carbon would be present.

Now, as the quantity of alcohol producible depends on the amount of carbon, it is evident if the carbon of these sugars were all fermented equally that an invert-sugar wort of 1,031·3 would lose a full degree of its original gravity more and yet produce no more alcohol than a cane-sugar wort of 1,030·2, and this holds good throughout for any invert-sugar wort as

* 1,055 degrees = 19·8 brewers' lbs. If 15·8 lb. cane-sugar dissolved and made up to a barrel gives a gravity of 6·12 (*v.* p. 112), 51·10 lb., disregarding a contraction that occurs with concentration, will give 19·8 lb., and, on inversion, would become 53·78 lb. of invert. Thus:—

342 (*from* $C_{12}H_{22}O_{11}$) : 360 (*from* $C_{12}H_{22}O_{11} + H_2O$) = 100 : 105·26.

compared with a cane-sugar wort of equal gravity, except that the higher the gravity, the more the divergency increases.

The first paragraph does not imply, as a friendly critic imagined, that "matter is made out of nothing," for if 100 lb. of cane-sugar yield on inversion 105·26 lb. of invert, it is by chemical combination with the elements of water obviously abstracted from the diluent fluid. The water molecules are not only added to the *credit* side, but withdrawn from the *debit*, the diluent. Increase of gravity on inversion may not be observed with moderate concentration, because fermentation starts almost simultaneously and masks the increase; but a solution of 1,100, set to ferment with a moderate quantity of yeast, may show 1,103 or 1,104 even 12 hours later.

"The Head."—"Foxy" Smell.—It was hinted in the opening chapter—where fermentation from its practical side was rather more fully treated than other operative processes—that picturesque names are not wanting for the different appearances of the "heads"; thus "rock," "bold rock," "cauliflower," "curl," "fair silvery head," and so on are all descriptive terms, and a great deal may be gathered from a close observation of these heads and from the smell coming over with the carbonic acid gas.

For instance, a faint and rather "foxy" smell may at some time or other be noticed, and this, if allowed to get round all the fermentations, would be a very serious matter, for the contaminated yeast carries on the taint. The elimination of the contaminated yeast is an obvious precaution, but no time should be lost in treating the wooden vessels (the writer believes the cause of infection to lie in the wooden vessels, especially the fermenting vessels) with bisulphite.

A periodic dressing of the fermenting tuns, or wherever they chance to be empty for a day or two, with calcic monosulphite applied in the form of thin whitewash and left on until the tuns are cleaned for use, will prevent the recurrence of this faint smell. Monosulphite is much less disagreeable to apply than bisulphite.

The Rise and Fall of the Head.—In a normal fermentation, the head, soon after the "rocks," or irregular, pointed masses of yeasty froth, have "come through" and covered the entire surface, begins to rise (of course, in a degree varying with the depth of the F. V., etc.), the individual rocks meantime rising up with the pressure of carbonic acid gas beneath, until they curl and finally topple over; and this rise of the whole head continues up to a certain point, say till the temperature has risen 5° or 6°, more or less, when it again subsides gradually, changing from the frothy "fobby" head into a yeasty one, after which stage, unless the said head be removed by skimming or otherwise dealt with when ripe for it, it will again begin to rise.

What are the Causes of these Phenomena?—Probably, that in the first stage, when cell-multiplication goes on more freely than fermentative action, the carbonic acid gas which is generated pushes up some of the newly-formed cells, wherever resistance is least, finally forcing upward and raising the head as a whole, and continuing to do so until such time as the generated gas can get away more easily, on account of the original density of the wort having been considerably reduced, or when fermentation rather than propagation having become predominant, there is not

that rapid formation of new cells of light specific gravity which at first occurred. [It will be observed that, other things being equal, the greater the original density of the wort the longer will the first rising of the head last.]

Finally, when fermentative action slackens, the yeast agglomerates at the surface (possibly its activity enabled it before to resist the upward impulse of the carbonic acid gas ; and this will seem more likely if we accept Nageli's theory), and presenting more of an obstacle than before to the passage of the gas, still being generated, is accordingly carried upwards. That this is so, viz., that the gas, hampered in its passage upwards, is the determining factor, is rendered the more tenable by the fact that the yeasty head begins, if left untouched, to sink again as the gas gradually disengages itself.

Poverty of the Yeast Outcrop, (*a*) Sluggish Fermentation.—The normal crop of yeast formerly amounted to five or six times the quantity of pitching-yeast, but with the lighter post-war beers yeast reproduction is correspondingly lower, but if it falls much below the normal amount obtained it should set the brewer inquiring where the screw is loose. Primarily, the scanty development of yeast is due to the formation of protoplasm not keeping pace with cell-formation, or in other words to a want of balance in the wort constituents.

Probably the proteins, though not deficient in point of quantity, are so in respect of the quality of diffusibility ; that is to say, the yeast cannot assimilate enough of them to correspond with its normal degree of growth whilst degrading the free maltose. The latter, relatively speaking, will not be very high (*excess* of maltose as a factor in poverty of outcrop, will be touched upon in the coming paragraph on " fiery " fermentations), but the compound bodies, known as malto-dextrins, and those too of high type, and therefore utterly beyond the power of the primary yeast to break up, will probably show an unduly high percentage in the wort-extract. The superabundance indeed of high-type malto-dextrins would alone be sufficient to account for a much-reduced yeast-crop, even if there were not reason to suppose that restricted peptonisation is concurrent.

This degeneration of the ferment is generally attended by more than the usual discoloration of the head, and that too persisting to a lower point of attenuation than usual, so that the *clean* yeasty head is a long time in coming. For this discoloration the passing of the hop-resin out of solution, as its solvent maltose gets broken up, is partly responsible, as in other cases ; but it is very probably also due to the action of oxygen upon the relatively large number of weakened cells, which are exposed to it for a longer time than usual—an action which occurs, more or less, when any yeast is exposed for some time to the air, and which may be a sort of combustion-process, exercised by its most energetic element upon the tissues of the older and weaker cells of the outer layer.

In such a case the remedy indicated seems to be (apart from the more thoroughgoing one of reforming the mashing system), " **dressing " with prepared Malt Extract Syrup** (*i.e.*, mixing some with a little wort, and rousing into the tun). The reason of this is that the new diastase introduced is capable of setting to work very energetically in degrading the malto-dextrins into free maltose—*i.e.*, from an obdurate to a readily fermentable constituent, while peptonisation is probably effected to some

extent simultaneously. [In the type of degeneration commencing with a "fiery" fermentation other methods seem preferable, for reasons hereafter given.]

Nor must we overlook the possible influence upon sluggishness of fermentation, of **nitrites** in the brewing water, as set forth by M. Emile Laurent. In a series of experimental fermentations he used a partly uniform medium (1,000 grammes water, 50 grammes saccharose, ·75 grammes potassium phosphate, ·1 gramme magnesium sulphate), and of this he set a check-flask, impregnated with a trace of high yeast, to ferment. To five other flasks he added various salts, each, however, *supplying nitrogen in the proportion of* 1 *gramme*. [These salts were respectively sulphate of ammonia 4·71 grammes, phosphate of ammonia 4·71, nitrate of potassium 7·22, nitrate of sodium 6·07, and *nitrite* of potassium 6·07.*] These were also "set" with a trace of high yeast.

The results were interesting. The sulphate of ammonia flask took the lead, but the one containing ammonia phosphate showed the largest crop ultimately (·174 gramme: ·110 gramme). The nitrate flasks yielded hardly more than the check flask, while the nitrite flask yielded *nil*.

Prepared Yeast Foods or Nutrients.—Potassium phosphate and ammonium carbonate are both recognised as yeast foods. To overcome the diminution of protein bodies and salts in light beers (which will tend to weaken and degenerate the yeast), an addition of mineral nutrients, such as ammonium carbonate, ammonium phosphate or sodium and potassium phosphate is advisable. The quantities advised are 4 ozs. of ammonium carbonate and 6 ozs. of potassium phosphate dissolved in a small quantity of water, or preferably this added to every 5 gallons or 50 lbs. of yeast at the time of brewing.

The main constituents of yeast-ash are phosphates of lime, magnesia and potash, and yeast itself was formerly favoured as a yeast nutrient. The yeast was calcined and then dissolved in a sulphurous acid solution, thus furnishing at least a yeast food which certainly possessed the advantage of being inexpensive. First mash-tun runnings being concentrated malt wort, containing all the essential mineral and organic elements of yeast, serves admirably as a stimulant when mixed with yeast and the whole permitted to remain for a time prior to pitching.

Increasing Body and "Head" Producing Capacity.—The addition of yeast in judicious proportions to the boiling wort produces the above results. The amount of ordinary liquid yeast necessary for this purpose without affecting flavour is from 15 to 20 lbs. for 60 brls. wort, the yeast being preferably washed with a little gypsum water and permitted to settle overnight. This was a common practice in the United States in the pre-prohibition days among public brewers.

Although Laurent suggests that the nitrates are reducible to nitrites by yeast—in fact, proved it by showing that the liquid originally containing the former subsequently answered to the test for the latter—he does not think that the former do much harm in actual fermentation, but that

* The nitrogen yielded is arrived at as follows: adding up the atomic weights, and taking the Sodium Nitrate $NaNO_3$ and Potassium Nitrate KNO_2 as examples, we find the first = (23 + 14 + 48) = 85, the second = (39·1 + 14 + 32) = 85·1, or practically 85. Dividing this by 14 (atomic weight of nitrogen) we get 6·07, the quantity required to yield 1 part of nitrogen.

nitrites, *nearly always co-existing*, do the harm. Even these would be innocuous in a neutral wort, for it is the **nitrous acid** set free by the acidity of the medium which does the mischief; but under normal conditions yeast secretes acid products enough (in conjunction with the normal acidity of the wort and possible products of lactic ferment) to set nitrous acid free.

From these conclusions it appears that brewers troubled with persistent sluggishness of fermentation, combined with scanty yeast outcrop, would do well to look closely into the character of their water-supply, even before making drastic changes in their mashing system.

(β) **Fiery Fermentations.**—In these, although they also determine poverty of yeast-crop, the want of balance is generally in the opposite direction. Excess of free maltose, inducing such a rampant fermentation that the whole fermenting vessel appears to be in a boil with the continuous rush of gas to the surface, is one factor; another is an unusually low percentage of assimilable nitrogenous food, caused probably by unduly high mashing heats, which for some reason or other have not the usual marked influence, at least to the usual extent, in raising the quantity and type of malto-dextrin.

The indication of the former cause has been given a few lines back; the latter will be rather manifested by the formation of bubbles, sometimes of considerable size, and full of gas, which finally burst on the surface. In neither case is any yeast formed unless it be at a somewhat late stage, when, for instance, in the first case the excess of maltose has been fermented away, and so the balance is restored, or when in either case the beer is "cleansed,"* when the effect probably of working under pressure causes a certain amount of yeast to be ejected. But the yeast from such fermentations can never be recommended for pitching purposes, albeit the beer from the second class of fiery fermentations, the one characterised by "bladdery heads," frequently is excellent, being "round," full, and limpid, and, maybe, superior to the average product of the brewery.

As this case is somewhat exceptional, involving the employment of extremely diastatic malt, seeing that with ordinary malt the high mashing temperature which limits the assimilable nitrogenous matter also increases the high-type malto-dextrin to an extent incompatible with early "conditioning," we shall limit our consideration of "fiery" fermentation to the first case, an altogether undesirable state of things, seeing that the resulting beer will be thin, and poor, and often "grey."

In the present case it would be obviously incorrect to add a Diastatic Malt Syrup, seeing that conversion has already been pushed to an extreme. Therefore, under such circumstances, the enzymes present in the malt extract should be destroyed by boiling, after which the solution should be cooled and added to the fermenting wort. By this means the deficiency in organic yeast nutrients is made good, and the lack of balance in the wort constituents is in some measure restored. We must further suppose that the resulting benefit comes from the increased viscosity of the wort, and perhaps from its mechanically assisting the yeast to conglomerate.

It has also been suggested that the fresh atmospheric air introduced with the whisked-up mixture acts as a stimulus to the yeast; but this in

* See Introductory Chapter.

such a case as we are now considering, where the activity is already too great, would be a questionable benefit.

The predisposing Causes of Fiery Fermentations.—Of these of course errors in the mashing system stand first, and amendment may be tried in the direction of limiting the amount of mashing liquor, or of raising its heat (tentatively by a degree or two at a time), or by both combined. Again, as to underlet, a small quantity of liquor so applied at a high temperature is less favourable to free-maltose formation than, and should consequently be employed in preference to, a larger quantity at lower temperature, but containing the same number of units of heat as the former. The said underlet, if used, should be put under as early as possible, and the "stand" after mashing might be somewhat shortened.

Other predisposing causes are slackness and probably acidity of malt. (Slackness apparently greatly enhances diastasic activity.) The use of old or of an insufficiency of hops, the oil and resin of which seem to promote the cohesion of the ferment; the use of stale and impure yeast, and perhaps, to a limited extent, barometric variations.

The following **Table of yeast-cell increase, etc., during the course of fermentation,** based on Mr. Adrian J. Brown's experiments, will be interesting as a standard, though probably only approximately exact for any given fermentation.

Hours after fermentation began.	Yeast-cells present for each one added at pitching	Grammes Alcohol per cent. (by weight).	Mean number of yeast cells present during the interval before time named.	Grammes of Alcohol per cent. formed in each such interval.
12	7·4	0·654	4·2	0·654
24	18·5	1·933	12·9	1·279
36	23·5	2·975	21·0	1·042
60	24·4	4·237	23·9	1·262
84	24·3	6·187	24·3	1·950

The experiments, it should be said, were made with a liquid containing 18% of dextrose, a medium probably of greater density than the one most favourable to yeast production.

Oxygen the Factor in Cell Reproduction.—A series of important investigations by Adrian J. Brown, which occupy over 16 pages of the *Chemical Society's Journal*, can only be given in summarised form here, but there can be little doubt, in spite of the investigator's modest attitude, that he has removed many points from the region of conjecture to one of practical certainty. The enquiries may be grouped as follows: (*a*) Influence of quantity of seed yeast on amounts reproduced; (*b*) restrictive effects of metabolic* products, whether volatile or non-volatile constituents exclusive of, and including alcohol and CO_2; (*c*) the favouring

* **Metabolism** and **Metabolic** are terms used to signify conversion processes occurring in living cells through enzymes or by operation of their protoplasm. Constructive metabolism (**anabolism**) is the building up of bodies from elements or compounds of simpler form—*e.g.*, formation of carbohydrates from CO_2 or starch from sugar. Destructive metabolism (**katabolism**) is the reverse process during which complex bodies are broken up into simpler form. Generally metabolic products of yeast imply, not alcohol and CO_2, but glycogen, proteolysed bodies, and the converse, and perhaps glycerine and succinic acid.

Symbiosis is the association of two different organisms which live together, both being benefited. Yeasts are said to be able to undergo similar associations. Will has reported a case of two varieties of yeast which have functioned in a brewery for 12 years without

influence of food supply; and (*d*) influence of oxygen. And although the last question was the main one, the preliminary enquiries gave very suggestive results.

One, the apparent indication that the rate of reproduction of new cells (*i.e.* of number of new cells found ÷ the number seeded) varies in a given time and tends to vary inversely as the square root of the number seeded, will be clearer from a few figures taken from tables given. The selections are four out of fourteen (Table I.) with dextrose solution, in yeast-water as nutrient, and four (Table II.) with malt wort of s.g. 1·053. It will be seen that decimal parts of a single cell are entered as seeded (col. A), but this is a reduction down to $\frac{1}{4000}$ of a cub. mm., the standard volume in which the reproduced cells could be counted. The first proportion 0·785 in Table II. = 3,140 cells per cub. mm. (= ·000061 cub. inch) is rather above that which a barrel seeded with 1 lb. of liquid yeast is calculated to contain. Temperatures of about 68-69 ° F. were maintained in the incubators in which the worts were fermenting. Column D needs explanation. It attempts to provide data for a mathematical consideration of the question; the fact that the square roots of the number of cells seeded × the rate of reproduction C (otherwise B ÷ A) are nearly identical for each series suggests that the rate will be in inverse proportion to the square roots of the cells originally sown.

TABLE I.—(AFTER 18 HOURS.)

Expt.	A. Cells at start	B. No. of cells after	C. Rate of Reproduction $= \frac{B}{A}$.	D. $\sqrt[2]{A} \times \frac{B}{A}$.	E. Grammes of alcohol in 100 c.c.
1	0·145	3·04	20·9	7·9	0·44
4	0·580	6·08	10·5	8·0	0·83
6	1·500	10·30	6·9	8·4	1·11
14	15·750	27·50	1·7	6·9	4·51

TABLE II.—(AFTER 17 HOURS.)

1	0·785	5·03	6·4	5·7	—
2	1·570	7·77	4·9	6·2	—
3	2·355	9·07	3·8	5·9	—
4	3·140	10·17	3·2	5·7	—

Further figures practically eliminate alcohol as having a retarding influence on cell-multiplication under ordinary conditions; worts to which varying quantities of alcohol had been added previous to fermentation and independent of any formed during fermentation (3·6% in the control non-alcoholised wort) exhibited no restriction below an added 4·2 grammes. Here the cell counting was deferred until multiplication had been completed; in another experiment, where the cells were counted after seventeen hours, a very limited effect on the reproductive rate was observed from an added 2·4% of alcohol, but if the above-noted experiments 1 and 4 (Table I.) be referred to it will be seen that the rate of cell-reproduction was in the second only half that of the first, which must be attributed to something else than the very small increase of alcohol, only ·39%.

Experiments were then made: (1) With a malt wort diluted with already fermented wort; (2) with similar wort diluted with distillate (containing volatile products); (3) wort with residue (containing non-volatile products); and (4) a check experiment, with wort correspondingly diluted with water; all being seeded with the same number of cells. Here the rate of reproduction was practically identical, the non-volatile products blend showing, if anything, the higher rate.

Experiments were next made with worts saturated with CO_2 and hydrogen respectively, these gases, well washed, being passed through for several hours before seeding and for two hours after; the flasks, too, being arranged to retain the gases under atmospheric pressure. Two flasks treated with each gas and two control flasks of

any noticeable change in their individual characteristics. A sort of equilibrium seems to have been established between the two varieties which permits them to live together without harming each other.

wort fermented under ordinary conditions were taken, the cells being counted in one of each sort at twenty hours and again after five days, with the following results.

	Cells added at start	Cells after 20 hours.	Cells after 5 days.
Experiment with CO_2 .	1·25	4·42	8·02
„ „ H .	1·25	4·92	8·70
„ „ air .	1·25	9·10	19·74

The fall in reproduction being substantially the same whether CO_2 or H were the saturating gas, it seems evident that their restrictive influence is negative, not positive, through exclusion of oxygen by them.

Instructive trials were made with non-aerated wort and wort through which a rapid current of air was passed during fermentation, two flasks of each being respectively seeded with cells in proportion 1 : 4. It will be seen that though aeration stimulated cell-reproduction with the higher rate of seeding, it did not do so with the lower, presumably because the cells of the sparser seeding had found oxygen for full development in the unaerated wort.

	Cells seeded	Cells after 17 hours.	Rate of reproduction.	Relative proportional rates of reproduction.
No. 1. Without air .	0·42	8·8	20·9	2·3 : 1
„ 2. „ „ .	1·68	15·2	9·0	
„ 3. With air .	0·42	7·7	18·3	1·4 : 1
„ 4. „ „ .	1·68	21·6	12·8	

Next, to test the influence of nutritive matter *per se* on cell-reproduction, a portion of wort of 1·090 sp. gr. was diluted with water to 1·060, giving two solutions containing nutritive matter in proportion 3 : 2. Two flasks of each, one aerated, the other not, were seeded with equal quantities of yeast, and cell-counting after sixty-nine hours gave the following figures :—

	Sp. grav of wort.	Total number of cells found.
Flask A (with air) .	1·090	55·0
„ B „ „ .	1·060	33·1
„ C (without air) .	1·090	19·9
„ D „ „ .	1·060	19·8

Comparison tends to show that under normal fermentation conditions (no *special* aeration) food supply, beyond an irreducible minimum, does not increase cell-reproduction, while the fact that in the continuously aerated A and B the cells, finally found, were in the proportion of 3 : 1·6, fairly similar to the 3 : 2 of the food supply, tends to show that when the supply of free oxygen is above the normal, it will do so.

The conclusion come to is that cell-reproduction in normal (unaerated) fermentations is conditioned and governed by O. originally at the disposal of the cells before reproduction begins. This conclusion explains : (1) Arrest of reproductive function of the cells under ordinary fermenting conditions, when others, *e g.*, food supply, should favour continuance. (Due to exhaustion of stimulus from O. originally available.) (2) Rapid fall in rate of reproduction observed in earlier stages ; it being natural that at commencement of reproduction, the influence of O. will be most active and that, as cells multiply, this will diminish rapidly. (3) The tendency to approach equality in the number of cells produced in different experiments with varying numbers of cells ; for the amount of O. at commencement of the experiments is constant, and conceivably its power of stimulation is constant and governs the reproductive power of the cells *as a whole*, irrespective of the number present.

Surplus Yeast.—The disposal of this is a problem sometimes not easy to solve, and the following method of preparing **Baker's Yeast**, as given by Thausing, may prove useful.

The fresh yeast is passed through a fine hair-sieve in order to remove the coarser contaminations. Then it is brought into eight or ten times its quantity of the coldest possible water, in which some carbonate of ammonia, soda, or potash (the first salt is preferable) has been dissolved, and mixed therewith in a deep vessel, which has sundry openings, closed with taps, one over the other. The quantity of the salt may be reckoned at 100 to 120 grammes per hectolitre (= 22 gallons) of yeast. The salts act as solvents of the hop-resin, remove the bitter from and purify the yeast at the same time, and that better than water alone can do.

When the yeast has settled, the separated and dirty water above it is allowed to flow off; cold water is again added, and the mixture thoroughly stirred. If the yeast is still not clean enough, a third lot of water is used, or a small quantity of ammonic carbonate (or one of the other salts) is added to the second water. The yeast, by frequent and continuous washing, gets weakened and loses its power ("*Trieb*") in baking. The washed yeast is wrapped up in pressure cloths) *Press-tücher*), moderately pressed, and kneaded up with dry starch, so that it becomes fairly dry, and yet can be formed into quadrangular pieces. The separate pieces are packed in paper and preserved until sold in a cool and dry place.

It is essential to have the water for washing very cold, the best plan being to throw some ice into the vessels, and let the latter stand in a *cold* cellar.

A suggested explanation of the fact that **one brewer's yeast finds flavour for baking, whilst another's, apparently stronger and better, does not.** The active ferment in bread-raising is supposed to be *Sacch. Minor* (Engel), which Messrs. Matthews & Lott say they have noticed in racking beers to the extent of 1% to 2%. Now, a high proportion of this, which would be an impurity in pitching yeast, seeing that it sometimes causes cloudy fret, would greatly enhance the value for baking purposes]

CHAPTER XII

CULTURE FROM A SINGLE CELL—WILD YEASTS

PASTEUR'S METHODS OF PURIFYING YEAST—SURVIVAL OF THE FITTEST—HANSEN'S THEORY—WILD YEASTS—DILUTION AND GELATINE METHODS OF ISOLATING A SINGLE CELL FOR CULTIVATION—ASCOSPORE FORMATION; FILM OR PELLICLE FORMATION—TABLE OF THE PRECEDING, SERVING FOR ANALYSIS OF YEASTS—PURE CULTURE ON AN INDUSTRIAL SCALE—TRIALS OF "PURE CULTURE" YEAST IN NORTH OF FRANCE—EXPERIENCE OF A BREWER THERE—"PURE CULTURE" YEAST IN AUSTRALIA.

Pasteur's and Hansen's Methods of Obtaining Pure Yeast compared.—Until M. Hansen's most important researches at Carlsberg were made public, the utmost that the scientific brewer hoped to do was to secure pure yeast by the culture system, recommended by M. Pasteur, and which may be said to have been based upon the law of "the survival of the fittest." That is to say, the ferment was to be cultivated under conditions which, though unfavourable to its own development, were still more unfavourable to the development of the disease-ferments. Consequently the latter might be expected to perish, whereas the yeast would survive.

Summarised, Pasteur's recommendations (see *Etudes sur la Bieer*, 1876, pp. 225, 226) resolve themselves into the following alternatives :—

1. To cultivate yeast in a 10% solution of sugar, boiled and cooled with access of filtered air only, and in shallow vessels covered with plates of glass.

2. To cultivate it in wort to which 1½% of tartaric acid, and from 2 to 3% of alcohol, have been added.

3. Or in wort to which a 10% solution of carbolic acid has been added in the proportion of 1 part solution to 100 parts of wort.

Obviously, however, these plans are scarcely available on a large scale, and Pasteur himself admits that the second of them is equally favourable to the growth of *Sacch. Pastorianus* to which he attributed a detrimental *rôle*, though were it only the determination of a vinous flavour, as he specially states, English brewers might afford to disregard and even welcome its presence.

He also relates that the use for pitching in the *Brasserie Tourtel* at Tantonville, of a yeast which he had obtained of remarkable purity by the carbolic acid method, resulted in the production of a beer of remarkable stability, compared with the other products of the same brewery, but which unfortunately always developed a yeasty flavour and want of brilliancy (*une cassure defectueuse*).

Therefore he admitted the possibility of the yeast undergoing some change, which would unfit it for practical use, albeit its purity from his point of view could not be questioned.

Other plans, based on the same leading idea, have been advocated—notably to use a certain proportion of salicylic acid, either in the fermenting wort—it being alleged that such an addition in moderation

inhibits the growth of bacteria whilst allowing the yeast to flourish, or, to wash the yeast with an aqueous solution of the acid containing not more than one part acid in 10,000 of water, and not less than one part in 20,000.

Even now, **M. Velten of Marseilles,** a distinguished practical and scientific brewer, zealously maintains that some such method, based on Pasteur's recommendations, would be amply sufficient, and therefore preferable to the more novel system, which we will now consider—the system based upon the researches of Hansen, the Danish *savant.*

He, although admitting the incalculable harm done by bacteria and Pasteur's *ferments de maladie* generally, is quite as strongly of opinion that yeast, apparently pure to ordinary microscopic observation, may contain within itself the causes of much evil, that, in fact, unpleasant flavours, turbidity, and so on, effects which are only second, if second at all, to the development of acidity, are due to certain types of yeast, which he has classified as " wild yeasts."

To avoid the detrimental influence of these wild yeasts, he advocates the cultivation of a crop of pitching yeast from a single cell, selected and isolated in a way to be described later on. It has yet to be shown that yeast, the progeny of one single cell, jealously preserved from contamination and therefore of one single and uniform type, can give the results, in point of flavour and condition, which the English brewer desires ; the possibility is strenuously denied by many, and indeed certain experiments which have been carried out at Burton-on-Trent are understood to have tended to negative it, nor can the results of practical experience on a larger scale in the north of France—to which reference will be made at some length later on in this chapter—be held to confirm it absolutely, as far as the information actually at hand enables a judgment to be formed.

But for bottom-fermentation beers there is positive evidence that pure yeast—*i.e.*, *Sacch. Cerevisiæ*, without intermixture of " wild yeasts "—answers extremely well, proper precaution being taken against over-attenuation. The contradiction, if one it be, between this successful result in the one case and its very questionable success in the other, may perhaps be explained by the fact that the low temperature, at which bottom fermentations are conducted, enables a large amount of carbonic acid, developed in the primary fermentation (and which would be lost in a top-fermentation) to be retained—the beer being, in fact, already saturated with it ; whereas a secondary fermentation (complementary cask fermentation), impossible, as it seems, to be got with *Sacch. Cerevisiæ* alone, is requisite for the due conditioning of top-fermentation beer.

If, however, we admit the undesirability of having any type of yeast except *Sacch. Cerevisiæ*, the true alcoholic yeast and the main constituent of every good commercial yeast, and even if we do not admit it *in toto*, few will be disposed to question the immense interest and value which M. Hansen's discoveries have for intelligent brewers.

Hansen's investigations, in so far as they aim at differentiating yeasts not only into types—which Pasteur and still more Reess had done to some extent before him—but into sub-types, though foreshadowed in 1878, only took the present definite direction in 1881, when he conceived the idea of obtaining growths, each cultivated from a single cell and therefore uniform, and of observing the characteristics of each separate culture, when enough had been obtained for that purpose. The problem—which

seems simple enough now it has been solved—was to ensure the derivation of the growth from a single cell, and from a single cell alone.

He had, ready to his hand, two methods of isolation, neither of which, however, was altogether satisfactory from his point of view—

(1) **The Dilution Method of Nageli** and
(2) **The Gelatine Plate Cultivation Method of Dr. Koch.**

The Dilution Method briefly consisted in taking a definite quantity of liquid containing the class of cells to be experimented on, and counting the number of cells therein (which may be most conveniently done by aid of a hæmatometer), then diluting an *equal* quantity to such an extent, that it might fairly be assumed that a certain small volume of the diluted fluid contained only one cell. For instance, suppose that in 1 c.c. (cubic centimetre) of the undiluted fluid 750 organisms were counted, then if 1 c.c. were taken and made up to 750 c.c. with *sterilised* water, there would probably be 1 cell in each c.c. of the diluted fluid.

Each centimetre, then, put into a flask with some *sterilised* nutritive fluid, would give rise, *in all probability*, to the required growth from a single cell. But the absolute certainty so essential was wanting, for it was impossible to distinguish between flasks which might have received several cells and those which had only received one, so that the method had to be modified to make it of scientific value.

The Gelatine Method of Dr. Koch also begins by a free dilution with sterilised water of the growth, whatever it may be, which is to be investigated. A small quantity of this diluted fluid is then transferred to a flask containing nutritive fluid and gelatine, which at its then temperature of 86° Fahr. does not stiffen. The flask is then vigorously shaken so as to disseminate the introduced cells evenly throughout the flask, which being done the contents of the latter are at once poured out upon a large plate, and immediately covered with a bell-glass.

As it cools, the mixture becomes solid, whereby the cells are isolated from one another, and in a few days whitish specks appear which are with great probability taken to be colonies derived from a single parent cell. Each speck is then removed to a culture flask of sterilised wort or other nutritive fluid, and a growth from each obtained. Still even here absolute certainty is not secured. Moreover, comparatively simple as the manipulation is, it is found that the addition of the gelatine decreases, as far as the saccharomycetes are concerned, the nutritive value of the wort to which it is added, and that therefore few but the more vigorous cells thrive in it.

