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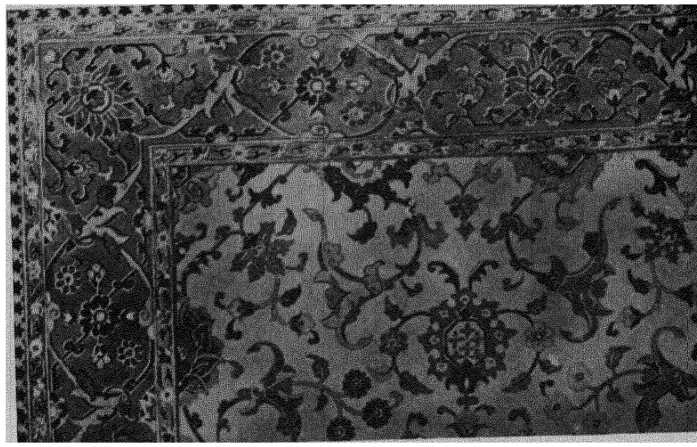

Akbar carpet

Malabar carpet

Indian Carpets

THE
WEALTH OF INDIA

A Dictionary of Indian Raw Materials and Industrial Products

INDUSTRIAL PRODUCTS
PART II

DELHI
1951

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II

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INTRODUCTION

The first part of the Industrial Products section of the Wealth of India—a Dictionary of Indian Raw Materials and Industrial Products—appeared in December 1948 and was warmly received by scientists and industrialists in the country. The appreciation accorded to it has been a source of encouragement to those engaged in the work of compiling the Dictionary.

The paucity of published information and statistical data relating to many industries and the reluctance on the part of certain industries to supply information have contributed to the unevenness noticeable in the treatment of subjects. These handicaps have been referred to in the introduction to the preceding part, and are due to the present transitional stage in India's industrial development.

The volume follows in the main the pattern of the first part. A noticeable departure is in respect of illustrations ; a large number of text figures—line drawings and half-tones —and plates have been included.

The following articles have been received from external contributors : Calcium chloride (The *Pioneer Magnesia Works Ltd.*), Canning (Dr. G. S. Siddappa), Canvas (The *Indian Jute Mills Association*), Activated Carbon (Dr. K. S. G. Doss), Carpentry and Cabinet-work (Mr. E. D. Simmons ; Shri P. V. Kurup), Railway carriages (Shri B. S. Sindhu), Ceramics—Pottery (Shri T. W. Talwalkar), Cigars and Cheroots (*Spencer and Co., Ltd.*), Carbonization of Coal (Drs. J. W. Whitaker and A. Lahiri), Coal tar (Mr. C. J. Fielder), Cocoa and Chocolate (Shri G. R. Sathe), Coir (Shri K. C. Karuna Karan), Copper acetate and aceto-arsenite (*Smith Stanistreet and Co., Ltd.*), Cotton ginning (*Indian Central Cotton Committee*), and Crucibles (Shri V. G. Iyer). These contributions have been suitably modified to conform to the requirements of the Dictionary. Informative notes on the following subjects have been received from external sources : Carbon dioxide (*Alembic Chemical Works Ltd.*), Carpets (*Kailas Carpet Co. ; E. Hill & Co., Ltd.*), Carts (*Directorate of Ordnance Factories*), Celluloid (Shri J. N. Ghosh), Cement—Portland (The *Cement Marketing Company of India, Ltd.*), Ceramics (*Government Porcelain Factory,* Bangalore ; Glass Technologist to the Government of U. P.), Chlorine (The *Mettur Chemical and Industrial Corporation, Ltd.*), Chromates, Dichromates and Chromium Compounds (*Government Dichromate Factory,* Belagula), Clocks (*India Meteorological Department*), Confectionary (*Indian Institute of Sugar Technology ; Indian Confectionary Manufacturers' Association*), Copper (*Indian Copper Corporation, Ltd.*), Cordage and Ropes (J. S. Quinn ; *Indian Rope Manufacturers' Association*), Cotton mill industry (*Indian Central Cotton Committee* ; Dr. C. N. K. Murthy), and Cutlery (Dr. G. P. Contractor). The Chief Editor wishes to acknowledge his gratitude to the authors of the articles and notes.

Thanks are due to the following industrial concerns for affording facilities to my colleagues to visit the factories and collect information : *Bararee Coke Co., Ltd.,* Kusunda ; *Bengal Chemical and Pharmaceutical Works, Ltd.,* Calcutta; *Bengal Potteries, Ltd.,* Calcutta; *Calcutta Chemical Co., Ltd.,* Calcutta ; *Daurala Sugar Works and Distillery,* Daurala ; *D. C. M. Clothing Factory,* Delhi ; *Ganges Rope Co., Ltd.,* Howrah ; *Hindustan Bicycle Manufacturing and Industrial Corporation, Ltd.,* Phulwari Shareef, Patna ; *Hindustan Gas Co., Ltd.,* Calcutta ; *Imperial Tobacco Company of India, Ltd.,* Calcutta ; *India Clock Mfg Co., Ltd.,* Tatanagar ; *India Cycle Mfg Co., Ltd.,* Calcutta ; *National Tobacco Co. of India, Ltd.,* Calcutta ; *Oriental Gas Co., Ltd.,* Calcutta ; *Parle Products Mfg Co.,* Bombay ; *Pure Products and Madhu Canning, Ltd.,* Bombay ; *Russa Distillery,* Calcutta ; *Shalimar Rope Works,* Howrah ; *Shalimar Tar Products (1935) Ltd.,* Lodna ; *Sirdar Carbonic Gas Co., Ltd.,* Delhi ; and *Tata Iron and Steel Co., Ltd.,* Jamshedpur.

Grateful acknowledgement is here made to the co-operation which has been extended to this work by several institutions, Government departments, individual scientists and

industrialists both in India and abroad. The sources of information have been numerous, and it is impossible to thank every one individually. The Chief Editor hesitates to make particular mention of any one, as every one whom he approached has been equally responsive. This abundance of goodwill for this undertaking is in itself a good augury for its future progress.

The Chief Editor desires to express his gratitude to Dr. Shanti Swarup Bhatnagar in particular and to each of the other members of the Editorial Committee for invaluable help, guidance, and criticism throughout the course of the compilation.

Thanks are due to the authorities of the Government Press, New Delhi, for the neat execution of the printing. But for their willing assistance, the printing of this volume would have been rendered difficult.

The Chief Editor desires to place on record his grateful appreciation of the unstinted labour and loyal co-operation of his colleagues and staff.

Suggestions for improvement will be gratefully received and made use of in subsequent parts.

20, Pusa Road,
New Delhi-5.
January, 1951.

B. N. SASTRI,
Chief Editor

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LIST OF BOOKS REFERRED TO

Alexander & Street	...	Metals in the service of Man, by W. Alexander & A. Street (Penguin Books, Harmondsworth), 1945.
Bader & Picker	..	Marketing Drugs & Cosmetics, by L Bader & S Picker (D. Van Nostrand Co., New York), 1947.
Bone & Himus		Coal Its Constitution & Uses, by W. A. Bone & G. W. Himus (Longmans, Green & Co., London), 1936
B P	..	The British Pharmacopoeia (Constable & Co, London), 1948.
Brady	...	Materials Handbook, by G. S Brady (McGraw-Hill Book Co., New York), 1947
Collings	...	Commercial Fertilizers, by H G Collings (H. K. Lewis & Co, London), 1947.
Crosbie-Walsh	...	Food Industries Manual, by T. Crosbie-Walsh (Leonard Hill Ltd, London), 1945
Cruess	...	Commercial Fruit and Vegetable Products, by W. V Cruess (McGraw-Hill Book Company, New York), 1938
Cushny	..	Cushny's Pharmacology & Therapeutics (J & A Churchill Ltd, London), 1947.
deNavarre	...	The Chemistry & Manufacture of Cosmetics, by M G deNavarre (D Van Nostrand Co, New York), 1947
Denston	...	A Text book of Pharmacognosy, by T C Denston (Sir Isaac Pitman & Sons Ltd, London), 1945
D E P	...	A Dictionary of the Economic Products of India, by G Watt (Govt. Press, Calcutta), 6 Vols, 1889-1899
Dixon	...	Coke and by-product Manufacture, by E C Dixon (Charles Griffin & Co, London), 1939
Frear	...	Chemistry of Insecticides & Fungicides, by D E H Frear (D. Van Nostrand Co, New York), 1945
Fuller	.	Chemistry & Analysis of Drugs & Medicines, by H C Fuller (John Wiley & Sons, New York), 1920
Gregory, 1942	...	Condensed Chemical Dictionary, by T C Gregory (Reinhold Publishing Corporation, New York), 1942
Gregory	.	Uses & Applications of Chemicals and Related Materials, by T C. Gregory (Reinhold Publishing Corporation, New York), 2 Vols, 1939
Haswell	. .	Horology, by J E Haswell (Chapman & Hall Ltd, London), 1947
Henry	...	The Plant Alkaloids, by T A Henry (J. & A. Churchill Ltd, London), 1949
Hilditch	..	The Industrial Chemistry of Fats and Waxes, by T. P Hilditch (Bailliere, Tindall & Cox, London), 1943
Hou	...	Manufacture of Soda, by T P Hou (Reinhold Publishing Corporation, New York), 1942
Jacobs	. .	The Chemistry & Technology of Food & Food Products (Interscience Publishers, New York), 2 Vols, 1944
Jones	...	Canning Practice & Control, by C Jones (Chapman & Hall Ltd., London), 1949
Jones, W R.	..	Minerals in Industry, by W. R Jones (Penguin Books, Harmondsworth)
Karrer	..	Organic Chemistry, by P Karrer (Elsevier Publishing Co, New York), 1947
Kobe	...	Inorganic Process Industries, by K. A Kobe (Macmillan Co., New York), 1948.
Liddell	...	Handbook of Non-Ferrous Metallurgy—Recovery of Metals, by D. M Liddell (McGraw-Hill Book Co, New York), 1945
Lowry	...	Chemistry of Coal Utilization, by H H Lowry (John Wiley & Sons, New York), 2 Vols., 1945
Mantell	.	Industrial Carbon, by C. L Mantell (D. Van Nostrand Co., New York), 1946.
Perry	...	Chemical Engineers Handbook, by J H Perry (McGraw-Hill Book Co, New York), 1941.
Prescott & Dunn	.	Industrial Microbiology, by S. C Prescott & C. G. Dunn (McGraw-Hill Book Co, New York), 1949
Prentiss	...	Chemicals in War, by A. M. Prentiss (McGraw-Hill Book Co, New York), 1937.
Poucher	. .	Perfumes, Cosmetics & Soaps, by W. A Poucher (Chapman & Hall, London), 3 Vols., 1950.

Rawlings	...	The Science of Clocks & Watches, by A L Rawlings (Sir Isaac Pitman & Sons, London), 1948
Riegel		Industrial Chemistry, by E R Riegel (Reinhold Publishing Corporation, New York), 1942
Roberts & Kartar Singh		Text book of Punjab Agriculture, by W Roberts and S B S Kartar Singh (Civil & Military Gazette Ltd, Lahore), 1947.
Rogers		Rogers' Industrial Chemistry, edited by C C Furans (D Van Nostrand Co, New York), 1943
Roush		The Mineral Industry, its Statistics, Technology & Trade, edited by G A Roush (McGraw-Hill Book Co, New York), 1941
Searle		An Encyclopaedia of the Ceramic Industries, by A B Searle (Ernest Benn Ltd, London), 3 Vols, 1929
Shreve		The Chemical Process Industries, by N R Shreve (McGraw-Hill Book Co, New York), 1945
Simmonds		Alcohol—Its production, properties, chemical & industrial applications, by C Simmonds (Macmillan & Co, Ltd, London), 1919
Thorpe		Thorpe's Dictionary of Applied Chemistry (Longmans, Green & Co, London), Vols 1-10, 1945-1950
Trotter		The Common Commercial Timbers of India and their Uses, by H Trotter (Govt Press, Delhi), 1944
Trotter, 1940		Manual of Indian Forest Utilisation, by H Trotter (Oxford University Press, London), 1940
U S D		The United States Dispensatory (J B Lippincott, Philadelphia), 1947
Van Nostrand		Van Nostrand's Scientific Encyclopaedia, (D Van Nostrand Co, New York), 1947
von Loesecke		Outlines of Food Technology, by H W von Loesecke (Reinhold Publishing Corporation, New York), 1942
Winton & Winton		The Structure and Composition of Foods, by A L Winton & K B Winton (John Wiley & Sons, New York), 4 Vols, 1935
With India, I	.	The Wealth of India—Raw Materials (C S I R, Delhi), Vol I, 1948
With India, Pt I		The Wealth of India—Industrial Products (C S I R, Delhi), Part I, 1948
Wood	.	Metallurgical Materials, Alloys & Manufacturing Processes, by V N. Wood (Chapman & Hall, London), 1946

LIST OF JOURNALS REFERRED TO

(The abbreviations are those given in the World List of Scientific Periodicals, 1934)

Allahabad Fmr	Allahabad Farmer, Allahabad
Annu Rep For Res Inst	Annual Report of the Forest Research Institute, Dehra Dun.
B I O.S. Rep	Report of the British Intelligence Objectives Sub-Committee, London.
Bombay Cotton Annual	Bombay Cotton Annual, Bombay
Bull Amer. ceram Soc	Bulletin of the American Ceramic Society, Easton, Pa
Bull Brit coal utilizn Res Ass	Bulletin of the British Coal Utilization Research Association, London.
Bull. Dep Agric Madras	Bulletin of the Department of Agriculture, Madras
Bull Dep Industr Comm U P (N S)	Bulletin of the Department of Industries & Commerce, U P. (New Series), Allahabad
Bull imp Inst, Lond	Bulletin of the Imperial Institute, London
Bull U S Bur Min	Bulletin of the United States Bureau of Mines, Washington
Ceylon Tr J	Ceylon Trade Journal, Colombo
Chem Abstr	Chemical Abstracts, New York
Chem Age	Chemical Age, London
Chem Engng	Chemical Engineering with Chemical and Metallurgical Engineering, New York
Chem Engng News	Chemical and Engineering News, New York
Chem & Ind	Chemistry and Industry, London
Chem metall Engng	Chemical Engineering with Chemical and Metallurgical Engineering, New York
Chem Tr J	Chemical Trade Journal and Chemical Engineering, Manchester
Chim et Industr	Chimie et industrie, Paris
Curr Sci	Current Science, Bangalore
E Afr agric J	East African Agricultural Journal, Nairobi
Eastern Econ	Eastern Economist, New Delhi
Econ Bot	Economic Botany, Lancaster, Pa
Fact	Fact, Alwaye
F I A T Final Rep	Final Report of the Field Information Agency—Technical, British Intelligence Objectives Sub-Committee, London.
Foreign Comm Wkly	Foreign Commerce Weekly, Washington
Gas J	Gas Journal, London
Gas Times	Gas Times
Gas World	Gas World, London
I & S Bull	I & S Bulletin, Delhi
Indian Coconut J	Indian Coconut Journal, Ernakulam
Indian Cott Growing Rev	Indian Cotton Growing Review, Bombay
Indian Fmg	Indian Farming, New Delhi
Indian For	Indian Forester, Dehra Dun
Indian For Bull (N S)	Indian Forest Bulletin (New Series), Delhi.
Indian For. Leafl	Indian Forest Leaflet, Dehra Dun
Indian For Rec	Indian Forest Records, Delhi
Indian Soap J	Indian Soap Journal, Calcutta
Indian Sug	Indian Sugar, Kanpur
Indian Text J	Indian Textile Journal, Bombay
Indian Tr Bull	Indian Trade Bulletin, Delhi.
Industr Chem.	Industrial Chemist, London
Industr Engng Chem	Industrial and Engineering Chemistry, Easton, Pa
Int. Chem Engng Process Industr	International Chemical Engineering Process Industries, London
J. Amer chem Soc	Journal of the American Chemical Society, Easton, Pa
J Indian ceram. Soc	Journal of the Indian Ceramic Society, Banaras
J Indian chem Soc	Journal of the Indian Chemical Society, Calcutta
J Indian Roads Congr.	Journal of the Indian Roads Congress, Delhi
J. Inst Fuel	Journal of the Institute of Fuel, London.
J. Inst. Met.	Journal of the Institute of Metals, London.
J. sci. industr. Res.	Journal of Scientific and Industrial Research, New Delhi.

Metal Market Rev.	Metal Market Review, Calcutta.
Mfg Chem.	Manufacturing Chemist, London.
Misc Bull, I C A R	Miscellaneous Bulletin, Indian Agricultural Research Institute, Delhi.
Nature	Nature, London
Oil Paint Drug Rep.	Oil, Paint & Drug Reporter, New York.
Perfum essent oil Rec.	Perfumery and Essential Oil Record, London.
Petrol Refiner	Petroleum Refiner.
Pharm Acta Helvet	Pharmaceutical Acta Helvetica, Zurich
Proc. Indian Roads Congr.	Proceedings of the Indian Roads Congress, New Delhi
Proc nat Inst Sci	Proceedings of the National Institute of Sciences of India, Delhi
Proc Sug. Technol. Assoc	Proceeding of the Sugar Technologists Association, Kanpur
Rec geol Surv India	Records of the Geological Survey of India, Calcutta.
Rep Fuel Res. Bd, Lond	Report of the Fuel Research Board, London
Rep Labour Conditions	Report on Labour Conditions Labour Investigation Committee, Government of India, Delhi
Rep Progr appl Chem	Annual Reports of the Society of Chemical Industry on the Progress of Applied Chemistry, London
Rep U S Bur Min	Report of the United States Bureau of Mines, Washington
Rubber Developments	Rubber Developments, British Rubber Development Board, London
Schimmel Rep	Schimmel Report, New York
Sci & Cult	Science and Culture, Calcutta
Soap Perfum Cosmetics, Year-bk	Soap, Perfumery and Cosmetics Year Book and Buyers' Guide
Technol Bull, Indian Cott Comm	Technological Bulletin, Indian Central Cotton Committee, Bombay.
Technol Leafl, Indian Cott Comm	Technological Leaflet, Indian Central Cotton Committee, Bombay
Tech. Pap. Fuel Res., Lond	Technical Papers, Fuel Research, Department of Scientific Research, London
Times Rev Industr	Times Review of Industry, London
Tobacco	Tobacco, New York
Trans ceram Soc	Transactions of the Ceramic Society, Tunstall
Trans Indian ceram Soc	Transactions of the Indian Ceramic Society, Banaras
Trans Indian Inst Metals	Transactions of the Indian Institute of Metals, Calcutta
Tr U K	Annual Statement of the Trade of the United Kingdom with British countries and Foreign countries, London

C

CAFFEINE

Caffeine (Theine), $C_8H_{10}O_2N_4$, is the principal alkaloidal constituent of tea, coffee and some other beverages, in which it occurs either free or combined as caffeine chlorogenate The percentages present in the different materials are· tea, 1 0—4·8; cola nuts, 2 7—3 6, coffee, 1·0—1·5; mate (*Ilex paraguariensis*), 1 25—2 0, and guarana (*Paullinia cupana*), 3 1—5·0. Cocoa waste contains theobromine from which caffeine can be obtained by methylation The leaves of a species of holly, *Ilex cassine* (indigenous to North America), from which the beverage Cassina is prepared, contains 1·0—1·6% caffeine

Commercial caffeine is obtained from tea waste or tea dust by solvent extraction When boiling water is used as solvent, the decoction is treated with litharge to precipitate gums and resinous matter and the filtrate concentrated until crystals of caffeine separate out. The product is purified by recrystallization from boiling water

Caffeine is also obtained as a by-product in the preparation of caffeine-free coffee Coffee beans are treated with superheated steam and extracted with benzene, chloroform, or alcohol to strip them of caffeine. The alkaloid is recovered from the extract by evaporation and purified by crystallization. A simple method for the preparation of caffeine from coffee has been described by Serra (*Chem. Abstr*, 1947, **41**, 1811) Coffee powder is treated with 10% ammonia and extracted with hot water The extract which contains about 0 3% caffeine, is concentrated, treated with ammonia, and further concentrated. The concentrate is cooled to 8—10°, hydrochloric acid added till no more precipitate is formed, and filtered. The filtrate contains crude caffeine which is purified by dissolving in 50% sodium hydroxide, reprecipitating with carbon dioxide, and centrifuging.

Large quantities of caffeine are manufactured in America by the methylation of theobromine ($C_7H_8O_2N_4$), obtained from the residual cacao cake after the Oil of Theobroma is extracted The process has largely replaced the older process of synthesis from uric acid, via 8-methylxanthine (Karrer, 807).

In view of the large increase in the demand for caffeine, particularly in the U S A , for the preparation of Cola drinks of which caffeine is a constituent, commercial production of caffeine by synthetic processes has received considerable attention A process using nitrogen and hydrogen has been recently developed, details have not been revealed The product obtained is reported to be of higher purity than caffeine obtained by other methods (*Chem. Engng News*, 1945, **23**, 2036, U S D , 177) A synthetic process starting from urea and cyanacetic ester was developed in Germany, but not commercially worked as the overall yield of caffeine was only 40—50% of the theoretical (*F I A T Final Rep* No 885).

Caffeine is manufactured in India from tea waste (caffeine content, 3 0—4 5%) available in abundance from the tea gardens of Darjeeling, Jalpaiguri, and Assam, by benzol (boiling range, 70—100°) extraction The raw material, mixed with soda and water, is charged into brass extractors fitted with condensers and working on the Soxhlet extractor principle On the completion of extraction, the solvent is distilled off and the residue taken up with water The aqueous extract is treated with basic lead acetate to eliminate chlorophyll, resin, waxes and gums, and filtered through bags. Excess of lead is removed from the filtrate by treatment with sulphuric acid and the lead-free filtrate decolorized with activated charcoal and concentrated. The caffeine which crystallizes out is separated on the centrifuge and dried at room temperature.

Caffeine crystallizes with one molecule of water from hot water, or anhydrous from alcohol, in slender silky needles It loses its water of crystallization at 100°. The anhydrous base melts at 234—35° and sublimes at 175° (Thorpe, II, 197). One part of caffeine dissolves in the following quantities of solvents at 25° water, 45 6; alcohol, 53 2, ether, 375, and chloroform, 8. It is bitter to taste and is a weak base neutral to litmus forming salts which dissociate during the evaporation of their aqueous solutions (Henry, 331).

Caffeine stimulates the central nervous system, especially the part associated with psychical

functions and increases the capacity for physical exertion. It is also a cardiac stimulant. Its most important physiological action is that on the kidney causing an increased secretion of urine Caffeine is excreted in the urine partly unchanged but chiefly as dimethyl xanthine, methyl xanthine, and xanthine.

Caffeine is used in medicine in admixture with acetanilide, acetyl salicylic acid, and phenacetin for the relief of nervous headache and migraine Taken in large doses, it is toxic. Caffeine stimulates the heart by both central and peripheral action but large doses cause cardiac inhibition Its effect on blood pressure is variable. If the central action predominates the blood pressure rises; a dominant peripheral action causes a fall (*Chem. Abstr*, 1939, **33**, 8788). It is employed in pharmaceutical preparations principally as caffeine citrate or citrated caffeine, prepared by evaporating to dryness aqueous solutions containing equal weights of caffeine and citric acid Caffeine citrate dissolves unchanged in water On diluting the solution, however, caffeine is deposited and on further addition of water, the solution again becomes clear An aqueous solution of caffeine citrate contains free citric acid and is incompatible with a number of compounds used in medicinal practice In recent pharmacopoeias citric acid has been replaced by sodium benzoate which enhances the solubility of caffeine in water

In India, caffeine is mainly produced in Calcutta. The *Bengal Chemical and Pharmaceutical Works Ltd*, and Messrs. *Smith Stanistreet & Co. Ltd*, are the largest producers The total annual output is about 20,000 lb and the target of production is 30,000 lb. (*Rep. Panel on Fine Chemicals, Drugs and Pharmaceuticals*, 1947, 20) There is an abundance of raw material for caffeine production in the country.

Large quantities of tea waste are exported to U.S.A., Canada, and Australia for caffeine extraction. The quantities exported in 1948-49 and 1949-50 were 6 7 and 8 0 million lb, valued at Rs. 14 lakhs and Rs. 16 7 lakhs respectively.

The price of caffeine per lb. in 1949 (in lb. bottles for 1 cwt. lots in cases f.o.r. Calcutta) was Rs. 23.

CALCIUM COMPOUNDS

Calcium compounds such as calcium carbonate, calcium phosphate, and calcium sulphate are widely distributed in nature. A large number of them are manufactured on account of their applications in industry. Calcium oxide and sulphate are extensively employed in building and chemical industries Calcium phosphate, nitrate, and cyanamide are useful as fertilizers Calcium carbide forms the source of acetylene which is an important starting material for the synthesis of many organic chemicals A large number of organic compounds of calcium find use in pharmacy.

Calcium acetate—*see* **Wood distillation**

Calcium arsenate

A number of calcium arsenates are theoretically possible. Commercial arsenates are mixtures of $CaHAsO$, $Ca_3(AsO_4)_2$, $Ca(OH)_2$, $CaCO_3$ and probably other calcium compounds They are made from calcium oxide and arsenic oxide (Frear, 14).

Calcium arsenate is an insecticide of considerable value conveniently applied in the form of dust Its relative instability is, however, a drawback to its extended use The newer safe commercial arsenates are mainly basic arsenates A combination of calcium arsenate, zinc sulphate, and hydrated lime in the proportion of 4·1.2 is effective in controlling codling moth (Frear, 16).

Calcium carbide

Calcium carbide is the basic material for the production of acetylene used in welding, as illuminant, and as the starting material for a wide range of synthetic resins, organic chemicals, solvents. and pharmaceuticals Calcium cyanamide is derived from calcium carbide The absence of a well-established carbide industry has impeded the growth of organic chemical industry in this country.

When lime and carbon are mixed together in proper proportions and heated to a temperature of 2,000°, the lime is reduced, and the liberated calcium combines with excess of carbon to form calcium carbide·

$$CaO + 3C \longrightarrow CaC_2 + CO - 177{,}800 \text{ cal.}$$

650 tons of carbon and 875 tons of lime are required for producing 1,000 tons of commercial carbide

The successful manufacture of calcium carbide has been rendered possible by the development of the industrial electric furnace. Arc-resistance furnaces in which heating is due partly to the resistance offered by the charge, and mostly to the sparking across the charge, are employed in carbide manufacture.

Both intermittent and continuous furnaces are employed. The former is known as the Ingot Furnace, as the carbide produced solidifies in the crucible and is obtained in the form of an ingot. The capacity of the furnace is small, and the

heat and electrical efficiencies are low. The process is unsatisfactory also on account of the varying quality of the product

The use of ingot furnaces has been practically abandoned in favour of the Hearth Electrode Tapping Furnaces of either non-continuous or continuous type, either single phase or three phase The single phase furnace has relatively low productive capacity and the power rating rarely exceeds 15,000 kw Recent designs have closed tops through which a single electrode is sealed, thereby rendering possible the utilization of carbon monoxide produced in the reaction, either as a source of heat or as a chemical reagent for the production of ammonia, alcohol, and other industrial chemicals (Rogers, I, 486) In the single phase circular furnace designed by Miguet, the electrode consumption is 2—4%, current density on the electrode, 35—50 amp /sq in , and energy consumption, 1 5—3 0 kw-hr per lb with an average efficiency of 60% (Thorpe, II, 218; Perry, 2812)

The more common carbide furnaces are of the three-phase type The hearth is made of rectangular brazed heavy steel plates, lined with a refractory, over which is a thick bed of carbon composed of large baked electrodes joined together by pitch and covered by a composition of fine coke and pitch. Carbon is perhaps the only refractory that withstands alkali and high heat inside the furnace The side walls are also lined with a refractory Modern furnaces are of large sizes and while furnaces of about 600 kv-amp. rating are in use, those of 20,000 kv-amp are not uncommon They are usually equipped with Soderberg or continuous electrodes, positioned by automatic electric hoisting or by hand-controlled electrical gear. As the electrodes are consumed, new sections are brought into position and continuous production is ensured Unlike fired graphite or graphitised carbon types, Soderberg electrodes are of the built up, *in situ*, self-baking type

The arc is produced by three suspended electrodes connected to a three-phase power supply The electrodes are preformed baked carbons, round in shape for smaller furnaces, and square to rectangular, for larger ones They extend to the centre of the furnace and are completely surrounded by the charge of lime and coke. As arcing occurs between the electrodes, the charge is heated to 1,800—2,000° when the reaction takes place, and the molten carbide is tapped continuously through a fore hole into cast iron chill-buggies (Kobe, 239)

The *Soviet Nitrogen Institute* is reported to have developed a process for the production of carbide which does not involve the use of the electric furnace According to a recent report (*J. Indian chem. Soc., Industr. & News Edn*, 1941, **4**, 43), blast furnaces are employed and high grade ferrosilicon is obtained as by-product Fuel gas suitable for synthesis of ammonia, methyl alcohol, and motor fuel is also obtained The process has been worked out on a pilot plant scale.

The treatment of carbide pigs requires special machinery For use in acetylene production the clean ingots are broken into lumps first in jaw crushers and later in slow rolls to minimize dust formation The pieces are screened to 2 in. size for large acetylene generators, pea-size for miners' lamps, and 16—30 mesh size for automobile lamps For the production of sodium cyanide, the crushed carbide is passed through a pebble mill to yield a powder 80% of which passes through a 40-mesh screen It is further powdered in a tube mill to Milled Carbide, 85% of which passes through a 200-mesh screen. The grinding is carried out in an atmosphere of nitrogen to prevent the formation of an explosive mixture (Riegel, 301)

A sheet-iron plant for making steel drums and air-tight cans for storing and transporting carbide is a necessary adjunct to the carbide factory. The standard packages are 100, 110, 200, and 220 lb net, and small tins containing 1—25 lb of carbide (Thorpe, II, 219)

The manufacture of calcium carbide is dependent on the availability of an abundant supply of cheap electric power Norway and Sweden are the world's largest producers of carbide.

Manufacture in India

The Eastern Group Supply Council, set up during the War to examine the supply position of heavy chemicals, averred that the only country under the Eastern Group with an exportable surplus of calcium carbide was South Africa The Council's requirements were estimated at 4,000—6,000 tons per annum, most of which was required for use in ship-repairing workshops South Africa's output fell far short of the requirements, and the Council recommended to the Government of India that a plant with a capacity of 10,000 tons of calcium carbide per annum should be set up India was in a position to undertake the production Limestone of suitable quality was located in Central India and coke conforming to the requirements was available in a particular seam of the Jharia coalfield. The power required could be drawn from the Jamadoba power station.

A number of efforts have been made to produce

calcium carbide on a small scale. Wood charcoal has been employed in a few cases, but its use for large scale production is said to be impracticable. Messrs. *Mysore Iron and Steel Co*, Mysore, and *Industrial Chemical Co.*, Coimbatore, produced small quantities of carbide during World War II. There is at present no indigenous production of calcium carbide; Messrs. *Birla Jute Manufacturing Co.* are setting up a 10-ton/day plant near Calcutta (Information from D.G.I. & S.).

Raw materials.—For commercial production, the requirements per ton of carbide are. anthracite or coke, 0·7 ton; lime, 1·1 ton; coal pitch, retort carbon, and tar, 0·05 ton; and electric power, 4,800 kw.-hr.

Coke.—As anthracite is not available in India, coke is the only alternative worth considering The coke required should be of medium hardness. It should be low in phosphorus, alumina, magnesia, sulphur, silica, iron. and volatile matter It is understood that Messrs. *Krebs & Co.*, Zurich (Switzerland), have studied the possibility of using coke of 18—20% ash content. Due to the presence of iron oxide and silica in the ash, a poor quality carbide giving 4·15 c ft of acetylene per lb. is obtained. This is not a drawback if the carbide is to be used as a basic material for the manufacture of chemicals If carbide is required for the production of calcium cyanamide, the resulting product will contain 15% N which is low.

Lime.—Lime should be added in the unslaked condition and should contain at least 92% CaO. It should be low in phosphorus, alumina, magnesia, silica, iron oxide, and sulphur It should be dense and should not crumble to powder during any stage of carbide manufacture Limestones occurring in Central Provinces and Central India have been examined by the Geological Survey of India and are considered to be suitable for carbide production.

Retort carbon. coal tar and pitch.—Retort carbon is used to reduce the ash content of the electrode paste. It is available from Digboi refineries of *Assam Oil Co*, and in small amounts from *Oriental Gas Co.*, Calcutta, and *Bombay Gas Co.*, Bombay. Coal tar and pitch of the required specifications are available in abundance.

The phosphorus content of coke and lime should be low, as its presence leads to the production of a product containing phosphide which gives phosphoretted hydrogen (phosphine, PH_3) with water. Phosphine is toxic and liable to spontaneous combustion. Alumina and magnesia, especially the latter, increase the viscosity of molten carbide in the furnace and cause serious difficulties in tapping and de-slagging. Silica and iron should be low to minimize ferro-silicon formation.

Commercial carbide contains: CaC_2, 85; CaO, 4; and C, 1%; it contains also small amounts of silicides, phosphides, and sulphides. The standard of quality for carbide is usually expressed in terms of c.ft of acetylene per lb. of carbide (Rogers, I, 488). According to the I.S.D. Sp. No. G/Chemicals-23A (1935), the carbide should yield not less than 4·8 c.ft. of acetylene per lb of carbide at 15·5°, and the gas should not contain more than 0·06% by vol. of phosphoretted hydrogen The carbide should be supplied in the form of lumps between ½ in. and 3 in. overall size.

Properties and Uses

The chief applications of calcium carbide are in the manufacture of calcium cyanamide, acetylene required in oxy-acetylene welding, synthesis of solvents and organic compounds required in the pharmaceutical and dyestuffs industries, and manufacture of synthetic rubbers and plastics. It is also used in signal fires. Sodium cyanide used for the recovery of gold in the ore treatment process is manufactured from calcium carbide. As a dehydrating agent, calcium carbide is employed in electrostatic work and in the food and solvent industries. It finds application in steel hardening, in the manufacture of graphite and hydrogen, and in the reduction of copper sulphide and metallic oxides (Gregory, 151).

Imports

The pre-War consumption of calcium carbide in India was about 4,200 tons per annum. During World War II, consumption rose to nearly 7,000 tons. The ship-building and automobile industries are likely to create a large demand for this material. The present requirements of the country are estimated at 7,000 tons per annum (*Rep.*,

TABLE 1—IMPORTS OF CALCIUM CARBIDE

	Qty. (1,000 tons)	Value (lakh Rs.)
1934/35-1938/39 (av.)	2·99	6·6
1939/40-1943/44 (av.)	3 58	13·0
1944-45	6 29	22 9
1945-46	4·55	16·7
1946-47	3 27	12·7
1947-48	4·28	18·9
1948-49	5 35	26·2
1949-50	10 27	53·1

Panel on Heavy Chemical and Electro-chemical Industries, 1946, 40).

Table 1 gives the imports of calcium carbide into India.

During the quinquennium ending 1938-39, about 1,052 tons were imported from Canada, 1,400 tons from Japan, and the rest from South Africa and Norway Calcium carbide is now obtained mainly from Canada.

Imports of calcium carbide are subject to a revenue duty of 30% *ad valorem*

Calcium carbonate

Calcium carbonate, $CaCO_3$, forms a major constituent of the earth's crust and occurs as massive beds of limestone, chalk, and marble It is the principal ingredient of egg-shells, mollusc shells, and corals It is also found as dolomite in which a part of the calcium is replaced by magnesium.

Chemically pure calcium carbonate is prepared in the laboratory by dissolving chalk, marble, or calcined oyster shells in hydrochloric acid, oxidizing the iron present to the ferric condition by oxidizing agents, precipitating the ferric oxide, alumina, and alkaline earth phosphates by ammonia or milk of lime, and finally precipitating the calcium in the filtrate by ammonium carbonate. The precipitate is washed and dried

Calcium carbonate is obtained as a by-product in ammonium sulphate manufacture When the plant of the *Fertilizers & Chemicals, Travancore, Ltd.*, Alwaye, works at full capacity, the by-product yield would be 18,000 tons of calcium carbonate sludge per annum. About 300,000 tons of calcium carbonate slurry would be available as a by-product from the *Sindri Fertilizer Factory* when working at full capacity.

Precipitated calcium carbonate of commerce is produced by reacting a boiling solution of calcium chloride with sodium carbonate, or by passing carbon dioxide into milk of lime suspension under controlled conditions. The properties of the precipitated product depend partly on the form in which the particles are precipitated and partly on the purity of the material. It is possible to prepare grades of uniform particle size from below 0·5μ diam. up to 40μ diam.

Precipitated calcium carbonate preparations, e.g., Suspenso, Calcene, and Aeromatt are used in paints and distempers, as base for body and face powders, and as filler and pigment in creams, lipsticks, ointments, salves, and skin preparations. Precipitated calcium carbonate adds strength and heat resistance to rubber. It is used as a filler in crayons, pencils, plastics, and cigarette paper, as an ingredient of sizing compositions for ropes and twines, and of fire-proofing compositions, and as an adsorbent in explosives and match-head compositions. It finds application in fermentation industries and in the production of printing inks. It is used as a source of calcium in dog biscuits and in poultry and stock feeds (Gregory, II, 60; Wilson, *Precipitated Calcium Carbonate*, 1948, 20).

Calcium carbonate of the pharmaceutical grade is one of the best antacids for peptic ulcer and other conditions of gastric hyper-acidity. Its constipating action in large doses is taken advantage of in the treatment of diarrhoea Tablet or powder containing 0 6 g calcium carbonate and 2 g sodium bicarbonate is commonly employed as Sippy Powder. It is largely used in the preparation of tooth powder, a typical recipe being: precipitated calcium carbonate, 935; castile soap, 50, saccharin, 2, oil of peppermint, 4, oil of cinnamon, 2, methyl salicylate, 8; and *para*-formaldehyde, 20 parts (U S.D , 190).

Calcium carbonate prepared by wet grinding and levigating natural chalk, called Whiting, is used as an extender in the pigment industry. Whiting mixed with 18% boiled linseed oil furnishes putty. Whiting finds use in the ceramic industry.

Testing.—Physical tests for precipitated calcium carbonate include colour, drop test, fissure point test, and flow point test (B S.S. No. 1460, 1948) Chemical tests include solubility and alkalinity. There are additional tests for products required for special purposes. They are: abrasiveness, calcite : aragonite ratio, viscosity, and sedimentation.

Calcium chloride

Calcium chloride is widely distributed in nature, but in small concentrations, as a constituent of saline matter dissolved in sea, spring, river, and lake waters Deposits of tachydrite and carnallite containing calcium chloride do not occur in India.

Manufacture.—Calcium chloride is obtained in large quantities as a by-product in many manufacturing processes, e g., potassium chlorate and soda ash. It is also obtained by the action of lime on magnesium chloride.

In the manufacture of potassium chlorate, chlorine is passed through lime slurry and the calcium chlorate thus formed is treated with potassium chloride to give calcium chloride and potassium chlorate. Potassium chlorate is separated by fractional crystallization and the mother

liquor is evaporated for the recovery of calcium chloride

Large quantities of calcium chloride are present in the distiller waste of the ammonia soda process for soda ash manufacture. For every ton of soda ash produced, one ton of calcium chloride is obtained. The composition of the waste liquor varies according to the quality of brine and limestone used, the volume of feed liquor to be distilled per ton of ash, the percentage decomposition in the towers, and the strength of milk of lime employed Normally, 10—12 cu m. of waste liquor containing 85—95 g /litre of calcium chloride are obtained per ton of soda ash.

The waste containing a small excess of free lime is carbonated by passing carbon dioxide gas. On allowing the solids to settle, calcium carbonate, magnesia, silica, and calcium sulphate separate out The supernatant solution containing calcium chloride, sodium chloride, and a small quantity of dissolved calcium sulphate, is concentrated in a double-effect evaporator when sodium chloride with calcium sulphate crystallizes out. The liquor (sp gr , 1 1) entering the first evaporator is concentrated to sp gr , 1 22 and fed to the second evaporator where it is further concentrated to sp. gr., 1 42, when practically all the salt settles out A small amount of Chloride of Lime is usually added to oxidize the iron present in solution. The clear liquor contains 42—45% calcium chloride and is known in commerce as Liquid Calcium Chloride

For obtaining the solid product, liquid calcium chloride is concentrated in cast iron pots until the product melts. The molten mass is pumped to steel drums, each of 650 lb capacity, and sealed. The product known in trade as 75% Calcium Chloride has the following composition: $CaCl_2$, 73 6, NaCl, 1 4, insoluble matter, 0 08; water (by difference), 24 7, and alkalinity as $Ca(OH)_2$, 0 14% According to a recent method, the waste liquor from soda ash manufacture is concentrated to 75% calcium chloride in a single evaporator by using high pressure steam, thereby effecting considerable heat economy.

Flaked Calcium Chloride is made by passing 75% molten calcium chloride through a flaking machine provided with revolving water cooled drums, as in the manufacture of flaked caustic soda.

Commercial anhydrous calcium chloride is prepared by heating 75% calcium chloride in a reverberatory furnace fired by producer gas or oil, the molten mass being frequently raked during the operation. A small quantity of calcium chloride decomposes during the process into lime and hydrogen chloride, the latter during its escape causes the mass to become porous. The resulting fused mass is known as 95% Calcium Chloride. The cooled anhydrous product, which is somewhat fluorescent, is packed in steel drums or paper-lined wooden barrels of 350—400 lb capacity and hermetically sealed

Powdered calcium chloride is manufactured by drying the granular calcium chloride in a rotary furnace heated by furnace gases. The coarse particles drop out at the lower end of the rotary, while the dust suspended in the current passes out at the upper end and is recovered in a collector containing anhydrous, non-caking calcium chloride (Hou, 253)

Calcium chloride may be prepared by the action of lime on magnesium chloride whereby magnesium hydroxide and calcium chloride are produced The reaction mixture is either filtered, or settled and the calcium chloride solution is evaporated to obtain the solid product

Calcium chloride is also obtained as a by-product in the manufacture of ossein from bones and in the manufacture of superphosphate from rock phosphate, chlorine, and sulphur These processes are of interest to India, as they indicate a possible outlet for by-product chlorine obtained in the electrolytic caustic soda industry Calcium chloride is obtained also as a by-product in the manufacture of chloroform from alcohol and acetone, and in the manufacture of sodium cyanide from calcium cyanamide.

Manufacture in India

The production of calcium chloride by the double decomposition of magnesium chloride and lime was started in 1941 by the *Pioneer Magnesia Works, Ltd.*, Kharaghoda. The capacity of the plant is 1,000 tons per annum. Magnesium chloride is obtained from the bitterns in salt pans after the removal of salt Kharaghoda bitterns are particularly rich (4 5%) in magnesium chloride Lime is obtained from Katni (C. P.). The reaction between magnesium chloride and lime is nearly quantitative at ordinary temperatures. The calcium chloride is separated from the pasty magnesium hydroxide by settling and filtration as a 20% solution, and concentrated in open pans at about 160° to 75% calcium chloride and packed in steel drums. The product has the following composition: $CaCl_2 \cdot 2H_2O$, 82·98; insolubles, 1 20; $CaSO_4$, 0·97; $MgCl_2 \cdot 6H_2O$, 4 43; KCl, 1·39; NaCl, 2·3; and water, 6·73%. 1·5 tons of magnesium chloride and 0·75 ton of lime (60%) are required to produce one ton of $CaCl_2 \cdot 2H_2O$. Magnesium hydroxide, which is the main by-

product in the process, can be converted into basic magnesium carbonate; for this purpose it is necessary to have high purity hydroxide, and this is ensured by the use of good quality lime

By-product recovery from soda ash waste liquor has been undertaken by Messrs. *Dhrangadhra Chemical Works, Ltd.* Only a part of the calcium chloride is thus recovered, the capacity of the plant being 500 tons per annum

During World War II, The *Mettur Chemical & Industrial Corporation, Ltd*, produced calcium chloride as a by-product in the manufacture of potassium chlorate A part of the calcium chloride solution obtained was utilized for the production of barium chloride. and the rest converted into 75% calcium chloride

Production.—The *Pioneer Magnesia Works* were the only producers of calcium chloride up to 1945, the annual production being 249 tons in 1941, 801 tons in 1942, 894 tons in 1943, 831 tons in 1944, and 791 tons in 1945 (Indian Tariff Bd, *Rep. Calcium Chloride Industry*, 1946, 8) The total production during 1946 and 1947 was 818 tons and 574 tons respectively of which 63—64% was produced by The *Pioneer Magnesia Works, Ltd.*, and the rest by *Dhrangadhra Chemical Works, Ltd*, (Indian Tariff Bd, *Rep Continuance of Protection to the Calcium Chloride Industry*, 1950, 8) The production during 1948 and 1949 was 943 and 175 tons respectively (Information from D G I & S.)

The cost of production of calcium chloride at the *Pioneer Magnesia Works, Ltd*, for the year 1948 was estimated at Rs 17-1-7 per cwt and the fair selling price at Rs 18-13-0 per cwt The Tariff Board has estimated fair selling prices of indigenous calcium chloride for the years 1950, 1951, and 1952 at Rs 14-11-2, Rs 12-6-11, and Rs. 12-6-1 respectively, and the landed cost *ex* duty of imported calcium chloride at Rs 8-11-4 during the same period (Indian Tariff Bd, *Rep*, 1950, 11, 13)

Consumption—The normal pre-War consumption of calcium chloride was about 900 tons per annum. During World War II, there was a heavy demand for the product In 1943-44, the production reached 1,000 tons The domestic demand for the years 1950-52 has been estimated at a maximum of 1,500 tons per annum

Properties and Uses.—Anhydrous calcium chloride (sp.gr.$^{20°}$, 2 15; m.p, 770—80°) is a highly deliquescent white solid The fused salt is phosphorescent. It forms a series of hydrates, the hexahydrate being the most stable at ordinary temperatures. It is used as a desiccating agent in industry and in the laboratory. Porous, granular calcium chloride, obtained by drying at a temperature slightly above 260°, is a more efficient desiccating agent than the fused salt because the action is due to absorption rather than hydration. It is used for drying gases and organic liquids such as ether and carbon disulphide It cannot be used to dry ammonia gas as it unites with the gas to form compounds such as $CaCl_2 \cdot 8NH_3$ In the anhydrous form calcium chloride catalyses the reaction between calcium carbide and nitrogen to form calcium cyanamide

The largest use for calcium chloride is in refrigeration and air conditioning The product used for this purpose should be free from magnesium chloride It is used also for freeze-proofing and thawing of coal, coke, stone, sand and ore, and for skid-proofing of roads It is a good anti-freeze for portland cement concrete and poster paste It is also used in the leather industry, in the manufacture of cement-fibre boards, and in textile sizing It is the starting material for precipitated calcium carbonate, calcium sulphate, and barium chloride In solution, it is applied for watering roads, for dust proofing, and surface binding Leakage of air and excessive wear in operating tyres of heavy duty trucks, tractors, farm equipment, etc, which are not fully inflated, are avoided by replacing air by calcium chloride solution (*J. sci industr. Res*, 1945-46, **4**, 357). It has been used in Australia in the production of artificial rain (*Rep Progr. appl Chem.*, 1947, **32**, 122). Calcium chloride solution can be employed for reclaiming salt water-logged soils (*Allahabad Fmr*, 1934, **8**, 93).

Calcium chloride finds use in medicine It is a local irritant In generalized oedema, calcium chloride is employed as an acid-producing diuretic A single intravenous injection of 0·25 g is reported to relieve tubercular diarrhoea Intravenous injection of calcium chloride is the specific antidote for magnesium poisoning. Renal colic responds to calcium injections. It should never be injected hypodermically and its intravenous use requires great caution owing to the danger of serious depression of cardiac function For injections a 5% solution in sterile distilled water is recommended (U S.D, 191)

Imports—Since there was no production of calcium chloride in India before World War II, the annual consumption then may be taken to be equal to the quantity imported. Table 1 gives imports of calcium chloride into India.

Almost the entire quantity comes from U.K. Imports from U K. are subject to a protective duty of Rs 3-4-0 per cwt., and those from other countries, Rs. 4-14-0 per cwt.

TABLE 1—IMPORTS OF CALCIUM CHLORIDE

	Qty. (tons)	Value (1,000 Rs.)
1936/37-1938/39 (av.)	894.7	76 76
1939/40-1943/44 (av)	548 3	73 09
1944-45	14.0	20.24
1945-46	32.4	19.11
1946-47	2.4	5.83
1947-48	93 0	44.46
1948-49	228.5	51.13
1949-50	285.0	78 99

Calcium cyanamide

Calcium cyanamide, $CaCN_2$, is an important alkaline nitrogenous fertilizer. About 5% of the nitrogen consumed in world's agricultural operations is obtained from it (Collings, 87) It has been marketed under the trade names, Aero-Cyanamid, Lime-nitrogen, Nitrolim, and Nitro-lime.

Raw materials.—Calcium cyanamide is obtained by passing purified nitrogen (from air) over calcium carbide heated to 1,000−1,100° in nitrifying ovens using calcium fluoride as catalyst. A continuous nitrifying oven similar to Herreshoff furnace is used in Sweden The reaction takes place according to the following equation

$$CaC_2 + N_2 \longrightarrow CaCN_2 + C + 72{,}700 \text{ cal.}$$

After the completion of the reaction, the mass is cooled and pulverized. Water is added to decompose free carbide if present and to hydrate the lime Mineral oil, to the extent of about 4%, is sometimes added to prevent the product from crumbling to dust A granular product preferred by farmers, is obtained by mixing the material (without added oil) with a binding material and granulating the mixture (Kobe, 242). It is graded between 12- and 100-mesh with <2% passing through 100-mesh.

For successful production cheap power, high purity lime, and low-ash coke are required. To produce 9,100 lb of commercial fertilizer containing 22% nitrogen, 10,400 lb. limestone, 3,500 lb. coke, 2,000 lb. coal, 9,000 kw.-hr. power, and 15 man-hours of direct labour are required (Shreve, 391).

Properties and Uses.—About 75% of the world's calcium cyanamide production is used as fertilizer. The grade used has the following approximate composition: $CaCN_2$. 63 0; $Ca(OH)_2$, 17·0; free carbon, 12; and limestone impurities, 4%. A dusting grade is sold in U.S.A as a herbicide and defoliant to kill broad-leafed weeds. Cotton plants are dusted with calcium cyanamide before picking the bolls. The plant sheds the leaves and mechanical picking of cotton is thereby facilitated (Collings, 93).

The high consumption of electric power, the high capital investment per ton of nitrogen, and the difficulties of handling raw materials, are disadvantages which have hampered the development of the cyanamide industry. Intensive research by existing large plants for developing new products based on cyanamide, non-competitive with ammonia, have led to the adaptation of plants for the manufacture of ammonia, cyanides, urea, free cyanamide, melamine, and other organic products not otherwise obtainable (Kobe, loc cit)

There is at present no production of calcium cyanamide in India The Mysore Government are stated to have sanctioned a scheme for manufacturing 25,000 tons of nitro-lime (*Indian Tr. Bull.*, 1949, **5**, 988).

Calcium cyanamide is imported into India free of duty

Calcium gluconate

Calcium gluconate, employed in medicine for the treatment of calcium deficiency, is an important article of commerce It is used in the form of pastes and powders, and it is a constituent of many proprietary medicines for the treatment of debility, low vitality, and susceptibility to disease.

Manufacture—Glucose can be oxidized to gluconic acid by using halogens as oxidants, or by passing a direct current through glucose solution containing a small quantity of sodium bromide and suspended calcium carbonate. In the latter case calcium gluconate is obtained From the commercial standpoint, the fermentation processes are of interest and have largely superseded the electrolytic processes (*Industr. Engng Chem.*, 1929, **21**, 1198, 1940, **32**, 107, 1379; *Mfg Chem.*, 1945, **16**, 239)

In the fermentation process developed by the Council of Scientific and Industrial Research, India, cane-sugar, *gur*, or molasses is employed in place of glucose as raw material. Molasses is abundantly available in India and is cheaper than commercial glucose. The yield obtained is more than 80% of the theoretical. An electrolytic process for the production of calcium gluconate from cane sugar solution has been worked out on a pilot plant scale (*J. sci industr. Res.*, 1943−44, **2**, 214; Balasundaram *et al.*, *Sci. & Cult.*, 1949-50, **15**, 483).

An enzymic method for the production of calcium gluconate has been recently patented

(*Indian Pat.* No 39441, 1948). The raw materials required are: glucose (10–15% solution) and calcium carbonate. The enzyme is prepared from the fungus mat of *Aspergillus niger* obtained as a waste product in the fermentative process for citric acid manufacture The fungus is washed free from spores, and the mycelium ground to a fine paste in a granite end-runner mill The paste formed may be used directly in the wet condition, or it may be dried in a vacuum desiccator at room temperature or by repeated washing with acetone A 10–15% glucose solution is used as substrate. 4–6% calcium carbonate and 7–10% ground mycelium (fresh weight) are added. The mixture is placed in a tall vessel, layered with toluene or paraffin as antiseptic, and vigorously aerated. Complete oxidation of glucose takes place in 4–6 days, and when the test for reducing sugar is negative, aeration is stopped and the protein matter coagulated by boiling for a short period. The solution is filtered and evaporated *in vacuo* till crystals of calcium gluconate appear On cooling, calcium gluconate separates out A further crop of crystals may be obtained from the mother liquor by further evaporation and addition of alcohol The yield of pure calcium gluconate is at least 60% of the weight of glucose used

The method is claimed to have the following advantages over the normal fermentation process (1) extreme simplicity, (2) utilization of waste fungal mycelium from citric acid fermentation, and (3) avoidance of side reactions with consequent increase in the yield of gluconic acid

Properties and Uses.—Calcium gluconate occurs as a white, tasteless, odourless, crystalline or granular powder. One gram of calcium gluconate dissolves in 30 c c of cold water and in about 5 c c of boiling water Although not very soluble in water, it readily forms super-saturated solutions in which form it is used for injection As dust or any extraneous matter is likely to precipitate the solid, stabilizers are added to prevent precipitation during administration or storage. It is insoluble in alcohol and many organic solvents

The important applications of calcium gluconate are in medicine It can be given in large doses by mouth or by intravenous or intramuscular injection. It provides a means of obtaining the physiological actions of calcium ion in counteracting calcium deficiency Intravenous administration is advocated as a prophylactic and as a therapeutic agent for poisons like carbon tetrachloride and DDT. It is an oral antidote for fluorine and oxalic acid poisoning (U S.D , 193) It can replace fruit acids with advantage in fruit jelly manufacture and in baking powders. It is also useful in the preparation of homogeneous pastes such as dentifrices and polishing agents (Thorpe, II. 297) Several combinations of calcium gluconate and other calcium salts are marketed as proprietary preparations.

Production—The normal annual demand for calcium gluconate in India is 90,000 lb and a major part of this quantity is imported into the country The indigenous production is estimated to be 500 lb.

Calcium hypochlorite

Calcium hypochlorite, $Ca(OCl)_2$, is used as a bleach, disinfectant, and oxidant It possesses the following advantages over bleaching powder: (1) free flowing, (2) greater uniformity, (3) non-deliquescence, (4) faster solution rate, (5) less insolubles, (6) greater stability, (7) higher available chlorine, (8) less corrosion, and (9) suitability for better packaging

Calcium hypochlorite was first produced in Germany in 1923 and shortly thereafter in U S A It is now produced under the trade names, Pittchlor, High Test Hypochlorite (HTH), Perchloron, Maxochlor, etc

It is produced commercially by chlorinating lime slurry or a mixture of lime and caustic soda, or by neutralizing a solution of hypochlorous acid with lime at low temperature The resulting solution of calcium hypochlorite is spray dried. or concentrated by evaporation *in vacuo* and dried

There has been no production of calcium hypochlorite in India so far. India imported 11,520 tons of bleaching powder valued at about Rs 39 lakhs, in 1948-49 This amount can be replaced by hypochlorite produced in India The minimum quantity of hypochlorite required may be estimated at 6,000 tons per annum. There is sufficient scope for setting up at least 2 plants each of 10 tons daily capacity. A plant with a capacity of 4 5 tons calcium hypochlorite per day is to be shortly set up in India [*I & S. Bull.*, 1949, **2**(4), 14].

U S.A is the main producer of calcium hypochlorite Production in 1947 was 10,955 short tons [*Oil Paint Drug Rep*, 1949, **156** (12), 40], while the production of bleaching powder in the same year was 24,129 short tons. The principal uses of calcium hypochlorite in U S A. are approximately as follows laundry, 50%; dairies and bakeries (washing udders, pails, walls, equipment, containers), 23%; chicken and cattle (sterilization, dusting of stock for fungus), 2%, sugar refining (bleaching), 5%; water works and swimming pools (disinfecting and deodorizing), 12%; and miscellaneous (general sanita-

tion, vegetable treatment, rug washing, breweries and wineries, hospitals, etc.), 8%. The cost of production in U.S.A. is estimated at $ 0·047 per lb. (50% chlorine) and the capital cost for a plant producing 6 tons per day is estimated at $ 350,000.

Calcium lactate

Calcium lactate, $Ca(C_3H_5O) \cdot 5H_2O$, is the most important salt of lactic acid on account of its pharmaceutical applications It can be directly obtained from lactic acid fermentation (With India, Pt. I, 29). Lactate of B. P. quality is prepared by the interaction of dilute lactic acid and calcium carbonate or by neutralizing lactic acid with calcium hydroxide, boiling to hydrolyze any calcium lactyl lactate, and finally precipitating excess calcium as carbonate by carbon dioxide (Eder & Büchi, *Pharm. Acta Helvet*, 1931, **6**, 118). Calcium lactate has been produced by the fermentation of non-denatured milk (Prescott & Dunn, 415)

Calcium lactate is being produced in India by Messrs *Calcutta Chemical Co., Ltd.*, Calcutta (annual production capacity, 10 tons), and Messrs. *Sarabhai Chemicals*, Ahmedabad (annual production capacity, 48 tons) The latter has plans to raise the production to 60 tons per annum Recently, the existing revenue duty at 36% *ad valorem* (standard) and 26% *ad valorem* (preferential) on calcium lactate has been converted into a protective duty at the same rates [*Indian Tr. Bull.*, 1950, **6**(17), 39].

The raw material employed is molasses or jaggery or mahua flower juice A solution containing 10% sucrose is fermented with *Lactobacillus bulgaricus*, or *L. delbrucku* or other suitable *Lactobacillus* in large wooden vats equipped with coils for steam heating or water cooling and an agitator. The contents are sterilized by boiling and cooled before inoculating the organism. On completion of the fermentation, which takes 7—10 days, the liquor is clarified by super-phosphate of lime. The lactic acid is converted into calcium lactate by the addition of lime to the required pH. The mash is filtered, treated with active carbon, filtered, and evaporated to sp. gr, 1 1—1 2, when calcium lactate crystallizes out A temperature not exceeding 15° is maintained. The first crop of crystals is dark, it is purified by repeating the active carbon treatment and filtering. At ordinary temperature calcium lactate crystallizes in large cauliflower-like masses. Crystallization is repeated until a product of the desired purity is obtained.

Uses.—Calcium lactate is extensively used in the treatment of calcium deficiency. It is said to be preferable to other calcium salts in the treatment of tetany. A mixture of approximately equal parts of calcium lactate and potassium chloride is effective in migraine and along with nicotinic acid, it has been used in urticaria (U S D., 198). As administration of calcium salts by injection is being increasingly adopted, the comparatively low-soluble calcium lactate is less favoured in calcium therapy; its use in various forms of oral medication, however, continues to be popular It is used as a blood coagulant in the treatment of haemorrhages and is administered to patients prior to dental operations to inhibit bleeding It is an ingredient of baking powders and bread.

Production—The production of calcium lactate in India during 1949 was about 11 tons (Information from D G I & S), which is reported to be 21 9% of the requirements (*Eastern Econ*, 1950, **14**, 514) Though the raw materials required for the production of calcium lactate are available in abundance, the cost of production is higher than that elsewhere on account of the uneconomical size of operations. Commercial lactic acid does not command a good market in India, only a small quantity of the acid being required in the tanning industry. Until the uses for lactic acid are expanded, the production of lactic acid has to be sustained mainly by the sale of calcium lactate for pharmaceutical purposes

Calcium nitrate

Calcium nitrate, sometimes called Norwegian Saltpetre, was the first synthetic nitrogenous fertilizer to be put on the market. It has not, however, proved to be entirely satisfactory for this purpose At the beginning of World War II, it accounted for about 8% of the nitrogen consumed in world's agriculture (Collings, 84) It is manufactured mainly in Europe.

Calcium nitrate is obtained by the treatment of nitric acid with lime or calcium carbonate. Ammonium nitrate is added to the reaction mixture to facilitate the crystallization of the salt and the solution evaporated to dryness.

Calcium nitrate is hygroscopic, and has to be packed in air-tight wooden kegs. Granular calcium nitrate free from dust is a commercial product. It contains about 15·5% nitrogen, which is immediately available to plants and is best suited for application to alkaline soils. Sodium nitrate is produced in Norway from calcium nitrate by passing an aqueous solution of the salt through sodium zeolite and revivifying

the calcium zeolite by flushing with sea water (Collings, 38).

There is no duty on imports of calcium nitrate for manurial purposes

Calcium oxide —*see* **Lime**

Calcium phosphate —*see* **Fertilizers**

Calcium soaps —*see* **Lubricating oils & greases**

Calcium sulphate

Calcium sulphate occurs in two forms, gypsum, $CaSO_4 \cdot 2H_2O$ and anhydrite, $CaSO_4$ The former is more frequently met with than the latter (For occurrences of the mineral, *see* Gypsum)

Calcium sulphate dihydrate, $CaSO_4 \cdot 2H_2O$, is obtained as a by-product in many industrial operations, e g, in the manufacture of phosphoric acid from rock phosphate, ossein from bones, and organic acids from their calcium salts by decomposition with sulphuric acid. It can be recovered from sea brine as a by-product of salt manufacture Calcium sulphate required for special purposes, such as for use in dentifrices, is prepared by the action of alkali sulphates on soluble calcium salts

Attempts are now being made in India to obtain gypsum as a by-product of the salt industry. The model salt factory at Trivandrum, and the *Mettur Chemical and Industrial Corporation, Ltd*, at Adirampatnam (Dt Tanjore), recover calcium sulphate as a regular practice In the Travancore model salt factory, gypsum is recovered from the second set of condensers where brine is concentrated from 12° Be. to 23° Be. At the beginning of the season, the beds of the condensers are tamped and the gypsum, which separates out and collects as a crust on the beds after all the brine is drained out towards the close of the season, is dried and collected by raking The crude gypsum, containing 80% $CaSO_4 \cdot 2H_2O$, is agitated with water in a cement cistern 3 or 4 times, to remove the adhering clay, and the clean crystals dried on bamboo mats. The yield of crude gypsum is reported to be about 7 tons per acre of the area covered by high density condensers (12—23° Be.), and that of washed gypsum ($CaSO_4 \cdot 2H_2O$, c. 7·74%), 4 tons. The *Digvijaya Singhji Salt Works*, Jamnagar, and the *Kandla Salt Works*, Kandla, recover gypsum to a small extent while reconditioning the condensers. The total quantity of gypsum recoverable as a by-product from Indian salt works is estimated at c. 100,000 tons per annum.

Uses.—When gypsum (sp. gr., 2·31) is heated to 100°, the hemihydrate, $2CaSO_4 \cdot H_2O$ (sp gr., 2 7), is formed Heating to 200—250° is necessary to remove all the water. The anhydrous salt fuses at a red heat without decomposition and crystallizes on cooling. Hydrated calcium sulphate is sparingly soluble in water, the maximum solubility being reached at 35° when 1 part of it dissolves in 393 parts of water, the solubility at 0° being 1 in 488 parts, and at 100°, 1 in 460 parts (Thorpe, II, 232) It may be precipitated in a gelatinous form by the addition of alcohol to an equal volume of a saturated solution of the salt

The largest use of gypsum in India is in the manufacture of ammonium sulphate. The *Fertilizers and Chemicals, Travancore, Ltd.*, Alwaye, is estimated to consume c 50,000 tons of calcium sulphate per year when the factory is in full production The *Sindri Fertilizer Factory* would require c 500,000 tons of gypsum Gypsum is used as a retarder in the production of Portland Cement for which 75,000—100,000 tons of gypsum are annually required Suitable processes have been worked out for the production of sulphuric acid from gypsum. Calcined gypsum, as Plaster of Paris, has many uses in industry Calcined gypsum is also employed as a building material and cement.

Among other uses of calcium sulphate may be mentioned manufacture of paints, polishing powder, artificial ivory, and size material for dyeing and calico printing It is also used in baking powders and self-raising flours Anhydrous calcium sulphate obtained by calcining gypsum to 230—250° is a valuable dehydrating agent in the laboratory for gases and organic liquids The hemihydrate formed can be readily dehydrated and re-used Calcium sulphate can also be used for the reclamation of alkali soils. but the reclamation is temporary and owing to the necessary repeated dressings, it is expensive (*Allahabad Fmr*, 1934, **8**, 94).

PLASTER OF PARIS

Plaster of Paris, calcium sulphate hemihydrate ($2CaSO_4 \cdot H_2O$), is obtained by calcining gypsum in shaft kilns, chamber ovens, battery ovens, rotary kilns, batch kettles, continuous kettles or hot mills (*B.I.O S. Rep.*, No 1490, 32). The conversion is accomplished commercially by two general methods. In the first method. finely ground gypsum is heated in a kettle or vertical cylinder with a concave bottom, equipped with a stirrer. The kettle is made in sections, so that the bottom, which burns out easily, may be replaced. It is heated by direct heat over a fire. 7—12 tons of gypsum are processed in one

batch. Any water which is not in chemical combination passes out accompanied by agitation of the powder giving the appearance of boiling. When the transition temperature of the dihydrate is reached, water escapes and the contents of the kettle again appear to boil The temperature is carefully watched and held below 170°. except with low-grade materials when it may be raised to 200°. At the end of the operation, the contents are run from a side door near the bottom into a fire-proof pit. After cooling, the product is ground, screened, and packaged.

In the second method, coarsely ground and dried rock gypsum is heated in a rotating kiln, both externally and internally by furnace gases The hot and partially dehydrated material is discharged into concrete bins lined with firebrick A part of the water is removed in the kiln and the remainder escapes from the stored material leaving the hemihydrate. The calcined product is cooled rapidly by passing air through it and the cooled product ground and screened This process may be carried out as a continuous operation.

A low water demand (or low consistency), high strength plaster of Paris of definite and controllable crystalline dimensions is obtained by autoclaving for one hour or more, a slurry of Terra Alba (finely ground gypsum) in the presence of about 0·1% soluble succinate, malate, citrate, or maleate, removing the water, and regrinding the product (Eberl & Ingram, *Industr. Engng Chem*, 1949, **41**, 1061) If the heating of gypsum is carried out at 250–500°, anhydrous $CaSO_4$ is obtained The product takes up water but slowly However, a few crystals of gypsum are usually present to serve as nuclei for the formation of dihydrate

The Indian Industry—Plaster of Paris, produced in large quantities in India, is of somewhat inferior quality The manufacturing process is wasteful The raw material is burned in a shed enclosed on three sides by brick or stone walls and covered by a tiled roof. Large pieces of gypsum are arranged on the floor to form a series of small arches parallel to the main walls of the shed; pieces of gypsum are stacked on the arches, the larger ones at the bottom, the size gradually decreasing with the height. Wood is heaped in the arches and lighted; the hot gases rising through the interstices between the lumps heat the mass driving off the water of hydration The resulting product is not homogeneous as the bottom layers are exposed to a higher temperature than the top ones

Plaster of Paris of good quality is manufactured by Messrs. *Hamam Works Ltd.*, Belgharria, Messrs. *Indian Mineral Industries Ltd.*, Calcutta, *Capital Industries*, Delhi, and *Government Procela.n Factory*, Bangalore.

Properties and Uses.—When plaster of Paris is mixed with water. it sets to a hard mass. Pure plaster of Paris normally hardens or sets within 5–15 min. after mixing with water. The setting rate is slow if the gypsum from which the plaster is made contains impurities. For building purposes, the plaster must be slow-setting. For ornamental use, the product should be white. It is a common practice to add retarders such as glue, saw dust or blood to plaster before marketing Artists and modellers generally mix gum acacia, glue or lime soap for retardation. Sodiumchloride is added to accelerate the setting

Plaster of Paris is used in hospital work mainly for providing mechanical support or to immobilize various parts of the body, as for instance, in fractures and sprains. Plaster jackets are used to support the thorax in tuberculosis of the spine Bandages saturated with dry powder are dipped in tepid water at the time of application. Dry calcium sulphate is recommended as an absorbent dressing in wounds, foul ulcers, etc. (U S D , 1379)

Building plaster comprising less pure and coarser grades, is employed for plastering. Retarders are not usually added Building plaster is used also in the manufacture of gypsum slabs, plates, blocks or bricks. Plates are reinforced with reeds or wood laths or steel rods They are fire-resistant, and are used for transformer buildings and pre-fab houses (*B.I.O.S. Rep.* No. 603) Light-weight foamed gypsum slabs, with ground chalk and aluminium sulphate as foaming agents, find use in building construction. Gypsum bound wood wool slabs are made by using plaster of Paris, a retarder is usually added to conform to the setting time schedule.

Gypsum calcined to high temperatures is used as plastering material both for undercoats and finishing coats in building construction. It can also be used to make slabs and bricks. What is known as Keene's Cement is made by burning gypsum at red heat, cooling, and impregnating the material with alum solution and heating again to a high temperature. Its use is restricted to tile work and casting ornamental work. Hard burnt gypsum is used for door facings, window sills, and floors.

Pure and finely ground calcined gypsum is used for casting and moulding purposes. A finely ground product of high purity is required for use as dental plaster.

TABLE 1.—IMPORTS OF GYPSUM & PLASTER OF PARIS*

	Qty. (tons)	Value (£)
1942	227	3,067
1943	27	431
1944	37	539
1945	79	1,188
1946	202	6,117

*Tr U K

The following tests are prescribed to assess the suitability of dehydrated gypsum for building materials and cement· (1) sieving, (2) setting time, (3) expansion on setting, (4) compressive strength, (5) spread on Southard viscometer, (6) specific surface, (7) rate of hydration, and (8) general chemical analysis

Imports.—Table 1 gives imports of gypsum cement, including burnt gypsum and plaster of Paris, into India from U.K

CAMPHOR

Camphor, $C_{10}H_{16}O$, a white crystalline solid with characteristic aroma, is obtained mainly from *Cinnamomum camphora,* growing extensively in Formosa, Japan, China, and Cochin China. Camphor is a constituent of a number of essential oils such as those from sassafras leaves (*Sassafras officinale*), cinnamon root (*Cinnamomum* spp.), spike (*Lavandula latifolia*), rosemary (*Rosemarinus officinalis*), and sage (*Salvia officinalis*) (Fuller, 608). It has a pungent aromatic taste followed by a sensation of coldness It burns with a bright smoky flame, volatilizes at ordinary temperature, and sublimes when heated Camphor has been synthesized, and large quantities of the synthetic product are now produced in U S.A. and U.K.

Camphor trees are cultivated in Australia, Italy, Algiers, California, and Florida. Experimental cultivation has been undertaken in India, Burma, Ceylon, Malaya, Java, West Indies, and East Africa, mainly with the idea of producing camphor from the leaves The cultivation of *C. camphora* in India has given encouraging results, though at present Indian camphor cannot compete in price with the imported product (Howard *et al., Indian For. Rec.,* 1928, **9**, pt. 7).

Prior to World War II, Formosa was the world's principal producer accounting for 80% of the supply of natural camphor, the remainder being obtained mainly from Japan and China. The industry was under the control of the Japanese Government, and through planned exploitation of the trees and systematic replanting, it was possible not only to maintain supplies but also to enhance production In China, on the other hand, uncontrolled exploitation led to a fall in output The annual world production of natural camphor is about 5,000 tons.

In Formosa, camphor is derived mainly from two varieties of *C camphora* locally known as Hon Shu and Ho Shu. The wood of the former, the most widely distributed of the camphor trees, on steam distillation yields approximately 0·8% crude camphor and 1 6% oil containing 50% dissolved camphor Ho Shu is distinguished from Hon Shu by the sweet odour of the wood and leaves On steam distillation, the wood yields about 2 4% oil but no solid camphor. The oil contains c 25% l-linalool and 35—40% camphor in solution (*Schimmel Rep*, 1946, 5)

Camphor formation is brought about through the agency of an enzyme present in the growing parts of the tree, particularly in the tissue within the cambium region Each layer of wood, as it is formed, is enriched by camphor Roots, trunk and large branches from 40—50 years old trees are used for distillation 1 lb of camphor is obtained from 20—40 lb of chipped material, the average yield per tree being about 11 lb. (Denston, 538; U S D , 205)

In the manufacture of natural camphor, the essential oil is first obtained by steam distillation Both in Japan and Formosa, the distillation is carried out in the plantations. Trunks, roots and large branches of felled trees are chipped and charged into crude earthen stills with perforated false bottoms The stills are connected through bamboo pipes to water-cooled condensers and heated in a steam or water bath The steam during its passage through the charge carries with it the oil and camphor and the volatile products are collected in a water-cooled receiver.

For recovering the camphor from the distillate, a number of devices are employed. In one, the upper portion of the air-tight water-cooled condenser is filled with clean rice straw on which a part of the camphor deposits, the oil (Oil of Camphor) dripping down along with the water being collected in a receiver. Alternatively, the oil and camphor are collected in the receiver along with the condensed water. The oil is separated and cooled when a part of the crude camphor separates out and is collected by filtration In yet another method, the receiver is changed when most of the terpenes distils over and crude camphor is collected in a separate receiver.

The practice in China is to boil the comminuted plant material in water under stirring until camphor adheres to the stirrer The liquor is strained and cooled when crude camphor separates out

In 1941-42, when supplies of camphor to Britain from Japan were cut off, the East African Agricultural Research Institute set up a factory at Lushoto, Tanganyika, for producing camphor (Hill, *E Afr. agric J*, 1946, **11**, 148). The raw material was obtained from plantations of C *camphora* established in East and West Usambara Mountains some thirty years before The camphor trees were felled, stripped of leaves and twigs and cut into billets. The leaves, twigs, and billets were chipped and charged into steel stills, 6 ft diam ×6 ft high Saturated steam was admitted to the stills under a pressure 80—100 lb per sq in. and distillation was continued for about six hours, though the bulk of camphor distilled over during the first two hours The camphor deposited on the inner walls and baffles of the condenser was scraped out, and additional solid camphor collected on wire strainers from the oily condensate floating on the water in the receiver. The oil was transferred to a separating tank for the removal of admixed water. No effort was made to recover additional camphor from the oil by freezing or distillation The average yield per acre of felled trees was 3,680 lb of solid camphor and oil (*Schimmel Rep*, 1946, 8). The cost of production, not including the cost of growing the trees, was estimated at 2s per lb of crude camphor. In January 1943, the value of the crude camphor as received in London was estimated at 5s 5d per lb, and of crude oil at 6d

Crude camphor contains 2 1—2 9% camphor oil besides moisture and other impurities For refining, the crude material is mixed with about one-fiftieth of its weight of quick lime and heated in iron vessels to about 100° to eliminate water and volatile oil On further heating to 175—200°, camphor sublimes and collects in the form of a block on the cone-shaped lid of the vessel The block is taken out and cut into slabs each weighing c. 2½ lb giving the BB Camphor of commerce (U S D, 205). In another process, the crude product is charged into a still connected to a large cooled receiver and heated when camphor sublimes and condenses in the form of small detached crystals or Camphor Flowers (Denston, loc. cit.)

BB Camphor contains c. 99 4% camphor. About a third of the product is subjected to further refining through sublimation after adding quick lime to eliminate traces of water. The slabs of Refined Camphor so obtained contain 99 6% camphor. Refined Camphor Powder (99 7% camphor) is made by blowing dry air through molten crude or BB Camphor and condensing the vapour

Dissolved camphor separated from Hon Shu oil by fractional distillation, crystallizes from the fraction distilling at 380—390°F. at 6 mm pressure This product is referred to as Reprocessed Camphor and is used for the preparation of BB Camphor and Refined Camphor (*Schimmel Rep*, 1946, 6)

The crude oil obtained after separating the camphor is fractionated through distillation into· (1) light fraction, collected up to about 200°, (2) middle fraction collected between 200° and 230° and consisting chiefly of camphor, and (3) heavy fraction collected above 230° (Denston, loc cit)

The light fraction or White Oil (sp gr, 0 875—0 900), contains mainly cineol, limonene, and pinene It is soluble in ether and chloroform and is used as a turpentine substitute and as an ingredient of soaps, polishes, varnishes, pharmaceutical preparations, and cleaners The heavy fraction, known as Brown Oil (sp gr, 1 018—1 026), contains mostly safrole and smaller amounts of terpineol and sesquiterpenes Safrole is crystallized by refrigeration and used in the preparation of heliotropin required in perfumery From the residue obtained by direct fire distillation, Blue Oil containing mainly sesquiterpene alcohols is obtained Another important by-product is Ho Oil, obtained from the camphor fraction of Ho Shu oil. Ho oil is a valuable perfume material as it contains a large proportion of *l*-linalool and some geraniol (*Schimmel Rep.*, 1946, 7).

Natural camphor is not produced to any considerable extent in India An area of about 8 acres in the Hallakarai Estate in Nilgiris carrying plants 20—60 years old, are intermittently exploited for camphor The leaves collected from the trees are steam distilled in copper stills. The water collected in the receiver is decanted from the crude camphor, the latter being pressed first in a screw press to extract the oil, and then in a hydraulic press. The yield of camphor is about 1% on the weight of the leaf (Narielwala & Rakshit, *Rep. of the Essential Oil Committee*, 1942, 12; Raghavan, *A Note on the Possibilities of Camphor Cultivation in South India*, 1940). The annual production in Hallakarai Estate is about 500 lb. of camphor and 150 lb. of camphor oil, both products having a ready market. The yield is about 60 lb. per acre,

though under favourable conditions a yield up to 180 lb. per acre may be expected (Howard *et al.*, loc cit.)

Other Possible Sources of Camphor

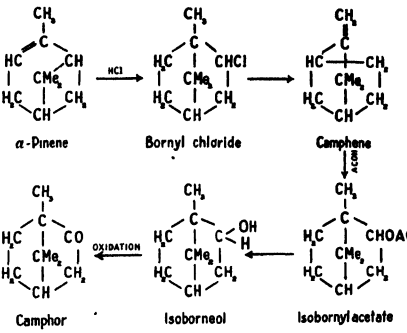
Camphor is also obtained from the oil distilled from the leaves of certain species of *Ocimum* or Camphor Basil, especially *O. canum* and *O kilimandscharicum*. *O. canum* grows fairly extensively in southern U S S R, where about 20 tons of medicinal camphor are stated to have been produced in 1936 (*Bull imp Inst, Lond*, 1941, **39**, 14). The volatile oil from *O canum*, which grows wild in north India, does not contain any camphor (Rakshit, *Perfum essent. Oil Rec*, 1938, **29**, 402). *O. kilimandscharicum* has been reported to contain 5% essential oil containing 47—74% camphor (*Bull. imp Inst, Lond*, 1941, **39**, 217). Experiments were conducted in the United States of America during the last War on the cultivation of this plant The Forest Research Institute, Dehra Dun, has undertaken the experimental cultivation of *O. kilimandscharicum* with seeds obtained from Kenya (*Annu Rep F R I*, 1942-43, 91).

A number of other plants give products which are but slightly different from Japan camphor. *Dryobalanops aromatica*, indigenous to Sumatra and Borneo, yields borneol (Bornyl Camphor or Borneo Camphor), $C_{10}H_{17}OH$ It is dextro-rotatary, soluble in alcohol, and slightly soluble in water. It is used in medicine and perfumery Blumea Camphor or Ngai Camphor, is obtained from *Blumea balsamifera* It is similar to Bornyl camphor but is laevo-rotatory (With India, I, 197)

A laevo-rotatory camphor is found in the oil of *Artemisia tridentata typica* and of *Matricaria parthemum*. *dl*-Camphor is a component of the oil from *Chrysanthemum sinense* var *japonica* (Thorpe, II, 240)

Synthetic Camphor

Synthetic camphor was produced commercially first in Germany during World War I. It is now produced in England, France, Russia, Italy, Switzerland, Spain, and the United States of America. In 1930, Germany produced 13 million lb. of synthetic camphor. The largest producer of synthetic camphor since 1933 is U.S.A. The plant at Deepwater, N.J., is reported to have an annual capacity of 4½ million lb. (U.S.D., 205). The starting material for the synthesis is α–pinene ($C_{10}H_{16}$), the principal constituent of the oil of turpentine. In one of the processes in use, the pinene obtained by the fractional distillation of turpentine is dried and converted into solid



bornyl chloride or pinene hydrochloride by treatment with dry hydrochloric acid gas. It is next converted into camphene through the action of alkalies or salts of fatty acids. The product is converted to isobornyl acetate by heating with glacial acetic acid and then saponified to isoborneol ($C_{10}H_{17}OH$). After purification, isoborneol, is oxidized to camphor by chromic acid or other oxidizing agent. Alternatively, camphene may be oxidized to camphor by chromic acid.

Synthetic camphor contains isofenchone, isoborneol, and bornyl chloride as impurities, which are removed to a large extent during the process of sublimation or crystallization from absolute alcohol Unlike natural camphor, the synthetic product is optically inactive. The synthetic product is sold in powder or tablet forms In spite of the enormous growth of the synthetic camphor industry, it is doubtful whether it can entirely displace the natural product, as the principal raw material for synthesis is turpentine, itself a natural product.

The oil of turpentine obtained from *Pinus longifolia* (Chir pine) occurring in India is poor in α-pinene [< 25% as compared with 60—70% in French and American oils obtained from *P. pinaster* (*P. maritima*) and *P. palustris* (*Bull. imp. Inst, Lond.*, 1941, **39**, 14)]. For the economic production of synthetic camphor, it would be necessary to select a source containing a minimum of 60% α-pinene, and the oil from *P longifolia* is considered to be unsuitable (Mulany & Watson, *J Indian chem. Soc.*, 1926, **3**, 263; Berry & Sarin, *Chem. & Ind.*, 1936, 605). Two other Indian species, *P. excelsa* (Himalayan Blue Pine) and *P. khasya*, are good sources of

γ-pinene, but the regions of their occurrence are inaccessible and commercial production of oil from these sources has not been possible so far. It is, however, possible to import α-pinene at economic prices from U S A So long as α-pinene is available at economic rates, manufacture of synthetic camphor will be profitable, and the possibilities of manufacturing the product in India deserve consideration. .

Properties and Uses

Several natural products are classed as camphor in the trade, but the name is strictly applicable only to oxygenated derivatives of terpenes and sesquiterpenes.

The principal characteristics of natural camphor are mol. wt, 152 1, m.p, 174-179°, b p, 204°, sp gr, 0 980—0 996, iod. val, 0 1, $[\sigma]_D^{16°}$, +40 to +42° (10% w/v solution in 95% alcohol) (*Schimmel Rep*, 1946, 71) It is soluble in 90% alcohol (1 part of camphor in 1 part of alcohol at 15 5°), very soluble in ether (1 in 0 6) and chloroform (1 in 0 25), freely soluble in fixed vegetable oils (1 in 3), oil of turpentine (1 in 1 5), and only slightly soluble in water (1 in 700) (B P., 118). When dropped on clean water it goes through rapid whirling movements; the movement stops on addition of oil

Uses—Camphor is used as a plasticizer for celluloid and other plastics More than 80% of the camphor produced is reported to be utilized in the celluloid industry It is used also in the manufacture of smokeless powder and disinfectants Camphor is extensively used in medicine, mainly in combination with other drugs, in pill and tablet forms It has been used as restorative for loss of consciousness and collapse, for depression and weakness in acute fevers, and for the most varied forms of failure of the heart and circulation (Cushny, 212) In such cases solutions of camphor in sterile olive oil are given as hypodermic injections It is an ingredient of expectorant mixtures Camphor is widely applied externally as a mild counter-irritant, as a rubefacient, and as a local anaesthetic, and forms, therefore, a common ingredient of stimulating and anodyne liniments and emollient ointments In India camphor is used as incense.

TABLE 1—CAMPHOR PRODUCTION IN FORMOSA
(in short tons)

	Crude Camphor	Reprocessed Camphor	BB Camphor	Refined Camphor
1936	876	1,783	1,896	675
1944	167	278	354	191
1945	104	—	—	75

TABLE 2—IMPORTS OF CAMPHOR

	Qty. (lb)	Value (Rs)
1934/35 1938/39 (av.)	1,946,899	21,90,116
1939/40-1943/44 (av.)	741,663	14,62,067
1944-45	100,964	1,98,454
1945 46	442,514	7,74,990
1946 47	349,705	14,17,754
1947 48	1,674,904	45,64,520
1948 49	1,238,613	23,37,761
1949-50	1,340,307	23,96,204

Trade

The world's annual camphor production is about 10,000 tons in normal conditions Before World War II, Japan, which was in possession of Formosa, held monopoly of the natural camphor industry During the War the industry suffered considerably and after the cessation of hostilities, Formosa was returned to China Table 1 gives the production in Formosa of Crude Camphor, Reprocessed Camphor, BB Camphor, and Refined Camphor (*Schimmel Rep*, 1946, 5, 6).

India's requirements of camphor are met largely by imports Table 2 gives data relating to imports of camphor into India

Japan was the principal source of supply in pre-War years, her share in the total imports being 52 5%. The remainder was imported from Germany, Italy, and Burma. U.S.A. supplied more than 90% of India's requirements in 1947-48, c 37% in 1948-49, and c 42% in 1949-50. Germany supplied c 56% in 1948-49, and a negligible quantity in 1949-50

Prices of camphor were subject to wide variation before the rise of the synthetic camphor industry Prices of natural camphor follow those of synthetic camphor which in turn depend on prices of turpentine. Prices up to 7s. 6d. per lb. were recorded during the Russo-Japanese War of 1904-6 and during the Great War, 1914-18 The lowest figure, about 1s. per lb. was reached during the period 1930-35 (Thorpe, loc. cit.). The price, in June, 1950, of camphor per lb. in U S A was:—natural camphor: powder, $0·45—0·55, tablets, $0·85—0·93; synthetic camphor: Technical grade, $0·42; USP grade (powder), $0·45—0·47; USP grade (tablets), $0·73—0·75.

CANDLES

Before the advent of paraffin wax, candles were made from bees-wax, spermaceti, and stearine and on account of the high cost, the use of candles was confined to churches and households of the wealthy class. These waxes have now been mostly displaced by paraffin wax, and the use of spermaceti and bees-wax is limited to candles required for ceremonial and special purposes. Spermaceti candles were in use as a photometric standard of illumination, but have now been entirely superseded by the pentane lamp, electric lamps, and more recently, by radiation standards. Stearine candles are exceptionally stable to heat and have high opacity. Paraffin wax, however, is superior to stearine as it shows no tendency to crack during cooling, possesses more lustre, and is better adapted for colouring and ornamentation.

Paraffin wax required for candle manufacture should neither be too hard nor too plastic. It should have a m.p. of 120—40°F. Burma petroleum gives a wax with m.p. up to 140°F. As hard wax shows a tendency to stick in the moulds, it is usual to blend it with stearine to give mixtures with a setting point range of 120—38°F. (Thorpe, II, 263) Candles are made in India from Digboi (Assam) paraffin wax. Stearine candles are made in Calcutta, Madras, Mysore, and Baroda.

Pure paraffin wax by itself is unsuitable, in most cases, for use in candle manufacture It liquefies readily under the action of heat and 'gutters' excessively Paraffin wax candles are deformed even under moderate heat. These defects are offset by mixing stearine to the extent of 2—30% with paraffin wax, which not only imparts resistance to bending in hot weather, but also gives a smooth appearance and facilitates the moulding operation (Thorpe, loc cit.). Higher percentages of stearine (m p, 130—133°F) are required if the melting point of the paraffin wax is lower than 130°F A composition of c 97% paraffin wax and 3% stearine gives a very good all-round product as regards rigidity, colour, and burning properties; these proportions are variable within certain limits (Hilditch, 410). During the War years when imports of stearine from U K were cut off, candles were produced in India without the addition of stearine. Coloured candles are made by adding a wax-soluble dye prior to moulding.

The Wick.—Twisted cotton and linen which were once in use as wicks are now being replaced by thin pleated cotton. The texture of wicks is designated by numbers 3—5, 3—8, 3—10, 3—15, etc., indicating the number of strands pleated together, thus 3—5 denotes a wick of 3 threads each of 5 strands pleated together. The pleated structure causes the wick to bend over when lighted so that the tip is in contact with the outer or oxidizing region of the flame and is completely burnt Pleated strands are treated with boiling dilute caustic soda solution, bleached with hypochlorite and washed. They are finally pickled in a solution containing certain inorganic salts—mixtures of ammonium phosphate, chloride or sulphate, borax, potassium chloride or chlorate, sulphuric and nitric acids, nitrates, silicates, or tungstates—which assist burning, minimize charring, and prevent glowing and smoking when the candle is extinguished. Wicks are usually imported;. most manufacturers in India, however use untreated cotton threads.

Manufacture—Candle manufacture consists in solidifying molten wax in tubular tin moulds, the wicks being held centrally in the mould while the wax is solidifying. The equipment used consists of a number of tin or solder tubes, slightly tapered, fixed vertically in a box through which cold water or steam can be circulated as required. The upper ends of the moulds are flush with the upper plate of the box, and the lower ends project through the bottom plate, and are fitted with conical tip moulds which are perforated to allow the passage of wicks. The tip moulds are carried on the upper end of hollow piston rods which slide up and down within the moulds. The pistons are mounted on a movable plate which can be moved up and down by a handle. When the plate is raised the pistons pass through the moulds and eject the finished candles. The upper plate of the box serves as a trough for molten wax.

The wick is supplied to each mould from separate spools fixed below the machine and fed through the hollow piston, through the hole in the tip mould, and finally through the centre of the mould and kept in position by the previous batch of candles clamped over the box.

A mixture of paraffin wax and stearine in the required proportions is heated with open steam and allowed to settle until clear. The hot mixture is poured into the trough over the box and fed into the moulds. Cold water is admitted through the box when the wax sets and the shrinkage due to cooling is made good by wax fed from the trough. The cooling time varies from 8 min. to an hour according to the size of the candles.

When the candles are ready for removal, the previous batch of candles are removed from the clamps by cutting the wicks with a knife. The

excess wax in the trough is scraped off with a knife for reuse. The candles in the mould are then ejected by raising the piston and clamped to a rack. The pistons are then lowered to their original position. The wicks now run from the candles to the spools through the moulds and the machine is ready for recharging with wax. As soon as the wax in the moulds sets, the wicks are cut between the top wax of this batch and the tips of the previous batch. In the first batch of candles the wicks are not truly centrally placed and the candles are often remelted

For coloured candles, aniline dyes are added to stearine before mixing with paraffin. Frosted candles and candles of various fancy shapes are sometimes made. Decorations are applied by transfer and protected by dipping in wax or shellac lacquer.

The process employed by the smaller establishments in Bengal is somewhat different. The moulding machine consists of two blocks which when joined together form a row of vertical moulds The wax is melted over direct fire and poured into the moulds which are first supplied with wicks Cold water is circulated through the blocks for setting, the blocks are separated and the candles stripped off Before starting the operation again, one half of the block mould is threaded with the wick.

Prepared candles are inspected before packing. Household candles are packed in paper cartons, stacked to dry, and finally packed in wooden boxes each containing 25—30 packets Coloured candles are wrapped in tissue paper before they are placed in cartons, and sometimes tissue paper is placed between layers of candles.

The most common size of candles is 10 oz. 32, used in festivals. Other sizes are 8 oz. 6, 10 oz. 6, 10 oz. 8, and 14 oz. 6. Household candles weigh 1 to 2 oz each.

Production and Trade.—Before World War II, large quantities of candles, manufactured in Burma by the *Burma Oil Co., Ltd.*, and *Indo-Burma Petroleum Co., Ltd.*, were being imported into India. The Indian industry was developed during World War II, when imports ceased and supplies of kerosene became scarce. The industry is located mainly in and around Calcutta. In 1943, there were about 160 small establishments in West Bengal employing more than 2,500 workers and producing candles worth Rs. 60 lakhs per annum. In 1947, the industry received a set-back due to the difficulty in obtaining supplies of paraffin wax, and the number of factories came down to 40, and production fell to about 3,000 tons per annum. In 1949, the production was about 1,200 tons (Information from the Department of Industries, West Bengal).

TABLE 1.—IMPORTS OF CANDLES

	Qty. (1,000 lb.)	Value (lakh Rs.)
1937/38-1938/39 (av)	2,996	9·37
1939/40-1941/42 (av.)	2,823	10·03
1942/43-1944/45 (av.)	145	5·09
1945-46	..	..
1946-47	15·7	0 1
1947-48	1 3	0 09
1948-49	0·7	0·04
1949-50	1·0	0·02

TABLE 2.—EXPORTS OF CANDLES

	Qty. (1,000 lb.)	Value (lakh Rs.)
1937/38-1939/40 (av.)	4 0	0·02
1940/41-1941/42 (av.)	9·1	0·04
1942/43-1943/44 (av.)	70 2	1·39
1944-45	..	..
1945-46	0·2	(a)
1946-47	211·6	3·16
1947 48	..	...
1948-49	3·6	0·05
1949-50	70·9	0 58

(a) negligible

Table 1 gives the imports of candles into India. Imports during pre-War years and up to 1941-42 came from Burma, smaller quantities were obtained from Japan, Belgium, and U K. Imports of candles are subject to a revenue duty of 30% *ad valorem*, and a preferential rate of 12% *ad valorem* in the case of imports from Burma.

Table 2 gives the exports of candles from India.

CANNING

One of the most important commercial processes developed in recent years for the preservation of foods is canning or hermetic sealing in metal or glass containers after heat sterilization. Food preservation is assured both by the destruction of spoilage organisms present in the materials, and by the prevention of infection from outside sources. Almost all the methods of preservation, excepting cold storage and dehydration, are covered by the term canning, and the materials handled cover a wide range and include fruits and vegetables, fish and meat products, and milk and dairy products, but not powders and dry

solids, such as biscuits, cocoa and coffee, which are sealed in tinplate containers for protection against insects, dust, and moisture.

Besides protecting foodstuffs against deterioration, canning has helped in creating products with great appeal to consumers, and in preparing food combinations of specified nutritive value for the convenience of those who have not the time or skill to make them from raw ingredients. Canning has also helped to overcome seasonal and regional gluts and scarcities, by preserving surpluses whenever and wherever available, and making them available in all seasons over wide regions. By utilizing surplus materials, the canning industry has not only prevented wastage but also helped to stabilize prices.

Although the method of preserving food in hermetically sealed containers dates back to early times, its development as a scientific process on a commercial scale is only about 50 years old. 14,442,000,000 lb of food were canned in 1935 in the major producing countries of the world (Jones, 1). During World War II, provision of food to armed forces in the far-flung operational areas posed new problems which were successfully met by the canning industry. Methods were developed not only for preserving foods, but also for conserving nutrients The modern canning industry is so highly organized in all its branches that labour-saving automatic devices are employed for many of the operations There are over 400 different kinds of food which are now canned and marketed.

Among the other methods of food preservation are dehydration and quick freezing Dehydrated foods have a shorter shelf-life than canned foods. Further, reconstituted foods from dehydrated materials, except in the case of certain vegetables, are inferior to canned foods in taste and appeal. Quick-frozen foods are superior to canned foods as they retain the natural flavour for longer periods, but suffer from the disadvantage that they have to be carried in the frozen state demanding special equipment for transportation and storage (Jones, 3).

Containers

The most important requirement of the canning industry is the container. Both tin cans and glass containers are used. Cans are generally made of tinned cold-rolled steel plates which have good corrosion resisting properties. The Sanitary Can, which is commonly used, is an open-top tin container which can be closed without the use of solder by double seaming. The Hole-and-Cap or Soldered Can is filled through a central hole and closed by soldering.

TABLE 1.—STANDARD SIZES OF CONTAINERS

Designation	Diam. (in.)	Height (in.)	Capacity (c.c.)
Picnic	$2\frac{11}{16}$	$3\frac{1}{2}$	240
A-1	$2\frac{11}{16}$	4	315
E-1	$3\frac{1}{16}$	4	395
A-1, Tall	$3\frac{1}{10}$	$4\frac{11}{16}$	475
A-2	$3\frac{7}{16}$	$4\frac{1}{2}$	580
E-2	$4\frac{1}{8}$	$4\frac{11}{16}$	730
A-2½	$4\frac{1}{16}$	$4\frac{11}{16}$	850
A-10	$6\frac{3}{16}$	7	3,050

Table 1 gives the standard sizes (overall) of cans employed in the canning industry

For preserving certain food products, lacquered cans in which the tin coating is covered by a layer of lacquer are employed. Lacquering prevents the action of water-soluble pigments on the base plate of the can. Purple or bright red fruits like plums and berries are canned in single- or double-lacquered cans. Vegetables like peas, which are rich in sulphur are canned in special lacquered containers to prevent the discoloration of the product Enamelled sanitary cans are used for fish preservation. The use of aluminium alloys, anodised or coated with a protective lacquer, for food canning has now been extensively developed Such containers lower shipping costs because of their light weight (*Metal Market Rev.*, 1950, 3(5), 9).

Glass containers while possessing the advantages of transparency and corrosion resistance are fragile; they are also heavier than tin cans Glass containers are particularly suitable for home canning, they are also convenient for preserving ketchups and fruit juices. Aseptic closures for bottles have received special consideration. The types used are: Band, Screw top, Tear-off, Seal, Crown cap, and Press-on lids. Screw tops are convenient for wide-mouthed bottles and crown caps for beverage bottles; press-on lids can be used to re-seal bottles after opening. Tear-off types are made of crimped aluminium foil.

Canning involves a series of operations depending on the nature of foods to be preserved. These may be classified under two heads· (1) preparation of foods for canning, and (2) canning proper.

PREPARATION OF FOODS

Fruits and Vegetables—The preparation required for canning depends on the type of food Fruits and vegetables are prepared as for the table Fruits are generally gathered when they are firm ripe, i e , not quite ripe for table use but have attained full size and flavour They are graded according to quality and size. Vegetables are gathered tender They are trimmed and, in many cases, blanched or heat treated with boiling water or live steam This operation cleans and wilts them so that a better control of the fill in the cans becomes possible, blanching removes disagreeable odours, improves colour, removes slime-forming ingredients, and inactivates enzymes.

Some fruits and vegetables require to be peeled, and this is effected either mechanically or by hand Steaming or immersion in boiling lye (0 55—1 0%) facilitates peeling. The material is sliced into rings, cubes, etc as required

Pulpy fruits like apricots, peaches, and pears are treated in a somewhat different manner Apricots are pitted by machine, ground, and sieved to a *pureé* It is mixed with an equal volume of cane sugar syrup (about 15° Bx), heated, and canned hot Peaches and pears are pitted or cored and peeled The fruit is steamed until soft and canned in the same way as apricot

At the time of filling the cans, or immediately after, weak brine (1—2%) is added to vegetables, and sugar syrup (40—55° Bx. at 175—180° F) to fruits. These additions facilitate heat transfer during sterilization, help retention of natural flavour and colour, and act as preservatives Coloured syrup is employed for canning strawberries

MEAT may be canned whole or in comminuted form. In the former case, the canned product has to be preserved under refrigeration The sterilization is not usually absolute, for both form and palatability suffer if full sterilization is aimed at Some meat products are given a preliminary cooking to pre-shrink them. The meats are freed from fat, bones, gristles, etc. by trimming and in some cases they are pickled with nitrite or common salt before canning They are then stuffed into cans, soup stock added, sealed, and vacuum packed In the case of sausages, either uncooked material prepared by chopping the meat and mixing with spices, salt, and other ingredients, or smoked and cooked sausages prepared from cured meat, is used for filling cans.

FISH is canned either in its own oil, or in olive, cotton seed, or other vegetable oils Some varieties are salted, smoked or otherwise cured, and tomato sauce, spices, etc , are added.

Salmon, sardine, herring, and tuna are the fish most commonly used for canning. Fresh sardines are beheaded, gutted, and thoroughly cleaned The cleaned fish are steeped in saturated brine for 20—30 min. and dried in the sun, or in mechanical driers till the external moisture is removed. The dried material is placed in wire baskets and cooked in a hot bath (217—240°F.) of cotton seed oil for a minute or two, and packed into cans after draining away the surplus oil The cans are filled completely with oil, sealed, tested for leakage, and processed Sardines are canned plain or with tomato or mustard sauce Canneries far away from fishing grounds receive their supplies in salted form Such material is washed, steamed for 8—20 min , dried, trimmed, and packed into cans

Automatic machines are employed for beheading and removing the viscera of salmons Tuna fish are cut for the removal of viscera but the heads and fins are left intact in the preliminary treatment The dressed and washed tuna are pre-cooked in wire baskets in steam chests at 218—220°F. They are then cleaned, heads, tails, and fins removed, the skin scraped away, and bones and dark meat removed. The cleaned white meat is filled into cans, salt and oil added, and the cans are ready for sealing

Prawns may be stocked in semi-dry condition, de-salted according to need, and packed in double lacquered cans or in bottles

Canned chicken keeps well almost indefinitely and is particularly useful in hot climates The chicken or adult fowl is steam-cooked or roasted, the period of cooking depending on the size and age of the bird Chickens under 1 5 lb. are a delicacy and are usually cooked whole

MILK is canned in the form of condensed milk (*see* Dairy Products). A variety of such products is available, e g , condensed full cream milk, sweetened, condensed full cream milk, unsweetened, condensed skimmed milk, sweetened or unsweetened; and canned cream. The high percentage of sugar in sweetened products prevents spoilage, unsweetened condensed milks are subjected to high temperatures and spoilage of such products is almost unknown.

FRUIT BEVERAGES—The canned fruit juice industry has made great strides, particularly in U.S A , in recent years. Prior to 1929, grape juice was the most important juice bottled, and about 1 million bottles were annually produced in U.S A. The present production is about 5 million gallons a year Tomato juice now ranks first among

canned fruit juices, canned pine-apple juice coming next in the order of importance Apple-juice is usually consumed fresh, and only a small quantity is bottled with sodium benzoate as preservative.

The growth of the fruit beverage industry is due partly to the recognition of the nutritive virtues of fruit juices, and partly to improvements in the quality of commercial packs. The high quality of the products is largely due to improvements in the methods of pasteurization and the use of enamelled tin containers for canning

Canned fruit beverages include Juices, Squashes, Cordials, and Syrups. The term juice refers to unconcentrated liquid products containing a substantial proportion of pulp and other cellular matter expressed from ripe fruits

The fruits required for the beverage industry should have characteristic flavour, aroma, and colour, and possess a palatable balance between acidity and sugar. Blending of juices from 2 or more varieties is often effected to secure this balance The fruits should be washed free from adhering dust, and micro-organisms on the surface should be eliminated by suitable aseptic treatment The methods employed for juice extraction depend on the structure of the fruits and the location and character of the juice-containing tissues. Most fruits are crushed and pressed for juice extraction Apples are crushed in graters or hammer mills The crushed fruits are pressed in a rack-and-cloth press at 150 lb /sq in Grapes are lightly crushed and heated to 135–160°F., before pressing in basket presses Pine-apples are peeled, coarsely shredded, and pressed in continuous screw presses Oranges are cut into halves and the juice and pulp reamed out either by hand or by rapidly revolving bronze cones. Lemons and grape-fruits are treated in a similar manner. Uncrushed whole fruits are subjected to moderate pressure in a basket press, the resulting juice has a purplish colour and a pleasing flavour. Tomatoes are crushed in a continuous press consisting of a revolving tapered screw inside a perforated metal cylinder. The fruits are warmed before juice expression, and the juice is salted before canning.

Aeration should be avoided during juice expulsion to minimize oxidative changes Fruit juices in general, and citrus juices in particular, are de-aerated by exposure to vacuum. Both colour and flavour are affected unless so treated De-aeration helps retention of fresh flavour and aroma.

Extracted juices are strained or screened to remove suspended solids. For obtaining clearer products, the juices are clarified and filtered after treatment with diatomaceous earth or other filter aids. They are also treated with pectin hydrolyzing enzymes for clarification Pomegranate juice is clarified by flash heating to 175–185°F, settling, and filtering.

Fruit Squashes are sweetened products obtained by mixing strained juices with filtered heavy sugar syrup to contain 35–40% sugar in the final product.

Fruit Cordials are obtained by adding sugar to clarified juices Preparations of the type of Lemon-barley and Grape-barley are refreshing cold drinks made by heating barley flour with water, mixing the cold extract with sugar to obtain a syrup of 50° Bx., straining and compounding with lemon or grape juice together with preservatives like sodium or potassium metabisulphite (Lal Singh *et al*, *Indian Fmg*, 1943, **4**, 297).

Fruit Concentrates and Syrups are other preparations from fruit juices Though the difference between the two is not clearly demarcated, the term syrup is reserved for highly sweetened products. The juice in syrups may be diluted or concentrated, and may contain added acids, flavours, and colours Concentrates prepared by removing part of the water from fruit juices, either by evaporation or by freezing, are used in the preparation of soft drinks and jellies.

Jams, Jellies, Marmalades, and Fruit Butters are sugar containing preparations which are preserved by canning Jams are made by cooking fruit pulp with sugar to the consistency of a jelly Any ripe fruit or blends of different ripe fruits can be used for making jams. Those commonly used are the smaller fruits and berries

The fruits are washed and pulped by cooking with water and the pulp screened. Sugar is then added, the proportion of sugar to fruit depending on the variety and ripeness of the fruit. Most jams should be concentrated to a boiling point of 218–221°F. Usually steam-jacketed kettles are used; vacuum concentration gives a superior product. Jams are packed in sterilized glass containers or cans and pasteurized at 180°F. for 30 min. and rapidly cooled Jams containing high concentration of sugar (70% or above) keep well in most climates and do not need to be pasteurized (Cruess, 370).

Jellies are viscous products containing not less than 45 parts by weight of fruit juice and 55 parts by weight of sugar. The mixture is concentrated by heat to such a consistency that jellying takes place on cooling The three essential ingredients of jellies are pectin, acid, and sugar, on the correct

proportioning of which depends the physical properties of the jelly.

Fruits are cooked in steam-jacketed kettles for converting pectose to pectin and for softening the fruit tissue. The kettle should preferably be of stainless steel, nickel, or monel metal. Sometimes fruits are crushed prior to heating The duration of heating and the amount of water added vary with the variety and texture of the fruit. The extract is filtered in a rack-and-cloth press after adding diatomaceous earth, or by settling, fining, and centrifuging The clear juice is mixed with sugar. High pectin fruit juices require more sugar In the case of fruit juices which are not sufficiently acid or which do not contain enough pectin, the two ingredients are added, and the ratio adjusted Tamarind jellose may also be used in the preparation of jellies (Rao, *J. sci. industr Res.*, 1948, **7B**, 89)

The juice is next concentrated by boiling at 220—221°F. in open steam-jacketed kettles, skimmed if necessary, and the boiling continued until the product forms a jelly of the desired consistency. Too long a boiling results in loss of flavour, discoloration, and hydrolysis of pectin. The jelly is poured hot into containers which are then hermetically sealed and pasteurized at a temperature of 180°F. for 30 min. The yield varies with the variety of fruit, its maturity and other conditions It is usually 350 gal. of jelly per ton of citrus fruits and 300 gal from sour berries (Cruess, 360).

A perfect jelly is a clear sparkling product, transparent and attractive in colour It should be tender enough to hold its shape when turned out of glass, yielding to the slight pressure of a spoon, but holding sharp clear edges where it is cut. It should not be syrupy, sticky, or gummy, and should retain the flavour and aroma of the original fruit (Cruess, 340).

MARMALADE is a clear fruit jelly containing suspended slices of fruit or peel English marmalades are usually made from bitter varieties of oranges American marmalades are made from culled oranges; the product is called Sweet Marmalade. Some marmalades are prepared from oranges, grape-fruits, or lemons.

The method of preparation is similar to that used for jellies except that a certain quantity of sliced peel is added to the clarified juice while cooking with sugar. In American practice the peels are prepared separately. The juice and the prepared peel are cooked together with sugar to the jellying point. Unpeeled oranges may also be used in the preparation of marmalades. In this case, the fruits are sliced and cooked until tender before the addition of sugar. The prepared marmalade is cooled to 150—180°F. before filling into the container; otherwise the peels are liable to come to the surface instead of remaining evenly distributed. The container is sealed, preferably under vacuum, and pasteurized at about 180°F.

Fruit butters are prepared by boiling screened fruit pulp with or without the addition of sugar, fruit juices, and spices to a homogenous semi-solid mass They differ from jellies in having a higher concentration of fruit and finer consistency Brown sugar is often substituted for white sugar The mixture is concentrated to a soluble solids content of not less than 43% (Jacobs, II. 612)

CANDIED AND CRYSTALLIZED FRUITS—Candied fruits are prepared by impregnating fruit with syrup until the sugar concentration in the fruit is sufficiently high to prevent spoilage. The impregnation is carried out in such a way that the fruit does not soften or jam, or become tough and shrivelled Firm fruits required for this preparation are first pitted or pricked and cooked in sugar syrup (30° Balling) for 1—2 min. The mixture is set aside for 24—48 hrs to permit even distribution of sugar between the fruit and syrup The process is repeated a number of times, the concentration of syrup being increased each time by about 5° Balling The prepared product should be plump and firm. The surface is cleaned by sponging with a wet cloth or by dipping in boiling water. Candied fruits are sometimes *glacéd* by coating with a thin layer of heavy syrup which dries to a more or less firm texture (Cruess, 380).

PRESERVES are made by cooking the prepared fruit in sugar syrup until the concentration of sugar reaches 55—70%. The fruit should retain its form, should be crisp rather than soft, and should be permeated with syrup without shrivelling. Fruit preserves are similar to jams with the difference that the preserves contain whole fruit or large pieces whereas jams contain crushed or disintegrated fruit.

Fruits for preserves are prepared as for canning. The prepared fruits are boiled in sugar syrup to the required extent, the boiling point of the syrup should be approximately 218—220°F., or the syrup should have a final concentration of 60—65° Balling. The fruits may be cooked for short durations on successive days in syrups of progressively increasing sugar concentration. Vacuum impregnated preserves have superior flavour and colour than those made in open kettles. The cooked product is rapidly cooled, filled into cans or

jars, and pasteurized in boiling water. Alternatively, the containers may be filled hot in which case further sterilization is unnecessary (Cruess, 373).

KETCHUP is made from strained fruit juice with spices, salt, sugar, and vinegar, with or without onions and garlic, and containing not less than 12% solids. The most suitable fruit for this preparation is tomato. Fully ripe tomatoes of intense red colour and mealy texture, of high acidity and rich flavour are preferred. The fruits are thoroughly washed, crushed raw, and briskly cooked for 3—5 min. at 40—60 lb./sq. in. pressure. The boiled mass is sieved. The *purée* so obtained is heated with the required amount of condiments (tied in a cloth bag) and sugar to a third of the original volume in a steam pan Vinegar is added about 5 min before stopping the cooking, and salt is added later The cloth bag with the condiments is removed and the finished hot product poured into sterilized bottles, corked, sealed, and pasteurized in boiling water for about 30 min. Chopped onions and garlic, cloves, cummin seed, cardamom, black pepper, red pepper, mace, and cinnamon are the spices used Grape ketchup and sauces from tomatoes are prepared in a similar manner.

CANNING

The canning operation involves washing of containers, filling, exhausting, closing, heat treatment or processing, cooling, labelling, and storage.

The cans should be washed free from dirt and traces of zinc salts left during can manufacture. The washed cans are kept in an inverted position till they are required for filling Glass containers must be thoroughly washed and dried

Prepared foods along with other ingredients when necessary are next filled into the washed cans Fruits are preserved in sugar solution, vegetables in brine, and meat products (but not sausages) in soup stock. Fruit juices and condensed milk are canned as such. The sugar solution and brine are prepared separately and poured into the can after filling with the main food material. It is necessary to keep a small amount of headspace, as otherwise the can is liable to bulge out during subsequent processing.

The filled cans are clinched, i.e., the lids are partially closed by a single seam so that an outlet is left for the air to escape. The partially closed cans are exhausted by a machine or vacuum created by steaming and cooling. Machine-exhausted cans pass automatically to a closing machine in which they are closed in a few seconds. In the steaming method, which is more common, the cans are passed in a zig-zag path through a tank containing hot water (82—85°) the water level in the tank being c. 1 in. below the top of the can. Alternatively, the cans may be heated by direct steam in a steam chest. The air in the headspace is replaced by steam which condenses during cooling thus leaving a partial vacuum inside the can The exhausted cans are double-seamed in an automatic machine. As spoilage in the canning industry is due mostly to faulty seaming, perfection is aimed at in this operation (Jones, 63).

The double-seamed containers are heat treated to destroy micro-organisms originally present in the canned food material The treatment should be such that the food is not overcooked. The temperatures employed for different materials are: fruits, slightly below 100°, vegetables, 112—115° (potatoes, slightly higher); meat, 118—120°, and condensed milk, c 117° (Jones, 66).

Processing or cooking of acid fruits is carried out in boiling water for 15—35 min, depending upon the texture of the fruit and its acidity. Highly acid (pH. of juice, 2·5—3·5) fruits like plums, peaches and apricots, are heated for a short duration as the organisms responsible for spoilage are easily destroyed by heat in the acid medium Fruits of pH 4·0—4·5 demand special attention Vegetables of low acidity cannot be processed in boiling water in open cookers, as thermophilic organisms like *Clostridium botulinus* are not easily destroyed, and under anaerobic conditions they produce toxic principles responsible for botulism or ptomaine poisoning. Vegetables are processed in retorts or pressure cookers at 10—15 lb /sq. in. (240—250°F) for 35—70 minutes Tomatoes, however, can be safely preserved by heating in open cookers for about 65 minutes (Siddappa & Mustafa, *Misc. Bull., I C A R* No 58, 1944).

A number of methods have been developed for the processing of fruit juices. The most important among them is pasteurization. Spore forming organisms which are not destroyed during pasteurization, are not harmful as they do not grow in acid media. Still or uncarbonated juices are pasteurized at 175°F. and juices of high acidity at a lower temperature, 140—150°F. The maximum safe time and temperature required to preserve a given juice vary with acidity, heat conductivity, and initial contamination.

Two methods are employed for pasteurization: (1) holding pasteurization, and (2) flash pasteurization. In the former, the juice is processed in the container at a relatively low temperature for a long period. The containers are filled either with cold or warm juice, sealed under vacuum,

pasteurized at about 165—180°F. for about 30 min, and rapidly cooled. Grapes, apple, and pomegranate juices are pasteurized by this method. In flash pasteurization, the juice is subjected to a sufficiently high temperature (170—190°F) for a relatively short time (1—3 min) (Jacobs, II, 600) The juice is passed through heated tubes or plates, the hot juice filled into sterilized cans or bottles, sealed, and rapidly cooled in water Alternatively, the pasteurized juice is filled cold or warm into bottles and sterilized again at about 165°F. Orange, grape-fruit, and pine-apple juices are generally flash pasteurized.

Strained tomato juice is preheated under vacuum to about 180—190°F, filled into sterilized cans and rapidly cooked. Alternatively, the juice is filled into cans, exhausted, sealed and processed for 15—40 min. depending on the size of the can.

Besides pasteurization, other methods are available for the preservation of fruit juices Large quantities of apple juice are preserved with sodium benzoate (0 05—0 1%) Orange juice is preserved with benzoate or sulphur dioxide. Grape juice may be preserved by sulphur dioxide and sulphites In Germany, Switzerland, and South Africa, the juices are filtered through bacterial filters and bottled in sterile bottles. The method demands rigorous control. Fruit juices, especially from grapes, apples, and oranges, may be preserved by freezing and storing at about 10°F.

Experimental studies on the effect of adding antibiotics like Subtilin, Aureomycin, Chloromycetin and Lupulon in small percentages to canned foods have led to the conclusion that the antibiotics conduce to rapid sterilizing and therefore to reduced canning costs (*Fact*, 1950, **4**, 369).

Both tin cans and glass bottles are employed as containers for fruit juices. Tomato, pine-apple, orange, lemon, grape-fruit, apricots, peaches, and pears are generally canned. Orange, lemon, and pomegranate juices are bottled. Grape and apple juices are both canned and bottled.

Processed cans are cooled quickly to about 110°F. to prevent overcooking, undue softening, and also to guard against stack-burning while the cans are held in store. If processing is inefficient fruits become soft and often acquire a dark or pink colour. Cooled cans are stored in cool dry stores for labelling, packing, and distribution.

Self heating food cans were introduced during World War II, and several millions of them were supplied to the armed forces. These cans, which are similar to the ordinary cans, are provided with a centre tube closed at one end and soldered to the can body. The can is filled with soup or other liquid food and closed and sterilized in the usual way. Into the centre tube is then introduced a heater cartridge containing the heating mixture, igniter and fuse, closed first with a cardboard disc with a central aparture for the fuse, and then with a press-in cap, bituminous paste is applied round the metal cap to give a moisture-proof seal. When required for use, the cap is opened and the fuse ignited In five minutes hot food is ready for use. A possible peace-time demand for such cans is in the provision of scratch meals at picnics and on other outdoor occasions (Caldwell & Gillies, *Industr Chem*, 1950, **26**, 301).

The Indian Industry

The development of the fruit canning industry in India, which had its beginnings in 1936, was stimulated by the work carried out under the auspices of the Indian Council of Agricultural Research Fruit research stations were established at Lyallpur and Quetta, and several research projects on fruit canning and preservation were worked out. A Fruit Products Research Laboratory was established in 1943 at Kodur in south India Work on the canning of fruits like apricots, peaches, pears, and plums, was undertaken at Quetta and on the standardization of methods for the preparation of citrus fruit juices at Lyallpur The results evoked wide interest and a number of factories were started in different parts of India, mostly in the Punjab, U P, and Bengal In November 1945, The Indian Fruit Preservers' Association had a total membership of 186 canning firms scattered all over the country

Fruits.—The fruits usually canned are peaches, apricots, pears, pine-apples, mangoes, plums, oranges, greengages, grape-fruits, lemons, guavas, litchis, figs, apples, berries, and cherries Of these the first seven are popular Canned mango is a speciality of the Indian canning industry The following varieties of mango are canned: Alphonso, Banganapalli, Dusehri, Safeda, Siroli, and Langra Experiments at Kodur have shown that Baneshan and Neelum varieties of mango are suitable for commercial canning. The selected fruits are washed, the skin peeled with a stainless steel knife, and the flesh cut vertically into slices. The slices are immersed in clean cold water to avoid contamination and discoloration due to exposure. Slices of uniform size are filled to about $\frac{3}{4}$th in the can, and syrup (29° Balling) added up to $\frac{1}{4}$ in. from the top. Generally A-1 Tall, A-2, and A-2$\frac{1}{2}$ cans are used. The

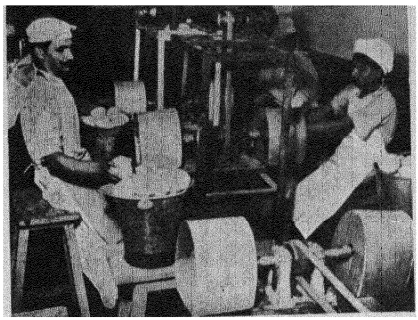


Fig. 1.—Preparing tomato ketchup

filled cans are heated in a boiling water bath for 5—7 min. according to size. Sterilized lids are put on, the cans are sealed quickly in an automatic double seamer, and processed for 13—20 min. in a boiling water bath. Mango pulp is also canned.

Fruit cocktails are canned mostly in A-2½ size, plain or lacquered, sanitary cans.

Recent work at the Government Fruit Products Research Laboratory at Kodur has shown that high quality canned products can be made from guavas and grape fruit. Work on the canning of melons, palmyrah kernel, and jack fruit has given encouraging results.

According to the Indian Army Specifications, canned fruits shall be free from added colouring matter except in the case of cherry where a small quantity of edible colour can be used. No sweetening material other than sucrose shall be used. The strength of the syrup shall not be less than 19% for fruits other than pear and not less than 15% for pear and fruit cocktail. The fruit cocktail shall consist of not less than 3 and not more than 5 of the following fruits: cherry, grape, orange, peaches, pears, and pine-apples. The limits of heavy metals in the canned fruits should be: Pb, $\not>$5 p.p.m.;Cu, $\not>$ 15 p.p.m.; Zn,$\not>$19 p.p.m.; Sn,$\not>$ 1 grain/lb.; and As, $\not>$ 0·01 grain/lb.

Besides the fruits, considerable quantities of lemon and orange squashes and cordials, jams and jellies, marmalades, preserves (Murabba), and candied and crystallized fruits are canned in India. The fruit juice canning industry has not yet attained a significant size. The popular products are: orange, pine-apple, and tomato juices. Fruit juices are usually preserved in sealed sanitary tin cans. The Fruit Products Order (F. P.O.) requires that the final product should contain only fruit juice. The minimum percentage of fruit juice in a squash should be 25. Popular squashes are orange, lemon, mango, and pine-apple. They are sold in sealed quart bottles. Barley waters are made from barley starch and lemon, orange, or grape-fruit juice. According to F.P.O., the percentage of barley starch should not be less than 0·25 and that of the fruit juice not less than 25.

