Rural Water Supply and Sanitation

THE WILEY FARM SERIES

EDITORS

A. K. GETMAN

Assistant Commissioner for Vocational Education,
New York State

E. R. EASTMAN

President and Editor, American Agriculturist

VEGETABLE PRODUCTION AND MARKETING. By Paul Work.

AN INTRODUCTION TO BREEDING FARM ANIMALS. By L. M. Winters.

FARM MANAGEMENT AND MARKETING. By V. B. Hart, M. C. Bond, and L. C. Cunningham.

PERMANENT AGRICULTURE. By Winfield Scott and J. B. Paul.

ELECTRICITY IN THE HOME AND ON THE FARM. By F. B. Wright. Second Edition.

GROWING TREE AND SMALL FRUITS. By H. B. Knapp and E. C. Auchter. Second Edition.

DAIRY CATTLE. By W. W. Yapp and W. B. Nevens. Third Edition.

FARM SOILS: THEIR MANAGEMENT AND FERTILIZATION. By E. L. Worthen. Fourth Edition.

RURAL WATER SUPPLY AND SANITATION. By F. B. Wright.

A WORKBOOK FOR STUDENTS IN FIELD CROPS. By W. A. Broyles.

CROP MANAGEMENT AND SOIL CONSERVATION. By J. F. Cox and L. E. Jackson. Second Edition.

THE YOUNG MAN IN FARMING. By A. K. Getman and P. W. Chapman.

PRODUCING FARM LIVESTOCK. By J. L. Edmonds, W. G. Kammlade, W. B. Nevens, R. R. Snapp, and W. E. Carroll.

WORKBOOK IN PRODUCING FARM LIVESTOCK. By J. L. Edmonds, W. G. Kammlade, W. B. Nevens, R. R. Snapp, and W. E. Carroll.

CORN AND CORN GROWING. By H. A. Wallace and E. N. Bressman. Fifth Edition (*in preparation*).

FARM MACHINERY. By A. A. Stone. Third Edition.

PRACTICAL POULTRY MANAGEMENT. By J. E. Rice and H. E. Botsford. Fifth Edition.

ORCHARD AND SMALL FRUIT CULTURE. By E. C. Auchter and H. B. Knapp. Third Edition.

Rural Water Supply and Sanitation

BY

FORREST B. WRIGHT, Ph.D.

Professor of Agricultural Engineering,
New York State College of Agriculture,
Cornell University, Ithaca, New York

NEW YORK
JOHN WILEY & SONS, Inc.
London: CHAPMAN & HALL, Limited

FOURTH PRINTING OCTOBER, 1950

Printed in the U. S. A.

DEDICATED

to the many housewives and farmers who have had to carry in a bucket all the water they used

PREFACE

This book is written for those who wish to gain a practical knowledge of water supply, sewage disposal, plumbing, and sanitation for rural homes and farms. Although the book is designed with the needs of the school classroom in mind, the subject matter should be equally useful to the rural home owner and the farmer. The book includes instruction on the more common jobs connected with water supply, sewage disposal, and sanitation, and supplements these jobs with a well-rounded discussion of the related subject matter. It has been the aim of the author to present the subject matter in such a way that one who masters the contents of the book should be able to take the fullest advantage of the possible water sources provided by nature, should be able to plan and construct a safe, convenient, and sanitary sewage disposal system, and should be able to service and keep in repair his plumbing and sewage-disposal systems at a minimum expense.

The book is divided into two parts. The first part consists of a series of practical jobs arranged more or less in order of difficulty, starting with the simpler ones. The second part consists of seven chapters of subject matter related to water supply, sewage disposal, and sanitation. At the beginning of the jobs in the first part of the book are references to the related subject matter in the second part. These references should be read carefully before the jobs are started.

The author gratefully acknowledges the very valuable suggestions given by the following members of the Department of Agricultural Engineering at Cornell University in the preparation of this book: Professors B. B. Robb, L. M. Roehl, J. C. McCurdy, C. N. Turner, and Mr. Harold Clough. Special acknowledgment is due Professor B. B. Robb, and Mr. Roy E.

Halverson, heating and plumbing engineer of Ithaca, N. Y., for their careful review of the manuscript.

The author is indebted also to the following persons for suggestions and contributions of subject matter: Professor C. N. Stark, bacteriologist, Cornell University; Professor J. A. Bizzell, agronomist, Cornell University; Mr. L. J. Cross, state chemist, Cornell University; Mr. L. F. Beers, engineer, Rochester, New York; Mr. C. A. Holmquist, director of the Division of Sanitation, and Mr. F. W. Gilcress, Division of Laboratories and Research, both of the Department of Health of the State of New York at Albany, New York, and Mr. S. H. McCrory, Chief, Bureau of Agricultural Engineering, U. S. D. A., Washington, D. C.

Acknowledgment is made to the following firms for contributions of subject matter and some of the illustrations: Goulds Pumps, Seneca Falls, New York; F. E. Myers and Brother, Company, Ashland, Ohio; Decatur Pumps Company, Decatur, Illinois; Sears, Roebuck and Company, Chicago, Illinois; and The Deming Company, Salem, Ohio.

SUGGESTIONS FOR TEACHERS

As a suggested procedure for the teacher who plans to use this book for class work, the following outline is presented.

1. Adapting the Jobs to the Time Available. If time is not available for a study of the complete book it is suggested that the teacher choose those jobs best suited to the needs and interests of the members of his class and concentrate on those until the skills and related subject of the jobs chosen have been thoroughly mastered. Any time available beyond this point might well be spent in study of the related subject matter in Part II, particularly Chapters I, II, V, VI, and VII.

2. Equipping the Shop or Classroom. If no equipment is on hand for the teaching of the first part of this book, it would be well to decide first upon what jobs are to be taught, then, from the lists of tools and materials at the beginning of the jobs chosen, to make a list of the tools and materials to be purchased. For most of the jobs few tools will be needed other than those found already on hand in almost any well-equipped school shop.

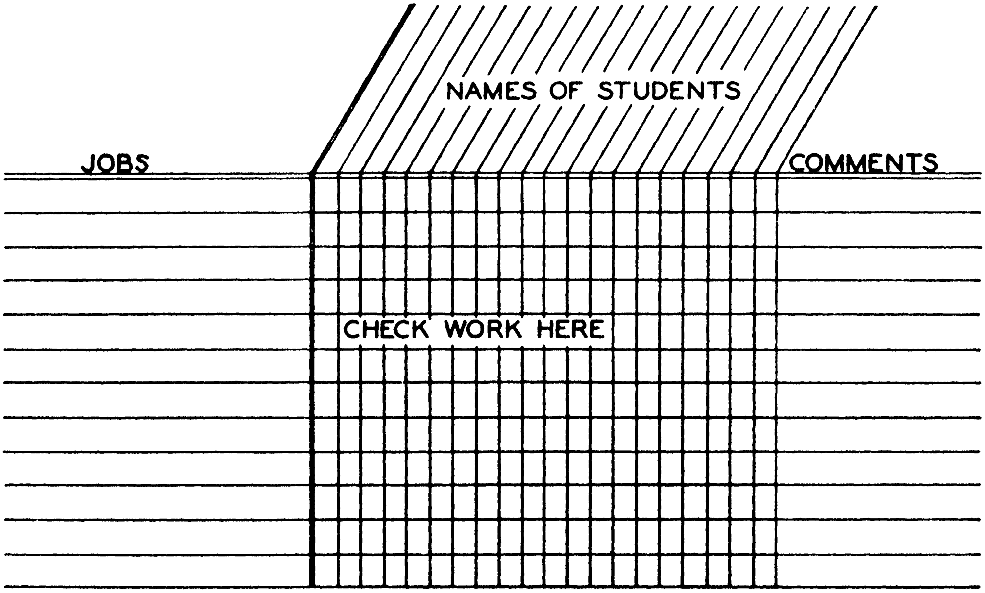
Much of the equipment needed, such as piping material, fittings, faucets, valves, pumps, and perhaps even water systems, can be purchased for small amounts or obtained on temporary consignment from local dealers, distributors, or manufacturers. It is suggested that as much as possible of the larger and more expensive equipment be obtained on temporary consignment because of the cost, because of the space it requires, and because of the fact that each year the newest and most up-to-date equipment can be obtained for the period of time devoted to this subject.

Part II of the book may be taught without special classroom equipment.

3. How to Use the Job Sheets. The job sheets are so designed that each student can check out the necessary tools and equipment, read the references, and perform the job with a minimum of help from the teacher. At the end of the jobs are lists of questions which the student should be able to answer after performing the job and reading the references. It is suggested that the students be trained to follow the instructions step by step from the beginning of the job to the end rather than to read the instructions and then lay the book aside while the job is being done.

In so far as is possible each job should be related to the students' own problems at home. It is often advisable to encourage them to bring in jobs from home or to do the jobs at home. This practice will add considerably to the students' interest in the work. In some of the jobs, such as cutting and threading pipe, "making" a joint, caulking a joint in soil pipe, the teacher can save the students much time by first giving a demonstration of the skills involved. The student should have no difficulty in following the job outline after witnessing a carefully planned demonstration.

4. *Keeping a Record of the Work.* As an aid in keeping a record



Progress Chart

of the work done by each student, it is suggested that the teacher make a progress chart similar to the one shown here, on which he can keep records. Across the top of this chart write the names of the students. In the left-hand column write the names of the jobs to be taught. As each student completes a job to the satisfaction of the teacher, the teacher may check under the student's name and opposite the job performed the grade of work done. In this way both the teacher and the student can see at a glance the progress made and the quality of work being done.

This arrangement also makes it easy to advance each student as fast as his ability warrants without interfering with the work of the other students. The teacher will find that after the first two or three periods the various members of the class will be working on a variety of jobs, and, therefore, using different tools and equipment. This makes it unnecessary to have a heavy duplication of equipment.

5. *Group Discussions.* If the outline above is followed, the instruction will be very largely individual. However, it will be found profitable to call the class together from time to time for a general discussion of some of the most difficult jobs and more particularly for a discussion of the related subject matter. Where possible these discussions should center about local conditions and local problems with which the students are familiar. A good time to have a general discussion is after all the members of a class have completed certain phases of the subject matter. This will afford an opportunity to clear up any points in connection with the work which might not have been understood.

After the work on this subject has been completed and before other work is taken up, one or two periods devoted to a summary discussion will enable the students to see each phase of the work in its proper relationship.

March, 1939 FORREST B. WRIGHT.

CONTENTS

PART I

PART II

INDEX OF TABLES

Rural Water Supply and Sanitation

PART I

JOB 1

CUTTING TO MEASURE, REAMING, AND THREADING A PIECE OF PIPE

When it is desirable to cut, ream, and thread a piece of pipe to connect two fittings, which must be located a fixed distance apart, the length of the pipe should equal the distance between the face of the fittings plus the length of the two threads which enter the fittings. On pipe sizes up to 1 in., allow ½ in. for each thread. For 1¼ in. to 3 in., allow ¾ in. for each thread. Figure 1–1 shows two fittings with the faces 1 ft. apart and the proper length of pipe to connect them.

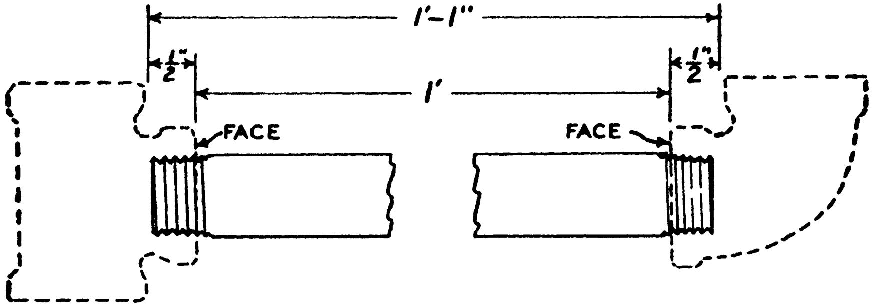


FIGURE 1–1.—One method of measuring a piece of ½-in. or ¾-in. pipe to join together two fittings.

Where very accurate measurements are necessary, as might be the case when installing a fixture, a good procedure is to measure distance *X* in Fig. 1–2 at *A*, from center to center of the pipes or fittings. Then mark off this distance on the floor. Lay fittings on the center marks as shown at *B* and measure the

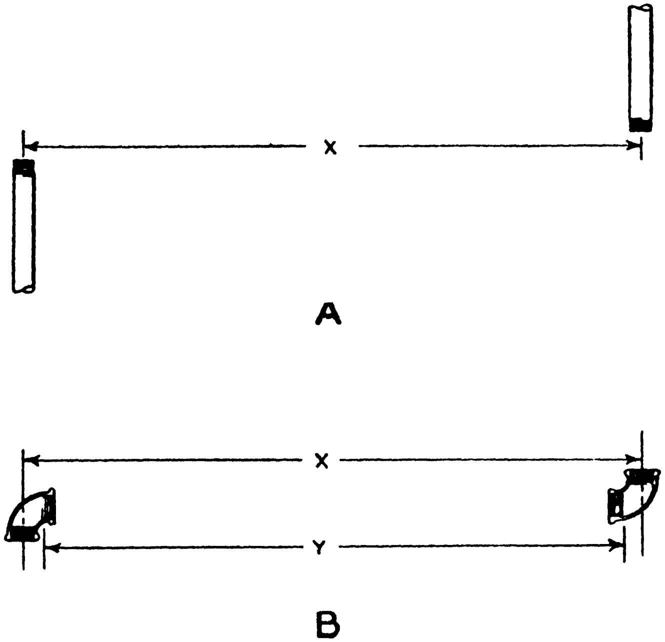


Figure 1-2.—A method of measuring from center to center of pipes to be joined.

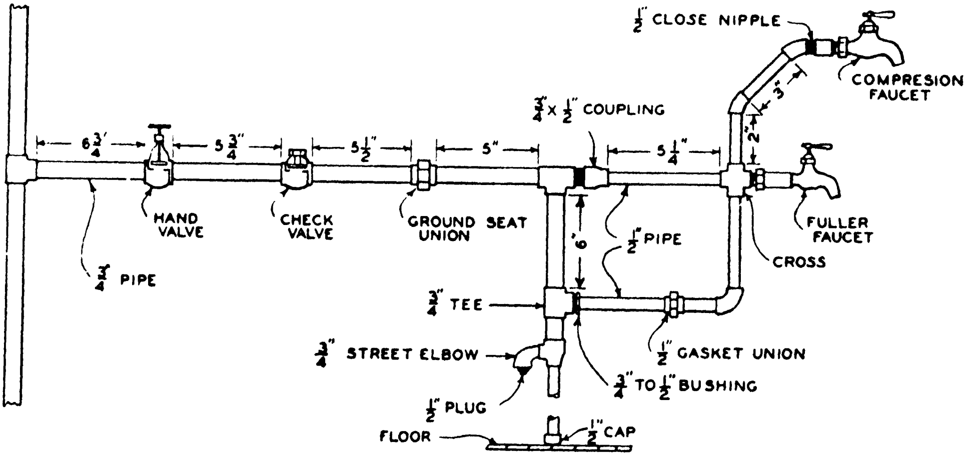


Figure 1-3.—A piping assembly suitable for practice in cutting pipe and "making" joints. This assembly contains the most common pipe sizes and the most common valves and fittings used in farm plumbing. When the assembly is completed the water pressure can be turned on it to test the joints, the valves, and the faucets. The faucets and valves may be used for practice in faucet and valve repair.

distance *Y* between the back of the threads. Distance *Y* will be the length to cut the pipe.

For practice cut, ream, and thread one length of pipe for the pipe assembly shown in Fig. 1–3. If this assembly has been started by others, select the next piece of pipe to be assembled.

Tools needed:

A measuring rule.
A piece of white chalk.
A pipe-cutting tool or
A hack saw.
A pipe reamer or
A round file.
A thread-cutting tool (stock and dies) of the proper size.
A can of thread-cutting oil.
A pipe vise.

Materials needed:

A piece of pipe of the desired size.
One pipe fitting or valve of the same size as the pipe.

Procedure:

1. Methods of cutting pipe:

Place the pipe in the pipe vise. Always screw the jaws of a pipe vise up tight so the pipe will not turn and strip off the galvanizing.

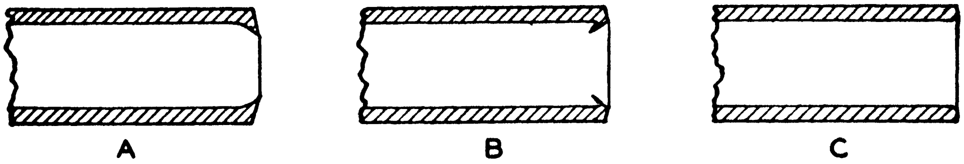


FIGURE 1–4.—At *A* is shown the burr made by a pipe cutter. At *B* is shown improper reaming. At *C* is shown pipe properly reamed.

For one who does a limited amount of plumbing a hack saw is a very satisfactory tool for cutting pipe of not more than

1 in. in diameter. The pipe-cutting tool is faster but is expensive and has no use other than for cutting pipe. It also leaves a burr on the inside of the pipe, as shown in Fig. 1–4 at *A*, which burr must be reamed out. A reamer means additional investment in tools.

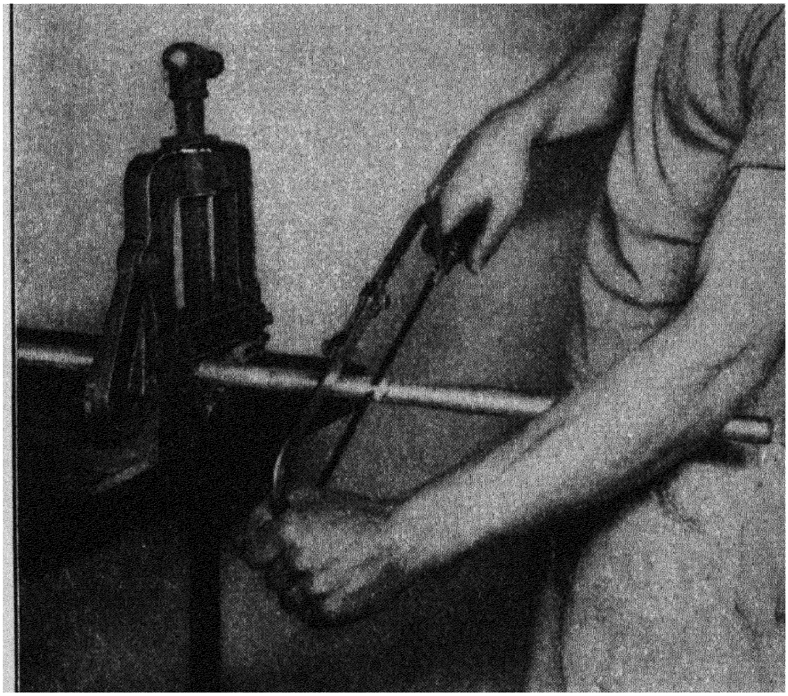


FIGURE 1–5.—Cutting pipe with a hack saw.

For practice, however, it would be well to cut pipe with both a hack saw and a pipe cutter, and make a comparison of the two methods.

When using a hack saw hold the saw at *right angles* to the pipe, as shown in Fig. 1–5, and saw at a rate of not more than 60 strokes per minute. Sawing too fast heats the saw blade and softens the teeth. Use full-length strokes with the saw. Remember that the teeth near the ends of the blade are as good as those in the middle.

A hack saw does not leave a burr on the inside of the pipe but may leave a rough edge. A few strokes with a round file will smooth the edge.

For practice, cut off a piece of ½-in. pipe with a hack saw.

When using a pipe-cutting tool place the tool on the pipe with the cutters on the mark, as shown in Fig. 1–6. Tighten the cutter to force the cutting wheel into the pipe. Swing the tool around the pipe to make the initial cut, being sure that the cutting wheel "tracks." After the initial cut, continue swinging

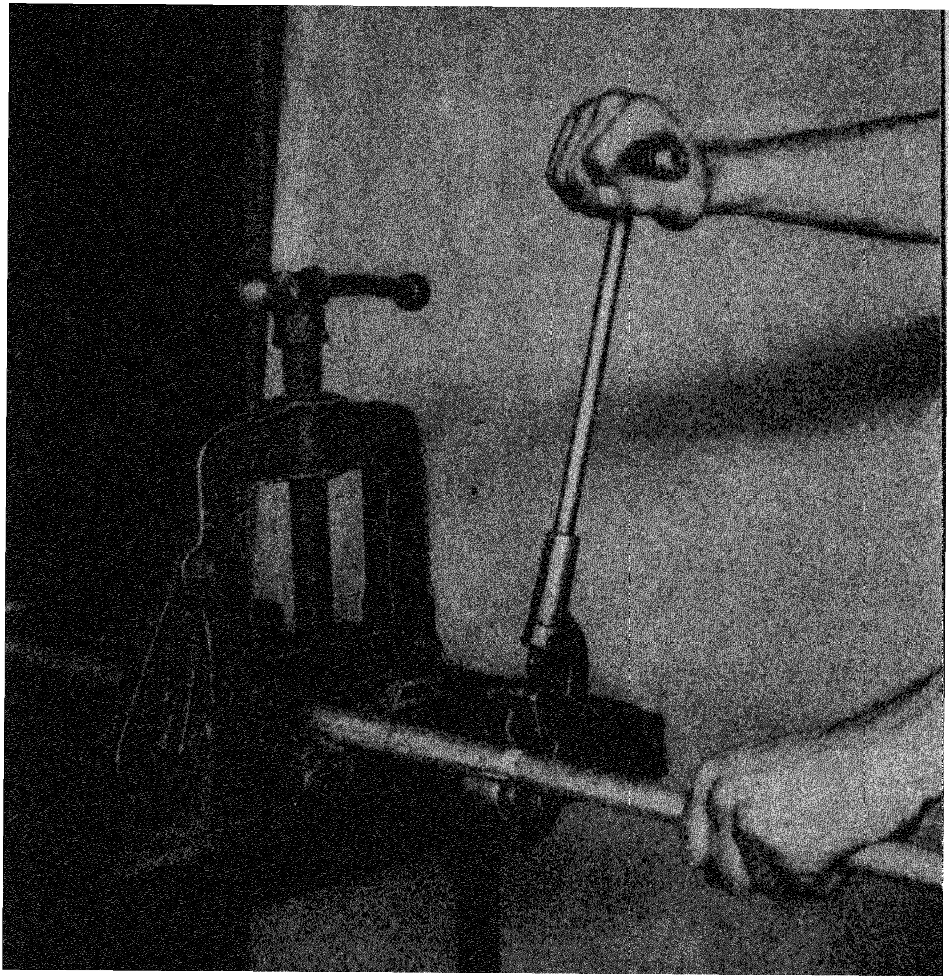


FIGURE 1–6.—Cutting pipe with a pipe cutter.

the tool around the pipe, tightening the cutters a little after each turn, until the pipe is cut off.

Cut off a piece of pipe with a pipe cutter.

2. Note the burr on the inside of the pipe. Unless this burr is removed it will decrease the flow of water through the pipe. The best way to remove the burr is with a pipe burring reamer, as shown in Fig. 1–7. Ream out the burr in the pipe you have cut. See Fig. 1–4.

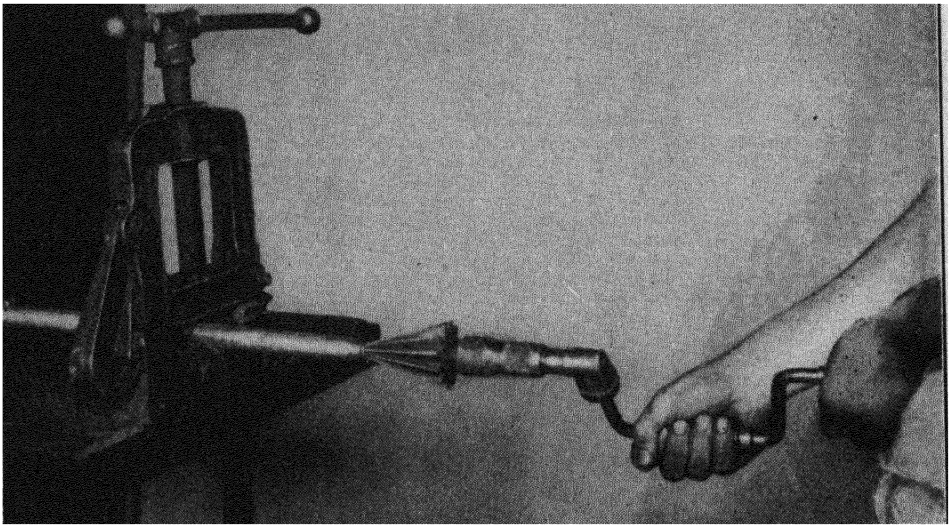


FIGURE 1–7.—Reaming the end of a pipe.

3. Measure the distance between the faces of the two fittings or valves which your pipe is to join, add ½ in. for each thread, and cut a piece of pipe to length. Use either of the above methods of cutting the pipe off.

4. Threading the pipe:

Pipe stocks and dies are used for threading pipe. These tools are made with two-handle stocks, Fig. 1–8, or with one handle and a ratchet, as shown in Fig. 1–9. The one-handle, ratchet type is easier to operate and is more accurate, but it is more expensive than the two-handle stock. Either type will cut good threads if in good condition and properly used.

Check over the pipe stock and die to see that it has dies and guide of the proper size and that the dies are correctly adjusted.

Place the tool on the end of the pipe, guide side first as shown in Figs. 1–8 and 1–9. Press the dies firmly against the end of the pipe and turn the stock in a clockwise direction, at the same time keeping the handle at right angles to the pipe.

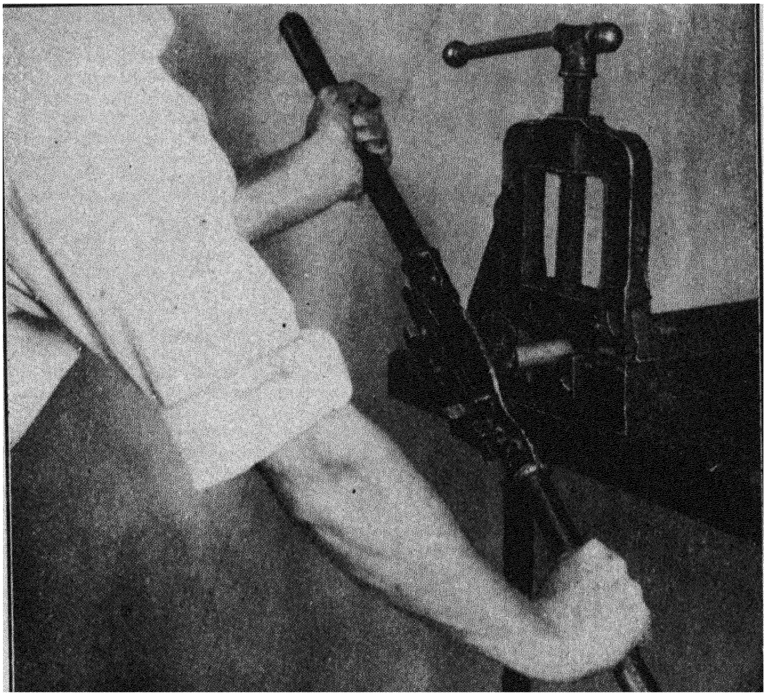


FIGURE 1–8.—Cutting a thread with a two-handle non-ratchet stock and die.

As soon as the threads are started, oil the dies and the end of the pipe with thread-cutting oil. This oil will aid in cutting a smooth thread and will make the dies easier to turn. It will also make the dies wear longer.

After each two or three complete turns of the dies, re-oil.

Turn the dies until the end of the pipe is flush with the outside face of the dies.

NOTE: If the pipe is a large one, 1¼ in. or more, the threads can be cut with greater ease by setting the dies back a little, if they are adjustable, for the first cut and then resetting them to place and cutting the thread down to size.

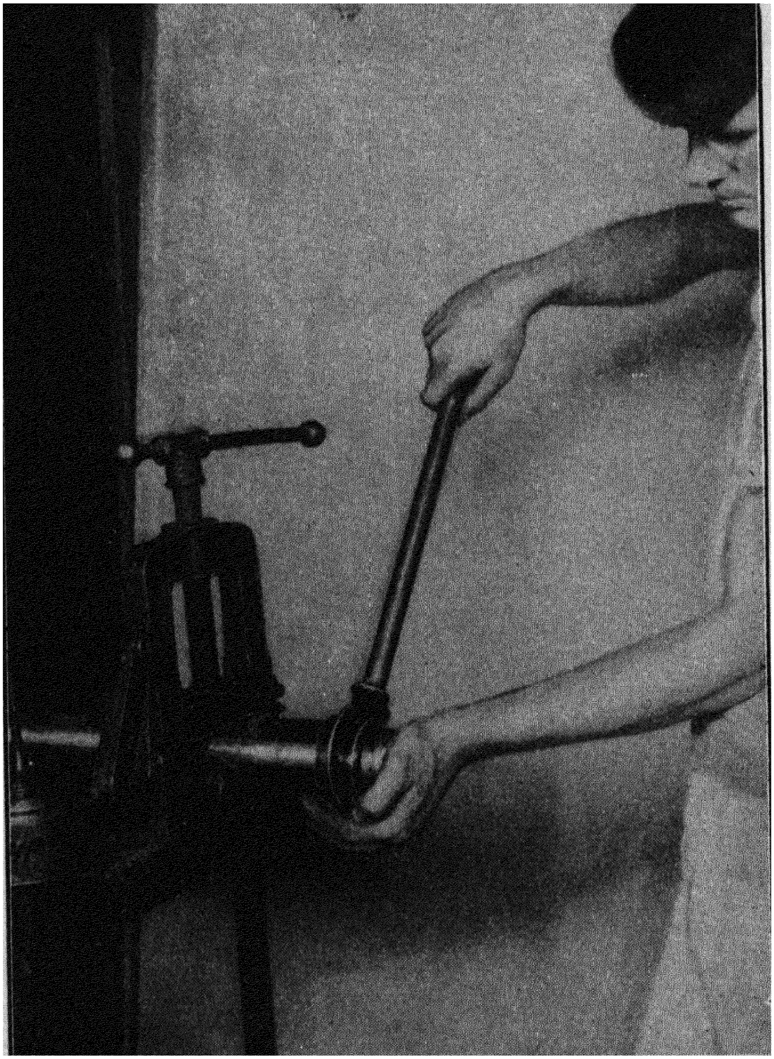


FIGURE 1-9.—Cutting a thread with a ratchet stock and die.

Remove the dies from the pipe, being careful that chips do not catch and spoil the threads. Turn the stock so that the dies are facing downward and strike the pipe a light blow with the handle of the stock. This will clean the die and the end of the pipe of chips.

5. Thread the other end of the pipe.

6. Try a fitting on the threads to make sure they are cut to the proper depth.

7. *Be sure to remove all metal chips from the inside of the pipe.* If this is not done the chips may lodge under faucet washers and cause leaks.

8. Assemble the pipe and fittings as directed in Job 2 and check your measurements.

QUESTIONS

1. Explain how to measure a length of pipe to connect two fittings.
2. Which method of cutting pipe do you prefer? Why?
3. Explain how to cut pipe properly with a hack saw.
4. Why should the burr be removed from pipe after cutting?
5. Why is thread-cutting oil used on the dies as the thread is being cut?
6. As you screw a fitting onto the end of the pipe, does it become tight gradually or suddenly? Explain why.

JOB 2

"MAKING" A THREADED JOINT

The plumber's term "making a joint" refers to the process of making a joint between a pipe and a fitting or valve, water tight.

Tools needed:

One pipe vise.
One Stilson wrench (pipe wrench).
One 12-in. monkey wrench.
One stiff-bristle paint brush.

Supplies needed:

One can of pipe-joint compound or lead paint.
One piece of threaded pipe (the piece threaded in Job 1 will do).
Pipe fittings or valves of the same size as the pipe.
A small quantity of candle wicking.

Procedure:

1. Place the pipe tightly in the vise with the threaded end close to the vise, as shown in Fig. 2–1.
2. With the paint brush cover the threads with pipe-joint compound or paint, brushing it well into the threads. This will help seal the joint.

NOTE: The pipe-joint compound should never be put in the fitting threads as it will be pushed ahead of the pipe and pile up, partially closing the pipe. Pipe-joint compound is better than paint because it does not dry hard and, therefore, the joint can be more easily taken apart. Covering the entire thread with pipe-joint compound tends to prevent rusting where the galvanizing has been cut off.

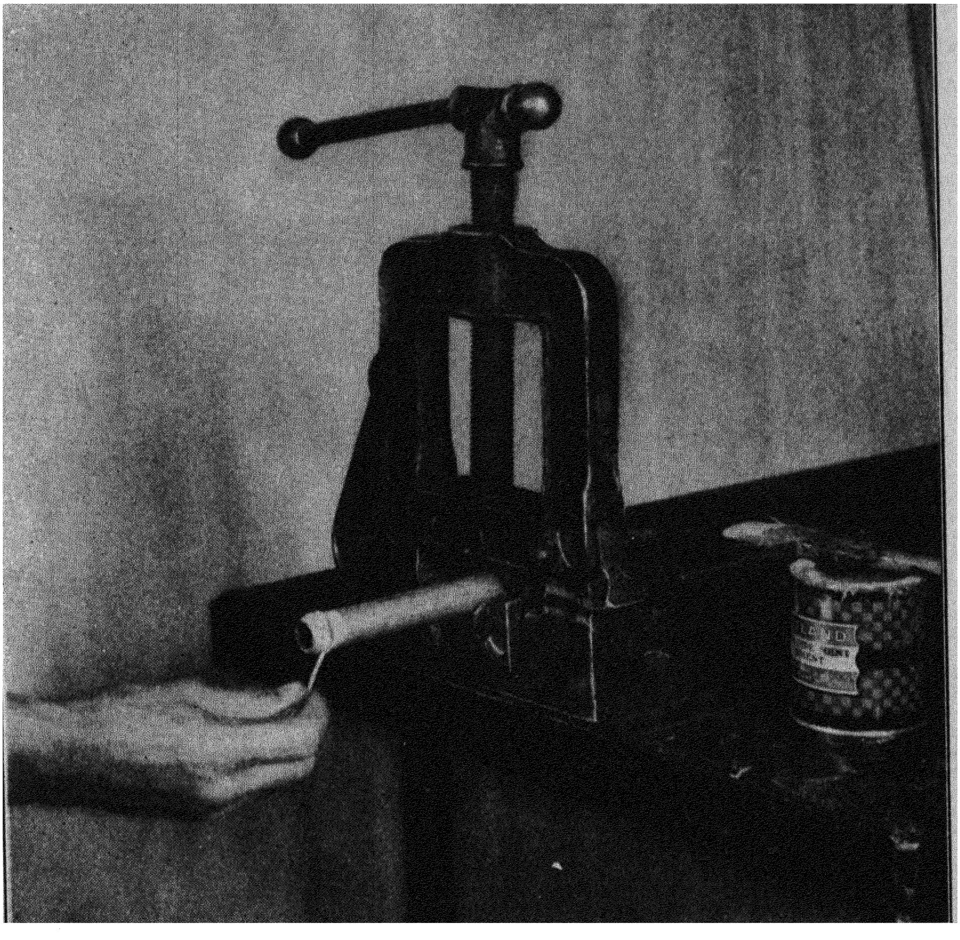


FIGURE 2-1.—Preparing the pipe threads for the fitting or valve. Pipe joint compound is first placed on the threads and then a short piece of candle wicking may be wrapped on the threads to insure an absolutely tight joint.

3. As an additional guarantee against leaks, candle wicking may be wrapped around the threads as shown in Fig. 2-1. The wrapping should be started toward the back of the thread and wrapped in a clockwise direction toward the end of the pipe.

In other words, wrap in the same direction that the fitting turns to screw on. A little additional pipe-joint compound on the candle wicking will hold it in place and lubricate it. The joint need not be screwed as tight with wicking as without. Joints made in pipe that will be enclosed before there is an opportunity to test them and joints made with old fittings and old pipe should always be wicked.

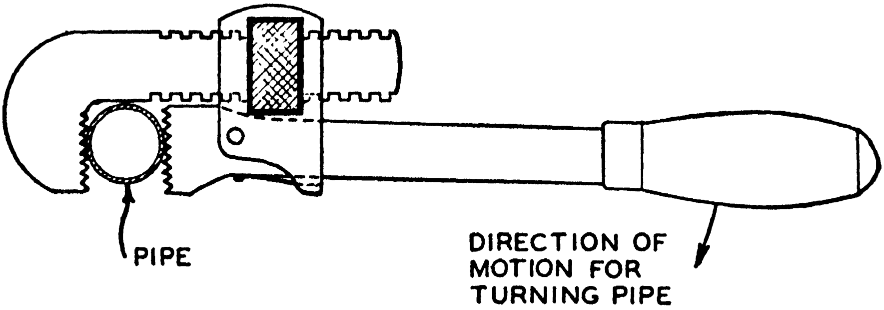


FIGURE 2–2.—Method of using a pipe wrench.

4. Start the fitting on the pipe (or the pipe in the fitting) by hand and tighten with the pipe wrench until reasonably tight. If turned too tight the fitting may be stretched or cracked.

NOTE: A pipe wrench will hold only when turned in one direction, as shown in Fig. 2–2. When the handle is moved in the opposite direction, the jaws of the wrench open up and release the pipe.

5. Wipe off excess pipe-joint compound.
6. Screw the other end of the pipe in place on the plumbing system by "making" the joint as directed above.

Brass is a relatively soft metal, therefore, when screwing a brass valve onto pipe, place a moneky wrench on the end of the valve next to the pipe, as shown in Fig. 2–3. When screwing pipe into a brass valve, hold that end of the valve next to the pipe with a monkey wrench, as shown in Fig. 2–4. This method will prevent twisting of the valve. Always tighten the bonnet and packing or gland nut (see Fig. 5–2) on a valve at the time of installation. A brass valve should not be placed in a vise as the pressure of the vise may squeeze the valve out of shape.

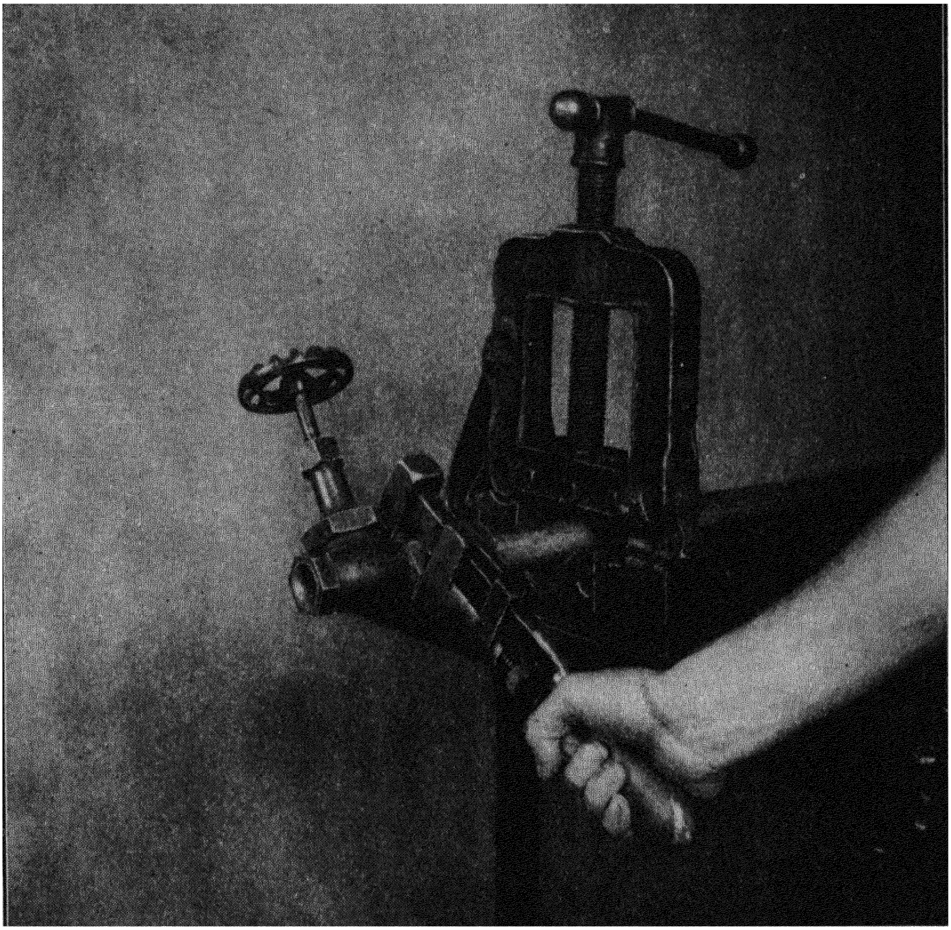


Figure 2–3.—Proper method of screwing a brass valve on the end of a pipe.

7. If the pipe cut in Job 1 is used here, measure the distance between fittings to check your measurements.

8. Plug or cap all openings and turn on the water pressure to test the joints.

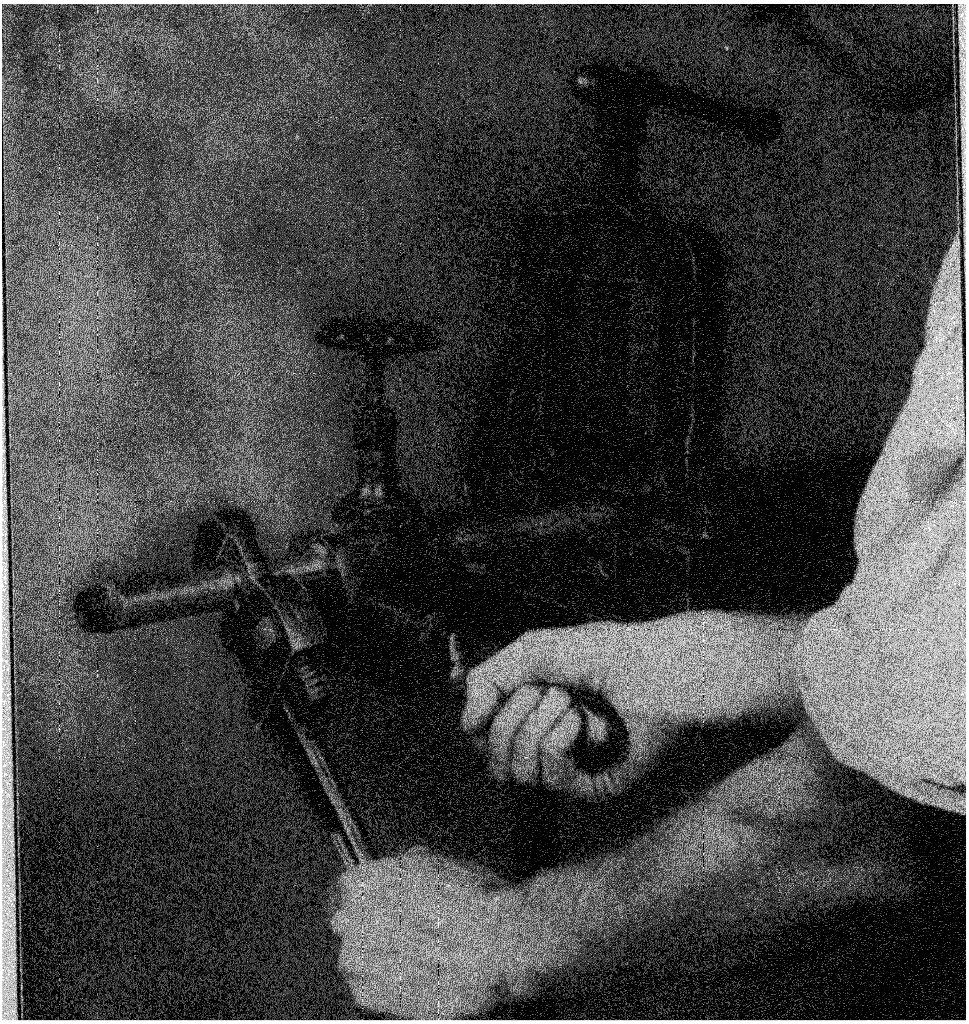


FIGURE 2–4.—Proper method of screwing a piece of pipe into a brass valve.

QUESTIONS

1. What is the meaning of the term "making" a joint?
2. What is the objection to placing the pipe-joint compound in the fitting instead of on the threads of the pipe?
3. Why is pipe-joint compound better than lead paint?
4. Of what advantage is the pipe-joint compound other than sealing the joint?
5. Why and where would you use candle wicking on a joint?
6. What precautions should be taken when installing brass valves?

JOB 3

PIPING MATERIALS AND TUBING FOR PLUMBING SYSTEMS

Reference: Chapter VI, pages 260–262

Materials needed:

An assortment of galvanized steel, galvanized copper-bearing steel, black steel, wrought iron, brass and copper pipe, and copper tubing. See Fig. 3–1.

A catalog of plumbing supplies.

Procedure:

1. With the materials before you and the catalog as a guide, study the samples and determine of what metals they are made, and their nominal sizes.
2. Compare the cost prices of the various materials.
3. What are the advantages of brass and copper over steel?
4. Practice judging pipe sizes until you can name them without measuring.
5. Give an example of the proper place to use each kind of piping or tubing which you have studied.

QUESTIONS

1. Where is black steel pipe used mostly?
2. What, if any, are the objections to the use of copper tubing?
3. Would you recommend the use of copper or brass in an inexpensive house?
4. How would you state the dimensions of nipples? (See catalog.)
5. Which would require more labor to install, galvanized steel pipe or copper tubing?

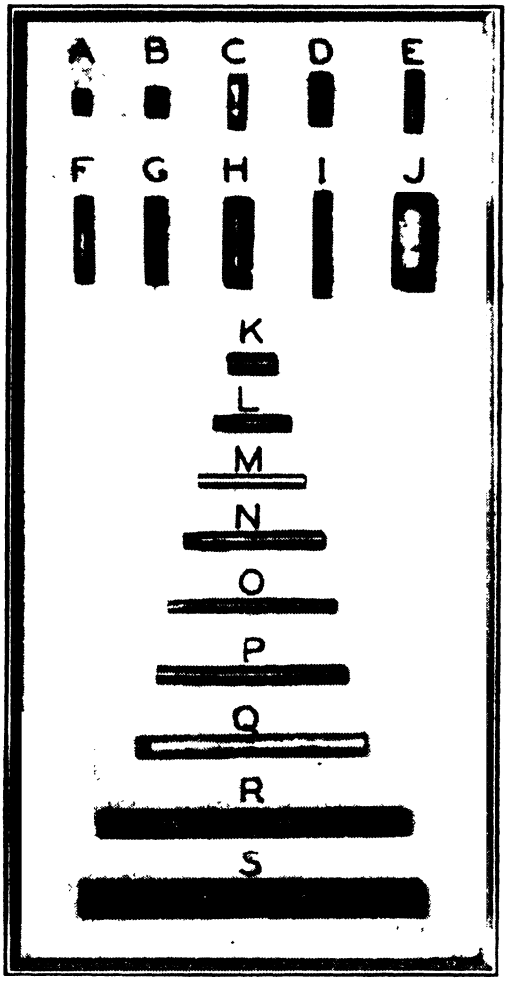


FIGURE 3-1.—An assortment of piping material.

The following materials are shown: *A*—½-in. black steel close nipple. *B*—¾-in. black steel close nipple. *C*—½-in. galvanized steel nipple 2½ in. long. *D*—¾-in. black steel nipple 2½ in. long. *E*—½-in. galvanized steel nipple 3 in. long. *F*—½-in. galvanized steel nipple 4-in. long. *G*—¾-in. black steel nipple stock. *H*—1-in. galvanized steel nipple 4 in. long. I—½-in. black wrought-iron nipple 5 in long. J—1½-in. galvanized steel nipple 4½ in. long. *K*—½-in. black steel pipe. One end reamed and the other end not reamed. *L*—½-in. galvanized steel nipple. One end has threads cut too deep, the other end has threads cut not deep enough. *M*—⅜-in. chromium-plated brass pipe. *N*—½-in. plain brass pipe. *O*—½-in. soft copper tubing. *P*—¾-in. hard copper tubing. *Q*—¼-in. galvanized copper-bearing steel pipe. *R*—1-in. black steel pipe. *S*—1¼-in. black steel pipe.

JOB 4

PIPE FITTINGS

Reference: Chapter VI, pages 260–262.

Supplies needed:

A selection of the most commonly used pipe fittings as shown in Fig. 4–1.

A catalog of plumbing supplies.

If possible a plumbing system which contains most of the common fittings.

Procedure:

1. With the fittings before you and the catalog as a guide:
   - *a.* Determine the correct name for each fitting.
   - *b.* Determine how to give the correct dimensions when ordering each type of fitting.
   - *c.* Determine where each type of fitting is used. If possible locate the fittings on some plumbing system and see where they are installed.
   - *d.* Practice identifying fittings and giving correct dimensions until you can do it without looking them up.

QUESTIONS

1. Which fittings could be used for splicing two pipes of the same size? For two pipes of different sizes?
2. Which fittings could be used to join a pipe line onto a tank where the pipe is smaller than the tank opening?
3. Where would you use gasket unions and where ground seat unions?
4. Give the rule for ordering a "T" fitting.
5. Where are bushings used?
6. Where are cast-iron fittings used, and why?
7. Name four methods of reducing the size of a pipe line.

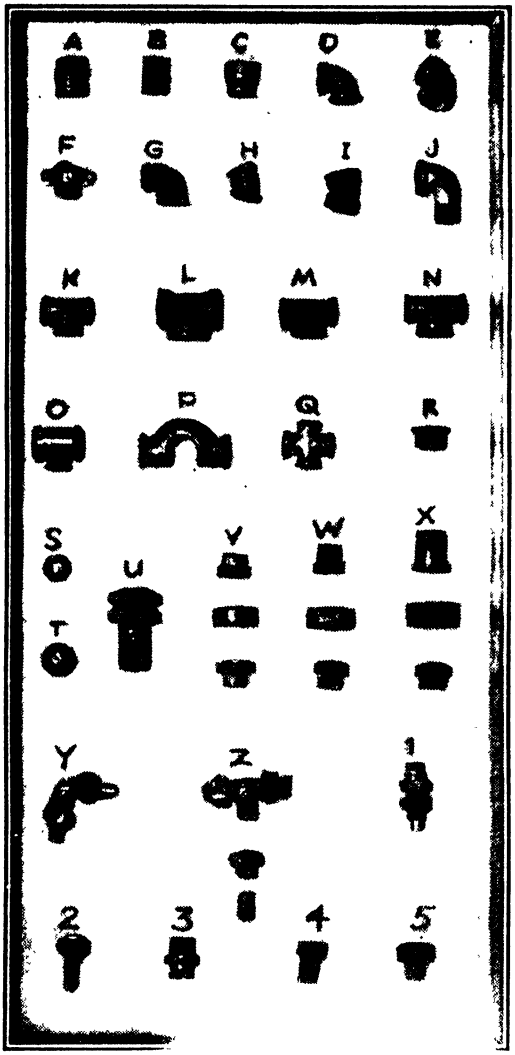


FIGURE 4–1.—An assortment of fittings for steel pipe and copper tubing.

The following fittings are shown: *A*—¾-in. galvanized malleable iron coupling. *B*—Right- and left-hand threaded malleable iron coupling. *C*—¾-in to ½-in. galvanized malleable iron coupling. *D*—½-in., 90°, galvanized malleable iron elbow. *E*—½-in., 90°, black cast-iron elbow. *F*—½-in. galvanized malleable iron bracket elbow. *G*—¾-in. to ½-in. black malleable iron reducing elbow. *H*—½-in., 45°, galvanized malleable iron elbow. *I*—½-in., 45°, black cast-iron elbow. *J*—¾-in. galvanized malleable iron street elbow. *K*—½-in. galvanized malleable iron tee. *L*—¾-in. black cast-iron tee. *M*—½-in. to ¾-in. galvanized malleable iron tee. *N*—⅜ in. by ½ in. by ¾ in. galvanized malleable iron tee. *O*—¾-in. to ¼-in. galvanized malleable iron tee. *P*—¾-in. galvanized malleable iron crossover. *Q*—⅜-in. galvanized malleable iron cross. *R*—¾-in. to ½-in. black malleable iron bushing. *S*—½-in. black malleable iron cap. *T*—1-in. black malleable iron plug. *U*—1-in. galvanized malleable iron tank union. *V*—½-in. galvanized malleable iron gasket-type union. *W*—½-in. galvanized malleable iron ground-seat union. *X*—¾-in. brass boiler union. *Y*—½-in., 90°, flared-type copper-to-copper elbow. *Z*—½-in. flared-type copper-to-copper tee. *1*—½-in. flared-type copper malleable adapter. Copper end threaded for sleeve nut. Iron end has standard pipe thread. 2—½-in. brass hose connector, female thread. 3—¾-in. brass hose adapter, male thread. 4—¾-in. brass hose connector, male thread. 5—½-in. brass hose adapter, male pipe thread and female hose thread.

JOB 5

VALVES

Reference: Chapter VI, page 260.

Supplies:

An assortment of the most commonly used valves as shown in Fig. 5–1. Cross-sectioned models are desirable but not necessary.

A catalog of plumbing supplies.

If possible a plumbing system having different types of valves.

Tools needed:

Screw driver.

Adjustable wrench.

Procedure:

With the assortment of valves before you and the catalog as a guide:

1. Determine the name of each type of valve.

There are three general classes of valves in common use on domestic water systems: (1) globe valves; (2) gate valves; and (3) check valves. In addition to these there may be one each of the following on a farm water system: a stop and waste valve, a hydrant valve, and a safety valve.

The globe valves and gate valves are used in pipe lines for convenience in closing the pipes to control the flow of water. They are hand operated. The check valves are installed in pipe lines to prevent a back flow of water. That is, they will allow water to flow through the pipe in one direction only. Check valves are automatic in operation, being opened and closed by changes in direction of pressure and flow.

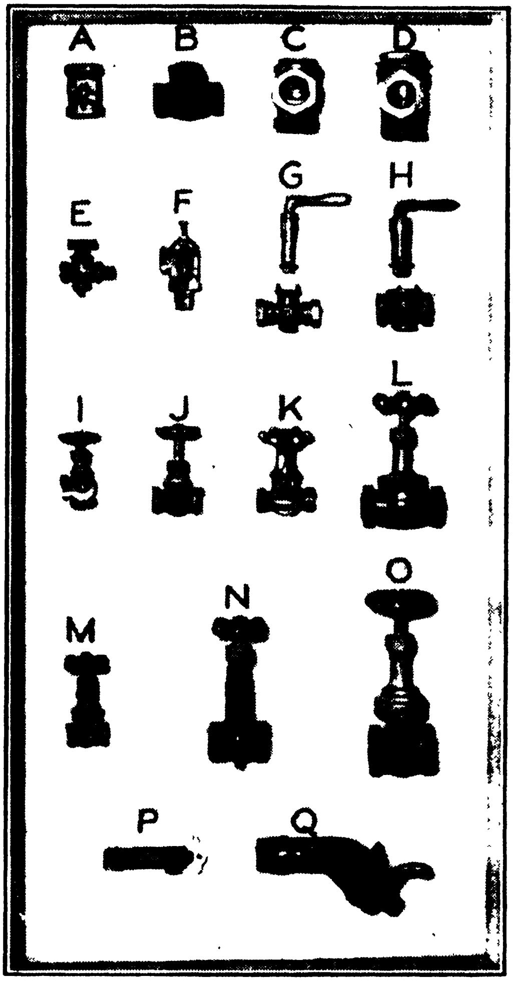


FIGURE 5–1.—An assortment of valves of various types.

A—3-in. vertical check valve, brass. *B*—¾-in. horizontal globe check valve, brass. *C*—1-in. angle check valve, brass. *D*—1-in. angle air-check valve, brass. *E*—⅜-in. ground key stop cock, brass. *F*—½-in. safety valve for water systems. *G*—½-in. stop and drain cock. *H*—¾-in. ground key stop cock. *I*—⅜-in. angle globe valve. *J*—½-in. globe valve. *K*—½-in. globe valve for air or glass line. *L*—¾-in. globe valve. *M*—⅜-in. gate valve. *N*—¾-in. gate valve, iron with brass inserts. *O*—1¼-in. gate valve, brass. *P*—barrel spigot (for light oil or fuel). *Q*—1¼-in. barrel spigot for molasses or heavy oil.

The Globe Valve. Figure 5–2 shows the construction of one type of globe valve.

The globe valve should be installed with the water pressure under the valve seat as shown, and, if installed in a line that must be drained, the stem should be in a horizontal position. If the valve is installed with the pressure on top of the seat, it is likely to leak around the stem when closed. If mounted with the stem in a vertical position, the valve cannot be entirely drained.

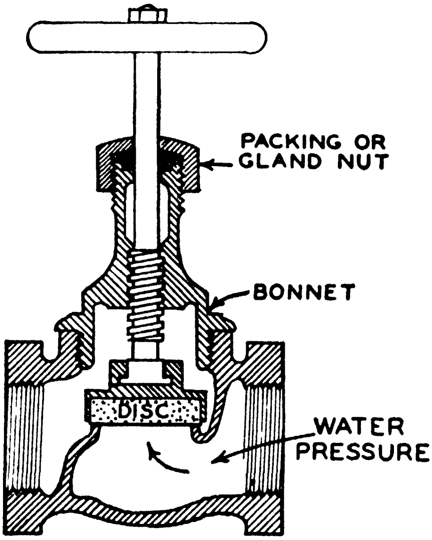


FIGURE 5–2.—Cross-section of one type of globe valve. Note that the pressure should be *under* the seat.

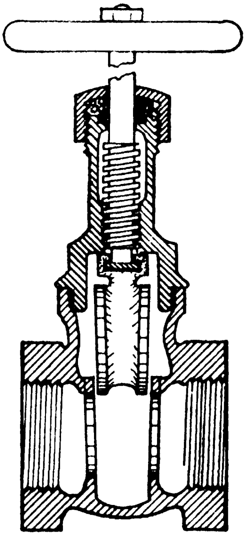


FIGURE 5–3.—Cross-section of a gate valve.

The best type of globe valve has a renewable disc and a renewable seat.

The Gate Valve. Figure 5–3 shows the construction of a common type of gate valve. Note that there are two seats and a wedge-shaped plunger that closes both seat openings. The seat openings are usually of the same diameter as the inside of the pipe for which the valve is made, and since they are in line with the axis of the pipe very little resistance is offered to the flow of water when the valve is completely open. The gate valve has a decided advantage over the globe valve in this respect. It is, therefore, used in preference to the globe valve where resistance to the flow of water is to be kept at a minimum. It will also control the flow equally well from either direction.