Hansen's Modification of Nageli's Dilution Plan is as follows :—

Having counted the number of cells in one drop of the fluid (and having been careful, with that object, to keep it from overflowing the outermost square of a number of fine lines engraved on a glass-slide, and crossing one another at right angles), he proceeds to dilute a similar drop with such an amount of sterilised water that, on shaking up the flask, a certain measurable quantity (say 2 c.c.), of which the half can be conveniently taken, ought to contain one cell. Then if quantities of 1 c.c. be withdrawn (the flask being well shaken before and between the withdrawals), and placed into flasks containing sterilised wort, and if these be then properly protected from the access of adventitious germs, the probability is that,

not only will one flask out of every two have been impregnated, but that the growth, when it does occur, will have had its origin in a single cell. But Hansen is not content with probability; his method requires the largest measure of certainty possible.

Accordingly, having impregnated the series of flasks as above, each of the series is vigorously shaken, so that in the event of more than one cell having found their way into any one flask, they may be separated and settle upon a different part of the bottom or sides of the flask. This it is practically certain they do, and that the entrance of more than one cell into any particular flask will be revealed by the appearance of more than one of the white specks, which are evidence of the position of a yeast (or other culture) centre.

If, then, careful examination of the flasks at the end of several days discovers only one such speck in any of them, there is the strongest ground for concluding that one cell only entered those particular flasks, and when these single colonies have been used for the impregnation of fresh flasks, containing sterilised nutritive solution, the pure culture is started.*

This, however, is only a first step; it is only clearing the ground for that analysis of yeast which has been rendered possible by Hansen's labours alone. There are two steps further:

(1) To investigate and note the effects produced in regard to flavour, soundness, condition, and brightness, by each variety of yeast, which had been isolated, and (2) To devise some plan of differentiating yeasts which, though apparently alike, have yet shown themselves dissimilar by inducing good or harmless changes in the one case, and positively hurtful changes in the other.

The former is comparatively simple, though lengthy; it obviously requires a series of actual fermentations to be carried out on a relatively large scale—one at least for every culture of yeast isolated—and finished so that eye and palate together may judge what the result has been. For the latter the course was by no means so plain; but the final outcome of much thought and patient research was that two means of differentiating yeasts, morphologically alike but otherwise unlike, existed which depended, first, on the length of time taken to form **ascospores,** under conditions covering a wide range of temperature, but constant for each set of experiments; and secondly, on their mode of **film or pellicle formation** also under varying conditions.

It has previously been mentioned that the yeast-cell under certain circumstances—and the fact was noticed by Reess, Engel, and others before Hansen—unfavourable for propagation in the way we now consider normal, viz., by budding, provides for its reproduction by developing endogenous spores, the protoplasm dividing itself generally into four separate masses, which being surrounded with a cell-wall are known as **ascospores** (ἀσκος = a skin or bag).

Accordingly Hansen, or those associated with him, arrive at these appropriate conditions conveniently by the use of small blocks made from plaster-of-Paris, on each of which, after they have been sterilised in a flame or otherwise, a small portion of the pure culture is smeared, the block being then placed in a small vessel of water provided with a cover, so that

* Of course these cultures are not on a scale adequate for commercial use, and a special apparatus has been designed by the experimenter for the production of large crops.

Synoptic Table for Yeast Analysis by Variations in Ascospore and Film Formations at Various Temperatures.

	Ascospore Formation.						Film Formation.					
	Max.	Min.	At Degrees Fahrenheit.				Feebly developed flecks at degrees Fahrenheit.				Max.	Min.
			62·6—64·4	77	81·5	86	42·8—44·6	68—71 6	91·4—93·2	100·4		
Sacch. Cerevisiæ I. . . The true alcoholic yeast of top or bottom fermentation. [*Sacch. Cerevisiæ II.* is a variety of the same type, both are in use at the Carlsberg Brewery.]	96·8 to 98·6	51·8 to 53·6	**Hours** 50	**Hours** 23	N.D.	**Hours** 20	**Months** 2–3	**Days** 7–10	**Days** 9–18	None	91·4 to 93·2	42·8 to 44·6
Sacch. Pastorianus I. . . As observed, is a "bottom" ferment, which gives a strong, bitter taste to beer.	86·0	37·4 to 39·2	35	25 (about)	**Hours** 24	30	1–2	8–15	None	None	78·8 to 82·4	37·4 to 41

Sacch. Pastorianus II. . As observed in top fermentation. Produces no evil result in beer.	81·5	37·4 to 39·2	36	25	34	None	1–2	8–15	None	None	78·8 to 82·4	37·4 to 41
Sacch. Pastorianus III. . Another top-fermentation form, which produces turbidity in beer.	81·5	47·3	44	28	35	None [86·9 to 88·7]	1–2	8–15	None	None	78·8 to 82·4	37·4 to 41
Sacch. Ellipsoideus I. . . The yeast of grapes. [Otherwise *S. Ellipticus.*]	88·7	44·6	33	21	N.D.	36	2–3	10–17	8–12	None	91·4 to 93·2	42·8 to 44·6
Sacch. Ellipsoideus II. . As observed, is a "bottom" fermentation form, causing yeast turbidity.	92·3	47·3	42	27	N.D.	23	1–2	4–6	3–4	**Days** 8–12	96·8 to 100·4	37·4 to 41

[*N.B.*—In the third column of the above list the time taken is placed on the left or the right of the *dotted line*, according as the lower or higher temperature of the range (62·6° or 64·4°) was used. The letters N.D.=*no data.*]

the water absorbed into its pores suffices to keep the surface just moist. The series of blocks, so arranged, are then placed in a thermostat, and kept at a uniform temperature, say of 18° C. (= 64·4° Fahr.), or of 25° C. (= 77° Fahr.), etc., as the case may be, and the *exact time* at which ascospores develop is in each case noted.

It will be observed from the preceding table, which has been drawn up with the aid of the lucid work by A. Jorgensen, that the former temperature allows of a very ready differentiation of *Sacch. cerevisiæ* from all the wild forms there given, while again a temperature of 81·5 enables a distinction to be made between the injurious *Sacch. Pastorianus I.*, and the harmless, if not useful, *Sacch. Pastorianus II.* Other differentiations will occur to those looking at the table, which might have been made larger, but has been purposely kept within comparatively narrow limits in order to make it synoptic.

The Film or Pellicle Formation observed as a second means of differentiating yeasts, are small flecks of (aerobian ?) yeast, which are formed towards the close of flask fermentations, in periods that vary with the conditions, as the foregoing table will show. The wort becomes lighter in colour, and the cells obtained are often elongated and approximate to the mycelial growth referred to in Chapter IX. Access of filtered air is necessary, and the flecks of the film can be distinguished from those of the ordinary aerobian ferments (*M. vini* and *M. aceti*), when the formation has advanced further by a difference of colour, the former being usually a distinct greyish-yellow, the latter grey.

It has been pointed out by Jorgensen that all top-yeast is by way of forming stronger and more numerous spores than cultivated bottom-yeast does; that the spores of the cultivated variety of the former, though larger and with better-defined cell-walls than those of the uncultivated variety, have not the clear and homogeneous structure which the latter has when young.

He also points out that at the temperature of 25° C. (= 77° Fahr.), the sporulation period of each variety is too close for a satisfactory analysis, and accordingly 59° Fahr. and even 53·6° Fahr. are preferable, as giving much more marked divergencies.

Cultivation of the Yeast in sufficient quantity for Pitching.—The method of culture from a single cell has hitherto only been described as far as the first stage—the introduction of the minute, almost microscopic, colonies into small Pasteur flasks of sterilised wort. It is next advisable to introduce the small crop from each of these into larger flasks of sterilised wort, and crops having been secured in the latter, it is possible to proceed to the cultivation on a larger scale.

For this Hansen has devised a special apparatus which, without entering into minute detail, may be stated to consist of four parts—viz., **(1) An air-pump, (2) An air reservoir, (3) A wort receiver, and (4) A fermentation cylinder.** All parts in contact with the wort are of well-tinned copper, and all, as well as those of the air-pump and air-receiver, are so arranged as to be thoroughly sterilised at any stage by the admission of superheated steam. The air-pump, which of course only pumps in filtered air, has been made an adjunct because of the proved necessity of aeration for the pure cultures, and the air-receiver, which contains air at a pressure of 3 or 4 atmospheres, enables the air to be introduced

with greater uniformity than would be possible with an air-pump alone.

The wort-receiver may be connected by a tube with the copper, but this is hardly necessary if wort can be introduced into it at an absolutely boiling temperature without the admission of contaminated outside air. The wort-receiver has a jacket, between the walls of which cold water can be made to circulate, in order to cool the wort to the desired temperature, and it is connected with the air-receiver so that the wort may be efficiently aerated before being mixed with the yeast. Then the fermentation cylinder is partially filled with wort, some of the pure culture introduced with precautions against infection, and the fermentation cylinder is then filled up to the highest advisable level. [Of course, the fermentation-cylinder has an outlet for carbonic acid gas; it is also provided with a stirring apparatus, actuated from the outside, for mixing wort and yeast thoroughly.]

There is a tap for drawing off the liquid mixed with the new yeast at the right moment; and in the arrangement at Carlsberg the fermentation cylinder is once partially emptied and once totally emptied (except for a small quantity of yeast, sufficient to start a fermentation in a fresh charge) every 10 days, enough yeast being got in that time to pitch 8 hectolitres (*i.e.*, 176 gallons) of wort.

Thus it will be seen that the production of a full crop of pure pitching yeast is not a very speedy affair, but from this point—up to which it has been conducted with precautions for absolute sterilisation the cultivation is carried on in fermenting vessels of the ordinary type. Undoubtedly, even in the purest air, infection by wild yeasts, bacteria, etc., now begins, but it is found in practice that sufficient purity is maintained for a considerable time, and that, for operations on an industrial scale, the culture does not require to be begun again *de novo*, in respect to the whole crop of pitching yeast, but that it is sufficient, when once a pure crop has been obtained, to reinforce it from time to time with fresh yeast developed on the pure culture system recently described. [Hansen found—it may be mentioned—that, when the proportion of wild yeasts was less than 2·44%, or perhaps we may say 2·5%, no evil results ensued.]

Experiments with Pure Cultures in Top-Fermentation Breweries (France).—These experiments have been mentioned earlier in the present chapter, and as detailed accounts from one point of view have come to hand, and as we were further enabled to get some first-hand information from the owner of a brewery on the spot and a letter from another gentleman connected with the trade there, which qualify those accounts somewhat, we think it would be interesting, before concluding this section, to give a *résumé* of what has been done in that locality, and extracts from the letters we have received.

The expert who presided over these pure-culture fermentations was M. Kokolinski, an analytical chemist of Lille, and the following is an abstract of his method, which we shall continue to refer to in the present tense. [It is stated that fifteen breweries in the Department du Nord had adopted it in 1892, four years after its first introduction into a top-fermentation brewery in Lille.]

To Select the Desirable Type.—A sample is taken from the yeast in general use, rather than from the first heads thrown up during fermenta-

tion. [First heads are found to contain fewer species of yeast than the pitching yeast, some of the best types being occasionally missing.]

A trace of the sample taken is submitted to gelatine culture, the individual cells being thus separated [?] ; then the colonies from at least 12 isolated cells are carefully observed—*e.g.*, the time is noted in which ascospores are formed, the same with pellicles, besides numerous details of fermentation and of the resulting beer, primary and secondary fermentation, etc.

The materials used, type of beer wanted, and the method of fermentation must be taken into account ; even then there is no certainty of succeeding at the first attempt. Often three or four sorts of yeast have to be tried before a satisfactory result is obtained.

When the desirable type is found, the cultivation on an industrial scale begins.

1. In Pasteur flasks.

2. In tinned-copper flasks, or covered copper cans of 24 litres' (nearly 5 gallons') capacity, capable of containing 16 litres (nearly 3½ gallons of wort) in active fermentation. [In these cultures M. Kokolinski attaches great importance to perfect sterilisation of wort, and he always operates in an Autoclave at a temperature of 115° to 120° C. (= 239° to 248° Fahr.).

3. The quantity produced by 2 is enough to prime a Hansen's apparatus if there be one, or to pitch 150 litres (about 32 gallons) of wort.

4. The yeast from the Hansen's apparatus (or from the 150 litres) is used to pitch 8 hectolitres (176 gallons) of fresh wort.

5. The yeast obtained from 4 suffices to pitch 37 barrels.

The beer got from the wort used in yeast-production, though a little flat, is perfectly sound, and can be used either directly or blended ; and though the first fermentations are sometimes not very active, M. Kokolinski says it is a mere question of acclimatisation, and that after the second or third generation the fermentation will resume its normal activity. He also finds—as has been stated before—that it is unnecessary to replace the whole yeast-store with pure yeast when a pure-culture store has once been obtained. Additions of pure yeast from time to time will do.

Never More than Two Types are blended.—A single type of yeast is easier to work and gives more regular fermentations, but it is sometimes necessary to select two types. The admixture of two types, however, has hitherto been found sufficient.

Commercial Yeast of North of France.—More than 60 different types (!) have been differentiated, of which 40 have been carefully studied and classified in M. Kokolinski's collection. Many of these types, the so-called "wild yeasts," are absolutely bad.

The alleged advantages are (1) That beers so brewed have the special flavour desired. (2) The flavour is regular, uniform, and well defined. (3) Clarification is easier and more rapid. (4) The beers resist bacterial agencies better and keep longer.

Moreover, M. Kokolinski claims that the advantage of using "pure culture" yeast is greater with high-fermentation beers than with those brewed on the low-fermentation (bottom fermentation), because the former have not the advantage, which the latter have, of cold to check the action of hurtful ferments, and to keep their growth down.

Of the two correspondents, who so kindly wrote to us, No. 1, the

Brewer, says, "I have made some trials of pure fermentation with Hansen's apparatus for about a year, and without having been completely successful, I may say that it has given me much satisfaction. There is, in effect, a very appreciable result in the regularity of the flavour of the beer and in the purity of the fermentation. Formerly, when I had a change of yeast the flavour of my beer was altered, and my customers did not find the uniformity indispensable to successful manufacture. It is a point of great importance to be able to re-establish the dominant yeast of a brewery at will.

" In the second place, this regeneration has, as corollary, the production of a pure yeast free from bacteria. I do not insist on this point, because it is beyond disproof that bacteria and sometimes wild yeasts are our worst enemies.

' Thus far the advantageous side of pure yeast. But now I must confess that in my case the reconstitution of a store of industrial yeast has been less easy to obtain than in other breweries. I have sometimes, according to the season, required 4, 5, or even 6 industrial cultures, before seeing the yeast recover the qualities of odour, colour and agglomeration. I repeat that other breweries have not experienced the same difficulties, and I ask myself why the yeast which I use is so difficult to set going.

" My opinion is that, for certain races, the mode of selection proposed by M. Hansen, viz., by gelatine culture,* takes the nature out of the cell (*denature la cellule*). The cell becomes sick, and no longer secretes the sort of mucus which agglomerates it to the other cells. Moreover, the beer produced by the first generation often has a yeasty taste.

" Have I perchance experimented badly ? Have I lighted on a bad kind of yeast ? One or the other of these hypotheses must be correct, because my colleagues have been able to obtain commercial yeast at the first attempt.

" Then I tried a mixture of two varieties, and succeeded better, but one of the two varieties stifled the other, which was less resistant.

" Whatever the cause may be, I have never since beginning my attempts had any bad flavours due to manufacture. My beers have not been flat, the attenuation has been constantly the same, and there has been no occasion to dread that which the detractors of Hansen's system everywhere proclaim.

" To sum up. This question has many obscure points, which time and practice will make clear ; but a progress there is, and in my opinion (who am only a very modest practitioner, with no intention of posing as a learned experimentalist) the system will one day or other become very practical for top-fermentation beers.

" I believe that the brewers of ' bottom-fermentation ' beers have a better chance than we of succeeding, because their yeast rests at the bottom of the vessel, and accordingly its alteration is less frequent and less probable. But we shall succeed after them, I doubt not."

My other correspondent does not take an optimist view, though he is unaware from sampling or trustworthy information how the change of ferment has modified the product. But he has not heard, he says, that the brewers working with yeast cultivated from a single cell have achieved any

* The dilution method, previously described, is preferable, it will be remembered, on ground of accuracy.

dazzling success. He is inclined, however, to attribute any want of marked success less to any inherent unfitness of the system for top-fermentation beers than to the light gravity of the beers in the North of France (worts of 9° to 10° Balling), conjecturing that such beers, exempt from all acidity beyond that normal to the malt they were made from, might easily taste insipid.

The "Pure Culture" in Australia.—Mr. de Bavay has placed upon record that his employment of a pure culture of *Sacch. Cerevisiæ* has been successful in Australia, his ales in bottle developing all the "condition" so essential to high quality. To this it has been objected that brewing conditions in Australia are very different from those which obtain in England. The employment of as much as 50% of high-class cane-sugar is not infrequent, and this might very well account for matter being left after the primary fermentation had apparently finished—either invert or maltose—which the primary yeast cells would be capable of degrading. The famous French chemist, Dumas, found that it takes twice as long to ferment cane-sugar as it does to ferment inverted—*i.e.*, the inversion takes as long as the fermentation, and where yeast has to ferment as much as 50% of sugar, it is far from unlikely, unless the primary fermentation were to be unduly prolonged, that primarily fermentable matter would pass into cask, and even into bottle, before being altogether split up into alcohol and carbonic acid. That intrusive secondary yeasts may find their way into exposed worts goes without saying.

English Experience.—Dr. Morris in 1901, in describing a series of pure-culture experiments extending over eight years, and in which over 2,000 barrels were fermented with one variety of yeast (though fresh ones were continually being isolated and tested), said that the beers were, as a rule, sound and well flavoured, but remained thin and flat. No after fermentation was produced, unless it were induced either by addition of cold-water malt extract or of priming. Dry hopping had a certain but delayed effect, due partly to diastasic power in the hops, and partly to introduction of wild yeasts with them. A point to be mentioned was a tendency to "sickness" shown by most of the pure-yeast beers, not accompanied by micro-organic growth, but due, it appeared, to chemical decomposition of the cell-contents of dead and wasted yeast. Generally at racking the pure yeast beers were drier and had a more "fruity" palate than normal beers.

Mr. Walter Riley writes (*Brewer's Journal*, August, 1904) that he has found it impossible to get any beer of higher gravity than 20 lb. into proper condition when fermented with a good type of single-cell yeast. He adds that of two lengths from the same worts made up to 16 lb. and 30 lb. respectively, and then fermented with the same single-cell yeast, the lighter beer will come into better condition, the heavier one having only a vinous taste and no "condition." But a 14-lb. beer, fermented with a selected type of single-cell yeast, was as full of life two years after as it was six weeks after being brewed. The addition of priming would be necessary to bring about conditioning by the heavier beers. He thinks, however, that the cure for some of the evils of "bottled beer" lies in the use of a properly selected single-cell yeast.

Selective Cultivation Fortification.—Jörgensen, speaking of the degeneration of a commercial yeast, marked by the resultant beers developing flavours and attenuation differing from the normal, says that *all the cells do not degenerate in such a case*, but if fermentations be started with single cells separated by solution, some of the new growths will show the acquired disagreeable character in a marked degree, other less so, but there will be some cells of the race which have not changed their character. From these he proposes to start pure cultures which will be used in improving or *fortifying yeasts which are giving satisfaction*. As an example he quotes certain

bottom yeasts, which induce a very strong fermentation, but, as a rule, slow and indifferent clarification. In such a case the object of systematic selection has been to separate out individual cells, which will produce the strong fermentation characteristic of the type, and yet ready clarification in the after fermentation.

Claussen's Brettanomyces.—The further theory about secondary fermentation comes from the Carlsberg Laboratory, its director, Dr. Claussen, claiming to show that *the* factor in the conditioning, with accompanying flavours, of British stock ales is not a yeast, but a non-sporulating budding fungus belonging to the **Torula group** (p. 290), which in compliment to us he names **Brettanomyces.** It forms, he says, considerable amounts of acid, more than any other torula, which, combining with existing alcohol, generate those ethereal bodies characteristic of fine English stock beers. Though producing no effective result in beers consumed in a week or so after the primary fermentation is ended, it is otherwise in five or six weeks. Though a constituent of normal British yeast, it is said to settle on the *bottom* of the fermenting vessel; it has been isolated from bottles of old English ale and stout. Claussen, though he did not use English-brewed worts, found that the CO_2, developing slowly, is very tenaciously held, and the result a lasting foamy head. He does not advocate its addition to pitching yeast but says that 125 c.c. per barrel added after the primary fermentation (even after Pasteurisation) gives the best results. Prof. Hansen, at Edinburgh, apparently endorsed Claussen's view. It was mentioned there that beers more or less alike after the primary fermentation, often differed after the complementary (secondary) one, and that though a single-cell yeast would bring about secondary fermentation, as long as any fermentable matter remained in the primarily fermented beer, that due to brettanomyces was a very different thing.

H. Seyffert (Russia) objects that previous attempts to get English flavours with imported organisms have failed on continuous use, *though successful at first*, and prophesies a similar result with brettanomyces.

A Summarised Utterance of Dr. Van Laer, though it will not command universal assent, may fitly close this chapter and subject: "The definition of pure yeast as crops grown from a single cell, so that during successive reproductions no other organisms are allowed to mix with them, is not broad enough. A good commercial yeast may consist of a mixture of types (*e.g. S, Cerevisiæ*, as well as *S. Ellipsoideus* and *S. Pastorianus*) capable of giving separately good practical results. It is, in fact, a commercial yeast free from microbes, saccharomycetes, or other fungoids injurious to the production of beer. There are varieties of *S. Pastorianus* and *S. Ellipsoideus* which give incomparably better beers than those produced by the agency of several *S. Cerevisiæ*. It is a mistake to suppose that it is necessary to have yeast with organisms of the *S. Cerevisiæ* type only, and that the yeast is bad because the cells are elliptical or elongated. It is absolutely impossible to judge beforehand of the practical value of a ferment by the shape of its cells. *S. Ellipsoideus* and *S. Pastorianus* may assume a round shape in certain stages of their development, and, on the other hand, *S. Cerevisiæ* may assume the appearance of *Ellipsoideus* or *Pastorianus*."

Saccharomyces Thermantitonum—The writers would like to have given details of this ungrammatically named but very interesting ferment, which appears able to ferment worts satisfactorily at a "cooler" temperature (say 120° F.), to agglomerate them into handy chunks, and generally to make a more or less mechanical process of fermentation. Unfortunately direct efforts made to get bottled samples have failed, doubtless through some misunderstanding, so that we cannot say how its products compare with normal bottled beers in condition, or otherwise than in the somewhat artificial conditions of a Brewers' Show.

CHAPTER XIII

TREATMENT OF BEER

TURBIDITY OF BEER—(i) FROM DEFECTIVE YEAST—(ii) FROM BACTERIA—(iii) FROM ALBUMINOIDS—(iv) FROM HOP-RESIN (AND HOP-SICKNESS)—(v) FROM AMYLOINS OF ABNORMALLY LOW TYPE—(vi) FROM MINERAL MATTER IN SUSPENSION—ROPINESS—YEAST-BITE—ANTISEPTICS—FININGS—DIFFERENT METHODS OF FINING—STORAGE OF PALE AND BITTER ALES—POROUS SPILES—SAMPLING—BOTTLING—FORCING TRAY—SIMPLER TEST FOR STABILITY IN BOTTLE.

A TOLERABLY accurate idea of the causes of acidity in beer has been obtainable since the publication of Pasteur's *Etudes sur la Bière*, but the causes of turbidity and yeast-bite are always further to seek, being involved in possible complications which make them obscure. We will, however, try to get some light thrown upon the causes of turbidity first. These are :—

(1) **Defective Yeast.**—And this defect may be due either (α) to insufficient nutrition or (β) to over-nutrition ; and this not only in the wort actually in course of fermentation, but during the past history of the yeast, which is the head more immediately under consideration.

Apart from the so-called " wild-yeasts," *Sacch. Ellipsoideus*, *Sacch. Pastorianus III.*, and *Sacch. Exiguus*, which definitely cause turbidity, it is easy to see that ill-nourished yeast, being only capable of reproduction and fermentative action in a modified way, will be less able than stronger yeast to deal with such factors of turbidity as are mentioned in some of the succeeding paragraphs. The aged cells, which are relatively very numerous in yeast of this description, with their thickened membranes through which the fermentable fluid does not readily pass, are, even if their vitality be only dormant, manifestly less able to break such fermentable matter up within a reasonable time.

And whether the young cells which such an enfeebled stock does produce be *Sacch. Exiguus*, as used to be supposed, or whether the latter belongs to a distinct type, to be classified with wild yeasts, there can be little doubt that a number of cells are produced of relatively light specific gravity, a quantity of which remain in the wort, and either do not subside at all, or easily rise to cloud the beer upon the slightest increase of temperature or vibration.

On the other hand, over-fed yeast, yeast clogged with nitrogen, is equally, without some special stimulation, incapable of performing those reproductive and fermentative functions which are so essential. Hayduck, who made exhaustive researches on this question, determining the nitrogen percentages most carefully, came to the conclusion that (1) The amount of nitrogen in pitching yeast increases with each fermentation ; (2) Increase of nitrogen up to a certain point increases the fermenting power of the yeast ; but (3) The capacity of the pitching yeast for assimilating the nitrogenous nourishment decreases as the yeast is repeatedly used—*i.e.*, as it becomes itself richer in nitrogen.

He accordingly recommended pitching at a higher temperature than ordinary (he himself set his experimental worts to ferment at 63½° Fahr.) and aeration, especially the latter, seeing that the admission of atmospheric air into worts during fermentation stimulates vigorous budding (as does the higher temperature to a less extent), and it is clear that the more vigorously yeast grows in a fluid containing a given quantity of nitrogenous matter, the more of the latter will then be absorbed, seeing that every yeast-cell formed requires some of it to form its protoplasm.

The course indicated to remedy this phase of turbidity, short of using acclimatised yeast derived from a pure culture, is to select yeast carefully (1) according to observed previous results—*i.e.*, eliminating for pitching purposes the yeast-crops of any gyle which has shown a marked tendency to yeast turbidity; and (2) by aid of the microscope, viz., to use those yeasts only which show cells of regular size (this is much better than cells, some abnormally large, others below the average) with well-defined vacuoles and practically free from worn-out cells with dark and granulated plasm. Particularly should the absence of small cells of *Sacch. Exiguus* be ascertained. Of course, too, relative freedom from bacteria is essential, and this indeed is, to some extent, a corollary of yeast-vigour.

It has been suggested that in the washing of yeast we have a means, generally satisfactory in result, of sorting out the small cells and other impurities, and this applies, not only to the small cells of *Sacch. Exiguus*, but to others of a larger type which are weakened or dead, or to bacteria. [It will be noticed that even in the extremely thin layer of a microscopic "field" the latter float at a higher level than the yeast cells do.]

The success of the operation depends upon the greater specific gravity of the more desirable cells. The *modus operandi* recommended is as follows. The yeast is to be mixed with a fairly large quantity of water at 32° Fahr., in a special receptacle, with a tap (or taps at different levels) in its side. As soon as the largest and heaviest cells have settled to the bottom of the receptacle, the turbid water above must be drawn off before the myriads of light cells and other impurities in suspension have time to settle. The precise temperature of the water is of importance; the yeast settles less readily in warmer water, and if suddenly chilled has a tendency to mass together, so that its cells cannot be sorted according to their specific gravity.

Two objections to this treatment occur: (1) If it be the practice to use uninverted cane-sugar to any extent, the yeast being deprived of its invertase, degradation of the sugar might possibly not take place. (2) The washing will lower the nitrogen percentage of the yeast (the said constituent in its compounds being very soluble) on which, up to a certain point, its vigour largely depends.

[Should this be the case a remedy may be found in a preliminary treatment of the selected yeast—*i.e.*, before pitching with it, but after the sorting-out process—with unhopped wort of fair gravity and in a shallow vessel. As a general rule, the wort should be *boiled* and filtered; unboiled wort, so added, might have too stimulative an effect in some cases, determining, as it probably would, some amyloin-degradation as well. Its proper sphere seems to be in a certain form of stubbornness to fining influence—hardly turbidity in the strict sense of the term, but referred to under that due to proteins.]

Turbidity from Sacch. Pastorianus, according to Hansen, is specially due to the sub-variety isolated as *Sacch. Pastorianus III.*, but it appears that where either sub-variety is in excess, the light specific gravity of the cells may cause a cloudiness more easily provoked (by vibrations, atmospheric changes, etc.) than allayed.

Matthews and Lott say that a distinctly unpleasant smell and flavour, especially the former, which often accompany a *Pastorianus* fret, may pass off and be succeeded by a normal fining, with gas production and the disappearance of the unpleasant symptoms of *Pastorianus* growth. They point out that, beyond casual impregnation of the store yeast by wild yeasts, predisposing causes to an undue growth of *Sacch. Pastorianus* probably are :—Insufficient attenuation and yeast-production, and further a combination of fineness and flatness at racking in conjunction therewith.

Turbidity from Sacch. Exiguus.—The cause of this has already been indicated as the lighter specific gravity of this elongated yeast. The turbidity is prolonged and (according to the writers lately referred to) accompanied by marked flatness, which is probably not unconnected with its inability to ferment maltose.

Turbidity from Sacch. Ellipsoideus.—This saccharomyces, according to Matthews and Lott, " is associated with cloudy frets and sickness," which are often, but not invariably, accompanied by " a stench." Conversely, they say, a bad stench is generally marked by the presence of *Sacch. Ellipsoideus*. Their opinion is that a beer which has gone through a bad *Sacch. Ellipsoideus* fret may, if otherwise sound, become quite palatable.

(2) **Turbidity due to Bacteria.**

The turbidity due to bacteria generally, unless in very aggravated cases, manifests itself in the secondary, rather than in the primary stage of fermentation, and oftenest, perhaps, after a beer has been bottled without full preliminary storage. The turbid fluid, examined under the microscope, then appears to be swarming with *micrococci* and *sarcina-like* forms (*diplococci* and sometimes *tetracocci*), generally associated with *Bacterium termo* and rod-like organisms. It is quite possible for such a beer, *i.e.*, one in which *micrococci* predominate, to remain, as it will, persistently turbid, and yet without developing excessive acidity ; to be, in fact, apart from its appearance, which always influences the palate, rather pleasant in flavour than otherwise.

This form of turbidity, should it occur in bulk, is very difficult to deal with, the very slight specific gravity of the organisms keeping them suspended, while their extreme minuteness enables them to elude the coagulated network of finings.