Pine-apple, guava, peaches, pears, apricots, berries of all kinds, cherries and plums are used in the preparation of jams. Various combinations of fruits are used to obtain blended flavours. Oranges and combinations of grape-fruit and lemon, orange are used in the preparation of marmalades.

Murabbas are similar to preserves, but are often spiced. The fruits are cooked either whole or in large pieces in heavy sugar syrup until the concentration of sugar reaches 55—70%. The fruit retains its shape and the finished product is surrounded by a clear thick syrup. A product of better flavour and colour is obtained by cooking the fruit for short periods on successive days, adding sugar each time until the syrup is

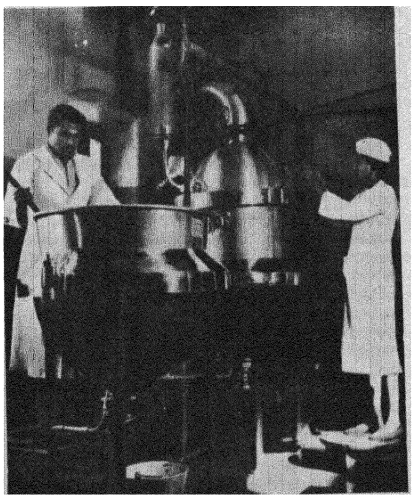


Fig. 2.—Scooping of fruit juice

sufficiently concentrated. The industry is well established in north India. Murabbas are made from fully developed, under-ripe or just ripe fruits of practically any type, those commonly used being, Amla (*Phyllanthus emblica*), mango, apple, peaches, pears, strawberry, apricots, cherries, and figs; vegetables such as carrots, are also used. Murabbas are packed either in tin containers or in sterilized glass jars.

Large quantitites of candied fruits are prepared and canned in India. The fruits commonly candied are: lemons and oranges, cut and dried orange and lemon peels, pears, pine-apples, apricots, grapes, greengage, and cherries. Petha (*Benincasa hispida*) and ginger are also candied (*see* Confectionery). These products are packed in tins or glass containers. Candied fruits are in great demand and are used as additions to cakes and puddings.

Vegetables.—The scope for developing vegetable canning industry in India appears to be somewhat limited. The principal consumers for canned vegetables are the Defence Services. At present, two types of canned vegetables are produced, viz., vegetables canned in brine, and vegetables, curried, cooked, and canned.

The following vegetables are canned in brine: potatoes, peas, cauliflower, tomatoes, carrots, red pumpkin, and cabbage. Potatoes, tomatoes, and red pumpkins are peeled, and carrots scraped. They are canned whole or in pieces in A-2½ size plain or lacquered open top cans, using brine with or without sugar as packing medium. The filled cans are exhausted and closed by a double seamer. The cans are processed in a pressure cooker.

For canning potatoes, selected and washed potatoes are blanched for c. 5 min. in boiling water and peeled. They are filled into A-2½ size plain cans and cold brine poured to fill the container. The cans are exhausted in live steam for 5 min., sealed, and processed for c. 40 min. at 240°F. at a pressure of 10 lb./sq. in., and cooled in running water.

According to Indian Army Specifications, the vegetables canned shall be prepared from selected raw vegetables of sound quality, fresh and free from disease, discoloration, insects and fungi. Only the edible portion of the vegetables shall be prepared for canning. The vegetables should be free from impurities, adulterants, chemical preservatives, and artificial colouring matter. The product shall have the taste and flavour characteristic of the vegetables used, and shall be free from any objectionable flavour. The net contents of each can shall not be less than 27 oz.

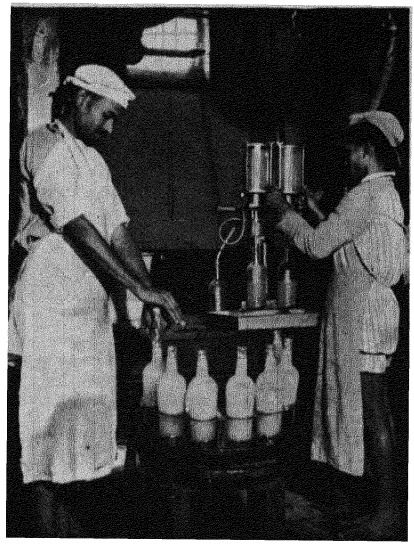


Fig. 3.—Bottling of squash

except in the case of potatoes where it shall not be less than 29 oz. Each can shall be printed, lithographed, or stencilled, giving particulars like description of contents, net wt., name of the manufacturer, date of manufacture, and the F.P.O. number. The specified limits for heavy metals in canned vegetables are: Pb, ⩽5 p.p.m.; Cu, ⩽ 15 p.p.m.; Zn, ⩽19 p.p.m.; Sn, ⩽1 grain/lb.; and As, ⩽ 0·01 grain/lb.

Tomatoes are packed in tomato juice; a mixture of salt and cane sugar or of cane sugar and dextrose not exceeding 2% may be added. They are packed in A-2½ lacquered or plain cans, double-seamed and processed.

The Indian Army Specification stipulates that canned tomatoes shall be prepared from ripe, whole tomatoes of uniform colour, free from blemishes, well-graded, peeled, cored and trimmed. The canned product shall be free from pieces of skins, stalks, cores, chemical preservatives, and artificial colouring matter. The product shall have the taste and flavour characteristic of canned tomatoes of good quality and be free from any objectionable flavours. The net

contents of canned tomatoes shall not be less than 28 lb.

Canned curried vegetables cooked to Indian tastes are a recent innovation. They are made mainly for the Army The following varieties are used potatoes, cauliflower, peas, tomatoes, carrots, cabbage, and Bhindi (*Hibiscus esculentus*). The vegetables are used whole or in pieces Combinations of potatoes and peas, potatoes and tomatoes, potatoes, cauliflower and tomatoes, potatoes, peas and cauliflower, potatoes and cauliflower, cabbage and peas, carrots and peas, are also used. The vegetables are fried in hydrogenated oil along with salt and spices such as rai, cumin seed, asafoetida, red dry chillies, turmeric, and coriander The curried vegetables are packed in A-2½ plain or lacquered cans, closed, and processed in a pressure cooker

Fish —The demand for canned fish in India is small and is met by imports from Europe and America The absence of regular supplies of fish, lack of good and cheap containers, and the short duration of the canning season (100 days in the year), have stood in the way of developing the industry in India A mobile cannery would perhaps provide an answer to the problem of irregular supplies of fresh fish (*Brochure Marketing of Fish in India*, 1948, 14)

The Madras Government established a factory for canning sardines in 1915 Mackerels, pomfrets, prawns and seer were also canned in small quantities The average yearly production of canned fish during the period 1915—1930 was 10—15 tons The product was exported chiefly to Malaya, Burma, and Indo-China The factory was closed in 1930 due to financial difficulties

Meat and Poultry —There is no meat canning industry in India at present Canning, however, offers enormous possibilities for meat foods cooked according to the recipes popular in India, e g, Pilao, Korma, Koftas, Rogan Josh, Keema, etc. There is scope also for the production of canned piggery products The annual demand for such products in India is estimated at 350,000 lb In addition, an export market may be developed in Burma and Indo-China. Tinned ham, bacon and sausages, comparing favourably with imported products, have been produced by Messrs. *Edward Keventer*, Aligarh

There is at present no production of canned chicken. The essence of chicken produced in Calcutta and Kanpur is packed in sealed ampoules for use as a recuperative food for convalescents. It is prepared by digesting dressed or minced chicken in an autoclave, the liquid extract is filtered and packed. The demand for this product is estimated at about Rs 2 lakhs per year

Nutritive Value

As canned products are cooked under controlled conditions, the nutritive value of the raw products is well preserved Calcium and phosphorus present in raw foods are rendered more easily available. The roughage is softened Cooking is more thorough and the food is easily digested (Kohman *et al*, *Industr Engng Chem*, 1934, **26**, 761; Jones, 270)

The effect of canning upon the vitamin value of foods is probably negligible, slight losses on prolonged storage are probable though not certain Much work has been done on the vitamin contents of canned fruits and vegetables, but little appears to have been done on canned fish and meat Vitamin A and carotene are not destroyed in canned meat, bottled vegetables, and fruits Vitamin B_1 is little affected by exposure to 100° in acid or faintly acid media, but it is readily destroyed by alkali even at low temperatures Vitamin B_2 is comparatively stable in acid media (pH 4 5—5 0), but it decomposes in strongly acid and alkaline media Fresh foods such as cabbage, cauliflower, carrots, bel (*Aegle marmelos*), etc give a higher ascorbic acid value on cooking Vitamin D is not destroyed by oxidation, heat, acid, or alkali. Vitamin E, like Vitamin A, is resistant to heat (Jones, 271)

As a result of studies on the influence of duration and temperature of storage on the vitamin contents of canned foods, it has been found that the retention of ascorbic acid and thiamine is affected by temperature of storage rather than by the storage period, while the reverse is true of riboflavin and niacin Carotene retention is not greatly affected by storage conditions Canned foods retain vitamins better when stored at 50°F than at higher temperatures (Guerrant *et al*, *Industr. Engng Chem*, 1948, **40**, 2258)

One of the advantages of canning is that the cans are not affected by insect and rodent pests Spoilage in canned foods may be due to underprocessing, leakage after processing, or to low sealing temperature Heat resistant spores may be present in under-processed cans containing foods with a pH 4 5 The organisms likely to be present are thermophilic types—aerobic flat sour group (*B. stearothermophilus*), the aerogenic anaerobe, *Clostridium thermosaccharolyticum*, and the non-aerogenic, hydrogen sulphide producing anaerobe, *Clostridium nigrificans*, and mesophilic types—putrefactive anaerobes and aerobic spore formers (Jacobs, II, 353) Aerobic flat sour

organisms produce acid but not gas. The cans remain flat. These bacteria predominate in low acid foods The product does not change greatly in appearance but develops a slight disagreeable odour Aerogenic anaerobes produce swelling of the container due to the formation of hydrogen (Hydrogen Swells). The food has the odour of butyric acid. *Clostridium nigrificans* produces hydrogen sulphide but its occurrence is rare. Putrefactive spoilage occurs chiefly in low acid foods and is characterized by the swelling of the can

Spoilage due to leakage is brought about by a variety of organisms including cocci and pleomorphic rods. The can swells, mostly due to carbon dioxide accumulation The contents of different cans vary greatly in odour and appearance, some are frothing, others are slimy.

The presence of food-borne pathogenic organisms, the most important of which is *Clostridium botulinum*, is responsible for cases of illness following the consumption of canned food.

Examination of canned foods.—Periodical examination of canned food, from stores as well as during manufacture, is a necessary and routine procedure The cans are examined for rust, bulge and leaks Blown cans are tested for the presence of hydrogen After opening, the contents are analyzed for metallic (tin, lead, copper, bismuth, zinc, and arsenic) contamination. Routine tests are made for percentage composition, metallic contamination, acidity, and artificial colours A complete bacteriological examination is carried out in the case of blown cans

Production and Trade

Table 2 gives the output and value of canned fruits and vegetable products during 1947-48

TABLE 2—OUTPUT OF CANNED PRODUCTS*

	Qty. (lb.)	Value (Rs)
Canned fruits	3,22,285	2,87,106
Canned vegetables	70,939	56,921
Fruit juices, squashes, cordials & syrups	34,06,232	27,14,165
Jams, jellies and marmalades	9,61,469	7,89,586
Ketchups	83,694	76,924
Candied and crystallized fruits	97,315	1,12,461
Preserves (Murabbas)	15,86,329	10,92,130
Total	65,28,263	51,29,293

* Indian Tariff Bd, *Rep. Continuance of protection to the Preserved Fruit Industry*, 1949,30.

TABLE 3—PRODUCTION COSTS AND FAIR SELLING PRICES*

	Cost of Production (Rs.)	Fair Selling Price (Rs.)
Peaches canned in syrup (24 × A-2½ sanitary cans ; content, 45 lb.)	37·933	38·833
Apricot jam (48 × 1½ lb. cans , content, 72 lb)	62·592	64·032
Orange marmalade (48 × 1½ lb cans , content, 72 lb.)	59 481	60 921
Orange squash (12 × 26 oz. bottles; content, 24 lb.)	20·465	20·705

*Indian Tariff Bd, *Rep* , 34 37

TABLE 4—PRICE OF CANNED FRUIT PRODUCTS

	Value (Rs)
Canned fruits (24 × A-2½ cans)	30—36
Jams (48 × 1½ lb. cans)	60
Marmalades (48 × 1½ lb. cans)	60
Murabbas, per lb.	1

TABLE 5—DUTY ON IMPORTS OF CANNED FOOD

	Nature of duty	Standard rate of duty (*ad valorem*)	
Vegetables (tomatoes, potatoes, onions, and cauliflower)	Preferential revenue	36%	24%*
Asparagus	-do-	24%	
Vegetables, other sorts	-do-	30%	
Fruits (apricots, berries, grapes, plums and prunes)	Protective	54%	60%**
Pineapple	-do-	52%	
Fruits, other sorts	-do-	50%	
Fruit juices (apricots, berries, grapes, pineapples, plums and prunes, or mixtures)	-do-	34%	40%**
Fruit juices, squashes, cordials, and syrups not otherwise specified	-do-	30%	*
Jams, jellies ; candied and crystallized fruits	-do-	80%	
Ketchups	Revenue	30%	
Soup, bacon, ham, and lard	-do-	25%	
Meat ; sardines, pilchards, and other fish	-do-	20%	

* For articles manufactured in British Colonies.
** For articles manufactured in countries other than British colonies.

TABLE 6—IMPORTS OF CANNED PRODUCTS

	Canned or bottled fruits		Jams and jellies		Canned fish		Condensed milk			
							Whole milk		Skimmed milk	
	Qty (1,000 cwt)	Value (lakh Rs)	Qty. (1,000 cwt.)	Value (lakh Rs)	Qty (1,000 cwt)	Value (lakh Rs)	Qty (1,000 cwt)	Value (lakh Rs)	Qty. (1,000 cwt)	Value (lakh Rs)
1934/35—1938/39 (av.)	45·04	10·90	18 97	6·82	44 09	10 81	24 57*	10 15*	23 89*	4·84*
1939/40—1943/44 (av.)	24 62	6 88	14 72	6·08	6 75	3 97	17·35	8 52	7 29	1·96
1944-45	3 69	1 74	17·41	7 05	0 86	0 85	34·89	21·43	0 28	0·06
1945-46	4 22	1·90	21·89	9 15	7 49	34 7	19 24	12 24	4·11	2·82
1946-47	7 75	3·69	7·50	4 08	7 24	6 50	92 19	59·07	0 41	0 26
1947-48	2 60	1·95	37 51	22·80	3 82	4 34	102 16	80 37	9 19	6 71
1948-49	5·17	3·97	3 71	3 01	2 68	3 68	231 58	175 68	19 36	14·44
1949 50	6 73	4·57	6·61	4·48	4 11	6 31	119·69	104·83	..	...

* Figures for 1938-39 only.

Table 3 gives the estimated cost of production and fair selling price in 1949 of different canned products (Indian Tariff Bd, *Rep*, 34-37).

Table 4 gives the average prices of canned fruit products in January 1950

Imports of canned products into India are subject to revenue and protective duties (Table 5)

CANVAS

The term canvas is applied to heavy fabrics manufactured from flax, cotton or jute, or from a mixture of cotton and jute The fabrics are generally water-proofed and used for tents, sails, awnings, beltings, and hose pipes

The canvas industry owes its development to World War II, and two of India's major industries co-operated in producing a new material—the cotton-jute union fabric, which met many exacting requirements of the Services during the emergency

Cotton canvas is a single warp woven fabric, while jute and jute-cotton union canvas are of double warp structure.

Jute canvas was introduced during the War as a substitute for cotton canvas in order to conserve cotton for special requirements It is a closely woven cloth of fine texture weighing 14—24 oz. per yd (36 in. width), and made from the better spinning types of white and tossa jute For the best grades, tossa jute of the highest quality is used and particular attention is given to the regularity of the warp yarn to obviate thicks and thins which may cause *pur* holes and subsequent trouble in proofing Special care is also given to beaming for ensuring uniform warp tension and to size for minimizing chafing of tightly packed warp threads in healds. Greater care than is usual is required also in preparing weft yarns to ensure regular shotting or picking. Jute canvas is widely used in India for boat hatch covers, sun blinds, covers for merchandise of all descriptions and, after application of linseed oil paint or impregnation with bituminous materials, as tarpaulins Two or more layers of cloth may be bonded together by bituminous materials It may be processed and rendered rot-proof and water-proof

The bulk of jute-cotton canvas manufactured in India during the War was used for the production of water holding stores The water-proof quality of closely woven union canvas is improved by scouring in a jigger with a hot solution of soap and soda. The water-proofness depends on the closeness of the weave and the swelling of the fibres on wetting For water holding stores such as tanks and troughs, the canvas is proofed by the application of a wax-aluminium stearate composition An improved quality of jute-cotton union canvas, in which bleached jute weft is used, possesses a high degree of water tightness It is compactly woven, scoured, and finished; it may be used for large water-holding stores without proofing treatment.

Indian cotton, jute, and jute-cotton canvases

are somewhat inferior to imported flax canvas in durability, but are otherwise of excellent quality. During the War years, the Indian industry acquired considerable experience in the manufacture of canvas, particularly of union canvas, and no other country has even approached the standard of quality attained by the Indian industry in this field The all-cotton canvas for motor hoods, developed by the jute industry in co-operation with the Ordnance Laboratories, Kanpur, is also of excellent quality. The Shirley Institute (Manchester) subsequently developed a special all-cotton canvas for which great claims were made, but as no direct comparison between the Indian and the Shirley product has been reported, it is not possible to draw any conclusion as to their relative merits

Uses —Among the many uses for canvas, mention may be made of water-proofed tarpaulins and wagon covers. During the War, the entire output of cotton canvas (18 oz.) was wax-proofed and used for tarpaulins The canvas was made in khaki and Scamic 207 shades. Cotton canvas (21 oz) was used for motor hoods. The material was wax-proofed (wax, 15% by wt) and shaded sand-brown or Scamic 207 and used as wagon covers. A part of the manufactured material dyed in Scamic 207 shade was rot-proofed and water-proofed and used in the manufacture of mat bridges Water-proofed jute canvas (19 oz) was largely used for tarpaulins. Considerable quantities of this material were shipped to Russia during the War as tentage. Rot-proofed canvas was used for stretchers A heavier canvas (20 oz) was used for the manufacture of store tents.

Jute-cotton union canvas was used in the manufacture of Chaguls and water tanks. The

TABLE 1—SPECIFICATIONS FOR COTTON DUCKS AND CANVASES

	Specification	Minimum weight per sq yd. oz	Threads per inch		Counts of yarn		Breaking strength on 3 in wide strip		Weave	Chief uses
			Warp	Weft	Warp	Weft	Warp lb.	Weft lb		
Canvas, cotton, light, scoured and rubberized	CX/82 (a)	9½	31/32	31/32	4½s	5s	290	310	Plain	Sheet ground inflatable heavy weight
Canvas, cotton, khaki, water-proofed	CXS/70	11	60	50	2/15s	2/15s	320	340	,,	Waterproof capes
Canvas, cotton, white or brown	CXS/82 (a)	11	88	56	9s	9s	350	300	Dosootie	Canvas shoe uppers
Duck, cotton, light, dyed/undyed or water-proofed	CXS/93	11/12	42	32	3/16s	3/16s	375	350	Plain	Ration bags, tools rolls, capes, tent components bonnet and radiator covers
Duck, cotton	C P. 40 W.S.Cl.A.	14	42	28	3/13s	3/13s	450	350	,,	Kit bags
Duck, cotton, heavy, dyed/undyed or water-proofed	CX/93	15	42	36	3/13s	3/13s	450	450	,,	Hold-alls, light waterproof covers and nose bags
Canvas, cotton, light, dyed/undyed or water-proofed	IND/TC/927	18	50	26	3/13s	6/16s	500	550	,,	Aprons, hold-alls, tank covers, valises, camp baths and basins
Canvas, cotton, khaki dyed and proofed	G/Tex/ C-45G	18	48/50	26	3/13s	6/16s	500	550	,,	Motor hoods, waterproof covers, and tarpaulins
Canvas, cotton, special, dyed and water-proofed	IND/TC/ 0129	20	70	64	3/16s	3/16s	580	750	Dosootie	Motor hoods, curtains, shelters, and portable mat bridges
Canvas, cotton, heavy	IND/TC/ 0127	24	60	20	3/10s	6/10s	700	600	Plain double warp	Stretchers camp bedsteads, chairs and stools, hold-alls for heavy tools, saddles, and nose bags

TABLE 2—SPECIFICATIONS FOR JUTE AND JUTE-COTTON UNION CANVASES

	Specification	Minimum wt. per sq yd. (oz)	Threads per inch		Counts of yarn		Breaking strength(4 in. wide strip)		Weave	Chief uses
			Warp	Weft	Warp	Weft	Warp	Weft		
Canvas, jute (White)	IM/2758	18	35 40	18 16	..	..	600	550	Plain (double warp)	Coarse bags
Canvas, jute (Tossa) special	IM/2101/C									
Grade A		,,	44	20	6½ lb. per spindle	7½ lb per spindle	725	750	,,	Stretchers, camp and deck chairs, tents, wagon covers, and tarpaulins
Grade B		,,	44	20	,,	,,	600	650	,,	Bags, tents, wagon covers, and tarpaulins
Grade C		,,	,,	,,	,,	,,	650	600	,,	Bags, tents, wagon covers, and tarpaulins
Canvas, jute-cotton union, scoured	IND/TC/2091	22	70	30	3/16s (cotton)	8½ lb / spindle (jute)	350*	500*	,,	Water-holding stores
Canvas, jute-cotton union, water-proofed	IM/2031	,,	,,	,,	,,	,,	,,	,,	,,	Water-holding stores

* 2 in. wide strip

chagul is a bag somewhat similar in shape to Mashk with a capacity of about 3/4 gallon. It is unproofed and is used for carrying drinking water. It allows a certain amount of water to evaporate from the outer walls thereby cooling the contents and permitting the individual soldier to carry his own supply of cold drinking water Chaguls were originally manufactured from flax canvas and the Indian jute-cotton union canvas was found to be equally efficient for the purpose.

Tables 1 and 2 give the specifications for (1) cotton canvases and ducks, and (2) jute and jute-cotton union canvases respectively, issued by the Indian Ordnance Service to which most canvases manufactured in India conform.

It is proposed to replace the ordnance cotton canvases and ducks by 12, 16, 20, and 24 oz /sq. yd. canvases and 10, 14, 18, and 22 oz /sq. yd. ducks. The new canvases are more closely woven and therefore offer a higher resistance to air than any of the existing varieties They can be used wherever windproofness is required. The new ducks are hard-wearing and can be normally used in the unproofed state where resistance to normal wear and tear is of greater importance than waterproofness. Also, it is proposed to abolish Grade C special jute canvas and to alter the breaking strength of Grade B special jute canvas to 625 lb. both in the warp and weft directions.

Production and Trade

There are at present 10 cotton mills equipped for producing cotton canvas, but only 3 of them are producing this item, the total number of looms in use being 50 Jute and jute-cotton union canvas are manufactured by jute mills.

Table 3 gives the annual production of canvas (jute and jute-cotton union) by jute mills who are members of the Indian Jute Mills Association

TABLE 3—PRODUCTION OF JUTE & UNION CANVAS*

	Qty. (tons)
1938-39	3,171
1939-40	4,407
1940-41	10,093
1941-42	7,483
1942-43	8,091
1943-44	7,463
1944-45	5,107
1945-46	4,079
1946-47	2,693
1947-48	1,787
1948 49	2,878

* Indian Jute Mills Association.

TABLE 4—IMPORTS OF CANVAS

	Cotton		Flax		Jute	
	Qty (lakh yds)	Value (lakh Rs)	Qty. (lakh yds.)	Value (lakh Rs.)	Qty (lakh yds.)	Value (lakh Rs.)
1934/35—1938/39 (av)	7 16	5 73	11 37	11 48	0 36	0 30
1939/40—1940/44 (av)	3 13	2 99	3 16	4 37	0 13	0 09
1944 45	0·11	0 18	0·08	0 42		
1945 46	0·11	0 24	0 59	0 40	.	.
1946 47	0·60	1·44	1 12	2 90	.	
1947-48	1·20	2 59	1 52	5 26	..	
1948-49	1·21	4·11	5 55	11 45	..	..
1949 50	0 95	2·52	1 33	4 27	..	

TABLE 5 —EXPORTS OF CANVAS

	Cotton		Jute	
	Qty (lakh yds)	Value (lakh Rs.)	Qty (lakh yds)	Value (lakh Rs.)
1934/35—1938/39 (av.)	0·48	0·25	2·53	0 64
1939/40—1943/44 (av.)	56·16	78·13	25·28	14 81
1946-47	3·02	5·66	21·85 (1,154·5 tons)	16 53
1947 48	1·59	3·92	16. 03 (757 4 tons)	18·19
1948-49	8. 03	15·19	9·52 (403·3 tons)	11 02
1949 50	14 52	24 97	13 52 (650 tons)	15 53

The production of cotton canvas in 1947 was 54 69 lakh yards corresponding to c. 1,295 tons (*Secnd Census of Manufactures, India*—1947, 459, 464). The production during August-December 1949 was 49 52 lakh yards

Data relating to imports and exports of canvas are given in Tables 4 and 5.

CARBON

Carbon is probably the most widely distributed element in nature. It occurs in two allotropic crystalline forms, viz, graphite (hexagonal system) and diamond (isomeric system), the former is soft and black, while diamond is hard and transparent Charcoal, coke, and carbon black, classified as amorphous carbon, are considered by some to represent a third allotropic form; they are said to be composed of very minute crystals of graphite by others. Carbon is an essential constituent of all vegetable and animal matter in which it occurs in combination with hydrogen, nitrogen, oxygen and other elements in an immense variety of compounds. Coal is carbonized vegetable matter found in seams or strata below earth's surface In combination with hydrogen it occurs as hydrocarbons in petroleum. It is also found in carbon dioxide in air (0·03%), as sodium bicarbonate in sea water, and as calcium and magnesium carbonates in sedimentary rocks such as chalk and dolomite

Many carbons of industrial value are prepared from coal and from organic vegetable and animal matter The resulting amorphous products include charcoal, coke, and petroleum coke. Several carbon products are prepared and used in the electrical and electro-chemical industries.

Carbon 13, a stable isotope of carbon (at. wt., 13), has recently come into prominence as a tracer element employed in the study of biological processes. It is obtained from carbon compounds by concentrating the minute quantity of the heavier isotope, normally present in them, by thermal diffusion methods. Carbon 14 or radioactive carbon, a product of the uranium atomic

pile, is used also as a tracer element in the study of plant and animal metabolism (U S.D., 223).

Carbon, activated

The term activated carbon, active carbon, or active charcoal, is usually applied to amorphous carbons possessing higher adsorption capacities than wood or animal charcoal Many processes were developed during World War I for the production of effective adsorbents for use in gas masks Industrial activated carbons in the form of pellets, granules, or fine powders, and with many industrial applications, are now on the market under different trade names

Commercial adsorbent carbons may be grouped into decolorizing, gas adsorbent, metal adsorbent, and medicinal carbons according to their physical structure, properties, and applications No one type of carbon can be used for all purposes A large variety of raw materials are available for the manufacture of these products Coal, petroleum coke, and wood charcoal are activated by gas activation Industrial wastes, e g , saw dust, bagasse, molasses, straw, tan bark waste, coconut pericarp and shell, corn cobs, paddy and groundnut husk, cocoa bean shell, distillery slop, waste mahua (*Madhuca indica*) flowers, waste wood pulp liquor, and filter press mud from sugar factories have been utilized for the production of active carbons by chemical activation

DECOLORIZING CARBONS

Decolorizing carbons are manufactured by (1) gas activation, in which the raw materials are first carbonized and the resulting charcoal heated to a high temperature in an oxidizing atmosphere; (2) chemical activation in which the raw materials are impregnated with a chemical, extruded, and carbonized; and (3) deposition of carbon on a porous inorganic base, no activation is needed in this case.

In the gas activation process, the raw material is carbonized under controlled conditions in closed retorts The resulting charcoal is crushed, screened, and heated in a second retort at 1,000° for 10—20 hrs in an atmosphere of air, carbon dioxide, chlorine, super-heated steam or a mixture of steam and air (Thorpe, II, 315, Perry, 1299). Raw materials which do not possess the necessary density and structure for direct conversion are briquetted prior to carbonization Briquetting gives a higher yield and a better product Bituminous coal, anthracite, petroleum coke, etc., are first carbonized, ground, and briquetted with a binder such as tar, pitch, petroleum oil, etc, recarbonized and gas activated In the process for the direct conversion of coal to activated carbon, the crushed material, screened to 1⅜ in pieces, is carbonized at 450—500°, and steam activated at 950° in continuous vertical retorts. The yield is about 12½% of the coal taken (Thorpe, II, 316).

For activation by chemical treatment, the raw material is ground and pasted with chemicals, e g , chlorides of zinc, calcium, and magnesium, alkalies, sulphuric acid, phosphoric acid, sodium silicate, boric acid, potassium sulphide, lime, ferric chloride, or potassium thiocyanate. The paste is extruded under pressure, dried, and carbonized in gas retorts at about 1,000° The charcoal is cooled, washed with hydrochloric acid and water to remove inorganic residues, and finally dried at about 300° A fluidization technique has been recently developed in France for the production of activated carbon (*Chem Tr. J.*, 1949, **124**, 702))

The third process gives a product with a porous structure and appreciable mechanical strength The raw material—saw dust, sea weed, peat, molasses, etc ,—is mixed with infusorial earth or pumice stone or insoluble salts, and the mixture strongly heated The carbon gets deposited on the porous inorganic base A similar product is obtained when a high ash vegetable product, such as paddy husk, containing an appreciable percentage of silica, is carbonized (Perry, 1298)

Decolorizing carbon is used for (1) removing or improving the colour and flavour of edible materials, such as agar-agar, beer, cider, wines, whisky, vinegar, fruit juices, gelatine, pectin, and cacao butter; (2) removing colour, odour, grease, and colloids from dry cleaning fluids such as naphtha, gasoline, carbon tetrachloride, etc , (3) dephenolizing effluent gas-works liquor, (4) freeing potable water from excess chlorine and traces of phenol to remove objectionable taste (certain types of carbon, e g , paddy husk carbon, are effective in the removal of fluorine), (5) removing oil and grease from boiler feed water and electroplating solutions; (6) recovering iodine from sea water, and bromine from brines, (7) reclaiming aniline, benzene, phenol, and camphor from trade wastes, and (8) preparation of biological products like vitamins, hormones, and enzymes

The liquid to be decolorized is mixed thoroughly with the required amount of carbon, the mixture is raised to a suitable temperature and stirred for 15-30 min The carbon is removed by settling or filtration. The extent of decolorization is dependent on the efficiency of mixing. Activated carbon has been employed as an adsorbent in penicillin production The drug is adsorbed on carbon from relatively weak solu-

tions and penicillin is quantitatively recovered by eluting the adsorbate A similar method is employed commercially for the manufacture of streptomycin and some hormones (U S.D , 248)

Active carbons have been used as carriers for catalysts, and also as contact catalysts in the manufacture of chlorinated hydrocarbons (Gregory, I, 166) They are used as catalytic dehydrogenating agents in the production of ketones from higher alcohols.

Testing.—The most important property of decolorizing carbon is its selective adsorption. This is assessed by measuring the adsorption of iodine, methylene blue, or phenol In carrying out comparative measurements, the pH should be maintained at a definite level Carbons required for decolorizing saccharine liquors are tested by measuring their power to decolorize molasses. Caramel solutions are also used The determination of water-soluble matter gives an idea of the extent of contamination that results by using carbon. Carbons with low ash are preferred in the pharmaceutical industry The pH of the aqueous extract is of value when carbon is used in unbuffered systems The moisture content influences the capacity of carbon to decolorize oils. The oil retention value is of importance in the oil refining industry as it gives an idea of the oil loss that occurs in the filter press cake The screen analysis gives a rough idea of filterability, which can be more directly determined by a regular test using a small filter press It also helps in ascertaining the suitability of carbon for percolation. The bulking value is of interest from the point of view of packing the carbon for transport Revivifiability cannot be tested by any general test, and has to be ascertained by actual trials

Gas Adsorbent Carbons

Gas and vapour adsorbent carbons are obtained by carbonizing coconut shells, cohune (*Attalea cohune*) nut shells, cherry stones, apricot stones, vegetable ivory, and anthracite (Child, *Curr Sci*, 1947, **16**, 6) In recent years, methods have been developed for using softer materials which are rendered hard and dense by briquetting The carbons are gas activated. A preparation useful for gas masks has been obtained by chlorinating bituminous coal (6—20 mesh) until a 100% increase in weight takes place, pelleting the chlorinated material with hydrolyzed starch as binder, baking, crushing (8—20 mesh), and steam activating at 800° (Boyk & Hass, *Industr. Engng Chem.*, 1946, **38**, 745). Gas adsorbent carbons are available in granular forms of specified mesh-ranges, e.g., 4×6; 12×20; i.e., retained by 6- and 20- mesh sieves, and passing throgh 4- and 12-mesh sieves

Gas adsorbent carbon is employed for the recovery of gasoline from natural gas. For this purpose, charcoal of 8—14 mesh is packed in cylindrical towers to proper depth supported on screens The gas is scrubbed through until the charcoal is saturated with gasoline The adsorbed material is recovered by forcing saturated steam through the mass and condensing the vapours The active carbon bed is revivified by cooling and drying by passing a stream of natural gas stripped of its gasoline.

Adsorbent carbon is employed in gas masks, for solvent recovery in extraction plants, benzene recovery from coal gas, and recovery of alcohol and other organic substances carried as vapour with fermentation gases. It is used also for the removal of hydrogen sulphide from town gas, for the purification of carbon dioxide from distillery gases, and for the maintenance of vacuum in containers for liquid air and, generally, in vacuum flasks In the laboratory, it is used for the production of high vacua, purification of gases, determination of vapour content in a carrier gas, etc.

Specification.—According to the Indian Army Specification active charcoal for gas adsorption in a respirator must be in the form of hard granules packed in clean, hermetically sealed drums and must conform to the following: (1) volume activity, not less than 12; (2) moisture content, 65—75% of the saturation value; (3) water soluble matter, 5% on dry charcoal; (4) acidity (calculated as sulphuric acid), 0·5%; (5) alkalinity (calculated as anhydrous sodium carbonate), 3·0%; (6) water-soluble chlorides, 0·5%; (7) softness, 10% of fines The sieve analysis should be as follows·

B S. Sieve No.	% Retained
6	Nil
7	not more than 0 5
Passing No. 7 and retained on No. 10	45—75
Passing No. 10 and retained on No. 14	20— 40
Passing No. 14 and retained on No. 18	3—15
Passing No 18	Not to exceed 4% of which not more than 1% of original material should pass through No. 24

For testing gas adsorbent carbons, the analytical data required are: (1) Service time, time required for the break through of a vapour under standard conditions of adsorption; (2) adsorption

value, weight of vapour adsorbed under conditions of saturation; and (3) retentivity value, weight of vapour held by a carbon through secondary valence bonds under standard conditions The service time is determined with carbon tetrachloride or chloropicrin and is of special interest in ascertaining its suitability for gas masks The adsorption value is of importance from the point of view of solvent recovery and retentivity, and provides information on the irreversible removal of certain components by adsorption from a gaseous mixture. Low retentivity would be a desirable characteristic when the adsorbate is to be recovered by desorption Heat of wetting by xylene can be comparatively easily measured and can be correlated with service time and adsorption value Moisture content is of special interest for assessing the suitability of carbon for gas masks, as the proper adsorption of toxic gases occurs only within certain limits of moisture content Sieve analysis provides an indication of the resistance offered by the material to the passage of gas through a given column of carbon The hardness test is carried out by subjecting the carbon to a wearing action on a shaker under standard conditions The production of too large a quantity of fines renders the carbon unfit for use in gas masks as they increase the resistance to breathing

Metal Adsorbent Chars

Metal adsorbent chars are prepared by alkali activation Structurally, they are identical with decolorizing carbons and are converted into the latter by acid treatment An active product is obtained by heating pine charcoal with alkali at 850° The product obtained has a negative charge when suspended in water, it flocculates at pH 3 8 and settles rapidly. At pH 3 8 it is electrically neutral and devoid of its metal adsorbing power. It, however, possesses the properties of a decolorizing char Treatment of the flocculated material with alkali does not restore the metal adsorbent property

Metal adsorbent chars may be used for winning gold and silver from cyanide solutions in hydrometallurgy, they have been successfully employed as precipitant in place of zinc, in the Yuanmi gold mine in Western Australia. There is apparently a saturation point for chars beyond which metals are not deposited from cyanide solutions (Perry, 321).

Medicinal Carbons

Activated carbon finds application in the preparation of pills and digestive tablets. Its adsorptive properties are utilized in the treatment of ailments of the stomach due to hyperacidity It removes toxic amines, organic acids of decomposed foods, and probably also bacteria from the intestinal tract Large doses, either alone or mixed with kaolin, are administered for diarrhoea It is used as a dressing for suppurating wounds Among the many important uses of medicinal charcoal may be mentioned its value as an antidote to various forms of poisoning, especially those due to mercury salts, strychnine, phenol, morphine, atropine, oxalic acid, mushroom, and poisons for which other antidotes are not available (U S D, 248)

The Indian Industry

Decolorizing carbon is used in appreciable amounts in oil refining, chemical, and pharmaceutical industries The quantities required for refining one ton of oil and one ton of sugar are respectively 12 lb and 45 lb

There has been a considerable amount of laboratory and pilot plant research in India on the production of active carbons Table 1 summarizes the recorded results

Small quantities of activated carbons are manufactured on a commercial scale from bagasse, filter press mud, and paddy husk The product is used for the refining of gur A few of the

TABLE 1.—PREPARATION OF ACTIVATED CARBONS

Raw Material	Activated by
Bagasse, paddy husk, groundnut husk, coconut shell, coir, molasses.	Sulphuric acid, zinc chloride, aluminium chloride [1]
Paddy husk	Zinc chloride [2]
Bagasse	Lime, calcium chloride [3]
Bagasse, saw dust, paddy husk, oil cakes [4]	
Press mud (from sulphitation sugar factories)	Calcium salts associated with mud [5]
Residue left after extraction of cane wax from sulphitation press mud	Calcium salts associated with mud [6]
Bagasse	Zinc chloride [7]
Groundnut husk,* coconut shell	Zinc chloride [8]
Bamboo *	Zinc chloride [9]

*Medicinal Charcoal

1 Rao & Rao, *J Indian chem. Soc. Industr & News Ed.*, 1939, **2**, 161, Rao & Rao, *Curr. Sci* 1937-38, **6**, 616. (2) Chokkanna & Narayanan, *Curr Sci.*, 1937 38, **6**, 617 (3) Chaturvedi *et al*, *Proc Sugar Technol Assoc*, 7th Convention, 1938-39, 177 (4) Banerji & Goswami, *J. Indian chem. Soc, Industr & News Ed.*, 1940, **3**, 375. (5) Doss & Jain, *Proc Sugar Technol. Assoc*, 9th Convention, 1940, Pt 1, 293 (6) Doss & Jain, *Indian Sug.* 1944, **7**, 149. (7) Doss & Jain, *J sci industr. Res*, 1944-45, **3**, 393. (8) Mukherjee & Bhattacharya, *ibid*, 1945-46, **4**, 235. (9) Mukherjee & Bhattacharya, *ibid*, 1947, **6B**, 8

TABLE 2.– CARBONS MANUFACTURED IN INDIA

Trade Name	Raw Material	Activator	Manufacturers
Decol A	Bagasse	Zinc chloride	*Decol & Co.*, Kanpur
Decol B	Filter press mud	None	,,
Vacticot [1]	Paddy husk	Sodium hydroxide	*Eastern Chemical Co.*, Calcutta.
Kiarit No. 500	Paddy husk	Soda ash-lime	*Kiarit (India)*

1. *Bull. Dep. Agric. Madras*, No 39, 1935; No 81, 1938; Sanyal *et al.*, *Bull. Dep Industr Comm., U P.*, (N S) No. 10, 1942, 3.

activated carbons manufactured in India are given in Table 2.

Messrs. *Calcutta Wood Distillation Co*, were producing activated carbon during the War period by the carbonization of hard wood, and activation by dry steam and compressed air Coconut shell charcoal was being produced in south India to meet military requirements (Child, *Curr. Sci.*, 1944, **13**, 245).

The annual requirement of activated carbon in India is estimated at 250 tons (*Rep. Panel on Fine Chemicals, Drugs and Pharmaceuticals*, 1947, 13).

There is considerable scope in India for the manufacture of activated carbon from coconut shells. It is estimated that 400–500 thousand tons of shells are available in India every year, of which only half is collected at present. Nearly two-thirds of the collected material is burnt as fuel, and from the rest about 24,000 tons of active carbon can be manufactured on the basis of 30% yield [Moudgil, *Indian Coconut J*, 1947-48, **1**(1), 27; *Rep. Marketing Coconut and Coconut Products in India*, 1944, 136] *Cochin Chemical Industries* have recently announced the starting of a factory in Ernakulam with an annual capacity, of 500 tons of activated carbon from coconut shell.

Imports—The major part of India's activated carbon requirements is now met by imports. Data relating to quantities imported are not available

The carbons imported into India, their preparation and properties are given in Table 3.

TABLE 3.—CHARACTERISTICS OF SOME IMPORTED ACTIVATED CARBONS*

Trade Name	Raw material and method of preparation	Structure	*p*H of water extract	Carbon %	Ash %	HCl-soluble ash %	Revivification
Carbrox ..	Paddy husk carbon deposited on porous inorganic base	Flocculent powder	6·5—7 0	94	6·5	0 5	
Carboraffin (Germany)	Saw dust activated by zinc chloride at 700°	Exceedingly fine (limestone has to be added during use)	2—3	84—87	3—4	..	..
Nuchar (U. S. A.)	Paper mill waste liquor, steam activated		6·8—7·4	97	2·5—4·5	2·0—3·0	Not revivified
Darco S-51 Darco G-60 (U. S. A.)	Lignite. Pasted with starch solution or calcium phosphate and dolomite—heated to 800—900° ; air and steam activated	Similar to bone char	4·5—6 5—6	74—76 93—96	23—26 3—6	0·5 0 2	Spent carbon made into a sludge permitting uniform drying and revivification.
Norit (Holland, England)	Birch wood carbonized, briquetted and steam activated at 800—1000°	Needles, like carbonized vegetable fibre	4—8·5	97—98	3—8	2—4	Reactivated after leaching out adsorbed materials by dilute HCl and washing.
Suchar (U. S. A.)	Waste sulphite cellulose liquors	Flocculent powder	6·7—7·4	95—96	3—5	2·5—3·5	Revivified by passing an electric current at 100 volts.

*Mantell, 117, 118, 127, 132.

CARBON DIOXIDE

Carbon dioxide, CO_2, also called carbonic acid gas or carbonic anhydride, finds many uses in industry. It is a colourless and odourless gas heavier than air occurring abundantly in nature. Ordinary air contains 0 03—0 04% carbon dioxide. It is a constituent (concentration, c. 4%) of the exhaled air of human beings and animals. Plant roots evolve carbon dioxide; there is a higher concentration of carbon dioxide in the air immediately above the soil surface than in atmospheric air. The concentrations of carbon dioxide in industrial gases are: blast-furnace gas, c. 11%, coal gas from retorts and ovens, 2—4%, producer gas, 4—5%, and water gas, 5—7%.

Carbon dioxide may be recovered from (1) mineral water springs, (2) water gas, (3) flue gases, lime kiln gases, and (4) fermentation gases It may also be prepared by the action of mineral acids on carbonates.

Carbon dioxide admixed with a little hydrogen sulphide and air is evolved from a few mineral water springs. It can be collected and freed from impurities by washing successively with potassium permanganate solution and water, and compressed in suitable containers.

Water gas contains 5—7% carbon dioxide and about 40% carbon monoxide. On passing the gas mixed with steam over a suitable catalyst, the monoxide is oxidized and a gas containing about 30% carbon dioxide is obtained. It is scrubbed with water under pressure (c. 25 atm.) when carbon dioxide goes into solution The gas is released from solution by heating and purified by passing over heated iron oxide

Furnace gases obtained from the combustion of coke or charcoal contain about 20% carbon dioxide by volume. The gases are passed through water scrubbers, whereby they are cooled and at the same time, stripped of the accompanying sulphur dioxide and dust The scrubbed gas is absorbed in potash lye from which carbon dioxide (99 9%) is liberated, scrubbed through potassium permanganate or dichromate solution to oxidize the organic impurities, and finally passed over heated copper filings. The pure and bone-dry gas thus obtained is cooled, compressed, and liquefied.

Carbon dioxide obtained as a by-product in the brewery and distillery industries is usually contaminated with water vapour, hydrogen sulphide, alcohol, aldehydes, and esters. For obtaining an odourless product, as required by the aerated water industry, the gas is cooled and purified by passing through dilute alcohol solution (to remove the entrained wash), scrubbed with water, passed through potassium dichromate and sulphuric acid scrubbers to oxidize the organic impurities, then through a tower containing calcium chloride for drying, and finally through activated carbon for deodorizing. Spent activated charcoal can be revivified by steaming. Silica gel may be used in the place of activated charcoal, the adsorption taking place under pressure (c 80 lb./sq in.) The gel is regenerated by heating in air. The purified gas is compressed to 60—70 atm and liquefied. For every 2½ gal. of 190 proof ethyl alcohol, 17 lb. of carbon dioxide are produced (Shreve, 121).

Lime kiln gas contains about 30% carbon dioxide The kiln may be fired externally with producer gas, or internally with coke (10% of the weight of limestone) and air blown in through the kiln Coke, low in sulphur content, should be used The kiln gas is purified by washing with water, and the carbon dioxide removed by flushing with potassium or sodium carbonate in washing towers containing coke-packed grids. Inert gases and unabsorbed carbon dioxide pass into the atmosphere, and the carbon dioxide which has passed into solution is recovered by heating

Magnesite kiln gases contain approximately 45—50% carbon dioxide. The gas obtained when magnesite is calcined in closed containers or muffles, needs but little purification treatment. The unit yield, however, is low. When shaft kilns are employed for heating magnesite, the whole efflux of gases is tapped, and the carbon dioxide is purified as in the case of lime kiln gases The yield is high.

The Indian Industry

Carbon dioxide required for industrial purposes is produced by the combustion of coke or wood. A part of the requirements is obtained as a by-product from distilleries. Carbon dioxide required for use in the manufacture of certain heavy chemicals and sugar is recovered from lime kiln gases. Other sources of carbon dioxide are not utilized at present in the country

The principal manufacturers of carbon dioxide by combusting coke are *Sirdar Carbonic Gas Co. Ltd.* with plants at Bombay, Calcutta, and Delhi (total capacity, 13 tons per day), *Hindustan Gas Co.*, Calcutta, and *Spencer & Co.*, Kanpur and Madras. Messrs. The *Fertilizers and Chemicals, Travancore, Ltd.*, Alwaye produce carbon dioxide by the combustion of wood. The *Sindri Fertilizer Factory* proposes to recover carbon dioxide from coke oven gas.

Hard coke of grade A with 80% carbon is

used in the manufacture of carbon dioxide from coke. The sulphur content of the coke should be low. The coke is first used in a producer, the gas from which is utilized for operating a gas engine; the exhaust gases from the engine containing as much as 18% carbon dioxide are treated to recover the gas A part of the producer gas is utilized as fuel for heating lye boilers. The gas engine is used for operating the compressors and other plants

The exhaust gases are passed through water scrubbers packed with lumps of limestone or sodium bicarbonate for cooling and removing sulphur dioxide, if present. The clean cooled gas is forced up through absorption towers packed with coke, and the carbon dioxide absorbed by a dilute solution (18°Be) of potassium carbonate flowing counter-current to the gas. The carbonated lye passes through a heat exchanger to the lye boiler where the absorbed carbon dioxide is liberated. The lye boiler is fired by producer gas, and the exhaust gases are also utilized for the recovery of carbon dioxide. The regenerated lye is pumped back to the absorption tower through the heat exchanger and cooled for further use.

The liberated gas is scrubbed with potassium permanganate solution to remove odorous and oxidizable impurities and passed through a water-cooled surface condenser. The purified cooled gas is compressed by a horizontal, multistage compressor working in four stages (2 atm., 3—4 atm., 10—15 atm, and 70—80 atm) or in three stages (1—3 atm., 10 atm., and 77 atm). Inter-coolers (water) serve to cool the gas after each stage of compression. The compressed gas is passed through activated carbon and calcium chloride, and liquefied by cooling to 30° in water-cooled pipes followed by ammonia refrigeration. The liquid is filled into cylinders under pressure and gravity. The output of carbon dioxide per lb of coke varies between 0 57 lb and 0 85 lb.

In the *Fertilizers and Chemicals, Travancore, Ltd.*, Alwaye, carbon dioxide required for the manufacture of ammonium sulphate is obtained from two sources, viz, producer gas used for nitrogen production, and spent gases from the hydrogen generator.

Wood fuel is the source of producer gas. The gas is combusted directly in a gas-fired Bonecourt boiler. The products of combustion, after cooling and washing in Lymn washers, are delivered to a Girbitol scrubber and stripped of carbon dioxide by 8% ethanolamine solution before delivery to the crude nitrogen gas holder. The carbon dioxide released by regenerating the ethanolamine absorbent is insufficient to meet the needs. A part of the spent gases containing 27—32% carbon dioxide obtained during the generation of hydrogen (by the reduction of producer gas by the steam-iron process) is passed through a second Lymn washer and Girbitol scrubber, for recovering additional carbon dioxide. The absorbed acid gases are separated from the amine solution by heating in a steam-heated reactivator. The lean solution, after passing through a heat exchanger and a water cooler, is returned to the absorption scrubber. The pressure in the reactivator is kept high enough to allow the carbon dioxide gas to flow through the acid gas cooler, and then to a gas holder of the oil-filmed annular seal type The gas contains: CO_2, 99·10%; O_2, 0·10%, CO, nil; H_2, 0·10%; CH_4, 0 5; N_2, 0 65% (Rutherford & Ruschin, *Int. Chem. Engng Process Industr.*, 1949, **30**, 516).

By-product carbon dioxide from distilleries is recovered by *Parry & Co*, Nellikuppam; The *Mysore Sugar Co. Ltd*, Mandya, *Russa Distillery*, Calcutta; The *Punjab Distillery Industries Ltd.*, Khasa, *Jagatjit Distilling & Allied Industries Ltd.*, Hamira (Kapurthala); and *Alembic Chemical Works Co Ltd.*, Baroda. The gas is collected, purified, compressed in cylinders, and utilized for aerated water manufacture. Carbon dioxide is also recovered in breweries, and the gas so collected is used for carbonating beer.

The more important aerated water factories in India obtain carbon dioxide from sodium carbonate by treatment with sulphuric acid (With India, Pt. I, 38). Liquid or solid carbon dioxide is used for this purpose in other countries.

The carbon dioxide required for the clarification of cane juice by the carbonatation process in the manufacture of sugar is obtained from lime kiln gases, which are directly employed without purification.

Specification.—The following specifications have been prescribed by the Indian Stores Department for carbon dioxide gas (I.S.D. Sp. No. G/Chemicals—25C, 1949): The carbonic acid gas shall contain at least 99% by volume of carbon dioxide and not more than 0 5% of carbon monoxide, and shall be supplied in sound, clean, and dry steel cylinders of 40 lb. capacity unless otherwise specified, which shall comply with the requirements of B.S.S. No. 401 for steel cylinders for the storage and transport of liquefiable gases. In charging cylinders, the filling ratio, i.e., the ratio of the gas in lb. to the weight of the water capacity of the cylinder shall not exceed 0 66. For the purpose of identification the cylinder containing carbonic acid gas shall be covered

with a coat of black paint with bands of white or aluminium paint as stipulated in the Indian Railway Conference Association Red Tariff No. 14 They shall also conform to the requirements laid down from time to time by the Chief Inspector of Explosives, India, for the packing and storage of carbonic acid gas

Liquid carbon dioxide is filled in cylinders of 50, 40, 25, or 20 lb capacity

PROPERTIES AND USES

Carbon dioxide gas (sp gr, 1 3833, d, 1 9767 g / litre at 0° and 760 mm) liquefies at −65° at 36 atm and solidifies at −72·2° Its p_c is 73 0 atm and t is 31·10° The gas is appreciably soluble in water under pressure 1 c c of water absorbs 1 71 c c carbon dioxide at 1 atm and 0°, 16 3 c c at 25 atm and 20°, 25 7 c c at 50 atm and 20°, and 0 36 c c at 1 atm and 60° It is not toxic, but air containing more than 30% of the gas may prove fatal in 30 min due to its suffocating action, air containing 4−6% carbon dioxide can be inhaled up to an hour without serious effects The maximum safe limit is 2−3%

Liquid carbon dioxide is a colourless, mobile liquid, sp gr. 1 06 at −34°, 0 947 at 0°, and 0 726 at 22 2°. It is almost insoluble in water (solubility, 0·04%) but readily soluble in alcohol or ether

The quantitative reduction of carbon dioxide to acetylene has been effected by passing the gas over barium metal at high temperature, BaC_2 formed is treated with water [*The Times Rev. Industr*, 1949, **3** (24), 21]

Uses—Gaseous carbon dioxide is used in the manufacture of soda ash (by the ammonia soda process), ammonium carbonate and bicarbonate It is also used in the manufacture of crystal sugar from cane juice by the carbonatation process. Other important uses include manufacture of aerated waters and beer, preparation of pure alumina from bauxite, salicylic acid from phenol, β−hydroxy naphthoic acid, synthesis of urea, and manufacture of white lead. It is also used, after reduction to monoxide, in the manufacture of methane and methanol.

Carbon dioxide gas has important therapeutic uses. Mixed with air or oxygen, it stimulates respiration in asphyxia, particularly in new born infants with arrested respiration. It is used to hasten the excretion of poisonous or other gases, such as carbon monoxide, and to produce full expansion of lungs in the treatment of atelectasis. Inhalation has been recommended for the relief of paroxysm in whooping cough, and for hastening recovery from ether anaesthesia. The breathing of 7−10% carbon dioxide in oxygen is the most effective remedy for persistent hiccup (U S.D., 224) Carboxide, a mixture of ethylene oxide and carbon dioxide, is used as fumigant

The beverage industry in the United States of America consumes about 90% of the total output of liquid carbon dioxide The liquid is used as fire extinguisher It is also used in blasting and mining operations, advantage being taken of the pressure developed on its release from a cartridge. The use of liquid carbon dioxide for this purpose is recommended wherever there is a risk of fire when ordinary explosives are employed The liquid has been used for driving torpedoes and for raising sunken ships (Thorpe, II, 328).

During World War II, many special applications were developed for liquid carbon dioxide. When released from pressure, the gas produced occupies 450 times the stored volume, life vests and rubber life boats and rafts can be inflated within a few seconds if provided with small cylinders containing liquid carbon dioxide (Mathieson, *Dry Ice*, 1946). Liquid carbon dioxide as a refrigerant possesses marked advantages over ammonia. The refrigeration units occupy less space and involve less maintenance and replacement charges The risk of leakage renders ammonia refrigeration unsuitable for hotels, cinemas, etc. Carbon dioxide refrigeration is employed for the cold storage of furs and flowers

In the merchandizing of liquid carbon dioxide, considerable expense is involved in handling the cylinders—full and empty It is necessary to instal relatively small plants in consuming centres to minimize handling costs (Shreve, 120). Bulk shipment of relatively low-pressure liquid carbon dioxide saves container cost and weight (Getz & Gurtz, *Industr Engng Chem*, 1941, **33**, 1124)

PRODUCTION AND CONSUMPTION

The production of carbon dioxide in India during 1947 was 63,453 cwt. (Information from D G.I & S.) Almost the entire production is used in the aerated water industry. This figure does not include the vast quantities of carbon dioxide produced and consumed in the manufacture of heavy chemicals, such as soda ash, ammonium sulphate, white lead, etc., and in the manufacture of sugar. In these cases, the gas is produced on and consumed in the factory. The *Fertilizers and Chemicals, Travancore, Ltd.*, Alwaye, are reported to be recovering about 100 short tons of gas per day, out of which 25 short tons are required for Merseburg reaction in ammonium sulphate production. The *Sindri Fertilizer Factory*, when in operation, is likely to

consume about 333 tons of carbon dioxide per day, leaving a surplus of 166 tons The consumption of carbon dioxide per ton of soda ash, ammonium sulphate, white lead, and sugar are 0 074, 0 123, 0 114, and 0 252 ton respectively. The total tonnage consumed is estimated to be. aerated waters, 3,200 tons, soda ash, 2,100 tons, ammonium sulphate, 8,000 tons, white lead, 200 tons, and sugar refineries, 37,100 tons. The percentage of carbon dioxide (as liquid and gas) utilized in the various industries in 1948, was roughly as follows aerated waters, 6, sugar, 74, ammonium sulphate, soda ash, and white lead, 20

Solid Carbon Dioxide (Dry Ice)

When liquid carbon dioxide is allowed to evaporate spontaneously, part of it solidifies due to cooling caused by the evaporation of liquid Based on this principle, three processes have been developed for the commercial production of dry ice, viz, Frick process, Carba process, and Mauri process

Dry Ice is not manufactured at present in India although plants for its production by the Carba process have been installed by *Hindustan Gas Co. Ltd*, Calcutta, *Spencer & Co*, Kanpur & Madras, and *Sirdar Carbonic Gas Co Ltd*, Bombay

In the Carba process, liquid carbon dioxide at a pressure of 60—70 atm./sq. in is introduced at the top of double-walled converters through special nozzles, when part of it expands. The sudden release of pressure to 2—3 atm causes the liquid to be super-cooled and part of it is converted into solid which falls as snow to the bottom of the inner tube A mixture of solid and liquid carbon dioxide collects at the bottom More liquid carbon dioxide is admitted, and the process is repeated until the entire chamber is filled with the solid product The escaping gas is drawn through the outer chamber, compressed, and returned to the system

In the Frick process, liquid carbon dioxide at about 1,100 lb /sq in and at 21° is expanded into cast steel press chambers closed at the top by a movable cover and provided by a hydraulically operated piston at the bottom Part of the liquid evaporates drawing its heat requirements from the incoming liquid which is thereby cooled and solidified to a fluffy snow. The gas formed is continuously drawn off and, after utilizing it to cool the incoming liquid, is compressed. When sufficient carbon dioxide has been expanded, the supply of liquid is stopped and the piston raised upwards to compress the mass into a solid block, and ejected by removing the top lid.

In the Mauri process, which is claimed to be the most efficient, carbon dioxide gas is directly converted into dry ice The gas is compressed to 85 lb /sq in, the heat of compression being removed by circulating water through cooling coils surrounding the gas chamber The compressed gas is further cooled by ammonia (obtained from ammonia evaporators) and finally passed into moulds cooled by liquid ammonia at a pressure of 3 lb /sq in and at −60° Under these conditions, carbon dioxide freezes to a solid, passing momentarily through the liquid phase Dry ice so obtained is dense The ammonia vapours are absorbed by weak ammonia liquor, from which liquid ammonia is subsequently produced.

Generally, dry ice is produced in blocks weighing 90 lb (8 in diam ×40 in long) and stored in insulated wooden boxes.

Properties—Solid carbon dioxide (sp gr, 1 53 at −79°, and 1 59 at −100°) melts at −56·6° at 5·2 atm; latent heat of fusion, 82 0 B. t u; wt. of gas, 0 117 lb per c ft, wt of solid, 90 lb per c. ft, latent heat of sublimation, 248 B t u, refrigerating effect, 275 B t u (Shreve, 119).

Uses—Dry ice is the refrigerant of choice for mobile units Weight for weight, dry ice is 3—6 times as effective as ice. The ice cream industry in the U S A consumes about 90% of the solid carbon dioxide. Dry ice refrigeration is extremely simple to operate The equipment has no moving parts, and initial and operation costs are lower than those of other refrigeration methods. The solid is easy to handle on account of its high latent heat, density, and insulating properties of the blanket of gas surrounding it. Food stuffs do not decay so fast in an atmosphere of carbon dioxide as they do in air (Mathieson, loc cit)

Dry ice is used in industry for shrink fits of large metal parts, for positioning heavy machinery during installation, and for refrigerating heat-treated aluminium alloy rivets in aeroplane construction. Crepe rubber, which is difficult to handle in its normal state, can be cut to proper size after freezing with dry ice. Thus, it is used in the manufacture of golf balls. Emergency uses of dry ice take advantage of its value both as a low temperature refrigerant and as a source of pressure. Broken water mains are sometimes frozen with dry ice on each side of the break to stop the flow of water long enough to enable repairs. Driven wells have been cleaned by using dry ice as a source of pressure to force back sand and silt clogging rock openings.

Solid carbon dioxide is replacing the liquid

product for carbonating aerated waters. When used for carbonating, the blocks of dry ice are placed in a container and heated with steam when the gas is evolved under pressure (Reich, *Chem. metall. Engng*, 1931, **38**, 136, 271). This procedure reduces transport charges as it does away with the heavy containers required for the liquid (Mathieson, loc cit.).

The use of solid carbon dioxide as a refrigerant is not widespread in this country. There is a great scope for its adoption especially for the preservation of foodstuffs (*Rep., Panel on Heavy Chemicals and Electrochemical Industries*, 1946, 34).

CARPENTRY AND CABINET-WORK

The woodworking industry comprises carpentry, joinery, cabinet-making, turnery, and cooperage.. Carpentry is the craft of working timber to materials especially of rough solid kinds required in constructional work, as in ship or house building. Joinery is the term applied to the making of furniture, interior fittings and other wood work generally lighter than carpentry products, consideration being given to the pleasing appearance of the joints, end grains, finish, and other factors. The chief features of joinery are clean and flat surfaces, straight and sharp arrises, close fittings, accurate dimensions, and proper selection of materials. Cabinet-making covers the finer work of the joiner, such as the making of writing desks, book cases, dining tables, side boards, almirahs, screens and others Wood carving is that part of the work of the skilled artisan which imparts an ornamental finish to the article. Turnery is the art of making ornamental mouldings on round pieces of timber with the help of a lathe. The manufacture of packing cases, crates, and cooperage also forms part of the woodworking industry.

Woodwork establishments include cottage units, and medium and large sized factories. The small units are scattered all over the rural areas, and hereditary carpenters ply their trade in their improvised workshops, turning out agricultural implements, carts, household furniture, toys, building materials, and boats, from locally available timbers to meet the local needs. The tools employed are mostly indigenous.

The medium sized units located in towns and cities, may be divided into three categories (1) established workshops with hand operated or power driven machinery; (2) units without workshops, and dealing in supplies secured through *mistries*. These units hire polishers only for giving attractive finishes to furniture and cabinetware supplied to them, and (3) establishments of individual *mistries*, in which a large variety of articles, from furniture tc toys. are turned out.

The factory scale woodworking establishments are the saw mills and Railway and Tramway Workshops.

Carpentry

Teak, sal, and deodar are the woods largely used in carpentry. Teak and sal are strong timbers; deodar is fairly strong; all of them are durable. Other structural Indian timbers used in carpentry are listed in Table 1. Strength is the main consideration in the selection of timber for structural work For bridge work, the timber should be strong and durable, and the surface should be able to stand up to continual wear and tear

Joinery and Cabinet-work

For architectural joinery and interior fitments of buildings, such as doors and windows, trusses and roof-work, coniferous woods are used. True soft woods are not available throughout the country, their occurrence being restricted to the Himalayan ranges The Indian timbers used in joinery and cabinet-making are listed in Table 1.

For high class furniture, cabinetware, and decorative panel work, the chief characteristics required in the wood are non-liability to crack, warp and split, retention of shape, ease of working, and colour, figure, and grain. A restricted group of timbers including teak is used for the work Prior to World War II, a considerable amount of Honduras mahogany was being imported.

A strong, elastic and tough wood is needed for making chairs. Lightness is desirable. In Europe, bent wood chairs are made of beech (*Fagus* spp.), which is steam-bent and dried. Steam-bending is not the practice in India, and chair parts are usually cut from solid timber. The commonly used chair wood in north India is sissoo (*Dalbergia sissoo*). In other parts of India, teak is largely used.

For camp furniture, a light and strong wood is needed. Imported camp furniture is usually made of ash (*Fraxinus* spp.) or birch (*Betula* spp.). There are few Indian woods with the shock-resisting quality comparable to that of ash. Mulberry (*Morus alba*) is probably the best Indian substitute. Bonsum (*Phoebe* spp.) is light, reasonably strong, and exceptionally free from splitting, cracking, and warping. Sissoo is used for camp beds. White cedar (*Dysoxylum malabaricum*) is popular in south India.

CARPENTRY AND CABINET-WORK

The main centres of carpentry and cabinet making industry are Bareilly, Calcutta, and Bombay. Bareilly is the largest centre in India for ordinary furniture Calcutta and Bombay are important for all classes of furniture. Other centres of importance are Kartarpur (Jullundur), Lucknow, Kanpur, Dehra Dun, Madras. and Bangalore There are small shops in almost every town and city for making the more common types of furniture The number of high class furniture manufacturers is limited, as the products are expensive and their use is restricted to the wealthy classes. The workshops are not fully mechanized, only the conversion and rough work being performed on machines. The industry is, therefore, mainly reliant on manual labour and such tools as planers, chisels, saws, spoke-shaves, etc., and the Indian carpenter's tools are in many cases different from those of the carpenter in Europe.

TABLE I —INDIAN TIMBERS USED FOR CARPENTRY AND CABINET-WORK

Name	Characteristics	Uses	Available in
Abies pindrow (Himalayan silver fir)	Creamy white; medium-textured, easy to saw and work.	Packing cases, containers and fruit crates; slack cooperage; cheap furniture; structural purposes.	Punjab, Kashmir, Tehri-Garhwal and other areas in North India
Acacia arabica (Babul)	Heavy, fairly close-textured, extremely strong, hard, and tough reddish brown; easy to work when green; takes a good finish and polish.	House posts, flooring, bridge work, turning	Throughout the drier regions of north, central, and south India.
Adina cordifolia (Haldu)	Light to moderately heavy, pale yellow, fairly hard and strong, easy to saw and machine and one of the best Indian woods to work by hand and to turn, takes polish remarkably well.	Excellent for turning, furniture, panelling and house fitments, most suitable for bathroom, and kitchen fitments.	U. P. (Gonda and Bahraich), Nepal Smaller quantities from other divisions of U. P, Bengal, Assam, Bihar, Orissa, C P, Bombay, Madras
Albizzia lebbek (Kokko)	Light, moderately hard, coarse-textured, dark brown, strong, elastic, and hard, difficult to saw and work; selected ones may be handsome.	Structural work, bridge work, high class furniture, interior decoration, and panelling	Andamans; also in limited quantities from Bengal, Assam, Bombay, Madras, C.P., Punjab, and U.P.
A. *odoratissima* (Black siris)	Heavy, somewhat fine-textured, brown timber; not easy to saw and work but takes a good finish and polish.	Valuable constructional and cabinet wood; slack cooperage.	C P, Assam, Bombay, U. P, Orissa, Madras.
A. procera (White siris)	Similar to *A lebbek*, but lighter and softer	Constructional purposes, furniture, camp beds	U P, Assam, Bengal, Bombay.
Anisoptera glabra (Kaunghmu)	Moderately hard and heavy, even- and coarse-textured, yellowish or reddish brown, easy to work and polish.	Crates, boxes and containers of all kinds; cheap furniture.	Burma and Bengal.
Anogeissus acuminata (Yon)	Heavy, fine-textured, greyish; very hard, strong, tough and elastic; hard to saw and work.	Camp furniture.	Burma.
A. latifolia (Axle-wood)	" "	" "	Deciduous forests in C. P., U. P., Bombay, Madras, Bihar, and Orissa.
Anthocephalus cadamba (Kadam)	Light, even-textured, white or creamy coloured; moderately strong; easy to saw and work.	Used extensively in Assam and Bengal for ceiling boards and light construction work, cheap boarding and packing case wood.	Bengal.

Name	Characteristics	Uses	Available in
Artocarpus chaplasha (Chaplash)	Light, moderately hard, coarse-textured, brown, ornamental, moderately hard and strong; saws easily and works well	Useful for constructional work, furniture, packing boxes, and decorative panelling	Assam and Bengal, also Andamans
A hirsuta (Aini)	Light, coarse-textured, golden yellow; strong and durable; easy to saw, turn, finish and polish.	Constructional work, furniture and turning, tight cooperage.	South India and Bombay.
A integrifolia (Jack)	Strong, easy to work	General carpentry, plain furniture and constructional work.	Throughout India; particularly from Madras and Bombay
Betula alnoides (Indian birch)	Even-textured, white or grey, easy to saw, work, turn and finish	Interior furniture and cabinet work, turning, etc, gramophone and wireless cabinets, camp furniture	Bengal.
Bischofia javanica (Bishop wood)	Coarse and even textured, reddish, not difficult to saw and work	Constructional purposes, selected planks make handsome panels for furniture.	Bengal and Assam.
Bombax malabaricum (Semul)	Soft and light, creamy white or pale pink, perishable; easy to saw and work but cannot be polished	Packing cases and oil casks, cooperage, ceiling boards; tea boxes	Throughout India except Punjab.
Boswellia serrata (Salai)	Coarse-textured; low strength and not durable, easy to work, can be polished after filling.	Cheap box work, packing cases, slack cooperage, inferior planking, cheap furniture	C P., Madras, Bombay, Bihar, Orissa, and U. P. (Jhansi Div.).
Bridelia retusa (Kashi)	Fairly even-textured and moderately heavy and hard, saws and machines easily and can be worked to a smooth finish.	House posts, rafters, floor boards, etc	Bombay, Bengal, Bihar, Orissa
Calophyllum spp (Poon)	Medium-textured, reddish brown, hard and strong, obtainable in great length; saws without difficulty and works to a fine surface.	Structural purposes; furniture.	South India (West coast).
Canarium strictum (Dhup)	Creamy white with a pinkish-grey or yellowish tint; moderately strong; easy to saw, work, and bring to a good finish	Packing boxes, interiors and backings of furniture.	Andaman Islands, Bengal and Assam, Coorg.
Carapa moluccensis (Pussur)	Heavy, fine-textured, ornamental, brownish red, easy to saw and can be finished to high smoothness	Furniture, gramophone and wireless cabinets.	Bengal
Castanopsis hystrix (Indian chestnut)	Creamy or creamy brown, uneven-textured; moderately strong; easy to saw and work to a good finish	First class constructional and interior building timber: furniture.	Bengal; limited quantities from Assam.
Cedrela toona (Toon)	Uneven-textured, light, reddish, easy to saw and work.	Most commonly used for cheap furniture and carved work; building purposes, tea and cigar boxes.	Plains and sub-Himalyan tracts, especially in Assam, Bengal and U. P.
Cedrus deodara (Deodar)	Light yellowish brown, medium to fine-textured, steady and durable; easy to saw and work to a smooth finish.	Suitable for structural work of all kinds, bridge work, window frames, light furniture, shingles.	Punjab and northern India.

Name	Characteristics	Uses	Available in
Chloroxylon swietenia (East Indian Satin wood)	Heavy, fine-textured, yellow; strong and hard ; difficult to saw.	Bridge building, furniture.	Bombay, C. P., Madras.
Chukrasia tabularis (Chickrassi)	Lustrous, fine-textured, brown ; often highly figured , easy to saw, work, turn, carve, and finish.	Furniture, house and building cabinet making.	Bengal and Assam.
Cinnamomum spp. (Cinnamon.)	Even-textured greyish , durable, easy to saw and work to a smooth finish , takes polish well and can be used for turning and carving.	Furniture, building and flooring ;	Bengal and Assam.
Cupressus torulosa (Cypress)	Straight-grained and even-textured ; extremely durable , easy to saw and work and takes a smooth finish.	Bridge building ; house construction and camp furniture.	U.P (Kumaon, Chakrata, and Tehri Garhwal).
Dalbergia latifolia (Indian rosewood).	Handsome, golden brown to deep purple with rich grain figuring ; very hard and durable ; difficult to saw ; takes a high polish.	Finest cabinet and furniture ; constructional wood.	Bombay, also Madras Coorg, C P., U. P., and Orissa.
D. sissoo (Sissoo)	Handsome, golden brown to dark brown with rich grain figuring ; easy to saw and work ; takes a smooth finish	,, ,,	Chiefly U. P. and Punjab; also Bengal, Assam, and Orissa.
Dillenia spp. (Dillenia)	Rough constructional wood of good strength ; coarse-textured, moderately strong but not very durable.	All-purpose constructional timber.	Bengal and Assam ; smaller lots from Bombay.
Diospyros melanoxylon (Ebony)	Extremely hard and tough , not difficult to saw and work in green state ; can be finished to a smooth polished surface.	Turnery, carving ; decorative flooring ; posts, rafters and poles.	Fair quantities from C. P. Madras, Bombay, Orissa, U. P
Dipterocarpus spp. (Gurjun, Jurul, Hollong)	Medium-textured, strong ; comparatively easy to saw and work but cannot be finished to a very smooth surface.	House building and general construction ; bridge work and plywood for tea chests.	Bengal, Assam, Madras and Coorg ; Andamans.
Duabanga sonneratioides (Lampati)	Light, coarse-textured ; not very strong ; easy to saw and work.	Packing cases and tea chests ; furniture ; structural purposes.	Assam and Bengal.
Dysoxylum malabaricum (White cedar)	Fine-textured ; saws and works with ease to a fine finish.	Tea chests ; barrels, house construction, furniture and camp furniture.	West coast, Madras, Coorg and Mysore.
Elaeocarpus robustus	Fine-textured ; moderately hard and strong ; difficult to saw but takes a fine finish.	Boxes	Bengal and Assam.
E. lanceaefolius	Light to moderately heavy, fine-textured ; moderately hard and strong ; saws and works easily, finishing to a lustrous, shining surface ; turns easily.	Boarding and tea box shooks.	Bengal (Kurseong and Kalimpong).

Name	Characteristics	Uses	Available in
Elaeocarpus tuberculatus	Light, fine-textured; moderately hard; saws easily and works to a fine finish.	Chiefly packing cases and cheap planking.	Kanara, Coorg, Mysore Travancore.
Gardenia spp. (Gardenia)	Fine-textured; moderately heavy and hard; well suited for turnery; hard to saw and plane.	Turnery and carving.	C. P., Bombay, U. P., and Bihar.
Gmelina arborea (Gamari)	Fairly close-textured, light yellowish brown with smooth feel; sturdy; easy to saw and work to a good finish.	A favourite with local craftsmen furniture, panelling, boxes, camp furniture, oil casks.	Bengal and Assam, limited supplies from C. P., Bombay, Orissa, and U P.
Hardwickia binata (Anjan)	Coarse-textured, hard, heavy, and strong, difficult to saw and work.	Posts and beams	Madras, Bombay, Mysore and C. P.
H pinnata (Piney)	Medium coarse-textured, reddish brown; selected stocks ornamental and handsome, strong and hard, easy to saw and work, finishes to a fine lustrous surface and takes high polish	Building purposes and furniture; selected stocks used for cabinet work.	Coorg, Travancore, and Ghat forests of Madras.
Heritiera fomes (Sundri)	Fine-textured, strong, elastic, and hard; extremely durable, not very difficult to saw or work; takes a high finish and polish	Heavy constructional work, house posts, etc	Bengal.
Holoptelea integrifolia (Kanju)	Even and medium-textured, light-coloured wood, easy to saw and machine, takes a good polish.	Cheap grades of furniture, panelling and door frames, box shooks, carving, etc.	U P.; limited quantities from Bihar, Orissa, C. P., Ghat forests of North Malabar
Hopea parviflora (Hopea)	Heavy, fine-textured, reddish brown, hard and durable; somewhat difficult to saw but takes a good finish and polish.	Constructional purposes, bridge-work; also for furniture.	West Coast.
H. odorata (Thingan)	Heavy, medium-textured, yellow, hard and durable, somewhat difficult to saw, but takes a good finish.	,, ,,	Bengal, Bombay, and Andamans.
Hymenodictyon excelsum (Kuthan)	Medium-textured, light; easy to saw and work, turns well, and can be brought to a fine finish.	Drums, slack and tight cooperage, box making	Assam, Bengal, Bihar, Orissa, and U. P.
Juglans regia (Walnut)	Even-textured greyish brown; often mottled and figured; relatively light for its strength and finishes to a fine surface; dried wood does not shrink, swell, or split even under adverse climatic conditions.	High class cabinet making; used in Kashmir and north India for carving.	Kashmir; smaller quantities from, Punjab and U. P.
Lagerstroemia flos-reginae (Jarul)	Medium-textured, reddish brown; easy to saw, work and turn; can be finished to a fine smooth surface and takes a good polish.	Fine constructional wood, furniture, and tight cooperage	Bengal and Assam; limited quantities from Bombay and Madras.

Name	Characteristics	Uses	Available in
Lagerstroemia lanceolata (Benteak)	Coarse-textured, reddish brown ; suitable for constructional purposes ; not difficult to saw and work, finishes to a fine smooth surface and takes a good polish.	Largely used for house building, furniture, and general carpentry, tight cooperage	Madras, Bombay, and Coorg.
L. parviflora (Lendi)	Coarse-textured ; moderately heavy, strong, and hard ; durable even under adverse conditions ; fairly easy to saw and work and can be finished to a fine surface	Used for building and constructional work, bridges, tight cooperage ; boxes.	Bengal, Assam, U. P., C.P., Bihar, Orissa, Bombay and Coorg.
Lannea grandis (Jhingan)	Even-textured, brownish red; easy to saw and work and can be turned or worked by hand to a beautiful finish, takes a high polish	House-building, furniture, carving, turnery, slack cooperage.	U. P , C P , Bengal, Bihar, Orissa, and Madras
Mangifera indica (Mango)	Coarse-textured, greyish brown , fairly strong, and steady ; retains shape well; can be easily sawn, worked and finished to a clean surface.	Cheap furniture, planking, floor and ceiling boards, tea chests, crates, dry cooperage	Throughout the greater part of India.
Melia azedarach (Persian Lilac)	Coarse and uneven-textured ; easy to saw; takes a high polish	Small boxes	Punjab (Changa Manga).
M. composita (Malabar nim wood)	More even-textured than *M. azedarach*, easy to saw and work; not durable in exposed situations.	Packing cases, cigar boxes, and ceiling planks	Assam, and Konkan, N Circars and from South Kanara to Tinnevelly.
Mesua ferrea (Mesua)	Medium-textured ; heavy, hard, strong, and durable ; difficult to saw.	Heavy constructional work, bridge work.	Assam, also Madras, Coorg and Cochin.
Michelia spp (Champ)	Medium-textured olive-brown , lustrous and smooth; light, easy to saw, machine and finish; works to a beautiful smooth surface and takes a good polish.	Excellent for light furniture and household fitments; boards and general joinery work; cabinet-making, box shooks, and bent-wood works.	Assam and Bengal.
Mitragyna parvifolia (Kaim)	Fine-textured with smooth feel, strong and hard; easy to saw; works to a smooth finish and takes a fine polish.	Turnery, slack and tight cooperage.	U. P. and Bihar; small quantities from Bombay, Madras, and Orissa.
Morus alba (Mulberry)	Medium coarse-textured, yellowish brown or golden brown ; higher shock resistance, shear and hardness than teak; easy to saw and work, can be carved or turned to a smooth surface; excellent for steam bending.	Excellent for furniture, especially for camp beds and chairs.	Punjab (Changa Manga).

Name	Characteristics	Uses	Available in
Ougeinia dalbergioides (Sandan)	Coarse-textured, light golden brown or reddish brown ; hard and fairly durabl , difficult to saw and work but can be brought to a fine finish, planes and turns well.	Good for constructional work and for light and loose cooperage; also for furniture.	Plains forests of India; best logs from the west coast of Bombay; also from C.P. Bihar, Orissa, and U P.
Palaquium ellipticum (Palli)	Light red to reddish brown, straight-grained, medium and even-textured, moderately heavy, not difficult to saw, works well and takes a good polish	Building purposes, cheap furniture, shingles.	Bombay southwards to Travancore and Coorg.
Phoebe hainesiana (Bonsum)	Light, easy to saw and work and takes a fine smooth surface.	Light furniture, cabinet making, gramophone cabinets, camp furniture	Bengal and Assam.
Picea morinda (Spruce)	Even-textured, good quality light weight wood of the 'deal' class, easy to saw and work and can be brought to a good finish.	Planking for ceilings and floors, general joinery, cheap furniture, boxes and crates; slack cooperage.	Northern India, Kashmir.
Pinus spp. *P. longifolia* (Chir) *P. excelsa* (Blue pine)	Fine-textured, good quality medium weight woods of the 'deal' class, Blue pine is slightly superior to chir; both reasonably strong, easy to saw and work. More suitable for paint and enamel finishes than for polish work.	Joinery and constructional work, house fitments, shingles, packing cases, light furniture.	Himalayan forests in Punjab and U.P.
Populus euphratica (Indian poplar)	Light, even-textured, reddish brown ; saws easily and works with ease; good turnery wood.	Planking, turnery and lacquer work.	Punjab
Pterocarpus dalbergioides (Andaman Padauk)	Strong and handsome, red-coloured ; rather coarse-textured; steady and not difficult to saw and machine and can be worked to a fine surface.	First class cabinet wood and a strong constructional timber, suitable for heavy carpentry, bridge work and furniture; used for parquet floor and one of the most decorative woods; camp furniture, and liquor casks.	Andaman Islands.
P. macrocarpus (Burma Padauk)	Moderately heavy, interlocked-grained, medium coarse-textured; extremely strong, hard and durable; difficult to saw; takes a good polish.	House-building, camp furniture.	Burma.
P. marsupium (Bijasal)	Medium-textured, golden brown, moderately heavy strong and hard; fairly easy to saw and work; takes a good finish and polish.	Building purposes; camp furniture; selected ornamental stock used for cabinet work.	C.P., Bombay, Coorg, Orissa, and U. P.
Schima wallichii (Chilauni)	Medium-textured, saws easily and works to a smooth surface.	Constructional purposes.	Assam and Bengal.

Name	Characteristics	Uses	Available in
Schleichera trijuga (Kusum)	Medium-textured; one of the heavy, hard, strong and tough woods, difficult to saw and work, finishes to a fine surface and turns well	Constructional purposes.	Bombay, Orissa, U.P, also C P., Bihar, and Madras.
Shorea robusta (Sal)	Medium-textured ; hard, heavy, strong, tough and durable , easy to saw when green.	Cconstructional and other purposes , cooperage.	U. P., C P., Bengal, Assam, Bihar, and Orissa.
Spondias mangifera (Hog plum)	Light, coarse-textured, easy to saw and work.	Packing cases	Khandesh and Panch Mahals
Sterculia campanulata (Papita)	Coarse-textured, creamy-white, light, easy to saw or work, machines well and can be brought to a good surface.	Box shooks	Andaman Islands
Swintonia floribunda (Civit)	Medium-textured, light-coloured , reasonably strong, easy to saw and work and machines to a good finish.	Candle boxes	Chittagong.
Syzygium cumini (Jaman)	Medium, coarse-textured, reddish brown to brownish grey ; strong and moderately heavy , not difficult to saw and work	Constructional work and house building ; selected for stock furniture and cabinet work , cooperage.	Throughout India.
Tectona grandis (Teak)	Medium weight, strong wood of average hardness and of outstanding merit in retention of shape and durability, relatively easy to saw and work, can be finished to a fair surface and takes polish well.	Most important wood for furniture, cooperage; carpentry.	Burma, Madras, Bombay, C P., Orissa, Bengal, Coorg and Central India.
Terminalia arjuna (Arjun)	Coarse-textured, moderately heavy and fairly decorative, dark-brown, not durable; not easy to saw and work and turns well and takes a good and lasting polish.	House building; selected stock for cabinet making	Bihar, Orissa, and U. P ; also west coast
T. belerica (Bahera)	Coarse-textured ; strong, perishable ; easy to saw and machine, but difficult to bring to a smooth surface	House building ; boxes and packing cases	Forests of Central, South and East India
T. bialata (Chuglam, Silvergrey).	Handsome, light-coloured, decorative, coarse-textured , strong and medium weight ; easy to convert and work ; can be finished to a fine smooth surface and takes a good polish.	All types of cabinet work ; especially suited for internal decoration	Andaman Islands.
T. chebula (Myrabolan)	Heavy, greyish, hard, tough and strong ; difficult to saw and work.	Constructional purposes.	Bombay, C P. and N. Circars and S. Deccan ; Burma.
T. myriocarpa (Hollock)	Coarse-textured, medium-weight ; sometimes with a wavy fiddle-back figure ; 75-80% as strong and hard as teak ; fairly easy to saw and work and can be finished to a fairly good surface	House building ; also for furniture ; plywood for tea chests.	Mainly Assam ; also Bengal.

Name	Characteristics	Uses	Available in
T. paniculata (Kindal)	Medium-textured, good strength ; not very difficult to saw and work.	Constructional and general utility purposes ; frequently used as a substitute for teak	Bombay and South West of Madras.
T. tomentosa (Laurel)	Dark-coloured, coarse-textured ; strong and hard ; normal straight-grained stock is easy to saw and work to good finish ; turns easily and takes excellent polish.	Building purposes, bridgework; selected figured stock used as cabinet wood of exceptional beauty.	Throughout India except Punjab and Assam
Tetrameles nudiflora (Baing)	Coarse-textured ; light and soft, easy to saw and work and finishes to a good surface.	Packing cases, tea chests and general box work ; light and slack cooperage.	Assam, Bengal, Madras, and Andaman Islands
Trewia nudiflora (Gutel)	Light, medium fine-textured, easy to saw and work to a smooth surface.	Packing cases and box shook	U. P. and Bengal ; small quantities from Bombay and Assam.
Vateria Indica (Vellapiney)	Medium-textured, light, saws and finishes to a good surface and takes a good polish.	Tea boxes, packing cases, interior work in houses and planking generally, also furniture	South west of Madras, Coorg, and Travancore
Xylia xylocarpa (Irul)	Medium to fine-textured, heavy and hard, not very easy to saw.	Heavy constructional work, poles, and general utility work.	Madras, Bombay, and Coorg, Small quantities from C P. and Orissa
X dolabriformis (Pyinkado)	Heavy, reddish brown ; difficult to saw but works to a smooth surface and takes a fine polish, extremely durable.	Constructional purposes,	Burma
Zanthoxylum rhetsa	Light greyish yellow to yellowish grey ; moderately heavy, even-textured; moderately hard and strong, saws and works easily, finishes to a smooth surface and takes a high polish.	Planks, rafters, and for chair-making.	Malabar.

A workshop for turning out standard types of doors and windows, furniture, tool handles, and packing cases should have in addition to the small hand tools the following labour-saving machinery. horizontal-, band-, circular-, frame-, and fret-saws, single spindle moulder, four cutter moulder, machines for thicknessing, tenoning, mortising, sand-papering, and rounding, and drilling lathes for turning and copying, panel planer, saw sharpening machine, glue press, and wood seasoning plant.

The wood required for carpentry and cabinet-making is received in solid, laminated, and veneer forms. Large sized workshops buy solid wood such as deodar, kail, chir, and fir in the form of logs (10—20 ft. long and 2—7 ft. girth), and sleepers (sizes varying from 12 ft.×10 in.×5 in. to 8 ft.×7 in.×4 in.). C.P. teak logs are available in 10—16 ft. length and 9—16 in. girth. Sal wood is obtained in the form of beams (16—20 ft long, 18 in wide and 1 ft thick) or *ballies* (max length, 30 ft and girth, less than 10 in) The quantities of logs of different girths available in the market are· 36—42 in, 20%, 42—52 in, 55%, 52—60 in, 15%; and 60 in and above, 10% About 50% of the logs available are 8—12 ft long, 30% are 12—15 ft long, and 20%, above 15 ft (Information from D.G I. & S) Smaller concerns obtain their supplies in the form of sliced logs from saw mills The lumber represents 15—20% of the cost of furniture and hence a proper selection of raw material of correct dimensions is essential for economy. In large concerns the lumber is codified at the saw stage so that a maximum conservation of material may be secured

The timber has to be first seasoned. This is necessary to ensure the retention of shape and the prevention of splits, shakes, and cracks in the

finished articles due to variations in atmospheric moisture Two methods are employed for seasoning—air seasoning and kiln seasoning. The latter is a controlled process and the product obtained has definite predictable properties A few woodworking factories in India have installed kiln-seasoning plants (*see* Wood seasoning)

Laminated wood, in the form of plywood is used in many types of furniture It has greater strength than ordinary wood of the same thickness, it does not crack or split due to variations in atmospheric moisture: it is available in standard graded sizes of considerable width Black-board is another laminated product commonly used in furniture production It is made from a core of jointed solid timber faced on either side with one or more veneers and is preferred to plywood where appearance of solidity in the furniture is demanded

Veneers are thin slices, 0 6—0·9 mm. thick, peeled off from boards selected for their decorative figuring. Veneers of oak and mahogany which are chiefly used in furniture work are received in bundles of 20—50 leaves Walnut and various burrs and curls are obtained as flitches and worked up into veneers before use.

Animal glue, fish glue, and casein glue are the adhesives commonly employed in medium-sized workshops. Bone and hide glues are employed in cottage industries These glues have to be heated with water before use They are not quick-setting, and they usually leave a dark glue line if the joint is not properly finished. The larger concerns employ imported synthetic resins, which can be applied cold. They set quickly and are waterproof. Some of the adhesives are of the liquid ready-for-use type, and are specially well adapted for use in making musical instruments Lactic and vegetable casein glues are used in plywood and toy manufactures.

Other materials used in the industry are screws, hinges, cabinet bolts, locks, handles, ball catches, castors, door handles, stays, hasps and staples, key face plates, adjustable shelf fittings, mirror fittings, plate and sheet glass, mirrors, canvas, gunny, coir, cotton, leatherette, cane, etc.

A large number of joints are used in wood work. Some are common to both carpentry and joinery. The joints employed in carpentry are. angle, bridle, cogging, dovetailing, halving, housing, keying, mitring, mortise and tenon. Lengthening joints include halved, finished, lapped, spliced, scarfed, and table joints. In joinery work such joints as tongue and groove, dowel, secret and slot screw, and hinging and shuttering joints are used.

Design plays an important part in carpentry and furniture manufacture Very few concerns in India employ designers and, in consequence, much of the work is imitative. There is a dearth of trained designers in the cabinet and joinery industries

The general procedure adopted in large concerns for the manufacture of first class cabinet and furniture is as follows The designer prepares his perspective sketches approved by the production manager and the customer, after which the working drawings are completed. These are sent to the cutting section, where timber which has already been converted and seasoned is cut for issue to the foreman, who is responsible for marking the timber for machine work, rebates, mouldings, mortices, tenons, dovetailings, sizing, etc The machined parts and the drawings are passed on to the cabinet maker, who assembles them according to the drawings The completed articles are inspected and sent to the polishing department for finishing.

The work of veneering is a part of machining. The veneers are selected, cut to the required length, jointed and glued to the core stock of plywood or black-board, and pressed in a hot or cold press The veneering of shaped or moulded furniture may be carried out by the use of special presses worked by compressed air.

Finishing.—A large variety of wood finishing materials are in use Articles exposed to moisture, and requiring frequent washing, such as dining room furniture, are given a dull wax finish. Drawing room and study room furniture are polished Doors and windows, staircase woodwork, etc., are varnished. Ceilings, match-boarding, wall panelling, etc, are coated with wood oil. Exposed wood-work is painted and rendered weather proof.

Staining is necessary to give a uniform shade to the articles. Powder or liquid stains may be employed. Water soluble stains are fast to light, but they have a tendency to raise grains and loosen fibres thus producing a rough surface which should be sanded before finishing. The stains are allowed to stand on the surface of wood for 24—40 hrs. before finishing. Spirit stains contain a certain quantity of water and therefore tend to raise grains and fibres to some extent. Oil stains penetrate deep into the wood and give a dark shade to the soft portions of the wood. Oil stains are partly soluble in the solvents used in varnishes and lacquers, and are accordingly liable to bleed and spoil the appearance of the finished surface.

After staining the wood, open pores and splits,

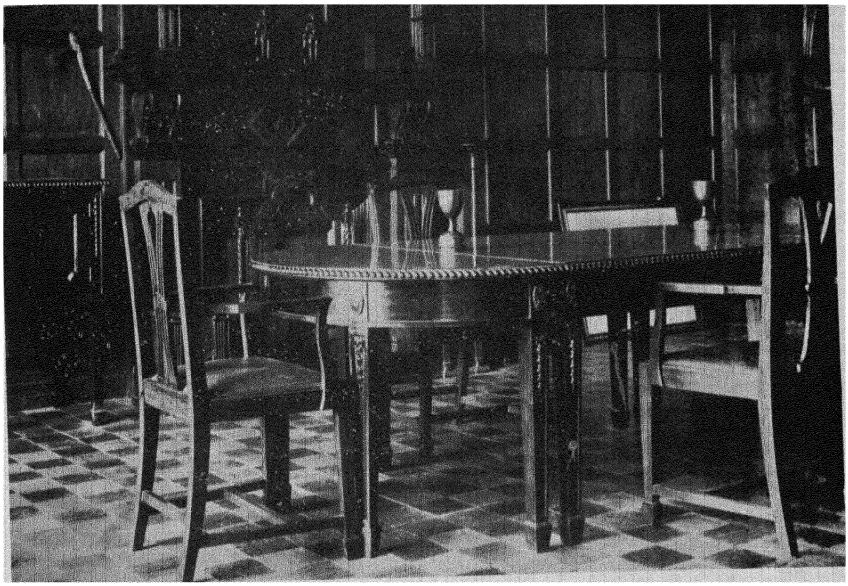


Fig. 4.—Furniture and panelling, Forest Research Institute, Dehra Dun

if any, in the surface are filled up. A composition of Silex, linseed oil, Japan drier, and colouring matter is used as filler. Drying takes about 16 hrs. There are other fillers with shorter drying periods. As the filler forms the foundation for the surface finish, the selection of the filler is important.

Wax finishing consists in rubbing the surface with bees-wax mixed with turpentine. A good wax polish is made by melting in a jacketed pot, ¼ lb. bees-wax, 1 oz. resin, and ¼ pint turpentine. The polish is applied twice or thrice to the surface of the wood, each coat of wax rubbed into the pores and allowed to stand for a few hours to enable the wax to harden and the turpentine to evaporate.

French polishing.—Articles of furniture used in drawing and study rooms, are finished with French polish (otherwise known as spirit varnish). The polish is prepared by dissolving soft resins such as shellac and sandarac resin in spirits of wine or methylated spirit with or without plasticizers and extenders. The polish dries quickly giving a hard and shiny surface. Three kinds of French polishes—Bleached Hard, White Hard, and Brown Hard—are in use. The first is colourless, and the last leaves a dark brown film. French polish is applied by a rubber and allowed to settle itself on wood after the spirit evaporates. The surface is gently rubbed with a smooth sandpaper to remove the excess of polish. The polishing is repeated three times, the last being done with diluted polish so that any excess of resinous matter that is deposited on the surface of the wood is removed by solution and evened out.

Turpentine varnish used for interior work is prepared by dissolving resinous materials in oil of turpentine or Venice turpentine. A good varnish dries with a hard and transparent surface but it takes a longer time than French polish for drying

Oil varnish is used largely for carriages, wagons, lorry bodies, ceilings, high class decorations, etc. They are made by dissolving resins

such as amber and copal in linseed oil. Oil varnishes are applied in the same manner as turpentine varnish, and require a long time to dry. They give a hard and durable film. The best quality of oil varnish is made from selected fossil resin and Baltic linseed oil.

Oiling.—Wood-ware is sometimes given a thick coating of double-boiled linseed oil. The coating is allowed to remain for about 24 hrs. and the excess oil wiped off by cloth. The oil penetrates into the pores of the wood and removes moisture. The finished surface has a dull appearance, the markings of woods with good figures are effectively brought out by this treatment.

Painting—For exposed woodwork of buildings, and garden, verandah and bath room furniture, painting is usually recommended in preference to other finishing methods. The paint film covers the surface completely and prevents water or moisture from penetrating into the wood and causing decay. Oil paints, varnish paints, enamel paints, etc., are applied by brush. Nitro-cellulose paints are applied by spraying.

Packing Cases and Cooperage

The manufacture of packing cases required for packing tea, coffee, tobacco, rubber, etc, received a great impetus during World War II. The timber required for packing cases should have the following properties: lightness, ease of working, non-liability to split when nails are driven into the wood, and freedom from shrinkage and warping. The timber should preferably have a whitish colour and should be easily available at low price. For packing tea, butter and other foodstuffs, the wood should be free from objectionable odours.

The lighter timbers such as simul (*Bombax malabaricum*), salai (*Boswellia serrata*), and mango (*Mangifera indica*) are employed for packing cases. Other common packing case woods are listed in Table 1. Imported deal wood is also used.

Considerable work has been carried out at the Forest Research Institute, Dehra Dun, on the improvement of designs for packing cases The following improvements have been suggested: (1) the use of ¾ in. thick battens at the ends instead of ½ in battens, (2) the use of more nails in the end battens than in the end planks in fixing sides to ends, (3) the use of larger and thicker nails (2¼ in long for ¾ in. planks), and (4) the use of hard wood battens for the ends (Limaye, *Indian For. Bull.*, No. 117, 1943)

The manufacture of tea boxes is a specialized industry for which 3-ply wood of standard 3/16 in. is used. It is strong, light, and cheap.

TABLE 2.— PRODUCTION OF PLYWOOD TEA CHESTS*

	Number		Number
1941	750,000	1946	1,000,000
1942	900,000	1947	1,600,000
1943	1,400,000	1948	2,500,000
1944	2,200,000	1949	2,000,000
1945	1,000,000		

* Plywood Manufacturers' Association of India.

Simul wood is extensively used for tea chests. Tea chests of good strength are made from hollock (*Terminalia myliocarpa*) and hollong (*Dipterocarpus* spp.).

The standard sizes of chests commonly used for packing tea are: (1) 19 in. ×19 in.×24 in.; (2) 19 in.×19 in.×22 in ; (3) 18 in.×18 in ×20 in ; (4) 17 in.×17 in.×19 in.; (5) 16 in ×16 in.×20 in ; and (6) 16 in.×16 in.×18 in. The total installed capacity of plywood factories in India manufacturing tea chests is estimated at 4 million per annum, but the actual production is much less (Information from Central Tea Board) Table 2 gives the total estimated production of plywood chests in India since 1941.

The manufacture of tea chest battens is a sizable industry. Prior to 1942, these were obtained from Sweden and Canada. Indigenous production was started in 1942. It is estimated that about 20,000 tons of wood are consumed in the industry. The chief wood used is fir and the yearly consumption of tea chest battens is about 55 lakh sets.

The Defence Department uses a large number of packing cases for which specifications have been framed by the Technical Development Establishment Stores Their internal dimensions range from 12 in.×6 in.×3 in. to 54 in.×18 in.×12 in

Cooperage comprises the manufacture of barrels, casks, tubes, drums, and other containers for holding liquids and dry goods Tight cooperage is required for liquids such as oils, beer and wine, and loose or slack cooperage for dry goods such as cement, flour, salt, lime, and rosin.

For tight cooperage, the wood should be strong, durable, non-shrinking, and impermeable to liquids. The wood should have straight grains and good fissibility. Also, it should not contain substances which may contaminate the contents of the barrel and impart to them any undesirable taste, odour, or colour. For loose cooperage, impermeability is not important, but the timber should have all other qualities specified for tight cooperage. Light weight and easy availability at a price which would enable the containers to compete with other forms of packing materials, e.g, sacks, paper and cloth bags, wooden boxes,

Fig. 5.—**Barrel making in Travancore**

and cartons, are other considerations in the choice of timber.

Oak (*Quercus* spp.) is the cooperage timber used in Europe and U.S.A. for wine casks. Chestnut is used for inferior barrels. Several woods have been tried by breweries in India, and *Grewia tiliaefolia, G. vestita, Ougeinia dalbergioides,* and *Quercus dilata* (Moru oak) are considered suitable (Table I). Teak is a good barrel wood where its odour is not objectionable.

Casks and barrels are made by binding together wooden side staves and end pieces by hoops. The staves are prepared by splitting wood radially as such sections show less shrinkage and, consequently, less leakage, than tangentially split wood. The split staves are shaped and bent to the required curve, the finished stave being thinner and narrower at the ends with a broad and thick centre to allow for the bulging. Side staves vary in length according to size and use to which the container is put. Hogshead staves are over 4 ft. in length, while the usual wine barrel staves are about $3\frac{1}{8}$ ft. to $3\frac{1}{8}$ ft. long. The breadth and thickness of staves also vary considerably according to the size of the container, but even in the same barrel, staves of widths varying from 2 to 4 in. may be found.

The head pieces are usually flat, but in large casks they are curved inwards to withstand the pressure of the contents. The hoops are of iron, except in the case of light containers for transitional use which are bound with split strips of elm, ash, and birch, or rough coppiced shoots of willow and hazel. For high grade tight barrels, the head pieces are dowelled to ensure a tight joint, while in loose cooperage the boards of the head pieces are joined with a plain butt joint similar to those in side staves.

Barrels required for goods like sugar and salt are made of one sheet of wood peeled from a log on a rotary peeling machine. Such barrels or drums are useful in small sizes; they are light but not strong (Trotter, 1940, 163).

During World War II, plywood containers, both cylindrical and rectangular, were being manufactured in India. Round drums are cylinders of plywood wound round 2 thick discs of ply— or solid wood forming the top and the bottom. In the larger sizes, iron or plywood bands are fixed round the cylinder at the top and bottom to give extra strength. The containers are suitable for packing moist or dry goods which do not affect wood and are not affected by the stain and odour of the wood. A sheet of 3-ply wood of the right size is prepared with an over-lapping sloping joint on both the edges to be joined and bent into cylindrical form, the two edges being cemented together in male and female mould presses. The ends of the cylinder are cut and levelled. The tops and bottoms are fixed to the inside wall with casein glue, and bolts and nuts fixed through the cylinder; at the same time the fixture is reinforced by iron bands fitted outside, and nailed before the glue sets. The top is provided with an opening, and fitted with a solid wooden stopper, a metal strip for locking, and a leather washer. A great variety of inner coatings have been suggested to make the containers leak-proof so that they can be used for liquids (Muhammad, *Indian For Leafl.,* No. 24, 1942).

A rectangular plywood container was designed by the Forest Research Institute, Dehra Dun. The four sides are made of ordinary 3-ply wood sheets, joined together by bent plywood corner pieces, rivets being used for fastening the corner pieces to the side sheets. The corner pieces are made in a V-shaped iron mould. The inners are placed in the moulds after applying casein cement, and pressed into shape. The tops and bottoms are of 7-ply wood and fixed in the same way as in round drums (*Indian For. Leafl.,* No. 26, 1942).

Wood Turning

Woods for turnery work may be divided into two classes—those used for domestic utensils such as milk jars, cups, bowls, etc., and those used for ornamental turnery such as legs for furniture and candlesticks. The articles belonging to the former class are made from selected pale-coloured or white woods. Finer articles are made from coloured and ornamental woods. The lathe used

is simple and inexpensive. It consists of two wooden pegs sunk into the ground, about 3 ft apart, through the pegs pass two iron spikes (centres) on which the timber to be turned is revolved by a piece of cord The wood revolves backwards and forwards, and during the latter motion, the skilled turner executes his work

By-products

The carpentry and woodwork industry produces a large amount of waste wood consisting of sawdust, shavings, and wood wool

Sawdust is used as fuel in special boiler furnaces. It does not burn easily as its mass smothers the fire due to insufficient air supply It is usually sprinkled into the boiler furnaces from above in small quantities at a time. Alternatively, the burning sawdust is kept in a state of forced ignition by suitable draught

Sawdust has been used for the manufacture of compressed boards The particles are held together by a binder and pressure applied to ensure rigidity By compounding with thermosetting resins fibre fillers, and dyes, structural boards can be obtained by compression moulding They have been used for cabinets. wall boards shoe lasts, hamper tops, coat hangers, toilet seats, plaques, etc The boards are used also for panelling and insulation Sawdust briquettes, made by compressing sawdust mixed with a suitable binder are used as fuel By using inflammable binders, briquettes which ignite readily are obtained They are used as fire-lighters

Sawdust is used as a packing material for small articles but for fragile goods such as glass and china, wood wool is preferred For litter, sawdust is superior to leaves or pine-needles as it absorbs liquids readily and is clean and healthy.

Sawdust is used for the production of cellulose, vinegar, alcohol, sugar, and oxalic acid, and in the preparation of explosives In forest nursery practice, it is spread between rows of seeds and of seedlings as a measure of protection against frost

Wood shavings are used as fuel and are particularly useful for kindling fire On account of their springiness, shavings are preferred to sawdust for litter. They are used as raw materials in many chemical industries, e g , for the production of cellulose, methyl alcohol, etc , and are preferred to sawdust as they do not 'pack' in the retorts

Wood wool is the name given to fine strips of wood shaved off from larger pieces by special machinery Waste wood is often used in its preparation Wood wool is light, clean, and elastic and serves as an ideal packing material for china and glass, and for fruits. It has been also used for stuffing mattresses.

A large part of the wood wool used in the Indian packaging industry is imported. The wool produced by the Wood Working Institute at Bareilly meets only a part of the requirements. Spruce (*Picea morinda*) is by far the best wood for wool as it is springy and odourless. Blue pine (*Pinus excelsa*) is considered to be the next best Wood wool from both these timbers is supplied to fruit orchards in the Punjab and Kumaon hills for packing peaches, apples, and apricots.

Imports and Exports

Table 3 gives the imports of furniture and cabinet-ware into India.

Table 4 gives the imports of tea chests into India

Out of the total imports in the quinquennium ending 1938-39, U K accounted for nearly 70%, there was no import from America In 1940-41, U S A supplied 72% of India's total imports. In 1946-47 and 1947-48, more than 90% of the imports were from U S A and in 1948-49, the share of U S A fell to about 60% and in 1949-50, to 8% Finland's share in 1949-50 was 56%

TABLE 3—IMPORTS OF FURNITURE AND CABINET-WARE

	Value (lakh Rs)
1934/35—1938/39(av)	13 20
1939/40—1943/44 (av)	4 13
1944-45	0 41
1945 46	3 19
1946-47	14 77
1947 48	21 14
1948-49	9 75
1949-50	13 81

TABLE 4—IMPORTS OF TEA CHESTS

	Value (lakh Rs.)
1934/35—1938/39 (av.)	62 72
1939/40—1943/44 (av.)	97 04
1944-45	190 41
1945-46	190 19
1946-47	138·62
1947-48	108·77
1948 49	188·77
1949-50	126 60

TABLE 5.—EXPORTS OF FURNITURE AND CABINET-WARE

	Value (lakh Rs)
1934/35—1938/39 (av.)	1 67
1939/40—1943/44 (av.)	1 62
1944-45	1 04
1945-46	2 40
1946-47	5 64
1947-48	9 37
1948-49	10 53
1949-50	10 10

Table 5 gives the exports of furniture and cabinetware from India.

CARPETS

Carpet is a thick fabric, commonly of wool, used for covering floors and stairs. It is usually composed of a woollen pile on a cotton base A pileless cotton fabric made mostly for the home market, Durri as it is called, is sometimes erroneously included under carpets The carpet industry is located mainly in north India

Carpet weaving in India dates back to the 15th century when carpets surpassing the Persian carpets in excellence were being produced by Indian artisans The industry, however, languished during the 17th and 18th centuries, and carpet manufacture was confined only to Kashmir in the early part of the 19th century In 1862 carpet weaving was introduced into a few jails in Punjab and other States Thus revived, the industry progressed satisfactorily till it suffered a set back again during the depression of 1930 and subsequent years. The Kashmir Government granted a subsidy in 1932 to rehabilitate the industry, and the subsidy was withdrawn in 1943 when the industry was well established

Uttar Pradesh.—The carpet industry is highly developed in many parts of U.P., particularly in Mirzapur, Bhadohi, Agra, Khamariah, Gopiganj, Madho Singh, Jaunpur, Jhansi, Shahjahanpur, Bareilly, Moradabad, Lucknow, and Kanpur. It is particularly well established in Mirzapur in which about 430 artisans are engaged in carpet weaving (*Rep. Marketing Wool and Hair, India,* 1946, Marketing Ser. No. 54, 34, Mukhtar, *Rep. Labour condition in Carpet Industry,* 1947, 6). There are 14 factories at Mirzapur and 11 at Bhadohi. The work is executed by master weavers who own looms and employ weavers. Mirzapur carpets are exported to the United Kingdom and the United States of America.

Kashmir—Carpet weaving is a well established industry in Kashmir. Before the depression of 1930, about 825 looms were at work, and carpets worth about Rs 26 lakhs were annually produced (Bhan, *Rep Economic Survey of Carpet Industry in Kashmir,* 1938, 10). There are now 7 factories in the State, all situated in Srinagar, and a fair number of independent workers in different parts of the city engaged in carpet manufacture. About 800 workers are engaged in the trade (Mukhtar, op. cit., 20).

Punjab—The industry is mainly located in Amritsar and Chheharatta There are seven factories employing in all 425 workers (Mukhtar, op cit., 33) In addition, there are a few independent producers.

Madras—Ellore, Wallajapet, and Masulipatam are the important centres of pile carpet manufacture in Madras Other centres are Salem and Vellore. Carpets manufactured by the *Ellore Pile Carpet Co-operative Weavers' Society* are mostly exported to foreign countries. About 1,50,000 sq yds or 6·7 lakh lb of carpets are manufactured in Madras State every year. (*India & Madras Presidency at a Glance,* 1st Ed, Pt III, 4)

Bihar—Carpet weaving is a cottage industry in Obra, Patna, and Sasaram

Hyderabad.—The carpets of Warangal made by cottage workers are well known all over India The Government has recently established a carpet weaving factory. During the last few years the number of looms has increased from 70 to 400 (*Indian Text. J.,* 1946, **57,** 260).

Gwalior—Gwalior is an important centre for the production of carpets of the cheaper quality. The State factory employs 310 workers (Mukhtar, op cit., 39)

Mysore—Once well known for carpets, the industry in Mysore is now mainly confined to the manufacture of druggets. There are two big and five small factories, and out of 250 looms, about 200 are distributed in Bangalore, and 50 in Yeswantpur, Kengeri, and Kolar (*Rep. Marketing Wool & Hair, India,* 34).

Bengal.—Only Asans are manufactured in Bengal on a cottage scale by weaving or felting. Carpets of Tibetan designs are produced at Kalimpong.

Jaipur, Bikaner, Baroda, Travancore, Porbunder, Rewa, and Indore are other prominent centres for carpet manufacture.

Raw Materials

Wool is the most important raw material in the carpet industry. It is an ideal surface for carpets as it can be spun to any thickness and dyed to any shade; also it retains its appearance and withstands reasonably hard wear In the manufacture of special qualities of carpets, wool is used in place of cotton for the warps and wefts of the base. Pulled wools are mostly used for ordinary carpets, while imported yarn is used for the more expensive types. The characteristics valued in the selection of carpet wools are springiness or resilience and colour.

Table 1 gives a list of carpet wools available in India.

The wool available locally is used for carpet manufacture in most centres Bikaner wool, particularly the Magra type, is considered to be one of the best for fine carpets and is in demand outside Bikaner In Kashmir and Punjab, imported Pashmina is used to a limited extent mainly for fine stitch. Carpet wool imported from Punjab, Madhya Pradesh, Rajputana, and Gwalior is used in U P Only inferior local wool is used in drugget manufacture.

The main carpet producing areas used an average of 3,794,000 lb. of wool per year for carpet weaving during the period 1937/38—1939/40. Of this, 54% was used in U.P., 18·4% in Madras, 15·5% in Mysore, and 11·8% in Punjab (*Brochure Marketing of Wool in India*, 1948, No. 2, 5). In addition, 64,000 lb. were used in Bengal, and 38,000 lb. in Bihar (*Rep. Marketing Wool & Hair, India*, 34).

Wool is sorted according to colour, staple, appearance, lustre, and fineness. In south India, grading is carried out in tanneries, the wools being sorted into light fawn, dark fawn, grey, black, and white. Limed wool is preferred for druggets owing to its cheapness; occasionally it is mixed with shorn wool up to 30% to give strength (*Rep Marketing Wool & Hair, India*, 67) The wool is washed thoroughly, dried in the sun, carded, and finally hand-spun; it is next dyed and washed when it is ready for the loom.

Vegetable dyes employed in carpet manufacture have now been replaced to a large extent by synthetic dyestuffs. Natural dyestuffs were used for Persian and old Indian carpets; for colour and beauty they are still unsurpassed.

TABLE 1.— INDIAN CARPET WOOLS*

Area	Types	Fineness	Staple length (in.)	Description
Bihar	Gorakhpur Dumbas, Local	Coarse	2—3	Dirty white to white coloured with 10—15% black and 5% grey
Bombay	Jonia (Palanpur)	Medium	3—5	White, yellow, coloured
	Nadiadi	Coarse	3—5	White and coloured
	Deccani .	Coarse	2	Black, white, and mixed
Baroda	Patanwali	Medium	2½—4½	90% white and yellow, 10% coloured
	Charothri	Coarse	3—4	White,and yellow, coloured
Cutch	Kutchi	Medium	3—5	95% white and yellow, 10% coloured
Punjab	Punjab Desi, Phari, Sotar, Munjal	Medium	3—4½	White and yellow
Madhya Pradesh	Deccani	Coarse	2½—4	60% grey and brown, black and 20% white
Himachal Pradesh	Hill type	Medium	3—6	White and coloured
Hyderabad	South Indian (a) Raichur, (b) Secundrabad	Coarse	1½—3½	80% black, grey, brown, 20% white
Madras	South Indian (a) Bellary, (b) Coimbatore	Coarse	2—4½	75% black, and grey, 25% white
Mysore	South Indian (a) Mysore (white), (b) Kolar (brown), (c) Davangere (grey)	Coarse	2—2½	75% black, brown, grey; and 25% white
Saurashtra	Jonia	Medium	3—5	75% white and yellow, 25% coloured
U P	Mewati, Bundelkhandi, and sub-Himalayan	Medium	3—7	75% white and 25% coloured
	Lower Gangetic	Coarse	2—3	
Rajasthan				
Bikaner	Magra	Coarse	5	Very white, white, and pale yellow
Jaisalmer	Bagri	Medium	3—4	White, pale yellow, yellow
Jaipur	Malpura, Shekhawati	,,	3—6	White, yellow, and coloured
Jodhpur	Marwar	,,	3—4	White, yellow, black and grey
Others	Rajputana, Beawar	,,	3—4	White, yellow, black, and grey
West Bengal	Bankura, Burdwan, and Murshidabad	Coarse	1½—2	Black, grey, white, and dark brown
Others	Carpet type	Coarse	1½—3	White and coloured

*Information from International Wool Secretariat.

The colours employed are, generally, light tones of pink, red, yellow, and blue, the sides being finished with darker shades.

Twisted cotton yarn is used for warp in all kinds of carpets, and for wefts in some carpets. In the manufacture of fine qualities of Persian carpets, cotton yarn is used for both warp and weft. It gives a lighter, better, and more compact foundation than wool. Twisted jute yarn is used as weft in carpets of inferior quality. Untwisted hemp yarn (2-ply), silk, and rayon are also sometimes used. Silk carpets are woven on silk warp and weft, the pile also being silk. These carpets are made only in Kashmir against orders. They have a brilliant sheen, but get soiled quickly, do not wear well like wool, and are less resilient than woollen carpets.

Carpet Weaving

Indian pile carpets are hand-made. The technique of weaving differs from that adopted for cotton textiles in that, besides weaving, the pile which gives the carpet its distinctive surface, has to be knotted. A vertical loom, consisting of two horizontal wooden rollers or beams between which the warp threads are stretched vertically, is employed. The beams rest on two upright posts, 6—7 ft. high, the space between them being the width of the carpet. The top roller (warp beam) holds the warp, and the bottom one (carpet beam), which is often placed in a trench dug below the ground level and fixed about one foot above the bottom of the trench, is used for rolling up the carpet as it is woven. The warp threads are tightened by turning the rollers in opposite directions. There are two threads in every warp, one in the front and one at the back. The loom is provided with a pair of horizontal poles fastened to the back and front threads of the warp by loops; each pole is fastened along its length to several bows which rest on a fixed beam, the string being fastened to the pole. There is a separate set of bows for each of the two threads. This device is meant for crossing the front and back threads of the warp for the insertion of the weft. Other appliances required are: a knife with a curved blade for cutting the pile ends, a heavy comb to beat the weft and the pile to give a compact texture, and a pair of scissors for trimming each row of pile after insertion.

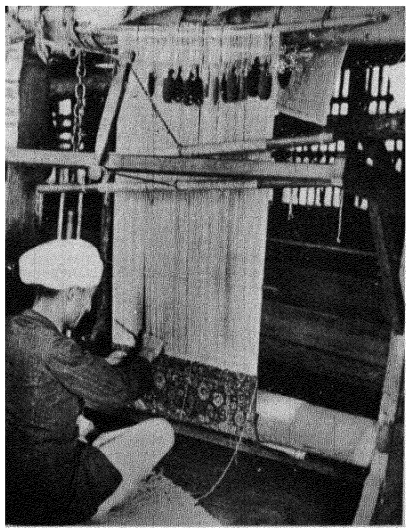


Fig. 6.—Carpet weaving

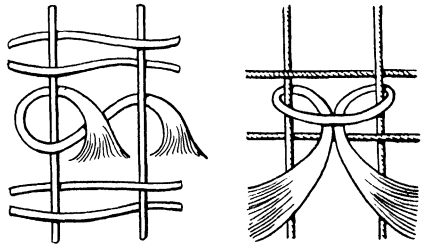


Fig. 7.—Carpet knots—(left) Senne; (right) Ghiordes

Dyed wool for the pile is hung overhead in the form of balls. The weaving commences when the weft threads are woven into the warp threads in the ordinary way making a border and fringe about 4—6 in. deep. A piece of wool is knotted round the warp threads, front and back, tuft by tuft. Usually the Persian or Senne knot in which the tufts of yarn come singly between each warp thread is used. Occasionally Turkish or Ghiordes knot is used in which the two ends of the pile yarn appear on the surface between adjacent warp threads passing around them. To put the Senne knot, a bit of wool is passed under the front thread, then over it from right to left, then passed underneath the corresponding back thread, then over it from

left to right, and finally the two ends are pulled at right angles to the warp, brought to the front, and cut to the required length of the pile This process is repeated for every warp with bits of coloured wool to conform to the pattern, until the row is completed When the first row is knotted, one or more weft threads are passed between the warp threads and pressed by a comb the teeth of which pass between the warp threads to give a close knit After each row of pile has been put in, the projecting ends are straightened by pulling and trimmed with scissors to the desired length Close trimming brings out more minutely the colour variations A second row of knots is put in, and the process continued till the whole carpet is completed Generally, stronger warp threads are employed on the sides for giving better support to the weft Sometimes, both warp and weft threads are dyed, either entirely or at the ends only, to give a coloured webbing to the finished piece A number of persons are engaged in the weaving simultaneously (generally one weaver for every 18 to 24 in of the carpet width)

After weaving, the carpet is spread on the ground for rubbing, brushing, and clipping to ensure that the pile is of uniform height A fortnight or a month is required, depending on the size, quality, and design, to complete one carpet

The pattern is drawn on a graph paper and is hung before the weaver to guide him in his work Simple patterns are woven from memory

The quality of a carpet is determined by the number of knots per sq in, which in turn is determined by the closeness of the warp threads, the number of weft threads thrown across after each row, and by the count of the threads The tighter and closer the knots, the more perpendicular will be the pile and the more durable, the carpet In coarse carpets, 4 or 5 weft threads are passed after each row of knots There is room for overlapping rows of yarn to untwist, thereby giving the carpet sheen and lustre Loosely woven long-piled carpets have more sheen than tightly woven short-piled carpets Also, the fewer and the lighter the weft threads are, the more flexible the carpet is Indian carpets woven at various centres range from a coarse quality containing 9 (3×3) knots, to fine quality containing 400 (20×20) knots to the sq in Some firms claim to make carpets with 3,000 (50×60) knots to the sq in

Indian carpets are highly artistic and are popular in foreign markets The expensive types are made in Srinagar, Amritsar, and Agra, while the more common bazaar qualities are made in Mirzapur, Gwalior, and a few other places The designs are generally copied from old Persian masterpieces, or are supplied by carpet dealers in Europe and America The latter are geometrical designs with good colour harmony In Kashmir, designs depicting landscapes in natural colours are in vogue Mirzapur carpets have characteristic medallations and floral designs depicting trees, leaves, and animals In Amritsar and at Agra, beautiful reproductions are made of famous old carpets exhibited in Vienna, South Kensington, and other museums

Trade

The prosperity of the Indian carpet industry depends largely on the extent of demand for the products in foreign markets About 90% of the superior grades of carpets are exported, and some of the bigger factories produce carpets only against orders from their agents in the United Kingdom and in the U S A Table 2 gives exports of woollen carpets and rugs from India

Exports from India increased from about Rs 25 lakhs, before the first World War to about Rs 80 lakhs soon after the War They declined during the depression of the thirties, but were revived soon after In 1937-38, India exported carpets valued at Rs 102 lakhs The United Kingdom and the U S A. were the chief customers till 1930, and each of these countries imported about 40% of India's production Canada, Australia, Japan, and Ceylon together accounted for nearly 10% During 1928-29 to 1938-39, exports to the United Kingdom were stimulated as a consequence of the Ottawa Agreement, and her share rose to 75%, while the share of U S A decreased to 10% The decline in export to the United States was due to the avail-

TABLE 2—EXPORTS OF CARPETS AND RUGS

	Qty (1,000 lb)	Value (lakh Rs)
1934/35—1938/39 (av)	9,869	88 0
1939/40—1943/44 (av)	5,017	59 2
1944-45	5,304	154 3
1945-46	10,011	233 0
1946-47	15,501	474 8
1947-48	10,035	322 5
1948-49	8,334	260 7
1949-50	10,324	329 1

A finished carpet

TABLE 3 —IMPORTS OF CARPETS AND FLOOR RUGS

	Qty. (1,000 lb)	Value (lakh Rs)
1934/35—1938/39 (av)	175 2	3 6
1939/40—1943/44 (av)	83 5	2 1
1944 45	2 7	0 1
1945-46	6 8	0 3
1946-47 . . .	77 2	4 0
1947 48 . . .	128 1	4 3
1948-49	243 2	11 6
1949-50	95 3	5 5

ability of machine-woven oriental carpets produced in that country and to the imposition of heavy tariff duties on imports

Exports again increased after World War II, the peak was reached in 1946-47 when India exported 15,501,398 lb of carpets and rugs valued at Rs 4,74,78,311 The main destinations were United States of America (25 6%), United Kingdom (22 1%), Canada (16 6%), and Australia (12 2%), the figures within brackets indicating the share in total exports More than 72% of the total exports from India in 1948-49 and c 78% in 1949-50 were to the United Kingdom

To encourage the export of carpets, the Cottage Industries Directorate of the Ministry of Industry and Supply arranges supplies at reasonable prices of wool, cotton, and dyes to carpet and drugget manufacturers It is proposed to establish regional dye houses in Madras, Mysore, U P , and Rajasthan with a view to raise the quality of goods, improve the designs, and provide a suitable inspection machinery before exports [*I & S. Bull*, 1949, **2**(4), 27]

Imports of carpets into India are negligible (Table 3) A small quantity is imported from the United Kingdom and Iran.