The globe valve has the advantage of quicker opening and closing, of longer life, and of being more easily repaired. Generally speaking, if the flow is in one direction only and if a valve is to be opened and closed frequently, the globe type is used; if opened and closed infrequently, if it is desired to keep friction at a minimum, or if it is desired to stop flow in either direction, the gate type is used.

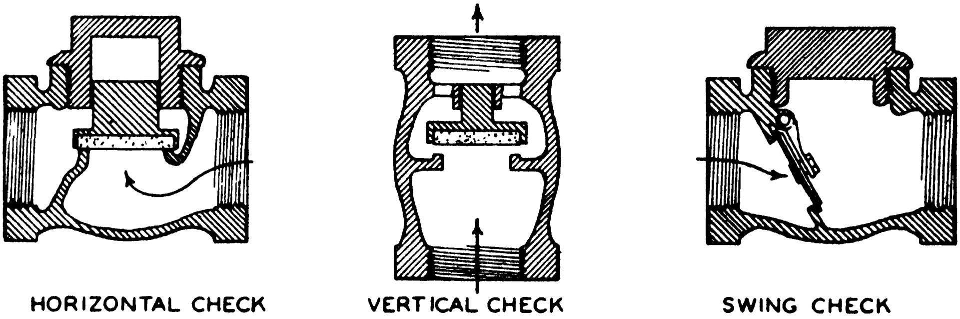


FIGURE 5–4.—Cross-sections of three types of check valves.

Check Valves. Figure 5-4 shows the construction of three types of check valves. The horizontal and swing checks must be installed in a horizontal position with the cap upward and with the flow in the direction of the arrows. The vertical check must be installed in a vertical position.

In all three of these check valves the water pressure under the seat will lift the check and let water pass through. If the pressure is reversed the check will be forced down on the seat and thus stop the flow.

Stop-and-Waste Valve. A stop-and-waste valve may be of the globe type or of the ground key type. It is used in a water line for shutting off the pressure and at the same time draining the pipes beyond the valve. On a farm water system it should be installed next to the tank on the faucet side or in the basement at the low point in the system. The valve must be installed with the drain opening on the house side of the plumbing.

Hydrant Valve. A hydrant valve is very similar to a stop-and-waste valve except that it is designed for installation underground with a handle which may be extended to the surface as shown in Fig. 5–5. When the valve is closed the pipe to the surface is drained back to the valve.

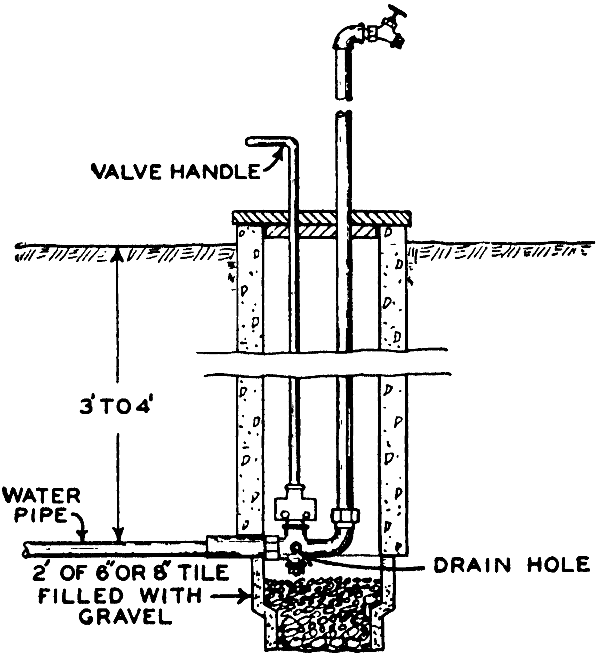


FIGURE 5–5.—A hydrant installation.

When the valve is closed the water pressure is shut off from the left and the drain hole is connected with the standing pipe. If the faucet is opened the water in the standing pipe will then drain out into the tile filled with gravel. As the valve and tile are below the frost line, there is no danger of freezing.

In Fig. 5–5 a faucet is shown on the upper end of the standing pipe. This faucet is not necessary but is recommended where water is to be drawn frequently. Frequent opening and closing of the hydrant valve may soon cause enough wear to make the valve leak.

The hydrant is shown here installed in a concrete pit. For a temporary hydrant the pit may be lined with wood planks. If copper tubing is used instead of steel pipe, a length or two of glazed tile around the handle extension may be sufficient as it is not likely that the pipes will have to be dug up for repairs.

Safety Valves. A safety valve is used on pressure-type water systems and on range boilers. The valve is held closed by a spring the tension of which can be adjusted over a wide range of pressures. When the water pressure under the seat exceeds the pressure of the spring on top of the seat the seat is lifted and the water flows through to relieve excessive pressure on the system. See Fig. 5–6. On automatic hot-water supply systems, such as a gas or electric heater, a safety valve with a temperature release as well as a pressure release should be used.

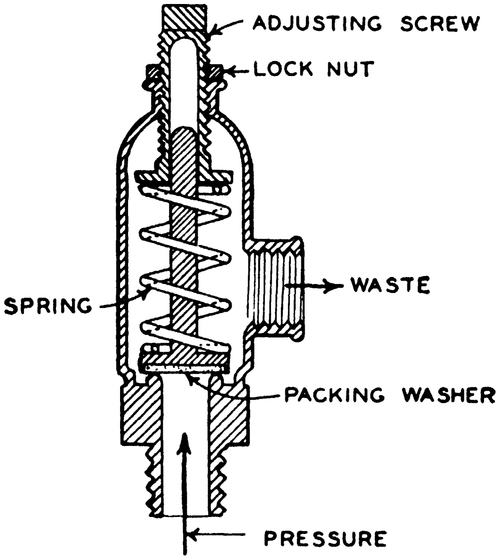


Figure 5–6.—One type of safety valve.

General. All valves are usually made of brass or have brass inserts for seats. In any case, when installing a brass valve, place the wrench on the end of the valve which is being screwed onto the pipe. Likewise, when screwing pipe into a valve, hold the end of the valve into which the pipe is being screwed with a wrench. This is to prevent the twisting of the valve and warping of the seat. See Figs. 2–3 and 2–4. Never place a brass valve in a vise.

Take the valves apart if they are not cross-sectioned and study their structure.

Determine where each type of valve is used. If possible locate each type on a plumbing system and see how it is installed.

QUESTIONS

1. Under what conditions would you use a gate valve in preference to a globe valve?
2. Which end of a globe valve should be toward the pressure?
3. Describe how to install correctly a swing check valve.
4. Explain how to screw correctly a brass valve on a pipe.

JOB 6

FAUCETS

Reference: Chapter VI, page 260.

Supplies needed:

An assortment of faucets as shown in Fig. 6–1. Cross-sectioned models if possible.
A plumbing-supply catalog.
If possible, a plumbing system having different types of faucets.

Tools needed:

A screw driver.
An adjustable wrench.

Procedure:

With the assortment of faucets before you and the catalog as a guide, determine the correct name of each type of faucet.

There are four types of faucets in general use, namely: (1) the standard compression type, illustrated in Fig. 6–2; (2) the fuller type, Fig. 6–3; (3) the ground key type, Fig. 6–4; and (4) the "quick-compression" type, Fig. 6–5.

The standard compression type of faucet closes *against* the pressure and has the washer held firmly in place with a screw which tends to prevent noise when the faucet is partly open. The washer is renewable on all compression faucets and on some the seat is also renewable.

A compression type of faucet is now available which has quick action. That is, it can be opened and closed by one-quarter to one-half of a turn of the handle. Any of the single faucets may be had with threads for hose connection.

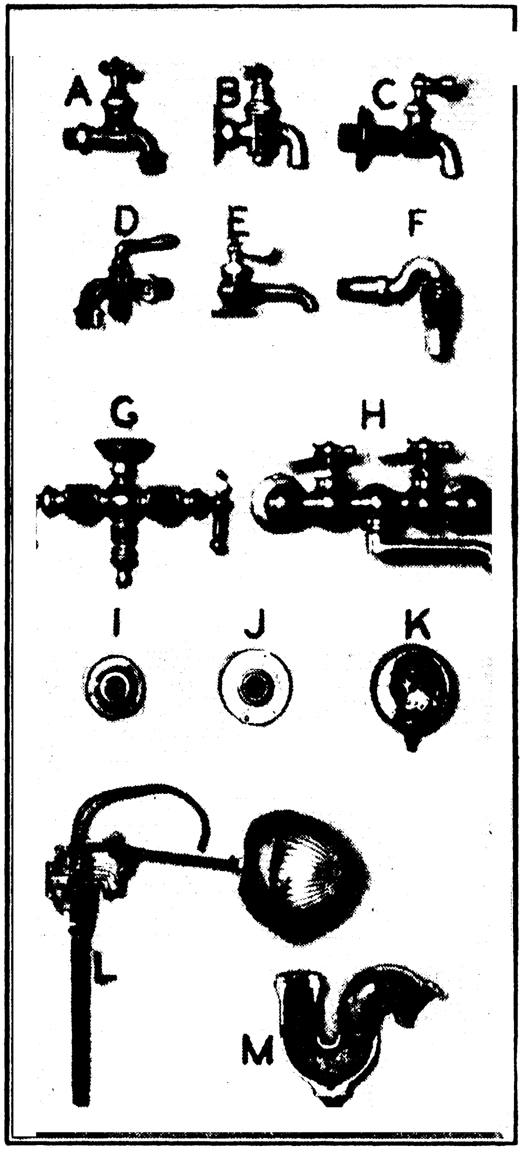


FIGURE 6-1 —An assortment of faucets and miscellaneous plumbing materials.

A—compression-type faucet with hose bib. *B*—self-closing faucet, plain bib. *C*—fuller-type faucet, plain bib. *D*—ground key faucet with hose bib. *E*—Quick compression-type faucet for lavatory. *F*—"Hajoca" plain bib faucet. *G*—fuller mixing faucet for bath tub. *H*—compression mixing faucet for sink. *I*—½-in. floor or wall flange, solid type. *J*—¾-in. floor flange, opening type. *K*—pressure gauge. *L*—ball cock for toilet tank. *M*—a trap.

The fuller type of faucet closes *with* the pressure. Instead of a washer, it has a rubber ball, which is attached to a long stem operated by a crank. This arrangement makes it possible to open the faucet completely with one half turn of the handle. This feature is its chief advantage. The ball is rather loosely held in place so that when only partly open it is likely to vibrate and make a great deal of noise. This is particularly true after the faucet is worn a little and if the water pressure is high. For this reason the fuller type is seldom used on high pressures. In fact, it is now seldom used at all on new work. There are, however, many of these in service on old installations. The ball, stem, and crank are renewable on the fuller faucets.

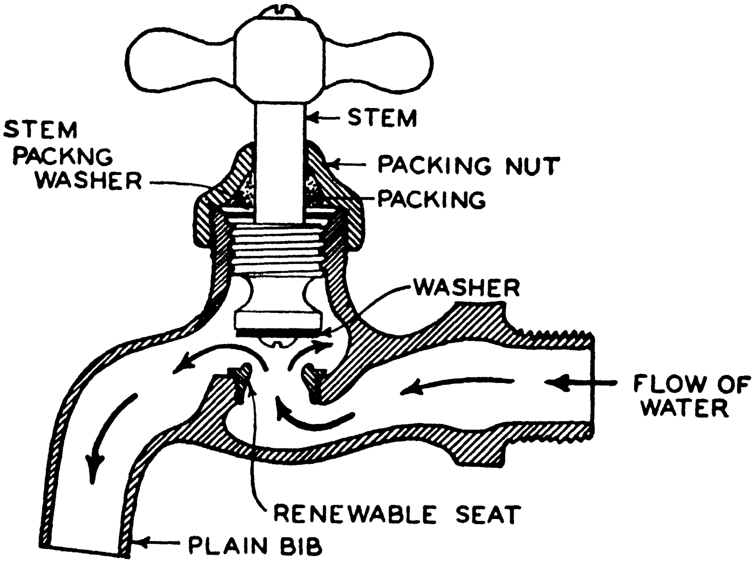


FIGURE 6–2.—Cross-section of a compression type of faucet. Note that the pressure is *under* the seat.

Figure 6–4 shows a relatively new type of quick-compression faucet which combines features of both the compression and fuller types. The washer is held firmly on the stem but closes *with* the pressure. As the washer is held firmly on the stem there is little tendency for it to vibrate. As may be seen from the drawing, both the seat and washer are easily and quickly renewed.

Another feature of this faucet is that it can be completely opened by one quarter turn of the handle.

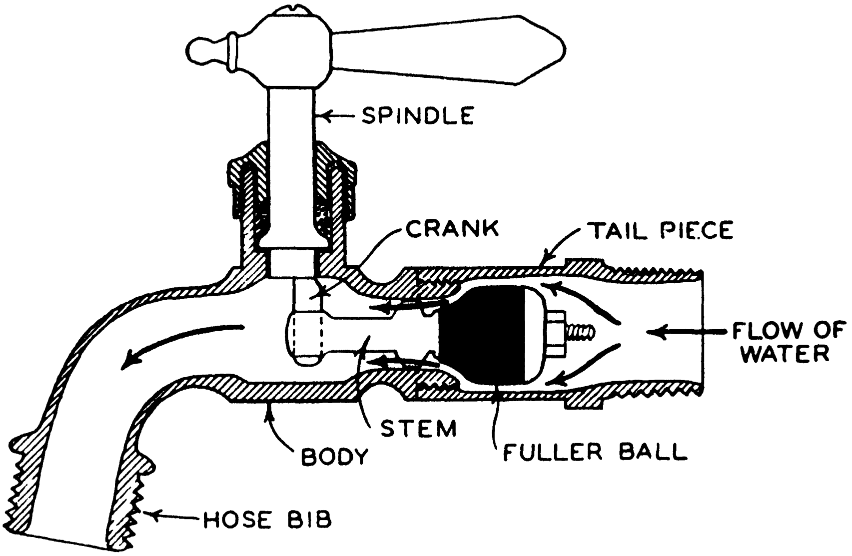


FIGURE 6–3.—Cross-section of a fuller type of faucet. Note that the pressure is behind the ball and will, therefore, tend to close the faucet.

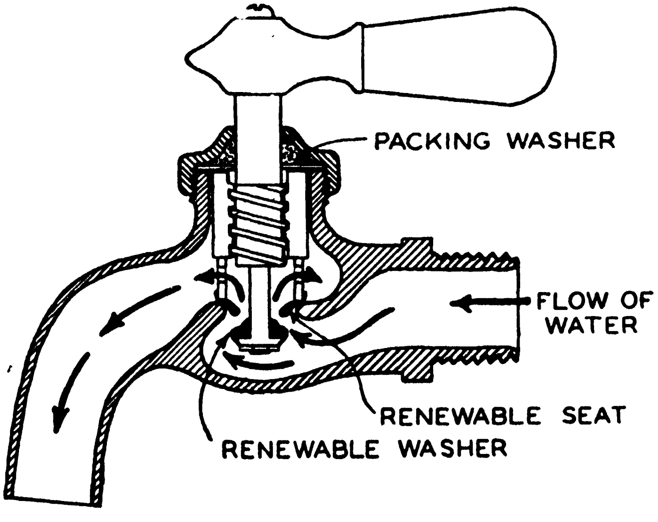


FIGURE 6–4.—Cross-section of a relatively new type of faucet with renewable seat and washer. Suitable for high pressures only.

All four of the above faucets are made in various forms, and may be had either single or double. When double, they are called mixing or "swing-spout" faucets and are used for mixing hot and cold water to any desired temperature. Figure 6–5 shows a typical mixing faucet for a sink. The spout swings for convenience in placing the water.

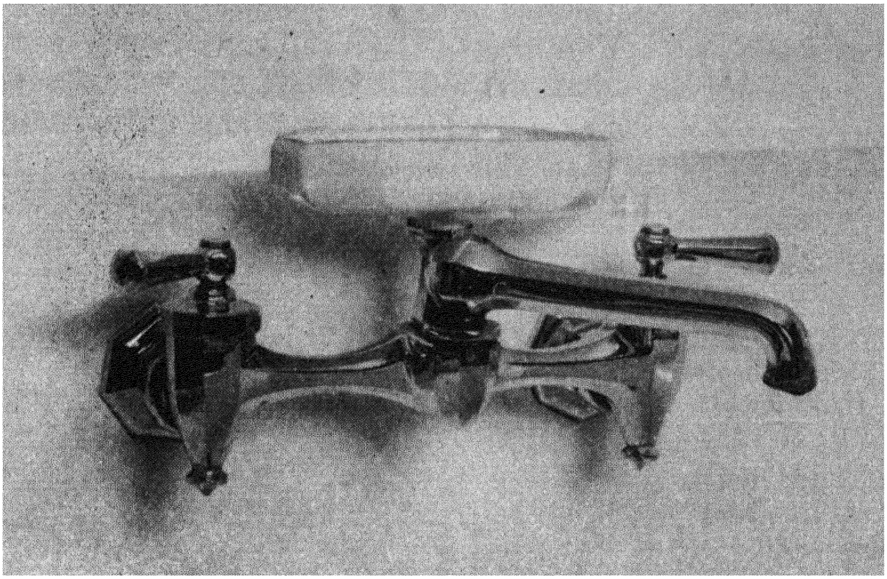


FIGURE 6–5.—A mixing faucet with a swing spout for a kitchen sink. This type of faucet is usually equipped with a soap tray and a strainer in the end of the spout to prevent spraying of the water.

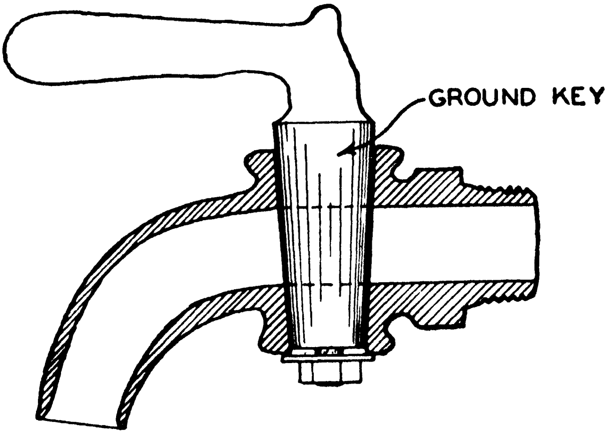


FIGURE 6–6.—Cross-section of a ground key type of faucet.

The ground key type of faucet, Fig. 6–6, is used in places where the liquid flowing through it would destroy the washers on other types and where quick action is also desirable. For example, it is used for acids, oils, and extremely hot water. This type of faucet is made entirely of brass and can be used for any liquids that will not attack brass. It is not suitable for places like a sink, where it would be opened and closed frequently, because the key wears and is then likely to leak.

Take apart the faucets you have if they are not cross-sectioned and examine their structure and condition.

QUESTIONS

1. What types of faucets are in most common use?
2. What are some advantages of a compression type of faucet over the fuller type?
3. Where would you use a ground key faucet?
4. Which of the faucets which you have studied would be the easiest to repair?

JOB 7

REPAIRING FAUCETS

Reference: Job 6.

Leaking faucets should be repaired because (1) the dripping water usually stains the porcelain of the plumbing fixtures; (2) a considerable quantity of water may be wasted over a long period of time; and (3) in the case of a leaking hot-water faucet there is not only a loss of water, but, what is more important, there is a considerable loss of heat.

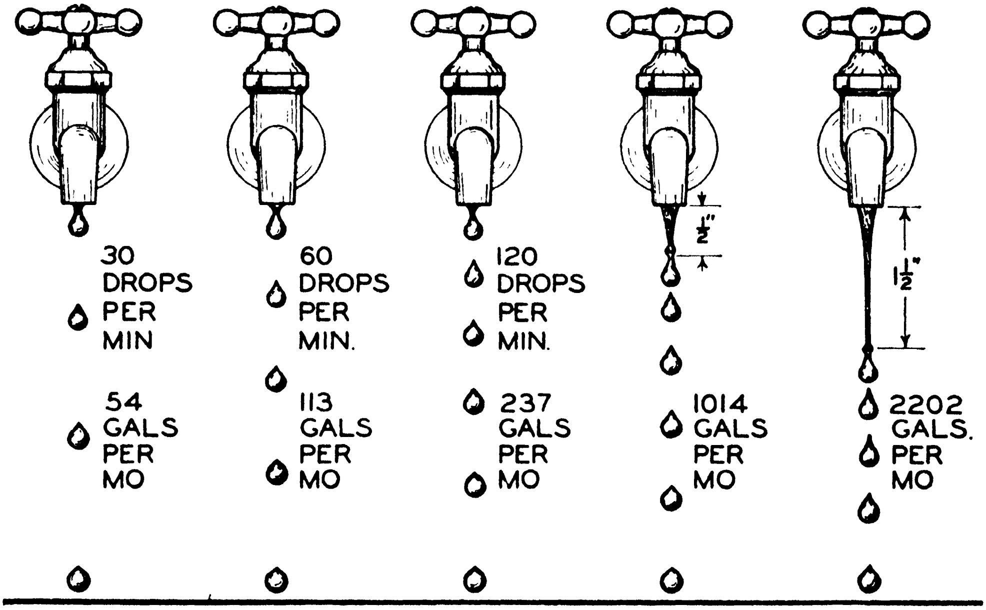


Figure 7–1.—Showing an average loss of water from leaking faucets over a period of one month.

Figure 7–1 shows an average loss of water from commonly used types of faucets at five different rates of dripping. The figures shown will not necessarily apply to any particular faucet because the size of drops varies widely with different faucets. However, from these average figures a rough estimate can be made as to the losses from an average group of faucets.

As stated above, in the case of a leaking hot-water faucet the loss of heat may be quite considerable. If the water is being heated by the house-heating plant, this will not necessarily increase the total cost of fuel for the house as a whole except during the summer. However, if the water is being heated by a device other than the house-heating plant, such as an electric or gas water heater, or even a coal heater, the water-heating costs may be increased materially. For example, with an automatic electric water heater set to heat the water to 140°F. an average of 1 kwhr. is consumed for every 3½ to 4 gal. of water heated. Assuming a heater with a high efficiency which will use 1 kwhr. for every 4 gal. of water, the additional energy required because of hot-water faucets leaking at the rates shown in Fig. 7–1 would be as follows:

Faucet leaking 30 drops per min.....	13.5 kwhr.
Faucet leaking 60 drops per min.....	28.2 kwhr.
Faucet leaking 120 drops per min.....	59.2 kwhr.
Faucet leaking ½ solid stream......	253.5 kwhr.
Faucet leaking 1½ solid stream......	550.5 kwhr.

If the electric rate for the above heater were 1½ cents per kwhr., the additional cost for heat due to the leaking faucets would be as follows:

	Additional cost per mo.	Additional cost per yr.
30 drops per min........	$0.20	$ 2.43
60 drops per min........	0.42	5.04
120 drops per min........	0.89	10.68
½ drop solid stream....	3.80	45.60
1½ drops solid stream....	8.26	99.12

Faucet washers can be purchased for 10 cents per dozen. New faucets can be purchased for as little as 75 cents.

It is obvious from the above figures that the little time and money spent repairing faucets yield good returns.

Supplies needed:

One or more leaky faucets.
An assortment of faucet washers.
An assortment of packing material.
An assortment of washer screws.

Tools needed:

A screw driver.
A 12-in. monkey wrench.
A piece of cloth for the jaws of the wrench to protect the finish of the faucet.
Sometimes a faucet reseating tool is necessary.

Procedure:

1. Examine the faucet to see where the leak is. If water is leaking at the spout the trouble is due either to a damaged washer or a damaged seat, or both. If the faucet leaks around the stem when open, the trouble is with the stem packing. See Figs. 6–2 6–3, and 6–4 for cross-sections of faucets.
2. After locating the leak, shut off the water.
3. Take the faucet apart and repair the worn or damaged part. If the faucet is chromium or nickel plated, use a cloth on the jaws of the wrench to protect the finish on the faucet. If the leak is at the washer, the washer should be renewed. In modern practice a composition washer made of asbestos and rubber is used on both the hot- and the cold-water faucets. A pure rubber washer should not be used on the hot-water faucet because it will soon be destroyed by the heat.

Faucet washers are made in the form of a flat disc as shown in Fig. 7–1, *A*, or with one side beveled as shown at *B*. The beveled washer is generally used for repair on old faucets as it will make a tighter fit if the seat is slightly worn or damaged. If the old washer is a flat disc type it may possibly be continued in service by turning it over.

Sometimes the screw which holds the washer in place corrodes to such an extent that it is impossible to remove it without destroying it. Frequently the screw will break off at the base of the washer. In such an event the end must be drilled out and a new screw used for repair.

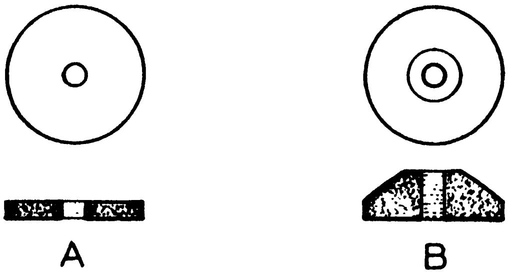


FIGURE 7–2.—Two types of faucet washers; at *A*, a flat disc type; at *B*, a beveled type.

If the leak is due to a damaged seat, the seat will have to be recut or renewed.

If the seat is non-renewable a new seat may be cut with a faucet reseating tool or the old seat may be reamed out, the opening threaded, and a renewable seat installed.

If the faucet has a renewable seat, and many of the better-grade faucets do, it will be necessary only to replace the old seat with a new one. As a rule a new washer and a new seat in a faucet make the old faucet function as well as a new one.

If the leak is at the stem, the stem packing should be renewed. Some faucets require a special packing, but for most a few turns of a candle wicking lubricated with vaseline or petrolatum is sufficient. The candle wicking can be lubricated by drawing it through a quantity of lubricant held in the fingers.

The wicking should be wound around the stem between the packing nut and the packing washer as shown in Figs. 6–2 and 6–4.

After the faucet has been repaired, re-assemble it and turn on the water to test it.

On fuller faucets the ball instead of the washer is renewed or tightened.

On the ground key type the key is tightened by means of the nut at the bottom. Ground key faucets should be kept lubricated to prevent wear.

QUESTIONS

1. Explain how to locate leaks on faucets.
2. Why does a faucet leak at the stem only when the faucet is open? Would this apply to valves also?
3. What type of washer is best for repairing old faucets?
4. What are mixing faucets and where are they used?
5. Give three reasons why leaking faucets should be repaired.
6. Assuming that an average family uses 300 gal. of hot water per month, what percentage of this amount would be wasted at each of the five leaking faucets shown in Fig. 7–1?

JOB 8

MAKING A JOINT IN LEAD PIPE

Probably the best type of joint in lead pipe is a "wiped" joint. A wiped joint requires special equipment and a great deal of skill to make; therefore not everyone is able to make a joint of this type. In lieu of a "wiped" joint, lead pipes can be joined by means of a union. A special "lead union" can be purchased or an ordinary gasket-type union can be used by cutting away the gasket collar.

Materials needed:

Two lengths of lead pipe at least 6 in. long.
A "lead union" or a gasket-type union of the same size as the lead pipe.

Tools needed:

A jack knife.
A ball pean hammer.
A lead flanging tool, if available.
Two 14-in. pipe wrenches (larger wrenches if the union is larger than 1 in.).
If a gasket union is used a hack saw and a vise will be needed for cutting the gasket collar and a round file for smoothing the inside edge of the cut.

Procedure:

1. If a gasket union of the type shown in Fig. 8-1 is used, the first step is to place the flanged end of the union in a vise and cut the gasket collar off with a hack saw.
2. With the file, smooth the inner edge of the cut.

3. With a hack saw, square the ends of the lead pipe to be joined.

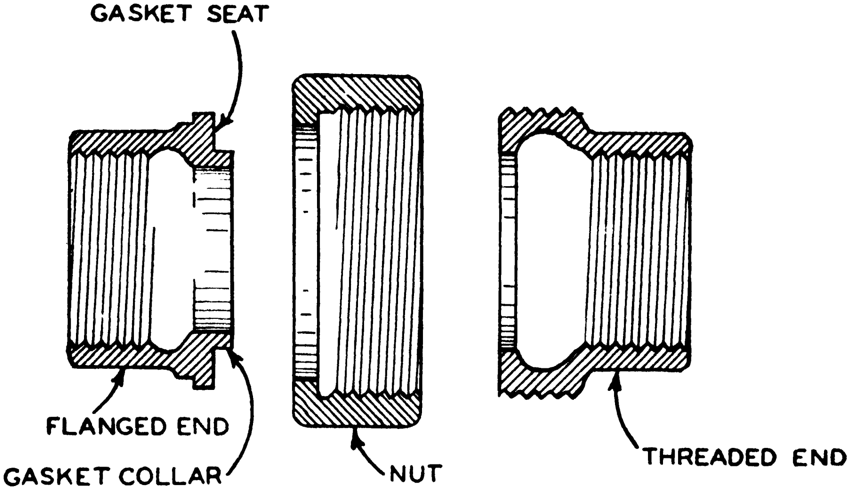


FIGURE 8–1.—Cross-section of a gasket type of union.

4. Place the lead pipe through each side of the union until it projects through ¼ in. If the gasket type of union is used the lead will have to be whittled down on the outside to permit it to pass through the union.

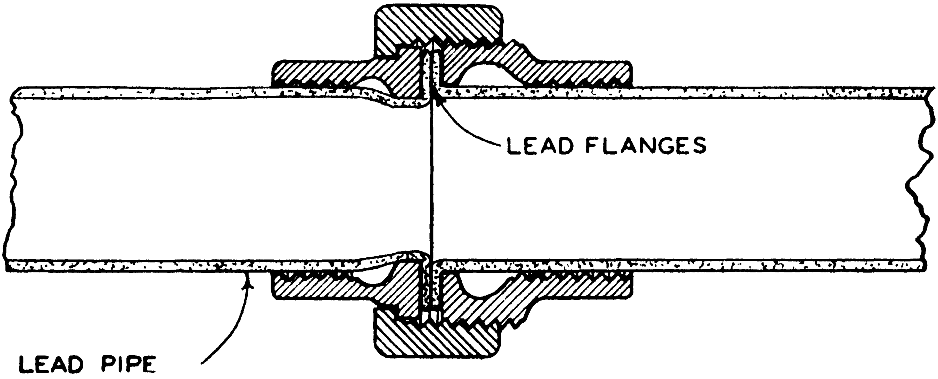


FIGURE 8–2.—Cross-section of lead pipe joint made with a union.

5. With the ball pean hammer, flange the lead over as shown in Fig. 8–2. A special flanging tool should be used for this purpose if one is available.

NOTE: If the other ends of the lead pipe are attached the union nut must be placed over the pipe before the flanged side of the union is installed.

6. Bring the two sides of the union together with the nut until the joint is water-tight.

7. Test for leaks if possible. If the joint is to be covered up under a floor or in a wall the joint *must* be tested before it is covered.

QUESTIONS

1. What are the relative merits of the two methods of making joints in lead pipe?

JOB 9

MAKING A JOINT IN COPPER TUBING

Reference: Chapter VI, pages 261–262.

When using copper tubing in building a plumbing system it is necessary to make joints where the tubing is to be branched and where it is to be connected to fixtures or iron pipe.

Two or more pieces of copper tubing may be joined by means of (1) compression copper fittings (for soft tubing) or (2) by sweating (soldering) the pieces together (for hard tubing). Copper tubing may be joined to iron pipe by means of copper-to-iron adapters.

Part A of this job gives instructions for making a joint with compression copper fittings and Part B for "sweating" a joint.

A. MAKING A JOINT WITH COMPRESSION COPPER FITTING

Tools needed:

One hack saw.
One round file.
One ½-in. flanging tool.
One hammer.
Two 10-in. crescent wrenches or monkey wrenches.

Materials needed:

A few feet of ½-in. medium (L) copper tubing.
One ½-in. threaded compression-type copper coupling or copper-to-iron union.

Procedure:

1. With a hack saw cut the end of the tubing off square.
2. With the file ream the inside of the tube and clean the in-

side to clear away sharp edges. Clean the filings from the tube. These filings if not removed may find their way to the faucets where they may be imbedded in the washers, causing leaks.

3. Place the sleeve nut over the end of the tubing as shown in Fig. 9–1.

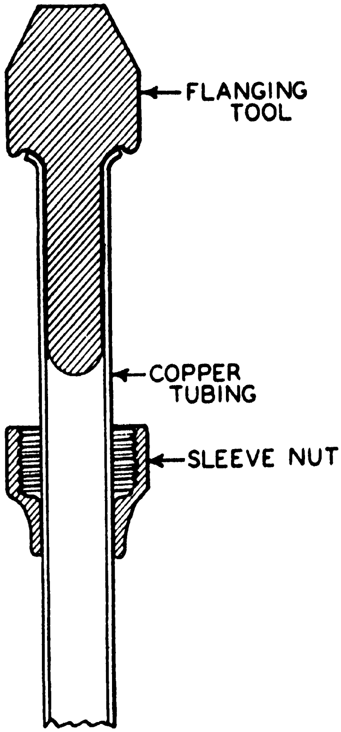


FIGURE 9–1.—Cross-section of copper tubing with flanging tool and sleeve nut in place.

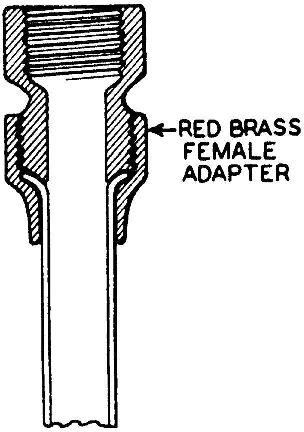


FIGURE 9–2.—Cross-section of copper-to-iron union joint complete.

4. Oil the shank of the flanging tool. Insert it in the end of the tubing and strike with a hammer until the flange has spread to fill the undercut of the flanging tool. See Fig. 9–1. Hold the tubing near the end when pounding to prevent bending.

5. Remove the flanging tool. Place a drop of oil in the threads of the sleeve nut. Screw the flange nut up tight on the body of the fitting with wrenches.

6. Test for leaks. As the sleeve nut is screwed up tight the soft

copper of the flanged tubing is pressed to conform to the shape of the end of the fitting, as shown in Fig. 9–2, thus serving as a gasket to make the joint water tight.

B. MAKING A SWEATED (SOLDERED) JOINT IN COPPER TUBING

Materials needed:

One length of ½-in. hard copper tubing.
One ½-in. sweat fitting.
Soldering flux or
Wire solder with acid core.

Tools needed:

One hack saw.
One piece of 00 steel wool.
One blowtorch.
One small paint brush.

Procedure:

1. Start the blowtorch.
2. Be sure the end of the tubing has not been dented. If the tubing has been cut with a hack saw, be sure that there are no burrs on the end.
3. Clean the outside of the end of the tubing and the inside of the fitting with 00 steel wool.
4. Apply a thin coat of soldering flux on the outside of the tube and on the inside of the fitting.
5. Place the fitting over the end of the tube as shown in Fig. 9–3.

NOTE: These joints can be soldered in any position as capillary attraction will carry the solder to place.

6. With the blowtorch heat the joint until the flux begins to "fry." Move the flame back and forth along the joint to heat it evenly. Be careful not to set fire to the building.
7. When the flux begins to "fry" touch the end of the wire

solder to the joint and hold it there until a drop of solder melts off and runs into the joint. When solder shows all the way around the joint seam, the job is complete.

8. Brush off surplus solder with paint brush.
9. Allow to cool.
10. Test for leaks.

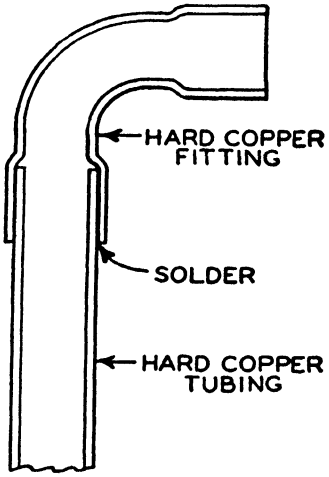


FIGURE 9–3.—Cross-section of soldered joint in hard copper tubing.

QUESTIONS

1. Under what conditions would you use soft copper tubing? Hard copper tubing?
2. Under what conditions would you use compression-type fittings? Sweated fittings?
3. What part does the flange on the end of tubing play in making a tight joint?
4. Name the steps in making a sweated joint.
5. Is copper tubing satisfactory for all kinds of water?

JOB 10

INSULATING PIPES

Reference: Job 11, page 51 and Chapter VI, pages 245, 246, 247, and 253.

Pipes are ordinarily insulated with tubular pipe covering which is made of asbestos, felt, or cork. The most common material used in domestic plumbing is air cell asbestos. The tubes are 3 ft. long and may be had in thicknesses from ½ in. to 3 in., usually designated as 2, 3, 4, 5, or 6 ply. Each ply is about ¼ in. thick. Walls of the tubes are constructed of layers of corrugated sheet asbestos with small dead-air spaces. It is these dead-air spaces that give the tubing its insulating value. For this reason the tubing should not be crushed. The tubing can be had in colors if desired.

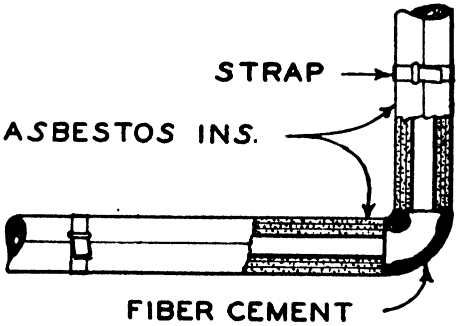


FIGURE 10–1.—An insulated pipe and an elbow insulated with asbestos fiber.

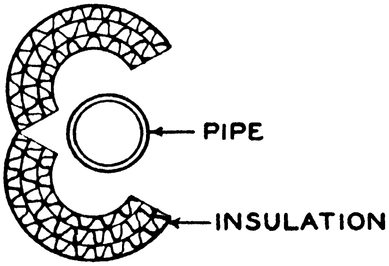


FIGURE 10–2.—Cross-section of pipe with air-cell insulation being placed over it.

The tubing is split in half parallel to the long axis, as shown in Fig. 10–1, so that it may be opened up for installing over the pipe, as shown in Fig. 10–2. The tubing is covered with cloth or paper which serves as a hinge on one side of the split. When installed, it is held in place by pasting or metal straps, or both. The most recent practice is to use asbestos paper-covered tubing and secure it with straps only. See Fig. 10–1.

For odd lengths, insulating tubing may be cut with a hand saw or a jack knife. Although molded asbestos covers can be bought for elbows, tees, and other fittings, it is common practice to insulate fittings with asbestos fiber and cement compound, mixed with water to form a paste. The paste is applied by hand and smoothed with a trowel.

Air cell asbestos is not recommended for cold-water-supply pipes because condensation in the summer time may wet the asbestos and destroy its insulating value. A felt pipe covering called "anti-sweat" covering is generally used for insulating cold-water pipes. In case "anti-sweat" covering is not available, the air cell asbestos can be waterproofed by wrapping it with tarred roofing paper held tightly in place with copper wire.

QUESTIONS

1. What pipes in a farm plumbing system would you insulate?
2. What types of insulation are available?
3. If a hot- and cold-water pipe were run side by side, which pipe would freeze first? Why?
4. Explain how to insulate cold-water-supply pipes.

JOB 11

THAWING FROZEN PIPE

There are four common methods of thawing frozen pipes: (1) by means of hot water, (2) by means of steam, (3) by means of a blowtorch, and (4) by means of an electric current. The first three are effective where the pipe is exposed, but are difficult to use on underground or otherwise enclosed pipe. Electric current is commonly used on underground and enclosed pipes.

A. Thawing with hot water:

1. Open a faucet or valve on the frozen line so that pressure from expansion will be relieved, and so that water will flow to clear the pipe when the frost has been removed.
2. Wrap the pipe throughout the frozen length with cloth which has been wet with warm water. See Fig. 11–1.
3. Pour hot water on the cloth from one end to the other until the ice is melted and the pipe is clear.

B. Thawing with a blowtorch:

1. Open a faucet or valve on the frozen line to allow for expansion and to allow water to flow when the pipe is cleared.
2. Start at the faucet or valve end of the frozen section and heat the pipe with the torch flame, moving the flame back and forth along the pipe for a foot or two at a time. Heat the pipe gradually in this manner throughout its frozen length until water flows freely.

Caution: Do not hold the torch to the pipe at one place too long as this may generate steam between two sections of ice and cause a dangerous explosion. *Also be very careful not to set fire to the building.*

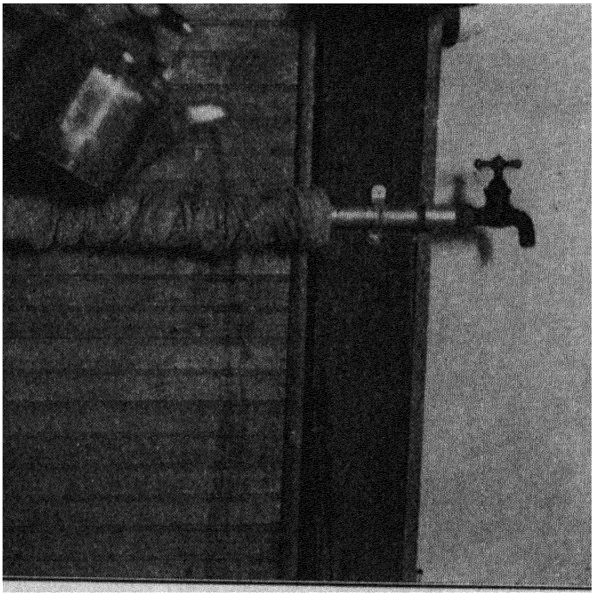


FIGURE 11–1.—Thawing a frozen pipe with hot water.

C. Thawing pipes with steam:

In places where it would be dangerous to use a blowtorch the steam method is very satisfactory.

For this operation some means of generating steam is necessary. Plumbers usually do this in a small tank set over a fire pot as shown in Fig. 11–2. The tank must be equipped with a blow-off valve for safety and should have a steam pressure gauge to indicate when ready for use.

Attached to the tank through a hand valve is a length of hose by means of which the steam can be plied on the pipe. The steam can be plied along the outside of the pipe at the frozen portion as with a blowtorch, or, if the pipe is larger than the hose and one end is open, the hose may be run through the pipe to the ice as shown in Fig. 11–3.

To operate: (1) fill the tank about one-fourth full of water;

(2) close the hand valve; (3) set the tank with water over the fire pot or other source of heat and let stand until 4 or 5 lb. of steam pressure has been developed; (4) open a faucet or valve on the frozen pipe line; (5) beginning at the open end of the frozen length ply the steam back and forth until the ice is melted; or, extend the hose up the pipe from an open end until the hose strikes the ice, then turn on the steam.

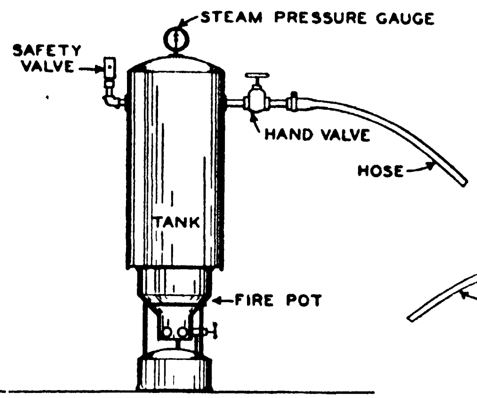


FIGURE 11-2.—A steam generator suitable for use in thawing frozen pipes.

FIGURE 11-3.—The steam hose may be extended up large sized pipe to the ice.

If the thawing is to be done at some distance from the tank it may be necessary to install a length of pipe and a valve at the end of the hose for convenience in controlling the steam. The valves used in this system should be globe valves with ground seats.

If no fire pot is available the tank may be heated in one of several other ways, such as on a stove, on a kerosene burner, a wood or coal fire, on an electric element, or on a forge.

D. Thawing pipes with electric current:

Power-line current may be used for this job if available. If power-line current is not available, portable gas-engine-driven generator sets such as electric welding outfits, may be substituted.

Regardless of the source, the current must be of relatively high amperage in order to produce heat in the pipe. As the resistance in pipe (copper tubing especially) is very low, a low voltage may be used. To obtain this from a power line, a step-down transformer is necessary. When generator sets are used, the voltage and amperage are regulated from the generator itself.

Many power companies have step-down transformers for the special purpose of thawing pipes. The services of these may be obtained if power-line current is available on the place.

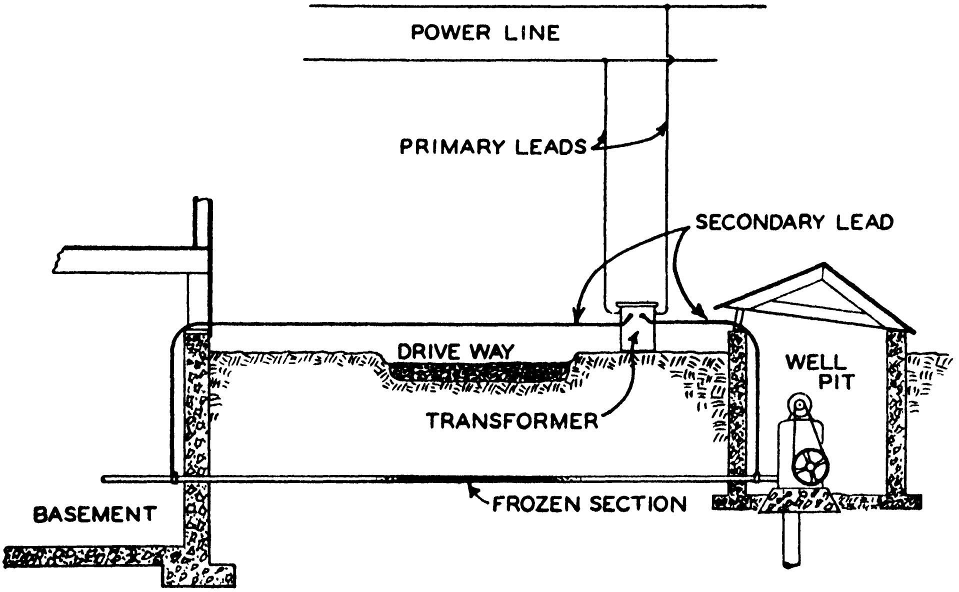


Figure 11–4.—A method of thawing a frozen pipe with electric current using a power line as a source of current.

Procedure:

A. Using transformers:

1. Connect the primary leads of the transformer to a source of current. See Fig. 11–4.

2. Connect the secondary leads of the transformer to the pipe, one on each side of the frozen section as shown. The leads should be tightly clamped to the pipe.

3. Open a faucet or valve on the frozen line.
4. Turn on the current and leave it on until water flows freely.

B. Using a generator set:

1. Connect the leads from the generator to the pipe in the manner shown for the secondary leads of the transformer.
2. Open a faucet.
3. Start the generator and allow current to flow through the pipe until water flows freely.

Wherever possible, additional protection should be given a pipe that has been frozen to prevent its freezing again. Pipes are very likely to burst if frozen solid, especially if they have been stretched by a previous freezing. Hot-water-supply pipes are more likely to freeze than cold-water pipes, because heating the water removes the air from it.

Exposed pipes and pipes in walls may be protected by wrapping with insulating material and protecting from cold drafts. Underground pipes may be protected by lowering the pipe below the frost line or by filling over the pipe to raise the frost level.

QUESTIONS

1. What four methods are commonly employed to thaw frozen pipes?
2. Which method is best for thawing underground pipes? Why?
3. When using electricity for thawing pipes, why do you need high amperage? Low voltage?
4. What are the suitable sources of current for thawing pipes?
5. What precautions should be taken with a frozen pipe after it has been thawed out?

JOB 12

REPAIRING A BROKEN PIPE

The best method of repairing a pipe is to replace it with a new one. It sometimes happens, however, that a pipe, not easily removed, breaks owing to rust, strain, or freezing.

If the break is in the nature of a split or a small hole, and the pressure on the water is not over 5 or 6 lb. (as might be the case in a heating system) an emergency repair may be made by shutting off the water, painting the pipe with lead paint, and then wrapping with friction tape. The paint should be allowed to dry before turning on the water pressure.

For a more permanent repair and for high pressures, saw out the broken section of pipe and replace with new pipe using a union for re-connection.

To repair with new pipe and a union:

Tools needed:

Hack saw.
Thread cutter.
Pipe wrenches.
Paint brush.

Materials needed:

New pipe of same length as broken one.
Union.
Plumber's dope.

Procedure:

1. Shut off the water.
2. With a hack saw, cut the leaky pipe in two at a convenient location.
3. Remove the two pieces of the leaky pipe.
4. From two pieces of new pipe joined with a union, make up a replacement unit of the same length as the old piece of pipe.

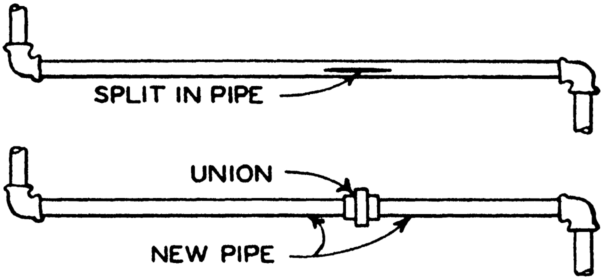


FIGURE 12–1.—A broken pipe repaired with new pipe and a union.

5. Screw each piece of the new pipe in place separately and then join them with a union. See Fig. 12–1.
6. Turn on the water pressure and test for leaks.

QUESTIONS

1. What are some common causes of leaking pipes?
2. Give a definition of a union.
3. Under what conditions could you repair a pipe with paint and friction tape?

JOB 13

CLEANING OUT TRAPS AND DRAIN PIPES

References: Chapter VI, page 245.

Traps:

In every home where there is a complete plumbing system, there are usually six traps which may need cleaning out occasionally.

The traps are located as follows (see Fig. 99):

1. In the toilet bowl.
2. In the floor near the bath tub.
3. Under the lavatory.
4. Under the kitchen sink.
5. Under the laundry tubs.
6. On the sewer pipe at a point just inside or outside the house foundation wall.

The function of these traps is to provide a water seal on the drain pipes to prevent sewer gases from escaping into the house.

The toilet trap (Fig. 13-1):

The most common cause of trouble in the toilet trap is the lodging of some object which is too large to pass through the hole. Such things as wads of wrapping paper and small toys are very likely to cause trouble. Sometimes these can be dislodged by means of a toilet plunger. If the plunger proves ineffective, try a sewer, drain, and trap auger. The augers consist of a flexible steel tube, having a hook on one end and a crank on the other. The tube can be forced through traps or other bends in drain pipes, to open them and loosen sediment so that it can be flushed out. If the auger fails it will be necessary to remove the toilet and clean the trap from underneath.

Bath-tub trap:

The bath-tub trap is likely to become obstructed by masses of hair, lint, soap, and other sediment which collects in it from the tub. This type of trap is easily cleaned by taking the cover plate off and removing the material through the top of the trap. See Fig. 13–2.

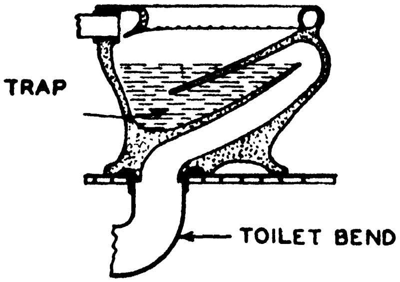


FIGURE 13–1.—Cross-section of a toilet bowl showing the type of trap used.

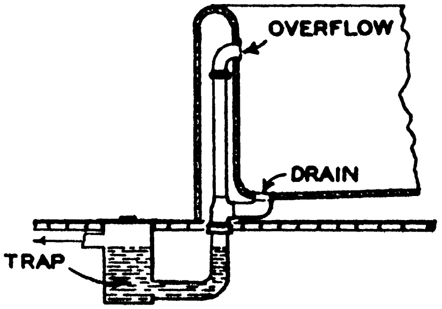


FIGURE 13–2.—A cross-section of a bath-tub trap. This type of trap is called a "non-siphoning" trap.

The lavatory trap:

Lavatory traps are sometimes stopped up by masses of hair and threads which collect on the strainer and extend down into the trap, as shown in Fig. 13–3. This mass of hair and thread will catch other sediment and plug the trap. To clean, take the trap apart and pull the obstructing material out. Sometimes it is necessary to pull some of the hair out from above, using a wire hook.

The sink trap:

The sink trap is likely to become stopped up with grease and food particles which lodge in the grease. Certain solvents can be run through the trap if it is not completely stopped up. These solvents will remove some of the grease and free other particles so that they can be flushed out. A better job can be done, however, if the trap is taken apart and cleaned thoroughly. Figure 13–3 shows one type of sink trap.

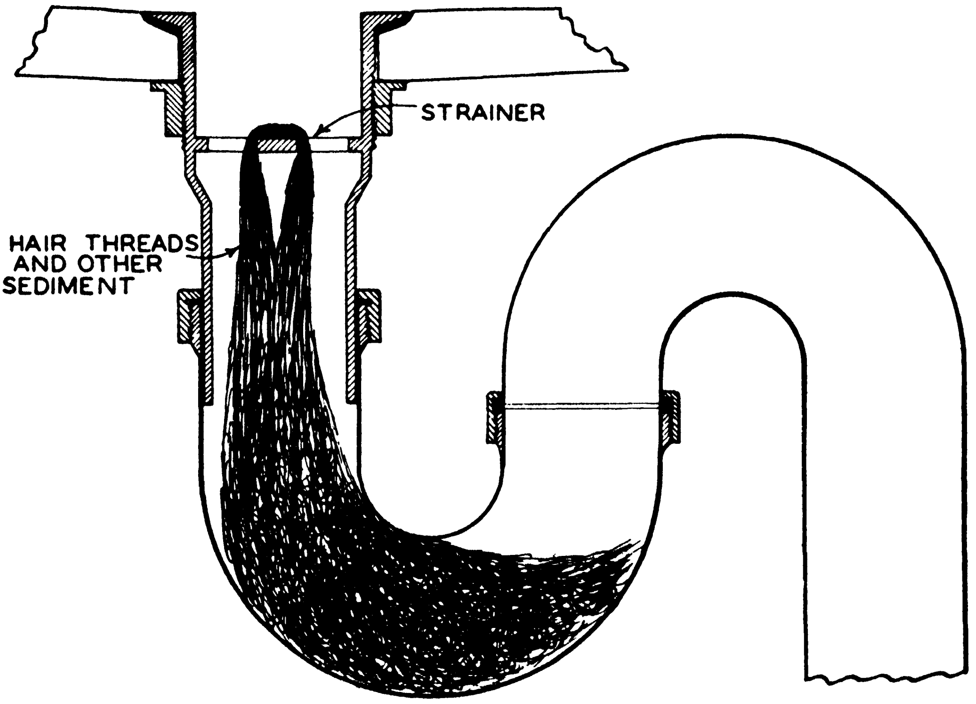


Figure 13–3.—Cross-section of a lavatory or sink trap showing how it may become stopped up.

If the drain pipe from the sink trap is stopped up, it may be opened by means of a sewer, drain, and trap auger, or it can be removed and cleaned by ramming with a stick or by standing it on end and jarring on a block of wood.

The laundry-tub trap will very likely be of the same type as the one on the sink. The method of cleaning would, therefore, be the same as for the sink trap.

Sewer trap:

Sewer traps sometimes become stopped up with sand, pieces of broken dishes, and other heavy material which will collect in the bend of the trap.

These traps can be partially cleaned out with a sewer, drain and trap auger.

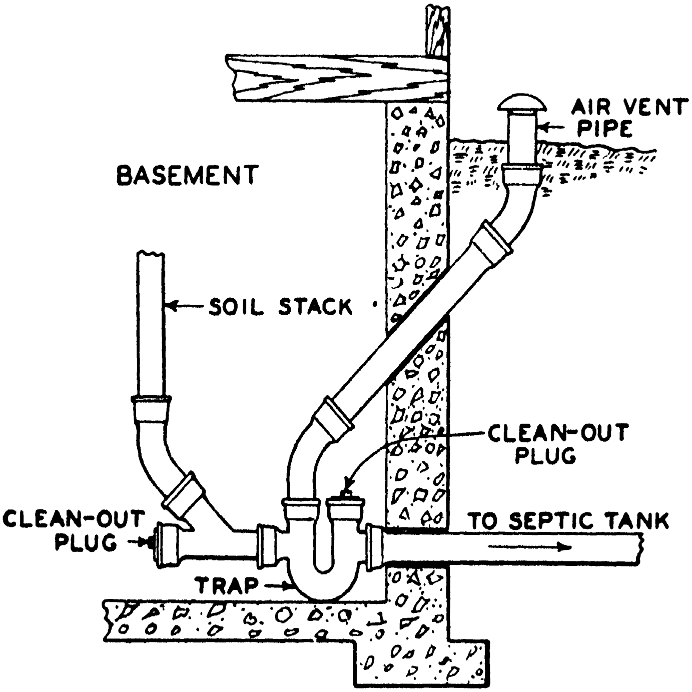


FIGURE 13–4.—A double vent opening running trap in a sewer line. The trap may be cleaned through either of the clean-out plugs.

A thorough job of cleaning can be done by removing the clean-out plugs on the trap (see Fig. 13–4) and scooping out the sediment.

QUESTIONS

1. What is the function of traps?
2. Name two methods of cleaning out a toilet trap.
3. What is the best method of cleaning a sewer trap?
4. Explain how a drain pipe may be cleaned out.

JOB 14

STUDYING AND REPAIRING TOILET TANKS

Materials needed:

A toilet tank, preferably one with a glass window in the side and connected up to water pressure and a drain pipe so it can be operated. See Fig. 14–1.