(3) **Turbidity due to Nitrogenous Bodies.**

The knowledge of the nitrogenous bodies or albuminoids, possessed even by the best-informed, is confessedly meagre and wanting in exactness, but there is reason to suppose that the fact of its total nitrogen being either below or above an arbitrarily fixed percentage does not necessarily decide the fitness or unfitness of a malt for brewing. It could not be known without a series of difficult tests how that nitrogen is distributed, how much of it exists in the form of diffusible compounds, or compounds easily rendered so (amides, peptones), and which would therefore at a later stage be assimilable. It has been stated, indeed, that as little as 1·2 per cent. of proteids in the malt could suffice for yeast nutriment, *if all could*

be utilised, but there is evidence (cf. p. 158), that a finished beer might hold a fair surplus of the proteid conversion-products in solution without affecting the brilliancy of the product, and even that the region of safety lies in having such excess in the less complex forms, in which alone assimilability exists. We know that persistent yeast weakness has occasionally to be met by adding to the wort some form of **Yeast Food**, and that the most effective of these are rich in peptones and amides ; whence it would appear that sometimes it is not a question of worts containing too much nitrogenous matter, but of not having enough in assimilable form.

Probably albumoses—factors in head-retention as they are—need to be counterbalanced by the less complex peptones and amides, and even in excess of the calls upon them, as stimulants of reproductive and fermentative power respectively, but it is not to be supposed that sharp conversion lines exist, as indicated by these names. Intermediate products of uncertain solubility appear to be formed in certain cases, ready, on the least disturbance of balance, such as abstraction of sugar by normal attenuation, development of acid, even of CO_2, and last, but not least, reduction of temperature, to pass out of solution in the form of a persistent haze. When malt becomes **slack** obscure changes occur affecting the proteins probably, and certainly increasing hydrolytic influences (more maltose in the worts), defects partially remediable by redrying and using immediately. Again, in ill-vegetated malts the proteins are likely to approximate somewhat to the barley type, to one of which, Mucedin, more soluble in hot than in cold water, in which it is very slightly so, the last runnings from "the goods" probably owe their greyness, *which cannot be removed by finings*.

Though exact percentages may depend on natural causes, much depends on the malting being in unison with these conditions—*i.e.*, to counteract their influence, when unfavourable, as far as possible.

A good development of acrospire and rootlets are undoubtedly favourable indices, connoting relative elimination of albuminoids ; but the writers think that the brewer is not without a further means of judging—viz., by observation of the wort's saturation point with regard to the above-mentioned bodies.

Seeing that these bodies are but slightly soluble in boiling water and insoluble in cold, it is probable that of two worts of equal gravity, the one which remained clear (after being boiled) when reduced to say 160°, would be less rich in them than one which clouded at 170° or 180°, that is to say, that **the saturation point** (the temperature at which these albuminoids go out of solution) is in proportion to and in fact rises with the quantity of albuminoids present.

A saturation-point, relatively high in temperature, accordingly indicates the necessity of replacing some portion of the malt, over rich in gluten and what not, by non-albuminoids, rice (flaked malt) and invert-sugar. It is a fact that light worts brewed with such materials, and under conditions such that no mucedin due to sparging could have possibly found its way into the copper, can after a very short boil be filtered (just to remove coagulated albumen) into a test-tube, perfectly bright, and that they will remain so when quite cold.

There is one type of turbidity, characterised by incomplete fining action—*i.e.*, when upon addition of finings to a sample in glass, a sort of

break readily begins but does not continue to brightness, or at least takes a long time about it, smeary-looking particles attaching themselves to the side of the glass, while a powdery rather than a flocculent precipitate falls to the bottom. Even upon keeping, probably the resulting beer gets very little brighter, but responds to the action of finings in carriage casks, with, however, a large quantity of " bottoms " or " pitchings."

This is the sort of turbidity that one is inclined to attribute to albuminoid influence, and perhaps to those albuminoids once coagulated but afterwards re-dissolved on boiling, the more so that it is characteristic rather of stronger beers, in which yeast reproduction is comparatively crippled, than of weaker qualities. Moreover, where such beers are of running character it is often necessary to use a lower mashing heat than the corresponding weaker beers would require (in order to limit the amount of malto-dextrin of high type), and the tendency of this is of course to increase the amount of albuminoid extract as well as that of the free maltose. Thus the fermentation is made more rapid, just when, as regards the removal of fine albuminoid particles, it ought to be steadier.

Any real difficulty from this source might be met by very distinctly raising the mashing temperatures, so as to reduce the amount of albuminoid extract, subsequently adding (if too large a quantity of malto-dextrin were likely to be present in the wort for early condition) either cold aqueous mal textract (ref. p. 311), or treating the yeast before pitching with cooled unboiled wort of energetic diastatic quality, which will not only give it a good start, but will also, as the malt-extract does, help to degrade the malto-dextrins into primarily fermentable maltose.

Aeration, by stimulating yeast-growth, may have some good effect.

The above suggestions will perhaps serve as a clue to causes which, as yet, cannot be formulated with precision.

(4) **Turbidity due to Hop-resin.**

That hop-resin may be a factor in the turbidity of beer, albeit only a secondary one, there is good reason to believe. That is to say that, in a perfectly brewed and fermented beer, a slight increase in the normal amount of hop-resin would have no detrimental influence, nay, probably might facilitate the action of finings, but in beer brewed so that cask-condition does not readily set in and then only feebly, any excess or even the normal amount of hop-resin may lead to a turbidity difficult to eradicate.

The hop-resin appears to be in solution in the earlier stages of fermentation, but to pass out of it to a great extent afterwards, some holding that the closely associated essential oil determines its solution, others, with more apparent probability, thinking that maltose is the determining solvent, and that, as this is fermented away, so the resin passes out of solution, helping to form, as it does so, the discoloured mass of amorphous matter seen upon the surface of fermenting tuns.

If this be so, there are more reasons than one why this form of turbidity should occur, as it does, in beers produced from a wort in which the ratio of free maltose was high ; for not only will more than the normal amount of resin pass into solution and then be thrown out of it, owing to the excess of solvent maltose present at first and then rapidly fermented away, but it will have less yeast to adhere to, and a lessened opportunity of doing so, because the yeast in a wort, with a high ratio of maltose, is so vigorously

engaged in breaking up that readily fermentable constituent as to have little tendency, comparatively speaking, to reproduction, and moreover, on account of this fermentative activity, the yeast which is produced is more rapidly evolved than is the case when the wort-constituents are better balanced.

According to any view too, including the latest theory of cask-conditioning, a wort in which free maltose was originally in excess, implies deferred and feeble secondary fermentation, just where a good secondary fermentation is wanted to get rid of the hop-resin turbidity, which has remained over from the primary fermentation.

Accordingly, the plan to adopt where trouble of this sort occurs, is to endeavour to decrease the ratio of free maltose by using higher mashing heats, which will have the effect too of determining a less rapid fermentation, and the presence of those bodies which play a leading part in a satisfactory secondary fermentation.

[Although the above seems the sounder view, certain authorities, as has been said, suspect the hop-oil of being the predisposing cause of trouble; Balling holding that the resin is dissolved under the influence of the ethereal oil, and that, if the latter were absent, the hop-resin would be completely thrown out by fermentation; Habich supposing that, as the hop-oil becomes volatilised in fermentation and storage, the resin, deprived of its decomposing agent, separates in fine particles, which remain suspended in the liquid.

There would be more ground for adhering to this view if it were found that ales with the most hop-flavour at racking were specially liable to this form of turbidity.]

To satisfy himself as to hop-resin being the cause of turbidity, the brewer may make a sample of his turbid beer alkaline with caustic potash or shake it up with ether; in either case a removal of turbidity indicates hop-resin as the cause, these reagents having no effect upon yeast-turbidity.

[Messrs. Matthews and Lott, however ("On the Action of Finings," *Trans. Inst. Brewing*, iv. No. 8), do not consider hop-resin turbidity so productive of trouble in beer-fining as is commonly supposed, because although an apparently stubborn opalescence ensued if a drop or two of alcoholic solution of hop-resin were added to distilled water, yet on finings being added, perfect clarification, as their experiments showed, usually resulted.

Decoctions of hops in water were for the most part stubborn in behaviour with finings, which the authors attribute to the hop-oil in a state of minute subdivision. The same decoction added to beer, however, caused the finings to separate in a more bulky form, the beer above being brilliant.]

(5) **Turbidity from Dry Hopping (Hop-Sickness).**—Though only transient with well-brewed, sound ales, it may be far otherwise with those of less satisfactory character. This form of turbidity should not in strictness be classed by itself, being partially due to some of the actual hop-constituents passing into the ale in a state of semi-solution, but even more to fermentative organisms, introduced with even the best of hops, and which accelerate the secondary fermentation. This acceleration, if excessive, may take the form of a persistent "fret," frequently attended

with a disagreeable " nose," which, however, passes off under favourable conditions.

(6) **Turbidity due to Amyloins of abnormally Low Type and Free Maltose.**

This form of turbidity is most likely to occur in summer, when wild yeasts are plentiful. These break down the amyloins (malto-dextrins) violently, not quietly as in winter, and accordingly fretfulness results even where the amyloins, though of rather low, are still of perfectly normal type.

It is supposed, however, that amyloins are sometimes formed of such abnormally low type (Maltose 19 : 1 Dextrin) that they are nearly as unresistant to the influence of primary yeast as is maltose itself. Consequently the impetus given to any primary yeast remaining in suspension by the inevitable aeration at the time of racking will be quite sufficient to induce a tumultuous fermentation, without the usual pause for the secondary ferments to begin.

Again, it may happen that owing to some defect in the yeast, or more probably to undue viscidity of the wort (malto-dextrin of abnormally *high* type being present), which would hamper the yeast in its action, all the *free maltose* is not degraded at the time of racking, and thus when the suspended primary yeast is invigorated by aeration, there is a constituent at hand very susceptible to its fermentative influence.

The presence of the low type amyloins referred to above would seem to be indicated when the primary fermentation is unduly prolonged, *i.e.*, when instead of the last head (in the case of skimmed beers) being taken off thirty hours, or at most thirty-six hours, from the time of the first skim, the skimming has to be continued nearly till the usual time of racking.

In any case the immediate remedy should be to use large quantities of pitching yeast (so that the low-type amyloins may be broken up more speedily) and to postpone, as far as possible, the time of fining, but rolling the casks about in cellar as often as possible by way of preliminary. We are inclined to think that the " working-out " system of fining would be better adapted than the ordinary method for this kind of turbidity, where early consumption is desired, but on this point practical experience is lacking.

The cure of course is to be sought earlier, and should turn, for running beers, on the employment of higher but evenly-dried malts, albeit higher mashing heats are supposed to be an even more potent factor for raising *type* of malto-dextrin.

(7) **Turbidity possibly caused by Mineral Matter in Suspension.**

Messrs. Matthews and Lott, in their valuable and suggestive paper on the action of finings, pointed out the possibility (of which they have strong evidence, though not enough to prove it actually) of the turbidity of certain stubborn ales being due to the presence of very minute crystals of phosphate of lime and magnesia.

Such crystals, they say, are discernible in some cloudy beers, and they find that obdurately dim beers are rendered much less so by applying a pressure of carbonic acid gas. The clearing that occurs cannot be due to solution of hop-resin or nitrogenous substances, the solubility of these bodies being lessened by acidity of the medium, but on the other hand, the phosphates spoken of are remarkably soluble in carbon dioxide.

This view is countenanced by the fact that a dull beer, on becoming

brisk, will often concurrently brighten, and they suggest, "as a rider," that the turbidity which bright beers acquire upon free exposure to the air may possibly be due to these same phosphates being thrown out of solution, in consequence of the escape of carbonic acid gas, and the thereby reduced acidity.

Ropiness. The Ropy Ferment.

This very unpleasant phenomenon—which, at its worst, makes the ale infected with it pour out like castor-oil, or even hang in strings, as it were, from a stirring-rod that has been dipped into it—seems to be the work of an organism or organisms which convert the fermentable sugar of the wort into **Mannite** and a gum-like body known as **Dextran,** but not in any precise proportion.

What these organisms are can hardly be unhesitatingly laid down, but Dr. Van Laer, Professor at the Brewing School of Ghent, has identified two kindred ferments which he names respectively *Bacillus viscosus I.* and *Bacillus viscosus II.*, in the sphere of which sugar, contrary to the accepted view, plays an unimportant (?) part. We will return to these presently.

Another organism which produces an analogous result in sugar refineries (whence its spores may easily be introduced into breweries) is *Leuconostoc mesenteroides*, an organism which occurs in twining chains of colourless minute spherical cells, each chain being enclosed in a relatively thick gelatinous sheath of toughish character.

This may be the chaplet form, which those following the earlier researches of M. Pasteur describe the ropy ferment to be. Others attribute the disease to *Pediococcus cerevisiæ*, a sort of sarcina, which at any rate appears to be frequently present in beer so infected. And, according to Lintner, the mould *Dematium pullulans* grown in beer-wort has the same effect.

All we can say with any degree of certainty is that beers in bottle are more liable to the malady than those in wood, consequently it is a fair inference that pressure stimulates the activity of the organisms, and that whatever the organism may be, it is capable of an anaerobic existence.

Further, we find that ropy beers lose their excessive viscosity if kept till acidity develops, and with ropy beers there is generally a tendency towards excessive development of lactic and butyric acids, so we may conclude that acidity, as such, is unfavourable to ropiness.

Again, lightly hopped beers are more liable to ropiness than those which are heavily hopped (well-hopped pale ales, perhaps, never go ropy), which may be connected with the general fact that an increase in the acidity percentage appears to discourage ropiness, or may be more due to the special type of acid, tannic, in which the hops are richest. The fact mentioned by Schutzenberger, that white wines, which are poorer in tannin than red wines, are much more liable than the latter to be attacked by the malady in question, strengthens the latter view.

Beyond a doubt the disease is the work of some organism, which gain a foothold through some uncleanliness, possibly beyond the brewer's control (*e.g.*, the earthy matter attaching to pigeons' claws has been found teeming with *Sarcina* germs, and they and other birds not unfrequently use the brewery as a resting-place).

But **predisposing causes seem to be** the use of *slack* and inferior malt, insufficient hopping, and a degree of acidity below the normal, whether the

latter be reduced by a large proportion of sugar used in brewing, or (as is sometimes done) by the addition of relatively large quantities of unboiled liquor to the fermenting vessel for the purpose of making up " length," if a longer one than the coppers can effectively boil is wanted.

Possibly the vicinity of the hayloft may have some influence (chopped hay infusion stimulates growth of *Sarcina*, which also is encouraged by the neutrality or alkalinity of its medium), as it has in the providing of other disease-ferments.

To return to Dr. Van Laer. In submitting to plate-cultivation a ropy beer deposit, in order to isolate certain *micrococci*, which appeared to be identical with Pasteur's chaplet form, he found that these cultivated *mic cocci* would not cause ropiness, but that certain slender rods (1·6 to 2·4 μ long and 0·8 μ in width) which were not at first suspected did cause it.

These organisms, whose behaviour he found to differ in wort, though it was similar in meat extract, he called respectively *Bacillus viscosus I.* and *Bacillus viscosus II.* Morphologically they hardly differ, unless it be that the former is a shade the more slender of the two.

Bacillus viscosus I., at the high temperature of 80½° Fahr., turned sterilised beer-wort ropy in 24 hours. In 48 hours it was as viscous as the albuminous part of an egg. Turbidity and a characteristic smell, with the liberation of much carbonic acid in the early stage, but lessening as viscosity increases, seem to be features of this fermentation. With *Bacillus viscosus II.* the evolution of carbonic acid gas was much less in amount.

Dr. Van Laer showed that a mixture of sucrose, peptone, and water in the proportions of 3 : 1 : 100, was rendered turbid and afterwards ropy by the No. 1 type, but that type No. 2 only made it turbid, unless the acidity due to peptone were neutralised by sodic bicarbonate, in which case type No. 2 was also capable of making the above-mentioned mixture ropy. He also found that gypsum in the brewing water promoted the vigour of the organism in question.

Jorgensen regards viscosity as a phenomenon nearly related to the commonly occurring zooglœa formation of certain bacteria.

E. Kramer (*Monatschrifte fur Chemie*) says that the gummy body produced during the mucous fermentation—viz., the substance $C_6H_{10}O_5$—can be isolated by precipitating the liquid with alcohol. It is an amorphous white substance, quite insoluble in water, and capable of being drawn out into threads. Solutions formed by dissolving it with alkali are yellow in colour, but iodine has no action upon it, and from the alkaline solution fine white compound crystals can be precipitated by alcohol.

He maintains that the active ferment is a different one according to the constitution of the liquid in respect of acidity,—*e.g.*, (1) that liquids containing saccharose, having either neutral or feebly alkaline reactions, suffer it under the influence of *Bacillus viscosus sacchari*, an organism 2·5 to 4 μ long, and 1 μ wide ; (2) That liquids containing glucose, and with acid reaction, suffer it from *Bacillus viscosus vini*, an anaerobic ferment 2 to 6 μ long and ·6 to ·8 μ wide ; and (3) That sweet liquids, with merely neutral reaction—*e.g.*, milk—suffer it from a *coccus* about 1 μ in diameter.

Kramer's views require confirmation, but it is hoped that by their inclusion in the above abstract the ground will be fairly covered.

Yeast-bite and Good Hop Flavour.—"Yeast-bitten" or "Barm-stricken" beers have been supposed to owe their disagreeable clinging bitter to some action of the alcohol in the beer towards the end of its primary fermentation upon the contents of the yeast-cell, an action mainly due to the high temperature at which it sometimes comes in contact with the latter; and it must be admitted that cautious cooling, as soon after skimming as is otherwise prudent, minimises the risk of its occurrence.

As a matter of fact, almost all beers, unless in very cold weather, may be attemperated twenty-four hours after the first skim, and pale and bitter ales somewhat earlier, without detriment; indeed, some brewers advocate a slight fall of temperature while the yeast is coming off, asserting, too, that a preferable hop-flavour is secured for that class of ale with a maximum of 68° Fahr.; and though it is difficult to lay down a hard-and-fast rule, the writers may state that their own practice is in general agreement with this view, providing always that the reduction in temperature is a natural one.

Further, absence of aeration is alleged to be a factor of some weight in yeast-bite, and the ales from one particular brewing centre are cited as characteristically affected in this way, as the writers believe without due warrant.

It is precisely stated that the oxygenation which the cleansing process brings about is sufficient to obviate yeast-bite, whilst skimming in one fermenting vessel without special aeration after the wort has left the refrigerator, is alleged to bring it about.

As to the value of this opinion, we can only say that we remember a year or two since tasting a large number of samples, representing every style of store beer, from one of the most important breweries worked on the cleansing system, *every one of which was yeast-bitten,* whilst samples representing thousands upon thousands of barrels, in the production of which aeration after pitching is quite exceptional, come under our notice without being found to have a trace of yeast-bite.

Moreover, Hansen's pronouncements show the probability of yeast-bite being due not to ordinary yeast, but to one of the wild types associated with it (*e.g., S. Pastorianus I.*), in which case the presence or absence of that, or a similarly acting type, is the all-important point, albeit prolonged high temperature in the alcoholic fluid may give a degree of importance to quite a small proportion of it, which with more careful attemperation it would not possess.

Preservatives.—These afford defensive weapons of undoubted value, and if used in the usual moderate proportions are, as far as we know, innocuous. They divide themselves broadly into salicylic acid on the one hand, and preservatives which owe their influence to combined sulphurous acid (*e.g.*, bisulphite of lime and such as kalium meta-sulphite or K. M. S.) on the other.

Salicylic Acid is the more difficult to use, in that being prepared in the form of a very light crystalline powder, it does not readily mix with a relatively large bulk of beer; in fact, it must be made into a paste with a small quantity of the liquid as a preliminary. It is much more soluble in

alcohol or glycerine than in beer or water, and one of the former solvents has been used to permit of the acid being added in the more convenient fluid form.

Salicylic acid is more costly and less potent than bisulphite of lime. Used in excess it flattens beer, and this more permanently than the rival antiseptics. Many brewers have found that beers in which it has been used develop peculiar flavours on lengthy storage, probably owing to decompositions which the acid undergoes. [It has a very complicated formula, and is prepared synthetically from phenol—carbolic acid—or from benzoic acid, being thus allied to the benzene series, aromatic coal-tar derivatives. When heated it breaks up into phenol and carbon dioxide.] But that this is not always the case, even with storage of some duration, it can be said from experience. It is the best preservative for "pressings" in summer time.

Bisulphite of Lime (see Glossary) and **K. M. S.** are both added at racking (the former at the rate of about a quarter of a pint per barrel), though it is sometimes recommended to use them, especially the K. M. S., in the mash-tun too. The latter is in the form of crystals, and for addition to casks, the manufacturers prepare it in convenient tablets of different sizes, the smallest being just the size required for a pin.

It is alleged that the potassic base with which the sulphurous acid is combined in K. M. S. is more stable than the calic base of the bisulphite, and the recommendation to use either in the mash doubtless turns on the fact that a small quantity has a much more effective deterrent influence on disease organisms (lactic and butyric) before their prodigious multiplication begins, than a larger quantity later, but the quantity so used is dissipated by the time the fermentation stage is reached.

What is known as **the Bisulphite smell or stench,** probably brought about by the reducing action of bacteria upon its sulphurous acid, resulting in the evolution of sulphuretted hydrogen, is (if always attributable to bisulphite when it occurs) a drawback. But even then, paradoxical as it may seem, the smell may be caused by using too little, rather than too much, of the bisulphite; because as long as there is sulphurous acid, free or ready to be liberated, the reducing action is held in check.

Used in excess, of course, it has a similar destructive influence on secondary ferments that salicylic acid seems to exert, and flattens the beer to which it has been so added.

The Action of Finings.—The fining of beer—that is the freeing it by artificial means of such suspended matter as interferes with its perfect brilliancy—is a necessary condition of modern competitive trade, and the demand for a beer free from any acidity beyond what is normal and absolutely bright. Capital must be turned over quickly, and it will be neither profitable nor safe to allow beers, except in comparatively limited quantity, to clarify spontaneously.

The action of finings is not very perfectly understood, but much valuable light has recently been thrown thereon by Messrs. Matthews and Lott in a paper read at a meeting of the Institute of Brewing. Although we cannot pretend to set forth all the results given in their paper, which should be read by every one interested in the subject, a few points summarised will supplement what was said under this head in Chapter I.

They first of all made **experiments to determine the best kind of acid,**

and somewhat contrary to the general view, they found that sulphurous acid did its work (that of cutting the isinglass) rather more quickly than either tartaric or acetic acids, and confirmed what was known before, that finings made with it were the least liable to mildew. They also experimented with lactic acid, and found it markedly superior to acetic acid, whence they conclude that, in finings made with sour beer, the effective cutting agent is the lactic and not the acetic acid.

[In one respect, that of clearness of the finings themselves, those made with lactic and acetic were both superior to those made with sulphurous acid.]

The strength of the acid used appears to have a marked effect. Beyond a certain point (some ·7 to 1% of H_2SO_3) the effective cutting diminishes with the concentration of the acid. Undiluted commercial acid, for instance (7·4% H_2SO_3), cut very slowly and gave a very thin solution. The authors say that about 1% of acidity (one gallon of commercial acid per barrel) at starting, and a finish of ·2% is a good strength, *i.e.*, one gallon of commercial sulphurous acid, strength 7·4% H_2SO_3, diluted with 6 gallons of water at first and made up eventually to 36 gallons. The quantity of isinglass, they say, should vary with the quality, $2\frac{3}{4}$ lb. of best Russian being ample and $3\frac{1}{2}$ lb. of inferior kinds.

In a sample of properly made finings the isinglass appears to be in a state of true solution (finings thinned with distilled water will pass through a filter paper), but a very slight alteration of condition is sufficient to throw the isinglass out of solution, and it is upon this that its fining capacity depends. The specific gravity of the isinglass particles, as thrown out of solution, is very close to that of the fluid in which they are, and according to their degree of compactness, *i.e.*, according as they are just heavier or just lighter than the corresponding bulk of the liquid, so they will sink or rise in the liquid, carrying with them more or less of the suspended matter, which interferes with the brightness of the beer.

And most brewers will agree that the beers which give the most brilliant results are those in which the finings rise to the top of the fining-glass, after a very short stay at the bottom, carried up it may be by bubbles of carbonic acid gas ; and if this be so, the more closely the specific gravity of the isinglass particles corresponds with that of the liquid, or in other words the finer and more widespread the mesh of the isinglass network (if the simile may be allowed) the better.

Probably this rise to the surface is followed by a fresh descent, as coagulation increases the density of the floating finings, otherwise unsatisfactory results would occur on draught, such as do sometimes occur with incomplete fining, when, for instance, the ale is drawn alternately brilliant and cloudy. This state of things, however, can hardly be due to the rise of the whole body of finings to the surface, and it may be taken for granted, from practical experience, that finings which rise *en masse* also settle in the same way.

This delicate and sensitive state of solution seems to depend upon the acidity of the finings, for if these are made slightly alkaline isinglass is thrown out of solution. This fact is of practical import, because it explains why a cloudy beer, with a high percentage of acidity, is not likely to fine readily. But it being manifestly impossible to make a beer

alkaline, this separation of the isinglass (making it act as an extremely fine-meshed net collecting particles of suspended matter) depends upon other causes whose action appears to be of a physical nature.

For example, experimenting on the influence of suspended matter, Messrs. Matthew and Lott found that cooler grounds and beer grounds, diffused in water, ensured a rapid precipitation of the finings, their action being perfect if the finings were somewhat in excess. Ordinary pitching yeast, suspended in water, was also got to fine perfectly, but washed yeast, free from bitter, was found, when no other matter was present, to be partially left in suspension, although it always caused coagulation of the finings.

Clay, powdered glass, asbestos, powdered or animal charcoal and other chemically inert matters, suspended in water, were also found to cause rapid coagulation of the finings, followed by speedy clarification. Finely ground malt, they say, will cause a nice separation ef finings from beer which does not take them readily, and it is their practice, in getting stubborn beers or worts ready for the polarimeter, to add powdered asbestos and a small quantity of finings before filtration.

The discovery of these facts is by no means without interest, because they help to explain why rolling about a cask—in fact, stirring up its sediment—of a beer which does not readily take finings, often assists the action of the latter materially. We say *helps* to explain, because carbonic acid as in solution, or even more so when just liberated from it, materially assists the action of finings.

With regard to the influence of mineral acids, they found that up to a certain point ·4% (over the normal ·1% of total acidity) of acetic acid did not hinder, but rather helped separation, whereas ·2% of lactic acid did affect the efficiency of the finings.

With regard to temperature, the experiments carried out show that finings cannot be expected to do their work effectively at a temperature below 50°.

The authors summarise the favourable and unfavourable conditions as follows :—

Favourable.	Unfavourable.
Dry hopping.	Unusual fineness at rack withou true brilliancy.
Presence of a certain amount of suspended matter in the racked beer.	Flatness.
The presence of alcohol.	Greyness from imperfect or slack malt.
Presence of carbonic acid gas at small pressure, and in a state of liberation.	Presence of bacteria (active).
Normal acidity.	Fret. Abnormal or unusually vigorous secondary fermentation.
Soluble bitter and astringent hop derivatives.	Excessive acidity.
A rising rather than a falling temperature of the liquid to which finings are added.	Excess of suspended yeast.

Further, they state it as their opinion that finings, for which the isinglass has been "cut" with sulphurous acid, give the best results with hard-water beers, while for those brewed with soft water, especially when they are running beers, finings prepared with tartaric acid, and still more those made with sour beer, answer best.

Methods of using Finings.

Occasionally, one sees paragraphs or communications in the brewing papers referring to " fining in tank " (*i.e.*, settling or racking back) ; and where there is a very keen competition trade, and abnormal freedom from " bottoms " is looked for, some form of preliminary fining may be necessary. Beer so treated, however, cannot be expected to rack brilliant (owing probably to certain previously soluble matters being thrown out of solution by oxidation), consequently re-fining is essential, and the freshly insoluble matter, forming the slight haze, will be generally sufficient to cause the isinglass to go out of solution on the principle previously stated.

Besides this necessity of double fining, there is the risk of unduly flattening the ale, as a remedy for which the addition of a little of what the Germans call *Krausen* (sometimes referred to in the English brewing organs as Kreising), viz., fermenting wort, may be found effective, but Thausing's caution never to take Krausen from a weak fermentation should be borne in mind.

The strictly legitimate way of using finings is in the trade or carriage casks, and this, for running beer, divides itself into two methods ; the first, adopted in the majority of country breweries, being the **" fining-in "** process, which means that a quart, or sometimes less, of finings per barrel is added to the carriage casks (the beer contained in which must be perfectly free from " fret "), and thoroughly mixed by stirring or rolling. This addition may be made either before the casks leave the brewery (whereby a quart of beer per barrel is saved, no inconsiderable matter in a large trade), or, what is better for the beer, if done in time and properly, in the retailer's cellar.

The **working-out, fining-out,** or **spurging-out method** is practised in some important centres, notably in London. It seems the one best adapted for a trade in which rapid maturity for delivery is aimed at (*e.g.*, four days from start to finish), a result arrived at by arranging the mashing conditions so that the fermentation would, under any circumstances, be vigorous, but by the avoidance of any early check with the attemperator—the heat perhaps running up to 70° Fahr. before the gyle is discharged into a finishing and racking back, where cooling influences are first brought to bear. Such beer is, as might be expected, sent out with the primary fermentation hardly completed, and the finings, added in the publican's cellar, and generally in excess, work out at the bunghole, bringing with them the sedimentary and suspended matter, which, if the " in-fining " method is adapted, must be got rid of before racking.

Fining Bitter and Pale Ales.—Although, with stock ales now out of vogue to a great extent, the practice of fining these ales is growing, we cannot but think, where time allows, that spontaneous clarification should not be interfered with.

And the ale should be allowed to go through all its cask-changes, spontaneous brilliancy at the end of them being the simplest criterion of ripeness for bottling.

Even with the cheapest beer intended for bottling, some short storage is advisable, for if finings are added before the secondary fermentation has properly begun, *i.e.*, at the time of racking, perfect brilliancy cannot be expected, the flavour of the added dry hops will not have become

diffused, and the result, even under favourable circumstances, will be a modified failure. Such beer, even if bottled bright, is less likely to remain so in bottle than a riper article would, and at any rate is certain to throw down a relatively heavy deposit which tells against it with consumers.