Imports of carpets are subject to a general revenue duty of 42% *ad valorem;* the duty on imports from U K is 30% *ad valorem.*

CARRIAGES, RAILWAY

The manufacture of railway carriages forms an important part of the work of the Indian railway workshops. The effective life of a timber body carriage is about 20 years, after which the maintenance costs rise so sharply that it is more economical to build the coach anew The railway workshops are mainly engaged in replacement work, and only a part of the resources is utilized for increasing the coaching stock. About 25,800 coaching vehicles were in service in March 1945, 21,000 vehicles were in service in the Indian Union in March 1949.

The construction of railway carriages in India was started in a few railway workshops in the early sixties of the 19th century, and by 1880 several railway workshops were equipped with plant and machinery for the production of carriages The early carriages were entirely of teak wood construction, and closely resembled those in service in England at that time. The typical four-wheeler, class III broad gauge carriage had outward opening doors, longitudinal or transverse seats with restricted dimensions in respect of hip width, depth and knee room, and seating accommodation for 40—60 passengers. The underframe was made of timber. The length varied from 20 to 30 ft and the tare was 3—15 tons Sunshades were provided to afford protection against sun In 1863, the Bombay, Baroda & Central India (B B & C.I) Railways introduced the double-deck class III carriage of unusual construction There were no benches on the upper deck due to dimensional limitations and the passengers had to squat on the floor

Bogie carriages were introduced at the beginning of the present century The doors opened inwards and the standard of amenities and comforts was improved The longitudinal seating arrangement was retained in the bogie stock The discarding of sunshades rendered possible the increase in body length to 70 ft with an overall width of 9½ ft and bogie centres 50 ft apart The adoption of the bogie increased the average weight of carriages from 9·76 tons (in 1885) to 36·8 tons (in 1908). The dead weight per seat increased in the same period from 0·16 ton to 0 306 ton

The continuous vacuum brake was introduced in 1900 Though compressed air brakes have now been introduced in U.S.A and Europe, the vacuum brake continues to be used in India on account of its comparative simplicity, and lower initial and maintenance costs Gas lighting was in wide use by 1900 and electric lighting was introduced on almost all the major railways by 1920. The adoption of fluorescent lighting is now under test.

Since the inception in 1929 of the Central Standards Office for Railways, the production of carriage bodies and underframes in railway and private workshops has followed a uniform pattern with attendant economies. Standard designs have been developed to promote to the maximum extent possible indigenous industries and the use of raw and finished products available from Indian sources.

There are at present 9 principal railway carriage workshops in India, viz, E I Railway workshops at Lillooah, Kanchrapara, and Lucknow, B B & C I Railway workshops at Ajmer and Parel (Bombay), G I P Railway workshop at Matunga (Bombay), B N Railway workshop at Kharagpur, M & S M Railway workshop at Perambur (Madras), and S I. Railway workshop at Golden Rock (Trichinopoly) The combined annual capacity of these workshops for the production of finished bogie carriages is about 500

Raw materials—The important raw materials required for the construction of carriages are timber and steel Timber for railway carriages and wagons should be sufficiently strong and durable, have good shock-resisting ability, should be reasonably free from seasoning defects, and should be available in sufficient quantities to ensure a continuous supply of not less than 500 tons per annum

Teak still holds the place of prime importance in the fabrication of body structures It has the outstanding men of retaining shape and is highly resistant to decay and insect attack It is receptive to decorative effects, such as carving, staining, and polishing It has a low coefficient of expansion and stands up in a surprising manner to the capricious changes of the Indian climate Experience has justified its use for carriage construction for nearly a century.

The chief difficulty in furthering the use of indigenous woods other than teak in carriage building, is apparently connected with inadequate supplies of properly seasoned timbers. Usually, the time between the felling of the tree and its arrival at the railway workshop is short, and the timber must be properly seasoned to render it serviceable The workshops, in many instances, cannot afford the space required for storing large stocks of raw and seasoned timbers The provision of kiln-seasoning plants would probably enable workshops to utilize larger proportions of indigenous woods other than teak.

Timbers other than teak used by railways for carriage work are

Pterocarpus dalbergioides—Panelling, casing boards, *Adina cordifolia*—Seats and casing boards; *Cedrus deodara*—Shutters, etc, *Dalbergia latifolia*—Furniture and flooring, *Acacia arabica*—Bolster beams, pillars, framing and floor boards. In addition to the above, the following timbers are used in fair quantities *Cedrela toona, Dipterocarpus* spp, *Lagerstroemia* spp, *Pinus longifolia* and *P excelsa, Pterocarpus marsupium, Terminalia tomentosa*, and *Xylia* spp Other timbers, recommended for various purposes in railway workshops are listed in Table 1 (Trotter, 1940, 149)

TABLE 1.—TIMBERS FOR RAILWAY CARRIAGES

Pillars, rails, cross-bars	Floor boards	Roof & ceiling boards	Partition boards	Panelling & decorative work	Doors & windows
Pterocarpus dalbergioides	*Dipterocarpus tuberculatus*	*Lagerstroemia hypoleuca*	*Lagerstroemia hypoleuca*	*Gmelina arborea*	*Lagerstroemia hypoleuca*
P macrocarpus	*D pilosus*	*L lanceolata*	*L flos-reginae*	*Adina cordifolia*	*L. flos reginae*
P. marsupium	*Hopea odorata*	*Terminalia procera*	*L lanceolata*	*Albizzia lebbek*	*Acacia arabica*
Albizzia lebbek	*H parviflora*	*Phoebe hamesiana*	*Pinus excelsa*	*Terminalia tomentosa*	*Gmelina arborea*
Lagerstroemia hypoleuca	*Terminalia tomentosa*	*Hopea odorata*	*P longifolia*	*T bialata*	*Pterocarpus dalbergioides*
L flos reginae		*H parviflora*	*Phoebe hamesiana*	*Pterocarpus dalbergioides*	*Dalbergia latifolia*
Dipterocarpus pilosus		*Gmelina arborea*	*Cedrus deodara*	*P. macrocarpus*	*D. sissoo*
Grewia tiliaefolia		*Adina cordifolia*	*Dipterocarpus tuberculatus*	*Dalbergia* spp.	*Chukrasia tabularis*
Anogeissus acuminata		*Calophyllum* spp.	*Hopea odorata*	*Pentace burmanica*	
Shorea assamica			*H. parviflora*	*Chukrasia tabularis*	
			Terminalia tomentosa		
			T bialata		
			Shorea assamica		
			Calophyllum spp.		

45,000 tons of indigenous woods were used in carriage and wagon shops in 1929-30. Out of this total, 31,000 tons (or 69%) were teak. In 1930-31, the figure for other indigenous timbers had risen to 50% of the total (Trotter, 1940, 147).

In addition to timber, a large variety of raw and finished materials, both indigenous and imported, is used in the construction of railway carriages. Among the indigenous materials used are: steel rolled sections and plates, wheels and axles, springs, buffing and draw gear, axle boxes, rubber fittings, and paints. The imported materials include train lighting equipment, batteries, glass, roof coverings, imitation leather for upholstery, and sanitary fittings.

The approximate quantities of raw materials required for building a standard broad gauge coach body (68 ft. long × 9 ft. 11 in. wide) are: timber logs, 30 tons; steel sections (including screws, bolts, etc.), 3—4 tons. The corresponding quantities for a standard metre gauge coach body (56 ft. 6 in. long. × 8 ft. 5 in. wide) are 20 tons and 2—3 tons respectively.

Underframe and *Body*.—The manufacture of steel underframes and bogies in India was started in the beginning of this century by Messrs. *Burn and Co.* and *Jessops and Co.* of Calcutta. Plant and machinery of *Peninsular Locomotives Co.* were acquired by Government in 1924, and subsequently by *Tata Engineering and Locomotive Co.* (Telco), and used for the construction of carriage underframes. Some of the underframes built by the Tatanagar factory over 30 years ago are still in service.

The timber body is fabricated either directly on the underframe or on the shop floor. Direct fabrication is generally favoured as it helps to maintain rigid joints. In the latter method, the body is jacked up after completion, the underframe placed in position, and the body lowered on the underframe.

The main sub-assemblies and components of a timber body carriage are: bottom framing, end framing, sides, bulk-heads, roof and ceiling, inside and outside panelling, and inside furnishing.

The cost of construction varies within wide limits depending on local conditions. A timber body takes about 15,000 man-hours for fabrication, and the present day cost of a Class III bogie carriage is approximately Rs. 80,000 of which the underframe and bogie account for about Rs. 25,000.

A small number of air-conditioned carriages built in railway workshops were placed on service nearly 15 years ago. They are fitted with ice-activated and electro-mechanical systems of air-conditioning.

The maintenance of carriages involves regular examination of vehicles while on run, and also thorough periodical overhaul and reconditioning. Carriages on mail and express services are overhauled at intervals of 6 and 9 months respectively, and those used less intensively are 'shopped' at intervals of 1—3 yrs. During periodical shopping, all gear subject to wear and tear is

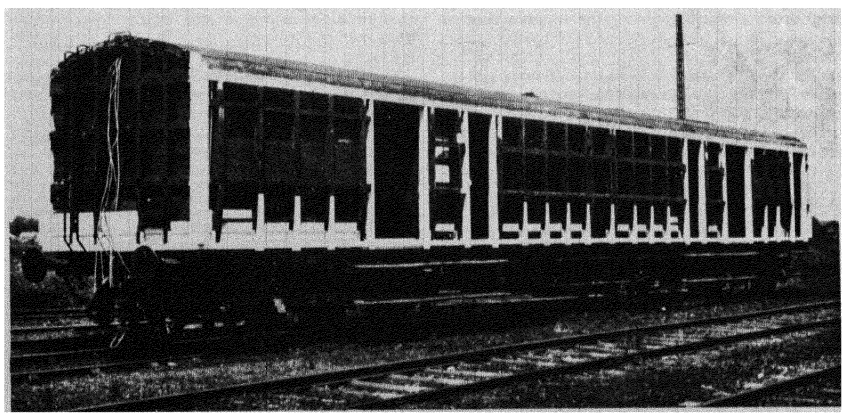


Fig. 8.—Superstructure of timber coach body

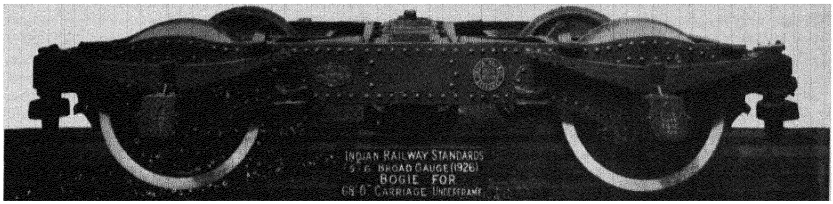


Fig. 9.—Bogie for carriage underframe

examined, and worn out components repaired or renewed. The interior furnishing is thoroughly overhauled and both the interior and exterior of the body fully or partially painted. Every 5 years the old paint is completely removed and all surfaces repainted. The time required for periodical overhaul in workshops varies from 10 to 22 days, divided between lighting, lifting, body repair, and paint shops. In certain cases, body repairs and painting account for 18 days out of the total of 22 days in the workshops.

All-steel Carriages

The construction of carriages was curtailed during World War II when the plant and machinery available in railway workshops were requisitioned for the production of war materials. Meanwhile, thousands of carriages had completed their normal span of 30 years' life and attained super-annuation. The *Hindustan Aircraft Ltd.*, which was started during the War for the maintenance of aircraft, took up the manufacture of all-steel Class III broad gauge carriage bodies on standard 68 ft. frames. The leading particulars of this type of coach are: length of body, 70 ft.; width of body, 10 ft.; seating capacity, 76; and tare weight, 40 tons.

The body structure is fabricated in mild steel sheets and pressings varying in thickness from 0·05 to 0·125 in. with cold closed rivets; about 70,000 rivets are used in each coach. Electric arc and fusion gas welding are used to a limited extent. Sub-assemblies are fabricated on jigs to facilitate interchangeability prior to final erection on the underframe to form a complete coach. The present output is four coaches per month, but the target is eight per month. Out of hundred coaches of this type ordered by the Railway Board, fifty had been delivered up to the end of Nov. 1949. Similar Class II coaches using the Class III shell are being planned. Tentative orders have also been placed with The *Hindustan Aircraft Ltd.*, for 100 all-metal class III broad gauge integral railway coaches.

Light-weight Carriages

The trend in recent years is towards the construction of light-weight carriages, which would result in operational economies and meet the demand for high speed operation. They are also adapted for the introduction of internal combustion engines. The increasing competition of road vehicles and airliners has necessitated high speed operation in railways both for short and long hauls, and light-weight carriages are indispensable for achieving the speeds required.

The basic materials for the construction of light-weight carriages are: low carbon copper-bearing steel; low alloy high tensile steel; stainless steels; and aluminium alloys. These materials can be cold-worked and effectively joined. Copper-bearing steel and high tensile steel are favoured on account of their low cost, resistance to corrosion, and good weldability. Stainless steel is used to some extent in U.S.A. The use of aluminium alloys is still in an experimental stage and no railway has yet built aluminium carriages.

The need for light-weight carriages has been keenly felt in India for some time past. Each ton of passenger train costs about Rs. 135 per year in coal, and on an average, about 15 tons of train are hauled for each ton of Class III passengers, and about 40 tons of train per ton of Class I passengers. The annual coal bill of the Indian railways is Rs. 22 crores. The saving in coal consumption possible from reduction in weight of the passenger carriage by about 20% would be enormous. To achieve this, reduction in weight even at about 20% greater cost would be justified.

In 1945, the Railway Board accepted the need for the introduction of all-metal light-weight carriages on broad gauge and metre gauge systems with improved amenity standards in Class III stock. Two experimental designs were prepared, one by the Central Standards Office embodying an all-welded construction, and the other

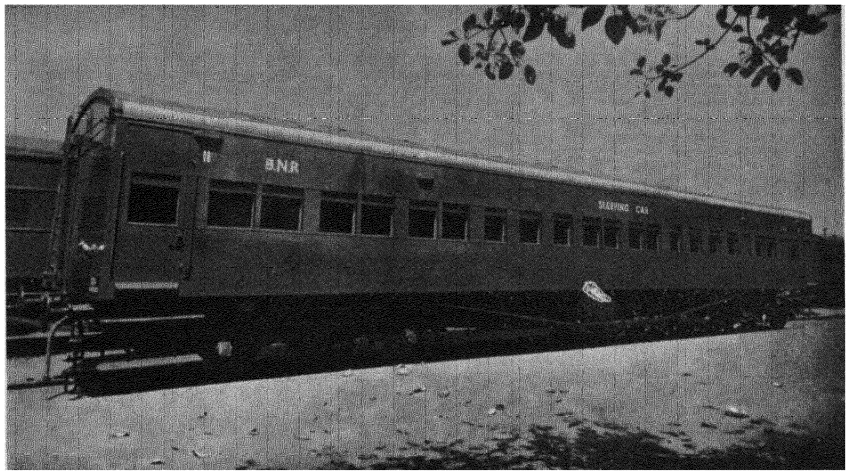


Fig. 10.—Railway sleeping car

by The *Hindustan Aircraft Ltd.*, featuring riveted-cum-welded construction. Two prototype coaches were built by *Braithwaites (India) Ltd.* Calcutta, and by The *Hindustan Aircraft Ltd.* for tests at the Railway Research Station Shakurbasti (Delhi). The experimental work and tests conducted have furnished useful technical data and proved the practicability of all-metal designs on Indian Railways.

The new designs of light-weight coaches which have been finalized, ensure maximum weight reduction consistent with strength and safety. The establishment of one or two factories in India for the mass production of such carriages to meet the requirements of railways is under examination.

The new carriage is of 'skin-stressed', tubular-girder construction and the body and underframe comprise an integral all-welded unit. Its trough type continuous underframe construction, which has been successfully employed in a few European countries, has made possible considerable reduction in weight. The anti-telescopic body ends, which can withstand sudden impacts of high intensity without suffering damage, ensure a measure of safety in accidents possessed by no other design hitherto tried in India. The body shell can withstand, without any of its numerous members showing signs of distress, a compression load of 200 tons applied at the centre line of the headstocks. The exterior of the coach presents a neat, sleek, and semi-streamlined appearance. The leading particulars of Indian light-weight all-metal Class III carriages are as follows: No. of seats, 80; weight of body, 21·5 tons; weight of bogie, 8·5 tons; tare, 30 tons; total length over buffers, 73 ft. 2 in.; bogie wheel base, 9 ft. 6 in.; floor height above rail-level, 4 ft. 3 in.; width of body, 10 ft. 8 in.; and weight per seat, 0·375 ton.

The bogies are of all-welded construction and feature self-aligning roller bearings mounted in cast steel axle boxes to take radial and axial loads in either direction, axle box guides working entirely in an oil bath, semi-elliptic springs with special leaf sections for self-lubrication, closed type pivots working in oil, and direct drive electric generators mounted on the bogie sole plates.

The new coach provides a high standard of amenities in Class III. The width and depth of seats, knee room, and the width of gangways have been increased. The transverse seating arrangement, electric fans, higher intensity of illumination, insulation against heat, wash basins and mirrors, and balanced glass windows, represent a considerable advance on the existing standards.

TABLE 2

	Existing coach	Light-weight coach
Seats:		
(a) Hip width	19½ in.	19½ in.
(b) Depth	18¾ in.	23 in.
(c) Knee room	19¼ in.	21 in.
(d) Seating arrangement	Longitudinal	Transverse
(e) Type	Plain	Contoured for comfort
Lighting; (foot candles/sq. ft. of floor area at 33 in. above floor level)	1·5	3
Fannage	Nil	1 (for 5 passengers)
Doors—clear opening	2 ft. 1 in.	2 ft. 3¾ in.
Glass windows	Plain with wood frame	Balanced windows with light-alloy frame
Insulation	None	Insulated

Table 2 summarizes the new scale of comforts compared with the existing schedule.

The light-weight class III coach weighs 30 tons as against 40 tons for the standard coach. But the operational economies made possible by the reduction in weight are partly vitiated by its lower carrying capacity of 80 compared with 96 passengers. The dead weight per seat for the new

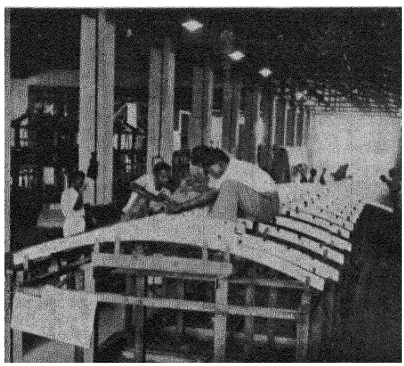


Fig. 11.—Fabrication of all-metal coach roof

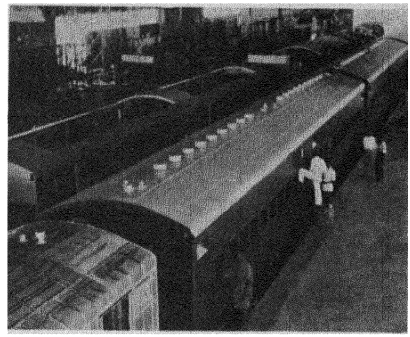


Fig. 12.—Finished all-metal coach

coach is, however, 10% less than that for the conventional coach. Less power will, therefore, be required to haul a train with identical capacity consisting of light-weight coaches.

Materials of indigenous origin will be used to the maximum possible extent. Of the 30 tons of materials required for the construction of a coach, 26 tons will be obtained from India's own resources. The following is a summary of different materials required for the new Class III coach:

	Tons
Steel plates, bars, etc.	20·05
Steel castings	0·40
Brass	0·20
Light alloys	1·20
Insulation	0·90
Timber	4·10
Train lighting equipment	2·00
Flooring composition, china, and miscellaneous fittings	1·15

Carriages, Tramway

Tramway carriages are built on old or imported bogie car trucks as and when required. The parts locally made are car bodies, underframes, and super-structures. Other requirements such as motors, controllers, circuit breakers, resistances, air brakes, peacock brakes, and trolley standards are imported. Some of the tramway companies have organized workshops for building carriages; others purchase their requirements.

The total annual consumption of wood in

tramway workshops at Calcutta is stated to be 128·5 tons of teak wood, 25 5 tons of English wood, and 2,288 tons of sal wood All the wood required for the cars and for sleepers of tramway lines are secured from sources outside West Bengal A small quantity of Jarrah wood (*Eucalyptus marginata* Sm) is imported from Australia In the wood working section of the Calcutta workshops, 136 carpenters are reported to be employed (*Rep Bengal Industrial Survey Committee*, 1947, 134) The total number of vehicles at present is 428 with a further 30 new vehicles ordered, while the number of vehicles in daily service is 333, comprising 300 first and second class tramcars for Calcutta and 30 cars for Howrah 50 cars are being built to a new design (*Industrial & Commercial India*, 1948-49, 278).

During the period December 1947 to August 1949, 29 double deck bogie tram cars were built by the *Bombay Electric Supply & Transport Undertaking* with trucks and electric equipment from scrapped single deck bogie tram cars The cost of each car fitted with air-brakes was c. Rs 35,000, the low cost was due to reuse of old equipment The cost of building a new double deck car with new trucks and electrical equipment is estimated at Rs 1,27,000 In addition to the above, 25 tram cars of standard dimensions were constructed on second-hand American single-deck bogie cars during the period July to November 1949

During the 3 years, 1947—1949, the *Madras Electric Tramways Ltd*, built annually 12 cars, the cost of a bogie tramcar being Rs 64,500 (body, Rs 17,000, equipment, Rs 37,000, air compresser, Rs 3,500, and one pair traction trucks, Rs. 7,000)

Imports of Carriages

Some parts required for carriages and railway coaches are imported from the United Kingdom The value of annual imports for the period 1934-35 to 1949-50 is given in Table 3

TABLE 3 — IMPORTS OF CARRIAGES
(In lakh Rs)

	Carriages & parts for railways	Tramcars	Total
1934/35-1938/39 (av.)	67 12	09	67 21
1939/40-1943/44 (av)	31 06	.	31 06
1944-45	49 50	..	49 50
1945-46	201 57	1 53	203 10
1946-47	305 97	..	305 97
1947-48	41 32		41·32
1948-49	52 26		52 26
1949-50	101 78	7 00	108 78

CARTS

The term cart is applied to all two-wheeled vehicles drawn by animals or human beings, and used in farming and transport It also includes wheeled carriages drawn by horses, mules, camels, or donkeys

Carts may be classified as horse-drawn, bullock-drawn, and man-drawn Horse-drawn vehicles are found in all the countries of the world In countries where there are few horses and fewer motor cars, bullock-drawn vehicles are widely used for transporting goods Man-drawn vehicles include hand-carts, delivery vans, wheel barrows, and rickshaws.

Horse-drawn carriages such as victorias, hackney carriages, tongas, and ekkas are found in cities and towns In south India, the bullock cart used for conveying persons is drawn by a single bullock The framework is mounted on springs and the wheels are fitted with solid rubber tyres Rickshaws—both man-drawn and cycle-drawn—offer another mode of conveyance in cities

Bullock Carts

Bullock carts form the bulk of animal driven vehicles in India. Buffaloes also are sometimes used for drawing carts, camels are employed for draught purposes in some parts of north India These carts are used on rural roads Less than one-third of the total roads in India is metalled, and only 16% of the mileage of metalled roads is properly surfaced for motor traffic Bullock carts provide the only means available for transporting agricultural produce from rural areas to marketing centres In fact, every ton of agricultural produce must be transported by cart in the first stage of the journey irrespective of the ultimate destination or the type of transport used in the end stage The cart is used also for transporting water, manure, etc, essential for agricultural operations

Bullock carts possess several features which have rendered their use popular These are low capital and maintenance costs, economy in running over distances up to 7 miles, lower loading lines, and suitability for transporting fragile loads These advantages are even more evident when rubber tyres are used for the wheels [Mernagh, *Rubber Developments*, 1949, 2(2), 21]

The more common bullock cart consists of a framework mounted on wooden wheels with steel tyres The hubs rotate on axle-trees and

are secured by linch pins. The axle is usually attached to the under surface of the spars

Raw materials—The different parts of a cart are subject to varying stresses and strains, and a selection of woods suitable for each part is necessary for ensuring working efficiency In actual practice, however, country carts are built from whatever wood is available irrespective of its suitability

A tough wood is essential for the framework The axle should be made of tough and hard wood Different woods are required for making the components of the wheel Thus hubs are subject to great stresses, and the wood used should be hard enough to prevent the spokes from working loose in the mortises in which they are inserted in the nave Straight-grained, strong, and elastic timber is necessary for the spokes The wood should be free from defects and should not warp or shrink The felloes are required to withstand crushing loads, and as they are subject to frequent wetting and drying, the wood required should be hard, strong, elastic, and durable. Naturally curved or steam-bent timber is best suited for felloes The grain should follow the line of the circumference of the wheel as nearly as possible In some parts of India, more especially in Madras, Bengal, and Bombay, solid wheels made of one piece of wood or of three pieces held together by iron tyres are common

Shafts and poles are made of split wood, but in carts intended solely for transporting goods, they are made of solid timber in the round The wood required for this purpose should be tough, elastic, straight-grained, and strong Bamboos are commonly used for buggy shafts, and split wood is also popular The woods suitable for the various parts of carts are listed in Table 1

Types—The styles of construction of bullock carts and their load capacities vary according to local conditions Wide variations in the dimensions of wheels are noticeable in different parts of the country The wheels differ as regards their diameter, thickness of rim, nature of tyre, number and dimensions of spokes, type and size of axle, and the nature of the hub Body designs and lengths of chassis also vary In hilly tracts, the maximum load permitted is half a ton while in flat regions the load may be up to 2½ tons Sketches for about 660 wheel types and carts have been collected by the Indian Roads Congress

The two common types of two-wheeled bullock carts are the Spoke type and the Arm type About 75% of the carts are fitted with spoke type wheels and the rest with arm type wheels The spoke type is common in tracts having metalled roads which can suffer a narrow tyre The wheels of four-wheeled carts are generally of the spoke type, and are tyred by a narrow steel strip The arm types with broad wooden tyred wheels, preponderate in alluvial and sandy tracts. They are heavy, require more tractive effort, and are more expensive to maintain Table 2 summarizes the characteristics of the two types of wheels [Vagh, *J Indian Roads Congr*, 1945, **9** (4), 49]

Both types of wheels employ hand-made axles and bearings The bearings are made of mild steel, and wear off quickly causing them to become slack and to wobble There is no provision

TABLE 1*

Part of the cart	Characteristics of the wood	Wood recommended or used
Framework	Tough	*Dipterocarpus* spp., *Dysoxylum malabaricum*, *Syzygium cumini*, *Lagerstroemia* spp, *Ougeinia dalbergioides*, *Terminalia bialata*.
Axle	Very tough and hard	Same as for hub; also *Anogeissus latifolia*.
Wheel hubs	Hard and tough	*Acacia arabica*, *A catechu*, *Chloroxylon swietenia*, *Hardwickia binata*, *Heritiera minor*, *Hopea parviflora*, *Mesua ferrea*, *Ougeinia dalbergioides*, *Schleichera trijuga*, *Shorea robusta*.
Wheel spokes	Straight-grained, strong, and elastic	*Acacia arabica*, *Anogeissus latifolia*, *Dalbergia sissoo*, *D. latifolia*, *Diospyros* spp., *Grewia tiliaefolia*, *Hardwickia binata*, *Heritiera minor*, *Shorea robusta*.
Wheel felloes	Hard, strong, elastic, and durable	*Acacia arabica*, *Dalbergia sissoo*, *D. latifolia*, *Grewia tiliaefolia*.,
Shafts and poles	Tough, elastic, straight-grained, and strong	*Anogeissus* spp., Bamboo, *Cassia glauca*, *Grewia* spp, *Thespesia populnea*.

* Trotter, 200

TABLE 2.—PARTICULARS OF CART WHEELS

	Spoke type	Arm type
Total number (lakhs)	130	43
Pre-war cost of construction* (Rs.)	15—35	15—35
Pre-war maintenance cost* (Rs.)	1 5—2 0	2·3—4 0
Average life (years)	15—20	(a) 4—5 (b) 10—15
Wheel diameter (inches)	42—66	42—60
Weight of each wheel (lb.)	140—260	200—275
Intensity of load (lb. per inch width of tyre)	500—800	500—800

*Per wheel (a) Wooden tyre (b) Steel tyre

TABLE 3.—NUMBER OF BULLOCK CARTS IN INDIA
(in thousands)

1919-20	5,976
1924-25	6,810
1930	7,809
1935	8,197
1940	8,716
1945	8,443*

* relates to Indian Union

TABLE 4.—BULLOCK CARTS

Number	87,16,000 (6% urban, 94% rural).
Capital invested	Rs. 261 crores (at Rs. 100 per cart and Rs. 200 for a pair of bullocks).
Load capacity	45,00,000 tons (at 0 75 ton each for urban carts, and 0 50 ton each for rural carts)*
Miles travelled per annum	59,300 lakhs (at 3,500 miles for urban and 500 miles for rural carts)

An urban cart handles about 11 times as much tonnage as a rural cart (Vesugar, *Proc. Indian Roads Congr.*, 1943, **8**, 185).

for proper lubrication.

Table 3 gives the total number of bullock carts in India (*Basic Road Statistics of India*, 1948-1949, 30).

Bullock carts handle about the same tonnage of goods as Indian railways. In numbers, capital invested, load carried, and miles travelled, carts play a considerably more important part in the country's economy than motor lorries (Vagh, loc. cit.).

Table 4 incorporates a few data relating to bullock carts in India (Vagh, loc. cit).

Improvements.—The requirements of a wheel for road service are. (1) ability to move with the least tractive effort, and (2) ability to meet normal conditions for transport with the least damage to road surface As the normal bullock cart wheel does not satisfy these requirements, improved designs have been suggested and tested Wheels with (1) hand-made axle and mild steel bearings, and (2) lathe-turned axles and cast iron bearings and fixtures for flexibility and self-alignment, were tested for tractive effort as well as for damage to various types of road surface—cement-concrete, W. B Macadam, earth road, and field track—with a view to laying down standards for various parts of the country [Vagh, *J. Indian Roads Congr*, 1949, **13**(2), 181]

It has been suggested that as a first measure the wheels now in use may be modified by reducing their diameter and increasing the tyre width Keeping the tractive effort and weight and construction of the wheel the same as those of the present ones, the tests have revealed that:

(1) in place of the present rural spoke type wheels ranging in diameter from 42 in to 48 in. × 2 in. wide, a 36 in. × 3½ in. wheel may be employed;

(2) in place of the urban spoke type wheels ranging in diameter from 54 in to 66 in × 2 in. tyre, a 48 in. × 4 in wheel may be employed, and

(3) in the case of arm type wheels, a wheel with a tyre width of 4½ in.—5 in and a wheel diameter of 36 in —48 in according to the weight of wheels may be employed. The proposed wheels will have a steel tyre on the full width of the felloe so that the latter will not wear out

It has also been suggested that after the first stage of development, the existing axles and bearings should be replaced by lathe-turned axles and cast iron bearings which will further reduce the tractive effort and thus prolong the life of bullocks and the useful period of their service. Also, fixtures for flexibility and self-alignment may be provided in the interest of roads. A new light wooden hub has been designed, which can be employed with either hand-made axles and M S. bearings or with lathe-turned axles and cast iron bearings.

Bullock carts are now being fitted with pneumatic tyres. The tyred wheel is fixed at both ends of the hub and is, therefore, properly positioned. The bearing is durable and provision is

made for lubrication Due to the greater area of contact between the road and the tyre, and consequent lower load per sq in. on the road surface, damage to roads is minimized, and economy in the making and maintenance of roads is rendered possible The Central P W D. has estimated that the destructive effect of steel-tyred carts on roads amounts to Rs. 228 per year per mile (Roberts & Kartar Singh, 110). Pneumatic tyred vehicles move 15—20% faster than iron tyred vehicles An animal normally draws half its own weight of load when harnessed to a steel-tyred vehicle, while with a vehicle provided with pneumatic tyres, it can draw twice the load. Carts fitted with pneumatic tyres are able to carry 55 mds. of sugarcane, as against 25 mds by ordinary carts, and Pusa pattern carts fitted with pneumatic tyres are now used by sugar mills all over the country Refuse carts maintained by municipal corporations and municipalities are now provided with pneumatic tyres; a single bullock is sufficient to pull the cart while with the older types, a pair of bullocks had to be harnessed Though the initial outlay on pneumatic tyres is high, their use is economical in the long run as the maintenance costs on tyres and vehicles are reduced. Twelve thousand sets of bullock cart pneumatic tyres were in use in India in 1936, and the number increased to 20,000 in 1939 (Mernagh, loc cit.)

The pneumatic tyres used for carts are designated A.D.V. (Animal-drawn vehicle), H D V. (Horse-drawn vehicle), S M V (Slow-moving vehicle), and land tyres The tyres are divided into two categories—low pressure tyres for farm work, and high pressure tyres for roads. A low pressure tyre has a load capacity up to 30 cwt., and operates at 70 lb inflation The manufacturers supply wheels, bearings (plain, ball or roller), axles, and brakes The use of hubs with ball bearings and of steel in the construction of the upper part of the cart are other improvements which are likely to stabilize the bullock cart as an integral part of India's agricultural economy.

Tongas.—The total number of tongas in the country has been estimated at about 3½ lakhs [Vagh, *J. Indian Roads Congr*, 1948, **12** (4), 10] These vehicles are in use only in urban areas. The tonga wheel consists of a lathe-turned axle and a machine finished cast iron bearing ¼ in thick. Lubrication is effected by fixing a grease cup at one end of the axle and a grease pocket at the other. The wheel is fixed at one end of the hub between a ¼ in. steel plate and a projection on the bearing. Both the bearing and the steel plate are fixed to the hub, the former with a lug and the latter with bolts. A variant of the tonga is the Jutka, also a horse-drawn vehicle found in south Indian towns

G C F. carts.—The following types of carts are manufactured in the *Gun Carriage Factory*, Jubbulpore.

(1) Ambulance—light, horse-drawn,
(2) Hand,
(3) Bullock-drawn,
(4) Water tank; and
(5) Transport.

The first 3 types are mostly of wood construction, only the axle-tree and fittings are of metal. The other two types are made almost entirely of steel, only the draught pole, driver seat, and spokes and felloes of wheels being made of wood

The water tank cart is designed to carry 118 gal. of water The tank is supported on saddle bands fitted to the intermediate cross-rails of the body frame Provision is made for the filling equipment consisting of an adapter pump, delivery hose, a chamber for clarifying powder, filter for clarification, cylinder, differential pump, and strainer hose The body consists of the axle-tree, gear brake, frame, draught hook, and props. Other parts are the draught poles, swingletree, and wheels

The body of the transport cart is built of angle steel and cross strips forming the bottom and the sides The summer is made of two angles riveted together A transom strengthened by gusset plates in the corners is riveted to the stay angle sight sides, this supports the body on the axle-tree to which the side plates are attached by a band and two bolts with nuts The transport cart is drawn by two mules and its tare weight with draft fittings is 6¼ cwt

Gun Carriages.—The principal raw materials required in the manufacture of gun carriages are nickel or carbon steels (supplied by The *Metal and Steel Factory*, Ishapore, and The *Tata Iron & Steel Co Ltd*), gun metal bars for non-ferrous items (cast in the *G C F. Factory*), and extruded non-ferrous metal bars (supplied by the *Ordnance Factory*, Katni)

Carriages for howitzers together with their trailers, carriages for light and heavy anti-tank guns, and carriages for medium and heavy anti-aircraft guns, etc., are the items manufactured and repaired at the *Gun Carriage Factory*, Jubbulpore The carriages are built in two portions, —super-structure and basic structure. The super-structure provides for the movement of the gun in action—recoil and run out, elevation and depression, and top traverse. The parts permit-

TABLE 5—IMPORTS OF CARTS AND CARRIAGES
(Value in lakh Rs.)

	Carriages & carts,	Parts of carriages & carts (excluding rubber tyres)	Total
1934/35-1938/39(av)	3 06	5 91	8 97
1939/40-1943/44(av)	1 55	2 51	4 06
1944-45	2 18	2 85	5 03
1945-46	3 47	6 98	10 45
1946 47	13 96	8 64	22 60
1947-48	5 32	5 85	11 17
1948 49	5 17	12 15	17 32
1949 50	9 84	17 81	27 65

ting these movements are the cradle, the carriage body, and the saddle.

The basic structure provides a steady support for the gun in action and for transporting the gun from place to place The parts of the structure which perform these functions are the trail, the axle-tree, and the wheels The trailer, consisting of the ammunition box, under-carriage, axle-tree, springs, perch, prop, wheels and brake, is designed to carry ammunition and stores

Approximately 1,000 skilled and semi-skilled workers, and 300 unskilled workers are normally engaged in the manufacture of carriages at the *Gun Carriage Factory,* Jubbulpore

Trade.—Table 5 gives the value of annual imports of carts and carriages (not mechanically propelled) into India.

CELLULOID

Celluloid represents one of the successful efforts of the chemist to produce synthetic substitutes for natural materials used in industry A process for its commercial production was worked out by the Hyatt brothers in the United States in 1868.

Raw materials—The raw materials required for the manufacture of celluloid are cotton linters or wood cellulose, nitric acid, sulphuric acid, ethyl alcohol or other solvent, camphor or other plasticizer, and pigments. The most important of these is cellulose from cotton linters More recently, refined wood pulp has been employed. The principal source of cotton linters is U.S.A., and the material is available either as raw linters or as standard purified product (Chemical Cotton). The production and standardization of Indian cotton linters for use in plastics are engaging the attention of the Indian Central Cotton Committee.

Manufacture.—The manufacture of celluloid may be conveniently divided into 3 stages, viz., preparation of nitrocellulose, plasticization of nitrocellulose with camphor, and the working of raw celluloid into finished articles

Preparation of Nitrocellulose.—Cotton linters are purified, bleached, and graded They are then treated under controlled conditions in a nitrating bath containing 58—60% sulphuric acid and 20—23% nitric acid (Thorpe, II, 443) The proportion of water to acids in the bath determines the degree of nitration of cellulose This is expressed in terms of per cent nitrogen and the percentage considered best for celluloid manufacture is 10 7—11·1 Commercial nitrocellulose, also called Nitrocotton is graded on the basis of nitrogen content or viscosity. In recent years, processes have been worked out for the production of stable nitrocellulose by vapour-phase nitration in which esterification of cellulose is accomplished by treatment with nitric acid vapour under reduced pressure (*Rep. Progr. appl Chem*, 1946, **31**, 390)

In the mechanical nitration process, now universally employed, cotton linters are stirred into the acid mixture in stainless steel vessels (nitrators or dippers) under controlled temperature The nitrated product is discharged into centrifuges and the nitrating acid spun out The fibrous cake obtained is stirred up with water and then boiled in a vat and thoroughly washed with water The boiling process reduces the acid content of the pulp to about 0 1% The product is bleached with hypochlorite solution and excess moisture removed by centrifuging. The wet fibrous cake thus obtained is treated with ethanol to reduce the moisture content. The alcohol is percolated through the cake, either in hydraulically operated filter presses or in centrifuges

Nitrocellulose produced in this manner retains the original fibrous structure and is safe to handle Two grades are in use for the production of plastics, celluloid cotton, containing about 10·8% N, and collodion cotton, containing 11·9—12·2% N The first grade is soluble in an alcoholic solution of camphor, while collodion cotton is soluble in ether-alcohol mixtures

Preparation of Celluloid—The plasticization of nitrocellulose is invariably carried out with camphor. Celluloid is in fact a nitrocellulose-camphor compound The flexibility, hardness, water and weather resistance, inflammability, and other properties of the plastic, can be varied

between wide limits by modifying the amount of plasticizer employed

For the manufacture of the flexible nitrocellulose film bases, the nitration is controlled to give a product with 11 5–12·2% N (Thorpe, II, 447). The product should have a medium viscosity and it should be colourless. The nitrated product is centrifuged, washed with dilute alkaline carbonate or bicarbonate to remove the last traces of acid, bleached, and thoroughly washed again It is formed into cakes and pressed, and stored wet till required for use.

The preparation of the plastic solution is relatively simple Dilute solutions of nitrocellulose, plasticizer, and solvent are prepared in mixers with suitable stirring gear, and suspended impurities are removed by filtration at pressures up to 100 lb /sq in A dough-like mass is obtained by reducing the proportion of solvent and working up in mixers of the Werner-Pfleiderer type. It is filtered under high pressure through wire gauze and cambric in hydraulic presses The plastic mass emerges from the filter in long rough cylindrical rods The volatile solvent present in the material is removed by repeated working on heated rolls when it emerges in the form of rough thick sheets or hides.

For the production of sheets, the hides are piled, trimmed to standard size (55 in ×22 in), and pressed in hydraulic presses under high pressure and temperature for several hours. Where decorative effects such as tortoise-shell or pearl are required, hides of varying colours are used according to a carefully worked out scheme to make up the block The finished rectangular block (usually 55 in ×22 in ×6 in.) is transferred to the slicing machine in which it is made to pass under a fixed inclined knife, and with each forward movement of the block a sheet of the required thickness is removed. The knife is automatically lowered at the end of each stroke ready to give the next cut, and on each cutting stroke a sheet is shaved from the block. The sliced sheets still contain a small amount of volatile solvent which is removed by hanging the sheets over seasoning stoves in which the temperature is controlled.

The sheet produced in this way bears on its surfaces the marks and irregularities of the cutting knife, and these are removed by subjecting it to heat and pressure between sheets of polished stainless steel or nickel, in a multiplatten press. Decorative or clear sheets varying from 5 mil. to 250 mil. or more in thickness are produced in this way. Thinner films such as those used in the photographic industry require special processing.

For the production of rods and tubes the material in the form of partially seasoned chips is fed into an extrusion machine which ejects it in the form of a rod or solid section, or round a mandrel to form tubular sections Tubes such as those required for barrels of fountain pens are produced from cut sheet by spiral winding

Powders for injection and compression-moulding are prepared from dried chips Commercial moulding powders are supplied in ground form of standard grain sizes.

Properties and Uses.—Untinted celluloid is a faint yellow, transparent, and tough colloid. The specific gravity varies, according to the camphor content, from 1·35 to 1 8 or more It is thermoplastic, softening at a temperature of 80° It can be moulded solid or hollow, sawn, turned, or drilled It is resistant to water, moderately strong acid solutions, weak alkalies in the cold, and practically all salt solutions It is softened by acetone, amyl acetate, and generally by carboxylic acid esters of low molecular weight, especially when mixed with alcohol

The industrial applications of celluloid include· (1) manufacture of articles of domestic use, such as knife handles, hair pins, spectacle frames, watch cases, buttons, pipes, mouth pieces, ash trays, and soap cases, (2) manufacture of fancy ware, such as brooches, bracelets, ear rings, imitation ivory products, handles for sticks and umbrellas, billiard balls, dolls and toys, (3) manufacture of emery discs, packing rings, tubes, valves, pistons, etc , (4) manufacture of varnishes for protecting metals from rust and oxidation, and waterproof fabrics, and (5) manufacture of cinematograph films

The Indian Industry

Cotton linters required for the manufacture of celluloid are available in India The production of linters before World War II was estimated at about 15,000 bales of 400 lb each (*Rep Panel on Paper, Pulp, Board & Chemical Industries*, 1946, 26) Sulphuric and nitric acids are available in sufficient quantities. Camphor has to be imported.

Trials have been carried out by The *Calcutta Celluloid Works Ltd* for the manufacture of celluloid sheets Actual production has not been started. Cellulose nitrate has been produced at the Cordite Factory, Aravankadu [*I. & S. Bull.*, 1949, 2(2), 19].

The first factory for manufacturing moulded celluloid articles was started in 1926 at Jessore (Eastern Pakistan). Other factories followed and

prior to World War II, moulded celluloid articles for domestic use, and a variety of luxury articles were being produced from raw celluloid sheets and rods imported from abroad.

Production & Trade —During the pre-War years, the 4 principal factories in Bengal produced annually goods worth Rs 1,62,500 (*Rep Bengal Industr Surv. Comm*, 1947, 128). The articles had a ready market in the country, a small quantity was exported to Burma, Straits Settlements, and South Africa. With the outbreak of World War II, imports of celluloid sheets stopped, and the production of moulded products was almost completely suspended

A large variety of celluloid goods were being imported from Japan and Germany before the War These included dolls, bangles, combs, films, spectacle frames, hair pins, tooth brushes, soap and powder boxes, stick and umbrella handles, mirror frames, cigarette cases, blotters, reeds (harmonium, organ, etc), razor handles, knife handles, clips, containers for toilet requisites, and other small items

The quantity and value of celluloid articles imported into India are not separately shown in published trade returns, they are recorded in import trade statistics according to the nature of the articles Thus celluloid cigarette holders are grouped under smokers' requisites of all kinds, celluloid toys, with toys of all kinds, and so on. From the figures supplied by the customs offices it was estimated that India imported annually more than Rs 160 lakhs worth of celluloid goods before the War (*Rep. Bengal Industr. Surv. Comm*, 1947, 128) The production in India hardly meets 2% of the internal demand for these goods

Table 1 gives the imports of articles of celluloid and like materials from U.K

TABLE 1*

	Buttons		Sheets, rods, tubes, etc.		Fancy goods
	Qty (gross)	Value (£)	Qty (cwt)	Value (£)	Value (£)
1942	1,024	325	298	5,839	411
1943	156	23	571	11,360	...
1944	17,880	3,775	94	2,313	...
1945	203,668	43,123	73	1,863	519
1946	108,453	23,015	259	6,517	19,343

* *Tr. U. K.*, 1946.

TABLE 2.-- IMPORTS OF RAW CINEMATOGRAPH FILM

	Qty. (Length in lakh ft.)
1934/35 1938/39 (av.)	676 3
1939/40 1943/44 (av)	821 5
1944 45	872 1
1945-46	808 9
946-47	1,286 2
1947-48	1,742 0
1948-49	1,564 2
1949-50	1,787.5

In addition to the above, considerable quantities of celluloid are imported in the form of raw cinematograph film. Cellulose nitrate base film is resistant to curling under high humidities, and its toughness enables reels to be run through the drive notches without breaking. Cellulose acetate base films are used only for certain special purposes, e.g, safety films and films for home use

Table 2 gives imports of raw cinematograph films into India.

A large amount of celluloid is also imported as photographic films and film packs, statistics for which are not available.

There is a good future for the celluloid industry in India The Panel on Plastics and Celluloid Industry recommended the setting up of one factory capable of manufacturing 50 million sq. ft of raw film of all types (motion picture, photographic, graphic art, and X-ray) per annum The Government of India has recently sought the cooperation of a Swiss group of manufacturers for the production of raw films in India The production capacity of the factory, which will be located in Mysore near Krishnarajasagara, is 19 million sq. ft of raw film per year.

CEMENT, PORTLAND

The term cement covers a wide variety of materials but in practice it is applied to structural cements used for building construction and other civil engineering purposes. The most important cement belonging to this class is Portland Cement, a fine grayish powder, formed by intimately mixing together calcareous and argillaceous and/or other silica, alumina, and iron oxide bearing materials, and roasting the mixture to form a clinker, The clinker is ground to a fine powder after adding a small amount of gypsum.

When cement is mixed with water, it sets to a hard mass of great strength. Mixed with sand

and aggregate, it forms cement concrete. Portland cement is superior to any other mortar material by virtue of its uniform composition and well defined properties In the form of cement concrete, it finds application in almost all kinds of construction work such as bridges, dams, buildings, roads, aerodrome runways, etc

Types of Cement—Several types of Portland cement are manufactured—normal or ordinary, rapid hardening, low heat, blast furnace, sulphate resistant, white, coloured, and sand cements Rapid hardening cement, also called high early strength cement, is a superior variety of cement, which attains its minimum strength more rapidly than normal or ordinary Portland cement Low heat Portland cement is characterized by its low heat of hydration and is of special value in the construction of dams Sulphate resistant cement is resistant to attack by chemical agents, especially sulphate solutions Portland blast furnace cement is obtained by mixing and grinding Portland cement clinker and granulated blast furnace slag This product has properties similar to those of Portland cement Sand cement is made by grinding together Portland cement clinker and special types of sand High alumina cement differs from Portland cement in having a long initial setting time, it has a high early strength and is specially resistant to the action of certain chemicals and fire

Ordinary Portland cement and rapid hardening cement are manufactured in India. Other types are not produced on a commercial scale

Indian Cement Industry

The first cement factory in India was started in Madras in 1904 by The *South India Industrials Ltd* It had a brief existence The manufacture of Portland cement on a large scale was started in 1914 by The *India Cement Co Ltd*, Porbandar (Kathiawar) World War I gave an impetus to the industry, and within the next two years, two more factories, one at Katni and the other at Lakheri (Bundi), commenced production The three factories, with a combined annual capacity of 0 85 lakh tons, supplied a considerable portion of India's requirements during the Great War.

Further expansion followed after the War due to the building boom, and seven new factories were erected during 1922—23 in Dwarka (Kathiawar), Japla (Bihar), Mehgaon (Jubbulpore, C.P.), Banmor (Gwalior), Wah (Punjab), Kymore (C P), and Shahbad (Hyderabad). These factories had a total annual installed capacity of 3 86 lakh tons. The three War-born factories had doubled their capacities and in 1924 there were altogether 10 factories with a total annual production capacity of 5·81 lakh tons

The demand for cement did not keep pace with the rising production, and the industry was faced with internal price cutting competition. Three of the new factories closed down, a few others incurred heavy losses. As a result of the recommendation of the Indian Tariff Board, the Government of India imposed a duty on imported cement in 1925 The Indian Cement Manufacturers' Association (I C M A) was established in 1926, and through its efforts the competition among producers was halted. The Concrete Association of India (C A I) came into being in 1927, and by providing free technical aid and advice it popularized the use of cement in the country The Cement Marketing Company of India Ltd (C M C I) was formed in 1930, and it took over the control of sale and distribution of cement from almost all the factories on the basis of an agreed system of quotas. These developments created favourable conditions for the expansion of the industry.

The demand for cement grew to such an extent that the member companies of the I C.M A found it necessary to establish two new factories—one at Madukarai (Coimbatore), and the other at Khalari (Bihar). The Madukarai factory came into production in 1935-36.

The quota system, although satisfactory in many respects, had certain limitations, especially as regards the economic distribution of cement, and it became evident that a complete co-ordination of manufacture and sale was essential in the interests of rationalization. A merger was brought about in 1936 and The Associated Cement Companies Ltd (A C C) took over the business and assets of all the companies then in operation, only The *Sone Valley Cement Co Ltd*, Japla, with a capacity of 1 5 lakh tons, keeping out of the merger The A C C was enabled to exercise almost complete control over production, sales, prices, and distribution of cement in the country By the end of 1936, the A C.C. had under its jurisdiction, 10 factories—3 in C P, 2 in Kathiawar, and 1 each in Gwalior, Bundi, Hyderabad, Punjab, and south India—with a combined capacity of over 9 lakh tons per year

A number of new factories were started from 1937 onwards—5 factories belonging to Dalmia group and located at Dalmianagar (Bihar), Shantinagar (Karachi), Dalmiapuram (Trichinopoly), Dandot (Punjab), and Dalmia Dadri (Jind), with a combined capacity of 5·5 lakh tons; one factory at Bezwada, and 4 factories belonging to the A.C.C. and located at Rohri (Sind), Surajpur (Patiala), Khalari (Bihar), and

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Mangalagiri (Madras) The A C.C factories at Mehgaon and Katni, in the meantime, having closed down, the production in that area was concentrated at the Kymore Works In 1939, an agreement was reached between the A.C C. and the Dalmia group, and the sale from all the factories was taken over by the C M C I

When World War II broke out, the Indian cement industry was well established and well organized The A C C had 12 factories, the Dalmia group had 5 factories, and there were 4 others, viz, The *Sone Valley Portland Cement Co Ltd* (Japla), The *Bhadravati Cement Factory*, (Bhadravati), The *Andhra Cement Co Ltd* (Bezwada), and The *Assam Bengal Cement Co Ltd* (Chhatak), (3 of the factories starting production in 1940 and 1941) During the War, The *Kalyanpur Lime & Cement Works, Ltd* was established, it started production at Banjari (Bihar) in May 1946. The total capacity of the factories at the end of the war was 26 15 lakh tons (A C C, 17 05, Dalmia group, 5 6, other factories, 3 5 lakh tons).

The A C C established a new factory at Jhinkpani (Chaibasa) in February 1947 With the partition of India in August 1947, 5 factories—those at Wah, Rohri, Karachi, Dandot, and Chhatak—went to Pakistan There were 18 factories in India with a total installed capacity of 21·15 lakh tons per year (A C C, 15 45, Dalmia group, 2 9, and other factories, 2 8 lakh tons) The total capital invested in the industry was Rs 25 8 crores The two major groups of producers—the A C C and the Dalmia group—separated themselves in March 1948.

A number of new factories and extensions to existing factories were planned in 1945 and an ambitious programme was drawn up to raise the yearly production to 6 million tons by 1952. The programme had to be revised considerably owing to the partition of India and the difficulties in securing adequate supplies of steel and other constructional materials.

Three new factories, viz., *India Cement Ltd*, Talaiyuthu (Tinnevelly), *Travancore Cement Ltd*, Kottayam, and *Shree Digvijay Cement Co.*, Seeka (Jamnagar), with a total rated capacity of 2 5 lakh tons per year have been recently established, and production started in June 1949. Extensions to a number of existing plants have been completed The total installed capacity of all the factories in Dec. 1949 was 28·15 lakh tons distributed as follows: A C C., 18 45; Dalmia group, 4 4; and other factories, 5 3 lakh tons. Table 1 gives the distribution of the installed capacity of the cement industry.

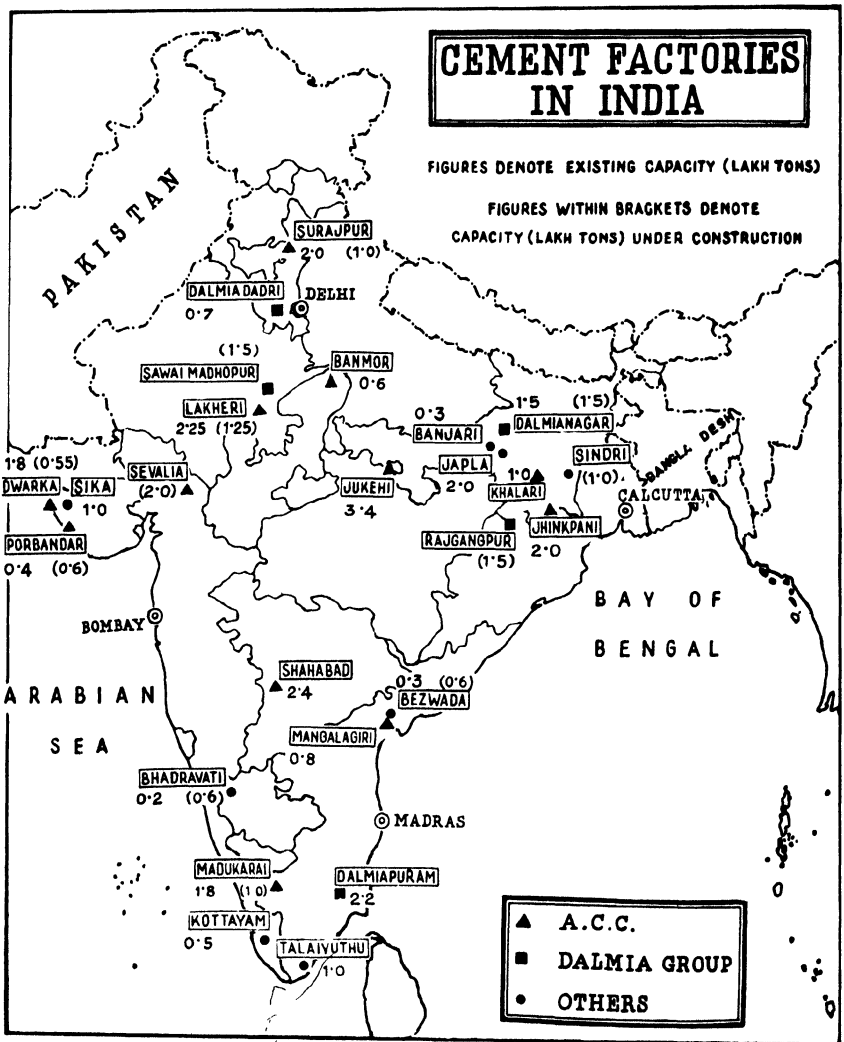
TABLE 1 —DISTRIBUTION OF INSTALLED CAPACITY

	Installed capacity (lakh tons)
Bihar	6 80
Madhya Bharat & Madhya Pradesh	4·00
Rajputana	2 25
Punjab (1)	2 70
Saurashtra	3·20
Hyderabad	2·40
Mysore	0 20
Travancore	0 50
Madras	6 10
Total.	28 15

TABLE 2 —ESTIMATED INSTALLED CAPACITY IN 1952

	Capacity (lakh tons)
A C C group	24 85
Dalmia group	8 90
Others—	
Sone Valley Portland Cement Co, Ltd, Japla	2·00
Kalyanpur Lime & Cement Works, Banjari	0·30
Andhra Cement Co, Ltd, Bezwada	0 90
Bhadravati Cement Factory, Bhadravati	0·80
Shree Digvijay Cement Co, Seeka	1·00
India Cement Ltd, Tinnevelly	1 00
Travancore Cement Ltd, Kottayam	0 50
Sindri Govt Project	1 00
Total	41 25

Three new factories, one at Sevalia (Bombay), belonging to A C C. (capacity 2 lakh tons/yr.), and two others belonging to the Dalmia group and located at Sawai Madhopur (Jaipur) and Mahanadi valley (Orissa), each having a capacity of 1·5 lakh tons per year, are expected to commence production by the end of 1952. Also, a Government factory (capacity, 1 lakh tons), may come into production at Sindri where cement will be manufactured as a by-product. No other new factory is likely to come into production by 1952 although the Government of U P. has on hand a proposal to establish a cement factory near Mirzapur with an annual installed capacity 2 lakh tons, and has placed orders for the necessary plant and equipment By 1952, the A C.C., and Dalmia group factories, *Andhra Cement Co.*, and *Bhadravati Cement Factory* are likely to extend the capacities of their existing works by another 7 1 lakh tons. This will bring the total installed capacity of the industry to 41·25 lakh tons (Table 2).



The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.

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Raw materials.—The raw materials for cement manufacture are calcareous and argillaceous materials which are found in many places in India in the form of limestone and clay or shale. These are mixed in suitable proportions to form the raw mix. Calcareous sand or sometimes marl is used in the place of limestone. Where cement rock, which contains the constituents in the required proportions, is available, the addition of clay is unnecessary. It is often necessary to add small amounts of correction materials such as iron ore, laterite, bauxite, and sand, to obtain a mixture which on calcination gives a product conforming to the specifications.

The raw mix contains 75—80% calcium carbonate and matched quantities of silica, aluminia, and iron, Alkalies are objectionable even in small proportions, and it is important that the raw materials should not contain more than 2·5% magnesia. Many Indian limestone deposits contain high proportions of magnesia and are, therefore, unsuitable for the manufacture of cement. It is also not possible to use limestone containing less than 75% calcium carbonate except in very special cases, and many limestone deposits in India are low in calcium carbonate to be useful for cement production. It is possible, in certain cases, to process the limestone to reduce the silica and raise the carbonate content.

Limestones suitable for cement manufacture occur in several parts of India. Suitable clay and shale deposits are found in most parts of India.

One ton of Portland cement requires c. 1·6 tons of limestone and clay, the proportions of the two ingredients varying according to their composition. As the setting up of a cement works involves heavy capital outlay, it is essential to make sure that sufficient raw materials of the desired qualities are available for 30 to 50 years.

One of the important requirements of the cement industry is gypsum ($CaSO_4$, $2H_2O$); the addition of this material to the extent of 3—5% is necessary to regulate the setting time of the product. Anhydrite ($CaSO_4$) may also be used. Gypsum is fairly widely distributed in India, and is mined in Bikaner, and in various places in south India. Some of the cement factories in north India obtain their supplies from Pakistan (Khewra and Dandot).

Large quantities of coal are required for roasting the raw materials. The coal is dried, pulverized, and blown into rotary kilns for calcining and

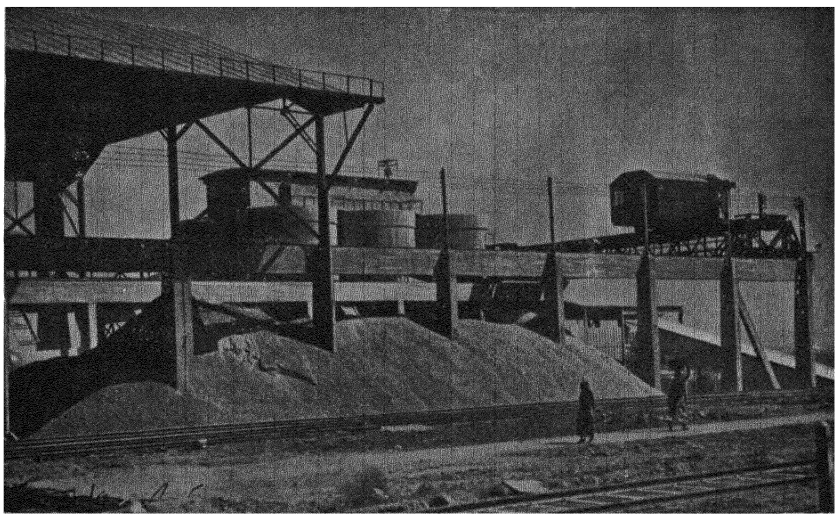


Fig. 14.—Crushed stone and other raw materials stored for cement manufacture

sintering the raw mix. The quality of coal is of considerable importance as it acts to some extent as a raw material by entering directly into the composition of the finished article. The coal should ignite rapidly and should have a high flame temperature, a not-too-high ash content, and a suitable ash composition. If these conditions are fulfilled it is possible to use coal of medium grade. The consumption of coal varies from 0·25 to 0·35 ton, per ton of cement, depending upon the quality of coal and the efficiency of the plant. Most cement factories have their own power stations and use for this purpose 0·1—0·15 ton coal per ton of cement produced.

The cement industry draws its coal supplies from the coal fields of Rewa, Pench valley, Singareni, etc., but mostly from the collieries in Bengal and Bihar. The total quantity of coal required to keep the existing factories in full production is approximately 75,000 tons per month.

Fuel oil can also be used, and some factories, now under construction, are being equipped to utilize both coal and oil for roasting and for power generation. The consumption of oil for roasting is about 0·15 ton per ton of cement. One of the cement plants in Burma uses natural gas as fuel.

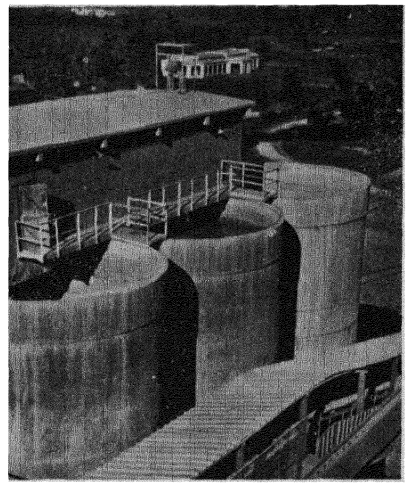


Fig. 15.—Slurry silos.

Manufacture

Cement is manufactured either by the wet process or the dry process. The former is more commonly employed in India. There are only two dry process plants in operation—one at Dalmia Dadri (Jind), and the other at Dalmiapuram (Trichinopoly), their total rated capacity being 140—150 thousand tons per year. The latter factory is now being enlarged, and equipped with machinery for wet processing.

Wet process.—The clay is treated in a wash mill and made into slurry. If the clay is not washable, it is charged into the grinding mill in the dry state. After a preliminary crushing in a hammer or other crusher lined with manganese steel wearing plates, the limestone is fed into the grinding mill, water added, and the material ground wet to a thin slip. The mix as it leaves the mill consists of finely ground particles (90—95% passing through a 170 mesh sieve) and 34—38% water.

The grinding mills are cylindrical, lined with wear-resistant manganese steel and cast iron plates, and divided into two or more compartments separated by screens. Steel balls of various sizes are placed in the compartments for grinding the charge. The mills (generally, 40 ft. × 8 ft. diam.) are worked by motors of 500—1,500 H.P. For certain raw materials, closed circuit grinding is advantageous; in this method the material is passed through a ball mill and a separator, and the coarse particles are returned to the mill for further grinding. A considerable saving in power is claimed, but the cost of installation is somewhat high.

The slip from the grinding mill is now pumped nto slurry tanks and stirred up mechanically by blowing in air. It is then transferred to storage basins and the composition adjusted. The mix is next pumped to the inlet end of the rotary kiln through a specially designed feeding apparatus, and calcined.

The rotary kiln is a refractory-lined long steel tube (usually, 300 ft. long × 9—10 ft. diam.) mounted on rollers. The tube is mounted in a slightly inclined position, and as it rotates (1—2 r.p.m.) the slurry slowly moves to the outlet end. Pulverized coal is blown into the kiln from the lower end and fired. The water in the slurry first evaporates, and when the dried mass reaches the central zone of the kiln, calcination takes place. The free lime produced combines with silica, alumina, and iron oxide, and at the high

temperature obtaining in the kiln, the charge sinters into small hard lumps of cement clinker. The temperature in the burning zone is 1,400–1,500°. It is most essential to keep the temperature in the kiln within predetermined limits, as at too low a temperature the chemical reactions will be incomplete, and at too high a temperature, the clinker melts giving a product which would be useless.

For economizing fuel, the kilns are provided with devices for improving the heat transfer to the slurry, and for preheating the air entering the kiln by the heat of the clinker as it cools down at the lower end of the kiln. Quick cooling as for instance by air quenching, in certain cases, improves the quality of the clinker.

The heat consumption in the rotary kilns, is estimated at 1,450—1,600 Cals. per kg. clinker. Part of it is utilized for the evaporation of water in the slurry and part for sintering; the rest is lost in smoke gases, the clinker, and radiation from the kiln. By minimizing the losses of heat in the smoke gases, it has now been possible to reduce the consumption to 1,300 Cals. per kg. clinker.

Practically all cement kilns in India are provided with clinker coolers, and the temperature of the clinker leaving the coolers is about 200—250°. The clinker is usually stored, after crushing oversized lumps, if any, for some time before final grinding.

The clinker is fed into the cement mill together with gypsum and ground to powder. The grinding mills are similar to those used for grinding the raw materials and contain two or more compartments separated by screens and partially filled with balls and Cylpebs. A draught of c. 65 mm. water is maintained in the mill to allow the cement to travel from one compartment to another. The cement is ground such that at least 90% of it passes through a 170 mesh sieve; usually the residue left on the sieve is 5—6%. Ground cement is stored in silos.

The cement is extracted from the silos by pneumatic extractors and screw conveyors, and packed in bags normally of 112 lb. Jute bags are mostly used in India for packing. A few factories use valve bags. A Bombay firm has recently installed a plant for the manufacture of cement paper bags. The A.C.C. is now packing cement

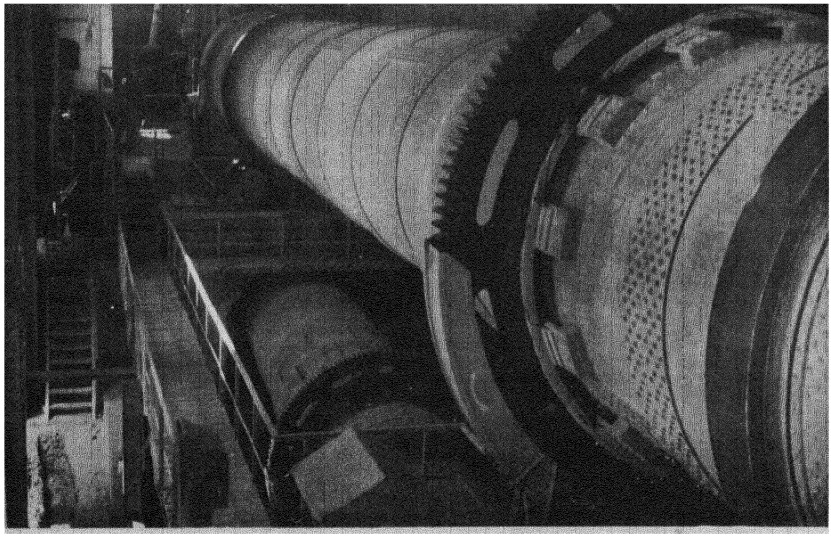


Fig. 16.—Dry process kiln and cooler, Dalmiapuram, S. India.

in paper bags (24 bags to the ton) as jute bags are in short supply. Packing and weighing have been mechanised in many factories.

Dry process.—In the dry process the raw materials are mixed in the dry state. The crushed raw materials are introduced into the grinding mill, and the ground material (more than 90% passing through 170 mesh) transported, usually by pneumatic transport, to storage silos where they are mixed and the composition adjusted

The raw meal is charged into granulating drums where it is moistened and formed into soft lumps or nodules containing 10—12% water, and subsequently calcined The rotary kiln employed is either a long tubular kiln similar to that employed in the wet process, or the Lepol kiln, which consists of an enclosed travelling grate followed by a short rotary kiln. The nodules are spread over the slowly travelling grate and heated by the hot gases from the rotary kiln The material falls into the rotary kiln where sintering and clinker formation take place. The clinker thus obtained is treated in the same manner as in the wet process.

In the dry process, the heat necessary for evaporating water from the slurry is economized, and the heat consumption is reduced to 1,000—1,100 Cals. per kg. clinker. The process has, however, certain drawbacks. Firstly, it is difficult to mix the materials thoroughly in the dry state, unless efficient power-driven mixers are employed For the drying of the raw materials, a certain amount of heat is required, and so also for the removal of water deliberately added to the mix for forming nodules The plant required for the dry process is somewhat more complicated than that required for the wet process. For these reasons, most cement factories prefer the wet process.

The power consumption in cement factories using the wet process is 100—125 kw.-hr per ton of cement A plant with an output of 300 tons per day will therefore require a power installation of 2,000—2,500 kw.

Special Cements.—The procedure for the manufacture of rapid hardening cement is the same as that for Portland cement The chemical composition of the raw mix is somewhat different. The lime content is higher, the burning is harder, and the cement is more finely ground (residue on 170 mesh sieve, $< 5\%$). The product is more expensive than Portland cement, and is

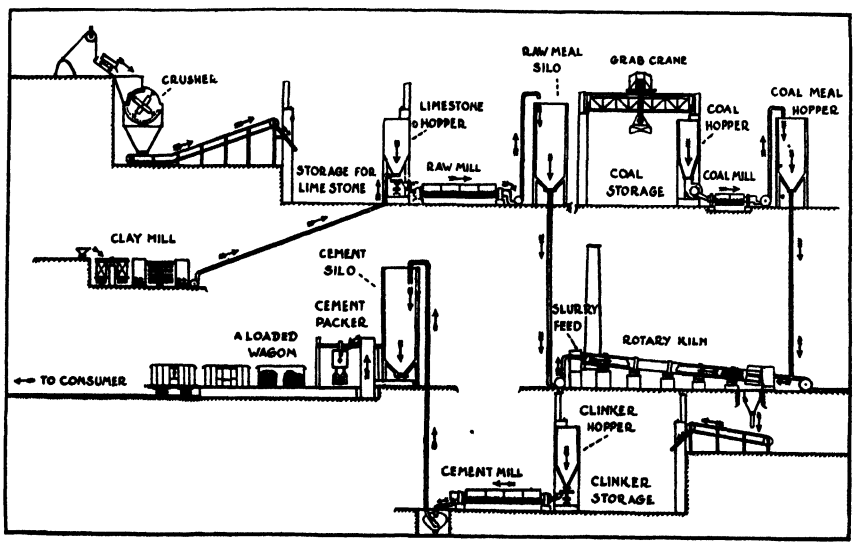


Fig. 17.—Lay-out of a typical A.C.C. Works.

manufactured only against specific demands The quantity produced is small, and in the period 1st August 1947 to 31st July 1948, the A C C. group produced only 1,113 tons of rapid hardening cement (Information from C M C I)

Low heat cement and sulphate resistant cement are made in the same way as Portland cement The raw mix compositions are somewhat different.

The raw materials required for the manufacture of white cement are limestone and bauxite They are mixed in suitable proportions, ground, and briquetted. The briquettes are fused or melted in reverberatory furnaces, rotary kilns, or electric furnaces The fused product is cooled and ground to a fine powder The production of high alumina cement has not been undertaken on a commercial scale in India

Improved techniques of cement manufacture have been developed in Europe In Germany, 3 plants are in operation in which roasting is effected in travelling grate furnaces of the Dwight -Lloyd type Low grade fuel can be used for firing and the cement produced is of good quality.

One of the far-reaching developments in the cement industry is the production of cement from raw materials so selected that valuable chemical products are obtained in addition to the cement. A process for the production of cement and sulphuric acid, developed in Germany, consists in calcining a mixture of gypsum, clay, and dried coal ground to a fine powder in a rotary kiln The sulphur dioxide produced by the calcination of gypsum is utilized for the production of sulphuric acid; the residual lime combines with clay giving Portland cement. A plant for the production of cement and sulphuric acid by this process was set up at Leverkusen in 1916; the process is also being worked at Billingham (England) and at Miramas (France) A process for the production of iron and cement has been developed in Denmark. It consists in heating iron ore together with the ingredients of cement in a reducing atmosphere in a rotary kiln. The metal is tapped off in a molten condition and the cement clinker forms the slag.

The Seailles process for the simultaneous production of cement and alumina is a more recent development. It consists in (1) kilning a silico-aluminous mixture with lime to form non-saturated calcium aluminates and dicalcium silicate, (2) solubilization of the calcium aluminates in dilute alkaline carbonate solution, (3) precipitation of lime by sodium carbonate, (4) precipitation of alumina by carbon dioxide which regenerates sodium carbonate, and (5) correcting the composition of the residue and re-kilning to obtain cement. This process has the special advantage that the composition of the cement can be adjusted according to requirements (Lafuma, *Chem. Age*, 1950, **62**, 264) The process can be combined with the cement-*cum*-sulphuric acid process by using gypsum in place of lime Working trials have shown that a self-disintegrating clinker containing soluble aluminates is readily obtained. The clinker is washed to extract the alumina, and the residue with suitable additions is kilned to produce Portland cement There are possibilities of adapting this technique to yield cement, alumina, and phosphorus or its derivates (Lafuma, loc cit)

Testing and Specifications

The quality of cement is adjudged by mechanical tests and chemical analysis Mechnical tests include those for the determination of fineness, consistency, strength, setting time, and soundness The fineness is determined by sieve analysis It gives an indication of the amount of sand which can be mixed with the cement. The determination of setting time is important; initial set should not occur before the mortar or concrete is placed, and delayed hardening causes damage to the cement. The setting time is determined with a Vicat needle apparatus The strength is determined by a tensile test on briquettes, one sq. in. cross section at the waist, made from a mortar composed of 1 part by wt. of cement to 3 parts standard cement (18—25 B.S. mesh). The soundness test, carried out by the Le Chatelier method, determines whether or not mortars and concretes made from cement are liable to expansion and therefore to disintegration The test detects the presence of excessive amounts of free calcium oxide which may cause deferred expansion due to slow slaking (Thorpe, II, 143).

Portland and other types of cement should conform to British Standard Specifications: B.S.S. 12: 1947, Portland Cement (Ordinary and Rapid Hardening); B.S.S 915: 1947, High Alumina Cement; B S S. 1370: 1947, Low Heat Portland Cement, B.S S 146. 1947, Portland Blast Furnace Cement.

For Portland cement, "the percentage of lime, after deduction of that necessary to combine with the sulphuric anhydride present, to silica, alumina, and iron oxide when calculated by the formula:

$$\frac{CaO}{2{\cdot}8\ SiO_2 + 1{\cdot}2\ Al_2O_3 + 0{\cdot}65\ Fe_2O_3}$$

shall not be greater than 1·02, nor less than 0 66. The ratio of the percentage of alumina to that of

iron oxide shall be not less than 0 66 The weight of insoluble residue shall not exceed 1 0%, that of magnesia shall not exceed 4%, and the total sulphur content, calculated as SO_3, shall not exceed 2 75%. The total loss on ignition shall not exceed 4%". Similar specifications have been laid down for other types of cements

Other requirements as per B S S for Portland and rapid hardening cements are given in Table 3.

Experience has shown that in order to produce a sound (i.e., a product which will not expand after setting) cement and, what is equally important, a cement which can be manufactured without operational difficulties, the various chemical constituents should be present in specified proportions and the hydraulic modulus $\left(\frac{CaO}{SiO_2 + Al_2O_3 + Fe_2O_3}\right)$ the lime-silica ratio $\left(\frac{CaO}{SiO_2}\right)$, the iron ratio $\left(\frac{Al_2O_3}{Fe_2O_3}\right)$, and the silica modulus $\left(\frac{SiO_2}{Al_2O_3 + Fe_2O_3}\right)$ should be kept within certain narrow limits. Even if the ratios are within the permissible range, the presence of small amounts of alkalies or sulphur renders the raw materials unsuitable for cement manufacture

Portland cements have the following range of composition CaO, 60—67, $Si O_2$, 17—25, Al_2O_3, 4—10; Fe_2O_3 0·1—5 MgO, 0—4, SO_3, 1 0—2·75, alkalies, 0 3—1; loss on ignition, 0—4%. The cement should not contain any free lime (CaO)

Table 4 gives the analytical values of Indian cements and raw materials.

Tricalcium silicate (3 CaO SiO_2) present in cement influences the hydraulic value and strength Rapid hardening cement contains a higher percentage of tricalcium silicate. Dicalcium silicate (2 CaO SiO_2) hydrates slowly, and is responsible for the development of the strength in the later stages Other compounds present in cement are tricalcium aluminate (3 CaO Al_2O_3), tetracalcium aluminoferrite (4 CaO Al_2O_3 Fe_2O_3). glass, and magnesia (MgO) Free lime, alkalies, gypsum, etc, present in small amounts in cement, influence its properties

Cement is not used as such in construction work as it is too sensitive to moisture conditions and is subject to internal stresses causing cracking and reduction in strength When mixed with sand and stone it is diluted and stabilized, giving a building material *par excellence* which when treated properly continues to gain strength with aging without developing cracks. The two forms in which cement is used mixed with aggregates are mortar and concrete

MORTARS are mixtures of cement and sand or other fine aggregates (below 3/16 in mesh in size), and are used mainly for bonding in masonry and as a surface covering (as in rendering and stucco)

The largest application of cement is in the form of CONCRETE which is a mixture of cement, sand (below 3/16 in mesh size), and coarse aggregate (above 3/16 in mesh size), and made into a solid mass The maximum size of coarse aggregate varies according to the purpose for which the concrete is required, ¾ in or 1½ in is a very common size, but for some purposes it may be limited to ½ in, while in heavy mass concrete it may be as high as 6 in or even more The common proportions for cement, sand, and coarse aggregate are 1 1½ 3, 1 2 4, 1 3 6 (Lea, *Lecture on Cement and Concrete, London*, 1945, 19) Concrete is used in building work of all types, for heavy engineering structures, roads, and for numerous other purposes In addition to their application *in situ*, large quantities of cement find an outlet in the manufacture of concrete products such as blocks, slabs, tiles, etc Concrete has high compressive strength and a

TABLE 3

	Portland cement	Rapid hardening cement
Fineness	Residue on B. S. 170 mesh test sieve, not to exceed 10%.	Residue on B S 170 mesh test sieve, not to exceed 5%
Setting time	Initial setting time, not less than 30 min Final, not more than 10 hrs	Initial setting time, not less than 30 min. Final, not more than 10 hrs
Tensile strength	Not less than 300 lb /sq in after 3 days; shall show after 7 days an increase on the tensile strength at 3 days, the value being not less than 375 lb /sq in	Not less than 300 lb /sq in after 1 day; shall show after 3 days an increase on the tensile strength at 1 day, the value being not less than 450 lb /sq in
Compressive strength	Not less than 1,600 lb./sq in after 3 days, shall show after 7 days an increase on the compressive strength at 3 days, the value being not less than 2,500 lb /sq in	Not less than 1,600 lb /sq in after 1 day, shall show after 3 days an increase on the compressive strength at 1 day the value being not less than 3,500 lb /sq. in
Soundness	Expansion not more than 10 mm.	Expansion not more than 10 mm

TABLE 4.—ANALYSIS OF RAW MATERIALS & CEMENT

	Limestone %	Clay %	Slurry %	Clinker %	Cement %
SiO_2	10 76	55 14	14·96	23 5	23·0
Fe_2O_3	0·91	7 68	1 27	2·2	2 19
Al_2O_3	1·89	17·01	2 90	6 1	5 97
CaO	47 33	7 03	43·98	66 7	64 86
MgO	1·11	2 16	1 11	1 10	1 00
SO_3	..	..			1 72
Losses	37 80	10·74	35 7	0 02	0 74

relatively low tensile strength

Plain concrete resists loads which tend to crush it, but it is relatively weak against forces which tend to bend it or pull it apart A particular type of concrete which is widely used at present is the reinforced concrete in which steel rods or heavy wire mesh are used as reinforcement around which the concrete is poured. On setting, the cement adheres strongly to the reinforcement and the composite material is able to withstand both high tensile and high compressive stresses

Production Costs and Prices

Cement factories are located near the sources of raw materials, and the cost of limestone and clay is comparatively small For every ton of cement produced, 0 25—0 50 ton of coal is required, and as it has often to be transported over long distances, it is a major item in the cost. The cost of coal varies from Rs 18—66 per ton, depending upon the distance over which it has to be conveyed and the means of transport Packing materials also constitute an important item in the cost of cement. Labour and stores are relatively minor items.

In computing the final cost of cement, transport of the finished product has to be taken into consideration. The location of the factory is thus a decisive factor in the economy of production. Factories located near the consumers' markets and coal deposits have many advantages.

The average all-India manufacturing cost of cement during the period 1948 and 1948-49 was about Rs. 54 per ton ex factory The minimum cost was Rs. 45 per ton and the maximum cost was Rs. 82 per ton. The average cost of the A.C.C. factories was Rs. 51·5 per ton. One of the most important factors responsible for this wide divergence in cost of manufacture is the freight on coal.

There was no fixed or all-India price for cement until 1937 when attempts were initiated to organize the industry on a planned basis There was, however, a gradual fall from Rs 52—66 per ton in 1930 to Rs 37—55 per ton in 1937. The average prices during the period 1929-30, 1930-31, 1933-34, and 1935-36 were respectively Rs. 54 12, Rs. 51 30, Rs 49 74, and Rs 45

With the entry of Dalmia cement into the market in 1938, there was serious competition between the A.C C and Dalmia group with consequent price cutting, and the prices fluctuated between Rs 26 and Rs 47 5 per ton during the years 1938—1940. The prices were stabilized in 1941 as a result of the agreement between the two groups to sell the product through the Cement Marketing Company of India, Ltd The price range was Rs 37—46 5 in 1941, and Rs 40—46·5 in 1942

With the imposition of control on cement in August 1942, the price of cement is being fixed by Government in consultation with the industry, and a uniform price obtains throughout the country, though there has been a steady rise in price due to increase in the prices of coal and jute bags, and in labour and transport charges From Rs 48 per ton in Dec. 1942, the price rose to Rs 87 5 per ton in Dec 1947. Since Aug. 15, 1948 it is Rs. 82 5 per ton for destination The price of cement produced by new factories has been fixed at Rs 90 per ton with effect from July 1949 for a period of one year in order to give them initial assistance.

Markets—The principal markets for cement in India are located in the Calcutta area, receiving supplies from Bihar factories, and Bombay and Gujarat areas, supplied by factories located at Shahbad, Lakheri, and in the west coast Punjab, U P, and Madras areas are also large consumers. The consumption of cement in Rajputana, Madhya Pradesh, Deccan and in the north east region is comparatively small

Production and Trade

The production of cement in India, which was 945 tons in 1914, increased to 87,000 tons by 1919. In 1937-38, the production was 1 2 million tons, and in 1938-39, 1·5 million tons. Table 5 gives the production of Portland cement in India for the period 1939—40 to 1949—50.

During the War years, the Government of India instituted control over the production and distribution of cement In March 1948, the system of distribution was revised. The available cement is now divided into two quotas—the Central quota and the States quota. The Central quota is operated by regional honorary cement

TABLE 5.— PRODUCTION OF CEMENT*

	Qty. (Tons)
1939–40	17,33,400
1940–41	17,27,453
1941–42	22,22,418
1942–43	21,82,800
1943–44	21,12,218
1944–45	20,43,551
1945–46	21,51,161
1946–47	20,27,238
1947–48	14,57,186†
1948–49	16,42,948†
1949–50	22,97,574†

* D G I &S , Monthly Statistics of the Production of Certain Selected Industries of India

† Relates to Indian Union (Monthly Statistics of the Production of Selected Industries of India, I & S , Ministry)

advisers of the six regions, viz , Delhi, Kanpur, Bengal, Madras, Coimbatore, and Bombay The remaining quota is distributed through controllers of different States who receive allotments from the Centre.

Imports.—Prior to 1914, India imported relatively large quantities of Portland cement, the quantity imported in 1914-15 amounting to 144,972 tons. In 1918-19, the quantity imported was only 27,177 tons In the years between the two Wars, the imports fluctuated between 133,268 tons in 1922-23 and 15,913 tons in 1938-39 During World War II, there was no import of cement for civilian use Small quantities of cement were being occasionally imported into India after the War, but since August 25, 1949, imports of cement under Open General License have been stopped, and imports are restricted to quantities included in Trade Agreements [*I & S. Bull* 1949, **2**(4), 39]

Table 6 gives imports of Portland cement into India.

TABLE 6 — IMPORTS OF PORTLAND CEMENT

	Qty (1,000 tons)	Value (lakh Rs)
1919/20–1923/24 (av.)	114 00	104 50
1934/35–1938/39 (av.)	42 10	13 97
1939/40–1943/44 (av)	2 85	1 49
1944–45	0·02	0 03
1945–46	0 43	0 75
1946–47	2 16	4 04
1947–48	2 75	5·55
1948–49	145 49	156 03
1949–50	302 85	271 83

The demand for cement has increased recently and the A C C. and Dalmia group have been permitted to import cement produced in their factories in Pakistan

Exports —A few of the Indian cement factories have a location favourable for export, and considerable amounts were being exported in pre-war years from *Dwarka Cement Works* at Port Okha, mainly to Persia, Ceylon, Indonesia, and Malaya The annual export was 20,000 tons in the years preceding the War, and 2,50,000 tons in 1942 Exports have now completely ceased owing to high internal demand.

The consumption of cement in India was 6—7 lb *per capita* in 1938, it rose to 10—11 lb in 1944. The *per capita* figure is still low in comparison with the corresponding figures in western countries; in U K , the *per capita* consumption in 1936 was 300 lb [*I & S Bull* , 1948, **1** (2), 18].

CERAMICS—POTTERY

The term ceramics was originally applied to pottery, its scope has now been broadened to include "all products fashioned from silicates or oxides and rendered durable in form and composition by a heat treatment applied at some stage of the process" (Barringer, *Bull Amer ceram. Soc* , 1939, **18**, 276)

The principal types of pottery articles are: table-ware or crockery, other types of white ware, sanitary ware, decorative and artistic ware, and industrial ware Crockery may be porous earthenware, vitreous porcelain, bone china, and sometimes, stoneware Hotel china is made from the best porcelain Sanitary ware is made of vitreous stoneware and porous earthenware Laboratory articles are made of chemical porcelain Chemical or acid-proof stoneware is used in process industries

Earthenware is opaque and hard enough to withstand ordinary usage, it has a porous body and can be glazed Coarse earthenware articles—jugs, jars, basins, kitchen utensils, etc ,—both glazed and unglazed, are common in the rural parts of India. Fine earthenware is stronger but not so strong as stone- or porcelain ware It has an almost white body and is fairly porous Glazed earthenware is used for all kinds of table- and toilet ware, and for some types of sanitary articles.

Stoneware has a dense vitrified body consisting essentially of a skeleton of unfused material, all the pores and interstices being largely filled by molten glass (Searle, III, 221) It is almost impervious to water, hard and opaque with a conchoidal fracture, and resistant to heat and strong acids.

On account of the plastic nature of the clay used stoneware can be made in larger sizes than porcelain, and the process of manufacture is simple

Coarse stoneware has a coloured body Many types of sanitary articles and domestic ware such as pickle and jam jars, jugs, tea-pots, ink-pots, etc, are of stoneware Fine stoneware has a light-coloured body, suitable for artistic and decorative work. Chemical stoneware such as tanks, jars, vats, etc, form a special variety of fine stoneware with high mechanical strength and resistance to thermal shock

Drain or sewer pipes are particular types of stoneware with 5% (maximum) porosity (Wood, *Trans ceram. Soc*, 1935, **34**, 269) The manufacture of drain pipes is a specialized branch of the ceramic industry

Porcelain has a dense, highly vitreous, white body Hard porcelain consists of a skeleton of felted mass of microscopic mullite crystals embedded in a felspathic glassy matrix together with some grains of quartz, and is translucent It is used for table-ware Chemical porcelain is a special form of hard porcelain used for laboratory work Electric porcelain used for insulators, switches, and other electrical appliances, possesses high mechanical strength, resistance to thermal shock, and dielectric properties

China-ware or Bone china is a special kind of soft porcelain It has a translucent vitrified body with a milky white appearance resembling alabaster The translucency is due to the use of bone ash as a fluxing agent It is superior to domestic earthenware in hardness, and is extensively used in England for the manufacture of high quality table-ware

For high tension (H T) and low tension (L T) electric insulation and electrical fittings, porcelain and stoneware are employed Glazed fireclay insulators are used for L T insulation, and steatite porcelain insulators are required wherever high voltages are involved Electrical porcelain and stoneware with sillimanite body are employed for H.T. insulators

The Indian Industry

Pottery is one of the most important village industries in India and there is hardly a village which does not have its own potter, or Kumhar, who employs the traditional techniques in making a large variety of vessels required for domestic use. Any locally available plastic clay forms the raw material for his work The clay is sometimes mixed with non-plastic earth or spent wood ashes or cow dung and kneaded by treading The mixture is passed through bamboo sieves and aged for about two weeks for 'souring' with kneadings at short intervals The article is shaped on the potter's wheel For large articles, a crude pot with the required mouth-size is first made on the wheel, it is removed for drying from the main clay mass by cutting with a thread or wire and partially dried in the sun The final shape is given by beating on a round polished stone with a slab of wood The articles are burnt in crude kilns The locally available fuel is stacked in the kiln, the articles are arranged one upon the other, and the spacings closed with fuel The upper part of the stack is covered with a layer of clay and the bottom is provided with a number of openings for firing Once it is ignited it is allowed to burn freely The kilned goods comprise over-burnt to under-burnt articles The products are not usually glazed

Art pottery—Artistic pottery is made throughout the country on a cottage industry scale The wares are shaped on the potter's wheel by throwing, or by pressing in clay moulds Important among Indian art pottery are the red-glazed pottery of Dinapore, black and silver pottery of Surajgarh (Bhagalpur), imitation bidri of Patna and Surat, painted and gilded pottery of Kotah and Amroha (Rajputana), glazed and unglazed pressed pottery of Madras and glazed pottery of Punjab (Das Gupta, *Prospect of Pottery Industry in Bengal*, 1940, *Industrial Survey Lecture Series* No 8, 10)

Chunar pottery (vases and toys) are fired at about 800° and coated with glaze Lead glaze or leadless glaze made from bottle glass and borax is employed The coated articles are fired at about 700° [Bose & Datar, *J Indian ceram Soc* 1932, **4**(2), 28]

Glazed faience pottery is produced in Khurja Khurja articles comprise flower pots and vases with floral designs, water jugs, powder pots, plates, and tea-pots The patterns and paintings are of Indo-Persian character, blue and green colours are imparted by cobalt salts and copper oxides in a highly alkaline glaze of soda glass The designs are painted by hand on dried articles or on a white engobe which is applied before baking-in ceramic colours, coated with a thick coating of transparent blue, green, yellow, red, or dark red glaze, and finally baked in a kiln The transparent glaze shows the multi-coloured decorations on a white background

Nizamabad pottery is famous for its lightness and shining black base The surface is rendered so smooth and polished that the fired ware shines without any glazing The articles are decorated with designs engraved on the surface and filled with tin or lead amalgam The neat designs and

Fig. 18.—Khurja art pottery

exquisite workmanship of Lucknow art pottery are comparable to some of the best art potteries of the world.

Development of Modern Industry.—The earliest pottery factory manufacturing glazed vitrified articles was established by Messrs. *Burn & Co.*, Raniganj, in 1860. The first porcelain factory was started in 1860 at Patharghatta (Bhagalpur Dt., Bihar) which produced high quality table china, porcelain, and Parian ware resembling the products of Staffordshire. This factory closed down shortly afterwards. The *Bengal Potteries, Ltd.*, was established in Calcutta towards the beginning of the present century. With the growing demand for porcelain and earthenware, other factories soon came into existence.

The first stoneware factory was started at Than (Kathiawar), thanks to the efforts of the *Paisa Fund Institute*, Talegaon. The glazed acid jars manufactured at Than proved popular, and to meet the expanding market needs, *Gwalior Potteries*, Gwalior and Delhi, and the *Bengal Potteries Ltd.*, Calcutta, started production of glazed jars.

The curtailment of imports during World War II served as a fillip to the Indian industry and several small factories came into existence. The bigger factories expanded production and some of them took up the manufacture of crockery and electric insulators.

There are in all about 40 pottery factories now in India including those producing insulators. The principal ones are: *Bengal Potteries Ltd.*, Calcutta (crockery and insulators); *Gwalior Potteries*, Gwalior and Delhi (earthenware, crockery, sanitary ware, and drain pipes); *Government Porcelain Factory*, Bangalore (crockery and insulators); *Burn & Co.*, Raniganj and Jubbulpore (drain pipes and sanitary ware); *Mysore Stoneware Pipes and Potteries Ltd.*, Bangalore (drain pipes); *Parashuram Pottery Works*, Wankaner, Nazarbagh, and Thanagarh (crockery, tiles, sanitary ware, and stoneware); The *East India Distilleries and Sugar Factories Ltd.*, Ranipet (acid jars); *Sundara Factory*, Travancore (crockery); *Hindusthan Potteries Ltd.*, Calcutta (electrical and sanitary ware); *Bihar Potteries* Ltd. Rupnarainpur (stoneware pipes, chemical

stoneware, and sanitary ware), *Prefect Pottery Co Ltd.*, Jubbulpore (stoneware pipes), *Reliance Fire Bricks and Pottery Co Ltd*, Jubbulpore (chemical stoneware), *Bombay Potteries and Tiles Ltd*, Bombay (earthenware, sanitary ware, and acid-proof ware); and *Stoneware Pipes (Madras) Ltd*, Trivellore (stoneware pipes)

Seven new factories are under construction The total installed capacity of the industry at present is 60,000 tons per annum (Information from D G I & S)

Raw Materials

The principal raw material of the ceramic industry is clay, which consists chiefly of hydrous aluminium silicate with varying quantities of mineral and organic impurities The properties of clay—relative hardness, particle size, amount and character of mineral impurities, plasticity, strength, drying conduct, water content, burning conduct and colour, shrinkage during drying, tendency to warp and crack, degree and rate of vitrification, porosity, texture and ability to take surface coatings, e g, glaze and engobes—largely determine the quality of articles produced from it China clays or kaolin and ball clays are principally used

Selected and washed china clay is required for porcelain The clay is mixed with a large volume of water and the mixture allowed to flow through a series of tanks and channels to separate the heavier impurities by settling The clay held in suspension is led into settling tanks, whence it is taken out and dried China clay is mixed with a small quantity of more plastic clay, usually ball clay, to facilitate moulding and to enhance dry strength Alkaline, siliceous, ferruginous, and other types of china clay may also be used (Searle, I, 202) Alkaline china clay containing up to 5% alkali is used for earthenware, fine pottery, and certain types of stoneware, siliceous china clay, containing up to 25% quartz, may be used for porcelain, low quality porcelain, stoneware, and earthenware are made from ferruginous china clay.

Ball clay is used in the ceramic industry mainly for bonding It contains iron, titanium, lime, magnesia, and alkalies as impurities It is highly plastic and possesses strong binding power. The bonding property is due to the extreme fineness of the clay particles and to the presence of organic matter Ball clay of good quality gives white or cream coloured bodies It cannot be used by itself for pottery as it shrinks and cracks during drying. It vitrifies at lower temperatures than china clay. Very little ball clay should be used, if at all, for cast ware

Fluxes are used for aiding vitrification, reducing porosity, increasing strength of cold articles, and for bonding The microcline form of potash or potash-soda felspar is commonly used as flux on account of its relative abundance and cheapness (Spencer, *Trans Indian ceram Soc.*, 1944, **3**, 113). Felspar-fluxed ware retains shape better than ware fluxed with lime, magnesia, whiting, barium oxide, zinc oxide, soda, potash, etc

To reduce shrinkage and consequent cracking during drying and firing, it is usual to add to the clay mixture non-plastic materials, mainly flint and quartz Calcined clay or grog is also sometimes added

Fine earthenware is generally made from white burning clays such as ball clay and china clay, felspar, flint or quartz is added \ English fine earthenware is made from china clay, ball clay, flint and Cornish stone The burnt article is white or pale cream, a small quantity of blue is sometimes added to produce a perfectly white body (Searle, I, 343) In Europe, cheap varieties of calcareous earthenware are manufactured from inferior red-burning clays containing iron oxide mixed with chalk or finely ground limestone, the material burns white on account of the powerful bleaching action of lime upon iron compounds.

Many types of stoneware are made from a single clay The clay should be sufficiently refractory to retain the shape during burning Unlike fireclay, it should completely vitrify to a dense body at a comparatively low temperature (1,200—1,300°) It should be sufficiently plastic and tough so that it can be shaped, and the shaped articles when dry should be strong enough to withstand handling Fat clays, moderately rich in silica, fluxes, and alumina, are suitable They should contain finely divided free silica to enable the ware to be salt-glazed The colour of the burnt product is not so important

Natural clays of the composition ' pure clay, 50, quartz, 45, and felspar, 5% are used for coarse stoneware In the absence of suitable natural clays, a mixture of fireclay with a fusible clay or felspar, or a low grade fireclay with sufficient iron to act as flux, may be employed (Searle, III, 225)

For the manufacture of fine stoneware products, a mixture of clay, sand or flint, and felspar (clay, 45—50, quartz, 35—40; and felspar, 15%) is generally used White stoneware is made from china and ball clays with additions of felspar and silica or flint The product is similar to porcelain except that it is opaque (Wood, loc cit)

For sewer or drainage pipes, the clay should be sufficiently plastic for moulding, and articles

made from it should have sufficient strength when dry and should not warp or crack during drying or burning. It should contain sufficient finely divided quartz so that articles can be salt-glazed. Red- or buff-burning, vitrifiable clay mixed with sand and grog, or low grade fireclays, are suitable. The clays are not usually washed or purified.

Porcelain is made from china clay and felspar. Only washed china clay of selected quality is used. A certain amount of purified ball clay is added for increasing plasticity. Flint or quartz is also added. Soft porcelain contains, in addition, one of the following: soda, potash, marble, whiting.

Highly plastic clays should not be used for hard porcelain. The clay should be reduced to sufficient fineness (about 200 mesh) before use, as coarse clay does not mix readily with felspar. Small proportions of calcium carbonate or calcium fluoride present as impurities in clay and felspar, serve as flux. Calcium carbonate reduces firing temperature and duration. Artificial soft porcelain is made mainly from silica and flux. Steatite porcelain is made from steatite, china clay, felspar, and flint. Steatite may be used by itself.

The raw materials required for ceramics are abundantly available throughout the country. The most important deposit of kaolin or china clay is in Patharghatta (Bhagalpur Dt.) which is worked by the *Bengal Potteries Ltd.*, and used in the manufacture of porcelain goods. The clay is said to be comparable to English Cornwall clay. The clay deposits of Hat Gamaria (Singhbhum) is of excellent quality, and is suitable for high class porcelain. Mangalhat (Santal Parganas) clay, used by *Bengal Potteries Ltd.*, is also of good quality. Other localities in Singhbhum in which china clay deposits occur are: Kashmandu, Katahpara, Mahuldia, Telaipi, Pandrasali, Majri, Madkumhatu, Metiabandi, Kharhindungri, and Dharadih (Misra, *Trans. Indian ceram. Soc.*, 1945, **4**, 46). Kaolin occurs in Nakum hills in Gwalior. China clay deposits of good quality are found in Delhi, Travancore, and Mysore. Workable deposits also occur in Rajahmundry, Baroda, and Hyderabad. With few exceptions china clays obtained in India are of inferior quality, and some factories import Cornish (English) clay for mixing with indigenous clays for the manufacture of high class porcelain articles.

Small quantities of ball clay are available at Baglata and Kerwali near Than (Bombay) but the quantity obtainable is not adequate to meet the needs of the Indian industry. Ball clay is imported from U.K., Germany, Belgium, and other countries. Imports are free of duty.

Felspar is obtained from Ajmer, Delhi, Chhindwara, Bhagalpur, and Mihijam. Mysore and Travancore factories obtain their requirements from Holenarsipore and Trichinopoly respectively. Quartz is found all over the country.

Clays of low fusibility required for salt-glazed sewer pipes and certain sanitary and domestic wares are widely distributed in the country; the more important occurrences are at Jubbulpore, Katni (C.P.), Raniganj (Bengal), Than Jn. (Kathiawar), Mysore, Alleppey (Travancore), and Madras (Crookshank, *Rec. geol. Surv. India*, 1941, **76**, Bull. No. 8, 8). Suitable clays also occur in Bikaner, Rewa, and Jammu, and at Khasi, Garo, and Jaintia hills.

Manufacture

The raw materials are separately ground and mixed. Wet grinding is generally adopted in Indian factories. Clays are only blunged with water after preliminary superficial grinding in an edge runner mill. Felspar is crushed in a jaw crusher, dry ground in an edge runner mill, and ground in ball mills with water. Quartz or flint are calcined before grinding. Generally, 30—35% water is added in wet grinding; a further 10—15% is added for discharging the slurry.

The ground materials are separately lawned through fine sieves (100 mesh or finer) and passed through electro-magnetic separators for removing iron. The clay slip, felspar slurry, and flint slurry are mixed in suitable proportions in a blunger, more water being added. The resultant slip is lawned again (through 160 mesh sieve) and passed through an electro-magnetic separator, stirred in

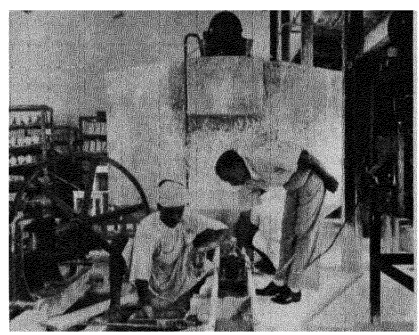


Fig. 19.—Electro-magnetic treatment of clay slip

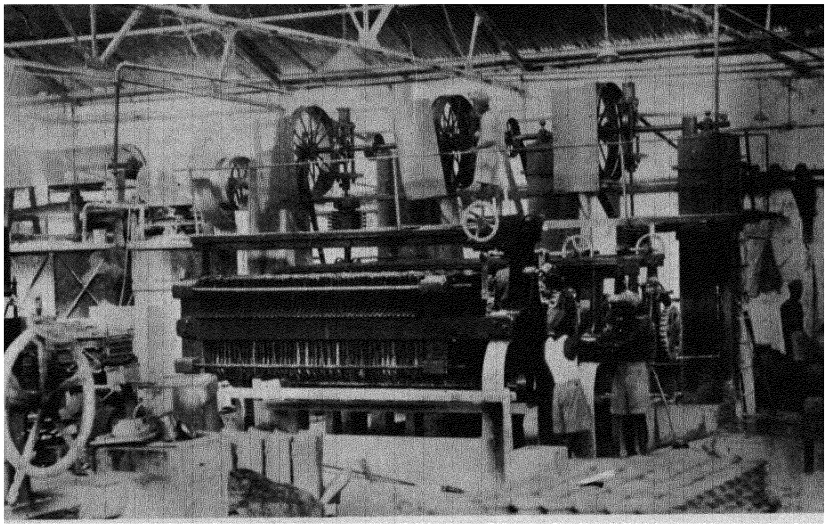


Fig. 20.—Slip house

a tank, and finally filter-pressed. The filter cakes thus obtained, containing 10—30% water, are aged for a few days to improve plasticity and to ensure even moisture distribution.

Three processes are in use for shaping articles, viz., plastic shaping (including turning on wheels hand-moulding, and jiggering and jolleying), dry pressing in moulds, and casting. Clays of different consistencies are required for each of these processes. A plastic mass is required for the first. The filter cake is kneaded and de-aired in vacuum pug mills to make it homogeneous and more plastic, and the pugs used for plastic shaping. The dry process utilizes filter cakes which are remixed with water and passed through a disintegrator.

For casting, the slip is used as such without filter pressing. Casting slips may be prepared also from filter cakes by pugging, souring, and blunging with about 35% water and 0·5% electrolyte (usually sodium carbonate and sodium silicate). The slip is lawned and passed through a magnetic separator before use. Trimming wastes obtained from throwing and jiggering operations may be used in preparing casting slips.

The throwing process, requires the use of the potter's or thrower's wheel, and only articles of circular cross section can be shaped. The wheel consists of a horizontal disc rigidly attached to the top of a vertical spindle which is rotated manually or by a motor. A wad of pugged clay thrown above the disc is shaped to a cone by the potter's fingers and depressed, the shaping and deshaping being repeated 2—3 times to "solidify" the clay mass. Any slurry that appears on the top of the cone is removed. The thrower then shapes the article, first by hollowing out the clay lump with

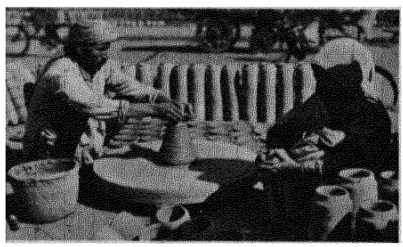


Fig. 21.—Potter's wheel

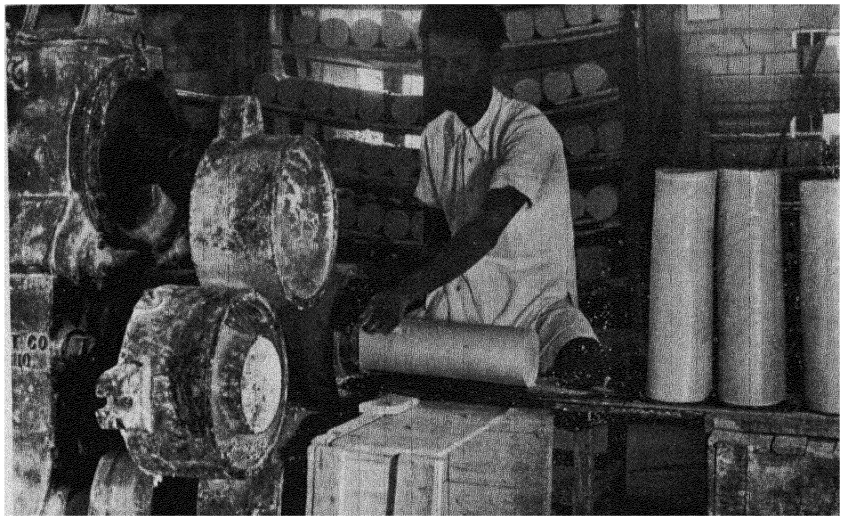


Fig. 22.—Horizontal pug mill

his fingers, and later with the help of a tool. Large pieces are thrown in 2 or 3 sections and fastened together by slip. This process is employed for earthenware, stoneware, and large electrical porcelain insulators. The formed article is separated from the disc by running a thin wire under it. The rough shaped articles are finished by turning. The smaller and commoner stoneware articles are finished on the wheel itself, but better class stoneware is finished by turning on lathes. Weathering and cracking are the principal defects in articles made by the throwing process.

Articles of large sizes, oval-shaped articles, jugs, etc., are hand moulded or pressed. A wad of pugged clay is pressed by hand on the inside of a plaster or other mould, which may be in one or more sections, so that the outside of the article takes the shape of the mould; the inside is shaped by hand. In the case of moulds with multiple sections, the sections of moulded clay are assembled together and the joints luted. On stiffening, the complete article separates itself from the mould. In the case of larger articles, mould sections are removed one by one. Hand pressed products are not so dense and compact as those obtained by mechanical pressing. This process permits the shaping of articles having different thicknesses in different portions. In making certain sanitary articles, particularly basins, inside moulds are used, the outside being shaped by hand. Chemical stoneware is made by hand-moulding. Medium-sized insulators are made by hand pressing in steel moulds. Large stoneware articles are also made by this method.

Jiggering.—Shallow articles—round or oval shaped—of earthenware, fine stoneware, and porcelain are made by jiggering. The articles are shaped by fixed tools (profiles) while the lump of clay is rotated in a plaster mould. The mould is fitted in a cup-shaped vessel (Jigger head) at the top of a rotating vertical shaft (jigger). A profile attached to a handle (jolley) is applied to the inside or outside of the mould. A lump of clay is placed on the rotating mould. The profile is lowered by the jolley so that it cuts and throws out the excess clay leaving the shaped article on the mould. In making hollow ware such as cups, small jugs, basins, etc., the profile is employed for forming the inside, while for shallow articles such as saucers and plates, the profile is used for

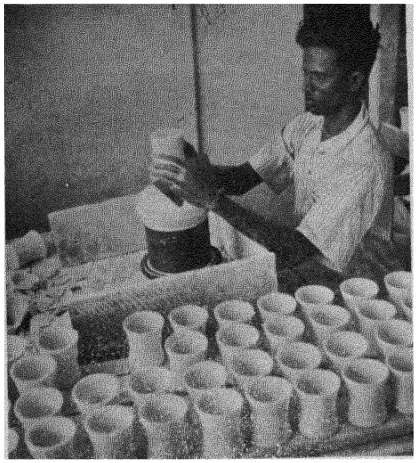


Fig. 23.—Shaping drinking vessels

the outside. The mould is removed along with the shaped article, and after drying, the article is removed, turned on wheels, and finished with a special tool and wet sponge.

Dry pressing in steel moulds is used only in special cases for forming articles of intricate shapes of specified sizes. Porcelain cleats, bushings, and medium-sized insulators are made by this process. Extreme care is necessary during pressing on account of low tolerances. The clay mixture from the filter press is dried thoroughly, remixed with about 6% of water and, sometimes, lubricants, disintegrated, and pressed in steel moulds under high pressure. Drain pipes are made in special pipe presses or by extrusion through pipe machines.

Casting.—Thin-walled porcelain and earthenware articles are made by casting. Cast articles are light and not so strong as those obtained by other methods. They are porous and suffer shrinkage during firing. Casting is particularly useful for making articles of complicated shapes such as tea-pots, flower vases, and jars. Sanitary ware can be cast accurately and with perfect homogeneity. Table-ware, floor and wall tiles, electrical and chemical porcelain ware are also made by casting. Plaster of paris moulds, in one piece or in sections, are employed. The casting slip is poured into the moulds and allowed to stand for 15–30 minutes. The plaster flocculates the suspended clay, and a deposit of clay adheres to the mould walls while the water liberated is absorbed by the plaster. When the required thickness of clay is built up, the excess slip is poured out. On standing, the body sets, shrinks from the mould, and separates out. The article is removed, trimmed, and dried. Small moulds, such as those used for tea-cups, are mounted in large numbers on one frame. Sometimes, particularly where thick-walled castings have to be made, a core is inserted.

In shaping certain types of articles, all the three processes are employed. High quality table-ware is made by casting followed by jiggering. Spark plugs, rods, and tubes are extruded, dried, and dry-ground by emery wheels to give the outer contour. Handles are cast separately and fixed to cups after jiggering. For making pin type insulators, the pugged clay is extruded in the form of a cylindrical mass, cut into required lengths, and shaped in plaster moulds by a pressing machine. The articles are jolleyed, threaded, dried, and turned on throwing wheels.

Finishing.—The formed products are dried by exposure to air in a drying yard. Seams and imperfections are removed with a knife and by wet sponging. Some articles such as plates and saucers are fettled or polished when dry on

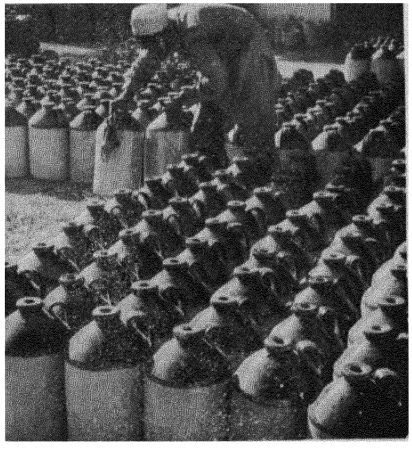


Fig. 24.—Acid jars

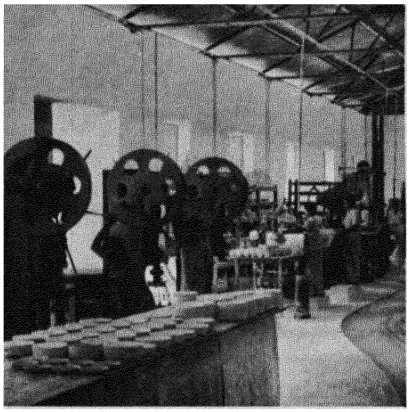


Fig. 25.—Automatic machines for the manufacture of ceramic ware

a whirler with emery or sand paper and finally by flannel cloth.

Glazing and Firing.—All ceramic ware, after shaping and drying, is baked or fired in special kilns. Unglazed pottery is fired in one stage. Glazed pottery is fired in two stages; the dried ware is fired to produce Biscuit ware which is coated with the glaze, dried, and fired for a second time (glost-firing) to vitrify the glaze.

Glazes are glassy coatings used for covering clay bodies for ornamentation and for rendering them impervious to moisture. The glaze is applied in the form of a slip by spraying, brushing, or dipping.

Glazes consist of basic oxides, sesquioxides, and acids. The glaze composition is so adjusted that it melts at the firing temperature and flows smoothly. The coefficient of expansion should be nearly the same as that of the body to prevent crazing. It should fuse at the correct temperature and should have the desired transparency and colour.

The principal glazes in use are the alkaline, felspathic, lead, and leadless glazes. Salt glaze is the most important alkaline glaze used for stoneware and sewage pipes. Felspathic glazes consist of silica and alumina with alkaline or alkaline-earth bases, and are used for hard porcelain, sanitary ware, and stoneware. Lead glazes are similar to felspathic glazes but have lower melting points owing to the presence of lead compounds they are brilliant and are used for almost every kind of ware. Lead-silica glazes are used for coarse earthenware, and fritted alkaline lead glazes, generally of the lead-boric acid type, for decorative earthenware. Leadless or alkaline-calcareous glazes are used for sanitary ware and table ware; they are similar in composition to commercial glasses, but contain a higher proportion of alumina to prevent devitrification.

Clay serves as the medium for the ingredients of the glazing composition. Felspar and lime are the principal fluxes. Other fluxes used are: barium compounds, zinc oxide, lead oxide, and boric acid. Tin oxide is added in small quantities to impart opacity. Compounds of cobalt, chromium, nickel, iron, manganese, uranium, copper, etc., are used as pigments. The ingredients are ground and mixed with clay and water to form a slip. Soluble materials such as borax and boric acid are first fritted with flint to make them insoluble. The frit so obtained is ground with the remaining ingredients (mill mix) and water in a ball mill to form the glaze slip.

Salt glaze is a soda-alumina glass coating formed *in situ* on the surface of the ware. Salt is thrown on the article at the end of the burning period, the alumina and silica necessary for glazing being withdrawn from the body of the ware. The resulting product is usually brown in colour due to the iron present in the body.

During firing, the clay particles are partially fused and permeated by a glassy magma which

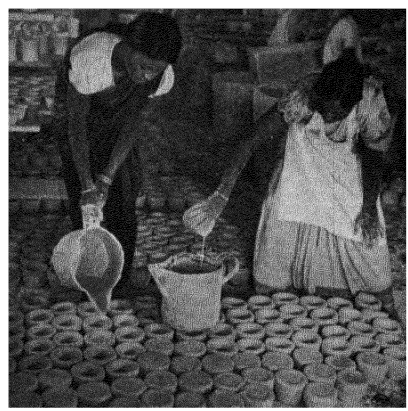


Fig. 26.—Casting of tea cups

unites the more refractory particles together into an almost impervious mass. Stoneware and porcelain ware are fired at a high temperature, and the firing is continued till the body is vitrified and the pores are completely filled up. The ware is protected from flame, smoke, and dirt by placing the articles in refractory enclosures or Saggars. The saggars also serve to protect the articles in the bottom layers from the load of the top layers.

Coarse earthenware is fired at about 800°. Fine earthenware is biscuited at 1,200—1,300°, and glost-fired at a lower temperature (about 1,100°) which is sufficient to produce a porous body; higher temperatures reduce porosity and the glaze is not retained. Porcelain ware is biscuited at a low temperature to make it sufficiently strong for subsequent handling, glaze slip applied, and the ware glost-fired at 1,350—1,450° at which temperature both the body and the glaze vitrify. High grade stoneware, domestic stoneware, and artware are biscuited at 900—1,000°, and glost-fired at 1,280—1,380°.

A one-stage process for glazing articles is sometimes employed. The dried ware is coated with glaze, and fired to vitrify both the body and the glaze. The process is economical in fuel and minimizes the risk of crazing. In India, one firm manufactures glazed earthenware cups and saucers by single firing. Stoneware of the heavy type is glazed in the clay state and fired.

Firing.—Three types of kilns are in use for firing, viz., intermittent or periodic kiln, continuous or ring kiln, and tunnel kiln. Pottery works in India generally employ intermittent kilns of the down-draught, single chamber type. Two chambered down-draught kilns are used in a few factories, the lower chamber for glost-firing and the upper chamber for biscuiting. Continuous or ring kilns and special kilns like muffle kilns are not used in India. Three factories have installed tunnel kilns for handling large production outputs; one of them is an electric tunnel kiln.

Decoration.—Two methods of decoration are employed—underglaze decoration and overglaze decoration. In the former, the decoration is applied direct to the body or to an engobe. Colours are applied by painting, dipping, spraying, stencilling, or transfer-printing. The colours are prepared by mixing pigments, metallic oxides such as alumina, lime, tin and zinc oxides, with china or other clay or with an essential oil. The decorated article is then glazed. The colours are more permanent than in overglaze decoration, but only a limited range of colours can be used owing to the high temperature of glost-firing.