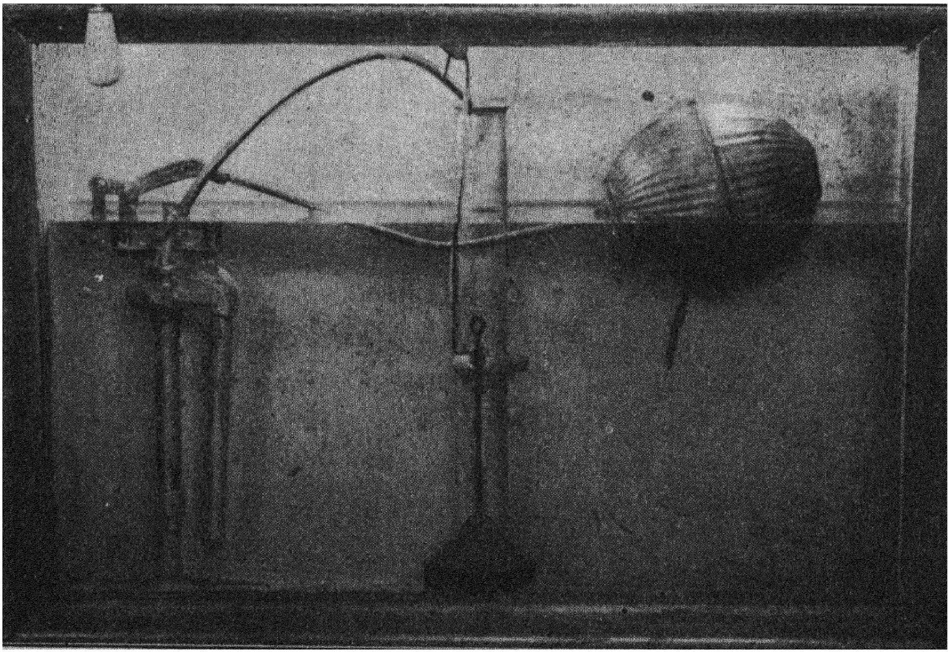


FIGURE 14–1.—A toilet tank with a glass front for classroom study. This arrangement permits easy observation of the action of the various parts.

Procedure:

1. With the tank filled with water operate the trip lever and observe exactly what happens at the flush valve, at the ball cock, and at the overflow pipe.

There are two common types of ball cocks or inlet valves. One is called the low down or submerged ball cock (Fig. 14–2) and the other, the elevated ball cock (Figs. 14–1 and 14–3). Which type is used in the tank you are studying?

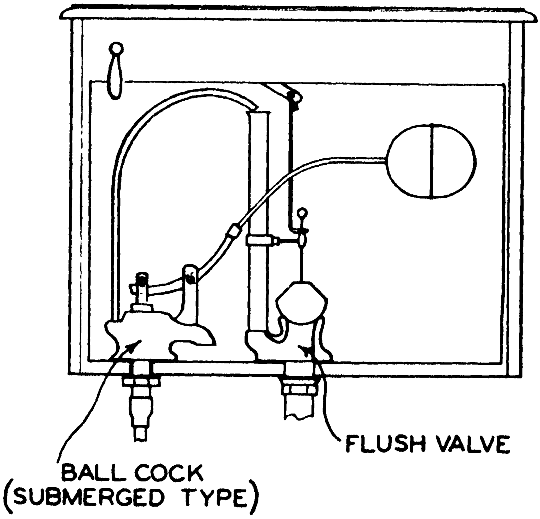


FIGURE 14–2.—A toilet tank with the "submerged" type of ball cock.

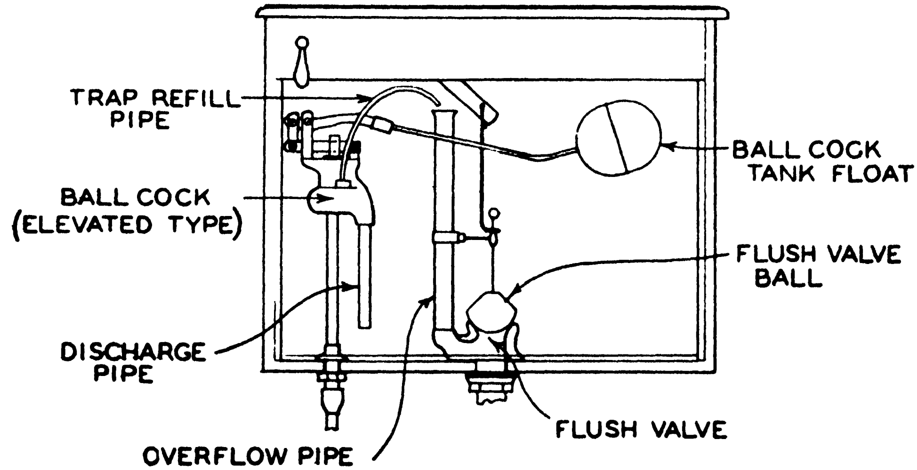


FIGURE 14–3.—A toilet tank with an elevated ball cock.

On the elevated ball cock there is a pipe leading downward from the discharge opening of the cock. This pipe discharges the incoming water below the surface of the water in the tank. This arrangement prevents splashing and reduces the noise of refilling. On the submerged cock this pipe is unnecessary.

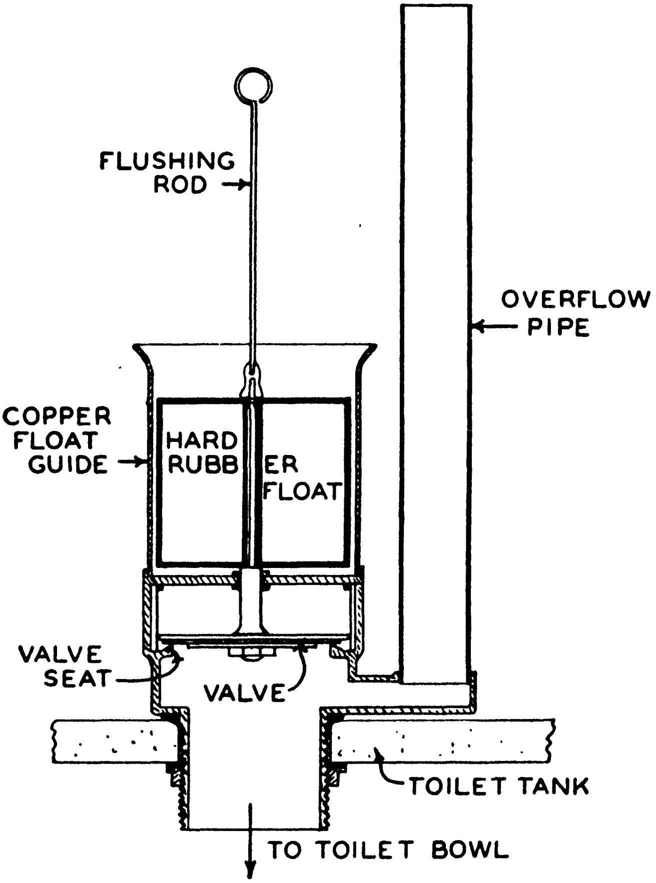


FIGURE 14–4.—Cross-section of improved high-quality flush valve for toilet tanks. Note that the valve is a leather washer held rigidly between two copper plates and that the float is *hard* rubber and is separate from the valve. Note also the guide for the float. This type of guide does not wear or get out of position as does the type shown in Figs. 14–1, 2 and 3.

2. If possible, study a cross-sectioned ball cock. These cocks are usually so designed that the water will pass through with a minimum of noise. How is this accomplished in the cock you are studying?

3. Extending upward from the ball cock is a small copper tube

leading over to the top of the overflow pipe. See if you can determine the purpose of this tube and how it operates? Is there any means of adjusting this tube?

4. From your experience and your study so far, what troubles do you think are likely to develop with this ball cock? How would you remedy each trouble?

	Trouble	*Remedy*
1.		
2.		
3.		
4.		
5.		

5. What adjustment can be made to change the volume of water in the tank?

6. Examine the flush valve.

   a. Of what material is the valve ball made?
   b. Is the valve ball hollow?
   c. What keeps the ball up during the flushing period?
   d. What keeps the ball in place over the valve seat?
   e. What forces cause the ball to reseat in the center of the valve?
   f. How would you renew the ball?

7. From your experience and your study what troubles do you think might develop with the flush valve? How would you remedy them?

	Trouble	*Remedy*
1.		
2.		
3.		
4.		
5.		

8. A relatively new type of flush valve is illustrated in Fig. 14–4. What might be some of its advantages over the other type illustrated in Figs. 14–1, –2, and –3?

9. What are the purposes of the overflow pipe? To what place does it discharge?

10. What is the correct amount of water to maintain in the tank? How may this be determined?

QUESTIONS

1. What are the functions of the following toilet tank parts:

   a. The ball cock?
   b. The refill tube?
   c. The ball-cock float?
   d. The overflow pipe?
   e. The flush valve?

2. If you found the toilet tank leaking into the toilet and discovered that water was going over the overflow, what might be the cause of the trouble?

3. If the tank was leaking and you found the water level low or down to the flush valve, what might be the cause of the trouble?

4. If the water in the trap of the toilet stands at a low level, what may be the trouble?

JOB 15

DETERMINING PIPE SIZES

Reference: Chapter V, pages 201–206.

The loss of head on flowing water in pipes due to friction is a very important consideration in the proper installation of a plumbing system or a pump. This factor is very often neglected entirely, with the result that the flow of water is not satisfactory.

Where long runs of pipe are used, as might be the case with a natural gravity water system or where a pump is located at some distance from the buildings, it is most necessary, for satisfactory operation of the system, to see that the pipes are large enough.

In order to determine the size of pipe to use in any case the following facts must be known:

1. The length, in feet, of the pipe to be used.
2. The number of fittings, valves, and faucets on the pipe line.
3. The kind and condition of pipe used.
4. The rate of flow of water desired in gallons per minute.
5. The amount of head available for forcing water through the pipe.
6. The altitude above sea level.

Length of pipe:

The actual length of the pipe should be measured from the source of water to the point of delivery; i.e., for a suction pipe to a pump, measure from the point in the well where the suction pipe ends to the pump.

Number of fittings, valves, and faucets:

The friction losses through 90° elbows may be considered approximately equal to the losses in 10 ft. of straight pipe of the same size as the elbow. The losses through 45° elbows are approximately one-half the losses through 90° elbows. Therefore, for each 90° elbow allow 10 ft. of straight pipe and for each 45° elbow allow 5 ft. of straight pipe.

The friction losses in valves and faucets vary widely with the type of valve or faucet used. No friction tables are available for calculating these losses. Therefore it is advisable to select pipe large enough to allow some remaining head for overcoming this friction. In the following problems we shall allow 5 ft. of head for each faucet and 3 ft. of head for each globe valve. The loss of head in a gate valve is so small that it may, under ordinary circumstances, be ignored.

Kind and condition of pipe:

The kind and condition of pipe used also affect materially the rate of flow of water. Most of the friction tables for steel pipe are based upon the use of pipe which is 10 or 15 years old. No satisfactory tables are available at present for copper tubing. The friction losses in smooth copper tubing, however, are less than in steel pipe of the same size.

Rate of discharge:

A faucet should ordinarily discharge at the rate of 3 to 5 gal. per minute when wide open. If two or more faucets or other discharge units are to be supplied simultaneously through the same pipe the discharge rate of all the units should be added to obtain the total rate of flow desired.

The amount of head available:

The amount of head available for forcing the water through the pipes is important because the more the head available the more we can afford to loose by friction; therefore, the smaller the pipe necessary. Conversely, with very little head available we cannot afford to loose much of it by friction and must, therefore, use larger pipes.

The elevation above sea level:

The elevation above sea level affects the suction lift of pumps; therefore in figuring size of suction pipes the elevation should be known. In the following problems we shall assume an elevation at sea level.

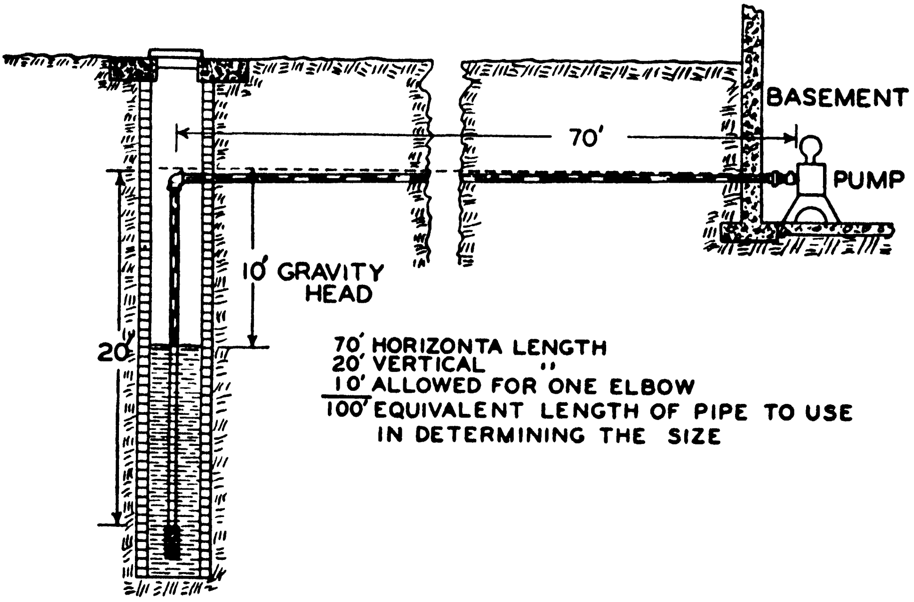


Figure 15–1.—Sketch for Example 1.

For practice in determining pipe sizes work out the solutions to the following problems. Use the friction table, Table I, page 67, in solving the problems.

The solution of such problems will be made easier if sketches are made as illustrated by Figs. 15–1 and 15–2.

Example 1. Determine the size of suction pipe for a pump.
In the case illustrated in Fig. 15–1, we find:

1. The actual length of pipe from the bottom of the well to the pump is

90 ft. There is one 90° elbow for which we shall allow 10 ft. of straight pipe. The equivalent length of pipe is, therefore, 100 ft.

2. The rate of flow is equal to the capacity of the pump, which we shall assume to be 4 gal. per minute.
3. The gravity head is 10 ft. The pump is capable of overcoming 22 ft. of gravity head. This leaves 12 ft. of head which we can use in overcoming friction.

In order to keep the cost down it is desirable to use the smallest pipe that will give full flow. The opening on the pump may be tapped for ¾-in. pipe. Our problem is to determine if this size pipe is large enough to allow the pump to deliver 4 gal. per minute.

Solution:

Referring to Table I, the column on the left, we find rate of flow in "gallons per minute." In this column locate 4 gal. per minute. From this, reading to the right, under ¾-in. pipe we find that the loss of head due to friction is 8.8 ft. in each 100 ft. of pipe. As we have the equivalent of 100 ft. of pipe and 12 ft. of head to overcome friction, the ¾-in. pipe will give full capacity with a little head to spare for overcoming the friction in the strainer, the union, and the check valve.

Example 2. A gravity storage tank is located on a hill back of the house. The tank has an elevation of 50 ft. above the faucet and requires 380 ft. of pipe with two elbows to make the connection. The rate of flow desired through the one faucet is 6 gal. per minute. What size pipe should be used? Refer to Fig. 15–2.

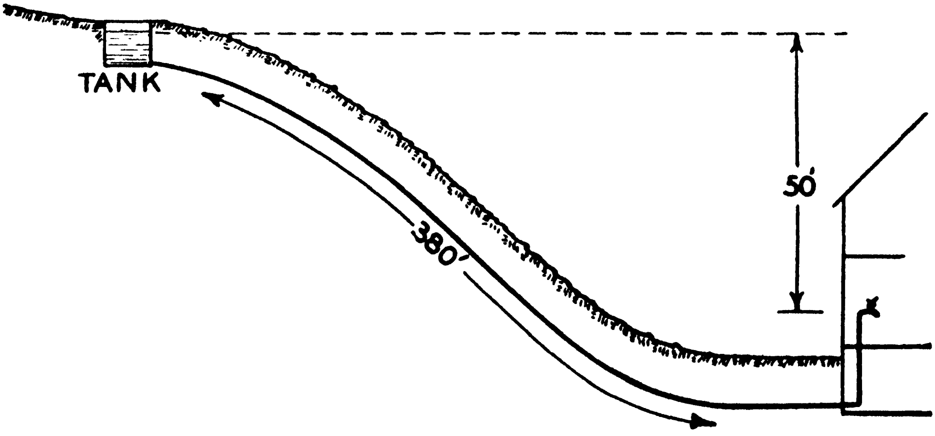


FIGURE 15–2.—Sketch for Example 2.

TABLE I

FRICTIONAL RESISTANCE TO FLOW OF WATER*

The figures in the body of the table below show the frictional resistance in feet of head per 100 feet of galvanized steel pipe for the indicated rates of flow of water in gallons per minute.

Frictional Resistance in Feet of Head per 100 Feet of Pipe

Rate of flow in gallons per minute	Sizes of pipe in inches							
	½″	¾″	1″	1¼″	1½″	2″	2½″	3″
0.5	1.4	0.2	..	..	..	..	..	..
1	5.2	0.7	0.2	..	..	..	..	..
2	18.6	2.5	0.6	0.2	..	..	..	..
3	39.1	5.2	1.2	0.4	0.2	..	..	..
4	..	8.8	2.1	0.7	0.3	..	..	..
5	..	13.3	3.1	1.1	0.4	0.1	..	..
6	..	18.6	4.4	1.5	0.6	0.2	..	..
8	..	31.6	7.4	2.5	1.0	0.3	..	..
10	..	..	11.2	3.8	1.5	0.4	..	..
12	..	..	15.6	5.3	2.2	0.5	..	..
14	..	..	21.0	7.1	2.9	0.7	0.2	..
16	..	..	26.6	9.1	3.7	0.9	0.3	..
18	..	..	33.0	11.3	4.6	1.2	0.4	..
20	..	..	..	13.7	5.5	1.4	0.5	0.2
25	..	..	..	20.6	8.4	2.1	0.7	0.3
30	..	..	..	29.0	11.7	2.9	1.0	0.4
35	..	..	..	38.5	15.5	3.9	1.3	0.5
40	..	..	..	..	19.8	5.0	1.7	0.7
45	..	..	..	..	24.6	6.2	2.1	0.9
50	..	..	..	..	30.0	7.5	2.5	1.0
75	..	..	..	..	..	15.8	5.3	2.2
100	..	..	..	..	..	27.0	8.9	3.7

NOTE: The friction in a 90° elbow is approximately equal to the friction in 10 ft. of straight pipe.

---

* Table compiled by Prof. B. A. Jennings.

This table is compiled from charts prepared by Professor E. W. Schoder according to his formula for fairly smooth pipes as follows:

$$h_f = 0.038V^{1.6} \div d^{1.25}.$$

Solution:

The equivalent length of pipe is equal to the measured length of 380 ft. plus 20 ft. allowed for the two elbows, or a total of 400 ft.

There is one faucet for which we shall allow 5 ft. of head.

The pipe to be used is galvanized steel pipe. Therefore, we can use the friction table shown in Table I.

The rate of flow is 6 gal. per minute.

The amount of head available is 50 ft.

The loss of head due to friction in the pipe, the elbows, and the faucet must not exceed 50 ft. with a rate of flow of 6 gal. per minute. If we allow 5 ft. of head for overcoming friction in the faucet we shall have 45 ft. of head remaining for overcoming friction in the pipe and elbows.

Referring to Table I in the column on the left with 6 gal. per minute flow, we find that the loss of head per 100 ft. of ¾-in. pipe is 18.6 ft. As we have the equivalent of 400 ft. of pipe, the total loss of head will be 18.6 × 4, or 74.4 ft. As this exceeds the 45 ft. of head available, ¾-in. pipe is not large enough. Referring again to Table I, we find that with 1-in. pipe the loss of head would be 4.4 ft. per 100 ft. of pipe. 4.4 × 4 = 17.6 ft. total friction head lost in 1-in. pipe. As we have 45 ft. of head available to overcome the 17.6 ft. of friction head, we find that 1-in. pipe may be used. In fact, a combination of 1-in. and ¾-in. pipe could be used, thus reducing the cost. For example, if 180 ft. of ¾-in. pipe and 220 ft. of 1-in. pipe were used, the total friction loss would be (18.6 × 1.8) + (4.4 × 2.2) = 43.16 ft. total loss of head.

Example 3. From a pressure tank in the basement of a house it is desired to pipe water to a tank in the basement of the barn 250 ft. away. There are no elbows and only gate valves are used. The maximum rate of flow desired for the cows is 18 gal. per minute. The minimum pressure on the water in the tank at the house is 20 lb. per square inch. The barn and house basements are on the same level. What size pipe should be used?

Sketch the installation.

Solution:

1. Length of pipe = 250 ft.
2. Rate of flow, 18 gal. per minute.
3. Head available is 20 lb. pressure per square inch × 2.3 ft. per pound, or 46 ft.

Referring to Table I, at 18 gal. per minute through 1-in. pipe, we find 33 ft. loss of head per 100 ft. of pipe. 33 × 2.5 = 82.5 ft. loss of head in the 250 ft. of pipe. As we have only 46 ft. of pressure head available, 1-in. pipe would not be large enough. Referring again to Table I, we find that with 1¼-in. pipe the loss of head would be 11.3 ft. per 100 ft. of pipe. 11.3 × 2.5

= 28.25 ft., total loss of head. Therefore, 1¼-in. pipe would be large enough or a combination of 1-in. and 1¼-in. pipe such that the total loss of head would not exceed 46 ft.

Problems:

1. A pitcher pump with a suction lift of 23 ft. is to be installed at a kitchen sink to draw water from a well in the yard 60 ft. distant, horizontally, from the sink. The water in the well stands at 20 ft. below the sink. There are two elbows. It is desired to pump water at the rate of 4 gal. per minute. What is the smallest-sized suction pipe that may be used? Sketch the installation.

Ans. 1-in. pipe.

2. A gravity storage tank located in the hay mow of the barn at an elevation of 35 ft. above the house faucet is to deliver water at the house 150 ft. away at a rate of 6 gal. per minute. There are to be 5 elbows in the line. What size pipe should be used to the house?

Ans. 1-in. pipe or a combination of 1- and ¾-in. pipe.

3. A pressure tank in the basement of a house is to supply water to a faucet in the bathroom on the second floor 25 ft. above the tank. Fifty feet of pipe and 5 elbows will be required to reach the bathroom. The desired rate of flow is 8 gal. per minute. The minimum pressure on the tank is 20 lb. What size pipe should be used?

Ans. 1-in. or a combination of 1- and ¾-in. pipe.

JOB 16

STUDYING A PLUMBING INSTALLATION

References: Chapters VI and VII and Job 15.

Materials needed:

Any good household plumbing installation.
Pencil and paper.

PART ONE—THE "SUPPLY" PLUMBING

Procedure:

1. Locate the source or sources of water for the property. Is it from a water main, a well, cistern, spring, stream, pond, or lake?

2. Does the water flow by natural gravity head or is it pumped?

3. If a pump is used, is it of the deep or shallow well type? Is it a reciprocating, centrifugal, or rotary pump or ram?

4. What is used for driving the pump: hand power, gas engine, electric motor, windmill, or water wheel? What horsepower is used?

5. Measure the distance and elevation of the pump from the source and determine if the suction pipe is of the correct size. See Job 15.

6. If a pressure storage tank is used, what is its total capacity in gallons? See Table II.

Estimate or measure the amount of water which could be drawn off between pumpings.

TABLE II

Capacity of Steel Tanks

Diam. Inches	Gals. per Ft. Length	Diam. Inches	Gals. per Ft. Length	Diam. Inches	Gals. per Ft. Length	Diam. Inches	Gals. per Ft. Length
12	5.87	20	16.32	27	29.74	34	47.16
13	6.89	21	17.99	28	31.99	35	49.98
14	8.00	22	19.75	29	34.31	36	52.88
15	9.18	23	21.58	30	36.72	37	55.86
16	10.44	24	23.50	31	39.21	38	58.92
17	11.79	25	25.50	32	41.78	39	62.06
18	13.22	26	27.58	33	44.43	40	65.28
19	14.73						

Courtesy Goulds Pumps.

7. At what pressure range does the pump operate?

8. Can the pressure be changed? If so, how?

9. How much pressure would be needed to force water to the highest faucet?

10. What means is employed for recharging the tank with air?

11. Is there a safety valve on the system?

12. Observe the plumbing fittings and valves used. Are they of the proper type and are they properly installed?

13. Is there any means of softening the water? Is the water hard enough to make softening desirable? (Test with soap solution. See Chapter I, pages 120–122.)

14. If possible follow the cold-water pipes through the building to all the outlets. Note the sizes and kinds of pipe, the location and kind of fittings, valves, and faucets used on this line.

15. Repeat step 14 on the hot-water line.

16. Is the water heated with:

wood
coal

gas
electricity or
oil?

Is the heater automatic?

17. Are any of the pipes insulated? If not, would you advise insulating them?

18. What fixtures are installed on this system? Of what materials are they made?

No.	Fixture	Material
	Sinks	
	Toilets	
	Lavatories	
	Tubs	
	Laundry tubs	

19. Is there a shower bath? If not, could one be installed without much expense? See Job 23.

PART TWO—THE "WASTE" PLUMBING

Procedure:

1. Trace the drain pipes from each fixture to the soil stack. Are any of the traps vented? If so, which ones? If not vented, are non-siphoning traps used?

2. What materials are used for the drains and soil stack?

3. What fittings are used on the drain pipes, drainage fittings or supply fittings?

4. Trace the soil stack from the roof to the sewage disposal system. Where is it vented?

5. Are there any clean-out plugs?
6. What type of sewage disposal system is used?

cesspool
septic tank
sewer main
other

QUESTIONS

1. What is the effect on a pump of using a suction pipe which is too small?

2. How hard should water be to make softening desirable for domestic purposes?

3. Under what conditions is it advisable to insulate the hot-water pipes?

4. List the improvements which you think should be made to this plumbing system.

5. Do you think that the waste pipes are properly vented?

6. What would be the approximate cost of a plumbing system such as this? (Prices may be obtained from a mail-order catalog.)

JOB 17

CUTTING CAST-IRON SOIL PIPE

Reference: Chapter VI, pages 257–259.

In almost any waste plumbing job it is necessary to cut one or more pieces of soil pipe. This is a very simple job but requires patience.

Supplies needed:

A length of cast-iron soil pipe (medium or extra heavy).
A block of wood (2 in. x 4 in.).

Tools needed:

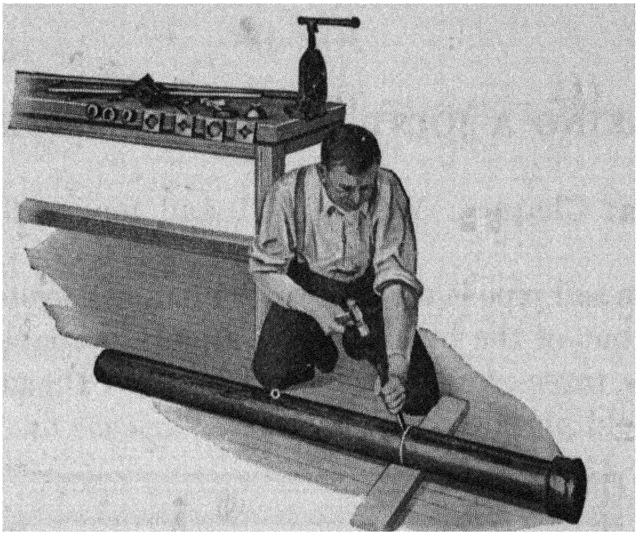
A piece of chalk.
A ½-in. sharp cold chisel.
A ball pean hammer.

NOTE: For cutting light-weight soil pipe, file or cut a groove around the pipe with a three-cornered file or hack saw, and tap lightly with a hammer around the pipe and along the line of the groove until the pipe breaks at the file mark.

Procedure for medium- or extra-heavy pipe:

1. Place the wood 2 x 4 flat on the floor.
2. With chalk, mark around the pipe at the point where it is to be cut.
3. Lay the pipe on the 2 x 4 with the chalk mark over the center of the 2 x 4 as shown in Fig. 17–1.
4. With the cold chisel and hammer cut a shallow groove all the way around the pipe. Lean the chisel toward you, as shown, to throw chips away from you.
5. After the initial groove is cut proceed around and around

the pipe in the same groove until the pipe breaks at the mark. It is not necessary to cut all the way through the pipe because it will break off after you have cut all the way around three or four times.



Courtesy Sears Roebuck and Co.

Figure 17–1.—A method of cutting cast-iron soil pipe.

JOB 18

CAULKING A JOINT IN CAST-IRON SOIL PIPE

References: Chapters VI and VII and mail-order plumbing catalog.

Cast-iron soil pipe is used in waste plumbing systems to carry the waste out of the building. Soil pipe is available in various sizes. Two-, three-, four- and six-inch sizes are the most common for household purposes.

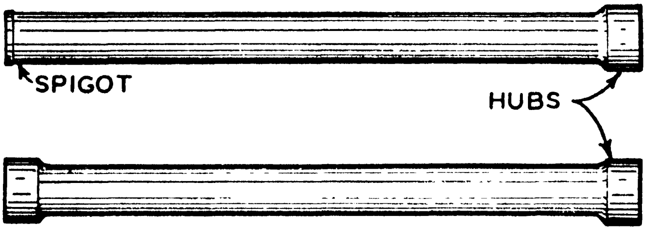


FIGURE 18–1.—Cast-iron soil pipe. Above length has one hub and a spigot. The lower length has two hubs.

Soil pipe is made with a hub on one or both ends, as shown in Fig. 18–1. All fittings also have one or more hubs, as shown in Fig. 18–4. Joints are made by placing the small end or spigot of one piece of pipe in the hub of another and caulking with oakum and lead. When properly done this kind of joint is very tight and strong.

When laid underground, joints can be made with cement mortar or bituminous joint compound, but oakum and lead joints are best because they do not crack or decompose and because they can be made tighter.

Supplies needed:

2 pieces of cast-iron soil pipe of the same size and weight; one piece must have a hub and the other must have a spigot end.

A quantity of oakum.
5 to 10 lb. of lead.
Gasoline fuel for melting pot.

Tools needed:

1 plumber's melting pot, or some other satisfactory device for melting lead in a ladle.
  1 pouring ladle.
A thin stick of hardwood for skimming the lead.
1 right-hand caulking chisel.
1 left-hand caulking chisel.
1 straight caulking iron.
1 yarning iron.
1 asbestos joint runner.

Procedure:

A. For an upright joint:

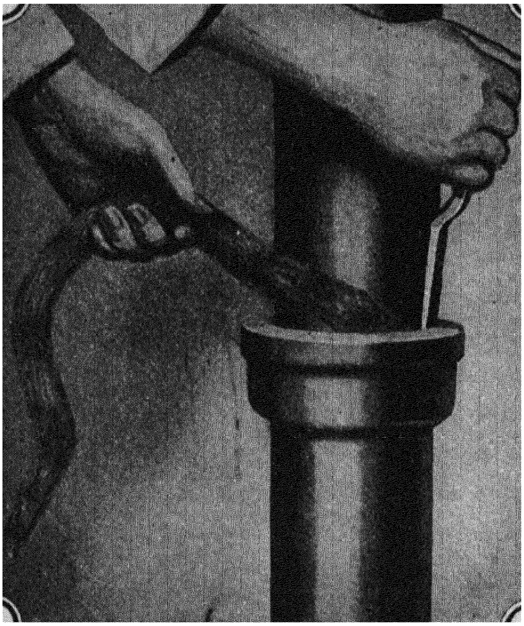
1. The first step is to start the melting pot and put the lead on to melt. The melting pot is started in the same manner as is a blowtorch. Use only clear gasoline in the pot as Ethyl gasoline will clog the torch.

NOTE: If no melting pot is available the lead may be melted by any other available means, such as over a gas burner, in a furnace, or in a forge.

2. As soon as the melting pot is started put the lead in the ladle and place the ladle over the fire. Pig lead or old scrap lead which is free of solder are suitable for this purpose.

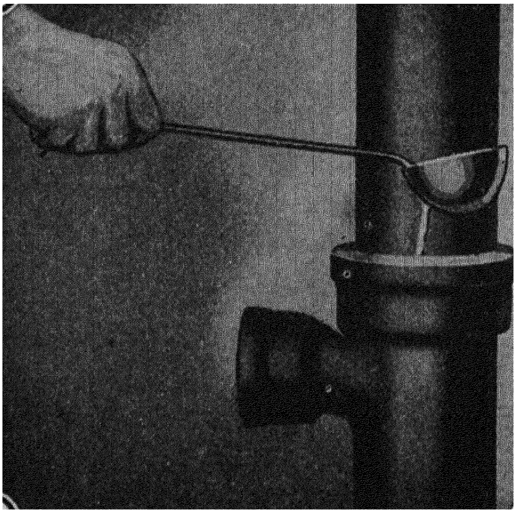
3. While the lead is melting, place the two pieces of pipe together with the spigot of one in the hub of the other, as shown in Fig. 18–2. Be sure that the upper pipe is centered in the hub and that it is securely held in place.

4. Using the yarning iron, pack the hub with oakum to within about ¾ in. of the top. See Fig. 18–2. Be sure the end of the spigot is all the way in the hub, and do not pack the oakum too



Courtesy Sears Roebuck and Co.

FIGURE 18-2.—Yarning the oakum in a joint.



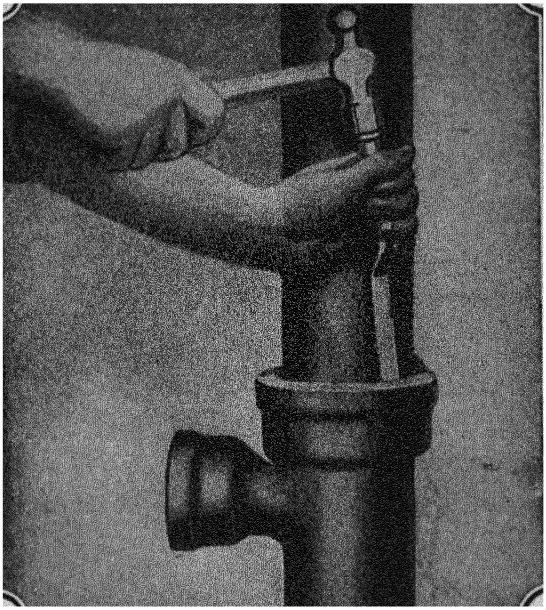
Courtesy Sears Roebuck and Co.

FIGURE 18-3.—Pouring the lead into a joint.

tight as it may be forced through to the inside, where it could cause stoppage.

5. After the lead has melted, skim it with a thin hardwood paddle to remove the foreign substances which float on top. Continue heating the lead until it will char the thin paddle.

6. Carry the ladle to the pipe and, pouring from one position only, fill the hub level full, as shown in Fig. 18–3. Best results are obtained if the entire joint is poured without interruption. If the pouring is interrupted the lead will harden and form a seam with the next pouring.



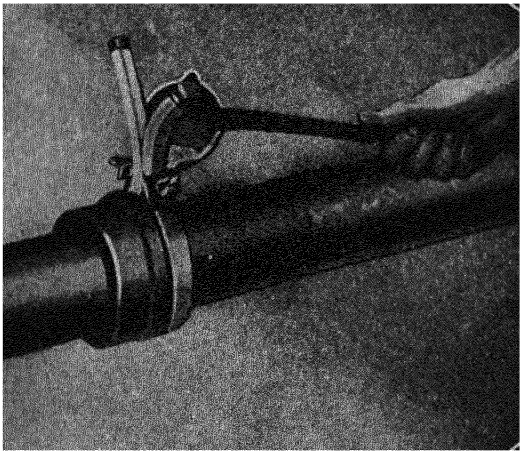
Courtesy Sears Roebuck and Co.

FIGURE 18–4.—Caulking the lead.

7. When the lead cools it will shrink away from the pipe and hub. To make a tight joint the lead must be caulked. On an upright pipe, where there is plenty of room all around the joint, the caulking can be done with the straight caulking chisel. When a joint is in cramped quarters, the right and left hand chisels must be used. Set the caulking chisel in the center of the lead and

strike it light blows with a hammer. See Fig. 18–4. Do not pound the lead down in one place, but proceed around and around the pipe, gradually bringing the whole ring of lead down tight. When the lead is tight cease caulking; otherwise you may crack the hub.

8. Fill the pipe with water to test the joint for leaks.



Courtesy Sears Roebuck and Co.

FIGURE 18–5.—Pouring lead into a horizontal joint.

B. For a horizontal joint:

When a joint must be poured in a horizontal position an asbestos joint runner may be used to hold the lead in place until hard.

1. Start the melting pot as directed for a vertical joint and place the lead on to melt.

2. Pack the joint with oakum.

3. Place the joint runner around the joint, as shown in Fig. 18–5. Be sure that the runner is tight all the way around and that the funnel is pointing toward the hub. After the runner is pulled up tight around the pipe it should be tapped toward the hub with a light hammer. A little asbestos fiber paste or clay chinked around the funnel will prevent the lead from escaping when the joint is nearly full.

4. With the lead at the proper temperature pour it down the funnel into the joint, being careful not to interrupt the flow of lead until the joint is full.

5. After the lead has hardened remove the runner.

6. Cut off the extra lead at the funnel position and caulk tightly as directed for the vertical joint. A hack saw or a cold chisel may be used to cut off the surplus lead.

7. Fill the pipe with water and test the joint.

QUESTIONS

1. Why is an oakum and lead joint the best for cast-iron soil pipe?
2. Would an oakum and lead joint be practical for vitrified tile? Why?
3. What are the common sizes of cast-iron soil pipe and where is each size used?
4. Explain how to prepare the lead for pouring.
5. Explain how to caulk the lead in a joint.

JOB 19

BUILDING A SEPTIC TANK*

Reference: Chapter VII, pages 264–275.

One of the best septic tanks is the reinforced concrete septic tank. These can be purchased ready-made or they can be poured on the premises.

There are a number of satisfactory designs for septic tanks. The one shown here is easy to build.

Figure 99 illustrates in cross-section the type of tank to be built in this job. The size illustrated in this job is large enough for a family of five people.

Supplies needed:

Boards for forms (unmatched ⅞-in. boards).
Six 2 x 4's, 8 ft. long.
4 heavy stakes, 2 ft. long.
Sand, gravel, and cement for a 1:2:4 mixture.
Reinforcing rods or heavy woven wire.
2 straight lengths of vitrified bell-sewer tile for inlet and outlet sewer pipes.
One 4-in. vitrified tile tee for outlet sewer pipe.
2-in. planking for baffles.
Water for mixing cement.
Nails.
Grease, oil, or soft soap for coating form boards.

Tools needed:

A spade.
A cement mixer or mixing board for hand mixing.

*** Measurements and much of text taken from Cornell Extension Bulletin 48, "Sewage Disposal for Rural Homes," by Professors H. W. Riley and J. C. McCurdy.**

Square point shovels.
Pails for water.
Hack saw or pliers for cutting reinforcement.
A heavy 2 x 4 for tamping the concrete.
A plumb bob.
A spirit level.
A 6-ft. folding rule.
A saw.
A hammer.

Procedure:

1. Assemble the outlet sewer tile as shown in Fig. 19–1 and let dry while the forms are being made and the hole is being dug.

2. Build the forms. (Determine the size of tank to be built as outlined in Chapter VII.)

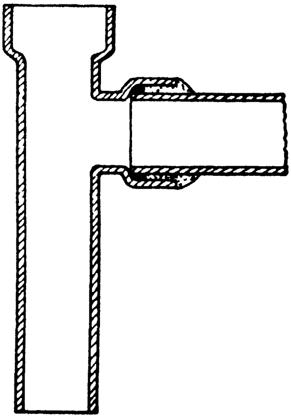


FIGURE 19–1.—A tile assembly ready to be placed in the outlet end of a septic tank.

The forms should be completed and ready to set before the pit is excavated in order that the concrete may be poured as quickly as possible after the pit is formed. This procedure often saves trouble from the earth's caving in and spoiling the outside earth form.

The forms for the covers should be made at the time the main form is made.

The sides of the form should be made first. The boards should be cut with a bevel on the ends, as shown in the detail sketch of Fig. 19–2, to facilitate their removal after the cement has hardened.

In nailing the side boards to the 2 x 4 uprights, *drive the nails through the 2 x 4 into the boards* and leave the heads of the nails sticking out far enough to permit pulling when the forms are to be removed. The ends of the side boards should extend 1/8 in. beyond the edge of the upright as shown in detail sketch.

The end boards should be cut to the width of the tank, minus

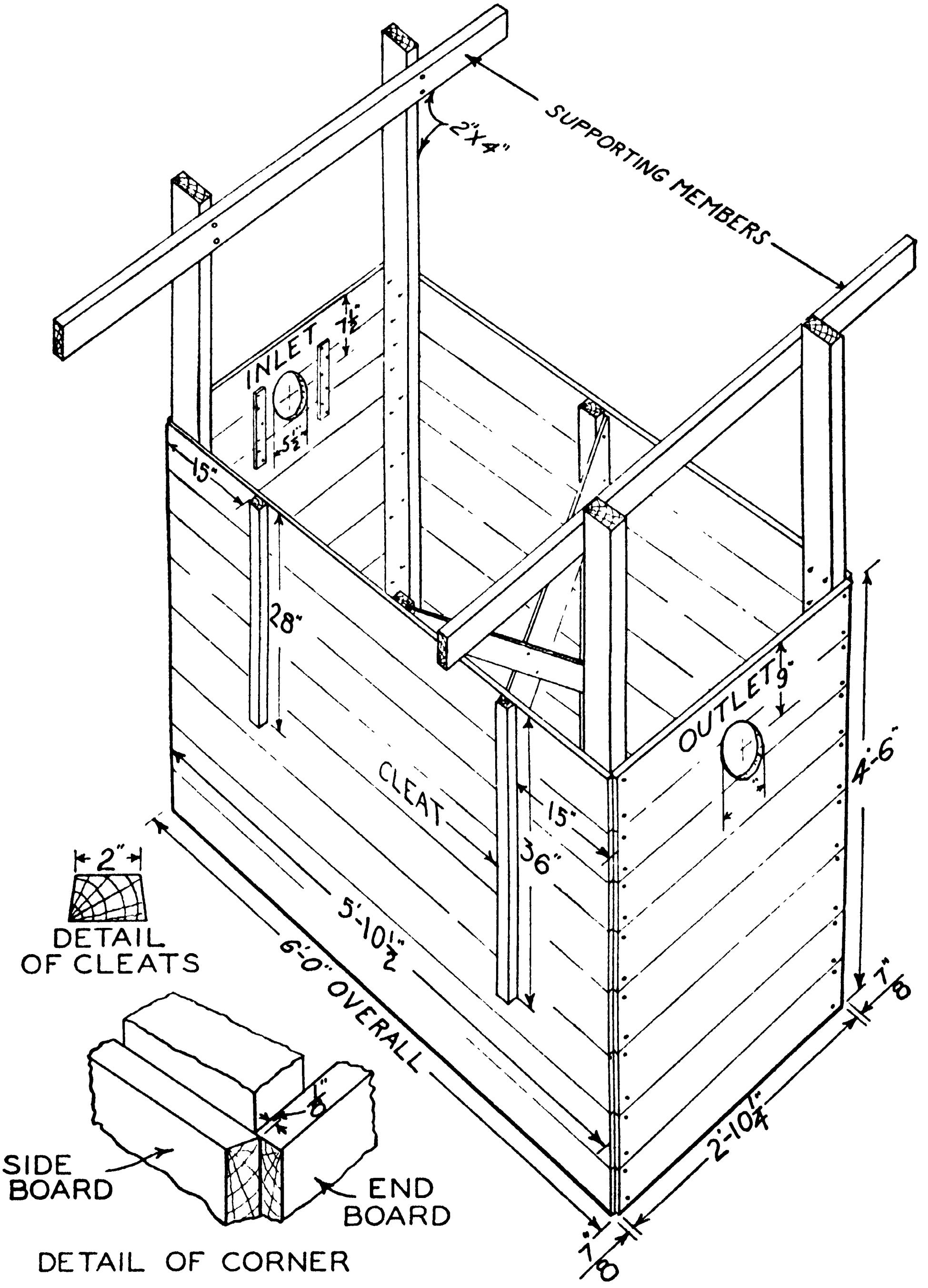


FIGURE 19–2.—Working drawing for the inside form of a septic tank showing the form ready to be placed in the pit. The 2 x 4's at the top of the corner posts are for supporting the form upon posts *P*, shown in Fig. 19–4. They should not be nailed in place until the pit is ready for the form.

the thickness of the two side boards. The ends should be slightly beveled.

Nail the end boards to the sides of the 2 x 4 uprights with small nails.

The holes for the inlet and outlet tiles should be cut in the end boards at this time. The inlet hole should be centered at 7½ in. from the top of the form and the outlet hole at 9 in. from the top, or 1½ in. lower than the inlet.

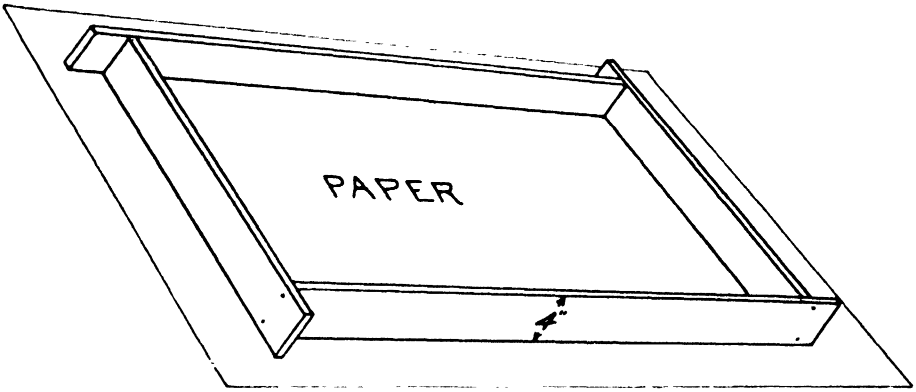


FIGURE 19–3.—Form for cover slabs for septic tank.

Brace the form on the inside as shown.

On the outside surface of the side boards nail beveled cleats to form the grooves in the concrete for the baffle boards. These cleats should be beveled as shown so that they may be easily removed.

Build the forms for the cover slabs. These forms may be a box 4 in. deep with the inside dimensions correct for the tank. See Fig. 19–3. When ready to pour the concrete, lay the form on a piece of paper spread on a flat smooth surface, as shown. The cover should be in two or three pieces to make it easy to handle.

Rings or handles of some kind should be set in the pieces for lifting them up. The cover slabs should be 4 in. thick and well reinforced. If the tank is extra wide or if there is to be a heavy load on top of the covers, the cover slabs should be thicker than 4 in.

3. Locate the place for the septic tank as directed in Chapter VII.

4. Lay out the plan of the pit for the tank.

If the soil is of a type and structure which will "stand up" the dimension of the pit should be the same as the outside dimensions of the tank. See Table VII, page 268. If the soil will not "stand up" an outside form will have to be used and the pit must be large enough to admit this form. For this job we will assume that no outside form is needed.

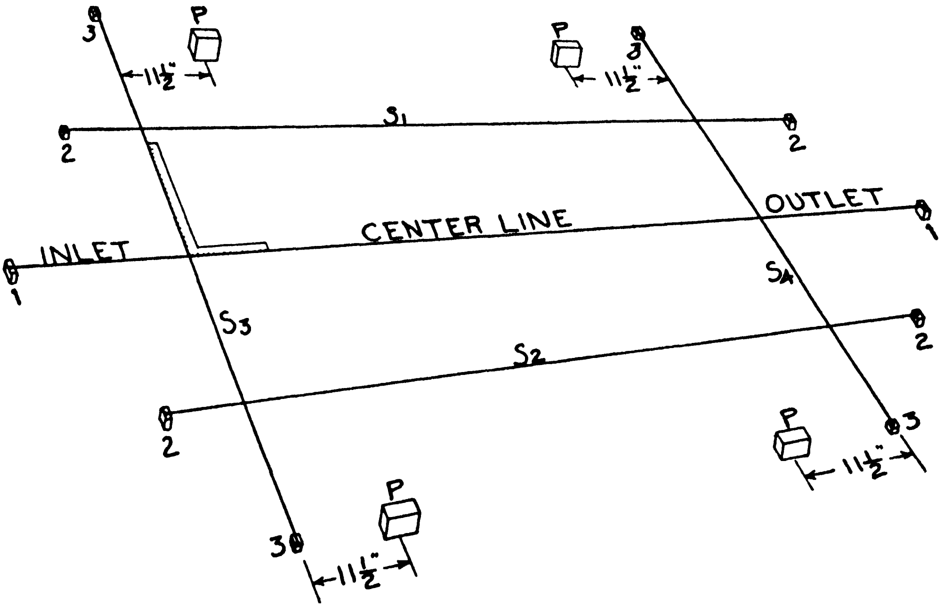


FIGURE 19–4.—An illustration of how to lay out a pit for a septic tank. All stakes should be driven before digging is started to avoid cave-ins.

To mark out the excavation proceed as follows:

a. Drive stakes 1 and stretch a center line over the tank location as shown in Fig. 19–4.

b. At each side of this center line and parallel to it, drive stakes 2 and stretch strings S_1 S_2, to mark the sides of the excavation. For a tank for five people these strings should be 2 ft. from the center line. Drive the stakes for these strings 2 or 3 ft. away from the location of the pit so that they will not be disturbed when digging.

c. Drive stakes 3 and at right angles to the center line stretch strings S_3 and S_4, to mark the ends of the excavation. For a tank for five people these strings should be 7 ft. apart. After strings, S_1, S_2, S_3, and S_4 have been stretched, the center line can be removed.

d. At points *P* drive heavy stakes so that their tops are on the same level. The exact height is not important, but they *must be on the same level.* These stakes are to support the form in the pit.

e. If the slope of the land from the house to the tank is rather steep, establish the grade line for the sewer pipe to the tank as directed in Job 21. This will give the depth at which the tank must be placed.

5. Excavate the pit.

The excavation should be started by digging the trenches for the inlet and outlet sewer pipe first. These trenches should be brought to the exact grade. Under average conditions the bottom of the inlet trench should be 25 to 27 in. below the surface of the ground and the outlet trench 1½ in. lower. These grade lines can be established from the grade line for the sewer or, if land from the house to the tank is practically level, the grade may be established from the straight edge on posts "*P*," as shown in Fig. 19–5.

After the bottom of the trenches are brought to grade the main pit may be excavated.

The depth of the pit can be gauged by measuring down from a straight edge placed on posts *P*, as shown in Fig. 19–5. The length of this measuring stick should be equal to the depth of the pit plus the height of posts *P* above the ground. If the lower 6 in. of the measuring stick is tacked on, as shown, it can be removed later and the longer piece used to gauge the concrete when the bottom of the tank is poured.

6. Pour the concrete.

a. Pour the bottom of the tank first.

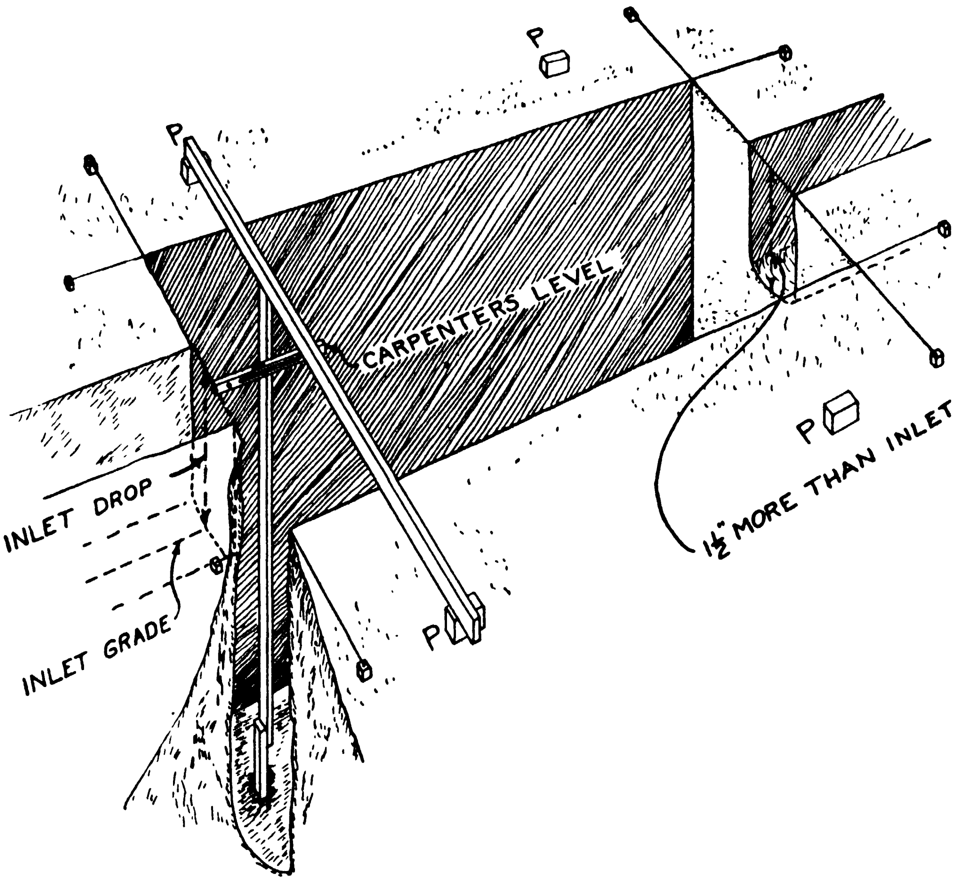


FIGURE 19-5.—A pit for a septic tank, showing how to grade the inlet and outlet trenches and the depth of the bottom.

If a concrete mixer is available the work will be made much easier. If no mixer is available the concrete may be mixed by hand on a mixing board. The cement, sand, and gravel should be mixed dry first and then water added slowly until the cement is wet through. Do not add more water than is needed to make the cement wet, as too much water weakens concrete.

Pour about half the thickness of the bottom, then add the reinforcement. Heavy woven wire fencing of 2- to 3-in. mesh, 3-in. iron rods or metal lath, make good reinforcement. In any case the reinforcement should be bent up at the ends and sides so that it will extend a foot or two up into the end and side walls.

After placing the reinforcement, finish pouring the bottom up to grade.

Tamp the concrete thoroughly to form a compact mixture. The tamping should be continued until water comes to the top of the concrete.

b. Apply to the outside of the form a coat of a mixture of raw linseed oil and kerosene in equal parts, or use old engine oil or soft soap. This will prevent the form from sticking to the concrete.

c. Nail the supporting 2 x 4's to the corner parts of the form. The position of these supports can be easily located by the measuring stick. With the form resting on a board, turn the measuring stick upside down and stand it on the board next to the form. Lay the supporting 2 x 4's on the end of the longer piece of the measuring stick as shown in Fig. 19–6. Nail the support to each corner post at this level, and the bottom of the form should just touch the concrete in the bottom when suspended from posts *P*.

d. Place the form in the pit with the supporting members resting on posts *P*. Be sure that the intake hole is at the end next to the house and that the form is level. If the concrete in the bottom has been carefully leveled, the lower edges of the form should just touch the concrete all the way around.

e. Place the reinforcement in the side and end spaces and pour concrete up to the inlet and outlet openings. Pour 6 to 8 in. of concrete at a time and tamp each layer until water comes to the surface.

f. Set the inlet and outlet tiles in place. Place the tee at the outlet end with the spigot end down as shown in Fig. 99. Be sure that the tiles do not extend into the tank far enough to interfere with the baffle boards. The inlet tile should project through the form about 2 in. The outlet tile assembly should be set so that the bell of the tee opening will set in the concrete as shown in Fig. 99.

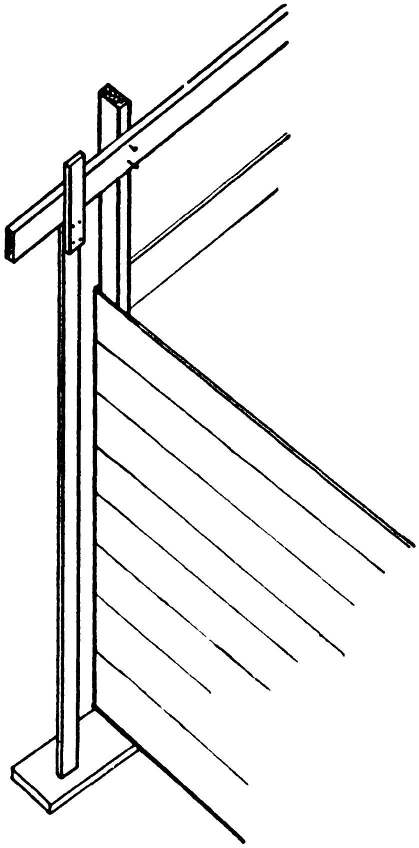


FIGURE 19–6.—Using the measuring stick to gauge the position of the supporting bars.

g. Finish pouring the sides and ends, being sure to tamp the concrete well around the inlet and outlet tiles.

h. Float the top of the sides and ends level and smooth.

i. Pour the cover slabs. These should be carefully reinforced, the reinforcement being placed about ¾ in. from the bottom surfaces of the covers. As soon as the concrete has set, cover with burlap and keep wet for three or four days until cured. The form may then be removed.

j. After the tank concrete has cured (allow three or four days) the forms may be removed. This may be done by first removing the bracing and then drawing the nails in the corner stakes which held the side boards in place. This will permit the removal of the ends and corner stakes after which the side boards may be removed one at a time. The form boards around the inlet and outlet tiles should be removed with special care so that the tiles will not be broken or loosened.

k. Cut the baffle boards to the required length and place them in the grooves.

Place the cover slabs over the tank and backfill with dirt.

As soon as the sewer line is connected and the absorption tile is in place, the tank will be ready for service.

QUESTIONS

1. Explain the principle of operation of a septic tank.
2. What arrangements are used to dispose of the effluent of a septic tank?
3. What should be the grade of the sewer pipe to the septic tank?
4. What is the function of the baffles?
5. Why should the outlet be lower than the inlet?
6. How often should a septic tank be cleaned out?
7. How should one dispose of materials from a septic tank when cleaning it?
8. What are the relative advantages and disadvantages of a septic tank and a cesspool?
9. How far should a septic tank be placed from a well?

JOB 20

BUILDING A CESSPOOL

Reference: Chapter VII, pages 272–277.

Where the soil is loose and porous and where there is little danger of polluting the water supply, the cesspool provides a satisfactory and relatively inexpensive means of sewage disposal.

Cesspools may be installed in single units or in a series of two or more. Where the soil is only moderately porous two cesspools in series are recommended. See Fig. 20–2.