Daily rolling about of the casks stimulates secondary fermentation, and consequently accelerates condition; accordingly, fairly satisfactory results may be got with average well-brewed light beers, fined some fortnight after racking (though longer, of course, is better), provided spontaneous brightening have decidedly begun earlier, and especially if steps have been taken to secure quasi-maturity by rolling.

The foregoing considerations of course apply as well to casks intended for consumption from the wood (other than "running" beers); and though it is sometimes the practice to add finings, at the time of racking, to firkins of semi-stock bitter ale and all casks below that size, in order to avoid the necessity of drawing shives when they are sent out, it is not one to be much commended.

Besides, where hopped beers are rolled, as has been recommended, it seems better to do this before the casks are topped up for good, this allowing the hops to get saturated more speedily; the rolling may then be renewed with advantage after the topping-up and final shiving.

Before dealing further with the question of bottling, a few words on the storage and sampling of bulk beers will not be out of place.

The temperature of the store cellar should not vary much from 55° especially for pale ales, though for running beers it may well be a degree or two higher. It was pointed out in Chapter I. that a due attention to storage temperature seems to determine flavour and condition in the most favourable sense.

A further *desideratum*, too often disregarded, is that the cellars should be dry. Damp air not only rusts the hoops of casks and causes the timber to perish, but, owing to its conductivity being greater than that of dry air, damp cellars are less uniform in temperature than those freer from moisture. Damp encourages the growth of mildews, and the effect of these, even if not so markedly detrimental as that of bacteria, is none the less in a destructive direction.

Porous Spiles and boring Casks (Spiling).—Porous spiles, inserted through the shive in order to let off excess of carbonic acid gas, not unfrequently get their pores clogged by the dried froth which has worked through them (and still more by dirt if the casks are rolled about with the porous spiles in them), and so cease to act. Sometimes, perhaps, it is fortunate that this is so, because porous spiles are frequently left in too long. They should be replaced by tight spiles directly the briskness of the complementary fermentation has subsided.

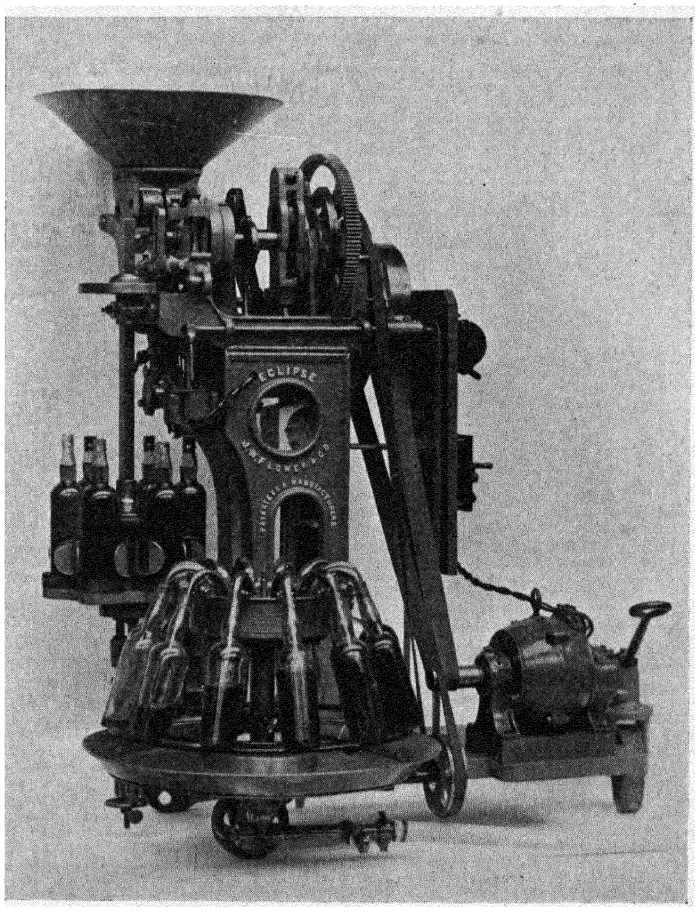
There is considerable difficulty in doing this when the ales are stacked, the breaking down and remaking of stacks being just one of those sorts of work that there never seems time for. Probably large firms would find their account in adopting an arrangement on the lines of that described on p. 362, whereby the making of stacks of any height is much facilitated.

Sampling by boring and after-insertion of a spile is a crude method, which, apart from the inducement it offers thirsty persons of lax morality, when they seek a cask-stave riddled with peg holes to insert one more

spile, has the further disadvantages that the ends of the spiles not only afford a harbour for filth, but that the timber of the cask, made jagged inside by constant boring, serves the same ill end.

The boring is often very carelessly done, too, especially outside the brewery, for example, in the edge of a stave, where the imperfectly rounded hole that is made cannot so easily be stopped by a spile.

On the whole, the use of the little conical corks, known as " tit-corks,"



Bottling and Corking Machine : The Natural System.

seems preferable with a view to sampling. One, or even two of these can be driven into existing spile-holes, and when it is desired to sample the cask, forced into the latter by means of a spile, just as a tap-cork is at tapping by the tail of the tap.

[When casks are habitually unheaded and scrubbed before refilling, the spile-ends can be cut off, but even then the objection to indiscriminate boring applies.]

The Bottling of Beers.—The Natural System.—Whether a beer is brewed especially for bottling or if only a portion of a gyle is reserved for that

purpose, there are a number of essential primary and secondary factors to be observed in order to ensure success.

A correctly produced beer to meet the demands of the modern consumer should exhibit the following main characteristics.

The flavour should be clean and free from yeastiness, with an apparent but not over pronounced hop aroma of a delicate character. The beer should be free from sweetness, drink full with a distinctive " bite " on the palate, carry a tenacious creamy head, possess a minimum of deposit and, above all, a brilliancy that immediately attracts the eye of the discriminating consumer.

To attain the standard of general character briefly outlined, the selection of a blend of brewing materials is a matter which calls for careful consideration. The malts must be friable, of a tint not exceeding 5 Lovibond, with a D.P. of 28—30, and while it is necessary that the malts should be full flavoured, it is equally of importance that they should not have been subjected to excessive kiln temperatures in the presence of moisture during the final stages, conditions of working which are evident in the flavour of the finished beer. As to the blend of malts, at least 25% of sound dry flavoured foreign should be employed, together with at least a similar proportion of invert sugar. No more important ingredient than hops for copper and cask use—especially the latter—enters into the question of selection of materials for the brewing of a beer for bottling. A judiciously selected blend of hops is always preferable, but especially is this advantageous in the production of bottled ales, and in the latter case the use of hops older than yearlings must be avoided. The hop rate necessary cannot be calculated on strictly mathematical proportions, but for our present purpose it may be said that economy in the quantity and quality of the hops employed is an erroneous policy commercially, and technically unworthy of adoption. A minimum rate of 7 oz. of copper hops per barrel for every 10° of original gravity collected, together with an addition to casks of 8 oz. per barrel of dry hops of superior aromatic and preservative properties and free from particles likely to create " floaters " in the beer, may be regarded as within the margin of safety.

Methods of working and every adjunct or medium that will ensure the refinement of the wort in each successive process should be adopted. Apart from such considerations as loss of extract resulting from the hurried collection of mash tun runnings, the wort should throughout be brilliant. Parti-gyles are advisable as they permit of an arrangement of the several copper lengths in a manner which will eliminate the crude proteins and albeit starch in the primary and final runnings, the absence of which minimises the amount of deposit in bottle which is confined to the yeasts and bacteria, if any, developed and precipitated during the generation of condition in storage. Parti-gyles, moreover, allow of the collection of the entire hop sparge or " splash " to the wort destined for an inferior quality draught beer of the running class.

We are of opinion that superior general technical results obtain when the full amount of hops are boiled for the total period allotted, instead of retaining a percentage of the whole for addition 20—40 minutes prior to turning out or casting, a custom that is still, nevertheless, continued in some notable breweries. Aroma is doubtless sacrificed by extending the

ebulition period to the full two hours—the maximum in our view—but any attempt to retain the volatile aromatic properties can only be secured, if successful, at the expense of leaving undissolved the remaining essential principles of the hop.

Copper finings is now a recognised media for the removal of matters in suspension in hot wort. There are brewers who contend that this valuable refining material deprives the wort of a certain amount of yeast nutrient. Carrageen does not render insoluble, nor does it precipitate, substances in solution. It only acts on matters in suspension which, if permitted to remain would interfere with the ultimate production in bottle of a brilliant ale with a low amount of deposit. Instead of employing the crude carrageen in large amounts better results are obtainable from one or other of the preparations with this moss as a base, which are supplied by brewers' manufacturing chemists. The cost is, moreover, infinitesimal.

Brilliancy of wort runnings from hop-back with correct aeration at this stage, together with due settlement on coolers are essential factors in the brewing of ale for bottling. Much has been written in respect to the type of yeast and system of fermentation regarded as the most suitable for ales to be sold in bottle, but brewers, except those in an unusually large way of business, must of necessity adhere to the class of ferment and method of tun-room working which yields the best general trade results.

Yorkshire and Scotch yeasts, being reproductive and therefore of a purgative and cleansing nature, are poor in attenuative properties, and it follows that the ales racked from these North Country barms are full and round on the palate and inclined to be mild if not actually sweet in flavour, characteristics which are opposed to the light-bitter and dry beverage preferred by the consumer of bottled goods. The original type of Burton yeast is highly attenuative, and therefore lacks reproductive qualities, but the former attribute can be modified, and the latter property increased by a study of yeast, its culture and functioning. It is possible, therefore, as the outcome of intelligent observation and the exercise of ordinary care, to secure a yeast that combines to some extent the reproductive advantages of the Northern type with the benefit obtained from attenuations somewhat modified in this instance, of the Midland ferment, which together yields an ale eminently suitable for bottling, so far, of course, as a type of yeast can manifest itself in this direction.

Whatever the class of yeast, kind of plant or system of fermentation is in use, it is necessary to insist upon a correct settlement of wort from the close of fermentation, and that the finished article is racked in that clear, but by no means bright condition in which the beer exhibits the presence of yeast cells resembling somewhat in form a " break."

The custom still obtains in some districts of adding finings to the settling tank or to the vessel from which the beer is racked. This yields a brilliant and flat ale, but one that is, by reason of its brilliancy and the absence of carbonic acid gas, especially susceptible to infection from the aerial micro-organisms which are seldom wholly absent from the majority of racking rooms. The type and rate of priming should both vary according to the season of the year. Priming in larger proportion and of a more fermentable character is necessary during the winter months than throughout the spring and summer. At all seasons a division of the total

sugar solution decided upon should be made, a portion being added at racking to stimulate early conditioning in cask, the remainder of the priming being added when the casks are stillaged preparatory to bottling. By this procedure, conditioning in bottle is considerably accelerated.

A common error among the inexperienced is to bottle ale before the secondary fermentation has reached completion in cask. It is argued that the stability of light ales is insufficient to permit of this period of maturation, but unless a gyle of ale possesses sufficient keeping qualities to undergo the necessary supplementary fermentation it is unfit for bottling purposes. Whatever the final attenuation of a beer may be at racking it will undergo a still further reduction of gravity in cask. With this additional fermentation a definite proportion of nitrogenous substances and resinous matter is thrown out of solution and is deposited in cask. It follows that with this diminution of the sugar content of the beer and consequent increase in alcohol, together with the elimination of proteins of dubious ultimate solubility and resins, the beer is cleaner and more matured in flavour, general characteristics which make for the production of an ideal bottled ale. To attain the conditions first named, it is necessary that the casks should be rolled regularly in cellar. This treatment considerably facilitates secondary fermentation, as it not only brings the sedimentary yeasts in continuous contact with the fermentable sugars present in the beer, but maintains the cask hops in suspension, thus permitting the diastase which the hops possess to act upon the sugars and renders soluble and semi-soluble the preserving, flavouring and aromatic properties of the hops. When the secondary fermentation is completed, a period dependent upon the original gravity of the ale and its opticity, the casks, with the addition of a further volume of priming are ready for transference to the bottling room. Before doing so, however, there are periods of the year when it is advisable to adopt the precaution of removing the deposit from the casks, which precipitate consists in the main of primary and secondary yeasts together with lactic and acetic acid forming bacteria. The removal of this deposit can be readily accomplished by the use of a valench.

The temperature of the bottling cellar should be as low as possible, without resorting to the reduction of temperature by mechanical means, an expense that need not be incurred. High temperatures would result in a further* conditioning in cask—to be avoided at this stage—and stimulate the development of disease-producing organisms if still present. Low temperatures, on the other hand, prevent further fermentation and saturates the beer with the carbonic acid gas produced previously, which in this condition is carried forward to bottle. Formerly it was considered that finings would not function at low temperatures, but this theory has been disproved. While on the subject of finings, there is much to be said in favour of dispensing with their services, if a beer will drop brilliant in cask without their aid within a reasonable period. When isinglass is employed, its presence is evident to some extent in the deposit in bottle and it follows that the amount of sediment is reduced in some measure when the use of finings can be avoided.

* With regard to "conditioning" Regnard and Melrens have shown that the yeasts are able to resist very strong pressures up to 1,000 atmospheres for one hour without killing it.

Directly the contents of the casks are "settled" and brilliant, the beer must be bottled and with expedition, no cessation of labour being allowed until the work is completed. Beer at this juncture is devoid of the protective influence of gas and is, therefore, peculiarly susceptible to infection from aerial micro-organisms.

The bottles, we need hardly add, must be clean and dry, and the corks washed and rendered more amenable to pressure by soaking in clean warm water which is, of course, subsequently drained off. Crown or crescent corks require no preliminary preparation, but screw stoppers are a different problem. The rubber rings can only be effectively dealt with by removal from the stoppers, a rigorous treatment and laborious process, the adoption of which is fully warranted by results.

Some bottle washing outfits include a mechanically driven steam-heated drying-machine upon which the cleaned bottles are placed immediately they leave the washing unit. The surface moisture is immediately absorbed by the anhydrous heated air passing over and into the bottles, which leave this final item of plant in a dry but warm condition, so that the bottles readily "sweat" in their transference to the bottling room, which, for reasons already explained, is maintained at a lower temperature. For this reason, therefore, the use of a mechanical driven dryer has been discarded in many bottleries.

It is surprising how little attention is paid to the matter of uniform filling by some bottlers, when regularity is so easily secured. Manufacturers are always prepared to supply pints or half-pints, securing that the ten or twenty-ounce capacity line reaches to within half an inch of the bottom surface of cork, crown, or stopper. If this limit is exceeded the unsightly film *Mycoderma Vini* has opportunities of development, even although every precaution is observed to obtain dry bottles and corks. To obviate the gathering of a film the filled bottles should be reversed or slanted in a manner that permits of the beer absorbing the oxygen present in the space between the surface of the fluid and the cork.

The storage room must of necessity be higher in temperature than the bottling cellar, such temperature it is generally agreed being between the limits of not below 50° Fahr. nor above 55° Fahr. It is impossible to state the length of period necessary to produce condition in bottle, as so many factors, adverse and favourable, are involved, many of which we have endeavoured to explain. There is the question, among others, of the amount and type of saccharine matter present in the beer at the bottling stage, and whether the temperature of the store is such that bottle conditioning is accelerated or hindered. Light gravity ales in bottle reach maturity and drinking condition in from a third to one-half the period required by high gravity malt produce.

Messrs. Bass & Company's Bottling Instructions.—

"The proper season for bottling pale ale commences in November and ends in June.

"Pale ale should not be bottled during the summer months, nor after hot weather has set in, even though the temperature should afterwards become cool.

"The ale should be placed bung upwards, in a cool, well-ventilated store, about 50° to 55° Fahr. temperature.

" If the ale should get into a brisk state of fermentation, a porous cane or porous oak spile should be inserted in the bung until the excessive fermentation has subsided, when a tight, close peg should be substituted.

" Ale should never be allowed to become flat.

" It should be bright and sparkling when bottled, but not fermenting. The bottles to be corked directly they are filled.

" In bottling, a tap with a tube reaching towards the bottom of the bottles should be used.

" When corked, the bottles to be piled standing upright, and not lying on their sides.

" When the ale becomes ripe, a sediment will be deposited in the bottles. In uncorking, be careful not to disturb it, but empty the contents of the bottle into a jug, keeping back the sediment."

A more convenient filler of bottles than the tap recommended is the syphon arrangement, made by several firms, by which four or six bottles, or even more, can be filled at once, the filling going on continuously.

The piling of the filled bottles, standing upright, is of course necessary to avoid the formation of a sediment on the sides; but the recommendation to do this at once is only actuated by convenience and to avoid double handling. Where the latter is not objected to it is certainly preferable to let the bottles lie on their sides for two or three days, after which they may be stacked, standing upright.

We cannot do better than quote the words of M. Pasteur (*Etudes sur la Bière*, p. 15), premising that the precaution seems more necessary with lightly hopped, low gravity bitter ales than with the stronger pale ales. Perhaps, too, it is not unconnected with the manner in which the bottling store is ventilated. He says :—

" The bottles must be laid down at first after bottling for twenty-four or forty-eight hours, and then stood upright again. This is because the air remaining between the cork and the surface of the liquid might give rise to the production of a film of mycoderma (Pasteur says *fleurs* simply). By laying the bottles down, the oxygen of this air gets absorbed by certain oxidisable principles of the liquid, and there is no further occasion to fear the film when the bottles are stood upright. The latter, too, could not remain lying down longer without risk, because the complementary fermentation might burst the bottles. Moreover, if the bottles stand upright, the deposit forms on the bottom, and not on the sides."

We think that the benefit depends as much upon the fact that the aerobian mycoderma germs, which have begun to make good their footing on the moistened neck of the bottle, get submerged and killed, as upon absorption of the oxygen; but whatever the reason the remedy is good.

[For cleaning bottles a weak solution of potash is very useful. The water used to rinse them should be cold, as the vapour given off by hot water condenses on the inside and does not dry readily. There is also the risk of breakage to be considered. Better even than this, I should like to see all bottles dried by a blast of hot air. Far too many damp bottles are filled.]

The Forcing Tray is a means of testing the stability of beer, which we owe to Mr. Horace Brown of Burton. Its usefulness comes in where large stocks have to be kept for prolonged periods; for a " hand to mouth "

trade a simpler process of determining fitness (such as the one to be described hereafter) will amply suffice.

The mode of manipulation is briefly as follows :—

Sundry small bottles (Pasteur flasks), of which we will assume ten or twelve to be kept going at once, whose only available outlet is a glass tube bent downwards at right angles to its first direction, are partly filled with water, and the nozzles of the tubes being connected with a small pipette by means of gutta-percha tubing, are separately held over a Bunsen. Boiling water and steam soon rush out, whereupon the point of the pipette is introduced into a portion of the ale to be tried, sufficient of which, of course, enters the bottle to fill the vacuum produced on the egress of the boiling water.

The nozzles of the bottles, the tubing being disconnected, are then placed in a small basin of mercury, whereby they are, as it were, hermetically sealed.

The bottles themselves stand upon a water-tray, *i.e.*, a wide but shallow metal box containing water, and their temperature is maintained at a uniform heat, say 80° Fahr., for a fortnight, by means of a burner beneath. The supply of gas is regulated by a gas regulator (Reichert's or Page's).

At the end of a fortnight the deposits are examined with a microscope, and according to the proportion of faulty types of ferment found, the beer is sentenced to speedy consumption or kept for stock.

The above, albeit with risk of breaking some of the bottles, seems the better plan for insuring sterilisation of the apparatus, but some operators are satisfied to fill the trial flasks direct from the fermenting vessels at the time of racking, of course only after a *thorough* cleaning of the bottles, and a preliminary rinse out with the beer under trial itself. [For full details refer to Messrs. Matthews and Lott's *Microscope in the Brewery and Malthouse*, pp. 128–137.

The simpler test for bottling fitness referred to above is to catch a small portion, say a pint and a half, of the beer in a *thoroughly* clean, clear glass, bottle and to put this in a water-bath, with a Bunsen burner beneath, regulating the latter so that the temperature keeps at a fairly uniform 90° Fahr. Beer so treated, and which then throws down no deposit in, say, four days, may, unless some exceptional probation is awaiting it, be bottled with all reasonable confidence.

Carbonating, Chilling, etc.—These processes, introduced for competitive purposes, must be briefly alluded to. There are two ways of carbonating beer, one in which a definite bulk of bright draught beer—*e.g.*, a hogshead or barrel, is charged with CO_2 from a cylinder of the liquefied gas and driven into the beer with strong agitation ; the other wherein the beer charge for each bottle is forced by a double-acting pump into five times its own bulk of CO_2, after which, as air can be practically excluded, it flows without fobbing into a bottle wherein a vacuum has been induced. The cost of the added gas should not exceed one halfpenny per dozen.

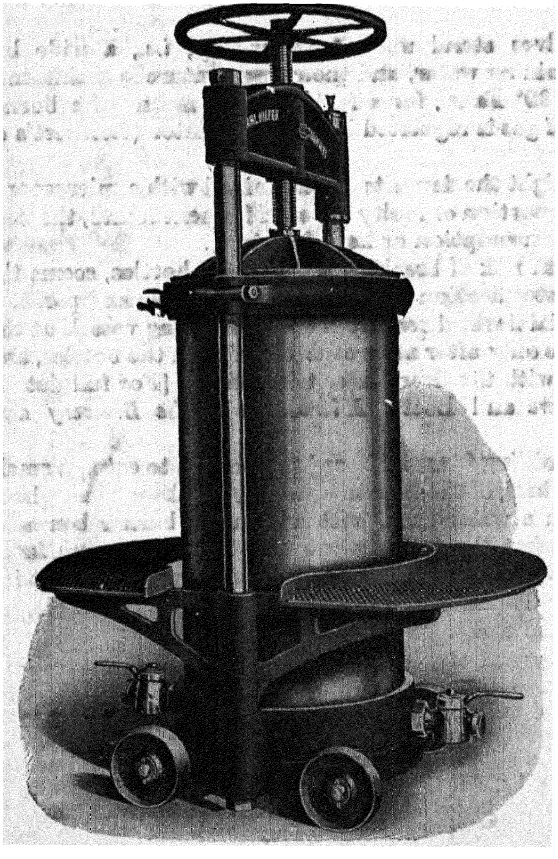
Chilling, followed by carbonation unless System 1 be adopted, divides itself into three methods : (1) Natural conditioning in casks of special strength, or small vats, and subsequent chilling. (2) Slow chilling in large casks. (3) Rapid chilling in special apparatus.

The object of chilling is to precipitate matters only slowly removable by natural conditioning, or which might induce a haze at low temperatures ; these, then, going out of their normal state of semi-solution on strong reduction of temperature, are removed by filtration. Obviously method 3 is more speedy and much more

economical in plant, space, and costly insulation ; these considerations may outweigh the better flavour conferred by the natural conditioning of No. 1 (handicapped further by the necessity of getting extreme and uniform condition for *each* cask) and the lower amount of slimy matter tending to clog the filters, precipitated as this is *before filtration*, during the lengthier chillings of 1 and 2. The cotton pulp of these filters must be removed and thoroughly washed between the operations, not merely rinsed by reverse flow of water, and the inlet should be 50 per cent. larger than the outlet, so that back pressure is maintained and air excluded.

The **Wittemann re-saturating process,** in which CO_2 taken direct from fermentations, and not denaturated by excessive compression, is used, with all its aroma, one fermentation supplying enough for eight, may indicate the system of the future for large plants.

Bottling on the Extended " Chilling " System.—The beer selected for bottling is transferred to a conditioning vessel, generally composed of copper and fitted externally with a pressure gauge, and to the beer finings are added. " Conditioning " is permitted to generate there until a definite pressure is reached dependent upon the trading circumstances of the district, type and original gravity of the beer, and other, and similar, influencing factors. The beer is then subjected to an extended chilling period, which primarily consists of passing the beverage over a brine refrigerator, the beer circulating one way and the brine another, the process in the course of time reducing its temperature from that of the room—maintained at approximately 56° F. —to 33° to 35° F. The beer then proceeds to the cold room, where it remains for a day or two at 28° to 33° F. as required. Installed in this room is an ammonia refrigerator and air compressor, the vessels in the room being, as in the case of those in the conditioning room, fitted with pressure gauges. From the cold room the beer, the main constituents of which, during the extended process briefly described, have been rendered insoluble by the influence of the low temperatures

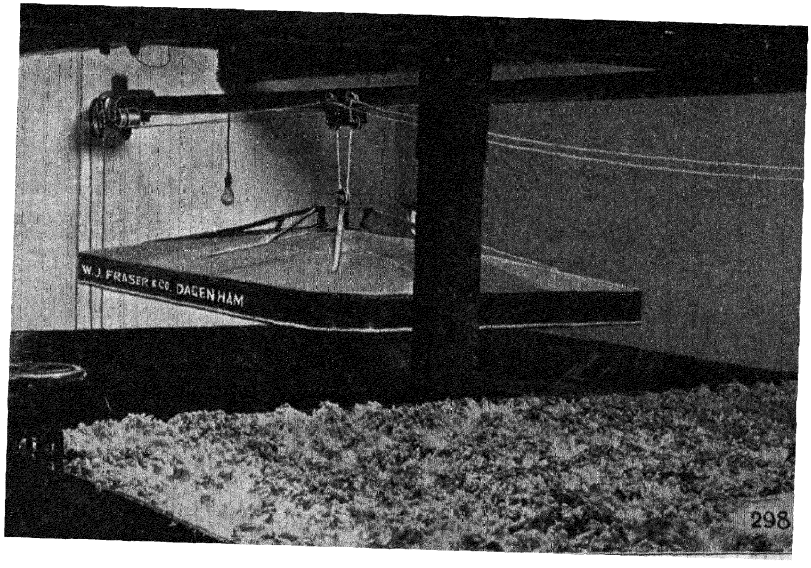


The Kiefer Filter.

employed, now passes through a Kiefer or other filter from which it emerges in a brilliant condition and fully saturated with liquefied CO_2. Upon removing the beer in bottle to normal atmospheric temperatures, the carbonic acid gas comes out of solution, condition is generated, and the beer is ready for delvery and immediate consumption if required.

The Mechanical Production of Cold.—Space will not permit of an explanation here of the fundamental principles upon which the mechanical production of cold is base. Readers, however, will experience no difficulty in obtaining a complete knowledge of the subject upon reference to any modern work on refrigeration.

Naturally Produced CO_2 for Carbonating Purposes.—The day is not far distant, we think, when chemically prepared carbon dioxide for car-

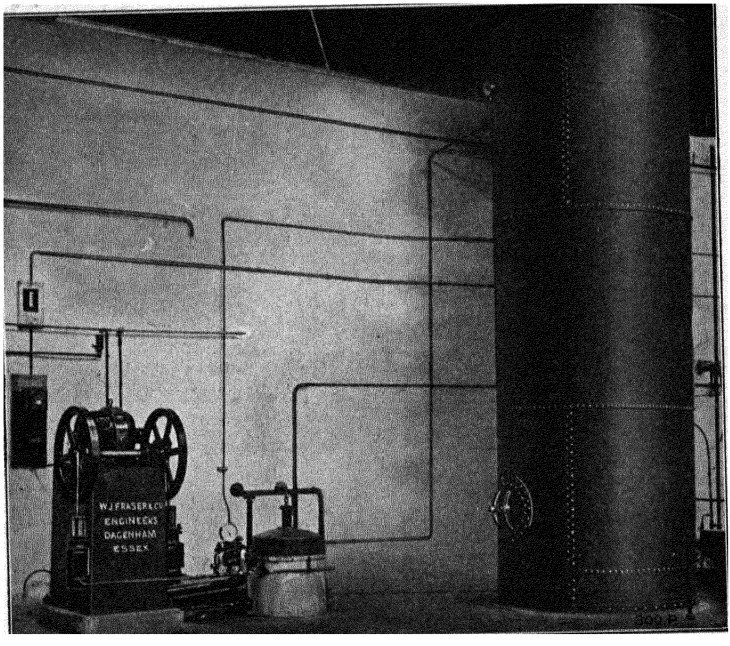


A typical collecting Bell Equipment in a large brewery.

bonating ales will be entirely superseded by the naturally produced gas collected from the fermenting vessels of breweries. Scientists have proved that the gas evolved from fermenting wort differs in analytical composition, physical characteristics, and in other aspects from the manufactured CO_2. The gas produced during the slow conditioning of ales bottled direct from casks gives rise to no disturbing consequences to the consumer as compared with the effect produced from drinking machine made aerated beverages. Henriot, of Paris, has shown why this occurs. Naturally formed carbonic acid gas, he says, is totally different in its physiological action from the artificially prepared CO_2. The former is absorbed promptly, whilst the latter is with difficulty assimilated, and produces distention of the stomach. Practically there is little difficulty in recognising the superior value of beers charged with natural gas. Some of the best brands of non-deposit ales on the market have been thus car-

bonated, and the establishments who have adopted this system are increasing in number.

If the CO_2 is collected from the F.V.'s at the correct stage, it will be practically free from air and the carbonating medium will thus possess the advantage of being devoid of atmospheric impurities. Natural CO_2 from wort contains the aromatic ethers developed during fermentation and these are re-introduced at bottling into the beer, increasing its palate-fulness and enhancing its flavour and aroma. The gas should be collected at low temperatures and during the early stages of fermentation in order to obtain the *highest* type of aromatic ethers. Care should be observed to avoid prolonging the collection of the gas until the late fermentation stages have been reached, the CO_2, from which will confer a yeasty flavour to the beer. The gas, moreover, should never be stored for long periods



Typical arrangement of Compressing and Storage Plant.

prior to using, as after a week or so from collection the gas undergoes a deterioration in general character. The plant is inexpensive to purchase, simple to work, and the expense of collection is virtually *nil*, nor does the installation necessitate any alteration to the existing plant of a brewery. If the gas is required also for carbonating mineral waters, it can be purified by passing it through a deodorizer, or be liquefied by a further compression process and charged into steel bottles for sale as " bottle gas " for industrial purposes.

A " Nitrometer " for estimating the air and other gaseous impurities present in CO_2 collected from F.V.'s can be obtained, with full instructions as to its application, from any scientific instrument manufacturer.