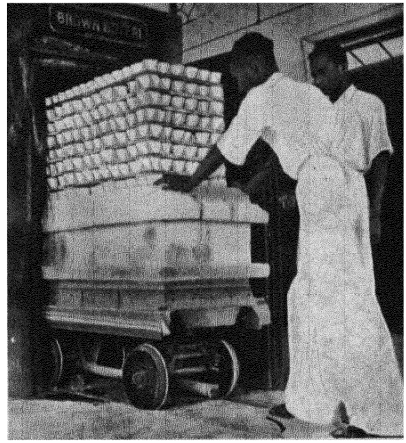


Fig. 27.—Electric tunnel kiln

In overglaze decoration, the article is decorated after the glaze is applied. The decorated ware is fired again at a low temperature for fixing the colours. The process is used for decorating fine earthenware, porcelain ware and, sometimes, coarse and fine stoneware. The most common form of overglaze decoration is decalcomania which is a process of transferring designs or pictures from paper transfers to the article. Hand painting is also common. The colours are mixed in an oil medium, or with a flux containing lead oxide, borax or boric acid to produce a fluid colour glaze of low melting point. A protective glaze is sometimes applied over the decoration. A variety of colours may be used for overglazed decoration on account of the low firing temperature. Beautiful multi-coloured designs can be painted upon finished goods by the use of lithographic papers.

Production and Trade

Three types of ceramic ware are now manufactured in India—white ware, stoneware, and insulators.

Indian white ware includes crockery both of the indigenous style (jars, bowls, plates, etc.) produced in Nagpur, Calcutta, Raniganj, and Jubbulpore, and of modern style (cups, saucers, milk jugs, sugar pots, coffee pots, dinner sets, soup plates, tea-pots, etc.) produced in Calcutta, Bangalore, Gwalior, and Morvi. Some types of

Fig. 28.—Decorating pottery

fine crockery such as egg cups, ornamental china cups, are produced only in small numbers. Decorated articles such as flower vases, toys, are also made. Earthen bodies are used for tea, dinner, and coffee sets, while tea-cups and saucers, teapots, milk jugs, sugar pots, etc., are made of porcelain.

The manufacture of stoneware acid and pickle jars is a well-established industry in India, and there are prospects of its further expansion. The manufacture of sanitary ware started during the War, is also rapidly expanding. Stoneware cups are also manufactured.

Porcelain insulators, such as cleats, connectors, fuses, switches, are made in Calcutta, Bangalore, Gwalior, Delhi, and Morvi. About 90% of the L.T. insulators required by Posts and Telegraphs, electrical utility undertakings, and radio industry, is manufactured in India. Suspension type H.T. insulators are also being made. The total installed capacity of both H.T. and L.T. insulators is 4·2 million pieces per annum. Chemical and laboratory porcelain articles such as basins, Buchner funnels, desiccator stands and textile accessories are being produced in India.

The total production of ceramics in 1939 was 8,700 tons (white ware, 2,000 tons; stoneware, 4,500 tons; and insulators, 2,200 tons). The production increased considerably during World War II, and c. 19,340 tons of ceramic products (whiteware, 5,640 tons; stoneware, 5,400 tons; and insulators, 8,300 tons) were manufactured in 1945. The production rose to 20,000 tons in 1947, and to 23,000 tons in 1948. Table 1 gives the production of ceramic ware in India during 1948 and 1949.

TABLE 1.—PRODUCTION OF CERAMIC WARE

	Qty. (Tons)	
	1948	1949
Porcelain ware	3,237	2,258
Earthenware	2,134	1,203
Stoneware	15,214	22,980
Sanitary ware	1,466	1,603
H. T. Insulators	89,879*	136,750*
L. T. „	2,503,031*	2,239,204*

*Numbers

TABLE 2.—IMPORTS OF EARTHENWARE AND PORCELAIN

(in lakh Rs)

	Earthenware			Porcelain		Total
	Pipes	Sanitary ware	Other kinds	Electrical porcelain	Other kinds	
1934/35–1938/39 (av)	0·23	8·29	10·33	1·41	25 25	45 52
1939/40–1943/44 (av.)	0·03	7 47	6 80	1 01	9 39	24 72
1944–45	..	7 80	10·30	1·78	0 37	20 25
1945–46	..	8·13	15·18	0·95	1 54	25·89
1946–47	0 01	10·89	42·00	1·80	5·12	59 82
1947–48	0·18	21·52	40·50	1·8	7 53	71 61
1948–49	.	17 40	6·98	1·69	2 54	28·61
1949–50	1 47	20·33	21 72	3·72	15 58	62 82

TABLE 3—IMPORTS OF CERAMIC WARE FROM U K *

	Qty (cwt)					Value (£)				
	1942	1943	1944	1945	1946	1942	1943	1944	1945	1946
Sanitary ware (earthenware)	4,773	2,719	5,122	7,129	7,345	21,631	14,037	25,574	36,227	45,909
Sanitary ware (fireclay)	1,343	1,349	1,138	3,231	6,468	3,491	3,123	2,633	8,136	21,617
Bone china	23	7	6	76	611	597	263	233	1,583	25,217
Other translucent pottery		3		49	954	..	28		831	15,725
Earthenware, non-vitrified (cooking utensils & others)	3,767	448	3,693	6,379	19,465	16,673	2,072	15,316	31,120	144,956
Earthenware, other sorts	130	179	244	343	587	1,082	798	2,508	3,225	6,151
Stoneware	1,066	135	364	565	895	6,180	774	2,136	3,662	4,762
Electrical ware (including insulators)	2,310	4,071	6,176	5,577	3,781	13,191	19,899	40,059	35,101	26,881

*Tr., U. K.

TABLE 4.—SHARES IN IMPORTS (%)

	Sanitary ware (earthenware)	Other kinds of earthenware	Electrical porcelain	Other kinds of porcelain
U. K.	77	64 0	40 9	6 0
Germany	11	7 0	27 5	2 0
Japan	6·6	19 3	29 0	90 0

TABLE 5—EXPORTS

	Value (lakh Rs.)
1933/34 1938/39 (av)	0 98
1939/40-1943/44 (av)	1 89
1944 45	7 58
1945 46	8 18
1946 47	17 95
1947 48	11 71
1948 49	13 05
1949 50	1 94

Imports.—Table 2 gives the imports of ceramic ware into India.

Table 3 gives the imports of ceramic ware into India from U. K.

The bulk of imports of earthenware and porcelain in pre-War years was from U K, Germany, and Japan Table 4 gives the shares of the three countries in total imports during the quinquennium ending 1938-39

Table 5 gives the exports of earthenware and porcelain from India.

The Panel on Refractories and Ceramic Industries of the Government of India fixed the annual increase in production over the 1946 figure for the first five years as follows: white ware, 1,128 tons; stoneware jars, 1,080 tons; and insulators, 1,245 tons. This represents an increase of 25%, 20%, and 15% per annum respectively over the 1946 production. The production of L.T. insulators is to be progressively raised to 1,000 tons and that of H.T. insulators to 600 tons. The production of earthenware cups, saucers, rice bowls, and rice dishes are to be increased by 100%, and that of white glazed and decorative tiles, sanitary ware hospital ware, chemical porcelain, etc., by 75%.

Charcoal, Retort— *see* **Wood distillation**

CHARCOAL, WOOD

Wood charcoal has been produced and used in India since ancient times. It is superior to wood as fuel, as it can be easily lighted, burns without emitting smoke, and gives an intense and steady heat.

Almost all species of wood can be carbonized to give charcoal, but some selection is necessary to obtain a product of good quality. Generally, any species of mature dense wood with narrow annular rings produces good charcoal. Rotten and old wood gives a light product.

When wood is heated in retorts, out of contact with air, it begins to carbonize at about 150° and moisture and volatile matter distil over. As the temperature rises cellulosic matter begins to decompose forming pyroligneous acid, methyl alcohol, acetone, hydrocarbons, carbon monoxide, and carbon dioxide, which escape from the retort, leaving behind charcoal. Black charcoal of good quality having a fixed carbon content of about 77% can be obtained by retorting wood at 350°, but in actual practice the temperature used is 500—600°.

Charcoal Kilns

Charcoal is obtained by burning wood in open pits, kilns, or retorts. Many types of pits and kilns are in use for charcoal making. They can be grouped under three major categories:

I. Indigenous kilns: (1) Open pit kiln, (2) improved pit kiln, (3) paraboloidal kiln, (4) oven kiln, including brick-walled oven, and (5) prismatic kiln and hill kiln;

II. Brick-walled kilns: (1) Nilgiri kiln, (2) conical brick kiln, and (3) Siamese kiln; and

III. Metal kilns: Forest Research Institute portable charcoal kiln.

The primitive open pit method is now practically obsolete; it accounts only for a small fraction of the total production. The pits are 3—5 ft. diam., 5 ft. deep with sides sloping outwards, the entire pit being lined with brick and mud. Fire is started at the centre of the bottom with twigs and split wood, over which billets are thrown and burnt till smoke ceases. From time to time further billets are added till the entire pit is filled with glowing charcoal. Water is then sprinkled and the pit covered with wet earth or turf, or corrugated iron sheets, leaving a small passage for the gases to escape. When the smoke ceases, all the holes are completely filled up and the pit allowed to cool for a day or two, and the charcoal taken out. The yield is about 18% calculated on the weight of dry wood. The product is inferior in quality and unsuitable for use in portable producers. Open pit kilns are suitable only for small charges. Complete carbonization cannot be secured when the charge is increased.

A modified pit kiln or the Improved pit kiln (Budhiraja & Dey, *Indian For. Leafl.*, No. 53, 1943, 4) has come into use in Australia. It is rectangular (12 ft. × 4½ ft. × 4½ ft.) in cross section. Air is admitted at the bottom through two large holes. Billets are arranged horizontally along the longer side, thinner ones being placed at the bottom. The pit is covered with corrugated sheets, with openings at the sides, one nearer the air holes for smoke to escape and the other for firing. The stack is fired through a vertical hole left open during stacking. It is then

Fig. 29.—Arrangement of logs in a charcoal kiln

covered with wood and closed with corrugated sheet and dry earth. About half an hour after firing, the size of the smoke outlet is decreased. Burning takes about 48 hrs. and carbonization is complete when a bluish smoke comes out. At this stage the smoke hole and the air inlets are closed and the kiln cooled down. After a day or two, the cover is taken off and the charcoal removed. The yields obtained with *Pinus longifolia* and *Dalbergia sissoo* woods are 20% and 28% respectively calculated on dry weight basis. The quality of the product is good and the charcoal is suitable for producers.

The bulk of charcoal used in India is made in Paraboloidal, mud walled kilns. The kiln is built in a paraboloid shape, the usual size being 8—10 ft. radius and 8 ft. high, and capacity, 800—1,200 stacked c. ft. of wood. Before stacking, a vertical flue is constructed in the centre of the kiln with the help of three stakes bound round with twisted grass. The firing is from the bottom for which purpose a narrow passage is left from the centre of the flue to the outside of the kiln. The whole stack is made up with two tiers of vertical and a top layer of horizontal billets about 2 ft. deep. The billets are stacked from the centre outwards, the thick ends pointing downwards, which gives the kiln the paraboloid shape. The thick billets are stacked about half way out from the centre where the heat is at its maximum. On the top of the first two tiers, billets are stacked horizontally, varying lengths being used to give the correct shape. The kiln is covered first with a thick layer of grass, leaves, and turf, and then plastered with wet earth or a mixture of fine earth and charcoal dust (Trotter 1940, 333).

Fig. 30.—Paraboloidal charcoal kiln

The chimney is filled with dry grass, twigs, and other combustible material, and when fire is introduced through the horizontal passage to this material it spreads outwards and the billets begin to burn. When the kiln is well lit, all passages are closed with billets and covered with grass and mud. The time taken for carbonization varies according to size, 7—10 days being necessary for the more common sizes. The rate of burning should be carefully controlled and cracks and crevices should be patched up as they appear. As burning proceeds a thick pungent yellowish brown smoke comes out, and when a clear blue flame appears all over the kiln right down to the base the carbonization is complete. The kiln is allowed to cool for a week or more before the charcoal is taken out.

Oven kilns are similar to the paraboloidal kilns and are erected on flat ground or in a pit 2 or 3 ft. deep with a thick covering of baked mud. The kiln may be used repeatedly. Firing is through a side hole which is also used for discharging the charcoal. Such kilns are in use in Oudh and at Changa Manga (Punjab). A type with brick lining is common in Daphar and Chichawatni plantations in Punjab (Chopra, *Indian For.*, 1938, **64**, 346).

Prismatic kilns are rectangular in cross section; the sides are rounded. They are in use in Madhya Pradesh and in Dehra Dun. They are usually 13—20 ft. long, 5 ft. broad, and 5—6 ft. high. The ground is cleared and two long poles planted 5 ft. apart along the length of the kiln. The wood is stacked crosswise and the kiln packed completely with wood pieces (2 in.—30 in. diam.), the thicker pieces being stacked at the bottom. The wood is so arranged that the stack is slightly sloping to one side. The firing hole is formed by 3 stones in the middle of the broad side of the kiln, and the long base supports serve as a duct for the fire to travel to the exit hole provided at the top of the sloping side of the kiln. The stack is covered with brushwood and earth, leaving out the firing hole and the top is covered with a layer of leaves 1 ft. thick kept in position by inclined poles. The fire is started by introducing burning splinters in the firing hole until the kiln is well lighted. Charcoal is removed through holes made as and when necessary.

Two days are required for charging and covering a kiln of 440 c. ft. capacity, 2 workers being employed; burning and cooling take 7—8 days. The charcoal produced is of good quality but is

usually admixed with burnt clay and stones. The advantage of this type of kiln is that large logs of wood can be employed without cutting them into billets It is, however, difficult to cover the kiln properly as there may be uneven settling during cooling (Budhiraja & Dey, op. cit., 11).

Modified designs of the common kilns are employed in the hills In the Hill kiln wood is stacked horizontally and a passage, running from the front to the rear, is provided for firing This passage is connected with a vent at the back (Trotter, 1940, 337) Burning is seldom even The method is in use in Uttar Pradesh

Brick-walled kilns are more or less permanent structures of octagonal shape The eight vertical walls and the basement are made of bricks and mud, and the roof and the door on one side are of corrugated galvanized sheets Such kilns are suitable for localities assured of continuous supplies of wood, and are in use only in the Nilgiris The air required for carbonization enters through small draught holes provided at the bottom and centre of each side The roof is also provided with a number of holes Two layers of billets, preferably round and unsplit, are stacked vertically above a layer of horizontally stacked billets, the central tier containing the bigger sizes When the stacking is completed the door is closed and rendered airtight with mud, all opening at the bottom and in the roof being kept open Firing is through a bottom hole and as the fire spreads the openings at the bottom and the top are gradually closed one by one, and when blue smoke comes out indicating the completion of carbonization, all the holes are closed and the kiln made airtight The kiln is allowed to cool for 2—3 days, and when sufficiently cool, the charcoal is removed through the door and bagged The average yield is about 21% on the dry weight of the wood (*Indian For Leafl*, 1943, No 54)

Portable metal kilns are preferred to indigenous and brick-walled kilns where wood is scarce The cost of transportation of wood can be saved by shifting the kilns to the regions of supply These kilns possess the following advantages over other types (1) quick carbonization, (2) quick cooling, (3) portability, (4) freedom from leaks, (5) adaptability to hill regions, (6) freedom from fire hazards, and (7) good yield and quality of product.

The Frikiln designed at the Forest Research Institute, Dehra Dun, has given uniformly satisfactory results (*Indian For Leafl*, No 55, 1943, 1) The kiln consists of a number of steel plates joined together from the sides and the top in equal number of sections by suitable devices, such as V-bars, bolts, and wedges, and made airtight with earth Air enters through holes at the base of each side and is distributed by a distribution box Smoke outlets are provided in the roof sections To instal the kiln the ground is first levelled and the side panels erected, leaving out one of the panels The first two layers of billets are placed vertically, followed by horizontal stacking, when the billets reach the doorway the side panel is closed and stacking is continued from the top The roof sections are then placed in position and all joints fitted up The kiln is fired from the top through a vertical central tunnel provided during stacking The hole is subsequently filled up with billets and covered Little attention is needed after firing When the carbonization is complete, blue smoke issues from the outlets. The air inlets and the smoke outlets are closed and covered with earth and the whole kiln allowed to cool The kiln is then opened and the charcoal discharged

Quality and Grading—The quality of charcoal depends on the species of wood used, method of carbonization and, to a large extent, on the skill and care with which it is made Good charcoal should be black and glistening with a bluish tinge, it should give a clear metallic note when struck on a hard object, it should be free from taste and smell, small pieces should adhere to the tongue, the transverse surface when rubbed should not soil the fingers, it should be capable of being easily lit, and should burn without producing smoke or flame, the ash content should be low and the moisture content should not exceed 5—6% The burning quality depends mainly on the percentage of fixed carbon, and this can be increased by carbonizing wood at a temperature at which most of the volatiles is distilled off, the resulting product being dense The quality of charcoal can be judged by the following characteristics· apparent specific gravity, true specific gravity, percentage of pores by volume, volatility, fixed carbon, and ash (Dey & Varma, *Indian For Leafl*, No 56, 1944)

Storage.—Proper storage of charcoal is important as the requirements for the year are obtained during one season It is usual to pack the charcoal in gunny bags and store them in godowns Charcoal absorbs considerable quantities of moisture, and for this reason storage godowns should be damp proof To avoid fire hazard due to spontaneous combustion, the bags used for packing should be free from oil and grease, and the godowns should be well-ventilated. Charcoal is seldom transported through long distances as it

is bulky and is liable to damage and loss during transit.

Charcoal for Portable Producers

The suitability of charcoal for producer gas plants has been known for a long time, but it was only during World War II that charcoal-fired producers came into extensive use in India, and a large number of buses and lorries was run on producer gas in order to conserve petrol

Charcoal burns readily forming a gaseous mixture rich in carbon monoxide, which when burnt, produces a gas free from tarry products. It can be, therefore, employed as a substitute for petrol About 14 lb of charcoal are equivalent to one gallon of petrol

The charcoal required for use in portable producers should be reasonably free from earthy impurities It should satisfy the following specifications (War Transport Dep, India, *Conference of Producer Gas Technical and Testing Officers*, 1944, 34)

(1) The charcoal shall be free from pieces of wood or bark, stones, etc, and reasonably free from loose ash, grit, and dirt The ash content should not exceed 4–6%

(2) It shall be reasonably free from tarry or volatile matter, which should not exceed 25–30%

(3) It shall be reasonably dry Air-dry charcoal should not ordinarily contain more than 6% moisture Charcoal with a moisture content exceeding 10% should be preferably dried before use

(4) It shall burn with a clear bluish flame, reasonably free from smoke and sparkling

The following woods have been found suitable for producing charcoal of the required characteristics (Ramaswami *et al*, *Indian For Leafl*, No 35, 1943): *Acacia arabica, A catechu, A leucophloea, Adina cordifolia, Aegle marmelos, Albizzia procera, Anogeissus latifolia, A pendula, Azadirachta indica, Butea monosperma, Casearia* spp, *Casuarina equisetifolia, Dalbergia sissoo, Diospyros embryopteris, Ficus glomerata, Holoptelea integrifolia, Kydia calycina, Mallotus philippinensis, Mangifera indica, Pieris ovalifolia, Pinus longifolia, Populus euphratica, Prosopis spicigera, Quercus dilatata, Q. incana, Sapium sebiferum, Shorea robusta, Syzygium cumini, Tamarindus indica, Terminalia arjuna, T. belerica, T tomentosa, Trewia nudiflora* and *Zizyphus jujuba*

Charcoal can be used along with rectified spirit, diesel oil, and green wood chips, in producers.

Uses

Wood charcoal is extensively used for ore smelting, and as fuel for blacksmiths' and metal workers' forges, and for numerous cottage industries Powdered charcoal is used in the manufacture of gun powder Retort charcoal is used in Bhadravati for smelting iron ores. Briquetted charcoal made from *Acacia* spp using either gum arabic or sorghum flour as binder is suitable for firing stationary boilers Charcoal briquettes made with pitch as the essential binder and gum arabic as the primary binder have been found to be satisfactory for firing locomotive boilers (Greene & Jewitt, *Nature*, 1944, **154**, 58)

Producer gas driven public vehicles utilize considerable quantities of charcoal The annual charcoal consumption in India is roughly 124,000 tons*

The quantity of wood used for charcoal production in 1944-45 in Indian States, except Assam, Bihar, East Punjab, and West Bengal was 72,409,000 c ft (*Indian Forest Statistics*, 1949, 27) Taking the average wt per c ft of timber as 37 lb and the yield of charcoal as approximately 20%, the total production of charcoal was 239,205 tons

Table 1 gives the approximate production of charcoal in some Indian States Data for other States are not available Madhya Pradesh

TABLE 1 —PRODUCTION OF CHARCOAL

	Qty. (Tons)
Madhya Pradesh	1,90,532
Bombay	1,01,000
Hyderabad	30,000
Orissa	14,600
Uttar Pradesh	8,734
Punjab	9,030
West Bengal	5,446

*No of producer gas vehicles in service on 31st March 1949	10,679.	
Mileage per vehicle per month of 25 days at 60 miles/day†	25 × 60 = 1,500	miles
Monthly consumption of charcoal per vehicle at 1 2 lb / mile†	1500 × 1 2 lb.	
Total monthly consumption of charcoal for 10,679 vehicles	1500 × 1 2 × 10,679 = 8581 tons	lb.
Loss as dust and fines during grading at 20%†	1,716 tons	
Total monthly requirement of charcoal	10,297 tons	
Yearly consumption of charcoal	123,564 tons	

†Ramaswami *et al*, loc cit,

supplies charcoal to Bombay and Delhi markets.

The consumption of charcoal during 1946 and 1947 in 29 major industries was 14,000 and 13,410 tons respectively (Second Census of Manufactures, India,— 1947, 1950, 66)

CHLORINE

Chlorine in the form of chlorides, e.g, rock salt, sea salt, sylvine, carnallite, is widely distributed in nature Chlorides are present in small concentrations in vegetable and animal tissues

The world's largest producer of chlorine at present is U S A The total installed capacity for chlorine production in the world was estimated to be 9,300 tons per day in 1949, production in 1948 was about 8,000 tons per day (Murray, *Industr Engng Chem*, 1949, **41**, 2157)

Chlorine is manufactured on a commercial scale by one of the three following processes

(1) Electrolysis of brine,
(2) Electrolysis of fused sodium chloride, and
(3) Action of nitric acid on sodium chloride (Solvay nitrosyl chloride process)

The first process accounts for 91% of the chlorine produced in U S A, 8% is produced by the electrolysis of fused chloride, and 1% only by the treatment of sodium chloride with acid (Murray, loc cit)

Properties—The more important physical constants of chlorine (at wt, 35·457) are *Chlorine gas—d*, 3·214g /litre at N T P, C_{p_0} 0 1159 cal /g. per °C (1 atm and 15°), $C_p - C_v$ 0·0301 cal /g; p_c, 76 atm, and t_c, +144°; *Liquid chlorine—d*, 1 468g /ml (0° and 3 65 atm), sp heat, 0 2257 cal /g per °C (between 0 and 24°), b p (at N T P),—34 6°, f p,—102°; and latent heat of vaporization, 67 1 cal /g (at −34·6°). One volume of liquid chlorine gives 462 vol of gas at N T P

Uses—Chlorine is one of the most versatile and widely used industrial chemicals The importance of chlorine as a raw material for chemical industry would be evident from the fact that in U S A, the production of chlorine which was 500,000 tons in 1940, rose to 1,615,000 tons in 1948 The uses of chlorine may be classified under three main heads (Murray, loc. cit):

(1) Direct use of chlorine in the treatment of a given product,
(2) Utilization of chlorine for the formation of an intermediate product which is ultimately converted into an end-product containing no chlorine; and
(3) Preparation of chlorinated compounds with specific characteristics.

The principal consuming industries of the first group are the pulp and paper industry, water purification and sewage treatment, and textile bleaching. This direct use of chlorine accounted for nearly 68% of the chlorine output in 1929 in U S A, more chlorine was so utilized in 1949 though the percentage figure was only 24.

Tetraethyl lead, ethylene and propylene glycols, phenol, and magnesium are examples of products of the second category About 30% of the chlorine output in U S A is utilized in the manufacture of such products.

The phenomenal increase in the consumption of chlorine in U S A is the outcome of the development of products of the third group The consumption of chlorine in the manufacture of such products increased from 6% in 1929 to 40% in 1949 Examples of such products are chlorinated solvents, such as carbon tetrachloride, tricholoroethylene, ethylene dichloride, methyl chloride, methylene chloride, vinyl and vinylidene plastics and silicones, insecticides, fungicides, bactericides and herbicides like DDT (Dichlorodiphenyl trichloroethane), 'Gammexane' (Benzene hexachloride), 2,4D (2, 4-dichlorophenoxyacetic acid), pentachlorophenol, inorganic chlorine compounds, e g, chlorides of aluminium, zinc, iron, barium, titanium, and silicon, and chlorates of sodium and potassium; chlorine compounds employed in military operations, and chlorinated oils, rubber, naphthalene, and waxes.

Chlorine and its compounds were extensively used during World War I in the production of smoke screens like BM, H C, FM, lachrymatories, vesicants, and toxic gases such as Tonite (chloracetone), Aquinite, Klop, and NC (chloropicrin), CN (chlorantophenone), mustard gas, phosgene, and chlorvinyl dichlorarsine (Prentiss, 133, 243)

Chlorination of fats, oils and hydrocarbons yields resins of industrial importance. Chlorination of naphthalene gives a mixture of chlornaphthalenes (m p. range, 60—125°) —Seekay Wax and Halowax—which are used as non-inflammable binding agents in the manufacture of insulating compositions They are used also in the production of smoke screens and insecticides, and as substitutes for camphor in the manufacture of nitrocellulose films (Bhatnagar *et al., J sci. industr. Res*, 1944, **3**, 340).

Chlorinated rubber derivatives find extensive application in lacquers and protective coatings. They are resistant to corrosion, weathering, moisture, gas, acid, alkali, and fire. Stable chlorinated rubbers are marketed under trade names, Tornesit, Alloprene, and Parlan.

Paraffin wax is chlorinated and condensed with various aromatic hydrocarbons in the presence of aluminium chloride to yield products such as Paraflow used as pour point depressors.

The analysis of chlorine usage in the U.S.A. for the year 1948 is as follows: chemicals, 75%; pulp bleaching, 12%; water treatment, 10%; textiles, miscellaneous uses, and exports, 3% [*Chem. Engng*, 1949, **56** (2), 115].

The Indian Industry

Chlorine is produced in India by the electrolysis of brine (Wlth India, Pt. I, 71). When an aqueous solution of sodium chloride is electrolysed in the conventional diaphragm cell, chlorine is produced at the anode, and hydrogen and caustic soda at the cathode. The chlorine, discharged from the cells at a temperature of c. 80°, is saturated with water vapour. A large part of the water is eliminated by cooling to about 15°. The cooled gas is drawn through a series of stoneware drying towers, in which conc. sulphuric acid is kept under circulation. The dried gas from the towers passes through a separator where the acid mist carried by the gas is retained, and the gas is drawn by centrifugal blowers or compressors of the Nash type to a set of refrigerated liquefying coils. Chlorine liquefies at −40° at atmospheric pressure and at 15° when the pressure is raised to 7·5 atm. Liquid chlorine is stored in tanks and sold in steel cylinders containing, usually, 57 or 150 lb. chlorine. In U.S.A., chlorine is transported in tank-cars holding 10−30 tons of liquid chlorine. The commercial product contains c. 98·6% chlorine. The impurities are: CO_2, 0·7; O_2, 0·2; CO, 0·01; H_2, nil; and others, 0·5%.

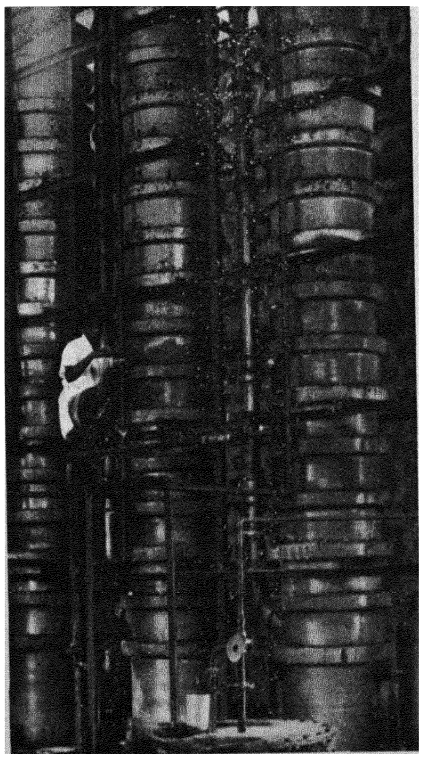


Fig. 31.—Chemical stoneware towers for drying chlorine

The salt required for the electrolytic cells must conform to the following specification: NaCl, 98·5; CaO, 0·28; MgO, trace; SO_3, 0·12; Fe_2O_3, trace; water insolubles, 0·57; and moisture, 0·07% (Rogers, I, 439). Industrial salt of this grade is not marketed in India, and a brine-purifying unit is a necessary adjunct to every alkali plant. The brine is purified by the addition of caustic soda to precipitate iron and magnesium, followed by sodium carbonate to precipitate calcium; the resulting solution, after settling, is filtered through sand to give a clarity of 98% (distilled water, 100). The brine fed to diaphragm cells should conform to the following specification:

Sp gr. $\frac{50°}{15°}$	1·186 (minimum)
NaCl	312 g./litre (minimum)
NaOH	0·4 to 0·60 g./litre (max.)
Na_2CO_3	0.40 to 0.60 g./litre ,,
Na_2SO_4	0·50 to 2·50 g./litre (max.)
Ca	4·0 p.p.m. ,,
Fe	0·3 p.p.m. ,,
Mg	0·5 p.p.m. ,,
Ba	None
Clarity	98% (minimum)

Chlorine is produced in India by the *Mettur Chemical and Industrial Corporation Ltd.*, Mettur Dam; The *Alkali and Chemical Corporation of India Ltd.*, Rishra; The *Tata Chemicals Ltd.*, Mithapur; The *Ahmedabad Manufacturing and Calico Printing Co. Ltd.*, Ahmedabad; and *D.C M.*

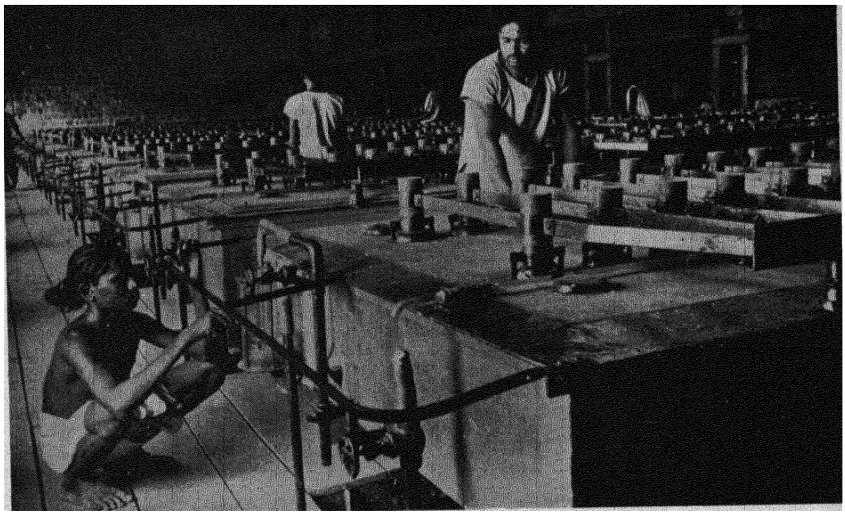


Fig. 32.—Electrolytic chlorine cells— Hooker type S

Chemical Works, Delhi. It is understood that several other firms have plans for producing electrolytic chlorine in the near future. The present total investment in the industry is over Rs. 5 crores, and the industry employs nearly 6,000 workers.

In addition to these manufacturers, several paper mills produce electrolytic chlorine for conversion into bleach liquor or bleaching powder. Five of the paper mills are reported to be producing 420 tons of chlorine, and 1,910 tons of bleaching powder annually (Indian Tariff Bd, *Rep. Caustic Soda & Bleaching Power Industry*, 1946, 5). Many textile mills are equipped with plants for producing bleach liquor by the electrolysis of brine.

Production and Trade

Table 1 gives the production of chlorine in India. Table 2 gives the production of liquid chlorine in India. The cost of production of liquid chlorine at Mettur has been estimated at Rs. 17-12-0 and Rs. 16-14-0 per cwt. for the two halves of the 2½ yr. period ending March 1949 (Indian Tariff Bd, *Rep.*, 18). The corresponding fair selling price has been estimated at Rs. 20-4-0

TABLE 1.—PRODUCTION OF CHLORINE

	Plant Capacity (Tons)	Actual Production* (Tons) 1948
Alkali & Chemical Corpn. of India Ltd., Rishra (I. C.-I.)	1,500†	1,452
Mettur Chemical & Industrial Corpn. Ltd., Mettur Dam	1,320‡	1,140
Tata Chemicals Ltd., Mithapur	2,346	473
Ahmedabad Manufacturing and Calico-printing Co. Ltd., Ahmedabad	1,800	771
D. C. M. Chemical Works, Delhi	1,300	**
	8,266	3,836

*For the year 1948. **Commenced production in 1949.

†To be increased to 4,150 tons by 1951 ‡To be increase by 2,600 tons.

TABLE 2.—PRODUCTION OF LIQUID CHLORINE*

	Qty. (Tons)
1946	1,500
1947	1,706
1948	1,800
1949	2,649

Monthly Statistics of the Production of Selected Industries of India

TABLE 3.—IMPORTS OF LIQUID CHLORINE*

	Qty. (lb.)	Value (Rs)
1937-38	668,428	2,49,220
1938-39	682,235	2,12,752
1939-40	519,871	1,59,203
1940-41	49,586	25,391
1941-42	..	..
1942-43	1,095	571
1943-44	62	31
1949-50	654	24,426

*There were no imports during the period 1944/45 to 1948/49

and Rs. 19-6-0 respectively

Prices of liquid chlorine in containers vary from 4 as. to 9 as per lb. depending on the nearness of the consuming market and availability of chlorine containers.

Table 3 gives the imports of liquid chlorine into India.

The distribution of chlorine usage in India in 1948 was as follows. liquid chlorine for water purification and textile bleaching, 45 3, bleaching powder, 27·4, bleach liquor, 20 5, chlorinated compounds, 5·2; and hydrochloric acid, 1·6%.

Future Developments—The Panel on Heavy Chemicals and Electrochemical Industries have fixed 40,000 tons of chlorine per annum as the five-year target of production (*Rep. Panel on Heavy Chemicals and Electro-Chemical Industries*, 1946, 21) The limited outlets for chlorine have hindered the expansion of electrolytic alkali industry in India. The panel has recommended the production of DDT and 'Gammexane' (30,000 tons each per annum) as a means of utilizing the chlorine produced A plant for the production of 500 tons 'Gammexane' per year has already been put up by the I C I. at Calcutta The manufacture of these insecticides and of sulphonamide (500,000 lb) and mepacrine (500,000 lb), and the contemplated development in the dyestuffs and plastics industries are expected to consume all the chlorine that may become available in the country.

Besides, plants for the production of synthetic phenol via chlorobenzene (10 tons/day) and of calcium hypochlorite (4·5 tons/day) are being set up in India. Production of bromine may also be expanded. Other possible uses of chlorine are: production of sulphuric acid from sodium sulphate, manufacture of mono- and di-calcium phosphates from rock phosphate, chlorination processes for the recovery of metals from ores and for the preparation of compounds useful in industry, gas chlorination or Pomilio process for the manufacture of cellulose, paper, or rayon from linters, bagasse, mixture of wood and straw. The Pomilio process is being utilized for paper pulp manufacture in India.

CHLOROFORM

Chloroform, $CHCl_3$, is a heavy colourless liquid used principally as a solvent in industry and as an anaesthetic and antiseptic in surgical and medical practice Its high toxicity is disadvantageous for anaesthetic purposes, and it is now largely replaced by ether in combination with nitrous oxide It is used also as a serum-preservative, insecticide, vermicide, and counter-irritant for external application It was used during the last War in the manufacture of hexa chlorethane required for smoke screens

Manufacture

Chloroform is produced by the action of bleaching powder on acetone or alcohol, when the following reactions take place

1. $2CH_3COCH_3 + 6CaCl_2 \rightarrow 2CHCl_3 + (CH_3COO)_2Ca + 2Ca(OH)_2 + 3CaCl_2$

2 (a) $CH_3CH_2OH + CaOCl_2 \rightarrow CH_3CHO + CaCl_2 + H_2O$

(b) $2CH_3CHO + 6CaOCl_2 \rightarrow 2CCl_3CHO + 3Ca(OH)_2 + 3CaCl_2$

(c) $2CCl_3CHO + Ca(OH)_2 \rightarrow 2CHCl_3 + Ca(COOH)_2$

The process utilized in the production of chloroform in India is based on reaction 2, in other countries acetone oxidation is the process generally employed. Bleaching powder acts on alcohol partly as an oxidizing agent and partly as a chlorinating agent, chloral being formed as an intermediate product This is decomposed by calcium hydroxide, formed during the second stage of the reaction, into chloroform and calcium formate. The reaction is brought about in a cast-iron still provided with stirring gear and

steam and cooling coils, and connected to a receiver through a condenser.

The raw materials are taken in the ratio of 4 parts of bleaching powder (32 5—34·5% available chlorine), 3 parts of alcohol (96%), and 13 parts of water (Simmonds, 333) Steam is let in and the temperature raised to 40°; the heat of the reaction raises the temperature further. The maximum temperature is not allowed to exceed 60°. Chloroform distils over and is collected in a receiver The fraction distilling at temperatures exceeding 60° is collected separately, it consists of alcohol saturated with chloroform The distillation is stopped when a sample of the distillate gives no turbidity with water.

Chloroform is separated from alcohol by washing with water in a narrow vertical cylinder, and rectified in a copper still rectifier. Under Indian conditions 18 gal of alcohol (96%) and 12 cwt. bleaching powder yield 100 lb of chloroform. Calcium chloride is obtained as a by-product.

A variation of the above process consists in chlorinating absolute alcohol with anyhydrous chlorine gas, and treating the chloral hydrate thus formed with alkali

For anaesthetic purposes, chloroform is further purified by washing with water and dil sulphuric acid, followed by lime water or dil sodium hydroxide solution The product is again washed with water until free from alkali, dried with fused calcium chloride, and distilled

Other processes—Reduction of carbon tetrachloride by nascent hydrogen provides a method of manufacturing chloroform which is now adopted in America A mixture of carbon tetrachloride and finely divided iron suspended in water is vigorously stirred Hydrochloric acid is added to react with iron and release the hydrogen required for the reduction of tetrachloride

Pure methane from natural gas has been utilized in America for the production of chloroform Methane is chlorinated stepwise either photochemically or thermally, to methyl chloride, methylene chloride, chloroform, and carbon tetrachloride The lower chlorinated hydrocarbons can be further chlorinated photo-chemically in the liquid phase, resulting in a mixture of chloroform and carbon tetrachloride Up to this stage the process is continuous. The resulting mixture of chloroform and carbon tetrachloride is separated by fractionation to produce U S P. chloroform (Hirschkind, *Industr. Engng Chem*, 1949, **41**, 2749)

A number of patents have been taken out for electrolytic methods of manufacturing chloroform from alcohol and acetone, but commercial production based on these methods appears to be insignificant (Thorpe, III, 79)

The development of methods for the economic production of acetaldehyde has pointed to the possibility of producing chloroform by the chlorination of acetaldehyde

Properties—Chloroform (sp gr $^{25°}$, 1·474—1·478, b p, 61°, and m p, −63 5°) is slightly soluble in water (1 volume in 200 volumes), and is readily miscible with dehydrated alcohol, ether and most organic solvents, and fixed and volatile oils It is non-inflammable, but the vapours form a highly poisonous oxidation product, carbonyl chloride or phosgene, $COCl_2$, which burns with a green flame

On exposure to air and light, chloroform is gradually oxidized, becoming contaminated with hydrochloric acid and carbonyl chloride The medicinal grade of chloroform is therefore preserved in glass stoppered, brown bottles and stored at a temperature below 30° Alcohol is used as stabilizer U S P grade chloroform contains 0 5—1·0% dehydrated alcohol, while the B P grade contains 1 0—2 0% by volume

Not more than 15% v/v of the B P grade (sp gr.$^{20°}$, 1 474—1 479) distils below 60°, the remainder distils between 60° and 62°. The residue on evaporation is not more than 0·004% (w/v). Limit tests have been prescribed for acidity, chloride, free chlorine, foreign organic matter, foreign chlorine compounds, decomposition products, and aldehyde (B P, 137)

Production and Trade

In pre-War years, small quantities of chloroform were manufactured in India by The *Alembic Chemical Works Ltd*, Baroda The annual production between the years 1932 and 1939 was 3,000 lb The product was not, however, marketed. During World War II, four firms set up plants with a total annual production of 60,000 lb. (*Bengal Chemical and Pharmaceutical Works, Ltd*, Calcutta, 35,000 lb, *Eastern Drug Company Ltd.*, Calcutta, 12,000 lb, *Mettur Chemical & Industrial Corporation Ltd*, Mettur Dam, 12,000 lb., and *Bharat Laboratory & Chemical Works*, Calcutta, 1,000 lb.) The production was sporadic and below capacity. The *Bengal Chemical and Pharmaceutical Works, Ltd*, produced 10, 504 lb. in 1943, 15,294 lb in 1944, 4,204 lb. in 1945, 20,000 lb. in 1947, and about 5,000—6,000 lb. in 1948. The other three factories have gone out of production (Indian Tariff Bd, *Rep. Chloroform etc.*, 1947, 5).

Imported chloroform is of two qualities—commercial and pharmaceutical The former is supplied in large bulk containers, and the latter,

TABLE 1.—IMPORTS OF CHLOROFORM FROM U.K *

	Qty. (lb)	Value (£)
1940	106,007	13,452
1941	182,850	22,452
1942	74,267	8,633
1943	157,038	19,256
1944	124,652	15,065
1945	68,441	8,613
1946	13,279	2,088

*Tr U K

TABLE 2 —PRICE OF CHLOROFORM

	I (July 1946) Commercial quality	II (Aug 1946) B P Quality	III (1946) B P Quality
	Rs a p.	Rs a p.	Rs a p.
Landed cost	1 9 4	2 10 6	2 9 4
Selling price	1 11 7	3 5 0	4 12 0

in lb bottles Pre-War imports were about 250,000 lb. per year of which 40,000 lb were of the anaesthetic quality Table 1 gives imports of chloroform into India from the United Kingdom during World War II Imports of chloroform are subject to a customs duty of 36% standard rate, and 24% *ad valorem* preferential rate for imports from U.K.

In 1938, the landed cost and the selling price per lb of chloroform (B P quality) from U K. was Rs 1-13-10 and Rs 2-5-4 respectively. Table 2 gives the price per lb of imported chloroform as given by 3 importing firms (Indian Tariff Bd, loc. cit)

The cost of manufacture per lb. of B P. chloroform in India was Rs 2-14-0 in 1945 In 1947 the cost of manufacture was estimated at Rs 3-4-4 per lb. The high cost is partly due to the high price of bleaching powder, Rs 13-8-0 per cwt., as against Rs. 7-8-0 per cwt in England.

CHROMATES, DICHROMATES, AND CHROMIUM COMPOUNDS

The chromates and dichromates (bichromates), especially of sodium and potassium, find extensive use in industry and form the starting materials for the production of other chromium compounds.

Chromates and dichromates

Raw materials.—The principal raw materials required in the manufacture of chromates and dichromates are chromite or chrome iron ore ($FeO.Cr_2O_3$), soda ash, lime or limestone, sulphuric acid, and potassium chloride or nitrate. The raw materials required for 1 ton of sodium dichromate are chrome ore, 1 7 tons, soda ash, 1 25 tons, sulphuric acid, 0·6 ton, and lime, 0 85 ton. For the preparation of dichromate, the chromite ore should contain 48–50% Cr_2O_3 and the silica content should be below 6%.

Manufacture —Sodium dichromate is obtained by roasting a mixture of finely crushed chrome ore, lime, and soda ash in a reverberatory furnace directly fired by fuel oil or coal. The flame does not come into direct contact with the mass, which is heated mainly by radiation. An oxidizing atmosphere is maintained in the furnace by blowing in excess of air The furnace is provided with a door for charging, and another for discharging the roasted mass The charge is roasted for 8 hours — 4 hours at the charge end and 4 hours at the discharge end The charge is raked by a steel tool every 15 minutes The roasting temperature is about 1,000°

The soluble sodium chromate is extracted from the roasted mass by percolation with water The extract is concentrated and the sodium chromate crystallized out For obtaining the dichromate, the extract is acidified with sulphuric acid in two stages In the first stage, soluble aluminium salts are eliminated, and in the second, the chromate is converted into dichromate After partial neutralization, the liquor is filter-pressed to remove the insoluble impurities, and the filtrate is further treated with sulphuric acid to complete the conversion of chromate to dichromate The neutralized liquor is concentrated in an evaporator heated by a closed steam coil and provided with a churning arrangement A steam pressure of 60–70 lb is maintained in the coil The concentrated (56° Bé) hot liquor containing sodium sulphate is discharged into a crystal catcher to retain sodium sulphate, and the clear dichromate liquor is taken for further concentration The sulphate in the crystal catcher is washed with steam and hot water and dried in vacuum

The clear dichromate liquor is concentrated to 68° Bé when all the sodium sulphate separates out. The sulphate is removed as before, and the dichromate liquor, free from sodium sulphate, is filter-pressed and concentrated. It is discharged into wooden vats lined with lead or mild steel plates, and the sodium dichromate allowed to

crystallize. After 2 or 3 weeks, the crystals are dug out, centrifuged, dried, and marketed in air-tight steel drums.

The sodium sulphate obtained as a by-product (one ton of $Na_2SO_4 \cdot 10H_2O$ for every ton of sodium dichromate) contains about 1% dichromate It is purified and sold as desiccated sodium sulphate for use in paper and textile industries. Sodium sulphate may be converted also into sodium sulphide.

Potassium dichromate is manufactured by almost all the factories manufacturing sodium dichromate. It is made by double decomposition of sodium dichromate with potassium chloride or potassium nitrate. To a solution of sodium dichromate (40—50° Bé) contained in an evaporator, the requisite quantity of potassium salt is added in small quantities, and the solution concentrated The liquor is discharged to crystallizing pans. The less soluble potassium dichromate crystallizes out The crystals formed are removed, centrifuged, dried, and packed in drums

Direct processes for the manufacture of potassium dichromate have been developed. Chrome ore, ground to 200-mesh, is fed into an agitated pressure vessel containing a 50% solution of caustic potash The quantity of chromite added is adjusted to leave a 10% excess of potash The mixture is heated in a rotary furnace at 2,000°, the frit thus formed is digested with water and calcium hydroxide, autoclaved in an atmosphere of carbon dioxide, filter-pressed, and washed. The filtrate, after concentration, is centrifuged and reautoclaved in the presence of carbon dioxide at 5 atm The potassium bicarbonate thrown out is removed by centrifuging, and the liquor concentrated and crystallized The crystals are dried in a rotary dryer. Potassium carbonate is obtained from the bicarbonate by calcination (*Chem. Tr. J*, 1946, **118**, 405)

Ammonium chromate and dichromate are prepared by mixing solutions of ammonia with chromic acid in proper proportions. Ammonium chromate may be obtained by treating sodium chromate solution with ammonia and saturating with carbon dioxide Sodium bicarbonate is precipated and ammonium chromate remains in solution

Properties and Uses—Sodium dichromate is obtained as red deliquescent crystals readily soluble in water (109 g in 100 c.c. of water at 15°). It is rendered anhydrous at 100° and decomposes on further heating. Sodium dichromate is extensively employed in tanning. Most shoe upper leathers are chrome-tanned. Dichromate is also used in the tanning of glove leathers and in the preparation of furs. It is used in the manufacture of mineral khaki.

Sodium dichromate is employed in the manufacture of chrome yellows, oranges, greens, and reds required in paint and printing ink industries. It finds application in metal treatments such as cleansing, preparing dipping compositions for brass, tin-plating, and galvanizing. It is used in pickling baths. A bath containing 4·5% sodium dichromate and 16% sulphuric acid is used in Indian mints for pickling annealed coin blanks (Mitter & Dighe, *J. sci. industr Res.*, 1943-44, **2**, 11). Magnesium alloys are dipped in dichromate solution for imparting corrosion resistance. Dichromate is also used for retarding corrosion in refrigeration brines, air conditioning equipment, air washers, coolers, condensers, automobiles, diesel engines, boilers, etc

Sodium dichromate finds use as an oxidizing agent in the preparation of many organic compounds, in petroleum refinery, and in the bleaching of fats and oils It is an ingredient of match head compositions, battery electrolytes and pastes, and of preservatives for anatomical specimens. It is used as a hardening agent for gums and gelatine in photographic plates. It renders glue insoluble, and this property is utilized in the gum-bichromate printing process. Among the miscellaneous uses may be mentioned its utilization in adhesives, wood preservation, staining, and manufacture of waxes and greases. Analysis of dichromate usage in U.S.A. is as follows: pigments, 42·6; metallurgical, 8·2, metal treating, 7·1; corrosion prevention, 1·1; chemical manufacture, 15·8; textile processing, 6·0, tanning, 15·6, export, 1·8; and miscellaneous, 10·0% (Stenerson, *Chem. Engng News*, 1947, **25**, 275).

Potassium dichromate is obtained in the form of anhydrous, large, orange-red, triclinic crystals. When heated to 236°, the triclinic or α form changes to the monoclinic or β form, melting at 397° and decomposing at 500°. The heat of fusion is 29·8 cal./g. It is moderately soluble in cold water (10 g. in 100 g. water at 15°) and readily soluble in hot water (100 g. of salt in 100 g. of water at 100°).

On account of its non-hygroscopic nature, potassium dichromate is used in preference to sodium dichromate in the manufacture of pyrotechnics, safety matches, and medicinal preparations. It is used in specialized textile and leather finishes such as glazed kid, in the manufacture of blue printing paper, ceramic colours, and wood preservatives. It is also used in the manufacture of zinc chromates widely employed

as priming and protective coats for ships and steel structures. Analysis of potassium dichromate usage in U.S.A. is as follows: pigments, 43·7; metallurgical, 7·4, metal treating, 5·6, corrosion prevention, 1·8, chemical manufacture, 5·0, textile processing, 4·1, tanning, 0·7; exports, 15·8; and miscellaneous, 23·3% (Stenerson, loc. cit).

Ammonium dichromate decomposes at 185° without melting. The decomposition becomes self-sustaining at about 225° It does not form hydrates. Ammonium dichromate is used in sensitizing solutions used in lithography It is employed in pyrotechnics, porcelain finishes, and in the preparation of various oxidation and reduction catalysts It is used also as a mordant It is the starting point for the manufacture of ammonium chromate and other chromium chemicals such as metal-ammonium chromates

Sodium chromate consists of lemon-yellow crystals with a metallic taste and alkaline reaction It exists as a decahydrate below 19·5° and is less soluble than sodium dichromate It is a valuable oxidizing agent and can be substituted for sodium dichromate in all its uses It forms a number of hydrates— decahydrate, hexahydrate, tetrahydrate, dihydrate, etc

Sodium chromate is not used in any significant quantity in industry, as the dichromate containing a higher proportion of chromic acid is generally preferred. It is used wherever reactions in neutral and alkaline media are involved, but even here, it can be replaced by a mixture of dichromate and caustic soda It is used as an anticorrosive in refrigeration and automobile cooling systems, and in the manufacture of pigments, textile finishes, photographic chemicals, and dyes. Rocket grenades and tracer bullets contain sodium chromate

Potassium chromate is obtained as anhydrous yellow rhombic prisms isomorphous with potassium sulphate. It dissolves in water, the heat of absorption being 5,254 cal./mol No hydrates are definitely known When heated, the rhombic or β form changes to the hexagonal or α form at 660° with absorption of 2,450 cal /mol. The α form melts at 977°.

Potassium chromate is highly poisonous, and produces a condition resembling diabetes Workers engaged in potassium chromate production suffer from slow-healing sores, for treating which sodium bisulphate is efficacious.

Potassium chromate has comparatively few industrial applications, since for most purposes the cheaper sodium salt can be employed It is specially used when an anhydrous, non-hygroscopic, alkaline compound or the absence of sodium is desired, as in medicinal and proprietary preparations. It is also used in photographic, textile and leather industries, manufacture of ink, and as an analytical reagent It is used in specialized ceramic and glass colours, and in special fluxing and metal-coating compositions such as those for covering welding electrodes

TABLE 1 — PROPERTIES OF CHROMATES & DICHROMATES

Compound	(sp gr 25°)	m p	Solubility in water (% by wt.) 0°	30°	100°
$Na_2Cr_2O_7$	2 348*	356 7	70 6*	75 00*	91 43
$K_2Cr_2O_7$	2 676	398	4 3	16 1	50 2
$(NH_4)_2Cr_2O_7$	2 155	decom.	15 16	31 98	60 8g
Na_2CrO_4	2 723	792	24 2†	46 8‡	56 1
K_2CrO_4	2 732 @ 18°	971	37 14	39 80	45 00

*dihydrate, †decahydrate, ‡tetrahydrate

Table 1 gives some of the important physical properties of chromates and dichromates (Hartford, *Industr Engng Chem*, 1949, **41**, 1993)

Prior to 1939, all the dichromates consumed in India were obtained by import, the principal source of supply being U K, during World War II, large supplies of dichromates were required to meet the demands of the Army for khaki cloth and tanned leather This demand and the assurance of post-war protection given by the Government acted as an impetus to the development of the dichromate industry in India A Chrome Control Order was promulgated to regulate the production, distribution, and cost of indigenous products

In 1946, there were 17 factories engaged in the production of dichromate with a total rated capacity of 6,220 tons Since then some of the factories have suspended production, and at present there are 11 factories working, some of them intermittently The principal producers of dichromate in India are *Buckingham & Carnatic Co. Ltd., Madras* (1,080 tons)*, *Cawnpore Chemicals*, Kanpur (1,200 tons), *Premier Chromate and Chemical Works*, Bombay (900 tons), *Pioneer Chromate Works Ltd*, Bombay (600 tons), *Golden Chemicals*, Bombay (540 tons); *Hindustan Chemical Works*, Bombay (480 tons), and *Government Dichromate Factory*, Belagula, Mysore (240 tons). The distribution of the factories is as follows: Madras, 1, Bombay, 4, Kanpur, 1, Calcutta, 4; Mysore, 1 (Indian Tariff Bd, *Rep. Continu-*

*Figures within the brackets indicate annual production capacities.

TABLE 2.- PRODUCTION OF DICHROMATES

	Qty. (Tons)
1943	2,769
1944	2,882
1945	3,225
1946	2,081
1947	2,306
1948	2,939
1949	1,720

†Monthly Statistics, Production of Selected Industries of India

ance of Protection to the Bichromate Industry, 1949, 22) The total installed capacity of the plants is 5,520 tons (*Monthly Statistics, Production of Selected Industries of India*, Jan 1950, 9) The capital invested is about Rs. 60 lakhs

PRODUCTION

Table 2 gives the production of dichromate in India The actual production is much less than the total installed capacity, the production during 1949 being only 31 2%. The Government of India have recently announced a short-term plan which envisages no actual increase in capacity but the utilization of a part of the idle capacity by stimulating internal consumption by encouraging the dyeing of mineral khaki and developing an export market.

The quality of the indigenous product has generally given satisfaction to the consuming industries The tanning industry demands a minimum purity of 98%, the percentage of sodium sulphate being less than 1 This quality is being adhered to by the members of the *Bichromate Manufacturers' Association of India*

The demand is much less than the rated capacity of the actual production. The Tariff Board has therefore asked the manufacturers (1) to produce chrome compounds in sufficient quantity so that consuming industries may not be required to search for substitutes, (2) to achieve a substantial reduction in the cost of production of dichromate, and (3) to develop an export market (Indian Tariff Bd, *Rep.*, 1949, 14).

Cost of Production.—The cost of production of sodium dichromate varies widely in Indian factories According to the Tariff Board's estimate, the cost of production of sodium dichromate, on the basis of annual output of 600 tons, would be Rs 78-2-0 per cwt Indian Tariff Bd, *Rep*, 1949, 10)

After an examination of the trend of c i f. prices and the cost of production in an economic unit of 600 tons capacity per annum, the Tariff Board estimates Rs 81-11-0 to be the fair selling price per cwt of sodium dichromate compared to the c i f prices of Rs 62-4-0 and Rs 71-10-0 per cwt of sodium and potassium dichromates respectively when imported from U K (Indian Tariff Bd., *Rep*, loc cit).

The trend in consumption in the next few years, according to the Tariff Board is as follows. tanning, 1,000, textile, 750; paints and pigments, 500, other industries, 150, total 2,400 tons (Indian Tariff Bd, *Rep Bichromates Industry*, 1947, 8) The annual domestic consumption of sodium dichromate and potassium dichromate for the years 1950 to 1952 has been estimated at 2,400 and 400 tons respectively, the latter figure represents the consumption in the match industry and for electroplating and chromic acid production (Indian Tariff Bd, *Rep*, 1949, 14)

Imports.—Table 3 gives the imports of dichromates into India The imports during recent years are negligible

In recent years, India has been exporting small quantities of dichromate—532 tons in 1947, 638 tons in 1948, and 175 tons in 1949 (8 months).

During the quinquennium ending 1938-39, U.K., Germany, and Japan were the principal suppliers of sodium dichromate, their shares being 69·3, 12 8, and 9 5% respectively In the next quinquennium, U K supplied 46 3% and U S A., 49·5% U K, Germany, and Japan were also the main suppliers of potassium dichromate before 1939 and their share in the imports during the quinquennium ending 1938-39 were 23 3, 37 4, and 27 5% respectively During the next five years, U S A supplied 61 4% of the total imports

Imports of dichromates and all other chrome compounds are subject to a protective duty of 30% *ad valorem*

TABLE 3.—IMPORTS OF DICHROMATES

	Sod dichromate		Pot dichromate	
	Qty (1,000 cwt)	Value (lakh Rs)	Qty. (1,000 cwt.)	Value (lakh Rs)
1934/35 1938/39(av.)	16 6	3 83	5 23	1 39
1939/40-1943/44 (av.)	41 1	19 41	2 99	1 98
1944-45	22 7	11 07	0 58	0 89
1945-46	nil	nil	(a)	(a)
1947 48	(a)	(a)	0·04	0 03

(a) negligible

Chromium pigments

A number of chromium compounds containing lead and zinc with extenders are extensively used as pigments. The yellow pigments, called Chrome Yellows, are particularly popular on account of their exceptional brilliance, great opacity, and excellent light-fastness.

CHROME YELLOW—Normal lead chromate, $PbCrO_4$ (sp gr, 6 3), is formed by adding a solution of sodium dichromate to a solution of lead nitrate or acetate The solutions are prepared separately, filtered, and the clear solutions run together into a precipitating tank After allowing the precipitate to settle, the supernatant liquid is drawn off, and the precipitate washed repeatedly with water The pigment is filter-pressed and dried at 30–50°.

Pure chrome yellow is too expensive for most purposes, and is liable to darken in colour Pigments of a paler tint, e g, Primrose Chrome, Lemon Chrome, and Middle Chrome, are prepared by mixing an appropriate quantity of sulphuric acid, glauber's salt or alum with the precipitating chromate solution The chromate is thus precipitated along with lead sulphate as mixed crystals, and pigments of varying shades may be produced by varying the proportion of lead sulphate A range of Reduced Chrome Yellows are made by admixture of barytes, gypsum, kaolin, or whiting, ground with water in the precipitating vat, and kept in agitation while the reacting solutions are run in so that the precipitate is deposited uniformly on the particles of the base

CHROME GREEN (Brunswick Green) is prepared by mixing Prussian blue with chrome yellow It is distinct from the more expensive and permanent chrome oxide green

CHROME ORANGE is obtained by replacing a part or whole of the normal lead chromate by basic chromate. It is generally obtained by precipitating the normal chromate, and then converting it into the basic compound by treatment with caustic soda or calcium hydroxide A deep orange pigment is produced if the whole normal chromate is converted to the basic salt, but if partially converted, intermediate tints are obtained. Reduced yellow chrome may be employed for other shades. Scarlet Chrome consists of mixed crystals of chromate, sulphate, and moybdate of lead (Thorpe, III, 113)

ZINC YELLOW, Zinc Chrome, or Butter Cup Yellow, $ZnCrO_4$, is a beautiful yellow pigment prepared by the addition of hot neutral zinc sulphate solution to potassium chromate solution It is also prepared by treating zinc oxide cream in water with sulphuric acid and precipitating zinc chromate by the addition of potassium dichromate solution The precipitate, after settling, is washed, filter-pressed, and dried. A modified pigment containing potassium is obtained by the addition of a paste of zinc oxide in water to a boiling solution of potassium dichromate The resultant product is slightly soluble in water, readily soluble in all acids, ammonia, and caustic soda. A semi-continuous process for the manufacture of zinc yellow has been developed in U S A (*Chem. Tr. J.*, 1949, **124**, 425)

The production of chrome pigments in India is estimated to be about 400–500 tons per annum, the principal centres of production being Calcutta, Bombay, Amritsar, and Mysore The annual requirement of these pigments is estimated to be 1,000 to 1,200 tons.

Chrome Alum—*see* Alum, chrome

Chromic Acid

Chromic acid is obtained by treating sodium dichromate and sulphuric acid (96%) in the ratio 4 2 3 04 in a steel tank fitted with an agitator and heating to 200° when the mass melts The molten mass separates into two distinct layers, the upper layer consisting of sodium bisulphate and the lower, of chromic acid The latter is drawn off into cast-iron pans, cooled, crushed, and packed (*Chem Tr. J*, 1946, **118**, 405) It is prepared also by mixing excess of conc sulphuric acid with a saturated solution of potassium or sodium dichromate, or by digesting barium chromate with dilute sulphuric acid and evaporating the filtrate It is possible to obtain chromic acid (98% purity in 90% yield) by treating potassium dichromate with 68% nitric acid and separating the chromic acid from the reaction products by fractional crystallization. The product thus obtained is suitable for chromium plating baths (Thorpe III, 102)

Chromium acetate

Chromous acetate, $Cr(C_2H_3O_2)_2 \cdot H_2O$, is prepared by the action of acetic acid on chromous hydroxide, followed by evaporation and crystallization It can also be obtained by adding a strong solution of chromous chloride (by the reduction of chromic chloride with zinc and hydrochloric acid) to a saturated solution of sodium acetate The precipitate formed is filtered and dried *in vacuo*. Chromium acetate is a greyish green powder or bluish green pasty mass, soluble in water and insoluble in alcohol. It is used in textile dyeing and printing, and in tanning. It is used as the starting material for the preparation of other chromous salts. A small

quantity of chromous acetate is produced in India.

Chromium sulphate

Chromic sulphate, $Cr_2(SO_4)_3\ xH_2O$, is obtained by treating chromic hydroxide with sulphuric acid. It forms a series of hydrates ranging in colour from violet to green. The anhydrous salt (sp. gr, 3·012) is a crystalline red powder. The 15-hydrate (sp. gr, 1·867) is the commercial product, and is available in dark green pearls, powder, and scales It is soluble in water. The salt is obtained by heating the commercial salt to 325° or above *in vacuo* Chromium sulphates are used as mordants in dyeing, in the preparation of green paints, varnishes, inks, and ceramic glazes, and in tanning.

Chromic sulphate is a by-product obtained in all processes in which dichromate and sulphuric acid are employed for oxidation purposes As an example, the introduction of the quaternary alloy of silver, copper, nickel, and zinc as a coinage metal by the Government of India necessitated the use of a pickling bath of dichromate and sulphuric acid for treating the annealed coin blanks. For the recovery of chromium from the pickling bath (daily output, 500 gal for 10 lakh coins per day), an electrolytic process, using lead anodes and copper cathodes, separated by a porous diaphragm, has been found satisfactory. Dichromate and sulphuric acid are recovered almost quantitatively (Mitter & Dighe, *J. sci. industr Res.*, 1943-44, **2**, 11).

Basic chromium sulphate, used in the tanning of hides, is produced in tanneries by the reduction of sodium dichromate, with reducing agents such as sulphur dioxide, sodium thiosulphate, starch, saw dust, molasses, glycerine, glycerine residues.

CIGARS AND CHEROOTS

Cigars and cheroots are made entirely of uncut tobacco by rolling three or four different varieties of tobacco leaves one above the other. They consist of three parts, the central core or the filler, the middle portion or the bunch wrapper which binds the filler and holds it in shape, and the outer wrapper which gives it the distinctive appearance as regards colour, texture, and smoothness of feel. The filler is the cigar proper which gives to it its special smoking quality. Cigars are usually smoked by the upper class They are generally truncated at one end and closed at the other; in a few varieties both ends are either truncated or closed. Cigars have generally double wrappings Cheroot is a cheaper and inferior type of cigar smoked by the middle class mostly in the south; it has a single wrapping and is truncated at both ends. Cigars are milder in flavour than cheroots.

India is an important cigar manufacturing country, other producers being Burma, Cuba, Jamaica, Holland and a few other countries in Europe, United States of America, Brazil, and the Philippines Cigars and cheroots are principally consumed in south India, the *per capita* consumption in the Madras State being 372, as compared to 1—5 in the rest of the country. The *per capita* consumption in the whole of India works out to 53. In Burma, the *per capita* consumption is 547 (*Rep Marketing Tobacco in India & Burma*, Marketing Ser No 10, 1938, 78).

Cigar manufacture in India is carried out almost entirely in Madras State, the chief centres being Trichinopoly and its suburb Woriur, Dindigul, and Madras City. High class cigars are exclusively made at Woriur, Dindigul, and Madras City The qualities manufactured in Madras State are specially intended for export. The well-known cigars of *Spencer and Co.* are made at Dindigul. The labour force at the Spencer's factory increased from 173 in 1939 to 437 in 1944. Cheroots are manufactured all over Madras on a cottage industry scale, the most important centres being Trichinopoly and Woriur. A few cheroot factories also make cigars Cheroots are manufactured in Madras and Hyderabad on a small scale There are at present 7 factories in Madras; Trichinopoly along with Woriur has nearly 400 cigar factories registered with the Excise Department, and Dindigul has 15 Cheroots and cigars are also made in Orissa and West Bengal.

Raw materials.—The three parts of a cigar or cheroot require different qualities of tobacco. Filler tobacco should have a sweet, pleasant aroma, emit an agreeable odour on burning, and should burn evenly with a firm white ash. The leaves used are medium to thick and light dark brown in colour. The size of the leaf is not important Leaf of the quality required, the Usikkappal variety, is grown in Trichinopoly and Coimbatore districts of Madras. They are brown to dark brown in colour, and have a thin texture and strong flavour Filler tobacco is also imported from Rangpur (Eastern Pakistan), the imported varieties being Pennsylvania, Sumatra, and Burmese Havana. For high class cigars, the Indian filler tobacco is blended with imported qualities—Havana, Brazil, Manila, and Java—to mellow the strength and the flavour. Filler leaf for cheroot is obtained mainly from East Godavari and Madura districts (the Mannakappal variety) and from Trichinopoly and

Coimbatore districts (the Usikappal variety) especially from Erode, Arvankurchi, Mettupalayam, Bhawani, Thammanpatti, and Dindigul (*Rep. Marketing Tobacco*, 324). The tobacco known as Jati, grown mainly in north Bengal, is used in Burma. There are several varieties of Jati but the Bhengi variety, which is greenish brown in colour, medium in texture and strength, about 15–22 in. long and 6–12 in. broad, is the one commonly employed. This tobacco is known as Poola Common in the Calcutta market. The other varieties used are Meenampalayam, Vattakappal, and Yerumaikappal, all grown in Coimbatore, Chebrole grown at Chebrole (Guntur Dt.), and Lankas grown on the exposed land in the river beds of Godavari and Kistna in East and West Godavari and Kistna districts. The price of filler tobacco grown in India varies from -/4/- to Re. 1 per lb. exclusive of duty.

Filler tobacco for cigars generally contains 2½ – 3½% nicotine, although some brands made in Trichinopoly contain only ½%. The common twisted cheroot of Madras is made from leaf having a nicotine content up to 5½% (*Rep. Marketing Tobacco*, 26).

Binder tobacco used for keeping the filler in place should be broad and fine in structure. It should be lighter in shade than filler tobacco. Indian leaf is used for binding inferior qualities, although some of the varieties are good enough to be used as substitutes for imported binder tobacco. These varieties are available from the same areas as those growing filler tobacco, and the price varies from Re. 1 to Rs. 3 per lb. exclusive of duty. For high class cigars, which are exported, binder tobacco is imported from Java, Sumatra, Havana, and Manila.

The wrapper leaf should be broad (9–12 in.), elastic, pliable, and soft. It should be glossy and lighter in colour than either the filler or the binder tobacco. A greenish brown colour is preferred. It must be free from any pronounced flavour and devoid of any bitter taste. Generally middle leaves are selected for wrapper purposes. Wrapper for high grade cigars is invariably imported from Rangpur (Eastern Pakistan), Sumatra, Florida, and occasionally from Java, Havana, Manila, and Holland, the value of imports to Dindigul and Trichinopoly for cigar manufacture in the pre-War years being Rs. 1½–2 lakhs. The imported

Fig. 33.—Storing of tobacco in a cigar factory

wrapper tobacco is thin in texture, silky, elastic, and bright in colour. Also, the veins are almost at right angles to the mid-rib and the interspace between the veins is wide. This is an important characteristic of wrapper tobacco. Its burning quality is also superior. A type of wrapper leaf, light brown to dark brown in colour, is grown in Rajahmundry and utilized for the less expensive brands of cigars. The price of Rajahmundry wrapper leaf ranges from Re. -/12/- to Rs. 5 per lb. exclusive of duty.

Wrapper leaf required for cheroot is wholly grown in India. The variety Kistna Lanka is used at Madura in addition to locally grown tobacco. This type is used for straight cheroots but for twisted cheroots, a leaf of medium thickness is preferred.

The production of cigar and cheroot leaves during 1934-35 was 5,044,000 lb. and 123,986,000 lb. respectively (*Rep. Marketing Tobacco,* 28). Excepting for a small quantity of cheroot leaves which are ground cured, almost the entire quantity of cigar and cheroot leaves are rack cured under shade. The selected leaves are graded according to colour and quality, and tied into bundles of 20—40 leaves. They are placed in heaps for fermentation which takes 1—3 months. The bundles are turned over from time to time. Cured tobacco is dried, pressed, baled, and stored till required for use.

Manufacture

The leaves received in the factory are first moistened with a water spray to make them pliable for stripping, and sorted into filler, binder, and wrapper tobaccos. The filler leaf used for cigars is moistened again and the ribs removed. No further treatment is necessary. Some manufacturers, however, add essential oils for flavouring. The tobacco is dried and blended with other grades of tobacco. In the case of cheroots, the filler leaf is often, as at Cannanore, subjected to a forced sweating by immersion in treacle water for a few minutes and keeping overnight.

For binder and wrapper tobacco, special attention is paid to stripping to prevent spoilage through tearing. Care is necessary in the cutting of wrapper tobacco to ensure that the side veins run straight up and down the cigar. The leaves are cut to proper shape and rolled in separate bundles in a moist condition ready for use.

In India and Burma, the manufacture of cigars and cheroots is done by hand, no machinery being employed. In Holland, United States of America, and other countries, most of the operations are carried out with the help of machinery, wrapping being done manually by skilled workers. The filler leaves are placed on a bunch wrapper and wound round into small cylinders. Rough cigars and cheroots are spirally wrapped with leaf strips commencing from the open or lighting end, and the edges are fastened securely with a gum which must be tasteless and colourless. To ensure a uniform product the cylinders or bunches are kept under pressure in a wooden mould (each mould having provision for 20 bunches, and made in 2 pieces) for some time. The wrapper leaf, which is kept ready in a rolled form, is then applied in a moist condition over the rough product. In the case of cheroots, the smoking ends are cut immediately after rolling. The cigars and cheroots so made are gauged, cut to proper lengths, and sorted according to size and colour. The moisture in the finished products is reduced to about 10—15% during storage in a conditioned drying room. Packing is usually done immediately after the product is taken out of the drying room. In the case of some cigars, a steaming treatment at 150—160° is given to render them immune to insect attack. Ring labels are put on the prepared products, which are then packed in boxes containing 25, 50, or 100 cigars or cheroots. Cigars are often wrapped in cellophane paper before packing.

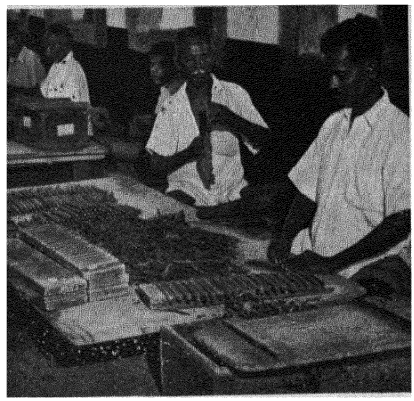


Fig. 34.—Cigar rolling

Cigars are made in lengths of 3¼, 3½, 3¾, 4¼, 4½, 5, 5½, and 6 inches. Cheroots are made in lengths of 3, 3¼, 3½, 4, 4½, and 5 inches.

Some of the imported brands of cigar manufactured in India are: Monaco Imperial Coronas, Coronas Majors, Purescos, Dindigul Coronas,

Fig. 35.—Arranging cigars in moulds

Flor de Madras, Coromandals, and Rex Coronas. A few popular brands of cheroots are Planters Special, Planters Ordinary, and Oriental Cheroots.

Large quantities of cigar packing boxes are made in south India from *Cedrela toona, Azadirachta indica,* and *Melia composita* (Trotter, 217). The boxes are covered by cellophane or other grease proof paper and packed in large wooden cases of varying sizes. The more usual size is 2½ ft.×2 ft.×1½ ft., a packed case weighing 1½–2 md. and containing 3,000–4,000 cigars.

Production and Trade

Table 1 gives the production of cigars and cheroots (price, 12 annas and above per hundred) in India. The figures given in the Table are only a fraction of the total production and relate to products which are subject to excise duty. The bulk of cigars and cheroots produced in India is priced less than 12 annas per hundred and is not subject to excise duty. Production data for such cheroots are not available, but an idea of the production may be had from the quantity of tobacco consumed. The total quantity of tobacco consumed for the production of cigars and cheroots was: 49·39 million lb. in 1947-48, 52·59 million lb. in 1948-49, and 49·10 million lb. in 1949-50. Approximately 5 million lb. of tobacco are consumed in the making of taxable cigars and cheroots made in factories. The rest is consumed mostly in smaller establishments and factories for making cheap non-taxable cheroots.

TABLE 1.—PRODUCTION OF CIGARS AND CHEROOTS

Price (Rs./100)	Excise duty (Rs./100)	Qty. (in 1,000) 1947-48	1948-49	1949-50
30 and above	12	43	33	32
25–30	10	41	41	28
20–25	8	40	76	73
15–20	6	298	273	198
10–15	4	562	580	435
5–10	2	2,388	2,853	2,202
2½–5	1	10,079	12,573	8,794
1½–2½	½	34,983	43,485	36,948
½–1½	¼	448,024	492,822	528,930
Total		496,458	552,736	577,640*

* In addition, 249,000 cigars and cheroots were produced

The major part of the dutiable cigars and cheroots is made from indigenous tobacco. The production of cigars containing imported tobacco in addition to indigenous tobacco was 3·53 millions in 1948-49 and 2·55 millions in 1949-50.

Imports.—Imports of cigars into India are small. Some quantity is imported from Burma and still smaller quantities from the Philippines, United Kingdom, Hongkong, the Netherlands, and Cuba. The cigars manufactured in Cuba (Havana cigars) are regarded as the best in the world. Table 2 gives the annual imports.

TABLE 2.—IMPORTS OF CIGARS

	Qty. (lb.)	Value (Rs.)
1929/30—1933/34 (av.)	25,120	1,19,416
1934/35—1938/39 (av.)	86,958	1,16,499
1939/40—1943/44 (av.)	147,542	1,16,661
1944-45	944	383
1945-46	83	1,626
1946-47	8,761	1,10,437
1947-48	9,641	95,806
1948-49	2,480	18,016
1949-50	11,168	61,144

TABLE 3—EXPORTS OF CIGARS

	Qty. (lb)	Value (Rs)
1929/30—1933/34 (av.)	1,54,486	1,17,413
1934/35—1938/39 (av)	55,218	79,216
1939/40—1943/44 (av)	36,061	61,624
1944 45	21,980	1,53,511
1945 46	39,253	2,01,553
1946-47	93,389	4,99,741
1947 48	52,406	3,64,345
1948-49	65,906	3,58,974
1949-50	16,784	87,453

TABLE 4.—PRICES OF CIGARS AND CHEROOTS

		Prices Rs	As.	
Flor de Spencer No. 1	Cigar	9	4	(per box of 50)
Spencer's Special Planters	Cheroot	5	3	,,
Spencer's Java Dawson	,,	5	6	,,
Little Randolphs	,,	3	0	,,
Madras Whiffs	,,	1	14	,,
Gateway of India	Cigar	28	0	(per 100)
Light of Persia	,,	18	0	,,
La Corona	,,	13	0	,,
Vinayagar No 1	Cheroot	1	9	,,

Up to 1942, Burma was the principal supplier, Philippines coming next Imports of cigars are subject to a revenue duty of 37½% *ad valorem*+ Rs 15-10-0 per lb

Exports.—A considerable quantity of cigars manufactured in Madras State is exported. The export, however, has recently diminished, chiefly because of increased duties in importing countries, increased consumption of cigarettes in preference to cigars in those countries, and the difficulty in obtaining sufficient tobacco of the qualities required. Table 3 summarizes the annual exports of cigars from India

In 1938-39, Madras supplied 86 3% of the total quantity of cigars exported to the United Kingdom, Straits Settlements, Siam, and other countries

Prices—Table 4 gives the prices (Dec 1949) of various brands of cigars and cheroots.

CIGARETTES

Cigarettes consist of finely cut tobacco rolled in specially manufactured paper. Their use has, in recent years, increased considerably, particularly in urban areas. During 1934-35, the *per capita* consumption of cigarettes in undivided India was 20, the *per capita* figures in the different States being. Assam, 44; Bombay, 41; Baroda, 39; Mysore, 37; Hyderabad, 30, Punjab, 20; Bengal, 19; Bihar, Orissa, Central Provinces, and Kashmir, 15 each, and U P and Madras, 10 each (*Rep. Marketing Tobacco, India & Burma,* Marketing Ser No 10, 1938, 77)

Prior to World War I, the indigenous manufacture of cigarettes was mainly concentrated in and around Calcutta and at Monghyr (Bihar) The industry was of a modest size, and the *Eastern India Cigarette Manufacturing Co*, Dum Dum, were the principal manufacturers employing, on an average, 1,150 labourers out of a total labour force of 1,454 employed by the industry The production increased after the War and new factories, big and small, sprang up all over the country to meet the increased demand. There are at present 21 factories, the principal ones being the *Tobacco Manufacturers (India) Ltd.*, with factories at Monghyr (Bihar), Saharanpur, Bangalore, Calcutta, and Bombay; The *National Tobacco Co. of India Ltd*, Calcutta; *Godfrey Phillips India Ltd*, Bombay, *Golden Tobacco Co. Ltd*, Bombay, *All Gold Tobacco Co*, Calcutta, *James Canterbury Ltd*, Calcutta, *International Cigarette Factory,* Howrah, *James Hilton & Sons,* Bombay; *Union Tobacco Co Ltd*, Calcutta; *Deccan Tobacco Co Ltd*, Poona, *Macropolo and Co. Ltd*, Bombay, *Maple Tobacco Co. Ltd*, Bombay and Bezwada, *Vazir Sultan Tobacco Co*, *Ltd*, Hyderabad, and *Hyderabad Deccan Cigarette Factory,* Hyderabad The elimination of foreign competition and the increased demand for cigarettes during the War contributed to the phenomenal growth of the indigenous industry A number of factories, mostly in Bombay, came into existence during the War period Employment of labour increased (the increase in Bangalore alone during the period 1939—1944 being 103%), and a change from single to double shift working became necessary. Almost all the well-known brands such as Player No 3, Wills Gold Flake, Three Castles, Capstan. Players, Wills, Scissors, Passing Show, and Berkeley are now manufactured in Indian factories.

Raw materials.—The principal raw materials required in cigarette manufacture are tobacco and cigarette paper The tobacco should have certain specific characteristics—strength, burning

character, ash, and aroma or flavour The tobacco is judged by the physical characteristics of the cured leaf, viz., colour, texture, size of leaf, and freedom from blemish. The Virginia leaf, most extensively employed in the cigarette industry, is 12—18 in. long and 6—9 in wide, although smaller sizes 6 in. × 3 in are also used. The presence of diseased patches and damaged leaf is particularly objectionable

Strength is perhaps the most important factor in smoking quality Cigarette tobacco should be mild with a nicotine content of not more than 2½%; it may be as low as ½% Colour and texture are usually an index of strength The colour of cigarette leaf ranges from bright lemon to reddish brown. Darker and thicker leaves are considered to be stronger. Cigarette leaf should be thin, fine, and silky, but if very thin and papery, it will not stand cutting. Harrison Special, the leaf of choice for cigarette manufacture, is thin, fine, and silky in texture, and has sufficient body to withstand cutting

The tobacco should have a uniform, slow, and continuous burning character and should leave a white ash It should have a pleasing flavour and be free from pungency, earthy odour, or any unusual aroma

Details regarding the physical characteristics of tobacco leaf for cigarettes are given in the *Tobacco Grading & Marketing Rules*, 1937

Natu or Desi leaf is thin to medium in texture, possesses a pleasing aroma, and is of mild or neutral strength; sometimes, it has an earthy odour The length of the leaf is about 15 in. and the breadth, between 6 and 9 in The colour ranges from light to dark brown The light and medium-coloured grades are used in the manufacture of cheap cigarettes, and the darker grades are sold as pipe and shag tobacco

Imported leaf was being largely used in the indigenous cigarette industry up to 1930-31, the use of leaf grown in India has increased a great deal since then, though large quantities of Virginia leaf, mostly from U S A , are still used in the production of certain brands. The pre-War average of annual imports was about 2 5 million lb. India imported on an average about 7·45 million lb. annually from the U S A during the quinquennium ending 1943-44

India holds a high place among the cigarette tobacco producing countries of the world. Harrison Special is the type of Virginia tobacco grown in all the cigarette tobacco growing tracts in India—Guntur, Kistna, and East and West Godavari districts, Mysore, and Satara. The Natu variety grown in Guntur, Kistna, and East and West Godavari districts, and the Desi variety grown in Muzaffarpur are used in the manufacture of the cheaper brands of cigarettes. The Guntur (Natu) variety having a light to dark brown colour, moderately thin texture, and pleasing aroma is the more important, while the Muzaffarpur (Desi) variety with an earthy flavour is not so popular

The annual production of flue cured Virginia tobacco in India is estimated at about 70 million lb and that of the sun cured (or rack cured) Virginia at about 5 million lb. The output of Natu tobacco in Guntur district was estimated at 47 million lb in 1947-48 Prior to World War I, 22—23 million lb. of leaf were annually consumed by the industry (*Rep Marketing Tobacco*, 321) In 1947-48, about 38 5 million lb of Virginia tobacco were used for cigarette manufacture (Information from the Indian Central Tobacco Committee) The total quantity of tobacco used in cigarettes during 1948-49 (ending June) was 40 33 million lb , of which 7 48 million lb. were imported The total quantity of cigarette tobacco cleared during 1949-50 was 36 69 million lb. (Information from Central Excises)

The *Indian Leaf Tobacco Development Co.* are the main purchasers of cigarette leaf produced both for export and for sale to factories in India.

Curing —Almost the entire quantity of Virginia leaf used in cigarette manufacture is flue cured, a small amount is rack cured Flue curing is adopted in Guntur for curing the better qualities of Natu tobacco. Flue curing is carried out in three stages in barns, 16 ft. × 16—20 ft × 20 ft., artificially heated by flue pipes leading from furnaces in which coal or wood is burnt as fuel. In the first stage, which takes 30—40 hrs , the leaf is yellowed at moderate temperature (85—100°F.) and high relative humidity In the second stage, the colour is fixed by holding the leaf at about 120°F for 16—24 hrs , the moisture from the leaves being allowed to escape through barnridge ventilators In the third and last stage, the ventilators are closed and the temperature raised to 165°F The leaf is then left in the barns overnight with doors open so that the tobacco absorbs moisture from the air and permits ready handling. The whole process takes 5—6 days, and the weight of the leaf is reduced to 18% Flue curing yields leaf of good colour and texture free from blemish. Of the 32·85 million lb. of indigenous tobacco consumed in 1948-49, about 22·6 million lb were flue cured. The imported tobacco used in cigarette manufacture is all flue cured.

In rack curing, the leaves are stitched on strings tied to racks specially erected, and left in

the sun or under shade. Rack curing is usually adopted for Natu tobacco.

Ground curing is the most common method employed in India for curing hookah and chewing tobacco. It is employed to a small extent in Bihar (Muzaffarpur Dt.) for curing Desi tobacco. The leaves are spread on the ground in the morning, stirred occasionally to prevent overheating, and collected into heaps in the evening. The process is continued until the midrib is quite dry. The leaves are then stripped from the stem.

Paper.—The paper used for wrapping cigarettes is a special type of close-textured tissue paper, free from pinholes, and conforming to a large number of exacting specifications. Thus, the paper should be clear and white, should not absorb colour from tobacco, should have sufficient tensile strength so that it can be used on machines turning out about 1,200 cigarettes per minute without tearing, should have the proper degree of combustibility—neither too slow nor too fast—and should be free from impurities which may affect the flavour of tobacco. The paper is made from selected raw materials like ramie, sunn hemp, and linseed fibre, and loaded with pure chalk to slow down the rate of combustion to the desired extent. It is lightly sized with rosin and alum. The weight of paper in a cigarette constitutes about 5% of the total weight, and approximately 13 bobbins of paper are required for the manufacture of one million cigarettes. A part of the tissue paper used in Indian factories is obtained by import from U.K., France, Yugoslavia, and U S.A. Imports in recent years have decreased considerably. Paper of the required quality is being manufactured in India during the last 3 years by the *Eastern Tissues Ltd.*, Raniganj, their approximate annual production capacity being 480 tons. A new factory, *Tribeni Tissues Ltd.*, with an annual rated capacity of 3,000 tons, is being erected near Calcutta. The present annual production of cigarette paper in India is estimated at 144,000 bobbins, which meets only 50% of the requirement. Table 1 gives the annual imports of cigarette paper from U.K.

In 1945, c. 12,650 cwt. of cigarette paper valued at c. $559,700 were imported from U.S.A.

TABLE 1.—IMPORTS OF CIGARETTE PAPER FROM U. K.*

	Booklet form		Other forms	
	Qty. (cwt.)	Value (£)	Qty. (cwt.)	Value (£.)
1942	80	1,913	7,634	66,874
1943	—	—	5,266	53,458
1944	269	6,986	9.360	89,981
1945	332	9,087	6,767	69,852
1946	167	4,265	6,791	72,300

Tr. U.K.

MANUFACTURE

The manufacture of cigarettes involves a number of elaborate and complex processes. Grading and blending of tobacco, on which depend the character and aroma of the manufactured product, are operations demanding extreme care. For each brand of cigarette, the correct grades of tobacco should be selected and blended in the right proportions. Crops of selected tobacco raised over a number of years are mixed together for use in cigarette manufacture to ensure uniformity.

Cigarette manufacture in its several stages is a highly mechanized process. The machinery in the different sections of a cigarette factory is operated in batteries of large numbers. The leaves are stored in an air-conditioned warehouse. For any given brand, a particular blend of several types of leaves in specified proportions is necessary. As the tobacco leaves received in the factory are too dry for processing, they are passed through a series of conditioned chambers where they are treated with live steam and water to render them soft and pliable. They are stacked in heaps for maturing. The matured leaves which are sweet and mellow, are pressed between pairs of rollers and cut by shearing blades into shreds (about 30 to 40 cuts or more per linear inch of the leaf). Stems are separately conditioned and flattened out by rolling prior to cutting.

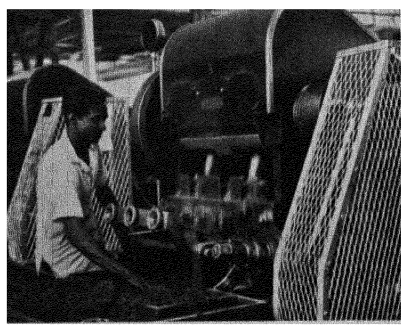


Fig. 36.—Shredding of cured tobacco leaf

Fig. 37.—A battery of machines for making cigarettes

The cut leaves and stems in required proportions are passed through a revolving cylinder in which hot air is circulated to remove excess moisture, and then cooled in another revolving cylinder, the dust being sieved out at the same time. This operation helps also to mix the cut leaves and stems thoroughly. The product so obtained is stored under regulated humidity conditions for a couple of days for further maturing before use.

The cut and dried tobacco is fed into hoppers of cigarette forming machines which are capable of making 1,000—1,200 cigarettes per minute. Here the shreds are carded and drawn over a wide chute by revolving rollers. The material is laid uniformly on paper unwound from bobbins. Before receiving the tobacco, the paper passes through a small printing unit which imprints the maker's name, brand, etc., on the paper. After receiving the tobacco, the paper passes through a folding unit where it is mechanically gummed and folded over the tobacco. The product thus made is an endless cigarette rod which is cut into desired lengths by a fast revolving steel knife as it passes under it.

The cut cigarettes, after inspection, are conditioned in trays in special rooms maintained at about 60% humidity. For manufacturing cork-tipped cigarettes, the paper before receiving the tobacco passes through a cork-tipping apparatus which fastens the tips securely at regular intervals.

The conditioned cigarettes are finally packed in cartons of 10 or are vacuum-packed in tins of 50 by automatic machines. Prior to packing in cartons, the cigarettes are wrapped in aluminium foil. The cartons are covered by cellophane, and packed in water-proof outers, each parcel containing 500 cigarettes. The parcels are packed in wooden

Fig. 38.—Cigarettes stored in an air-conditioned room for curing

cases of various sizes. High class cigarettes are packed in cases weighing 1½—2 md., each case containing 25,000—30,000 cigarettes. Cheaper brands are consigned in wooden cases weighing 3—3½ md. and containing 50,000 cigarettes. Foreign cigarettes and cut tobacco are consigned in dealwood cases (3 ft.×2½ ft.×2 ft.) weighing about 2½ md. and containing 25,000 cigarettes.

The cigarettes produced are round in form, 25, 25·5, or 26 mm. in circumference and 70 or 72 mm. in length.

The moisture content of the cigarette is an important factor as it affects the smoking and keeping qualities. If the tobacco is too dry, it is liable to break off and drop out of the open ends; it burns too freely and rapidly and the smoke is strong, sharp, and pungent. On the other hand, if it is too moist it will not burn properly and will need excessive puffing on the part of the smoker; also the smoke lacks quality. Cigarettes are conditioned to retain 12% moisture which is the optimum (*Tobacco*, 1946, **123**, No. 6, 6). In the United States of America, glycerine (2—3% on the weight of tobacco) or diethylene glycol (3—4%) is added to increase the moisture holding properties of tobacco. No additives are used for this purpose in Indian factories.

Production and Trade

The average annual production of cigarettes in 1938 was estimated at 7,500 million (*Rep. Marketing Tobacco*, 321). The production in 1946, 1947, 1948, 1949, and the first ten months of 1950 was 23,821, 18,879, 21,825, 21,891, and 19,585 millions respectively. The installed capacity of the plants is 30,000 million cigarettes per annum (*Monthly Statistics of the Production of Selected Industries of India*).

Imports.—Large quantities of cigarettes were imported into India during the years immediately following World War I. 4·13 million lb. of cigarettes, valued at Rs. 180 lakhs, were imported annually during the quinquennium 1921—26. The imports declined since 1930-31, and the manufacture of cigarettes using home-grown tobacco steadily increased. Indigenous manufacture was stimulated by the *Swadeshi* movement leading to

TABLE 2 — IMPORTS OF CIGARETTES

	Qty. (million lb)	Value (lakh Rs.)
1929/30–1933/34 (av.)	2 24	87·29
1934/35–1938/39 (av)	0 91	33 31
1939/40–1943/44 (av.)	0·98	34 17
1944–45	0 01	1·35
1945–46	0 12	8 97
1946–47	0 94	73·44
1947–48	1·09	84 58
1948–49	0 79	64·80
1949–50	0 11	11 09

TABLE 3 — EXPORTS OF CIGARETTES

	Qty (million lb.)	Value (lakh Rs.)
1929/30–1933/34 (av.)	0·29	2 57
1934/35–1938/39 (av)	1 05	27 94
1939/40–1943/44 (av)	0 94	37 16
1944–45	0·12	3 00
1945–46	0 03	0 88
1946–47	0 79	50 77
1947–48	0 28	26 91
1948–49	1 84	147 90
1949–50	1 31	50 91

the boycott of foreign goods. About 99% of Indian requirements are now met by indigenous production Table 2 gives the imports of cigarettes into India

The principal supplier of cigarettes is United Kingdom, her average annual share in the import during the quinquennium ending 1948-49 being 93·7% in quantity and 95 0% in value

Data relating to exports of Indian cigarettes are summarized in Table 3

Exports showed a remarkable increase between 1936-37 and 1940-41—from about 0 3 million lb to 1 63 million lb The increase in exports after 1947-48 is mainly due to the partition of the country. The principal importers of Indian cigarettes are Ceylon and Pakistan

Due to the varying rates of taxation, and the wide range of income groups, the qualities and prices of manufactured cigarettes in India show greater variations than in any other country. Imported cigarettes and the products made in India with high proportions of imported tobacco are the most expensive. Cigarettes containing a reduced proportion of imported leaf come next, followed by those containing only Indian flue cured tobacco. Brands made from rack cured tobacco, which bear the lowest rate of taxation, are priced the lowest. Imported cigarettes are usually retailed at about Rs. 4 per tin of 50, and cigarettes made in India vary from about Rs 3-8-0 to 7½ as for 50.

Cigarettes are subject to import duty. The imposition of heavy import duties gave an impetus to the manufacture in India of cigarettes from home-grown and imported tobacco. Imports are at present subject to a revenue duty of 37½% *ad valorem* plus Rs 39-1-0 per 1,000 or Rs 15-10-0 per lb, whichever is higher. The duty on imported tobacco is Rs. 9-6-0 per lb The duty on exports of cigarettes, which was reduced from 15% to 7½% towards the close of 1949, has been recently abolished in order to encourage exports.

All forms of processed tobacco used in cigarette manufacture are subject to excise duty, the duty varying according to the variety of tobacco and the content of imported tobacco in the processed product The duty ranges from Re. 1 per lb. on flue cured tobacco when no imported tobacco is used, to Rs 7-8-0 per lb when the cigarette contains more than 60% by weight of flue cured imported tobacco. Tobacco, other than flue cured, is subject to an excise duty of 9 as. per lb. The revenue realized during 1946-47 from tobacco used in cigarette manufacture was approximately Rs 8 crores

Since March 1948, an excise duty has been imposed on manufactured cigarettes, the duty varying according to their selling prices. The rates of duty per 1,000 cigarettes are, Rs. 12-8-0 (Rs 50 and above), Rs 10 (Rs 40—50), Rs. 7-8-0, (Rs 30—40), Rs 6-4-0 (Rs. 25—30), Rs. 5 (Rs 20—25), Rs 3-12-0 (Rs 15—20), Rs. 2-8-0 (Rs 10—15), and Rs. 1-4-0 (< Rs 10), the figures in brackets indicating the prices. The realizations from *ad valorem* duty during the years 1948-49 and 1949-50 were respectively Rs. 6·28 crores and Rs 5 81 crores.

CLOCKS AND WATCHES

The clock is a time-measuring instrument in which an oscillating pendulum is employed as time counter, the term is applied also to stationary time-indicating mechanisms, controlled by a balance wheel and spring, employed either alone or in conjunction with other instruments. Watches are small-sized portable instruments for personal wear or adornment and used for purposes requiring the measurement of time.

The components of a clock or watch mechanism are: (1) a source of motive power, (2) a device for controlling and regulating the expenditure of power, and (3) a 'train' for the transmission of motive power to the 'escapement' and time-indicating device The source of motive power may be a raised weight or a coiled spring, or it may be an electrical device The motion is restrained by the intermittent action of the escapement and controlled by the swing of a pendulum or the vibration of a balance wheel and its spring. The train consists of a series of toothed wheels and pinions between the driving force and the escapement In some cases, a striking mechanism is operated in conjunction with the visual recording mechanism, an electrical signal, a paper-reel, or other method for recording the time may also be employed according to requirements (Haswell, 20)

Clocks

In the more usual types of clocks, the counting and maintenance of time are both performed by the escapement. The clocks are either weight-driven or spring-driven Some are fitted with calendars, alarums, and striking and chiming mechanisms to mark hours, half hours, and quarter hours.

The motive power in weight-driven clocks is the potential energy stored in the weight Three types of weight-driven clocks are in use (1) Regulators used in astronomical observatories and in institutions where high accuracy in time is demanded, (2) long-case or Grandfather clocks, and (3) turret clocks built into towers of churches and public buildings

Spring-driven clocks derive their motive power from the energy stored in coiled springs A large variety of such clocks are available They may be grouped into three classes, viz., bracket, dial, and portable clocks

The actual time counter is the pendulum, its motion being maintained by the escapement, which gives periodic impulses while, at the same time, the motion of the escape wheel is arrested until the oscillation of the pendulum is completed. The escapement thus serves as a mechanism for both counting and impelling the pendulum. It consists of a toothed wheel driven by two pallets engaged by the teeth of the escape wheel. The shape of the pallets and their distance from the pallet arbor in comparison with the radius of the escape wheel are important

Domestic clocks are fitted with recoil escapements. The wheel is driven backward slightly by the motion of the pendulum after the impulse is transmitted and the next tooth engages the locking. As a result, the second hand carried by the arbor of the escapement recoils a little after each tick Astronomical regulators and turret clocks are provided with dead-beat escapement which does not show the recoil. The locking faces of the pallets and the wheel teeth are so made that when a tooth engages the locking, the wheel remains stationary during the completion of the oscillation of the pendulum. During the period of rest on the locking, the power behind an escape wheel may either continue to press each tooth in turn against the moving surface of the pallets causing friction or is cut off, as it were, from the pallets while the pendulum is permitted to swing freely (Haswell, 46).

The train of a clock consists of a series of toothed wheels The series of wheels comprise units having alternately large and small number of teeth In the ordinary clock, a 'great wheel' is directly driven by the motive power The wheel is linked to a centre pinion and wheel which completes one revolution per hour Hence it carries the minute hand An intermediate pinion wheel is sometimes used to prolong the duration of the driving force The centre wheel engages the 'third' pinion and wheel, which in turn drives the escape pinion and wheel The second hand is fixed to the arbor of the escape pinion which rotates once in a minute An auxiliary motion work enables a wheel to rotate at 1/12 or 1/24 of the velocity of the centre arbor for recording hours (Haswell, 57)

The striking mechanism consists of a separate train driven by a second weight or coiled spring Another train, distinct from the going and striking mechanisms, is employed for producing chimes

In electric clocks, the pendulum swing is electrically maintained and a separate mechanism is employed for counting Electrical clocks may be self-contained or a master clock may be used for controlling a number of slave dials Electrically wound clocks and synchronous motor clocks are also in use

Watches

Portable time-pieces and watches consist of a frame work, a main-spring and a means for winding it, a train of wheels with hands and a dial, the escapement, balance wheel, and hair spring.

The motive power is obtained from a coiled main-spring Two different types of mainsprings are used: (a) those known as Lever and (b) those known as Going Barrel, Geneva and Lepine, the latter being more modern. The increased length and reduced strength of the latter type minimize to some extent the variations in force

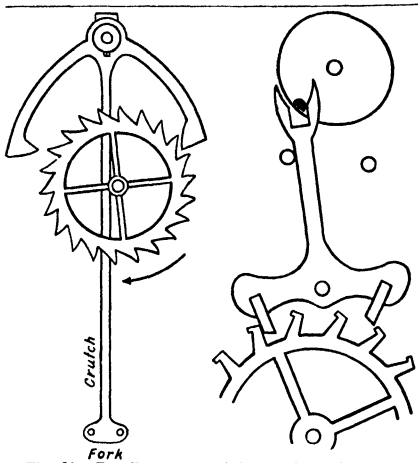


Fig. 39.—Recoil escapement for clocks (left) Lever escapement for watches (right)

between consecutive coils of the spring

The time is controlled by a balance wheel and a balance spring The balance wheel moving over a vertical axis vibrates to and fro describing an arc of a circle In most modern watches the wheel makes 18,000 to-and-fro vibrations in an hour. Each vibration releases a tooth of the escape wheel from one of the two pallets An additional wheel and pinion, known as the 'fourth' wheel and pinion, is employed to utilize the more frequent vibrations in a watch. This wheel makes one revolution in a minute The pinion is provided with a pivot which projects through the dial and carries a seconds hand. In the case of a balance wheel which executes 18,000 to-and-fro motions in an hour, the escape wheel has 15 teeth, and the period of a complete rotation is 6 seconds Table 1 gives a few combinations of wheels frequently employed in watch trains.

The earlier watches were fitted with recoil type verge escapement. It was replaced by Graham's cylinder or horizontal escapement which was brought to perfection in Switzerland and is still used in low-priced watches Watches are now provided with lever escapement The chronometer escapement, which is equally satisfactory, is not adaptable to pocket watches.

Modern American and Swiss watches employ lever escapement which differs from the old English form in having levers at right angles to the line of pallets and not parallel to them, as in the English form. The pivots of the escape wheel, lever, and balance are planted in a straight line. The action between the escape wheel and the pallet is similar to that in the dead-beat clock escapement, the difference being that in the former the impulse lasts from about 4° before to 5° after the zero position of the lever The roller is mounted on the balance staff and receives the impulse from the lever by its D-shaped pin (Rawlings, 162).

Production

Mass production techniques are employed in the clock and watch industry in many countries. The components are made by two processes: (1) machining or turning, and (2) blanking and pressing

Raw materials—Brasses and steels of various specifications are required in clock and watch manufacture Many components are made from leaded brass. Three types of alloys are used·

TABLE 1—COMBINATIONS OF WHEELS FOR WATCH TRAINS*

Centre wheel	Third pinion	Third wheel	Fourth pinion	Fourth wheel	Escape pinion	Beats per hour	
64	8	60	8	60	6	18,000	Usual in Swiss horizontals
64	8	60	8	70	7	18,000	General seconds trains
64	8	60	8	80	8	18,000	
80	10	75	10	80	8	18,000	
80	10	75	10	72	8	16,200	High numbers
64	8	60	8	63	7	16,200	Usual numbers
64	8	60	8	60	7	15,428	Old style English levers
64	8	60	8	56	7	14,400	

*Haswell, 139

TABLE 2.—TYPES OF CARBON STEEL REQUIRED FOR CLOCKS AND WATCHES*

	Analysis						Mechanical properties	
	C %	Si %	Mn %	P %	S %	Pb %	Size	Tensile strength (tons/sq in.)
1.	0·15–0 20	0·30 (max.)	0·60–0 80	0·04(max.)	0·20–0 25	..	All sizes	37–42
2.	0 12–0 15	0·20 ,,	0 60–0·90	0·05 ,,	0 20–0 25	0·15–0 25	All sizes	37–42
3	0·40–0 45	0 30 ,,	0·70–0 90	0 05 ,,	0·20–0·30	..	All sizes	50–60
4.	0 60–0 75	0 30 ,,	0·70–0·80	0 05 ,,	0·20–0·25	0 15–0·20	All sizes	38–45
							Up to and including 2·0 mm	55–65
							Over 2·0mm.	50–60
5.	0 90–1·10	0·30 ,,	0 40–0 80	0·05 ,,	0·05(max.)	0 15–0 20	All sizes	42–46
							Up to and including 2 0 mm.	60–65
							Over 2·0 mm.	50–60

*Tricker, loc cit.

(1) B S S No 249· Cu, 55—60%, Pb, 2—3 5%, impurities, 0·75% max ; and Zn, remainder, minimum tensile stress, 25 tons/sq in ; (2) alloy containing· Cu, 58—60, Pb, 1 5—2·0%, Sn and Fe, 0·10% max each, impurities, 0 50% max , and Zn, remainder, minimum tensile stress, 30—38 tons/sq. in ; and (3) alloy containing Cu, 60—63%; Pb, 2·0%, impurities, 0 75% max , and Zn, remainder (Tricker, *J Inst. Met*, 1949, **75**, 883).

Pinions, spindles, screws, arbors, etc , are made from sulphurized free-cutting mild steel rods (tensile strength, 37—42 tons/sq in , and hardness, 70—200 D P N) For bearing screws, the steel is cyanide-cased Table 2 gives the types of carbon steel rod materials required for the manufacture of clocks and watches

Blanked and formed components—Plates and wheels are made from special brass, preferably α/β type, as in many clock movements the bearings of pinions are merely holes in the plates. Brass strips for stamping and piercing holes should produce no burrs, must be dead flat, and must remain flat after stamping Leaded brass is suitable. The strips are cold rolled to 140—165 D P N. (tensile strength, 33—37 tons/sq. in ; elongation, 7—20%) for plates and large wheels, and to 160—190 D P.N (tensile strength, 37—40 tons/sq in ; elongation, 3—9%) for other wheels. Specially treated Duralumin is also used for plates and wheels For bezels, slip rings, cases, etc , lead-free brass (B S S Nos 265, 266, and 267) are required Special leaded nickel silver (Pb, 2% and Ni, 12—15%) is generally used for escapement (Tricker, loc cit)

Clock and watch hands, escape wheels, etc , are made from high strip or mild steel (C, 0·9—1·10; Si, 0·30 max.; Mn, 0·40—0·80; and S and P, 0·05% each) Blanked and formed components are also made from bright mild steel conforming to B S S No 1449 (1948) (Tricker, loc. cit).

Spring materials—Main springs are made from (1) straight 1% carbon steel (C, 0·95—1·05, Si, 0 30 max , Mn, 0 40 max , S and P, 0 025% max each, D P N , 540—700) for table clocks and watches, and (2) silico-manganese steel (Cu, 0·55—0 65, Si, 1 80—2 20, Mn, 0 70—1 00, and S and P, 0 035% max each, D P N , 540—620) for clocks Tests of evaluation include tensile strength, D.P N hardness, and 180°- bend test round a specified diameter varying with the thickness of the strip. Carbon steel spring is oil- or air-hardened at about 780—800° and tempered at 260—320°

Recently the use of Elgiloy (Co, 40, Cr, 20, Ni, 15 5; Fe, 15, Mo, 7, Mn, 2, C, 0 15, and Be, 0·03%, D P N., 640—700) for watch springs has been suggested Billets of this alloy are hot-rolled to 0 05—0·06 in , solution-treated at about 1,100—1,200°, then cold-rolled to spring thickness of 0·004—0 006 in. without intermediate anneals, and finally precipitation-hardened for about 5 hrs. at 480° to give the required properties The alloy has corrosion-resisting and non-magnetic properties (Tricker, loc. cit)

Hair-springs are made from phosphor bronze containing 7—8% Sn. Good elastic properties are imparted by cold-working and by adjusting the setting temperature. Phosphor bronze springs have displaced steel springs in alarum clocks.

Temperature compensation is essential in all time-measuring devices. In ordinary watches, this is effected by using solid brass or nickel silver, for balance wheels with a hair spring of invar or elinvar steel. These steels have a negligible thermo-elastic co-efficient and are

TABLE 3.—MATERIALS USED FOR HAIR-SPRING*

	Approximate analysis (%)	Young's Modulus, E, lb./sq. in. × 10^6	Uses
Phosphor bronze	Sn, 7 ; P, 0·25 ; remainder, Cu	16	General use for clocks and return springs
Elinvar	Ni, 35; Cr, 8 ; C, 0·06 ; remainder, Fe	23	Used for temperature compensation as in watches
Metelinvar	Ni, 40 ; Cr, 6 ; W, 3 ; Mn, 2 ; Mo, 1·5 ; C, 0·60; remainder, Fe	24	,,
Nivarox	Ni, 35 ; Cr, 8 ; Ti, 1·0 ; Be, 0·9; C, 0·06 ; remainder, Fe	25	,,
Steel	C, 0·90–1·10	28	Used in a few clocks ; also for watches with bimetallic balance.

*Tricker, loc. cit.

non-magnetic. A split balance bi-metal rim with steel hair-spring is used in chronometers and high class watches. Table 3 lists the materials used for hair-springs.

Small magnets used in synchronous electric clocks are made from strips of special magnet alloys, such as Alni, Alnico, and Alcomax by hot stamping. Sintered bronze bearings are used with clock movements, particularly in electric clocks as it is difficult to re-oil bearings of fast moving trains. Sintered bronze (10% Sn) bearings provide a reservoir of fresh oil and can last for a long time without re-oiling.

In addition to the above mentioned raw materials, stainless steel, aluminium, gold, platinum, etc., are used for making watch cases. Sometimes, the cases are chromium plated. Luminous dials are also manufactured for special types of watches. Sapphires or rubies are used as bearings for watch pivots; synthetic rubies are now used for this purpose.

The Indian Industry

A number of tower clocks have been made in India since 1926, and set up in public buildings in south India, thanks to the pioneering efforts of Dr. H. Parmeswaran. The India Meteorological Department has carried out a considerable amount of work on the manufacture of clock mechanisms for radiosonde and seismological instruments. In the initial stages, components of imported timepieces were utilized. With the stoppage of imports, the Department utilized its workshop facilities to cut gears and pinions, and developed new techniques for making hair-springs. The

Fig. 40.—A time piece made of radiosonde clock components

dimensions of balance wheels were altered to suit whatever main-springs could be obtained in the market. The number of radiosonde clocks produced per day in the Department's workshops is 6, the production cost being Rs. 13 per clock, which can be reduced by at least 50% by increasing the output.

The Department is now in a position to fabricate time pieces similar to those available commercially. A few time pieces were actually made by assembling the components used in the radiosonde clock. The cost of a time piece, when made in small numbers (6 per day), is about Rs. 30 each, which can be reduced considerably if the output is increased.

Special clock movements required for self-recording meteorological instruments have also been made. A double-speed clock movement was designed and assembled for an altitude recording instrument in 1940; its performance was comparable to the clock movement fitted in the Askania instrument.

An accurate 8-day weight-driven clock was designed and constructed at Poona for use with the Wood-Andersen seismograph. The escapement is of the dead-beat type. The pendulum is of invar and carries a steel bob whose position can be adjusted by the use of a brass nut. The seconds hand is attached to the long pivot of the escape wheel arbor. To obviate any tendency to reverse the motion of the train and to drive the seconds hand backwards during winding, a device known as 'maintaining power' was incorporated in the clock. The dial was made by engraving on a sheet of Dilecto of 1/8 in. thickness. The escapement pallets, etc., were made from old and unserviceable files by suitable heat treatment.

An electrically wound, spring movement pendulum clock has been recently made at Poona. It needs no attention if the supply of power for starting the winding motor is assured. The cost of the precision clock works out to Rs. 350.

Commercial production of clocks has been undertaken in India since 1942 when The *Indian Clock Manufacturing Co. Ltd.*, Tatanagar, was started with an output of 4—5 clocks per day. More recently, The *Time Instruments (India) Ltd.* Ghatkopar (Bombay), and *Master Clock and Watch Works Ltd.*, Bhavnagar, have started clock manufacture. The former has a capacity of 2,000 clocks per month, and turns out non-striking, 8-day winding, round shaped clocks, with 10 and 12 in. dials; rectangular shaped clocks are also made. The production of the second factory is about 50 clocks a day, which is to be shortly increased to 100. A number of small firms, such as *Dutex Clock Co.*, Calcutta, *Scientific Manufacturing Co.*, Morvi, *Hindustan Clock Works*, Poona, and *Swadeshi Electric Clock Mfg. Co.*, Bombay, also produce clocks. The U. P. Government has under consideration the establishment of a factory for the manufacture of watches and clocks with the help of Swiss experts and equipment.

The bigger factories are equipped with modern machinery, such as wheel cutting machines, precision drilling machines, thread cutting machines, milling machines, precision lathes, jig boring machines, screw cutting machines, punching and blanking presses, and grinding and polishing machines. Automatic machines have been installed for turning out smaller components.

Indian clock manufacturers make all the parts and produce American and Ansonia types of clocks, both striking and non-striking. M.S. rods and hard bright steel wires required for making axles, pivots, etc., are obtained from The *Indian Steel and Wire Products Ltd.*, Tatanagar. Special heavy drawn brass and main-springs are imported from U.K. and Japan. Special steels for axles, hands, etc., are imported from Sweden.

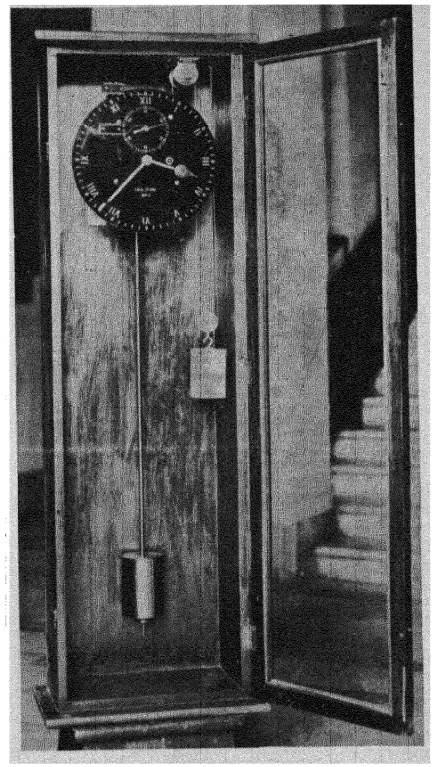


Fig. 41.—Weight-driven clock

The frame-work of the clock consists of two brass plates stamped out from sheets. The bearings are drilled. Wheels are made by stamping out circles from brass sheet and cutting the teeth by milling machines. Some factories use punching machines to cut out toothed wheels in one operation. Barrels are made from rods by precision automatic lathes, and axles and pinions from hardened and tempered steel wire. The train movement is fixed in between the brass plates. The pendulum rod is a stout steel wire flattened

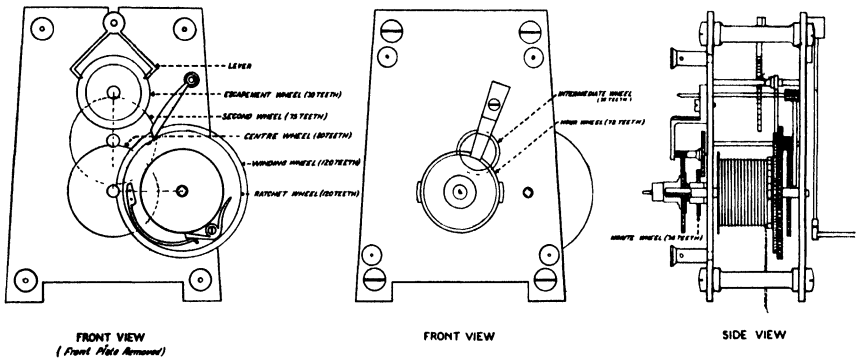


Fig. 42 —Weight-driven clock mechanism

at one end to act as a spring A brass bob is attached to the other end Black steel sheets and tin plates are used for punching out dials, minute and hour hands, components of clock cases and cover Cases are of wood and plywood veneers Bezels are made from brass sheets

Trade

Practically the entire requirements of clocks and watches are obtained from abroad Table 4 gives the imports of clocks, watches, and parts thereof into India

The shares of various countries reckoned on the value of imports of clocks and timepieces during the quinquennium ending 1938-39, were· Japan, 49, Germany, 31, U.S A , 12, and Switzerland, 4%. Of the total value of watches imported during the same period, Switzerland accounted for 94%, and Germany for less than 2% About 64% of the imports of clock and watch parts were from Japan The average landed cost during the period was a little less than Rs 3 per clock, and a little over Rs 4-8-0 per watch

The position changed considerably after the War During 1948-49, time pieces were imported from France (34 2%), Switzerland (29·8%), U. K. (15 5%), Japan (11·4%), U S A (4·5%), and Italy

TABLE 4 —IMPORTS OF CLOCKS AND WATCHES

	Clocks and time-pieces		Watches		Parts of clocks and watches	Total
	No (1,000)	Value (lakh Rs)	No (1,000)	Value (lakh Rs)	Value (lakh Rs)	Value (lakh Rs)
1934/35–1938/39 (av)	457 6	13 56	422 8	19·52	0·88	33 96
1939/40–1943/44 (av)	78·4	3·47	362 5	28 19	0 45	32 11
1944–45	51·4	1·77	272 9	33 91	0 09	35 77
1945–46	172·3	8·43	487·7	79 70	1 12	89 25
1946–47	122·1	11·39	349·2	61 94	1 45	74 78
1947–48	329·0	34·27	763·6	327·05	4 90	366 21
1948–49	412·5	36·63	1,040 4	217 30	5 47	259 41
1949–50	(a)	(a)	(a)	(a)	(a)	142 41

(a) not available

TABLE 5.—IMPORTS OF CLOCKS, WATCHES AND COMPONENTS FROM SWITZERLAND*

(in 1,000 Swiss francs)

	1944	1945	1946	1947	1948	1949
Clocks :						
Pendulum and Alarum clocks and parts	57·4	287·8	352·3	1,462·2	786·8	907·4
Automobile clocks	0·9	—	—	0 09	—	0·04
Electric clocks and accessories	—	—	—	—	—	3 25
Watches :						
Wrist watches	11,798·5	13,022 4	10,670 3	30,061 2	20,296 0	20,210·2
Pocket watches	276·2	367·9	203 1	605·6	286 1	341·0
Timepieces with pocket watch mechanism	74·3	89·3	99·7	1,048·6	332·3	280 2
Complete mechanisms of Pocket & wrist watches	0·3	0·8	—	10·2	0 3	1 85
Watch cases of common metals, plated, silver, gold and platinum	0·07	3·4	8·5	7·5	13 8	35 1
Other components of pocket watches	241 3	534 2	502·9	1,764 5	1,078 3	862 6
Total	12,449·0	14,305 8	11,836 8	34,959·9	22,793 6	22,641 6

*Information from Swiss Embassy, New Delhi

(4·0%), the figures within brackets showing the shares in the total value of imports. About 96% of the watches imported during the period came from Switzerland. Small quantities of watch and clock parts were imported from Switzerland (66·9%), and U. K (19·2%). About 86% of the total imports during 1948-49 and 73·5% in 1949-50 came from Switzerland.

Table 5 gives the imports of clocks and watches from Switzerland

Imports of clocks, watches, and parts thereof are subject to a revenue duty of 75% *ad valorem;* the duty on one-day alarum clocks is 50% *ad valorem.*

The Indian clock industry is still in its infancy. With a large internal market and the duty imposed on imports, there is considerable scope for developing the industry in India There is an increasing demand for master-cum-slave clock mechanisms required for use in public and commercial institutions. The manufacture of alternating current synchronous main clocks is easy, lending itself to small scale production (Parameswaran, *private communication*).

CLOTHING

The production of garments as an industry in India, is a comparatively recent development. It is a sizeable industry in some foreign countries, notably in U K , Japan, and U S A During World War II, many new improvements were introduced in the industry, particularly as a result of statistical analyses of sizes and tastes of users and the mechanization of the different manufacturing operations

One of the advantages of mass production is that the cloth can be utilized to the last inch avoiding wastage, the saving in cloth is reckoned to be 5—10%. Ready-made clothes are less expensive and more durable than individually tailored articles Large scale production is particularly useful for making uniforms required for personnel employed in railways, posts and telegraphs, military and police, dockyards, shipping companies, banks, hospitals, catering establishments, scouts associations, etc

The Indian Industry

The growth of the ready-made clothes industry in India has been slow, due mainly to the diversity in customs and tastes of people living in different parts of the country. Before World War I, there were but two Army clothing factories, one at Madras and the other at Alipore (Calcutta), with a combined monthly output of 40,000 garments. Eighteen temporary factories were established to meet the demand of the Armed Forces during the Great War In 1931 there was but one factory at Shahjahanpur with a monthly output of about

75,000 garments. In 1939, when World War II broke out, there were in addition to the Shahjahanpur factory two other small units, one at Perambur (Madras) and the other at Moghalpura (Lahore) owned by the Madras and Southern Mahratta Railway and the North Western Railway respectively to meet their own requirements. Besides, a few medium-sized factories had been established in the larger cities for manufacturing ready-made garments for civilian use. There was also an export trade with Burma, South Africa, and the Far East. The bulk of the internal civilian demand, however, was met by tailoring shops.

The demand for military clothing increased to a great extent during the last War, and the industry had to be considerably expanded. The output of the Shahjahanpur factory was increased, and 8 new factories were established at Lahore, Madras, Calcutta, Agra, Sialkot, Delhi, Secunderabad, and Bombay. Three factories started at Kanpur, Lahore, and Sialkot, primarily for manufacturing parachutes, also produced tailored articles. A few of these factories were engaged in cutting the cloth to specifications, the cut pieces being made over to contractors for stitching (*Rep. Panel on Ready-made Clothing Industry,* 1946, 4). India was the principal source of supply for the Allied Forces in Europe, Asia, and Africa.

During 1942-43, the clothing factories produced about 100 million garments valued at Rs. 50 crores, for which about 300 million yards of cloth valued at Rs. 45 crores were utilized. The number of skilled, semi-skilled, un-skilled, and supervisory staff in army clothing factories was c. 33,000 in December 1944. In addition, 200,000 workers were employed by contractors throughout the country (*Rep. Panel,* loc. cit.). 298 million tailored items were produced during the period September 1939 to December 1943 (*Indian Text. J.*, 1945, **56**, 111). The ordnance factories supplied 78·84 million tailored items of clothing from 215 million yards of textiles, over 5,600 million yards of sewing thread, and over 500 million buttons (*Indian Text. J.*, 1945, **55**, 352A). The industry supplied in all about 400 million tailored units during the War period.