Materials needed:

A quantity of stone, brick or tile for laying up the wall.
A large flat stone or cement slab for a cover.
1 length of 4-in. vitrified bell-sewer tile.

Tools needed:

A long-handled spade.
A pick.
A stone mason's hammer if the wall is to be laid up with stone.

Procedure:

1. Locate the cesspool according to instructions in Chapter VII.
2. Determine the size needed.
3. Excavate the pit. The bottom of the pit should be above the water table, if any.
4. Level the outer rim of the bottom of the pit to provide a good foundation for the wall.
5. Lay the wall up without mortar to within 2 or 3 ft. of the ground surface, as shown in Fig. 20–1. The wall should be laid very carefully to prevent collapse.

6. Place the inlet sewer tile in position at the top of the vertical wall as shown.

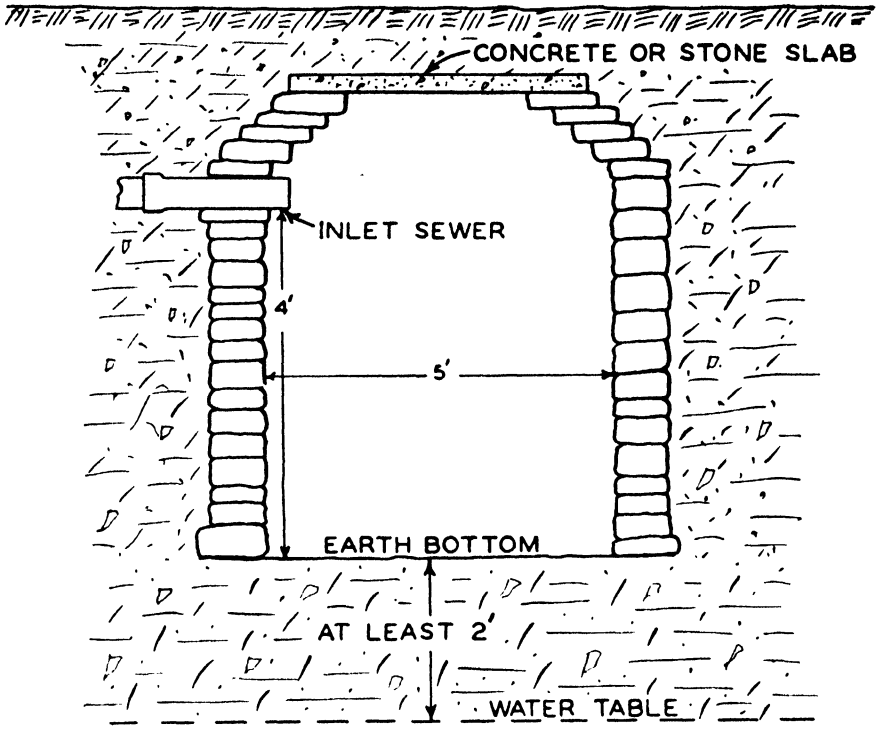
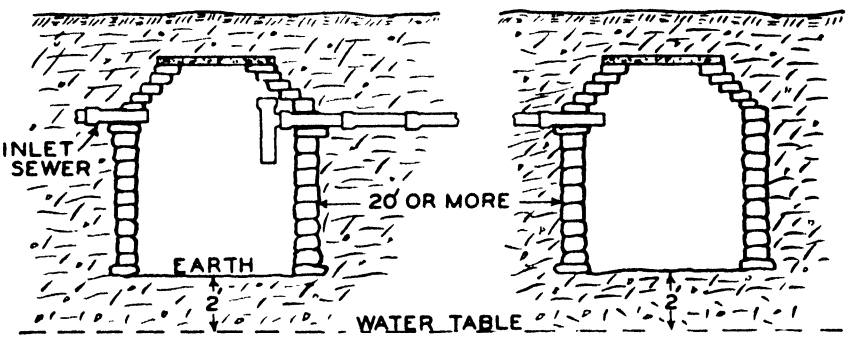


FIGURE 20–1.—Cross-section of one type of single cesspool. The walls are laid up without mortar. The single cesspool is satisfactory in porous soil.



Courtesy New York State Department of Health.

FIGURE 20–2.—Two cesspools in series. This is a good arrangement if the soil is medium heavy to heavy.

7. Draw in the top 1½ ft. or 2 ft. of the wall to a small opening which can be covered with a slab.

8. Backfill around the wall and over the cover. Be sure to tamp earth solidly around the tile to hold it in a horizontal position. The bell end must be left uncovered in order to start the line of sewer tile to the house.

QUESTIONS

1. Explain how a cesspool operates.
2. What precautions should be taken in locating a cesspool?
3. Why should the wall be laid up *without* mortar?
4. What is the advantage of having two cesspools in series?
5. What can be done with a cesspool when it fills up?

JOB 21

LAYING SEWER TILE AND DRAIN TILE

References: Chapters I, pages 130–132, V, page 221, VI, pages 245–246, 257–260, 262–263, VII.

A. SEWER TILE

The sewer tile and drain tile for the absorption field must be carefully laid in order to make the sewage system function properly.

The sewer tile from the house to the septic tank or cesspool may be of cast-iron soil pipe or vitrified clay tile. Of these, cast-iron sewer pipe with lead-caulked joints is considered the best, because if the joints are well made they are leak proof and root proof. If the sewer pipe passes within 50 ft. of a well, the cast-iron pipe with leaded joints should certainly be used.

Where the sewer pipe is at a safe distance from the well and where economy is important the vitrified clay tile may be used. For ordinary household purposes the tile should be 4, 5, or 6 in. in diameter, depending upon the amount of sewage to be handled. If cast-iron tile is used the 4-in. size is usually satisfactory. If vitrified clay tile is used the size should be 5 or 6 in.

Regardless of the kind of pipe, it should be laid in a straight line, if possible, and, on a uniform grade, the inside should be as smooth as possible.

Stoppage in sewer pipes is caused by (1) broken pipes, (2) poor grading, (3) solids of excessive size, such as newspapers, rags, children's toys, and large pieces of garbage, (4) excessive amounts of grease, and (5) poor joints which may offer obstructions or may permit roots to enter the pipe in search of water.

Materials needed:

Sewer tile or cast-iron soil pipe.
If cast-iron soil pipe is to be used, the material for caulking a lead joint, as indicated in Job 18, should be secured.
If vitrified sewer tile is to be used, a quantity of sand and cement or bituminous compound for sealing the joints is necessary.
Stakes and boards for grade line.
In some cases, a sewage divider may be needed.
Nails.

Tools needed:

Pick and shovel.
Carpenter's level.
Stout string.
Hammer and cold chisel if tile is to be cut.

Procedure:

The procedure in laying tile of any kind is first to establish the grade for the trench. If the trench is properly graded, the rest of the work is made easier.

The grade for a sewer pipe should be about 2 per cent. In other words, 2 ft. in 100 ft. of length, or ½ ft. for every 25 ft. of length.

Establishing a grade for a sewer line:

To establish a grade for the sewer line proceed as follows:

1. At the house where the sewer is to come through the foundation, drive two stakes 4 or 5 ft. apart, one on each side of the proposed trench, as shown in Fig. 21–1.

2. Across these stakes nail a straight board called a "batter board" (see inset), being sure that the top edge is level. A carpenter's level may be used for leveling.

3. At a point 25 ft. away from the first stakes, drive two more stakes.

4. Across these stakes nail another batter board at a point 6 in. lower than the first board.

5. At a point 25 ft. from the second set of stakes place another batter board and so continue with the line of stakes and batter boards to the septic tank or cesspool location.

When the batter boards are all up, sight over the top of them to determine if the top edges are in a straight line as they should be.

6. In the top edge of each board drive a nail directly over the center of the proposed trench. When finished these nails should be in a straight line. A string may be used to align the nails.

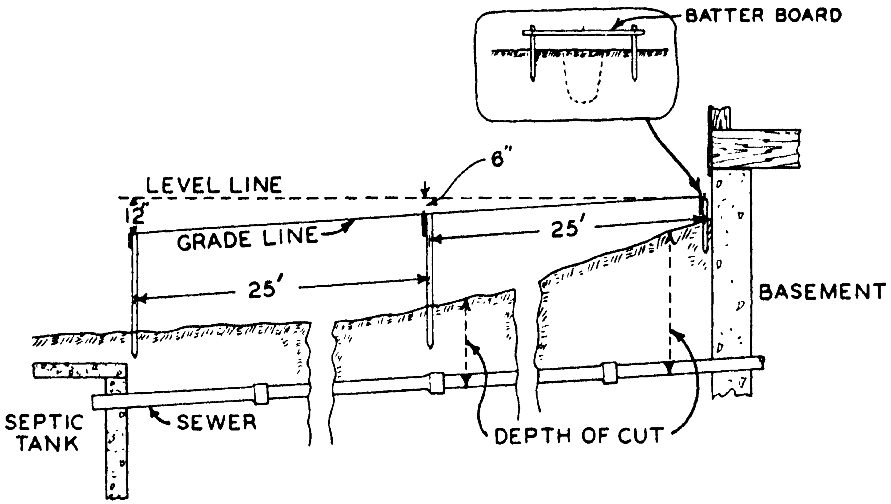


FIGURE 21-1.—Method of establishing a grade line for sewer or absorption tile. Note that the pipe is parallel to the grade line regardless of the contour of the soil.

7. Stretch a stout string from nail to nail for the full length of the trench.

NOTE: If the cesspool or septic tank grade has already been established, work may begin at that end.

Assume that the inlet tile of the septic tank is in place and that the bottom edge is 4 ft. below the grade string at that point. The bottom of the trench should be 4 ft. below the string at all points up to the foundation. This grade should be maintained regardless of the contour of the soil surface. See Fig. 21-1.

Laying sewer tile:

If cast-iron soil pipe is used the joints should be caulked with oakum and lead, as directed in Job 18.

For vitrified clay bell tile the joints can be made with cement mortar or bituminous joint compound as follows:

1. Start at the septic tank or cesspool end, laying the tile with the bell toward the house as shown in Fig. 21–2.

2. At the location of each bell scoop out a hole large enough to admit the bell and to give room to work around the joint.

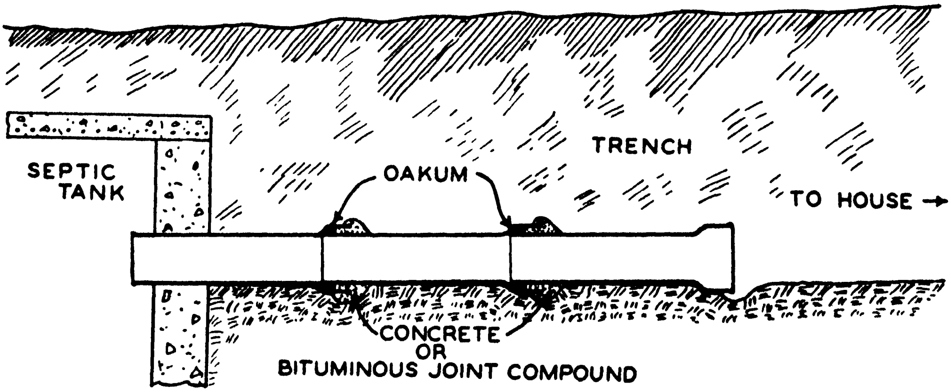


FIGURE 21–2.—Method of laying vitrified bell-sewer tile using oakum and cement mortar to seal the joints.

3. Place the spigot end of a tile in the bell end of the preceding tile.

4. Pack one turn of oakum around the tile inside the bell and tamp to the back of the bell. This ring of oakum serves two purposes. It centers the tile in the bell and tends to prevent mortar from working through the joint into the inside of the tile. Do not pack the oakum so tight that it will be forced through the joint to the inside of the tile.

5. Fill the bell with a 1:2 (1, cement: 2, sand) mix of cement mortar or a bituminous joint compound. If mortar is used, it should not be too wet and should be carefully packed all the way around the joint. Use mortar or joint compound generously at the end of the bell, as shown.

6. After the joints have been made and the mortar or joint compound has set, the trench should be backfilled with about 1 ft. of earth which is free of large stones. The earth should be carefully packed around the bell joints to give them adequate support.

The remainder of the backfill can be made with a plow or a scraper.

Replace the sod.

If it is necessary to make a bend in the sewer line with a deflection greater than 5 in. in 2 ft., a curved tile should be used.

If it is desired to cut vitrified sewer tile it may be done by filling the tile with dry sand well packed and then cutting with a hammer and cold chisel in the same way as directed in Job 17 for cutting cast-iron soil pipe.

B. DRAIN TILE

Materials needed:

Drain tile.
Gravel, cinders, or broken stone.
A quality of roofing paper to cover the joints between tiles.

Tools needed:

Same as listed for sewer tile.

Procedure:

Establishing the grade for drain tile:

To establish a grade for drain tile for the absorption field proceed as for sewer tile, except the grade should be ½ per cent to 1 per cent or 1½ in. to 3 in. per 25 ft. of length in loose soil and ¾ in. to 1½ in. in heavy soil. Also the absorption tile should be laid no deeper than is necessary to protect it from frost and from a plow. In the South 10 to 12 in. and in the North 16 to 18 in. are satisfactory depths. If absorption tile is laid deeper than 18 in., the bacterial action will be slow and the tile may become useless in a short time. Where the natural slope of the land exceeds these grades, the tile may be laid as shown in Figs. 100 and 101, pages 271 and 272.

Laying the tile:

1. With the grade established and the ditch dug to grade, lay the tile in the bottom of the trench, end to end, with a space of about ⅛ in. at the joints, as shown in Fig. 21–3.

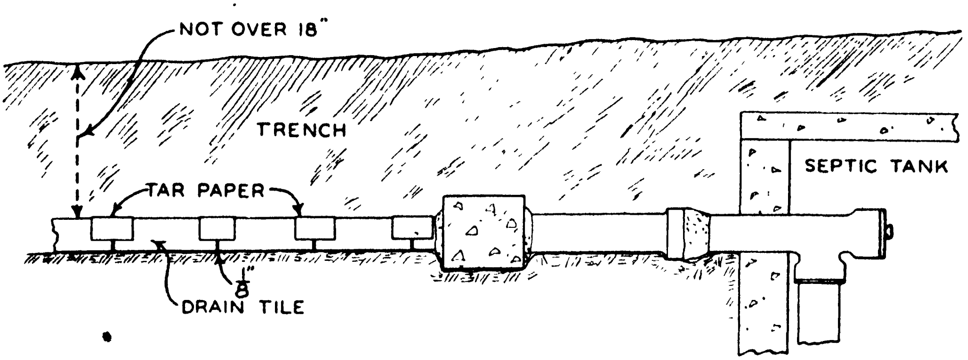


FIGURE 21–3.—Method of laying the effluent tile and absorption tile from a septic tank. Only one line of absorption tile is shown here, but often two lines leave the sewer through a divider as shown in Figure 99.

2. Over each joint place a piece of tar paper about 6 in. wide and long enough to reach two-thirds the way around the tile, as shown in Figs. 21–3 and 21–4.

3. If sewage dividers are used, the ends of the tile should be set in the divider with cement mortar.

4. Cover the tile with 6 to 10 in. of coarse soil, gravel, broken stone, or cinders.

In loose, porous soil the tile may be covered with the natural soil as shown in *A* in Fig. 21–4.

If the soil is medium heavy it is advisable to dig a wider trench and fill around and over the tile with gravel, cinders or broken stone as shown at *B*.

If the soil is heavy, a wider and deeper trench should be dug and about 6 in. of gravel or broken stone placed all the way around the tile as shown at *C*. If the soil is extremely fine, a strip of tar paper or boards should be laid over the gravel to keep the soil from filtering downward and into the tile.

5. Backfill the remainder of the trench with natural soil, placing the top soil on last.
6. Replace the sod.

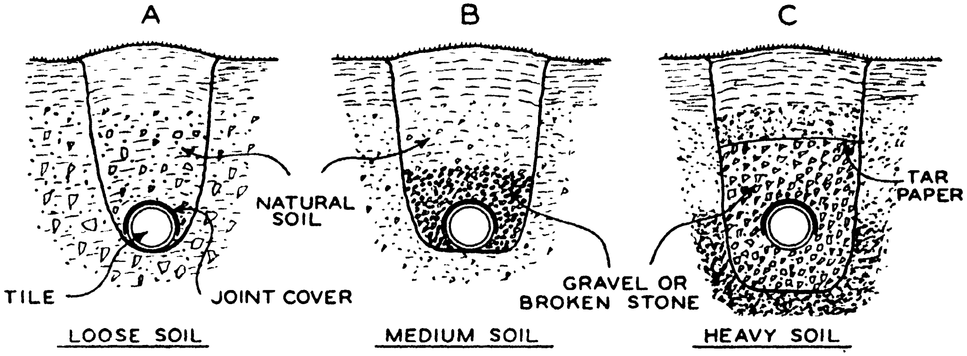


FIGURE 21–4.—Three methods of backfilling an absorption tile. At *A*, tile laid in porous soil; at *B* tile laid in medium heavy soil; and at *C*, tile laid in heavy soil.

QUESTIONS

1. Why is it important to maintain the proper grade in laying sewer tile? Drain tile?
2. Explain how to make a joint in sewer pipe using cement mortar.
3. Explain how to determine the amount of drain tile to install.
4. Explain how to lay drain tile properly.
5. Explain how to backfill on a sewer tile. A drain tile.

JOB 22

CALCULATING HORSEPOWER TO PUMP WATER

It is very important to have adequate power on a pump to insure long life for the engine or motor and to insure full capacity from the pump.

There are three factors which determine the load on the pump power unit. They are as follows:

1. The *rate* (gallons per minute) at which water is being pumped.
2. The *total head* in feet, on the water which is being pumped.
3. The *efficiency* of the pump.

The rate at which water is pumped depends upon the size and speed of the pump.

The total head against which the water is pumped is determined by (1) the actual vertical distance in feet (gravity head) through which the water is pumped (for example, if the water is pumped up from 20 ft. down in the well to a tank 5 ft. above the pump, the total gravity head is 25 ft.); (2) the friction head caused by friction of the water in the pipes; (3) the pressure head against which the water is pumped.

The efficiency of the pump will depend upon the design and condition of repair of the pump. For this job we shall assume that the pump is of good design and is in good repair, and, therefore, will have high efficiency.

The formula for calculating horsepower to pump water may be stated as follows:

$$\text{Horsepower} = \frac{\text{Wt. of water in lb. per min.} \times \text{total head in ft.}}{\text{33,000 ft.-lb. per min.} \times \text{efficiency of pump}}$$

The use of the formula is illustrated by the following examples.

Example 1. A shallow well pump is to pump water at the rate of 300 gal. per hour from a well in which the water, in dry seasons, is 20 ft. below the pump. The water is to be discharged into a pressure tank to a level of 2 ft. above the pump. The maximum tank pressure is 45 lb. per square inch.

The suction pipe is 1 in. in diameter and is 90 ft. long. It has one elbow at the well. The discharge pipe is very short and straight; therefore, the friction losses in it may be omitted.

The pump efficiency is 80 per cent.

What horsepower motor is required?

Electric motors of a type which might be used on farms for pumping water are available in the following horsepower sizes: ⅛, ⅙, ¼, ⅓, ½, ¾, 1, 1½, 2, 3, 5, and 7½. When the horsepower requirements exceed any given unit size, even by a small margin, the next larger size should be used.

Solution:

The solution of such a problem is usually clarified by making a sketch of the situation as illustrated in Fig. 22–1.

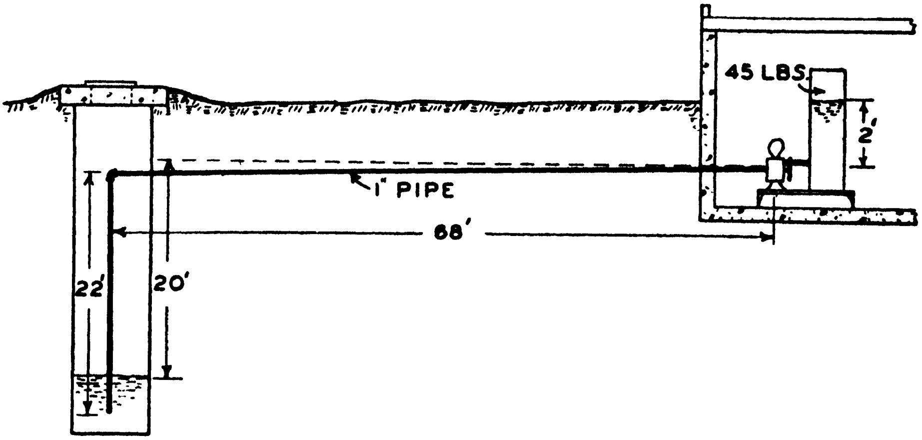


FIGURE 22–1.—Sketch for Example 1.

The first factor affecting the horsepower is the rate of pumping. In this problem the rate is 300 gal. per hour or 5 gal. per minute. In our formula we wish to express this in pounds per minute; therefore, 5 gal. per minute × 8.3 lb. per gallon = *41.5 lb.* per minute.

The second factor is the *total head.* The total head is made up of (1)the gravity head + the (2) friction head + (3) the pressure head.

The ***gravity head*** in our problem is ***22 ft.*** (20 ft. at the well and 2 ft. at the tank).

The *friction head* is determined by reference to a friction table. By reference to Table I, on page 67, we find that the loss of head due to friction in 100 ft. (22 + 68 + 10 ft. for one elbow) of 1-in. pipe with a rate of flow of 5 gal. per minute is *3.1 ft.*

The *pressure head* is determined by multiplying the pounds pressure by 2.3. One pound of pressure will maintain a column of water 2.3 ft. high. In this problem the pressure head would be 45 × 2.3 or *103.5 ft.*

The total head then is 22 ft. gravity head + 3.1 ft. friction head + 103.5 ft. pressure head, or a total of 128.6 ft.

Substituting the above values in our formula we have:

$$\text{Horsepower} = \frac{\text{Wt. of water in lb. per min.} \times \text{total head in feet}}{33{,}000 \times \text{efficiency of pump}}$$

$$= \frac{41.5 \times 128.6}{33{,}000 \times 80\%} = \frac{5336.9}{26{,}400} = 0.202 + \text{hp.} \qquad \textit{Ans.}$$

This is more than $\frac{1}{6}$ hp.; therefore, the next size, or $\frac{1}{4}$-hp. motor, should be used.

Example 2. A deep well pump is to pump water at the rate of 240 gal. per hour from a well in which the water is 90 ft. below the pumping head. The water must be elevated 25 ft. to a storage tank in the basement, as shown in Fig. 22-2. The maximum tank pressure is 40 lbs.

The drop pipe in the well is $1\frac{1}{2}$-in. pipe and is 100 ft. long. The discharge pipe is 1 in. and is 55 ft. long, having two elbows.

The efficiency of the pump is 50 per cent.

What horsepower motor is required?

Solution:

1. Weight of water

240 gal. per hour = 4 gal. per minute; 4 × 8.3 = *33.2 lb. of water per minute*

2. Total head

(*a*) gravity head = 90 + 25 = 115 ft.

(*b*) friction head in

100 ft. of $1\frac{1}{2}$-in. drop pipe = 0.3 ft.

75 ft. of 1-in. discharge pipe = $\frac{75}{100}$ of 2.1 = 1.58 ft.

Total friction head = 1.88 ft.

(*c*) pressure head = 40 × 2.3 = 92 ft.

(*d*) Total head = 115 ft. + 1.88 ft. + 92 ft. = 208.88 ft.

3. Pump efficiency 50 per cent.

Substituting in the formula:

$$\text{Horsepower} = \frac{33.2 \text{ lb.} \times 208.88 \text{ ft. of head}}{33{,}000 \times 50\% \text{ efficiency}}$$

$$= \frac{6{,}934.81}{16{,}500} = 0.42 \text{ hp.}$$

This is more than $\frac{1}{3}$ but less than $\frac{1}{2}$ hp.; therefore, a $\frac{1}{2}$ hp. motor should be used.

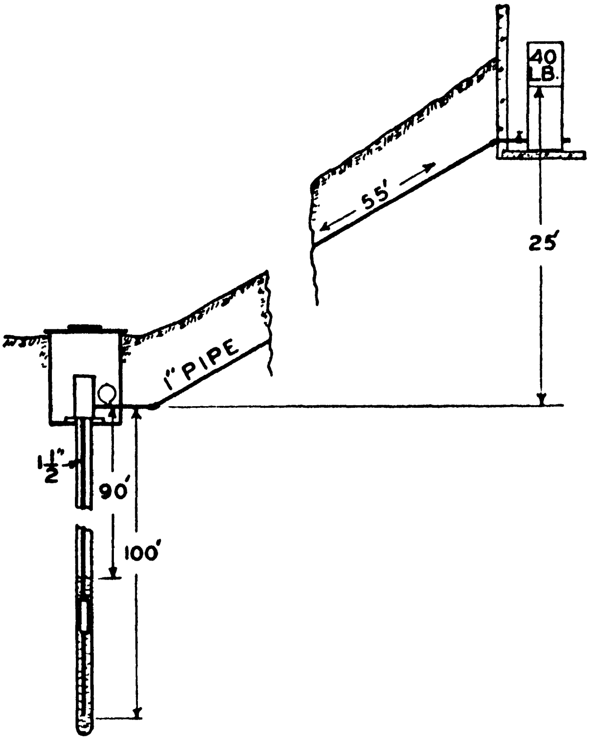


FIGURE 22-2.—Sketch for Example 2.

Example 3. A shallow well pump is to pump at the rate of 600 gal. per hour from a spring in which the water is 5 ft. below the pump, as shown in Fig. 22-3. The water is to be delivered to a gravity storage tank on a hill at an elevation of 150 ft. above the pump.

The suction pipe is 1½ in. in diameter and is 10 ft. long. It has one elbow. The discharge pipe is 1¼ in. in diameter and is 500 ft. long. There are no elbows.

The efficiency of the pump is 75 per cent.

What horsepower motor would be required?

Solution:

1. Weight of water per minute = 10 gal. per min. × 8.3 lb. = 83 lb.
2. Total head

gravity head = 150 + 5 = 155 ft.

friction head in 10 ft. of 1½-in. pipe = $\frac{20}{100}$ of 1.5 = .15 ft.

friction head in 500 ft. of 1¼-in. pipe = 5 × 3.8 = 19.00 ft.
pressure head—no pressure head in open tank
Total head = 155 ft. + 0.15 ft. + 19 ft. = 174.15 ft.

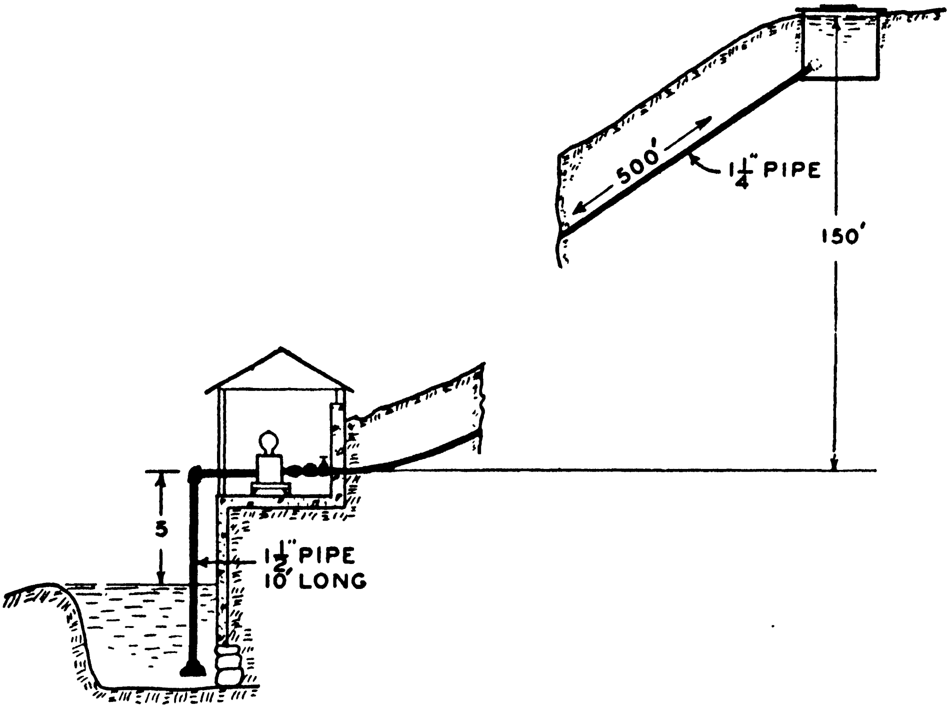


FIGURE 22–3.—Sketch for Example 3.

Substituting in the formula

$$\text{Horsepower} = \frac{83 \text{ lb.} \times 174.15 \text{ ft. of head}}{33{,}000 \times 75\% \text{ efficiency}}$$

$$= \frac{14{,}454.4}{24{,}750} = 0.58 + \text{horsepower.} \qquad \textit{Ans.}$$

This is a little more than ½ hp.; therefore, a ¾-hp. motor should be used.

Practice problems

1. A shallow well pump is to pump at the rate of 300 gal. per hour from a well in which the water in dry seasons is 3 ft. below the pump. The water is to be delivered into a pressure tank to a level of 2 ft. above the pump. The maximum tank pressure is 40 lb. per square inch.

The suction pipe is ¾ in. in diameter and is 5 ft. long. It has one elbow. The discharge pipe is ¾ in. and is 5 ft. long. It has one elbow.

The efficiency of the pump is 65 per cent.

What horsepower motor would be required?

2. What horsepower would be required if the above pump was discharging into an open gravity storage tank located at the same elevation as the above pressure tank?

3. If, in the installation of problem 1, the suction line were installed with 4 elbows and the discharge line with 5 elbows, what horsepower motor would be required?

4. A pump is to pump water at the rate of 30 gal. per minute from a creek in which the water is 10 ft. below the level of the pump. The water is to be elevated to an open ditch 30 ft. above the pump.

The suction pipe is 1½ in. in diameter and is 15 ft. long. It has one elbow. The discharge pipe is 1¼ in. in diameter and is 1000 ft. long. It has no elbows.

The efficiency of the pump is 65 per cent.

What horsepower motor is required?

5. If in the above installation the discharge pipe were 1½ in. in diameter, what horsepower would be required?

6. If the system of problem 4 were converted to a hydropneumatic pressure system with a maximum pressure of 50 lb. on a sprinkler nozzle, what horsepower would be required?

JOB 23

INSTALLING A SHOWER BATH

Reference: Fig. 99, page 258.

A shower bath is considered by many to be a very valuable addition to a plumbing system. A shower bath is economical of hot water and may be more sanitary than a tub bath.

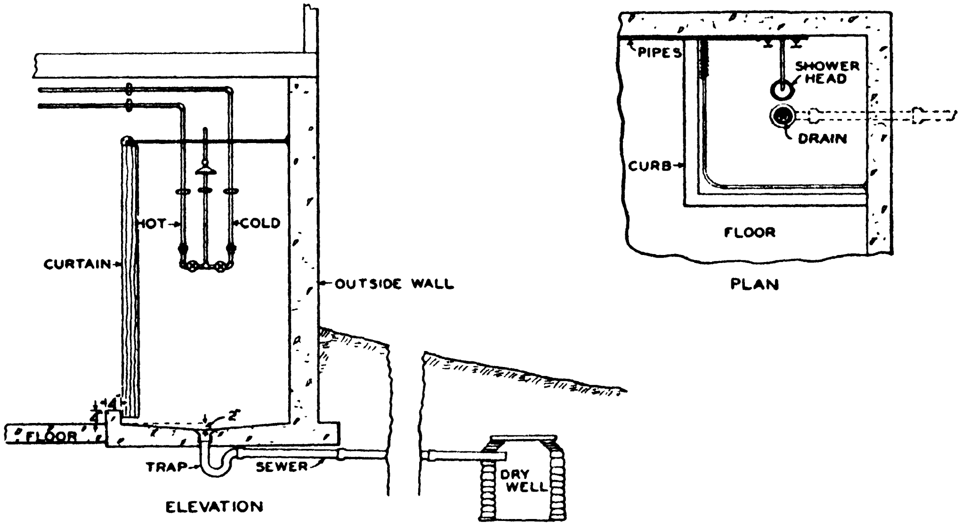


FIGURE 23–1.—Elevation and plan of a relatively inexpensive shower bath for the basement or barn.

To install a shower bath in a bathroom is a complicated job requiring the services of a plumber. With a little knowledge of plumbing practice, however, anyone should be able to install a shower in the basement or somewhere around the barns.

There are a number of different methods of constructing a shower bath. The one shown here is simple and relatively inexpensive.

Both hot and cold water should be supplied to a shower; but if running water is not available on the farm, a "summer-time shower" can be supplied from a gravity tank located in the upper part of the house or in the hay mow, which tank may be filled with rain water from the roof or by means of a hand-force pump at a well.

Location of Shower Bath. The shower bath should be located in a clean place which is free from drafts and should have a water-tight base. A drain should be provided to lead the water to a sewer or to a dry well or cesspool, as shown in Fig. 23–1.

A convenient location for a shower bath is in the corner of the basement or of some room in the lower floor of the barn, or other out-building. By locating the shower in a corner two walls are provided, which makes it easy and inexpensive to install a curtain rod and a shower curtain. Also a corner location usually gives a better opportunity to install the drain.

In this job we shall assume that both hot and cold running water are available.

Materials needed:

Materials for a 1–2–3 mix of concrete for the base of the shower.
A trap for the drain.
Enough 3-or 4-in. sewer tile to lay from the drain trap to the dry well.
½-in. pipe and fittings for bringing the water to the shower location and to make the curtain rod.
Pipe straps.
Two hand valves.
A shower head.
A shower curtain with rings.
Stones, brick, or tile to wall up the dry well.

Tools needed:

Pick and shovels.
Tools for mixing concrete.
Plumbing tools. See Jobs 1 and 2.

Procedure:

1. Remove a corner block of the cement floor 4 or 5 ft. square.

2. Dig the dry well pit and then the trench in as far as the center of the shower base.

3. Build the forms for the curbing around the shower. The curbing should extend 4 in. above the floor.

4. Set the drain and trap in place and lay the drain beyond the outside wall of the building.

The level of the top of the drain should be 2 in. below the original floor level.

5. Fill in around the tile and the trap with earth well tamped in place.

6. Pour the bottom of the shower base first, sloping the surface evenly from the drain to the floor level.

This pouring should be carefully tamped and should be floated with a wood float before it sets. Do not trowel the base as this will make it slick.

7. Place the curbing forms in place and pour the concrete. Curbing will be necessary only on the sides away from the walls.

8. Finish laying the drain and building the dry well.

9. After the cement has set (allow three or four days) the forms may be removed.

10. Tap the hot- and cold-water pipes at some convenient location and install the pipes, valves, and shower head as shown in Fig. 23–1.

The pipes may be supported on the joists or, if the pipes must be supported on a concrete wall, it may be necessary to drill holes in the concrete and fill the holes with wood pegs or lead to take the screws.

11. Install the curtain rod. This may be a piece of ½-in. or ⅜-in. galvanized steel pipe bent at right angles and supported from floor plates fastened to the walls as shown.

12. Install the curtain.

JOB 24

LEVELING TO DETERMINE GRAVITY HEAD ON WATER SYSTEMS

Reference: Chapter V, pages 224–225.

Often in the development of a water system, particularly the gravity types of systems, or in the installation of a hydraulic ram, it is desirable to know the difference in elevation between the source of water and the point where the water is to be used, as, for example, between a spring and the house or barn.

Leveling to determine differences in elevation is known as "differential leveling." When very careful work must be done, as in laying out a building foundation, a good leveling instrument should be used. When leveling for a water system a satisfactory job may be done by means of a carpenter's level, as follows:


FIGURE 24–1.—A carpenter's level equipped with clamp-on sights.

Equipment needed:

Carpenter's level, preferably one equipped with sights. See Fig. 24–1.
Stick or rod 10 or 12 ft. long, marked off in tenths of a foot from the bottom up, as shown in Fig. 24–2.
A wooden box about 1 ft. x 2 ft., or a barrel.
Paper and pencil.

Procedure:

If the difference in elevation between the two points in question is not too great and if the distance between them is not so far that readings cannot be taken on a rod, the procedure may be as follows:

1. Set the level up between the two points, as shown in Fig.

24–3. Point the level toward one of the points in question, as shown, and wedge or block it up until the bubble shows that it is level.

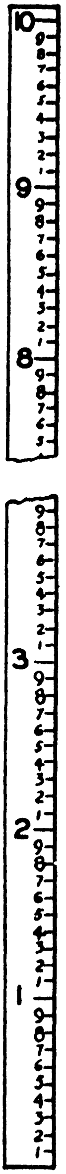


FIGURE 24–2.—A rod marked off for use in leveling.

2. Ask a helper to set the rod on point *A*, toward which the level is sighted. If this point is the source of water, the rod should be supported on a stone or stake at the surface of the water as shown.

3. Look through the sights and take a reading on the rod. If the rod is too far away to read the figures, it may be necessary to ask the helper to hold a pencil or a stick across the rod in line with the cross hair of the sights in order to get the reading.

4. Record the reading. In the illustration, Fig. 24–3, the reading is 1 ft.

5. Ask the helper to move the rod to the other point *B*.

6. Turn the level around with the sights pointing toward point *B*, being sure that the level is level.

7. Take the reading on the rod. In Fig. 24–3 the reading is 9 ft. We now know that the line of sights on the level is 1 ft. above the first point *A* and 9 ft. above the second point *B*. Therefore, the difference in elevation between points *A* and *B* is equal to the difference between the two readings, 9 ft. and 1 ft., or 8 ft.

In Fig. 24–3 the faucet is 5 ft. above point *B*. Therefore, to obtain the height of the spring above the faucet, subtract 5 ft. from 8 ft. The spring, therefore, has an elevation of 3 ft. above the faucet.

If the difference in elevation between two points is obviously more than the length of the rod, or if the distance between them is too great to take readings, it will be necessary to set the level up at two or more stations and take a series of readings. Such a series of readings is called a "line of levels." The procedure is essentially the same as outlined above but is duplicated successively toward point *B*

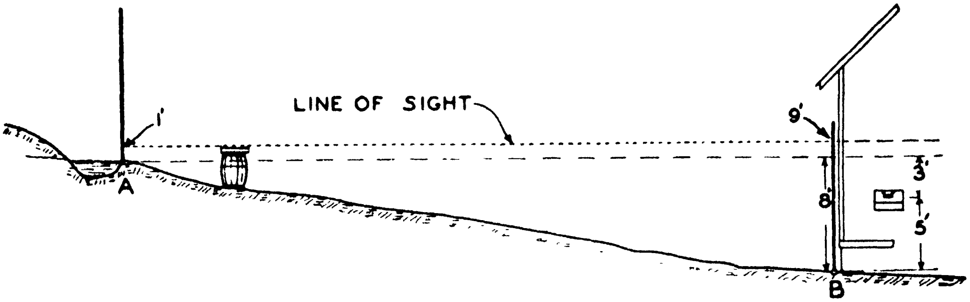


FIGURE 24–3.—A method of measuring differences in elevation between two points which are close together.

as shown in Figs. 24–4 and 24–5, until the entire distance between the two points has been covered.

At each location or station of the level a sight is taken backward on the rod at its last location and then one forward on the

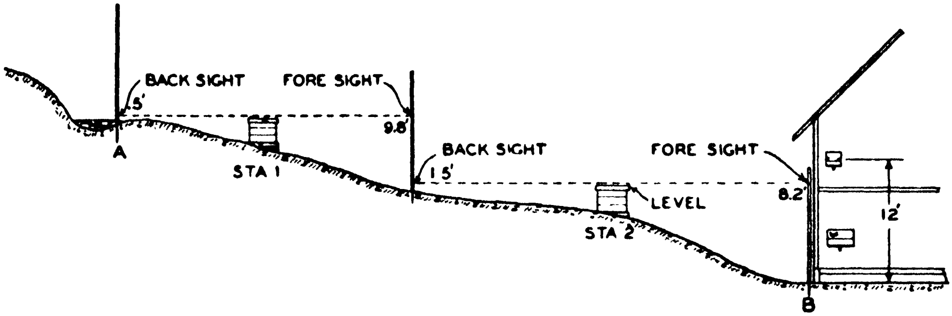


FIGURE 24–4.—One method of running a line of levels.

rod at a new location. The sights taken backward are called *backsights* and those taken forward are called *foresights.*

For most accurate results the rod should be an equal distance from the level on the backsight and the foresight at each station as shown.

The readings on the rod should be set down on paper, as shown below, with all the backsights in one column and all the foresights in another column. When the leveling is finished the difference in elevation between the two points in question may be obtained by finding the difference between the *sum* of the foresights and the *sum* of the backsights. In the case illustrated in Fig. 24–4 the sum of the foresights is 18 ft. and the sum of the backsights is 2 ft. The difference in elevation between points *A* and *B* is, therefore, 16 ft.

FIELD NOTES FOR FIGURE 24–4

Station	Backsights	Foresights
1	0.5 ft.	9.8 ft.
2	1.5 ft.	8.2 ft.
	2.0 ft.	18.0 ft.

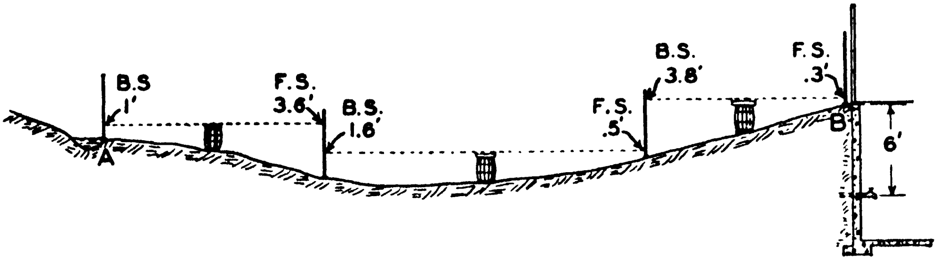


FIGURE 24–5.—A line of levels showing the difference in elevation between points *A* and *B*.

If the sum of the foresights is *greater* than the sum of the backsights, then point *B* is below point *A*, as is the case in Fig. 24–4. If the sum of the foresights is *less* than the sum of the backsights, as would be the case if the levels of Fig. 24–4 were run from the house to the spring, or as is shown in Fig. 24–5, then the last point is above the first point.

In any event, the difference in elevation between the last point *B* and the highest faucet must be taken into consideration in order to determine the difference in elevation between the source of water and the faucet. In Fig. 24–3 the difference in elevation is 3 ft., as has been shown. In Fig. 24–4 the faucet is 12 ft. above point *B*. The difference in elevation between *A* and *B* is 16 ft.; therefore, the spring at point *A* is 4 ft. above the faucet. In Fig. 24–5 the faucet is 6 ft. below point *B*. Point *B* is 2 ft. above point *A* at the spring; therefore, the spring is 4 ft. above the faucet.

PART II

CHAPTER I

NATURE AND SOURCES OF WATER

Importance of Good Water. The use of water by man, plants, and animals is universal. Without it there can be no life.

In our homes, whether in the city or in the country, water is essential for cleanliness and health. On the farm, in addition to household uses, water is essential for the growth of crops and animals and is a very important factor in the production of milk and eggs.

The Nature of Water. Pure water is composed of two elements, hydrogen and oxygen. There are two parts of hydrogen to one part of oxygen. The chemical symbol is H_2O. Water exists in three states: (1) as a liquid, (2) as a solid (ice and snow), and (3) as a gas (steam).

Sources of Water for Farm Use. Of the total annual rainfall, about one-third evaporates from the earth and plant foliage into the air again, one-third runs off as surface water, and one-third percolates into the ground to form our underground water supply.

Ground Water. A part of this underground water finds its way through soil and rock to the ocean, lakes, and underground streams; a part finds its way into porous spaces and cavities of the soil and rock; and a part finds its way to the surface again by seepage where it may form springs, wells, lakes, ponds, bogs, and swamps. Figure 1 illustrates the movement of ground water. The earth's crust is made up of layers of different kinds of soil and rock. Water can readily pass through some of these, such as sand, gravel, loam, sandstone, and sandy limestone. Some types

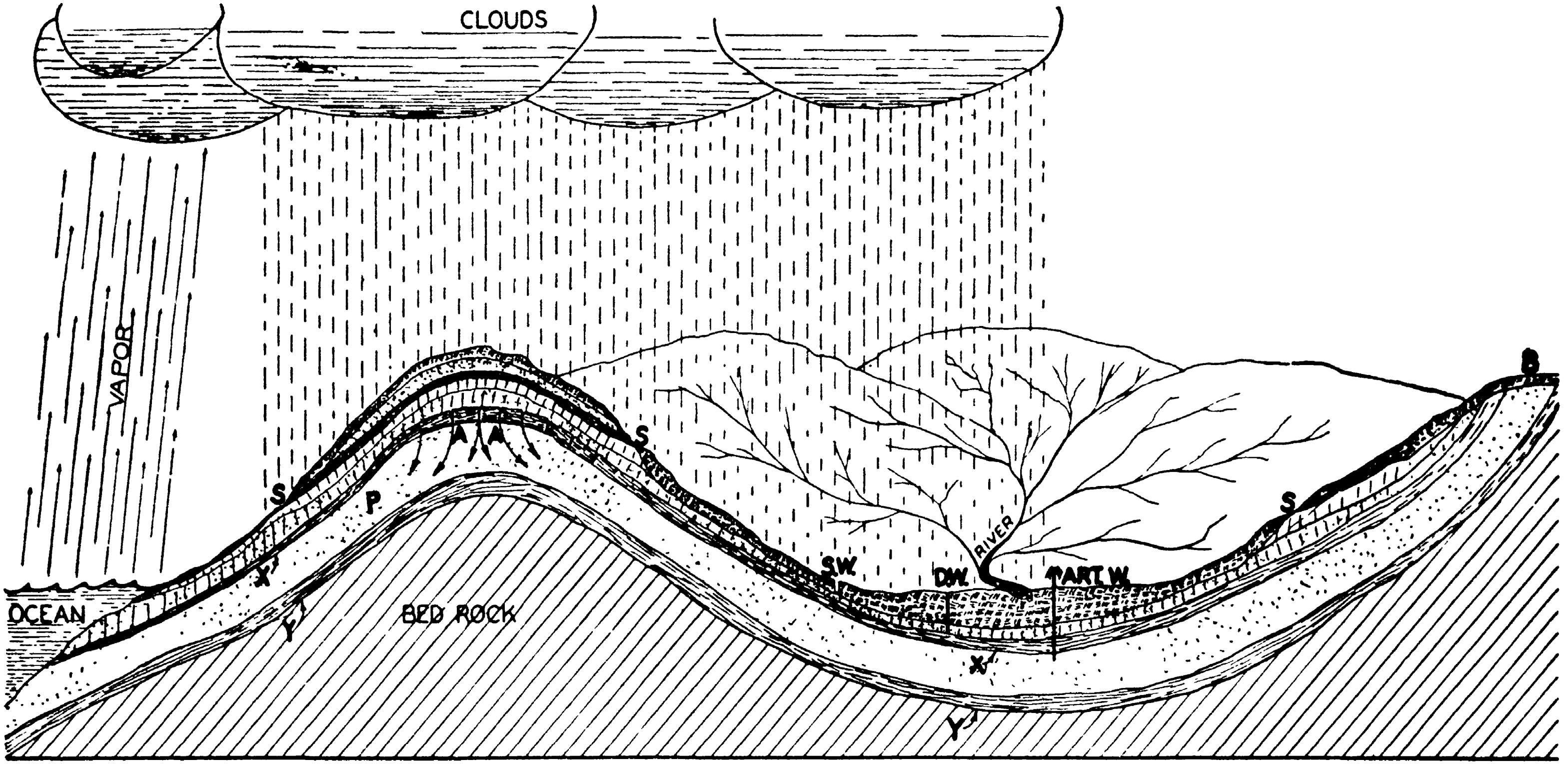


FIGURE 1.—A cross-section of a possible arrangement of the earth's crust showing how rain water may be distributed. A part of the rainfall runs off at the surface forming creeks and rivers; a part may soak into the ground and return to the surface at springs, *S*, or wells, *S.W.* and *D.W.*; yet another portion may percolate deeper through cracks and faults, *A.A.* & *B.*, into a porous strata *P*, where it may be carried many miles to the ocean or to artesian wells, Art. *W*.

of soil and rock, such as clay, shale, marl, marble, and granite, are practically impervious to water, unless they have cracks or seams. As shown on the hill at the left in Fig. 1, the rain water may percolate through the soil and into porous strata, some of it passing on through and some following the course of the rock, perhaps on top of a less porous layer, until it reaches the surface by seepage. If the rock lies in such a position as to converge this seepage at one point, a spring such as *S*, in Fig. 1, will be formed.

The water which passes into deeper layers may reappear as springs farther down the slope, and may feed shallow wells (*S.W.*) or deep wells (*D.W.*)

Sometimes water will find its way through cracks or seams as shown at *AA* into porous strata lying between two impervious strata, *X* and *Y*, or it may enter at an exposed end of the porous strata, as shown at *B*. If there are dips in these impervious layers of rock as shown, some of the water may accumulate between the two high points, thus building up a head or pressure on the water at the low point. If a well is drilled through the top layer at a low point (see *Art. W*, Fig. 1), the water will flow out the top of the well because of the pressure existing upon it underground. Such wells are known as artesian wells. Sometimes the water from such a well spouts to a considerable height when first tapped. After a time, however, the flow may diminish until it just equals the water soaking into the porous strata. Artesian wells are so-called after the French province Artois, where the first of such wells was drilled. Sometimes the water from these wells is hot and often it is brackish.

Character of Ground Water. The character of the water which we take from our springs and wells depends upon the nature of the soil and rock through which it has passed. If it has percolated through soil and rock where there is very little water-soluble material and where there is no form of pollution, it may be *soft water* and, because of the filtering action of the soil, may be cleaner and purer than rain water caught from a roof. He who has such a spring or well is fortunate indeed. As a rule, however, the water dissolves certain minerals from the soil and rock and carries them along in solution. Common salt, iron, sulphur, calcium, and magnesium are the most common minerals found in underground water. In some localities ground water may contain only small amounts of minerals; in others one or more minerals may be present in large quantities. When excessive quantities of minerals are present the water is likely to have an unpleasant taste.

Hard Water. Water which contains carbonates in quantity will not readily form a lather with soap. Such water is known as *hard water*. Hard water is most common in limestone regions and in regions where there are deposits of gypsum. Hardness from limestone is due to the presence of calcium carbonate. Hardness from gypsum is due to the presence of calcium sulphate. Hardness from calcium carbonate (limestone) is referred to as *temporary hardness* because the lime can be removed from the water by boiling. Hardness from calcium sulphate (gypsum) is referred to as permanent hardness because it cannot be removed by boiling.

Hard water is less desirable than soft water for domestic uses for several reasons. First, it requires an excessive amount of soap for washing purposes. Second, the soap together with the lime forms an insoluble precipitate which appears as flakes on the water and which, in large quantities, looks more or less like cottage cheese and may, if the water is *very hard*, fill up a septic tank or cesspool in a relatively short time. Also this precipitate will lodge in the fiber of clothing washed in the water, making the clothing stiff and harsh. Third, with temporary hard water, the lime may precipitate in quantity in pipes and in plumbing fixtures, thus reducing and eventually stopping the flow of water. This is particularly true if the water is heated. Fourth, the human skin may become roughened and chapped from washing in hard water. Fifth, hard water leaves spots and streaks on dishes and glassware unless they are polished after washing.

Hardness of water may be measured in terms of grains of calcium carbonate or calcium sulphate per gallon or in terms of parts per million. Water with less than 10 grains of hardness is considered to be fairly soft. Water with 10 to 20 grains of hardness is considered to be moderately hard and, for domestic purposes in hot-water pipes, should be softened. With a hardness of 25 grains per gallon or more softeners are essential. Water with a hardness of 50 grains per gallon or more is considered unsuitable for domestic purposes.

Testing Water for Hardness. To get an exact measure of the hardness of water a rather elaborate procedure is required. However, a fairly accurate measure can be made by the so-called "Soap Test" as follows:

1. Secure a clean, small glass bottle (about 80 cc. in capacity).
2. Into this bottle place 22 cc. of the water to be tested.
3. To this water add *Standard Soap Solution* (obtainable at drug stores), one drop at a time, until a substantial lather forms on the water after shaking. Best results are obtained if the soap solution is added with a dropper.
4. Shake the bottle vigorously after each drop of soap solution is added. The number of drops of soap solution required to form a substantial lather indicates the number of grains of hardness. Thus, if it requires 8 drops of soap solution to form a lather, the water tested has approximately 8 grains of hardness.

Chemists often express the hardness of water in terms of "parts per million." Seventeen and one-tenth (17.1) parts per million is equal to one grain of hardness. Thus, water having six (6) grains of hardness would contain 6 × 17.1 or 102.6, parts of, lime or gypsum in each one million (1,000,000) parts of water.

Water Softeners. Commercial devices known as "water softeners" are available for removing the "hardness" from water. These softeners consist of a tank of chemicals through which the water flows on its way to the hot-water supply tank. The chemicals reduce the calcium content of the water as it passes through. Eventually the chemicals lose the power of removing calcium and are then recharged by washing with salt brine.

These softeners are available for commercial or domestic use. The domestic type is ordinarily used for softening the hot-water supply only, the softener being installed in the cold-water line leading to the hot-water supply tank.

If the water contains a considerable quantity of iron, an iron filter should be used ahead of the softener as the iron may accumulate in the softener and destroy its effectiveness. Also, the removal of the iron from the water will make clearer water and will reduce the staining of plumbing fixtures and clothing washed in the water.

Organic Matter in Ground Water. In addition to minerals the ground water may contain organic matter picked up from decayed vegetation, animals, or from sewage on or in the soil through which it passes. This organic matter may be in solution or it may be in the form of living micro-organisms. The presence of organic matter in solution may not be harmful except for the fact that the organic matter provides food for living organisms which might be and usually are present. The presence of plenty of food in the water may enable the living organisms to multiply rapidly. Organic matter in solution may also affect the taste of the water.

The presence of living micro-organisms may or may not be harmful, depending upon the kind of organisms present. Well and spring water may contain large numbers of living organisms and in thickly populated areas there is great danger of disease-producing organisms getting into the water. According to health authorities it sometimes happens that such diseases as typhoid fever, paratyphoid, Asiatic cholera, or dysentery spread through a community because the germs get into the underground water supply.

Wells and springs on farms may be polluted in the same manner, unless they are carefully protected. The most dangerous source of pollution is from human feces. Deposits of human feces should never be made on the surface of the ground anywhere near a water supply.

In order to be sure that water is safe for drinking purposes, it should be tested by a health officer. Such tests are made free of charge in some states. See Chapter V for detailed instructions.

Water Table. The water table is that level in the earth's crust where the pore spaces in the soil and rock are saturated with water. In many localities there is no definite water table. In other localities there may be a temporary water table which exists only in wet seasons or immediately after a rain. In low-lying regions, particularly along the course of streams or near the shores of lakes, there may exist a permanent water table the level of which fluctuates with the level of the water in the stream or lake.

The presence of a water table in the soil will tend to increase the flow into a well which penetrates below that level. However, a definite water table is not essential to a good well. Soil and rock may contain a considerable quantity of *free water* and yet not be saturated. This free water may flow to a well or spring in sufficient quantity to provide an adequate supply. Sometimes it is necessary to drill to a considerable depth in order to get an adequate flow.

Where there is no definite water table and where there is very little free water in the upper soil and rock, it may be necessary to drill through bed rock until deep water-bearing strata are reached.

Springs and Wells. At low points along valleys, in ravines and gulleys where the surface of the ground dips down below the level of the water table or below the level where there is plenty of free water in the soil or rock, there is likely to be seepage of water to the surface. If the seepage is concentrated in one place a spring will be formed. See Figs. 1 and 2. If the seepage is along the line of an outcropping of rock, a swamp or bog may be formed.

Unfortunately, springs do not always occur at the most convenient locations for buildings. Therefore, in order to use the spring water in our buildings, it is sometimes necessary to make a long carry or to install a rather expensive piping system. In such cases it may be better to construct a well near the buildings which will extend down into the soil and rock below the level of free ground water.

Types of Wells. *Shallow Wells.* For convenience in selecting pumps, wells are classified into two groups, namely, "shallow" wells and "deep" wells. A shallow well is one in which the water level always stands within "sucking" distance of a pump cylinder located at or near the top of the well. The sucking distance varies with the type of pump and the altitude of the well above sea level. At sea level the sucking distance is 22 to 28 ft., depending upon the type of pump used. For any type of pump, the sucking distance decreases about 1 ft. for every 1000 ft. of elevation above sea level. See Table III. Figures. 3 and 4 illustrate shallow wells. Pumps which can be used for pumping from such wells are called shallow-well pumps.

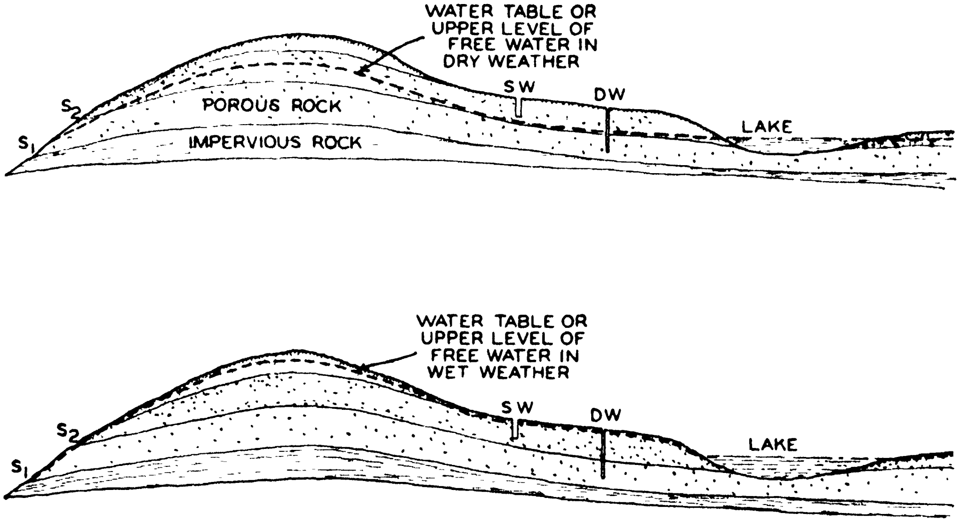


FIGURE 2.—Above, ground water in dry weather. The water table or free water is low because of lack of rainfall. Spring 2 (S_2) and the shallow well (*S.W.*) are dry.