The Management of Beer in Brewery Cellars.—Revolutionary changes in theory and practice have occurred in brewing during the past twenty years as in other professions. An example of this may be quoted from an article which appeared in a work published in the early 'eighties dealing with the question of racking. "It is of great importance," the writer states, "to allow beer after it has ceased working to flatten. This is fulfilled by leaving the casks open; the time sufficient for this purpose must be regulated according to the temperature." Indeed, some of the brewers of the Victorian era, in order to secure for their produce a thorough "flattening" resorted to re-racking the beer frequently. That contamination from air-borne organisms attend the exposure of beer has now been proved. Aeration at any period subsequent to the close of the primary fermentation is fatal to the stability and brilliancy of the finished beer, and there is no necessity to expose the contents of casks in cellars to the influence of an atmosphere of doubtful purity from the racking stage until the beer is actually placed before the consumer. Priming, finings, colouring, and beer for "topping up" can, by employing an injector, be pumped through the spile-hole, a method that serves the threefold purpose of securing a thorough distribution of the various additions to the bulk in cask without the beer being exposed to the air, involving risk of infection and loss of CO_2.

Apart from the consideration of other factors the essential properties in present-day ales are brilliancy and condition, both of which qualities may be lost by want of knowledge and the exercise of care in cellar management. In South Wales and other industrial districts the principal demand is for mild ales which are forwarded to customers on the day of racking. The addition of cask hops to beers of this character would not only result in a waste of expensive brewing material, inasmuch as the beers would be consumed before the dry hops could yield up the constituents for which they were employed, but a further loss would occur by the hops absorbing beer which could not be recovered by the publican. Obviously, true secondary fermentation does not take place in beers of this type and condition in the correct sense of the term is not secured. The agitation and slight aeration which accompanies racking acts upon the CO_2 carried forward from the tuns at that stage, causing the gas to come out of solution, which enables the retailer to present the beer to the consumer in a pleasing and palatable condition. In the production of quick running ales of this class the cellar management in the brewery consists merely in observing that the finings and priming are accurately added. With regard to the latter, if the correct type and quantity of sugar is employed it will enhance the appearance and "head" of the beer and considerably increase its palate-fulness. Many brewers in the districts referred to add both finings and priming through the bunghole of cask prior to commencing racking. The practice of adding priming in this manner serves its purpose, and is labour-saving, but the casks should then be rolled to distribute the sugar solution before the finings are injected. By pumping the latter through the spile-hole a certain degree of air-pressure is created in the cask, which is not lost when the beer reaches the consumer.

While the output of the districts we have been considering is mainly confined to quick-running ales supplied to the public trade, the produce of

the typical country and city breweries is composed of a greater variety of brands distributed usually over a wider area to private as well as public customers who demand the flavour and bite which accompanies true secondary fermentation. Considerable skill must be exercised and care observed in the cellar management of beers for this class of trade in order to retain and promote condition throughout the long periods during which the casks remain on draught. Much, of course, depends upon the selection of brewing materials and the methods of manufacture adopted with a view to obtaining a finished beer, the residue of which at racking is not of a readily fermentable type.

Cask condition in cellar should not occur under any circumstances before a week from date of racking if the beers are expected to exhibit the general characteristics of semi-stock ales for any length of time, while being drawn upon by the consumer at irregular intervals. All casks for this trade should after reaching the cellar be subjected to rolling for several days in order to break up and soak the added hops, and to bring the cask yeasts into contact with the residual sugars present in the beer. The correct amount of condition to be generated in order to obtain the best results while on draught depends upon the season of the year ; bearing in mind always that the finings to some extent adversely affects condition. Beers which in brewers' parlance are " on the move " are not in a sufficiently advanced condition to withstand the flattening influence of finings together with the much greater chilling effects which result when beer is forwarded to the trade during the winter months.

On the other hand, the extent of cask fermentation first described is ample if beers are delivered in warm weather, especially if the amount of condition is assisted by priming. We advocate the employment of correctly selected sugar solutions for promoting and maintaining condition in beers for every description of trade. In the case of exceptionally light ales in which large priming rates are permissible, the sugar solution should be added in portions as to one-half at racking and the balance at forwarding. With beers of 15 lb. to 17 lb. gravity a fourth of the total priming arranged for should be added at racking, and the balance when delivery takes place. The full amount of sugar solution should be added at this stage to beers in excess of the gravity named.

Part of the regular duty of the foreman cellarman is to observe that none of the stock under his care should be allowed to generate excessive condition in the brewery, which results in the reduction in the type and amount of unattenuated sugars in cask upon which we depend, apart from the priming, for sustained condition while on draught. This should only occur in well-managed establishments during unexpected periods of lessened output and then only in respect to beers of high gravity of which only small gyles are now, unfortunately, produced. The viscosity of the finings diluted and ready for use should be subjected to a weekly control by the aid of a simply understood instrument procurable for the purpose from any brewers' scientific instrument dealer. A correctly cut sample of finings when freely diluted with water in a glass contains no " floaters " or particles of unmodified isinglass. It is a common mistake to suppose that if an increased quantity of finings is employed the clarifying of stubborn ales is facilitated. The maximum rate of diluted finings which should be added to cask at any time is one quart per barrel. Any excess of this

quantity creates an excess of bottoms and involves the risk of the solution of finings re-dissolving and producing a haze in the beer.

In breweries where several classes of beers are supplied in casks of various sizes it is essential to adopt a system of weekly stock-taking. This consists of recording in a book specially ruled to contain the items of every brew in the cellars, and carrying forward the amount of each. To this aggregate amount is added the quantities of beer expected to rack from the fermenting or settling vessels. The total is summarised under separate headings and the weekly sales of each type of beer are readily calculated by the following method. To the previous week's summary is added the net volume in tuns of any particular brand, from which is deducted the total summarised stock of this beer for the week under review. The adoption of this procedure entails very little labour and serves several purposes in connection with cellar management. It is best to record the total stock and sales up to and including the Thursday of any week. With such a book of reference before him the brewer can observe at a glance his several stocks and total sales, which he can compare with the corresponding periods of preceding years. From this record the brewing requirements for the following week can at once be arranged, and the best methods of disposing of any surplus units of stock can be considered. Occasions arise when there is a lowered demand for any particular brand or size of cask, and in order to maintain all stocks of a uniform pre-arranged age at time of forwarding it becomes necessary to work off this surplus in other beers. The contents of these casks can be blended when rendered bright with younger produce of a similar gravity or, in the case of heavy ales to beers of a lower gravity, and preferably of a running type.

CHAPTER XIV

THE BREWERY AND PLANT

CHOICE OF SITE—PURCHASE OR HIRE OF EXISTING BREWERY—TOWER PRINCIPLE—SEMI-GRAVITATION—STRUCTURAL ESSENTIALS—LABOUR SAVERS—STACKING APPARATUS—FLOORING—WELLS—PUMPS—TRANSMISSION OF MOTION—SHAFTING—COUPLING—CLUTCH—KEYS, ETC.—WHEEL WORK AND BELTING—PRESERVING BELTS—SCREWS—THE BOILER AND ITS FITTINGS—MECHANICAL STOKERS—ENGINE—SACK HOISTS—SCREENS—LIQUOR BACKS—MALT-MILLS—"JACOB'S LADDERS"—GRIST CASES—EXTERNAL MASHERS—RAKES—MASH-TUNS—COPPERS—UNDER BACK AND HOP BACK—COOLERS—ATOMISING PLANT—CLIMAX AERATOR—REFRIGERATORS—ICE-MAKING MACHINES (COMPRESSED AIR: ABSORPTION COMPRESSION: VACUUM)—FERMENTING-TUNS AND FITTINGS—CASK-PLANT—CASK-CLEANING—HINTS ON CLEANLINESS.

ALTHOUGH the undoubted tendency is for existing breweries to be closed rather than for new ones to be started, the latter possibility is not so inconceivable that a few truisms need be out of place. Let us "convey" a few of them.

The Choice of the Place in which a brewery is to be erected is one of the main points to be considered. A suitable locality is one where there is a demand for good beer, through the scarcity of breweries in the neighbourhood able to produce it. It is hard for a new concern to make its way when surrounded by long-established breweries of high reputation, with a connection already formed, and it is, in fact, only rendered possible by the production of an extraordinarily good, or a specially cheap article. Good means of communication, it is true, tend to neutralise the effect of this crushing rivalry, by enabling the brewer to send his beer to a distance and thus widen the field of his operations. But, on the other hand, the difficulties of management and the risk increase the more he has to depend upon distant markets.

The fact that raw materials of first-rate quality, especially barley, are to be obtained in any neighbourhood, may help to recommend it for the site of a brewery, but should never be made a consideration of paramount importance, as they can be conveyed much more easily from place to place than the beer that is made from them.*

I will now quote from one of us words which will apply to the erection of a brewery for an existing trade.

"It may seem superfluous to insist on the necessity of a copious supply of pure water, yet how often is this essential left to chance!

"A dry and airy site should be selected, with a good natural fall for drainage purposes, and heed should be given to the configuration of the ground so as to utilise elevations for portions of the structure, whereby the advantages of what is known as the gravitating system may be attained at a lesser outlay in bricks and mortar. Cellarage may be made much more cheaply under certain circumstances than under others, for

* Thausing, *Die Theorie u. Praxis der Malzbereitung u. Bierfabrikation.*

instance, by tunnelling into the side of a chalk hill, instead of excavating deeply into a piece of level ground." *

Chalk with its excellent self-supporting power is not always attainable, and therefore another relatively cheap way of forming effective cellarage, capable of supporting great weights, may be named. It avoids, too, the delay of excavation at the outset, and expense of building strong brickwork piers and arches. The material used is concrete.†

Deep trenches are dug, lower than the required depth of the cellarage, and these are filled with concrete. The surface of the spaces between is then rounded to form the curve of an arch, and the whole covered with a thick layer of concrete. The soil underneath can then be left until the cellarage is wanted, or excavated as soon as the concrete is thoroughly dry, the building proceeding all the time. A span of fully ten feet is safe; indeed, the writer has seen concrete arches, supporting considerable weight, of nearly twice that span.

Another useful way of employing concrete for cellarage is to construct the outer walls in 4½-inch brickwork, with occasional rows of headers (*i.e.*, bricks placed endwise), filling up the interspaces between wall and earth outside with concrete and arching over by means of curved corrugated iron springing from transverse girders, the whole being finally covered in with a substantial thickness of concrete. This method will be found particularly suitable for cellarage under large malt-houses.

What has been urged respecting the erection of new breweries also holds good in **the purchase or hiring of an already existing one**, with the additional necessity in the latter case of considering the producing capacity, the condition of the buildings and machinery, whether the plan on which it is laid out is satisfactory and its several parts suitably arranged. The reputation of the brewery, moreover, is by no means a matter of indifference. A bad name is one of the most difficult things in the world to overcome, and prejudices continue rampant long after all justification for them is past.

If space allowed we should dwell on this important point at some length, albeit somewhat beyond the scope of this work. We must limit ourselves, however, to one hint—viz., that the *status* of any brewery may be gauged by the *status* of its "tied" houses, and accordingly intending purchasers should demand a complete history of *every such house and its barrelage.*

A flourishing brewery is one which has its tied houses let at reasonable rentals to responsible men, paying regularly for their goods and *at full local prices.*

* "Papers on the Modern System of Brewing," *Brewer's Guardian*, 230.

† Concrete is an artificial stone (said, in fact, to be half as strong again as Portland stone) composed of a mixture of Portland or other cement with gravel, sand, powdered granite, etc., so tempered as to set in a hard mass. Concrete blocks, each weighing 330 tons, have been used, while bridges and houses have been made of it all in one piece.

For cellar floors the cement should be mixed with plenty of burnt brick; burnt brick-earth rather than broken brick-bats, or the clinkers from gasworks. This cement always dries rapidly, and when hot from the works does so with such speed that there is no time to apply it properly, and fresh water must be added, to the detriment of its cohesive strength. In such a case the addition of a little old beer materially delays the drying of the cement.

For further suggestions we must refer our readers elsewhere.*

Finally, when a suitable site has been found and the question of ways and means duly debated and sifted, on what principle is a brewery to be built? **The gravitating, or tower principle** is undoubtedly the best for moderate-sized and small plants, though to enable, as its name implies, the whole process of manufacture to be conducted without the necessity of once pumping the wort, the buildings for a large brewery would have to be carried to such a height as to render its adoption there impossible.

The increased initial expense is also a drawback, so is the difficulty of afterwards enlarging a brewery constructed on this principle. On the other had, its undoubted advantages are the entire suppression of wort and beer pumps, and indeed the relatively small amount of pumping required altogether.

Accordingly for large plants a combination of both plans is advisable,—viz., **the semi-gravitation principle,** where only one pumping of wort takes place. This involves in the case of a 60 or 70-quarter plant a height not exceeding 36 feet for the main walls of the brewery, and of 55 to 60 feet for the more elevated part where the cold-liquor back is placed.

An arrangement which seems as good as any is obtained with a line of rails running the whole length of the racking and loading-up cellar, and close up to the boiler-house to enable coal to be easily unloaded. There will be a through draught across the coolers, and no great masses of brickwork to prevent the steam from getting away from the copper-side in certain states of the wind.

The cellarage beneath the racking and loading-out stage is supposed to be excavated some six feet, and the latter to be raised enough above the ground level to make it even with the floor of the trucks which come up alongside. There will, of course, be several doors for loading into the latter, and if the distance between the rails and basement is so arranged that the side flaps of the trucks are supported in the doorways, they will prove a convenience in loading.

The most crying essential is good drainage, and it is quite possible and much to be recommended in constructing a new brewery not to have *one single drain* within the structure, but to carry all the putrescible off-scourings of the various vessels to the outside by means of very deep wooden shoots. This is quite feasible, and is done in one large brewery within the writers' knowledge.

The next thing is, insist on **all shafts, clutches, and mortise-wheels being made accessible.** Brewery architects apparently like to tuck these things, especially the latter, neatly out of sight; they are quite capable, for instance—incredible as it may seem—of so designing the shaft which drives the well-pumps, that if the wooden cogs of the mortise-wheel, which is keyed on to it, break (and they always go several at a time), it cannot be raised for the purpose of moving the wheel, but has to be drawn out bodily. This is an operation which consumes much time.

Haylofts and Oat-stores, if still used, should on no account be anywhere near the fermenting-room, and it would be better if the prevalent

* A pamphlet "The Financial Elements of Brewing," by Mr. W. W. Ingall, of 22, Moorgate Street, Chartered Accountant, is instructive on this and other points.

winds did not blow from them towards the brewery. Hay teems with the spores of bacilli, and the light dust from corn is hardly less fertile, so that if stores for them adjoin the fermenting-room, pure yeast is not to be expected.

In constructing a malthouse connected with the brewery, **ample bin-room for malt** should be provided. For example, in a 60-quarter house, making a rather long season, four 350-quarter bins are not enough to keep different qualities of malt separate, especially if the season is begun with a bin or two of old malt in stock. And indeed if one hurries on to a just filled-up bin in order to get it empty, nine times out of ten it is not the oldest malt at the bottom, although the opening through which it passes is there, which is got, but a mixture consisting largely of hot malt from the top, the tendency being for a funnel-shaped depression to form, down which, after the first start, the upper part of the bin-contents comes down before the lower.

[As these bins will often be fitted up by a local carpenter, it will be well to have a formula for calculating the weights sufficient to break the supporting beams, premising that no beam ought to be subjected to more than one-fifth its breaking weight.

The formula is $\frac{b \times d^2}{l} s$ = breaking weight in cwts. where b = breadth (in inches), d = depth (in inches), l = length (in feet), and s = the strain, the latter varying with different timbers, being as 5 for oak, and 3 for Riga fir.]

Bins are often made without due regard to the hygroscopic character of malt, and to the fact that slack malt—say malt containing over 5% of moisture—is very detrimental. Good sound well-stored brewing malt contains 2% to 3%.

To prevent greater absorption of moisture than this, a precaution would be to line the bins with zinc or sheet-iron, but in reasonably dry positions wooden bins alone, made of seasoned material and well-tongued, give satisfactory results.

If **a Screw (Archimedean screw or "creeper")** is to be fitted up for bringing over from the malthouse the malt required for each brewing, care should be taken that the light metal blades, which are bolted on to the central revolving shaft, work with such accuracy against the bottom part of the cylindrical tube, which encloses the whole, that practically all the malt shot into the malthouse-hopper is brought over for crushing. Supposing only a depth of half an inch is left unground along a length of say 70 feet, that is an appreciable quantity, and a good portion of it is doubtless introduced into the next grist in an extremely slack condition. The latest method of conveyance is to blow the malt direct to the mills, where prior to the grain reaching the hopper it can be automatically weighed.

The Malt-mills should be so arranged that the grist need not be carried up to a very great height, or have a great fall into the grist-case, the tendency in such cases being to separate the husks from the flour. If this separation is excessive it causes bad drainage from the mash-tun, and what are known as "dead mashes."

Fixed pipes, without facilities for admitting steam, or at any rate copious supplies of boiling water, into them, should be avoided; and

wherever it is possible, there should be unions for the easy disconnection of lengths of piping.

Three-throw pumps are not supposed to stand steaming (and therefore rotary pumps have been recommended for moderate lifts), but this is mainly so when the buckets are of leather; there is no reason why with care (introducing steam fairly high up, and, if necessary, just covering pumps with liquor) the wort-mains, fitted with them, should not be steamed.

Where steam is used for boiling wort and liquor there should be **a sufficiency of check valves.** It is, for instance, most inconvenient to have only the ordinary steam valves attached to the liquor-backs available to shut off steam therefrom, for supposing that the thread of one of them gets so worn that all at once it will not hold, it will be impossible to remove the valve for repair, or to insert a new one until the entire brewing is ended.

Convenient Labour-saving arrangements are—

1. **A Descending Platform for Lowering Casks** from the racking floor, and in connection with this a light line of rails, laid on a gentle incline, so that the casks may roll away by their own momentum directly they are lowered. Directly the platform reaches the ground, a triangular block of wood juts up through a hole in the platform floor, and tilts the cask off. This triangular block of wood may be made to turn through a right-angle so as either to direct the cask on to the line of rails, which will probably carry it to some distant store (say under an adjoining malt-house) or to push it off into the cellar where the platform actually descends.

The platform itself works between guides, and is supported by strong chains passing over a roller and having a weight at their other end, just heavy enough to cause the platform to rise when unloaded, though of course the added weight of a barrel of beer is enough to make it descend. To prevent this descent being too rapid a brake is fitted to the roller, and from the lever-arm of this a rope hangs within easy reach both of the racking floor and of the platform itself, so that a man, standing on either, can with one hand stop the barrel midway, and so regulate the pace of its decent.

2. **A Cask Hoist,** consisting of two endless chains, inclined at an angle of 45° from the floor whence the casks have to be raised. Pairs of horns, one on each chain, occur at intervals, and as the latter revolve, come up from beneath a platform at the foot of the apparatus and catch up any cask which has been rolled there for that purpose, and convey it to the higher floor. The chains revolve round drums keyed on to short shafts, the upper of which has a "pulley" on it too. To this upper pulley motion is conveyed by a belt from a large shaft overhead, and of course, when the hoist is not in use, the belt is shifted on to a "loose pulley."

Hydraulic lifts can be used if there is a good water pressure. One firm that the writers know of utilises the company's water passing to their liquor backs in this way. Electric lifts are, however, gaining in favour as they possess local advantages over others, all worthy of consideration.

3. **Stacking apparatus in the Store itself.**—A long horizontal rod or shaft spans the entire width of the store and has wheels at either end of

it, which run smoothly on two rails, that, high overhead, skirt the longer walls of the store. A wheel of larger diameter, fixed on the centre of the rod, makes the latter revolve with it when set in motion by the pulling of an endless chain, which passes round its deeply grooved circumference. This central wheel can be kept in position by a number of light steel rods converging from its circumference to some point along the rod on either side.

When the endless chain, previously mentioned, is pulled one way or the other, the whole apparatus moves backwards or forwards with the greatest ease to any desired point. An arrangement of pulleys and ratchet-wheel then enables a man to raise a barrel, slowly but surely, to the required height. The writers have seen a store-cellar where casks are "ridden" ten or twelve high by means of this appliance.

[An adaptation of this apparatus has been found useful in malthouses, for moving green malt considerable distances.]

4. Traps in the bottom of the mash-tun for shovelling out grains, which are to be conveyed into a grain tank outside by an endless belt, or what is far more durable, by two endless gun-metal chains working in a shoot, and having upright pieces of wood fixed on them transversely at short intervals.

5. A direct connection between the hop-weighing room and the copper-side by means of a shaft, closing with a door on the copper stage and with a trap-door on the floor above. The hops, weighed up in bags, are thrown down this, and even if there are several different quantities they can be thrown down in the reverse order to that in which they will be required, so that the bag which will be wanted last lies at the bottom, and the one which will be wanted first at the top of the heap, and so on.

Minor, but far from unimportant points are :—

1. That the fermenting room should have its **windows facing north** if possible [windows of southerly and westerly aspect have to be shuttered up in summer time].

2. **The walls,** where the "thrust" of weight above is not excessive, **should be made hollow,** and this is especially the case in fermenting rooms, where the conditions favouring growth of mildew ought to be as restricted as possible. To this end **glazed bricks** as a lining for the walls are highly recommended.

3. Roofing, should generally speaking, and especially over coolers, be of tiles, which do not cause such rapid condensation of the vapour given off as slate roofs do.

[Pan tiles are better than plain tiles, a "square" of the former being hardly more than half the weight of a "square" of the latter, and moreover the studs or knobs, which catch upon the supporting battens, are less liable to perish than the pegs or pins used to retain plain tiles and slates in a similar position. The curves of the pan tiles form channels for the rain to run down to the gutters.]

4. The roofage area can be utilised for the collection of soft water for the boilers ; but the tank in which such water is stored should neither be far from nor much below the level of the donkey-engine which pumps all water (except that which may be carried in by an injector) into the boiler.

Flooring of Cellars.—The large flagstones, at one time so much used for the flooring of racking cellars, have now got into disrepute owing to

the fact that, unless of great size and exceptionally well set, they become loose, with the result that liquid and yeasty matter of a very offensive character accumulates beneath them. Amongst the best materials are either asphalte, which the writers have known to withstand the stress of ten years' hard wear without needing repair, or granolithic paving material, which would probably not cost more than half as much as the asphalte. The granolithic is unquestionably a splendid material (excellent for malthouse floors too), and can be formed into large slabs capable of sustaining considerable weight.

Cheaper but nevertheless lasting flooring can be formed of Portland cement concrete, prepared as previously directed, the final face being of the same material, but rather finer in texture, and applied in the form of grout, *i.e.*, in a freely liquid state, and finished off quickly. Such a floor might, on an emergency, be fit for use in two days from completion.

The hard dark-coloured bricks, such as are used in stables, make a flooring cheaper almost than concrete. They can be laid " on bed " or " on edge," the latter where a smooth surface is desired. But to make a thorough job of the floor there should be an understratum of concrete, or failing this, the soil beneath the bricks should be well rammed and bottomed with stones.

The Well.—In the arrangement suggested for a 70-quarter brewery the well is planned within the four walls of the brewery, and if room can be spared there for withdrawing buckets, rods, etc., when necessary, the nearer it is to the engine the better, and a sheltered position renders the blocking of the rising-main by frost less probable than it might otherwise be. In the case of Artesian well the pumps may be placed in the actual bore tube, the well being beneath the engine-room, and traps being made in the floor to get at the working parts.

We must, however, confess to a preference for an independent pumping arrangement in the shape of a **gas engine,** which is speedily got to work (in a minute or two at the outside), and the cost of which after the first installation is comparatively trifling.

Such an engine is also very useful at the motive power of the barley hoist or of the elevator carrying malt just thrown off kiln up to bins in the adjoining malthouse, seeing that these calls, coming at irregular intervals, sometimes cause inconvenience and interrupt the regular routine of brewing operations when they are made upon the ordinary steam motive power of the brewery. The same remarks apply with equal, if not even greater, force to electric-motors which are now extremely reliable, installed at a lower cost in comparison with gas engines, while electricity for power purposes is now obtainable from local municipal undertakings at charges which, although in some instances nominally high, have many advantages over every other power system available.

Various methods of supporting the sides of wells are recommended, the old method of steining with brickwork being somewhat superseded, amongst which may be named (1) Steining with concrete, *i.e.*, a wooden drum being let down as the excavation proceeds the interspace between the side and drum is filled up with concrete. (2) The employment of ready-prepared concrete cylinders, which may be of large diameter, *e.g.*, 4 feet, and which, as excavation proceeds, carry themselves down by

their own weight. (3) The employment in a similar way of cast or wrought-iron cylinders.

The driving of side headings, especially in the chalk formation, has already been recommended (Chap. III.), but where there is a reasonable chance of tapping a good spring, albeit at a considerable depth, it is usual to excavate the first part, say for 100 feet or so, and to bore the rest, the barrels of the three-throw pumps, prolonged by stand-pipes, which come well above the highest water level, being fixed at the bottom of the excavation, or as an alternative the pump-barrels may be fixed so as to be above the water level, but with a suction-pipe going downwards and fitting into the bore-pipe itself.

Pumps, as usually fitted in breweries, are either suction, or rather lift or force pumps (three-throw pumps giving a continuous stream), rotary, or centrifugal.

The **three-throw pump** is merely a triplet form of the common pump, the buckets, fitted on short rods known as plungers, working downwards in the barrels, and there being a valve or "clack" in the lower part of the plungers on which the buckets fit. There is also a clack in a distinct chamber at the lower part of each barrel, and this opens upwards in response to the suction caused as the plunger is drawn up, admitting liquid to fill the vacuum. As the plunger descends again *its* valve is forced open, the liquid rushing through it, but closes again directly the plunger begins to ascend. Thus at each downward and upward stroke the three plungers force upward as much liquid as can occupy the space between them and the bottom valves or "clacks." There are also three delivery valves in the box to which the upper parts of the barrels are bolted, relieving the plungers of the pressure of a high vertical column of liquid. An air chamber of copper, at the base of the rising main, minimises the pressure on the pipes.

The alternate or successive motion is got from a crank with two deeply U-shaped bends (and which is best made of wrought iron, though very large cranks are sometimes cast) forming three curves, on each of which one "throw" is fitted.

These are practically the only pumps of the three sorts named which can suck, and they are therefore used in wells; they are also used for pumping wort from hop-back to coolers, there being an impression that rotary pumps have, compared with them, but inferior lifting power.

However incorrect this view may be, rotary pumps certainly have but very inconsiderable power of suction, unless fitted with a "foot-valve," and must accordingly be placed below the level of the liquid they have to raise so that it may flow into them, but, when fitted with a foot-valve, it is said that they are capable of drawing water some twenty-five feet.

Rotary pumps may be made in the form of an elliptical case with two flattened sides, through the latter of which two spindles pass, closer to one another than to the rounded ends. On each of these spindles is a wheel with four cogs or less, gearing into each other in the centre, and working closely against both the rounded ends and the flattened sides of the case. The liquid, compressed by the outer cogs directly they begin to come together, is prevented from escaping, otherwise than up the outlet pipe, by the gearing of the cogs in the centre.

Sometimes they are made with a single spindle on which a disc of metal is keyed, this disc having four deeply U-shaped cavities in its circumference. In each of these a cylindrical roller, very nearly as long as the case is wide, is placed, and these, of course, rotate with the metal disc, at the same time revolving on their seating, so that wear and tear of parts is equalised as much as possible. The centrifugal force, driving these outward, forces them closely against the inner circumference of the pump-case, and thus they drive before them any liquid rising into the hollow case, and force it into the corresponding outlet pipe in its upper part. As many as 400 revolutions per minute may be advisable with these pumps, but they will do their work with much slower speed.

Centrifugal pumps act somewhat differently, and require a high rate of speed, at least 700 to 800 revolutions a minute, which speed is got by having the driving belt pass from a large pulley on a shaft, revolving at ordinary pace, to a very much smaller pulley on the spindle of the pump, whereby the speed of the first shaft's revolution is multiplied by the number of times that the diameter of the large pulley exceeds that of the smaller.

The construction of the pump is as follows. In the middle of the case into which the inlet pipe leads is a relatively small wheel, revolving with the spindle, and this wheel is fitted with a number of bent paddles. These, as soon as the fluid flows in, seize hold of it in their rapid revolution and dash it by centrifugal force against the inner circumference of the case, whence it flies off, at a tangent, up the outlet pipe.

(It will be remembered that a tangent is defined as a straight line touching a circle, but not cutting it, as is the case with one at right angles to the latter's diameter, and the pipe in question is placed at a tangent to the circumference of the pump-case.)

Before we touch upon the vessel in which the motive power is generated,—viz., the boiler,—let us devote a few pages to motion in general, and the way in which it is transmitted, for the benefit of the inexpert.

Motion may be transmitted (1) **By gearing,** or (2) **By belting,** and, as a matter of fact, a combination of the two is generally adopted.

With the former a breakage, though of comparatively rare occurrence, is a somewhat serious matter, involving stoppage of operations for a shorter or longer time ; with the latter it is generally merely the lacing of a strap, or maybe the strap or belt itself, which can be promptly put to rights.

It is true that a pulley (see lower down) sometimes breaks, if habitually subjected to great strains, but even a risk like this may be cheerfully faced, if the precaution has been taken to have split-pulley duplicates for important points. (A split pulley being one that has been cast in halves, so that it can be slipped on and the two halves bolted together, without the necessity of moving the shaft on which it has to be " keyed.")

In either case **Shafting**—a main shaft and a number of other shafts—will be required, and these, though wrought iron is the better material, are very usually cast. For the convenience of fixing, twenty feet is generally the limit of length, and where longer lengths are required **Couplings** are resorted to. These may be either per-

manent or movable (where the shafts are to be frequently disconnected).

Of the first class are the solid coupling or **box-butt,** the **flange** and the **claw-coupling**—most suitable for small, medium and large shafts respectively.

When the box-butt is used, the ends of the shafting are swelled out, both to enable the key-ways to be cut without weakening the shaft, and also in order that the box, which of course has to be of the same diameter, or only a fraction of an inch larger, may slip over collars on the shaft. This makes them clumsy for large shafts.

In flange-jointing the flanges are also keyed on, and the bolt-holes must necessarily be exactly opposite each other. A drawback, both of this and of the former, is their rigidity, which becomes apparent if the shafts were originally badly adjusted, or have got out of truth by wearing down of **the bearings,** or, at least, which would become apparent with heavy shafting. Light shafts " give " a little.

Claw-coupling is effected by means of two solid castings, the one of which has two or more projecting, square-ended teeth corresponding to hollows in the other. Their centres are so pierced that they can be slipped on to the shaft-ends, they are then fitted closely into one another, and held in their places by stout sunk keys, forming, as has been said, the strongest coupling for large shafts.