The factories had to keep pace not only with the increasing demands, but also with the changes and improvements in patterns and designs. In 1944 there was a significant increase in the demand for hospital clothing, prisoners-of-war clothing, and clothing for Chinese troops.

Fig. 43.—Cutting of cloth by machines

TABLE 1.—PRODUCTION OF ARMY CLOTHING IN INDIA
(in 1000)

	1939-40*	1940-41	1941-42	1942-43	1943-44	1944-45	1945-46†
Battle dress blouses or trousers	—	606	1,590	3,018	13,662	17,780	3,123
Khaki drill trousers	14	397	4,027	5,964	2,190	5,708	1,010
Shirts	304	4,891	12,772	14,057	4,739	4,416	5,781
Shorts	561	3,077	10,805	13,763	7,199	4,063	558

*Relates to September–March.
† „ to April–August.

Table 1 gives the production of army clothing in India during World War II (*Statistics relating to India's War Effort*, 1947, 11).

Raw materials.—The raw materials used are cotton and woollen textiles, sewing thread, buttons, buckles, oil-skin, etc., all available in the country. The requirements for special types of garments are met by imports. Rayons are used in considerable quantities for ladies' and children's wearing apparel.

Manufacture.—Each type of garment is designed and graded to conform to a set of standard sizes and fittings based on statistical data relating to users' tastes and requirements. The component parts are patterned by experts, and the sizes and shapes are marked out on cardboard in tailor's crayon. The markings are perforated by a machine. The perforated piece, or Marsden Lay as it is called, is used for marking the cloth for cutting. A separate lay is prepared for each standard group of measurements.

The cloth is spread out on rows of cutting

Fig. 44.—Stitching of clothes

tables, 60—100 ft. long and 4 ft. wide, accommodating a pile of 50 to 100 pieces of cloth one above the other (about 6 in. thick) The pile is kept stretched by clips, sometimes laying machines are employed The lay is placed on the top layer of cloth, and chalk powder sprinkled on it. When the lay is removed, the chalked pattern is left on the cloth

Cutting is effected by electrically driven or hand operated cloth cutters and band saw machines. The pieces are first cut into blocks 4—6 ft in length to facilitate handling and the cloth blocks are fed to band saws for cutting the component parts. Two types of cloth cutting machines are in use, viz, circular knife machines and straight knife machines, the latter being used for more accurate work and for cutting corners, etc.

From the cut piles, the different parts required to form a garment piece are sorted out and bundled A shirt has generally 16 parts and a pant 13 parts The bundles go to the issue section of the tailoring department whence they are distributed to tailors for stitching

Stitching is carried out by hand-sewing, treadle-sewing or electrically driven sewing machines Decorative stitching and general decoration work in women's and children's clothes are done by hand, or by special machines such as those used for hem-stitching, faggoting, tucking, gauging, scalloping, and pinking machines The stitched garments are taken to the button-holing and button-fastening machines whence they emerge as ready-made garments Those made from fine cloth are bleached if required, after which the measurements are checked

The garments are pressed by electric irons and sent to packing tables where each garment is individually checked, folded, and wrapped in cellophane or plio-film cover, stamped to specify the price and name of the manufacturer, and sent to the despatching or marketing section

Types of clothing—The Army clothing factories make the following items of clothing: battle dress, serge suits, great coats, shirts, shorts and trousers of all types, head-wear, mosquito nets, water-proof capes, flags and embroidered badges, cloth bags of all kinds, cotton bandoliers for small arms and mortar ammunition, oil-skin containers for scientific stores used in amphibious warfare, and special clothing for workers in dairy farms and explosives factories The railway clothing factories make coats, trousers, shorts, shirts, boiler suits, aprons, leggings, bags, and flags The civilian clothing factories make a large assortment of items including coats—Jodhpur, lounge.

TABLE 2—IMPORTS OF CLOTHING FROM U K †
Value (£)

	1942	1943	1944	1945	1946
Outer garments for men and boys					
Overcoats of wool or mixed with other materials	176	—	139	4,209	21,920
Coats, waistcoats, trousers and the like	1,353	622	3,954	15,714	39,303
Other sorts	1,587	1,668	1,709	1,482	9,249
Mackintoshes, oil-skins and similar proofed garments	682	—	18,343	4,645	11,922
Outer garments for women, girls & infants					
Overcoats, cloaks, coats and the like	144	—	971	5,934	36,627
Other sorts	1,000	—	1,056	4,390	14,272
Under garments*					
Shirts including collars and cuffs	2,200	136	183	7,499	15,221
Other sorts	660	87	1,778	4,684	12,228
Total	7,802	2,513	28,133	48,557	160,742

†*Tr. U K.* *excluding hosiery

double-breasted, sherwanis, doctor's aprons—, pants, half pants, pyjamas, sleeping suits, overalls, shirts, bush shirts, pillow covers, bed sheets, cushions, bolsters, and miscellaneous types such as neckties, petticoats, frocks, etc.

The demand for military clothing has considerably declined The production of clothing during April-September 1946 was. battle dress trousers, 696,390, water-proof capes, 320,099, overalls combination, 157,718, and cotton short trousers, 895,577.

The *Delhi Cloth Mills*, Delhi, *Bangalore Dress Manufacturing Co*, Bangalore, and *Bengal Dress Mfg Co Ltd*, Madras, are engaged in the production of clothing for civilians The daily capacity of the Bangalore factory is 10,000 garments, while that of the Delhi factory is about 1,000

The Panel on clothing recommended the establishment of 5 ready-made clothing factories to be located at Madras, Bombay, Calcutta, Delhi, and Jullundur The panel also recommended that the industry should, in the first stage, manufacture shirts, trousers and shorts for the urban market, and *kurtas* and pyjamas for the rural market Each factory is to have a minimum production capacity of 10,800 garments per day comprising shirts and *kurtas*, 3,600, trousers, 3,600, and shorts and pyjamas, 3,600 (*Rep Panel*, 5).

TRADE

Table 2 gives the imports of clothing into India from U K

The total value of clothing imported from U K. during 1947, 1948, and 1949 was £213,377, £248,564, and £262,718 respectively

Table 3 gives the imports of second-hand clothing into India principally from U. K and U S.A

TABLE 3.—IMPORTS OF SECOND-HAND CLOTHING

	Value (lakh Rs)
1934/35—1938/39 (av)	9 47
1939/40—1943/44 (av)	6 28
1944-45	6·40
1945-46	15 53
1946-47	63 09
1947-48	51 42
1948-49	24·38
1949-50	82 33

COAL CARBONIZATION

Industrial coal carbonization is effected by heating selected varieties of coal in ovens or retorts out of contact with air. During the process, the liberated volatile products react with one another forming a complex mixture of gases and vapours, and a more or less coherent and porous residue, known as coke, consisting of fixed carbon and the ash of the original coal The gases and vapours are drawn through condensing plant for recovering the by-products and the purified coal gas, consisting of a mixture of hydrogen, methane, olefines, carbon monoxide, carbon dioxide, and nitrogen is led to a gas holder

The nature and quantity of products obtained by coal carbonization depend essentially upon the kind of coal used and the conditions of treatment Three types of carbonization are distinguished according to the temperature of carbonization, viz, (1) High Temperature Carbonization at 900—1,200°, (2) Low Temperature Carbonization at 450—650°, and (3) Medium Temperature Carbonization at 650—800°. High temperature carbonization is adopted for the manufacture of coke required in the metallurgical industries and for the production of coal gas Coke ovens are usually installed in iron and steel works and at collieries for the production of strong, coherent, non-volatile metallurgical coke for use in blast furnaces and in foundries A high yield of gas and a comparatively low yield of thick heavy tar are obtained Coal is carbonized in gas works mainly for producing gas required for domestic and industrial heating and lighting Low temperature carbonization gives a soft, free-burning, smokeless semi-coke, containing sufficient volatiles for easy ignition in domestic fire-grates, a low yield of rich gas (650—750 B.t.u /c. ft) and a comparatively high yield of thin light tar ,or coal oil (15—20 gal./ton as compared to 4—12 gal. in high temperature carbonization). Paraffinic compounds predominate in the tar, and tar acids, notably cresylic acids occur in quantity. Medium temperature carbonization gives products and yields which are intermediate between the two.

Table 1 gives the yields of products obtained by different methods of carbonization

The rank and composition of the coal determine, to a large degree, the quality and quantity of the products. Generally, bituminous coals viz., coking coal (v m, 18—32%; oxygen, 4—8%) and gas coal (v m, 30—40%; f c, 60—68%; oxygen, 8—12%) are utilized for coal carbonization. Coking coals are of two types· (1) the hard coking coal (v.m., 26—32%, f.c., 68—74%, oxygen,

TABLE 1.—PRODUCTS OF COAL CARBONIZATION
(Yield per ton of coal)

	Low Temperature (450—650°)	Medium Temperature (650—800°)	High Temperature (900—1,200°)
Coke	0·75 ton high grade smokeless fuel (with 10% volatiles)	0·75 ton soft coke (with 5% volatiles)	0·725 ton hard coke (with no volatiles)
Gas	4,000 c. ft. (750 B. t. u / c. ft)	6,000 c ft (630 B. t. u / c ft)	13,000 c ft (500 B. t u / c ft)
Coal tar or coal oil	18—24 gal.	16—20 gal.	5—10 gal.
Light oil recoverable from gas	2½ gal.	2½ gal.	2 gal.

4—10%) giving a strong coke, and (2) the low volatile or short flame coking coal (v.m., 18—26%; f c, 74—82%; oxygen, 4—6%) giving a dense coke Both cokes are suitable for metallurgical purposes. Gas coal gives a softer and more open-textured porous coke as a by-product. Lignite, ligno-bituminous (steam) coals, and anthracite are non-coking. Coals containing low volatile matter (<17%), high moisture (> 5%), and high volatile matter (>40%) are seldom of good coking quality.

The petrological components of coal also influence carbonization. The physical structures of bright coals (mainly clarain) are markedly different from those of dull coal (durain). Clarains and vitrains are highly caking (agglomerating) and swell on carbonization Most durains and fusains do not easily coke, have little agglomerating power, and do not swell. Indian coking coals contain a large amount of durain. Blends of clarain and durain, however, which predominate in the Jharia coalfields, give excellent coke, such coal is often termed Banded Coal.

Some coals yield a compact hard coke without any increase in the original volume. If the coke is of good quality, it can be used for blast furnace purposes where strength is particularly required. Such are the coking coals of the Barakar series of the Giridih, Jharia, and Raniganj coalfields. Assam coals yield a moderately good coke but contain a large percentage of sulphur. Desulphurization of Assam coals is said to be effected by carbonization at 800° in the presence of alumina and ammonia gas (Ghosh & Brewer, *Industr. Engng Chem.*, 1950, **42**, 1550).

Bituminous coals, on distillation, lose water, hydrogen sulphide, carbon dioxide, and carbon monoxide between 250° and 375°. As the temperature is raised to 500°, methane, paraffins, and olefines are evolved in large quantities, and at still higher temperatures and especially above 700°, there is a rapid evolution of hydrogen, probably due to the cracking of hydrocarbons These stages are clearly marked in brown coal, while in bituminous coals there is overlapping

When heated out of contact with air, coking coal begins to soften at 300—350° and becomes fluid or plastic, the plasticity increasing up to a temperature of about 400° The plasticity varies with different coals and at different temperatures, and coals containing 25—35% volatile matter generally have high plasticity This plastic condition is essential for the production of coke and is brought about by the melting of certain constituents of the original coal or of the primary decomposition products and subsequent solution or dispersion of the solid residue (Dixon, 48) During this stage there is an active evolution of gas which, due to the resistance offered by the plastic mass and the sealing action of the oil film, produces a pressure and causes the mass to swell. The gas in trying to escape through the swollen mass facilitates agglomeration and helps to produce a coke of uniform cellular structure. Beyond 500°, gases continue to be evolved but the fluidity decreases, and the mass shrinks Such shrinkage is essential for the production of hard coke.

During coking the coal in contact with the walls of the oven (c. 1,000°) softens and forms a plastic layer along the wall. As the heating is continued the plastic layer proceeds inwards—towards the middle of the charge. Meanwhile, the hot gases and vapours pass outwards to the walls through the hot carbonizing mass and are partially decomposed or cracked depositing carbon, normally in graphitic layers. Most coals produce a pressure of about 0·2—1·0 lb./sq in. during coking. High pressure is reached at the place where the plastic zones meet, and is followed by a fall in pressure when the gases previously held in the middle of the charge between the plastic zones are released Unduly high pressures may cause damage to the ovens. Low volatile coals are liable to create dangerous pressures during coking. In the United States of America such coals are coked only in admixture with high volatile coals; this gives, incidentally, an improved coke.

Coke Ovens

Of the total coal carbonized in India, over 96% is subjected to high temperature carbonization in coke ovens (generally with by-product recovery) for the production of metallurgical coke. A small

quantity, about 1·5 lakh tons of coal per month, is carbonized in gas works

The by-product coking industry is of comparatively recent growth The first plant was built in 1909 at Giridih for the East Indian Railway by *Simon Carves Ltd* Over 50 ovens capable of producing about 300 tons of coke per day are still in operation Other coke oven plants operating at present are (1) *Tata Iron and Steel Co. Ltd*, Jamshedpur, (2) *Indian Iron and Steel Co Ltd*, Hirapur and Kulti; (3) *Lodna Colliery Co* (1920) *Ltd*, Lodna (Jharia), (4) *The Burrakar Coal Co. Ltd*, Loyabad (Jharia), (5) *Bararee Coke Co. Ltd.*, Kusunda (Jharia); and (6) *Bhowrah Coke Co*, Bhowrah (Jharia).

Coal Composition and Blending —Good metallurgical coal is known to occur in (1) seams XII to XVIII in Jharia coalfields, (2) Ramnagar, Laidih, and Begunia seams in the Raniganj coalfield, (3) the Lower and Upper Karharbari seams in the Giridih coalfields, and (4) the Kargali seam in the East Bokaro coalfields and certain seams in the West Bokaro coalfield Workable coking coals are found also in the Karanpura and Kanhan valley fields Till recently, only Jharia coals were being utilized for coke making.

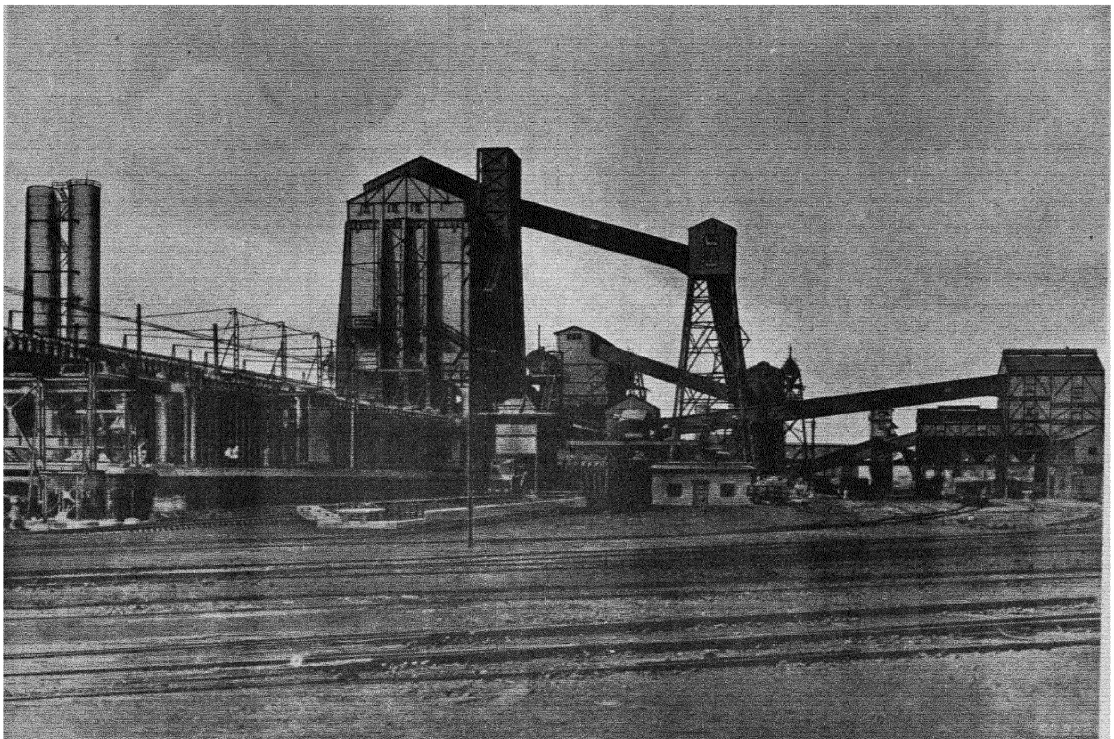
The steel companies in India utilize coking coal conforming to the following specifications ash $\not>$ 15% for coals having 30% v m on an ash-free basis, v m., c 30% on ash-free basis and 26% in coal having 15% ash; f c, depending on ash and v m; P, $\not>$ 0 15%, S, $\not>$ 0 60% (a slightly higher sulphur is tolerated if the ash content is much lower than the specified amount), caking index (Tata Index), $\not<$ 15 (i e., roughly 22·5 B S S. Index) The physical standards laid down by the Indian steel companies are considered to be too rigid and a little liberalization will make available for metallurgical purposes many grades of coal and will greatly increase the available metallurgical fuel reserves in the country The *Committee on Conservation of Metallurgical Coal* have therefore recommended that coking coal containing up to 17% ash should be consumed. Some of the works at present use Selected B (ash, 15—17%) coals with coals of Selected A (ash, 15%) grade. The usual mixture used in *Tata's* coke ovens is a blend of low and medium volatile coking coals, drawn almost entirely from the Jharia field Generally two or more varieties are blended with a view to improving the quality of coke.

At present, about 8 million tons of metallurgical coal are mined every year of which less than 3 million tons are actually carbonized for metallurgical purposes. The reserves of metallurgical coal in India are limited and have been estimated by the *Committee on Conservation of Mettallurgical Coal* at 2750 million tons (Selected A coal with 15% ash or less, 500 million tons, Selected B coal with 15—17% ash or less, 750 million tons; and Grades I & II coals with over 17% ash, 1,500 million tons) This is expected to yield 2,100 million tons of beneficiated coking coals of which 1,600 million tons can be recovered with modern mining methods Assuming that one-fourth of the weakly coking coals can be blended, the Committee has estimated the total coal available for coking at about 2,000 million tons.

Considerable amount of work has been carried out on the possibility of blending limited amounts of non-coking or weakly coking coals with good coking coals to give coke of metallurgical quality. Recent trials have shown that when mixed with good coking coal of caking index 15 (*Tisco* method) or over, coals of caking index 13—14 may be blended to the extent of 30—40%, coals of caking index 8—12, to the extent of 20—30%; and coals of caking index below 8, to the extent of 10—20% The high ash content of good to fair coking Jharia coals (below seam X) precludes their immediate utilization for coke manufacture, unless they are blended with other good coking coals of low ash content. These high ash good coking coals, therefore, along with others of the semi-coking type, should be washed to reduce their ash content and thereby rendered suitable for the coking industry Also certain Raniganj coals, such as the Dishergarh and Poniati seam coals, on account of their better caking characteristics, are usable in high proportions for the production of metallurgical coke. It has been proved that the Begonia and Dishergarh coals which are essentially bright coals containing less durain than Jharia coking coals, are by themselves fairly good coking coals, and hence behave satisfactorily in blends. The suitability of the Begonia seam coal by itself, and of the Sanctoria seam up to 30% blend with normal coke oven coal has been confirmed by oven tests (C S I R., *Rep. The Blending of Coals for Coking*, 1948, ix, 27)

As a result of trials carried out on coke blending The *Tata Iron & Steel Co. Ltd.* are now using blends containing 40% Begonia coal (ash $<$ 15%; v.m, *c.* 30%) and two other coals to the extent of 35% and 25% from Jharia coalfield.

Prior to blending, coal may be subjected to washing to reduce the ash content. It is necessary to have a low ash content in the coke required for blast furnaces if the efficiency of the furnace is to be maintained. Too much ash in



Simon-Carves Coke ovens at Jamshedpur

the coke reduces its calorific value, and additional flux (calcium carbonate) is required for slagging and, consequently, extra heat expenditure becomes necessary This means more coke and more ash. Washing also improves resistance to shattering and abradability of coke by regulating the distribution of ash in the coal Tests carried out in the Fuel Research Institute show promising results from the washing of coal of No. X seam in certain areas The seam yields 60% clean product with 16–17% ash, and the rest contains 30% ash. Better results have been obtained with coal from Kargali seam. Coal washing has not been practised in India except on a very restricted scale Two coal washeries are being erected

In 1948, 2·59 million tons of coking coal were carbonized. The annual rated coal throughput of the coal carbonization industry is 3 84 million tons consisting of: iron and steel industry, 3 14 million tons, colliery coke ovens, 0 55 million tons; and Beehive ovens, 0 15 million tons In addition, 1 million tons of coking coal will be required by 1954 for the projected new steel works and another 269,000 tons for the fertilizer works at Sindri (*Rep, Indian Coalfields Comm*, 1946, I, 77) Table 2 gives the actual consumption of coking coal in India by coke ovens

TABLE 2.—CONSUMPTION OF COKING COAL
(million tons)

	1946	1947	1948
By-product ovens			
Iron & steel works	3 09	2 32	2·02
Collieries	0·31	0 32	0·36
Beehive ovens	(a)	(a)	0·21
Total	2 40	2·64	2·59

(a) not avilable

Types of Ovens.—Coke is produced both in by-product recovery coke ovens and in Beehive ovens located in 25 collieries (South Kujama, New Mariinel, East Bhuggatdih, and Dhansar collieries) in the Jharia coalfields Out of a total of 2·59 million tons of coal carbonized in 1948, 2·38 million tons were carbonized in by-product ovens and the rest in Beehive ovens.

Beehive ovens consist of hive-shaped brick ovens, 12 ft. diam.×8 ft. high, built in trenches back-to-back with a common flue The ovens are charged through a hole at the top to a depth of 3 ft, and the heat from the previous operation initiates the distillation. The distilled volatile matter is mixed with air and burnt inside the ovens as fuel The products of combustion pass out from the top and may be used in waste heat boilers Coking is effected by the downward heat from burning gases in the ovens. The air supply is stopped after some time, and the charge allowed to bake. The ovens are dischargd after 2–3 days through a side door, and the coke is immediately quenched with water to prevent its burning away

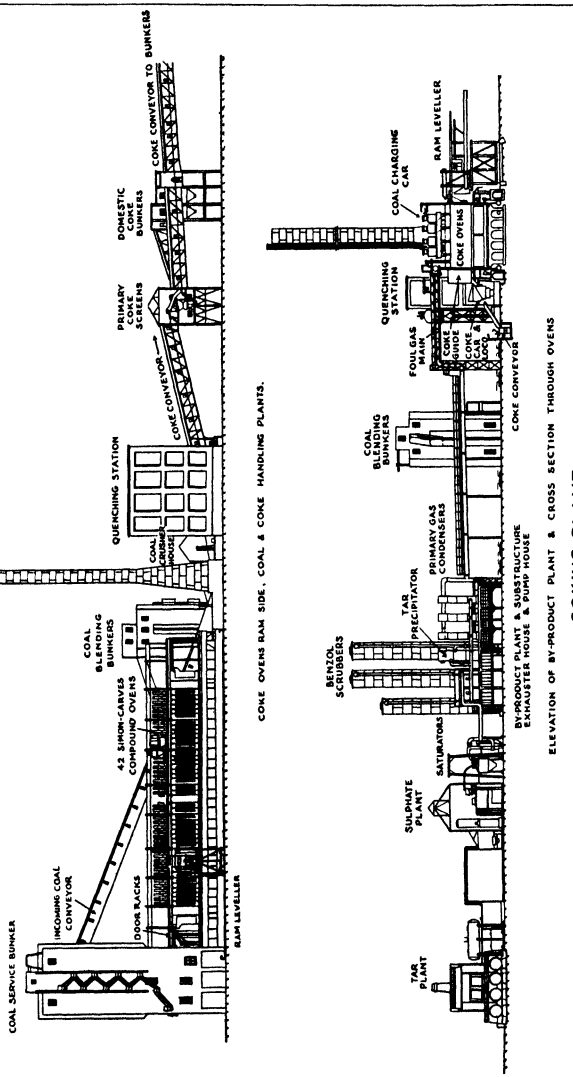
The coke produced is good, hard, strong, cellular, and silvery in appearance. In spite of the excellent coke obtained, the process is wasteful owing to the loss of by-products, of sensible heat, and of heat in the unburned portions of the liquid and gaseous products Beehive ovens have therefore been replaced by by-product coking plants, and are now used only as auxiliaries in periods when there is an unusually large demand for coke

By-product ovens—In by-product coke ovens the coal is carbonized in narrow, high, and relatively long chambers or ovens of rectangular shape, built in groups or batteries with the length of the oven at right angles to the length of the battery The older types are the slow-burning waste-heat ovens, smaller in size than the modern regenerative ovens. The waste-heat ovens use at least 80% of the gas produced, and the burnt gases from the flues are used for steam raising

The modern ovens are equipped with regenerators to recover the sensible heat from flue gases They are built of silicon refractories and are usually 40–50 ft long, 14–15 ft. high, and 15–24 in wide They are built in batteries of 30–60, and installations of over 100 are not uncommon The ovens are fitted with removable doors and have a slight taper from one end to the other to facilitate discharge of coke, the wider end being the discharge end Such ovens operate with a flue temperature of 1,150–1,350° depending on the type of coke required, and have a throughput of 18–24 tons of coal per day The normal coking time is 18–24 hours.

The ovens are heated by burning a part of the gas generated in the process Modern ovens are provided with vertical flues on each side with a view to economize gas consumption and to ensure that the greatest possible area of the oven wall (and thus of coal) is uniformly heated. To recover the sensible heat, the ovens are provided with regenerators located at the base of the battery.

In the older types of ovens, gas is supplied by fireclay nozzles or jets, one for each vertical flue, fitted to the horizontal gas supply tube of



COKING PLANT

Fig. 45.

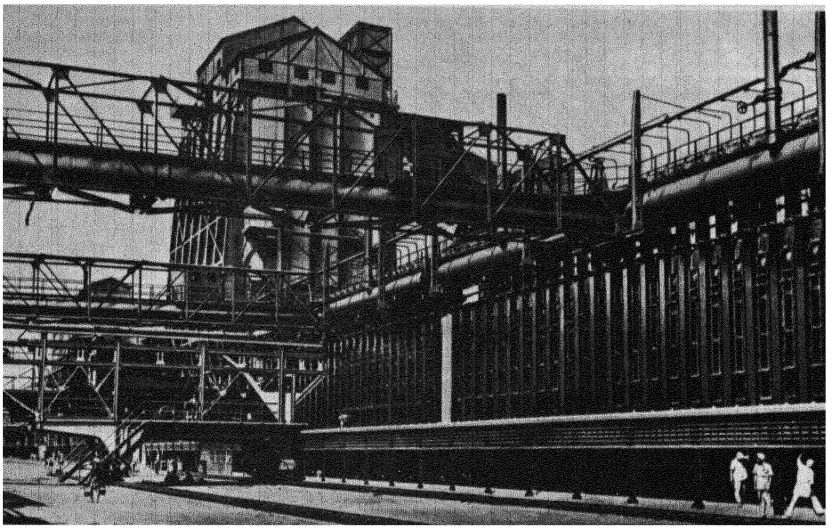


Fig. 46.—Simon-carves ovens—Tisco, Jamshedpur.

hollow fireclay bricks running along the battery. Preheated air enters the flues from the underlying regenerators. This system has certain drawbacks owing to leakage of gas from tubes, and as the nozzles are located in a region of intense heat, the density of the gas is reduced, and decomposition of by-products takes place inside the tubes and nozzles with deposition of carbon which is difficult to remove. Most modern ovens are equipped with the underjet system of heating in which the gas mains and burner jets are located in a spacious basement formed by a reinforced concrete sub-structure supporting the oven; they are accessible from all sides for inspection and adjustment.

Coke ovens are heated by the gases produced by coking, about 40—50% of the gas evolved being thus utilized. The demand for coal gas (525—550 B.t.u./c. ft.) is considerable in industrial and populous areas. Consequently, in some places, the ovens are heated by lean gas, e.g., producer gas (125—135 B.t.u./c. ft.) generated from small coke and breeze, or blast furnace gas (90—95 B.t.u./c. ft.). In such cases additional regeneration is used for heating the lean gas.

The coking plant generally used in India is the Simon-Carves plant with vertical heating flues. Each oven is provided with a regenerator at the bottom for preheating the air; when lean gas (e.g., blast furnace gas) is used both air and gas are preheated. Simon-Carves batteries in the *Tata Iron and Steel Co. Ltd.* are fired with lean gas.

Table 3 gives the number and types of by-product ovens installed in the different works.

The total number of ovens in operation is 788, of which 673 are Simon-Carves, 50 Wilputte, 40 Koppers, and 25 Semet Solvey.

The coking capacity of by-product coke ovens in India is 3,691,100 tons per annum distributed as follows: Simon-Carves, 3,227,100 tons; Wilputte, 288,000 tons; Koppers, 98,000 tons; and Semet Solvey, 78,000 tons. However, due to shortage of coal, the output of coke has been seriously reduced during the last few years.

Coke Oven Operation.—At the *Tata Iron and Steel Co. Ltd.*, the blended coal is crushed in a hammer mill so that 80—90% of the coal passes through a 1/8 in. mesh sieve. Finer grinding, although giving better coke and better control, results in a large percentage of dust. The crushed coal is elevated to storage bunkers from which

TABLE 3.—TYPES OF BY-PRODUCT COKE OVENS

		Oven	No.	Rated annual coal throughput (tons)
1	*Tata Iron and Steel Co. Ltd*, Jamshedpur	Simon-Carves, compound Wilputte, regenerative	164 50	1,692,000
2	*Indian Iron & Steel Co Ltd.*, Kulti	Simon-Carves, regenerative " , waste heat	102 30	295,600
3	*Indian Iron & Steel Co Ltd*, Hirapur	Simon-Carves, Waste heat " , regenerative " , compound	80 40 112	1,155,500
4.	*State Railway Coal Department*, Giridih*	Simon-Carves, vertical flue, regenerative	50	150,000
5.	*Lodna Colliery Co (1920) Ltd*, Lodna	Simon-Carves, horizontal flue, waste heat	60	132,000
6	*Bararee Coke Co Ltd*, Kusunda	Simon-Carves, horizontal flue, waste heat	35	90,000
7.	The *Burrakar Coal Ltd*, Loyabad.	Koppers, regenerative	40	98,000
8	*Bhowra Coke Co.* Bhowra	Semet Solvey, waste heat	25	78,000

*Present coal throughput about 70,000 tons.

the ovens are charged through 4 or 5 charging holes at the top which are normally kept sealed. The fuel bed is raked level and a clear passage left above the coal surface for gases and vapours to escape The charging holes and the door are then closed, and the oven connected to the hydraulic mains by the ascension pipe through a valve.

The distillation starts soon after charging, and it is continued until practically all the volatile matter is expelled. For optimum efficiency, a slight positive pressure at the bottom of the oven is necessary to prevent infiltration of air and consequent local heating in the oven chamber The gases and vapours evolved pass through the ascension pipe to the collecting main from which they are drawn off by an exhauster in the by-product plant Smoking during charging is prevented by operating a steam jet in the ascension pipe which creates a suction on the top of the coal bed; the steam jet is shut off after the levelling has been completed.

At the end of the coking period, which usually takes 14—20 hrs, the doors are opened and the coke is pushed out of the oven by a ramming machine, the operation taking less than 60 seconds. The hot coke falls on to a slowly moving iron truck. At the end of the discharge, the ram is withdrawn, the doors replaced and the oven is ready for a new charge of coal. The coke car goes immediately to a tower where the hot coke is quenched in ½—2 min. by a water spray. Dry quenching by inert gas circulation is used in some countries, the hot gases being fed to waste heat boilers.

The quenched coke is dumped on to a sloping wharf for draining excess water and the coke conveyed to the screening plant. The following sizes of coke are obtained in the *Tata's* plant. blast furnace coke, $> 1\frac{1}{2}$ in; nut coke, $\frac{3}{4}$—$1\frac{1}{2}$ in. partly used for metallurgical purposes; pearl coke, $\frac{3}{8}$—$\frac{3}{4}$ in used for domestic purposes; and coke breeze, $< \frac{3}{8}$ in. used in boilers.

Charging and pushing are done in series according to a schedule, to prevent any drop in wall temperature which would take place if adjacent ovens are charged and pushed in succession. In the works of the *Tata Iron and Steel Co*, a Simon-Carves battery of 55 ovens is operated according to the following schedule: the 1's ovens, i.e., 1, 11, 21, 31, 41, and 51 are pushed one after the other; when the series is completed, 5 is added and the 6's ovens are pushed. This is followed in turn by the 3's, 5's, 2's, and 4's alternated by those obtained by adding 5 to each of them (i.e., 8's, 10's, 7's, and 9's). The cycle is completed, and the 1's series is ready for pushing.

The coking speed for ordinary metallurgical

coke in by-product ovens is 1·0—1·1 in. per hr. (Lowry, I, 781). One of the factors controlling coking is the rate of heating of charge in the oven. The optimum can be gauged only from experience, but for most good coking coals and blends, the coking rate is 0·85—0·95 in. per hr This is really the rate of travel of the plastic zone or layer. For an 18 in. wide oven, a period of 10 hrs. would be required for the plastic layers to meet Further heating is necessary to raise the temperature to the higher levels required for producing metallurgical coke.

In the by-product plant, the volatile gases and vapours are treated in an elaborate system of washing, scrubbing, and purifying units, where they are freed from ammonia, tar, and benzol, and finally led to the gas holder, from which the gas is used either for oven heating or for other purposes.

Metallurgical coke—The primary product of coal carbonization is metallurgical coke, mostly used for blast furnaces. It is also required for foundry work, non-ferrous smelting, and producer gas plants.

The chief requirements of metallurgical coke are purity, strength, size, and structure The limits of purity for metallurgical coke are ash, 10%; S, 1·25%; and P, 0·02%. For use with high grade iron ore, the coke may have an ash content up to 23% It is necessary, however, to have a uniform coke, as variations involve adjustments and alterations in the operating conditions of the blast furnace Washing of coal prior to coking is therefore recommended.

Blast furnace coke should have sufficient mechanical strength (hardness and surface strength) to withstand the crushing load of the overburden in the furnace These properties are measured by shatter and abradability tests.

Besides acting as fuel, coke also acts as a spacing medium permitting a well-distributed blast of air to flow through the furnace charge, hence the size and strength of the coke are important. To a certain extent, size is related to strength. For use in blast furnace, sizes of 2—4 in. are preferred.

The coke should have at least 40% porosity so that a large surface is exposed for reaction with furnace gases. A mixture of low volatile coals with high volatile (high oxygen) or medium volatile coals gives, as a rule, a coke with uniform structure, i.e., more regular cells, less cracks, and larger coke pieces. The structure is also governed by the proportion of durain and clarain in the coal. The presence of durain up to 30% may not be harmful, but any undue excess weakens the resulting coke In the United Kingdom, the addition of fusain dust up to 3% of the coal charge in the ovens has been found to improve certain cokes, yielding large lumps of good hardness.

Metallurgical coke should have the following characteristics ash, 22·5% (maximum), v m., > 1·0%, f.c, 75·0% (minimum); shatter index on 2 in /1½ in, 82—92% or over, Breslau's test (total on 40 mm), 80% or over, Haven's stability (total on 1 in.), 50% or over, and porosity, 42% or over (*Rep.* C.S.I R, op cit, 14).

For foundry work, the coke should have a high calorific value and hardness to withstand severe abrasion and burden It should be dense, of fairly large size, and should have the following characteristics· ash, <8%; S, <0·8%, P, < 0 02%, water, < 1·5%, and shatter index, > 90% on 1½ in (Dixon, 91)

An important requirement of coke for use in producer plant is 'reactivity', which means (1) reaction rate with oxygen or air, i e, combustibility, (2) activity in reducing carbon dioxide to carbon monoxide, and (3) activity in reacting with steam Good metallurgical cokes are relatively non-reactive and are therefore difficult to ignite and are not preferred for producers. High volatile and high oxygen coals, which are almost non-coking, yield reactive cokes

75—80% of the coal carbonized is obtained as coke Production of hard coke has considerably decreased in recent years due mainly to the difficulty of obtaining suitable coals. Table 4 gives the production of hard coke in India.·

Small quantities of hard coke are exported to Burma, and to Middle and Far East countries. Table 5 gives the export of hard coke from India.

The present production of hard coke is insufficient to meet the needs of Indian industry The Government have appointed a committee to suggest ways and means of increasing its output

TABLE 4—PRODUCTION OF HARD COKE

(million tons)

	1935-1939 (av)	1940	1946	1947	1948
By-product ovens Iron & Steel works	1·48	1 84	1·43	1 61	1 39
Collieries	0 33	0 26	0 25	0·23	0 26
Beehive ovens	(a)	(a)	(a)	(a)	0 15
Total	1 81	2 10	1 68	1 84	1 80

(a) not available

TABLE 5 —EXPORTS OF HARD COKE

	Qty. (Tons)	Value (Rs)
1934/35—1938/39 (av.)	9,735	1,90,105
1939/40—1943/44 (av)	16,416	3,80,230
1944-45	150	6,470
1945-46	430	15,910
1946-47	1,032	42,657
1947-48	5,480	2,62,939
1948-49	12,996	7,69,540
1949-50	190	11,009

The committee has examined and assessed the present and future demands for hard coke and suggested methods of meeting the demands and in particular has made recommendations regarding the most suitable process of manufacture and the optimum size and number of evens. The committee has also assessed the relative advantages and disadvantages of (1) producing more coke in Sindri than is required for consumption in the fertilizer factory, (2) establishing new coke ovens at Giridih, and (3) establishing new coke ovens in the suburbs of Calcutta, taking into account the comparative capital and working costs, the utilization of gas and other by-products, and the cost of transport of coal, coke, and other by-products This report is under the consideration of the committee.

Gas Works

Coal is distilled for gas production by the *Oriental Gas Co Ltd*, Calcutta, and the *Bombay Gas Co. Ltd*, Bombay. The gas is supplied for domestic and industrial purposes in the cities of Calcutta and Bombay The residual coke, coal tar, distillate oils, and refined naphthalene are marketed

Raw material—Coal for gas production should yield a large volume of gas, marketable coke, and a fair yield of tar. For this purpose caking coals of v m, 32—40%, f c., 60—68%, and oxygen, 10—14% are required. The coal should have a low ash content A proximate analysis of good gas coal is. moisture, 1·5; ash, 11·0, v.m, 34 5; and f c, 54·5%, cal val, 13,000 B t.u./lb. (Savage, *Proc. nat Inst Sci*, 1940, **6**, 357) As Indian coals contain small percentages of pyrite (S $< 0.5\%$), the resulting gas contains hydrogen sulphide ($<1\%$).

Retorts.—Coal is subjected to high temperature carbonization in chambers or gas retorts which are relatively smaller in size than coke ovens and of a different shape. Two types of retorts —horizontal and vertical—are in use. The retorts are of fire-brick, and built in small units or bunches of 5 or 10 with heating flues in between The horizontal retorts employed in India are roughly half-cylindrical, the flat side forming the base The retorts used by the *Oriental Gas Co Ltd* are 20 ft long, 22 in wide, and 16 in high, set in a bed of 4 tiers of two retorts, each having a capacity of 9½ cwt, the retorts employed by the *Bombay Gas Co. Ltd* are 20 ft. long, 24 in wide, and 16½ in high

Operation—The retorts are heated by producer gas generated in producers built below the retort setting The producers are fitted with one or more combustion chambers and the hot gases are circulated through the flues round the retorts, the waste heat being used for heating boilers. A part of the hot coke from the retort is used in the producers for gas generation.

The retorts in each tier are charged in turn so that the whole operation covers 10—11 hrs The gas generated in each bed is derived from coal in 4 different stages of carbonization and the resulting gas is, therefore, well-mixed before passing through the condensers, washing plant, etc, to the gas holders

The temperature of carbonization is 1,250—1,300° At the end of the coking period, the coke is discharged and quenched The gases from the retorts are led to the ascension pipe and hydraulic mains, and as in the by-product coke oven plant, freed from tar, gas liquor, and light oil fraction In the *Oriental Gas Co*, the gas is scrubbed in a rotary scrubber with water The scrubbed gas is passed through cyanide washers and finally through P and A (Pelouze and Audouin) tar extractors The gas is freed from hydrogen sulphide by passing it through a set of cast-iron boxes (purifiers) containing colloidal hydrated ferric oxide rendered alkaline, when the following reaction takes place:

$$Fe_2O_3 + 3H_2S \rightarrow Fe_2S_3 + 3H_2O$$

The adsorbent is revivified by aeration.

The purified gas is forced through metering devices by gas boosters into gas holders of 3—4 million c ft capacity, whence it is distributed through a governor to the mains. The gas holders are of telescopic design, i e, expansible in stages, each stage being sealed by water levels, the pressure being ½ lb /sq in

Coal gas is often enriched with blue or carburetted water gas, or occasionally with producer

TABLE 6.—GAS PRODUCTION & COAL CONSUMPTION

	Coal consumed (tons)	Gas generated (million c. ft.)
1947	143,505	2,113 7
1948	148,269	2,120·2
1949	140,424	2,040 5

gas. In Calcutta the gas is supplied without enrichment It has a calorific value of 450 B t u / c. ft The *Bombay Gas Works* enrich the gas supply with blue water gas

Table 6 gives the amount of coal consumed and gas produced in India

The percentage consumption of gas for different purposes in Calcutta during 1948 was. industrial, 35 57; domestic, 32·58; public lighting, 22 34, hospitals, 6·27, private lighting, 2 37, and schools & colleges, 0·87% There is a larger demand for gas in the winter months than during summer In 1948, 3 8 million c ft of gas per day were consumed during the 6 winter months, as compared with 3·1 million c ft of gas per day during the 6 summer months The consumption of gas in Bombay was 18 9 and 19 6%, for public lighting during 1948 and 1949 respectively, and 70 4 and 69·2% for private lighting and heating including 8% for industrial use.

The resulting coke is often weak as compared to metallurgical coke The coke produced by the *Oriental Gas Works* has the following average composition moisture, 3·65, ash, 21·55, v.m, 2·73; and f.c., 75—72%, cal val, 11,410 B.t.u./lb. The gas coke is used for domestic consumption.

By-products Recovery

The crude gas as it leaves the ovens (c. 800°) contains steam, tarry vapours, naphthalene, benzol, and ammonia, all of which are condensible; in addition, it contains the normal constituents of unpurified coal gas viz., hydrogen, methane, olefines, carbon monoxide, carbon dioxide, hydrogen sulphide, hydrogen cyanide, and nitrogen.

The crude gas leaves the oven by the ascension pipe and passes to the hydraulic mains which are about half full of liquor and tar. The ascension pipe is bent over and dips into the liquid which thus acts as a seal for each oven when the retort is opened for charging. Steady cooling is aimed at in order to remove naphthalene, and to condense the tars in the following order. (1) heavy tars in the hydraulic mains, (2) medium tars in the foul or suction mains which connect the hydraulic mains to the condensers, and (3) light tar and tar fog in a separate part of the plant. The condensers may be air-cooled or water-cooled. Most of the tar and about half of the ammonia are condensed, the latter being found in the aqueous layer or ammonia liquor (or simply liquor) in the tar wells.

The exhauster, which is placed next to the condensers, draws the gas from the ovens through the condensers and then forces it through the purifying plant consisting of. (1) a tar fog purifier in which the gas is bubbled in a fine stream through ammonia liquor (electrical precipitation plant may be employed for this purpose), (2) ammonia scrubbers in which the ammonia is recovered from the gas by spraying with weak liquor, (3) benzol scrubbing towers in which the gas is scrubbed with a solvent oil for extracting benzol, and (4) iron oxide purifiers for the removal of hydrogen sulphide from the gas In the condensing and scrubbing plant, the gas is first treated for the recovery of tar and the light oils are the last to be removed, in between these processes, ammonia is removed as ammonium sulphate or sometimes as ammonia liquor. The purified gas may be used as such for heating and illumination or it may be further treated to obtain a variety of gas mixtures for the synthesis of organic chemicals.

The crude gas from the ovens contains about 120 grains of hydrogen cyanide per 100 c. ft. About 30% of this is removed as ammonium cyanide and thiocyanate, and the remainder is absorbed by iron oxide to give ferrocyanide and thiocyanate. These may be recovered from the spent oxide if desired Hydrogen cyanide may also be recovered by washing the gases with an alkaline solution of ferrous sulphate, before they pass on to the iron oxide purifier.

The liquor and tar are run to a tar well where they form two distinct layers and are separately drawn off Part of the liquor goes to the hydraulic mains and the remainder is used in the manufacture of ammonium sulphate.

Light tar and tar fog are separated by cyclone extractors, impact extractors, or by electrostatic precipitation, the last being the most efficient. In the rotary or cyclone tar extractor, the gases are drawn through an iron casing in which a fan revolves at 600 r.p.m. and the gas stream sprayed with water. In the impact type, such as the P and A. extractor, the tar and other constituents are drawn against a combination of perforated and plain plates The tar globules pass through the perforations and impinge on the

plates, condensation being thereby effected. In electrostatic precipitation, the gas enters a chamber from the top, descends round the outside of a number of vertical tubes, and rises upwards inside them, finally leaving the chamber through an outlet. Charged electrodes run through the centres of the tubes, and particles of tar and moisture which are not precipitated mechanically during the descent around the tube, are deposited on the inside walls of the tubes due to electrostatic repulsion as the gas streams upwards The precipitated tar and moisture collect at the base of the chamber and pass to storage through a seal pot.

Coal tar (q v.)—Tar is recovered in all carbonization plants, except from the Beehive ovens

Ammonia.—By-product ammonia industry has suffered in importance since 1918, due to rapid developments in the production of synthetic ammonia. Only a few coke oven plants in U S.A (less than half the number) recover ammonia (Collings, 53)

Three processes are available for the recovery of ammonia from coal gas, viz., indirect, direct, and semi-direct processes The indirect process is employed only in gas works Ammonium sulphate is recovered in 4 coke oven plants in India by the semi-direct process. A direct recovery plant is in operation at Kusunda.

In the indirect process, the ammonia obtained as liquor in different coolers and scrubbers is steam distilled after the addition of milk of lime, and the ammonia passes into the saturator containing dil. sulphuric acid. In the direct process, the tar-free gas is passed direct to the saturator The process is simple and economical, but is not much used as the sulphate produced is coloured. In the semi-direct process, the pre-cooled gases are further cooled to condense the tar and a substantial part of the water vapour carrying all the fixed and a part of free ammonia The main gas stream containing the bulk of free ammonia is freed from tar fog and passed into the saturator The liquor obtained by cooling is distilled, and the liberated ammonia mixed with the main gas flow prior to its entry into the saturator The process has definite advantages over the direct process, no scrubbing is necessary, and the need to distil the large quantities of scrubbed liquid is obviated The ammonium sulphate obtained is not coloured

The sulphate settles at the conical bottom of the saturator as a pasty mass of crystals, and is ejected by steam or compressed air on to a table for draining off the mother liquor. The salt is finally centrifuged after neutralization, if necessary, dried in a steam-heated drier, and packed in bags for the market. The ammonium sulphate should be free from traces of moisture and free acid, for if these are present, the product cakes up and becomes lumpy Neutralization with ammonia or ammonium carbonate and proper drying are therefore important. The final product is suitable for use as fertilizer (With India, Pt. 1, 97).

The yield of sulphate is 20—28 lb. per ton of coal carbonized The production in pre-War years was c 25,000 tons, in 1944, 20,000 tons of sulphate were produced The production during the 3 years 1946 to 1948 was 19,000, 18,400, and 16,200 tons respectively.

Benzol—The gas from the saturator contains vapours of benzene, toluene, xylene and higher homologues. They are not removed by simple condensation as their partial pressures are less than their equilibrium vapour pressures Other substances which may be present in the gas are naphthalene, hydrocyanic acid, hydrogen sulphide, and carbon disulphide

The first benzol recovery unit (100,000 gal / yr) was installed in 1920 at the works of the *Bararee Coke Co* , Kusunda. This was followed, a few years later, by another unit (37,500 gal./ yr) at Giridih During World War II, benzol recovery plants were installed by the Government of India in the iron and steel works at Jamshedpur and Hirapur The annual capacity of these units is as follows benzene, 2 1 million gal , toluene, 0 42 million gal , and solvent naphtha, 0·1 million gal (*Rep Indian Coalfields Comm.*, 1946, I, 229). A crude benzol plant is in operation at Kulti.

Benzol or light oil is stripped from the gas by scrubbing with a solvent oil (creosote is the solvent employed by *Bararee Coke Co.*, crude petroleum oil is used in Jamshedpur). Prior to this treatment, he gas is freed from naphthalene (c 10—30 grains per 1,000 c. ft) in a naphthalene scrubber by spraying cold water

The cooled gas from the naphthalene scrubber, is scrubbed with absorption oil circulated countercurrent to the gas flow in a series of towers or in static or rotary multi-film washers (*Gas World*, 1942, **117**, 59, *Gas J.*, 1943, **242**, 753) It is not usual to extract all the benzol hydrocarbons from the gas, as such elimination lowers the calorific value of the gas. The recovery efficiency of individual products can be controlled by using absorption oils saturated to varying degrees. Thus by using saturated absorption oil, toluene and xylene can be recovered at the expense of benzene, while if a partially stripped absorption

oil is used, benzene recovery is effected at the cost of toluene and xylene.

The benzolized oil after pre-heating to about 95° in a heat exchanger passes down the stripping still and is distilled with low pressure (10 lb) live steam, when the benzol hydrocarbons are liberated. The light oil obtained is washed with conc. sulphuric acid to remove unsaturated, easily resinifiable hydrocarbons (hexene, cyclopentadiene, etc) and bases, neutralized with caustic soda to remove acid constituents, especially phenols, and finally washed with cold water. The debenzolized absorption oil is continually recycled for further use A notable advance in benzol recovery is the adoption of vacuum conditions for stripping (*Gas World*, 1942, **117**, 670)

Light oil can also be recovered by adsorption with activated carbon and silica gel. The activated carbon process is simple and automatic, and its high efficiency (90%) is unaffected by changes in temperature However, the process is not flexible, and is unsuitable for gas containing hydrogen sulphide. It is rarely used in coking practice [Reed, *Bull Brit Coal Utilizn Res. Ass*, 1945, **9**, (8), 230, *Gas J.*, 1944, **243**, 318, 345, 379, *Gas World*, 1944, **120**, 142, *Gas Times*, 1944, **41**, 28]

Crude benzol consisting chiefly of benzene, toluene, and xylenes is designated 50/90's, indicating that 50% by volume distils at 100°, and 90% at 120° It is fractionated into 3 or more 'cuts', e g, motor benzol, benzene, toluene, xylenes, and solvent naphtha Each of these is refined with conc sulphuric acid and caustic soda solution for the removal of sulphur compounds—hydrogen sulphide (H_2S), carbon disulphide (CS_2), thiophene (C_6H_4S), and various mercaptans and organic sulphides—and gum-forming compounds, viz, cyclo-pentadiene (C_5H_6), styrene (C_8H_8), indene (C_9H_8), and cumarone (C_8H_6O) (Fielder, *J sci. indust Res*, 1946, **4**, 467). Each fraction is refractionated under reduced pressure in rectifying stills. Individual xylenes are not usually separated from each other and their mixture with the higher boiling fraction of light oil is marketed under the name Solvent Naphtha.

In Indian practice the crude benzol is redistilled in rectifiers into three fractions. (1) benzol containing mostly benzene and some toluene, (2) toluol containing mostly toluene and some naphtha, and (3) still-bottom containing solvent naphtha and xylene. The first fraction on redistillation gives pure benzene and some toluene, whereas the second fraction gives pure toluene and some naphtha. The first two fractions may be mixed and sold as motor benzol. The still-bottom is usually marketed as such for making varnishes. Occasionally it is redistilled to give xylenes and light and heavy solvent naphthas.

Benzene (C_6H_6) is the simplest member of the aromatic hydrocarbons. It is a highly refracting liquid boiling at 80 2° and melting at 5·5°. It is soluble in water to a very small extent and is miscible in all proportions with ether and other organic solvents.

The bulk of the benzene (c. 80%) obtained from the coking industry is marketed as motor benzol It is mixed with petrol in quantities up to 50% for use as motor fuel The blends have better anti-knock properties, and higher heat of combustion per gallon than ordinary petrol. The distillation range for motor benzol is specified as· not less than 60% at 100°, not less than 85% at 120°, and not less than 95% at 145°. It must also conform to colour, oxidation, and maximum sulphur tests In U.S A., the demand for benzene for chemical uses is so great that there is little production of motor benzol

The following commercial grades of benzol are specified in B S S. No 135 (1939) (1) 90's Benzol, 90—95% boiling at 100°; 97% boiling at 115°, (2) Industrial Benzole, boiling range similar to motor benzol, free from unsaturateds, (3) Pure Benzol, 5—95% distilling within a range of 0·5°, and (4) Pure Benzol for nitration, 5—97% distilling within a range of 0 4° between 79·5° and 80·5°.

The industrial uses of benzene are extensive. As solvent, it is employed in the production of paints, varnishes, lacquers, polishes and leather dressings, rubber and water-proofing solutions, cleaning and degreasing agents, and adhesives and plastics

Pure benzene is widely employed in the chemical industry It is converted by nitration to nitrobenzenes from which aniline and benzidine are manufactured. Sulphonation and chlorination of benzene yield benzene sulphonic acid and chlorobenzene respectively from which phenol (*see* Coal Tar) can be synthesized. From these compounds are derived a large number of dyestuff intermediates, which also find important uses in the fine chemical industry. p-Dichloro benzene and DDT are important insecticides derived from benzene. A recent development is the catalytic alkylation of benzene with propylene, obtained from petroleum refinery gases, to form cumene (isopropyl benzene), a hydrocarbon of high octane rating, which is blended with high performance aviation petrol.

Benzene is used in U.S.A. for the manufacture of styrene, synthetic phenol, nylon, aniline,

solvents, diphenyl, synthetic detergents, monochlorobenzene, dichlorobenzene, nitrobenzene, etc. [*Chem. Engng*, 1949, **56** (2), 118].

The production of pure benzene in India is insignificant. It is anticipated, however, that with the development of chemical and dyestuff industries, the demand for pure benzene and industrial benzol would increase. About 1 million gallons of motor benzol were produced annually during 1946–1948

Toluene ($C_6H_5CH_3$)—Toluene is the second member of the aromatic hydrocarbons Commercial toluene is extracted and refined in the same manner as benzene A considerable proportion of the toluene extracted from coke oven gas is included in motor benzol.

During World War II, the toluene required for explosives (T.N T) was obtained in U.S A. mainly from heavy petroleum naphtha by the hydroforming process (*Chem. metall. Engng*, 1941, **48**, 77, *Petrol Refiner*, 1943, **22**, 95, *Chem Engng*, loc. cit) A plant was erected in Germany for the production of toluene by the catalytic interaction of benzene with methanol using an acid zinc silicophosphate catalyst (*Chem Tr J*, 1946, **118**, 369)

B.S.S No 805 (1939) for toluene is as follows. (1) Pure Toluol, 5–95% boiling within 1°; (2) Pure Toluol for nitration, 5–97% boiling within 0 4° (between 110 and 111°), (3) 90 Toluol, 5% (maximum) boiling at 101°, and 90% (minimum) at 120°; and (4) 95 Toluol, 5% (maximum) boiling at 107 5°, and 95% (minimum) at 120°. These products must conform to tests for colour, acid, and maximum sulphur content The present production of toluene in India is negligible.

Pure toluene, although not so widely employed in the chemical industry as benzene, is of considerable importance in the synthesis of saccharin, drugs, pharmaceuticals, and dyestuff intermediates It is employed as an industrial solvent for alkaloids, cellulose esters, dopes, enamels, lacquers, varnishes, resins, rosins, and waxes. It is also used to extract animal and vegetable fats and oils and for degreasing bone and hair.

Toluene is employed in U.S.A. for the production of benzyl chloride, benzal chloride, benzoyl chloride, benzotrichloride, benzoic acid, sodium benzoate, benzaldehyde, benzene hexachloride, and cinnamic acid (Shearon, *et al.*, *Industr. Engng Chem*, 1949, **41**, 1812).

Xylenes [$C_6H_4(CH_3)_2$].—There are three isomeric xylenes: *ortho*-xylene (b p, 144·5°; m.p., −25·2°), *meta*-xylene (b p, 139·1°; m p., −47·9°), and *para*-xylene (b.p., 138·44°, m p, 13·3°). The xylenes are recovered from coke oven and gas works gases, but a more important source of xylenes is petroleum. Out of 63 million gal. of xylene produced in U.S.A. in 1948, 55 million gal. were obtained from petroleum (*Chem. Engng*, loc. cit.). About 30 million lb. of *ortho*-xylene are reported to be made in U.S.A. per year by the petroleum refineries by hydroforming (Weiss & Weiss, *Chem Engng News*, 1949, **27**, 972).

The separation of the three isomeric xylenes is somewhat difficult and requires special equipment Xylenes are generally used as such without separation for technical purposes. The mixture of xylenes is a solvent widely used in the paint and rubber industries and in the preparation of printing inks.

Fractions heavier than the xylenes are marketed as Heavy Solvent Naphtha. They are used as solvent for paints, varnishes, ester gum, enamels, pitches, bitumen, and also in disinfestation naphthas. They are also used as illuminant and for the preparation of coumarone resins. Xylenes are becoming increasingly important as raw materials for plastics Other uses are for the manufacture of moth proofing agents, pharmaceuticals, sulphonic acids, xylene musks (perfumes), phthalic anhydride and other intermediates (Lowry, II, 1153).

B S.S No. 458 (1939) for xylenes includes. (1) 2° xylol, 5–97% boiling within 2° (between 138° and 142°), (2) 3° xylol, 5–95% boiling within 3° (between 138° and 144°), and (3) 5° xylol, 5–95% boiling within 5° (between 135° and 145°). These are acid-washed xylols and have a flash point (Abel) of not below 75°F.

The present production of xylene in India is negligible.

The following coal tar solvent naphthas are included in B S S No 479 (1939)· (1) coal tar solvent naphtha 95/160, 5% (maximum) boiling at 125°, and 96% (minimum) boiling at 160°, (2) coal tar solvent naphtha 90/160, 90% (minimum) boiling at 160°; (3) heavy coal tar naptha 90/190, 5% (maximum) boiling at 160°, and 90% (minimum), boiling at 190°; (4) heavy coal tar naphtha 90/190 (unrectified); and (5) heavy coal tar naphtha 90/200 (unrectified). Heavy napthas have a flash point (Abel) not below 75°F.

Coke Oven Gas.—The gas obtained from benzol recovery plant may amount to 10,000 c. ft. per ton of coal with a calorific value of 450–500 B t.u./c. ft. It is generally used without further treatment for heating coke ovens. If the coke oven plant is situated in or near a steel plant, the surplus gas and practically the entire output from compound ovens is utilized for heating steel and other industrial furnaces. When the gas is

required for public utilities, however, it has to be purified by passing through colloidal hydrated ferric oxide to remove the hydrogen sulphide (0·7 —1·5% by volume). The presence of sulphur is objectionable for certain types of industrial heating.

Processes for eliminating hydrogen sulphide by washing have been developed In the Seabord process a weak solution of sodium carbonate is employed. An aqueous solution of ethanolamine is employed in the Girbitol process. Hydrogen sulphide is subsequently recovered and used for the production of sulphuric acid, or sulphur may be recovered by partial combustion in a Claus kiln In the Ferrox process, an alkaline soda ash solution containing suspended iron oxide is used to scrub the gas in towers containing wooden grids. Sodium hydrosulphide is formed which on aeration is oxidized to sulphur (Lowry, II, 971, 984, 990).

$$Na_2CO_3+H_2S\longrightarrow NaHS+NaHCO_3$$
$$NaHS+NaHCO_3+\tfrac{1}{2}O_2\longrightarrow Na_2CO_3+H_2O+S$$

In the Thylox process (Lowry, II, 973), a neutral thioarsenate salt is used for scrubbing the gas. A higher thioarsenate is produced, by reaction with hydrogen sulphide, and on subsequent aeration, sulphur is precipitated and the arsenic compound is reconverted to the original thioarsenate

$$Na_4As_2S_5O_2+H_2S\longrightarrow Na_4As_2S_6O+H_2O$$
$$Na_4As_2S_6O+\tfrac{1}{2}O_2\longrightarrow Na_4As_2S_5O_2+S$$

Other organic sulphur compounds, such as carbon disulphide, thiophene, carbon oxysulphide, mercaptans, etc., occur in minor amounts as impurities. Carbon disulphide and thiophene may be removed by benzol washing. Attention is not usually given to the removal of these impurities.

Coke oven gas may be used as a source of hydrogen and ethylene, for ammonia synthesis in the form of hydrogen-nitrogen mixture, and for hydrocarbon synthesis in the form of hydrogen-carbon monoxide mixture. Compression-refrigeration methods, such as the Claude and Linde processes are used for producing hydrogen and ethylene, and a gas mixture for ammonia synthesis. In both processes, the gas is purified, compressed, and allowed to cool by expansion until all the gas constituents other than hydrogen are liquefied. The liquid on fractional distillation is separated into three fractions— ethylene, methane, and carbon monoxide The processes differ only in the method of cooling In the Claude process the compressed gas (30—40 atm.) is allowed to expand while doing external work, whereas in the Linde process the compressed gas (100—200 atm.) is expanded at atmospheric pressure without performing external work. The compressed gas remaining after liquefaction consists of hydrogen. It is washed with liquid nitrogen which completely removes the impurities and forms a 3.1 mixture of hydrogen and nitrogen for ammonia synthesis (Reed, loc. cit.)

For obtaining a 2:1 mixture of hydrogen and carbon monoxide, the gas may be reformed by converting the methane fraction at about 1,200° into carbon dioxide, water, and oxygen. In the Fischer process, the gas containing methane is passed along with steam through coke in a water gas generator and mixed with the resulting gases. In the Linde process, the gas is passed through a bed of coke maintained at 1,200—1,350° along with a controlled supply of oxygen. It is claimed that 90—95% of methane in the gas is converted by this method. Both Kuhlmann and Koppers processes make use of thermal reformation at hot inert surfaces where the gas and steam react The Koppers process is more efficient and is widely used in Germany. In the *I G. Farbenindustrie* catalytic process, a mixture of steam and carbon dioxide react with methane on a reduced nickel surface at about 800° (Reed, loc. cit.).

Low Temperature Carbonization

Considerable work has been carried out on low temperature carbonization of coal at the Fuel Research Station, England A large number of processes have been suggested, but few have been successfully developed to the stage of commercial exploitation The costs involved are high and the prices realizable for the principal products are low.

Low temperature carbonization of brown coal is an established industry in Germany. Two million tons of raw tar are produced annually from 35 million tons of lignite During World War II, aviation spirit and motor fuel were produced in quantity by hydrogenation of tar, and paraffin wax was extracted Low temperature carbonization of bituminous coals yields a reactive coke which can be utilized for the production of synthesis gas for Fischer-Tropsch process. Low temperature carbonization of bituminous coal is now carried out only in the United Kingdom, though during the War a few plants were in operation in Japan.

Types of Ovens—The ovens may be heated externally and/or internally. Also the ovens may be stationary or revolving, horizontal or vertical. The process may be continuous or intermittent, and the coal charges may be at rest or kept moving.

Externally heated ovens give a lower output per retort; hence a large number of retorts involving heavy capital outlay is required. The

Coalite plant (Bone & Himus, 388) widely used in the United Kingdom consists of stationary retorts which are worked intermittently. The retorts, which are made of special alloy steel, are heated by radiant heat inside chambers built of firebrick chequer-work, and a nest of 12 retorts is connected to a common head and a common base. Non-swelling bituminous slacks or blends of coal with breeze are used Each retort carbonizes about 11 cwt of coal in 4 hrs. The residual fuel is discharged into sealed cooling chambers below each retort and the gaseous products drawn off into hydraulic mains The uncondensed gases are detarred by electrostatic precipitation and then passed through oil scrubbers for the recovery of gas spirit. One ton of coal (v m , 30%) gives. coke, 14 cwt.; tar, 18 gal ; gas, 4,000—4,500 c ft.; and gas spirit, 4 gal The coke (v m , 5—6%) is of good quality, and is used as domestic fuel

Another oven of the externally heated type is the stationary narrow brick retort developed by the Fuel Research Station, England (*Tech Pap., Fuel Res Lond* No 35 & 38, 1933; *Rep Fuel Res. Bd Lond*, 1931—35) designed to operate in the same manner as the continuous vertical retorts used in coal gas manufacture The coal is fed at the top and the coke removed continuously at the bottom into a coke chamber and steam-quenched. Heating is effected by means of horizontal flue inside retort walls. The throughput is 6—10 tons of coal in 24 hrs The approximate yield per ton of coal (moisture, 3%; v m , 35·5%; ash, 7%) of standard caking power is coke, 14·4 cwt., tar, 15·2 gal., gas, 6·455 c. ft., and gas spirit, 1·4 gal

Internally heated ovens involve less capital expenditure and give a higher output, but the resulting gas is diluted and thus has a low calorific value. Also, the process restricts the type and size of coal to be used, as only weak-coking lump coals (3—4 in) can be successfully treated. The temperature of carbonization being higher, the nature of products is different and the recovery of tar and spirit from the large gas yields is difficult and expensive

A particular type of internally heated retort is the Lurgi carbonizer which has come into much prominence It has been tried commercially in Germany and Japan, (*Rep. U S. Bur Min.* No. 7430, 1948). In 1939, 18 Lurgi plants were in operation in various parts of the world with a total capacity of 42,000 tons of coal per day. The plant is suitable for carbonizing high volatile bituminous coal of weakly caking quality (C. I., 2—3). Strongly coking coal cannot be used nor can completely non-caking coal be used due to the formation of excessive quantity of fines. The carbonizer is generally built in groups of four retorts, each having a capacity of 300 tons of coal per day. It consists of an upper chamber in which the sized (4 in) coal is dried at 250° by upward flowing waste gases and a lower retort in which the dried coal is carbonized at 600° by hot combustion gases passing through a specially designed flue and gas diffuser. The carbonized coal is passed to a third chamber where it is cooled to 100° before discharge The moving parts in the plant are the rotors of gas circulating blowers, scraper for preventing accumulation of dust and tar in the gas off-take mains, the reciprocating grate for removi semi-coke from the carbonation zones, and the rotary seal valves for discharging the cooled semi-coke into a belt conveyor 300 tons of coal on carbonization give 200 tons of semi-coke, 4,148 gal or 15·4 tons of fuel oil, 1,490,400 c ft of gas (122 B.t u /c ft), 713 gal. or 2 13 tons of motor gasoline, 5 7 tons of pitch, 4 6 tons of cresylic acid, and 0·85 ton of crude paraffin

Efforts have been made in India for setting up low temperature carbonization plants for the production of soft coke and recovery of by-products. During World War II an experimental plant (60 tons coal/day) was installed by the Bihar Government at East Ena Colliery, Jharia. It is of the German Kohler Gas type, internally heated and continuously operated. Great difficulty has been experienced in working the plant, and it has remained unproductive It is suitable for carbonizing weak or medium-coking, non-swelling, high volatile coals of graded size. The original plant was designed to carbonize coal briquettes or brown coals, using producer gas for heating A proposal to install a small plant (25 tons/day) in Hyderabad is under consideration

Soft coke—Low temperature carbonization of coal without by-product recovery is carried out in India for the production of soft coke. During the slump period 1925—35, production of smokeless domestic fuel from low grade coals was started in the Jharia coalfields In 1929, the Indian Soft Coke Cess Act was enacted for the promotion of soft coke industry in Bengal, Bihar and Orissa. A Soft Coke Cess Committee, financed by the proceeds of a cess of 2 annas/ton of soft coke despatched by rail from Bengal, Bihar and Orissa, was formed for promoting the sale and for improving the methods of manufacture of soft coke.

Bengal and Bihar coal fields are the principal suppliers of soft coke. In 1941, there were over

TABLE 1.—SOFT COKE FROM JHARIA FIELDS

	Qty. (tons)
1917	225,120
1927	608,612
1937	830,784
1940	962,825

165 registered collieries manufacturing soft coke

The method of manufacture is wasteful. The coal is stacked in heaps or *bhattas* of 15—20 tons with flues or chimneys The fuels which are equally spaced are first erected with large pieces of raw coal, and the space between them is filled with coal pieces of varying dimensions The stacks vary in size from small heaps to large stacks, 25 ft ×30 ft at the base and 7—8 ft high Fires are started in each of the flues The flames are smothered at intervals with slack or dust coal or ash to control the passage of air into various parts of the stack About 7—10 days are required for carbonization, after which the stacks are quenched by spraying water The resulting soft coke is a mass of charred coal, half burnt coal, and more or less completely carbonized coke. It is graded and marketed as domestic fuel.

PRODUCTION

Table 1 gives the despatches of soft coke from the Jharia fields

The present average figure from Jharia coalfields is about 900,000 tons An additional 100,000 tons are produced in other coalfields The total of 1,000,000 tons is obtained by the carbonization of c 1·3 million tons of coal (*Rep Indian Coalfields Comm*, 1946, I, 45)

COAL TAR

Coal tar is the dark brown or black, oily, and viscous fluid of characteristic odour which separates from the gases formed during the destructive distillation of coal It is a mixture of a large number of chemical compounds, about 200 of which have been extracted and identified. Formerly coal tar was considered to be a waste product, and its disposal was a source of embarrassment to the industry. The position is now changed, and coal tar forms an important raw material for the chemical industry.

During the process of coking or carbonization, coal is subjected to destructive distillation in suitably designed retorts or ovens and the volatile products passed into collecting mains, coolers, and detarrers, for separating the liquid and solid components from gaseous products. Coal tar thus obtained is associated with ammoniacal liquor which may be partially separated by settling in open tanks.

Coal tar is a colloidal suspension of carbonaceous particles or micelles in an oily medium composed of a mixture of solid and liquid compounds The micelles (free carbons, f c) vary considerably in size from macrons to microns down to ultra-microns Each micelle consists of a core of fusible resinous matter of high carbon/hydrogen ratio, surrounded by protective layers of more fusible resins. The viscosity, specific gravity, and chemical composition of coal tars vary appreciably according to the condition under which coking or carbonization takes place The yield and composition of tar depends mainly on (1) the rank and composition of the coal carbonized; (2) design of coke oven or retort; (3) temperature of coking, and (4) rate of coking The tars obtained in industrial processing conform to the following main types·

(1) High temperature coal tar (coke oven)
(2) Low temperature coal tar
(3) High temperature coal tar (Horizontal retort) } as work
(4) High temperature coal tar (Vertical retort—continuous or intermittent) } tar
(5) (a) Producer gas coal tar,
(b) Blast furnace coal tar, and
(c) Water gas tar.

The principal object of the destructive distillation of coal being the production of coke or coal gas, the coking process is designed to give the maximum yield of either metallurgical coke or coal gas of desired specifications, and the production of coal tar is incidental. There has been very little work on the conditions necessary for the production of tars of specified properties

Low temperature (450—700°) carbonization produces a high yield (8—13% by wt of coal) of a brown, thin, oily liquid in which paraffinic compounds are present to an appreciable extent On the other hand, the tar obtained in high temperature (900—1,200°) carbonization, is a thick black, viscid fluid which is predominantly aromatic in character This difference in the character and composition of the tars is due to the fact that in the latter case the primary tar, first produced by the thermal decomposition of coal, is further decomposed, the nature and extent of decomposition being governed by a number of factors such as the design and size of the oven and the temperature in the space above the coal charge. The differences between the two tars

will be clear from the figures given in Tables 1 and 2 (Fisher, *Bull U S Bur Min*, No. 412, 1938).

Analyses of representative high temperature coke oven tars (U.S A.) gave the following average composition (Table 3).

Table 4 gives the physical properties of coal tars obtained from different processes.

TABLE 1 – CHARACTERISTICS OF COAL TARS

	Low temperature coal tars (600°)	High temperature coal tars (1,000°)
Yield of tar (% by wt.)	8 56	5 66
Sp gr.	1 06	1 18
Tar acids (% by vol.)	18 4	4 6
Tar bases ,,	1 1	1 3
Neutral oils ,,	40 0	26 0

TABLE 2 —COMPOSITION OF NEUTRAL OILS

	Low temperature coal tars (% by vol)	High temperature coal tars (% by vol)
Olefines	12 9	13·3
Aromatics	61 3	83 3
Paraffins	25 8	3 3

TABLE 3 —CONSTITUENTS OF TAR*

	%(by wt) on dry tar
Light oil :	
Crude benzene and toluene	0 3
Coumarone, indene, etc	0·6
Xylenes, cumenes, and isomers	1 1
Middle and heavy oils :	
Naphthalene	10 9
Unidentified oils in range of naphthalene and methylnaphthalenes	1 7
Monomethylnaphthalenes	2 5
Dimethylnaphthalenes	3 4
Acenaphthene	1 4
Unidentified oil in range of acenaphthene	1 0
Fluorene	1 6
Unidentified oil in range of fluorene	1 2
Anthracene oil	
Phenanthrene	4 0
Anthracene	1·1
Carbazole, etc.	2 3
Unidentified oils, anthracene range	5·4
Phenol	0 7
Phenol homologues (largely cresols and xylenols)	1 5
Tar bases	2 3
Yellow solids of pitch oils	0 6
Pitch greases	6 4
Resinous bodies	5 3
Pitch (m p , 460° F)	44 7

*Lowry, II, 1,326

TABLE 4—PHYSICAL PROPERTIES OF COAL TARS*

	Retort gas tar		Oven gas tar	
	Horizental retort	Vertical retort	Slot oven	Sole flue oven
Sp gr. at 15 5°	1 24—1 30	1·13—1 16	1 10—1·25	1·085—1·110
Viscosity (Engler) 100 c c at 100° in seconds	160—640	40—45	40—95	..
Free carbon or insoluble in benzol–toluol %	20—40	2—6	4– 15	2—6
Unsulphonated residue %	..	0—5	0—5	..
Light oil (up to 210°), % by vol.	1—3 5	2—10	0 5—4	6·7—15
Middle oil, heavy oil and anthracene oil (210-355°), % by vol	25—30	40—45	30—55	55—62
Total oil to pitch (m p , 140°F), % by vol	13—20	26—29	15—39	c. 50
Total oil to pitch (m p , 200°F), % by vol	18 – 23	c 37	29—40	50—60

* Rogers, I, 650

hydraulic mains, and in the scrubbers or condensers of gas works. It is less fluid, contains less of the lighter hydrocarbons, more naphthalene, anthracene and allied oils, and more free carbon than tar from other sources

Producer gas tar contains large percentages of water and free carbon, and small amount of oils It yields on distillation a friable pitch of no commercial value Blast furnace tar is a low heat tar (sp gr, 0·94—1 00) obtained from blast furnaces when fed with coal instead of coke It contains more phenoloid and basic components (phenoloids, 5—10%, basic substances, 2—5%) than ordinary coal tar, and about 16% paraffin oils The phenoloid substances are similar to those derived from the distillation of wood and lignite These tars are entirely different from coal tar. Water gas tar is obtained during the manufacture of carburetted water gas for illuminating purposes It differs from other tars in its being entirely free from tar acids and ammoniacal liquor, and in its containing but a small percentage (usually $<2\%$) of free carbon Dry water gas tar, on distillation, yields 5—15% light oil, 30—50% heavy oil, and 35—60% pitch (Rogers, I, 649).

Only high temperature coal tar is manufactured in India A small amount of coal tar is produced in horizontal retorts by the *Oriental Gas Co*, Calcutta, and *Bombay Gas Co*, Bombay Low temperature tar is not produced in India

The total capacity for the production of coke oven tar is 88,000 tons per annum, and the yield of tar from coal is 2·5% (by wt) or 4—5 gal per ton of coal coked Of this 73,800 tons (84%) is produced by the *Tata Iron and Steel Co* at Jamshedpur and the *Indian Iron and Steel Co* at Hirapur and Kulti near Asansol The remainder is produced by colliery coke oven plants The joint capacity of the two gas works amounts to 6,500 tons of coal tar per annum bringing the total production capacity to 94,500 tons The yield of gas works coal tar is 10 gal or 5% (by wt) per ton of coal carbonized

Composition and properties—Low temperature tar contains olefines, naphthenes, paraffins, phenols, and pyridine bases, while benzene and its homologues and naphthalene and anthracene salts are absent. High temperature tar contains pitch, benzene and its homologues, naphthalene, anthracene, and traces of aliphatic hydrocarbons (Lowry, II, 1301)

High temperature coke oven tars produced in India vary somewhat in composition The analytical values given in Table 5 are indicative of the nature of the three main types of Indian coal tars

Type A is representative of the coal tar produced in the rapid coking ovens operating at 1,200° Coal tars of this type constitute 85% of the total tar production, and are characterized by comparatively low oil and tar acids, and high naphthalene contents Type B is representative of coal tars produced in coking ovens operating at 900° Coal tars of this type constitute 8% of the total tar production, and are characterized by high oil and tar acid, and low naphthalene and free carbon contents Type C is representative of gas works coal tar which comprises 7% of the total It is characterized by high oil, tar acid, and free carbon contents

TABLE 5 — ANALYSIS OF INDIAN COAL TARS

	A	B	C
Viscosity* (at 30° in secs)	5—15	1—5	<1
Sp gr at 15°	1 18—1 22	1 10—1 16	1 195
Ammoniacal liquor, %	1—3	2—5	2—5
Oils distilling up to 200°, % by wt.	1.5	4	8
„ „ from 200 to 270°, „ „ „	10—15	15—20	18
„ „ „ 270 to 300° „ „ „	5—7	6—8	5
Crude tar acids, % by vol	0.8—2.0	2.5—4.5	3.5
Crude naphthalene, % by wt.	2 0—8 0	1.0—2.0	2 5
Medium pitch (softening pt., 70°), % by wt.	60—65	50—60	65
Free carbon insoluble in toluol, % by wt.	6—10	2—4	17

* Redwood, Modified B.R.T A (British Road Tar Association) method

Uses.—About 90% of the net production of coal tar in India is subjected to distillation. The rest is used chiefly for coating country boats and for the treatment of fishing nets, wooden poles, iron poles, etc.

There was a considerable glut of coal tar in India during the period 1934—38, and the chief producers of coke oven coal tar jointly arranged for disposing of the surplus as fuel (cal. value, 15,000—16,500 B.t.u./lb.) in the steel works after satisfying the demands of distillers and dealers. About 15,000 tons were disposed of annually in this manner. The demand for tar distillation products increased, and its use as fuel was discontinued in 1938 Coal tar was used as fuel again in 1942 to meet the shortage of coal in the steel works.

In countries other than U S A, where motor fuels are not so abundant, low temperature tars are hydrogenated to obtain petrol and diesel fuels The possibility of producing commercial products like gasoline, cresylic acid, fuel oil, domestic coke etc. by the pyrolysis of low temperature coal tars have been extensively studied (Egloff *et al., Industr. Engng Chem,* 1940, **32**, 39).

Coal tar of pharmacopoeial standard is used in therapy as a substitute for wood tar in external applications to relieve itching and to combat inflammation in such diseases as lichen ruber, prurigo, eczema, etc. It is less irritating than wood tar and less likely to produce toxic conditions after absorption. It is most frezinc oxide-petrolatum ointment has been used for ringworm and as an antipruritic application for skin diseases A combination of 4% coal tar distillate, 3% sulphur, and 3% salicylic acid in a water-soluble base is used for eczema-dermatitis and fungous infections such as athlete's foot and ringworm of the scalp Coal tar solution in alcohol and quillaja (*Quillaja saponaria*) is used in diluted form as a wash for eczema, and a chloroformic solution is used as antiseptic in the treatment of skin diseases (U S D, 1185).

Production

Table 6 shows the gross and net annual production of coke oven coal tar in India since 1935.

In 1940-41 the gross production reached the peak value of 82,000 tons; in 1941-42 the net production reached its maximum of 74,250 tons.

The quantity of tar available for disposal, prior to 1942-43, was 90—95% of the gross production, a part being retained at producers' works for internal use. More tar is now consumed by producers, and during 1947/48—1948/49,2 only 53—58% of the gross production was available for disposal.

TABLE 6.—PRODUCTION OF COKE OVEN TAR

	Gross (tons)	Net (tons)
1935/36—1938/39 (av.)	62,500	57,250
1939/40—1942/43 (av.)	76,450	65,200
1943–44	64,500	38,500
1944–45	60,000	37,500
1945–46	67,500	40,000
1946–47	64,000	38,000
1947–48	64,000	37,000
1948-49	62,000	34,000

The average price of crude tar ex works was Rs 43 per ton during 1935/36—1936/37, and Rs. 50 per ton during 1937/38—1938/39. During the next 7 years, the price was maintained at Rs. 55 per ton The price in recent years was 1946-47, Rs 62, 1947-48, Rs. 70; and 1948-49, Rs 74 per ton.

Coal Tar Distillation

A large number of chemical compounds have been identified in high temperature coal tar, but the crudes obtained by distillation form the most important products from the commercial point of view. The principal crudes are: creosote and other distillates, road tars, and industrial pitches. Various chemicals are present in these crudes, but actually only a few are present in sufficient quantities for commercial extraction. The principal products recovered are: tar acids, naphthalene, anthracene, carbazole, and pyridine

The main object of distillation is to remove the volatile oils from the pitch, and to effect a preliminary fractionation of the distillates, which, in their turn, are worked up singly. Coal tar is fractionated into light oil, middle oil, heavy oil or creosote oil, anthracene oil, and pitch

The Indian coal tar distillation industry utilizes only the coke oven tars as raw material. The main distillers are the *Shalimar Tar Products* (1935) *Ltd.*, Lodna, *Bararee Coke Co. Ltd.*, Kusunda, both located in the Jharia coalfields, and the *Bengal Chemical and Pharmaceutical Works Ltd.*, Panihati (near Calcutta). The combined distillation capacity of these works is more than sufficient to deal with the maximum production of crude coal tar from all the coke oven installations in the country. In addition, small quantities of gas works tar are distilled in a number of plants located in Calcutta and Bombay.

Two processes are employed for distilling tar—the intermittent and the continuous. In the intermittent process, pot stills are used, and on completion of the distillation, the still is cleared of the residue and charged again for subsequent

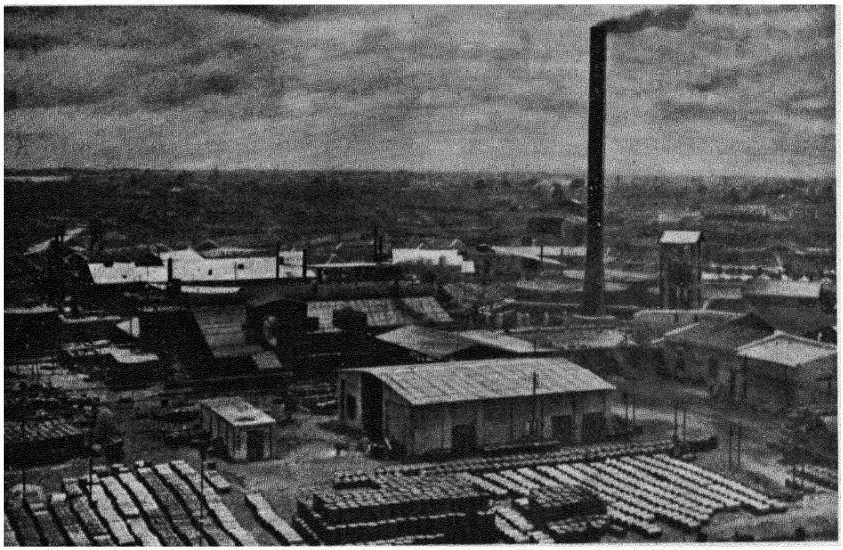


Fig. 47.—Tar products refinery

distillation. In the continuous process, tar is fed at one end and the products are drawn from different portions of the plant at definite temperature ranges; economy in heat consumption is secured and a maximum yield of volatile products ensured. Pot stills, T.I.C. (*Thermal Industrial Chemical Research Co., Ltd.*) stills, and Cascade stills (continuous) are used in India. Except the *Shalimar Tar Products* (1935) *Ltd.*, which use only Cascade and T.I.C. stills, all the other works employ pot stills. Tube or pipe stills which are used in large tar distillation plants in U.K. and U.S.A. are not in use in India.

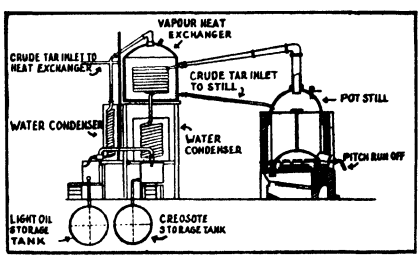


Fig. 48.—Tar pot still

Prior to distillation, tar is allowed to stand in tanks to separate the ammoniacal liquor.

Pot stills of capacities varying from 10 to 30 tons per charge are employed for distillation. The still, made of mild steel, is cylindrical in shape with a concave bottom, and is set vertically in brick work. The vapours are led to a fractionating column and thence to a water-cooled condenser. Heating is regulated in the initial stages, until the water present in the tar is expelled to avoid frothing. The distillates are collected in a series of 'cuts' of increasing b.p. range or, according to increasing sp. gr. range. To overcome the trouble due to frothing, and at the same time to effect fuel economy, modern pot still installations are operated on the double still system, in which the hot vapours from the fire heated still pass through a dehydrator—a coil immersed in the crude tar for the next charge; the tar in the dehydrator loses water, and the light oils which

are carried over with the water vapour are condensed and collected.

When the distillation is complete (24—28 hrs.), the residual tar or pitch is drawn through a drain pipe via a cooler to storage or to pitch bays.

The four main fractions obtained by distillation are: (1) light oil (up to 170°), (2) middle oil or carbolic oil (170—230°), (3) heavy oil (230—270°), and (4) anthracene oil (270—340° or higher)

Cracking during the later stages of distillation in pot stills is reduced by the admission of dry steam into the still and circulation of inert gases such as carbon dioxide or nitrogen.

By distilling in vacuum, the final tar temperatures are lowered and the yield of oil increased.

Horizontal intermittent stills are preferred in America The satisfactory operation of these stills depends on the skill of the operator. The present trend is towards continuous units which lend themselves to regulated operation leading to lower labour costs, fuel economy, and relatively high output per unit of capital expenditure.

Cascade still—The Cascade still operating in one of the distillation works in India is designed on the model of the still originally employed in the petroleum refining industry. The distillation takes place in a series of three horizontal cylindrical shells through which the coal tar gravitates in a steady flow The temperature is stepped up in successive stills and the vapours are drawn off and condensed to yield distillates of increasing specific gravity and boiling point range. The incoming crude first passes through a heat exchanger and is heated by the outgoing residue The distillation is carried to the point at which the pitch residue has the desired softening point range (25—50°, 70 ± 5°, 100° and upwards). When distilling to a medium pitch residue, the operating temperatures of the three stills are 230°, 255°, and 320° respectively. The first still incorporates a special design to facilitate the evaporation of water present and so obviate frothing, while in the subsequent stills open steam is supplied by perforated pipes to maintain agitation, assist distillation, and reduce coking at the still bottoms. The fractionation of the distillate is effected in the overhead columns. The vapours are cooled in water-cooled coil condensers and the condensates are allowed to cool and settle for several days.

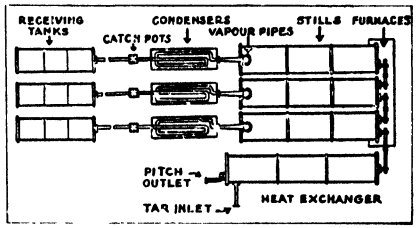


Fig. 49.—Continuous tar still

The distillate from the first still conforms to the middle or carbolic oil fraction which, after straining from the solid deposit of crude naphthalene paste, is treated for the extraction of tar acids. The distillates from the second and third stills are usually blended and, after separating the solid anthracene paste, are sold as creosote for wood preservation

The residual product from the last still after passing through the heat exchanger is either run into barrels, drums or pitch bays where it solidifies or to mixing tanks where it is blended with selected oils to conform to various road tar specifications

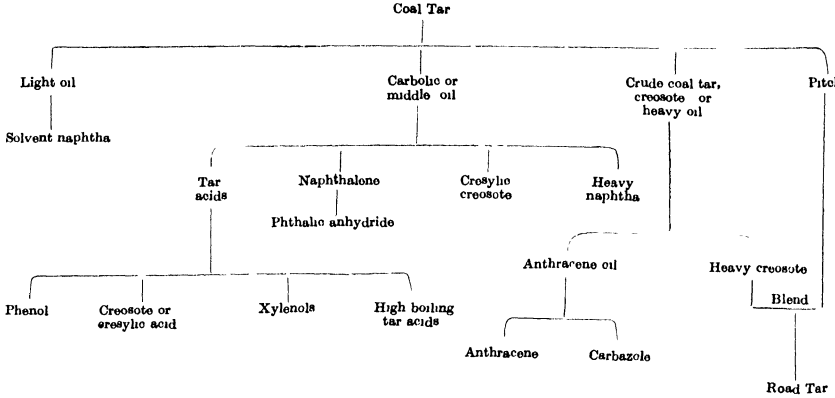
The tube still consists of a series of tubes set in an oil-fired furnace, through which crude tar is passed in a continuous stream at a relatively high speed. The hot tar is then flashed into a column where the vapours are fractionated into a number of distillate cuts in a single operation Tube stills operating on the multi-flash system in which one column is used for each fraction and the charge is made to flow through them in series, are also in use.

In the T I C distillation units, the crude tar, instead of circulating through tubes as in tube stills, circulates in a thin film (¼ in. thick) over a layer of molten lead. The hot tar is flashed into a single column. The tar passes through the still in three minutes and the pitch formation is low. Provision is made for mechanically sweeping out impurities on the surface of the metal to the pitch outlet The distillation rate and the yields of distillates are high.

The temperatures at which the crudes are distilled depend on the type of residue required. Carbolic oil fraction distils over between 170° and 230°, and coal tar creosote, between 230° (or 200°) and the point at which the residual pitch is drawn. The distillate obtained below 170° is the light oil fraction or crude naphtha consisting of benzene, toluene, xylene, etc, together with small quantities of tar acids, tar bases, hydrocarbons of the paraffin and cyclo-paraffin series, and the resin-forming compounds such as coumarone and indene.

The yield of light oil from coke oven tar is negligible and is not generally further treated. Whatever oil is collected is used as Refined

COKE OVEN TAR DISTILLATION



Solvent Naphtha Gas works tar contains appreciable quantities of light oil

The middle or carbolic oil contains up to 25% (by vol) of tar acids—phenols, cresols, xylenols, and other high boiling acids It is either treated for the recovery of tar acids or is sold as cresylic creosote after separating naphthalene The fraction distilling between 160° and 190° is marketed as Heavy Naphtha

Coal tar creosote, which is the principal product of coal tar distillation, is the fraction which distils between 230° and 300° (or 360°) It is generally marketed without further refining as wood preservative Sometimes, the fraction boiling above 270° (sp gr, $>1\ 09$) is recovered separately as Anthracene Oil. Anthracene and carbazole obtained from this fraction are important raw materials for the dye-stuff industry Coal tar creosote also contains small quantities of tar acids and phenols which can be recovered if desired

TABLE 7—COAL TAR DISTILLED IN INDIA

	Qty (Tons)
1933–34	26,500
1935–36	30,000
1937–38	44,700
1939–40	46,200
1940–41	51,000
1941–42	61,700
1942–43	47,000
1943–44	33,700
1944–45	33,000
1945–46	40,000
1946–47	31,500
1947–48	33,000
1948–49	30,000

The residue constituting 60–85% of the raw tar is either road tar or coal tar pitch, depending on the extent to which the volatiles are removed through distillation The pitch is graded as soft, medium, or hard, according to the softening range

Production—The quantity of coal tar distilled and refined in India steadily increased from 15,000 tons in 1930 to over 60,000 tons in 1942 Table 7 gives the quantities of coal tar distilled in India since 1933–34

Coal Tar Products

Primary distillation of coal tar effects only a rough separation of the constituents Prior to 1939, tar distillers in India confined their attention to the production of road tars, creosote, and pitch During the past decade, efforts have been made to recover naphthalene, phenol, cresylic acid and, occasionally, anthracene and carbazole.

Solvent naphtha.—The light oil fraction or crude naphtha may be treated for the manufacture of benzol by the removal of phenols, bases, and unsaturated hydrocarbons, or for the

manufacture of benzene, toluene, xylene, and solvent naphthas of different grades. The yield of coal tar light oil is small, and solvent naphtha, distilling between 120° and 160°, is obtained from crude benzol recovered from coke oven gas.

Pyridine is the parent substance of the tar bases extracted from the distillates by washing with dilute mineral acid. It is a liquid (b.p., 116°) possessing a pungent and unpleasant odour. In the presence of tar acids it forms loosely bonded salts boiling up to 180°. As extracted from crude benzol, light oil, and other coal tar distillates, the tar bases comprise a mixture with a boiling range of 116°—250°. After extracting the tar acids, the distillates are mixed with sulphuric acid and, on standing, an acid layer settles out. This is diluted with water, neutralized with lime or caustic soda, and steam distilled. The pyridine bases distil over and form a separate layer on the addition of caustic soda solution in which they are insoluble. The crude pyridines, after dehyration, are fractionally distilled to specified boiling point ranges.

Refined pyridine bases are marketed commercially in two standard grades, viz., (1) 90% boiling below 140°, (2) 90% boiling below 160°. They are mixtures of pyridine with picolines, lutidines, collidines and higher homologues.

Although used on a small scale in the manufacture of dyes and pharmaceuticals, the main uses for pyridine are as denaturant for spirit and as industrial solvent.

Tar bases are present in coke oven tars to the extent of 2—3%, of which pyridine itself forms less than 10%. Commercial pyridine is produced in India on a small scale from gas works coal tar distillates.

Naphthalene.—Crude coal tar contains 1—10% naphthalene, the percentage increasing with the coking temperature. The middle oil on cooling yields a crystalline deposit consisting primarily of naphthalene. It is whizzed in a centrifuge and hot-pressed in a steam-heated hydraulic press to yield crude naphthalene blocks. For the preparation of moth balls, the crude naphthalene is further purified by melting and treating successively with conc. sulphuric acid, caustic soda solution, followed by washing with water and crystallization. It is finally distilled under vacuum when a refined product melting at 79·5—80° is obtained. It may be melted and crystallized, or cast into blocks, or pulverized and made into balls. On subliming, naphthalene is obtained in flake form which may be employed for preserving and curing skins and hides.

Naphthalene is mainly used as insecticide and moth repellant in the preservation of clothes and

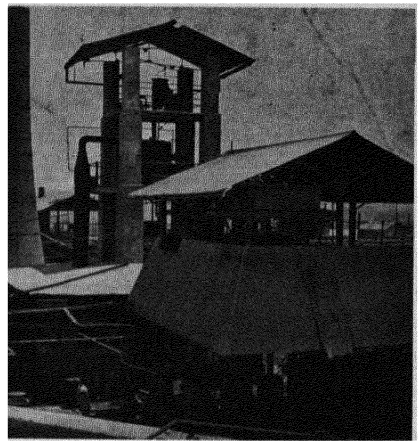


Fig. 50.—Naphthalene distillation and refinery unit

fabrics. It is used in the manufacture of phthalic anhydride, β-naphthol, anthraquinone, tetralin, decalin, and chlorinated naphthalenes.

Naphthalene is obtained in 4% yield from Indian coke oven tar. Allowing for the reduced tonnage of crude tar normally available for distillation, c. 1,500 tons of refined naphthalene can be annually recovered economically. The quantity actually produced in India is about 800 tons per annum, most of which is used for moth proofing of clothes (Information from D.G.I. & S.). A method for production of phthalic anhydride from naphthalene by vapour phase oxidation in the presence of vanadium catalyst was evolved in the laboratories of the Council of Scientific and Industrial Research, India (Indian patent No. 29,374, 1948). It is now being worked commercially by the *Shalimar Tar Products* (1935) Ltd.

Table 8 gives imports of naphthalene into India.

Of the average annual imports of 9,329 cwt. during the quinquennium ending 1938-39, Belgium supplied 53·5; Japan, 14·5; Czechoslavakia, 10·7; Germany, 8·8; United Kingdom, 7·6; and Union of South Africa, 3·1%.

Imports of naphthalene are subject to a revenue duty of 30% *ad valorem.*

Tar acids are present in the middle or carbolic oil fraction constituting 10—20% of the tar. The chief members of this group are: phenol, cresylic

TABLE 8.—IMPORTS OF NAPHTHALENE

	Qty. (cwt)	Value (Rs)
1934/35—1938/39 (av.)	9,329	1,37,861
1939/40—1943/44 (av)	4,014	96,224
1944–45	4,444	2,22,564
1945–46	4,349	2,18,252
1946–47	2,103	1,37,792
1947–48	1,042	78,548
1948–49	1,424	68,214
1949–50	1,589	82,443

acids (*o*-, *m*-, and *p*-cresols) and xylenols. Middle oil also contains high boiling tar acids

After separating naphthalene, the middle oil fraction is agitated with 10% caustic soda solution in a paddle agitator mixer The phenols dissolve in the alkali and pass into the aqueous layer which is separated from the neutral oil layer Caustic soda shows a greater affinity to phenol than to cresols and heavier tar acids, and advantage is taken of this fact to neutralize the tar acids in stages and separate phenol from cresols and xylenols

The tar acids from the caustic soda extract are liberated by reaction with carbon dioxide or dil sulphuric acid Carbon dioxide treatment is preferred as the sodium carbonate formed can be recausticized and utilized for further extraction

The liberated tar acids are separated from the aqueous sodium carbonate solution by decantation, dehydrated, and fractionally distilled to give phenol, cresols, and xylenols These cuts on refractionation yield high purity phenol and o-cresol. The high boiling tar acids are obtained as cuts with definite boiling ranges.

The percentage yield of tar acids (total yield, 0·4% of which 0·1% is phenol and 0·15%, cresols) from Indian coke oven tar is low as compared with the yield from tars distilled in U K. and U.S A. (total yield, 4 5% by vol. of which 0·7% is phenol and 1 5%, cresols and xylenols). Coke oven tars produced at lower temperatures contain a higher percentage (3·5%) of crude tar acids, of which 0·4% is phenol and 0·9%, cresols

The potential annual recovery of refined tar acids from 90,000 tons of crude tar is estimated to be: phenol, 100 tons; cresols, 150 tons; and high boiling tar acids, 175 tons. The actual production in 1949 was: phenol, 12 tons; and cresols, 16 tons (Information from D.G I. & S.). These yields are quite inadequate to meet the demands, and if allowance is made for the reduced tonnage of crude tar normally available for distillation, it is estimated that not more than half the potential yield is likely to be attained

Phenol.—Pure phenol (m p , 41°; b p , 181 7°) is the parent member of a series of compounds present in tar acids It is soluble in water to the extent of 1 part in 13. It first received prominence as an antiseptic under the name carbolic acid. Although it is still used as an antiseptic, it has the disadvantage of being a poison and is caustic to the skin, and for these reasons it has been to a large extent replaced by cresols and high boiling phenols Partially refined phenol, known in the trade as carbolic acid 60's, (m p , <15°) contains water and cresols as impurities (B S S No 515—1938) Commercial pure phenol should conform to B S S. No 523—1938

The major part (c. 75%) of phenol is now manufactured by synthetic processes developed during World War I, when large quantities of phenol were required for the production of picric acid Three processes are now employed According to one of these, sodium benzene sulphonate, obtained by sulphonation of benzene, is fused with caustic soda to form sodium phenate; the phenol is released from the salt with mineral acids This process involves the use of 4·3 lb. of chemicals per lb of phenol The process has been partly superseded in U S A by the more economical process of hydrolyzing chlorobenzene to obtain phenol In the Dow process, chlorobenzene is hydrolyzed at high temperature and pressure (3,000 lb /sq in) with dilute sodium carbonate solution in the presence of a copper catalyst. In the more recent Raschig process (B I O S. Final Rep No 507), benzene is treated with hydrochloric acid in the presence of air and a catalyst to produce chlorobenzene Hydrolysis of the chlorobenzene is brought about by steam at high temperature in the presence of catalysts Hydrochloric acid is evolved in the second stage, and is recovered and utilized in the first stage It is estimated that in 1947 about 48% of the production of synthetic phenol (245 million lb) in U S.A. was via chlorobenzene, 43% by sulphonation of benzene, and 9% by the Raschig process (Skeen, *Chem Engng News*, 1948, **26**, 2256; *Chem. Tr. J.*, 1948, **123**, 249).

A large quantity (c 60%) of the phenol produced is used in the manufacture of synthetic resins of the phenol-formaldehyde type. Nitration of phenol yields picric acid. Phenol is utilized in the synthesis of a number of antiseptics, drugs and dyes via mononitro and sulphonic acid derivatives. Carbonation of phenol yields salicylic acid. Phenol is employed in the manufacture of wetting

TABLE 9 —IMPORTS OF CARBOLIC ACID

	Qty. (cwt)	Value (Rs)
1934/35—1938/39 (av)	729	36,580
1939/40– 1943/44 (av.)	831	59,318
1944–45	5,818	5,67,775
1945–46	1,661	1,65,561
1946–47	267	14,375
1947–48	108	7,265
1948–49	583	42,327
1949–50	3,443	2,90,332

agents and detergents, synthetic tannins, perfumes, insecticides and germicides, plasticizers, and photographic developers It is also used as a selective solvent in some industrial operations, especially in the refining of lubricating oils.

Table 9 gives the imports of carbolic acid into India The shares in imports of different countries during the quinquennium ending 1938-39 were U K, 62 5, Germany, 20 0, and Japan, 14 0%

Imports of carbolic acid are subject to a revenue duty of 30% *ad valorem*

Cresylic acid and Cresols —All the three isomeric cresols (*ortho*, b p 190·8°, *meta*, b p 202 8°, and *para*, b p 202·1°) occur in tar acids. Like phenol, the cresols have valuable bactericidal properties and the advantage of being less toxic As they are only slightly soluble in water (1 part in 50) they have to be used in the emulsified form Lysol, one of the well known commercial brands of emulsified cresol, is used as a surgical antiseptic (*see* Disinfectants) Cresol B P excludes the lower boiling o-cresol

Cresylic acid (tricresol) is employed in germicidal soaps, as a preservative for leather, glues and adhesives, and in certain applications as wetting agent and selective solvent The Duosol process for the production of high grade lubricating oil employs a mixture of phenol and cresol in conjunction with liquid propane for the solvent extraction of waxes and asphalts

o-Cresol is converted to tricresyl phosphate and widely used as plasticizer The mixed cresols are employed as anti-oxidants or gum-inhibitors in motor fuels The cresols are employed in the manufacture of dye-stuff intermediates, perfumes, and formaldehyde resins

The plastics control specification includes three grades of cresols, the value of the grade increasing with *m*-cresol content.

	Grade 1 %	Grade 2 %	Grade 3 %
m Cresol	40 42	49 51	52 53
o-Cresol	10·15	6 80	6·80

Other specifications for cresols are. B S S. 517 (1948) for cresylic acid of high o-cresol content; B S.S 521 (1948) for cresylic acid of 50/55% *m*-cresol content, B S S 522 (1948) for *o*-, *m*-, and *p*-cresols, and B S S. 524 (1948) for refined cresylic acid

Creosote oil.—Creosote oil is the oil or blend of oils distilling above 200° Primary distillation of coal tar yields a series of creosote oil fractions which may be given further treatment and blended to specifications for various uses The main creosotes marketed are Cresylic Creosote, Creosote Oil for wood preservation, and Creosote Oil for benzol recovery.

Cresylic creosote is obained from the middle oil fraction after separating naphthalene and diluting with various percentages (20—40% by vol) of high boiling tar acids prepared from the middle oil It is sold for the manufacture of coal tar disinfectants (*see* Disinfectants) This creosote should have a sp g of c 1 0 and should contain a specified proportion of tar acids by volume

Creosote oil for wood preservation is a wide range fraction of creosote oil boiling mostly above 235° It is unequalled as a cheap timber preservative Creosote oil is easily absorbed into the pores of most sapwoods, remains firmly fixed, and renders the wood markedly durable Creosote treatment is best carried out under pressure in specially designed plant which ensures overall penetration Coal tar creosote for the preservation of timber is governed by B S S 144—1936 (amended in 1941) On this is based the I S D. Specification G/O P 33C for creosote oil

Heavy creosote oil, known as Anthracene Oil or Green Oil (b p, >270, sp. gr., >1·08), is used for the preservative treatment of timbers by brushing The anthracene oil must be strained free from solid crude anthracene before use

Prior to 1939, approximately 1,500 tons of creosote were consumed annually for wood preservation, mainly for the treatment of railway sleepers. During World War II considerable quantities were employed for the treatment of wooden planks and poles required for the erection of temporary huts-ments The production of creosote was stepped up to 3,500 tons in 1942 Due to the reduced quantity of coal tar available for distillation, the production in 1948 dropped to 1,800 tons (Information from D G I & S). There is no import of creosote into India.

Creosote oil for benzol recovery is a middle creosote (b.p range, 230—300°) containing less than 8% solid constituents. This grade is covered by the I.S.D. Specification G/Misc. 93 (1941). Its consumption in India is small, as under tropical conditions, Gas or Straw Oil from petroleum refineries is found to be more efficient for scrubbing This grade of creosote oil is employed in the preparation of bitumen emulsions and cut-backs, by virtue of its surface tension and good wetting property. It is used in ore separations and flotation processes.

Other uses for creosote oil are· preparation of sheep dips, oil washes for orchard trees, fuel for heating, and diesel fuel for internal combustion engines. It is also used as an ingredient of car axle grease in admixture with lime, and as a starting material for the manufacture of lamp black (Gregory, I, 192) Creosote which is not suitable for wood preservation can be hydrogenated to yield high octane spirit

Anthracene—The heavy oil fraction obtained when coal tar is distilled from pitch contains up to 0·5% anthracene This fraction on cooling and settling gives a sediment containing 6—10% oil It is separated by filtration through bag filters or plate filter presses, washed with solvent naphtha, centrifuged, and pressed The anthracene cake containing about 20% anthracene is treated with light solvent naphtha when a semi-refined product containing approximately 45% anthracene is obtained It is melted and again centrifuged to remove the oil The resulting product contains impurities like carbazole and phenanthrene The carbazole is recovered by treatment with pyridine base solvents when anthracene of 90—95% purity is obtained Phenanthrene is removed by treatment with naphtha Carbazole is a basic chemical required in the dye-stuff industry

Anthracene on oxidation forms anthraquinone from which is derived a large series of vat dyes In recent years anthraquinone is mainly synthesized from phthalic anhydride and benzene Alizarin (di-hydroxy anthraquinone) is the parent substance of the important alizarin group of mordant dyes of which Turkey Red is an example

Refined anthracene is not at present manufactured in India, but it can be made available if required. The potential production from 90,000 tons of crude tar is 450 tons per annum Under actual conditions, economic recovery of anthracene from Indian crude tar is not likely to exceed 200 tons annually The recovery of carbazole is about the same as anthracene

Coal Tar Pitch is the black or dark brown, solid or semi-solid, fusible and agglomerative residue remaining after partial evaporation or fractional distillation of tars and tar products. It is desirable that the derivation of the pitch be indicated (high temperature coal tar pitch, low temperature coal tar pitch, etc)

Coal tar pitch is designated as soft, medium-hard, or hard, according to the softening point. There is no sharp line of distinction between a viscous road tar and a soft pitch and these products overlap to some extent

Soft pitch consists of solid or semi-solid residues with a softening point (Ring and Ball method) below 60°. Soft pitch is used as a base for black bituminous paints, as a felt saturant, and for blending with road tars Coal tar pitch is resistant to corrosive action, and is used in the preparation of bituminous paints for coating iron, steel, and other structural materials.

Medium-hard pitch has a softening point (Ring and Ball method) between 60° and 75° and has a wide variety of uses It is employed in roofing mastics, damp-proof coursing, pipeline coatings, dipping solutions for castings, and deck caulking and jointing compounds According to I S D Specification No G/O P 66A for coal tar medium pitch, the softening point range is 70—75°

Hard pitch has a softening point (Ring and Ball method) above 75° The principal use for this grade is for briquetting fuel, e g, coal dust. Hard pitch is also employed in forming electrodes, carbon brushes, electric batteries, and Clay Pigeons.

Fluxed pitches are made from a pitch with a softening point of 78° (Ring and Ball method) by fluxing with suitable heavy tar oils

B S S No 1310 (1946) for coal tar pitches defines 5 grades differing in softening points from 33° to 78° (Ring and Ball method) and covers the range required by the building industry

Pitch-coke results when coal tar pitch is retorted and all volatile products are driven off This product is utilized in metallurgical industries for special castings and for electrode manufacture

The annual production of coal tar pitch in India during the period 1939—1945 amounted to approximately 7,000 tons, this has since dropped to about 4,000 tons in 1949

Table 10 gives the imports of coal tar and pitch into India

The shares of different countries in the imports during the quinquennium ending 1938-39 were· United Kingdom, 47 8, Japan, 43 8; and U.S A, 5·8%.

Imports of coal tar and pitch are subject to a revenue duty of 30% *ad valorem*.

TABLE 10 —IMPORTS OF COAL TAR AND PITCH

	Qty. (cwt)	Value (Rs)
1934/35—1938/39 (av)	67,270	2,15,822
1939/40—1943/44 (av.)	23,933	1,58,233
1944-45	1,758	26,631
1945-46	12,650	1,38,559
1946-47	8,487	1,18,702
1947-48	10,600	1,85,504
1948-49	16,484	2,32,772
1949-50	16,483	2,31,832

Road Tar.—According to the *British Standard Glossary of Highway Engineering Terms,* Road Tar is a product prepared by treating high temperature coal tar in such a manner that it conforms to a specification which defines its applicability for some type of surface construction It is prepared by topping or distilling crude coal tar to a stage where most of the phenols and naphthalenes are removed, and a residue consisting of pitch dissolved in the less volatile oils and conforming to the desired road tar specification is obtained It is preferable, however, to distil the crude coal tar to the consistency of a soft pitch and then to oil back with a selected distillate, e g, heavy creosote from which the naphthalene and tar acids have been extracted The blending must be accurately carried out in order that the viscosity range and other requirements of the specification are fully met.

The most important property of a road tar is its consistency. This is determined by the viscometer which measures the time in seconds taken for a given volume of binder to flow through a standard orifice (10 mm) at a given temperature A modified form of the Redwood Viscometer as approved by the *British Road Tar Association* (B.R T.A.) is used for the determination. The temperature of the test is so adjusted that the time of flow falls within the range of 10 to 140 sec.

The grades of road tars now employed for surface treatment are of such viscosity as to need heating prior to application on the road. Such road tars are able to penetrate and stabilize the water-bound macadam as well as to set reasonably quickly and bond with the stone metal chippings.

Road tar specifications cover a wide range of viscosities and the selection of the tar is determined by the type of surface construction Low temperature coal tars do not yield satisfactory road tars

Table 11 gives the I S D Specification G/Misc 72-A (1935) for coal tar for purposes which is based on B S S No 76 (1930 & 1931).

The corresponding B S Specification has since been changed, and at present road tar in U.K is governed by B.S S. No 76 (1946) according to which road tars have been divided into types A, B, and C based not on viscosity but on road requirements, and covers a wider range of products Road tars 1, 2, and 3 belong to type A of the new B S Specification The division into A, B, and C is related to their rates of setting on exposure, as distinguished from the immediate set due to fall in temperature at the time of application which is a function of viscosity; type A has rapid setting properties; type C which is a special material is slow setting, and type B occupies an intermediate position.

TABLE 11.—SPECIFICATIONS FOR ROAD TARS

	Road Tar 1	Road Tar 2	Road Tar 3
Consistency or viscosity within the range	10—40 sec at 30°	40—125 sec at 30°	70—120 sec. at 35°
Water or ammoniacal liquor	<0·5% by wt	<0·5% by wt.	<0·5% by wt.
Other distillate (light oils) below 200°.	<1% by wt	<1% by wt	<1% by wt.
Distillate between 200° and 270°.	9·5—21·0%	8 0—16·0%	6·0—12 0%
Distillate between 270°—300° (heavy oils)	3 5—12·0%	3 5 -12·0%	3·0—8·0%
Phenols or crude tar acids	<5 0% by vol.	<4·0% by vol.	<2 0% by vol.
Naphthalene	<6 0% by wt	<5·0% by wt	<3 0% by wt.
Free carbon	Max 20% by wt.	6·0—21·0% by wt.	8·0—22·0% by wt.

TABLE 12.—PRODUCTION OF ROAD TAR

	Qty (Tons)
1933	22,000
1934	25,000
1939	34,000
1942	46,000
1943	27,000
1944	18,000
1945	18,500
1946	19,000
1947	20,000
1948	17,000

The viscosity range of the tar has been extended in the new specification and in order to enable the viscosity to be expressed on a single scale, a new system of indicating viscosity called Equiviscous Temperature (E.V.T) has been introduced. This is the temperature in °C at which the tar has a time of flow of 50 seconds as measured by the standard viscometer. According to the new B.S.S, Road Tar 1, 2, and 3 have E.V.T. values 28 7°, 28 7—35°, and 37—40° respectively.

Besides, the permissible variations in the proportions of oils and other constituents are reduced and a maximum limit for the total distillate has been included But the most important requirement which is newly introduced is the softening point of the distillation residue and this is particularly useful in excluding unsuitable road tars.

For Indian conditions, types B and C are not particularly well suited and Type A covers all requirements. The adoption of the new specification would enable road engineers to stipulate a narrower range of viscosity for the road tars they require.

Coal tar primers, road tar emulsions, tar-bitumen mixtures, fillerised and blown tars have been developed in other countries. Up to the present, however, such materials have not been employed in India on other than an experimental scale.

Table 12 gives the production of road tar in India.

These figures appear small, in comparison with the annual production of road tars in U.K. and U.S.A. (c. 800,000 tons in each country).

There has been no appreciable import of road tars into India although considerable quantities (c. 40,000 tons) of asphaltic bitumen are imported annually for road construction.

DISTILLATION OF LOW TEMPERATURE TAR

Low temperature tar, on distillation in pipe stills, gives. tar acids, 22, diesel oil, 22; washed light oil, 3, cresylic pitch, 4, heavy residue, 20; paraffin wax, 1 5, and fuel oils, fluxing oils and residues, 27 5% (Bristow, *J Inst. Fuel*, 1937, **10**, 43). The principal distillation products are phenols, spirit, and diesel fuels The phenolic fraction consists of c 65% of monohydric and 30% of dihydric alcohols (catechol, resorcinol, etc). The ammoniacal liquor contains 1—2% of phenolic compounds. Low temperature tar is thus a valuable source of raw materials for the synthetic resin and plastic industries

The spirit distilled from low temperature tar is a valuable motor fuel of high octane number and low gumming tendency. It is also suitable for aviation purposes It is composed of 25% paraffins and naphthas, 50% olefines, and 25% aromatics, and is comparable to motor spirit produced from natural petroleum

Diesel fuel produced from low temperature tar has a low cetane value and has to be either blended with hydrocarbon oils, or doped and rendered suitable for high speed diesel engines

The chlorinated xylenols from low temperature tar have high germicidal properties

The olefinic unsaturated compounds present in the low temperature tar are similar to those present in petroleum, and may be used in the production of synthetic chemicals Low temperature tar is suitable for hydrogenation and for the production of petrol.

COCOA AND CHOCOLATE

The first factory in India for the manufacture of cocoa and chocolate was started during World War I at Bilimoria (Bombay) The factory had to be closed down soon after the war due to competition from imported products The chocolate confectionery industry utilizing imported chocolate, however, was well established in large cities like Calcutta, Bombay, and Madras. A second attempt was made in Bombay in 1936 to manufacture cocoa and chocolate, but the factory failed as the size of operations was uneconomical. Yet another attempt to establish the industry was made during World War II, and due to imposition of restrictions on imports and, the increased demand from the armed forces, the attempt proved successful Messrs. *Sathe Biscuit & Chocolate Co Ltd*, Poona, commenced production of cocoa powder on a small scale and chocolate manufacture was taken up in

1941 The production gradually increased and the present capacity is estimated at 5,000 cwt of covering chocolate and 1000 cwt. of cocoa powder (Indian Tariff Bd, *Rep Continuance of Protection to Cocoa Powder and Chocolate Industry*, 1949, 7) There are three other factories in India producing chocolate *Pure Products and Madhu Canning Ltd*, Bombay, producing covering chocolate for confectionery and cocoa powder, *G G Chocolate Factory, Agra, Producing* small quantities of eating chocolate; and the *East India Distilleries and Sugar Factories Ltd*, Madras, producing covering chocolate and eating chocolate. There are also a number of confectionery manufacturers using chocolate produced in Bombay or imported from abroad The position has recently changed, the only firm which was in continuous production during 1947 and 1948 was Messrs *Sathe Biscuit and Chocolate Co Ltd*, Poona The *Pure Products and Madhu Canning Ltd*, Bombay have recently installed a new plant for making chocolate with an annual capacity of 600 tons

In addition to the above, *Cadbury-Fry (Export) Ltd*, who have so far been importing cocoa and chocolate into the country, are at present erecting a plant in Bombay for the processing and packing of cocoa imported in bulk containers during the initial stages It is proposed in due course to equip the factory with plant required for the production of cocoa powder for cacao bean

Raw Materials

The most important raw material for the industry is cacao bean The cacao tree, *Theobroma cacao* Linn, is indigenous to Central America and is grown extensively in Brazil, Gold Coast (West Africa), West Indies, and Ceylon The Brazilian beans are considered to be the best, the West African ranking second, those from Ceylon taking the third place Experimental cultivation of cacao was attempted in Kumtha Forest in North Kanara Dt of Bombay The beans produced were of poor quality and cultivation was abandoned Supplies of cacao bean were hitherto drawn entirely from Ceylon, but with the lifting of international control on its distribution in June 1949, supplies are now obtained from Brazil and West Africa also In the years 1943-44 and 1944-45, India imported 1,319 and 1,147 cwt respectively of cacao beans from Ceylon. Cacao beans are at present imported free of duty The beans are light in colour and possess excellent aroma and flavour

Other materials required for chocolate manufacture are cacao butter and sugar. The former is obtained from roasted cacao beans by expression It is a yellowish fat, made up of about 55% of oleopalmitostearin and 20% of oleodistearin with minor amounts of stearodiolein, palmitodiolein, and oleodipalmitin It has the following characteristics sp. gr $\frac{15^\circ}{15^\circ}$, 0·970: n^{60° 1·450, setting point, 23—26°, m p, 33—35°, sap val, 192—195, acid val, 1—3; iod. val., 35—42, m p. of combined fatty acids, 48—53° (Hilditch, 111) The butter is useful because of its two valuable properties of freedom from rancidity and its blandness (Cheney, *Econ. Bot*, 1947, **1**, 259) It is hard and brittle This property which is due to its specific structure renders it specially suitable for confectionery.

The sugar employed for incorporation in chocolate should be free from invert sugar It should contain 99 5—99 9% sucrose

Manufacture

Cacao beans required for cocoa and chocolate manufacture are freed from the adhering pulp of pods through fermentation, a process which not only facilitates the removal of the pulp but also improves the flavour and aroma of the product Fermented beans are cleaned and dried to a moisture content of 5—8%. The dried beans are cleaned by hand, and roasted carefully in rotary drums over fire or by hot air or superheated steam at 160—315° This treatment leads to the development of the typical chocolate flavour and aroma, decreases the tannin content, and helps to loosen the shells. The roasting also changes the colour to dark brown. The roasted beans are cooled, and gently crushed soon after to fracture the husk and break down the kernels into their natural angular fragments or nibs after which the nibs, husks, and the germs are separated by winnowing and sifting The beans contain on an average 80% nibs, 12—13% husks, and 1% germs The roasted nibs have the following percentage composition moisture, 2·72; protein, 12 12, theobromine, 1 04, caffeine, 0 40; fat, 50 12; pure starch, 8 07, crude starch, 11—16; fibre, 2 64, other carbohydrates, 19 57, total ash, 3 32, water soluble ash, 1 16; acid insoluble ash, 0 02 (Jacobs, II, 567, Winton & Winton, IV, 121).

The nibs containing 50—55% fat constitute the basis of all cocoa and chocolate preparations. They are pulverized in a hot stone or steel mill, when they are reduced to a homogeneous molten mass owing to the high content of low melting fat. The resulting thick cream or paste is run into moulds to give Block Cocoa.

The cocoa mass, is subjected to high pressure (1—3 tons/sq in) at a temperature of 70—80° to remove the fat. Cacao butter flows

out and is solidified in moulds. The residual cocoa mass still retains about 25% of the fat originally present in the beans (Jacobs, II, 580) It is cooled, ground in special mills, and sifted through fine silk screens. The fine powder, mixed with flavouring materials and homogenized, is the cocoa from which the beverage is prepared.