Below, ground water in wet weather. The ground water is high owing to plentiful rainfall. During such periods Spring 2 and the shallow well will flow, and Spring 1 and the deep well will have increased flow.

Deep Wells. A deep well is one in which the water level is, or at times may be, below sucking distance of a pump cylinder located at or near the top of the well. To pump water from such a well the cylinder must be lowered into the well until it is within sucking distance of the water. In practice the cylinder is usually placed down in the water to avoid the loss of priming. Figures 5 and 6 illustrate deep wells. Pumps used on deep wells are called deep-well pumps.

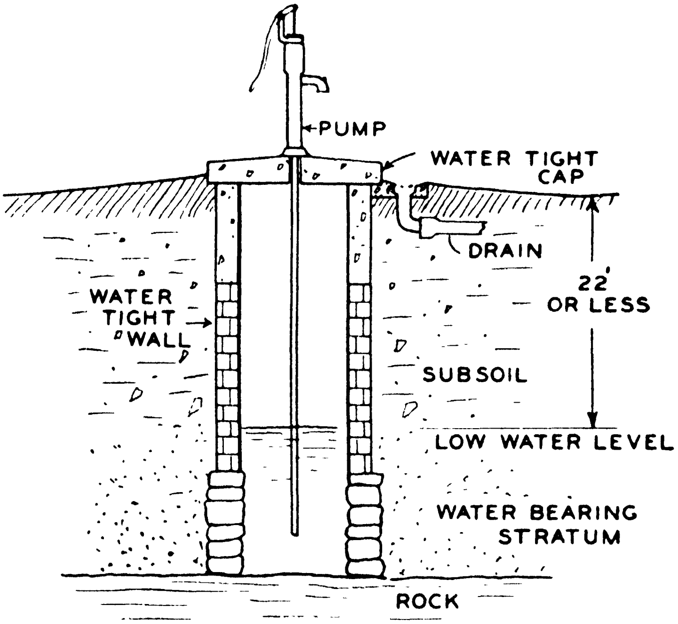


FIGURE 3.—A shallow dug well with pump on the top. The bottom part of the well wall is laid up without mortar. The top part should be made water-tight with mortar between the stones and sand and cement plaster or by use of concrete. If the well is large in diameter and, therefore, requires a heavy cover, a manhole should be constructed in the top.

Types of Well Construction. There are three types of construction for deep and shallow wells, namely, dug wells, drilled wells, and driven wells.

Dug Wells. The dug well is usually a round hole or shaft dug into the ground by hand and extending below the level of ground water in dry weather. The hole is from 3 to 6 ft. in diameter and is walled up with stone, brick, or concrete as shown in Figs. 3 and 4. Good construction requires the upper part of the wall to be water-tight to keep out surface water. The well cap should be sealed to the top of the well wall and should extend at least 5 in. above the surface of the ground. The ground surface should be graded away from the well cap.

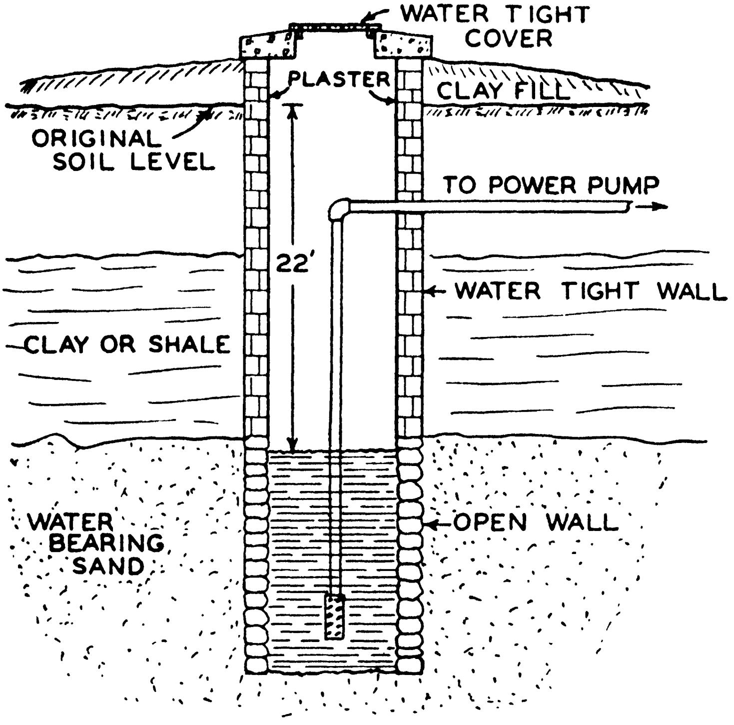


FIGURE 4.—A shallow dug well with pump located at a distance from the well. The level of the water is within 22 ft. of the ground surface. The top part of this well wall is laid up with stone and mortar and is plastered on the inside with cement mortar.

Dug wells are usually of the shallow well type, although in regions where the bed rock is deep, there are some deep dug wells.

Drilled Wells. The drilled well consists of a hole 4 to 8 in. in diameter drilled into the ground as shown in Figs. 5 and 6. A special well-drilling rig is required for this job. At the present writing the cost of drilling ranges from $1.50 to $2.50 per foot of depth. The upper part of the hole is lined with a steel pipe called a "casing." The lower end of the casing should extend at least into the bed rock as shown. If the bed rock is porous and quite close to the surface, the casing should extend into this rock for at least 20 ft. Well drillers have means of sealing the lower end of the casing so that surface water will not flow down the outside of the casing and enter the well.

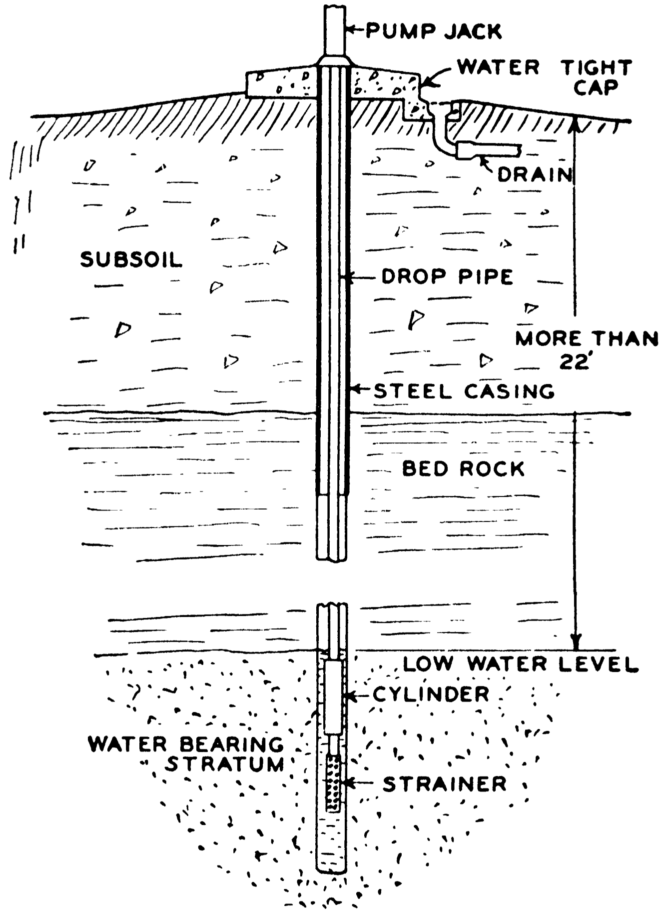


FIGURE 5.—A deep drilled well with the cylinder in the water and the pump jack at the top of the well. The level of the water is more than 22 ft. from the ground surface.

Drilled wells may be of either the shallow- or deep-well type.

Sometimes, in a deep drilled well the water level rises to and remains within a few feet of the top of the well. If this water level cannot be lowered by ordinary pumping then the well may be classed as a shallow well and a shallow-well type of pump may be used.

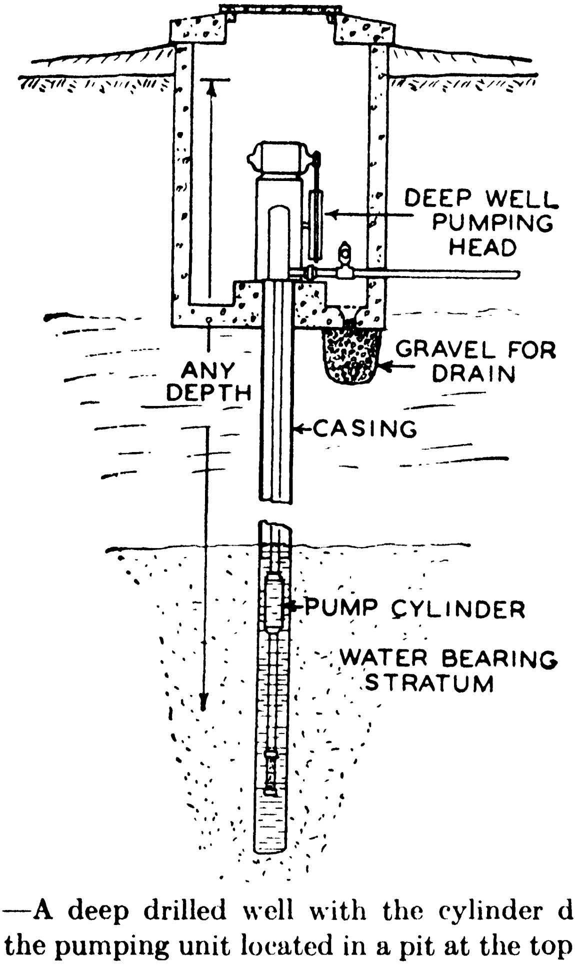


FIGURE 6.—A deep drilled well with the cylinder down in the water and the pumping unit located in a pit at the top of the well.

The deep well should be capped the same as the shallow well, or, if a pit is made at the top of the well, the floor of the pit should be sealed around the casing, leaving the casing extending several inches above the floor as shown in Fig. 6. A drain should be provided to lead excess water away from the pit.

Driven Wells. The driven well consists of a pipe driven into the earth as shown in Figs. 7 and 9. On the lower end of the pipe is a "well point," Fig. 8, sharp on one end and having a strainer through which water can enter the pipe. The pipe is driven into soil or sand until the well point penetrates to such a depth that a satisfactory flow of water is obtained.

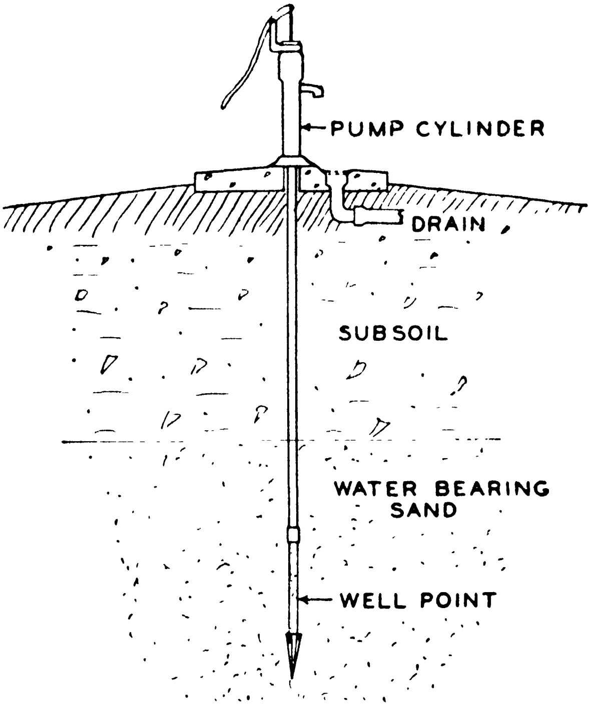
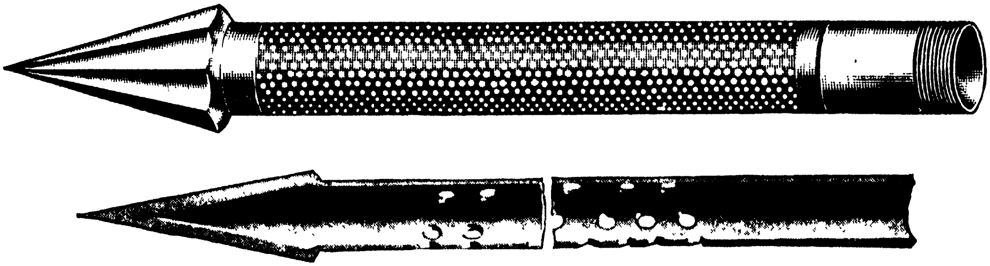


FIGURE 7.—A driven shallow well with the pump at the top of the well.

Driven wells may be either shallow or deep. If shallow, the pump may be connected directly to the driven pipe as shown in Figs. 7 and 9. If the well is deep, a deep-well cylinder and drop pipe may be installed inside the driven pipe.

Driven wells are relatively inexpensive, but they cannot be had except in localities where the nature of the soil will permit driving a pipe below the water table or below the level of free ground water. Pipe used for driving should not be smaller than 1 in. and should be made of extra heavy steel. The driven well should be properly capped with concrete, and surface drainage should be provided to carry away surface water.



Courtesy F. E. Myers & Bro. Co.

FIGURE 8.—One type of well point. Well points are usually made of forged steel.

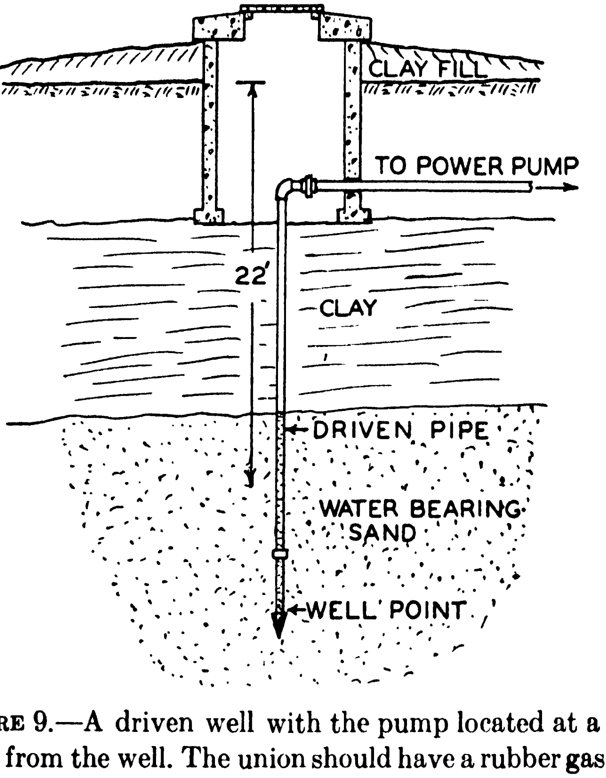


FIGURE 9.—A driven well with the pump located at a distance from the well. The union should have a rubber gasket.

How to Protect Spring and Well Water from Pollution. Ground water occurs where nature puts it, but the purity of the water flowing from springs and wells is determined by the condition of the soil over and through which the water passes. Unhealthy soil conditions are usually man-made. The more people there are in any given area, the more likely is the soil to be contaminated.

As water passes downward through the soil and rock it is filtered to a certain extent. The deeper the soil and rock through which it passes, the more likely it is to be well filtered. Conversely, the shallower the soil and rock through which it passes the less it is filtered. For this reason, everything else being equal, water taken from a deep source is more likely to be pure than water taken from a shallow source.

Pollution of ground water is usually caused by contamination of the soil by human sewage, animal manure, or decaying organic matter such as dead animals, grave yards, or dumps. The most dangerous of these is human sewage because it is most likely to carry human-disease germs. Of primary importance, then, is the location of the sewage disposal system with respect to the water supply. See Chapter VII. The septic tank, the cesspool, and the outdoor privy, particularly the cesspool and the privy, should never be located up grade from the water supply. They should be below the source of water and as far away as possible. Figure 10 illustrates the manner in which a well may be polluted from different sources. Figure 11 illustrates a satisfactory location of the well with respect to the sewage system and the barn.

It sometimes happens that the slant of the bed rock is opposite to the slope of the ground, in which case the sewage may find its way back to the well even though the sewage system is below the ground level at the well.

Another source of pollution is surface water. Springs and wells should be so banked or boxed in that surface water does not enter. Wells should have good sloping concrete caps extending well above the ground surface and the cap should be sealed to the top of the well wall or casing. See Figs. 3, 4, 5, 6, 7, and 9. The pump should fit tightly on the cap. Wells having no pump on top should be kept closed with a tight-fitting cover, as shown in Figs. 4, 6, and 9. Where the pump is on top of the well, a drain should be provided as shown in Figs. 3, 5, and 7 to carry waste water away.

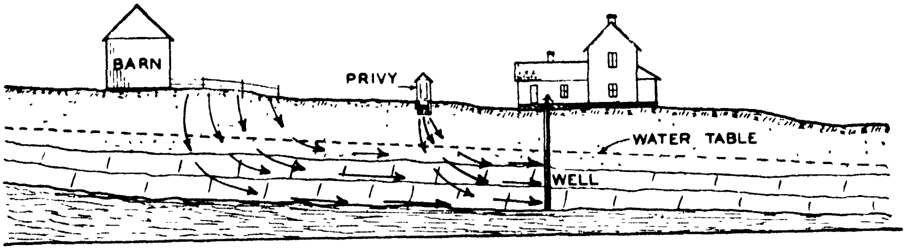


FIGURE 10.—A very poor well location. In such a case the well is likely to be badly polluted from the privy and the barnyard.

The ground surface in the vicinity of the well or spring, particularly on the up-hill side, should be kept clean and free from sources of pollution. Figure 12 shows a cross-section and plan view of one method of protecting a spring from surface pollution.

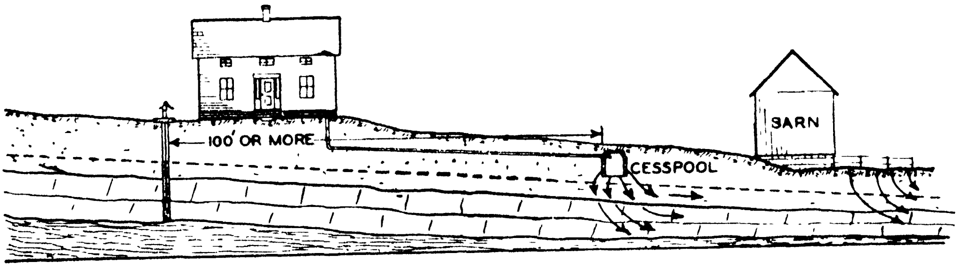


FIGURE 11.—A satisfactory location of well with respect to cesspool and barn.

Cisterns. In regions where there is at least a fair amount of rainfall, rain water is often collected from building roofs and stored in cisterns. In some rural sections of the country, cistern water is used for all domestic purposes, including drinking. This is particularly true where ground water is difficult to obtain or where the ground water obtainable is for any reason

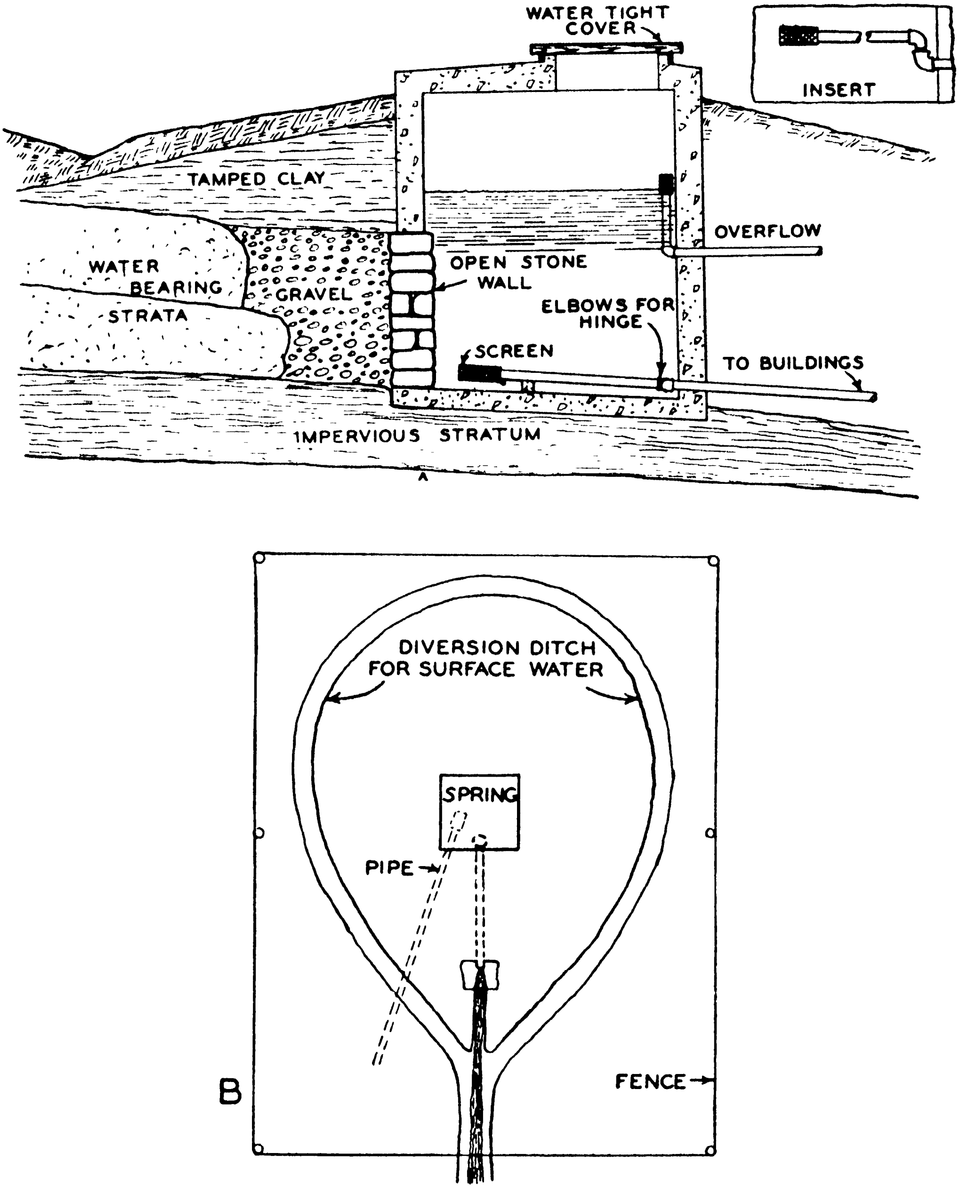


FIGURE 12.—At *A*, a suitable storage basin for a strong spring. For a weak spring the arrangement shown in Figure 79 or 80 should be used. The insert shows the assembly for the discharge pipe which permits the screen to be lifted above the water for cleaning. At *B* is a plan view showing a diversion ditch for surface water and a fence to keep animals away.

unsatisfactory. When cistern water is used for drinking, the cistern should be filled only with clean rain water and should be well protected from contamination from surface water, dust, rodents, and other foreign matter.

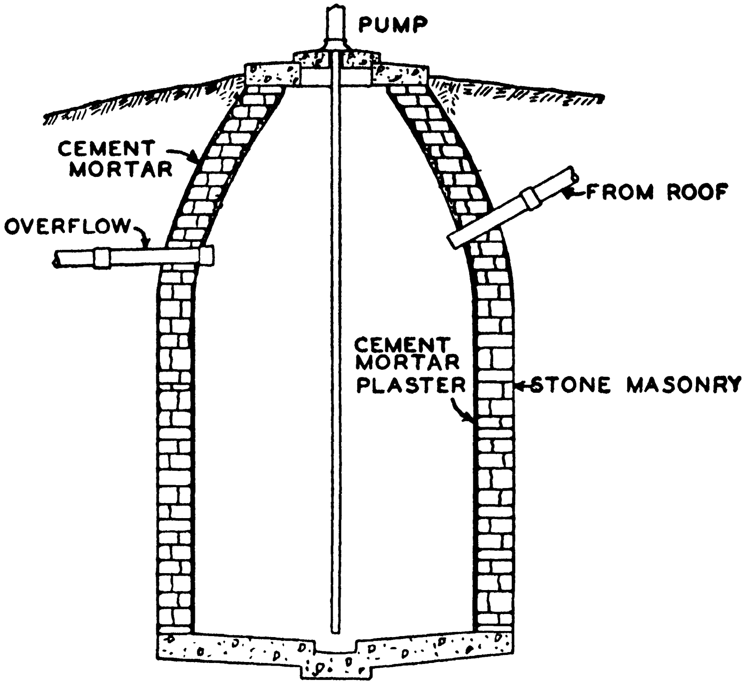


FIGURE 13.—An underground cistern walled up with stone and mortar and plastered on the inside with cement mortar. It is also good practice to plaster the outside of the wall near the top to help keep out surface water. This type of cistern is suitable for use at a barn, or to supply soft water for the hot-water side of a plumbing system, provided it is filled only with clean water.

The first step in protecting cistern water from pollution is to build a water-tight cistern. Figures 13, 14, 15, and 16 illustrate different types of cistern construction. The top should be so constructed that no surface water can enter and, of course, there should be no leaks at the sides or bottom. If the cistern is in a basement it should be covered or shut off by partitions from the rest of the basement, as shown in Fig. 14, to eliminate cellar dust from the water. Also precautions should be taken to exclude rodents and animals of all kinds. Where there is a possibility that animals may get into the water, it is good practice to keep a clean board floating on the surface of the water so that, if a rodent does get in, he can climb onto the board and stay there until rescued.

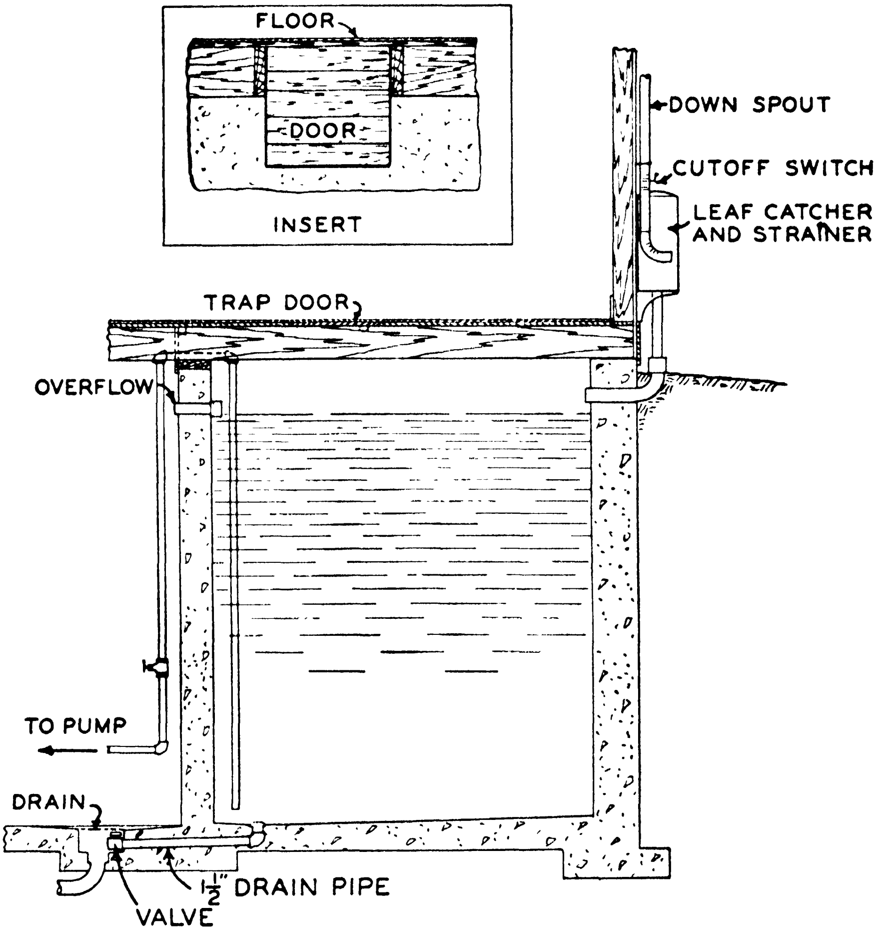


FIGURE 14.—A cistern suitable for a basement. The foundation wall serves as one or more sides of the cistern, the other walls being constructed of concrete and serving as additional supports for the house. Note that the cistern is entirely enclosed to keep out dust and rodents and that a leaf catcher and strainer is provided on the down-spout. Entrance to the cistern for cleaning and repairs may be had through a trap door, as shown, or through a special door in the side between two floor sills as shown in the insert.

With a properly constructed cistern the next step is to see that the water entering the cistern is as pure as possible. It is best to allow water to flow to the cistern only after the roof has been washed for a few minutes by the rain. Cool fall and spring rains are best for filling the cistern.

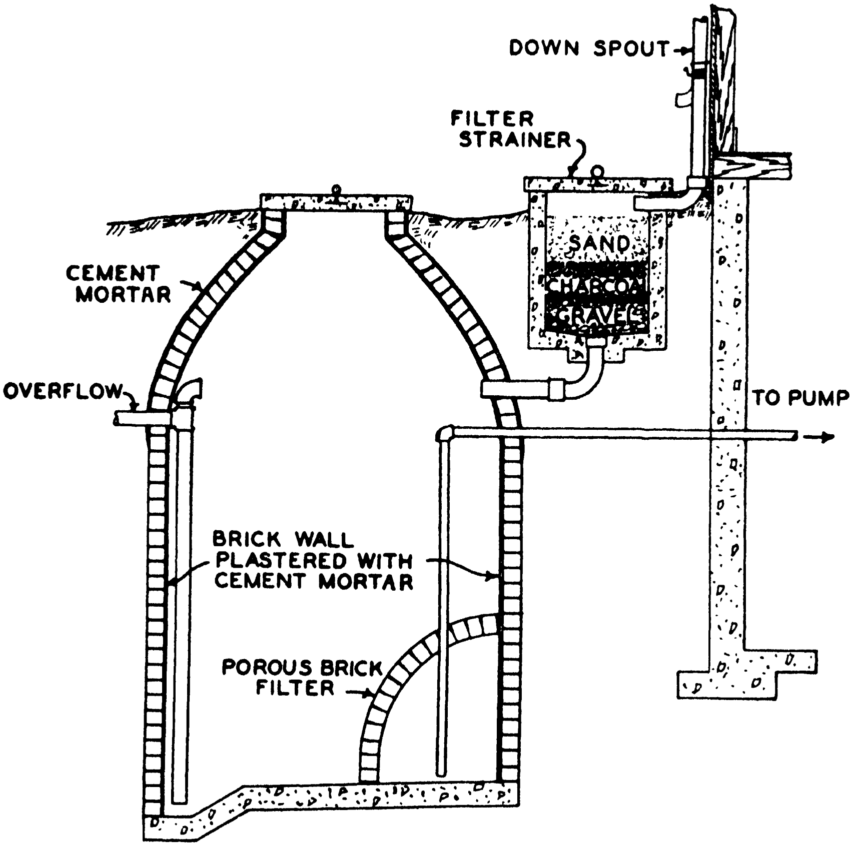


FIGURE 15.—A brick-and-mortar underground cistern provided with a sand-charcoal-gravel filter to catch the major portion of the foreign matter and a porous brick filter around the pump suction pipe to purify the water further. The bottom of the cistern slopes toward a sump on one side from which the overflow pipe extends. The incoming water tends to wash sediment off the brick filter and the floor and toward the sump. When the cistern overflows, the rush of water to the bottom of the overflow pipe tends to flush the sediment out of the cistern. This type of cistern should provide water suitable for drinking purposes.

In spite of precautions in filling a cistern there is likely to be some foreign material entering occasionally. For this reason, where the water is to be used for cooking and drinking purposes, it is best to provide a filter such as is shown in Figs. 15 and 16, through which the water must pass on its way to the cistern. Such a filter, if cleaned regularly, will greatly improve the quality of the water. It should be remembered, however, that filters of this type do not provide absolute assurance of pure water.

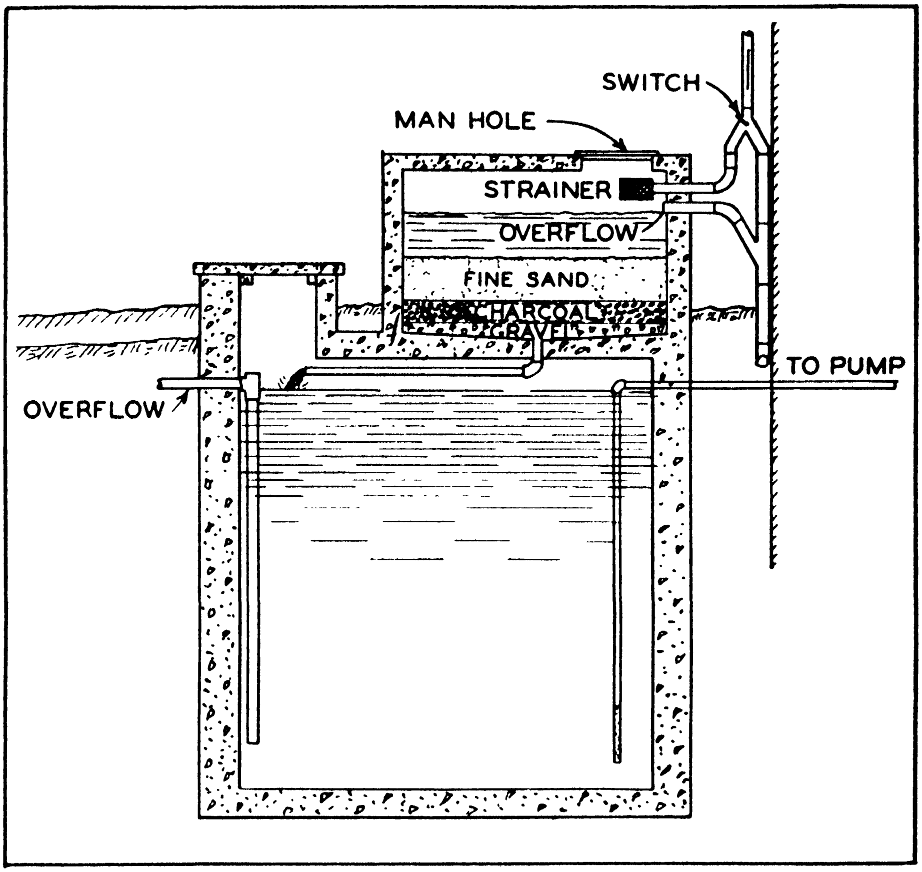


Figure 16.—A sanitary type of cistern suggested by the New York State Department of Health.

Emergency Protection from Polluted Water. In case there is any question as to the purity of water, it is best to boil that which is used for drinking and cooking. Water boiled for 10 to 20 mins. will be free of harmful germs. If facilities for boiling are not available, a fairly reliable protection against typhoid is to sterilize water with iodine. Add one drop of tincture of iodine for each quart of water and allow to stand for 30 mins. before using.

The New York State Department of Health recommends the following treatment for emergency use: "Mix one level teaspoonful of chloride of lime from a freshly opened can with one quart of water. Add one teaspoonful of this solution to each two gallons of water to be treated. The solution should be made up fresh weekly. The treated water should be stored in such a manner as to make subsequent contamination impossible."

Before any extensive use is made of chemical treatments a health officer should be consulted as to the exact treatment to use.

There is available on the market chlorinators for purifying drinking water. These devices can be attached to the water system in such a manner that chlorine will be added as the water flows from the pump to the tank. Because the amount of chlorine needed varies with varying conditions of the water, a health officer should be consulted before a chlorinator is installed.

CHAPTER II

PUMPS: PRINCIPLES OF OPERATION AND TYPES

It is a well-known fact that water will not flow up hill. In the great majority of farm homes the source of water is below the level of the house. When this is true, in order to get the water up to where it is to be used it must be bailed, carried, or pumped. Bailing and carrying water by hand are laborious tasks. Most people prefer to use a pump where possible.

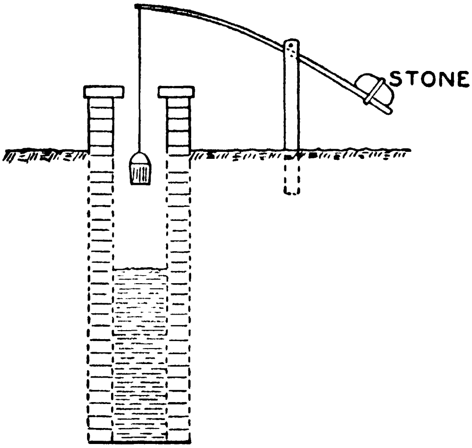


FIGURE 17.—Evanglin well.

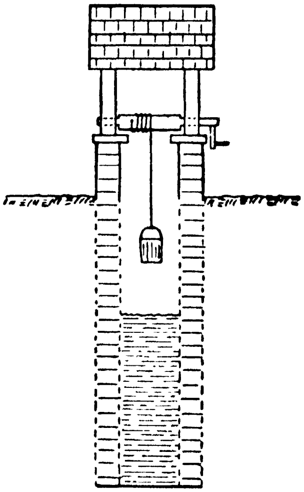


FIGURE 18.—Well with windlass.

The type of pump to use in any particular case depends upon several conditions. The following brief outline of the different types of domestic pumps, their principles of operation and uses, will give the reader an idea as to the type to choose.

Pumps. Two of the more common methods of pumping water used by the past generations are shown in Figs. 17 and 18. These, of course, are not really pumps but are improved means of drawing water by hand. Two more modern methods are shown in Figs. 19 and 20. These are called pumps and are quite common in the southern, middle, and western parts of the United States.

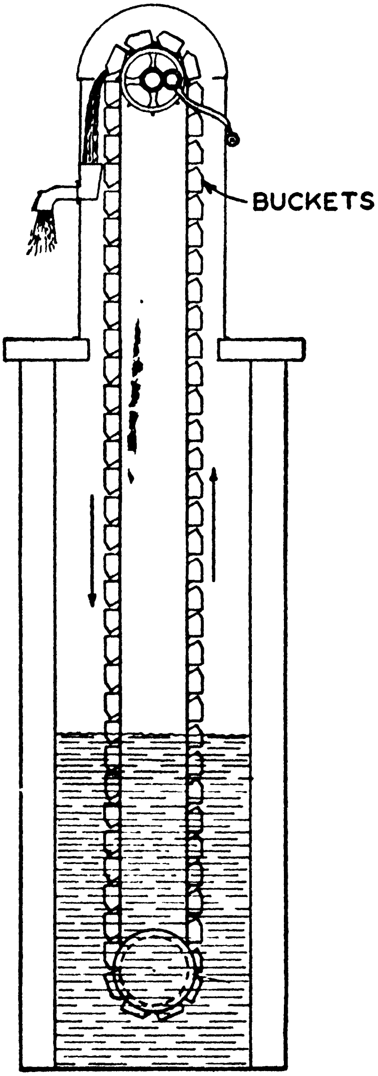


FIGURE 19.—Bucket pump.

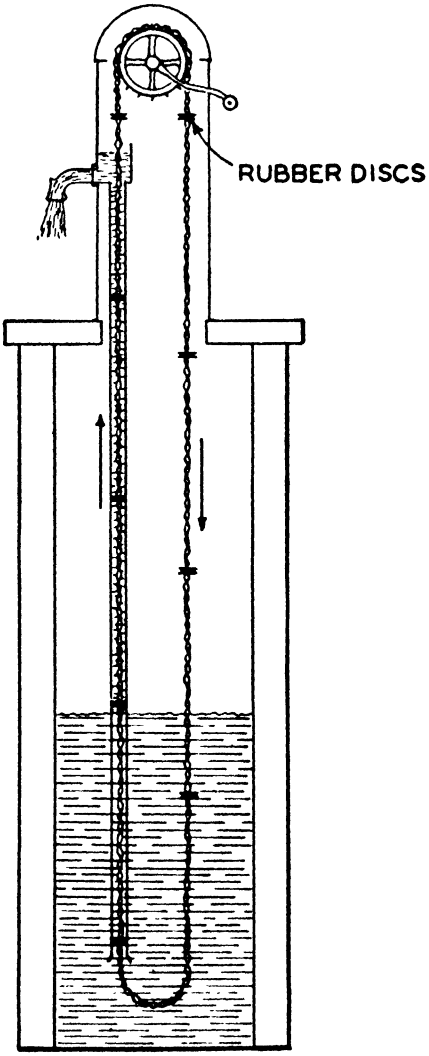


FIGURE 20.—Chain pump.

All the above four pumps lift water by means of some mechanical device such as a bucket or rubber washer, which gets under the water and carries it upward. The bucket and chain pumps are quite inexpensive, give long service, and pump large quantities of water, but they will deliver water only to the spout. From there it must be carried by some other means.

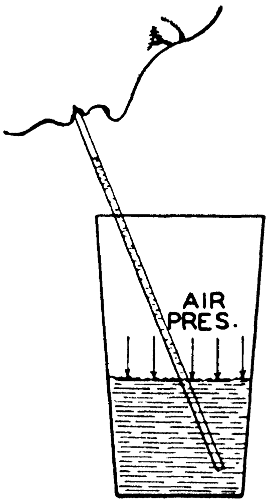


Figure 21.—Atmospheric pressure pushes the soda water up through the straw when air is drawn out of it.

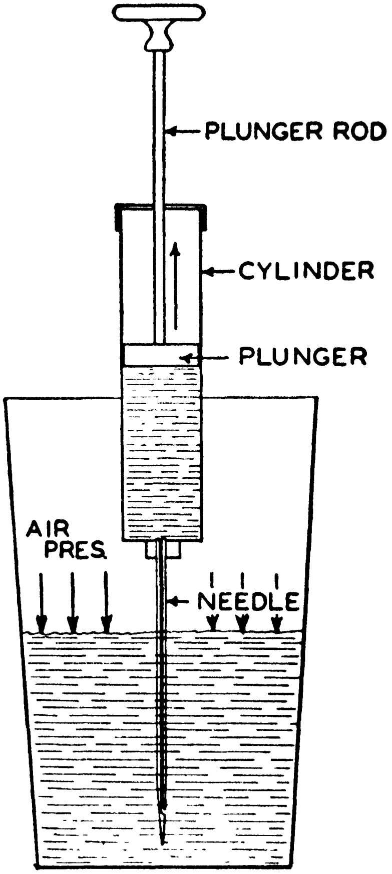


Figure 22.—Atmospheric pressure on the liquid in the glass forces the liquid up into the syringe when the plunger is raised toward the top of the cylinder.

There is another and larger class of pumps commonly called "suction" pumps which depend for their operation upon atmospheric pressure. It is this class of pumps which is most common and to which we wish to give most of our attention.

Principle of Operation of "Suction" Pumps. *How "Suction" Pumps Obtain Water from the Source.* Contrary to popular opinion, suction pumps do not "lift" water up from the source. Rather the pump reduces the atmospheric pressure on the water *in* the suction pipe, and the atmospheric pressure on the water *outside* the suction pipe pushes the water up and into the pump. The principle is the same as that of drawing soda water through a straw, as shown in Fig. 21, or of filling a syringe, as shown in Fig. 22.

Atmospheric Pressure. Although we may not ordinarily think of it, the air which we breathe has weight. At sea level the atmosphere exerts a pressure of 14.7 lb. per square inch of surface. At higher levels the pressure is less, as is shown by the following table.

TABLE III

BAROMETRIC PRESSURES AT DIFFERENT ALTITUDES

With Equivalent Head of Water and the Vertical Suction Lift of Pumps

	Barometric Pressure Lb. per Sq. In.	Equivalent Head of Water, Feet	*Practical Suction Lift of Pumps, Feet
Sea level	14.70	33.95	22
¼ mile (1,320 ft.) above sea level	14.02	32.38	21
½ mile (2,640 ft.) above sea level	13.33	30.79	20
¾ mile (3,960 ft.) above sea level	12.66	29.24	18
1 mile (5,280 ft.) above sea level	12.02	27.76	17
1¼ mile (6,600 ft.) above sea level	11.42	26.38	16
1½ mile (7,920 ft.) above sea level	10.88	25.13	15
2 mile (10,560 ft.) above sea level	9.88	22.82	14

*** Practical suction lift of pumps is equal to the vertical distance to which water is to be lifted plus the head of friction and other losses, if any.**

Courtesy of Goulds Pumps, Inc.

If we assume that the water in a well is at sea level, on each square inch of surface of water the atmosphere will exert a pressure of 14.7 lb. per square inch as shown in Fig. 23*A*. This uniform pressure levels the surface of the water so that it stands at the same level inside and outside the pipe. "Water seeks its own level."

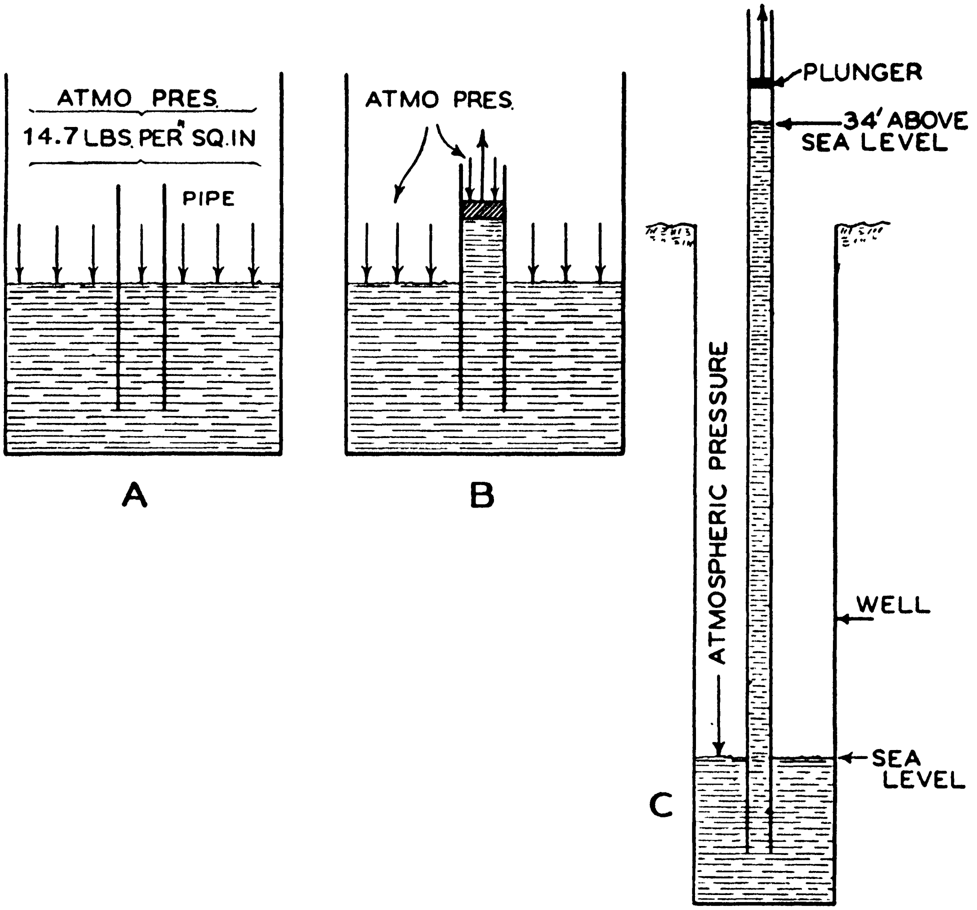


Figure 23.—At *A* the pipe is open and the pressure is the same inside the pipe and outside the pipe. At *B* the plunger has lifted the air and disturbed the balance of pressure. At *C* is shown maximum height to which water can be forced by atmospheric pressure.

Now if an air-tight plunger is placed in the pipe at water level and the plunger is raised as shown at *B*, the atmospheric pressure on the water in the pipe is reduced. This causes an unbalanced condition along the surface of the water, and the water will rise in the pipe. The water rises, not because the plunger is pulling up on it, but because there is greater pressure on the water outside the pipe than there is on the inside of the pipe. If a long pipe is used, as shown at *C*, and the plunger is drawn continuously upward, water will be forced up the pipe by the atmospheric pressure on the surface of the water in the well until the weight per square inch of the column of water in the pipe equals the weight per square inch of the atmosphere or 14.7 lb. per square inch. A column of water approximately 34 ft. high is required to exert a pressure of 14.7 lb. per square inch.

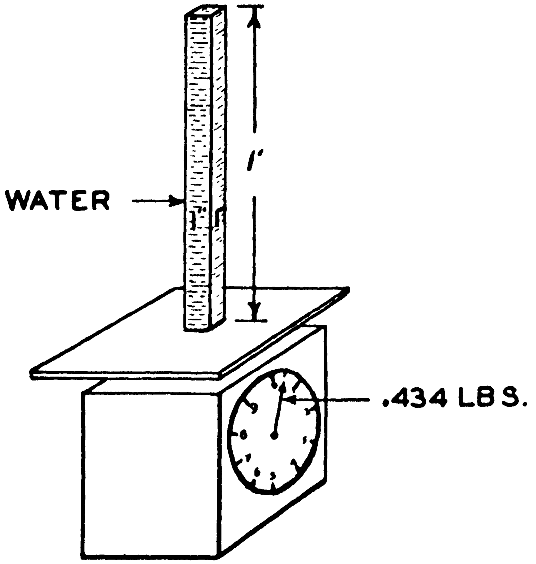


Figure 24.—A column of water 1 in. square and 1 ft. high weighs 0.434 lb. The scales were set for the tare of the container.

Water weighs 62.5 lb. per cubic foot. On the base of a cubic foot of water there are 144 sq. in. Over each square inch of surface stands a column of water 1 in. square and 1 ft. high. By dividing 62.5 lb. by 144 sq. in. we find that this 1-in. square column of water weighs 0.434 lb. See Fig. 24. If a column of water 1 ft. high weighs 0.434 lb. per square inch, it would require a column 34 ft. high to weigh 14.7 lb. per square inch (14.7 ÷ .434 = 34 ft.). At this height the weight of the column of water would exactly balance the weight of the atmosphere on the water in the well; therefore, no matter how much higher the plunger is drawn, the water will rise only to the 34-ft. level. This then is the theoretical maximum height to which any pump, operating at sea level, could cause water to rise. This height would be obtained only when the pump could create a perfect vacuum.

Ordinary water pumps are not capable of creating perfect vacuums. This, together with the fact that there are likely to be small leaks in the pipe and entrained vapors in the water, reduces the practical "suction lift" of ordinary pumps to about 22 ft. at sea level. Guaranteed suction lifts on pumps of various makes range from 22 to 28 ft. In this book we shall consider 22 ft. as the practical suction lift of pumps. Pumps in poor repair will have less suction lift than pumps in good repair.

If the location of the water is higher than sea level, both the theoretical and practical suction lifts are decreased, as may be seen in Table III. At an elevation of 5000 feet, which is equivalent to that of the plains immediately east of the Rocky Mountains, the practical suction lift is only about 17 ft.

Effect of Friction on "Suction Lift." In a practical installation the suction lift in feet is made up of the vertical distance in feet through which the water is lifted plus the additional feet of head due to friction. Loss of head due to friction is discussed in detail in Chapter V.

After water has entered a pump it can easily be discharged in a number of ways as will be explained later.

Shallow- and Deep-Well Pumps. Pumps of all types may be grouped into two general classifications, namely, *shallow-well* pumps and *deep-well* pumps.

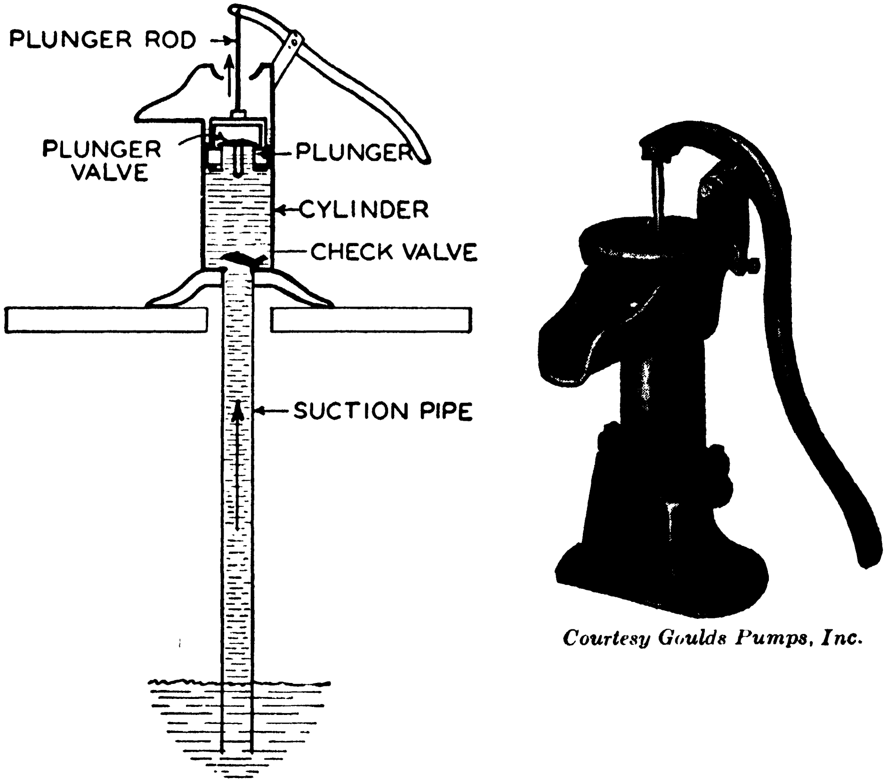
Shallow-Well Pumps. Shallow-well pumps are those designed to pump from "shallow" sources. (Water within 22 ft. vertical distance of the pump location at sea level.) Usually the pump and all other working parts are above ground. Shallow-well pumps may be located directly over the source, as shown in Figs. 3 and 7, or at some distance to one side, as shown in Figs. 4 and 9. Generally speaking, shallow-well pumps are less expensive to buy, less trouble to install, and easier to service and repair. The fact that they can be located at some distance from the well means that often they can be installed in the house, thus eliminating extra expense for frost protection.

Deep-Well Pumps. Deep-well pumps are those designed to pump from "deep" sources. (Water at more than 22 ft. vertical distance from pump location.) Inasmuch as a pump cylinder must *always* be within suction distance of the water, a deep-well cylinder must be placed down in the well, as shown in Figs. 5 and 6. As a rule the cylinder is placed in the water to avoid loss of priming. With the cylinder down in the well the pumping head *must* be located directly over the well as shown.

Deep-well pumps are more expensive than shallow-well pumps of the same capacity. This is due to the extra mechanism of the pumping unit, to the extra pipe needed, to the larger motor necessary, and possibly to the extra expense of protecting from frost. If the source or water is a "deep" source, however, the deep-well pump *must* be provided. Sometimes by lowering a shallow-well pump into a pit over the well or placing it in a basement, it can be placed within reach of the water, thus eliminating the extra cost of the deep-well unit.

Types of Shallow- and Deep-Well Pumps. For practical reasons pumps are not constructed as illustrated in Fig. 23. Such a device would cause the water to rise but would not make it available for use. There are three general types of ordinary water pumps as follows: (1) the reciprocating pump having a cylinder with a reciprocating plunger, piston, or diaphragm, and two or more valves (Figs. 25–38, inclusive); (2) the rotary pump having rotating gears with only a check valve in the line (see Fig. 39); (3) the centrifugal pump having an impeller in a housing, with only a check valve in the line (see Fig. 40).

Each of these three general types of pumps is manufactured in several forms to meet the needs of various pumping conditions. The three general types as used for pumping water will now be taken up in detail.



Courtesy Goulds Pumps, Inc.

FIGURE 25.—Cross-section and picture of a "pitcher" lift pump for shallow wells.

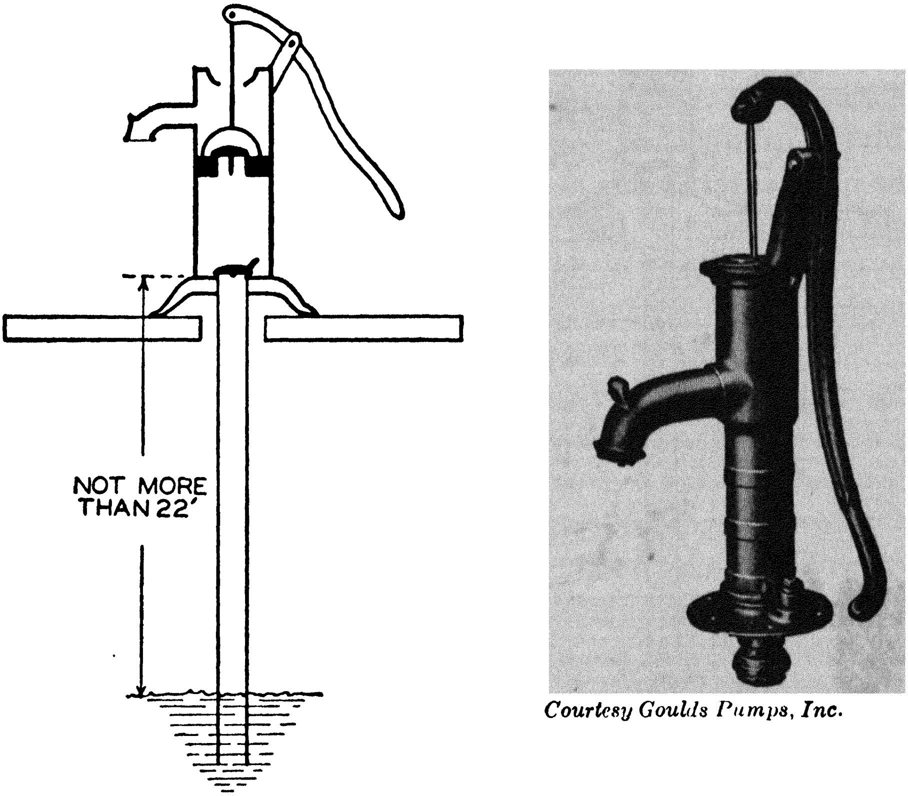
Reciprocating Pumps. Of the reciprocating pumps the following are the most common:

1. "Lift" pump.
2. Simple force pump.
3. Differential force pump.
4. Double-acting force pump.
5. Displacement force pump.
6. Diaphram force pump.

Lift pumps. Lift pumps are designed for bringing water out of the well to the level of the spout only. They are available for either deep or shallow wells. Figs. 25, 26, and 27 show three common forms of lift pumps.