Of movable couplings—*i.e.*, where the shafts have to be frequently connected and disconnected—**the clutch** is the most usual. It is, in effect, a claw-coupling, save that, instead of both of the claw-castings being fixed by keys, one of them slides upon its shaft and is held in its place, as long as the temporary connection is wanted, by some simple mechanical means.

Keys, of which mention has been made, are wedge-shaped pieces of metal, generally steel, used to secure wheels, riggers, etc., on to shafts, and they may be either hollow, flat, or sunk keys. The former are only adapted for light work, seeing that their under surface is rounded to the shape of the shaft, and that it consequently only acts by friction. Their chief recommendation is that the wheels, etc., fixed by them, can be easily shifted from one position on the shaft to another, which is not the case with either flat keys, which are flattened at the bottom, and fit closely on to a flat place filed on the shaft, or with sunk keys, which have a " key-bed " or " key-way " filed out for them in the shaft itself.

The latter, accordingly, is the best kind of key for fixing wheels subjected to heavy strains ; the flat key is more used for securing pulleys (driven by belting) and wheels where the strain is light.

The key is also " sunk " into the boss surrounding the " eye " of the wheel or pulley, and it is in these, and not in the shaft, that the taper, corresponding to the taper of the key, should be made. The keys, of course, are driven home tight.

Sometimes a pulley, etc., may be required to slide along a shaft. A groove of the required length is then cut in the shaft, and the key slides with its pulley or wheel, being either dovetailed into the boss or having a head which fits into a round hole in the boss of the wheel.

Bearings * are the surfaces of contact between a shaft and its support, and they may be **bushes** (hollow cylinders of brass, steel, etc., in which the shaft revolves) or **journals,** consisting of movable pieces called **steps,** the better arrangement when the friction is considerable.

Plummer-blocks or Pedestals are a form of support for a shaft, consisting either of a standard bolted to the frame of a machine or connected with it by a bracket. The upper part of the pedestal is hollowed out to receive the bearings (steps), and above these a cover is placed and bolted down to keep the steps in position—*i.e.*, the top step *in contact* with the shaft. Oil-cups, or better, self-acting Lubricators, are fitted on to the covers or caps, and oil-ways cut in the steps to carry the oil down to the shaft, where it comes in contact with them.

A familiar instance of plummer-blocks are the uprights supporting the bent crank of the three-throw pumps, attached to the hop-back, but the brackets which come from the walls in different parts of the brewery, and support the shafting, are virtually, though not nominally, plummer-blocks too.

Shafts are kept from moving lengthwise from their bearings by **collars** fixed on either side of the latter, and these may be either cylindrical pieces of larger diameter than the shaft and welded to it, or where such an arrangement would prevent the fixing of wheels or pulleys, **loose collars,** attached to the shaft by means of a screw, are used.

Bearings are fitted with lubricators to minimise friction, but **where pressure per square inch is excessive** it is found (*teste* Mr. T. Box in his rather technical book on mill-gearing) that the oil is squeezed out, so that the contact virtually becomes that of metal with metal. In such a case increasing the diameter and width of the bearing may have a good effect because, although the total pressure remains constant, it is distributed over a greater number of square inches. On the whole, however, increasing the diameter alone does not diminish the tendency to heating ; for although the pressure will be spread over a greater number of square inches thereby, the *velocity* of the moving parts is also greatly increased.

The plan, therefore, where heating is feared, is to increase the *width* of the bearing, and with high speeds this should sometimes be to the diameter in the ratio 5 : 1, whereas 3 : 2, or an even lower ratio, is usual in ordinary cases. A wide bearing wears more evenly than a narrow one.

Where the driving is done by gearing, **wheels** of various kinds all provided with teeth are employed, but where the connection from shaft to shaft is by belting, the latter is slipped on to **pulleys or riggers.**

[It may be mentioned that the wheel or pulley, from which the motion is transmitted to another wheel or pulley, is termed the **Driver**, the second wheel or pulley being **the Follower**.]

Spur-wheels are those used to transmit motion from one parallel shaft to another (though, of course, if the shafts are very far apart, belting must be resorted to), and by giving suitable diameters to the respective wheels,

* The term is not limited, however, to surfaces of contact with rotating pieces. It is used in connection with to-and-fro movement—*e.g.*, slide-bars of engines, or with screw-movement. In the latter case the bearings are " nuts."

the rate of revolution for the respective shafts can be made to vary at will.

Spur-wheels have either iron or wooden teeth (cogs), in the latter case being mortise wheels, and the distance from centre to centre of the adjoining teeth is known as the **pitch** of the wheel. A convenient ratio of pitch to length of teeth is 4 : 3 (inches), but rather closer than that with smaller teeth.

There is a technical difference of opinion, whether this pitch is to be calculated as a straight line or chord from centre to centre, or as a curved line or arc. But the latter seems the better plan, as then the diameter of the wheels is in exact ratio to the number of teeth, which is otherwise not the case.*

Where shafts cannot be fixed parallel, but can be so placed with regard to one another that their ends come almost into contact, the shafts being also in the same plane, motion can be transmitted from one to the other by means of **Bevel wheels.** [Belting is, of course, an impossibility.]

Bevel wheels, then, are wheels shaped upon a cone with the apex cut off (they are the *frusta* of cones), and have teeth running along the latter lengthwise and gearing into the teeth of the other apex-less cone. When the shafts are at right angles, so that the bevel-wheels are of equal size, and would, if a flat sketch of them, with the apex of the cone thrown in, were attempted, be represented each by an equilateral triangle, they are **Mitre-wheels.**

But for one purpose of the brewery, in which translation is generally from one shaft to another at right angles to it, viz., for driving the mashing machinery inside the mash-tun, deeply toothed wheels, one of the usual type, the other a **Core-wheel** (*i.e.*, one with *cogs* at right angles to its diameter), will be found most convenient, as they can be readily thrown in and out of gear.

Mortise-wheels are the wooden-cogged wheels (horn-beam, with a transverse strength about three-tenths that of cast-iron, is the usual wood), which gear in with iron wheels. They are used for well-pumps, etc., to minimise noise. The teeth of the all-iron wheel are usually shorter than those where iron works against iron, because the cogs have to be made relatively thick for their length, and consequently the iron teeth, which gear in with them, must be proportionately slighter, which, were they of the usual length, would involve weakness.

The relative thickness usually is three-fifths the pitch for the cog and two-fifths the pitch for the iron tooth. The cogs are cut out square at the lower end, where they are driven into the mortises of the wheel, but where they gear in are slightly taper.

Wheels are sometimes **shrouded**—*i.e.*, the teeth are protected by a flange, coming up to part of the length of the teeth, say up to the pitch-

* The diameter of a wheel is got by imagining the latter's "pitch-circle," *i.e.*, regarding it as a plain cylinder, driving its adjacent wheel (considered as another plain cylinder) by frictional contact. The pitch-circle is practically near the middle of the length of the teeth, rather above than below, and its diameter may be got by multiplying the number of teeth by their pitch and dividing by 3·1416 (ratio of circumference to diameter taken as 1). Thus the diameter of a wheel with 100 teeth and 2 inch pitch $= \frac{100 \times 2}{13{\cdot}416}$ = 63·66 inches at pitch-line.

line. If the flange comes up to the points of the teeth, the spaces between the latter become, in effect, mortises in the face of the wheel.

With wheels of equal strength shrouding is of no value, because obviously only one of the pair can be shrouded, and their combined strength is determined by that of the weaker member. Moreover, for reasons too technical for insertion here, shrouding does not always impart strength. Its chief value is to reduce disproportion of strength, which occurs in certain cases, if the correct forms of teeth have been adhered to—*e.g.*, when a small pinion is working with a rack or large wheel. In such a case shrouding the teeth of the former may increase their strength very considerably.

Other things being equal, the power exerted by a wheel increases with the number of teeth in gear at the same time.

Clearance is the portion of the pitch which the tooth gearing-in does not completely fill, and which is allowed for slight errors of workmanship. With mortise-wheels little or no clearance is necessary, as the cogs can be trimmed to fit accurately.

Motion transmitted by Belting.—The method has certain advantages over wheelwork, where space is not particularly limited—viz., Economy; Power of putting shafts any distance apart within reasonable limits (nor does variation of distance alter rate of motion); Lessened risk of breakage (a sudden strain which might break wheelwork only causes a belt to slip on the pulley).

Pulleys or Riggers (as the wheel-like pieces on which belts turn are called) are generally curved on the surface of contact with the belt, so that the greatest diameter of the pulley is in the middle of its breadth. The curve is about half-inch per foot of rim.

This helps to keep the belt central on the pulley, the tendency of the moving belt being to rise to the pulley's highest part.

The rims of pulleys are turned after casting, which makes them balance better. It will be noticed, too, that the arms are sometimes curved, a form which gives best to the contraction of the rim, as it cools after casting, but otherwise straight arms, if properly proportioned and of oval section, appear to be the strongest.

Split pulleys have already been referred to.

A loose pulley is one running free upon a shaft, and is useful for taking belts when not in use, to avoid friction of their edges. Such a pulley should have its boss made very deep, equal at least in width to its rim, and bushed with gun-metal.

It may be made to act as a fast and loose pulley alternately, in situations where it is inconvenient to slip a belt over a revolving fast pulley, a lever from some accessible place actuating it.

Belts, or bands, are fastened by lacing or riveting. Except where it is desirable to avoid any momentary friction beyond what is inevitable and necessary, the former is the better plan, enabling belts to be easily tightened when they stretch, as new belts, at all events, will.

When the shafts are wanted to travel in the *same* direction the **open belt** arrangement is adopted, but when the shafts have to turn in *contrary* directions **the belt is crossed.** The crossed belt brings a greater amount of its surface into contact with the pulleys than the open belt arrangement does, and this gives a firmer grip.

A belt will always slip first on that pulley the smaller arc of which in contact with it; and with the open belt arrangement, except where there is a belt-guide, this will always be the smaller pulley.

The nice gradation of speed required in some factories, and got either by speed pulleys or cones, is not necessary in a brewery, but nevertheless there will be certain variations of speed, and everything will not be going on at a uniform rate. For example, the external mashing machine, say the form known as Steele's, requires to be driven rather fast—viz., at the rate of 120 to 180 revolutions a minute; consequently the pulley keyed on to the end of the shaft, which rotates inside the cylinder, that is *the follower*, should be only one-third the diameter of the *driving* pulley, seeing that for the crank-shaft of the engine 60 to 70 revolutions per minute should be the limit.

Internal rakes should revolve slowly; consequently the follower (in this case a cogged wheel) should bear to the driver the ratio of 3 : 2.

Wort-pumps, again, must not be rattled along fast, and here the following pulley may bear to the driver the ratio of 3 : 1.

Driving belts should be well greased every three months. After washing them with lukewarm water, leather grease is to be well rubbed in. The following recipe may be useful. Fish-oil 4 parts; lard or tallow 1 part; colophonium 1 part; wood-tar 1 part.

Saturation with castor-oil is also stated to have great effect in increasing durability of belts, in fact, to be the best preservative means known. Belts treated with it are less prone to slip, and it is said that this treatment sometimes increases their driving power by 50%.

Screws.—The two usual kinds (other than those familiar in carpentry work) are V or triangular threaded, and square-threaded [the thread is the ridge or projecting part; the distance between two consecutive threads is the pitch.]

The former are used chiefly for studs, bolts, and set-screws; the latter for transmitting motion by means of slides, and in a brewery exclusively for moving a slide itself—*e.g.*, the slides at the bottom of a grist or grain-case, where the slide travels to and fro with the nut which is an integral part of it. The *pitch* of such a screw may be defined as the distance moved through by the nut in one revolution of the screw.

Screws moving from left to right, *i.e.*, as the hands of a watch, are right-handed screws; those moving in the opposite direction are left-handed.

The Boilers.—It will be impossible to treat boilers, and still less exhaustively, but we will deal with a few of the main features, and touch on some points which experience has shown us to be of practical value. For the rest we must refer our readers to the usual manuals. There is, in particular, a capital little treatise, issued by the publishers of this volume, and priced at 6d., called "The Safe Use of Steam."

The type used in breweries is usually the double-flued **Lancashire boiler,** a modification of the single-flued Cornish boiler, adopted because of the liability to collapse of very large flues, unless made of such a thickness of metal as to be unsuitable.

The flues, with the furnaces in their front part (upper half), pass first the whole length of the boiler (within the boiler, be it understood, thus largely diminishing its cubic content), then at the back of the

ıler * the heated gases either divide and pass along two side flues, joining again when the front of the boiler is reached to pass along a flue beneath the boiler, which conducts them into the chimney-stalk or shaft. Or the progress is reversed, the gases first passing all together underneath the boiler to the front part, dividing there into the two side flues, from the ends of which they pass into the chimney.

In any case there are three outside flues, lined with firebrick, but having as much of the surface of the boiler exposed in them as is consistent with the proper support of the latter. As to whether it is better to take the gases into the side flues before the bottom one, or *vice versâ*, different opinions exist. With the former plan there is less risk of burning the boiler-plates, owing to sediment forming just where the fire would otherwise be hottest, and it is, maybe, more convenient for the back damper; but on the other hand, where the feed-water contains much carbonate of lime, etc., the fact that the hottest part is just where the water level is continually varying greatly increases the formation of a hard "rock" there. [And this, be it remembered, in a position whence it is least easily removed, because in chipping men can only get a constrained sideways blow at it, instead of the downright blow at the bottom, whence, moreover, "blowing off" will remove much before it gets hardened on.]

Moreover, the bottom is naturally the coldest part, and anything which relatively intensifies this increases the strain on the boiler. This was always a fault of Lancashire boilers, and Galloway tubes (slightly tapering tubes which pass through the internal flue diagonally) were invented to obviate this. These tubes are either welded into the flues or riveted, and certainly promote circulation of the water, increasing heating surface too and strengthening the flue itself.

The side flues must not be too narrow (say 9 inches, at least, in upper part for a 40 H.P. boiler), for heated gases will not go up into a narrow space if they can expand better elsewhere.

The "**setting-blocks,**" concave-topped blocks of fire-clay, on which the boiler rests, should, with their brickwork beneath, be fairly deep (say thirteen courses of brickwork and the setting-block), which leaves a good space for ash and soot.

Furnace-bars are in 2 (or 3) lengths—very long bars are unmanageable—and have cross-bearer supports at their mid-length. In front they rest upon the **Deadplate,** at the back upon the **Bridge,** which is generally of firebrick. [Note that only firebricks *with smooth faces* should be used. Clinkers† stick on rough edges, and then in clinkering, portions of the brick, or perhaps the whole brick, may be torn away.] The depth of the grate is limited by the fireman's reach, and it will be usually 5 to 7 feet.

There are many **patent furnace bars,** but **tubular bars** (applicable to coppers too) merit most attention. The bar itself is of cast iron, as other bars are, but unlike others it is cast round a wrought-iron tube, which prevents it from warping, adds considerable strength, keeps

* With the so-called **breeches-flued boiler,** the two internal flues, containing the furnaces, unite into one large cylindrical flue just behind the bridges.

† The injury to bars done by clinkers can be lessened by using chalk in the following manner. Two or three shovelfuls of dry chalk, in pieces about the size of a walnut, are to be placed on the bars first, and the fire laid and lighted over them. Half a shovelful should be thrown on three or four times a day when coaling up, and this will effectually prevent the clinkers from sticking to the bars.

the bar cool by allowing a current of cold air to enter, and conducts this air, suitably warmed, to the back of the furnace, where it helps the combustion of the unburnt matter given off from the fuel as smoke. The face of the bar is also chilled ¾ inch deep, so that clinkers do not adhere.

The combustion is also facilitated by stoking each furnace alternately, so that one is burning brightly while the other is giving off unburnt hydrocarbon matter, the heated gases from the former to some extent burning this matter from the "green fire."

The shell of the boiler is made of plates of wrought-iron or mild steel (containing about 0·1% of carbon), and from 3 to 4½ feet in width, the lines of rivets connecting them running round the circumference of the boiler. Occasionally the joints are welded, and this, if properly done, prevents leakage and external corrosion; but that it is so is not easily ascertained for certain, so that riveting is the usual plan, the furnace-tube joints alone being welded. The boiler ends are fitted in and held, either by means of flanges or internal or external angle-irons, which are riveted on to the main shell.

Riveted joints have to be caulked—*i.e.*, the edges of the plates are burred down by means of a special tool, a kind of cold chisel.

The principal boiler fittings are :—

1. **Safety valve,** weighed to blow off at the maximum working pressure, say 50 lb. for a brewery with non-condensing engine, and boiling, heating liquor, etc., by steam. [Precautions to be observed with this and other fittings will be given below under the Manchester Boiler Insurance and Steam Power Company's "Instructions to Firemen."]

2. **Gauge glasses,** connected at top and bottom with the boiler (but with shut-off cocks), to enable the fireman to ascertain that the water is at the proper level. There is a blow-through cock at the bottom which helps to keep the tubes and their upper and lower inlets clear.

3. **Gauge cocks** (useful if the gauge-glasses break), one below the average water-level, the other well above it. In the absence of the gauge-glasses they must be tried frequently; as long as steam issues from the upper and water from the lower, the level is approximately right. Even when not in use they should be turned on periodically to keep them from furring up.

4. **Pressure gauge,** which purports to show the existing pressure in the boiler.

5. **Fusible plug,** a plug or disc of soft metal (lead), fixed in the hottest part of the boiler, the crown of the furnace-tube, so that if the water level gets below this and the plate becomes heated, the fusible plug will melt and the steam rush out to extinguish the fire.

6. **Steam whistle,** fixed in the upper part of the steam chest, if there is one, and with a spring to keep the steam inlet closed, until a certain pressure beyond that at which the safety valve blows off is reached, when the resistance of the spring is overcome, and the whistle by the continuous noise it makes calls attention to the fact. It is useful in the event of steam, through carelessness, getting up at night, or of the safety valve being overloaded.

7. **The float,** another water-level indicator.

8. **Man-holes,** one at the top, one (*alias* **the mudhole**) low down in front end of the boiler. These are taken out when the boiler is cleaned,

and when they are replaced a close-fitting joint is made by means of a mixture of red and white lead well beaten up and stiffened with yarn. If these joints leak they must be remade at once. The manhole cover generally fits up from the inside of the boiler against a flange on a strengthening iron ring, and is held in its place by a bridge-bar, nut, and bolt.

9. **Blow-off cock** at the bottom of the front of the boiler and connected with a pipe running into the drain. This, besides being the cock used for emptying the boiler, is for periodically (every day, or every other day) letting off an inch or so of the boiling water, preferably, so as not to risk shaking the boiler, when the pressure has got as low as 20 lb. This is especially useful when some effective agent, causing a sludgy precipitate, is used in the feed-water.

Obviously the blow-off cock must be accurately ground in to prevent leakage.

Adjuncts to a Boiler are :—

(i) **Donkey Engine and Pump.**—A compact combination, working independently of the main engine (and in this respect superior to the old form of feed-pump, which could only work when the engine was running). Its steam-piston and its pump-piston are at opposite ends of the same rod. Between each boiler and the donkey is a check valve, and the clicking of this as it rises and falls in its seat with every stroke is an indication that the pump is throwing, and not, in engineer's parlance, "taking the pet." There should be a small cock, the "pet-cock," on the boilerward side of the pump in the feed-pipe, and generally a stream of water issuing from this, on its being opened, is also a sign that the pump is working properly. Not always, however, for the pump will sometimes "take the pet" with very hot water, and, therefore, it is well to have provision for lowering the temperature of the water in the hot well.

The check valves are constructed so that they can be screwed down firmly on their seats, if it be wished to pump into one boiler out of two or more ; otherwise the back pressure of steam, of course, keeps them tight when the pump is not working.

(ii) **The Injector.**—A subsidiary feed apparatus, which forces water into the boiler by the pressure of the latter's own steam (which, however, must be pure steam taken from the highest part of the boiler), and this, too, against the pressure of both steam and water in the boiler. No completely satisfactory explanation of its working is, as far as the writer knows, yet issued, but it undoubtedly depends on the admission of a jet of steam and the simultaneous admission of a larger quantity of water, in which the steam *instantly* condenses. Though much of the momentum is lost (say 1⅛ if the steam condenses in 12 times its weight of water) the united stream still rushes on at 130 feet per second at least, and this, combined with its concentration upon a given point (in which two funnel-shaped, *i.e.*, narrowing, passages, doubtless play their part), will probably give the outline of the explanation. Or putting it otherwise, the combined steam and water jet still retains a velocity greater than that possessed by water alone issuing under the same pressure.

One thing is certain, that the injector will not act with water of a temperature above 120°—in some instances 90°—and this suggests that immediate condensation of the steam is an essential factor.

(iii) **Mechanical Stokers.**—Among the best known are those of Vickers

of Earlestown, Lancashire, Sinclair of Leith, Cass of Bolton, and Andrews' Helix underfeeder, and of a somewhat different type, the sprinkling stokers (Bennis and Proctor).

The coals are fed either by hand or by a shoot into a hopper in front of the furnace, whence they fall, or are pushed, in a continuous thin stream on to the front of the fire, save in the case of the sprinkling stoker, which throws them (something like a person dealing cards) on to the top, and is thus better adapted for dealing with very fine coal which is practically in the form of dust.

In the former three stokers, the result is got by an alternating movement of solid firebars. The firebars move backward all together for a space of 2 or 3 inches, carrying the fuel with them; then they return into their original position one by one, but sliding under the fire. Then after an interval they all move back again together, and this continuous movement not only carries the fire regularly backwards, but breaks it up, and prevents the formation of clinkers. [Stokers of this type are superseding the old stoker of Jukes, in which firebars, linked together to form an endless chain, passed round two revolving drums, which kept them constantly and with them the fire moving slowly backward.]

The Helix-underfeeder consists of screws of wide thread, revolving in the direction of their length, which carry the coal from the hopper along channels under the grate, whence it is forced up beneath the fire, the latter being always fed from below.

It is said that the annual saving effected by using "slack" instead of larger coal (rendered possible by these mechanical stokers) may amount to as much as £150 per boiler. Further, they lessen the firemen's labour, and as the furnace doors have not to be opened, the usual inrush of cold air is avoided.

Oil Fuel.—Up to the present the admittedly high price of crude oil debars its more general adoption in breweries as a fuel. The potentialities of oil fuel, however, are very great as it possesses an intense calorific power, produces little or no smoke, its use obviates stoking and the labour involved in the removal of ashes, and other practical advantages.

Boiler-heating (and Copper-boiling) by Gas.—In this method, which has been adopted in one large brewery within our knowledge, the coals are fed into a large retort and there converted into crude gas. No attempt is made at purification, but the gas is conducted direct into a flue connected with the boiler and kindled there, so that the whole flue is filled with blazing gas. Similarly, it is conducted underneath and round the coppers, which are, in effect, fire-coppers but without the necessity of stoking them direct, so that, instead of damping down the fires, it is only requisite to cut off the supply of gas.

Boiler Corrosion, External or Internal.—External corrosion will occur from several causes—*e.g.*, (α) careless setting in too much, and that impure, lime. (β) Setting on a damp foundation without proper means of drainage. (γ) Inattention to "weeps" (slight leakages) of the boiler plates at the rivets. (δ) Contact of ashes carelessly allowed to accumulate; alkaline salts contained therein, in conjunction with damp, attack the iron. (ϵ) Leakage round brass cocks, fittings, etc., attached to the shell of the boiler, inciting galvanic action between the dissimilar metals.

Internal corrosion is rapidly caused by the joint action of oxygen and

carbonic acid, which all spring waters contain, in a moist state, though singly, or even combined, when dry, their action is inappreciable.

Grease (from lubricants) in condensed water used as feed is also most destructive, the *lime-soap* forming by its combination with lime salts decomposing again at high temperatures into a free acid, oleic acid, and a residue, which adheres to the surface, while the acid attacks the iron.

Sulphuric acid, developed under pressure from certain waters, notably those containing iron sulphate, may ultimately prove destructive, albeit produced in infinitesimal traces, seeing that, not being volatile, it accumulates.

Chlorides of sodium and magnesium are also destructive, especially in the presence of carbonic acid and air.

Incrustation (Boiler Scale).—This, the consequence of the feed-water containing carbonate of lime and silica (even more objectionable when organic matter is present, too), is unwelcome, because it involves a loss of power from the fuel. [It is said that scale $\frac{1}{4}$ inch thick means a loss of 38%, while if $\frac{1}{2}$ inch thick it means a loss of 60%.]

On the other hand, it sometimes forms a protection against the corrosive agencies indicated above. For instance, at Glasgow, it was found that a range of new boilers, in which the freshly introduced supply from Loch Katrine was used instead of the former calcareous water, suffered rapid corrosion, while an old boiler, in which calcareous water had been used, but which had not been scaled before the introduction of the new supply, showed no signs of it, and it was actually found necessary to feed in *lime and water* until an artificial protecting scale was obtained. No condenser, possibly containing grease, being used, the corrosion could be traced with certainty to the limeless new supply.

Remedies are caustic soda, washing soda alone or mixed with lime, and patent remedies (*e.g.*, "Anti-lithon"). Caustic soda, which should contain not more than 2% of impurities (no common salt), is effective, but some of it is carried over by the steam into the cylinder of the engine, and is very destructive to all the packings with which it comes in contact.

Soda, besides preventing scale, corrects the acidity of water, and by absorbing carbonic acid, prevents its acting in the way of rusting.

"Anti-lithon," though somewhat costly, is very effective with certain calcareous waters, but in others its effects are less marked.

The "**Instructions to Firemen,**" given by the Boiler Insurance and Steam Power Company, Manchester, are so valuable that we shall append them here.

"Water gauges should be blown out frequently during the day and the glasses and passages kept open and clean. More accidents happen from want of attention to water gauges than from all other causes put together.

"Safety-valves should be tried at least once a day to make sure that they will act freely. Overloading or neglect leads to most disastrous results.

"Pressure gauges, where fitted with cocks, should be tried occasionally by shutting off the steam, and letting the pointer run back to zero. For this purpose the cock to the gauge should be arranged to open to the atmosphere when shut off from the boiler.

"Blow-off cocks should be taken apart, examined and greased every time the boiler is cleaned. Make certain that water is not escaping when the cock is supposed to be closed.

"Check-valves, or self-acting feed-valves, should be taken out and examined

every time the boiler is cleaned. When the feed-pump is at work frequently satisfy yourself that the valve is acting.

"Fusible plugs should be examined every time the boiler is cleaned, and carefully scraped clean on both the water and fire sides. If this is not done the plug will be useless.

"To save coal, keep the boiler clean inside and outside. If there is a plentiful supply of steam keep a thick fire, but if short of steam work with a thin fire, but keeping the bars fully and evenly covered. Firing a furnace on each side alternately tends to prevent smoke.

"To preserve and keep the boiler in good repair, raise steam slowly. Never light fires till the water shows in the gauge glass. Never empty under pressure, but allow the boiler and brickwork to cool before running the water off.

"Clean the boiler inside regularly once a month, oftener if the water is bad. Clean all flues once a month, stop any leakages, and prevent any dampness in the seatings or covering. Carefully examine plates subject to direct action of fire, the underside of the boiler and any parts in contact with brickwork or with copper or brass, where water is present.

"If the boiler is not required for some time, and it cannot be conveniently emptied and thoroughly dried, fill it quite full with water, and put in a quantity of common soda.

"Should the water get too low, draw fires at once as a rule; or if the furnace-crown appears to be red-hot, it is best to smother the fire with wet ashes, wet slack, or any earth that may be at hand. The dampers may then be closed. If the engine is running or the feed-pump delivering into the boiler, do not stop them, but if not working do not start them, and do not attempt to blow off the steam until the fire is out, and the overheated plates have cooled."

The Steam Engine.—This subject must be briefly dealt with, and mainly in connection with brewery work, text-books on it being numerous. Be it remarked, however, that though the arrangement in the plan given for a 70-quarter brewery of having the malt-mills just over the engine-room is convenient for the shafting, and moreover allows of ready access from one to the other, the fine dust, which is bound to come down in quantity, is by no means conducive to that bright and smart appearance which every driver who is good for anything delights in.

Stationary engines are either **condensing or non-condensing,** the former being again either simple or compound (*i.e.*, expansion engines, in which high-pressure steam, introduced first into the smaller of two cylinders, passes, after doing its work there, into a second larger cylinder, and, expanding, completes its work at low pressure*). These cylinders are generally placed either side by side, or one behind the other (tandem arrangement), though occasionally with the larger cylinder horizontal, and the smaller inclined above it, with its connecting rod working upon the same crank-pin.

The condenser (in condensing engines) will be in line with the cylinder, so that the tail-rod of the piston drives the plunger and piston-rod in the former. Condensers are either *jet* or *surface* condensers, the steam being condensed in the former by a jet of cold water, in the latter by contact with thin metallic surfaces, say brass tubes through which cold water is being forced. A pump (air-pump) connected with the bottom of the chamber draws off the water and any air.

* The steam may pass either direct from the small cylinder to the large, or there may be a receiver interposed, in which the steam can be superheated by hotter steam from the boiler, passing through tubes.

Though expansion engines are seen in breweries, the usual type will be the horizontal non-condensing engine, the exhaust steam being passed through a heater (a large cylinder with a number of vertical tubes inside through which the "exhaust" passes, leaving any grease, due to lubricants, in a chamber at the bottom) in order to heat the water which the "donkey" is pumping into the boiler.

It must be taken for granted that the reader knows how the steam acts on the piston (on alternate sides), and how the latter is made steam-tight in the cylinder, although working with a minimum of friction, and the section be concluded with an enumeration of working parts, with a word of explanation here and there.

The principal parts of an engine are :—Cylinder, Piston, Piston-rod, Crosshead (joining piston-rod on to connecting-rod, and working between guides on sliding surfaces), Crank-pin and Crank, or, better than this, a Crank-disc (a circular piece of bright cast iron, which translates the to-and-fro motion of the piston into circular motion), Fly-wheel (which by its momentum carries the engine over the "dead-points," *i.e.*, the beginning and end of the piston's stroke), keyed on to the end of the crank shaft, which should be made of *steel*, the Fly-wheel itself being of bright cast iron. Steam-ports (openings for admission of steam into the cylinder, one on either side of the piston), closed and opened alternately by the Slide-valve (in the form of a hollow box, with accurately planed projecting ends). This valve is just proportioned so that, as it travels to and fro (driven by a rod worked from an eccentric keyed on to the crank-shaft), one port is *outside* its projecting end, and by this steam enters, while the other is *within* the hollow part, and is thus put into connection with the exhaust pipe. The valve, of course, works in a valve-casing, through which the steam-pipe passes, and which in larger engines is generally a separate casting bolted on to the cylinder.