Soluble, Dutch Process Cocoa or Alkalized Cocoa is prepared by treating the beans prior to roasting, or the milled nibs before pressing, or the cocoa cake, with 2–3% alkali (potassium, sodium, or ammonium carbonate, or sodium bicarbonate) This treatment neutralizes the free acids present, gives a product with a darker and richer colour which is less bitter and possesses more body on the palate, the product emulsifies much more easily with milk than the untreated product. It has a pH of 6 8–7 5 while the untreated cocoa has a pH of 5 2–6 0 (von Loesecke, 394)

Cocoa powder readily absorbs moisture from air and should be carefully packed in sealed containers.

Chocolate —The majority of chocolate preparations contain sugar Some preparations, used for special purposes, are unsweetened or contain saccharin as sweetening agent Chocolate consumed as beverage often contains up to 20% arrowroot starch or some other farinaceous substance Chocolate contains more fat than beverage cocoa, and in its manufacture block cocoa is employed as such In the preparation of products of high quality, cacao butter, obtained as a by-product in cocoa manufacture, is added and the fat content augmented Due to the high price of cacao butter, however, cheaper non-greasy digestible fats, having the hard and brittle, or snap properties of cacao butter, and a low m p (not exceeding 37–38°), are sometimes used to replace cacao butter either wholly or in part Important among such substitutes is Borneo tallow (*Shorea* spp) and refined and deodorized stearines from cocoanut and palm kernel oils More recently hydrogenated coconut and palm kernel oil are being employed (Thorpe, III, 234)

Plain chocolate is prepared by incorporating sugar, cacao butter, and flavouring materials with cocoa mass, and grinding the mixture in a mill or melangeur, to a fine particle size Eating chocolate contains about 50% sugar. Sucrose should be finely ground before incorporation. Vanilla is the principal flavouring agent, though other essential oils, e g , cinnamon, clove, mace and nutmeg are sometimes used The ground mass is then refined by passing it repeatedly through water-cooled massive steel rollers to give a smooth velvety mass without grit More cacao butter is added and the mixture is conched or subjected to rolling pressure in a granite rectangular box fitted with granite rollers having a to-and-fro motion Conching, which is continued for 12–96 hrs , has the effect of removing moisture, mellowing, and eliminating harshness and acidity. It also helps in securing a homogeneous velvety mixture in which every particle of sugar is uniformly coated with cacao butter and improves the keeping properties (Crosbie-Walsh, 220) The conched mass is transferred to tanks and stirred at 120–130°F This treatment liquefies the fat and ensures its uniform distribution throughout the material thus minimizing the tendency for fat bloom

The tempered chocolate is cooled, and moulded into blocks, bars, cakes, and fancy shapes Refrigerated moulds are used for removing the liberated latent heat, the rate of heat removal being so controlled that the fat sets in a finely crystalline form

Milk chocolate contains in addition dried milk powder The proportion of ingredients used by different makers vary. The following may be taken as a typical composition fat-free cocoa mass, 15, cacao butter, 25, sugar, 40, and milk powder, 20% (Thorpe, III, 86) The average composition of English milk chocolate is . protein, 7·4, milk fat, 5·5, cacao butter, 26 3, lactose, 8·0, and sucrose, 43·2% (Winton & Winton, IV, 127)

For better grades of chocolate, milk powder is replaced by block milk which is condensed milk containing about 50% sugar, 40% milk solids, and 10% water (Crosbie-Walsh, 269). Chocolates containing block milk are said to have better texture and better keeping quality than those made with dried milk. Freshly prepared condensed milk may also be incorporated. The product obtained is reported to have the characteristic fresh milk flavour.

One of the main defects of chocolate is its tendency to bloom. Fat bloom due to deposition of fat particles on the surface makes the product greasy and gives it a misty appearance Also, during crystallization, the heat liberated melts the low melting fractions of the fat, redistributes them and causes fat bloom. Fat bloom may also be caused by storage at high temperatures when the cacao butter melts and rises to the surface, solidifying again on cooling.

Fat bloom can be eliminated by tempering prior to moulding and storage. Prolonged conching reduces the tendency to fat bloom. Addition of lecithin, or about 0 5% cacao butter

which has been blown with air at 250° for a prolonged period greatly reduces the tendency to bloom (Hilditch, 311).

If chocolate is stored in an atmosphere of high humidity, the moisture that condenses on the surface dissolves a part of the sugar and, as the humidity decreases, the water evaporates and sugar crystals appear on the surface causing sugar bloom.

Cheaper brands of chocolates contain wheat or potato flour, rice, arrowroot, dextrin, and ground cacao shell. These may be regarded as adulterants

Nuts, chiefly hazel and almond, are often incorporated in plain and milk chocolate to give nut chocolate and nut milk chocolate

Many types of chocolates are manufactured and sold in which chocolate forms an envelope or covering for other products such as creams, biscuits, dried fruits and nuts, fruit jelly, liqueurs, and medicinal preparations such as pills The most important among these products is covered cream The cream is made either of powdered sugar or a mixture of this with glucose with or without flavouring and colouring materials The mixture is melted and poured into moulds to set. It is than covered by melted chocolate either by dipping or by pouring, uniformity being ensured by using a rocking table (Thorpe, loc cit)

Chocolate should be carefully packed, and stored at controlled temperature and humidity Canning of chocolate has been developed in the U.S.A.

Shells and cacao butter are obtained as by-products of the cocoa industry. Shells exposed to sunlight are a rich source of vitamin D. They are sometimes used after grinding for incorporation in the cheaper grades of cocoa and chocolate. Occasionally they are used as a beverage under the name cocoa tea. They are used also as stock feed and fertilizer.

Cocoa is used as a beverage; chocolate is used mainly as confectionery, and to a smaller extent as beverage. The food value of cocoa is 183 units as compared with turnips, 8; carrots, 12, potatoes, 26, rice, 102, wheat, 106; peas, 113, and oat meal, 117 (Thorpe, III, 88). It has a stimulating effect due to theobromine (2·2—3·5% in cocoa) Cocoa is used in preparing patent food products like Ovaltine, Bourn Vita, Malted Cocoa, Milo, etc. Eating chocolate has a high calorific value (2,538 cal /lb). During World War II, chocolate was used as special ration for armed forces and for feeding children in occupied countries. It is also employed as a medium for administering calcium and vitamins A, B, C, and D (*What Industry Owes to Chemical Science*, 1945, 41).

Production and Trade

The production of cocoa powder and chocolate in India in 1946 was about 460 tons (*Sathe Biscuit and Chocolate Co Ltd*, Poona, 300 tons, *Pure Products and Madhu Canning Ltd*, Bombay, 75 tons; and others, 85 tons) (Indian Tariff Bd, *Rep. Cocoa Powder and Chocolate Industry*, 1946, 4).

Accurate estimates of the actual production are not possible The production of *Sathe Biscuit and Chocolate Co Ltd.* in 1947 and 1948 was 2,170 cwt., and 1,004 cwt respectively Their production during Jan—Oct 1949 was negligible on account of accumulation of stocks (Indian Tariff Bd, *Rep*, 1949, 7) During the 6 months ending 31st Dec 1949, they produced only 84 cwt of cocoa powder and 55 cwt of chocolate of all kinds (private communication) The consumption of chocolate in India also is small, the demand being estimated at about 15,000 cwt. (cocoa powder, 2,500 cwt, covering chocolate, 4,000 cwt, and covering chocolate contained in eating chocolate, 8,500 cwt) (Indian Tariff Bd, *Rep*, loc cit)

Covering chocolate produced in India is somewhat inferior in texture and low in fat content These defects are due primarily to the shortage of supplies of graded cacao beans and lack of adequate machinery.

Imports —Prior to World War II, the entire demand for chocolate and cocoa powder was met by imports mainly from U K In 1942-43 and 1943-44 imports were mainly from South Africa. Table 1 gives the imports into India.

It is understood that out of the total imports, half was cocoa powder and half was covering chocolate

On the recommendation of the Tariff Board, the Government of India have recently converted

TABLE 1.—IMPORTS OF COCOA & CHOCOLATE

	Qty. (cwt)	Value (Rs)
1934/35—1938/39 (av.)	4,576	3,36,192
1939/40—1943/44 (av.)	4,448	2,99,357
1944-45	2,686	2,07,654
1945-46	4,002	4,12,063
1946-47	2,867	2,74,731
1947-48	9,929	14,93,613
1948-49	11,624	19,79,870
1949-50	4,855	854,788

the 30% *ad valorem* revenue duty on imports of cocoa powder and covering chocolate into 30% *ad valorem* protective duty.

The actual cost of production during 1948 was: cocoa powder, Rs. 1-15-4/lb.; and covering chocolate, Rs. 2-1-7/lb. The Tariff Board estimated the cost of production for the period 1950-51 at: Rs. 1-5-2/lb. for cocoa powder; and Rs. 1-9-0/lb. for covering chocolate; the corresponding fair selling prices were estimated at Rs. 1-6-5 and Rs. 1-10-3 respectively. Compared to the above figures, the landed costs including duty at 30% *ad valorem* of imported chocolate are. cocoa powder (Nestles, in ½ lb. tins), Rs 1-11-2/lb.; and covering chocolate (Nestles), Rs. 2-4-9/lb. (Indian Tariff Bd, *Rep*, 1949, 11—13, 16) The cost of production in the factory of *Sathe Biscuit and Chocolate Co. Ltd.* during the 6 months ending 31st Dec. 1949 was: cocoa powder, Rs 1-12-1/lb, covering chocolate, Rs 2-1-1/lb, and milk chocolate, Rs. 2-5-2/lb. (private communication).

COFFEE

The bulk of coffee grown in India is *Coffea arabica*, the main centres of production being Madras, Coorg, Mysore, Travancore Cochin, and Orissa The habit of drinking coffee is widespread in the south, and the coffee industry is mainly confined to the south Indian States.

The coffee berry, as obtained from the plant, has to be processed before marketing Two methods are in vogue, the wet and the dry In the former process, picked fresh berries from the plantations are passed through a pulper to remove the major part of the fleshy tissue, the remaining adhering pulp being separated from the endocarp by fermentation and washing. Coffee in this form has a soft parchment covering and is known as Parchment The beans are then subjected to a process of curing.

The principal curing centres are Mangalore, 4; Tellicherry, 1; Calicut, 2; Coimbatore, 2; Kannankurichi, 3; Mettupalayam, 3, Pattiveeranpatti, 2, Fraserpet (Coorg), 1, Hunsur, 1, Mysore, 1, and Chikmagalur, 1; the figures indicating the number of units [*I. & S. Bull.*, 1950, **3**(1), 8].

The dry method consists in sun-drying the berries till the outer skin and the parchment covering dry up leaving the beans loose inside The dried berries are then pounded or hulled. The coffee pounded on the estate is called Arabic Estate Pounded Bulk or Robusta Estate Pounded Bulk and this coffee is not sized. The cherry coffee which is processed in curing works is not only hulled but sized and garbled and is marketed under the trade name of Arabica Cherry or Robusta Cherry as the case may be. Mangalore and Coimbatore are the principal curing centres for cherry coffee.

Arabica cherry coffee is sometimes polished for improving the appearance. This is effected in a polishing machine by rubbing the beans against each other and removing the outer silvery skin whereby the beans attain a uniform bluish green colour Polishing is carried out in Coimbatore, Mangalore, Virudhunagar, Mysore, and other centres. The beans may also be coloured, but the sale of coloured coffee is prohibited in Madras and Mysore. A special type of coffee called Monsooned Coffee is also prepared for export.

Cured coffee is graded according to sizes and shapes. The different plantation grades are: Peaberry (oval shaped beans), O or A (first size in flats—bold, heavy, and well formed); B (slightly smaller than O or A), C (slightly smaller than B); Triage (pale, foxy, discoloured, black-spotted beans including bits); and Blacks and Bits. In Mangalore, Tellicherry, Hunsur, and Mysore, parchment is graded into Peaberry, A, B, and C, while in Calicut and Coimbatore, the grading is Peaberry, O, A, B, and C. Cherry coffee is graded into Peaberry, A, B, and C. Monsooned cherry is sized into AA (corresponding to O grade of plantation), and Basanelly (mixture of A, B, and C grades) (*Rep. Marketing Coffee, India,* Marketing Ser 21, 1940, 181).

Parchment and cherry are usually packed in single gunny bags, in some estates, parchment coffee is packed in double bags, the inner one being made of cotton drill.

Coffee Products—Cured coffee beans have to be roasted and powdered for the preparation of coffee beverage. In the chief coffee consuming areas—Madras, Coorg, and Mysore—raw coffee is purchased from the market, and roasted and ground in the homes of consumers. In recent years, the consumption of manufactured ground coffee, both in homes and in restaurants, has greatly increased and a number of factories manufacturing ground coffee have come into existence in cities, towns, and even villages, particularly in Madras State. These small-sized units are equipped with roasters and grinders of simple design The production of ground coffee on a manufacturing scale has been undertaken by a few establishments in Bombay, Coimbatore, Salem, Bangalore, Madras, and Chikmagalur, the major producers being *Polson Ltd.*, Bombay, *United Coffee Supply Co., Ltd.*, Coimbatore, and *Brooke Bond (India) Ltd.*, Coimbatore.

The manufacture of coffee powder involves the following operations: (1) roasting, (2) grinding, (3) blending, and (4) packing.

Roasting is necessary to render the bean friable and to impart to the product the characteristic aroma and flavour. During this process, water is driven off, a large part of the sugar is caramelised and the caffetannic acid content is reduced by about half. A slight loss of caffeine usually takes place. The flavour which is considered to be due largely to 2-thiolfuran and its methyl and ethyl esters, together with some other sulphur compounds, depends largely on the manner and extent of roasting (*Rep. Progr. appl. Chem.*, 1947, **32**, 386). Roasting also brings about an increase in the nicotinic acid content from 16—55 mg./g. to 95—263 mg./g. Over-roasting renders coffee bitter and acrid, while under-roasting affects the extraction of caffeine in the liquor. The liquoring quality of coffee is greatly influenced by roasting.

Roasting is controlled according to the nature of the bean, and the taste of the consumer. A light roast is preferred in U. K.; in Scandinavia and South India, a dark roast is desired. A slow roast is favoured by some and quick roast by others.

In north India, coffee beans are roasted in iron pans over open fires. Sometimes, sand is added to quicken roasting and to remove the silver skin adhering to the bean. The time taken for roasting 3·5—4 lb. of beans is 8—12 min. Shallow iron pans are used in Cochin. The beans are kept continuously stirred, and when the beans begin to split, they are taken out and spread on the floor for cooling.

Electric roasters with 2—10 lb. capacity are now available in the market. The heating coils are wound round a carrier in the centre of a horizontal drum which is rotated by a motor. A spoon is provided at the side to withdraw test samples. When the beans are roasted to the standard colour, the current is switched off, and the beans dropped into a closed container and cooled by a fan.

The roaster employed by manufacturers in south India is a perforated cylindrical drum mounted horizontally on a stand and rotated by hand over an open fire. 25—60 lb. of beans are charged into the drum and the roasting is completed in 15—30 min. The roasted beans are spread on iron plates or wooden planks for cooling and vigorously fanned. Sometimes sand is mixed with the beans during roasting for securing an even roast.

The bigger factories employ gas or coke as fuel for roasting. The beans are placed in iron drums of 50—1,000 lb. capacity, provided with a number of holes for the escape of water vapour and gases. Open iron bins which are set in motion at a prescribed speed are also employed. Each roast takes 20—40 min. The roasting is stopped when the beans attain the colour of a standard roasted sample. Some roasting machines are equipped with automatic gears for roasting coffee to definite weight (from 112 lb. to 92, 94 or 96 lb.). Due to variations in the moisture content of the charge, roasting periods vary. The roasted product is spread out for cooling either on iron or wooden platforms and fanned for 10—15 min. The cooling must be quick in order to preserve the flavour and aroma and the keeping quality of the roasted beans is improved by rapid cooling. Surface cooling closes the pores and seals the berry. Different grades and types are mixed according to specified proportions and packed in tins preferably under inert gas.

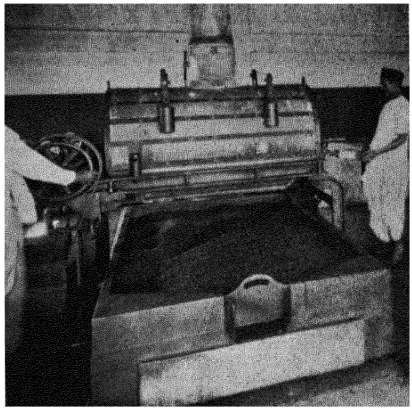


Fig. 51.—Roasting of coffee beans

Automatic coffee roasting machines have been developed in U.S.A., in which roasting is effected by infra-red heating.

The loss in weight during roasting depends on the quality of the beans and on the degree of roasting. Other conditions being the same, coffee loses 12 25% of its weight when roasted to a yellowish brown colour, and 23—25% of its weight when roasted to dark brown. The loss in Assam coffee, which contains a large percent-

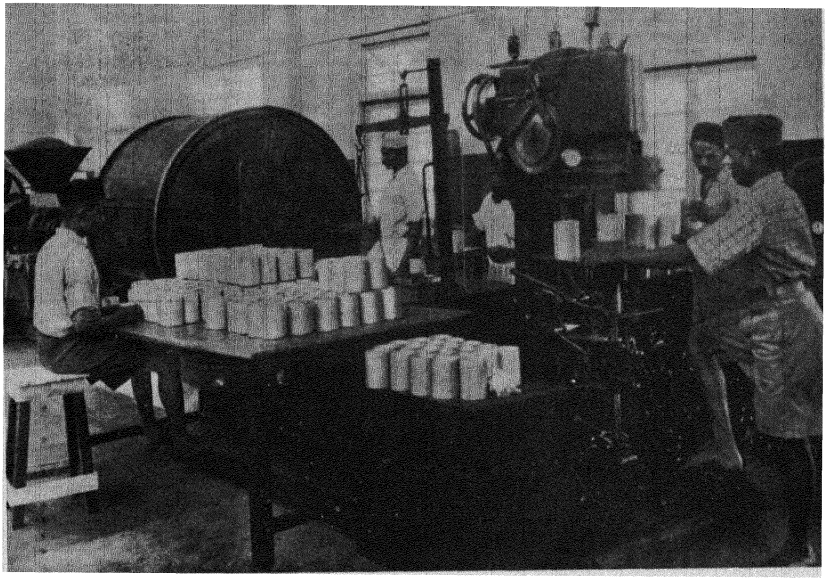


Fig. 52.—Grinding, blending & vacuum-packing of coffee

age of moisture, may be as high as 50% (*Rep. Marketing Coffee*, 242).

Roasted beans are sold in the market as such, the quantity figuring in the annual trade being about 600 cwt. (*Rep. Marketing Coffee*, 184). Grade designations for roasted coffee are: Extra Large Flats (from O grade beans), Large Flats (from A), Small Flats (from B and C), and Peaberry. All the beans should be roasted to the same degree of colour and the designation 'light roast' or dark roast applied along with grade designation. The roasted beans shall be packed in fresh condition after roasting (*Rep. Marketing Coffee*, 336).

Grinding.—The bulk of roasted beans is ground to powder and sold as ground coffee. Dealers in freshly ground coffee use grinding machines, operated by hand or by electricity. Electric grinders are common in towns and are popular as they facilitate quick service. Bigger factories use grinders with an output of 50—1,000 lb. per hr. and worked by oil or steam engine at a regulated speed. Roasted beans are ground to three sizes, viz., fine, medium, and coarse. Coarse ground powder retains aroma and flavour better and longer than fine ground powder. Coarse ground powder is more suitable for preparing coffee decoction by percolation. On the other hand fine ground coffee gives a decoction with high body. A mixture of both grades, in the proportion 90 of fine to 10 of coarse, is said to give a liquor with excellent cup-quality.

Blending.—A proper assessment of the cup characteristics of coffee produced in different areas is a necessary prerequisite for blending. Some coffees give liquors which are thick, rich, and pungent, while others give thin liquors lacking in aroma. Strength, flavour, aroma, and acidity are the chief criteria in judging the quality of coffee, and judicious blending of different grades brings out these qualities to the best advantage (*Rep. Marketing Coffee*, 243).

Two types of coffee powder are marketed, viz. pure coffee prepared from coffee beans only and

TABLE 1.—GRADE SPECIFICATIONS FOR PURE ARABICA COFFEE POWDER*

Grade	Minimum quantity (%) standing on		Maximum quantity (%) passing through	Total acidity ‡	General characteristics
	20-mesh sieve	40-mesh sieve	60-mesh sieve		
Special	40	80	Nil	20 0	No appreciable quantity shall pass through a 80-mesh sieve The ground coffee shall be the product of roasted arabica coffee beans only containing no added husk or other substances and shall be in sound dry† free condition with no rancid or other obnoxious flavour.
Coarse ground	—	80	2	17·5	
Fine ground	—	60	5	15 0	
					The nitrogen content shall not be less than 2 or more than 2 75% The ash content shall be between 3 and 5%, and the ash shall be feathery, bluish-white in colour, and entirely soluble in dil. HCl.

Rep. Marketing coffee, 337 ; † Moisture content shall not exceed 1% ;
‡ Total acidity in 100 g. of ground coffee in c c. N. HCl

French coffee containing chicory. One or more grades of coffee may be blended to give the desired qualities of pure coffee The proportions of grades and types used in blends by manufacturers of proprietary brands are kept secret. Some manufacturers use cherry triage and blacks and bits or robusta in all blends. The different grades of bean may be roasted separately, mixed, and ground, or they may be roasted and ground separately and mixed in drums. Analysis of pure coffee gives the following results: moisture, 4–6, ash, 3·5—5 (colour, white), caffeine, 1—1 3, extract, 21—26 (24 av), fats. petroleum spirit extract, 10—12 and by maceration by method, 13%

Table 1 gives the grade specifications for pure arabica coffee powder

French coffee is a blend of coffee with chicory. Different States have framed legislation for permissible chicory admixture under the Food Adulteration Act, usually, the proportion of chicory should not exceed 50% The percentage should be marked on the label on the containers, and when the percentage exceeds 50, the label should be marked "Chicory blended with coffee" and the proportion should be indicated.

Chicory is imported in powder form in steel barrels of one cwt. or more About 10,000 cwt. are imported annually into Bombay and Madras, chiefly from Denmark, U K., and Germany (*Rep. Marketing Coffee*, 244)

Packing—The characteristic flavour of freshly prepared coffee is due to fat-soluble principles, and proper packing to prevent oxidation changes and consequent staling is of vital importance. Packing in an inert atmosphere of carbon dioxide is considered to be most suitable, and is adopted by the principal manufacturers of ground coffee. Vacuum-packing is adopted by smaller concerns.

Manufacturers of proprietary brands of coffee use containers of 2-oz , ¼-lb , ½-lb., 1-lb , 5-lb , and 15-lb capacity Roasters who undertake despatches of powder to other firms use kerosene tins for packing

Cherry husk is sometimes used as an adulterant of coffee. About 10,000 cwt of cherry husk were reported to be so used annually before 1939. Bengal gram, *Cassia tora*, oil seeds, burnt sugar, tamarind seed, and saw dust are among other adulterants used Mysore and Coorg have prohibited the use of cherry husk for adulteration (*Rep Marketing Coffee*, 246)

Many of the adulterants can be easily detected by microscopic examination Other tests employed are determination of aqueous extract, sugar (high for the usual adulterants), fat, and caffeine (low for adulterated products). The ash of coffee is practically free from silica, while that of the common adulterants contain silica.

Pure coffee extract (1 in 10 parts of water, raised to b p for 0·5 min , filtered, and cooled) has a lower density than the extracts of adulterants including chicory The relative colouring powers of roasted coffee and chicory form the basis of a simple test for the detection of chicory in coffee powders. When a few grains of the chicory-containing sample are placed in water, a brownish cloud is observed, which diffuses through the water; pure coffee does not give any colouration. Chicory readily sinks in water. The percentage of water-soluble matter in chicory is 21—35%, while that in coffee is 75—85% (Thorpe, III, 255).

Other Coffee Products

Coffee is also marketed in the form of tablets, flake coffee, and prepared coffee. Coffee tablets

are produced in India on a small scale. Flake and prepared coffee are not manufactured. For the preparation of tablets, ground coffee is mixed with chicory powder and the mixture pressed in a tableting machine after the addition of a binding material such as glucose, to the extent of 15%. Tablet coffee is available in many sizes and shapes

Flake coffee (0·06 in diam and 0·003 in thick) is prepared by passing ground coffee through rollers under pressure The flakes are more readily extracted by water than other forms (Jacobs, I, 856).

Processed coffee is marketed as Decaffeinated or Decaffeinised Coffee in which caffeine is removed to some degree by solvent extraction The beans are then roasted and powdered Dry coffee extract or Soluble Coffee is prepared by extracting the soluble portion from ground coffee by percolation with hot water, evaporating the extract to a syrup, and drying in a vacuum drier Soluble coffee is said to be popular in U K and U S A Coffee extracts and essences are prepared by pouring boiling water on coarsely ground roasted coffee in large flat cylindrical containers fitted with filter cloth and concentrating the extract in vacuum at 170°F to the consistency of a syrup Sugar is added and the mixture diluted with water The essence is packed in bottles

Production and Trade—A rough estimate of the total production of coffee products can be made from the releases of the Central Coffee Pool Table 2 gives the estimated amount of cured coffee available for home consumption and the output of coffee powder in India [*I & S Bull*, 1950, **3** (1), 17].

The popular brands of coffee are Polsons (Royal Blend Pure, Sunlight Pure, Hotel Blend, and French), Stanes (Red Label Pure, French, White Ensign, and Red Ensign), and Brook Bond's (French and Dilkhush)

TABLE 2

	Available for home consumption (Tons)	Output of coffee powder* (Tons)
19383/9—1940/41 (av)	8,841	7,073
1941/42—1943/44 (av)	12,263	9,810
1944/45—1946/47 (av)	14,887	11,910
1947/48—1948/49 (av)	17,078	13,662

* Calculated on the basis of 20% loss during roasting

TABLE 3.—PRICES OF ROASTED GROUND COFFEE

		1 lb tin Rs as p	½ lb tin Rs as p	¼ lb tin Rs. as. p
Royal Blend, Pure (doz tins)		29-4-0	15-0-0	
French coffee	(„)	27-0-0	14-4-0	7-5-0
Maxwell House Coffee*	(lb)	4-4-0		
Nescafe†	(„)	7-0-0 to 7-8-0		

*imported brand †imported soluble coffee

Table 3 gives the prices of Polsons coffee and two brands of foreign coffee powder popular in India in February 1950

Imports—Separate data on imports of roasted and ground coffee are not available A revenue duty of 36% *ad valorem* is levied on imports of coffee, canned or bottled, from foreign countries, with a preferential rate of 24% *ad valorem* if obtained from U K

COIR INDUSTRY

Coir is an industrial fibre extracted from coconut husks and used for matting, rugs, carpets, and other types of floor covering, cordage, and twines. Long and coarse fibres are used for brushes and brooms, and short and curly ones for stuffing upholstery Coir offers immense possibilities for profitable utilization on account of its resistance to white ants Treated fibre is not disintegrated by bacteria or hardened by water It can be impregnated with bituminous and resinuous compositions and used as protective lagging for underground pipes and cables. During World War II, coir was used for making roads with good wearing surfaces

India is the largest producer of coir and coir manufactures, and excepting Ceylon, nowhere else are appreciable quantities produced The industry is located mainly in Travancore, Cochin, and along the Malabar coast Among the factors contributing to the development of the industry in this area are the existence of extensive coconut plantations and vast stretches of backwaters which are particularly well suited for retting. Coir is manufactured in smaller quantities in Mysore, Orissa, Bengal, and in the Ratnagiri and Kanara districts of Bombay.

The coir industry in Travancore provides employment to 30,000 families comprising 2,00,000 workers engaged in the extraction of fibre and spinning of yarn. In addition, 30,000 workers are

engaged in the mats and matting industry of whom about 10,000 are concentrated in Alleppey. About 40,000 workers are employed in Cochin (Mukhtar, *Rep Labour Conditions in Coir and Mats and Matting Industry*, 1945, 1) In Ceylon, the coir spinning and weaving industry employs over 50,000 workers (*Ceylon Tr J.*, 1948, **13**, 342).

Coir Fibre

The preparation of coir fibre consists in husking the coconut, retting the husk, and beating the retted husk to separate the fibre from adhering impurities. The husking is carried out soon after plucking the coconuts.

Green husks are retted in pits, the bottoms of which are covered with sand and the sides, lined with coconut leaves, adjoining backwaters. The pits are covered with coconut leaves and mud Sometimes, as in Anjengo, the husks are placed in coir nets and kept floating on water for a few days and then sunk by weighting with clay and coconut leaves. Husks may also be retted in pits connected to backwaters by canals. The tidal action of the backwaters helps to remove the decomposed binding materials, this periodical change of water being an important condition favouring retting.

In localities having no backwaters near by, retting is effected by either burying the husks, in sandy soils or by immersing them in pools of water. The husks so treated for short periods yield low grade, coarse, brown fibre with a large admixture of impurities (*Rep Panel Coir, Rope, Cordage and other fibre Industries*, 1946, 6)

Retting takes 6—10 months If properly carried out, a clean fibre of light golden colour, free from dirt is obtained. The best coir is produced in Anjengo and Paravur.

Green husks are generally used for retting Coir is sometimes made from dry husks by immersion in water for about 12 hours and beating out the fibre Green husks are sometimes directly treated for obtaining fibre without retting. The fibre obtained in this way is inferior and is known in the trade as Unsoaked Coir

A number of patented processes, e g., Nanji process, Elod and Thomas process, Rowell process, Van der Jagt process, Hayer-Gratze process, and Heparol process have been developed for retting None of these has been adopted in this country and no information is available on the relative merits of the processes under Indian conditions.

Retted husks are removed from pits, washed. and beaten with short wooden mallets or clubs to extract the fibre. The coarse and fine fibres are separated by hand. The process is laborious. An adult woman worker can handle about 45 husks in a day.

The fibres are cleaned, dried in shade, and beaten (willowed) with poles to remove adhering pith The fibres are then combed in a specially designed comber consisting of a number of flat-teethed iron blades mounted spirally on a wooden shaft revolving inside a drum This operation cleans, straightens, smoothens, and softens the fibres and lays them parallel to one another. A yield of 1 candy (672 lb) of fibre is obtained from 3,500—4,000 nuts (*Rep Panel*, 7)

Coir fibres thus prepared are graded into 3 classes, viz, mat fibre, curled fibre, and bristle fibre. The bulk of the fibre produced in India is mat fibre which is suitable for spinning into yarn and manufacturing mats, ropes, and twines. Curled fibre is obtained mostly from unretted husk and the yield is low It is mostly used in upholstery. Bristle fibre which is coarse and thick is not prepared in India, the country's requirements being met by imports from Ceylon. Clean mat fibre is pressed into bales of 200—224 lb. for export.

Coir Yarn

Spinning of coir yarn is a cottage industry in Travancore, Cochin, and Malabar. The yarn is spun either by hand or by wheels Hand-spinning is common throughout Malabar, while spinning by wheel is common in many places in Travancore. All the yarns are two-ply.

In hand-spinning, the fibre is rotated between the palms with a clockwise twist and when of sufficient length, the threads are taken in twos and twisted together in the opposite direction The spun yarn is held in position by the toes while other slivers are prepared and added. 4—5 lb of yarn can be made by one worker in a day of 8 hours. Combed fibre is not used for hand-spinning.

Wheel-spinning is controlled by petty capitalists Two wheels are used, one containing two spindles is fixed to the ground, and the other with one spindle is movable A group of three workers is required for spinning, one to turn the stationary wheel and two to make the strands which go to make the yarn. Each worker starting from the fixed wheel spins the fibre to the requisite thickness, the stationary wheel being rotated to give the necessary twist. When the strand is 50—60 ft long, the fixed wheel is stopped and the two free ends of the strands are hooked to the single spindle of the movable wheel which is then gently rotated to give the two-strand yarn a twist in the opposite direction. As the yarn is being

made, this wheel is moved towards the fixed wheel. A triangular block of wood grooved on the sides is held between the strands to regulate the counter twist, prevent knots and kinks, and bind the strands close (Sharma, *Coir Industry in Travancore*, Bull. Dep. Industr. Travancore, No. 31, 1932, 9). About 100 strands each of 50 ft. and weighing approximately 25 lb. can be produced by a group of three workers in one day.

Hand-spun yarn is soft, and the twist and thickness are even, while wheel-spun yarn has a hard twist and lacks evenness.

The quality of yarn is judged by the thickness, colour, appearance, twist, and strength. The different varieties are known by the place of manufacture. The well known varieties produced in Travancore, Cochin, and Malabar, and known to the trade are:

TRAVANCORE — *Anjengo superior, Anjengo ordinary* or *Mangadan, Ashtamudi, Alapat, Aratory, Vycome,* and *Beach.*

COCHIN — *Fine weaving yarn* (soft twist), *Rope yarn* (soft twist), *Vycome, Parur,* and *M. K. yarns.*

MALABAR — *Beypore, Quilandy, Calicut* (fine unsoaked) and *Div yarn* (from Laccadives and Maldives).

Excepting *Alapat, Vycome, Beach, Beypore,* and *Quilandy* yarns, all others are hard-twisted. The varieties common in Calicut and Ponnani markets are *Kadalundi, Ponnani, Chowghat, Ariyalur, Kallai,* and *Parapangadi* grades; these are all hand-spun weaving yarns. In Ceylon, coir yarn is sold in two grades, *Kogalla* and *Colombo,* with sub-divisions according to texture and thickness. Superior grades are further classified according to fineness and evenness of twist, and sub-divided according to colour into 2 or 3 grades. Cheaper types are sub-divided into grades denoted by numbers according to their colour, evenness of twist, and amount of pith (*Rep. Marketing Coconut and Coconut Products,* Marketing Ser. No. 46, 1944, 140).

The most important types of wheel-spun yarns are *Anjengo, Aratory,* and *Ashtamudi,* while *Alapat, Vycome,* and *Beach* are the best known among hand-spun yarns.

Beach yarn, produced from imperfectly retted husks, is of low grade, contains a large quantity

Fig. 53.—Sorting of coir yarn

of pith, and is reddish brown in colour. Its tensile strength is also low. Cochin yarn is somewhat coarser and is mostly exported; a few superior types are now being produced. About 40—50% of the yarn produced in Cochin is rope yarn. A small quantity of *Vycome* yarn is utilized in making mats and mattings. Malabar yarn is mostly hand-twisted; weel-spun yarn is now being produced in increasing quantities.

The sorted yarn is sold to wholesale dealers in cylindrical bundles of one local maund or multiples thereof. These reach the main assembling and distributing centres, e.g., Alleppey and Cochin, which are the principal production centres of mats and carpets. Some of the exporting firms and manufacturers have their own agencies to collect yarns from producing areas and to grade and reel them into hanks. The yarn for export is regraded and reeled into hanks of 450 yds., each weighing 2½ lb., and hydraulically pressed into bales of 3 cwt. Inferior grades are made into *dholls* of 5 or 7 lb. for transport in cargo boats as broken stowage. For inland markets the yarn is made into bundles.

Coir yarn of superior quality is used in the manufacture of mats and mattings, rugs, and carpets. Inferior varieties are used for ropes. Coir bags made of Travancore yarn are used in tea gardens for transporting tea leaves, and for lifting coal from mines in Bengal, Assam, and Central India (Patel, 239). Coir beltings were used as substitutes for leather belting which became scarce during World War I. Coir screenings were used for camouflage purposes.

Mats and Matting

The mats and matting industry is well established in Travancore. The industry which was confined to Alleppey until 1914, has since extended to most of the villages of the Malabar coastal area. In 1938 there were 249 factories in the villages and 41 in Alleppey town. The total number of matting looms and mat looms were 4,335 and 7,350 respectively, Alleppey's share being 2,374 and 2,180. In December 1944, the total number of factories, large and small, increased to 360 including 46 in Alleppey town. The smaller factories, with low labour and capital costs, are in a position to compete with factory products (*Rep. Board of Conciliation of Trade Disputes in the Mats and Matting Industry, Trivandrum*, 1939, 83; *Mukhtar*, op. cit., 2; *Rep. Panel*, 3). There are three small factories in Cochin. Mats and mattings are also manufactured to a small extent in Malabar district and in Bengal.

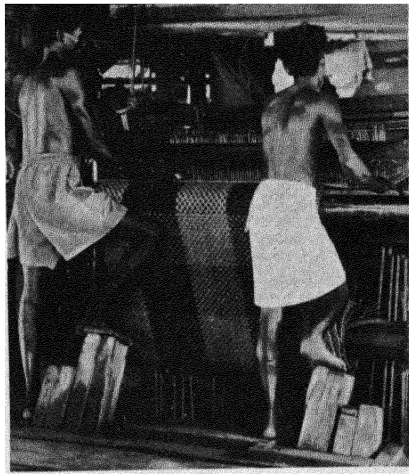


Fig. 54.—Weaving of coir matting

Mats are woven on wooden handlooms. Powerlooms are scarcely used as due to the coarseness of the fibre, shuttles take but short lengths of yarn and need frequent replacement. Wheel-spun yarn is mostly used for warp and hand-spun yarn for weft.

Processed yarn obtained by treatment with dilute sulphuric acid, washing, and drying in shade is used for better varieties of mats. The quality of matting is judged by the number of warps for a standard width of 36 in.

The yarn is first wound on bobbins and transferred to a creel. The warping is done between sticks or by means of a peg board, the yarn from the bobbins being passed on to the warping drum and the requisite width prepared by warping the sections on a weaver's beam which is then fixed to the loom.

There are many types of matting, the more common ones being two-shaft and four-shaft mattings. In the former, the warp yarns are held in two frames which alternately go up and down, and a weft is passed between the shed every time they move. The matting will be plain or striped according as the warp is of one colour or of different colours. Four frames are used for four-shaft matting in which simple repeat designs such as 'diamonds' are produced. Jacquard

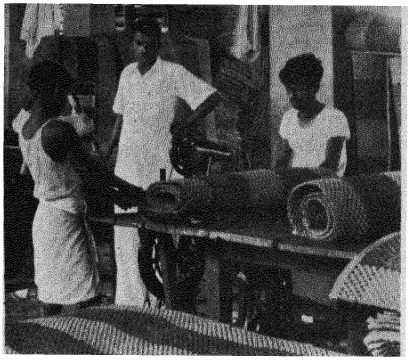


Fig. 55.—Stitching coir rugs

cards and Dobby machines required for complicated designs are rarely used. Coloured designs on mattings are obtained by the use of coloured yarns.

Mattings, rugs, and carpets made in a large variety of patterns and designs provide attractive and damp-proof floor coverings. The standard trade size for matting is 36 in. × 50 yds. Matting is also available in widths of 9 in. or multiples up to 72 in. Both plain and fancy mattings are available in 50 yds. rolls, which are wrapped in hessian cloth for despatch to markets.

Jute floor coverings are now competing with coir products. The latter are superior by virtue of their hard-wearing and damp-proof qualities.

Brush door-mats—plain, 'inlaid' or 'fancy'—are generally made from inferior yarn, usually *Beach*. The superior *Vycome* yarn and imported hard fibre from Ceylon are also used. They are woven on a simple loom on which the warp is tightly drawn and the rows of tufts for the pile are inserted simultaneously with weft weaving. To quicken the process of inserting tufts, a device consisting of a slotted iron rod, sufficiently long to cover the width of the warp, is employed. The tuft strand is wound round the rod which simultaneously passes underneath alternate warps. A thin knife edge is inserted into the slot which is held upwards and drawn along the whole length of the rod cutting the strand whereby a complete row of tufts is formed. The weft is then knocked in, which along with the warp forms a firm base for tufts. Any desired pitch of mat can be made ranging between 600 and 1,200 tufts per sq. ft. depending upon the fineness of the warp thread and of the tuft yarn, number of warp threads per foot of the loom roller, and the closeness of the knocking in. The mats are then cut to the required lengths and braided. They are next dried, sheared, and finally trimmed and sometimes bleached. The colour designs are then stencilled.

The design for inlaid mats is traced on ruled papers in which each tuft knot is represented by a square. Wherever the design cuts a row of tufts the winding of the tuft yarn is stopped and yarn of the required colour inserted. The work is slow and demands considerable skill on the part of the operators.

For finer qualities of plain and fancy door mats, unspun coir is used for piles. Two warp beams, one above the other, are used. The warp on the lower beam is drawn taut on the loom and is manipulated by two heald frames taking alternate threads. The upper beam has two weighted coiled ropes. Small sheaths of fibre are knotted around the strings of the lower layer of the taut warp, a weft is knocked in, and the positions of the heald frames changed. Then the lower layer of the taut warp and the loose warp of the upper beam are woven together with the weft forming a backing for the mat. Designs are woven by using fibre sheaths of various colours. After weaving the mats are stitched and braided, sheared by machine, and finally trimmed with

Fig. 56.—Clipping of fibre mats

scissors to give a good relief to the pattern. Fibre mats are made in attractive designs. Mats of poor colour are bleached before packing. These products are more expensive than ordinary brush door-mats.

Creel-mats are warp-piled fabrics Loose and tight warps are employed as in the case of fibre mats. The loose warp is carried over a slotted rod to form loops while the texture is woven with the taut warp and weft The loops are cut into tufts by a knife inserted in the slot of the iron rod and facing upwards.

Other Coir Products

Shock-proof packing material for ammunition boxes has been made from coir and linseed oil. A process for producing such material has been developed in the Laboratories of the Council of Scientific and Industrial Research Hard boards resembling Masonite have been prepared from coir. The boards are suitable for table tops, doors panels, and battery containers Attempts were also made to make moulding powder containing coir dust (*J sci industr. Res.*, 1943-44, **2**, 174).

Large quantities of coir dust are available from the coir industry and its proper utilization has been the subject of investigation in India, Ceylon, and Puerto Rico About 1½ candies of pith, short fibre, and outer skin are obtained as by-products for every candy of coir yarn manufactured. A part of the dust is now used as fuel. Coir dust or cocopeat can be utilized as packing, stuffing, and heat-insulating material. It has been used for improving soil drainage and as a mulching, rooting, soil conditioning, and seed germinating medium (Hume, *Econ. Bot.*, 1949, **3**, 42)

Production and Trade

The estimated production of manufactured and unmanufactured coir during pre-War years was Madras, 25,038 tons, Travancore, 80,000 tons, Cochin, 17,000 tons, Bengal, 225 tons. These figures are approximate, and are based on exports. During World War II, the production declined owing to the closing down of normal markets, shortage of labour, and uneconomic returns. The Panel on Fibre Industries recommended a post-War target of 2,29,125 tons of manufactured and unmanufactured coir made up as follows. Travancore, 1,00,000 tons, Madras, 1 00,000 tons, Cochin, 19,000 tons; Bombay, 7,500 tons, Mysore, 2,400 tons; and Bengal, 225 tons (*Rep. Panel*, 8, 10).

Owing to the stoppage of supplies of Manila and sisal during the War years, coir fibre and yarn found many new applications.

TABLE 1.— AVERAGE PRICES OF COIR PRODUCTS*

Fibre (per cwt.)	Price Rs.	a.	p.
FFF	40	0	0
FF	37	0	0
F	34	0	0
Coir yarns (per cwt.)			
Anjengo†	65	0	0
Aratory	55	0	0
Vycome	45	0	0
Coir Mats (per sq. ft)			
L. B	0	9	6
M. B.	0	15	6
C. L. X	0	8	0
Coir Matting (per sq yd.)			
Anjengo diamonds	2	8	0
Anjengo tiles	2	9	0
Anjengo stripes	2	4	0
Aratory diamonds	2	1	0
Aratory tiles	2	2	0
Aratory stripes	1	15	0
Vycome diamonds	1	13	0
Vycome tiles	1	13	0
Vycome stripes	1	9	0

* all prices are f o r Alleppey

†The present (Jan. 1951) price is Rs. 83–11–0/cwt.

Prices —The average market prices of different qualities of coir products in November 1949 are given in Table 1

As compared to the prices for coir products in the earlier part of the year, the prices recorded in Table 1 are high, in some cases the prices increased by 100%. There has been a steady rise in the prices, the main reasons for which are the short supply of retted husk and the increased demand in U K , Germany, and Holland

Exports —Coir products for export are shipped mainly through Alleppey and Cochin ports. Tables 2 and 3 give the volume and value of goods exported from Travancore (mainly Alleppey port) and the rest of India (mainly Cochin port).

The export of coir yarn has been fairly steady. During the period 1928-29 to 1937-38, the annual export averaged 1 million cwt. On account of the high duty on coir manufactures, most of the European countries import yarn, the major part (80%) of which is used for the production of mattings.

TABLE 2 —EXPORTS OF COIR GOODS FROM TRAVANCORE*
(1,000 cwt. and lakh Rs)

	Fibre		Yarn		Mats & Mattings		Other Sorts		Total	
	Qty	Val	Qty	Val.	Qty.	Val.	Qty	Val.	Qty	Val
1935/36—1938/39 (av)	2 2	0·16	205 0	21·32	235·8	51·68	109 7	26·81	552·7	99·97
1939/40—1941/42 (av)	6·2	0 32	128 9	12 98	96·5	19·69	72 5	19 74	304·0	52·73
1946–47	—	—	14·0	6 56	3·5	3·57	4·1	4 52	21·6	14·65
1947–48	—	—	137·3	72·23	31·2	23·22	37·9	44 23	206 4	139·68
1948–49	—	—	156 1	74 83	93·5	61·38	62 2	72 09	311·8	208·30

**Trade Statistics relating to the Maritime States in Kathiawar and the State of Travancore*

TABLE 3 —EXPORTS OF COIR GOODS FROM THE REST OF INDIA
(1,000 cwt and lakh Rs)

	Fibre		Yarn		Mats & Matting		Other Sorts		Total	
	Qty	Val	Qty	Val	Qty	Val.	Qty	Val	Qty	Val
1934/35—1938/39 (av)	2 7	0 24	578 0	58 52	58·0	20 45	23 3	8 81	662 0	88 02
1939/40—1943/44 (av)	10 6	0 75	427 3	45 88	122·9	33 87	41·8	12·78	602 6	93 28
1944–45	6·8	1·26	396 0	89 78	223·6	102·77	1·1	0 86	627 5	194 67
1945–46	7·5	1 52	452 4	120·85	276·1	163·27	26 5	12·11	762·5	297·75
1946–47	12·4	3·34	589 0	223 85	436·7	323 95	34·9	30·46	1,073 0	581 60
1947–48	7 0	2 36	750·0	322 55	194·0	172 75	26 6	30 30	977·6	527 96
1948–49	9·6	2 93	695 1	298·31	159.8	134 21	14·4	14·14	878 9	449 59
1949–50	8·8	2·59	1,089·2	324·06	366·0	257 62	92·7	83 30	1,556·7	667·57

The shares of various countries in the purchase of coir yarn from Travancore during 1938-39 were Germany, 23 0, U.K, 22 7, Netherlands, 11 9, Burma, 9 5, Italy, 9 0, Belgium, 4 9, Austria, 4·3; and U S.A, 3 3%. The figures for coir mats and mattings were U K, 73·1, Austria, 6 1, U.S A., 4·4; and New Zealand, 4·3% There were no exports of coir goods from Travancore during the years 1943-44 to 1945-46 The exports have since been resumed. During 1947-48, U.K. imported 56 2% of yarn and 48·7% of the matting exported from Travancore. Netherlands imported 25·5% of the total yarn and, U S.A. and Austria imported 19·2% and 17·8% respectively of the matting exported from Travancore. The shares of U K. during 1948-49 were: yarn, 50·6%; mats and mattings, 53·4%.

As regards exports from the rest of India, the principal customers for coir yarn during the year 1938-39 were: Germany, 24 6; U.K., 14·2; Netherlands, 12 4; Burma, 8·8; Belgium, 7·4; France, 6·3; Italy, 4·8; U.S.A., 4·5; and Portugal, 3·5%. The shares in the exports of coir mattings during the same period were U K, 66 4; Australia, 8 3; U S A, 7 2, Canada, 3 4, and South Africa, 2·4%. During 1949-50, the shares in the exports of coir yarn were. U K, 16 3, Netherlands, 16 1, Burma, 14·7, and U S A, 4·9%, the shares in exports of mats and mattings for the same period being· U K, 63 9, U S A., 13·9, Australia, 11 5, and New Zealand, 1·4%

Only about 60% of the coconut husks available in Travancore and Cochin are at present utilized The husks from the hinterland are not used owing to the lack of retting and transport facilities Improvement in transport would facilitate the movement of husks to the backwater areas Only 3—4% of the husks available in Bombay, and 0·06% of those available in Bengal are at present utilized for coir manufacture (*Rep. Panel*, 20).

An important requirement of the coir industry is grading. In the absence of grading and standardization coir is not likely to find a place among

the industrial fibres quoted in foreign markets The Travancore Government have sponsored a Ware House Bill with a view to grading the product. There is also need for introducing a common standard of weights throughout the coir-producing areas. At present fibre and yarn are measured in candies and maunds which differ from place to place.

COMBS

Combs are among the many articles of daily use, and on account of wear and tear necessitating frequent replacement, they are produced in large numbers Combs are made in several shapes and sizes to suit varied requirements and tastes They may be classified under these groups dressing combs, rat-tail combs, utility combs, fine combs, pocket combs, and bobby combs The raw materials for their manufacture include wood, horn and bone, celluloid, and plastics Metal, ivory, and sandalwood combs are not uncommon in India.

Wooden Combs

Wooden combs, such as those used by Sikhs and Burmese ladies in their hair, form an important industry in India. Combs of high quality are made of box wood (*Buxus sempervirens*), haldu (*Aldina cordifolia*), and sandalwood (*Santalum album*), while cheaper combs are made of Bel (*Aegle marmelos*), *Carissa* spp, *Crataeva religiosa*, rosewood (*Dalbergia* spp), ebony (*Diospyros* spp.), *Gardenia* spp, Gomari (*Gmelina arborea*), *Holarrhena antidysenterica*, Kanju (*Holoptelea integrifolia*), *Olea ferruginea*, Kaira (*Mitragyna parvifolia*), and *Wrightia* spp Other woods used locally for combs are horse chestnut (*Aesculus indica*), Shaitan wood (*Alstonia scholaris*), Salai (*Boswellia serrata*), *toon* (*Cedrela toona*), *Celtis australis*, *Givotia rottleriformis*, *Melia indica*, *Pistacia integerrima*, Padauk (*Pterocarpus* spp), and *Tecoma undulata* (Trotter, 1940, 175)

The manufacture of wooden combs is essentially a cottage industry The instruments required are a saw, a lathe, and a cold chisel. The wood is first soaked in water and cut into the required shape. The teeth are cut manually by a fine saw, and the comb finally cleaned and polished. Haldu combs are sometimes coloured black. Ebony combs are generally carved and given a coating of oil. A cubic foot of wood gives 600—700 combs and one person, in a day, can cut into shape about 250 combs, or cut teeth on about 250 combs, or clean and polish about 500 combs. Statistics relating to production and trade are not available.

Wooden combs are manufactured in or near centres of pilgrimage, such as Tirupati and Rameswaram, in Madras. Nallabalum, Mekkani, Nekki and Nallabalasa (*Canthium* spp) woods are commonly used.

In U P wooden combs are made in Agra, Allahabad, Bijnor, Pilibhit, and Saharanpur districts The wood used is mainly haldu and ebony, and to a smaller extent, Papri, Kaima, and Khinni or Dudhi, and Farrash The finished products are sent to Delhi, Rajputana, Calcutta, Bombay, Madras, and to various places in U P

The manufacture of combs was, until recently, a flourishing industry in Amritsar The industry is reported to be dying out

Amalner in East Khandesh district of Bombay is a reputed manufacturing centre of wooden combs Black sisal obtained from West Khandesh is the wood employed

Horn Combs

The raw material employed is buffalo horn, which is abundantly available in Madras, Orissa, and Hyderabad The material obtained from Madras is considered to be of good quality, and is in great demand by manufacturers in Midnapore The principal centres of the horn comb industry lie in Ganjam district (Orissa), Midnapore district (West Bengal), and Hyderabad.

Only the hollow portion of the horn is used in comb making, the solid portion at the base being rejected. The instruments required are cutting saws, *Biash* for chiselling the outer portions of the horn, curved chisels for cleaning the inside of the horn, tongs, wooden presses, saws for shaping, tooth files, tooth cutting saws (big and small), and scrapers (Dep Industries, Bengal, *Rep. Bengal Industrial Survey Comm*, 1947, 154) The hollow part of the horn is sliced crosswise and heated in a luminous flame to render it plastic It is then pressed between two wooden frames and soaked in water for about 24 hrs. The softened horn is taken out from the water, re-heated, and pressed. The pressed material is planed with adzes and rasps and roughly shaped with the help of a template. The sides of the blank meant for toothing are levelled with rasps and the body of the comb is given the final shape and the required polish with the help of rasps and scrapers Toothing is done manually in three different operations with tenon saws The comb may be further treated to give an artistic finish. The polishing is generally done by womenfolk with the help of the dry leaves of Gharasana (*Pterospermum suberifolium*) tree. These leaves act like fine-grained sand-paper, and the treated combs are finally polished with wood charcoal.

The time taken for making one comb is 10–30 minutes depending upon the size of the article and the type of finish given

Cuttack and Parlakimedi (Ganjam district) have long been the principal centres of horn comb industry in Orissa The industry has recently spread to Bilaspur Comb making is mostly a cottage industry and no unit employs more than 10 persons The total quantity of buffalo horns consumed is about 40 tons per year, the total output of combs being 7 tons Waste pieces and fragments are used for making buttons and other small utility articles Knife-shaped, bracket-shaped, rectangular and many other forms with single or double tooth strips, plain, or artistically finished, are manufactured A type, locally called Telapura comb has in it a reservoir for oil so that hair is automatically oiled during use Combs made in Orissa are exported to Bombay, Calcutta, and many other market centres

The horn comb industry of Bengal was a flourishing cottage industry prior to the introduction of celluloid and plastic combs Daspur (Ghatal sub-division) and Paskura (Tamluk sub-division), both in Midnapore district, are now the main centres of production More than 6,000 persons are at present employed by the industry

The combs are cheap and of fair quality. During World War II, these centres supplied a large part of the requirements of the Defence Services It is estimated that no less than 30,00,000 pieces were produced between 1942 and 1946 and supplied to the Government of India through the Directorate of Industries, Bengal The demand has considerably declined in recent years The present estimated monthly consumption a raw horns is stated to be 3,000 mds (Information from Department of Industries, West Bengal)

Horn combs are manufactured to a small extent in Sambhal in Moradabad district (U P.) and in a few other places in U.P.

Celluloid and Plastic Combs

Celluloid is now extensively employed for comb manufacture Prior to World War II, celluloid combs of various descriptions were being manufactured on a fairly large scale in Calcutta and Jessore from rods and sheets imported from Japan

Celluloid sheets of proper thickness are sawn into suitable sizes and smoothened by warming under gentle pressure The teeth are cut as in the case of horn combs. The combs are polished with pumice and tripoli powder, water being allowed to drop on them to prevent heating and softening Fancy combs are shaped after softening in hot water or occasionally over a charcoal fire. Cheaper combs are made by warming hard-dried thick plates and cutting the teeth in a stamping press The resulting products have teeth devoid of taper A better product is obtained by stamping out the teeth from freshly prepared plates. The finished combs are dried without warping in a suitable apparatus.

Plastic combs are now manufactured mostly from thermoplastic materials The raw materials used in India include polystyrene imported from U S A and Canada, and cellulose acetate, imported from U K

A sizeable plastic comb industry exists in Bombay and in Calcutta Polystyrene articles possess high dimensional stability and negligible water-absorption They combine rigidity with good mechanical strength, and articles of sparkling clarity or of any desired colour can be produced. Since they are light, more pieces per lb are obtained

Plastic combs are manufactured by injection moulding Measured quantities of moulding power are fed into an electrically heated injection cylinder The granules softening under heat and pressure in the cylinder are forced through an orifice under high pressure into a closed and tightly locked comb mould The mass hardens into shape by cooling in the cavity of the mould. The mould is opened and the article ejected or removed The machine has automatic controls and all operations are performed in a continuous and fast cycle of 15–45 sec Comb moulds contain multiple cavities varying from 2 to 24, and the number of combs per cycle varies accordingly

Approximately 350,000 gross of plastic combs of all types are said to be manufactured annually in India The manufactured types include pocket combs, 5 in and 5½ in long with fine and coarse teeth, pocket combs, 5 in. long with all fine teeth, gents' and ladies' combs, 7 in long with coarse and fine teeth, gents' comb 7 in long with all fine teeth, gents' comb, 8½ in. long with coarse and fine teeth; barber's comb, 7½ in long with coarse and fine teeth, and dandruff (double sided) combs with fine teeth.

Miscellaneous Combs

Ivory combs are manufactured in Mysore, Travancore, Cochin, Jaipur, and Poona These are expensive and are used only by the rich. Combs made of sandalwood are made in Mysore, and sold in all places in India.

The best material for combs is said to be tortoise shell which, however, is expensive.

TABLE 1 —IMPORTS OF HAIR COMBS FROM U K.*

	Qty. (gross)	Value (£)
1942	10,947	14,156
1943	563	1,169
1944	18,051	38,051
1945	36,460	96,578
1946	97,056	247,867

*Tr U K

Vulcanite is an excellent substitute for tortoise shell, but a proper selection of the material is essential and the space between the teeth should be grooved. Metal combs are not popular

Separate statistics of imports of combs into India are not available Vulcanite combs were being imported from Austria into India in pre-War years Table 1 gives the import from U K. of hair combs and blanks during the 5 years, 1942-46

CONCH SHELL INDUSTRY

Bangles, bracelets, armlets, and other trinkets made of conch shell (Hindi—*Sankha*) have been used for centuries as adornment by Hindu women and a sizeable industry has been in existence particularly in Bengal

The main centres of production are Nadia, Bankura, and Burdwan districts of Bengal Calcutta also is an important centre of production and the main emporium for gathering the raw material from *chank* fisheries in south India and Ceylon. The work is carried out by Shankaris or conch shell artisans on a cottage industry basis. In the south, Pamban, on Ramnad coast, was once a centre of conch shell products

The *chank* required by the industry is drawn from the fisheries in Tinnevelly (Tuticorin fishery), Ramnad, the east coast (south Arcot and Tanjore), Travancore, and Kathiawar. A large quantity of *chank* is obtained also from the fisheries in the north of Ceylon. Travancore shell or Doani is of excellent quality and is highly valued on account of its white colour and uniform size Shells from Tuticorin and Baroda come next Ceylon shells have a reddish hue and are utilized in making bangles of the cheaper quality. A small quantity of *chank* is imported also from Japan

Large-sized and fully formed shells are required for producing bangles of high quality. Generally, four bangles are cut out from each shell, occasionally, if the size of the shell is large enough, 6 or even 8 bangles may be cut from one shell. The two middle bangles form a pair. The two side bangles cut from one shell form sets with the corresponding side pieces cut from a similar shell.

In the manufacture of bangles, the spiral core inside the shell is first removed and this operation is carried out by expert artisans. The shell is held by the feet, as in a vice, and dextrously cut with a large and rather unwieldy form of saw to the required shape. A machine for cutting conch shell bangles by a powder-driven disc has been developed by the Department of Industries, Bengal, and is now in use (Mitter, *Bull. Dep. Industr, Bengal*, No 24, 1927) The outer surface of the cut rings are polished by rubbing against a flat sand-stone and the inner side by rubbing against a sand-covered mandrill The decorative work is carried out by artisans with simple tools.

Bangles and bracelets are delicately formed and neatly ornamented with notches on the edge and various designs along the centre. They may be decorated with bands of gold filled into carefully drilled grooves They may be set with pearls, rubies, and other precious stones. More usually they are given variegated colour designs, the popular colours being shades of red and green Coloured lac is melted and filled into the grooves of the engraved pattern, the excess being removed by dressing and polishing.

From the pieces of shell left over after the bangles are cut out, rings, buttons, chains, and toy figures are made Beads are made from the spirals The chippings and filings are sold to lime manufacturers The filings are believed to have therapeutic properties and are used by indigenous physicians for medicinal purposes

Data relating to the total outturn of the industry are not available The total consumption of raw materials and total annual production in undivided Bengal were estimated to be worth Rs 32,600 and Rs. 10 lakhs respectively; the number of workers engaged in the industry was 2,000 (Dep Industries, Bengal, *Rep Bengal Industries Survey Comm*, 1947, 151).

Changing fashions and high prices of *chank* products are responsible for the decline of the industry. The raw material which has to be transported over long distances accounts for 60% of the cost of production

CONFECTIONERY

Confectionery or sweetmeats are preserved edible delicacies consisting of a solid or crystalline phase and a liquid or non-crystalline phase, the relative proportions of which determine the

type of confectionery. The principal types of confectionery are hard boiled goods, caramel and toffee, satin goods, comfits or dragees, and lozenges. Indigenous confectioneries include Mithai, Rasagollas, Sandesh, and crystallized fruits

Sugar is the principal ingredient of confectionery. In pre-War years, approximately 15,000 tons of sugar were utilized annually in the manufacture of boiled sweets (*Rep Marketing of Sugar, India*, Marketing Ser No 23, 1943, 126) The industry received a great impetus during World War II, due to restrictions on imports and increased demand from the Defence Services 8,300 tons of sugar were allocated annually to 33 sugar factories for the manufacture of sugar confectionery on a large scale After the cessation of hostilities, a few confectionery factories closed down, while others expanded production and re-equipped the factories with modern machinery In 1946, there were 30 important confectionery factories in the country distributed as follows U P 15, Bihar 6, Bombay 4, Sind 2, Madras 1, Punjab 1, and Bengal 1 In addition, a large number of small concerns were producing sugar confectionery with indigenous equipment The principal confectionery manufacturers are *Daurala Sugar Works*, Daurala, *Parry & Co*, Madras, *C. & E Morton (India)* Ltd, Marhowrah, *Parle Products Mfg. Co*, Bombay, *Pure Products and Madhu Canning Ltd*, Bombay, *Dr D Writer & Co*, Bombay, *J B Mangaram*, Gwalior, *Deccan Sugar & Abkhari Co Ltd*, Samalkot, The *Ravalgaon Sugar Farm, Ltd*, Ravalgaon, *G G Industries*, Agra; *Rohtas Industries*, Dalmianagar, *Lily Biscuit Co*, Calcutta, *Swastika Confectionery*, Bihta, *K. C P Ltd*, Madras, and *Southern India Confectionery*, Kumbakonam The biggest factory, owned by *Parry & Co* (*East India Distilleries and Sugar Factories Ltd*), has an annual capacity of 30 million lb, and produces about 5 million lb of sweetmeats per year

Raw Materials

The principal ingredients of confectionery are sugar, flavouring materials, and colours. Sweetening agents other than sugar used in confectionery are corn syrup, sugarcane juice syrup, sugar syrup, golden syrup, molasses, and honey Other raw materials used in confectionery are pectins and gums, starch, cereal flours, and various kinds of nuts and fruits

White crystal sugar with a polarization value of 99·9° is suitable for the manufacture of quality confections. Amorphous sugar is used in the manufacture of toffees and other confections which are non-gritty to the palate. It is prepared by rapidly cooling a highly supersaturated solution of sugar under vigorous stirring.

The use of corn syrup permits a greater holding of dissolved sugars Fondants made with corn syrup contain more than 84% sugar in the liquid phase as against 67% in preparations made only with sucrose The high sugar concentration prevents fermentation and drying Glucose with a high dextrin content is preferred for toffee Corn syrup should be crystal clear, should not contain more than 18% water, and should not change colour when boiled The annual requirement of corn syrup for sugar confectionery has been estimated at 3,000 tons

The flavour of confectionery is of importance as it influences not only the sense of small and taste, but also the 'mouthfeel' or the physical effect of the food in the mouth (Jacobs, I, 835) The flavouring essences commonly employed are vanilla, lemon oil, orange oil, peppermint oil, menthol, coumarin, and other natural products Honey is also used as a flavouring agent Synthetic flavours consisting of esters, ketones, alcohols, etc, simulating the distinctive aromas of fruits like strawberry, raspberry, pineapple, lemon, orange, and banana are also used Acid taste is imparted by the addition of tartaric, citric, malic, acetic, and lactic acids When citrus oils are used for flavouring, it is usual to add citric acid to give the sour taste Modified chocolate imparts a bitter taste, in high class confections especially those flavoured by citrus oils, naringin is added to give the bitter taste and to enhance the piquant flavour (Jacobs, loc cit)

A variety of natural and synthetic edible colours are employed for colouring confectionery The colours are incorporated in the form of pastes or in glycerine suspensions The confection is usually given the colour of the fruit or flower whose flavour has been reproduced Synthetic colours used are Indanthrene Blue FCF and Indigotine for blue shade, Guinea Green B, Light Green SF Yellowish, and Fast Green FCF for green shade; Orange I and Orange SS for orange shade, Ponceau 3R, Ponceau SX, Amaranth, Erythrosine, and Oil Red XO for red shade, and Naphthol Yellow S, Nahthol Yellow S-potassium salt, Yellow AB, Yellow OB, Tartrazine, and Sunset Yellow FCF for yellow shade They should be absolutely pure and free from harmful impurities particularly traces of arsenic and heavy metals. They should have high fastness to heat. Common natural colours used are carmine, caramel, saffron, turmeric, and cochineal

Gums and gelatine are also used in confectionery Gum arabic acts as a stabilizer; it prevents crystallization of sucrose and thickens the

mix Gum tragacanth is used along with gum arabic in lozenges. Gelatine of edible quality, in sheet or powder form, is used in pastilles. For pan goods and caramel confectionery, flour and starch are required. Corn flour is used as dusting powder and in moulding. Nuts commonly used in coated confections are almonds, peanuts, walnuts, and cashew nuts Among the seeds used are caraway, aniseed, and fennel.

Invert sugar is usually added for cutting the grain or preventing graining, which normally occurs when supersaturated solutions present in sugar boilings are cooled down It is obtained by the hydrolysis of 96% acidified sugar solution (pH 3—4) with invertase The acid is neutralized with soda ash to approximately pH 6 Dextrose crystallizes out, and the mass is beaten to produce a semi-plastic creamy product The addition of invert sugar slows down the crystallization rate of sucrose Glucose (corn syrup) is also used for this purpose Cream of tartar (potassium acid tartrate), acetic acid, tartaric acid, or citric acid are sometimes added to the mix to hydrolyze a portion of sucrose to invert sugar Excess invert sugar produces a soft product

With the exception of corn syrup, flavours, and colours, all the other raw materials required in the confectionery industry are available in India Attempts have been made to produce corn syrup in starch factories in India, and small quantities were produced during the period 1943—46 The production has now stopped due to shortage of maize supplies

Manufacture

The simplest form of sugar confectionery is hard candy or hard sugar boilings, e g, acid drops, pear drops, bulls'-eyes, etc A solution of cane sugar, to which invert sugar or glucose, or a chemical reagent ('doctor') for bringing about partial inversion is added, is cooked in a steam-jacketed kettle, and transferred under suction to a vacuum cooker and concentrated Vacuum boiling gives a light coloured product A supersaturated sugar solution with a glass-like consistency is obtained The product is quickly cooled by spreading on an oiled, water-cooled table or plate Flavouring and colouring materials are added and the product thoroughly mixed It is cut into shapes by frame cutters In the open-fire boiling process, a certain amount of caramelisation takes place which imparts a characteristic flavour to the product For mass production, the mix is passed as a thin film over heated coils in a steam-jacketed cooking tube, then to a revolving cooling table, whence to drop rollers

A particular variety of hard sugar boiling is the so-called Pulled or Satin Goods or Satinettes In their preparation, the cooled sugar boiling is kneaded, pulled and lapped a number of times during which treatment tiny air bubbles are incorporated into the mass The appearance of the product depends on the duration of pulling. Short pulling gives a satin, silk-like finish; prolonged pulling and lapping imparts a chalky appearance

The cooking temperature for hard boiled products is 300-310°F A lower temperature (280-290°F) is employed for the preparation of pulled or satin goods The maximum temperature employed in vacuum boiling for hard boiled products is 260-270°F; the temperature for pulled products is somewhat lower

Hard and pulled goods may be employed in the production of Filled Goods Pulled candy of different colours are arranged on a table to give the required design on rolling, the batch is rolled in an automatic batch feeder by tapered rollers into a rope, which is passed through sizing rolls, cut, and moulded into different shapes in automatic machines The goods are dried by air and twist-wrapped To produce Soft-centred Products, honey, jam, chocolate, etc, are introduced into the sugar batch before the rope leaves the batch former with the result that the filling is surrounded by a uniform casing of sugar

Caramel and toffee contain milk and butter in addition to the usual ingredients, the former being softer, in the commoner varieties, butter is partly or wholly replaced by coconut or cacao butter or margarine In the manufacture of caramels, butter and milk are emulsified in a homogenizer to a creamy product, and added along with other ingredients—icing sugar, corn syrup, corn flour or cashew powder—to the boiling pan fitted with mechanical stirrers The mixture is cooked (260—280°F) rapidly The material is poured on oiled slabs, flavoured, and moulded by casting. Low grade caramels are made from sugar, gur, hydrogenated vegetable fat, and wheat flour A particular variety of caramel, known as coconut caramel, contains desiccated coconut

Toffee is cooked to a higher temperature, (290—300°F) than caramel so that caramelisation occurs, and the resulting product is cut and not cast. The temperature employed in vacuum boilers is about 230—240°F. The product from the boiling pan is poured on a cooled slab, and, on setting, cut with a die. Alternatively, it is fed into an automatic batch feeder, formed into a rope by size rollers, and fed to an automatic plastic cut-and-wrap machine Plain toffee

is prepared from sugar and corn syrup only, and differs from hard sugar boilings in respect of cooking temperature Milk and fats are added to the better varieties to impart flavour and to develop a softer and more pliable texture. Unwrapped toffee contains flour

Coated confections, also known as Pan coated Confections, Comfits or Dragees consist of nuts or seeds, or boiled goods or chewing gum, coated with a hard glossy sugar covering The nuts or other centres are placed in a rotating coating pan and given an under-coat of gum arabic or gelatine (10%) and sugar syrup (30° Be.), and a final coating of sugar. For the latter a supersaturated sugar solution is added in small quantities and the pan rotated until the moisture from the syrup evaporates and leaves a thin sugar coating on the centres. The coating process is repeated a number of times until the required size is built up. The material is dried after each coating by hot air, dusting with flour or other starchy material facilitates drying High grade products are covered with sugar only The polish and smoothness of the coated goods are due to continual rubbing against one another and against the sides of the pan They are finished in a special polishing pan lined with heavy wax-coated canvas, dried, and packed

Fondants have the same composition as hard sugar boilings (sugar, 60, water, 20, and corn syrup, 20%) (von Loesecke, 425) The mixture of sugar, corn syrup, and invert sugar (or cream of tartar) is cooked at 234—240°F If the cooking is properly carried out, the syrup produced, when dropped into cold water, forms a soft ball which flattens on removal The supersaturated solution from the cooker is carefully cooled and whipped for 3—5 minutes to induce the formation of minute crystals of sucrose It is then thinned with sugar syrup, cooling it all the time to remove the heat of crystallization The product is ripened or cured for 24 hours or more when the water present distributes itself uniformly throughout the mass Acid fondants are obtained when acid is added to invert part of the sugar and glucose fondants are obtained when corn syrup is used (Jacobs, II 587).

The texture of the fondant varies according to the graining of the supersaturated sugar solution The nature of the grains produced depends on the degree of sucrose inversion, concentrations of dextrose and invert sugar present, cooking time and temperature, manipulation of fondant mixture addition of colloidal ingredients, e g egg-albumin and gelatine, and the period of curing or ripening (Jacobs, loc cit.). All the sugar must be thoroughly dissolved before boiling During boiling, the solution should be stirred to prevent caramelisation; it should not be stirred after boiling as it facilitates crystallization.

Lozenges are prepared by cold mixing of icing sugar, gum arabic, gelatine, or stearine, and flavouring materials Two types of lozenges are produced Plain lozenges are made by cutting pieces from a sheet of dough and drying them in air Cut lozenges are made from mixtures of icing sugar and flour (in low-priced goods) with gums as binding agents The mixture is rolled or extruded into sheets, cut into required shapes and sizes, and hardened by heating Colouring and flavouring materials are introduced at the time of kneading or during hardening. Compressed lozenges are prepared with stearine and gelatine as binding agents The same procedure is employed in the production of medicated products

Lozenges should have good snap or brittleness for which thorough and intimate mixing of dough is essential. The drying temperature should not exceed 105°F and lozenges should not be left longer than is necessary in the drying stoves

Jelly crystal is made by mixing refined sugar with gelatine solution, flavour, and colour. No cooking is needed Jujubes are made by mixing cooked glucose and sugar solution with gelatine solution, flavouring and colouring materials, and finally starch-moulded The products, after they have been removed from the moulds, are slightly moistened with water and coated with refined white sugar.

Confections are wrapped in glassine, cellophane, or waxed paper, and packed in tin containers Boiled goods are packed in 2, 3, 4, 7, and 32 lb. tin containers, and toffee in 2, 4, 7, 22, and 28 lb containers.

Modern factories are equipped with steam and vacuum pans for boiling, drop-cutting machines, pulling machines, toffee-cutting machines, mechanized units for making plastic sweets, satin goods, soft-centred goods and lozenges, revolving comfit pans, tableting machines, wrapping and packing machines for boiled sweets, toffees, etc. The smaller concerns employ coal fired furnaces, cast-iron cooling slabs, hand rollers for boiled goods, satin goods making machinery, copper revolving pans, sugar grinders, and other appliances The processing is mainly done by hand Coated goods are made in copper revolving pans which are heated from beneath, and lozenges are made with hand punches and wrapped by hand.

TABLE 1 —PRICES OF CONFECTIONERY PRODUCTS

	Rs	a		Rs.	a.
Hard boiled goods	1	0	to	1	1
Satin goods	1	1	,,	1	3
Wrapped goods	1	8	,,	1	10
Soft-centred varieties	1	11	,,	1	13
Toffee	1	8	,,	1	14
Milk caramel	1	8	,,	1	11
Comfits					
Rifle balls	0	14	,,	1	0
Peanuts	1	4			
Almonds	1	8			
Lozenges	1	7			
Jujubes	1	14			

The production costs vary widely in different factories The variation in the costs of hard boiled goods is from Rs 50 to Rs 95 per cwt , toffee, from Rs 150 to Rs 200 per cwt , and lozenges and comfits, from Rs 60 to Rs 80 per cwt. The landed cost of English toffee in July 1949 was Rs 233-8-0 per cwt in 4 lb tins, while the price of toffee sold by one of the leading Indian manufacturers in 4 lb decorated tins ranged from Rs 234-8-0 to Rs 304-8-0 per cwt

Table 1 gives the present prices of various products manufactured by one of the leading confectionery manufacturers in north India

Production and Trade

It is difficult to estimate the total output of sugar confection manufactured in the country as a large proportion of it is produced by small concerns Sugar factories in India produced 5,000, 6,621, and 6,359 tons during the years 1942-43, 1943-44, and 1944-45 respectively The quotas of sugar sanctioned for confectionery manufacture during the period of sugar control were 11,210 tons in 1944-45, 10,100 tons in 1945-46, and 10,000 tons in 1946-47 The output of confectionery in 1947-48 has been estimated at c 12,000 tons The quota of sugar sanctioned in 1950 is about 600 tons per month The total demand of confectionery in India is estimated at 30,000 tons a year

TABLE 2.—IMPORTS OF CONFECTIONERY

	Qty (cwt)	Value (Rs)
1934/35—1938/39 (av)	29,907	19,57 398
1939/40—1943/44 (av)	8,927	7,13,189
1944-45	1,015	1,40,597
1945-46	2,806	2,93,823
1946-47	4,657	3,66,778
1947-48	18,789	20,58,328
1948-49	10,969	22,99,497
1949-50	2,764	5,98,133

TABLE 3 —EXPORTS OF CONFECTIONERY

	Qty (cwt)	Value (Rs)
1934/35—1938/39 (av.)	2,542	1,03,492
1939/40—1943/44 (av.)	12,151	6,99,423
1944-45	168	17,532
1945-46	151	18,176
1946-47	105	10,600
1947-48	4	400
1948-49	11,423	11,72,230
1949-50	764	98 499

Table 2 gives the imports of confectionery into India Imports of confectionery are subject to 60% *ad valorem* duty

Table 3 gives the exports of confectionery from India In 1943-44, Iraq, Iran, and Ceylon were the main importing countries

Sugar confection is wholesome and nutritious It is a high calory food When eaten alone or in considerable amount (c ¼ lb), it depresses the secretion of gastric juices and delays evacuation of the stomach, there is a resulting tendency of the stomach juices to absorb water from the lining of the stomach which, in turn, causes irritation (Jacobs, I, 837)

Indian Confections

In addition to boiled sugar goods a large variety of confections and sweetmeats are made throughout the country, especially in cities. There are no organized factories as in the case of sugar confectionery A number of large concerns, especially in Calcutta, employ several hundred workmen in preparing sweetmeats The preparations are entirely hand-made.

Raw materials —The principal raw materials used in Indian confectionery are sugar, Chhana (casein) and Khoa (evaporated milk), pulse meal, wheat flour, rice flour, Suji (samolina), ghee, and colouring materials Raisins, almonds, pistachios, cashew nuts, spices, and condiments are added Pulse meal in usually fresh ground. Refined sugar is used for high class confections, if ordinary

sugar has to be used, it is refined by stirring up a boiling solution of the sugar which milk when the impurities separate out in the form of a scum and are ladled off The process is repeated a number of times till scum formation ceases when milk is added. Gur is used only for cheap products.

Indian confectionery may be classified into five groups: (1) Mithai made from sugar, rice flour, and pulse meal; (2) sweets made from sugar and chhana; (3) Chhana products boiled in syrup, (4) fried wheat flour products treated with sugar syrup; and (5) miscellaneous products *Manufacture of Confectionery,* 1945, 132)

The first group comprises Bundia, Mihidana, Bundi-laddu, Darbesh, Jilebi, Motichur, etc. They are prepared by frying a homogeneous batter made from pulse meal, rice flour and water, in ghee and soaking the product in sugar syrup For Bundia, Mihidana, Motichur, Darbesh and like products, the batter is poured on a flat skimmer containing a large number of perforations which is kept jerking against the side of the frying pan to allow drops of the batter to fall The fried product is removed from the bath and transferred to a warm sugar syrup of proper consistency The soaked product is separated from the syrup, and dried Different products are made from batters of different consistencies and from different pulse meals Sweetened fritters are taken in handfuls and made into balls to give Mihidana and Bundi-laddu To facilitate balling, a small quantity of ghee and water may be added, and raisins, slices of pistachios, almonds, etc, are incorporated. Coloured and plain fritters are mixed with Khoa previously brayed and sifted, raisins and other materials added and the mixture made into balls of Darbesh.

Jilebi is made in a slightly different way Flour (Maida) and Suji are kneaded with a small quantity of curd and aniseed water, and fermented. The dough is mixed with rice flour or Baison (gram flour), and made into a batter with the consistency of honey or treacle. The batter is dropped in a thin stream into a flat frying pan containing boiling ghee, the stream being laid in circles of progressively diminishing diameter to produce coiled shapes. The fried product is soaked in hot, thin, sugar syrup. Saffron colour and essence are generally added to the syrup. A product somewhat similar to Jilebi is Amriti made from Kalai (*Phaseolus mungo*) pulse paste, rice flour, sugar, and ghee.

Sandesh belongs to the second group. It is made by cooking Chhana with sugar. Freshly prepared Chhana is pressed to remove the whey, care being taken to see that no fat passes out. It is broken into small lumps and kneaded into a soft pliable dough on a wooden tray and cooked with sugar on a low fire, stirring and kneading with a wooden spatula till all the moisture is driven out. The proportion of Chhana to sugar varies according to the type of Sandesh required, and a wide variety of textures, coarse and fine grained, hard or soft, are possible. The product is flavoured with powdered nutmeg, mace, cardamom and, sometimes, rose water, rose otto, or fruit juices. The cooked product is pressed into a variety of shapes and sizes in wooden moulds.

Rasagolla, Pantooa, Chum Chum and like products come under the third group. They are prepared by boiling Chhana in sugar syrup. Rasagolla is a popular preparation throughout northern India. Arrowroot, suji, or maida (wheat flour) and sugar are mixed with Chhana in a wooden platter and kneaded into a soft dough, shaped into small balls, and cooked in a boiling thin syrup in a deep pan, care being taken to maintain the strength of the syrup by frequent additions of water to make up the loss by evaporation The boiling process may be continued till the balls begin to sink in the syrup. The cooked balls are transferred into hot syrup stock and kept for a few hours to allow the syrup to permeate the Rasagolla and render it soft, juicy, and spongy For the more expensive varieties, such as Rajbhog, scented Khoa is inserted into the dough ball before cooking in syrup

Pantooa and other products are made by frying dough in ghee on a low fire until brown, and soaking the fried mass in syrup. Khoa is added to Chhana and kneaded to give a smooth texture and to improve the taste Pantooa has an elongated shape Gulab-jaman is prepared from a stiff dough, pulverized and sifted Khoa, and maida. The dough is shaped into balls or elongated cylindrical shapes, friend in ghee until light brown and soaked in syrup.

Khaja, Gaja, etc, belong to the fourth group. Wheat flour is kneaded after adding water and ghee to give a soft dough. The dough is rolled into a sheet on a flat plate with a rolling pin. The sheet is cut into different shapes and sizes, fried in ghee until brown and crisp, and transferred to a warm syrup of somewhat thick consistency The product is taken out and dried.

Another popular Indian confection is Pera made from concentrated sweetened milk The mixture of milk and sugar is boiled under stirring until it thickens and becomes elastic. It is cooled and shaped into small flattened cakes or Peras. Barfis

are made from Khoa powder mixed with sugar syrup under gentle heating. When the mass attains a buttery consistency, heating is stopped, flavours added, and the mixture poured into a flat-bottomed dish for setting It is then cut into various shapes with a wet knife

Candied or crystallized fruit is prepared by impregnating fruit with syrup. Crystallized and candied fruits are *glacéd* by a coating of heavy syrup which dries to a more or less firm structure.

A large variety of fruits are candied in India. Petha (*Benincasa hispida*) is particularly popular. The fruit is washed, peeled, and cut into pieces after eliminating the pith The pieces are rendered firm by immersion in lime water and pricked to make them translucent and to facilitate the penetration of sugar They are again immersed in lime water, washed thoroughly with water, and cooked for about 10 minutes in boiling water containing a little alum to whiten them and to render them soft and spongy They are then transferred to sugar syrup and cooked intermittently, the concentration of syrup being progressively raised The cooked slices are dried after adding a few drops of Keora (*Pandamus tectorius*) essence

Indian confectionery is packed in cardboard cartons and paper packing cases for distribution. Rasagollas and Petha are availabale in hermetically sealed cans

The output of candied and crystallized fruits during the year ended 30th June 1948 was 97,315 lb valued at Rs 1,21,461 (Indian Tariff Bd, *Rep Continuance of Protection to the Preserved Fruit Industry*, 1949, 30).

COPPER

Copper is by far the most important non-ferrous metal used in industry. By virtue of its valuable physical and mechanical properties, long life, comparative cheapness and high scrap value, it occupies a position next only to iron and steel in commercial importance. About half the output of copper is used for electrical purposes. The rest is used in the form of alloys, the most important among them being the brasses and the bronzes.

Metallurgy —Chalcopyrite Cu_2S. Fe_2S_3 occurring in admixture with pyrite, pyrotite, etc., forms the ore from which the world's largest supply of copper is derived. Such ores carry appreciable amounts of gold and silver. Two methods are used for extracting the metal from the ore—the pyrometallurgical or the dry method widely employed in the treatment of sulphide ores and the hydrometallurgical or wet method. The latter is limited in its application, and is employed for the treatment of low grade oxidized ores and oxidized tailings Sulphide ores and effluents from flotation plants containing soluble copper salts can also be treated by this method.

Pyrometallurgical method.—The metal is recovered by the following sequence of operations: (1) concentration or beneficiation of ore, (2) roasting, (3) smelting to matte, (4) conversion of matte to 'blister copper', and (5) refining of blister copper

The sulphide ore, owing to its low copper content, is first concentrated, usually by froth flotation, prior to roasting. The concentrate is roasted to oxidize the sulphur present in excess of the amount required to form Cu_2S with all the copper present and to form FeS with some of the iron present in the charge The sulphur dioxide produced is used in the manufacture of sulphuric acid.

The McDougall furnace is usually employed for roasting, the heat required being provided by the oxidation of sulphur Copper sulphide is oxidized less rapidly than iron sulphide and the roasting is so regulated that the calcine contains a larger part of the copper as sulphide.

The calcine is smelted in a reverberatory or blast furnace The use of the blast furnace is confined to rough ore, oxide ore, and ores containing silver and gold Reverberatory furnaces are used for concentrates During the smelting, iron is preferentially oxidized, and the iron oxide so formed is separated as slag from the matte, which is a complex mixture of cuprous and iron sulphides with sulphides of certain other metals present in the ore. The matte is blown with compressed air (12—15 lb./sq in) in basic-lined Bessemer converters when part of the sulphur is removed as sulphur dioxide. The iron oxide is fluxed with silica and removed. The heat required to keep the metal molten is supplied by the oxidation of iron sulphide About 160,000—200,000 c ft. of air are required per ton of blister produced (Liddell, 244). The residue in the converter consists of cuprous sulphide, the precious metals, and a few impurities.

On further blowing, the copper sulphide is oxidized and the operation is stopped when all the sulphur is burnt off The resulting product, blister copper, is cast into cakes for subsequent treatment. Blister copper contains 96—99% copper and 2—5% impurities, e.g, sulphur, oxygen, arsenic, and iron. It is porous and brittle, and retains the precious metals present in the original ore.

The blisters are fire-refined or furnace treated, and if sufficient amounts of precious metals are present they are further refined by the electrolytic method. The electrolytic method is also applied when copper free from lead and zinc is required. The bulk of copper now produced is electrolytically refined. The cost of the process is often covered by the value of the precious metals recovered. For fire-refining, pigs of copper are slowly melted in a reverberatory furnace under highly oxidizing conditions until the impurities are oxidized and removed either by volatilization or by fluxing. Part of the copper is oxidized during the process and the metal is saturated with cuprous oxide. The slag is removed, and the metal covered with coke or charcoal and poled with green wood poles During this treatment, considerable agitation of the metal takes place and the oxide is reduced to metallic copper by the gases given off by the poles The process is continued until the oxygen content is reduced to 0·03—0 05%. The product thus obtained contains over 99 2% copper and is known as 'tough pitch'. It is cast into pigs, ingots, or other shapes

In electrolytic refining, copper sulphate acidified with sulphuric acid is used as electrolyte. The copper to be refined forms the anode, the cathode being pure copper During the electrolysis, impurities like iron, nickel, cobalt, zinc, arsenic, and antimony pass into solution, while the precious metals, gold, silver, and platinum, the rare metals, selenium and tellurium, and lead, accumulate as insoluble anode slime; a few other impurities pass partly into solution and partly into slime In the multiple electrolysis process, the cathodes alternate with the anodes and are connected in parallel. In the series system, the cathodes and anodes are connected in pairs

The copper produced by the multiple system per kw per day at a density of 18 amp /sq ft is 165—180 lb., while in the series system, the production is 340—380 lb. (Liddell, 262) The multiple system is more commonly adopted, as it requires less care in operation, but is costlier owing to higher consumption of current and bigger capital outlay. Electrolytic copper contains 99 98% copper and traces of reducible gases. It is remelted, oxidized, poled, and finally cast.

Hydrometallurgical method.—In the wet method, the natural or roasted ore is leached with solvents such as dilute sulphuric acid, dilute solutions of ammonia and ammonium salts, solutions of sulphur dioxide, ferric chloride, etc., and the copper is recovered from the leached solution either by precipitation with metallic iron or by electro-deposition (Liddell, 345).

Secondary Copper

In addition to the copper derived from ores, a secondary source of copper is the recovered metal from copper scrap. The secondary copper industry utilizes commercial copper and copper alloy scrap. The collection and grading of scrap is important. U K. produced during 1942-44 about 2,250,000 tons of copper of which about 1,000,000 tons or nearly 42 5% was secondary copper, in U S A. electrolytic copper accounted for 221,882 tons of the 984,231 tons of secondary copper produced during 1943-44 [Mitter, *Metal Market Rev.*, 1950, **3** (1), 23]

Two kinds of scrap are employed: (1) industrial scrap in the form of borings, turnings, clippings, punchings, etc, resulting from the manufacture of wrought and cast metal and alloys, and (2) scraps, such as wire, sheet, rods, pipes, utensils, castings, etc, arising from fabricated metal products which have outlived their usefulness. Scrap may be either reprocessed for the recovery of virgin metal or converted into standard alloys Highly contaminated scrap cannot be directly used for making standard alloys Such scrap—drosses, slags, skimmings, etc—in which copper or oxidized copper is entrapped, and scraps containing low concentration of copper and consequently unsuitable for preparing standard alloys, are treated for the recovery of copper (*Rep Panel Non-ferrous Metal Industries*, 87) The methods employed for this purpose are similar to those used in the conventional processing of ores or concentrates, and involve the use of reverberatory furnaces and fluxing and reducing agents The reduced metal is then fire-refined, followed by electrolytic refining where desired. For economic reasons it is preferable to select scrap of a specified quality, extract copper, and utilize it for preparing standard alloys. Sometimes it may be necessary to add virgin metal or secondary metal or alloy to the molten scrap in order to bring the concentration of copper to the level required for processing.

Alternatively, different grades of scrap may be melted separately, assayed for copper, and then mixed in the calculated proportions to obtain a standard composition before subjecting it to the recovery treatment.

The methods of refining copper scrap have been intensively studied in Germany, Japan, and U.S.A. In one of the processes developed in Germany, the scrap is oxidized selectively in a converter by passing gas or steam through the molten scrap,

thereby liberating oxides of tin, lead, zinc, and antimony The copper so obtained and assaying 96–98% is fire-refined to 98–99% purity It is finally refined by the electrolytic process. In U S A, a high temperature electric furnace treatment has been adopted Molten scrap is distilled in a resistor electric distillation furnace when zinc, lead, tin, aluminium, manganese, etc, distil over The residual material is refined in a converter by melting with a flux of sand, lime, and iron ore in suitable proportions to form a low fusion slag In another process, brass scrap is heated under controlled conditions to such a temperature that most of the metals present is removed by volatilization The zinc so obtained is recovered as spelter (Mitter, loc cit)

PROPERTIES

Pure commercial copper has the following physical properties at wt, 63 57, sp gr, 8·93; m p, 1,083°, b p, 2,325°, thermal conductivity, 0 92 cal /sq cm./cm /sec /°C, sp heat, 0 92 cal /g /°, coefficient of thermal expansion, 16 6 x 10^{-6}/°C, at 20°, latent heat of fusion, 41 7–50 46 cal /g, and electrical resistivity, 1 7241 microhms/c c at 20° (Copper Develop Assoc, *Copper Data*, 1947, 17, 20) Among its valuable properties mention may be made of the following

(1) *High ductility and malleability*—Copper can be rolled into sheets less than 1/500 in thick, drawn into wire 1/1000 in. diam, pressed, rolled, spun, coined, and cold-headed Several copper alloys, notably brass, have similar properties.

(2) *High thermal and electrical conductivity per unit volume*—Higher than for any other metal except silver, which is but slightly superior to copper in this respect

(3) *Ease of fabrication.*—Copper and most of its alloys can be joined with ease by soldering, brazing, and welding It can be fabricated by cold working, such as rolling, drawing, pressing, and by hot working, such as pressing, extrusion, and stamping, and by machining

(4) *Resistance to many forms of corrosion*

(5) *Attractive colour*—Copper is the only metal except gold with a distinctive colour. The colour of copper and its alloys range from red in the pure metal to chocolate, ochre, golden yellow, or white in its various alloys.

Copper is an extremely tough metal and has a remarkable resistance to fracture from sudden shock loads. Its strength and hardness are enhanced by cold working; the hardening can be removed, when necessary, by annealing at about 500° It can be hot worked at 800–900°. Copper maintains its strength at somewhat elevated temperatures and possesses ideal hot working properties Table 1 gives some of the mechanical properties of copper (Copper Develop Assoc, op cit, 2)

TABLE 1.—MECHANICAL PROPERTIES OF COPPER

	Tensile strength Tons/sq in	Elongation % on 2 in.	Brinell hardness	Density (approx)
Cast	10–11	25–30	40–45	8 5
Cold worked*	20–26	5–20	80–100	8 9
Annealed (after cold working)*	14–16	50–60	45–55	8 9

*Sections of thickness exceeding about 1/8 inch

When compared with ferrous metals, copper is extremely resistant to atmospheric corrosion. When exposed to air, copper forms on its surface a continuous oxide film which, unlike the rust on ferrous metals, does not absorb moisture and resists further attack Exposure to moist sulphur dioxide or chlorides leads to the formation of a bright pale green film of basic sulphate or chloride and of basic carbonate formed by slow reaction with moist carbon dioxide; the oxy-salts gradually become mineralised and the green patina so formed is extremely resistant to further attack Under stringent service conditions copper and its alloys withstand corrosion to a greater extent than other materials of comparable price

Copper is not affected by dilute sulphuric or acetic acid in the absence of air. In general, plant and equipment made of copper can be used for processes involving the use of dilute acids, caustic alkalies, solutions of salts like aluminium chloride, calcium chloride, aluminium sulphate, zinc chloride, etc It cannot be used in contact with ammonia, nitric acid, acid chromate, ferric chloride, mercury salts, perchlorates, and persulphates It is suitable for underground service on account of its high resistance to corrosion by soil

The physical properties of copper are affected by certain impurities Iron forms brittle solid solutions and antimony affects the cold working property Phosphorus in small amounts is a deoxidant but in excess causes brittleness and impairs electrical conductivity. Bismuth forms a eutectic with copper and causes brittleness, adversely affects the cold working property and reduces tensile strength even when it is present to the extent of 0·002%.

Commercial Grades—Commercial copper is available in a variety of grades, among which the following are important: High Conductivity (HC) copper, Refined (Best Select, BS) copper, and Arsenical copper. Where electrolytic

refining process have been adopted for the production of HC copper, the product is referred to as Electrolytic or Electro copper. Commercial grades containing a small percentage (0·025–0·08%) of oxygen in the form of cuprous oxide are known as Tough Pitch copper, e.g., Tough Pitch HC copper (electrolytic and fire-refined), Tough Pitch Arsenical copper and Tough Pitch BS copper. Tough Pitch copper may be deoxidized to give Deoxidized copper, such as Phosphorus Deoxidized Arsenical and Non-Arsenical coppers, and Oxygen-free High Conductivity (OFHC) copper. Other grades are Chile bars, Lake copper, Castings, and Secondary copper.

By far the greatest proportion of copper is marketed as HC copper (over 99 95% Cu) It is used mainly in the electrical industry It is used also wherever high thermal conductivity is required and in alloys required for coinage, ammunition, etc., where high purity copper is demanded

BS copper produced by fire-refining usually contains over 99·7% Cu, and is used generally in the manufacture of alloys

Arsenical copper contains 0·3–0·5% arsenic; it has higher strength and toughness than refined copper The addition of arsenic raises the endurance limit as determined by fatigue tests, enhances the softening temperature during annealing (by about 100°), improves the retention of strength and prevents excessive scaling of the metal at elevated temperatures. Arsenic affects the electrical conductivity markedly.

Tough pitch arsenical copper can be deoxidized with phosphorus or other deoxidizers, e.g, silicon, lithium, magnesium, beryllium, and calcium to give a high purity product with improved ductility and malleability. It can be readily welded. Oxygen-free high conductivity copper has high ductility and is resistant to the action or reducing gases. It is particularly well adapted for edge bending, deep drawing, and spinning operations

Copper ingots produced in Chile, weighing 200 lb and assaying 95–99% Cu with small percentages of gold and silver, are known to the trade as Chile bars. Lake copper is smelter-refined copper assaying over 99·8% Cu, produced from the copper deposits of Lake Superior Casting copper (U S A) is a smelter-refined product containing 98·5–99·75% Cu; it includes some secondary copper.

Uses

The high electrical conductivity of pure copper makes it particularly valuable for the manufacture of cables and wires required for electrical transmission, windings, electrodes, lightning conductors, earthing systems, switchgear, electric lamp caps and sockets, signalling equipment, and for various electrical equipments in electric locomotives, tramways, automobiles, radio broadcasting, etc, and wire cloth. Its high thermal conductivity is taken advantage of in the use of copper for radiators and cooling systems in internal combustion engines, refrigerator tubes, coils and vessels, locomotive fire boxes, air-conditioning equipment, stills, evaporators, and cooking utensils. As it is highly resistant to corrosion, it is employed for fabricating plant required for the chemical industry, and tubing for water distributing systems Finely divided copper is used as a decorative material for ceramic coatings and as catalyst in organic syntheses Copper is also employed in the manufacture of copper salts required for pigments, medical preparations, insecticides, and water purifiers Cuprous oxide and copper naphthenate are ingredients of anti-fouling paints for ships' bottoms, mildew prevention and rot proofing compositions for fabrics, and timber preservatives

Copper Alloys

Copper alloys are next only to iron and steel in commercial importance. The more important alloys are copper-zinc, copper-tin, copper-aluminium, and copper-nickel. An alloy containing 1% cadmium is used in the manufacture of electrical transmission wires Copper-beryllium alloys have attained great importance in engineering industries

Copper-zinc Alloys—Zinc lowers the melting point and enhances the ductility of copper The hardness increases and reaches a maximum when the alloy contains 45% zinc, the ductility increases up to 30% concentration The colour of the alloys varies from coppery red to yellow with increasing proportions of zinc Important among the copper-zinc alloys are the brasses which contain 55–80% copper Two principal brasses are in use, viz , α-brasses (Cu, > 63%) in which all the zinc is in solid solution, and the α-β-brasses (Cu, 57–61%) which in addition to σ-constituents also contain β-constituents Other alloys of the copper-zinc series are the low brasses or gliding metals (Cu, 80–90%; Zn, 10–20%), and the alloys containing less than 55% Cu. Brasses have good resistance to atmospheric corrosion They can be cast, extruded, forged, pressed, drawn, and machined.

α-Brasses are generally straight alloys, suitable for cold working. The more important among them are: Cartridge brass (Cu, 70%), and Basis brass (Cu, 63%) The former has high

ductility and can be cold worked without fracture. It can be annealed at 500–600° It is used wherever a highly ductile material is required for fabrication as in deep drawing It is used in the manufacture of cartridge cases and radiator shells of complex shapes and for other industrial purposes. The 65/35 alloy is cheaper and possesses good cold working properties Basis brass (Cu, 63%, Zn, 37%) is a generally purpose alloy suitable for forming operations.

The addition to brass of lead up to 2% confers good machining properties at the same time lowering ductility. Articles fabricated from such brasses take a good finish Leaded brasses (Cu, 62 5%, Zn, 36%, and Pb, 1 5%) are used for engraving and machining (shearing, notching, etc) Admiralty brass (Cu, 70, Zn, 29, and Pb, 1%) has better corrosion-resistance than 70/30 brass and is used for making condenser tubes The 85/15 brass (Red brass) is also used for condenser tubes and cooling units generally

α β Brasses are specially suitable for hot working and casting They are often mixed with other elements to form high tensile brasses Yellow Metal (Cu, 60%) is the most useful alloy of this group It is used for hand-fabricated utensils. Finished yellow metal sheets have a rough surface due to hot working and they cannot be employed in the fabrication of highly polished products Some yellow metals also contain small quantities of lead in part replacement of zinc Naval brass (Cu, 62, Zn, 37, and Sn, 1%) is not particularly ductile in the cold state but it can be hot worked to form tubes, rods, and sections; it has better corrosion resistance than 60/40 brass. Leaded naval brass (Cu, 61, Sn, 1, Pb, 0 5–2 0, and Zn, to make up 100) has a special application in stampings and forgings where machinability is a primary requirement

High tensile brasses, mainly manganese bronze and aluminium bronze, are generally prepared from 60/40 brass (α-β—group) by the addition of small quantities ($\frac{1}{2}$–3%) of manganese, aluminium, tin, iron, and, occasionally, silicon, and nickel Manganese acts as a deoxidizer, enhances its value for casting and corrects the tendency to form large grains during crystallization Aluminium increases the proportion of β-constituents which decrease ductility and impart higher strength and hardness to brass Tin (0 5–1 0%) enhances corrosive resistance, and iron improves forging properties and refines the structure High tensile brasses are employed for a wide range of castings from very large marine propellers, valve chests, pump castings, locomotive axle boxes, etc., to small die cast parts. High tensile brasses can be extruded. Manganese bronzes, which contain up to 2% manganese and low proportions of tin and other metals, are hard and strong with high resistance to corrosion by sea water They are used extensively for propellers, rudders, valve parts, and ships' fittings The addition of 3% aluminium increases tensile strength in the cast state to 40 tons/sq in and the Brinell hardness to 160, at the same time reducing elongation by 30—50% (Wood, 264)

The common gilding metals contain 80—90% copper They have a golden colour, and they can be rolled at ordinary temperatures into thin sheets They are used for imitation gold jewellery and decorative architectural work. They can be brazed and enamelled and possess better corrosion-resistance than brasses of lower copper content Alloys containing less than 55% copper have only β-constituents; they are used for brazing copper and nickel alloys An alloy commonly employed for this purpose contains equal parts of copper and zinc

Nickel silver—Copper-zinc alloys containing comparatively large amounts of nickel are known as Nickel silver (formerly known as German silver). These alloys which are of considerable commercial importance are of two types, α and α-β The former contain Cu, 55–65%; Zn, 13–27%, Ni, 10–30%, with iron, manganese, and lead as impurities, and are generally cold-worked By increasing the nickel content, the colour progressively changes to silvery white and the corrosion-resisting property is greatly enhanced There is little advantage, however, in increasing the nickel content beyond 18%, unless the alloy is specially required for decorative work The most widely used alloys contain 15–18% Ni The best α-β nickel silver contains Cu. 45; Zn, 45, and Ni, 10% It is used in the form of extruded sections for architectural and ornamental purposes on account of its silvery colour and good hot working properties

Nickel silvers are used mainly for cutlery and tableware, imitation jewellery, military badges, plumbing fixtures, architectural metal work. and fittings in automobiles, ships, and railways. They are also widely used for electro-plated nickel silver (EPNS) ware The 18% Ni alloy is valuable particularly for spinning operations Alloys having high electrical resistance are used in the manufacture of rheostats and electrical instruments

Copper-tin Alloys—Bronzes contain 2–18% tin together with small percentages of additives, e.g., zinc and phosphorus which confer special

properties on the resulting alloy. Tin increases hardness, strength, and ductility of copper. In concentration up to 6% tin forms solid solutions with copper and yields brass-like alloys. When the concentration exceeds 6%, a heterogeneous structure is formed consisting of a matrix of bronze and a tin-rich phase which acts as a hardener. Two important bronzes are phosphor bronze (containing phosphorus) and gun metal (containing zinc) Small additions of nickel and lead modify the mechanical and corrosion-resisting properties of bronzes.

Phosphor bronzes containing. Cu, 82—94, Sn., 4 75—13; P, 1 (maximum), and Pb, 3·4% (maximum). Alloys containing less than 7% tin and about 0·1% phosphorus contain both tin and phosphorus in solid solution and are malleable, possess good corrosion-resistance and corrosion fatigue properties, and are suitable for cold working They are used for making hair-springs for clocks, fuse-springs and electrical contact mechanisms where resilience, non-magnetic properties, and corrosion-resistance are the properties sought; they are used also for valve and pump spindles, boiler fittings, etc. Alloys containing 10—13% tin and 0 3—1·0% phosphorus contain a hard constituent, Cu_3P. Such alloys possess increased fluidity and are extensively used for casting bearings and components which are required to endure heavy compressive loads, such as gun mounting rings, parts of moving bridges, and turn-table and rolling mill bearings (Alexander & Street, 139, With India, Pt. 1, 133).

Gun metals.—Zinc hardens bronze and counteracts the softening effect of lead added to facilitate machining Gun metals are cast with ease and are used chiefly in the form of pressure-resisting castings The best known gun metal is the Admiralty gun metal (Cu, 88, Sn, 10; and Zn, 2%). It is fine-grained, has a pleasing colour, takes a high polish, and is harder and more corrosion-resisting than other gun metal alloys. It is widely used for marine purposes, pump bodies, valves, and high pressure steam plants. Gun metals containing lower concentrations of tin and higher concentrations of zinc (Cu, 84—90, Sn, 4—8; Zn, 4—7; and Pb, 1—7%) and more ductile, easier to cast, and less porous (Wood, 267). They are frequently used as substitutes for Admiralty gun metal in order to economize the use of tin; the present most widely used alloys are the 86/7/5/2 and 85/5/5/5 gun metals.

Bell metal (Cu, 80; and Sn, 20%) is used for fabricating machine parts. It is hard, brittle, and sonorous, and it is employed in making bells and gongs. A particular alloy (Cu, 78; and Sn, 22%) is extensively used, especially in Bengal, for making utensils A type of gun metal, Bharan, is used for the manufacture of tumblers and cups. Other inferior types of gun metal used are Bela and Bharat (With India, Pt. 1, 169).

Speculum metal contains Cu, 66, and Sn, 34%, other metals, e g, arsenic, antimony, lead, and nickel may also be added It can be polished and used as light reflectors.

Leaded bronzes —Copper-tin bronzes containing 5—25% lead are known as leaded bronzes. Those, in which the plasticity increases with the increase in lead content, are of considerable importance for medium and low-duty bearings where some measure of plasticity is desired or where lubrication may be imperfect, or where the 'mating' material is soft steel which is scored by harder materials (With India, Pt 1, 133) Leaded bronzes containing 20—25% lead are known as plastic bronzes

Nickel brones —Small quantities of nickel are sometimes added to bronzes and gun metals to minimize segregation of the components and improve the casting quality, especially of leaded bronzes The well-known Ajax Plastic Bronze contains 1% nickel (Bureau of Information on Nickel, *Some Applications of Nickel and Nickel Alloys* H_{39}, 18) When added to lead-free bronzes containing 0 25% manganese, nickel (5—10%) improves the physical properties and renders them suitable for heat treatment. Nickel bronzes are extensively used in marine engineering High nickel bronzes (over 10% Ni) possess excellent wearing and corrosion-resisting properties and are extensively employed for fittings which come into contact with corrosive liquids.

Antimony bronzes contain antimony as an essential constituent One of these (Cu, 79, Ni, 8, Pb, 10, Sn, 2, and Sb, 1%) is suitable for bearings and is said to have wearing qualities superior to leaded bronzes containing 10% tin and 10% lead.

Silicon bronzes —Copper alloys containing up to 4% silicon and less than 1% manganese, iron, zinc, aluminium and other elements are known as silicon bronzes, though they do not contain tin. The best known among them are Everdur (U.S A.) and P.M G metal (U.K). They are suitable for hot and cold working, are comparable to mild steel in strength, have excellent corrosion-resistance against acids, and possess good welding properties. They are useful for chemical plant construction.

Copper-lead alloys containing 20—40% lead are used for bearings (With India, Pt. 1, 132).

Copper-aluminium alloys are known as aluminium bronzes though they do not contain tin. They may be grouped under 2 types (1) containing up to 9 8% aluminium (usually less than 7·5%), forming a single solid solution, and (2) containing 9—11% aluminium Alloys of the first type have considerable strength, high elongation, and can be readily cold worked to produce seamless tubes, strips and sheets, wires, etc, and annealed They have excellent resistance to corrosion and to oxidation on heating They are used in making condenser tubes, ships' fittings, pickling crates, and as steel substitutes where non-magnetic properties and strength are required (Alexander & Street, 140) An alloy containing about 7% aluminium is used for architectural decoration, and imitation gold articles are made from alloys containing 4—5% aluminium Alloys of the second type have better corrosion resistance and are generally hot worked and used for a variety of engineering applications, e g, gears and bearings An alloy containing 10% aluminium is three times as strong as mild steel and tough Alloys containing 9 5% aluminium are suited for die casting

Copper-nickel alloys—Copper and nickel alloy together in all proportions to form a continuous series of solid solutions Nickel imparts a white colour to the alloy and enhances the strength, hardness, and corrosion-resistance of copper The alloys retain strength at high temperatures They may be hot or cold worked and drop forged An alloy containing 2% nickel is used for locomotive fire boxes and boiler tubes Cupro-nickels containing about 20% nickel are white, ductile, and are eminently suitable for cold working They are used for bullet envelopes, condenser tubes, and decorative purposes The 75/25 alloy is used for coinage The 70/30 alloy is used for condensers and cooling tubes and for marine and land power services Alloys containing higher percentage of nickel (c 45%) have high electrical resistance and low temperature coefficient Constantan, Eureka, and Ferry are among the alloys used in the form of wires in electrical industry Similar alloys are employed for decorative and architectural purposes

In the higher nickel range, the most important and widely used alloy is Monel (Cu, 29; Ni, 68, Fe, 1, Mn, 1%, with smaller percentages of Si, S, and C), a natural alloy made by the *International Nickel Corporation* from the copper ores of Sudbury, Ontario (Canada) It is silver white in colour, highly ductile, and has a tensile strength and hardness approximately equal to that of steel, with the added advantage of being resistant to corrosion. It retains its strength even at fairly high temperatures and a high degree of resistance to fatigue under corrosive conditions. It can be cast, hot or cold worked, welded, soldered, and brazed Monel can be hardened considerably by cold working. It is extensively used in sheet, rod, wire, and cast forms for containers, valves, pumps, centrifugal filters, pipe fittings, and many forms of equipment used in chemical, food, and textile industries Of particular interest is its use for equipment exposed to sea water and high temperature steam Aluminium and silicon are added to obtain modified monels such as K-Monel (3 5% Al), Monel-H (2·5—3·0% Si), and Monel-S (3 35% Si)

Copper-beryllium alloys.—The addition of 1—2 5% beryllium to copper gives an alloy with high fatigue-, corrosion-, and wear-resisting properties, and good electrical conductivity. Cu-Be alloys have a high tensile strength up to 200,000 lb/sq in, comparable to that of tool steel, and a Brinell hardness up to 400 (Johnson, 159) They are used for springs, tools, surgical and dental instruments, watch parts, and welding electrodes

Copper-manganese alloys—An alloy (Cu, 84, Mn, 12, and Ni, 4%), known as Manganin, is used as standard resistance in electrical instruments.

Copper-cadmium alloys—For overhead transmission of electricity, copper containing c 0 9% Cd is employed Cadmium increases the tensile strength by 50%, the electrical conductivity being reduced by only 15% It increases the fatigue resistance of copper, and this property is made use of in the manufacture of flexible telephone cords

The principal copper alloys and their compositions are given in Table 2.

The Indian Copper Industry

The *Indian Copper Corporation Ltd* (I C C), Ghatsila (Singhbhum), the only producer of copper in India, was established in 1924 A smelter was erected at Maubhandar, 6 miles from the Mosabani mines, and production of metal was started towards the close of 1928. In 1930, a rolling mill for the production of yellow metal sheets was installed The factory was expanded in 1933 when the production capacity was raised by 50% (*J sci industr Res*, 1944-45, **3**, 275).

The I.C C utilizes chalcopyrite obtained from Mosabani and Badia mines adjoining each other, and another mine at Dhobani, a mile to the west of Mosabani The total resources of copper ore in Bihar mine field were estimated in 1939 to be 852,300 short tons with an average of 2·85% Cu.

TABLE 2.— PRINCIPAL COPPER ALLOYS

	% Composition					
	Copper	Tin	Zinc	Iron	Nickel	Other elements
Bronze	75–90	25 10				
Phosphor bronze	86	13				P, 0·25
Manganese bronze	59	1	up to 40			Mn, 0 3
Aluminium bronze	81 5–90	0–0 5			0–6	Al, 7–12
Silicon bronze	95–98	2–5				Si, 2–5
Brass	60–70		40–30			
Dutch metal	80		20			
Bell metal	80	20				
Speculum metal	66–68	34–32				
Gun metal	87	10	3			
German silver	25–50		35–25		35–10	
Delta metal	60		38 2	1·8		
Monel metal	27			2–3	68	
Constantan	60				40	
Indian copper coinage*						
Pice	97					
½-anna, 1 anna, and 2 annas (cupro-nickel)	75					

*Total amount of copper used in Indian Coinage in 1948, 450 tons

The ore treated during 1929-45 contained 2·214% Cu.

The I C.C employs a total of 8,000 persons of whom 5,500 are employed in the mines and in the workshops at Mosabani and 2,500 are engaged in the reduction works and rolling mills at Maubhandar.

The ore is crushed at the mines in a Blake Crusher to +3 in. The crushed material is passed over Gyrex vibrating 3/8 in. screens, the waste rock from the oversize being removed by hand picking. The picked ore is further crushed in a Symons Cone Crusher and the crushed product (70% passing through 3/8 in. screen) and screen undersize are taken on a belt conveyor to storage bins whence they are transported to Maubhandar for smelting. A typical screen analysis of the crushed ore gave the following values. +1 in., 0·6, +½ in., 16·9, +3/8 in., 19·4; +¼ in, 19·8; and −¼ in., 43·3%. The ore is ground in Hardinge ball mills with Dorr Classifiers in closed circuit to the requisite degree of fineness (*c.* 47% on 200-mesh). Quicklime is added to the feed of the Hardinge mills as depressant of pyrite and pH regulator. The pulp is concentrated in pneumatic froth flotation cells with additions of pine oil (frother), potassium ethyl xanthate (collector), and Calgon and soda ash (diffusion agents), when over 97% of the copper is recovered as concentrate carrying approximately 27–28% Cu. The tailings are pumped away and settled on adjoining waste land. The concentrate is thickened in Dorr thickeners, filtered in Oliver filters and dried on Lowden dryers. The dried concentrate, containing approximately 5·5–6·5% water, is smelted at 1,200–1,500° in a reverberatory furnace (daily capacity, 250 tons) and the matte (40–42% Cu) produced is treated in a converter with air blown at a pressure of 14 lb./sq. in., to give blister copper. As the capacity of the concentration plant is higher than the smelting furnace, the excess concentrate is sometimes roasted in a Herreshoff furnace and the calcine added to the smelting charge. This raises the grade of the matte and helps in increasing the production of blister copper (Barry, *Trans. Indian Inst. Metals*, 1949, **3**, 333). Blister copper (97·5% Cu) is fire-refined and cast into ingots of 28 lb each (BS or Best Select copper, assaying 99·2–99·6% Cu). The slag obtained during converting and refining is returned to the smelting furnace

All the furnaces are fired by pulverized coal.

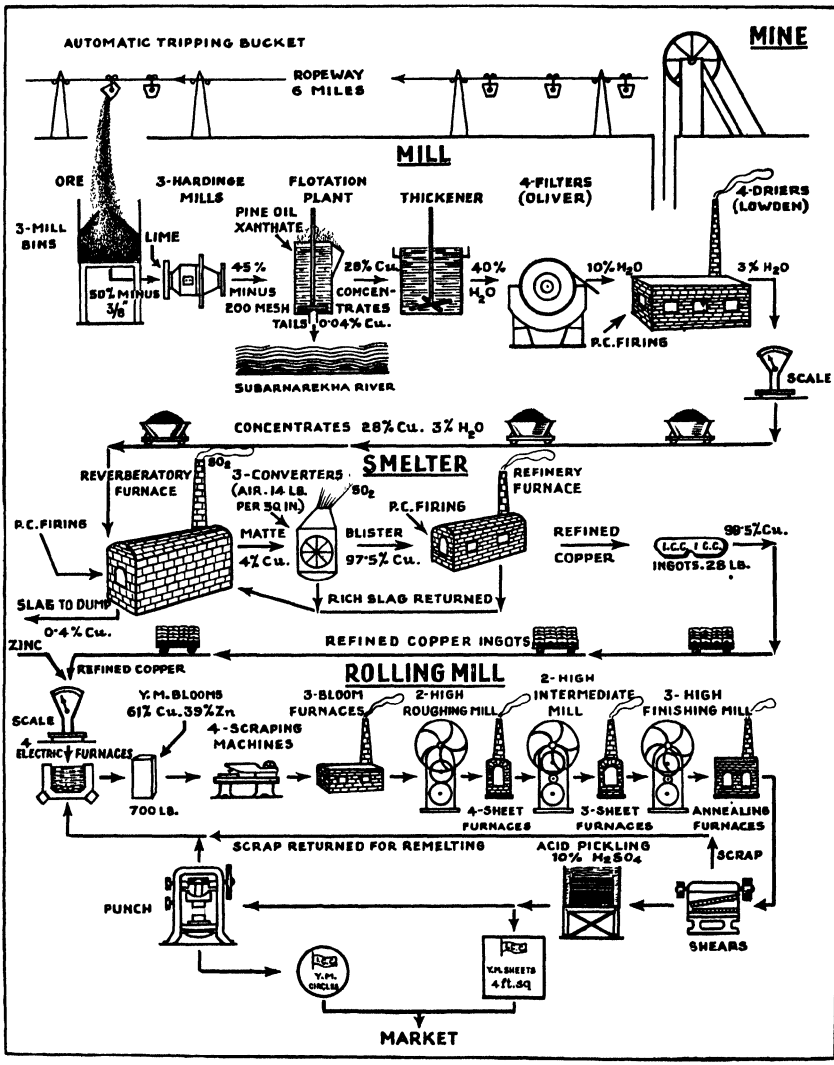


Fig. 57.—Manufacture of copper—flow sheet.

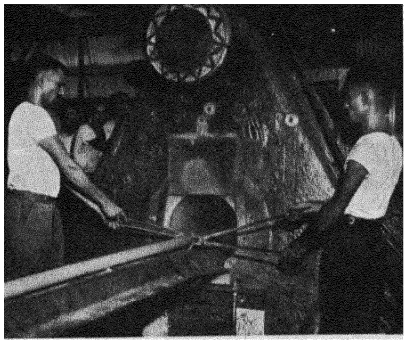


Fig. 58.—Extrusion of brass rods

No electrolytic refining is carried out by the I.C.C. as the ore is reported to contain no precious metals.

The production of secondary copper was developed in India during World War II. In the years preceding 1939, the bulk of brass, bronze, and other alloy scrap was being exported, the total quantity exported during 1937 being 1,000 tons; only a small quantity was refined. The secondary copper industry is located mainly in Calcutta and Bombay; smaller units are operated in Jaipur, Meerut, Mirzapur, and Madras. The scrap is collected from different sources (discarded gun metals, brass and bronze machine parts and fittings, bell metal radiators, scrap from motor cars, copper wire and cable-scrap, copper clad steel, bimetal scrap, domestic utensils, copper bearing foundry ashes and drosses) and is usually mixed before selling for processing. The annual collection of scrap domestic utensils made of copper and brass is estimated to be 30,000 tons (Mitter, loc. cit.). The Non-ferrous Metals Panel has recommended that for the progress of the secondary metal industry it is essential to classify scraps and scrap dealers should be trained in the techniques of segregating and grading of scraps (*Rep. Panel*, 84).

A part of the scrap, such as broken utensils, is utilized by brass and bell metal workers on a cottage industry basis. The scrap is melted in clay pots heated by charcoal fires, and the molten metal is poured into clay moulds, the ingots so produced being subsequently used.

Coke-fired pot furnaces used for melting brass have been superseded by low-frequency electric induction furnaces. The smaller units, however, still continue to use pot furnaces and gas or oil fired tilting furnaces.

Fabrication.—Copper and brass rods and bars are made by hot and cold rolling and drawing, and also by extrusion at the *Katni Ordnance Factory*. Arsenical copper rods for railways are manufactured only by the *Jaipur Metal Industries*. Black copper rods (¼ in.—¾ in. diam.) are manufactured by the *National Rolling Mills*, Calcutta, a subsidiary of the *National Cables Ltd.*, by hot rolling of imported HC wire bars (4 in. × 4 in. × 48 in.); they are used for the manufacture of cables. Phosphor bronze rods and sections are produced in small quantities as the demand for them is limited.

Only a small quantity of copper sheets and circles are produced by hot rolling. 10—21 S.W.G. sheets are made by the I.C.C. A small amount of coiled rolled sheets and circles is also produced.

60/40 hot-rolled brass sheets, 4 ft. × 4 ft., 10—22 S.W.G. and brass circles of large diameter, required for the manufacture of utensils, are produced by the I.C.C. Sheets 2 ft. wide are produced by the smaller rolling mills. The quantity of cold-rolled brass sheets produced is, however, small. Small quantities of brass strips in coils are also produced, and the demand, especially for 70/30 and 65/35 qualities, appears to be considerable. Leaded brass sheets (60/40) containing 1·25% lead are also manufactured for use in tube-well strainers. Phosphor bronze and nickel silver sheets are not produced at present. Seamless copper and brass tubes, up to ½ in. outside diam., are produced by the *National Pipes and Tubes Co. Ltd.*, Calcutta.

Brass wires for wire-netting and engineering purposes are being produced in India since 1941-42. Electrolytic copper wire is produced by

TABLE 3.

	Cost of production (per cwt.)		Landed cost* (per cwt.)	
	Rs.	a.	Rs.	a.
Copper	53	7	66	0
Brass ingots	53	0	46	11
Gun metal (Cu, 88; Sn, 10; Zn, & 2%)	106	12	75	0
Gun metal (Cu, 85; Sn, 5; Zn, 5; & Pb, 5%)	91	4	63	0
Brass sheet	105	0	84	15
Arsenical copper rods	126	0	95	0

*excluding duty

Indian Cable Co, and since 1943, by the *National Insulated Cable Co* of India.