The *principle of operation* of the lift pump is as following:

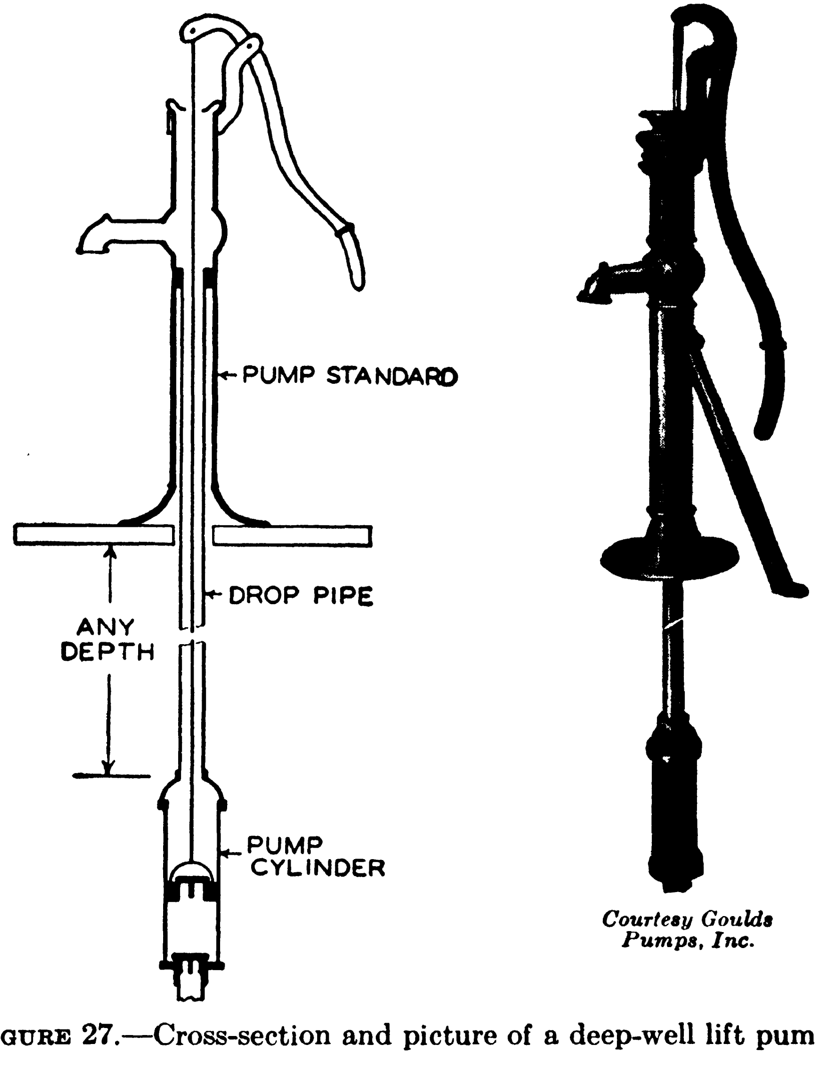
1. With the pump primed, as shown at *A*, in Fig. 28, the plunger is raised. As air cannot pass the plunger owing to the water seal, a part of the atmospheric pressure is lifted off the water in the pipe. The air and water in the pipe follow the plunger upward. The space in the cylinder below the plunger filling with air from the pipe.
2. At the top of the cylinder the plunger stops, the check valve closes of its own weight, thus trapping air in the cylinder.
3. On the next down stroke the entrapped air is compressed between the plunger and the bottom of the cylinder. When the pressure becomes greater than the atmospheric pres-



Courtesy Goulds Pumps, Inc.

FIGURE 26.—Cross-section and picture of a spout lift pump for shallow wells

sure above the plunger, plus the weight of the valve, the air will lift the valve and escape through the priming water as shown at *B*.



Courtesy Goulds Pumps, Inc.

FIGURE 27.—Cross-section and picture of a deep-well lift pump.

4. On the next up stroke more air will be drawn out of the pipe and the water will rise higher, eventually flowing into the cylinder under the plunger as shown at *C*.
5. With the cylinder and pipe full of water as at *C*, the check valve closes, trapping water in the cylinder.

6. On the next down stroke the plunger and valve pass through the water as shown at *D*.
7. When the plunger reaches the bottom of the cylinder and stops, the plunger valve closes, thus trapping the water above the plunger, as shown at *E*.
8. On the next up stroke the water above the plunger is lifted out of the pump as shown at *F*. At the same time more water is drawn into the cylinder through the check valve.

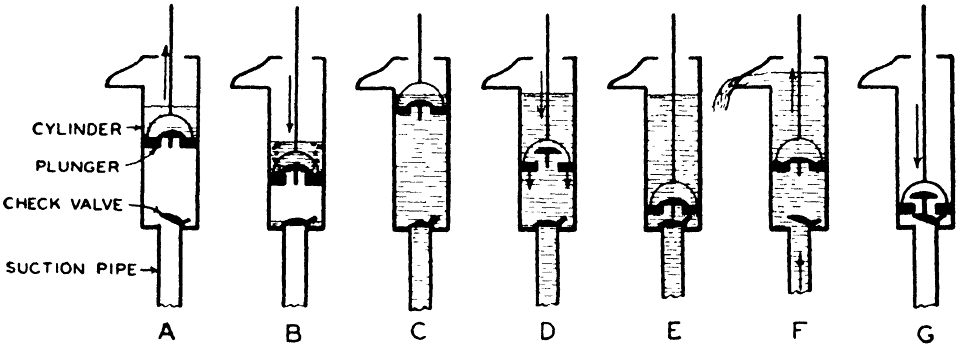
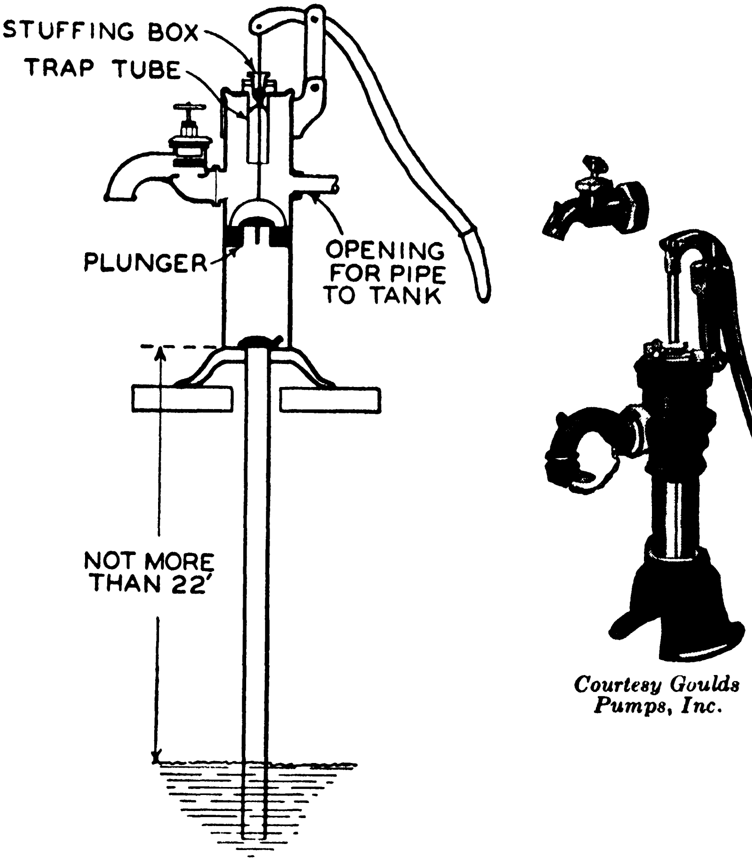


FIGURE 28.—Illustrating at A, B, C, D, E, and F the stages in the operation of a lift pump. At G is illustrated the manner in which the pump can be drained.

9. On each successive down stroke step *E* is repeated, and on each successive up stroke step *F* is repeated. Thus the pump delivers water on each up stroke.

As the shallow-well lift pump is installed above ground and frequently out of doors or in a cold room, it is necessary that the pump and suction pipe be drained to prevent freezing. To drain, the handle is lifted as far as it will go. This forces the plunger down against the projection on the side of the check valve, causing the check valve to open as shown at *G*. As the check valve opens, it strikes the guide on the plunger valve forcing the plunger valve open. Thus, with both valves open, the water is free to drain back to the source.

Note that this type of pump is open at the top and cannot, therefore, force water any higher than the spout. It is commonly used on shallow wells and cisterns to pump water at the kitchen sink, at the well, into drinking troughs, etc.

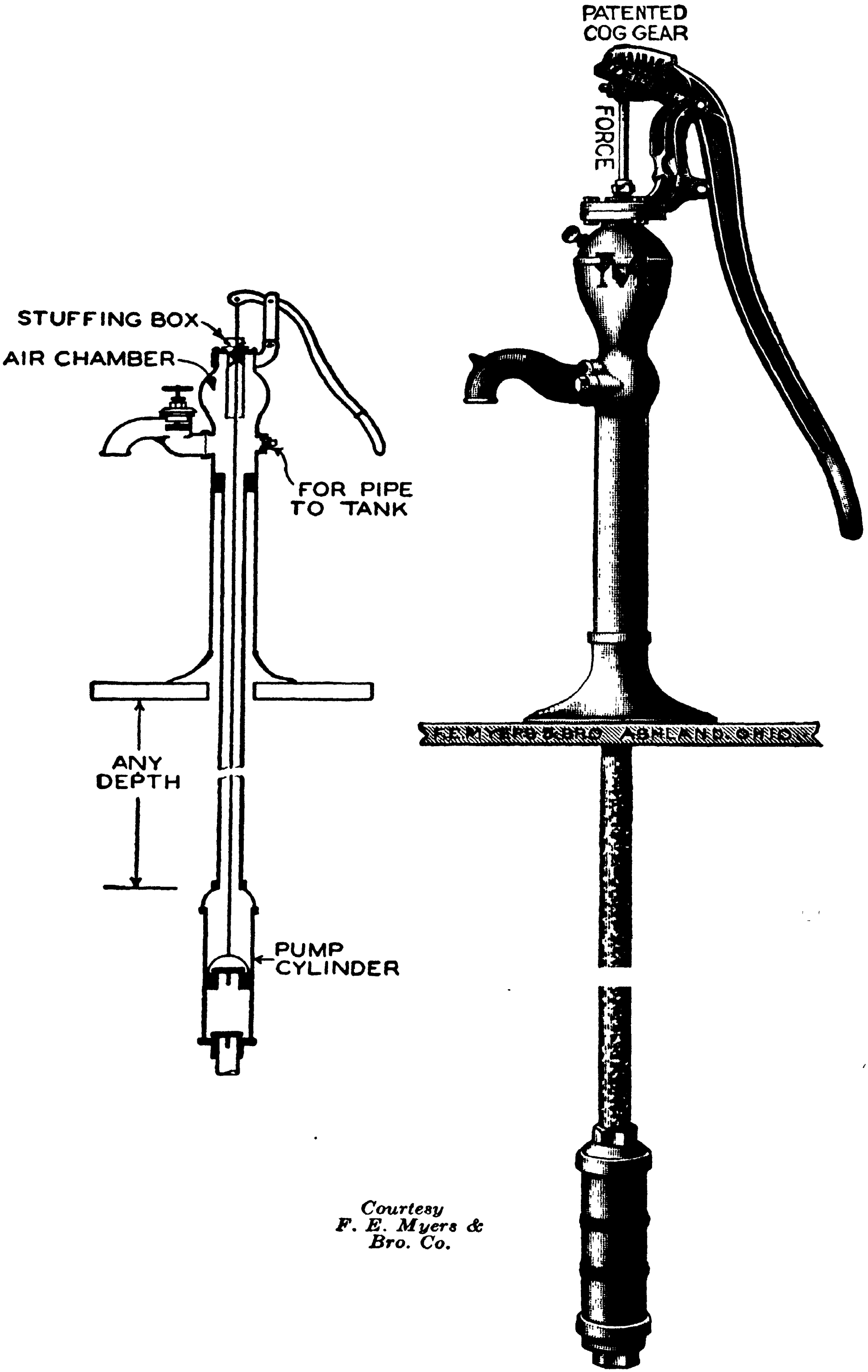


Courtesy Goulds Pumps, Inc.

FIGURE 29.—A cross-section and picture of a shallow-well simple force pump. This pump can be used to deliver water at the spout or, by closing the valve on the spout, may be made to deliver water to a tank through a pipe as shown at the right in the cross-section drawing.

Simple force pumps. Force pumps are designed to bring water from the source in the same manner as lift pumps do and, in addition, *to force the water to a level higher than the pump or to force it into a pressure tank.* They are available for use on either deep or shallow wells, as shown in Figs. 29 and 30.

The *principle of operation* of this type of force pump is the



Courtesy
F. E. Myers &
Bro. Co.

FIGURE 30.—A cross-section and picture of a deep-well force pump. Note that the cylinder is located down in the well.

same as that of the lift pump illustrated in Fig. 28, as far as getting water into the cylinder of the pump is concerned. The difference lies in the fact that the pump can "force" water to an elevated or pressure tank. This is made possible by the addition of a stuffing box at the top which encloses the pump cylinder. See Figs. 29 and 30.

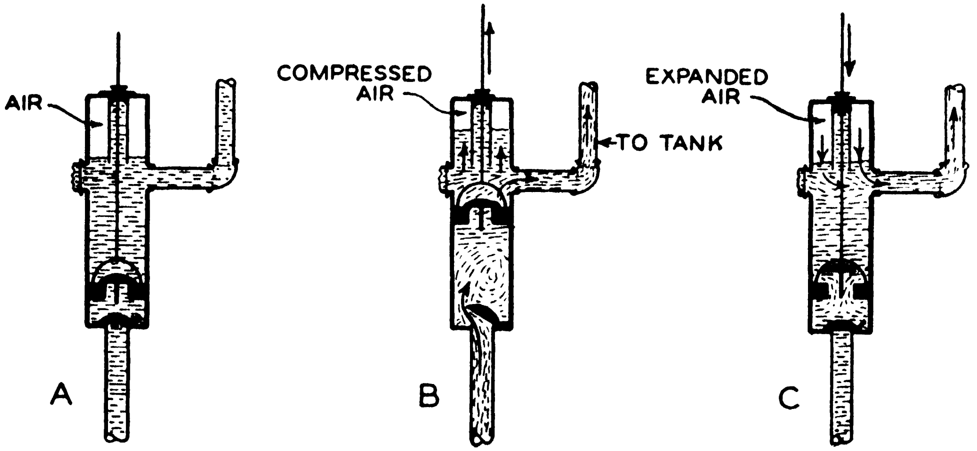


FIGURE 31.—A cross-section showing three stages of operation of a simple force pump. At *A* the pump is stationary; at *B* the plunger is moving upward drawing in water below the plunger and discharge above; at *C* the plunger is moving downward through the water while the air in the air chamber maintains a flow from the pump.

The stuffing box fits water-tight around the plunger rod, yet is free enough to allow the plunger rod to slide through it.

In addition to the stuffing box, simple force pumps are equipped with an air chamber, the function of which is to provide a more uniform flow through the discharge pipe. The operation of the air chamber is as follows:

1. With the pump primed with water and the air chamber properly primed with air, the conditions are as shown in Fig. 31 at *A*. The air in the air chamber is at atmospheric pressure or slightly above, depending upon the back pressure from the tank.
2. On the up stroke of the plunger a part of the discharged

water enters the air chamber, compressing the air above it as shown at B. The remainder flows out through the discharge pipe. This reduces the flow through the discharge pipe during the discharge stroke.

3. At the end of the discharge stroke, and while the plunger is going down, the compressed air in the air chamber expands and continues to force water out of the air chamber and through the discharge pipe, as shown at C.

In this manner a more or less uniform flow of water is maintained in the discharge pipe. A uniform flow is desirable because it eliminates pounding in the pipes and also makes the pump easier to operate.

The air chamber may be located on the discharge pipe, but a more common location is shown in Figs. 29 and 30. With this arrangement a trap tube is provided around the plunger rod to prevent loss of all the air through the stuffing box.

As the pump is working, the air in the trap tube will leak out at the stuffing box, allowing water to fill the tube. The water wets the packing, making it tighter and providing lubrication for the plunger rod.

Differential force pump. A differential force pump is a pump to which has been added a differential cylinder and piston. Differential pumps are available for deep or shallow wells as shown in Figs. 32 and 33.

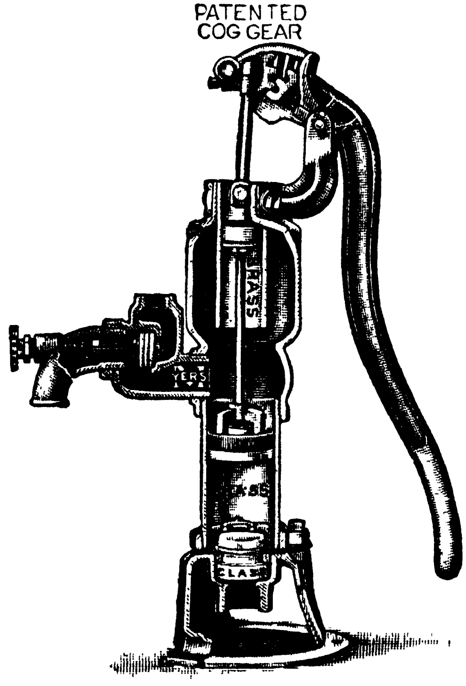
Owing to the effect of the differential cylinder, this type of pump can be operated against high heads with smaller power units than the simple force pump. For this reason they are popular for windmill and electric motor drives.

The principle of operation of the differential force pump is as follows:

1. The lower, main cylinder operates in the same manner as does the simple lift pump. At the top of the pump is located a differential cylinder in which there is a solid plunger attached to the plunger rod. This solid plunger

moves up and down in the differential cylinder as the main plunger moves up and down in the main cylinder.

2. On the up stroke of the plungers the main cylinder discharges three ways, as shown in Fig. 34 at *A*. A part of the water goes out the discharge pipe, a part into the air chamber, and a part into the differential cylinder, following the differential plunger as it goes up. This means that only a



Courtesy F. E. Myers & Bro. Co.

FIGURE 32.—Cross-section of a shallow-well differential pump. Note that the plunger in the differential cylinder is a solid plunger without valves. This plunger and the differential cylinder take the place of the stuffing box and the trap tube shown on the simple force pump of Figure 29.

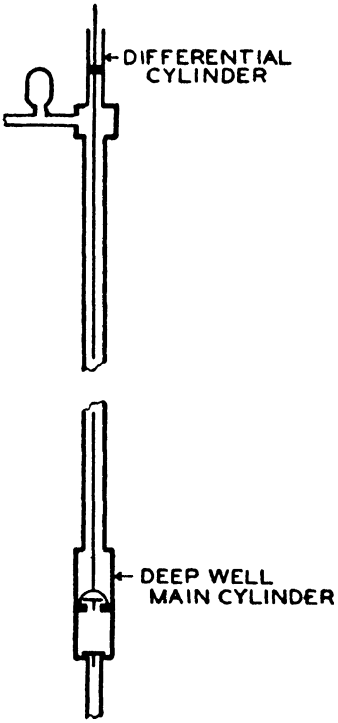


FIGURE 33.—Cross-section of a deep-well differential pump. Note that the differential cylinder is at the top and the main cylinder is down in the well.

part of the water, perhaps three-fourths, must be discharged against pressure on the up stroke. This lowers the up stroke peak load, which makes it possible to pump with less wind or to use a smaller electric motor or other power unit.

3. At the top of the up stroke, while the plungers are motionless, the air chamber maintains a flow through the pipe.

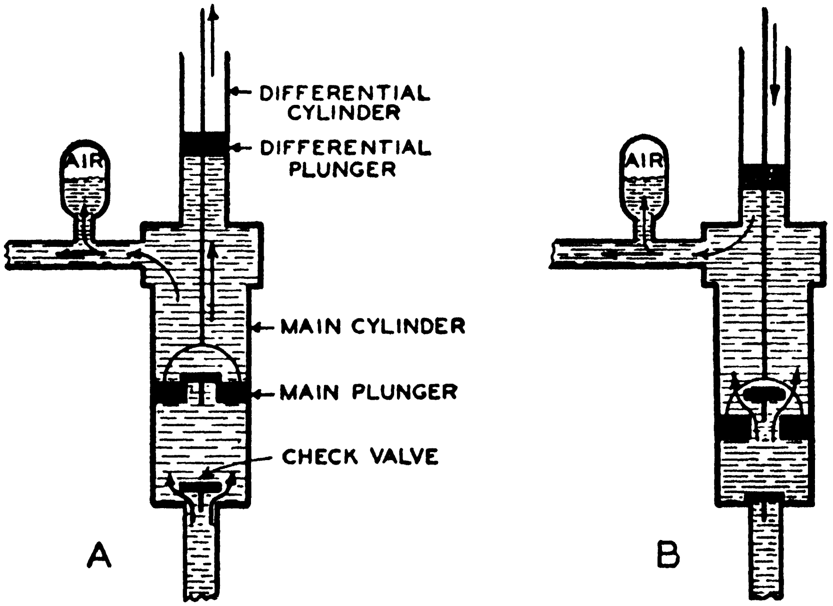


FIGURE 34.—Cross-section of differential pump at two stages in its operation. At *A* water is being drawn from the well below the main plunger and at the same time is being discharged above the main plunger to three places, the tank, the air chamber, and the differential cylinder.

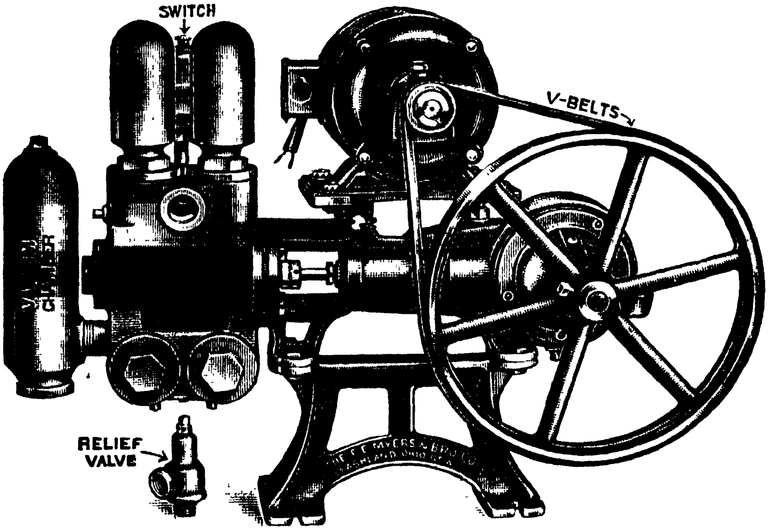
At *B* the main plunger is passing downward through the water while the differential plunger is discharging.

4. On the down stroke the differential plunger discharges into the air chamber and the discharge pipe, as shown at *B*, thus recharging the air chamber and continuing the discharge flow.
5. When the plungers stop on the down stroke the air expands, maintaining the flow until the plungers start upward again.

In this way the pump maintains a fairly uniform discharge flow.

Note that the pump draws from the source only on the *up* stroke but discharges on *both* strokes. It is not a double-acting pump.

Double-acting force pump. Double-acting force pumps are designed to draw and discharge water on both strokes. A very common form of this pump is the horizontal double-acting shallow well pump shown in Figs. 35 and 36. This form is used extensively on domestic water systems.



Courtesy F. E. Myers & Bro. Co.

FIGURE 35.—A horizontal double-acting force pump.

Double-acting pumps are also available for deep-well operation.

The *principle of operation* of the double-acting pump is illustrated in Fig. 36.

When the plunger moves to the right in the cylinder, as shown at *A*, water is drawn in at the lower left and simultaneously a discharge takes place on the upper right. On the reverse stroke the intake is on the lower right and the discharge is on the upper left. The air chamber maintains a flow between strokes.

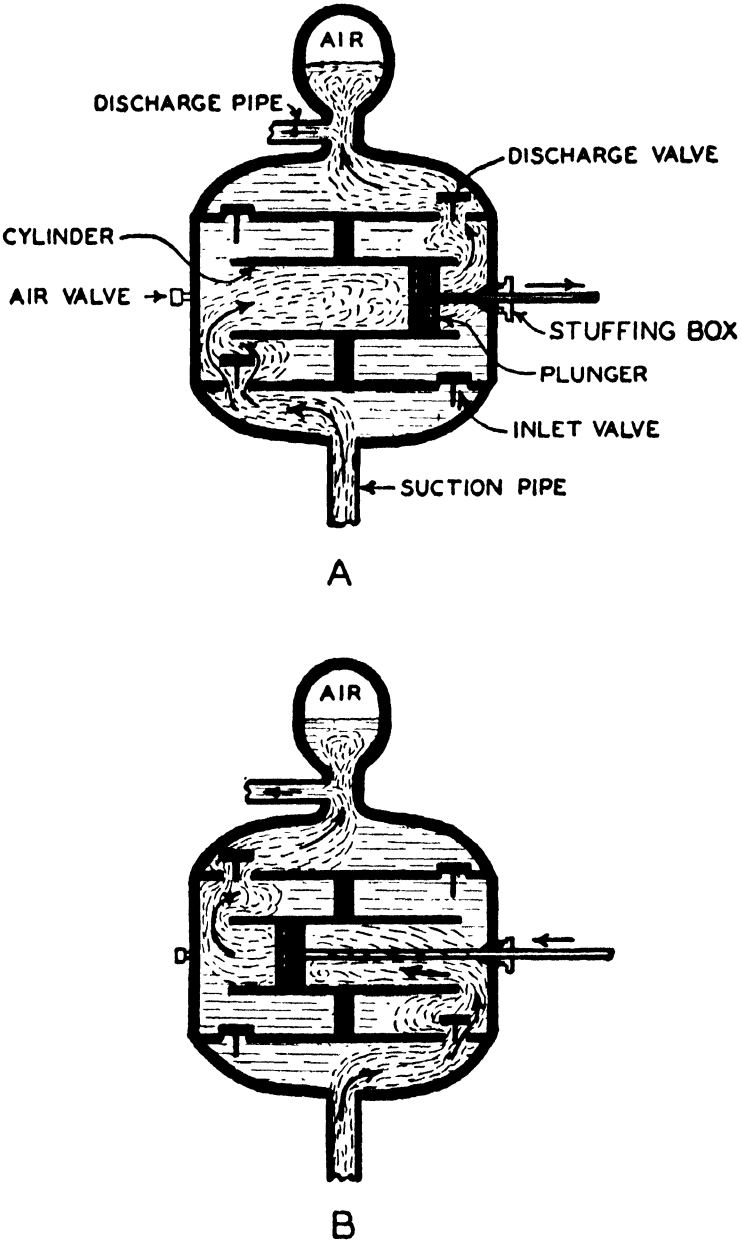


FIGURE 36.—Two stages of operation of a horizontal double-acting pump. At *A* the intake is on the lower left and the discharge is on the upper right.

At *B* on the next stroke the intake is on the lower right and the discharge is on the upper left.

Displacement force pump. The displacement pump is not commonly used on farms except in spray rigs. It is especially adapted for building high pressures and for handling liquid-containing abrasives and corrosive materials. Some of the spray pumps have vitrified linings in the cylinders to resist corrosion.

Figure 37 illustrates the principle of construction of the displacement pump.

Principle of operation of the displacement force pump is as follows.

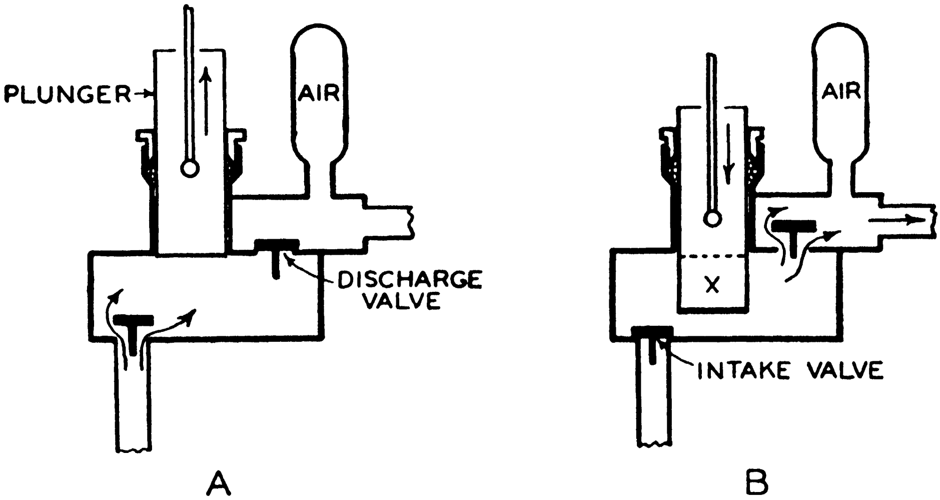


FIGURE 37.—Cross-section of a displacement pump. At *A*, intake stroke; at *B*, discharge stroke.

When the plunger is drawn up, as shown in Fig. 37 at *A*, the pressure in the cylinder is decreased. This decreased pressure permits atmospheric pressure to force liquid into the cylinder.

On the down stroke of the plunger the intake valve is closed, and the plunger will displace its volume *X* out through the discharge valve.

Owing to the large open spaces about the plunger when it is down, abrasive materials can pass through with a minimum of damage to the plunger or cylinder.

Displacement pumps are ordinarily used only on "shallow" sources. They work best where the suction head is very low.

Diaphragm force pump. The diaphragm pump is seldom used for pumping water except for irrigation purposes, emptying construction ditches, etc., and then only at very low heads. However, every farm which has an automobile is likely to have one of these pumps because the fuel pump on the modern car is a diaphragm pump.

Because of its peculiar construction the diaphragm pump can handle safely liquids containing considerable sediment. Also, their rate of discharge can be varied over a wide range without altering the pump in any way.

The principle of construction is illustrated in Fig. 38.

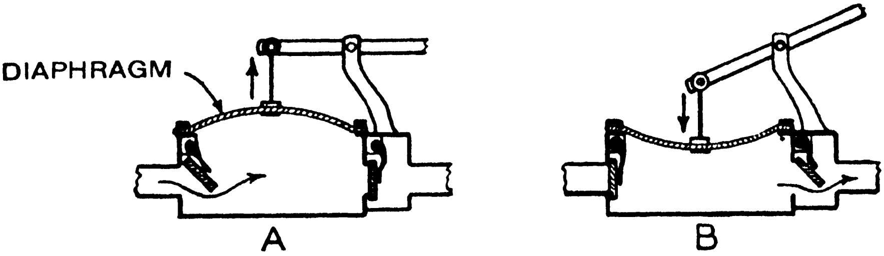


FIGURE 38.—Cross-section of a diaphragm pump. At *A*, intake stroke; at *B*, discharge stroke.

This is the *principle of operation* of the diaphragm force pump.

As the diaphragm is lifted, liquid is drawn in through the inlet valve at the left as shown. When the diaphragm is depressed, liquid is forced out at the right.

In the automobile fuel pump the diaphragm is moved by a cam or eccentric on the cam shaft and a spring. The rate of pumping fuel is governed automatically by varying the length of the stroke on the diaphragm.

Rotary force pumps. Rotary pumps consist of two rotating gears meshed together in a housing with very close clearances as shown in Fig. 39. Power is applied to only one of the gears, which in turn drives the other gear.

Principle of operation of the rotary force pump is as follows:

1. The direction of rotation is as shown. When the teeth dis-

engage, a partial vacuum is created over the intake. This permits atmospheric pressure to force liquid into the pump filling up the spaces between the teeth.

2. As rotation continues the liquid between the teeth is carried around the outer sides of the pump to the point where the teeth remesh. As the teeth remesh the liquid between them is squeezed out, thus building up a pressure under the discharge.

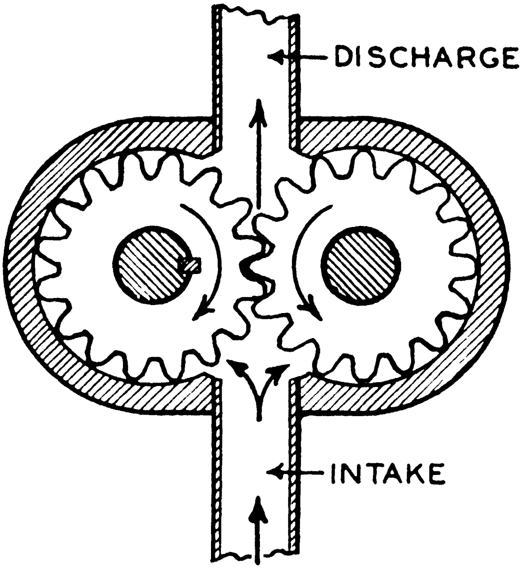


FIGURE 39.—A rotary pump.

Uses. Although there are rotary water pumps on the market they are not widely used. Having no valves they are very well adapted for pumping heavy liquids and, for this reason, are universally used as oil pumps on automobiles, trucks, and tractors.

Rotary pumps can be driven by belts, gears, or direct drive. The discharge is very uniform at constant speeds and heads.

Centrifugal force pumps. Centrifugal pumps consist of an impeller mounted in a housing which may or may not have fairly close clearances. Figure 40 illustrates the principle of construction. There is only one moving part.

Principle of operation of the centrifugal force pump is outlined below. The direction of rotation of the impeller is as shown.

1. When the pump is primed the housing and impeller are filled with water. As the impeller rotates, water is thrown out of the impeller blades by centrifugal force. This reduces the pressure at the center of the impeller and more water will flow in through the intake to fill the partial vacuum.

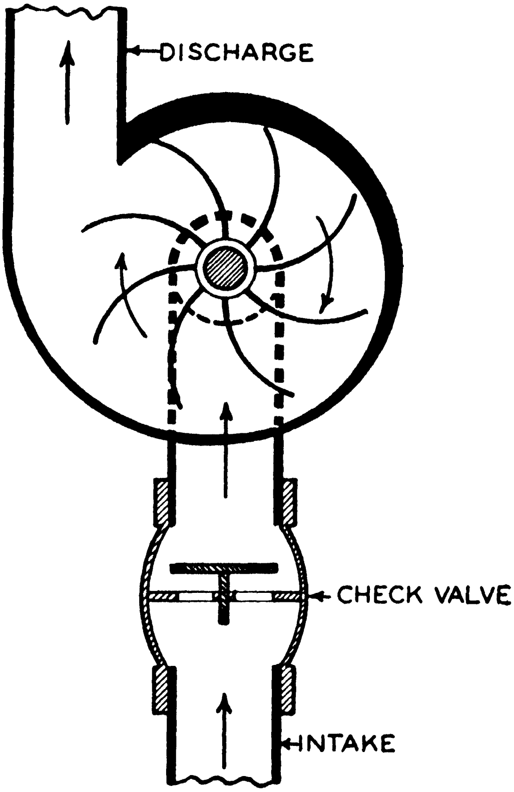
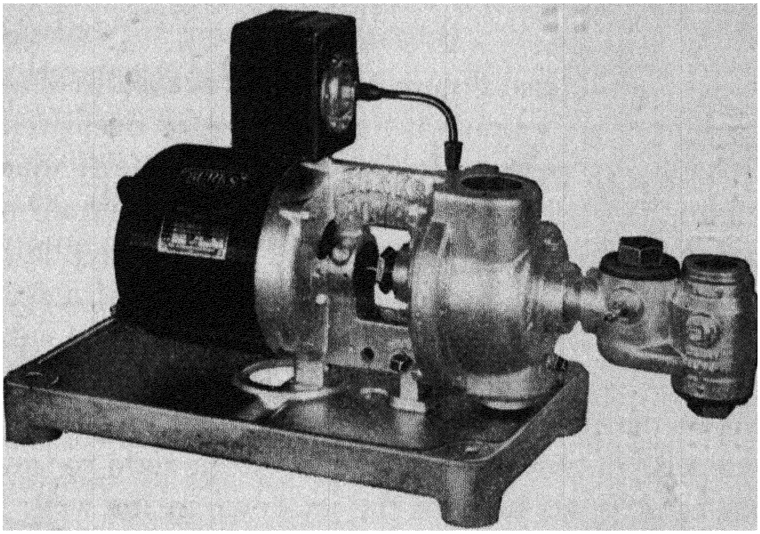


FIGURE 40.—A centrifugal pump.

2. As the impeller continues to rotate the water just admitted will in turn be thrown out, more will flow in to take its place, etc. In this way a constant stream of water is moved through the pump.
3. As the water is thrown out of the impeller it builds up a

pressure on the rim of the housing. The housing has increasing clearance from the impeller toward the discharge. This allows the water from the impeller to move toward the discharge.

Uses. The centrifugal type of pump has wide application. It is most efficient for handling large volumes of water at low heads. As it has no valves it can handle a wide variety of liquids and, if designed for the purpose, can handle liquids with considerable sediment without difficulty. It is a relatively inexpensive pump, is easy to maintain, and is efficient in operation if used for the purpose for which it was designed.



Courtesy Decatur Pump Co.

FIGURE 41.—A modified form of centrifugal pump. This particular pump is said by the manufacturer to have a suction head of 28 ft. and to be capable of operating against pressures up to 80 lb.

To meet the wide range of pumping conditions centrifugal pumps are of many designs. In no other pump is it so important that the design exactly suit the needs.

Although centrifugal pumps work best at low heads, there are several modified forms which give excellent performance on pressure systems. See Fig. 41.

Centrifugal pumps are available for deep or shallow wells.

Some common farm uses for the centrifugal pump are:

1. Irrigation.
2. Drainage.
3. Cellar drains.
4. Water supply.
5. Washing machines.
6. Water-circulating pumps on water-cooled gasoline engines of all kinds.

Ejector or Jet Pumps. Figure 42 illustrates the use of a centrifugal pump in conjunction with an ejector for deep-well operation. This type of pump, commonly known as an "ejector" or "jet" pump, can be used to lift water to a maximum of 90 ft. vertical distance from the water in the well to the pump at the top. The pump can be located over the well or at a reasonable distance away. For best operation the jet should be submerged from 5 to 10 ft. below the water level in the well.

As shown in the illustration, the pump discharges in two directions. One discharge pipe leads off to the right to the storage tank; the other leads back to the jet down in the well.

The *principle of operation* is as follows:

1. With the pump and both drop pipes completely filled with water the pump is started.
2. The pump at the top immediately discharges water toward the automatic regulator at the right of the pump and downward through the right-hand pipe toward the jet.
3. Water is discharged through the jet at a high velocity, thus creating a partial vacuum at that point.
4. Owing to this partial vacuum, water flows from the well through the strainer and foot valve to the body of the jet, where it is mixed with the water from the jet nozzle and carried upward to within suction distance of the pump at the top.
5. As soon as the pump obtains this additional water from the

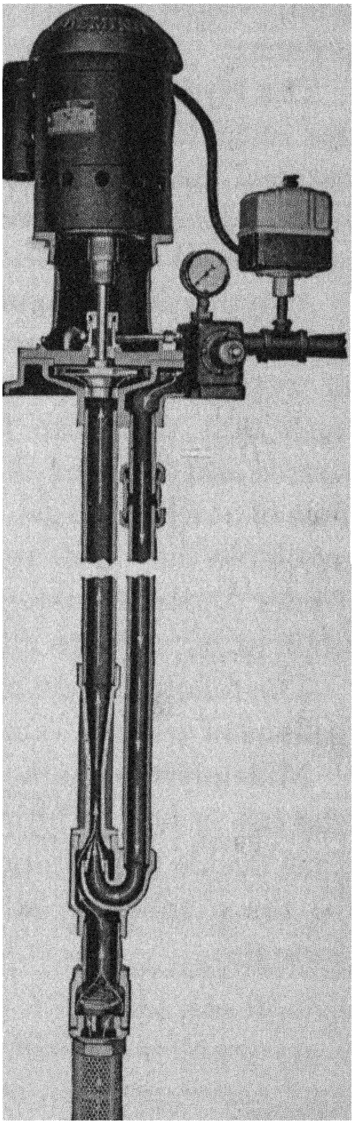
well, the pressure is increased and the control valve in the automatic regulator is forced open, allowing water to pass through to the storage tank.

6. From this point on, the pump discharges both to the storage tank and to the jet, the control valve regulating the pressure on the jet. The control valve can be adjusted for pressures suitable for the depth of the well.
7. When the pump stops, the foot valve prevents a backflow of water, thus holding the pump priming until the next start.

For operation on shallow wells this centrifugal pump can be used without the jet. A single drop pipe, with foot valve and strainer at the lower end, takes the place of the jet and pipes shown here.

The ejector can also be used in conjunction with shallow-well reciprocating force pumps.

This jet pump is quiet in operation and occupies very little floor space. The motor and pump do not have to be installed over the well, which, in some cases, eliminates expensive frost-proof construction at the well. There is only one moving part, and that is located above ground where it is easy to service. Its use is limited to wells where the water is within 90 ft. of the top.



Courtesy The Deming Co.

FIGURE 42.—One type of Ejector or Jet Pump.

Some types of force pumps are built of materials of different strength for operation at different pressure ranges. Where high pressures (above 45 lb.) are to be used be sure to purchase a pump which is built of materials heavy enough to stand the pressure.

The Hydraulic Ram.* Where natural water-supply conditions are suitable, a hydraulic ram provides a satisfactory and economical means of pumping water. A properly installed ram delivers water at practically no cost except interest on investment and a small depreciation cost.

A hydraulic ram pumps water by means of water power. For this reason it is necessary not only to have a sufficient quantity of water available at the source, but also the location must be such that there can be a certain minimum fall between the source and the ram. A spring, stream, or artesian well having a flow of at least 1½ gal. per minute and so located that there is an available fall of 20 in. or more will operate a hydraulic ram. Under these *minimum* conditions a ram will pump a small amount of water to a height of 25 ft.

The following rule may be used for calculating the number of gallons of water a ram will deliver per hour to any given point.

Multiply the number of gallons per minute of supply water by the fall in feet. Multiply this product by the factor forty (40), then divide the product by the elevation in feet. The result will be the number of gallons delivered per hour. Expressed as a formula:

$$\text{Gallons per hour} = \frac{V \times F \times 40}{E},$$

Where

V = gallons per minute of supply water.
F = fall in feet.
E = vertical elevation in feet water is to be raised.

---

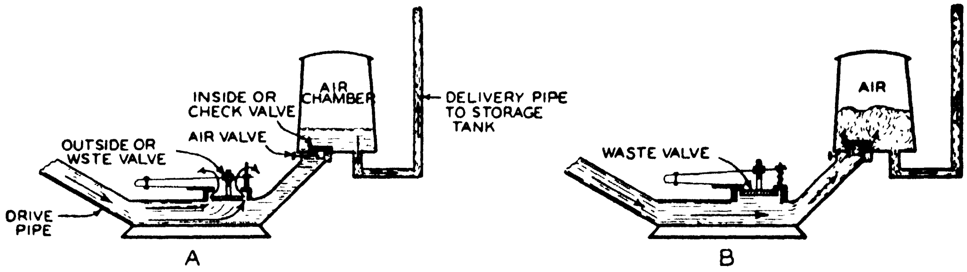
* The author is indebted to the Rife Ram and Pump Works Division of Waynesboro, Va., for the illustrations and much of the text on rams.

Example: The flow of water at the source is 20 gal. per minute, the fall to the ram is 5 ft., and the vertical elevation water is to be pumped is 50 ft. Substituting in the formula, we have

$$\frac{20 \times 5 \times 40}{50} = \frac{4{,}000}{50} = 80 \text{ gal. per hour.}$$

Eighty (80) gallons per hour times 24 hr. equals 1,920 gal. per day.

Under average discharge conditions a ram will deliver to the storage tank only a small portion of the water which flows through it. For this reason the rate of flow of the source must be greater than needed for a straight gravity system.



Courtesy Rife Ram & Pump Works.

FIGURE 43.—Two stages in the operation of a single acting hydraulic ram. At *A*, the waste valve is open and water in the drive pipe is gaining momentum; at *B*, the waste valve has closed and the ramming action of the water in the drive pipe is forcing water into the air chamber.

Types of Rams. Two types of rams are available, namely, (1) the single acting and (2) the double acting. The single-acting ram delivers to the storage tank a part of the water which operates the ram. This type is satisfactory if the source provides clean pure water. The majority of rams in service are of this type. See Figs. 43 and 45. The double-acting ram is so designed that it can use one source of water for power to pump water from another source. See Figs. 44 and 48.

Rams can be used to pump direct to an open faucet, to a gravity storage tank, or to a pressure tank. If a gravity tank is used, it should be provided with an overflow. If a pressure tank is used, it should be equipped with a reliable weighted type of relief valve. As a rule a ram will work best when discharging

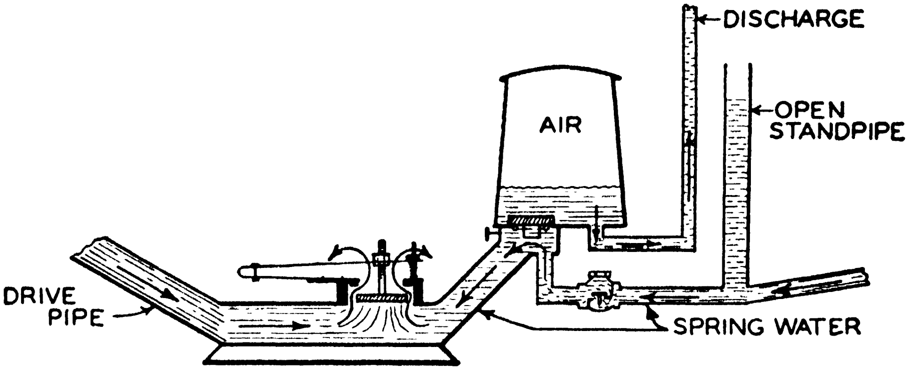


FIGURE 44.—A double-acting hydraulic ram. The spring water comes in from the right while the ramming water comes in from the left.

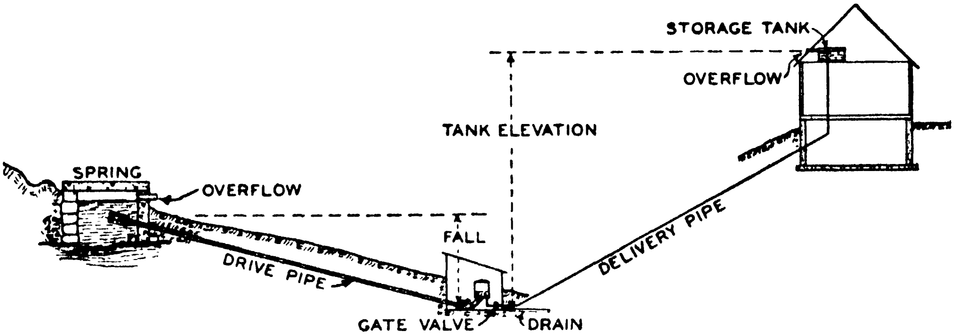


FIGURE 45.—A ram installation to pump spring water to a tank in the attic, using the spring water for power. Any type of storage tank may be used and it may be located on a tower, on a hill, in the barn, or in any other convenient place. This is the most common type of installation but must be varied to suit local conditions.

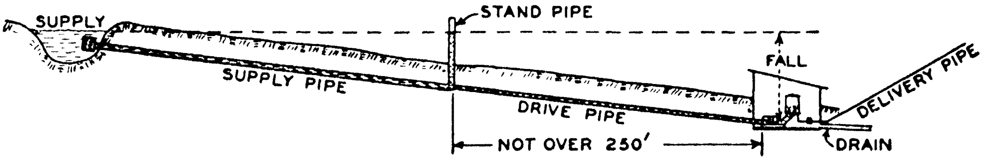


FIGURE 46.—A ram installation where the ram must be located over 250 ft. from the source. The supply pipe must always be one size larger than the drive pipe and the top of the stand pipe should extend above the level of the source.

If the supply pipe must come in at an angle the construction should be similar to the supply arrangement shown in Fig. 48.

into an open gravity storage tank because the discharge pressure is fairly constant. The discharge pipe should enter the tank at or near the top as shown in Fig. 45.

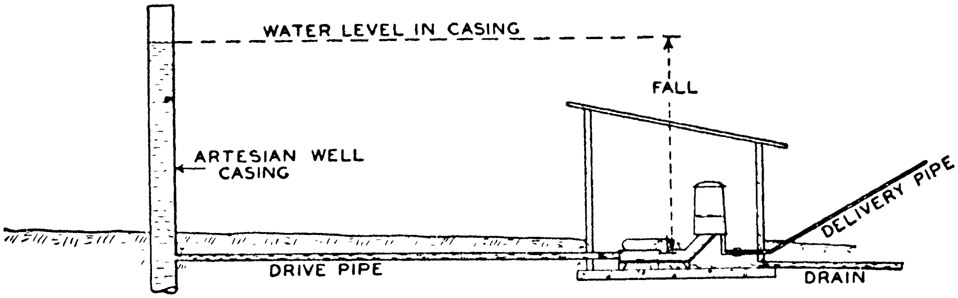


FIGURE 47.—A ram installation on an artesian well. The head on the water in casing causes the flow through the drive pipe.

Minimum Requirements for Successful Operation. In order for a ram to operate satisfactorily the following conditions must prevail.

1. There must be a rate of flow of at least 1½ gal. per minute.
2. There must be at least 20 in. of fall to the supply water.
3. The drive pipe must be a straight pipe of a size suitable for the size of ram.

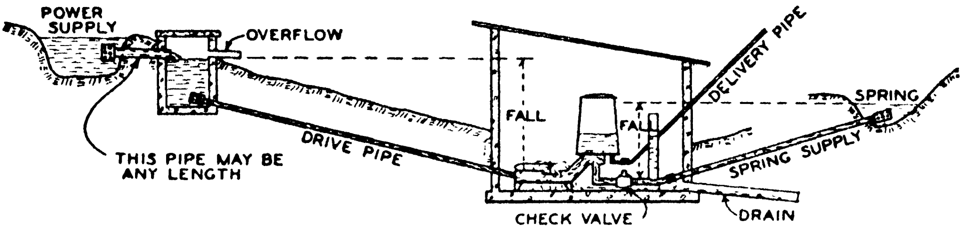


FIGURE 48.—A double-acting hydraulic ram installation. Water from the source on the left is used for power to pump spring water from the right. The spring supply pipe should have a stand pipe as shown and must have a check valve.

4. The *minimum* length of drive pipe is 25 ft. The *maximum* length is 250 ft.
5. The upper end of the drive pipe should be at least 12 in.

below the surface of the water, and should have a screen to prevent solids from entering.

6. The discharge pipe must be of the size recommended by the manufacturer of the ram.
7. Provision must be made for draining waste water from the ram so that it will not be flooded.
8. The ram must be protected from extreme frost conditions.

These minimum conditions do not assure an adequate quantity of water for all purposes.

Principle of Operation. The principle of operation of the ram is as follows:

1. With the ram and drive pipe full of water, as shown in Fig. 43 at *A*, the ramming action is started by opening the waste valve by hand.
2. As the water flows out the waste valve, it gains speed and momentum in the drive pipe.
3. When the water flowing past the waste valve has gained a certain velocity, the waste valve is forced closed suddenly, as shown at *B*.
4. The momentum of the moving water in the drive pipe causes a ramming action which forces water through the discharge valve at the base of the air chamber.
5. The water entering the air chamber compresses the air above it until the air pressure equals the pressure from moving water in the drive pipe.
6. At this point the discharge valve closes, trapping the water above it.
7. The air pressure then forces the entrapped water out the discharge pipe to the storage tank.
8. Immediately after the closing of the discharge valve there is a rebound, or backward flow, of the water in the drive pipe. This rebound reduces the pressure under the waste valve, causing it to open.
9. As soon as the waste valve opens, water again starts to run

to waste, building up momentum in the drive pipe. At this point the cycle is complete.

10. Also at the instant of rebound and low pressure a very small amount of air is drawn in through the air or snifting valve, which air collects under the discharge valve. On the next ramming stroke this air will pass through the valve and into the air chamber. In this way the air chamber is kept constantly charged with air.

Typical Ram Installations. Figures 45, 46, 47, and 48 illustrate a number of typical ram installations.

Selecting a Ram. The best procedure for selecting a ram is to send to the manufacturer the following information and purchase the ram recommended by him.

1. Flow of Supply Water in Gallons per Minute. This should be measured and not estimated. The flow can be measured by means of a bucket, as described on page 208 of this book. Measurement should be made in dry weather when the flow is at its lowest point.
2. The Vertical Fall in Feet from the Source to the Ram Location. This can be measured with a level, as described in Job 24.
3. Distance between Point of Supply and Place Where Ram Is to Be Located.
4. Vertical Height above Ram the Water Is to Be Raised.
5. Pipe Line Distance Water Is to Be Delivered.
6. Number of Gallons Required per Day of 24 Hours. This can be calculated from the table on page 208.

Minor Difficulties That May Be Encountered with Hydraulic Rams and the Remedies.* *Ram Stopping with Outside Valve Up.* This indicates that the pressure and water are leaking back through inside valve.

---

* Data for this section on the difficulties and remedies in the use of hydraulic rams are by courtesy of Rife Ram and Pump Works, Waynesboro, Virginia.

Remedy. Take off air chamber, remove inside valve, clean off valve seat, and remove any other obstructions under the valve. If valve is badly worn it should be turned over or replaced with a new one.

Ram Running but Delivering No Water. This indicates that the inside valve is leaking or there is a leak in discharge pipe.

Remedy. First remove air chamber and inside valve and clean as instructed above. If this does not remedy the trouble, then test delivery pipe by closing the end at ram, and with a bucket fill up the delivery pipe from discharge end. If you can fill the pipe and it stands full it proves that the pipe is all right, but if the water sinks away it indicates a leak in delivery pipe, which will have to be found and repaired.

Ram Stopping with Outside Valve Down. This indicates that there are obstructions or air in the drive pipe.

Remedy. First remove the obstructions, if there are any. If no obstruction can be found, then raise the valve up against the seat and hold or wedge it there for 15 or 20 min.; the drive pipe filling with water will force the air out. Then push down on valve to start ram working.

Uneven Strokes or Fluttering Sound. This indicates there is air in drive pipe.

Remedy. This may be caused by loose joints or leaks somewhere in drive pipe, or the intake end may be too near the surface of water. The drive pipe must be laid on a straight incline; with all joints made up tight, and with intake end not less than 8 in. under surface of the water.

Double-Acting Ram Pumping Creek Water. This indicates the check washer in globe valve is leaking.

Remedy. Unscrew top of globe check valve on the double-acting connection. Remove the check holder. The small rubber check washer underneath can be either turned over or ground down, or if worn too badly will have to be replaced with a new one. The only other reason for a double-acting ram pumping creek water would be spring waters getting excessively low or spring supply pipe's becoming filled with sand or silt.

Air Chamber Filling Up with Water. This indicates air valve is out of adjustment.

Remedy. The brass air-feeder pin should be so adjusted that a very small jet of water escapes at each stroke of the ram and momentarily later, a little air is sucked in to supply the air chamber with air, thus preventing water logging. A shortage of air in the air chamber causes a pulsating flow of water at the point of discharge (timed with the stroke of the ram) usually producing a metallic sound, and if allowed to continue will result in breaking bolts or other parts of the ram. The air pin should be opened to allow more water to escape, thus increasing the supply of air sucked in. Should the ram be taking in too much air this will show up in the delivery pipe, in which case the air pin should be slightly closed. Absence of air in air chamber causes bolts to break.

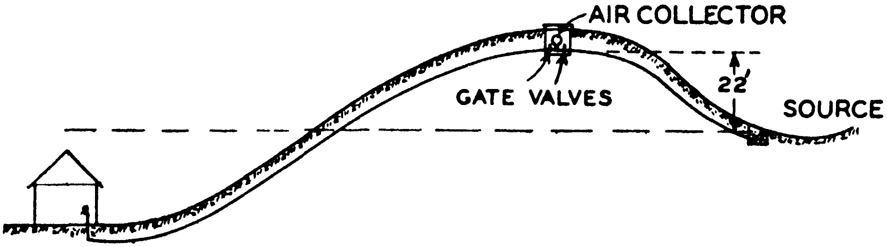


FIGURE 49.—A siphon gravity water system used for getting water over a hill. Extreme care must be taken in such an installation to have all the pipe absolutely tight. Even a small air leak will very quickly break the siphon action.

The Siphon. Sometimes a siphon can be used to transfer water from the source to the point of consumption. This is practical only when the source is higher than the faucets and when there is a rise between the source and the faucets as shown in Fig. 49.

Principle of Operation. The principle of operation of the siphon is as follows:

1. The tube, pipe, hose, or other enclosed water conductor must be filled completely with water, as shown in Fig. 50.
2. The discharge end must then be placed at a point below the level of the water at the source. As soon as this is done, the weight of the column of water *B* becomes greater than the weight of column *A*. This unbalanced condition causes water to flow over the high point, producing a continuous flow as long as the height of column *B* is greater than the height of column *A*.

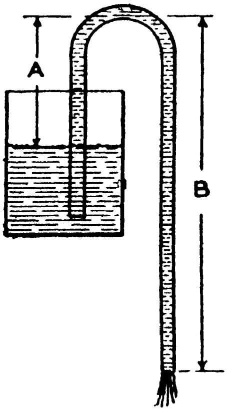


FIGURE 50.—Illustrating the principle of the siphon.

As with a pump, the force causing the water to rise through column *A* is atmospheric pressure on the surface of the water at the source. For this reason the height of column *A* cannot be more than 34 ft. In actual practice it should be considerably less than 34 ft.

With a siphon installed as shown in Fig. 49, an air or gas collector should be installed at the high point to collect air or gas bubbles that would otherwise collect in the pipe and break the siphon. This air collector must be filled with water occasionally to prevent air from overflowing into the pipe line.

*

CHAPTER III

TYPES OF WATER SYSTEMS

The term "water system" here applies to such equipment as pump, tank, connecting pipes, valves, and controls used to deliver running water from the source to the supply plumbing system.

The majority of domestic water systems may be classified under three headings, namely: (1) gravity water systems; (2) hydropneumatic water systems; and (3) pneumatic water systems. There are variations and combinations of these three main classes of water systems, some of which will be discussed here.

GRAVITY WATER SYSTEMS

A gravity water system is one having a tank or storage reservoir located higher than the faucets from which tank or reservoir water flows to the faucets by the force of gravity.