To reduce friction, which, owing to the pressure of the incoming steam, is very considerable with valves of large surface, two valves, closing one port each, are adopted, and then they are, of course, worked by separate eccentrics and eccentric rods. The valve casing may also have, on the side remote from the crank-shaft, a screw-arrangement for reducing or enlarging the apertures of the ports, a very useful addition where the calls upon the engine are so varied as in a brewery.

The Governors are the two balls of metal suspended on either side of a vertical spindle, which, whenever the speed of the engine unduly increases, fly outwards by centrifugal force, and either by means of a lever and throttle-valve or, in a more complicated manner, by reducing the *travel* of the slide-valve, cut off some of the steam from the cylinder, and so almost immediately correct the speed. They get their impulse from a belt running on one pulley, keyed on to the crank-shaft, and on another smaller pulley, the horizontal spindle of which has at its other end a pinion gearing into another pinion upon the vertical spindle whence the balls above mentioned depend.

The Eccentrics are circular pieces of metal fastened on to a shaft eccentrically, *i.e.*, at some point other than its centre, the distance between this point and the centre being known as their *eccentricity*. Round this circular plate a ring of metal, connected with the rod, moves freely ; and it is obvious that, with each revolution of the shaft, the part

of the ring connected with the rod will move *to* and *fro* for a distance equal to twice the eccentricity.

Thus the crank-shaft with its end farthest from the engine working in a plummer-block, will very probably have keyed on to it, first the fly-wheel, next a large pulley, round which a stout belt passes to a loose pulley overhead and from one-half to one-third the size, which, when made a "fast" pulley by means of a clutch, actuates the malt-rolls, then a toothed-wheel gearing in with another of such a size that the shaft on which the latter is keyed passes underneath the bed-plate of the engine and serves to drive the well-pumps, then the pulley for the governor belt, next the two eccentrics, and finally the crank-disc which, of course, must be nearly in line with the piston.

Lubricators are fitted to all points of friction; in most cases box-shaped receptacles for tow, saturated with oil; but for the slide-valves and piston a lubricator is found effective. One does for both purposes, the steam carrying the lubricant into the cylinder.

The above is, of course, a very incomplete account of the steam-engine; nevertheless the writer hopes it may help the pupil who is not afraid of asking questions to find out a good deal about it. It will, at any rate, supply him with some raw material for inquiries.

We will now deal with other parts of the plant in a cursory way.

Sack and other Hoists.—Use is generally made of friction gearing, where two wheels having a number (five or six) of square grooves in their peripheries, are so arranged that the grooves of one are opposite the thread-like projections of the other, and accordingly, when brought together, they interlock and form closely joined bearing surfaces. [The grooves, of course, run the length of the circumference, not as the indentations between the teeth of spur-wheels do.]

The usual arrangement is to have one such wheel, the smaller keyed on to a revolving shaft, the larger wheel opposite to it, which is fixed on to the end of the spindle of a drum, being with the latter at rest, until both are raised by a lever. Directly the wheels interlock the drum revolves, and the sack, cask, or what not, suspended from it rises as desired. Descending motion is got by releasing the lever.

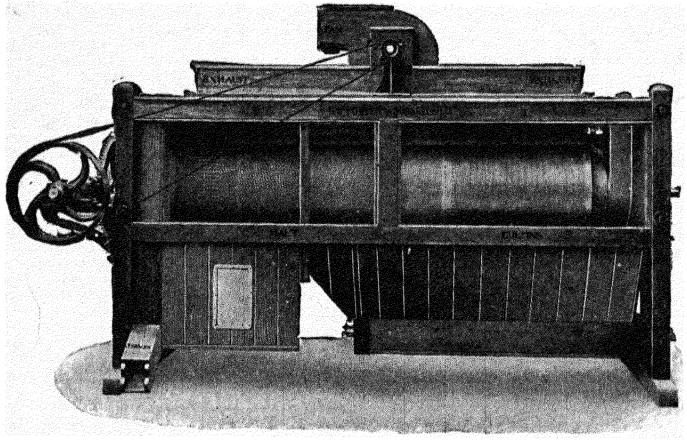
The enlarged barrel is for the purpose of increasing the speed of chain *after* it has started and the smaller ends allow of a slower speed, both for starting the sack and landing it. The hoist is put in motion by a small pulley pressing on the driving belt and tightening it, and by this means any degree of tension can be put on it either for lifting or lowering sacks.

Barley and Malt Screens.—A simple but effective specimen of the former is one on the principle of an "overshot" waterwheel. The barley coming out of a shoot on to a wooden wheel turns the latter round with considerable force. Below this wheel are two inclined wire slides, one over the other, the uppermost of which is moved to and fro by the revolutions of the wheel, and thus the needful check is given to the course of the barley, which comes into contact with the wires in such a way that almost every thin grain and much of that which is broken gets removed.

For malt we think the cylindrical form of screen, with mesh of three varying degrees of coarseness, preferable to the flat form, insomuch as it

separates not only the dust, but thin corn and large stones too. The malt, in its passage through the somewhat inclined cylinder, first comes into contact with the finest mesh, by which the dust is removed; by the somewhat coarser mesh succeeding the small corns are removed, dropping into their special receptacle; through the next mesh, coarser still, the good malt falls; and finally, through the open end of the cylinder, peas, stones, and anything too large to pass the screens are discharged.

The Cold-liquor Back.—The size of this, the highest vessel in the brewery, must depend upon whether it is relied upon for attemperating or not. Some brewers use their well supply for brewing and cooling, but get their attemperating supply from the local waterworks, if there is reason to think the pressure from the latter will be more constant. But if attemperating is done with water from the brewery well, there should be a subsidiary attemperating-back kept always up *to the same level* by a ball-cock, so that the pressure may be uniform and the size of the main-



Malt Screen.

liquor back should be *at least* on the scale of five barrels per quarter brewed. [Where, say, 1,000 barrels per week are brewed on the average, 160 barrels may easily be run out within twelve hours, and so the attemperating stop altogether, without speaking of the continuously diminishing pressure.]

Of course fresh liquor is the best for cooling, and the certainty of a copious well supply will render some reduction of size possible.

Liquor backs are now generally made of cast-iron panels bolted together (joints made tight by planing the turned edges and painting them just before bolting tight), though Dantzic fir is still no unknown material. The width is about half the length, and they are made relatively shallow (3 to 4 feet), because the greater the area the more the weight will be distributed.

Hot-liquor Backs.—Their contents may be heated either by free steam from the boiler, by a coil, or by a tubular heater (Worssam's make). The former plan is objectionable for more reasons than one—viz., the risk of introducing impurities (perhaps not very great if the vessels are a good

height above the boilers), the dilution of the water's saline properties, and the noise that free steam makes when so used. Coils must be placed so that the water from condensed steam readily drains away, towards the trap if one is used. In the latter case the pipes must be somewhat stronger than they would have to be if steam simply passed through the coil unobstructed, the pressure with a trap, which mainly lets the condensed liquid alone pass, being so much greater.

It is not easy to keep the joints of these pipes, of which several together, brazed to one flange, skirt the inside of the back, from leaking sometimes ; further the contact of iron and copper, of which material the coil is usually made, in steam brings about a destructive galvanic action between the metals, which necessitates some form of insulation. Perhaps the worst defect is that, as the pipes are necessarily some distance, relatively speaking, from the bottom of the back, the water below them does not get heated equally with the water above, so that, unless the mashing supply is drawn from well above the level of the coil, it is apt for some minutes to come down at a lower temperature than that required. [A bent-tube thermometer should always be inserted in the down pipe close to the "Steele" or other external masher.]

It is said that Worssam's high-pressure heater, by promoting circulation, obviates this drawback. The heater is, in effect, a large drum or cylinder of metal, through which a large number of tubes pass lengthwise. Steam (a pressure of at least 50 lb. recommended) is admitted into and passes through the drum, heating the water in the tubes, which immediately rushes out of their upper ends, and is replaced by cold or cooler water entering at the lower ends, and thus, till the desired temperature is reached, the entire contents of the vessel is kept in a state of more or less active movement.

The apparatus can be supplied with lining tubes of copper. These can be drawn out for cleaning, and are accordingly useful when the water is very calcareous.

[The same apparatus is fitted into wort coppers. It has been objected that the tubes would get choked with hops, but this is said not to be the case in practice. They are used in some of the largest London breweries and provincial breweries.

Malt mills, in common with other units of brewery plant, have been brought to a very high state of perfection, the old type of malt mill having one pair of rolls has been entirely superseded by malt mills having a combination of rolls.

The very efficient products of the modern brewer's engineer are now made in varying combinations. Some makers employ four rolls placed in pairs one above the other, grinding in two stages with an intervening sieve, whilst other manufacturers utilise the same number of rolls so placed that the malt can be ground in three stages, grading of the grist being effected between each stage by two separate sieves.

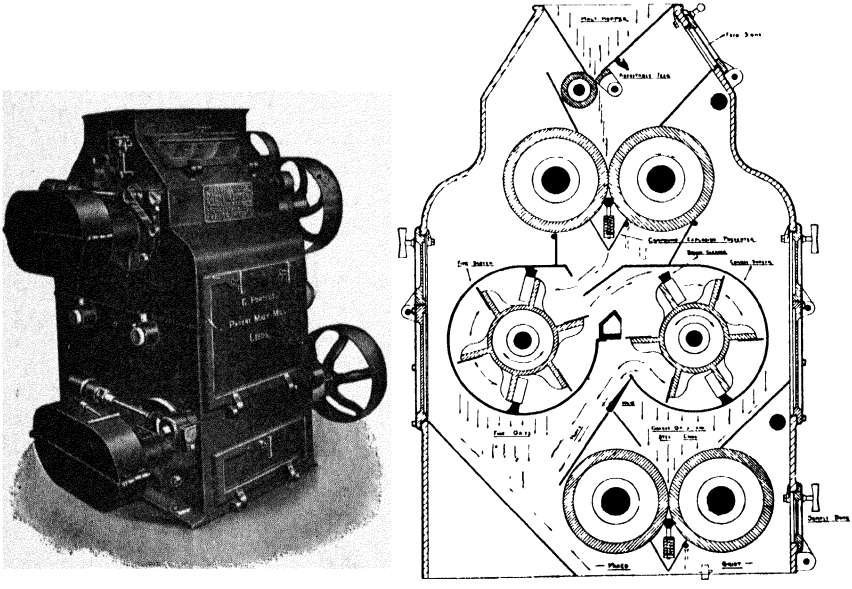
In other designs five rolls and even six rolls are used ; in both cases the grinding is effected in three stages, giving the brewer a complete control over the constitution of the grist he wishes to produce.

The type of grist every brewer should aim to obtain is one containing the highest percentage of small granular grits with a minimum of coarse grits and flour (whole flaky husks well defined), which will be amenable

to the action of the liquefying and saccharifying enzymes in the mash-tun.

In order to achieve this object it is necessary to grind the malt in stages on the principle of separation and elimination of the finished grist from each grinding; the introduction of the third grinding stage reduces the hard ends of the malt, the unmodified portion of the grain, to fine grits without injuring the husks, the conversion of which in the mash tun gives a greater yield of extract. In addition English and foreign malts and malts of unequal size can be blended before grinding, the whole of the separated products from each stage are finally discharged from the malt mill to the grist case as a perfectly homogeneous grist.

The condition of the grist is largely dependent upon the method employed in the primary grinding or first break. The malt should be fed



Four-Rolled Malt-Mill.

with its longitudinal axis parallel to the axes of the rolls; this is effected by a special type of feed roller and guiding plate.

The reciprocating sieves which are operated from the roll shafts should have a large sieving area to ensure a perfect separation of the various constituents of the grist. Anti-explosion plates must be provided to each pair of rolls; one of the most simple methods and at the same time most effective, is to arrange the plates under each pair of rolls so that the products of grinding coming from the rolls piles up, excluding the air.

Facilities are provided for taking samples from each grinding stage, so arranged to be taken simultaneously, which enables the brewer to ascertain the nature of the combined grist in the grist case.

In the best designs of malt mills the setting of the individual rolls is arranged by what may be termed parallel adjustment, ensuring an even spacing along the entire length of the face of the rolls, the setting being indicated by a micrometer reading by means of an indicator and sector.

Each set of rolls can be set independently of one another and a further feature of the most up-to-date malt mills is the provision of strong springs, which, although they are not affected when malt is being ground, they allow the rolls to open should any large particle of iron or steel pass the magnets, which are placed above the feed roll, or other foreign body find its way inadvertently to the rolls, preventing the train of gears which drive the several rolls from being damaged.

Each malt mill is a complete self contained unit enclosed in a dust tight casing, all bearings being self-lubricated and the gears enclosed in an oil-bath gear case.

The Elevator (Jacob's Ladder).—An endless belt, on which tinned or galvanised iron cups are riveted, rotating, within an iron case, round a top and bottom pulley. It is advisable to have it driven from the top, as then, owing to the weight of the cups and belt giving more " bite," it is not necessary to keep the belt so tight, as would be necessary if the driving were from the bottom. There may be a screw arrangement connected with the lower pulley, enabling it to be raised or lowered, so that the belt may be readily tightened as required.

There should be convenient doors, for inspecting the working of the cups, at some point or points in their upward career, and they should be allowed to run on for some minutes after the grinding is finished to ensure their being emptied. We also hold with giving the elevator case a few smart taps with a mallet, in order to detach as much of the adherent flour as possible. This should certainly be done after brown malt has been crushed. Black malt, we think, should be ground into sacks and be shot into the grist-case ; the risk of colouring a following pale-beer brew is too great to admit of sending it up by the elevators.

Grist Cases, or Grist Hoppers.—Their position with regard to the mash-tun depends upon there being only an internal mashing arrangement (rakes), or on a combination of the latter with an external masher, of which that known as " Steele's " is the usual type. In the former case they will be directly over the mash-tuns, and will have four or more slides to allow the grist to be rapidly let into the mash-tun while the rakes are revolving.

In the latter, each " hopper " will only, generally speaking, have one outlet at bottom, with slide working with a square-threaded screw, and their position manifestly depends upon whether one Steele does duty for two tuns or not. In the former case the two hoppers will be, as it were, one structure, divided by a central partition.

Wrought iron, with as smooth an inner surface as possible, and painted inside and out, is now the usual material, but wood (well-seasoned deal), zinc-lined, has the advantage of not causing such rapid condensation of the steam, which inevitably finds its way into its interior.

The lower part of the grist-case should slope to the " Steele's " at an angle of about 45 degrees. A much less angle than that, meaning that the sloping sides are carried up unduly high (as I have seen them where exigencies of space have necessitated such an arrangement), causes the grist to come down by fits and starts, while a wider angle also interferes with the regular flow.

There should be an opening at the top, whence a man can push down every particle of grist within reach at the end of the mash, and *there should*

certainly be a movable piece, a shoot or box, between the bottom of the grist-case and the Steele's. Otherwise there is great difficulty in cleaning the parts round the slides properly, and pasty matter collects there which soon gets abominably sour.

The area allowed for a grist-case is about 12 cubic feet per quarter (for a hopper for whole-grain about 10).

External Mashers are either self-acting or require driving. The former type is generally used for small plants only, though it is possible, by having several (one connected with each outlet of the grist-case), to make them available for dealing with large quantities of grist. Ready detachability for cleaning is their recommendation in the latter case. Maitland's, Gregory's, or Riley's are, we should say, the most usual forms, the first-named having revolving paddles actuated by the downward rush of the water, the last two having no mixing parts, but subjecting the ground malt, as it comes down through the inner part of the cylinder, to continuous fine jets of heated water proceeding from numerous holes pierced in the inner face of the cylinder's hollow jacket.

"Steele's," the most widely used form, requires driving. It consists of a shaft, with a number of short arms at right angles to it, rotating in a cylinder of iron or copper. The grist and liquor enter the cylinder at one end, at two separate openings, and when mixed by the revolving arms fall into the mash-tun at the other, the open end of the cylinder. This is the simplest form, but the machine may be fitted with a screw to feed the grist. There should be openings (closed during mashing) in both top and grist-case ends for cleaning out the cylinder.

Powerful "Steeles" are made which will mash sixty quarters in ten to fifteen minutes; but a lower power than that is preferable.

The rate of speed may vary from 120 to 180 revolutions per minute, the lower rate being adapted to machines of larger diameter.

Mash-tuns and Mashing Tackle (Rakes).—Mash-tuns are either of wood (oak sides, bottom of Dantzic fir) or cast iron, the sides of the former tapering upwards slightly (to allow of the hoops being tightly driven), while in the iron tuns they are quite vertical. This, as Mr. Southby pointed out, causes "the goods" to rise better in iron tuns than in those of wood.

Iron mash-tuns, if properly managed, give no coloration to the wort, but in the leading pale-ale centres there is still a prejudice in favour of wood, and, where expense is no object, with gun-metal fittings.

Tuns of either material require to be thoroughly heated before use, but those of iron most of all, on account of the rapidity with which heat would otherwise be absorbed from the mash. A good plan is to turn in free steam, after which run in a sufficiency of water not exceeding 165° F. to cover the false bottom.

The capacity of a mash-tun should be quite $3\frac{1}{2}$ barrels of liquor per quarter of malt, which allows a clear $2\frac{1}{2}$ barrels per quarter for mashing the malt with. The proportion of depth to diameter recommended varies from equality (about 5 feet each) in 5-quarter mash-tuns to as 1 : 2 (7 feet and 14 feet) in full-sized 50-quarter tuns.

The largest mash-tuns which we know of are 120 and 160 quarters respectively, but Mr. Southby thinks a capacity equal to 100 quarters should be the limit.

The internal mashing machine (or Porcupine)* consists of the following parts—viz., a vertical shaft, either driven by steam power from above, or from below (in which case it passes through a stuffing-box in the centre of the mash-tun bottom with a gland bolted on underneath). In the former case it works a foot-step (on gun-metal bearing, which is bolted to the bottom of the mash-tun inside) with a bevel wheel cast on, driving, as the vertical shaft rotates, a horizontal single or double rake-shaft, in line, by means of a bevel or bevel wheels gearing into it. The horizontal rake-shaft has a number (7 or 8) of *wrought* iron rakes bolted on, rotating with the shaft.

On the outer end of the rake-shaft is a toothed pinion, working on a circular rack, skirting the tun about half-way up. It is usual to have, one above and one below the rack, two rakes, which move with the shaft, but without rotating. These serve to push "the goods" from the edges.

In the largest mash-tuns it is necessary to have two tiers of rakes, one above the other, but driven from the same vertical shaft, although at different rates of speed.

Iron mash-tuns, of course, have to be lagged with felt or one or other of the many non-conducting materials and boarded round.

Mash Tun Covers and False Bottoms.—The raised covers, with the sides closed in by shutters, sometimes seen, are not to be recommended.

The simplest arrangement is to have two nearly semi-circular covers (of well-seasoned wood, tongued), hinged on to a permanent narrow wooden bridge (just wide enough to allow of an opening being made in it for the sparger to work). The two covers are properly counterpoised to allow of their being readily opened or closed, and fit down close on the upper edge of the mash-tun.

The false-bottom plates, two semi-circular, the rest roughly triangular, *stand, when down,* upon wooden feet, about $1\frac{1}{2}$ to 2 inches from the real bottom of the run. They are either *drilled* with holes, from $\frac{1}{16}$ to $\frac{1}{8}$ inch in diameter (countersunk and not over one inch apart), or have slots for drainage—long slits—radiating from the centre, the latter being now the more usual plan. Its drawback is that it tends to weakness of the cast-iron plate. Plates of copper, gun-metal or phosphor-bronze give the best drainage area for their surface, but are costly.

Spargers.—The modern spargers differ in construction from the original, and the present type indeed is a considerable improvement on its immediate predecessor. The latest design revolves on ball bearings at a high speed, if necessary, and the perforations in the arms are so numerous and so minute that the water is dispersed in a semi-atomised form, or an intensely fine spray, which minimises the weight of the falling liquor upon the goods which, so far as the effect of sparging is concerned, obviates the danger of flooding.

It is important that the sparge-liquor should be delivered evenly over the whole surface of the goods. An appliance (Messrs. Wilson & Co.'s) for testing this is described on p. 257. Small spargers have two arms, larger more.

Coppers : heated by Fire direct, or by Steam.

Fire coppers are either :—

1. Closed dome, the form used in the large London breweries, especially

* A name perhaps never heard now, though it survives in French as *Porc-epic Anglais.*

for porter. The steam escapes through a pipe in the upper part of the dome, and sometimes there is a safety-valve too. Occasionally a shaft, driven from above, is fixed in the copper, and has arms at right angles, from which looped chains depend of just such a length as to sweep the bottom of the copper, as the shaft slowly revolves while the copper is boiling.

2. Open coppers, which are, of course, the easiest of *fire* coppers to clean (all fire coppers, however, want much more *scouring* than steam coppers do, and owing to this and the effect of the flame, wear out much more quickly than the latter), but require constant watching and *hard rousing* whenever they threaten to boil over. (See Fountains and Cones, below.)

3. Dome and Pan Copper. The dome is less rounded than in No. 1, forming, in fact, the bottom of the pan, which is generally of a capacity nearly half the *boiling* capacity of the copper. The sides of the pan are carried up in continuation of the sides of the copper, and there is an opening in the crown of the dome, from which a short, wide tube, firmly riveted on, is carried up level with the rim of the pan. There is also a hole, closed by a long-handled plug, in the lowest part of the pan.

When the copper is boiling strongly the plug is withdrawn, and the wort which boils out of the central aperture falls into the pan, and finds its way back at once through the plug-hole into the copper.

Towards the end of the boil, when the copper has steadied down, and it is desired to have some fresh wort ready " to save the copper " directly the first wort is turned out, the plug is replaced and fresh wort pumped or run into the pan.

We believe this to be by far the best arrangement for fire coppers of this specific type, the only precaution necessary being to see that the plug fits well, and that no gritty matter gets round it or the plug-hole before the unboiled wort is pumped into the pan.

Size and Shape of Fire-coppers.—In Burton, as a rule, relatively small coppers (within 100 barrels) find favour, on the ground that less coloration ensues than would if the depth of wort were greater ; in London, even for the largest plant, 350 barrels is considered a good working limit of size, it being preferable to have several coppers of comparatively medium size, than half the number of very large ones, as then one can much more easily be spared for repairs. [However, a size capable of boiling 500 to 600 barrels is not unknown.]

The bottoms of fire-coppers are dished upwards termed the " crown " (in steam-coppers downwards referred to as the " bowl "), and the diameter in extreme instances where free evaporation is desired, may equal or even exceed the depth.

Furnace and Flues (Fire-coppers).—As with boilers, there is a bridge at the back of the furnace, and this extends upward to within a foot, more or less, of the copper-bottom. A flue, or flues, lined with firebrick, start from the combustion-chamber behind it, and go as high as the part—" the bench "—where the copper widens out.

On the flues, in relation to the furnace, and on the shape of the copper, the style of boil doubtless depends. As a rule, fire-coppers boil more from the centre, while steam-coppers boil from the sides (especially from that where the steam inlet is), but sometimes they boil from back to front. A

well-known system of copper-setting depends on having a copper with very broad base, and with such coppers the boil will be central.

Coppers boiled by Steam.—These consist of a hemispherical copper pan made all in one piece (say of ½ inch metal for a 9 ft. pan), with a wrought or cast-iron jacket outside it, an average space of at least three inches, diminishing to one at top, being left between jacket and pan, and the steam space being, of course, made thoroughly tight at the junction. Wrought-iron plates for the jacket of a 9-ft. pan should be ⅜ inch thick, and it should be covered with some non-conducting composition.

The sides of the copper—and in this case the *actual* depth should exceed the diameter *—are of less substance than the pan, but should be of a thickness averaging 7 lb. per square foot (No. 9, B. W. G.), and the edge at the top will be turned over 3 inch angle iron to keep the copper from buckling.

Wort is discharged through the centre of the bottom of the jacket, the delivery pipe passing through the steam space between it and the pan.

The fittings comprise a steam-inlet valve, actuated by a long handle, carried up to the copper stage, the handle or bar being fitted on the top portion with a wheel, so that steam can be immediately turned off by the man watching the copper, on its threatening to boil over; a safety-valve connected with the jacket to prevent undue pressure, and a cock in the upper part of the latter for escape of heated air, which, owing to the great expansive force of air when suddenly heated, is a necessary precaution.

There must be a condensed water outlet pipe and steam trap, so that condensed water only may pass to the condensed water tank. Steam-inlets, though often single, may be multiplied, and it is recommended to have three or even four for a large copper.

A mercurial reducing valve, designed to reduce the strain while retaining the increased heat of high pressure in the boiler, may be added, but a lock-up dead-weight safety valve of large area is thought to be as effective at a much less cost.

Fountains and Cones.—These are both appliances arranged to prevent coppers in strong ebullition from boiling over, and to promote circulation of the boiling wort, but as they are objectionable in more ways than one, they need not detain us long. Not only is there the danger, especially with fountains, if the upper pipe gets choked with hops, of their being forced bodily out of the copper by steam generated underneath, in which case a very serious accident might ensue, but there is the further drawback —still with fountains rather than cones—that the hops get so disintegrated as to be incapable of acting as an effective wort-filter in the hop-back.

A sketch of a fountain may be seen in any Brewing organ; cones, of the shape their name implies, except that there is a relatively large opening (18 inches to 2 feet) at the apex, are suspended, counterpoised so that they can easily be lowered or raised, within the boiling wort, which dashes through the opening at the top, and flows back through the space (some two inches) between the lower edge of the cone and the sides of the copper.

* The calculations in Chapter V. were made for steam-coppers having a depth greater than the diameter. With relatively shallower coppers evaporation would, of course, be more considerable.

The Underback and Hop-back.—The size of the underback has been treated of in a previous chapter ; it should certainly have a coil, but a single tube (as being more easily cleaned) is preferable here to the three or four smaller tubes brazed into one flange, albeit the heating power of the latter arrangement is greater for the same quantity of steam.

A circular form is more convenient for a small hop-back (cast iron, with gun metal, or phosphor-bronze, slotted false-bottom plates), but rectangular vessels are preferable when large volumes of wort are dealt with, as they admit of the use of two spargers working simultaneously. There should be air-vents from under the false bottom ; with outlets at each of the four angles of the vessel.

Wort Pumps were referred to earlier in the chapter.

Coolers should be of iron or copper, the former of course being much the cheaper, and soon getting coated with an insoluble film of tannate of iron from the hops, which prevents any discoloration from the action of hop-tannin upon the metal. Unused iron coolers should be protected by a coating of whitewash.

Hanford-Stanford Atomising Plant.—The wort is delivered on to the cooler (which may be fairly deep) in a more or less fine spray through a number of nozzles, a certain pressure being attained by appendages like ordinary safety-valves to each. These can be adjusted easily to any required pressure, and the fineness of the spray be increased therewith or diminished. Wires connected, one with each of the safety-valves, have their other ends brought on to a control board, easily accessible, where the adjustment is made.

It is stated that a saving is effected in refrigerating water by a sudden drop of 80° to 100° which occurs, and that this sudden fall of temperature causes a much freer precipitation.

Aerator or Float Valve.—Consists of a pipe or copper tube open at the top and ribbed at the sides, upon which a copper device floats lightly on the surface of the wort in the coolers. The tube is just big enough to be inserted in the cooler outlet. On opening the outlet tap to the refrigerator (whereby suction is begun), the wort from the cooler, being higher than the refrigerator, will at once begin to syphon up the ribbed sides of the exterior of the tube or pipe, and then flow steadily down the inner tube and over the refrigerators.

The idea is that the supply of liquid running down is always taken from the top, and that consequently the brightest and coolest wort is run down. This simple and inexpensive adjunct serves its purpose admirably and can be obtained from any brewery engineer of repute.

Refrigerators are of two classes, viz. (1) those in which the wort flows outside, exposed to view, and the water inside, and (2) those in which the wort flows inside the pipes and the water outside.

Class 1 is subdivided into vertical, horizontal, and circular.

Those where the wort flows outside are altogether preferable on the score of cleanliness, the vertical form being generally adopted where there is a sufficient fall. In this shape Lawrence's and the improved Baudelot are widely used, the former being made of corrugated metal (the water passages inside follow the corrugations), while in the Baudelot the tubes are of oval section and each provided with tiny projections like the teeth of a fine saw, which secure the even distribution of the wort.

In another make (S. Briggs & Co.) the tubes are of seamless copper, and have each a rib or feather which fits into a groove in the tube below, and the surface is thus everywhere accessible and the strength great. The chance which this construction gives of removing a damaged tube is one advantage over that of Lawrence's.

In no case should there be any brazed joints, for the alternate expansion and contraction occurring would be certain to ultimately set them leaking, and the waterways should be readily accessible (see hints on cleanliness, below). Lawrence's pattern is supported on trunnions, so that the whole refrigerator can be turned upside down, if found necessary, with comparative ease.

In all of these refrigerators the wort flows in one direction—viz., from top to bottom, while the water flows in the contrary direction, entering the refrigerator tubes at the bottom and making its exit at the top. In some vertical refrigerators, however, the water progresses upwards from side to side of the machine, instead of from bottom to top, *i.e.*, or in precisely the opposite direction to the flow of wort. [The water, after leaving the refrigerator, is sometimes carried into the hot-liquor backs for mashing next day. The plan—unless where water is scarce—is one of which the wisdom is doubtful.]

Of horizontal refrigerators the pattern put forth by Bridle of Bridport was the first resembling those now used, but nowadays Morton's, with great cooling surface, is the one most often seen. Inaccessibility for cleaning, as compared with the verticals, is the drawback of this and other horizontals.

Where space is limited, circular refrigerators are most effective. One (by Shears & Co.), standing beside a Morton, did, within our knowledge, over two-thirds of the work, though occupying certainly less than one-third of the ground-space taken up by its horizontal competitor.

The quantity of cooling water required is a consideration. One of the authorities says that horizontals required at least twice as much as verticals. Verticals require two barrels, more or less (according to season), to cool down one barrel of wort.

Cold producing (Ice) Machines.—Formerly introduced into a few large breweries, the advent of the chilling process has led to a much wider use of them. Those before the public may be divided into :

(1) Compressed-air machines.

(2) Evaporation machines, divided into (α) those with a compression pump ; (β) those acting by absorption ; (γ) vacuum machines (only domestic sizes successful).