Table 3 gives the cost of production and landed cost of copper and brass (Indian Tariff Bd, *Rep Non-ferrous Metal Industries*, 1946, 15, 22).

Production and Trade

U S A. is the biggest producer of copper in the world Chile comes second Other important producers are Northern Rhodesia, Canada, and Belgian Congo Since World War I, Chile, South America, Africa, and Canada have steadily increased their outputs.

Table 4 gives the world production and consumption of copper during the year 1947.

TABLE 4.—PRODUCTION & CONSUMPTION in 1947* (in 1,000 short tons)

	Production (Smelter basis)	Country	Consumption
U.S A.	1.073†	U S.A.	1,383
Chile	450	United Kingdom	392
Rhodesia	218	France	128
Canada	199	Canada	109
Belgian Congo	166	Sweden	72
Mexico	62	Belgium	67
South Africa	32	Switzerland	25
Other Americas	20	Australia	23
Australia	15	India	21
India	6	Netherlands	11
		Denmark	4
Total	2,241		2,235

**Metal Market Rev.*, 1949, 1 (25), 118

†Includes 113,500 short tons from scrap

In 1948, U.S.A. produced 980,498 tons of crude copper and 1,233,697 tons of refined copper; the corresponding production during 1949 was 907,652 tons and 1,056,463 tons. The total production outside U.S A. was 1,271,884 tons of crude copper and 1,072,229 tons of refined copper during 1948, and 1,270,433 tons of crude copper and 1,076,114 tons of refined copper in 1949 [*Metal Market Rev.*, 1950, 3 (2), 4].

U S A. is the largest consumer of copper. The consumption under various heads in 1939 was as follows electrical manufactures, 23·1; telegraph and telephone, 4·87, light and power lines, 8·36, other wires, 11 86; automobiles, 10 61; buildings, 11·11, automatic refrigerators, 1·25, other uses, 22·36, and manufactures for export, 6·48% (Roush, 187).

TABLE 5 —OUTPUT OF COPPER & YELLOW METAL (I C C)

	Ore milled (Tons)	Refined copper (Tons)	Yellow metal (Tons)
1929—1933 (av)	137,090	3,184	3,188
1934—1938 (av)	297,991	6,512	8,017
1939—1943 (av)	343,916	6,236	8,654
1944	306,718	5,730	6,681
1945	308,791	6,000	7,873
1946	329,005	6,311	8,441
1947	305,687	5,931	9,567
1948	309,109	5,863	9,563
1949	310,065	6,390	9,919

* The output of refined copper for the first ten months of 1950 was 5,392 tons.

TABLE 6 —PRODUCTION OF COPPER PRODUCTS (IN TONS) DURING 1949*

	Ingots, slabs, billets, etc.	Sheets and strips	Discs and circles	Rods and bars	Wire	Copper alloys other than brass	Domestic utensils	Other copper products
West Bengal	617		..	8,986	2,247	.	1	743
Bombay (including Baroda)	11	1,623	..	143	6	753	192	126
U P		.	37	..	..	..	16	30
East Punjab..	..	2	94	..	..	..	24	..
Madras, Bihar, C P & Berar, Delhi & Jaipur	584	12	132	2	28	43	32	308
Total	1,212	1,637	263	9,131	2,281	796	265	1,207

*Second Census of Manufactures India—1947, 1950, II, 596. West Bengal produced 17,38,000 yds. of cable.

TABLE 7 —PRODUCTION OF BRASS PRODUCTS (IN TONS) DURING 1947*

	Ingots	Sheets and strips	Discs and circles	Rods and bars	Wire	Domestic utensils	Other brass products
West Bengal	557	122	184	17	15	57	271
Bombay (including Baroda)	762	1,667	520	254	96	3,755	589
U P	10		122	..		129	117
East Punjab		7	342	..		793	105
Madras, Bihar, C P & Berar, Delhi, & Jaipur	470	9,505	234	648		533	43
Total	1,799	11,301	1,402	919	111	5,267	1,125

*Second Census of Manufactures India—1947, 1950, II, 597

TABLE 8 —PRODUCTION OF OTHER COPPER ALLOYS*

	Bell metal ingots (tons)	Gun metal (tons)	German silver ingots (tons)
West Bengal	93	381	..
Bombay (including Baroda)	8	572	5
U P			
East Punjab			..
Madras, Bihar, C P & Berar, Delhi & Jaipur	.	802	
Total	121	1,755	5

*Second Census of Manufactures, India—1947, 1950, II, 591

TABLE 9 -ANNUAL PRODUCTION AND REQUIREMENT OF COPPER AND BRASS MANUFACTURES*

	Requirement (tons)	production capacity (tons)
Brass & copper sheets, circles & strips	40,000—50,000	15,000
Copper and brass rods (other than black copper rods)	3,000	5,000
Arsenical copper rods	500	1,000
Black copper rods	10,000	30,000
Copper and brass tubes	1,000	100
Copper & brass wires (for purposes other than electrical)	2,000	4,000
Bare copper (electrolytic wire)	10,000	24,000

*Indian Tariff Bd, Rep , 20, 21, 28

The installed capacity of the I C C is 7,000 tons of copper per year Table 5 gives the quantity of copper ore milled and the quantities of refined copper and yellow metal produced by the I C C since the beginning of their operations in 1929

Out of 9,919 tons of yellow metal produced in 1949, 9,227 tons were sheets and 692 tons were circles

Tables 6, 7, and 8 give the quantities of copper and copper alloys offered for sale in India during 1947, these figures are indicative of the actual production

The indigenous production of copper in India is about 15% of the total requirements, now estimated at about 35,000 tons per annum The requirements are expected to increase when other industries, e g , manufacture of radio transmitters, heavy electrical equipment, cables, etc , are set up within the country [*Metal Market Rev* , 1950, 2 (22), 6]

The Tariff Board estimated the total annual requirements of copper for the next few years at 70,000 tons comprising electrolytic copper, 10,000 tons, copper for alloys other than brass, 20,000 tons, and semi-manufactures of brass and copper, 40,000 tons (Indian Tariff Bd, *Rep* , 5) The production is estimated at 7,000 tons per annum by the I C C and 5,000 tons per annum from scrap. There is thus a deficit of 58,000 tons of copper, both fire-refined and electrolytic. The annual requirement of yellow metal has been estimated at 96,500 tons, including 15,000 tons for gun metal, bronze, and bell metal The Indian production capacity is estimated at 1,00,000 tons per annum and is likely to be raised to 1,30,000 tons in the near future with the Installation of electric furnaces (Indian Tariff Bd, *Rep* , 13, 15) Table 9

TABLE 10.—IMPORTS OF COPPER AND COPPER PRODUCTS
Qty (1,000 tons,) and Val (lakh Rs.)

	1934/35–1938/39 (av)		1939/40–1943/44 (av)		1944/45–1946/47 (av)		1947–48		1948–49		1949–50	
	Qty	Val	Qty	Val	Qty	Val	Qty.	Val	Qty	Val.	Qty.	Val.
Unwrought												
Tiles, ingots, cakes, bricks, and slabs	34·64	11·44	50 95	22·15	174 65*	95 89*	185·17	144 07	555·87	481·77	440 75	400·51
Other sorts	0 44	0 12	39·32	15 45	18 00†	9 70†	95·00	84 57	81 42	74 33	134 00	139 95
Wrought												
Braziers	0 38	0·11	0 01	0·01			..		0·05	0·08		
Rods	66·94	21·20	149·64	75 70	117.77	59 75	0·47	0·45	0 66	0·63	0·13	0·18
Sheets	191 01	61·98	29 20	16 62	68·07	55·03	105·44	104·91	39·17	51·22	12·27	16 31
Tubes	4 18	2 01	3·83	3·47	2·28	2 58	1·94	3 60	5 84	7 99	3 39	5 99
Wires (excluding Telegraph & Telephone)	9·24	3 72	6 37	4·37	1 66	1·38	1·46	1·37	0·95	1 39	0·21	0·37
Other sorts	11 21	5·73	14 78	7 79	123·64	60 42	12·98	14 42	34 34	26 83	8·09	10 65
Old copper for re-manufacture	5 61	1 47	7 74	2 83	26 00	12 69	42 83	25 61	146 20	107 74	89 41	66 50
Total	323 64	107 78	301 84	148 38	532 07	297 44	445 28	379 00	864 49	751 97	688 25	6424 0

* Average for 2 yrs. only. † for 1946—47 only

TABLE 11 —IMPORTS OF BRASS, BRONZE, AND SIMILAR ALLOYS
Qty (1,000 tons) and Val (lakh Rs)

	1934/35–1938/39 (av.)		1939/40–1943/44 (av)		1944/45–1946/47		1947–48		1948–49		1949–50	
	Qty.	Val	Qty	Val	Qty	Val	Qty	Val	Qty	Val.	Qty	Val.
Unwrought	1 52	0·41	0 44	0 14	104 80	48·09	39·02	22.61	1 04	0 58	1 14	0 58
Wrought :												
Yellow metal Sheets	282 94	76 27	30 88	11 92	155 77*	100 98*	159·33	148·19	76·22	88·28	4 63	5·57
Yellow metal Circles	44 92	13 96	4 34	2 23	..	.	0 30	0 26	2·00	2 61	..	
Rods	5 051	6 70	14 59	8 82	17·59	9 29	5 74	4 39	8 51	9 69	8 30	7 60
Sheets	3 13	1 16	1 37	0 82	16 76	11 99	4 30	4 85	1 61	2 29	19·68	9 94
Tubes	4·04	1 85	1 76	1 69	3 04	3 48	4 97	6 22	2 96	5·11	5 85	9 75
Wire	7 68	2 82	4 80	3 43	1 95	2 24	0·57	0 84	0·88	1·65	5 95	6·94
Wood screws	1·40	1 31	1 18	1 77	1 54	2 62	0 87	2 89	0 76	3 00	0 82	3 05
Other sorts.	30 97	13 52	20 06	13·02	84 77	44·88	107 94	65 24	223·08	145 03	251 14	163 95
TOTAL	402 08	118 93	79 42	43·85	386 22	228 57	323 03	255 49	317 06	258·24	297·51	207·39

* Average for 2 years only

TABLE 12.—IMPORTS OF GERMAN SILVER
(including nickel silver)

	Qty (1,000 cwt)	Value (lakh Rs)
1934/35—1938/39 (av.)	26·19	14 14
1939/40—1943/44 (av)	10·57	4·05
1944–45	negligible	negligible
1945–46	0·02	0·02
1946–47	14·69	11·22
1947–48	27·30	21·57
1948–49	38 72	109·00
1949–50	44 46	84 59

gives the annual requirements and production capacity for various copper manufactures in India

Imports.—Tables 10, 11 and 12 give the imports.

In the pre-war period (quinquennium ending 1938-39) copper products were imported from the following countries, the figures within brackets being their percentage shares in the imports. *unwrought copper*—Portuguese E Africa (41 9), South Africa (21 5), U S A. (19·2), and U K (13·4), *braziers*—Germany (100), *copper rods.*—U S A (49·8), Japan (40·7), U.K. (5·8) and Germany (2·4), *copper sheets.*—U K. (43 6), Germany (41·4), and U S A. (11 8), *copper tubes*—Germany (63 5), U K. (16·3), and Japan (15·2), *copper wire* (excluding telegraph and telephone wires).—Japan (45 8), Germany (29·6), and U K (22·1) Taking all the items together, U K, Germany, U S A, and Japan were the principal countries from which India imported copper, their respective shares being: 30 6, 27 5, 19·2, and 12 0%

In the quinquennium ending 1938-39, Germany, U.K, and Japan were the main suppliers of brass, bronze, and other copper alloys to India, their respective shares in the total imports being 47 5, 29 0, and 20·8%. In the same period the percentages shares of the different countries in the imports of various products were *rods*—Japan, 41 9, U K., 19 9, *sheets.*—Germany, 73·2, U K, 13·1, *tubes.*—Germany, 61 9, Japan, 17 2, U K, 7 9, *wires.*—Japan, 64·5, Germany, 24 3, U K, 9·9; *wood screws*—Belgium, 37 1, U K, 31 3, Japan, 24 8, *unwrought.*—U K, 71·1, Germany, 19·7. The corresponding figures for yellow metal sheets and circles are not available Imports of circles stopped during World War II and prior to the War, Japan and Germany shared equally in the imports.

During the quinquennium ending 1938-39, the imports of German and nickel silver were distributed as follows Germany (28·1%), U K. (25·5%), Japan (15 2%), Italy (12·1%), and Australia (11 1%) During World War II, these alloys were obtained mainly from U K and U S A

Exports—Small quantities of copper and copper alloys are exported from India Table 13 gives the exports of wrought copper, brass, bronze, and other alloys

There is no duty on imports of copper scrap and unwrought copper including electrolytic wire bars into India. Imports of all other copper products are subject to protective duties at the rates given in Table 14

TABLE 13—EXPORTS OF WROUGHT COPPER, BRASS, BRONZE, AND OTHER ALLOYS

	Copper		Brass, bronze, and other alloys	
	Qty. (1,000 cwt)	Value (lakh Rs)	Qty. (1,000 cwt)	Value (lakh Rs)
1934/35—1938/39 (av)	112 01	14·43	12·86	6 76
1939/40—1943/44 (av.)	1·11	1·32	6·42	6 24
1944–45	0·08	0·25	5 99	43 11
1945–46	0·10	0·14	3·77	17·61
1946–47	3·47	1 09	0·42	1 82
1947–48	0·34	0·46	3·07	3 74
1948–49	0·57	1·30	5 06	6 21
1949–50	1·55	3·19	8·35	15 42

TABLE 14 – IMPORT DUTY ON COPPER MANUFACTURES

	Duty (ad valorem)
Copper rods other than electrolytic Copper rod	35% on British manuf; 45% on others
Electrolytic copper rods (or black copper rods) in coils	20% on British manuf; 30% on others
Other copper manufactures	24% on British manuf; 36% on others
Brass, unwrought	10%
Brass wires and rods	35%
Yellow metal other than brass (such as gun metal, bronze, bell metal, phosphor bronze, and manufactures)	30%
Other brass manufactures	30%
German silver, nickel silver, and cupro-nickel	30%
Electrolytic copper wire	30%

COPPER COMPOUNDS

Copper forms two series of salts, cuprous salts and cupric salts. The latter are the more important, but numerous chemical applications depend on the transformation of one series of salts to the other, i e, on the change in the valency of copper. Nearly all copper salts are coloured, soluble in water, and poisonous

Copper acetate

Normal copper acetate, $Cu(CH_3COO)_2 \cdot H_2O$ is prepared by dissolving cupric oxide or verdigris in acetic acid, or by the action of copper sulphate on the acetates of lead, calcium, or barium It is a bluish-green, efflorescent, crystalline substance [sp gr, 1·9, m p., 240° (*decom*)], 1 part of which is soluble in 20 parts of cold water, 5 parts of boiling water, 25 parts of alcohol, and 10 parts of glycerine It is used in the manufacture of pigments

Under the name Crystals of Venus, copper acetate was used in therapy as astringent, caustic, and fungicide. It has now passed almost completely out of medicinal use (U S.D, 1412)

Copper acetate was prepared and marketed in small quantities in pre-war years by Messrs. *Field Research Station*, Lahore.

Basic copper acetate or verdigris is made in France by immersing copper plates in marcs or residues of grapes from wine manufacture, which have undergone spontaneous acetic fermentation. The plates coated with verdigris are taken out, exposed to air for 2–3 days, and the coating scraped off. The plates are again returned to the fermenting mass This procedure is repeated until all the copper is acted upon. The verdigris is kneaded into cakes in leather bags and dried. The product, consisting principally of basic acetate $Cu_2O(CH_3COO)_2$, is a greenish blue powder with faint acetic odour, partly soluble in water, and soluble in dilute acids and ammonia It is used in the manufacture of Paris Green and other pigments, as insecticide and fungicide, in dyeing and printing textile fabrics, and in the preparation of gilder's wax. It is used as a dusting powder, ointment, and plaster, particularly for corns and insufflation in pulmonary tuberculosis It is now chiefly used in veterinary medicine for proliferations. It is an ingredient of catalytic preparations

Copper aceto-arsenite.—Paris Green, Imperial Green, Schweinfurt's Green, Vienna Green, Mitis Green

Paris Green, $3\ CuOAs_2O_3 \cdot Cu(CH\ COO)_2$, is manufactured by mixing aq solutions of arsenious oxide and verdigris, boiling the mixture, and adding acetic acid It is also obtained by mixing a hot solution of white arsenic in sodium carbonate with the calculated quantity of copper sulphate solution. It is a micro-crystalline, emerald green powder, soluble in ammonia and acids, but insoluble in water The commercial product contains 53–55% arsenic as As_2O_3, with soluble arsenic below 3%

It is extensively employed as larvicide as it fulfils more closely the requirements of an anopheles larvicide than any other known preparation For use, it is diluted (to contain 1–5% of the substance) with road dust, powdered soapstone, fine sand, etc, and dusted over ditches, small streams, irrigation channels, etc, by hand or by rotary blowers.

A large part of the Paris green, required for anti-malarial purposes, is imported into this country. The principal manufacturers in India are Messrs *Smith Stanistreet and Co, Ltd*, Calcutta. The target of production in India has been fixed at 5,000 tons to be reached by 1957 (*Rep. Panel, Chemicals, Drugs and Pharmaceuticals*, 1947, 12).

Copper arsenate

Copper arsenate is employed as insecticide. The methods now used in its preparation yield an impure product. An electrolytic process for its preparation has been recently developed (Singh & Sivaramakrishnan, *J. Indian chem. Soc.*, 1950, **27**, 9).

Basic copper arsenate, Cu ($CuOHAsO_4$) is reported to be an effective and stable insecticide (Frear, 30).

Copper arsenite

Two copper arsenites are known, the *ortho*-arsenite or Scheele's Green, and the *meta*-arsenite Scheele's green, $3CuO\ As_2O_3 \times H_2O$, is produced by mixing a 2% solution of copper sulphate with a solution of arsenious oxide in soda ash solution, and adding a dilute solution of caustic soda while stirring until all the copper is precipitated The precipitate is washed, filter-pressed, and dried at about 35° By varying the relative proportions of arsenious acid and alkali, greens of varying tones—from pale to dark green—can be obtained Scheele's green was formerly used largely for calico printing and for colouring wall papers It was also used as an intestinal antiseptic It is now employed as a wood preservative

Copper *meta*-arsenite, $CuAs_2O_4$, is prepared from scrap copper and white arsenic Copper scrap is dissolved in ammonium chloride and the solution mixed with arsenious acid to precipitate *meta*-arsenite The precipitate is filtered, washed, and spray dried The ammonium chloride is recycled A pilot plant for *meta*-arsenite manufacture was operated for the first time in U S A in 1939 (Miller, *Industr Engng Chem*, 1947, **39**, 1521) Copper *meta*-arsenite is cheaper and more effective than Paris green as mosquito larvicide.

Copper carbonate

Basic copper carbonates, occur in nature as Malachite, $CuCO_3\ Cu(OH)_2$ and Azurite, $2CuCO_3\ Cu(OH)_2$. Basic copper carbonate, $Cu(OH)_2\ CuCO_3\ H_2O$, is obtained as a precipitate when a solution of soluble carbonate is added to a solution of a soluble cupric salt Normal copper carbonate has not been prepared.

Basic copper carbonate is a dark green to blue powder soluble in dilute acids or ammonia and insoluble in water and alcohol It is used as a pigment and drier in oil-boiling, as insecticide, and in pyrotechnics It has been used in medicine as an antidote for phosphorus poisoning, as an external application in the form of ointment (containing 10—20% salt), and as an astringent in the place of sulphate (U S D, 1412) Malachite is widely used in the treatment of seeds, particularly wheat, for the control of bunt, *Tilletia tritici* (Frear, 165).

Copper chloride

Like other salts of copper, copper chloride exists in two forms, cuprous chloride and cupric chloride Cuprous chloride, Cu_2Cl_2 (sp gr, 3 53, m p, 422°), is prepared by boiling cupric chloride with hydrochloric acid and copper turnings On addition of water, it is precipitated as white crystals The hydrochloric acid solution of cuprous chloride, when exposed to air, absorbs oxygen and acquires a brownish colour, subsequently depositing a pale bluish green insoluble copper oxychloride, $CuCl_2\ 3Cu(OH)_2$. An identical substance, Brunswick Green, is prepared by boiling a solution of copper sulphate with a small quantity of bleaching powder solution or by exposing copper turnings moistened with hydrochloric acid to air

Cuprous oxychloride is reported to be more germicidal in its action than copper sulphate

Cupric chloride, $CuCl_2$, may be obtained as a fused buff-coloured anhydrous mass by heating copper in a stream of chlorine It may be prepared by dissolving the oxide in hydrochloric acid It crystallizes in grass-green prisms or needles containing 2 mol of water, $CuCl_2\ 2H_2O$ (sp gr, 2 47), which turn pale blue when dried *in vacuo* It is extremely soluble in water. The anhydrous form is yellow (sp gr, 3 054, m p, 498°)

Cupric chloride is used as an oxidizing agent, a catalyst (Deacon chlorine process), and a mordant in dyeing and printing textile fabrics It is employed in disinfection, in pyrotechnics, and in metallurgy It is occasionally used in medicine as a substitute for copper sulphate for its astringent and antiseptic properties.

Copper naphthenate

Copper naphthenate is made by adding screened copper acetate, copper hydroxide, or copper carbonate in calculated quantities to distilled naphthenic acids heated to 300°F, the rate of addition being controlled to keep foaming at a minimum When all the water is removed, the product is ready for packing Another method is based on precipitating the soluble sodium naphthenate soaps with a solution of copper sulphate (Davidsohn, *Industr. Chem*, 1950, **26**, 385).

Copper naphthenate, a dark green or emerald green substance (sp gr, 1 010—1·132; Cu content in commercial preparations, 8—11%), is used as a fungicide in the preservative treatment of timber, tarpaulins, ropes, etc. During World War II, copper naphthenate was extensively employed in the treatment of tarpaulins, ropes, sand bags, and wooden boats It does not produce dermatitis, can be applied in the form of paint when dissolved in petroleum solvent, and is free from objectionable odour. The cost of treatment is comparable to that of pentachlorophenol which is now used for the same purpose. Because of

its superior fungicidal activity, it is being increasingly used in conjunction with creosote in the treatment of timber (*Industr. Engng Chem.*, 1949, **41**, 2087). Among the minor uses may be mentioned its application as a stabilizer for gasoline, lubricating oils and transformer oils, and plastics, and as a termite-proofing agent in building construction (Gregory, II, 86).

Copper nitrate

Copper nitrate, $Cu(NO_3)_2 \cdot 3H_2O$, is obtained by dissolving copper oxide or carbonate in nitric acid and evaporating the solution. It is produced in India by Messrs. *Sambhu Nath and Sons*, Amritsar It is a dark blue crystalline product containing 3 mol. of water (m p, 114 5°). It boils at 170° evolving nitric acid fumes and forming a green basic salt, which on further heating gives off nitrogen peroxide, oxygen, and water, leaving a residue of copper oxide Hydrated crystals containing 9 mol of water are obtained at low temperatures, −20° to −24°, while crystals containing 6 mol of water are obtained between −20° and +26°.

Copper nitrate is used in the preparation of photographic emulsions and insecticides. It is used also in electroplating, in colouring metals, or as a mordant in textile dyeing. $Cu(NO_3)_2 \cdot 6H_2O$ is used in paper and ceramic industries.

Copper oxide

There are several oxides of copper, among which cuprous oxide, Cu_2O, and cupric oxide, CuO, are important Cuprous oxide occurs in nature as cuprite or red copper ore It is prepared by heating finely divided copper in air below red heat; by reducing an alkaline copper solution with glucose or sugar; or by heating 5 parts of cupric oxide with 4 parts of copper powder in a covered crucible An electrolytic method, which yields a product of colloidal structure with high fungicidal value, has been recently described (*Rep Progr appl. Chem*, 1948, **33**, 183).

Cuprous oxide (sp. gr, 6·0; m p, 1,235°), is insoluble in water and soluble in acids and alkalies. The colour of pure cuprous oxide is a function of the particle size (range of sizes, 0·9 μ to 2·57μ), the smaller particles being yellow. The oxide is used to impart a red colour to glass and ceramics; it is used also in electroplating, in A C rectifiers, and as a catalyst in the preparation of organic compounds. Its photoelectric properties are utilized in the construction of photoelectric cells (Brady, 199; Thorpe, III, 354). It is used in seed treatment both on account of its protective action against damping-off organism, *Pythium ultimum*, and fungicidal properties. Its value for this purpose varies with particle size, the smaller particles being more efficient. It is usually applied at the rate of 3 lb./100 gal and is compatible with most spray materials except lime-sulphur (Frear, 164).

Cupric oxide (black copper oxide) is prepared by heating copper nitrate or carbonate to dull redness or the sulphate to a high temperature. It can also be obtained by heating finely divided copper or cuprous oxide in air or oxygen. It is a hygroscopic, brownish black, amorphous powder (sp gr., 6 4), insoluble in water and alcohol. It dissolves in acids with the formation of cupric salts It is soluble to some extent in oils, and hence copper cooking vessels require constant cleaning (Thorpe, loc cit)

It is used for colouring ceramics green or blue, and as a catalyst in the preparation of organic compounds It was formerly used as a discutient in chronic lymphadenitis It is also asserted to be an active taenicide of low toxicity (U.S D., 1412).

Copper sulphate

Copper sulphate, Blue Copperas, is known in the anhydrous form as $CuSO_4$, and in hydrated forms as $CuSO_4 \cdot H_2O$, $CuSO_4 \cdot 3H_2O$, and $CuSO_4 \cdot 5H_2O$ In the form of penthahydrate it occurs as chalcanthite in Chili, Arizona, and elsewhere.

Copper sulphate may be prepared by dissolving metallic copper or copper oxide in sulphuric acid, solution being assisted by the addition of nitric acid or sodium nitrate. For large scale manufacture, metallic copper scrap is heated with excess of sulphur in a reverberatory furnace, with air excluded, to form copper sulphide. Air is admitted, and heating continued at dull redness when the sulphide is oxidized to sulphate. The hot mass is discharged into dilute sulphuric acid, the solution decanted, concentrated, and crystallized. The sulphate thus produced is of a high degree of purity. Copper pyrites may be used in place of copper scrap, if the presence of iron in the product is not injurious in the applications for which the copper sulphate is required. Commercial sulphate required for agricultural purposes is prepared from pyrites. By carefully adjusting the temperature of roasting, iron sulphate may be converted into oxide, while the copper sulphate remains almost unaffected. Alternatively, the iron may be oxidized by nitric acid and removed as oxide by boiling with copper oxide, or by boiling with lead peroxide followed by the addition of barium carbonate.

$CuSO_4 \cdot 5H_2O$ is an azure blue crystalline product, sp gr., 2·286, soluble in water (12·9 g. at 0°; 18·5 g. at 25°; 42·4 g. at 100°, in 100 g. of water). When heated, it loses 2 mol of water at 30°, 4 mol. at 100°, and nearly all the water of hydration at 260°. The white anhydrous residue (sp. gr., 3·606) is hygroscopic turning blue on absorption of water It decomposes at 650—750° giving a residue of copper oxide

Copper sulphate is the most important salt of copper and forms the starting material for the preparation of a large number of copper compounds used in commerce It is used principally as fungicide, it is used also in calico printing, dyeing, electroplating, and in galvanic cells In the anhydrous form it can be used as a dehydrating agent. It is a catalyst in the preparation of esters from lower aliphatic acids and olefines. It is used for destroying low forms of vegetable and animal life in ponds, and as a constituent of wood preservatives

Copper sulphate is sometimes used in the treatment of anaemia It is irritant, astringent, and antiseptic In 0 3 g doses it is a prompt and active emetic, and may be used to evacuate the stomach in various forms of poisoning, especially in phosphorus poisoning, where it plays the dual part of combining with phosphorus to form phosphide and acting as an emetic A 1% solution is beneficial for phosphorus burns of the skin Its disinfectant power is moderate in the presence of proteins, and against sporulating organisms it is ineffective Subconjunctival injections of a 1% solution with 4% procaine have been claimed by certain ophthalmologists to be effective in trachoma and in 0 25—0 5% solution, it is a stimulant collyrium in conjunctivitis and styes. Retention enemas of 1 in 5,000 solution have been used for amoebic and chronic bacillary dysentery (U S D, 348).

Production—Copper sulphate is produced by The *Bengal Chemical and Pharmaceutical Works*, Calcutta, *Alembic Chemical Works Co. Ltd*, Baroda; *Mysore Chemical Mfg Co. Ltd.*, and The *Mysore Chemicals and Fertilizers Ltd*, Mysore, and a few other concerns in India, from scrap copper and sulphuric acid.

According to I.S.D Specification (No G/Chemicals-18C) copper sulphate qualities 1 and 2, shall contain not less than 98·5% $CuSO_4 5H_2O$, iron calculated as hydrated iron sulphate, $FeSO_4 \cdot 7H_2O$, shall not be more than 0·15% and 0·5% respectively in qualities 1 and 2. All crystals shall pass through a wire sieve of mesh 1 inch in the case of quality 1, and 1½ inch in the case of quality 2, but not more than 1% shall pass through a wire sieve of mesh ¼ in Copper sulphate (quality 1), required by the Posts and Telegraphs Department for use in Daniel cells shall be capable of giving a minimum output of 90 amp hrs. per lb when tested in a Gravity Daniel Cell of 16 oz size, and also shall be suitable in other respects for such use.

TABLE 1.—IMPORTS OF COPPER SULPHATE

	Qty. (cwt.)	Value. (Rs)
1934/35—1938/39 (av)	31,664	4,14,393
1939/40—1943/44 (av)	31,785	10,14,066
1944-45	32,127	12,07,854
1945-46	12,071	3,97,536
1946-47	16,033	5,33,566
1947-48	26,194	6,29,699
1948-49	25,529	9,57,354
1949-50	22,227	8,70,655

The total installed capacity for the production of copper sulphate in India is about 1,500 tons per annum, 424 tons of copper sulphate were produced in 1948 and 450 tons in 1949 (Information from D G I &S)

Copper sulphate is chiefly consumed in India by the coffee, tea, and rubber estates and by the departments of agriculture (*Rep Panel, Heavy Chemicals and Electro-Chemical Industries*, 1946, 9)

Imports—Considerable quantities of copper sulphate are imported into India (Table 1) Prior to World War II, the Indian demand was met mostly by imports from U K, Germany, and Belgium In 1942-43, U S A supplied 16,625 cwt and Egypt, 28,051 cwt Imports of copper sulphate into India are subject to a preferential revenue duty of 26% *ad valorem* when obtained from U K and British Colonies, and 36% *ad valorem* when obtained from other countries About 80% of the imports is used for agricultural purposes. During the War, 2,000 tons of copper sulphate were used for rot-proofing of jute bags.

Copper sulphide

There are two sulphides of copper corresponding to the two oxides They are found in nature as copper glance or chalcocite (Cu_2S) and indigo copper or covellite (CuS)

Cuprous sulphide is formed when copper is heated with sulphur or when copper sulphate is heated with sodium thiosulphate It is obtained as a black powder or as lumps (sp. gr, 5·80;

m.p. 1,130°), soluble in nitric acid and insoluble in water. It is dimorphous (transition temp., 91°). It is used in protective paints for ships.

Cupric sulphide is prepared by heating cuprous sulphide with sulphur at a temperature below the melting point of sulphur, by digesting cuprous sulphide with cold strong nitric acid, or by passing hydrogen sulphide through an aqueous solution of a soluble cupric salt It is obtained as a paste by precipitating a solution of copper sulphate with sodium sulphide Cupric sulphide (sp. gr., 4·60; m.p., 1,100°) is soluble in nitric acid. It is used in calico printing for developing aniline black, and in protective paints for ships

CORDAGE AND ROPES

The term cordage refers to a wide variety of flexible products such as ropes and cables, twines and cords, derived primarily from spun vegetable fibres. Rope is stranded cordage (diam , 3/16 in.), made by laying or twisting together three or more strands Ropes are also made by twisting 3 or 4 ordinary ropes together. Twine is less than 3/16 in. diam. and is composed of two or more yarns, binder twine is a single yarn product Cord is an indefinite term meaning thin rope or thick string made by twisting several yarns together Lines are made up to 1 in or 1½ in. diam. and are used for sounding, fishing, measuring, etc

Ropes are usually plain or hawser laid. They are made of 3 strands and are available in all sizes from ½ in. circum upwards Four-strand ropes, known as shroud laid ropes, are available in all sizes from 1½ in circum. upwards; they are superior to hawser laid ropes as regards roundness. When ropes are made with more than three strands a hollow core is formed in the centre which is filled by a central cord serving as a cushion for the covering strands. Cable laid ropes are made from three or more hawser laid ropes and are available in sizes from 5 in. circum upwards, they have greater elasticity and flexibility than hawser laid ropes of the same circumference but less strength.

More than half the quantity of ropes produced is consumed by the shipping and fishing industries and the Navy. Ropes are also used in oil-well drilling, and for power transmission and machine drives. In the farm it is used for tying cattle, drawing water from wells, etc. The building and engineering industries utilize considerable quantities of rope.

Twines are mostly used for binding or tying and for sewing and netting.

Ropes of high quality are produced by the aid

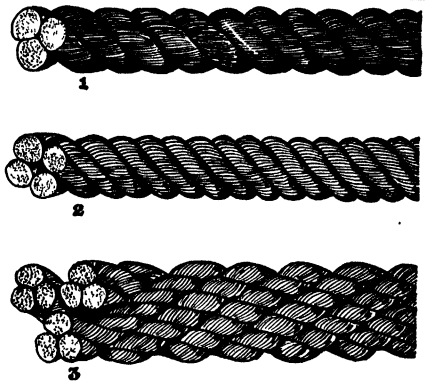


Fig. 59.—Construction of ropes—1 hawser laid; 2. shroud laid; 3. cable laid.

of machines in rope making factories. Rope making on a factory scale was started in Calcutta in 1780 by Messrs *W H Harton & Co Ltd* Other factories followed, prominent among them being *G D Banerji & Co , Ltd.*, (1840); *Shalimar Rope Works Ltd*, (1847); *S. C Mullick & Co.*, (1869); *Ganges Rope Co Ltd*, (1903); and the *Bengal Rope Works*, (1918) These factories are situated in and around Calcutta In some of them the processing is done wholly by machinery, while in others, the bulk of the work is carried out manually. Their output varies from 30 tons to 1,000 tons per month. The *Ganges Rope Works*, which supplied approximately 55% of the requirements of the Defence Services during World War II, is the largest among the factories, and was completely modernized in 1938 The total capital employed by the industry is over a crore of rupees, and the factories provide employment to about 3,500 workers

A large number of small units have also been established in Calcutta and Bombay for the manufacture of ropes. Hand spinning and twisting of strands into ropes and cordage are well established cottage industries throughout India. Wire ropes are not manufactured in India.

Raw Materials

The principal cordage fibres are: Sisal, Manila, Henequen, and True Hemp. The first three hard fibres are primarily used for making ropes, more than 85% of the world production of these and other hard fibres being consumed for this purpose (*Foreign Comm. Weekly*, 1949, **36**, 5). They are

also used for making cheap twines and lines. True hemp, which is a soft fibre, is employed mainly for sewing twine, book binders' twine, fishing line, log line, boat lacing, and similar cordage

The principal hard fibres used for cordage in India are Manila and sisal Both are imported into the country Small quantities of Cebu-Maguey or Cantala fibre, Henequen, Bombay Aloe fibre, and coir are also used, of these the first two are imported into the country True hemp is used only in negligible quantities

Manila fibre or Abaca, obtained from *Musa textiles*, is grown mainly in the Philippines Small quantities are produced in North Borneo and Indonesia The fibre is 5—16 ft long, strong, and durable and is considered to be the best fibre especially for marine cordage Manila rope is used for well-drilling, hoisting, and power transmission The different grades are I, J-1, G, J-2, S-2, S-3 and K Two qualities are recognized in the trade, the Davao or special quality and Ordinary.

Sisal, from *Agave sisalana* Perr, is cultivated in Africa, Indonesia, Haiti, and Brazil It is obtained from British East Africa which is by far the world's largest producer The fibre is 3 5—6 ft long, possesses an attractive light yellow or cream colour and is hard, strong, and durable It is one of the cheapest fibres used for ropes, twines, and cords. During World War II, sisal came into prominence owing to the stoppage of Manila fibre supplies and its usefulness for marine cordage has now been well established It is nearly equal to Manila fibre for most purposes (*Bull imp Inst, Lond*, 1931, **29**, 17) The different grades of sisal used are No 1, A, No 2, No 3 Long, No 3 Short, Rejections, Tow

A small amount (20,000 cwt) of sisal of the East African grade is produced in Sambalpur Dt (Orissa) and is used by the Calcutta rope factories. The fibre is also produced in Bombay and other places and used locally.

Henequen, obtained from *Agave fourcroydes* Lem., is mainly grown in Mexico Small quantities are also grown in Cuba and El Salvador It is a hard, rather coarse fibre, light yellow in colour, and 2 5—3 5 ft long. It is inferior to East African sisal and is used for cord and small ropes.

True hemp is the most important among the cordage fibres The hemp plant is cultivated in Italy, France, U S S R, Poland, and U S.A. The fibre is soft, 4—12 ft. long, and creamy white in colour The Italian product is of the highest quality, followed by French hemp Russian and Polish hemps are inferior Both hemp line and hemp tow are used. True hemp is mainly used for making strong twines It is obtained in India in small quantities in Garhwal, Kashmir, Simla Hill States, Kangra, and Travancore (Sircar, *Misc Bull I C A R*, No 66, 1948, 33)

Maguey from *Agave cantala* Roxb. is grown mainly in the Philippines (Manila Maguey or Cebu Maguey) and in the East Indies (Cantala fibre) It is finer but less strong than sisal and is used for second grade ropes and cordage

Bombay Aloe fibre is obtained from *A cantala* Roxb, growing in Deccan and is extracted on a commercial scale in Bombay It is inferior to sisal in strength but is preferred on account of its cheapness and whiteness, which gives it the appearance of sisal The fibre is used mostly for household and agricultural ropes Approximately 40,000 cwt of aloe fibre is annually produced (Sircar, op cit, 5)

A small amount of fibre is obtained from *A. veracruz* from Sabaya (Bihar) and Madras (Anantapur Dt) and sold to Calcutta rope factories Veracruz fibre is coarser than Cantala fibre, lacks lustre, but is comparable to it in strength

Coir obtained from the husk of *Cocos nucifera* is used extensively in south India for cordage manufacture It is also used in mechanised rope factories It is resistant to the action of water and has the property of elongation without breaking which makes it an important material for rope making

Other fibres used for ropes are Istle (Tampico fibre) produced in Mexico, New Zealand flax or hemp (Phormium fibre), Bowstring hemp (Sansevieria) in Africa and New Guinea, and Caroa in Brazil These fibres are not at present used in India

Among the soft fibres used in India are cotton, jute, and occasionally sunn hemp and Deccan hemp Jute obtained both from *Corchorus capsularis* and *C olitorius* is the cheapest fibre used in the cordage industry

Sunn hemp is obtained from the bast of *Crotalaria juncea* cultivated in the Philibit and Moradabad Dt (U P), in the Punjab, the Madhya-Pradesh, Hyderabad, and in certain parts of Bombay, Orissa and Bengal (Bengal hemp) The Ganjam quality which accounts for nearly 43% of the total Indian production and Bengal hemp are used for making ropes, strings, and unsized 2-ply twines (Sutlis) Of the total production of sunn hemp about 60% is used for ropes and 10% for twines. Considerable quantities of Bengal hemp are utilized in the rural

TABLE 1.—IMPORTS OF FIBRES
quantity (cwt.) and value (Rs.)

	Sisal		Manila		Cantala		True hemp	
	Qty.	Val.	Qty.	Val.	Qty.	Val.	Qty.	Val.
1934/35—1938/39 (av)	1,200	15,738	28,091	4,16,827	1,185	15,046	132	6,621
1939–40	11,392	1,59,668	36,214	5,65,644	808	9,578	..	..
1940–41	5,657	97,144	95,642	27,06,927	2,028	29,323	..	..
1941–42	39,473	6,74,679	93,322	16,52,243		..	..	..
1942–43	92,901	20,29,459	13,622	3,05,261	..	..	..	..
1943–44	100,550	20,31,163	..	..	..	.	..	..
1944–45	193,209	43,38,749	..		..		..	..
1945–46	152,869	36,39,497	..	.	..	.	..	..
1946–47	11,000	2,51,597	..	..	..	..	..	..
1947–48	92,952	47,46,570	..	.	..	..	..	..
1948–49	13,382	6,45,824	..	..	..	.	..	..
1949–50	64,141	41,59,898	..	..	..	.	..	..

areas around Calcutta for making twines and lines on a cottage industry basis 140,000 cwt. of sunn hemp grown in India were consumed by the rope factories in 1943-44.

Cordage and ropes manufactured in India are solely from natural vegetable fibres. Nylon, the synthetic fibre, used for rope manufacture in other countries has not been used in Indian industry so far. Nylon yarn has high tensile strength (31—32 tons/sq. in.), high elasticity (recovering within 10% of its original length after applying a load equal to 50% of the breaking load), and high degree of extensibility. It is non-inflammable, resistant to water, and easy to handle when wet or dry. It is resistant to micro-organisms and chemicals and does not deteriorate during storage Nylon ropes have been used for glider towing, mountain warfare and rock climbing, and for admiralty purposes.

Bombay or Deccan hemp also called Bimlipatam jute in Madras is extracted from *Hibiscus cannabinus*. It is used for ropes and unsized twines.

The imports of fibres are shown in Table 1.

Imports of hard fibre were subject to duty in the pre-war years. This stimulated the import of rope from Japan, which rose from 7 cwt. in 1929-30 to 11,266 cwt. in 1935-36. The duty on imports of Manila fibre was abolished during World War II, while that on sisal and maguey fibre imports was abolished in 1948 All hard fibres are now imported free of duty.

MANUFACTURE

The manufacture of cordage consists of two stages, preparation of yarn and rope making.

Preparation of yarn—Excepting cotton and coir yarn, other yarns used in cordage are spun in the rope factory. Cotton yarn is spun in cotton mills and supplied to the rope factories. The existing plants in the rope factories are not adapted to the spinning of short, wiry, hard coir fibres and hence coir yarn is obtained in the form of 2-ply strands from south India

Yarn is made by hackling the fibre, drawing, and spinning Different grades of fibre are mixed in the required proportions and the mixed fibres combed and straightened in a Good's No. 1 hackling and spreading machine in which the fibre, fed through a pair of rollers, is carried along a slow moving series of bars connected by endless chains, the bars being studded with sharp steel gill pins which work like a comb. The fibres are next carried along by a fast moving chain which hackles or combs out the ends of fibres and splits up the bunches into finer groups, straightening and parallelizing them at the same time, and removing the dirt and foreign matter. The hackled fibres are delivered by a front drawing roller in a heavy continuous stream or sliver which is coiled by hand or machine into a can.

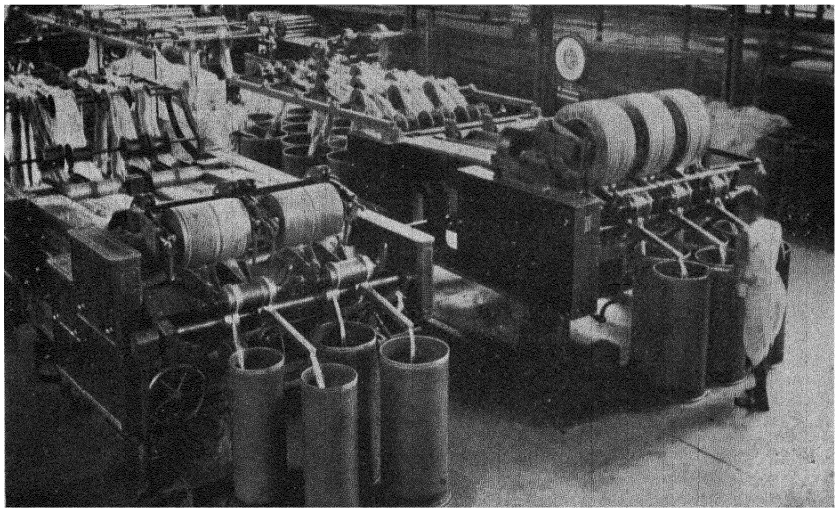


Fig. 60.—Hard fibre drawing frames

The operation is repeated 3—5 times, depending on the type of product required, in Good's machines, each operation resulting in a thinner and more even sliver. These machines differ from Good's No. 1 machine in having gill pins set closer together and a higher delivery speed. They parallelize the fibre still further and produce a uniform silver by doubling and drafting.

The sliver from the final Good's machine is drawn and doubled 3 or 4 times in drawing frames, in each of which 4—8 slivers are doubled and drawn. The front roller draws out the silver through the gills.

Spinning.—The sliver from the finisher drawing frame is spun in automatic jenny spinning machines or in automatic doffing gill spinning frames, the latter being preferred for hard fibres. In the jenny spinners, the sliver is fed through a tunnel shaped tube, a pair of feed rollers and another similar tube, into a chain gill sheet and then drawn through a twist tube by a haul pulley mounted in a flyer. The yarn passes round guide pulleys to a bobbin mounted on a spindle in the flyer.

Gill spinning is efficient and is especially well adapted for yarns lighter than 600 ft./lb.; it gives a stronger product (breaking strain increased by 10%). The sliver from the finisher drawing frame is fed by a pair of rollers to a gill sheet and the final drawn out sliver is led to a flyer which twists it into yarn and lays it on the bobbin. The flyer speed varies from 1,800 r.p.m. for coarse (200—400 ft./lb) yarn, to 3,000 r.p.m. for fine yarn. The twist is given by the ratio of the flyer speed (r.p.m.) to length delivered. Gill spun yarns have more projecting fibres than yarns spun in automatic jenny spinners due to the higher flyer speed.

The method used for spinning soft hemp fibres is somewhat different. The hemp is first hackled, resulting in approximately 70% line fibre and 30% tow. The line fibre is processed in the same manner as hard fibre by doubling and drawing until a final sliver of the desired weight/length is produced, which is then spun on a suitably designed Gill spinner. Soft hemp yarns are used for the preparation of dressed and tarred lines for marine use. The hemp tow is mostly used in the manufacture of tarred oakum for caulking purposes.

Jute is carded before spinning.

Both hard and soft fibres are dressed with batching emulsions in order to lubricate the fibres and thereby facilitate their passing through gill pins, to soften them, to serve as a preservative, and to provide internal lubrication to the rope. The emulsion is made by batching oil, soap, beeswax, and grease. Invert water-in-oil emulsion is used for hard fibres and is applied to the fibre on the slow chain of Good's No. 1 machine. Soft fibres are batched with oil-in-water emulsion.

Yarn size.—A rope yarn is designated by a number which indicates the number of yarns of a particular length or weight required to make one strand of a 3 in. circum. hawser laid rope. Thus, 24 yarns of No. 24's rope yarn will be required for forming one strand. The weight/length of yarn is equal to length in ft. per lb. of yarn divided by 15. Rope yarns are made from 18 to 40 numbers. The numbers required for sisal and Manila ropes are: 40's for 1 in. circum.; 30's for 1¼–3 in. circum.; and 24's and 25's for all higher sizes.

Rope making.—The diameter of strands used for rope making is determined by the diameter and construction of the rope; the number of yarns required for a strand are determined by the strand diameter and the yarn number. Having settled the number of yarns in a strand and the number of strands in a rope, any required size of rope can be made. The twist in the strand and the angle of lay of the rope are important. A good rope should have strands in which the outside yarn should have an angle of twist from 27–32°. The angle of lay denotes the angle of twist in a rope or the angle of the strands to the centre line of the rope. The lay can either be left- or right-hand and is opposite to the twist in the strands. Yarns are usually given a left-hand twist, and strands a right-hand twist. Ropes are made with soft (32–34°), medium (37°), and hard (39–40°) lays for various purposes. Soft laid strands are used for forming the primary ropes in a cable-laid rope.

Hard fibre ropes are made either in the 'rope walk' or on 'house machines'. The latter are employed for small sizes up to 1¾ in. circum. The rope walk is used for higher sizes, for 2 in. to 24 in. or more. Ropes from soft fibres such as soft hemp, flax, and cotton are usually made in house machines.

Rope Walk.—A modern rope walk consists of the bobbin bank, the 'foreboard', the 'traveller' and the 'top cart', all in the same line. The bobbin bank contains the yarn. The foreboard has attached to it a register plate with a number of holes through which the yarns are drawn to

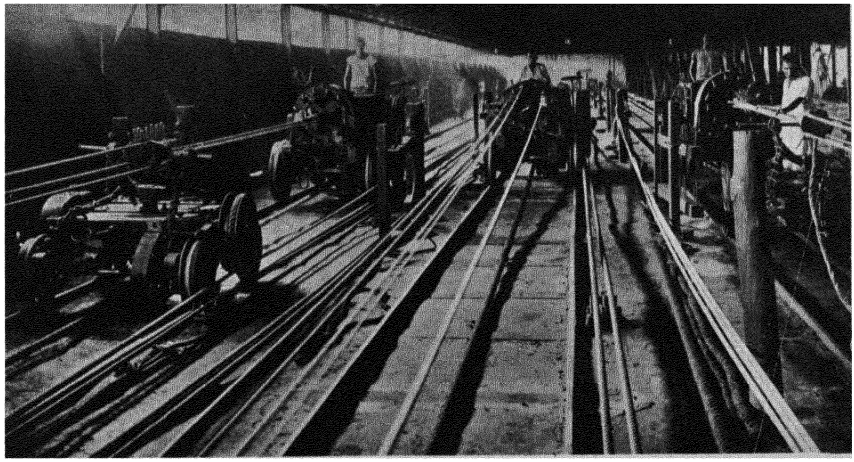


Fig. 61.—Ropewalk showing 'travellers'

form the strand and a few hooks which can be rotated by gear arrangement. The traveller also has a number of hooks attached, and moves along rails from one end of the walk to the other, drawing and twisting the strands and laying the rope. The top cart, also running on the same rails, carries a 'top', which is a conical hardwood piece with grooves for guiding the strands.

The required number of yarns of the correct number are passed from the bobbin bank through the register plate, through a tube, and then attached to a hook in the traveller. As the traveller moves down the walk, the hook revolves drawing out and twisting the yarns into a strand. Several strands can be drawn simultaneously. The number of yarns for forming a strand with a particular rope yarn increases with the rope size (for 24's yarn, the number increases from 11 to 384 for sizes from 2—12 in. circum.). When the required length of the strand is obtained, it is removed and hitched to posts at the side of the walk, and further strands are drawn. The top cart is not used during stranding.

In the next operation, the required number of strands for the rope is attached to a single hook in the traveller, and to separate hooks in the foreboard. In between, the strands pass through the grooves of the top in the top cart. During laying, the hooks in the foreboard impart the correct retaining twist to the strand (in the same direction as in the original strands), while the hook in the traveller gives an opposite twist and lays them into a rope. The lay of the rope is controlled by the speed of the top cart which is moved automatically by the pressure of the strands against the smaller end of the top, its speed being controlled by the pressure on a pair of ropes linked round the bar of the top cart and wrapped round the laid ropes.

House machine.—The compound stranding and laying machine consists of 3 or 4 large flyers in which are mounted cradles carrying rope yarn bobbins. Each bobbin revolves on its own axis; at the same time the cradle and bobbin revolve on the axis of the flyer. The flyers twist the strands and supply them to another flyer for laying the rope. In another type of house machine, yarns from the bobbin bank are formed into strands by drawing them through a twist tube and over haul pulleys. The bobbins from the strander are put on the creel flyers of the laying or closing machine.

Twine and Cord making.—Soft fibre cords and twines are produced mostly by twisting. Tube twisting frames are employed in which yarns from bobbin banks are drawn through a twist

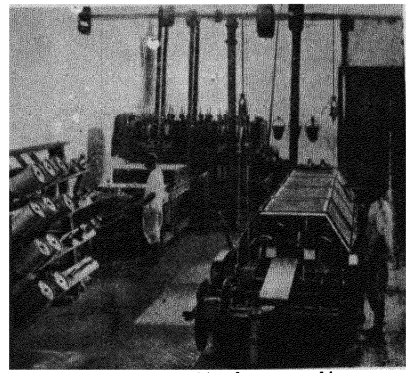


Fig. 62.—House machine for rope making

tube by haul pulleys mounted inside the flyer. Alternatively, a pair of rollers delivers the yarn from the bobbin bank to the flyer. The former method is used for making cords of high quality. The cords may be retwisted in the opposite direction to produce what are known as imitation cabled cords.

For making cabled cords (2-, 3-, or 4-ply cords), the strands are first prepared on a former and cabled in a machine similar to the tube twisting frame in which the creel flyers are carried vertically. A similar machine is used for making 2-, 3-, or 4-ply cabled cord twines. A cord walk which is similar to the rope walk may also be employed for making soft fibre cords and twines.

Cords and twines made from hard fibre are mostly laid or cabled, and only occasionally twisted in automatic doffing twisting frames. For making cabled or laid twines and cords, a 3-ply twine laying machine is generally used. It consists of two laying flyers mounted on a cast-iron frame; and two creel flyers in a separate frame for imparting the retaining twist.

All the machinery required for yarn spinning and rope making is imported from the United Kingdom and the United States of America.

Treatment of rope.—Cordages and ropes are often made from yarn treated with tar, bitumen, oil, or polishing compositions. In the case of coir, the rope is first made and then treated with batching oil. Tarring is the most common treatment; the yarn is drawn through a hot tar bath and the excess removed by a die. The treatment protects

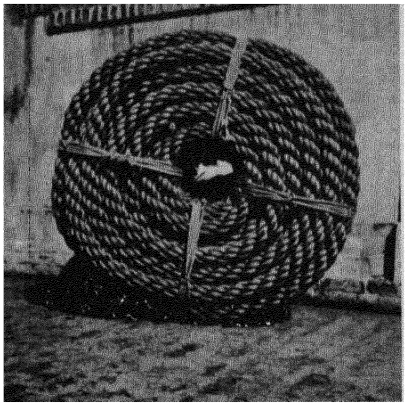


Fig. 63.—Manila rope, cable laid.

the fibres against the effects of moisture. The tar absorption should be kept at a minimum as otherwise the breaking strength of the rope is lowered. Stockholm tar or pinewood tar is used for this purpose.

Twines, especially those made from soft fibres, are polished with different compositions containing starch, soap, tallow, paraffin wax, glue, talc, and water. Hard fibre twines are seldom polished. Sometimes, yarns are dyed before stranding.

Packing.—Ropes are supplied in coils of 120 fathoms (720 ft.), unless otherwise specified. They are wrapped in water proof paper and covered by cloth. Small ropes are supplied in hanks. Cords and twines are wound in the form of balls. Twine balls are usually waisted, i.e., the centre is squeezed and a few yards of the twine wrapped tightly around the waist. Alternatively, twine is wound upon a central cone in a spooling machine, or on a bare spindle by a cheesing machine.

Types of products.—The factories are equipped for the manufacture of ropes and twines of all descriptions. The types produced are Manila ropes (special, standard, and merchant qualities), sisal rope, oiled coir rope, cotton rope, jute rope, hemp rope, and yellow rope. In addition, a number of hemp lines, both dressed and tarred, are manufactured, e.g., Log line, Seizing line, Deep Sea lead line, Hand lead line, Temperband cord, Signal Halyard, Mar line, Bolt rope, Rat line, Spun yarn, Europe rope, House line, Hambrolines, Lanyard, and Heald cord.

PRODUCTION

The total capacity of the six mechanised factories in India is estimated at about 100,000 cwt. of Manila, sisal, aloe, and cebu maguey cordage per year, working on a double shift basis. If the cordage manufactured from sunn hemp, jute, cotton yarn, and coir yarn is also included, the total annual production in India may be put at about 240,000 cwt. valued at Rs. 85—95 lakhs. During World War II, Indian production was stepped up to nearly three times the normal output by working all the seven days in the week on a 24 hr. basis. The production has now gone down, and all the factories are working single shift. Table 2 gives the production figures of the biggest factory, viz., *Ganges Rope Co. Ltd.*, during the period 1945—49.

Table 3 gives the consumption of Sisal and other hard fibres by Bengal Rope factories.

Quality and Specification.—Factory-made ropes are required to conform to the following specifications of the Indian Army and the Navy: G/Tex/H-7A for Manila ropes, G/Tex/Misc.-49 for coir rope, G/Tex/Misc.-45A for twines (cotton, jute, hemp, and flax) and I.M. 2857 for sisal ropes. The lay of the cordage shall be right-hand. The cordage shall be well and evenly laid and free from defects of any kind; the British specification lays down the following angles of lay: Manila ropes 37° for hawser laid, 39° for shroud laid,

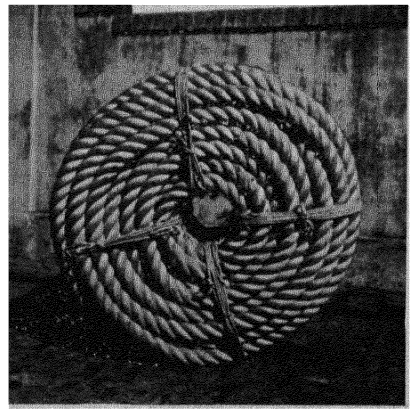


Fig. 64.—Sisal rope, hawser laid.

TABLE 2.—PRODUCTION OF ROPE BY GANGES ROPE CO. LTD.
Qty. (cwt.)

	Manila and sisal rope	Coir rope	Indian hemp rope	Jute rope	Cotton rope	Jute twine
1944–45	83,434	10,743	55,061	41,694	372	60
1945–46	58,817	36,220	20,600	8,797	301	29,102
1946–47	42,122	18,017	2,181	9,235	102	48,408
1947–48	30,068	18,968	991	3,193	36	25,938
1948–49	37,022	18,597	812	6,240	45	1,280

TABLE 3.—CONSUMPTION OF HARD FIBRES

	Qty. (cwt.)
1945–46	111,240
1946–47	80,660
1947–48	42,120
1948–49	45,000

and 37° for 9-strand cable; the corresponding figures for sisal ropes are: 39°, 42°, and 37°; the weight shall be in accordance with the schedule for the size of the cordage.

Storage of rope.—Ropes should be protected from damp and heat. It is preferable to store them in well-ventilated sheds maintained at about 70°F. and 65% R.H. Wet or damp ropes should not be dried by heating as this renders the fibres brittle and the ropes useless for service.

The Cottage Rope Industry

Large quantities of rope and twine are made throughout the country from locally available fibres. Among the fibres used in cottage industry coir, sunn hemp, and jute are important. In addition, a large number of fibres of minor importance have been used or experimented upon in various parts of the country for making ropes and twines. These include: *Abroma augusta, Abutilon* spp., *Ananas comosus, Antiaris toxicaria, Bauhinia vahlii, Boehmeria nivea, Borassus flabellifer, Calotropis gigantea, C. procera, Cannabis sativa, Careya arborea, Caryota urens, Cordia dichotoma, C. rothii, Girardinia heterophylla, G. disperma, G. elastica, G. oppositifolia, Grewia tiliaefolia, Hardwickia binata, Helicteres isora, Hibiscus* spp., *Kydia calycina, Malachra capitata, Marsdenia tenacissima, M. volubilis, Pandamus* spp., *Phormium lenax, Saccharum munja, S. spontaneum, Sansivieria zeylanica, Sesbania bispinosa, S. grandiflora, Sida rhombifolia, Sterculia foetida, S. urens, S. villosa, Themeda arundinacea, Trema orientalis, Typha elephantina, Urena lobata* and *Villebrunea integrifolia* (Trotter, 1940, 228; D.E.P., II, 566).

The fibre is hackled either by hand or on wooden boards studded with steel pins. The cleaned fibre is spun into yarn with the help of a charkha. The fibre is twisted into yarn by the fingers, made into a loop, and inserted into the hook of a whirl which is driven by a wheel. As the wheel is rotated, the worker walks down the rope walk, feeding the fibres into the twisted yarn. When he reaches the end of the walk, the yarn is taken off the whirl and wound round a reel for use in the next operation.

The required number of yarns to form the strand are attached to the free ends of three cranks fixed in a wooden frame (tackle board); the other ends of the three strands pass through

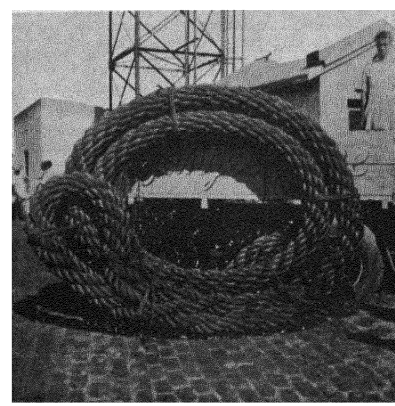


Fig. 65.—Coir rope, cable laid

three holes of a wooden piece at the other end. The strands are twisted by turning the cranks. When all the strands have received sufficient twist the wooden piece is gradually brought towards the tackle board The rope is then formed from the twisted strands

Sunn hemp is the fibre mainly employed for the preparation of twine. This industry covers almost all the sunn hemp producing areas, the more important areas being Kanpur, Banaras, Partabgarh, Azamgarh, and Moradabad in U P., Saran in Bihar, and Chandernagore, Baidyabati, Seoraphuli, Chatra, Kotrung, Baruipur, and Calcutta in West Bengal.

In pre-war years, about 10,000 workers were engaged in twine making in the Calcutta area producing 6,000–6,500 md twine, log line, and rope per month from Bengal hemp Of the total production, twine accounted for 10%, log line (¾ in circum) 80%, and rope (1–2 in circum) 10% About 75% of the production was exported to Rangoon, Colombo, Malaya, Java, Hongkong, Aden, and Mauritius, the rest being retained for fishing nets, sporting nets, packing twines, etc The production increased considerably during the war Several thousand tons of twine were used for the production of camouflage nets. The present production is estimated to be 25% of the pre-war output

Hemp ropes and Sutli worth about 180 lakh rupees are annually produced in U P (Directorate of Cottage Industry, U P, *Let Figures Tell*, 1949, 50)

Jute rope.—Considerable quantities of raw jute are used for making ropes and twines throughout the jute growing areas of Bengal, Bihar, and Assam The products are mostly consumed locally, small quantities of the finer qualities are sent to Calcutta and up-country markets. Jute rope is made in all the jute baling presses Ropes meant for *kutcha* bales are about 1 in. thick and 50–60 ft. long (wt, 4–5 lb). For *pucca* bales, the ropes are given a harder twist, and are made in greater lengths.

A number of jute mills in Calcutta produce jute ropes and twines on the jack wheel principle, and some of them employ twisting machines

Jute twines of different qualities and thicknesses are used extensively in India and abroad. Three classes of twines are made, viz., country twine, export twine, and sacking twine.

Country twine is utilized in India for a large variety of purposes, particularly for sewing, carpet making, and for general tying purposes. It is made from sacking yarn (13 or 15 lb. per spindle) in 3- to 5-ply, and supplied in hanks of two sizes, 72 in and 90 in. circum The hanks are made into bundles of 14 or 56 lb. and finally into bales of 5 or 10 mds.

Export twine is meant for general tying purposes, sacking, garden twine, packing for pipe joints, cable binding, etc. It is made from both hessian and sacking yarn for export to Australia, New Zealand, and South America. Hessian twine is made in three colours, viz, white (from light coloured jute), golden brown (from Tossa), and blue (dyed) It is made from 8 lb yarn in hanks of 6 oz or 8 oz, bundles of 9 lb, and bales of 450 or 820 lb Sacking twine is made from 12 lb yarn of natural colour.

During the war period, jute rope and cordage required for the Navy were rendered rot- and water-proof The proofing compositions employed were (1) coal tar pitch-oil-solvent mixture, with or without a copper preservative, (2) bitumen-wax-solvent mixture with copper preservative, and (3) tar oil distillate mixture

Separate figures for the production of jute rope and twine are not available Table 4 giving the figures for jute goods other than hessian, sacking, twist and yarn includes rope and twine

Coir ropes.—The making of coir ropes on a cottage industry basis is localized in the coconut growing areas of Travancore and Cochin. Coir ropes are made also in Orissa and in North Kanara district of Bombay. They are used locally for drawing water, and other purposes. During the war, large quantities of coir ropes were made to meet defence requirements (Table 5) (*Rep. Panel, Coir, Rope, Cordage, and other Fibre Industries*, 1946, 9)

TABLE 4*

	Qty. (cwt)
1938–39	52,620
1946–47	34,820
1947–48	44,960
1948–49	37,520

*Information from Indian Jute Mills Association

TABLE 5

	Qty. (ft.)	Value (Rs)
1942	42,54,000	29,000
1943	1,24,50,000	1,35,000
1944	54,00,000	2,36,000
1945 (estimate)	24,00,000	1,50,000

TABLE 6.—IMPORTS OF ROPES AND TWINES

	Veg fibres (other than cotton & jute)		Jute rope and twine		Cotton rope	
	Qty. (cwt.)	Value (Rs.)	Qty (cwt)	Value (Rs.)	Qty (cwt)	Value (Rs)
1934/35—1938/39 (av)	22,971	7,79,625	817	20,580	6,377	6,25,156
1939/40—1943/44 (av)	11,114	3,96,588	337	27,240	3,971	5,71,401
1944–45	712	27,251	..	..	3,466	6,42,010
1945–46	2,820	1,90,546	..	.	3.352	6,60,224
1946–47	2,858	1,48,028	.	..	4,651	10,69,614
1947–48	1,766	1,61,850		..	5,905	17,70,674
1948–49	2,421	4,59,422			5,813	18,96,898
1949–50	2,074	3,11,264			2,091	6,76,215

TABLE 7 —EXPORTS OF ROPES AND TWINES

	Veg fibres (other than jute & cotton)		Jute rope and twine	
	Qty (cwt)	Value (Rs.)	Qty. (cwt,)	Value (Rs)
1934/35—1938/39 (av)	51,960	7.80,125	128,969	15,72,002
1939/40—1943/44 (av)	53,279	10,96,415	120,384	24,95,593
1944–45	53,833	17,40,066	40,705	15,29,711
1945–46	35,834	16,58,865	32,838	11,66,582
1946–47	73,842	39,98,161	44,175	18,91,024
1947–48	41,195	27,74,103	57,083	34,39,676
1948–49	98,788	45,98,243	116,285	77,54,339
1949–50	79,961	43,33,458	134,361	1,06,20,380

Prior to World War II, considerable quantities of transmission ropes, made from Manila fibre and cotton, were imported from the United Kingdom. A cheaper variety, known as yellow rope, was also imported from Japan in large quantities.

Imports of cordage, rope, and twine made from vegetable fibres other than cotton and jute, are subject to a revenue duty of 30% *ad valorem* There is a preferential duty on imports of cotton rope.

Table 7 gives the exports of ropes and twines from India

Indian ropes were supplied during the war to Middle East countries and Russia The shares in the exports during 1948-49 were Pakistan, 33·7%, and Straits Settlements, 26 7% The corresponding figures for 1949-50 were 23% and 30%

Small quantities of hand-made coir rope are exported from the ports of Cochin, Calicut, and Alleppey During the year ending 30th June

TABLE 8.—PRICES OF ROPES

	Price (Rs /cwt.)
Manila rope	
Special quality	180
Standard ,,	160
Merchant ,,	140
Sisal rope	120
Coir rope, oiled	
1st quality	75
2nd ,,	60
Indian hemp rope	90
Cotton rope	3 75*
Jute twine	60†

*per lb †per md.

1937-38, 15,270 cwt. were supplied (*Rep. Panel*, 26). Exports of coir rope made in rope factories are given in Table 7.

Prices.—The market prices of rope in December 1949 are given in Table 8.

COSMETICS

The term cosmetics means articles intended to be rubbed, poured, sprinkled, or sprayed on, or introduced into or otherwise applied to the human body or any part thereof for cleansing, beautifying, promoting attractiveness, or altering the appearance, and also articles intended for use as a component of any such articles, except that such term shall not include soap (Van Nostrand, 398).

Cosmetics may be considered under four main heads: (1) decorative, e.g, nail enamels, hair lacquers, lipsticks, etc; (2) corrective, e.g, light face powders and rouges; (3) protective, e.g., day creams and heavy face powders, and (4) curative or therapeutic, e.g., anti-perspirants and hair preparations. For manufacturing purposes cosmetics may be classified into the following groups: (1) creams, (2) lotions, (3) powders, (4) make-up preparations, and (5) miscellaneous products, such as mouth washes, hair-waving fluids, manicure preparations, depilatories, etc.

The cosmetics industry is a large-sized industry in U.S.A. The *per capita* consumption of cosmetics in U.S.A. was $5·69 in 1947. America exported toilet preparations valued at 1,574 million dollars in 1945. The percentage use of different cosmetics in U S.A. in 1947 was as follows: cream, 11·3; perfumes, cologne and lotions, 10·8; face powder, 9·0; lipstick, 3·5; and products for the care of hand, 2·8 [*Indian Soap J.*, 1949-50, **15** (2), 68].

Raw Materials

The more important raw materials utilized in the cosmetics industry are: distilled water and perfumed water, absorption bases, emulsifiers, stabilizers, preservatives, emollients, medicinal ingredients, perfumes, and colours. Absorption bases include vegetable oils (especially almond oil), animal fats, hydrogenated fats and oils, waxes (beeswax, carnauba wax, spermaceti), lanolin, and mineral oils and waxes.

The emulsifiers used in the industry are fatty oil soaps, triethanolamine, lanolin, gums and mucilages (acacia and tragacanth), agar agar, sodium alginate, alcohols (cetyl and stearyl alcohols) and their sulphonated derivatives, esters of glycol, glycerol, sorbitol and mannitol with fatty acids Colloidal clays (bentonite), and synthetic non-fermentable colloids (cellulose ethers) are also used Talc is the most important basic material used in the preparation of toilet powders. Auxiliary substances such as glycerine, dulcitol, lecithin, thymol, naphthol, naphthylamines, *para*-hydroxybenzoic esters, formaldehyde, benzoic acid, chlorobutanol, and alcohol are also used.

Essential oils, synthetic coal tar perfumes, and resins and oleoresins (balsam of Peru, gum benzoin) are used for perfuming cosmetic products Musk, civet, and ambergris are also used to a limited extent

The colours for rouges, lipsticks, grease paints, eyebrow pencils, etc, are natural lakes (ultramarine, ochre, sienna, amber, etc), vegetable colours (alkanet, annatto, indigo, alizarin, cochineal, turmeric, chlorophyll, cudbear, henna, and caramel), and certain coal tar colours (deNavarre, 183).

In addition, sulphites and ethanolamine are employed in preparing permanent waving preparations, sulphides in depilatories, etc.

Creams

Toilet creams are of three types—cold creams, vanishing creams, and water-free creams

Cold creams are finely divided emulsions of either water-in-oil or oil-in-water types. The basic ingredients are beeswax, oil, borax, and water The soap (sodium ceroate) formed by the reaction of borax with the fatty acid component of beeswax acts as the emulsifier for oils and waxes in water Mineral oil (65—110 Saybolt units) is generally used; sweet almond oil may be employed to give softer products. Paraffin wax and spermaceti are also sometimes used.

Important among the cold creams are cleansing creams and skin foods; other cold creams are emollient, lubricating, biological, and massage creams (deNavarre, 214).

Cleansing creams have low melting points; they liquefy instantly, remove dirt and cleanse pores They are softer than emollient or massage creams. The consistency of the creams depends on the relative proportions of wax and water. They are mostly water-in-oil emulsions but some popular makes are of the oil-in-water type. A good product should liquefy at body temperature and should have a viscosity low enough to permit easy spreading, but sufficiently high to retain dust and insoluble foreign matter in suspension. It should be able to cleanse the skin surface and leave the skin smooth, relaxed, refreshed, non-greasy, and clean.

Skin foods nourish, beautify, soften, and revive relaxed and faded tissues, and remove lines and pimples They contain a high percentage of the absorption base Lubricating and emollient creams also contain skin-softening agents, e g., cetyl alcohol, lanolin, cacao butter, lecithin, waxes, hydrogenated oils, etc, and contain more water than skin foods Biological creams are similar to skin foods but contain hormones, vitamins, or glandular preparations Massage creams are combinations of skin foods and cleansing creams.

For the preparation of creams, the oils, fats, and waxes are melted to a clear solution and a hot aqueous solution of borax is slowly added under stirring, the temperature being maintained at 68—72°. The selected perfume is added while cooling at 45—50° and the mass well stirred. The cream is poured at c. 42° Sometimes, the cream is stirred until cold, allowed to set for a day, perfumed, passed through an ointment mill, and packed warm. This treatment gives a soft fine-grained product. Vitamins and other ingredients are added along with the perfume. Table 1 gives a few typical formulae for cold creams.

TABLE 1.—TYPICAL FORMULAE FOR COLD CREAMS*

	Cleansing	Skin food	Biological	Massage
Liquid paraffin	75	52	25	45
Lanolin	..	4	25	4
Paraffin wax	15		..	
Ceresin	..	..		30
Beeswax	10	6	7	30
Spermaceti	.	4	6	..
Borax	1	1	0·5	6
Water	12	33	36·5	45
Perfume	as reqd.	as reqd.		

**Soap Perfum. Cosmetics Yearbk*, 1936, 59

Vanishing creams are oil-in-water emulsions of stearic acid in water containing soap. The basic ingredients are stearic acid, alkali (potash, soda ash, caustic potash, caustic soda, borax, triethanolamine, etc), water, and glycerine A part of the stearic acid is saponified with the alkali and the resulting soap emulsifies the bulk of the acid. Stearic acid forms 15—25% of the mixture, and 15—35% of it is saponified. The alkali used and the extent of saponification determine the consistency of the product The addition of glycerine helps the spreading of the cream without rolling and prevents rapid drying up; it may be substituted by either diethyleneglycol monoethylether or sorbitol. Mineral or vegetable oils and cacao butter are occasionally added.

Vanishing creams are available in several forms, e g., face cream, hand cream, medicated cream, deodorant cream, etc Face cream protects and beautifies the skin and acts as a base for face powders. It is soft and leaves on the skin a thin invisible film with a pearly sheen. A typical vanishing cream (face cream) has the following composition: stearic acid, 24; potassium hydroxide, 1, glycerine, 5, diglycol stearate, 6; and water, 64 parts (*Soap Perfum. Cosmetics Yearbk*, 1936, 59)

Medicated cream contains in addition, methanol, camphor, phenol, eucalyptus oil, etc. Deodorant creams contain deodorants and anti-perspirants

Hand creams are used to soften and whiten hands and to remove toughness and chafing They are similar to vanishing creams but contain less soap Small amounts of mucilages and skin softeners are often incorporated Snows are soft vanishing creams made with a combination of sodium and potassium alkalies.

For preparing vanishing creams, stearic acid is melted and heated to about 85°, and an aqueous solution containing the alkali and glycerine, also heated to c 85°, is slowly added under continuous stirring. The resulting curdy, jelly-like viscous mass is turned over from time to time until the crust formation during cooling ceases. The cream is set aside overnight, then mixed with perfume, and filled into containers The final product acquires the required body a few days after packing.

Water-free creams are made by melting and mixing together fats and waxes, stirring with pigments and perfumes, and working in a colloid mill Any purified fat, wax, oil, or hydrogenated oil may be used Commercial preparations include liquefying creams, bleach creams, massage

creams, emollient creams, deodorant creams, medicated creams, eye creams, and hair and scalp creams (hair pomades and brilliantines).

Liquefying creams used for cleansing are made from light mineral oils (viscosity, 65/75 Saybolt units) and waxes (ozokerite, ceresin, paraffin, beeswax, petrolatum). Medicated creams are made from petrolatum, refined lard, hydrogenated lard and oils, and their mixtures, the medicinals used being mercury compounds, zinc peroxide, bismuth subnitrate, zinc oxide, resorcinol, salicylic acid, and benzoic acid Massage creams are generally made from hydrogenated cotton seed oil containing antioxidants. Deodorant creams are made from petrolatum, mineral oil, and deodorants, such as zinc oxide, and benzoic, salicyclic, and boric acids (deNavarre, 268)

Solid brilliantines are prepared from 'short fibre' petrolatum, solidified mineral and sometimes vegetable oils They are made from yellow petrolatum jelly by stiffening with ceresin or beeswax and tinted with an oil-soluble yellow dye or chlorophyll, stearic acid and light mineral oil may also be added to modify the petroleum jelly Liquid brilliantines are made with any mineral oil with a pour point of 10°F or lower Vegetable oils are added to prevent stickiness

Toilet Powders

Toilet powders are of two types—face powders and talcum powders Face powders are blends of white pigments suitably tinted and perfumed, and are employed to conceal the colour of the part of the body to which they are applied, and to impart to the skin the colour of the powders The following ingredients are used in their preparation (1) bases—talc, kaolin, precipitated chalk, magnesium carbonate, (2) covering agents—zinc oxide and titanium dioxide, (3) adhesives—zinc or magnesium stearates, and (4) starches, preferably rice starch (deNavarre, 333). These are pulverized, sifted, mixed in the desired proportions, suitably coloured, and perfumed

Talc is the base most widely used, and it constitutes about 50% of the powder, it gives a high degree of 'slip' (smoothness), whiteness, and bulk per unit weight, its covering power is low French and Italian talcs are preferred by virtue of their excellent slip and smoothness Colloidal kaolin and precipitated chalk have poor slip and adhesiveness, but possess good absorption and fair covering power They are, sometimes, used along with talc as fillers, they also serve as media for absorbing perfumes Magnesium carbonate is sometimes added in small quantities.

Zinc oxide has good covering power and adhesive and water-absorbing properties Titanium dioxide is even better; it is physiologically inert and is more opaque though less dense Colloidal kaolin, precipitated chalk, magnesium carbonate, and magnesium stearate also possess good covering properties.

Zinc and magnesium stearates are added in small quantities (5—10%) to give adhesiveness or staying-on power to the powder, the former being preferred In some preparations, stearates are replaced by prepared powder bases, which possess high adhesiveness and are bulky, odourless, and white

Starch, especially rice starch, is the material *par excellence* for imparting bloom and a peach-like finish to the skin Small quantities assist ease of application Rice starch retains delicate perfumes owing to its small particle size (6—9 μ) Face powders made in U K and Europe are usually heavy, while those made in U S A are of a light or medium character Also, the American products are of finer particle size than the average English or Continental products

The colouring materials used are insoluble earth pigments and lakes They are incorporated with talc or other base in a ball mill and mixed with the other ingredients Water- or spirit-soluble dyes are rarely used, when used, they are sprayed on one of the absorbent materials, dried, powdered, and mixed with other ingredients

In the preparation of face powders, the raw materials are separately pulverized and sifted, and then mixed in the desired proportions The perfume is incorporated at the last stage Generally, it is mixed with talc, precipitated light chalk, magnesium carbonate, or starch, thoroughly dispersed, matured for at least a week, and added to the coloured powder The particle size is important and at every stage the ingredients are sifted Horizontal mixers (fitted with screw agitators) and ball and grinding mills are used. Face powders are sifted through 90—160 mesh or even finer sieves The sifting operation can be eliminated by 'micronizing' (air-spinning) the particles The ingredients of the mix are introduced into a closed chamber into which purified cold air is forced at a speed of over 1000 miles/hr and the particles whirled at a high speed Particles of micron (μ) size find their way to the central exit of the chamber

Talcum powder is primarily used for alleviating irritation of the skin due to heat or other causes It possesses hardly any covering power. Talcum powder used after bath has less slip and is considerably more absorbent than face powders It contains 80—90% talc, the remainder being boric acid, zinc oxide, zinc stearate, light magnesium

TABLE 2.

	Face powder			Talcum powder		
	Light	Medium	Heavy	General purposes	Body	Baby
Talc	75	78	64	85	50	70
Precipitated chalk	5	8	10	12	25	5
Kaolin (colloidal)	..	..	..	..	15	9 75
Zinc oxide	15	..	15	.	..	..
Titanium dioxide	..	7	5	..	..	..
Zinc stearate	5	7	6	2	4	5
Boric acid	..	..	..	..	5	10

*deNavarre, 357.

carbonate, and sometimes starch and perfumes The more common talcum powders contain 95% talc and 5% perfumed precipitated chalk, they may or may not be tinted They are prepared in the same way as face powders

Body powders contain a large proportion of absorbing agents such as precipitated light chalk together with adhesives (zinc stearate) Baby powders are delicately perfumed and are usually borated or rendered antiseptic by the addition of *c* 0·15% oxyquinoline sulphate Foot powders contain deodorizing substances (zinc peroxide, salicylic, benzoic, or boric acid), fungicides and astringent substances (alum, boric acid, etc).

The composition of a few face and talcum powders are given in Table 2.

Make-up Preparations

Make-up preparations, applied to eyes, lips, cheeks, or face, to enhance the natural beauty and attractiveness, include lipsticks, rouge, eyeshadows, eyebrow pencils, and facial make-ups.

Lipsticks.—The base of lipsticks is a semi-solid mixture of oil and wax. Oil-soluble pigments, e.g, dibromo- or tetrabromo-fluorescin, called bromo acid, and insoluble colour lakes are incorporated into the base. The base for a shiny lipstick contains a relatively high proportion of castor oil, liquid paraffin, and petroleum jelly, for matt products, waxes and cetyl alcohol are employed. Hydrogenated oils, cacao butter, ozokerite, lanolin, and ceresin may also be used. The waxes are melted and added to a solution of bromo acid in castor oil, and mixed with liquid oils in which the pigments are previously incorporated. The preparation is poured into moulds at 5—10° and chilled. Flavouring agents such as coumarin, methyl coumarin, vanillin, and ethyl vanillin, and perfumes, e g, rose, jasmin, and orange blossom, are incorporated Lipsticks should be easy to apply, must not crumble or crack, must not sweat, and should have a melting range of 55—60°. They should not be greasy

Liquid lipsticks consist of solutions of ethyl cellulose and a plasticizer in ethyl alcohol and isopropyl alcohol to which colouring agents and perfumes are added The film produced can be removed with an alcoholic solvent

Rouges.—Rouges are of two types—compact rouge and cream rouge Compact rouge is used for colouring cheeks and to modify the contours of the face The composition and the method of preparation are somewhat similar to those of face powder compacts A typical formulation consists of precipitated chalk, zinc oxide, talc, a water-soluble dyestuff, and a binding agent The mixture is dried, sifted, and compressed

Cream rouges are of two types—non-evaporating vanishing cream base with oil-soluble dyes, and cold cream base with insoluble pigments The former is more popular A good product should spread easily and evenly without any drag, and it should not cause any irritation Cream rough need not be applied repeatedly

Facial make-ups are of two types—stick cosmetics and powder creams Stick cosmetics consist of opaque pigments and colouring materials incorporated in an oil-wax base The fats are melted, mixed, and the pigment added while stirring The mix is passed through a colloid mill, perfumed when sufficiently cool, and poured into moulds Powder creams are similar in composition to vanishing or greasy creams

Eyebrow pencil applied for modifying the shape and colour of eyebrows is made from a base similar to that of lipstick The ingredients used are waxes, hydrogenated fats, lamp black, umber, and burnt sienna A typical formulation contains, cacao butter, 20; hydrogenated coconut oil, 20; ceresin, 35, and lamp black 25% The fats and waxes are melted, colours ground in, and the resulting mixture passed through an ointment mill and moulded into the form of a lipstick. Eyebrow pencils should not break or crumble, and the colour should spread easily and evenly.

Eyeshadow, used for giving an attractive background to the eyes, is made from a colourless base consisting of petrolatum, ceresin, spermaceti, lanolin, and mineral oil. The base is melted and mixed with zinc oxide and a lake colour, worked in a colloid mill, and poured into containers

Eyeshadows are made in blue, green, brown, and, sometimes, grey colours They should not be greasy, should lend themselves to be spread easily, and should be readily removable

Mascaras, used for darkening eyelashes, are made in brown and black colours, and may be liquid or creamy in consistency Beeswax or carnauba wax is melted, pigment added, and the mixture emulsified with an aqueous solution of triethanolamine The resulting emulsion is cooled, cured for a few days, worked in a colloid mill, and finally filled into tubes

MISCELLANEOUS PREPARATIONS

Dentifrices—Tooth powders, tooth pastes or creams, and liquid dentifrices should be able to remove accumulations of debris and deposits from teeth without causing injury Certain products are claimed to strengthen gums and to cure dental ailments.

Tooth pastes consist of an abrasive or polishing agent (35—45%), an excipient or binder (45—65%), foaming agent (0 5—1·0%), lubricant (c 1·5%), sweetening material, flavour, diluent, and other ingredients to give special properties. The binder, sweetening agent, and lubricant are mixed, the polishing agent added, followed by the foaming agent, flavour, and diluent The whole mass is mixed, worked in an ointment mill, and filled into collapsible tubes (deNavarre, 506)

The ingredients used in the formulation of tooth pastes are (1) *polishing agents*—precipitated chalk, di- and tri-calcium phosphates, calcium sulphate, talc, kaolin, and mica, (2) *binders*—mucilages, sodium alginate, gums, pectins, glycerine, glycerite of starch, honey or sugar syrup, and purified bentonite; (3) *foaming agents*—soaps (from tallow-coconut, olive oil-soda, and palm oil), wetting agents, synthetic foaming agents, (4) *lubricants*—mineral oil and petrolatum to aid in extruding the paste from the tube, (5) *sweetener*—saccharin, glycerine, sugar, or honey; (6) *flavouring agents*, (7) *diluents*—water, glycerine, and sorbitol syrup, and (8) *special ingredients*—potassium chlorate, sodium perborate, peroxides, pepsin, pancreatin or other enzymes, iodides, quinine, salol and other salicylates, medicinal herbs such as neem, astringents, stain-removers, etc

Tooth powder is composed of a polishing agent (88—95%), foaming agent (1—10%), sweetener (0·1—0·2%), and flavour (2%). The ingredients for each one of these items are the same as those used for tooth pastes Binders, excipients, lubricants, and diluents are not used The different ingredients are mixed, sifted through a 100-mesh sieve, and packed (deNavarre, 512)

Liquid dentifrices consist of solutions of non-irritating wetting agents (5—7%), aqueous solution of alcohol (25—35%), saccharin, and colouring materials

Manicure Products—The principal manicure products are nail varnish, cuticle remover, and nail white. Nail varnishes used for tinting and polishing nails are of the varnish type containing nitrocellulose with a plasticizer dissolved in a mixture of amyl alcohol, ethyl acetate, and isopropyl alcohol. The varnish, when applied with a small brush, should spread evenly, adhere without cracking, and dry rapidly.

Cuticle removers are used for the removal of dead cuticles by softening. They contain caustic alkali in small concentration and glycerine or tribasic sodium phosphate

Nail whites are used for whitening the underside of the nail tips They contain pigments embodied in a salve-like base, the usual ingredients being zinc oxide or titanium dioxide, zinc peroxide, petroleum jelly, liquid paraffin, and talc. Nail whites should spread easily and evenly, and they should be readily removable with soap and water.

Depilatories contain sulphides which attack hair keratin Cream depilatories are made by passing hydrogen sulphide through milk of lime (of creamy consistency), the resulting product being mixed with light calcined magnesia and a perfume Liquid depilatories are made by mixing barium sulphide (6—8%) with water, and after vigorous shaking, the decanted solution is mixed with 10% glycerine and a small quantity of methanol Solutions of 1—2% sodium sulphide in water containing glycerine or glycol ether are used as emollients and preservatives Powder depilatories are prepared by mixing 5—50% of barium and strontium sulphides with diluents such as kaolin, talc, and starch They are applied as pastes after adding water

Lotions—Lotions are fluid preparations containing medicaments with the desired action on the skin Three types of lotions are in use: (1) those containing gum but no alcohol, e g , hand lotions, bleach lotions, emulsified lotions, etc ; (2) those containing alcohol but no gum, e g , hair lotions, astringent lotions, pre-shaving lotions, stimulating lotions, body-rubs, etc , and (3) those containing small quantities of alcohol, e g., skin fresheners, cleansing lotions, after-shave lotions, etc

Gummy lotions usually contain ½—3% gum such as acacia gum or karaya gum, mucilages from linseed or quince seed, and sodium alginate. Hand lotions usually contain rose water and 15—25% glycerine.

Eau-de-Cologne is a lotion of the second type. It is a solution in weak spirit of essential oils such as bergamot oil, lemon oil or other citrus oil, oil of neroli, lavender oil or rosemary oil. The purity and source of the alcohol employed as the solvent is an important consideration Perfectly neutral and highly rectified potato spirit is the most useful for this purpose but treble distilled molasses spirit may be substituted For *de luxe* products maturing for one year is essential but this can be rdeuced to one month by the addition of ½% benzoin R or ambergris or clary sage oil A typical formula contains the following· lime oil, expressed, 5, bergamot oil, 10, Portugal oil, 7, Rose oil, virgin, 1; Rosemary oil, 1, Alcohol 90%, 1000, and water 100 parts This is distilled and to 1000 c c a mixture of 2 parts of neroli oil, 0 25 of clary sage oil, and 1 part of benzyl isoeugenol are added and the product matured for a month (Poucher, II, 299) In cheaper types the essential oils are replaced by synthetic substitutes

Hair lotions applied with massage are said to prevent loss of hair They contain 90% water and traces of stimulating medicaments, e g., balsam of Peru, bay rum, borax, chloral hydrate, capsicum, cantharides, cholesterol, cinchona tincture, formic acid spirit, jaborandi tincture, lecithin, mercuric chloride, pilocarpine and its salts, quinine and its salts, resorcin and its acetate, salicylic acid, sulphur, tannin, etc DDT hair lotions are now available in the market Some hair lotions contain a solution of castor oil in specially denatured spirit with tincture of benzoin to remove the greasiness and odour of castor oil The ingredients are dissolved in alcohol, set aside for a few days, and filtered

Astringent lotions are applied to the face after cleaning but before using make-ups, to tone up the skin and the cause the pores to close They have a soothing effect on the skin when applied after shaving Lilac, lavender, bay rum, and distilled extract of witch hazel when dissolved in 50% alcohol give lotions of this type. A good astringent lotion is made from alum (0·5%) and glycerine (2 5%) in rose water Calamine lotion is made from zinc oxide, glycerol, calamine, rose water, and sometimes lime water.

Cleansing lotions loosen impurities without stretching the pore openings. They are of two types· (1) solutions of cleansing materials such as diethylene glycol monoethyl ether and wetting agents in aqueous alcoholic solutions, and (2) emulsions of mineral oils in water using trienthanolamine, lauryl salts, etc., as emulsifiers. Antiperspirant lotions contain aluminium and zinc salts in water. Deodorant lotions contain formaldehyde and its derivatives, benzoin, solutions of peroxide, and witch hazel with perfumes and water (deNavarre, 287)

The Indian Industry

Hair oils, Surmas, and Kajals have been used in India for a long time The use of henna for colouring nails and of turmeric powder during bath by women for tinting the face and presumably for preventing hair growth is widespread in India

The manufacture of cosmetics is of recent origin The well-known cosmetic manufacturers in India are Messrs *Bengal Chemical & Pharmaceutical Works, Ltd*, Calcutta, *Smith Stanistreet & Co Ltd*, Calcutta, *Himani Ltd*, Calcutta, *Calcutta Chemical Co Ltd*, Calcutta, *E. S. Patanwala & Co*, Bombay, *Colgate Palmolive (India) Ltd.*, Bombay, *Lever Bros (India) Ltd*, Bombay, *Geoffrey Manners Ltd*, Bombay, *Group Laboratories (India) Ltd*, Bombay Messrs *Tata Oil Mills Co, Ltd., Bombay*, Swastik *Oil Co*, Bombay, *Ramtirth Brahmi Oil Co*, *Bengal Chemical & Pharmaceutical Works, Ltd*, *Calcutta Chemical Co, Ltd*, *E S Patanwala & Co*, and a large number of other firms manufacture hair oils

Vegetable oils, soaps, and glycerine required in the cosmetic industry are available in sufficient quantities Talc occurs widely in India, the product from Dagotha (Jaipur) is particularly suitable for the manufacture of cosmetics Natural perfuming materials and dyes are also available Lanolin was being prepared in India during the war period. Among the imported products used in the cosmetics industry are beeswax, benzoic acid, borax and boric acid, precipitated calcium carbonate, carbitol, dicalcium phosphate, magnesium carbonate, magnesium silicate, saccharin, sodium benzoate, sodium saccharinate, stearic acid, triethanolamine, zinc stearate, essential oils, and dyestuffs (Information from D G I & S)

The following types of cosmetics are made in India· hair oils, hair lotions, pomade, brilliantine, lime juice and glycerine, creams and snows, talcum powder, and tooth pastes and powder

Hair oils occupy the first place among cosmetic products in India. The oil is neutralized with caustic soda to remove the free fatty acids, decolorized with activated carbon, filter-pressed, and mixed with colours and perfumes The oil and perfume are mixed and left aside for some days. The clear oil is filled into dry bottles, the most popular sizes being 1 lb., 6 oz, and 4 oz Perfumed coconut, til, and caster oils are popular The perfumes mostly used for hair oils are rose, jasmin, champaka, and, to a lesser extent, Fougere and Chypre. The present price of coconut and

TABLE 3.—PRODUCTION OF COSMETICS*

	Qty. (1,000 lb.)
Talcum powders	1,008
Creams	448
Tooth paste	1,232
Tooth powder	336

*Information from D G I & S

castor hair oils is Rs. 2-8-0 to Rs 3-4-0 per lb. (1 lb. bottle) and Re. 0-10-0 to 1-2-0 per bottle containg 4-6 oz Mineral oils are common adulterants of vegetable hair oils

Indigenous methods of hair oil manufacture are extant in certain localities In Kanauj, flowers of Bel (*Aegle marmelos*), Chameli (*Jasminum* spp) and Kewda (*Pandanus tectorius*) are spread between layers of sesamum seeds, spent flowers being replaced from time to time by fresh ones. The seeds saturated with the flower perfume are expressed, and the oil sold either as such or after dilution with popular varieties of vegetable oils In south India hair oils are prepared by soaking aromatic roots and spices in vegetable oils The aromatic mixture has the double action of perfuming the oil and of stimulating growth of hair.

Lime juice glycerine is a hair preparation manufactured in India. It is obtained by the emulsification of a mixture of lime water and liquid paraffin with glycerine, and perfuming the emulsion.

Face powders are produced in limited quantities in India; talcum powders are, however, manufactured in considerable quantities. The manufacturers obtain supplies of talc and other ingredients in the ground state, mix them together in suitable proportions, and pack them in attractive containers after perfuming.

Tooth powders with chalk base, and tooth pastes are manufactured in small quantities Lipsticks, manicure preparations, eau-de-Cologne and other lotions are produced in the country.

Production and Trade

Table 3 gives the approximate annual production of cosmetics in India.

Statistics relating to the production of hair oil are not available The total production in the bigger factories is estimated at 7 million bottles per annum

Imports—Tables 4 and 5 give imports of cosmetic products into India from U S A. and U K.

Table 6 gives the imports of toilet requisites in recent years In the Sea-Borne Trade, cosmetics are not separately listed but the item toilet requisites includes almost all the cosmetic articles and

TABLE 4.—IMPORTS OF COSMETICS AND TOILET REQUISITES FROM U S A

	Value (1,000 lb)					
	1939	1940	1941	1943	1944	1945
Dental creams	337	217	51	439	190	200
Other dentifrices	15	14	7	2	31	13
Talcum powder	133	74	15	4	123	152
Face compact powder		12	6			107
Cold cream	63	39	12	41	184	71
Vanishing cream	60	40	13	59	203	69
Other creams, lotions, and balms	12	10	6	23	30	45
Rouge	4	4	15	(a)	9	12
Lipsticks	9	8	6	(a)	64	133
Other cosmetics	3	2	2	23	1	3
Manicuring preparations	32	23	10	.	10	54
Depilatories and deodorants	3	2	1	..	.	2
Hair preparations	44	31	18	143	561	101
Perfumes and toilet products	5	5	9		(a)	4
Other toilet preparations	6	13	5	16	7	12

(a) negligible **Perfum. essent. oil Rec.*, Annual Special No , 1942; Baden & Picker, Table 25.

TABLE 5.—IMPORTS OF COSMETICS FROM U K

	Qty. (1,000 lb)					Value (1,000 £)				
	1942	1943	1944	1945	1946	1942	1943	1944	1945	1946
Tooth paste and powder; liquid preparations for dental purposes and mouth washes.	76·6	155 3	674 7	497 3	748·4	15·6	26·9	122·3	91·6	123. 5
Toilet paste or powder ' toilet cream, lipstick, rouge, and grease-paint	562·5	99 5	365 7	1,277·7	3,057 6	74 9	11·5	55 1	225.1	480 5
Bath salts and essences, smelling salts, scented sachets, and prepared fuller's earth.	44·4	1 1	9 0	18·6	51·4	4 2	0·1	1·3	3. 0	5 5
Other preparations for use on the face, hair, or body	549 4	118 9	244 9	824 8	1,269 1	72·1	16·9	30 5	102 9	211·3

TABLE 6.—IMPORTS OF TOILET REQUISITES

Value (lakh Rs)

1944-45	69 6
1945-46	146 8
1946-47	292 2
1947-48	367 9
1948-49	42 0
1949-50	112·9

hence may be taken as an indication of imports of cosmetics

COTTON GINNING AND BALING

Seed cotton or *kapas*, as harvested, contains both lint and seed, the latter forming about two-thirds of the weight of *kapas*. The lint is attached to the seed rather tenaciously, and the ginning process employed for separating the two is so designed that little damage results either to the seed or to the fibre

The ginning industry is of a seasonal character. The season follows closely the harvesting of cotton and varies in different regions It is September—April in Punjab, Madras, and U P, October—June in C.P. & Berar and Khandesh, and February—April in Gujarat. The factories in Hubli (Bombay State) work intermittently throughout the year, though the major part of the cotton is ginned soon after the cotton harvest. The ginning operation is not carried out throughout the year, as the quality of cotton suffers at the high temperature prevalent in summer and short staple cottons cannot be stored for long periods. The total number of working days in the ginning season is about 150; in some areas it does not exceed 100.

The bulk of gins and presses are distributed in the black cotton soil tracts of Bombay, C P & Berar A few are located in Madras and Punjab The main ginning and pressing centres in India are *Bombay*—Hubli, Palej, Viramgam, Dhulia, Dondaicha, Jalgaon, Pachora, Chalisgaon, and Broach, *C P & Berar*—Amraoti, Buldana, Akola, Nagpur, Nimar, and Wardha; *Madras*—Tirupur, Ramnad, and Bellary, and *Punjab*—Amritsar

The number of ginning factories in India was 1,225 in 1919 and 1,941 in 1946 (Table 1).

There are more ginning factories than are

TABLE 1.—GINS AND PRESSES IN INDIA*

	No of factories			Av no of persons employed daily (1946)
	1929	1939	1946	
Madras	395	473	484	20,578
Bombay	678	634	469	21,970
Bengal	16	8	6	686
U P	96	70	42	1,966
Punjab	316	311	(a)	19,580
Bihar and Orissa	1	1	1	46
C. P and Berar	617	393	331	24,473
Assam	1	3	3	320
Ajmere-Merwara	26	21	15	1,294
Hyderabad	221	168	191	13,732
Mysore	27	21	13	677
Baroda	132	112	96	8,552
Central India States	263	258	173	8,417
Rajputana States	41	42	27	2,807
Bombay States	27	29	29	2,202
Western India States	62	99	61	4,868
Total	2,919	2,643	1,941	132,168

* *Bombay Cotton Annual* (a) not available

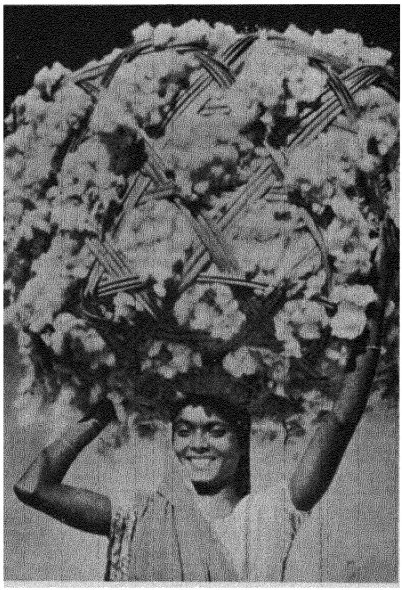


Fig. 66.—A cotton picker

necessary to delint the harvested crop. To eliminate unhealthy competition, which is likely to develop under such conditions, a system of pooling has been adopted in different areas. According to the system, ginning is carried out in a few factories, selected by turn, the others being kept idle. The charges for ginning are standardized. A part of the collection sufficient to cover the actual cost of ginning and pressing is retained by the working factories, and the remainder is handed over to the pool. At the end of the season the accumulated amount is divided *pro rata* among member gins.

Gin owners in Khandesh and Madhya Pradesh are not usually traders in cotton. They undertake to gin cotton for customers at a fixed rate. In Gujarat, ginning is carried out mostly by cotton merchants who purchase seed cotton from farmers, gin it in their factories, and sell the ginned product to spinners and exporters. There are a few large-sized establishments in Bombay engaged in ginning and exporting baled cotton.

Ginning.—Cotton is ginned, on a cottage industry basis, in the Charkha and the Foot Roller. The charkha gin, the accepted forerunner of the modern roller gin, consists of 2 small rollers about a foot long, one of iron and the other of wood, each with one end turned into an endless screw and so geared that when the wooden roller is turned by a handle, the other turns in the opposite direction. When seed cotton is fed between the rollers the fibres are drawn forward and torn away from the seeds. 4—5 lb. of ginned cotton fibre can be turned out from one charkha by one worker in one day. The foot roller gin has become practically obsolete though still in use in a few places. It consists of a flat stone (square or round), on which cotton is spread and the seeds pressed out by the rolling action of an iron roller (*c.* 18 in. long) tapering towards the extremities. One worker can turn out 4—6 lb. of clean cotton in one day by using this appliance.

The percentage of seed cotton treated in indigenous gins is small. The bulk of cotton is ginned on a factory scale by power-driven machinery. Two types of gins are employed, roller gins and saw gins. Roller gins are more common. In 1926, there were 64,141 roller gins and 94 saw gins operating in India; in 1935, there were 73,920 roller gin units and 107 saw gins. The latter are said to be more suitable for ginning American cottons than for indigenous cotton varieties.

The ginning machines are provided with a precleaner for removing trash, leaf, hull segments, dust, etc., and for opening the matted locks of *kapas*. The cotton is opened by breaker rollers, spiked cylinders, or lickers-in as the case may be, and the dust sucked up by a fan or taken away by a screw conveyor along with other trash. The seed cotton is fed either through a chute or by a lattice feeder.

The gin most commonly used in India is the Macarthy gin. The rollers are made up of a series of circular compressed washers cut from leather, wood, cardboard-cum-coir, paper, etc. The roller presses against a fixed doctor knife blade, while a beater knife moves up and down close to the doctor knife and overlapping it over an adjustable distance called the overlap. In the double acting gin two beater knives, which rise and fall alternately at equal speeds, are provided. The feeding arrangement in a single roller gin is a fixed grid, and in a double roller gin, a grid with a reciprocating motion. The fibres are drawn in between the roller and the doctor knife, while the seed, separated by the reciprocating action of the beater knife, falls through the grid into a box. The ginned fibre moves out on the other side of the revolving roller.

The saw gin (brush type) is equipped with 60—70 saws arranged on bars in sections of 5 The cotton entering the machine is carried by the saw teeth until the seeds come into contact with the ribs of the gin, when the saw strips off the fibre from the seeds A revolving brush removes the fibres from the saws, and as it rotates at a high speed, creates a blast of air which carries the fibre along a flue to a condenser. The seeds pass down a chute at the opposite side of the machine. In a second type of saw gin used in India, air blast, created by a pressure fan, removes the lint from the gin The motes are separated from the fibre by the centrifugal force, and the air nozzle is so positioned that the air does not interfere with the dropping motes The lint is carried through the flue to a condenser in which the fibre is retained on screens The seeds drop into a ditch provided for the purpose

Considerable work has been carried out at the Technological Laboratory of the Indian Central Cotton Committee on the comparative efficiency of pre-cleaning machines and on the effect of such factors as overlap setting, roller speed, etc, in roller gins, and rate of feed, saw speed, etc, in saw gins, on the quality of ginned cotton The following conclusions have been reached.

(1) The maximum output per hour is obtained by the use of Hardwicke-Etter opener for the pre-cleaning operation. This extracting and cleaning machine consumes the least amount of power, and removes the largest amount of trash in most cottons, except in the short staple varieties

(2) The output per hour is the highest, and the power consumed is the least in saw gins

(3) In 9 cottons out of 12, the output per hour from a saw gin increases and the power consumed decreases when the saw speed is increased.

(4) The ginning percentage in most cottons tends to be higher in roller gins than in saw gins

(5) In the double roller gin, high output is combined with low consumption in most cottons with 5/16 in overlap With *Umri Bani*, 6/16 in and 5/16 in overlaps gave the same output. The best outputs were obtained with 6/16 in overlap in ginning *Jarila*, 1/4 in overlap in *Mollisoni*, 6/32 in. and 7/32 in overlaps in *Sind N. R.*

(6) In the single roller gin, the highest output and least power consumption were secured with 3/8 in. overlap in 5 cottons out of 12. For ginning *Surat 1027 A.L F* 3/8 in. and ½ in. overlaps gave the best results; 4/16 in. overlap for *Umri Bani* and *Wagad*, and 5/8 in overlap for 289F/K 25, gave the highest outputs.

(7) The yarn strengths of different cottons are influenced by the type of gin employed Thus *Surat 1027 A L F* and *Punjab American 4 F* give stronger yarns when treated in the saw gin, *Wagad* and *Umri Bani* yield stronger yarns when ginned in the double roller or single roller gins, and *Jarila* and *Mollisoni* give stronger yarns when ginned in single roller gins (Ahmad, *Technol. Leafl. Indian Cott. Comm*, 1944-45, Nos 7—20)

TABLE 2 —GINNING PERCENTAGES OF COTTONS†

Cotton	Season	Saw gin*	Double roller gin	Single roller gin
Jayawant	1943–44	26·4	27·0	27·2
Surat 1027 A L F	1941–42	32 4	33 4	33 1
,,	1943–44	34 0	34 8	34 4
Wagad	1942–43	34·1	36 7	35 3
Jarila	1942–43	31·2	33 2	32·8
Verum	1940–41	27 8	29 7	29 5
,,	1941–42	27 6	29·9	29·8
Umri Bani	1942–43	25·4	27·1	26 6
Gaoram 6	1943–44	28 8	30 4	29 8
Cambodia Co 2	1943–44	33·6	35·3	34·0
Average		30·1	31 8	31 2

† Sen, *Technol Bull, Indian Cott Comm*, Ser A, No 70, 1943,4

* If allowance is made for partially ginned seeds left in the seed box of the saw gin, the ginning percentage would be increased by 0 5%

Table 2 gives the ginning percentages (i e, weight and number of hairs, and seed weight) of standard Indian cottons

Pressing.—Ginned cotton is marketed in the form of pressed bales The cotton is passed through an opener and beaten by machine or hand to separate extraneous material. For transporting ginned cotton to pressing factories, loose bales—*Boras* or *Dokrahs*—are made by pressing cotton into sacks and trampling. Each *bora* contains 200—300 lb. of cotton Compressed bales are made in screw presses, hydraulic presses, or geared presses Hydraulic presses operated by steam, gas, or electricity are commonly used in India. They consist of hydraulic cylinders, baling chambers, and loose cotton boxes arranged in one line. The backward stroke of the ram of the hydraulic cylinder draws the cotton from the loose cotton box into the baling chamber and the forward stroke of the ram compresses the cotton, which is then wrapped in hessian and secured by

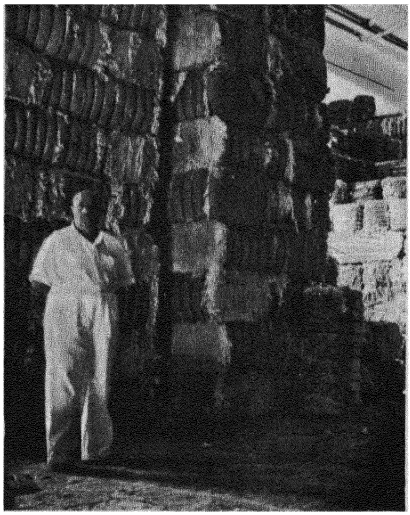


Fig. 67.—Ginned cotton pressed into bales

hoops. While the cotton is being compressed in the baling chamber, the loose cotton box is filled and kept ready for the second backward stroke of the ram. As many as 50 bales (each of 400 lb.) are pressed in an hour. The main types of presses used are Hodgart press, Nasmyth press, and Cummine press, the size of bales pressed being respectively: 51½ in. × 20¼ in. × 18¼ in., 48 in. × 16 in. × 18½ in., and 49 in. × 18¾ in. × 18¾ in. There is a considerable variation in the weight and density of bales. The usual weight is 392 lb. net (wt. of hessian and hoops, 8 lb.) and density, 40 lb./c.ft.

Jute hessian is generally used for baling. Experimental trials on the practicability of using cotton cloth as bale cover have been carried out in the Cotton Technological Laboratory, Bombay (Nanjundayya & Ahmad, *Technol. Bull. Indian Cott. Comm.* Ser. A, No. 69, 1943, 1).

The ginning and pressing of cotton is regulated by the Cotton Ginning and Pressing Factories Act, 1929. According to the provisions of this Act, balers are required to mark the bale distinctively and in serial number, so that if any fault is discovered in a particular consignment, even at a distant date or place, it could be traced to the baler.

In a few pressing centres, a municipal tax of 1–2 annas per bale is levied. A cess of 2 annas per bale has been imposed on all cotton exported or consumed by mills. Unbaled cotton is subject to a cess of 6 pies per 100 lb. The cost of ginning in important centres in C.P. and Bombay varied between Rs. 2-8-0 and Rs. 6-8-0 per bale during the period 1933-36. The present cost of ginning and pressing of cotton is Rs. 20–22 per bale.

Table 3 gives the quantity of cotton baled in India during the 11 years ending 1948-49.

Table 4 gives the quantity of cotton baled in different States.

The figures for cotton pressed do not cover the entire cotton crop. Ginned but unpressed cotton and *kapas* are utilized for hand spinning and making quilts and mattresses, for which data are not available.

By-product Linters

Cotton seed from ginning factories bears about 2% by weight of short fibres known in the trade as Fuzz or Linters, which can be extracted and utilized in industry. The delinting machines employed for the separation of linters work on the same principle as the saw gin except that the saws have finer teeth and are set closer together. Three types of machines are in use in India—the Continental, Carvers, and Verner machines. Indigenous delinting machines are also used. Usually 40–80 lb. of linters are extracted from one ton of seeds, but a yield of 200 lb. is possible. All cotton seeds, however, do not bear extractable linters. Seeds separated from the fuzzy varieties of cotton, viz., *P.A. 289F/43, 289F/K25, Cambodia Co2,* and *Upland Gadag* are used for extracting

TABLE 3.—QUANTITY OF COTTON BALED†

	Qty. (1,000 running bales)
1938-39	5,218·8
1939-40	5,001·4
1940-41	6,096·9
1941-42	6,079·4
1942-43	4,232·7
1943-44	4,987·5
1944-45	3,813·5
1945-46	3,599·0
1946-47	2,264·3*
1947-48	2,663·2*
1948-49	1,671·3*

†*Bombay Cotton Annual.*

*Figures relate to Indian Union only.

TABLE 4 — COTTON PRESSED IN INDIAN STATES*
(running bales)

	1946-47	1947-48	1948-49
Ajmer-Merwara	17,187	19,295	22,567
Assam	4,558	4,844	7,384
Berar	403,300	523,048	312,595
C. P.	118,310	134,947	79,207
Kutch	6,314	7,454	1,261
Madras	179,452	313,861	208,155
U. P.	2,784	1,086	276
West Bengal	6,952	6,932	4,245
Bombay	383,348	562,597	300,077
States merged with Bombay	220,625	274,765	173,772
East Punjab	136,979	43,919	46,938
Patiala & East-Punjab States Union	126,831	73,481	52,331
Madhya Bharat	143,059	172,836	62,261
Saurashtra	130,059	104,044	55,802
Rajasthan	70,382	59,954	81,513
Bhopal	1,694	2,131	993
Hyderabad	279,719	313,002	228,721
Junagadh	16,150	10,612	10 056
Mysore	16,563	34,384	23,131
Total	2,264,266	2,663,192	1,671,285

**Bombay Cotton Annual*

linters (Thoria, *Technol Bull, Indian Cott Comm*, Ser B, No 34, 1943, 17)

The production of ungraded linters was started in India in 1936 A few ginning factories and cotton seed oil companies, including Messrs *Govindram Seksaria Oil Mills*, Hyderabad, Messrs *Volkart United Press Co*, Mirpurkhas, Messrs *B C G A (Punjab) Ltd*, Khanewal, and *Birla Cotton Factory*, Okara, have installed saw gins and produce ungraded cotton linters. The production before the War was estimated at about 15,000 bales (of 400 lb.) of linters. It is estimated that 75,000 bales of linters could be produced annually in India (*Rep. Panel, Paper, Pulp, Board and Chemical Cotton Industries*, 1947, 25)

Purified cotton linters constitute a valuable raw material for paper, plastics, rayons, lacquers, explosives, and other industrial products based on cellulose. Three qualities of cotton linters are produced in U S A viz, First cut, Second cut, and Mill run. The yield of first cut varies from 20 to 75 lb, that of second cut, from 100 to 200 lb per ton of seed. A fourth type, known as Hull fibre, consists of fuzz tenaciously attached to seed coats or hulls and is extracted from decorticated or whole seeds in special machines (*Rep. Panel*, loc cit). The U S Dep. of Agriculture classifies linters into 7 grades according to length, colour, character, and amount of trash The first grade contains a fair proportion of fibres which can be spun and it is utilized for spinning low grades of yarn required in the manufacture of mats and fleece-lined products Grades 2, 3, and 4 are used for stuffing mattresses, pillows and cushions, and for felts Grades 5, 6, and 7, referred to as Chemical Grades, are used for the manufacture of chemical cotton First cut linter gives grades 1 and 2, mill run, grades 3 and 4, and the second cut, grades 5, 6, and 7 (Thoria & Ahmad, *Technol Bull, Indian Cott Comm*, Ser B, No. 34, 1943, 19)

COTTON MILL INDUSTRY

The cotton mill industry with a capital investment of Rs 73 crores is the biggest industry in India It utilizes 42 lakhs bales of cotton and provides employment to over 4,66,000 workers. It is the largest exporting industry, contributing about Rs 14 crores to the national income From the point of view of cotton consumed the Indian industry occupies the second place, and from the point of view of installed capacity of spindles and looms, it occupies the fifth place, among the textile industries in the world

The first cotton mill to be started in India was the *Bowreah Cotton Mill Company*, Calcutta, in 1818 The first cotton spinning mill in Bombay was established in 1851 and in Ahmedabad, in 1859 By 1861, there were in all 9 cotton mills in India The growth of the industry suffered temporarily as a result of increased export of raw cotton to Lancashire during the years of the American Civil War 38 mills were started, mostly in Bombay State, during 1870-85. The introduction of mechanical improvements, such as the substitution of the Ring Frame for the Mule in spinning, and the Revolving Flat Card for the Roller Card, gave a further impetus, and more mills were erected with new machinery. Except for a few temporary setbacks due to famines and plagues during 1885—1900, the industry progressed steadily. The fall in the exchange value of the rupee during 1873-97 and the inauguration of the Swadeshi Movement in 1895 favoured the growth of the industry. In 1899-1900, there were in all 193 mills with 4,945,783 spindles and 40,124 looms representing a capital investment of Rs. 20 crores.

During the period 1900-39, several cotton mills were set up in upcountry districts. World War I gave a fillip to the industry when demand for cotton manufactures increased and imports were restricted The wartime prosperity continued up to 1932 This was followed by a period of depression which lasted till about 1937-38. At the time of the outbreak of World War II, there were 389 mills in India with 10,059,370 spindles and 202,464 looms.

The war gave a further impetus to the industry which expanded rapidly to meet the increased demand for cotton manufactures resulting from the stoppage of imports and heavy Army orders.

Table 1 gives data relating to the growth of the Indian cotton mill industry during the first half of the twentieth century.

Location and distribution.—In the earlier stages of the industry considerable quantities of coarse yarn were being spun and exported to China and Japan Bombay, the biggest cotton market in India with ample facilities for export, was the exclusive centre for yarn production and trade till 1877 With the rise of Japan as a producer of cotton manufactures and the loss of the China market, Indian industry turned its attention to the production of cloth The location of mills was guided more by the proximity of consuming centres than by facilities for export Ahmedabad rose into prominence owing to its nearness to the cotton growing tracts and big markets The development of hydro-electric and other power projects in Madras and U P gave a fillip to the industry in those States During 1921-39, the number of mills outside Bombay and particularly in Madras, Bengal, U P., and Central India increased by 101, while the increase in Bombay was 31 During the period 1939-47, the number of mills outside Bombay increased by 31, the new mills being located mostly in Madras and Bengal The industry is now well distributed all over the country.

The shift of emphasis from spinning to weaving in the Indian cotton mill industry will be apparent from the figures giving the proportions of spindles to looms in various years. In 1900-01, there were on an average 121 spindles for every loom, in 1918-19, the proportion was 57 spindles to one loom, and in 1938-39, 49 spindles to 1 loom.

Bombay holds the leading position among the States in the Indian cotton mill industry. Out of 408 mills in the Indian Union in 1947-48, 209 were distributed in Bombay, the principal centres of production being Bombay, Ahmedabad, and Sholapur. Most of the mills are engaged in both spinning and weaving.

TABLE 1 —GROWTH OF THE COTTON MILL INDUSTRY

	No. of Mills	No of spindles	No. of looms
1900–01	193	50,06,936	41,180
1904–05	197	51,63,486	50,139
1909–10	263	61,95,671	82,725
1914–15*	272	68,48,744	1,08,009
1919–20	253	87,63,076	1,19,012
1924–25	337	85,10,633	1,54,292
1929–30	348	91,24,768	1,79,250
1934–35	365	96,85,175	1,98,867
1938–39	389	100,59,370	2,02,464
1939–40†	388	100,05,785	2,00,076
1944–45	417	102,38,131	2,02,388
1945–46	421	103,05,169	2,02,814
1946–47	423	103,53,973	2,02,662
1947–48‡	408	102,65,841	1,97,469

*Figures prior to 1914-15 are for years ending 30th June , subsequent figures are for years ending 31st August
†From 1939–40 onwards, Burma and Ceylon are excluded
‡For Indian Union only

The growth of the cotton mill industry in Madras has been remarkably rapid In the 2 decades following 1929, the number of mills increased from 12 to 73, and the number of spindles

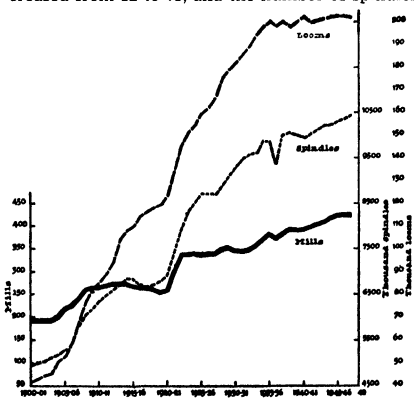
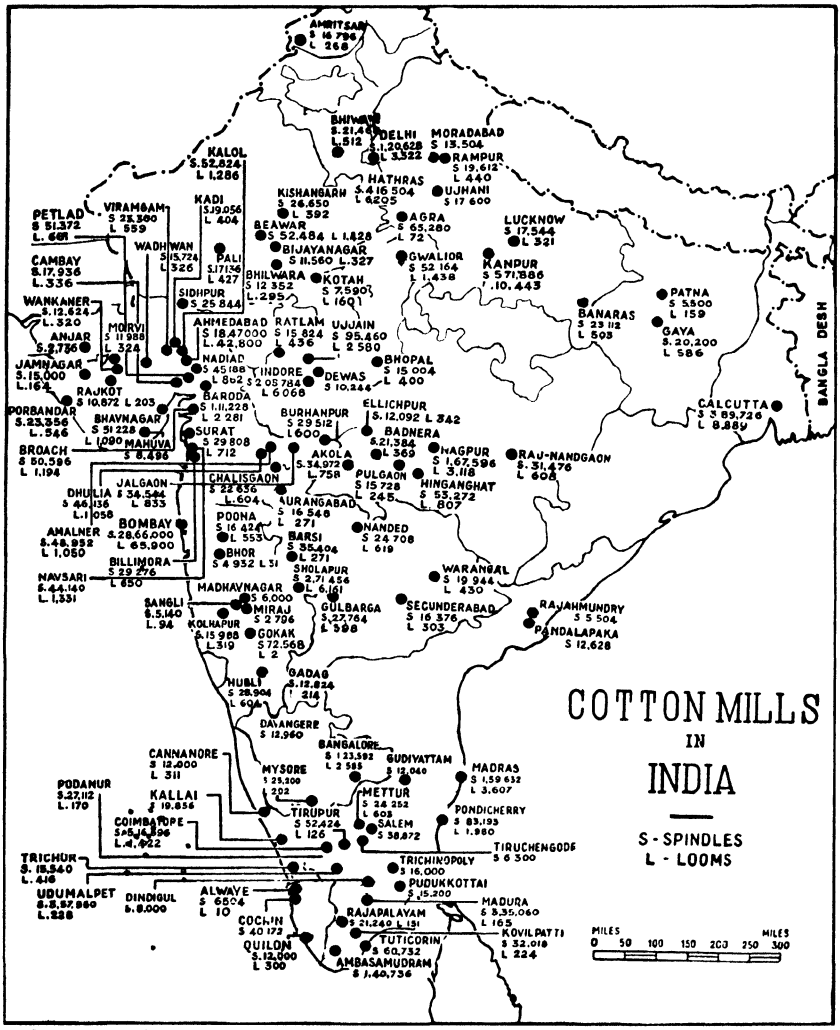


Fig. 68.—Progress of cotton mill industry in India



The territorial waters of India extend into the sea to a distance of twelve nautical miles

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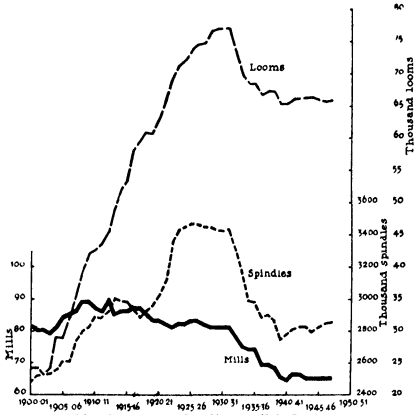


Fig. 70.—Progress of cotton mill industry in Bombay Island

and looms from 4,40,360 and 3,139 to 16,30,054 and 7,976 respectively The important mill centres are Madras, Madura, and Coimbatore The industry is mostly concerned with spinning, and out of 73 mills, 47 are engaged solely on spinning, the average number of spindles per loom for the whole State is 204.