There are three types of gravity systems. One is the "natural" gravity where the source of the water is high enough above the faucets to provide a satisfactory flow, as in the case of a spring on a hill above the house. See Fig. 51. Another type is the "pumped-" gravity system where a pump or hydraulic ram is used to elevate the water to a gravity storage tank located above the faucets. See Fig. 52. The third type is the "siphon-" gravity system. This system may be used where the source of water is higher than the faucets, but is located over a hill from the buildings. See Fig. 49.

The natural-gravity water system, when properly installed, is usually quite satisfactory, provided the water at the source is pure, plentiful, and at sufficient height to give a good flow at the faucets. One distinct advantage of this system is that there is no operating cost. Also, such systems are very simple mechanically and, therefore, when properly installed, have a very

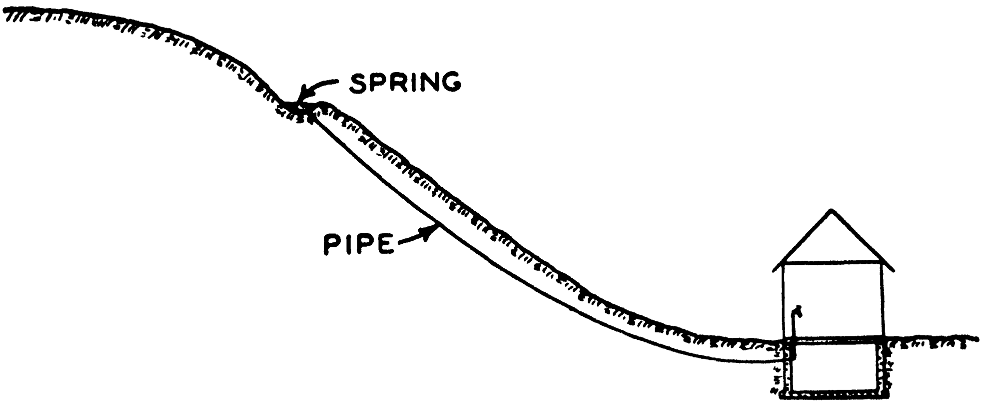


Figure 51.—A "natural-gravity" water system.

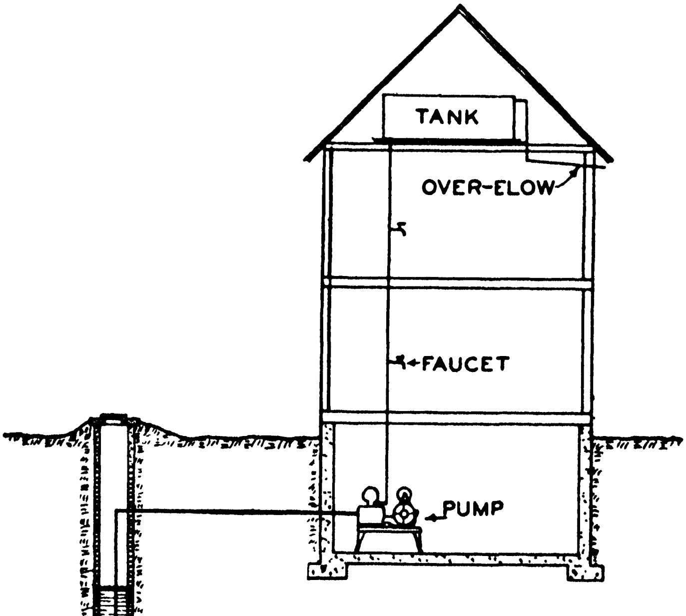


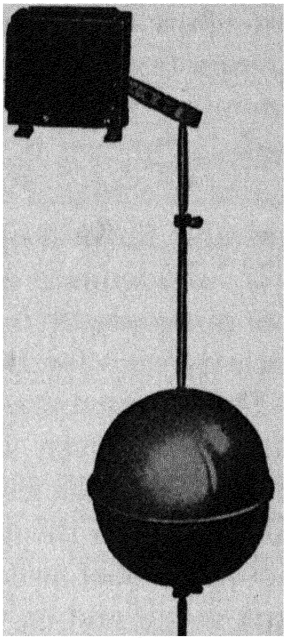
Figure 52.—A "pumped"-gravity system.

low maintenance cost. In some cases, because of the distance from the source of water to the buildings, the initial cost of installing such a system may be quite high. Against this cost, however, should be balanced the initial cost *plus* the operating cost of a pumping system.

In most hilly sections where there is considerable rainfall there are many opportunities for developing natural-gravity water systems. Many of these systems have been tried and have been unsatisfactory because they were not properly developed. The most common cause of failure is the use of pipe which is too small.

The pumped-gravity water system is commonly used (1) where the pumping device is a windmill, or a hydraulic ram, or (2) where large volumes of water must be stored.

In some sections of the country, windmills are used extensively for pumping water. The pumped-gravity system is very satisfactory where windmill power is used because a large storage capacity can be had at a relatively low cost. A large storage capacity is desirable to provide water for days when there is no wind. When a hydraulic ram is used for pumping water, the rate of discharge to the tank may be very small. Yet, if the ram runs 24 hr. a day and a large storage tank is provided, the supply may be adequate. For this reason, large gravity storage tanks



Courtesy Goulds Pumps, Inc.

FIGURE 53.—Electric float switch. This switch will automatically start and stop small motors coincident with change of liquid level in an open tank or sump.

It is a two-pole float switch for open tank service. Used with small motors or as a pilot switch in connection with automatic starter for operating larger motors. Furnished complete with 8-in. diameter float, 5-ft. operating rod, and two adjustable stops. This switch can also be used to short-circuit low tension ignition to stop gasoline engine when tank is filled. When so ordered this switch can be furnished to control pump used for sump operation.

are often used with rams. Another advantage of a gravity storage tank in connection with an hydraulic ram is that, by extending the discharge pipe from the ram to the top of the tank, as shown in Fig. 45, the ram can be made to operate against a constant discharge head. A constant discharge head is desirable for best operation of a ram.

If an adequate overflow is provided on the storage tank, a ram pumped-gravity water system can be made to operate without attention for long periods of time.

The pumped-gravity system can be made semi-automatic if gas-engine-driven and completely automatic if electric-motor-driven. With the gas engine a float switch, Fig. 53, located in the tank, shuts off the ignition when the tank is full. With the electric motor the float switch in the tank turns the current off when the tank is full and on when nearly empty.

The siphon-gravity water system has the same advantages as the natural-gravity system except that it must be more carefully installed and requires more attention to keep it in operation.

The following is a list of advantages and disadvantages of gravity water systems:

SYSTEMS

Natural Gravity

Advantages

1. No operating cost.
2. Low maintenance cost.
3. Where the source of water is near by, the installation costs may be low.
4. When provided with proper overflow is completely self-operating.

Disadvantages

1. Difficulty of obtaining sufficient pressure.
2. Where the source of water is a long distance away, the cost of installation may be high because of the amount of pipe needed.

Pumped Gravity

Advantages

1. May be cheapest to install. This is especially true if large volumes of water are to be stored. A pressure tank costs several times as much as an open gravity tank of the same capacity.
2. May cost slightly less to operate than pressure systems.

Disadvantages

1. Difficulty of elevating the tank high enough to give good pressure.
2. Difficulty of protecting the tank from freezing.
3. If the tank is located in the attic, its weight may require reinforcement of the attic supports.
4. With a tank in the attic leaks may cause water to run down through the house and ruin the plaster.
5. Water is likely to become stale and, in the summer, very warm.
6. It is difficult to keep the water sanitary with an open tank.

Siphon Gravity

Same items as for natural gravity, excepting its disadvantage of requiring more attention to operate.

HYDROPNEUMATIC WATER SYSTEMS

The hydropneumatic water system is, at present, the most popular type of system. The purchase price and installation costs are moderate, and the type of service rendered is very satisfactory, particularly so when powered with electric motors, because with electric motors the system can be made completely automatic. Figures 54, 55, and 56 illustrate hydropneumatic systems.

The gas-engine and electric-motor-driven systems are very similar except for the difference in the power unit and the fact that the gas-engine-driven type is semi-automatic (automatic stopping) whereas the electric-motor-driven type is completely automatic (both starting and stopping).

The Principle of Operation. When the pump, either deep- or shallow-well, is operating, water is pumped from the source into the closed tank near the bottom. See Fig. 54. As the level of the water rises in the tank, the air in the top of the tank is compressed, thus building up a pressure. Under the usual operating conditions, when the tank is about three-fourths full of water, level *X* in Fig. 54, the pressure in the tank will be approximately 40 lbs. per square inch. As these systems come from the factory the automatic switches are usually set so that they will open at 40-lbs. pressure and close at 20-lbs. pressure. Therefore, assuming that the pressure range of the switch has not been changed, at this point the switch will automatically open. If the system is powered with a gas engine the switch functions to shut off the

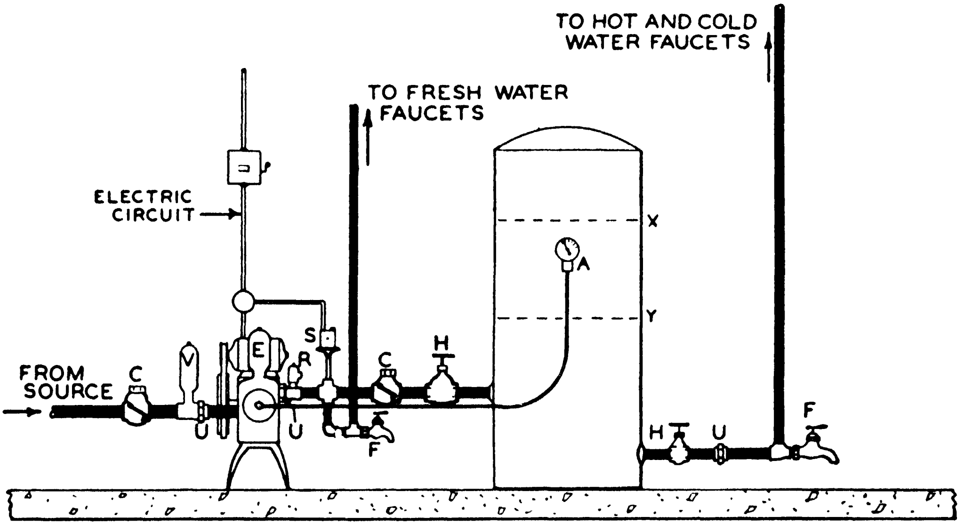
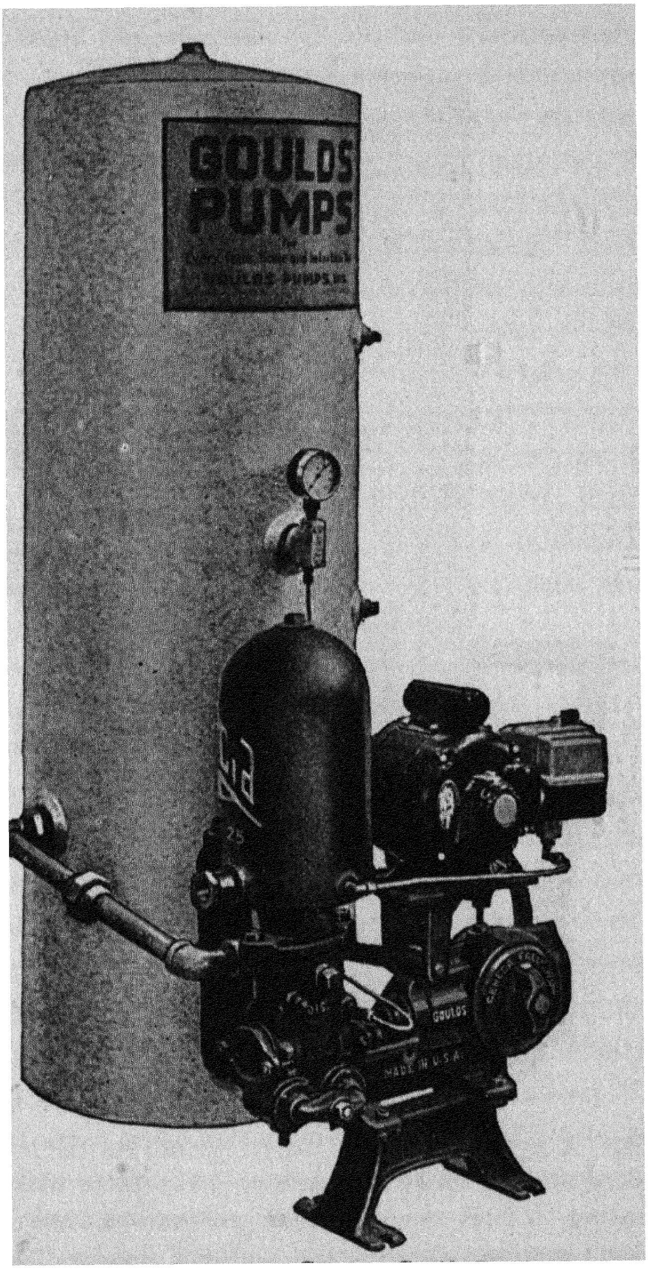


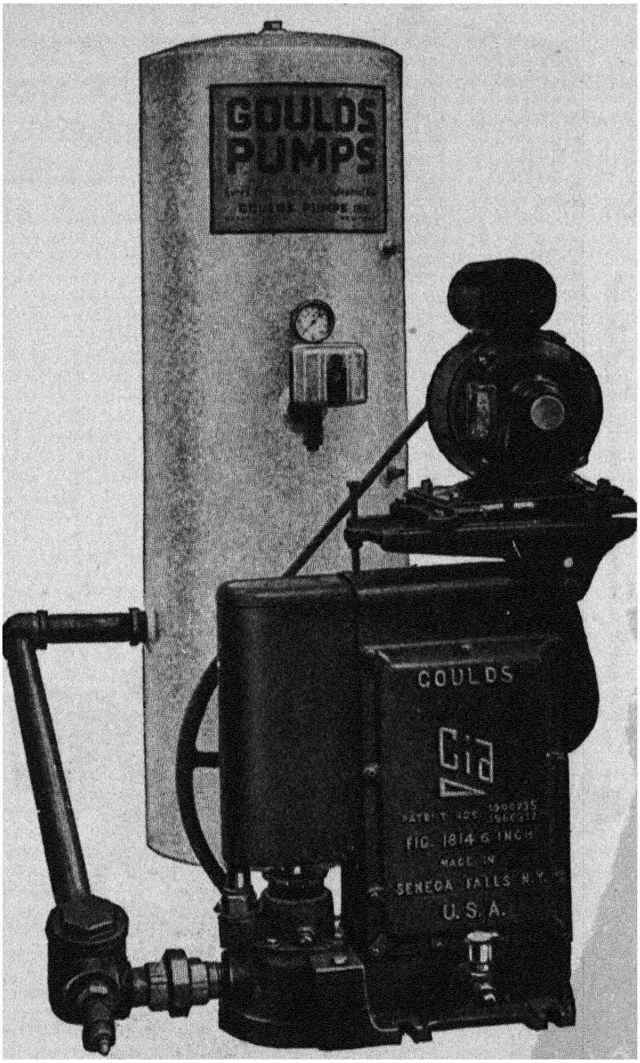
FIGURE 54.—A hydropneumatic water system for shallow wells. This system is arranged to deliver both stored and fresh water.

A—Automatic air-volume control. *C*—Check valves. *E*—Expansion chamber on pump. *F*—Faucets or valves for draining system. *H*—Hand valves. *R*—Pressure-relief valve (safety valve). *S*—Automatic switch. *U*—Unions. *V*—Vacuum chamber on suction pipe.



Courtesy Goulds Pumps, Inc.

FIGURE 55.—A hydropneumatic water system for shallow-wells. Capacity 500 gal. per hour. Suitable for large farms, homes, groups of tourist cabins, country schools, estates, etc. Has 42-gal. pressure storage tank with pipe and fittings to connect tank to pump. Supplied with ⅓ hp. motor.



Courtesy Goulds Pumps, Inc.

FIGURE 56.—A hydropneumatic water system for deep wells. This 6-in. stroke automatic-oiling deep-well system is complete with adjustable top motor mounting. V-belt drive, 42-gal. galvanized tank, automatic air-volume control, pressure switch with overload and low voltage protection incorporated, pressure gauge, relief valve, check valve, and galvanized piping connecting pump and tank; 110–220 volts, 60-cycle, single-phase, dual-voltage, capacitor-type motor in fractional sizes, or repulsion induction type for 1 hp. a-c., or 115 or 230 volts d-c. motor of required size.

ignition and stop the engine. With the electric-motor-driven systems the switch turns off the current and stops the motor.

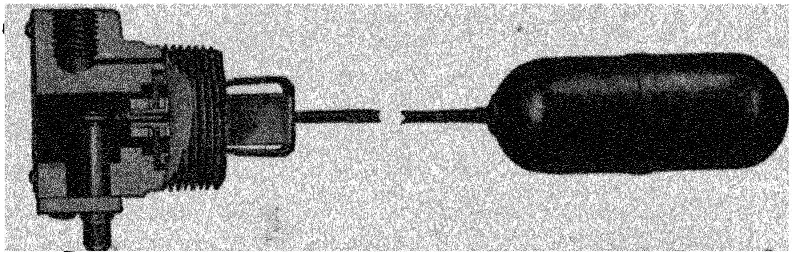
The 40-lbs. pressure of the air on the water in the tank will force the water out through the discharge pipe to the faucets when open. As water is drawn out, the level of the water in the tank is lowered, thus allowing the air to expand. As the air expands the pressure drops, so that by the time the water level is at about one-half the height of the tank, level *Y*, Fig. 54, the pressure will be down to 20 lbs. per square inch. At this point the automatic switch on the electric system turns the current on, starting the motor and the pump. With a gas-engine system the pump will not start until the engine is cranked; therefore, the pressure may go on down until it is very noticeable at the faucets. Once started, either system will run until the pressure is again restored to 40 lbs. per square inch.

If, for any reason, the pump is not started when the pressure drops to 20 lbs., water may still be drawn out, thus further reducing the pressure. Therefore, if the faucet from which water is being drawn is not too high above the tank, it is possible to draw the water down to one-fourth of the tank volume. This makes it possible, in case of motor failure or pump trouble, to draw off a volume of water equal to one-half the total volume of the tank. Naturally the larger the tank the greater this volume will be.

Most of the automatic switches are adjustable so that the pressure range on the system may be changed if desired. Excessive pressures should not be used, however, unless it is certain that the pump and tank are built to withstand such pressures. Domestic pumps and tanks are available with maximum pressure ratings from 43 lbs. to 100 lbs.

Air-Volume Control. When air and water are confined together under pressure the water will absorb the air. As the water is drawn out, the air is carried out with it. In time this will cause the tank to become "water-logged", that is, filled with water only. When the tank becomes water-logged the pressure drops very quickly when water is drawn out. Therefore, the pump will start each time a faucet is opened. To avoid this condition provision must be made for replenishing the air in the tank.

As the air must be *forced* into the tank against pressure a pump must be used. With shallow well systems the water pump is allowed to pump a little air along with the water. This is done by installing a snifting valve (similar to a bicycle valve) on the pump. On recent models of these systems this snifting valve is connected to a float valve up on the side of the tank. See *A*, Fig. 54 and Fig. 57. This float valve, called the "Automatic Air-Volume Control," allows the pump to pump air when the level of the water in the tank rises above normal owing to the loss of air from the tank. In this way the desired volume of air is automatically maintained in the tank at all times. Without this automatic air-volume control the snifting valve on the end of the pump must be regulated by hand.

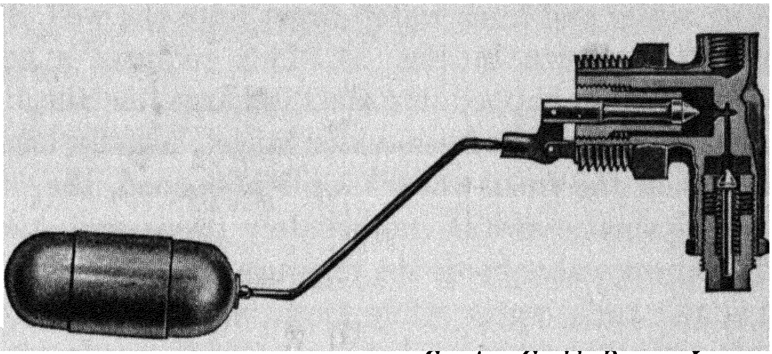


Courtesy Goulds Pumps, Inc.

FIGURE 57.—Air-volume control for shallow-well systems. Will not operate unless pump is fitted with air snifting valve. Body threaded for 1¼-in. pipe tapping in side of tank. Connected to pump air valve by 3⁄16 in. O.D. copper tube. Automatically maintains correct air cushion in pressure tank by a float controlled valve that does nothing except open and close entrance to tube that furnishes air to pump. It is not intended to and does not relieve excess air from pressure tank. When new air is needed float rises and opens air tube entrance. Snifting valve can then draw air and pump forces both air and water into tank. Furnished complete with tube and fittings necessary to connect with pump. Good for 100 lb. maximum pressure. When ordering be sure to specify "For Shallow Well."

On deep well pumps the water pump is not generally used to pump air as it is usually submerged in the water. Therefore, a separate air pump is attached to the pumping head at the top of the well. This is a small pump, but is large enough to supply all the air needed. In some cases, too much air is pumped; therefore, an automatic blow-off valve may be installed on a tank which will blow off the excess air. See Fig. 58.

Hydropneumatic systems are available for operation on deep or shallow wells, cisterns, streams, ponds, lakes, or any other source of water.



Courtesy Goulds Pumps, Inc

FIGURE 58.—Air-volume control for deep-well systems. Body threaded for 1¼-in. pipe tapping in side of tank. Automatically maintains correct amount of air in pressure tank. A simple device equipped with two valves: the inner, non-adjustable, float-controlled; the outer valve, spring-controlled with screw adjustment to regulate pressure setting. The inner valve simply opens and closes passage way connecting outer valve to inside of tank. Only when inner valve is open and tank near its highest pressure can outer valve vent excess air from tank. Pump air attachment must deliver a small amount of air to tank continuously. Good for 150 lb. maximum pressure. When ordering be sure to specify "For Deep Well."

Safety Devices. The hydropneumatic system should have, in addition to the automatic switch, a pressure-relief valve, *R*, in Fig. 54, as an additional safety device. If this valve is omitted and the automatic switch fails to operate, the pressure tank may "blow up" with serious damages to life and property. This pressure-relief valve should be inspected at least twice a year to see that it is in working order.

On most of the recent models there is also provided an overload and low-voltage protective device for the motor. This device may be an intergal part of the automatic switch or it may be installed on or inside the motor. Its purpose is to open the electric circuit and stop the motor if for any reason the motor becomes too hot. Some forms of the device automatically reset and start the motor again when it has cooled off; others must be reset by hand.

Fresh-Water Connections. Hydropneumatic systems of either the deep- or shallow-well type may be arranged to deliver both stored tank water and fresh water direct from the well. Such an arrangement is shown in Fig. 54. This requires a separate fresh-water pipe line tapped into the discharge line ahead of the check valve and run to a fresh-water faucet, usually located at the sink. When the fresh-water faucet is opened, the pressure under the automatic switch immediately drops and starts the pump. The check valve holds the pressure back from the switch and holds the tank water while fresh water is being drawn. When this arrangement is used on a deep-well system the automatic switch must be located between the check valve and the pump. As a rule, this fresh water arrangement is unnecessary unless the storage tank is located in a warm place, or unless a large tank is used.

Advantages and Disadvantages of Gas-Engine-Driven Hydropneumatic Systems

Advantages

1. Compact. Require little room.
2. Can be installed at almost any convenient location in any of the buildings, or in a pit in the ground.
3. Will provide any degree of pressure up to 100 lbs.
4. Owing to the possible higher pressures, they are very satisfactory for sprinkling, car washing, and to some extent for fire fighting.

Disadvantages

1. The gas engine is noisy and requires frequent servicing.
2. Does not start automatically.
3. Require either a large and expensive pressure tank or frequent starting by hand.
4. The initial cost is likely to be higher than for the electric-driven system.

Advantages

5. Also, owing to the possible higher pressures, smaller pipes can be used to the faucets.
6. As the water is not exposed to the atmosphere, they are more sanitary than open gravity systems.
7. Can be used wherever gas engines can be run.

ADVANTAGES AND DISADVANTAGES OF ELECTRIC-DRIVEN HYDROPNEUMATIC WATER SYSTEMS

Advantages

Same as for the gas engine-driven system with the following additional advantages:

1. If properly installed they are practically noiseless and require a minimum of attention.
2. Are completely automatic. Provide a water service comparable with that from city mains.
3. Owing to the automatic feature, a small and inexpensive storage tank may be used.
4. The operating cost is very low.
5. The initial cost is, in most cases, quite low.

Disadvantages

1. Cannot be used except where electricity is available.

PNEUMATIC WATER SYSTEMS

A third type of water system is the pneumatic system. This is not a common type, but is useful in some situations.

Principle of Operation. On this system an air compressor pumps air under pressure into a closed tank. The air is piped from this tank to the pump in the well. The air, under pressure, acts like a piston in the cylinder to force the water out and up to the faucets. There is no water storage with this system; therefore, it delivers only fresh water. The pump will operate in a shallow source or in deep wells up to 80 ft.

Ordinarily these systems are not used where less expensive types of systems can be used. There are certain situations, however, where other types do not give satisfaction. For example, if the source of water is over a hill from the buildings, a suction pump at the house may give trouble owing to the accumulation of air at the high point in the suction pipe. The pneumatic system will operate satisfactorily in such a situation because the water is *forced* over the hill.

ADVANTAGES AND DISADVANTAGES OF PNEUMATIC SYSTEMS

Advantages

1. Can pump from any number of sources with one power unit.
2. Always provide fresh water.
3. Will operate in some places where other types of pumps will not.
4. Compressed air is made available for other purposes, such as tires, and for spray painting.

Disadvantages

1. High initial cost.
2. Rather complicated mechanically; therefore, maintenance cost may be high.

COMBINATION GRAVITY AND HYDROPNEUMATIC SYSTEMS

There are several designs of these systems that are more or less commonly used. The combination illustrated in Fig. 59 is more or less common in dairying regions. It may be used where large volumes of water need to be stored for the barns, yet fresh water under high pressure is desired at the house. As shown in the illustration the hydropneumatic system takes water from the source and supplies it directly to the house. At the same time it periodically supplies water to the gravity storage tank through a separate line. The gravity tank can be filled by hand operation of valve *A* or by a float controlled valve in the storage tank. This type of system is sometimes referred to as the "Michigan System."

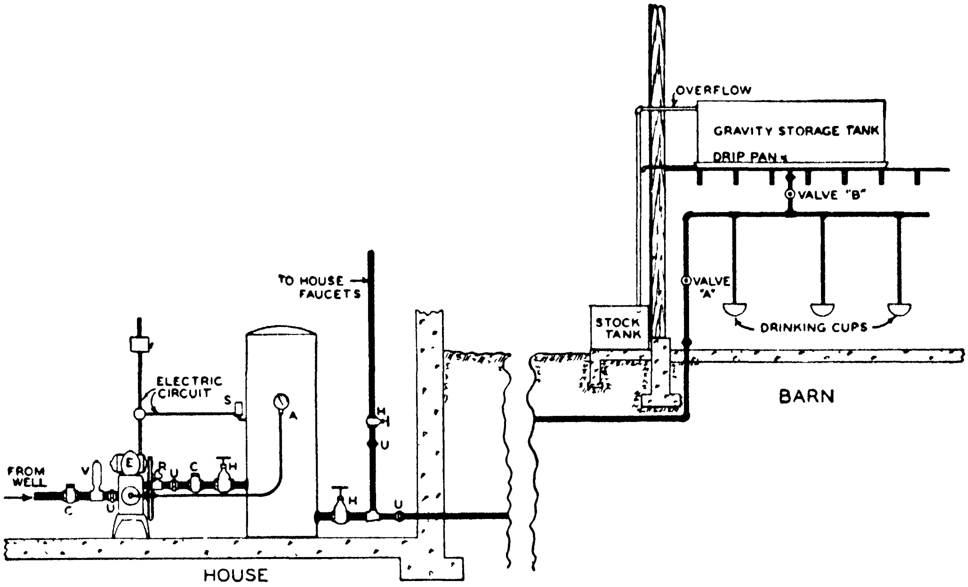


FIGURE 59.—A combination gravity and hydropneumatic system. This system is designed to pump water for both house and barns.

A—Automatic air-volume control. *C*—Check valves. *E*—Expansion chamber on pump. *H*—Hand valves. *R*—Pressure-relief valve (safety valve). *S*—Automatic switch. *U*—Unions. *V*—Vacuum chamber on suction line.

By placing another valve *B* in the line just below the tank, the drinking cups can be supplied directly from the pressure tank in the house in case of needed repairs on the gravity tank.

ADVANTAGES AND DISADVANTAGES OF THE COMBINATION GRAVITY AND HYDROPNEUMATIC SYSTEMS

Advantages	*Disadvantages*
1. Provide a very economical means of storing a large volume of water. The open gravity tank is much cheaper than a pressure tank having the same capacity.	1. The extra storage tank requires room, must be protected from frost, and is a small, but added, expense for installation.
2. The system of Fig. 59 provides	

Advantages

water at low pressure for drinking cups, thus reducing leaks and spurting when the cup valves are opened.

3. Reduces pounding noises in the pressure system.
4. Provide large storage to carry over in case of a breakdown at the pump.
5. Provide any desired pressure at the house independent of the pressure at the barns.

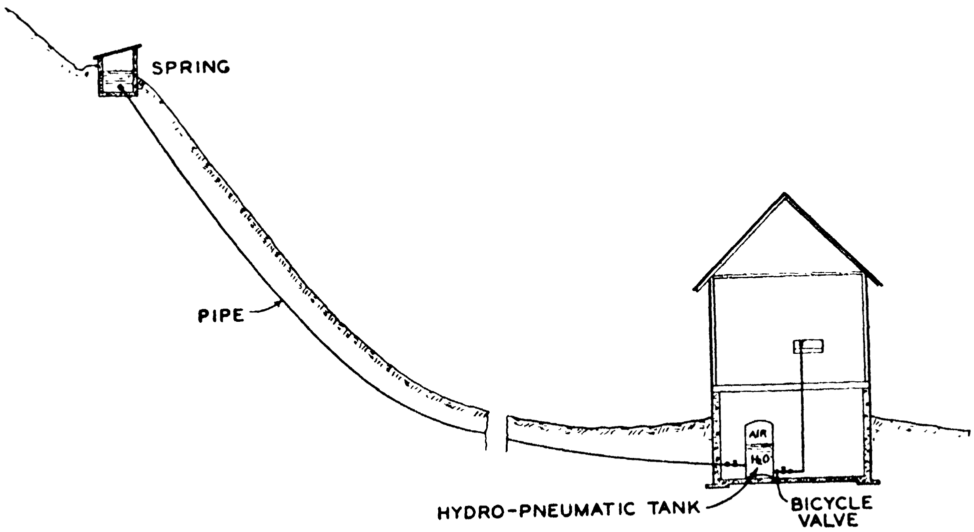


FIGURE 60.—A combination gravity and hydropneumatic water system using the force of gravity slowly to build up pressure in the tank through a small and relatively inexpensive pipe. The air pressure in the tank will give a good flow to near-by faucets for short periods at frequent intervals. A bicycle valve installed in a tee between the tank and the hand valve on the discharge side makes it possible to pump air into the tank when necessary.

This system has the advantage of being more sanitary than one with an open storage tank.

Figures 60 and 61 illustrate two other designs for combination gravity and hydropneumatic systems. The design shown in

Fig. 60 would be suitable where the source of water is high enough above the faucets to give good pressure, but is so far away that it would be very expensive to use pipe large enough to give a satisfactory flow at the faucets. By installing small pipe and a pressure tank, as shown, the water will flow slowly into the tank compressing the air above it. This air pressure will function to deliver a satisfactory flow of water to near-by faucets, just as will a hydropneumatic system. As the air in the tank will be slowly carried out by the water, some means must be provided for recharging the tank with air. A bicycle valve installed on the tank and a tire pump make a satisfactory arrangement.

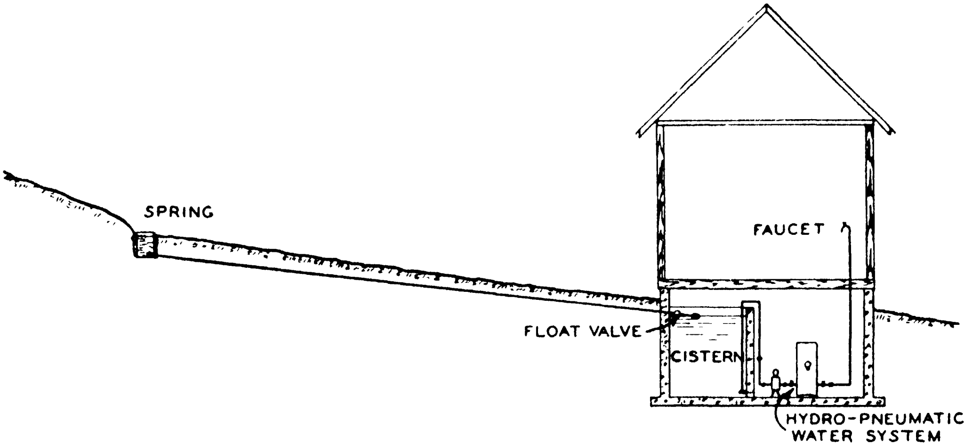


FIGURE 61.—A combination gravity and hydropneumatic water system using the force of gravity to deliver the water to a tank or cistern in the buildings. A hydropneumatic water system is used to deliver the water from the storage tank or cistern to the faucets. This system is suitable (1) where the spring is not high enough above the faucets to give a satisfactory flow, (2) where the spring is weak and so located that it would be difficult to build adequate storage at the spring, and (3) where the distance to the spring is so great that the cost of large pipe would be prohibitive. An overflow should be provided on the cistern, or in case there is no cellar drain, a float valve should be installed as shown on the end of the pipe from the spring to stop the flow from the spring when the cistern is full.

The design shown in Fig. 61 is suitable where the source of water is not high enough above the faucets to provide adequate pressure and where the distance is so great that the use of large pipe would be too expensive. Here the force of gravity is made use of to get the water to the buildings in a small but constant stream. The water accumulates in a storage tank from which it is delivered to the faucets by means of a hydropneumatic system.

CHAPTER IV

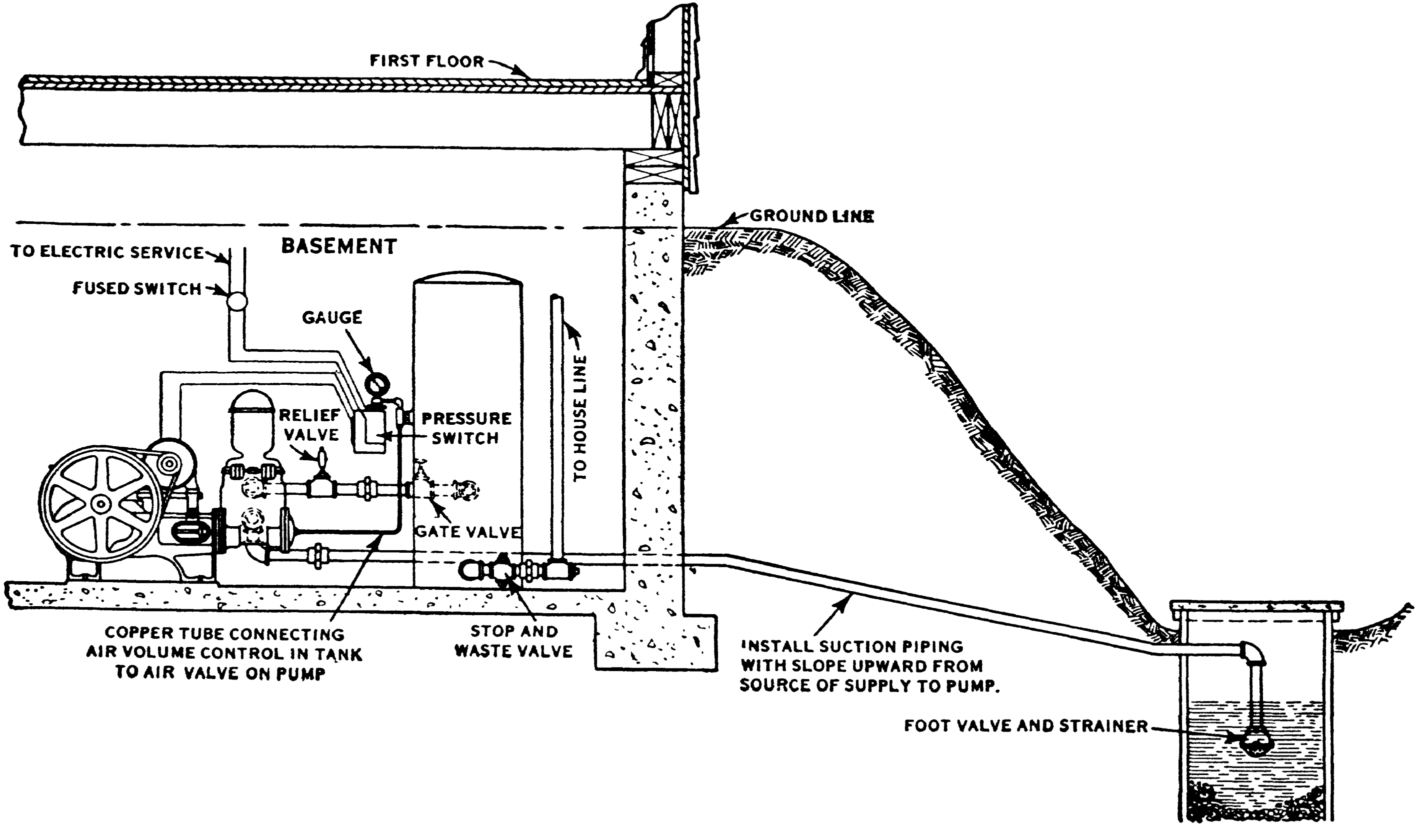
TYPICAL INSTALLATIONS OF GRAVITY AND HYDROPNEUMATIC SYSTEMS

Gravity-system installations are shown in Figs. 51 and 52.

Hydropneumatic Installations. When installing a hydropneumatic water system the location of the well, the pump, and the tank should have very careful consideration. In cold climates the pump, the tank, and the pipes must be protected from frost.

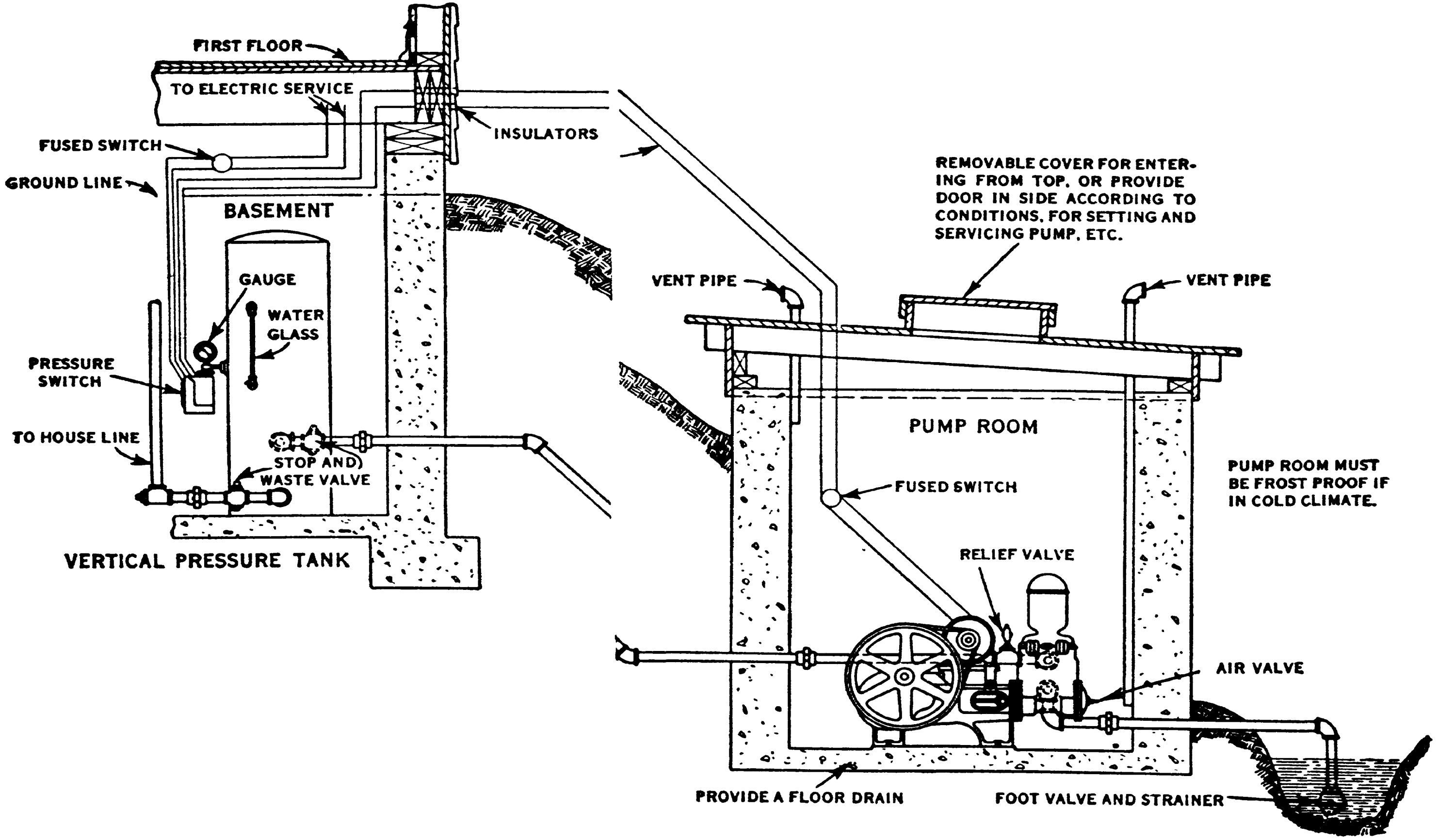
One of the most convenient locations for such a system is in the basement. If the source of water is a shallow well which is not too far away, the pump can draw the water from the well to the basement, and then force it into the tank as shown in Fig. 62. If the source is beyond the reach of the pump from the basement, the pump must be located outside and within reach of the water as shown in Fig. 63. The pump must be enclosed to protect it from frost. If the source of water is a deep well, the pumping head must be at the well or the "jet" type of deep-well pump must be used. The location and type of well are, therefore, determining factors in the location and type of pump.

An excellent location for a deep well and pump is adjacent to the basement, as shown in Figs. 64 and 65. A pit constructed as an extension of the foundation wall, as shown, but open into the basement, gives frost protection to the pump, provides ventilation for the motor and pump, is easily accessible for oiling and adjustments, and requires a minimum of piping and wiring. The man hole over the well permits the pulling of the well pipe if necessary. In case the well is not adjacent to the basement, the pump may be installed in a pit, as shown in Fig. 66, or in a frost-proof building. The tank may be located near the pump or in the basement.



Courtesy Goulds Pumps, Inc.

FIGURE 62.—A hydropneumatic system with a shallow-well pump located in the basement. The water is drawn from a source at a distance from the house and discharged into a pressure tank near the pump.

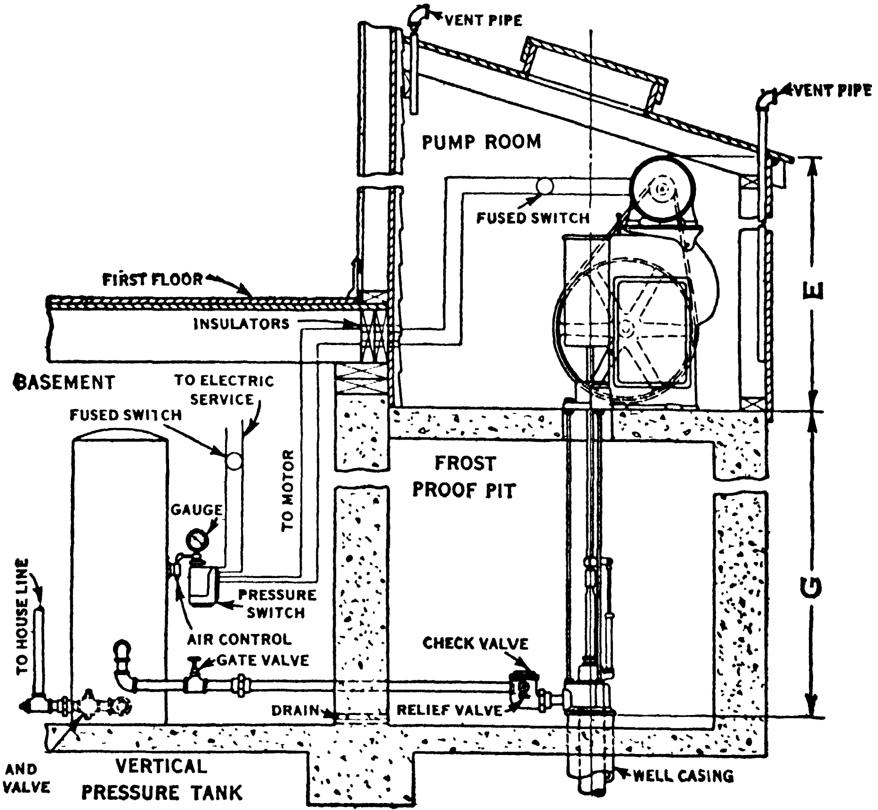


Courtesy Goulds Pumps, Inc.

FIGURE 63.—A hydropneumatic system with a shallow well pump located near the source of water. The water is drawn from the near by source and is then forced through a pipe into a tank in the building. The pump and pipes must be protected from frost.

In addition to the above typical installations, the following may be used for special cases:

1. The installations shown in Figs. 49, 59, 60, and 61.
2. For pumping from two wells in which the water stands at approximately the same level. See Figs. 84 and 85.



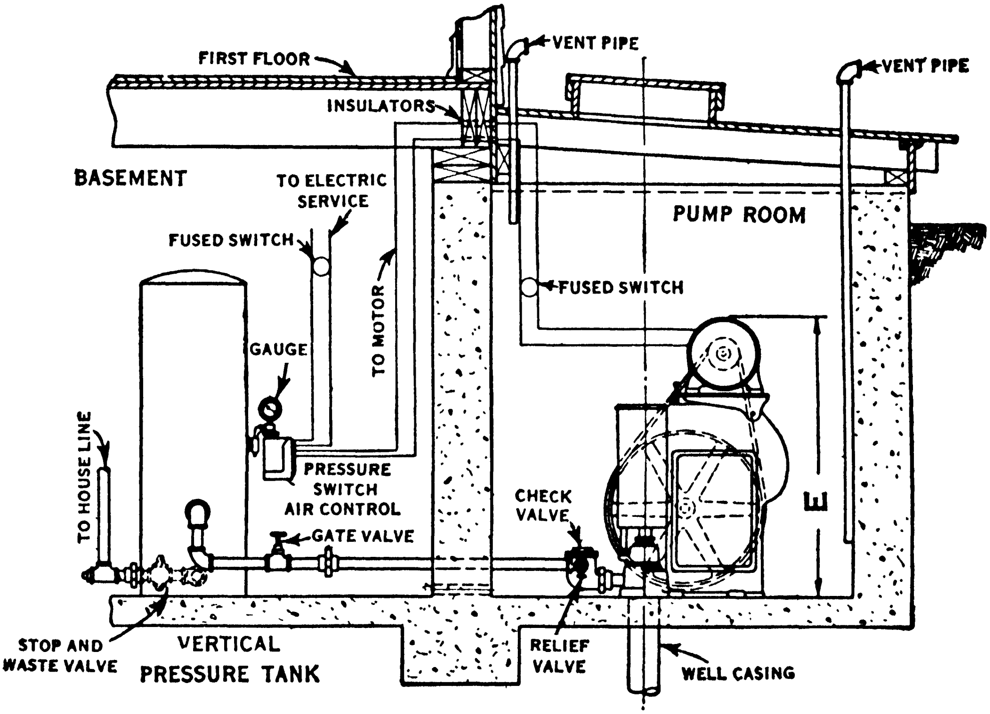
Courtesy Goulds Pumps, Inc.

FIGURE 64.—A hydropneumatic system with a deep well pump located adjacent to the building. The pumping head is located in an insulated building above ground. An antifreeze attachment is located in the frost-proof pit. This makes it possible to keep the water below the frost line.

3. For pumping from a well for the cold-water faucets and from a cistern for the hot-water faucets. See Figs. 67 and 68.

The best arrangement for this plan is to use two automatic pumps as shown in Fig. 67. The two systems can be interconnected through a pipe with a valve so that either system can be made to supply water to both sides of the plumbing system.

An alternate but generally less satisfactory arrangement is shown in Fig. 68. Balanced against the lower cost are the additional labor and time required to operate it and the fact that there is a possibility of polluting the well water with cistern water. To operate the system of Fig. 68 the double-throw switch is thrown to the cistern water-tank side, valves 1 and 2 are opened, and valves 3 and 4 are closed. The pump charges the large tank with cistern water and shuts off. The cistern water tank should be large enough to hold about one day's supply.

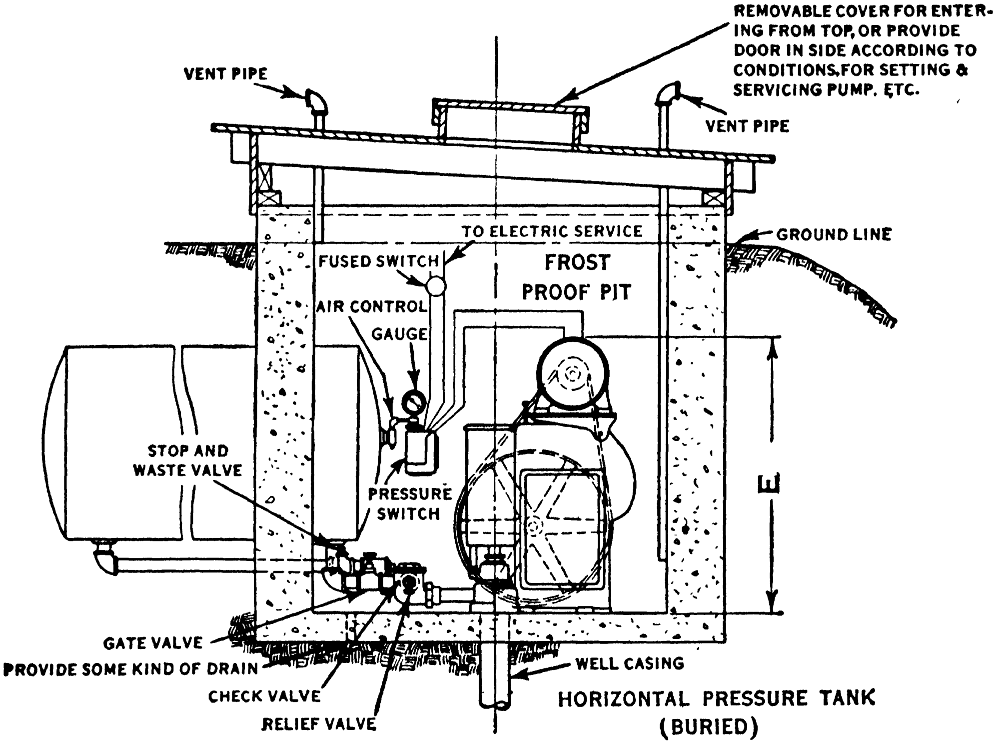


Courtesy Goulds Pumps, Inc.

FIGURE 65.—A hydropneumatic system with a deep-well pump located adjacent to the building. Here the pumping head is located in a frost proof pit below the frost level. There should be a door opening into the pit from the basement.

When the cistern water tank is full, the double-throw switch is thrown back to the well-tank side, valves 1 and 2 are closed, and valves 3 and 4 are opened. While the system is so set the pump will stop and start automatically through the day to supply well water.

Owing to the fact that there is cistern water in the pump when turned back on the well, the well water and cistern water may be mixed unless the cistern water is flushed out before valve 3 is opened.



Courtesy Goulds Pumps, Inc.

FIGURE 66.—A deep-well pumping unit located in a pit at some distance from the house. The tank may be at the pit as shown, or in the basement.

*

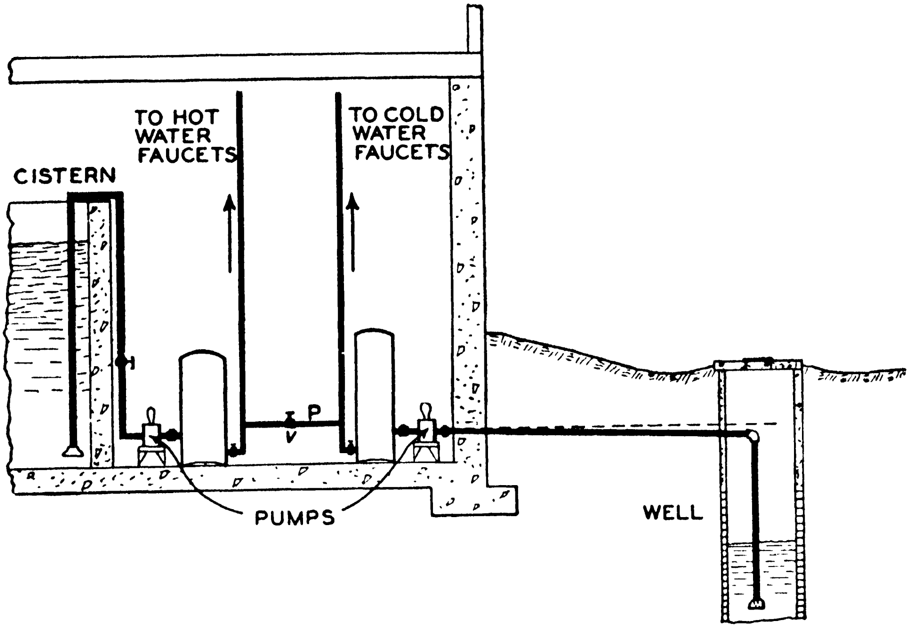


FIGURE 67.—An arrangement for pumping well water to the cold-water faucets, toilets, watering troughs, etc., and cistern water to the hot-water faucet. This plan requires two pumps but is quite satisfactory. A deep-well pump could be used to pump the well water.

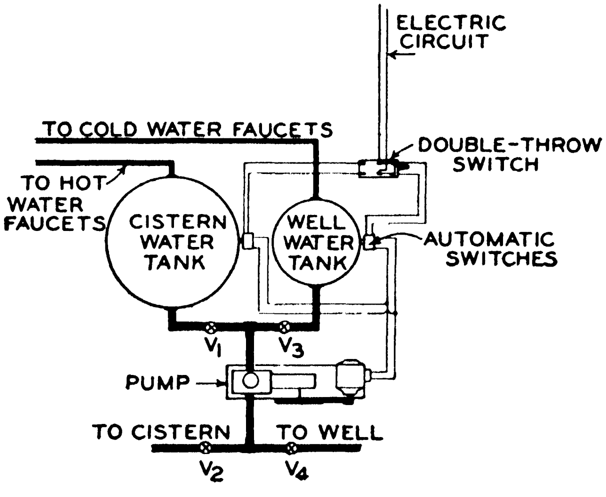


FIGURE 68.—An arrangement for using the same pump for pumping both well water for the cold-water faucets and cistern water for hot-water faucets. This plan requires considerable attention and is not considered as sanitary as the plan shown in Fig. 67.

CHAPTER V

PROBLEMS OF INSTALLATION OF WATER SYSTEMS

Many problems arise in connection with the installation of the various types of water systems. Because of lack of space only the more common ones will be discussed here.

Head. Always, when handling water through pipes and pumps, we have the problems of "head" to deal with. When used in connection with handling water, head refers to the vertical height of a column of water above a certain point, and is considered as causing or counteracting the flow of water. For example, if water stands at a height of 20 ft. in a pipe, as shown in Fig. 69, there will be 20 ft. of head on the bottom end of the pipe. This 20 ft. of head will exert a total pressure on the bottom of the pipe equal to the weight of the column of water. This pressure is expressed in terms of pounds per square inch. A column of water 1 in. square and 1 ft. high weighs 0.434 lb. See Chapter II, p. 144, and Fig. 24. Therefore, the pressure per square inch on the bottom of the pipe equals 20 ft. x 0.434 lb. per square foot, or 8.68 lb. per square inch. If the bottom of the pipe were opened this head would cause water to flow out.

Although head is the same wherever it is found, we ordinarily speak of four kinds, namely: gravity head, pressure head, friction head, and "suction" head.

Gravity Head. Gravity head is the actual vertical height of a column of water. The head shown in Fig. 69 is gravity head.

Pressure Head. Pressure head is the vertical height to which any given pressure will force water. One pound of pressure will force water to a height of 2.3 ft. The pressure head in feet, then, is equal to the pounds pressure x 2.3. For example, in Fig. 70, with 10 lb. pressure per square inch in the tank, the water will rise in the pipe to a height of 23 ft. (10 lb. x 2.3).

Friction Head. Friction head is the head required to overcome friction between flowing water and pipes. Water is caused to flow through pipes by gravity head, pressure head, or "suction" head. It is retarded in its flow by friction which is measured in head and called "friction head." Thus, friction head may be considered as lost head or obstructing head. In order to have any flow of water the gravity, pressure, or suction head must first overcome the friction head.

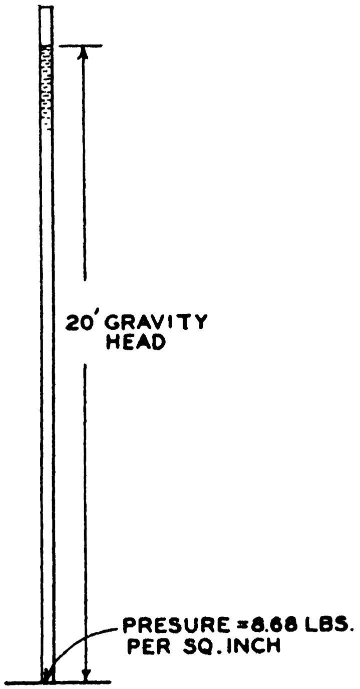


FIGURE 69.—Gravity head.