The construction of (1) depends on the fact that ordinary air compressed very strongly becomes enormously hot : for example, under a pressure of 65 lb. absolute the temperature is about 300° F. If, then, this is done in a strong cylinder and the heated air be afterwards cooled down while under the same pressure by cold water circulating through a system of pipes within it, obviously (such a vast number of heat units having been withdrawn) upon allowing the compressed air to expand to its original bulk, an enormous fall of temperature will occur. Windhausen, using a compression of *three* atmospheres only, got a temperature of 58° F. under zero !

In these machines the piston has great resistance to overcome, and very

strong construction is needed, involving a higher first cost. This, and some complication in the working, owing to the absorption of water by the air, even when the same air is being used over and over again (the liquid having to be got rid of either as water or ice), have perhaps militated against the use of air machines in breweries. On the other hand, the air may be made to do work on expansion, if this takes place behind a piston in the expansion vessel (the usual plan being to cut off at one-third of the stroke), and this work, supplemented by the engine, used for compression again. In good machines the actual efficiency, allowing for losses, is about five-eighths of the theoretical. Where only moderately low temperatures are wanted, and these obtainable by direct discharge of cooled and expanded air, instead of employing it to cool brine circulating through it in pipes, surely some comparatively simple arrangement might be designed for working by moderate power.*

The Evaporation Machines depend upon the physical fact that many fluid bodies, on passing into the gaseous state, lock up heat, or render it latent. Alternate compression and expansion of the frigorofic agent, anhydrous ammonia or carbonic anhydride, is the means adopted, the cold, occurring upon the latter phase, being transferred by means of brine circulating in contact with the expansion pipes. The gas, warmed by the contact, and further heated by work done by the compressor-pump, is forced into a compressor—which may consist of very strong steel pipes, arranged refrigerator-wise, over which water flows—and when reduced below the temperature corresponding with its boiling point at any given pressure, is liquefied. Thus anhydrous ammonia has a boiling-point of —37° F.: obviously then its vapour could not be liquefied by ordinary water at atmospheric pressure ; but a pressure of 150 lb. per sq. inch corresponds with a raised boiling-point of 84° F., and on any reduction of temperature below this, the pressure being still maintained, liquefaction begins again. In other words work is done in compressing the gas against its own pressure. This energy is translated into heat, which raises the temperature of the gas, the compression temperature amounting in some machines to 180° or 220° F. for an absolute pressure of 130 lb. In Linde's compressor this is avoided by conveyance of a minute portion of liquid ammonia into the pump with the vapour at the commencement of each stroke, which by its own vaporisation cools the pump down to a refrigerating temperature, minimising friction and influencing discharge of the gas at but a little over the temperature of the condensing water, in lieu of the high one stated above. In the **Absorption Machines** advantage is taken of the readiness with which this gas is taken up by water to recover it when its effective cooling influence has been expended. From the aqueous solution the gas is driven off by steam and passes into a condenser coil downwards, outside of which condensing water flows upward. The ammoniated gas, passing through a series of traps in the coil for catching and ejecting watery particles, and accumulating beneath the lowest trap, liquefies by its own pressure. For reasons too many to state here, this method has not proved fully efficient, but it is now claimed that by addition of an extra vessel, called a rectifier, which enables the fluid to be enriched by more prolonged contact with the gas than was

* There is such an arrangement, worked by water power, delivering cooled air at a distance of nearly half a mile into the workings of a Devonshire copper mine.

possible before, an efficiency 30% beyond that of the compression machines has been obtained. If so, a mechanical difficulty of the compression machine, the difficulty of making the piston gas-tight, will be avoided.

The ammonia used is not, of course, the liquid known as such, but the gas of which the liquid is a solution only. Its obvious advantages are counterbalanced by the fact that it attacks copper and brass, wherefore these metals cannot be used for ammonia machines, where steel must be employed. Carbonic anhydride has not this drawback, a quality which, first indicating its suitability for marine work, has led to its use in other installations. Machines worked with it are more compact, but the proportion of loss on expansion, owing to the respective latent and liquid heats of the two gases, is as 0·351 (for CO_2) : 0·110 (for ammonia).

Of the **Vacuum Ice Machine,** devised by Raoul Pictet and improved by Windhausen, much was hoped, an effective output of 12 tons daily having been secured with one machine. The principle is now only adopted for machines making small quantities of ice (Fleuss machine). It depended on the fact that water, when the pressure upon it is reduced below the atmospheric, evaporates (and the nearer the reduction approaches an absolute vacuum, the more rapid is the evaporation), so that when one-sixth of the bulk has been removed, the remaining five-sixths turn to ice. Sulphuric acid, through which the suction passes, absorbs the abstracted vapour, and with it the heat that the water loses. About 3 lb. of ice can be turned out for each pound of sulphuric acid before the latter becomes too weak for further absorption.

Fermenting Vessels or Gyle-tuns.—Reference here will be limited to skimming vessels, cleansing having been dealt with in Chapter I.

Where a **Collecting or Gathering Vessel** (not shown on the plan of a 70-quarter brewery) is adopted, the wort *must* remain there for not less than twelve hours or till its gravity has been ascertained by an excise officer. The advantages of having one are (i) Uniformity of gravity when the contents are divided amongst smaller vessels. (ii) That, as samples are only taken whilst the fermenting wort is in them, the contents of fermenting vessels are not interfered with by the excise officer. (iii) The first dirty head (coagulated albuminous matter), and much sedimentary matter remain behind. (iv) Aeration—but not invariably a benefit.

Fermenting Vessels are generally of wood (slate has been tried, but is more sensitive to external temperature), viz., English or foreign oak, or Dantzic (yellow) fir. The timber should be well seasoned, *i.e.*, free from sap as well as from shakes and *knots*. [The latter, if they exist, must be bored out and the opening plugged with sound wood.] Now, however, as mentioned, earlier in this work glass lined metal vessels, and aluminium vats are now extensively adopted.

The vessels are either round, oval, or square. The square shape is the more economical both of space and in other respects, as there need be no lost corners, and several can be constructed together with much saving of partition timber. The inside corners undoubtedly afford a harbour for dirt, and vessels constructed with rounded corners are now employed.

In rounds and ovals the staves run upwards, say for twenty-four inches above the *highest* filling point, to form yeast boarding ; this additional length being afterwards cut away from a few of the staves to form a manhole and dipping place. A frame is fitted into the manhole, and this is closed, if necessary, by movable boards.

I think the best way of seasoning *oak* vessels is to fill them with cold water in which salt, at the rate of a pound per barrel, has been dissolved, after one or two preliminary soakings, for a day or two each, with waste refrigerator liquor.

For seasoning fermenting vessels of fir, Mr. Southby recommends the following course. First scald by filling with boiling water; on the following day run the water out, and whitewash with a mixture of 2½ lb. of chloride of lime in one gallon of water. This having remained on for 24 hours, a second wash, made of 1 part common hydrochloric acid (muriatic acid) to 4 parts water, is to be applied. Twelve or fourteen hours later the vessel is to be washed several times with water at 212°, and finally with bisulphite of lime solution, which destroys any smell of chlorine.

He also pointed out that quicklime injures oak, by forming a soluble compound with its astringent juices, whence it becomes soft and porous. On the other hand, it does not injure resinous woods, as it forms an insoluble compound with their resins.

The removal of the yeast by skimming is effected, generally, either through a **parachute** connected with a pipe penetrating the centre of the bottom of the tun, or through a **sluice** (Griffin & Pearce's), a smoothly planed slide of metal working against smooth inside edges of an iron frame, bolted on to the tun, the slide being raised or lowered by a rack and pinion on each side.

Sluices are, as a rule, arranged to work into a slate yeast back on the same floor, but where floor space is more of an object than height, there is no reason why the yeast should not be conveyed by a vertical shoot to the floor below. As *data* for the size of these yeast-receiving backs on the floor of the fermenting room (of course the bottom of the F.V. itself is really lower than this floor, the tun having been lowered through a hole cut therein, so as to rest on girders beneath), the following particulars may serve. When two fermenting tuns work into the same slate back (" yeast back "), an allowance of two cubic feet, *liberal measure*, per barrel of the fermenting wort will probably always suffice, especially seeing that both tuns will not be working simultaneously.

But with fairly strong worts, and where the full content is fermented, that proportion will hardly suffice, unless precautions are taken to keep the yeast-back on drain. Thus a yeast-back 10 ft. × 9 ft. × 3 ft. 4 in. working out at 306 cubic feet, inside measure, is enough for a 150 barrel round.

Fermenting vessels up to 150 barrels can generally be skimmed by hand, but above that size they require some form of **mechanical skimmer.** For rounds a skimming-board revolving round a central rod, and capable of being raised and lowered as well as rotated from the outside of the tun, pushes the yeast before it into a trough, which extends (instead of a parachute) from the centre to the edge of the tun, provided like the parachute with a down pipe, going through the bottom of the tun.

Squares may have a similar trough, extending along one of their sides, and into this a yeast-board, travelling on a wheeled framework, from end to end of the tun, pushes all the yeast.

Attemperators are made of tinned copper pipe, and are either fixed or movable, the latter not being adapted for tuns of large size, that of 80

barrels' capacity being about the limit. Beyond that they would have to be excessively cumbrous.

Fixed attemperators of tinned copper pipe, which should be *oval* in section, as this gives more cooling power than the round form, are made in lengths, bolted together in such a way that the whole forms a continuous coil circling the tun about three times. The water inlet is at the higher part of the coil, the outlet at the lower, and here the pipe carried to the outside of the tun, and which is continued by a rising pipe with a " swan-neck " end, should have a small draw-off cock for emptying the attemperator, in case of severe frost occurring when the fermenting vessel is not filled.

Movable attemperators are suspended with chains and balance-weights, and are connected with the mains by india-rubber hose. The whole weight is usually taken by a single wrought-iron chain, attached by a ring to which four short lengths of brass chain converge. The result is that if air gets into the pipes the attemperators sway about a good deal, and I cannot but think that suspension by four vertical chains (in connection with which a very simple arrangement for raising or lowering the attemperator might be made without counterpoise weights) would be preferable.

A Rotary Pump for rousing, raising, when the handle is turned one way, a continuous stream of wort, or when the action is reversed, pumping air into the fermenting wort, is a useful adjunct to the fermenting room.

Casks are made of foreign (Memel) oak, as a rule. The timber should be free from worm-holes and sap. It comes to hand in lengths (*balk* or juggle) of rather over six feet, and of a thickness which admits of three stave lengths being got. Foreign oak, being straighter in the grain than English, admits of being split ; English has to be sawn. Moreover, the latter warps when steamed.

Barrel staves are 31 inches in length ; kilderkin staves 25 inches, and care should be taken to divide the timber lengths so as to avoid waste.

The pieces of which the heads are made are joined together by dowel pins (wooden pegs) and bevelled round, so as to fit into the croze grooves. The chamfered edges (afterwards painted) form the chime.

The hoops of hogsheads and barrels are known as the end, bulge, and quarter hoops respectively ; kilderkins (generally *) and firkins only have end and bulge hoops.

Casks are classed as stout, intermediate, or slight, according to the thickness of the staves. The thickness of the heads and width of hoops also vary.

The thickness of the *staves* runs as follows :—

	Stout.	Inter-mediate.	Slight.
	inches.	inches.	inch.
Hogsheads . .	1½	1¼	1
Barrels . . .	1½	1⅛	1
Kilderkins . .	1¼	1⅛	1
Firkins . . .	1¼	1⅛	1

Cooper's Wages in 1926.

Burton-on-Trent Journeymen Coopers.—Rates for Enlarging and Repairing Beer Casks.

* Slight kilderkins, however, are hooped with six hoops, like barrels.

Enlarging Beer Casks.

Limit one stave or strip and one piece in each head. Payment as repairs for extra pieces.

	Ordinary.	Drawn joints.	New timber shaved out.
	s. d.	s. d.	s. d.
Butts	3 2	3 2½	—
Hogsheads	2 4	2 4½	2 5
Barrels	2 0	2 0½	2 1
Kilderkins	1 8	1 8½	1 9
12 galls., and under ..	1 7	1 7½	1 8

Repairing.

First Limit, one stave or one piece heading.

	s. d.	s. d.	s. d.
Butts	1 0¾	1 1¼	—
Hogsheads	9¾	10¼	10¾
Barrels	7½	8	8½
Kilderkins, and all under..	6½	7	7½

Second Limit, two heads.

	s. d.	s. d.	s. d.
Butts	2 1½	2 2½	—
Hogsheads	1 7½	1 8½	1 9½
Barrels	1 3	1 4	1 5
Kilderkins, and all under..	1 1	1 2	1 3

For every stave that exceeds these limits the prices to be as follows :—Butts 4d., Hogsheads 3d., Barrels 2½d., Kilderkins and all under 2d.

Extra staves beyond limits required to be clean shaved to be paid extra as follows :—Hogsheads and all under ½d. per stave. Drawn joints :—Hogsheads and all under ¼d. per stave.

Renewals or alterations of hoops :—Butt end and bulge 1½d. each, Hogsheads and all under, end and bulge 1d. each, all other ½d. each.

Grooving.—Where casks require to be crozed and chimed beyond the new timber put in to be paid 2d. per end extra or to be done daywork.

Rivets in repairing ½d. each.

An additional percentage, varying with the cost of living, to be paid on above rates. In Burton-on-Trent this, at present, is 82½%.

London, Eastern, Home and Southern Counties.

The following piecework rates shall carry the percentage plusage increase as decided from time to time by the National Joint Industrial Council of the Cooperage Industry.

Cobbling Brewers' Casks.

Cobbling not exceeding two staves, one stave and one piece of heading or a repaired head, to be paid as follows :—

	s. d.
Butts	1 3
Puncheons	1 2
Hogsheads	1 0
Barrels and half-hogsheads	11
Kilderkins and 12 gallons	10
Firkins and all under	9

Exceeding above, but not more than three staves, two staves and a head repaired, or both heads repaired, half the price of cobbling extra.

Exceeding above, but not more than five staves, three staves and one head repaired, one stave and both heads repaired, one stave and a made head or a made head and head repaired, double the price of cobbling.

If more than this is required, each extra piece shall be charged for according to following scale :—Butts and puncheons, 4d. ; Hogsheads, barrels and half-hogsheads, 3d. ; Kilderkins and all under, 2d.

A head requiring more than one, or a repaired head requiring to be re-shaped, to count a made head.

A made head to count three pieces.

All made heads to be cut into proper shape.

(*Note.*—The definition " re-shaped " to mean heads requiring cutting in practically all round ; a head requiring only to be " trimmed " with the knife does not come under the term " re-shaped.")

Ginger-beer casks to be allowed one extra piece all through, provided joints are not levelled.

Casks enlarged or reduced, the price of cobbling extra. Case staves to be provided.

Making own case staves, price of bending in extra, viz., butts, puncheons and hogsheads, 1s. each stave, barrels, half-hogsheads, kilderkins and 12 gallons, 8d. each stave, all under 6d. each stave. This not to apply to new casks.

For cleaning casks inside with hollowing knife or shave, the price and half of shaving out if not cobbled, if cobbled, shaving out price extra. This price to include unheading and heading up.

Firing brewers' stinking casks, the price of cobbling to be paid.

When fired and shaved, double the price of shaving. These prices do not include cobbling.

Setting straight iron on butts and puncheons, 2d. each hoop extra, all under 1d. each hoop extra.

Setting extra wide iron or repaired casks to be paid extra.

Brand or scribe marks to be taken out, 1d. each and extra ; if the heads are taken out for this purpose, the price of cobbling.

All casks given in to be cobbled without a suitable set of hoops, 1d. per hoop extra to be paid from butts to kilderkins ; all under ½d. per hoop extra.

Boring all holes, branding and bushing, to be paid day work.

Making bad joints sound to be paid as follows :—One or two joints as one piece, over two and up to four as two pieces, over four and up to six as three pieces, providing instructions are given to do the same.

Special made casks requiring extra labour to be paid price and half of cobbling extra.

Narrow case staves to be provided for similar made casks ; if cobbled with wide staves payment to be made for staves taken out.

All cobblers to be trimmed in ; failing which a basic of increase of 2d. per cask to be paid.

All casks cobbled with American or English oak timber to be paid a basic increase of ½d. per piece. (Such payment not to apply when heading is dressed by machinery.)

[A case is a complete set of staves bent into the form of a cask without heads.]

Burton brewers pay coopers, daywork, 1s. 7d. per hour for a week of forty-seven hours (slightly lower rates may be arranged in exceptional cases, such as old men, of 1s. 6d. or 1s. 5d. per hour); brewery labourers, 56s. per week for a week of forty-eight hours.

To Season New Casks.—Fill them with very hot liquor and washing soda. Most of the colouring matter and woody flavour will be extracted in thirty-six hours. The casks should then be filled with water and "spent hops." Fill, however, for the first time, with black beer.

For pronounced "**stinkers**" there is supposed to be no cure, but the chloride of lime whitewash treatment, succeeded by muriatic acid and bi-sulphite successively, each being driven in by steam, might certainly be tried, also permanganate of potash.

For moderate cases a foreign journal suggested treatment with strong solution of bicarbonate of soda till it soaks into the pores. Then, after draining and rinsing, water acidulated with HCl is added, the evolved CO_2 being supposed to drive out putrescent matter. The use of permanganate of potash has also met with some success.

Cask-washing Machines.—The simplest form of effective arrangement for cask-washing (apart from taking out the heads of and hand-scrubbing each cask) is to have a series of nozzles, through which, by duplicate cocks, either steam or boiling water can be delivered. A modification is the Pontifex apparatus, where steam and water are admitted in a similar way, the water being boiled on its way, or within the cask.

Other machines have been designed to give a thorough revolving motion in all directions to the cask, which is filled with boiling water, followed by steam and its sterilising influence on timber.

This chapter having already reached an inordinate length, we must pass over other pieces of plant, amongst which are yeast presses, yeast storage backs (less necessary if the slate yeast-backs described above are in a cool situation, and moderate fermenting heats the rule), and we will conclude with a few hints on general cleanliness and general arrangement (taking the latter first) which have not yet come within our purview.

Modern machines are made by the majority of brewery engineers, and are doubtless well known to readers, through the medium of the trade papers and exhibits at the annual Brewers' Exhibition.

Supplementary Remarks on General Arrangement.—Waste pipes from any vessel used to contain wort or beer should never be directly connected with the drain, for two reasons. (1) The certainty of increased contamination by bacteria, and (2) the risk that, through a cock being left open inadvertently, loss of wort or beer might occur without being noticed.

Wort mains (of tinned copper pipe in moderate lengths connected by unions) should have a fall of at least one inch in ten feet.

Steam or water pipes may be of wrought or cast iron, but in either case the bends should be as easy as possible, avoiding *sharp elbows*.

[N.B.—It is well to specify that large cast-iron pipes should be cast in vertical moulds, as the thickness of the metal is more uniform, and it sets more compactly.]

Hollow cast-iron columns, on account of their liability to vary in thickness in different parts (note the hint in brackets above), are less used

than formerly for supporting great weights, the preference being given to a smaller *solid* shaft with four ribs or feathers.

Steel girders are lighter and stronger than iron.

Supplementary Remarks on Cleanliness.—All mains and wort pumps should be periodically charged with a strong potash solution, even though hot liquor be pumped through before each brewing. Hot liquor should be pumped through, and the nearer boiling the better, at the close of each day's work. Steam is the best of all.

The screens of malt-mills are apt, with neglect, to get clogged to some extent, and became, so far, ineffective.

Liquor-backs should be emptied and cleaned every week, even when the liquor supply is pure.

In the mash-tun grains are sometimes left adhering to the cogs of the rack, etc. Wooden tuns sometimes have a rim, and beneath this is the neglected spot if any.

Wooden hop-backs and coolers should be treated with bisulphite, or frequently whitened with monosulphite made into a thin cream.

Refrigerators should neither be allowed to get coated with deposit outside, nor slime inside. For the latter, a periodical (monthly) charging with a solution of lime and washing soda mixed will suffice; for the former, except in the case of horizontals, which can be charged with potash solution, nothing but scrupulous brushing and plenty of water avails.

Racking hose and the sampling taps (if any) and racking cocks of fermenting vessels require attention, and finally, do not grudge time or labour spent in whitewashing walls or keeping down the accumulation of cobwebs and fungoid growths in the less accessible parts of the brewery over coppers and coolers.

This may seem a vain saying to many, but we hardly know yet what condition of things is so trivial as to be incapable of bringing about a serious result.

APPENDIX A.

LIST OF THE HOP-GROWING PARISHES OF KENT, HEREFORDSHIRE, AND WORCESTERSHIRE.

Lettered to show in what division they lie, with nine Surrey parishes ranking as West Kent. E = East Kent; M = Mid Kent; W = West Kent; B = Bastard East Kent; H = The Hill; Wd. = Weald; S = Surrey (names of parishes in black letters).

Acol	E	Canterbury	E	Farleigh (East)	M
Addington	M	Capel	Wd.	,, (West)	M
Adisham	E	Chalk	H	Farnborough	H
Aldington	B	Challock	E	Farningham	H
Alkham	E	Charing	E	Faversham	E
Allington	M	Chart-next-Sutton	M	Fawkham	H
Appledore	B	Chart, Great	E	Fordwich	E
Ash	E	Chart, Little	E	Frindsbury	H
Ash	H	Chartham	E	Frinstead	E
Ashford	E	Chatham	H	Frittenden	Wd.
Ashurst	Wd.	Chelsfield	H		
Aylesford	M	Chevening	W	Gillingham	H
		Chiddingstone	Wd.	Godmersham	E
Badlesmere	E	Chilham	E	**Godstone**	**S**
Barfreston	E	Chislet	E	Goodnestone (by Faversham)	E
Barham	E	Cliffe	H	Goodnestone (by Wingham)	E
Barming	M	Cobham	H	Goudhurst	Wd.
Bapchild	E	Cooling	H	Gravener	E
Bearsted	M	Cowden	W		
Beckenham	H	Cranbrook	Wd.	Hadlow	Wd.
Bekesbourne	E	Crayford	H	Halling	M
Benenden	Wd.	Cray, North	H	Halstead	H
Bethersden	B	Cray, St. Mary	H	Halstow (High)	H
Bicknor	E	Cray, St. Paul's	H	,, (Lower)	E
Bidborough	Wd.	**Crowhurst**	**S**	Ham	E
Biddenden	Wd.	Crundale	E	Harbledown	E
Bilsington	B	Cudham	H	Hardres (Great)	E
Birchington	E	Cuxton	H	,, (Lower)	E
Bircholt	E			,, (Upper)	E
Birling	M	Darenth	H	Harrietsham	E & M
Bishopsbourne	E	Davington	E	Hartley	H
Blean	E	Debtling	M	Hartlip	E
Bobbing	E	Denton	E	Hastingleigh	E
Bonnington	B	Ditton	M	Hawkhurst	Wd.
Borden	E	Doddington	E	Headcorn	Wd.
Boughton Aluph	E	Dunkirk	E	Herne	E
Boughton-under-Blean	E			Hernehill	E
Boughton Malherbe	E	East Langdon	E	Hever	Wd.
Boughton Monchelsea	M	Eastling	E	High Halden	Wd.
Boxley	M	Eastry	E	Higham	H
Brabourne	E	Eastwell	E	Hinxhill	E
Brasted	W	Ebony	B	Hoath	E
Bredgar	E	Edenbridge	W	Hollingbourne	M
Bredhurst	E	Egerton	E	Hothfield	E
Brenchley	Wd.	Elham	E	Hoo	H
Bridge	E	Elmstead	E	Horsmonden	Wd.
Bromley	H	Elmstone	E	Horton Kirby	H
Brook	E	Eltham	H	Hucking	E
Broomfield	M	Eynsford	H	Hunton	M
Burham	M	Eythorne	E		
		Ewell	E		

Ickham	E
Ifield	H
Ightham	M
Ivychurch	B
Iwade	E
Kemsing	M
Kenardington	B
Kennington	E
Kingsdown	H
Kingsdown	E
Kingsnorth	B
Kingstone	E
Knockholt	M
Lamberhurst*	Wd.
Langley	M
Leaveland	E
Leeds	M
Leigh	Wd.
Lenham	E
Leybourne	M
Limpsfield	S
Lingfield	S
Linton	M
Littlebourne	E
Longfield	H
Loose	M
Luddenham	E
Luddesdown	H
Lullingstone	H
Luton	M
Lydden	E
Lydsing	M
Lyminge	E
Lympne	E
Lynsted	E
Maidstone	M
Malling (East and West)	M
Marden	Wd.
Meopham	H
Mereworth	M
Mersham	E
Milton (by Canterbury)	E
Milton (by Sittingbourne)	E
Milton Chapel	E
Milstead	E
Minster	E
Moldash	E
Mongeham	E
Monk's Horton	E
Monkton	E
Marston	E
Nackington	E
Nettlestead	M
Newington	E
Newenden	Wd.
Newnham	E
Nonington	E
Northfleet	H
Northdown	E
Norton	E
Nursted	H
Nutfield	S
Offham	M
Old Romney	B
Orlestone	B
Orpington	H
Ospringe	E
Otford	H
Otham	M
Otterden	E
Oxted	S
Paddock Wood	Wd.
Patrixbourne	E
Peckham (East)	M
,, (West)	M
Pembury	Wd.
Penshurst	Wd.
Petham	E
Plaxtol	M
Pluckley	E
Postling	B
Preston-by-Faversham	E
Preston-by-Wingham	E
Rainham	E
Reculver	E
Ridley	H
Rochester	H
Rodmersham	E
Rolvenden	Wd.
Ruckinge	B
Ryarsh	M
Sandhurst	Wd.
Sarre	E
Seal	W
Seasalter	E
Selling	E
Sellinge	E
Sevenoaks	W
Sevington	E
Shadoxhurst	B
Sheldwich	E
Shepherdswell (Sibertswould)	E
Shipbourne	M
Sholden	E
Shoreham	H
Shorne	H
Sittingbourne	E
Smarden	B
Smeeth	E
Snodland	M
Southborough	Wd.
Southfleet	H
Speldhurst	Wd.
Stalisfield	E
Stanford	E
Stansted	H
Staple	E
Staplehurst	Wd.
St. Dunstan's	E
St. Lawrence	E
St. Margaret's	H
St. Margaret's (at Cliffe)	E
St. Mary's	B
St. Nicholas	E
St. Peter's	E
St. Stephen's	E
Stelling	E
Stockbury	E
Stodmarsh	E
Stoke	H
Stone	H
Stone-by-Appledore	B
Stone-by-Faversham	E
Strood	H
Stourmouth	E
Stouting	E
Sturry	E
Sundridge	W
Sutton (at Hone)	H
,, (by Dover)	E
,, (East)	M
,, (Town)	M
Sutton Valence	M
Swanscombe	H
Swingfield	E
Tandridge	S
Tatsfield	S
Tenterden	Wd.
Teston	M
Teynham	E
Thannington	E
Throwley	E
Thurnham	M
Tilmanstone	E
Titsey	S
Tong	E
Trosley	M
Trottersclife	M
Tudeley	Wd.
Tunbridge	Wd.
Tunstall	E
Ulcombe	E & M
Underriver	M
Upchurch	E
Waldershare	E
Waltham	E
Warden	E
Warehorne	B
Wateringbury	M
Westbere	E
Westerham	W
Westwell	E
Whitstable	E
Wickham	E
Willesborough	W
Wilmington	H
Wingham	E
Witchling	E
Wittersham	B
Womenswould	E
Woodchurch	B
Woodnesboro'	E

* Part in Sussex.

Wootton . . .	E
Wormshill. . .	E
Wouldham . .	M
Wrotham . . .	M
Wye. . . .	E
YALDING . . .	M

List of Parishes in the county of Hereford, in which Hops were returned on the 4th June, 1925.

Wolferlow
Cradley
Evesbatch
Acton Beauchamp
Avenbury
Bishops Froome
Felton
Linten
Little Cowarne
Moreton Jeffries
Much Cowarne
Peacombe and Grendon Warren
Stanford Bishop
Stoke Lacey
Ullingswick
Whetbourne
Madley
Sollershope
Upton Bishop
Yatton
Birley
Bridge Sollars
Canon Pyon
Dilwyn
King's Pyan
Norton Canon
Bodenham
Docklow
Eye
Coddington
Hope under Dinmore
Ashperton
Aylton
Mathon
Eastnor
Humber
Kimbolton
Leominster
Little Hereford
Middleton-on-Hill
Monkland
Newton
Ocle Pychard
Bartestree and Donnington
Burghill
Credenhill
Marden
Mordiford
Moreton-on-Lugg
Pipe of Lyde
Preston Wynne
Stoke Edith
Sutton
Westhide
Weston Beggard
Withington
Eggleton
Stretton Grandison
Farrington
Woolhope
Yarkhill
Lugwardine
Sedbury Rural
Little Marcle
Much Marcle
Munsley
Pixley
Putley
Bosbury
Canon Frome
Castle Frome
Colwall
Wellington Heath

List of Parishes in the county of Worcester in which Hops were returned on the 4th June, 1925.

Harrington
Croome d'Abitot
Shelsley Kings
Shelsley Walsh
Stanford
Stockton
Bransford
Broughton Hackett
Grimley
Holt
Kempsey
Powick
St. John in Bedwardine
St. Peter's Worcester
North Hallow
Norton Juxta Kempsey
East Ham
Newland (Gt. Malvern)
Abberley
Clifton-on-Teme
Shelsley Beauchamp
Fladbury
Wick
Lindridge
Orleton
Rochford
Tenbury
Leigh
Martley
Alfrick
Broadwas
Doddenham
Knightwick
Lulsley
Suckley
Cotheridge
Gnarlford
Madresfield

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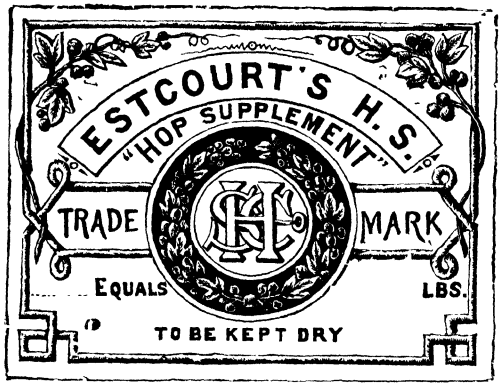

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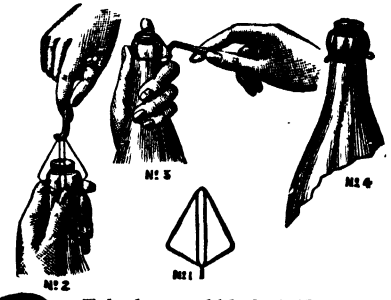

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