In West Bengal, cotton mills are distributed in 24-Parganas, Howrah, and Hooghly 12 mills with 5,71,886 spindles and 10,443 looms are located in Kanpur. There are 11 mills in Madhya Pradesh (M P.) including the Empress Mill at

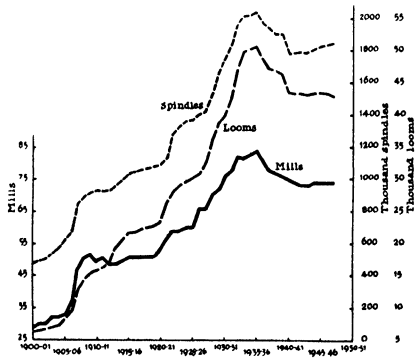


Fig. 71.—Progress of cotton mill industry in Ahmedabad

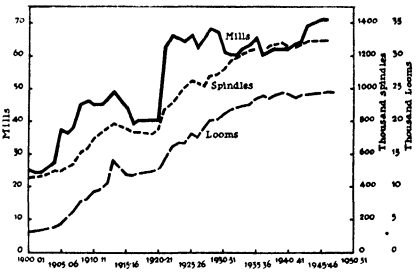


Fig. 72.—Progress of cotton mill industry in the rest of Bombay State

Nagpur with 5 units The number of spindles and looms in M P is 2,97,584 and 5,378 respectively Punjab is important as a producer of cotton, there are only 4 cotton mills in the State. Other important mill centres are Delhi, Indore, Baroda, Bangalore, and Mysore 36 new mills (West Bengal, 14, Madras, 8, Bombay, 3, M P, 3; Mysore, 3, U P, 2, Travancore, 2, and Orissa, 1) were under construction in August 1948.

The cotton mill industry now represents a capital investment of over Rs 73 crores; of this about Rs. 37 8 crores (52%) is invested in Bombay State The paid-up capital (in lakh Rs.) of mills as on 31st August 1948 was distributed as follows Bombay Island, 1,931 8, Ahmedabad, 898 1; rest of Bombay State, 950 1, Rajputana, 158·1; Berar, 89 6, M P, 288 3, Bihar, 20·1, Hyderabad, 134 8, Central India, 277·7, West Bengal, 376·3, Punjab, 14·8, Delhi, 309·3; U.P., 543·2; Madras, 1,108 9, Travancore, 9 4, Mysore, 130 1; and Pondicherry, 61·1. The cotton textile development plan envisages the erection of 75 new mills. 2 mills came into production in 1948, 10 reached the production stage in 1949, and 19 are in the process of erection.

Table 2 gives details regarding the cotton spinning and weaving mills in the different States.

Raw Material

Cotton.—Prior to the partition of the country the cotton used in Indian mills was mostly home-grown. A small quantity of long staple cotton was imported from East Africa and Egypt for the production of fine yarns. Indian short staple (below 7/8 in.) cotton is suitable for spinning yarn up to 16s warp or 20s weft. About half the output of medium staple cotton (7/8 in.—1 in.) can be spun to 24—30s warp, and the remaining half for spinning 16—24s warp. There are two

TABLE 2.—COTTON SPINNING AND WEAVING MILLS (31ST AUGUST 1948)§

	Number of mills	Number of spindles	Number of looms	Average number of workers	Cotton consumed (bales of 3·5 cwt.)
Bombay					
Bombay City and Island	65	28,66,150	65,880	1,22,791	12,29,440
Ahmedabad	74	18,47,388	42,816	76,240	6,24,268
Rest of Bombay State	70	12,93,822	26,507	67,600	5,00,384
Rajputana	10	1,32,868	3,029	8,461	76,636
Berar	4	68,448	1,474	4,130	39,376
M. P	7	2,97,584	5,378	17,709	1,37,322
Bihar	2	25,700	745	1,342	4,512
Hyderabad	6	1,18,420	2,462	7,375	69,144
Central India	17	3,97,480	10,922	25,722	2,49,344
West Bengal	29	3,89,726	8,909	21,208	1,29,430
Punjab	4	38,264	780	1,709	11,360
Delhi†	6	1,20,628	3,322	6,294	91,198
Uttar Pradesh‡	28	7,75,860	12,102	30,176	3,40,050
Madras‡	73	16,30,054	7,976	58,745	5,80,016
Travancore	2	18,504	310	264	4,462
Mysore	8	1,61,752	2,877	10,671	75,678
Pondicherry	3	83,193	1,980	6,040	37,550
TOTAL.	408*	1,02,65,841	1,97,469	4,66,477	42,00,170

* excluding 36 mills which have either been registered or are being erected †1 mill not working ‡2 mills not working.

§ The number of mills, spindles, and looms as on 1st January 1950 was 362, 1,05,54,455, and 1,91,495 respectively

strains of long staple cotton (> 1 in) grown in the country, suitable for spinning yarn of higher counts These are the *Punjab/American 289F/43* and *289F/K25* (staple length, $1\frac{1}{32}$ in $-1\frac{1}{16}$ in , spinning capacity, 30s warp or 40s weft), and *Co 3* and *Co 4* (staple length, $1\frac{1}{8}$ in $-1\frac{1}{16}$ in ; spinning capacity, 40s warp) grown chiefly in the southern districts of Madras State The estimated average production of Indian long staple cotton is less than 400,000 bales (392 lb. net/bale) (Mahta, *Indian Cott Growing Rev.*, 1947, **1**, 8)

Since the division of the country, the position has changed The only long staple cotton available at present in the Indian Union is the Cambodia cotton, the total production of which during 1947-48 was 120,000 bales as against the total production of 2,116,000 bales of cotton during the same period (Sen, *Technol. Bull, Indian Cott. Comm.*, 1949, Ser A, No. 72, 2).

Out of 3,811,000 bales of cotton used in the mills in 1938-39, 3,151,000 bales (82 5%) were produced in India and the rest was imported The industry expanded considerably during the war, and in 1944-45 the consumption of cotton reached 4,887,996 bales The consumption decreased in later years and in 1946-47 the mills used 39 4 lakh bales out of which 38 6 lakh bales (98%) were consumed in the Indian Union, of this 21 4 lakh bales were grown in India, the remaining 17 2 lakhs bales being obtained from Pakistan (10 2 lakh bales) and other countries (*Bombay Cotton Annual*, 1947-48, No 29, 47) The import from Pakistan was mostly long staple cotton

The mill consumption of cotton during 1947-48 was 42 lakh bales, out of which about 28·6 lakh bales were drawn from sources within the country The production of Indian cotton in that year was only 21·2 lakh bales, out of which 8 lakh bales of short staple cotton were exported It will be thus seen that there is a severe shortage of cotton for the mills and the requirements during 1947-48 were met by drawing heavily on

TABLE 3.—CONSUMPTION OF COTTON IN MILLS*
(bales)

	Indian cotton	Pakistan cotton	Other foreign cotton	Total
1941-42	2,863,247	1,006,201	566,785	4,436,233
1942-43	3,029,776	1,360,929	464,522	4,855,227
1943-44	2,854,255	1,344,051	633,671	4,831,977
1944-45	2,991,767	1,253,007	643,222	4,887,996
1945-46	2,696,960	1,261,564	604,650	4,563,174
1946-47	2,144,671	1,016,836	695,981	3,857,488
1947-48	2,863,450	723,216	624,216	4,210,882
1948-49	3,123,915	410,956	719,765	4,254,636

*Figures prior to 1946-47 relate to consumption by mills in undivided India

the carry over with the mills and the trade.

Table 3 gives the consumption of cotton in Indian cotton mills

Table 4 gives the consumption of different varieties of Indian and foreign cotton in Indian mills.

Imports of cotton are subject to a revenue duty of 2 annas per lb, but are exempt from customs duty if the cotton imported is the produce of Pakistan In order to encourage exports of fine and superfine cloth of Indian manufacture, the Government of India have recently announced their decision to grant, for the present, a rebate of import duty on foreign cotton entering into the production of such cloth The rebate will be paid at the flat rate of 2 annas per lb. on the net weight of all export of 'Fine' and 'Superfine' cloth, as defined in item No 12 in the First Schedule to the Central Excises and Salt Act, 1944 The concession came into effect from 1st Feb., 1950

Towards the end of March 1948 an agreement was reached between India and Pakistan for the

TABLE 4.—CONSUMPTION OF INDIAN AND FOREIGN COTTONS

Variety	Indian Cotton 1947-48	Indian Cotton 1948-49	Variety	Foreign Cotton 1947-48	Foreign Cotton 1948-49
Bengal Deshi	140,393	169,927			
Oomras (short staple)	279,129	266,203	Egyptians	305,697	325,850
Oomras (long staple)	1,013,392	1,099,708	Sudan Egyptians	81,053	52,539
Buri (American seed)	15,157	42,062	Sudan Americans	7,817	7,581
East Punjab American medium staple	*	43,471	East Africans	195,315	185,967
Westerns/Northerns :			Afghans	2,835	834
			Americans		
(a) Ordinary	85,729	87,083	(a) Peruvians	21,281	20,932
(b) Farm .	122,155	139,138	(b) Other Americans	5,182	51,731
Coconadas/Warangal	12,990	35,805	Belgian Congo	2,761	773
Comptas and Uplands	170,575	197,384	West Punjab Deshi	†	4,475
Cambodias/Tinnevellies/ Salems	309,449	265,266	West Punjab American (medium staple)	* 199,462	67,757
Surti	150,704	122,469	West Punjab American (long staple)	312,249	154,587
Broach.			Sind American (medium staple)	22,154	10,754
(a) Fair staple	48,227	86,085	Sind American (long staple)	189,351	173,383
(b) Farm	124,048	254,129	Other Foreign Cotton	2,275	3,558
Dhollerahs	377,922	307,061			
Other Indian	13,580	8,024	Total	1,347,432	1,130.721
Total	2,863,450	3,123,915			

*Included under W Punjab American (medium staple). †Included under Bengal Deshi

exchange of cotton for cloth. Pakistan agreed to supply 650,000 bales of cotton in lieu of 300,000 bales of cloth. The actual receipts were 363,749 bales of cotton; Pakistan purchased only 200,000 bales of Indian cloth. During 1949-50 Pakistan agreed to supply 450,000 bales of cotton but India could not purchase the cotton as the Pakistani rupee was over-valued by 44% in terms of the Indian rupee.

On account of the shortage of cotton, a few Indian mills had to close down. Steps are being taken to grow suitable varieties in India. The target of production for the season 1950-51 is 36 lakh bales.

Small quantities of rayon yarn are used in Indian cotton mills for borders and stripes in cotton piecegoods. Staple fibre is also used to a small extent for mixing with cotton, especially for tapestries.

In addition to fibres, large quantities of chemicals and related materials required for sizing, bleaching, dyeing, printing, and finishing are consumed by the cotton textile industry. Table 5 gives the quantities of chemicals and sizing

TABLE 5.—CHEMICALS & SIZING MATERIALS

	(tons) 1946	1947
Tallow	2,836	3,000
China clay	3,975	3,231
Gums and resins	1,279	1,130
Maize starch	11,449	3,171
Tapioca	5,799	1,795
Flour	6,883	13,795
Other starches	12,633	14,970
Zinc chloride	365	381
Sulphuric acid	1,933	1,987
Hydrochloric acid	589	497
Caustic soda	20,831	6,532
Soda ash.	13,375	9,029
Bleaching powder	2,921	3,857
Sodium hydrosulphite	756	908
Common salt	12,444	14,291
Colours	1,178	(a)

Second Census of Manufactures, India—1947, 1950.
(a) not avaible

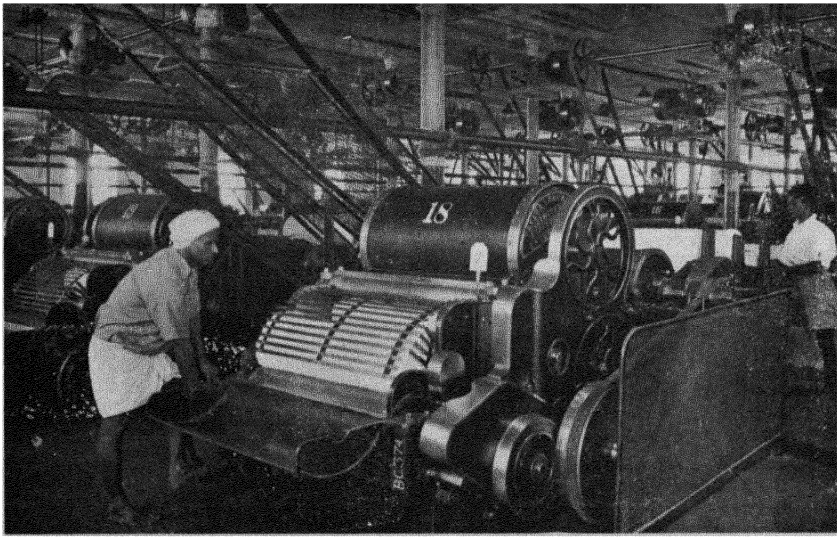


Fig. 73.—Scutching, the final process in cleaning and opening of cotton

materials consumed by the Indian cotton textile industry during 1946 and 1947.

MANUFACTURE

Cleaning.—The cotton which comes to the mill in large bales is cleaned by passage through Bale Breakers, Openers and Scutchers or Pickers, or through continuous blowroom machinery. The bale breaker tears into small pieces the hard knotted lumps of cotton from the compressed bale. During the process dust, dirt, leaves, stems, etc., are shaken loose and the partially cleaned cotton passes to a mixing stack, whence it goes to the opening equipment in which it is further opened up and freed from impurities by beaters. The breaker scutcher which follows produces a broad sheet of fibre in the form of a lap. The laps are fed to intermediate and finisher scutchers to secure homogeneous and clean laps.

Carding.—The laps from the blowroom are passed through carding machines which open and clean the cotton further and eliminate a part of the short fibres. During this process complete fibre to fibre separation takes place as rapidly revolving fine wire points fixed on a cylinder carry forward fibres from the laps against a series of slow revolving flats covered with still finer points. The thick lap is drawn out in a thin layer or web. The carded web is removed from the cylinder by a doffer and drawn into a sliver, c. 1 in. diam., by passage through a trumpet mouth, then between calender rollers, and finally delivered through a coiler where it is laid in superimposed coils in slowly rotating roving cans.

Combing.—The bulk of cotton yarn is spun from carded slivers; for medium and fine count yarns (45–50s and above) the sliver has to be combed in which operation short fibres, if present, are removed and cotton freed from neps and particles of foreign matter which may not have been eliminated in the earlier operations. Combing is necessary particularly for long staple cottons, e.g., Sea-Island, Egyptian, East African, and the better grades of Indian cotton (*Technol. Bull., Indian Cott. Comm.*, Ser. A, Nos. 27 & 44). For feeding the card slivers to the comber several card slivers are first converted into a lap by combining and driving them through a sliver lap machine comprising drawing rollers, calender rollers, and lap-formers. The laps are doubled and drafted in a ribbon lap machine, the lap so obtained being fed to the comber. In some mills, carded slivers are passed through one head of drawing machine before they are fed to sliver lap machines.

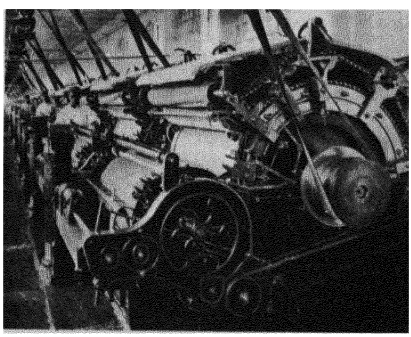
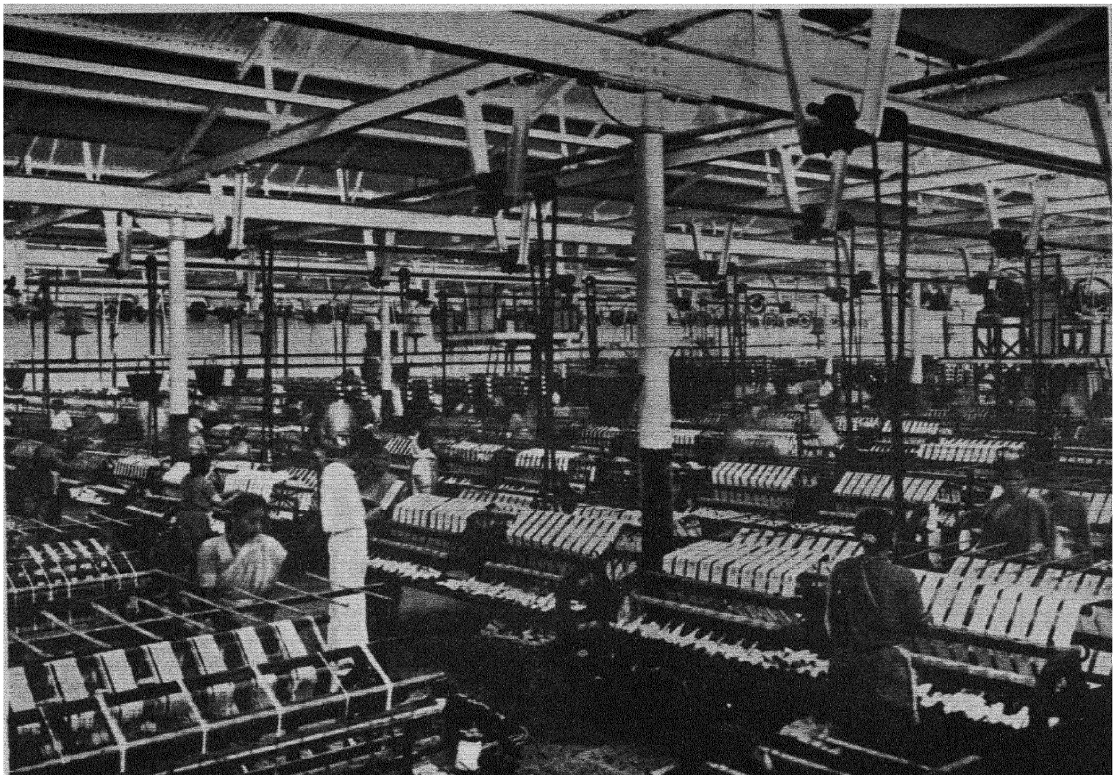


Fig. 74.—Carding of cotton

The essential parts of the comb are: a device for intermittently feeding a fringe of either the sliver or ribbon lap, an arrangement of combs which pass through the fringe at the right time, a rear combing arrangement and a means for piecing up successively combed fringes. The combed web is passed through a trumpet mouth and a pair of calender rolls; the slivers from different heads are superimposed, drafted in a draw box, calendered, and coiled in cans.

Drawing.—Six or eight slivers from the carding engine or the comber are doubled and drawn out in a Draw Frame consisting of sets of rollers revolving at different speeds, thereby drawing out and parallelizing the fibres further and combining them into a single sliver with the same diameter as the original sliver. The slivers are put through the drawing heads 2–4 times according to the quality of cotton. The final sliver passes through a pair of calender rolls, then through a coiler, and is laid in a can ready for the slubbing frame.

Roving.—The sliver is passed through Flyer or Speed Frames to straighten the fibres, to parallelize them, to reduce the size of the sliver, and to impart sufficient twist so that it may be maintained in continuous length, without breaking while winding and unwinding in speed frame bobbins. The speed frame consists of the slubbing frame, the intermediate frame, and the roving frame and, for long staple cottons, a fine roving or jack frame. The sliver is drawn through a set of drafting rollers, twisted by flyers, and finally wound on bobbins. The intermediate frame receives the slubbing bobbins, the roving frame receives the intermediate bobbins, and in



Reeling of cotton yarn

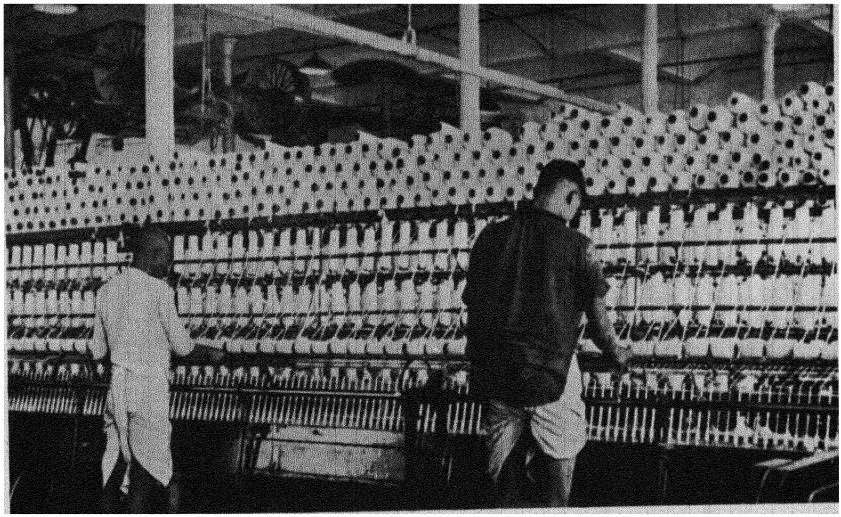


Fig. 75.—Cotton spinning mules

both cases, more drafts and consequently more twist is imparted.

Spinning.—The drawn out roving is spun into the finished yarn on a ring spinning frame or on the mule. In ring spinning, the darwing, twisting, and bobbin-winding all take place simultaneously and continuously. Three lines of rollers are employed and, as in speed frames, a draft is introduced for drawing out the slivers. The principal parts of the ring frame are the drawing rollers, the spindles, the ring, the thread guide wire, separators, and travellers. Yarns up to 100 counts can be spun conveniently in a ring frame. The yarn from the drawing rollers passes through an eye directly over the centre of the spindle and is drawn to the traveller on the ring, which is a circular flanged track within which the spindle is centred, and from there to the bobbin on the spindle. The spindle which revolves at a high speed causes the traveller (a semi-circular piece of steel) to revolve at almost the same speed as the spindle itself. Each revolution of the traveller puts a twist on the yarn and the bobbin winds up the spun yarn from the rollers. At the same time the ring moves up and down as the frame runs which causes the spun twisted yarn to wind on to the bobbin in an ascending and descending spiral giving a uniform yarn package on the bobbin.

Mule spinning consists of three distinct operations in sequence, viz., drafting and twisting, backing off, and winding. The action is intermittent, the drawing and twisting being stopped while the twisted yarn is wound on bare spindles in successive layers to form the cop bottom, parallel body, and top of the cop. Mule spun yarn is said to be softer, firmer, more even, and more suitable for knitting and other purposes. The resulting cop can be used directly, whereas yarn from ring bobbins must be rewound on warper's bobbins or reeled into hanks or skeins. The mule is a large machine about 10 ft. wide and 140 ft. long, of which about 130 ft. is taken up by the spindle. A weft mule may have up to 1,380 spindles and a warp mule, 1,130 spindles. The machines are arranged in pairs for convenience in handling. Mule spinning is well adapted for yarns of low counts.

Doubling—For some purposes two or more threads have to be combined by a process of doubling. The ring bobbins are wound on flanged bobbins or upon straight or tapering

Fig. 76.—Warping

spools in the winding frame, and placed in the creel of a doubling or twisting frame in which the yarns are twisted together into one thread. The yarn may be singed by passing over a gas flame at a rapid rate to remove all projecting fibres and to impart lustre and smoothness.

Warp and Weft yarns.—Yarn required for the warp should have a greater twist than that for the weft as it is subjected to considerable friction and strain during weaving. The weft or filling yarn is ready for use immediately after spinning, and is rewound straight from the spindles or cops on shuttle bobbins. It is reeled only in special cases for bleaching or dyeing.

The warp yarn is normally sized and rendered strong. Sizing also imparts a feel to grey piecegoods, and gives weight and appearance to cheap qualities of cloth. The warp is sized in a slasher. The packages are mounted on a creel and the warp yarns are wound on a beamer. Warp from a series of beamers is passed through a size box, squeezed between rolls as it leaves the size box, and wound on a drying cylinder for drying. The dried warp is carried to the warp beam of the loom. Hank sizing is employed for coloured and bleached yarns, and for grey yarns required for fancy coloured woven goods. Filling yarn is hank sized when required.

The principal sizing agent is starch. Gums, softeners, penetrants, preservatives, loading agents, etc., are added. Thick boiling starches prepared from maize, sago, potato, tapioca, rice, and wheat are used for sizing. Maize and sago starches are often chemically treated to produce thin boiling starches. Tamarind seed powder was employed as a sizing substitute for starch which was in short supply during the war period.

Softeners are added to keep the size from rapid drying, to give flexibility and pliability to the starch film, to provide surface lubrication, and to increase the penetrability. The principal softener used in textile sizing is tallow. Other fats and some vegetable oils rendered soluble by sulphonation are also employed. A number of proprietary softeners are available in the market. Gums toughen starch films, and yarns treated with gum-containing sizes possess good strength.

Penetrating agents—soaps, sulphonated oils, organic surface active chemicals—are used in

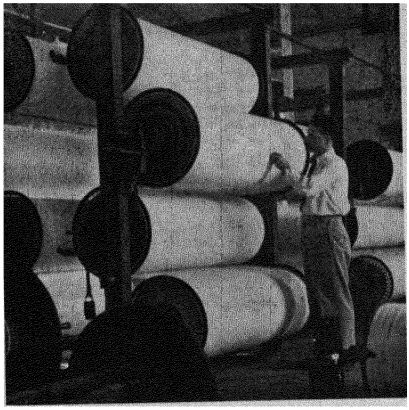


Fig. 77.—Back beams ready for sizing

sizing compositions containing insoluble or unemulsifiable ingredients.

To prevent mildew and bacterial growth on cloth, preservatives—copper sulphate and chlorides of calcium, magnesium, and zinc—are added to sizing mixtures. Proprietary softners generally contain preservatives.

Inert loading agents are added to give weight and body to cloth. China clay and talc are usually employed as fillers in warp sizing.

Weaving.—Power looms are commonly used for weaving in Indian cotton mills. Sized warp yarns are wound on the warp beam at the back of the loom. The warp ends are drawn through the heddle eyes of healds, the number of which is determined by the design to be woven. The warp ends pass through a reed, as wide as the fabric to be woven, consisting of a flat wire comb fixed in a frame to the cloth beam. The healds split the warp into two groups, upper and lower. During weaving the harnesses lower and raise the two groups of threads alternately thereby forming a shed or V-opening through which the shuttle passes. The reed serves to space evenly the yarn ends and to beat the filling yarn or pick into the preceding weft yarn. It also acts as a backrest to the shuttle during its passage across the cloth.

During weaving the warp yarns are unwound from the warp beam and the woven fabric is wound on the cloth beam continuously. Three processes are involved in the weaving operation: shedding, picking, and beating-up. When the loom is in motion, the harness moves up and down rapidly, thus making a shed of alternate warp threads for the passage of the weft yarn. The shuttle carrying the weft yarn is propelled at a high speed by the picker stick through the shed across the cloth. The shed is now closed and the reed pushes the loose pick or filling yarn up against the previous weft yarn to form the fell of the cloth. This sequence of shedding, picking, and beating-up is repeated over and over again at a high speed (80–260 times per minute) till the cloth to be woven is finished. The number of picks per inch, and hence the compactness of the cloth, depends on the take-up motion. The pattern is controlled by the method of lacing the warp and weft threads, which again depends on the number of harnesses employed. In the simplest type of weave, 2 healds are used so that alternate yarns are drawn through each heald resulting in half the ends being up and half down alternately as the shuttle passes through the shed. For intricate patterns more than two healds are required, and a Dobby loom may contain up to 26 healds.

Three types of looms are in use: plain loom, dobby loom, and Jacquard loom. In the plain loom up to 7 healds can be used. The dobby loom is used for the production of figured weaves and patterns. Jacquard loom is used for more complicated weaves and large patterns. The jacquard head allows individual warp threads to be lowered or raised by a series of hooks to form the shed. The patterns are woven by means of jacquard cards which are punched into holes depending on the design. Each card represents one filling or weft in the fabric, and as many cards are used as are required for one repeat of the pattern.

Out of 2 lakh power looms installed in Indian mills, only 700 are automatic. There are a few obvious defects in the operation of the ordinary power loom. The loom has to be stopped every few minutes for replenishing the weft in the shuttle. The weaver has to keep a constant watch over the warp to detect imperfections, particularly breakages. When the imperfection is detected the loom should be stopped, the yarn mended and drawn through the heald and reed, and weaving resumed. In the automatic loom, the weaving is continuous, the weft being supplied from a battery of shuttles or pirns which are kept charged. Automatic looms are provided with a mechanism which stops the loom immediately a warp thread breaks. The introduction of the warp stop motion has enabled the weaver

to manage a large number of automatic looms. Tayoda automatic looms made in Japan are used in some Indian mills. Automatic looms are also made in India

Weaves and Designs.—Three fundamental weaves are employed in cotton textiles—plain weave, twill weave, and satin weave. All other weaves are variants of these fundamental weaves Plain weaves are used in the manufacture of calico, long cloth, cambric, mull, canvas, crepe, voile, nainsook, etc, in which the warp and filling threads interlace alternately The first warp thread is over the first pick or filling and under the second, while the second warp thread is the reverse of the first, completing one repeat of the weave on two ends and two picks Variations of plain weave are the rib and basket weaves In the rib weave, a number of warps or a number of wefts are combined into one yarn In the basket weave, two or more warp yarns are woven with two or more wefts.

Drill, jean, and certain shirtings are of twill weave which gives a strong, heavy, and close-textured fabric, softer and more flexible than fabrics of the plain weave. Warps and wefts are interlaced in such a way that diagonal lines or ridges are formed across the fabric In coarse serge, the weft yarn passes alternately over and under two warp yarns

A lustrous and bright finished fabric is obtained from the satin weave in which more warp yarn than filling is used to obtain the lustrous side If there are more fillings than warps on one side, the weave is called sateen, mercerized cotton fabrics are usually of sateen weave

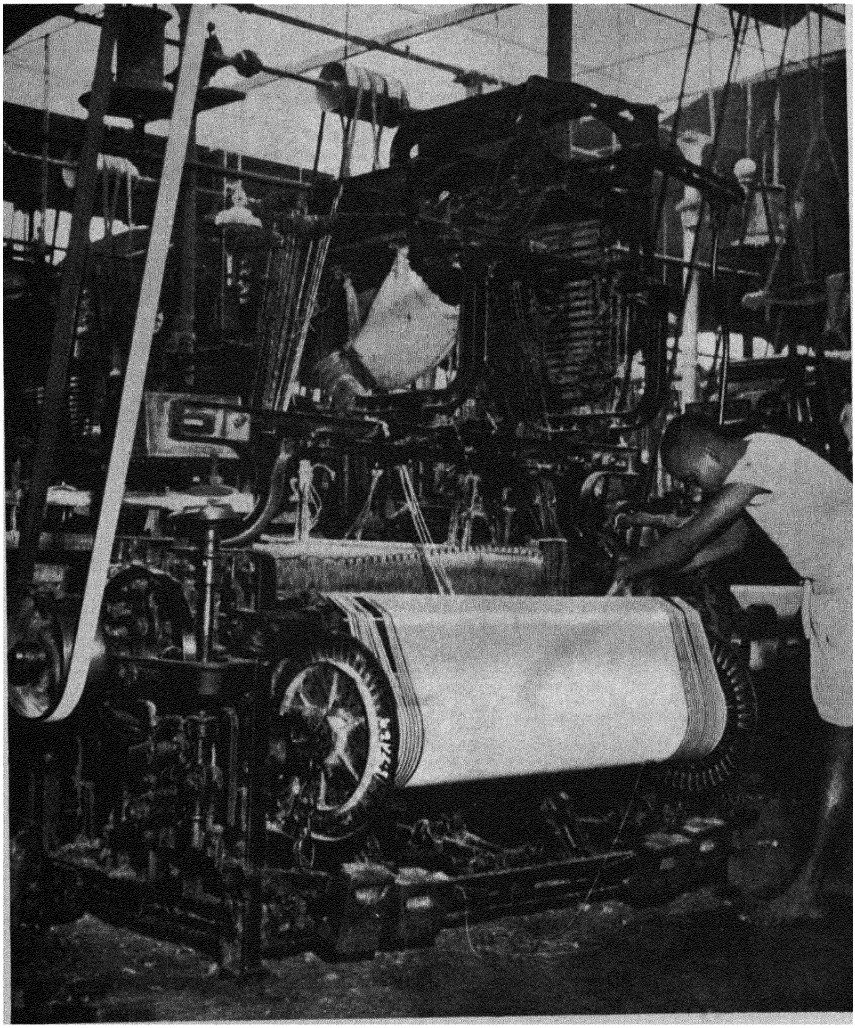
Other weaves in use are pile weave—velvet, Turkish towelling, etc, jacquard weave—containing floral designs and figures, and dobby weave—for simple designs and borders

Bleaching.—The object of bleaching is to produce a white fabric by the elimination of foreign substances such as oils, waxes, proteins, pectic and mineral matter added during the processing of yarn into cloth, and by the removal of the natural colouring matter present in the cotton. The degree of bleaching depends on the purpose for which the cloth is required. For printed fabrics a base of extreme whiteness with absorbent properties is required, and the cloth is madder bleached For goods to be sold as finished white material, a thorough bleaching is not necessary and the woven product is market bleached

Bleaching involves desizing, scouring or boiling in alkaline liquor, and the elimination of the natural colouring matter. The cloth pieces are sewn end-to-end in batches of 2—3 tons. Faced cloth like drills, sateens, etc, should be so sewn that the pieces face the same way. Shirtings, poplins, and cloth intended for printing are signed to burn away protruding fibres from the surface. This is effected by passing the cloth rapidly (100—150 yds/min) over red hot copper plates or over the flames of gas burners and then between the nips of a mangle revolving in a water box The cloth in rope form is steeped in vats containing desizing liquor for 24 hrs. at 35—50° or overnight at 60°, when diastatic enzymes (added to the liquor in the form of malt, mould, bacterial or pancreatic preparations) convert the starch into soluble products which are removed by washing

The desized cloth is steeped in alkaline liquor—milk of lime, caustic soda or soda ash solution Milk of lime is used for madder bleach, caustic soda for market bleach, and soda ash for light scouring The impregnated cloth is plaited down in closed kiers and hot alkaline scouring liquor circulated under 10—30 lb pressure for 8—24 hrs This treatment removes all impurities Oils are converted into soaps, proteins are hydrolyzed, pectic matter is converted into soluble salts of pectic acid, mineral matter goes into solution, and unsaponifiable matter is emulsified in the presence of soluble soaps formed. The scoured cloth is washed with cold water, and passed through a washing machine containing dil hydrochloric acid (1—2°Tw) for decomposing calcium salts formed during scouring The scoured goods are washed and again kier-boiled at high pressure with washing soda solution (3—4% on the wt of cloth) and rosin soap (1½—2% on the weight of cloth) for 3—4 hrs. to remove the free fatty acids left on the cloth The alkaline liquor is drained out and the goods are once again washed

The cloth thus freed from cotton wax and other impurities is subjected to bleaching or chemicking Calcium or sodium hypochlorite, hydrogen peroxide, sodium peroxide, perborates, and permanganates may be employed for bleaching; hypochlorites are more commonly used on account of their low cost. Peroxides are used for delicate goods. Washed cloth in the rope form is impregnated with the bleach liquor and piled up for several hours when hypochlorous acid is formed due to the reaction of atmospheric carbon dioxide on the hypochlorites, which in turn is decomposed into hydrochloric acid and oxygen. The nascent oxygen thus liberated oxidizes the colouring matter. After chemicking, the goods are washed and soured in a dil.



Jacquard loom

solution (1–2° Tw.) of hydrochloric acid to remove calcium carbonate and any residual hypochlorite. The cloth is washed thoroughly to remove the acid. Sometimes the cloth is passed through a dil. solution of an antichlor like sodium bisulphite prior to the final washing.

The operations involved in market bleach are for the most part identical with that of madder bleach with certain modifications. The cloth is not usually singed, and kier-boiling is carried out with dil. caustic soda solution (2–3° Tw) for 8–12 hrs. in open kiers or for 2–8 hrs in pressure kiers. The cloth is washed, soured with dil. sulphuric or hydrochloric acid, washed, and again boiled with caustic soda solution (1–2° Tw.) for 8 hrs. It is then washed and treated with bleach liquor. After the final wash the goods are passed through a tinting solution of indigo to neutralize the slight yellow shade and impart a white tint.

For goods required for dyeing the treatment is less drastic. Cloth for dyeing plain Alizarin red or Turkey red is given a Turkey red bleach The cloth is not usually singed. The goods are boiled in water for about 2 hrs. and washed. The washed goods are boiled twice with caustic soda solution and no chemicking is necessary The boiled goods are washed, soured with dil sulphuric or hydrochloric acid, washed, and dried. Goods to be dyed to medium and light shades are given a half bleach, i.e., the goods after boiling with alkali are chemiked in dil. bleaching powder solution (0 5° Tw.) for 1–2 hrs. and washed

Finishing.—The object of finishing is to improve the appearance, feel, and serviceability of the material The cloth may be treated also to impart to it the appearance of silk or linen or wool.

The finish applied to cotton may be pure, assisted, or stiffened Goods required for printing or dyeing are given a pure finish The treatment is mechanical, the bleached cloth is opened out, stretched to rectify the width and calendered. In assisted finishing, binding and stiffening agents are applied to the cloth to improve the appearance. For stiffened finishes stiffening compositions containing binding, filling, and weighting ingredients are applied to the cloth prior to mechanical finishing. Starch is the commonest stiffening agent and can be used by itself or along with soap, tallow, sulphonated oils, quaternary ammonium compounds, etc. The filling agents are china clay, French chalk or talc; Epsom salt and Glauber's salt are used as weighting agents.

Before calendering, the cloth is moistened to render the cellulose plastic. Different effects are produced from calender bowls made variously from iron, steel, cotton, and paper, and applied either hot or cold according to requirements. Special calenders with engraved lines give Schreiner finish or lustrous embossed finish.

Sanforization obviates shrinkage of cloth during laundering. In this treatment the cloth is rendered soft and pliable by steam or water sprays, the width is controlled to its fully shrunk measurement by a felt blanket on a roller, and the fabric is longitudinally compressed to prevent further shrinking. The process can be applied to goods in any condition. It renders the cloth strong and compact Sanforized cloth does not shrink by more than 1% as a result of repeated washing Cotton drills, suitings, coatings, tussores, and poplin shirtings are sanforized by the *Buckingham and Carnatic Company Ltd.*, Madras

Among other finishing processes for cotton fabrics may be mentioned water-proofing shower-proofing, mildew-proofing, anti-crease, and fire-resistant treatments Special effects are produced by the deposition inside the fibre of cellulose derivatives, rubber, synthetic resins, etc. Urea formaldehyde and melamine formaldehyde are employed to give an anti-crease finish After the application of the resin-forming composition in the appropriate form, the goods are cured or polymerized by heating The *Buckingham and Carnatic Company Ltd*, apply anti-crease finishes to suitings, tussores, gaberdines, etc, which are sold under the trade names Hanava and Riviera Cellulose ethers give organdie, buckram, and linenized finishes These fabrics are washable Cellulose acetate is used to give stiffness and body to cotton goods.

Mercerization, or treatment of cotton yarn or cloth under tension with caustic soda solution, gives a lustrous finish, increases strenth, and enhances affinity for dyes Scoured goods in open width are passed through a concentrated solution (50–66° Tw.) of caustic soda at one end of a special range, allowing it to relax for a short distance of its travel, pulling it out to approximately its grey dimensions while it is still saturated with alkali, and finally washing with dilute caustic soda and hot and cold water. The mercerized cloth is scoured, washed, and processed as required. Sometimes yarn in hank or warp form is mercerized in the unscoured state.

Testing.—Tests for quality control during manufacture are not carried out as a rule in all the Indian mills. Standards for lea strengths of

yarn and for cloth construction data—reed, pick, and count of warp and weft—have been specified. In the case of special articles, the specifications are more detailed and include the breaking strength of cloth

Production and Trade

Yarn.—Table 6 gives data relating to the production of yarns of different counts in Indian mills

In the early stages of the cotton mill industry in India, a large proportion of spun yarn was of the coarse variety, the production of yarn above 40s being insignificant. As the industry developed the production of coarse yarn decreased, that of 21—30s steadily increased In 1938-39, the proportion of different yarns were 1—20s, 52·8, 21—30s, 26 2, 31—40s, 12·9, and above 40s, 7 0% In recent years, substantial progress has been made in the production of yarns of higher counts

Table 7 gives the production of yarn in different centres

Bombay is by far the biggest producer of cotton yarn in India In the opening years of the present century more than 70% of Indian production was concentrated in that State, the shares of the principal producing centres within the State being: Bombay Island, 57, Ahmedabad, 8; and rest of Bombay, 8% With the spread of cotton mill industry in other parts of India, the importance of Bombay as the chief producer of yarn suffered The shares of various centres in yarn production in 1937-38 were: Bombay Island, 28, Ahmedabad, 16, rest of Bombay, 7; and rest of India, 49% The loss in Bombay's share was mainly in the coarse varieties (< 20s), the production decreasing from 284 million lb during 1901/02—1903/04 (av) to 143 million lb in 1937-38, in all other varieties, there was an increase The distribution of production of all types of yarn in 1947-48 was Bombay, 668 8, Madras, 171 7, U P, 113 7, C P and Berar, 54·3; West Bengal, 44 9, Delhi, 27 0, Ajmer-Merwara, 13 1, Punjab, 6 9, Bihar, 2·1, and other States, 227 2 million lb

TABLE 6.—PRODUCTION OF COTTON YARN
(million lb.)

	Counts						
	1–10s	11–20s	21–30s	31–40s	over 40s	Waste	Total
1900–01		281	58	11	3		35
1909–10	135	353	119	16	4		627
1919–20	84	347	184	17	4		636
1929–30	105	388	272	46	15	7	833
1938–39	137	551	341	168	92	14	1,303
1943–44	163	869	374	170	85	19	1,680
1944–45	180	855	336	168	90	22	1,651
1945–46	183	819	343	156	91	23	1,615
1946–47	152	628	271	151	118	18	1,338
1947–48*	141	657	236	149	131	15	1,330

*relates to Indian Union

The production of cotton yarn in 1949, and the first ten months of 1950 was 1,359 and 972 million lb respectively (*Monthly statistics of the production of selected Industries in India*)

TABLE 7.—PRODUCTION OF COTTON YARN
(million lb)

		Bombay Island	Ahmedabad	Rest of Bombay	Rest of India	Total
1901/02—1903/04	(av)	326	45	46	159	576
1919/20—1921/22	(av)	336	79	53	195	663
1937–38		331	184	77	568	1160
1947–48*		385	196	88	661	1330

*relates to Indian Union

Woven goods—Table 8 gives the production of all woven cotton goods in India in million lb.

Table 9 gives the production of cotton piecegoods alone, in million yds

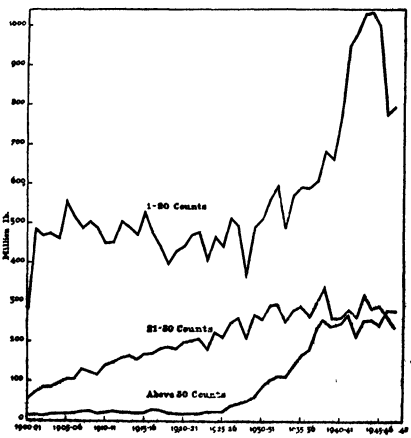


Fig 78.—Production of cotton yarn

TABLE 8.—PRODUCTION OF WOVEN COTTON GOODS
(million lb.)

	1938-39	1943-44	1944-45	1945-46	1946-47	1947-48
Grey and bleached piecegoods						
Chadars	30·7	19 6	20 4	17 7	15·7	11 9
Dhotis	279 3	231 6	200·1	257·2	241 2	248·4
Drills and jeans	35·2	67 3	74 0	67 8	60 0	49·4
Cambrics and lawns	20·3	30 4	31·7	23 4	16·6	17·0
Printers	3·2	3 4	5·1	7 7	5·6	6·2
Shirtings and longcloth	224·7	312 4	301 0	285 0	24·2	211·3
T. cloth, domestics and sheetings	50·3	78·6	78·9	79 2	67·4	59·6
Tent cloth	5 4	65 2	94·8	37 3	9·8	3 0
Khadi, dungri or khaddar	36·8	24 8	26 8	31·5	29·4	27·1
Other sorts	27·9	92 4	88 7	73·8	56·9	51·8
Coloured piecegoods	178 4	233·3	238 3	256·0	190 4	180 7
Woven goods (other than piecegoods)	28·3	33 7	39·7	38·0	29·3	32 7
Total	920·5	1192·7	1199 5	1174 6	946·5	899 1

TABLE 9.—PRODUCTION OF WOVEN COTTON PIECEGOODS
(million yds.)

	1909–10	1919–20	1929–30	1938–39	1943–44	1944–45	1945–46	1946–47	1947–48
Grey and bleached									
Chadars	51	68	66	74·6	46 8	47·1	38 1	36·8	27·6
Dhotis	249	338	776	1,454·8	1,121·7	984·1	1,243·9	1,198·5	1,221·3
Drills and jeans	22	81	100	135 2	205 8	216·9	192·0	182 1	150·7
Cambrics and lawns	4	8	3	167·2	252 8	245·2	167·2	114·0	108·4
Printers	33	30	19	16.7	24·1	31·1	37 9	25·5	29 8
Shirtings and longcloth	245	444	585	1,040·1	1,381 6	1,302·9	1,201·9	948·3	919 0
T. cloth, domestics and sheetings	140	122	91	183·2	259·5	256·7	253·3	220·8	203 6
Tent cloth	6	6	8	14·2	130·0	184·0	73·7	22·2	7·0
Khadi, dungri or khaddar	...	..	125	118·2	76·7	81·6	93 6	90·5	83·1
Coloured piecegoods	192	476	604	932·1	1,105·3	1,118·4	1,125·6	813·8	808·3
Other sorts	20	67	41	132 2	266·3	258·4	248·4	237 3	221·1
Total	964	1,640	2,419	4,269 2	4,870 6	4,726·5	4,675·6	3,889·8	3,770·0

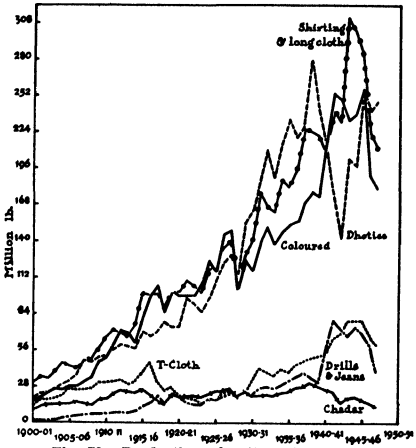


Fig. 79.—Production of cotton piecegoods

There have been three well marked periods in the development of the weaving industry in India. In the first period preceding the close of World War I, the production of most items of cotton piecegoods increased steadily from year to year During the period between the two wars, despite competition from foreign goods, the production increased rapidly The total production in 1930-31 was more than twice, and in 1938-39 more than thrice, that in 1918-19 Compared to the pre-war output, the production of dhotis increased four-fold and that of coloured goods, two-fold. During World War II the output of piecegoods increased still further, and in 1943-44 the production reached the peak value of 4,871 million yards The production of all woven cotton goods in 1949 and the first ten months of 1950 was 3904 2 and 3028·3 million yds respectively (*Monthly Statistics of Production of Selected Industries in India*)

TABLE 10
(million yds.)

	Bombay Island	Ahmeda-bad	Rest of Bombay	Rest of India	Total
1901/02–1903/04 (av.)	293	102	47	99	541
1919/20–1921/22 (av.)	874	372	125	280	1,651
1937–38	1,376	1,087	260	1,361	4,084
1946–47	1,302	824	282	1,481	3,890

TABLE 11—PRODUCTION IN VARIOUS STATES 1947–48.
(million yds.)

	Grey	Coloured	Total
Bombay	1,745 6	604·3	2,349·9
Madras	54·9	39 9	94·8
West Bengal	141 4	16·2	157·6
U. P.	252·5	8 6	26 ·1
Ajmer Merwara	28·0		28 0
Punjab	27 1	1·4	28·5
Delhi	56·6	13 7	70 3
M. P.	77 8	11 2	89 0
Bihar	6 9	0 1	7 0
Other States	570·9	112 9	683 8
Total	2,961·7	808 3	3,770·0

Table 10 gives the production of cotton piecegoods at various centres

Ahmedabad is the most important producer of coloured piecegoods Both Bombay and Ahmedabad are major producers of dhotis. The smaller mills at Ahmedabad specialize in the manufacture of coloured piecegoods, and those in Bombay are mainly engaged in the production of standard types of piecegoods such as dhotis, shirtings and long cloth.

Table 11 gives the production of cotton piecegoods at various centres during 1947-48.

Imports and Exports.—Table 12 gives the imports of cotton yarn and twist into India.

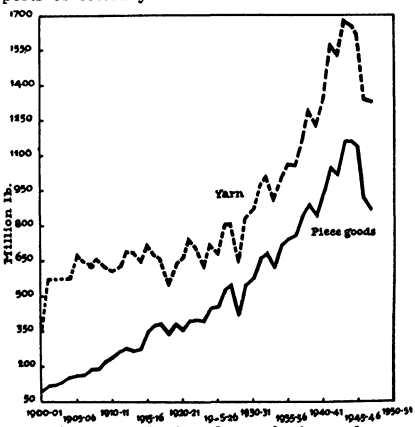


Fig. 80.—Production of yarn & piecegoods

TABLE 12 —IMPORTS OF COTTON YARN AND TWIST
(1,000 lb.)

	1934/35–1938/39 (av)	1939/40–1943/44 (av)	1944–45	1945–46	1946–47	1947–48	1948–49	1949–50
Single grey								
1—10s	164 0	324 8	1 4	1 1	.	194 7	694·4	2,044 7
11—20s	60·3	379 1						
21—30s	656·7	28 4	0·9	0·2	19 3	549·1	189·0	609 8
31—40s	5,897·2	722·1	.	34·1	34·7	248·9	1,920·1	3,442 4
41—50s	432·0	279·8	2·5	12·8	21·4	121·1	355·6	117 2
51—60s	4,133 0	1,393·5	26 7	44 8	65·3	1,072·6	2,767 1	4,286 5
Above 60s	1,371·2	193 4						
Grey, folded	6,845·8	4,240·2		neg.		132 7	898·6	2,150·2
White, bleached	2,934·0	564·4	0 8	10·4	59·8	305 9	240·7	336·2
Single, coloured								
1—20s	111 3	86 0	13 5	2 7	2 3	7 4	4 3	47·7
21—30s	119 8	7·2						
31—40s	252 6	34 9			.		..	2 0
41—50s	10 2	19 7	..	..	2 9	..	6 0	
Above 50s	196 5	54 4		0 6	11 2	79 1	43 2	31·0
Coloured, folded	173 3	24 6			.	0 3		9 0
Mercerized	9,733·2	4,927 7				117 5	37 4	426 6
Unspecified	23 0	774 3	146 1	16 6	0 4	5,974 6	3,927 1	585·9
Total	33,113 9	14,054 4	192·0	123 3	217 3	8,803·9	11,083·4	14,089·0
Total val. (lakh Rs)	295 9	144·6	4·02	3·68	9 18	309 32	450 11	576 86

The imposition of a protective duty on yarn in 1927 and the abolition of excise duty in 1926 did not result in any substantial fall in the imports This is due to the fact that although during the period of protection, imports of grey and coloured yarns of lower and medium counts decreased, imports of twists, mercerized yarn, and yarns of higher counts increased The fall in imports of counts lower than 40s was due to the progress made by Indian mills in spinning counts between 21s and 40s

About 95% of the yarn imported into India in 1926-27 came from U K and Japan. This figure was reduced to 57% in 1931-32 due to imports of grey yarn from China which amounted to about 42% of the total imports. Before World War II, Japan and U K, and to a lesser extent China, were the principal exporting countries of yarn to India, the shares of U K. and Japan in the imports during 1938-39 being 13 and 58% respectively

During World War II the imports dropped rapidly. 41 million lb. were imported in 1939-40, 8 million lb in 1941-42, 1 million lb in 1942-43, 630 thousand lb in 1943-44, 192 thousand lb in 1944-45, and 123 thousand lb. in 1945-46 The imports have again increased, the principal exporters to India in 1948-49 being U K and U S A, their shares were 49·3 and 17 2% respectively In 1949-50, U K, Japan, and Italy were the principal exporters, their shares being 43 3, 36·0, and 13·3% respectively

Almost all the imported yarn is used in handlooms and small power looms. The Tariff Board estimated that out of 31 million lb. of yarn imported in 1932, 30 million lb. were used in handlooms In recent years, however, the consumption of foreign yarn for handloom weaving has diminished Out of the 360 million lb of cotton yarn consumed in 1947 for handlooms, 33 million lb. (9%) were of foreign origin (*Rep. Fact Finding Committee, Handlooms and Mills*, 1942, 112)

Table 13 gives the import of cotton piecegoods into India

The imports of foreign cloth into India dropped

TABLE 13 —IMPORTS OF COTTON PIECEGOODS
(million yds)

	1934/35–1938/39 (av).	1939/40–1943/44 (av).	1944–45	1945–46	1946–47	1947–48	1948–49	1949–50
Plain grey	166 06	73·25	0·05	0·03	0·12	0·29	1·39	26·38
Bordered grey	90·30	20·51		neg	neg	0 10	2·50	0·26
White (bleached)	229·90	55 24	1 44	1·14	3·60	9·38	16 55	19·66
Printed	177 91	56·25	2·14	0·70	6·34	4·25	10·33	10·65
Piece dyed	94 96	33·58	1·52	0·89	5·53	11·67	13·23	13·93
Woven, coloured	19·37	6·06	0·06	0·42	0·62	1·99	3·51	2·45
Total	778·50	244·89	5·20	3 19	16 21	27 68	47·51	73·33
Total value (lakh Rs)	1,360 9	464 5	32·32	43 22	239 63	429 97	929 41	1,069 94

for the first time during World War I, when it decreased to an average of 1,810 million yds. from the pre-war quinquennium average of 2,617 million yds Although the imports increased after the war, the pre-war position was never regained During the three years, 1927/28—1929/30, the imports reached 1,900 million lb , but with the abolition of excise duty in 1926 and the imposition of protective duty on imported cotton piecegoods in 1930, the imports dropped once again. Other factors which contributed to the steep fall in imports were the Swadeshi Movement and the general trade depression The imports of grey and white goods fell to a greater extent than coloured goods There was a further reduction in imports during World War II. In 1944-45 and 1945-46, the quantities of cloth imported were 5 20 and 3·19 million yards respectively There is a slight revival of imports mostly of the finer varieties of white, printed and dyed cloth in which the indigenous production is inadequate

U K was the principal source of supply of cloth to India Out of a total of 1,788 million yds imported in 1926-27, 1,467 million yds (82%) were from U K. and 244 million yds. (13%) from Japan The corresponding figures in 1938-39 were 207 5 million yds (32 8%) and 424 8 million yds (65 6%) During the war period imports were almost entirely from C K During 1948-49 and 1949-50, over 78% and 54% of the imports were obtained from U.K. which was the main source for bleached, coloured, and printed goods

Table 14 gives the exports of cotton yarn from India

At the beginning of the present century India had a large export trade in twists and yarns, mostly with China During the quinquennium ending 1913-14, India exported about 201 million lb of twist and yarn. The quantity exported fell to about 130 million lb during World War I, and to 82 million lb in the quinquennium ending 1923-24 The progressive fall in export was due to the loss of the China market, which drew its requirements from Japan During 1938-39, the quantities (in million lb) exported to various countries were. Burma, 12·4, Hongkong, 8 2; Straits Settlements, 5 5, Syria, 3·4, Aden, 1, Iraq, 13, Philippines, 1, and Siam, 1

During World War II, there was an increased demand for yarn from the neighbouring countries and exports increased reaching the peak figure of 89 3 million lb in 1941-42. Since then there has been a fall in exports.

Table 15 gives the exports of cotton piecegoods from India.

Cotton piecegoods valued at £2,126,806 were exported from Bombay in 1875 to Russia, America, and China During World War I, the average export increased from 90 million yds. in the pre-war period to about 155 million yds. During World War II, there was a steep rise in exports, the figure for April-June 1943 being 232% higher than that in the corresponding period in 1941, and a peak export figure of 819 million yds was attained in 1942-43 as compared with 771 million yds. in 1941-42 and 177 million yds. in 1938-39.

In July 1942 the export of piecegoods was controlled under a quota system based on exports during 1941-42. This step was necessary to ensure adequate supplies within the country. The restrictions on exports were further tightened, and

TABLE 14 —EXPORTS OF COTTON TWISTS AND YARNS
(1,000 lb)

	1934/35–1938/39 (av)	1939/40–1943/44 (av)	1944–45	1945–46	1946–47	1947–48	1948–49	1949–50
Grey								
1–10s	5 317	10,151						
11–20s	12 723	20,102						
21–30s	1 334	6.220	14,567 10	13,381 57	3,296 75	40 58	5.604 98	60,408 52
31–40s	1,502	5.768						
Above 40s	291	3,364						
Twofolds	207	445						2 0
Coloured								
1–20s	161	460						
21–40s	183	717	779 50	1,173 13	431 94		1 56	258 88
Above 40s	5	85						
Twofolds (doubles)	3	3		.			.	.
White bleached								
1–40s	155	1,469	399 34	163 20	60 20	1 00	1,059 60	1,317 40
Above 40s	5	193	4 00					26 00
Unspecified	652	2,441	1,166·88	93 38	2 00		741 40	280 71
Total	22,538	51,418	16.916 82	14,811 28	3.790 89	41 58	7,407 54	62.293·51
Total value (lakh Rs)	111 7	403 4	228 05	149 71	44 18	0 56	128 93	1,129 72

TABLE 15 —EXPORTS OF COTTON PIECEGOODS
(1,000 yds)

	1934/35—1938/39 (av)	1938/39—1943/44 (av)	1944–45	1945–46	1946–47	1947–48	1948–49	1949–50
Grey (unbleached)	39,479	194,421	215,707	238,144	132,872	68,302	91,926	279,686
White (bleached)	6,475	80,763	63,170	54,428	41,551	30,781	66,368	129,722
Coloured, printed or dyed	83,811	257,631	144,142	164,573	143,895	93,340	182,634	280,592
Total	129,765	532,815	423.019	457,145	318,318	192,422	340,928	690,000
Total value (lakh Rs)	354 5	2,372·8	3.379 29	3,055 21	2,496 21	1,802 76	3,625 08	5,758 83

the permissible maximum was fixed at 600 million yds per annum. The principal buyers of Indian piecegoods were Australia, Anglo-Egyptian Sudan, Ceylon, Kenya, Iraq, Iran, Aden, Arabia, Abyssinia, Tanganyika, Portuguese East Africa, Mauritius, Madagascar, South Africa, Palestine, and Turkey. Exports since 1946 have been limited to 300 million yds per annum.

At the beginning of 1948 exports began to decline, due to rise in prices following decontrol, and competition from other countries, particularly Japan. In 1948, the export (excluding Pakistan) was only 50% of the target of 300 million yds.

In March 1949 the Government liberalized the export policy and the quota for exports of cotton piecegoods was fixed at 1,000 million yds. for the period Sept. 1949 to Dec. 1950. Mills were encouraged to ship cloth direct. Also, exports to new destinations were encouraged. The export duty levied on cloth was abolished in June 1949 and restrictions on export of fine, super fine, grey, and bleached cloth, as well as cloth of extra width were lifted. The devaluation gave a further fillip to export. Exports to Pakistan, however, remained low and after devaluation of the rupee her offtake was further reduced

Tariff —The tariff on cotton textiles has greatly influenced the development of the mill industry in India A 5% duty was levied in 1874 on imports of yarn and piecegoods, and this was gradually reduced and abolished in 1882. In 1896, a duty of 3½% was imposed on all imported and indigenous woven goods The excise duty on imported goods was raised to 7½% in 1917, and to 11% in 1921 There was no duty on imports of yarn till 1922, when a duty of 5% was imposed

The loss of export trade with China, the fall in the sterling value of the rupee, Japanese competition, and labour troubles, all affected the industry after the post-war boom. To counteract the depression the excise duty of 3½% was abolished in March 1926, and in September 1927, a minimum specific duty of 1½ annas per lb. or 5% *ad valorem* was levied on imported cotton yarn under the Yarn Protection Act of 1927

In 1930, the duty on imports of piecegoods was raised (under the Cotton Textile Industry Protection Act of 1930) from 11% to 15% on British and 20% on foreign goods with an alternative minimum specific duty in either case of 3½ annas per lb on plain grey goods. In 1931 the duties were raised by another 5%, and a surcharge of 25% imposed bringing the scale of duties to 25% on British goods and 31¼% on foreign goods with a minimum specific duty of 4⅜ annas per lb. on plain greys. In Sept 1931 the duty on cotton yarn was raised to 6¼% *ad valorem* or 1⅝ annas per lb. whichever was higher

The question of protection was complicated by the Ottawa Trade Agreement of 1932, according to which U K agreed to purchase Indian cotton in lieu of preferences granted to her in the finer qualities of piecegoods As competition from Japan continued to increase due to the depreciation of the yen, the duty on non-British piecegoods was raised in August 1932 to 50% *ad valorem* or 5½ annas per lb and again in June 1933 to 75% *ad valorem* or 6¾ annas per lb., and the Indo-Japanese Trade Convention of 1904 was denounced This resulted in the boycott of Indian cotton by Japan. In January 1934, an Indo-Japanese agreement was reached under the terms of which, the duty on Japanese piecegoods was reduced to 50% *ad valorem* with a minimum specific duty of 5¼ annas per lb. On plain greys, Japan agreed to purchase a fixed amount of cotton against import of Japanese piecegoods by India. The Indo-British Agreement (Mody-Lees Pact, 1933) brought a reduction of duty on British piecegoods and yarn in exchange for an undertaking on the part of U K to consume Indian cotton in increasing quantities.

The question of tariffs was reviewed by the Indian Tariff Board in 1934, and the Textile Protection Act fixed the rates of duty in May 1934 at 5% on British and 6¼% on non-British yarns with a corresponding alternative minimum specific duty of 1½ annas and 1⅞ annas per lb on counts up to and including 50s and at 6% and 7½% respectively, on yarns of counts above 50s. Also, the rates of duty on piecegoods were fixed at 25% and 50% on British and non-British goods respectively with a minimum specific duty of 4⅜ annas and 5½ annas per lb on plain greys The duty on all British piecegoods with the exception of prints was reduced in June 1936 to 20% with a minimum specific duty of 3½ annas per lb on plain grey goods. In April 1939, the Ottawa Agreement was replaced by the Indo-British Trade Agreement by which the duty on British piecegoods was further reduced to 15% or 2⅝ annas per lb whichever was higher in the case of grey goods, 17½% in the case of printed goods, and 15% for others These rates were subject to a reduction of 2½% if imports were less than 350 million yds , and to an equal increase if imports exceeded 500 million yds In April 1940, the duties on British grey goods excluding bordered chadars, dhotis, saris, and scarves were reduced to 12½% *ad valorem* or 2 1/16 annas per lb., on printed goods to 15% *ad valorem*, on printed piecegoods and printed fabrics not otherwise specified to 12½% *ad valorem*, and on other British fabrics to 12½% *ad valorem* The Indo-Japanese Agreement was extended up to March 1940, the entry of Japan into the war made a further extension or modification impossible

The Indian Tariff Act expired in March 1947 The question came up for re-examination by the Tariff Board and a new schedule of duties on imports of yarn and piecegoods (Table 16) was formulated

An excise duty of 25% *ad valorem* was imposed on superfine cloth produced by the Indian cotton mills with effect from January 1949. The export duty of 10% was abolished in June 1949 in order to encourage export.

Control —During World War II, production increased at a phenomenal rate due to stoppage of imports and increase in demand within the country. There was also a demand for Indian cloth in Australia, Ceylon, South Africa, East Africa, and in the Middle and Near East countries. These factors contributed to a sharp rise in prices and in April-May 1943 the prices were c. 400% over the pre-war level. A system of control was imposed to check the rise in prices, to increase production by

TABLE 16.—STANDARD RATES OF DUTY ON IMPORTS OF COTTON YARN AND PIECEGOODS

	British manufacture	Other than British manufacture
I Twist and Yarn*		
Above 50s	6% *ad valorem*	7½% *ad valorem*
50s and below	5% *ad valorem* or 1¼ annas per lb whichever is higher *plus* one-fifth of the total duty	6¼% *ad valorem* or 1¾ annas per lb whichever is higher *plus* one-fifth of the total duty
II Cotton fabrics (containing more than 99% cotton)		
(a) Grey piecegoods (excluding bordered grey chadars, dhotis, saris and scarves)	15% *ad valorem* or 2⅛ annas per lb whichever is higher *plus* one-fifth of the total duty (12½% *ad valorem* or 2 1/16 annas per lb whichever is higher *plus* one fifth of the total duty)†	50% *ad valorem* or 5¼ annas per lb. *plus* one-fifth of the total duty.
(b) Printed piecegoods and fabrics	21% *ad valorem* (18% *ad valorem*)†	60% *ad valorem*
(c) Cotton piecegoods and fabrics not otherwise specified	18% *ad valorem* (15% *ad valorem*)†	60% *ad valorem*
III Fabrics containing over 50 but not more than 90% cotton, and not containing more than 10% silk, or 10% artificial silk, or 10% wool	37½% *ad valorem*	75% *ad valorem*
IV Fabrics, not otherwise specified, containing not more than 10% silk, or 10% artificial silk or 10% wool, 50% cotton	37½% *ad valorem*	37½% *ad valorem*
V Sateens, velvets, velveteens, etc		
Printed	21% *ad valorem*	42% *ad valorem*
Others	18% *ad valorem*	42% *ad valorem*

*Government of India, Ministry of Finance (Revenue Division) Notification No 45- Customs, dated the 23rd October 1948, Cotton yarn is exempt from payment of customs duty leviable thereon

†Government of India, Commerce Department, Notification No 20T, dated the 16th April 1940

controlling the supply and cost of mill stores, to regulate the prices of raw cotton, and to supervise the distribution of cloth from mills to retailers. Under the Cotton Cloth and Yarn (Control) Order of June 1943, all cloth produced after 31st July 1943 was to be stamped with ex-mill and retail prices, and the stocks held on that date had to be disposed of before specified dates; also the maximum prices for different varieties of cloth were fixed. As a result of these measures, and the fixation of ceiling prices which were revised from time to time, prices of cotton manufactures scaled down gradually. There was an increase in production although not to the extent anticipated, and in the year 1943-44 a peak production of 4871 million yards was reached. The increase in production was achieved by employing multiple shifts, enhancing the bonus to workers, reducing holidays and rationalizing of production by limiting the types of yarn and cloth produced The control was operated through a Textile Control Board, representing trade, consumers, labour, and handloom interests, which tendered advice to Government through the Textile Commissioner The Board set up sub-committees for fixation of prices, production, standardization, transport, distribution, mill stores, and export The Cotton Cloth Movement (Control) Order 1943 was promulgated with the object of regulating the distribution of cloth

The wartime control was continued up to the end of 1947, when all the provisions excepting

the control on the distribution of yarn were removed In May 1948, the Textile Control Board was replaced by the Textile Advisory Committee which was set up to advise Government from time to time on cotton textile policy and on various matters relating to the price and distribution of cloth and cotton Production increased after decontrol, but there was still scarcity of cloth and the prices rose to abnormally high levels A partial control was reimposed on 31st July 1948 according to which 30—40% of mill production was to be requisitioned for distribution on a rationed basis, 20—25% to be sold through fair price shops organized by manufacturers, and the remainder to be released for sale through normal trade channels Stocks accumulated in mills due to the inability of buyers to lift their allocations, and new measures were formulated for the movement of cloth from mills to consumers

A fresh scheme for the standardization of cloth was introduced in January 1949 The production control is intended to eliminate non-durable qualities, and to restrict varieties largely to plain grey or bleached utility cloth.

Prices—Table 17 gives the prices (statutory control) of cotton yarn and manufacturers in the last week of December, 1950

TABLE 17

Yarn	Price Rs a p
10s (per lb.)	1 2 0
16s ,,	1 6 2
20s ,,	1 8 7 to 1 10 2
40s	2 3 11
Manufactures	
Grey shirting, 35″×48 yds × 9 lb. (per piece)	14 13 9
Leopard cloth 43″×38 yds × 11¼ lb. (per lb)	1 13 6
Dhotis with grey 1/8″ Naki border 41″×10/2×2-15/16 lb. (per pair)	5 4 0
Coloured crepe shirting (per yd)	0 11 7
M 81 Bleached Mull 48″ in width and 20 yds (per piece)	13 12 0

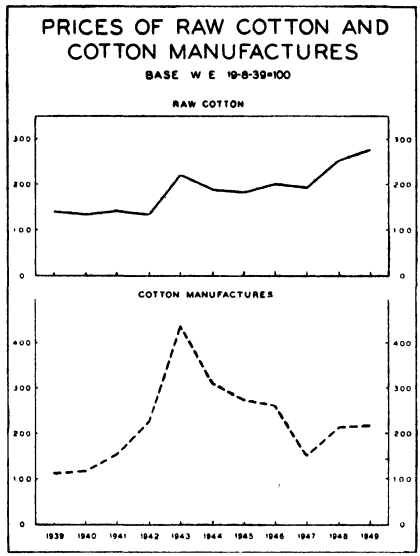


Fig. 81

CRAYONS AND PASTELS

Two types of crayons are produced in India—chalk crayons and marking crayons The former are used for writing on black-boards, and the latter for marking on cloth, cardboard, metal, jute goods, glass, and other materials Pastels are used for map drawing and pastel drawing The making of crayons and pastels is a cottage industry in many parts of India They are produced on a large scale in Delhi, Agra, and Kumbakonam (Madras)

Chalk Crayons—The raw materials required are gypsum, calcium carbonate, and pigments Washed and powdered gypsum, freed from earth and other associated impurities, is heated in iron cauldrons to remove water of hydration (loss in wt , 15%) The product is powdered and sieved (80—100 mesh), mixed with water containing gum and bleaching powder, and poured into greased brass moulds When set, the moulds are opened and the crayons removed to wire gauge trays and dried in the sun.

For coloured chalk crayons, the ground material is dry-mixed with neutral pigments,—red ochre, yellow ochre, Prussian blue (Chinese blue),

yellow chrome, ultramarine blue, etc,—and the mixed powder moulded as in the case of white chalk crayon

The equipment required is a brass mould in 2 sections, each section containing a number of semi-circular grooves When the 2 parts are brought into juxtaposition, a number of holes of circular cross section are formed

Crayons are packed in dealwood boxes holding 1 gross pieces One maund of gypsum gives 8 gross pieces of crayon

Marking Crayons—Marking crayons are made in many colours and in many grades of hardness Clay, plaster of Paris, pigments, and dyes are intimately mixed in mixing machines, pasted with water and the dough squirted through a machine The resulting sticks are dried, and one end sharpened

Pastels.—The chief raw material for pastels is china clay, which should be neither too smooth nor too gritty Clay of the required quality is available in Gwalior, Delhi, and Bikaner, in Bihar and Orissa, and in Madhya Pradesh. The clay is washed in tanks to free it from gritty materials and mica, mixed with neutral pigments, —red ochre, yellow ochre, ultramarine blue, etc, —and made into a dough with water It is kneaded in rollers and squirted into thin cylinders The cylinders are spread over stone slabs in lengths of two feet and dried They are cut into smaller lengths, one of the ends shaped to a point with a pencil knife, and packed in cardboard cartons

Figures for the production and imports of crayons and pastels are not available.

CRUCIBLES

A large variety of refractory materials—clay, graphite, alumina, asbestos, carborundum, chromite, lime, magnesite, zirconia, thoria, ceria, and others—is used in the manufacture of crucibles. The most important among the refractories is graphite, crucibles made of graphite which are extensively used in the metallurgical industry

55% of the world's graphite mined in 1913 was utilized for crucible manufacture The use of graphite for this purpose declined in later years when the steel manufacturing industry dispensed with the use of graphite crucibles. In 1933 only 18% of the mined graphite was used in crucible manufacture (Jones, W.R, 55). In recent years, graphite crucibles have once again come into prominence for melting non-ferrous metals and alloys. They are used in India for melting yellow metal and coinage alloys.

Graphite crucibles possess certain advantages over fireclay crucibles. They are non-porous and therefore do not absorb molten metals as fireclay crucibles do The crucibles have smooth walls and permit metals to flow easily Graphite minimizes oxidation of the charge and facilitates heat transfer Graphite crucibles do not crack due to sudden fluctuations in temperature The high thermal and electrical conductivities, the high melting point, and spalling resistance make graphite the material *par excellence* for the manufacture of melting receptacles

Raw materials—Graphite contains carbon, 70—99%, ash, 1—27%, volatile matter, small quantities Graphite required for crucible manufacture should contain at least 85% carbon and should be free from mica, pyrites, iron oxide, and other non-volatile impurities Mica is one of the most objectionable impurities as it fuses during use and causes pin holes Carbonates leave shrinkage cavities

Flaky graphite is used for making crucibles as it requires less bonding material than amorphous graphite for attaining the plasticity required for shaping The material is ground and graded to conform to specifications for particle size, toughness of flakes, burning rate, and packed volume. A grade of Madagascar graphite suitable for making crucibles has the following size-grading over 20 mesh, 7 8%; between 20 and 35 mesh, 65 7%, between 30 and 65 mesh, 24 9%, and passing 65 mesh, 1·6% The specifications for an accepted U S A grade are the material should pass through 20 mesh and be retained on 50 mesh, material passing through 28 mesh and retained on 35 mesh, 75%, carbon, 80—95%, bulk density, 100g occupy 129 c c after repeated shaking and jolting, sulphur, objectionable in more than traces (Johnstone, *Industr Chem*, 1947, **23**, 29) Ground Ceylon graphite satisfies the requirements, it is flaky, dense, and contains 93% carbons

Plastic fireclay is used as bonding material The clay should be highly plastic and possess good covering power; it should protect graphite against burning, it should adhere to graphite particles and impart sufficient green strength, it should be free from impurities which act as low melting fluxes, it should have adequate refractoriness so that the crucible may be resistant to slag action at the temperature of application, it should have a long vitrification range and should conform to the following specifications pore ratio, 1·1, modulus of rupture when fixed with an equal volume of sand, 325 lb /sq in, vitrification temperature, not higher than 1,150°, it should withstand firing at 1,400°; refractoriness, similar to

those of cones 31 and 33 (1,690° and 1,730°). A mixture of several clays is preferred to a single clay. The penetration of the crucible wall by clay and metal can be minimized by proportioning the ingredients so that the particle sizes lie within prescribed limits

The addition of sand and china clay increases refractoriness, excess of china clay, however, shortens the life of the crucible Free silica tends to decrease shrinkage during burning Grog is added to control shrinkage and porosity and to prevent premature cracking Carborundum may be added to improve thermal shock resistance

Manufacture.—The proportion of ingredients in the mix varies according to the purpose for which the crucible is required A composition usually employed contains. graphite, 40—50%; silicon carbide, 10—20%; grog, 0—5%, and fireclay, 30—40%. Larger proportions of graphites are used in making better grades of crucibles Water is added and the mix homogenized by treading, panning, and pugging The paste is aged or soured in a cool underground storage and repeatedly pugged to improved plasticity It may be de-aired by passing it through a double pug mill provided with a shredding device and vacuum chamber, this improves the plasticity and workability of the paste, prevents the formation of air blisters in crucibles and imparts toughness and resistance to abrasion, corrosion, and spalling

Crucibles are moulded by hand or are shaped on wheels and jiggers and jolleys They may also be pressed and cast. Crucibles of the more common sizes are made by pressing, a stiff mix is required for this process. Larger sizes are hand-moulded. A soft mix is required for jiggering, and articles made by this process are porous

The shaped articles are dried under controlled conditions. They are usually dried on racks in rooms heated to 80—100° by steam pipes or by radiant heat from kilns and ovens employed for burning the crucibles. After about 24 hours they are removed from the racks, sleeked or sponged over to give a smooth dense skin and thus the burning away of graphite during use is minimized. The crucibles are then backed in a reducing atmosphere, the final baking temperature depending on the type of fireclay employed They are arranged in saggars filled with coke dust and fired in stages. A properly baked crucible emits a clear metallic sound when struck. The crucibles are taken out of the kiln after cooling, given a coat of organic varnish, and stored in waterproof covers.

Sizes.—Graphite crucibles are available in a large number a standard sizes designated by Dixon numbers. Sizes 0 to 0000 vary in outer diameter from 1½ in. to 2⅜ in. and in outer height from 2 to 3 in. Sizes 1 to 20 have an external diameter varying from 3⅛—7¾ in. and outer height of 3⅜—10¼ in. The external diameter and height of size 400 is 19-11/16 in. and 24-5/6 in respectively Crucibles holding 75—80 lb are used for melting steel.

INDIAN INDUSTRY

India's requirements of graphite were wholly met by imports from Germany, U K, U.S A, and Japan before 1939. Crucible manufacture was undertaken in the country during the war and the industry has since made great progress The principal firms engaged in the manufacture are: The *Himalaya Potteries Ltd.*, Balawali; The *Patna State Graphite Co. Ltd*, Titilagarh, *Jhaveri & Co Ltd.*, Calcutta; The *Indian Crucible Works*, Rajahmundry, and Messrs *Alladin Virjee Nathani & Co. Ltd*, Bombay A few factories have been recently established at Rajahmundry and Mirzapur.

The graphite is obtained mainly from Ceylon Deposits of flaky graphite occur in three localities in India—Travancore, East Godavari, and Patna State. Their carbon contents are low, and the composition and structure show great variations Some work has been carried out on the processing of Indian graphites to render them suitable for crucible manufacture Processed graphite is now utilized in some Indian factories (Mazumdar, *J. sci. industr. Res*, 1948, **7B**, 187). The grades used are ordinary and medium lump varieties with c. 92% carbon. Chips containing less carbon and dust containing 70—75% carbon are occasionally utilized. Imports of graphite from Ceylon and subject to a duty of 36% *ad valorem* and imports from British colonies, to a duty of 24% *ad valorem*

Graphite is crushed with wooden mallets and hand operated stamps and ground in *chakkis*. Jaw crushers and disc pulverizers are occasionally employed The ground product is sieved and graded Fireclay grog, binders, carborundum, plasticizers, and deflocculants are sometimes mixed with ground graphite.

Crucibles are usually made by hand shaping. A wooden or machined cast iron mould and a plunger of the same material are employed. A known weight of the pasted mix is made into slugs by 'wedging', placed in the mould and rammed with a porcelain rammer. The plunger is rotated several times until the ring of the plunger reaches the neck of the mould. The plunger is swiftly rotated before withdrawing in

TABLE 1.—IMPORTS OF GRAPHITE CRUCIBLES FROM U K

	Qty. (cwt)	Value (Rs)
1934/35—1938/39 (av)	4,157	1,84,466
1939/40—1943/44 (av)	4,425	3,11,604
1944-45	9,482	7,77,175
1945-46	4,813	3,81,466
1946-47	5,661	5,88 365
1947-48	6,991	7,39,998
1948-49	9,898	11,07,640
1949-50	10,365	10,95,157

order to give a good finish to the shaped article

Baking is effected in potters' down-draught kilns, the final temperature being 900—1,000° The duration of firing from the drying stage to the finishing stage is about 24—30 hrs.

Crucibles of sizes up to 60 have been produced in India and possibilities for producing sizes up to 100 have been proved.

Graphite crucibles are subject to severe strains during use due to repeated heating to c 1,200° and rapid cooling. They are also required to carry considerable weights of charge The durability of crucibles is, therefore, a matter of vital importance for the user Imported crucibles are able to stand as many as 100 heats. The Indian products are inferior in this respect.

Indigenous crucibles have given reasonably good service in the cast iron foundry but have not proved so satisfactory in the brass and steel foundries They burst under load and frequently fail due to 'shot holing' The latter is probably caused by flux concentration at certain points and non-uniformity of texture. The failure of crucibles in brass foundries is due to the penetration of the metal right through the walls Inadequate attention to the selection of materials and to processing and finishing accounts for the inferior qualities of indigenous products.

Statistics relating to the production of graphite crucibles in India are not available. The production is small; the major part of the requirements is met by imports from the United Kingdom Table 1 gives the imports of graphite crucibles into India.

CUTLERY

The term cutlery was originally applied to include all sharp-edged cutting tools and appliances. During the past one century, the growth of the industry has been so prodigious and the number of edged and cutting tools has grown so large, that it has become necessary to restrict the term to a particular group of appliances Edged instruments and tools such as saws, chisels, and drills form a distinct group, and are now separated from cutlery Certain articles, e g, forks and spoons, though not sharp-edged instruments, have been brought into the field of cutlery The industry thus includes the manufacture of sharp-edged instruments such as knives, scissors, shears, clippers, razors, safety razor blades, daggers and swords, and articles of domestic use like forks and spoons.

The production of high class cutlery is predominantly a small scale industry, and it is stated that it cannot be completely mechanized In the production of middle-class cutlery there is wide scope for adopting mechanized processes, and in the production of cheap lines, there is no room for any but mass manufacture to meet competition.

English cutlery, particularly Sheffield cutlery, is world famous The total average number of workers employed in the Sheffield industry, excluding outworkers, was 12,661 in 1948 [*Times Rev Ind*, 1950, 4(41), 64] Germany was the biggest exporter of cutlery before the war Other producers are U S A , Japan, France, Sweden, and Czechoslovakia

The production of cutlery involves three main operations (1) forging of parts, (2) heat treatment, grinding, glazing and polishing, and (3) assembling and finishing All the operations are seldom undertaken in a single establishment. Usually the forging of blades is undertaken by a specialist firm, and the blades are sold to establishments who grind and polish the blades, assemble the parts, and produce the finished goods Grinding is sometimes undertaken by independent workers who buy blanks and sell ground and polished blades to assemblers.

Raw Material

Two types of cutlery steel are employed, the original type (C, 0 35; Cr, 13·35, Si, 0·2, Mn, 0 35; S, 0 03 max.; and P, 0·03% max), and the modified type (C, 0 7, Cr, 16 5, Si, 0 4, Mn, 0·45, S, 0 03 max , and P, 0·03% max.) Articles of cutlery made from these steels have greater intrinsic hardness, and retain the cutting edge longer than those from other steels. Both steels have a narrow carbon range. Forging becomes difficult when the carbon content is increased; hardness decreases if the carbon content is lowered. Chromium influences the pearlite structure; thus annealed 13%

TABLE 1.—HEAT TREATMENT OF CUTLERY STEELS
(Temperature range °F)

	Original type	Modified type
Forging	1,700–2,000	1,700–2,000
Softening for machining	1,400–1,450	1,400–1,450
Annealing for softness	1,575–1,675	1,625–1,675
Preheating	1,450–1,500	1,450–1,500
Hardening	1,775–1,850	1,825–1,925
Tempering	350–900	300–800

Cr steel containing 0·3% C is entirely pearlitic, i.e., it is structurally the same as a plain high carbon steel containing 0·9% C

For securing the requisite hardness and resilience, it is necessary to subject cutlery steels to heat treatment under controlled conditions Table 1 gives the temperature ranges for the various operations.

The stock is preheated and soaked for a considerable time in the softening range It is hardened by air cooling or by quenching in water or brine The higher the quenching temperature, the better is the stain resistance

Tempering is effected in a salt bath or oven. Hardened and tempered stainless steels have high tensile strengths up to 200,000 lb/sq in The properties of a hardened and tempered 0·3% C and 13% Cr stainless steel are B H N (Brinell hardness number), 175, ultimate strength, 99,950 lb./sq. in, tensile strength, 65,000 lb/sq in, elongation (in 2 in gauge length), 27%, and reduction in area, 58%

Stainless cutlery steels have high corrosion resistance and are not affected or stained by fruit and vegetable acids, and by lye or ammonia.

Table 2 gives the standard British and American compositions for cutlery steels.

Table 3 gives the composition of steel used by cutlery manufacturers in Sheffield.

High carbon steels are sometimes employed in cutlery manufacture They have the following composition: C, 0·55—0·75, Mn, 0·75 max., Si, 0·35; S, 0·04 max., and P, 0·04% max.

For forks and spoons, nickel silver (nickel brass) is generally used. English table cutlery is made from nickel silver of B S 790 grade, and most electro-plated nickel silver (E P N S) cuttery conforms to this specification

High grade silver-plated table-ware such as knives, forks, and spoons are made from nickel silver containing 18% nickel. Nickel silver has distinct advantages over other materials for table-ware cutlery: when the silver plate becomes worn, the spot is not noticeable since the colour of nickel silver matches that of silver, nickel silver does not work-harden as rapidly as other alloys and can be worked to a greater degree without anneal, it has a high tensile strength, hardness and good spring qualities which permit flexing without distortion; a high lustre can be given by buffing and the silver plate adheres readily with a minimum of preparation [*Industr. Canada*, 1950, **51** (3), 231].

High quality stainless steel cutlery is forged from round stock Inferior quality knives and forks are made by fabrication methods The stock is hot-rolled to the desired size and annealed Blanks are cut out and heat treated to give the required degree of hardness and resiliency They are then ground (wet grinding in the initial stages, and dry grinding for finishing), polished, and mounted in handles

A method has been recently developed for producing cutlery blanks from sheet steel by the application of heat and hydraulic pressure in one process to form the bolster and tang of a knife blade The blanks are produced to precise measurements and are suitable for machine grinding They are flat and, therefore, well adapted for direct mounting in plastic handles [*Times Rev Ind*, 1949, **3**(35), 64] Another development is the manufacture of 'frozen heat' cutlery Stainless steel knives, which do not need sharpening for at least 3 years, are made by what is called the frozen heat process by *Robeson Cutlery Co Inc*, U S.A. The process

TABLE 2.—COMPOSITION OF CUTLERY STEELS (%)

	British steels		American steels (AISI*)			
	EN56A	EN56D	414	416	440A	440C
C	0 12 max.	0 25–0·35	0·15 max	0·15 max	0·60–0 75	0 95 1 20
Si	1·0	1·0				
Mn	1·0	1 0			.	
Ni	1·0	1 0	1·25–2 5	..	..	.
Cr	12–14	12–14	11 5–13 5	12–14	16–18	16–18
S	0·05	0 05				..
P	0 05	0 05	..	..	..	..
Zr		..	..	0 06	..	.
Mo	..			0·06	0 75	.

*American Iron and Steel Institute

TABLE 3.—COMPOSITION OF SHEFFIELD CUTLERY STEELS*

	Specification	Type	Composition %*				
			C	Cr	Ni	Mn	Si
Sanderson Bros., and Newbould Ltd.	4379	Non-stain crucible Cutlery quality	0·28–0·35	12·75 13 5	0 45 0 55	..	
Jessop & Sons; and J. J Saville & Co	R2,	Medium C and 13% Cr steel;	2·0	13		.	.
	R–10	Austenitic 12/12 steel (supplied in softened condition)	0·12	12	12		0 5
Thomas Firth; and John Brown	1162	Firth F. H. stainless steel	0·25	12–14			
Firth Vickers Stainless Steel Ltd.	FH		0·3	13	..	0·2	0 2
	FG	..	0·25	13·5		0·25	0 25
	DDQ	Staybrite	0·1	12·5	12·5	0·3	0 3

*S and P always below 0 05% each

involves a superheat treatment followed by quick freezing. Knife blades are heated to a temperature below the melting point, quenched in oil at 140°F and placed in a chamber at sub-zero temperature. After the freezing period the blades are stress relieved, cooled, and tempered (*McGraw Hill Digest*, 1949, Dec 24)

INDIAN INDUSTRY

Cutlery is produced in India, on a cottage industry basis, in many villages and towns throughout the country. The products of certain regions—Aligarh, Meerut, and Moradabad in U.P. and Kanchannagar in West Bengal—enjoy considerable reputation. Data relating to the number of units, workers employed, and volume of production are not available. In recent years, large scale production has been established, particularly in Bombay and Calcutta.

Nizamabad, Wazirabad, and Bhera in Punjab are reputed centres of cutlery manufacture The industry has flourished in these places since the days of Moghul and Sikh supremacy A few factories, some of them equipped with power-driven plants, have been established in Amritsar for the manufacture of table cutlery and razor blades (Saini, *Manufacture of Cutlery and Surgical Instruments in the Punjab*, 1936, 5).

Cutlery manufacture in West Bengal is concentrated in Calcutta, Kanchannagar (Burdwan dt.), Ghoom (Darjeeling dt.), and Shahaspur (Bankura dt.). Several small and medium sized factories have been recently started in Calcutta. Some of them are equipped with modern machinery for grinding, drilling, polishing, and other operations (Ghose, *Bull. Dep Industr., Bengal*, No. 95, 1940). The knives and scissors made in Kanchannagar and Shahaspur are well known. The articles produced in these centres are distributed from Calcutta Ghoom is noted for its *kukris*

Bombay, Jamnagar, Cutch, Bhuj, Shirohi, and a few areas in Kathiawar are important centres for cutlery in Bombay State

Cutlery is manufactured at Aligarh, Meerut, Allahabad, Hardoi, Qaimganj (Farrukhabad) and Shahjahanpur in U.P. The *Dayalbagh Industries* in Agra have been producing a large variety of cutlery on a factory scale. The scissors manufactured in Meerut and neighbouring villages and in Aligarh are well known The industry reached the height of its prosperity during World War I when nearly 2,000 workers were employed for manufacturing scissors required in the Army clothing factories and in hospitals. There were 200 furnaces, each with an average capacity of 36 scissors per day. There are, at present, nearly 200 furnaces at Meerut, and 100 furnaces in the neighbouring villages of Ruhaser, Pohally, Lohia, etc. The present manufacturing capacity of Meerut is nearly 1,000 dozens of scissors of different qualities and sizes per day. Spoons and forks, knives and *sarotas* are produced at Moradabad, Meerut, Aligarh, Etah, Farrukhabad, Rampur, Shahjahanpur, Kanauj, Hardoi, and Kairana (Muzaffarnagar).

The manufacture of safety razor blades has been undertaken in two factories one located at Ujjain and the other at Bombay. One of them is

capable of turning out 80,000 blades per day of 8 hrs. The present output is reported to be 2½ lakh blades per month.

Scissors are produced on a small scale in Travancore

Raw Materials

The raw material generally employed is low-carbon shear steel imported from England, Germany, and Belgium. It is an inferior grade of steel sold in the form of bars. For the manufacture of high class knives and razors, old and worn out files purchased from railway workshops are utilized by Indian manufacturers particularly in Punjab, Bengal, and Bombay The large knives carried by Gurkha soldiers (*kukris*) are manufactured from old files at Ghoom (Ghose, op cit) Broken clock springs are also used. Hoof iron, approximating in composition to wrought iron, is employed for the cheaper grades of cutlery A small proportion of steel consumed in cutlery factories is supplied by the *Tata Iron and Steel Co* During World War II, the industry depended almost entirely upon Tata steel and scrap steel

Table 4 gives the composition of cutlery steels produced by the *Tata Iron and Steel Co*

Imported steels of charcoal carbon quality are used in the manufacture of safety razor blades They have the following approximate composition C, 1 20—1·30; Cr, 0·2—0 3, Mn, 0 25—0 35, S, 0 25, P, 0·25, and Si, 0 15—0·25%

Many items of cutlery are provided with handles or hafts. Shisham wood (*Dalbergia sissoo*) buffalo horns, ivory, tortoise shell, xylonite, and mother of pearl are used for handles Wood and horn are available locally; other materials are usually imported. Stag horn, which is at present exported to U K., is an excellent material for making handles Stag horn handles appear to be popular in U S A and Canada on account of their good finish and ability to withstand climatic variations

Brass was used for making spoons and forks in pre-war years. They were nickelplated for use. Nickel silver containing 5% or less nickel, was also being used At present nickel silver containing 10—25% Ni is used for spoons and forks

TABLE 4 – COMPOSITION OF TATA CUTLERY STEELS (%)

	Plain carbon	High carbon	Low carbon
C	0 65-0 75 or 0 55-0 65	0 25-0 45	0 15-0 25
Mn	0 4 max	1 0 max.	1·0 max
Si	0 35	1·0 ,,	1 0 ,,
Cr		12	12
Ni	.	1 0 max	1 0 max
S	0 04 max	0·045 ,,	0 045 ,,
P	0·04 ,,	0 045 ,,	0 045 ,,

Manufacture

The principal operations involved in cutlery manufacture are. forging and hammering, annealing, shaping and filing, hardening and tempering, grinding, polishing and finishing. These operations are carried out in most centres by manual labour A few factories in Punjab, West Bengal, and Bombay are equipped with power-driven lathes and machinery for grinding, shaping, milling, drilling, and polishing

The operations involved in the manufacture of knife blades, starting with a steel bar, are the following The steel bar is heated in a clay furnace to the requisite temperature, beaten to shape and cut to size Two experienced workers, working 10 hours a day, can turn out 125—300 blades according to size and quality The blade is annealed by heating to red heat in a low fire and cooling slowly The annealed blade is straightened and filed to the proper form and shape The blade is then hardened by heating to dull red heat in a charcoal fire and dipping it in vegetable oil or brine It is tempered by reheating and slow cooling. The blade is ground on rough and fine emery wheels, finished, and polished on leather and cloth wheels (Saini, op cit , 9).

For the production of scissors, a piece of iron is hammered out and welded to one end of a piece of steel The other end of the iron is drawn out and bent round to form the handle or bow. The blades and handles are filed to shape, sharpened on whet-stones, and polished. Polished blades of the same sizes are riveted together to form a pair of scissors Scissors are also made by casting.

Spoons and Forks.—For the manufacture of spoons and forks, nickel silver in ingot form is cold rolled into sheets of the required thickness with frequent annealing at c. 700°. The steel is pickled in 10% sulphuric acid containing sodium dichromate (1 lb. sodium dichromate/gallon of 10% sulphuric acid). Spoons are made from pickled steel either by drop stamping or pressing. In the former process the sheet should be of the same thickness as that of the

centre of the stale The sheet is cut into strips of the desired width, cross rolled at each end on open ended steel rolls to the thickness necessary for the spoon bowl and stale end. Strips for forks are also cross rolled at the stale end and prong end Blanks are cut from the strip, one at a time, in a blanking press; in the case of forks the prongs are pierced leaving a projecting bar across The blanks are then drop-stamped The stales are stamped first. Spoon bowls are dished in steel dies and bowled in a steel punch in a zinc bed, while forks are pronged and bent in one operation

In the pressing method, the sheet is rolled to a gauge corresponding to the thinnest portion of the stale. The sheet is then sheared to the required width and fed to the blanking press at each stroke of which two blanks are formed. The middle portion of the stale is thickened by slightly reducing its width in a friction press at about 40 tons/sq in pressure The blanks for spoons are rolled in two stages to the correct gauge and width of the bowl in rocker rolls An intermediate annealing is given during this operation but spoon blanks after final rolling are not generally annealed so that they may remain hard and springy The bowls are next clipped to shape in a power press followed by shaping in a friction press. The stales are pressed first, followed by the dishing and bowling operations In the case of forks, the stale is pressed first followed by the pronging operation which also bends the prongs to shape

Spoons and forks are then polished and buffed, cleaned, and electroplated Articles made from 10—15% nickel silver are usually nickel plated, those made from 20—25% nickel silver do not need plating

Razor blades—Razor blades are made from steel strips 0·881 in wide and 0·005 in or 0 006 in. thick In the Swedish method employed in one of the Indian factories, a conveyor band carries individual blades on pins for processing. In the American method the continuous steel strip is processed and finished blades are broken from coils in the final operation

Varieties of products—The articles manufactured in India include a variety of knives and scissors, razors, nail clippers, *kukris*, sickles, etc. Swords, daggers and *kirpans*, and a large assortment of knives are Punjab's specialities In Bengal, pruning knives for tea gardens are manufactured on a large scale Standarized raw materials are not insisted upon by producers. and the products, though well finished and polished, are inadequately hardened and tempered.

Production and Trade

In the absence of statistical returns, it is not possible to estimate with any accuracy the volume of production of cutlery articles in India, which is by no means insignificant It was estimated that articles to the value of Rs 2·65 lakhs were produced annually in Punjab before World War II (Saini, op cit, 6) The production increased considerably during the war The demand by the Defence Department in 1943 was 5,800,000 pieces valued at Rs 96 lakhs The total production may be estimated to be twice this quantity The demand in 1944 was only 30% of that in 1943 (Thomas, *Rep Develop. Industr. War Supplies*, 1944, 75). The average annual production of scissors and razors in U P is estimated at Rs 9 lakhs, that of spoons, forks, knives, and *sarotas*, at Rs 60 lakhs.

Prior to World War I, India imported annually cutlery valued at about Rs 22 lakhs (average for the years 1909/10—1913/14). Germany was the largest exporter, U K. and U S A coming next The imports declined during the war, but were revived soon after, the value of imports in 1920-21 was Rs 55 lakhs In 1930-31 and subsequent years, the imports fell and there has been little improvement since then

Table 5 gives the imports of cutlery into India.

Germany and United Kingdom were the principal suppliers before World War II The major part of the requirements of cheap cutlery came from Germany. About 60% of the total imports during the decade preceding the war was from that country. High grade cutlery was obtained mostly from U K., which accounted for nearly one-third of the total imports. U S A supplied high grade cutlery before and during World War I, but the imports declined after the war Japan had no place in the Indian trade before 1914 During the war, when imports from Europe stopped, Japan stepped in and established a market for cutlery goods in India Table 6 gives the imports of cutlery into India from U K.

The present import duty on cutlery is 37½% *ad valorem* with a preferential rate of 10% on cutlery manufactured in Burma Imports of gold- and silver-plated cutlery are subject to a revenue duty of 75% *ad valorem*

Future prospects—The indigenous production falls far short of the demand of the internal market. The quality of scissors, knives, and other items of cutlery manufactured in certain centres is satisfactory. and these products can stand competition with imported products There are possibilities for expanding the industry and

TABLE 5.—IMPORTS OF CUTLERY

	Pruning knives	Safety razors		Blades		Other components of safety razors	Other razors*		Other cutlery
	Value (Rs.)	Qty. (Doz)	Value (Rs.)	Qty. (Gross)	Value (Rs.)	Value (Rs.)	Qty. (Doz)	Value (Rs.)	Value (Rs)
1934/35—1938/39 (av.)	1,72,838	..	.	..	..		.	.	26,56,949
1939/40—1943/44 (av)	1,58,002	56,530	1,77,659	2,72,567	8,64,025	297	5,076	40,046	3,97,173
1944–45	1,39,579	350	3,998	3,43,977	19,23,532	2,103	..	..	3,96,987
1945–46	1,84,567	97,661	6,35,453	5,53,249	28,11,931	..	153	6,967	9,03,872
1946–47	2,89,024	244,773	22,44,741	9,35,395	43,10,822	6,929	8,376	1,34,557	13,35,454
1947–48	2,02,672	97,965	8,52,714	1,723,879	93,94,433	600	1,833	45,515	8,48,815
1948–49	3,02,931	36,910	3,95,855	282,164	32,92,764	..	1,188	64,890	2,38,054
1949–50	3,48,383	481,784	31,57,847	89,799	7,24,465	904	751	32,205	9,82,486

*Includes scissors (grape, lamp, nail, button hole, clipping), shears, hair cutters and clippers but does not include spoons and forks for which separate figures are not available

TABLE 6 —IMPORTS OF CUTLERY FROM U K *

		Qty.					Value (£)				
		1942	1943	1944	1945	1946	1942	1943	1944	1945	1946
Knives with folding blades	(doz)	6,147	1,646	3,771	21,100	43,897	2,682	656	1,539	9,987	18,734
Table cutlery including dessert carvers and bread knives	(doz.)		..	..	..	28,593	..	..	..	..	35,126
Other knives	(doz.)	12,963	3,897	24,926	35,278	6,838	10,134	5,511	22,557	36,781	11,472
Scissors (Other than secateurs, but including tailor's shears) and blades and blanks therefor made wholly or partly of steel or iron	(doz pairs)	1,378		77	6,380	..	749	..	209	3,022	..
Safety razors complete	(doz.)	17,606	.	42	30.469	228,127	8,304	..	27	17,010	158,237
Safety razor blades	(gross.)	71 760	14,074	15,138	114,746	159,572	28,418	5,597	6,478	60,963	81,093
Hair clippers (other than electrically operated)	(nos)	6,482			7,617	50,936	1,685			2,131	15,834
Other cutlery ware not specified		..	..	..	.	.	661	309	1,703	4,129	4,500
Spoons and forks	(doz.)	11,422	..	9,575	51,499	45,829	3,792		2,205	12,245	23,062

*Tr. U. K.

provided adequate attention is paid to the selection of raw materials, training of labour, and introduction and time- and labour-saving machinery, its development is assured.

CYCLES

The Indian bicycle manufacturing industry is still in its infancy. It was started in 1938 and production commenced towards the end of 1941. With a large unsatisfied internal market, and the possibility of a considerable increase in the use of bicycles in the country, the industry has immense scope for expansion and development.

The *India Cycle Mfg. Co. Ltd*, Calcutta was formed in 1938, and in the following year The *Hindustan Bicycle Manufacturing and Industrial Corporation Ltd*, Patna and *Hind Cycles Ltd*, Bombay were registered The outbreak of the war soon after gave a fillip to the industry. There was a heavy curtailment in imports, and Indian requirements had to be met by indigenous production The *Hind Cycles Ltd.* commenced production in November 1941 and the *Hindustan Bicycles Mfg. and Industrial Corporation Ltd.*, in 1942. The output of the two factories was 21,741 bicyles in 1942, of which the share of *Hind Cycles* was 17,641 (Thomas, *Rep Develop. Industr. War Supplies*, 1944, 72) The *Indian Cycle Mfg Co. Ltd.*, being unable to import plant and equipment necessary for the production of complete bicycles, confined its activities to the manufacture of cycle parts and accessories.

The *Hind Cycles Ltd* is the largest concern in the field with an invested capital of Rs. 50 lakhs, and a rated capacity of 60,000 bicycles per year It is proposed to produce 70,000 bicycles in 1950, and 84,000 in 1951 The *Hindustan Bicycle Mfg. and Industrial Corporation Ltd*, Patna, with an invested capital of Rs 12½ lakhs, has a rated capacity of 35,000 bicycles per year. The number of workers employed in the two concerns is c 730 and 525 respectively. The *India Cycle Mfg Co Ltd.*, with a subscribed capital of Rs. 3½ lakhs, has a rated capacity of Rs. 7 lakhs worth of cycle parts and accessories.

Besides these three factories, there are more than 150 workshops engaged in the production of cycle parts and accessories, spread over Punjab and West Bengal, mainly at Ludhiana, Jullundur, Delhi, and Calcutta. 50,000 workers are reported to be employed in this industry in Punjab (Indian Tariff Bd, *Rep. Continuance of Protection to the Bicycle Industry*, 1949, 4). A large part of the country's requirements during World War II was supplied by these units. Agreement has been reached between the bicycle factories and these workshops, according to which the latter would manufacture and supply components under the technical supervision of, the factories and in accordance with their specifications.

Most of the components required for assembling the bicycle are manufactured by the three factories in India. These include frames, handle bars, mudguards, B.B. spindles, chain wheels and crank shafts, forks, wheel rims pedals, gear cases, chain guard and covers, hub grinders, B B. cups and lock rings, front and rear hubs, saddles, lever brakes, expander bolts, head lock nuts, cotter pins, etc Accessories such as lamps, carriers and stands, bells, pumps, tool bags, and reflectors are also manufactured.

Free-wheels, chains, and ball-bearings are not, at present, produced in India, they are imported almost entirely from U K The manufacture of these items is to be shortly undertaken by the *Indo-Belga Engineering Company, Ltd.*, Ahmedabad The new factory has a rated capacity of 500 free-wheels and 1000 chains per day of 8 hours (Information from D.G.I. & S). The *Hindustan Motors Ltd*, Bombay have completed plans to manufacture free-wheels. The *National Bearing Co.*, Jaipur have put on the market steel balls of all the 3 sizes required in a bicycle.

Spokes and nipples are manufactured in India, but in insufficient numbers. A part of the requirements has to be imported. The present estimated annual requirements (in numbers) of the parts are. free-wheels, 1,20,000, chains, 1,20,000, steel balls, 2,00,000, spokes and nipples. 75,000 (Information from D G I & S.)

Raw Materials

The basic raw material for bicycle manufacture is steel, the gross quantity required for one bicycle, including saddle parts, being c. 47 lb. A variety of steels are specified for the different parts, the main types being cold rolled bright sheets and strips, M.S. bright bars, and M.S. wires. With the exception of cold rolled bright strips, other steels required are produced in the country.

Sheets and strips are made from low carbon steels of uniform thickness and width, in gauges of 10 to 24 They are required for making frame parts (front, upper, lower, and rear pipes), fork neck, seat pillar, handle bar, handle bar neck, chain stay, seat stay, pedal pipe, wheel rims, and saddle bridge distance pipe The Indian factories fabricate these parts from black steel plates produced by the *Tata Iron and Steel Co. Ltd.* The plates are deep drawn, double pickl-

ed, and hot rolled with cold passes. The plates are available in 2 sizes — 6 ft.×3 ft. or 4 ft.×8 ft. — and are sheared to strips of proper width. Electrically welded steel tubes required for frame work are imported from U.K. and U.S.A.

Sheet steels of various gauges are required for the manufacture of mudguards, chain wheels, race and axle cups, dust covers, fork arms, hub body pipes and spoke rings, saddle bridges, brake lifting arms, spanner plates, lugs, connecting links, brackets, washers, screw nuts, brake shoes, clips, sleeves, bridges, etc. Steel sheets for these purposes are obtained from indigenous sources.

Free cutting M.S. bright bars required for automatic and semi-automatic machines used in bicycle factories are produced in India. They are obtained in round, square, and hexagonal sections, and used in making B.B. spindles, hub spindles, pedal spindles, axle cases, crank arms, bolts, nuts and screws, cotter pins, brake arms, brake arm brackets, connecting rods, adjusters, etc. En-32 case hardening, and non-case hardening steels conforming to American SAE.1112, and pickled to give a smooth surface and perfect roundness, are supplied by the *Tata Iron and Steel Co. Ltd.*, in sizes ½ in.—1⅝ in. Sizes below ½ in. are supplied by the *Indian Steel and Wire Products Ltd.*, Tatanagar.

Low carbon, cold finished steel wires and other types of special steel wires, e.g., spring steel wire, are supplied by the *Indian Steel and Wire Products Ltd.*, in sizes 0·135 in. to 0·349 in. with a tolerance of 0·002 in. The wires are required for rivets, brake connecting and adjusting rods, etc. Brass wires, 3/16 in. diam., are used for making nipples.

Most of the components of a cycle have to go through 5 or 6 different operations, each requiring a die or a tool. A continuous mass production of all these components requires 1000—1,200 dies. A part of the requirements for die and high-speed tool steel is met by supplies from the *Tata Iron & Steel Co. Ltd.* and the *Mysore Iron and Steel Co., Bhadravati*; the major part is imported.

The imports of raw materials in 1949 were: cold drawn bright strips, 810 tons; free cutting bright bar, 817 tons; steel strips, 250 tons; steel tubes (welded), 396 tons; and steel tubes (solid drawn), 60 tons (Information from D.G.I. & S.).

Other materials used in the production of bicycles are rubber parts—tubes, tyres, handle grips, pedal rubbers, brake rubber—and minor items of consumable stores. All the rubber parts required are produced in the country. About 75,50,000 tubes and tyres were produced in 1947, 71,60,000 in 1948, and 77,40,111 in 1949. Imports of these items into India are insignificant though in the pre-war period large numbers of tyres and tubes were obtained from foreign countries, particularly U.K. The consumable stores required include nickel anodes, bronze, wires, colouring, brazing and electro-chemical materials, emery powder, leather, etc. Most of these are available in the country.

Manufacture

A bicycle consists of about 200 components grouped into fifteen sub-assemblies, and the manufacture includes about a thousand operations. Production is organized under a number of sections such as pipe section, press section, welding section, machining section, lock and smith section, heat treatment section, tool section, finishing, plating and painting section, and assembly section. The operations are automatic or semi-automatic.

For the fabrication of pipes required for the frame work, fork neck, seat pillar, handle bar, handle bar neck, chain stay, seat stay, etc., Tata plates (6 ft.×3 ft., or 4 ft.×8 ft.) are sheared to

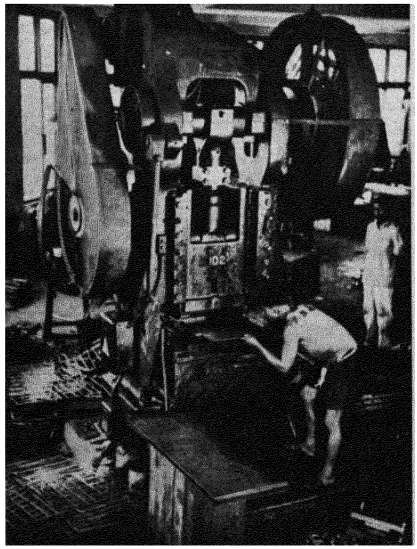


Fig. 82.—Blanking of fork blades for cycles

the required width, welded together to make a long strip, and drawn on the pipe drawing machine.

The rim is made in a rim rolling machine. The rolled strip which is obtained in the form of coils is cut, and the individual rims are sized, cut if necessary, and the ends ground in a rim end grinding machine. The rims are then butt welded and finally gas welded. The welded product is ground again and flattened in a stabilizing machine. Mudguards are also made in the same machine with different sets of rolls, and cut into the rear and front pieces.

Cranks, pedal parts, B.B. axles, cones, frame fittings, etc., are made from bar stock by hot forging. Blanks are heated and forged on the pneumatic hammer to proper sizes and the edges trimmed. They are then finished in the machine shop. Bar stock is used also for making bolts, nuts, screws, brake parts, etc.

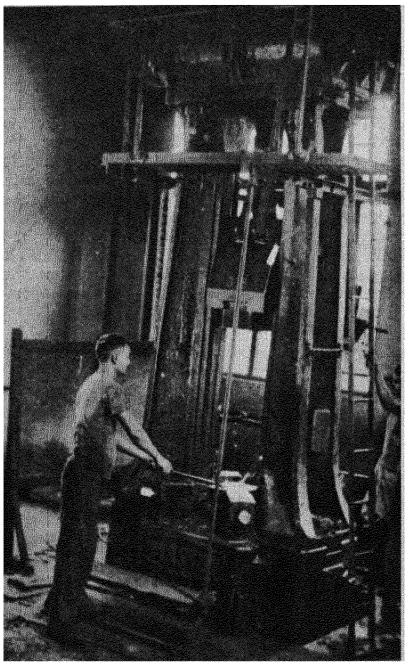


Fig. 83.—Drop stamping of cycle cranks

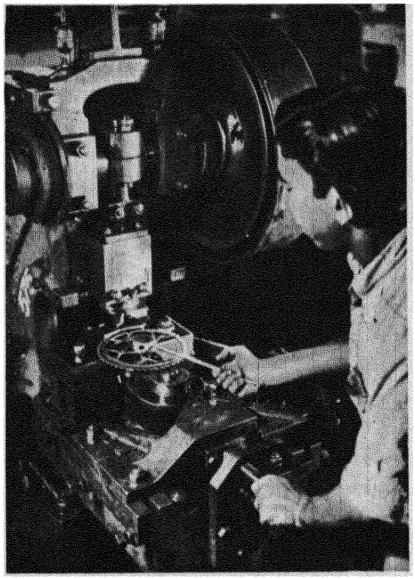


Fig. 84.—Cutting of cycle chain wheels

In the press section, equipped with power presses (10—75 tons), the components made from sheet metal are subjected to the following operations: punching, drawing, trimming, and drilling.

The component parts of the frames, fork, handle bars, etc., are fitted, joined by liquid brazing which ensures perfect safety as regards joints, and rough ground. A pipe bending machine is employed for making handle bars and other bent parts.

All pipes, rods, and cylindrical parts of diam. ¼ in.—5 in. are ground in a centreless grinding machine to exact dimensions. Bearing parts are case-hardened in cyanide bath at 1,400°F. and quenched in water. All brazed parts, such as frames, forks, are cleaned by sand blasting. Some parts are annealed.

All parts except frames, mudguards, and forks are electroplated. Handlebars, rims, chain wheels, crank arms, bells, etc., are pickled in acid

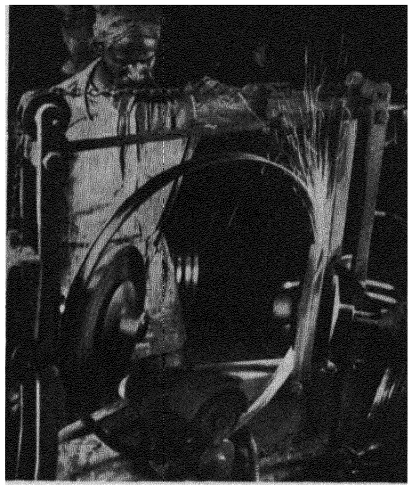


Fig. 85.—Polishing of cycle rims

and nickel plated; some parts are given chromium coating. Spokes, nipples, washers, and other small components are barrel plated. Other parts, such as frames, forks, mudguards, etc., are pickled, painted, and stove-enamelled, lined and printed by transfers. Some parts, such as frames, forks, and mudguards, are bonderized before stove-enamelling. This treatment, which consists of heating the part in zinc phosphate solution after pickling, imparts anti-rust properties.

The finished products are issued for wheel and other sub-assemblies, and the sub-assemblies are assembled into complete bicycles. They are inspected and despatched.

Types.—The bicycles produced in India are mainly roadsters. Lady's, racing, and boy's models are also made. Tandem and carrier bicycles are not manufactured.

The D.G.I. & S. have drawn up the provisional specification No. G/Misc./889 (1949) for indigenous cycles. The specification lays down standards for (1) sizes of tubes used in the frame, seat tube, forks, handle bar, etc.; (2) crank bar; (3) chain wheel; (4) chain; (5) hubs; (6) axle and axle cones; (7) free wheels; (8) pedals; (9) brake rods; (10) mudguards; (11) spokes; (12) wheel rims; (13) saddle main springs; and (14) saddles. Also, the

TABLE 1.—IMPORTS OF BICYCLES

	Bicycles		Parts and accessories (lakh Rs.)
	Nos. (1,000 s)	Value (lakh Rs.)	
1929/30—1933/34 (av.)	81	28·8	56·3
1934/35—1938/39 (av.)	142	44·0	63·1
1939/40—1943/44 (av.)	48	22·0	28·1
1944–45	37	25·2	29·4
1945–46	76	54·8	54·0
1946–47	213	180·9	97·2
1947–48	262	250·3	194·8
1948–49	264	247·6	150·9
1949–50	268	251·9	159·2

chemical composition of the materials used and the physical tests such as tensile strength, wrapping test, bend test, and the heat treatment to be given are specified.

Production and Trade

The production of complete bicycles (including spare parts and accessories expressed in terms of complete bicycles) were: 50,650 in 1946; 48,827 in 1947; 64,740 in 1948, and 87,922 in 1949. During the first ten months of 1950, 80,610 complete cycles were produced. The annual output of bicycle parts and accessories from the workshops in Punjab is reported to be worth about Rs. 60 lakhs (Indian Tariff Bd, loc. cit.).

Imports.—Till 1939, all the bicycles required in the country were obtained by import. Table 1 gives the number and value of bicycles, and the value of parts and accessories, annually imported into India during the period 1929—50.

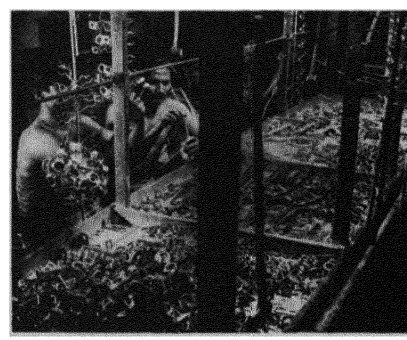


Fig. 86.—Loading cycle parts for electroplating

TABLE 2.—IMPORTS OF BICYCLES AND PARTS FROM U. K.*

	Qty.					Value (£)				
	1942	1943	1944	1945	1946	1942	1943	1944	1945	1946
Cycles (nos.)	15,943	27,252	32,740	64,751	209,877	63,490	127,039	152,688	304,281	1,200,768
Bells (nos)	12,902	1,080	3,268	30,760	163,696	971	55	152	1,926	11,639
Electric dynamo lighting sets (nos)	1,503	7,390	6,449	10,930	22,014	776	3,610	3,275	5,746	14,527
Electric lamps adapted for use on cycles (nos.)	787	264	500	4,200	71,927	103	65	60	369	6,031
Frames and frame tubes (cwt)	2,131	3,648	4,204	8,324	4,441	20,450	39,445	42,140	69,404	60,479
Free wheels† (cwt.)			..	.	1,602	..	..		.	36,528
Handle bars ,,	409	676	1,136	1,130	622	3,926	8,383	14,155	10,328	6,344
Inflators† ,,	.	.	.	.	2,059	.	..	..	..	62,180
Saddles (nos)	11,360	20,340	24,239	29,545	49,426	4,306	8,294	9,986	13,394	22,254
Wheels and parts thereof, with or without tyres (cwt.)	2,856	2,691	3,786	3.76'	5,300	14,152	14,434	31,284	41,281	76,363
Other parts	4,025	3,115	5,276	8,818	16,676	43,401	42,503	60,625	108,122	234,365

Tr. U.K. †Not shown separately prior to 1946

TABLE 3.—IMPORTS OF CYCLE TYRES AND TUBES

	Tubes		Tyres	
	Qty (No)	Value (Rs.)	Qty. (No)	Value (Rs.)
1934/35—1938/39 (av.)	1,882,248	8,85,290	1,374,392	16,96,377
1939/40—1943/44 (av.)	310,271	173,454	322,220	4,55,119
1944-45	14,938	15,926	39,146	84,110
1945-46	3,425	6,975	3,133	15,628
1946-47	2,228	3,965	3,446	17,404
1947-48	2,188	5,808	1,533	9,449
1948-49	5,872	12,490	8,823	23,554
1949-50	19,415	30,077	26,357	1,12,3

Before World War II, bicycles were imported mainly from U.K., Japan, and Germany In the quinquennium ending 1938-39, U.K. supplied 93·2% of the total imports of bicycles and 58·6% of parts and accessories. The share of Japan during the same period was: bicycles, 6·1%, and parts and accessories, 23%. The imports have increased considerably since the war. The share of the United Kingdom in imports during the years 1946-47, 1947-48, 1948-49, and 1949-50 were 95, 76, 89, and 84% respectively.

Table 2 gives imports of bicycles and parts and accessories into India from U K.

The imports from U.K have increased considerably in recent years 299,723, 207,332, and 350,776 complete bicycles valued at £2,003,991, £ 1,368,169, and £ 2,276,777 were imported during 1947, 1948, and 1949 respectively. The corresponding values of parts and accessories imported during the 3 years were £ 574,411, £ 513,884, and £757,364.

Table 3 gives the imports of rubber tyres and tubes during the period 1934-50.

Prior to April 2 1949, imports of bicycles and cycle parts and accessories were subject to a protective duty of 24% *ad valorem*, if of British manufacture and 36% *ad valorem*, if of non-British manufacture The rates have since been revised, and the corresponding increased rates are 60% and 70% respectively.

The demand for bicycles in the Indian Union has been estimated at 375,000 in 1950-51 and 400,000 in 1951-52. The fair selling price of Indian bicycles is estimated at Rs. 129 in 1950, and Rs. 127 in 1951. The landed cost of a standard gent's bicycle, 24 in frame, without accessories (*Phillips Model A.G.24*) is Rs. 106-9-3 (Indian Tariff Bd, *Rep.*, 8, 14).