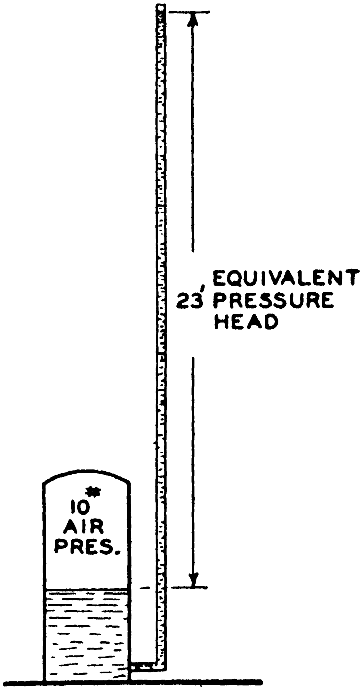


FIGURE 70.—Pressure head. The pressure of the air on the water in the tank is 10 lb. per square inch. Therefore, the pressure head is equivalent to 23 ft. gravity head.

The amount of head lost due to friction depends upon several factors such as (1) the length of pipe, (2) the diameter of the pipe, (3) the smoothness of the inside of the pipe, (4) the number and kind of fittings, valves, and faucets in the pipe line, and (5) the rate of flow. For example:

1. *The longer the pipe, the greater the loss of head due to friction for any given diameter of pipe and rate of flow.* Thus with 1-in. pipe and a rate of flow of 5 gal. per minute, as shown in Fig. 71*B*, the loss of head through 100 ft. is 1.3 ft., through 200 ft. is 2.6 ft., through 300 ft. is 3.9 ft., etc.

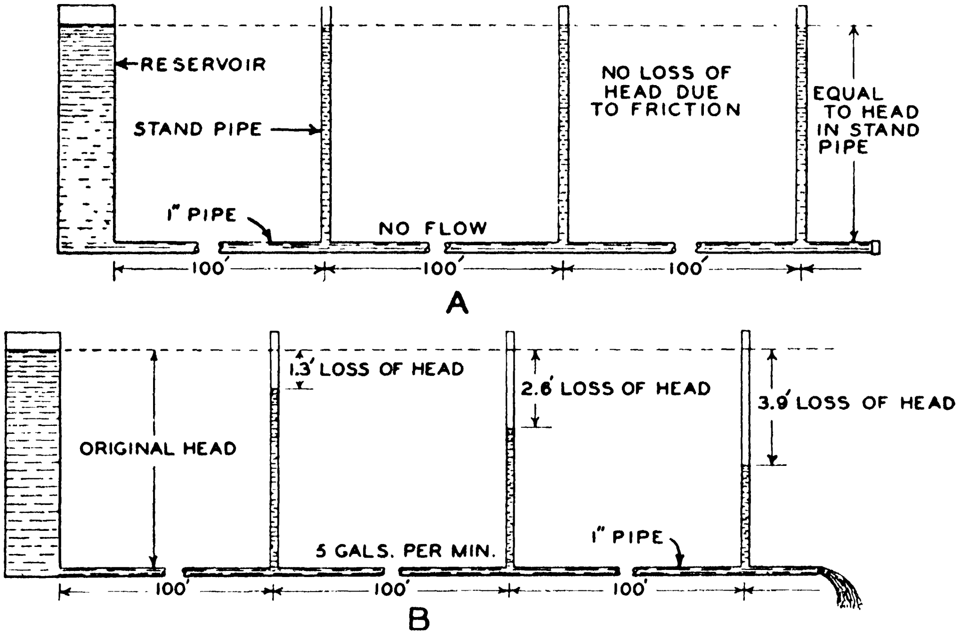


FIGURE 71.—Loss of head due to friction. If stand pipes were erected on a pipe line as shown at *A* and the system filled with water, and if there were no flow through the pipe, the water would stand at the same level in all the stand pipes. If the water is allowed to flow at the rate of 5 gal. per minute as indicated at *B*, the level of the water in each successive stand pipe will be lower because of the loss of head by friction along the pipe line.

2. *The smaller the diameter of any given length of pipe, the greater the friction losses for any given rate of flow.* Thus with a rate of flow of 5 gal. per minute through 100 ft. of ¾-in. pipe, as shown in Fig. 72 at *A*, the loss of head due to friction is 5.8 ft. Through 1-in. pipe for the same rate of flow, the loss is only 1.3

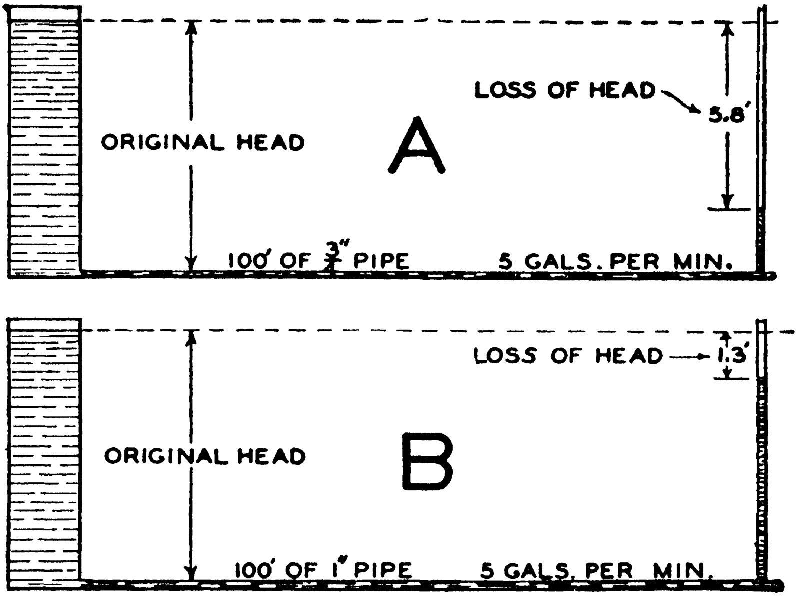


Figure 72.—Other things being equal, the loss of head due to friction is greater in a small pipe than in a large pipe.

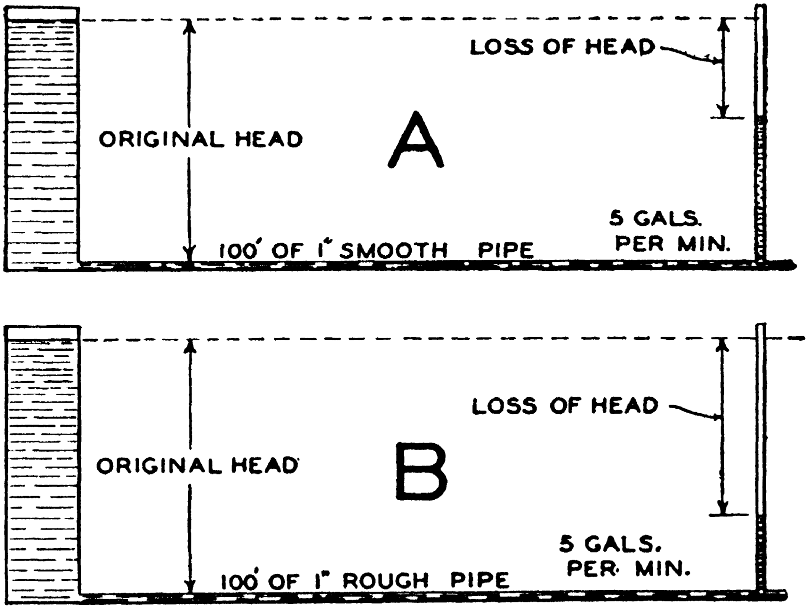


Figure 73.—Other things being equal, the loss of head due to friction is greater in a rough pipe than in a smooth pipe.

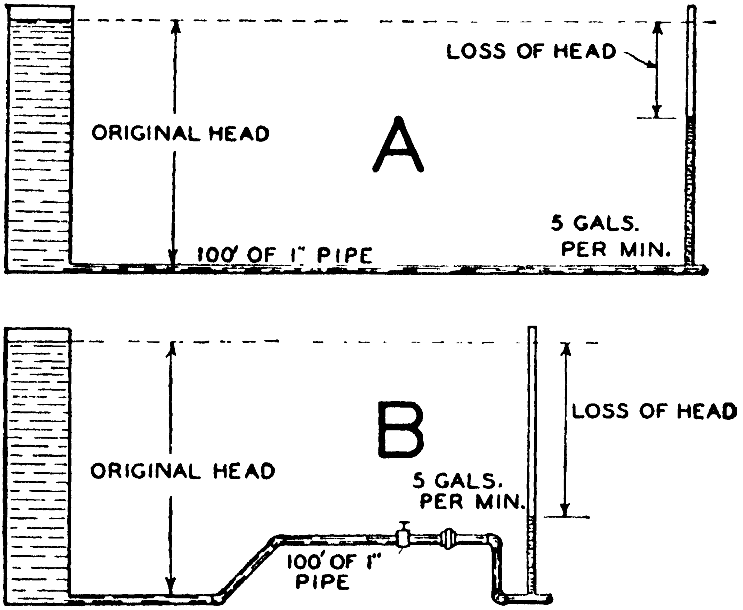


FIGURE 74.—Other things being equal, the loss of head due to friction is greater in a crooked pipe or a pipe with many fittings than it is in a straight pipe with few fittings.

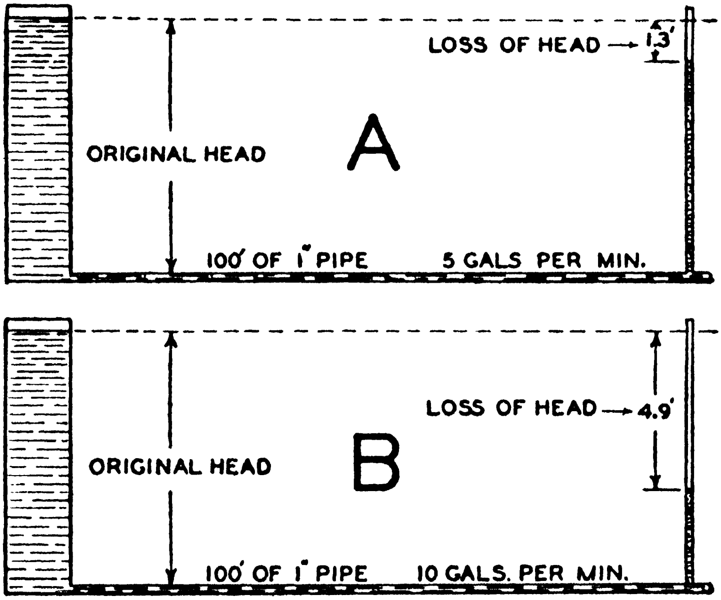


FIGURE 75.—The loss of head due to friction varies with the rate of flow of water.

ft., as shown at *B*. Doubling the diameter of a pipe increases its capacity four times.

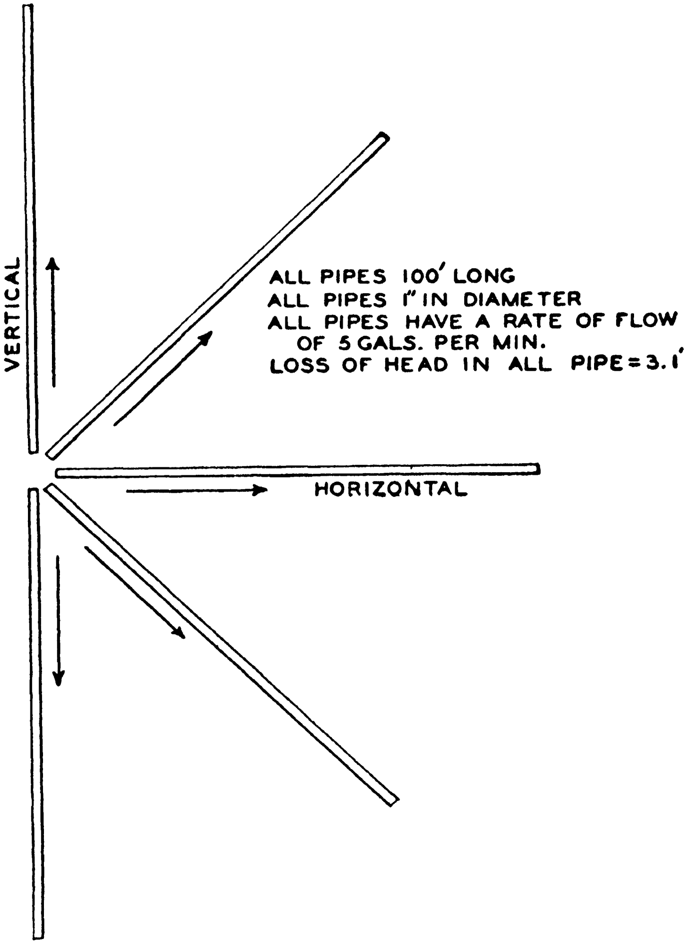


FIGURE 76.—The loss of head due to friction is not affected by the angular position of the pipe.

3. *The smoother the inner surface of any given pipe, the less the friction losses for any given rate of flow.* Thus the losses in pipe *A*, Fig. 73, are less than in pipe *B*.

4. *The fewer the fittings and valves on a pipe line, the less the friction losses for any given rate of flow.* Thus the losses in pipe *A*, Fig. 74, are less than in pipe *B*.

5. *The higher the rate of flow through any given pipe, the greater the friction losses.* Thus with a rate of flow of 5 gal. per minute through 100 ft. of 1-in. pipe, as shown in Fig. 75, at *A*, the loss of head due to friction is 1.3 ft. If the rate of flow were increased to 10 gal. per minute, as shown at *B*, the loss of head due to friction would be 4.9 ft. Friction increases as the square of the velocity.

6. *Friction losses are not affected by the angular position of the pipe.* The friction losses under similar pipe and rate of flow conditions will be the same whether the water flows up hill or down hill. In Fig. 76 the losses due to friction are the same in each pipe.

7. *Friction losses are not affected by the pressure on the water in the pipes.*

USE OF FRICTION TABLES. The losses of head due to friction in various sizes of pipe and with various rates of flow are presented in Table I, page 67. By use of this friction table, one may readily determine the friction losses or rate of flow under several conditions. See Job 15.

Suction Head. Suction head, a term applied to pumps, is considered as the total equivalent head in feet on the suction side of the pump against which the pump must work in order to get water. The equivalent suction head is made up of (1) gravity head and (2) friction head. For example, if a pump is "sucking" water through a vertical distance of 15 ft. as shown in Fig. 77, the suction head on the pump will be 15 ft. plus the friction head, whatever that may be.

Where the pump is located at some distance from the well as shown in Fig. 15–1, the amount of friction head may be very considerable. If the actual vertical distance between the water level and the pump were 15 ft. and the long horizontal suction pipe caused 5 ft. additional head owing to friction, then the pump would be working against a total of 20 ft. of equivalent suction head.

Most pump manufacturers guarantee their pumps to work against at least 22 ft. of suction head at sea level. Some guarantee a suction lift of as much as 28 ft. at sea level.

Sources of Supply. It is important to know the following things about the source of supply:

1. Is the supply adequate for the needs?
2. If not adequate, how may the supply be increased?
3. Is the water pure and free from excessive foreign matter?

Adequate Supply. It is important to know that the source of supply, whatever it be, is adequate to meet the water needs. This is particularly true if an automatic pumping system providing running water is to be used. It often happens that a well or spring, which has for years supplied enough water when carried by bucket, proves entirely inadequate when a pump and plumbing system is installed. Therefore, before an automatic pump is installed the rate of flow of the spring or well should be carefully determined. This should be done in dry weather in order to measure the *minimum* flow.

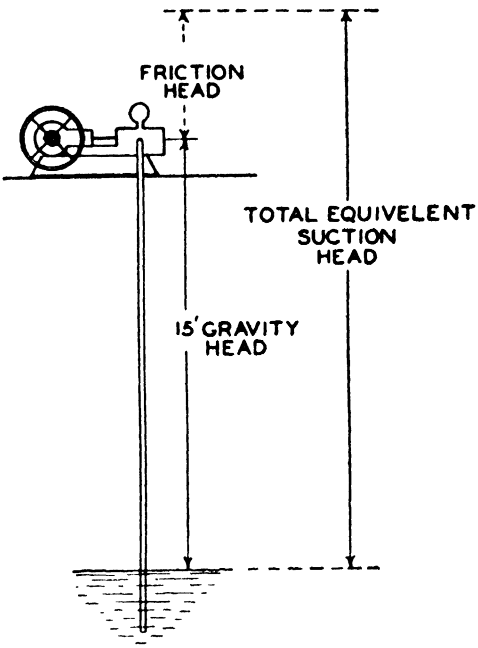


FIGURE 77.—"Suction" head on a pump is made up of gravity head plus friction head.

The rate of flow of a spring may be determined by bailing from the spring pool or by erecting a temporary dam below the spring, as shown in Fig. 78, and catching the water in a pail below the dam. By counting the gallons collected over a period of time, the rate of flow per hour or per day can be calculated. Thus, if on the average a 3-gal. pail is filled in 6 min., the rate of flow is ½ gal. per minute. One-half gallon per minute is equal to

30 gal. per hour, or 720 gal. per day. The rate of flow from a spring cannot be accurately determined by merely observing the water flowing through a pipe.

TABLE IV

Average Daily Consumption of Water

Use	Gallons per 24 hours
For each person where there is running water in the kitchen only	12
For each person where there is running water in the kitchen, bathroom, and laundry	25
Each horse	12
Each steer, heifer, or dry cow	12
Each milk-producing cow	30
Each hog	2
Each sheep	1½
Poultry (per 100 birds)	4

In order to determine the adequacy of the flow, the daily water needs must be known. The needs will vary with different families, but in Table IV is shown an average daily consumption for various purposes. By use of this table the needs can be

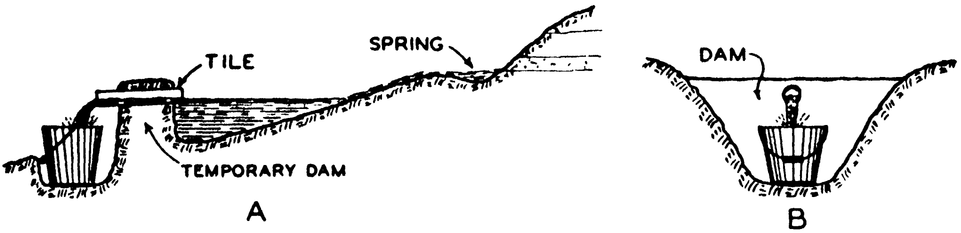


Figure 78.—One method of measuring the flow of water from a spring. At *A*, a cross section view, at *B* a front view.

estimated and the flow at the source checked against the needs. Thus, if on a farm where there are five people living in the house, which has running water in the kitchen, bathroom, and laundry, and there are 4 horses, 15 milch cows, 3 hogs, 20 sheep, and 500 birds, the daily water needs of this farm will be:

5 people	× 25	gal.	per	person	per	day	= 125	gal.
4 horses	× 12	”	”	head	”	”	= 48	”
15 cows	× 25	”	”	”	”	”	= 375	”
3 hogs	× 2	”	”	”	”	”	= 6	”
20 sheep	× 1½	”	”	”	”	”	= 30	”
500 birds	× 4		per	100	”	”	= 20	”
						Total	604	gal.

With a daily need of 604 gal. and a dry-weather daily flow from the spring of 720 gal., this farm would be assured of ample water for all purposes throughout the year, provided, of course, that all the water from the spring was collected in an adequate storage basin.

Checking the flow of a well is usually more of a problem than checking a spring because of the larger volume of water standing in the well.

The flow of a well can be measured in two ways: (1) by bailing or pumping the water level down a few feet and then bailing and measuring only as fast as the water flows in; (2) bailing or pumping the well almost dry and then bailing and measuring as fast as the water flows in. Of these two methods the first is probably the more accurate, because, when the level of the water is lowered a considerable distance the flow will be increased above normal for several hours. If bailing or pumping at a rapid rate fails to lower the level of the water materially the well, no doubt, is adequate for all ordinary purposes.

The adequacy of the well will be determined to some extent by its storage capacity. The storage capacity plus the rate of flow should be sufficient to take care of peak demands. As drilled wells usually have less storage capacity than dug wells, the drilled well should have a better flow to meet the same demands.

The daily flow from a well can be checked for adequacy against the needs as estimated by means of Table IV.

Adequate Supply from a Cistern. If the source of water is a cistern, the size of cistern needed will depend upon the demand and the amount and distribution of the rainfall. An indication

TABLE V

NUMBER OF GALLONS IN ROUND CISTERNS AND TANKS

Depth in Feet	Diameter in Feet					
	5	6	7	8	9	10
5..........	725	1,060	1,440	1,875	2,380	2,925
6..........	870	1,270	1,728	2,250	2,855	3,510
7..........	1,015	1,480	2,016	2,625	3,330	4,112
8..........	1,160	1,690	2,304	3,000	3,805	4,680
9..........	1,305	1,900	2,592	3,375	4,280	5,265
10..........	1,450	2,110	2,880	3,750	4,755	5,850

Depth in Feet	Diameter in Feet					
	11	12	13	14	15	16
5..........	3,550	4,237	4,960	5,765	6,698	7,520
6..........	4,260	5,084	5,952	6,918	8,038	9,024
7..........	4,970	5,931	6,944	8,071	9,378	10,528
8..........	5,680	6,778	7,936	9,224	10,718	12,032
9..........	6,380	7,625	8,928	10,377	12,058	13,536
10..........	7,100	8,472	9,920	11,530	13,398	15,040

Courtesy of Gould Pumps, Inc.

of the size needed may be obtained by inquiring of neighbors who depend upon cisterns for water. Table V gives the capacities of round cisterns of various sizes.

If the cistern is rectangular the capacity in gallons may be determined by finding the cubical content in feet and multiplying by 7.48.

How to Increase an Inadequate Water Supply. If the existing source or sources of water prove to be inadequate by the foregoing checks, the supply may possibly be increased in a number of ways. The following are some of the most common methods used under the various conditions as listed.

Condition 1

Where the only source of water is an inadequate spring:

A weak flow from a spring may be due to one or more of the following conditions:

- (a) Spring located above the dry-weather water table. See Figs. 1 and 2.
- (*b*) Spring hole not well cared for.
- (*c*) Spring flow dammed up.
- (*d*) Water being lost in soil around spring.
- (*e*) Water being drained away to another well or spring near by.

Remedy

For conditions (*a*) and (*e*) there are no remedies except to find other sources. Condition (*b*) can be remedied by keeping the spring hole clean and preventing the water from leaching away. If the vein becomes covered with mud and leaves the water may be diverted to other outlets. If the soil at the spring is porous the water may "sink" as it flows from the vein. A watertight catch basin will improve this condition. See Figs. 12, 79, and 80.

The effect of condition (*c*) is the same as that of condition (*b*) except that the damming up is caused by an improperly constructed storage basin. Many springs are located along the edge

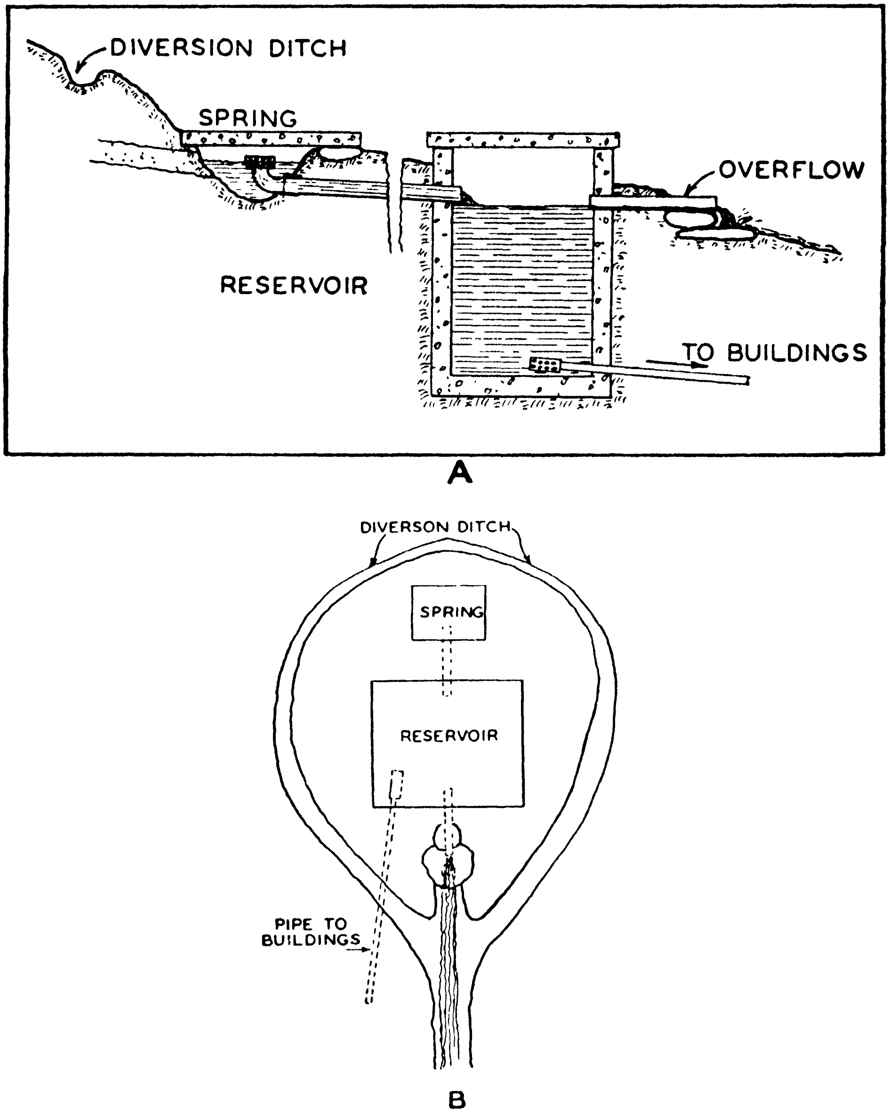


Figure 79.—A suitable storage basin for a weak spring. The storage basin can be located at any distance from the spring as indicated at *A*. At *B* is a plan view of such an installation.

of layers of bed rock, over or through which the water flows to the spring. The presence of the spring may be due to a low place or a crevice in the rock. In such a case the damming up of the water may divert it to some other outlet. The storage basin for a weak spring should be located far enough below the spring to permit free flow from the spring as is shown in Figs. 79 and 80. The flow of 24 hr. may be sufficient for a day's use if *all* the water is caught and stored.

Condition (*d*) may be remedied by the use of collecting tile, as shown in Fig. 81. Sometimes the water seeps out of a layer of rock along a considerable distance at the foot of a slope forming a bog or swamp in the area of the spring. Drain tile arranged as shown will collect this water and direct it to the spring. The tile should be laid in gravel at a depth of about 4 ft., and covered with heavy clay to keep out surface water. The entire area so drained should be fenced to keep animals away and a diversion ditch should be dug above the area to divert surface water.

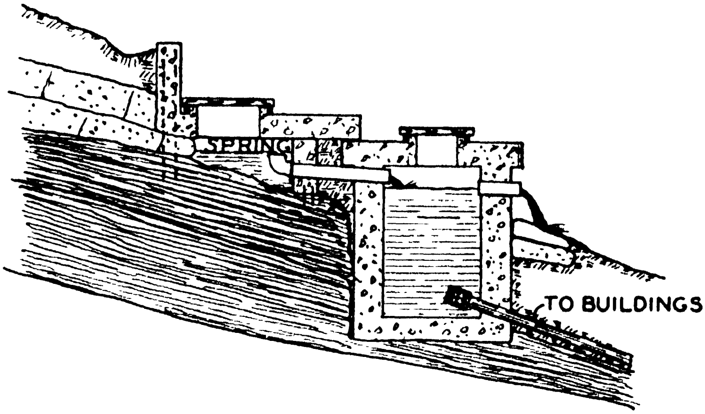


FIGURE 80.—A suitable storage basin for a weak spring having the storage basin adjacent to the spring.

Condition ?

Where the only source of water is an inadequate dug or drilled well:

A well may be inadequate from one or more of the following causes:

(*a*) Well not deep enough to penetrate water table or below free ground water level.
(*b*) Well filled with mud.
(*c*) Not enough storage capacity in well.

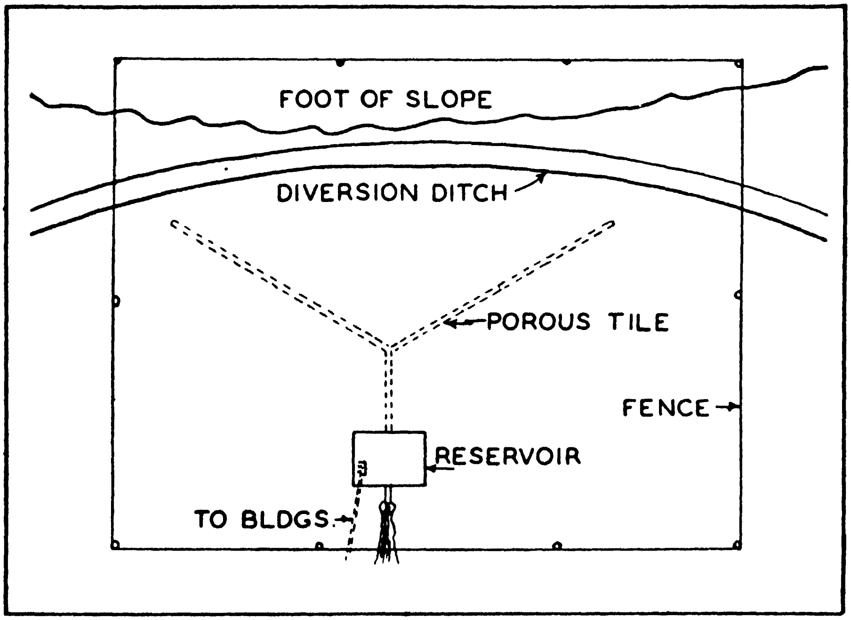


FIGURE 81.—One method of increasing the flow of a spring. The porous tile collects the water at the base of a slope and diverts it to the storage basin. Note the diversion ditch and the fence.

Remedy

(*a*) If the well is not deep enough to penetrate below the dry-weather water table it will become very weak or dry up in dry weather. See Figs. 1 and 2. In most cases, in regions where wells are common, an adequate supply of water can be obtained if the well is dug or drilled deep enough. In some locations there is danger of striking salt, sulphur, or objectionable minerals at great depth, but usually the quantity at least can be increased.

If the well is a dug well the best method of going deeper is to drill through the bottom as shown in Fig. 82. In drilled wells the old hole may be extended by additional drilling.

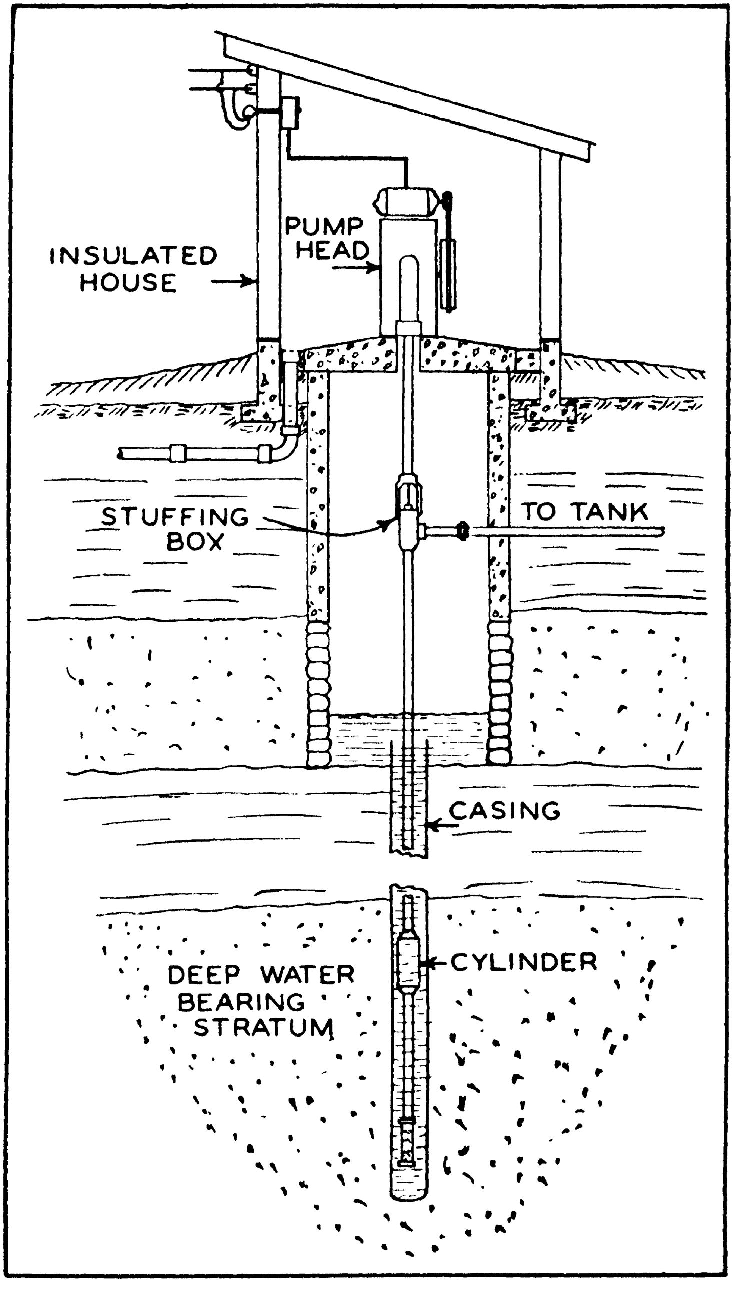


FIGURE 82.—The flow of water in a dug well may possibly be increased by drilling deeper through the bottom.

(*b*) If the well is an old one the flow may be obstructed by an accumulation of sediment in the bottom. This may be bailed out with ordinary buckets in a dug well. In drilled wells a well-driller's bail should be used. Figure 83 illustrates what may happen to restrict the flow in a drilled well. To bail out such a well the drop pipe must first be removed. It is never safe to "shoot" a well with explosives. There is just as much danger of losing the present supply as there is of increasing it. In the case of Fig. 83 the explosives might only force the sediment into the water-bearing stratum, thus clogging the pores and further decreasing the flow. Again, explosives may open cracks in the bed rock and allow the water to flow away from the well instead of to it.

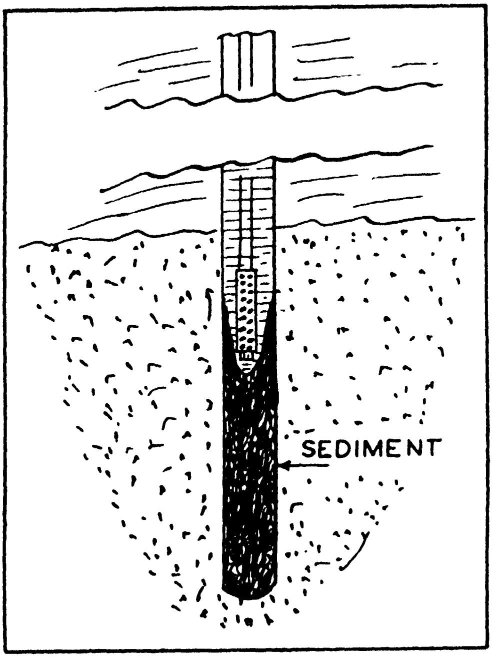


FIGURE 83.—Sediment in the bottom of a well may restrict the flow.

(*c*) If the well has not enough storage capacity the solution is to increase either its diameter or its depth, or both. In some cases, however, it is cheaper to dig another well to supplement the old one.

Condition 3

Where the only source is an inadequate driven well:

A driven well may have a weak flow due to one or more of the following causes:

(*a*) Well point strainer filled with sediment.
(*b*) Well point not deep enough in sand.
(*c*) Water being drained away by other wells or outlets.
(*d*) Not enough free water in ground.

Remedy

(*a*) If the well is an old one the strainer may be filled with mud or tightly packed sand. This condition can *sometimes* be remedied by firing a very small charge of explosives in the pipe with a cap on the top of the pipe. There is on the market a special device for this purpose. An ordinary 12-gauge shot-gun shell is used. The explosion will sometimes clean the strainer and thus increase the flow of water. The process is more or less dangerous, however, and if not properly done may do more damage than good.

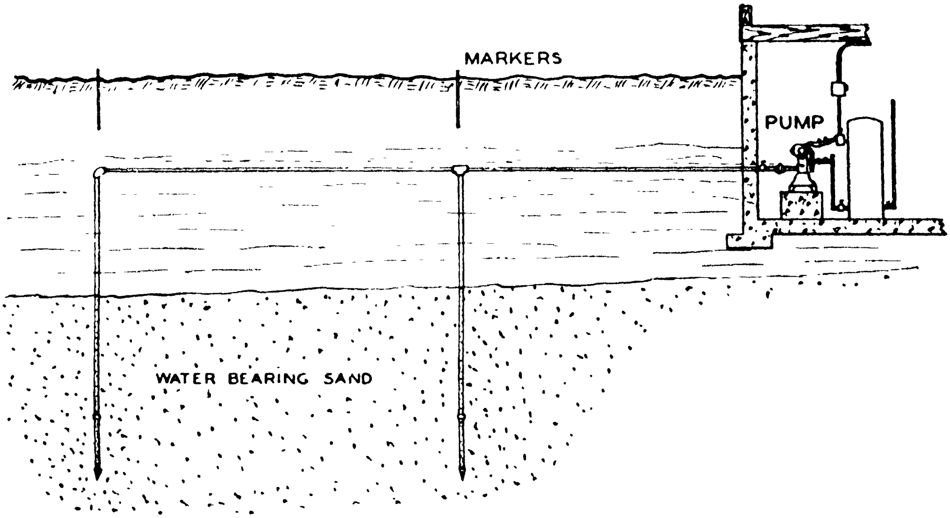


FIGURE 84.—An arrangement for increasing the water supply where driven wells are possible.

(*b*) If the well point is not deep enough it may possibly be driven lower.

(*c*) If the water is being drained away from the well there is no remedy unless the drainage can be checked.

Driven wells are usually in sand or gravel through which water flows rather freely. If other wells are located near by, and these wells are pumped hard, the water may be drawn away from the well in question.

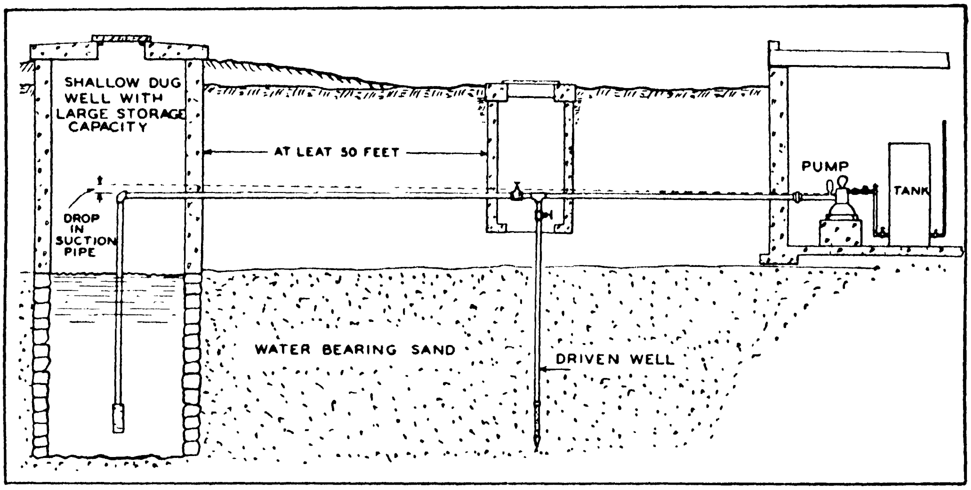


FIGURE 85.—A driven well and a dug well connected to the same pump. The valve arrangement enables one to pump from either or both wells. The valves should be of the gate type and should be made accessible as shown. The packing around the valve stems must be kept tight. The union should have a rubber gasket.

(*d*) If the indications are that there is only a limited amount of water in the ground at the well, a second well may be driven at a distance of at least 25 ft. from the first and both wells connected to the same pump, as shown in Fig. 84. Fig. 85 shows a driven well supplemented by a dug well.

Condition 4

Where the only source of water is an inadequate cistern:

A cistern water supply may be inadequate for one or more of the following reasons:

(*a*) Not large enough.
(*b*) Not enough roof to catch water.
(*c*) Gutters and down spouts in poor condition.
(*d*) Not enough rainfall.
(*e*) Leaks in the cistern wall or floor.

Remedy

(*a*) The remedy for condition (*a*) is obviously to enlarge the cistern or to build additional ones. See Figs. 13, 14, 15, and 16 for plans of cistern.

(*b*) Sometimes only a part of the roof water is being diverted to the cistern. In such a case additional gutters and down spouts on the remainder of the roof will increase the supply.

(*c*) Leaky gutters and down spouts will, of course, cause a part of the water to be diverted from the cistern. The obvious remedy is to repair the gutters and down spouts.

(*d*) The only remedy where the rainfall is inadequate is to provide additional roof area and storage space to catch and hold what rain does fall.

(*e*) If the cistern leaks the obvious remedy is to repair it.

Condition 5

Where both a spring and a well are available:

Where both a spring and a well are available, if only one of these sources is in use, the obvious solution is to tap the other source. If the well is in use but has proved inadequate and a spring is available, either for gravity flow or for pumping, a storage reservoir, such as suggested in Figs. 61 and 79, probably would supply the necessary additional water.

Where more water is needed than both spring and well will provide, an additional supply can be had by making another well or building one or more cisterns.

Condition 6

Where both a spring and a cistern are available:

Where both a spring and a cistern are available, the supply may be increased by enlarging the storage at the spring, or, in case there is gravity head on the spring, by allowing the spring to flow constantly into the present cistern or an additional storage space, as suggested in Fig. 61.

Another solution, of course, would be to dig or drill an adequate well if water-bearing stratum is near enough to the surface.

Condition 7

Where both a well and a cistern are available:

Where both a well and a cistern are available, the supply may be increased (1) by enlarging the storage capacity of the well (if a dug well), (2) by enlarging or building additional cisterns, or (3) by drilling deeper in the old well. If the well is weak, the supply can sometimes be increased by using a small capacity pump and a large storage tank. With this arrangement the well may be able to keep up with the small pump over a long period of time while the large storage tank is being filled. The large storage tank, together with the output of the pump, may satisfactorily carry over the peak demand periods, especially so if a cistern is available for a part of the demand.

Condition 8

Where two wells are available:

Where two wells are available the supply may be increased by:

(*a*) Pumping from both wells, as suggested in Figs. 84 and 85, provided both are of the shallow-well type and the surface of water is on the same level.
(*b*) Enlarging the storage capacity of one or both wells.
(*c*) Going deeper in one or both wells.
(*d*) Constructing one or more cisterns as auxiliary supply.

If one is a deep well and the other a shallow well, or if the two wells are widely separated or at widely different levels, a pump will be required for each well.

Condition 9

Where a lake, pond, or stream is available in addition to a good source of drinking water:

Where a lake, pond, or stream is available, either for gravity flow or for pumping and in addition to an inadequate well or spring, the supply may be increased by tapping this additional source. In this case, unless gravity pressure is available, two pumps should be used and two separate piping systems so that the well or spring water can be used for drinking, cooking, and washing dishes, while the lake, pond, or stream water can be used for watering animals, sprinkling, irrigation, laundry, and bathroom.

Purity of Water. It is essential to the health of the family that the water used for household purposes be pure water, as has been pointed out in Chapter I. The source of water should be well protected from pollution. In fact, it is best in any case to have the water tested by a health officer before using it for drinking purposes. Many state departments of health have facilities for testing water and will make the test without charge. On the following page is a reprint of the "Regulations Concerning the Examination of Samples of Water" as set forth by the New York State Department of Health.

The usual procedure is to call on the local health officer for an inspection of your water supply. The health officer will inspect your supply, take samples if necessary, and send them to a laboratory for examination. These examinations determine the absence or presence of pollution at the time of sampling. In some cases, if requested, tests will be made for mineral content. This is desirable if the water is likely to be quite hard or to contain salt, sulphur, or iron.

Once a safe source of water has been obtained precautions should be taken to see that the source is not polluted in the future.

Sediment in Water. If the source of water is roily in wet

Form No. 61-a. 8-6-36-200 (17A-1124)

Public Health is Purchasable.
Within Natural Limitations Any Community Can Determine Its Own Death Rate.

EDWARD S. GODFREY, JR., M. D.
COMMISSIONER

PAUL B. BROOKS, M. D.
DEPUTY COMMISSIONER

NEW YORK
STATE DEPARTMENT
OF HEALTH
NEW SCOTLAND AVE.
ALBANY

DIVISION OF
LABORATORIES AND
RESEARCH

AUGUSTUS B. WADSWORTH, M. D.
DIRECTOR

REGULATIONS CONCERNING THE EXAMINATION OF SAMPLES OF WATER

The laboratory examines samples of water whenever the results of the examination are likely to be directly applicable to the prevention of disease and the protection of the public health.

Questions concerning private water supplies must be referred to the local health officer.

If the health officer or the district state health officer desires a laboratory examination in connection with his investigation of a public or private water supply, he should request of the laboratory the necessary containers and state his reasons for desiring the examination.

He should state in his requests for the containers the number of chemical samples and the number of bacterial samples he wishes to take in the course of the investigation of a water supply. Whenever a large sample for chemical examination is taken, one bacterial sample should also be taken at the same point in the supply, although other bacterial samples may also be taken from other points in the supply, if necessary.

All containers are sent by express, collect, and should be returned to the laboratory by express, prepaid.

No samples will be examined unless containers furnished by the department are used.

On receiving the containers the health officer should select the information blank descriptive of the water to be examined and answer all the questions relating to the conditions which he has found in his inspection. No reports will be made upon samples, the sources of which have not been so inspected that all the inquiries can be answered. Having completed his inspection and made his report of it on the information blanks, the health officer should take the necessary samples following explicitly all directions.

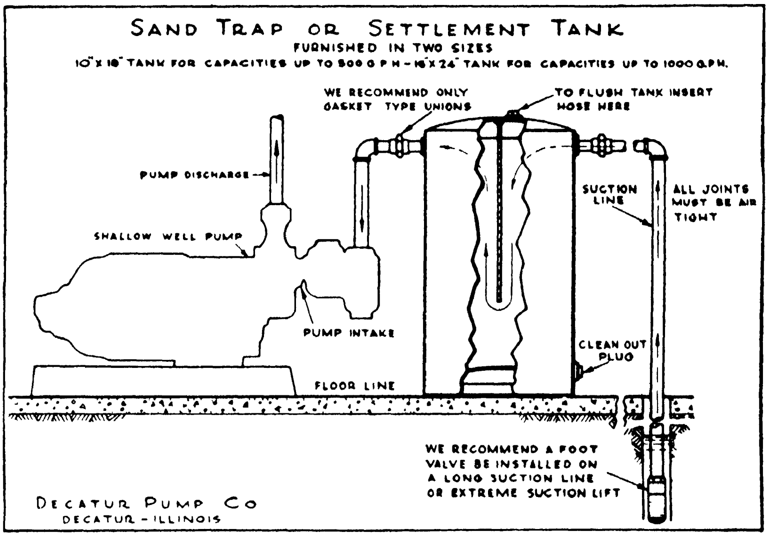
THE LABORATORY EXAMINATION DETERMINES THE PRESENCE OR ABSENCE OF POLLUTION AT THE TIME OF THE SAMPLING.

THE FIELD INSPECTION DETERMINES THE SOURCES AND THE NATURE OF THE POLLUTION AND THUS THE SIGNIFICANCE OF ITS PRESENCE OR ABSENCE.

(Courtesy of N. Y. State Dept. of Health, by permission of Mr. F. W. Gilcreas.)

weather it is an indication that surface water is entering. This is dangerous from a health standpoint and should be prevented. The use of diversion ditches, tight covers, and grading, as suggested in Figs. 3, 4 and 12 are most effective in preventing surface pollution.

In some cases there may be a very fine sand in well or spring water. It is desirable to eliminate this sand for health reasons and to protect the pump from excessive wear. A sand trap, as suggested in Fig. 86, is effective for this purpose.



Courtesy of Decatur Pump Co.

FIGURE 86.—A settling tank on the suction line of a pump makes an effective sand trap. It will also trap other abrasive material which might be in the water.

Type of System to Install. The type of water system to install depends upon a great many factors. A review of Chapters II and III will call to mind the advantages and disadvantages of the various types of pumps and water systems.

The following general rules will serve as a guide in the choice of types of system:

1. If a good natural-gravity system is possible and can be installed without excessive cost, it is the logical first choice.

2. If natural gravity is not available and if large volumes of water need to be stored or if the power for pumping is from a windmill or a hydraulic ram, then the pumped-gravity system is the first and logical choice.

3. If natural gravity is not available and if only moderate amounts of water need to be stored, the hydropneumatic system is the logical choice, particularly so where high pressures are desired and where electricity is available.

4. If the situation is such that both high pressure and large-volume storage are needed, as might be the case on a large dairy farm, then the combination gravity and hydropneumatic system illustrated in Fig. 59 would be first choice.

5. If the situation is such that the ordinary deep- or shallow-well pumps will not operate satisfactorily or if expense is of little consideration, then the pneumatic system may be the logical choice in any case, except on wells having depths greater than 80 ft.

Considerations for Installing a Gravity Water System: *A. Natural Gravity.* In regions where there are wooded hills and an ample rainfall there are likely to be many opportunities for the development of natural-gravity water systems. Many attempts to develop such water systems have failed for lack of knowledge of the proper procedure. The most common cause of failure is the use of pipe which is too small. Other causes are lack of adequate storage capacity, misjudgment of head available, and failure properly to protect the pipes from frost. One conspicuous failure in a community discourages other attempts to develop fine natural sources of water. Conversely, one conspicuous success encourages more development.

Head available. The first problem in developing a natural-gravity water system is to determine the amount of head available. This is necessary as a check on the adequacy of the head and also in order to determine the size of pipe to use. It is not safe to depend upon eye measurements of head, particularly if the spring is some distance from the buildings. A spring which may appear to be much higher than the buildings may, upon measurement, prove to be actually below the buildings.

The height of the spring above the highest faucet may best be determined by a professional surveyor or engineer. However, a fairly accurate measurement can be made by an amateur by means of a carpenter's level equipped with clamp sights, as directed in Job 24. These clamp-on sights may be purchased through hardware stores for about $1.50.

Location of and type of storage tank or reservoir. The storage tank or reservoir can be located at the spring or at the buildings. Figs. 51 and 60 illustrate reservoirs at the spring and Figs. 52 and 61 illustrate reservoir at the buildings.

Some of the common methods of providing storage at a spring are: (1) to sink an open-bottom barrel over the spring; (2) to dig and wall up a hole at the spring, as shown in Fig. 60; (3) to construct a concrete reservoir below the spring, as shown in Figs. 79 and 80; or (4) to build a small permanent dam across the spring branch below the spring.

Sometimes, because of hard rock or danger of flooding from a near-by stream, it is difficult to construct a satisfactory reservoir at the spring. In such cases the reservoir may be located at some distance and the water carried to it by pipe.

The pipe leading from the reservoir to the buildings should have a strainer on the end as shown. The overflow from the reservoir should fall on stones to prevent undermining the walls.

If the spring or other source of water is far away, yet is higher than the top of the buildings, and if there is a good place in or near the buildings for a gravity storage tank, it may be cheaper to use a small pipe from the spring to the storage tank, allowing water to flow through this pipe continuously. The water can then be drawn from the storage tank as needed.

Sometimes there is between the spring and the house a rise in the ground. If this rise is higher than the spring, the water will not flow to the house over the rise except by siphoning. Siphoning water over a hill is not satisfactory unless great care is exercised in selecting and laying the pipes and unless an air chamber is installed at the highest point in the siphon. See Chapter II, page 173.

Size of reservoir. The reservoir should be large enough to store enough water for the peak demands of the day.

Size of pipe to use. The method of determining the size of pipe to use is explained in Job 15.

Frost protection. Be sure that the pipe can be laid deep enough in the ground to protect it from frost. Table VI, furnished by the United States Department of Agriculture, gives a fair guide

TABLE VI

DEPTHS AT WHICH TO LAY SMALL WATER PIPES IN DIFFERENT STATES

State	Depth, Feet	State	Depth, Feet
Alabama	1½ to 2	Mississippi	1½ to 2½
Arkansas	1½ to 3	Missouri	3 to 5
California	2 to 4	Montana	5 to 7
Colorado	3 to 5	Nebraska	4 to 5½
Connecticut	4 to 5	New Hampshire	4 to 6
Florida	1 to 2	New Jersey	3½ to 4½
Georgia	1½ to 2	New Mexico	2 to 3
Idaho	4 to 6	New York	4 to 6
Illinois	3½ to 6	North Carolina	2 to 3
Indiana	3½ to 5½	North Dakota	5 to 9
Iowa	5 to 6	Ohio	3½ to 5½
Kansas	2½ to 4½	Pennsylvania	3½ to 5½
Kentucky	2 to 3½	Tennessee	2 to 3
Louisiana	1½ to 2	Texas	1½ to 3
Maine	4½ to 6	Virginia	2 to 3½
Massachusetts	4 to 6	Wisconsin	5 to 7
Michigan	4 to 7	Wyoming	5 to 6
Minnesota	5 to 9	District of Columbia	4

Courtesy of U. S. D. A.

to the depth at which to lay small water-supply pipes in various states.

Flowing water does not freeze as readily as still water; therefore, if there is enough water available so that a faucet can be left open in cold weather, the pipes are not likely to freeze if laid at a shallower depth than shown in this table. It is much safer, however, to place the pipes below the frost line.

The character of the soil in which the pipe is laid affects the depth to which frost penetrates. Under sod, the frost does not go as deep as in hard-packed barren soil. Frost penetrates unusually deep under roads and driveways and in wet soil.

Pipes laid deep in the ground also provide cooler water in the summer time.

B. Pumped Gravity. Where there is no opportunity for natural gravity, yet it is desirable to store large volumes of water, the pumped-gravity system may be cheapest and most satisfactory.

The location and type of storage tank for a pumped-gravity system. One of the most important considerations in a pumped-gravity system is the location of the storage tank. In the first place, it must be higher than the highest faucet. It is desirable to have it as near the faucets as is practical in order to avoid the use of large pipe. In cold climates it must be protected from freezing and in all cases it should be protected from dirt and pollution.

The common locations of gravity storage tanks are (1) on a near-by hill, (2) in the attic of the house, (3) in the barn, and (4) on a tower.

A tank set in the ground on a near-by hill, as shown in Fig. 60, is preferably located. The difficulty is that the hill is not always near by. Such a tank is protected from frost in the winter, from heat in the summer, from winds at all times, and leaks are not damaging to buildings. There is, however, a danger of pollution unless the tank is well built. The sides of the tank should extend above the ground surface at least 10 in., and it should have a tight cover.

A tank in the attic has the advantage of being near the faucets but, unless the house is especially built for it, the weight is objectionable. Also, a leak sometimes ruins the plaster on rooms below. Unless there is a central-heating plant in the house, the water may freeze in the winter. Unless the tank is well insulated, the water may become very warm in the summer. An attic tank should have an overflow as shown in Fig. 52. Also, a drip pan should be placed under the tank to catch water which will condense on the outside of the tank in the summer. In some regions this condensation may be enough to spoil the plaster and rot the sills under the tank.

As shown in Fig. 52, if the faucets are located between the pump and the tank, there need be only one pipe between the faucets and the tank, the same pipe serving to take water to the tank and to bring it back to the faucets.

If the storage tank is to supply water to a dairy herd, a good location for the tank is on the floor of the hay mow above the cattle, as shown in Fig. 59. If the floor of the hay mow is higher than the house faucets, this same tank can be made to supply water to the house also. The tank can be covered with hay or straw to protect it from frost, and the animal heat from the stable may temper the water somewhat in the winter time, so that the cows will drink more. Some provision should be made to give access to the tank in case of needed repairs.

In warm climates, a good location for the tank is on a tower near the buildings. Where windmills are used, the tank is sometimes placed in the windmill tower. In cold climates, it is difficult to protect a tower tank from freezing.

Type of pump to use. Any type of deep- or shallow-well force pump or a hydraulic ram may be used to fill a gravity storage tank. The pumps may be powered by hand, by windmill, gas engine, or electric motors. If conditions are such that the discharge pressure must be in excess of 45 lb. be sure to install a high-pressure pump.

Size of pump to buy. Domestic power pumps are obtainable with capacities ranging from 200 gal. per hour up to 1000 gal. per hour or more. The tendency at the present time is to install a large capacity pump, 400 to 600 gal. per hour, if there is plenty of water at the source. This gives adequate capacity for peak demands, provides fresher water, and may be of some use in fighting fire, sprinkling, irrigation, spraying, etc.

By Table IV the water consumption per day can be estimated. With this figure in mind select a pump of the proper size to deliver that amount by running 2 or 3 hr. per day. If future expansion of water needs are anticipated, an over-sized pump should be installed.

Considerations for Installing Hydropneumatic Water Systems. The following considerations are important when installing a hydropneumatic water system:

1. Source of water.
2. Demands on water system.
3. Type and capacity of pump and tank.
4. Power available for operating pump.
5. Safety devices for the system.
6. Location of pump and storage tank.
7. Sizes and installation of pipes.
8. Reducing noise.
9. Type and make of system to buy.

Source of water. It is important that the source of water be pure, adequate for the needs, and available at a reasonable cost. To obtain water at a reasonable cost the source should be near the buildings and near the surface of the ground. Very deep wells are expensive to drill and require expensive pumping equipment.

Demands. The water demand, as calculated from Table IV, page 208, will be a determining factor in calculating the size of storage tank and the pump capacity. Where the source of water is strong the present tendency is to use a large capacity pump because the large pump provides plenty of water for long peak demands such as might occur when irrigating, sprinkling, fire fighting, or filling spray rigs. The demand is also necessary for determining the adequacy of the supply.

Type and capacity of pump to use. The type of pump to buy depends upon:

1. The source. If a shallow well, a shallow-well pump may be used. If a deep well, a deep-well pump will be required.
2. Pressure to be pumped against.

The capacity of the pump needed should be determined by (1) the water demands and (2) the amount of water at the source.

If there is plenty of water at the source the pump should be large enough to supply the peak demand. This is particularly true where a dairy herd is to be watered from the pump. For example, 30 head of cattle may need 60 to 80 gal. of water within 20 min. This need may come at a time when the water demands at the house are high also, so that the total demand for that 20-min. period may easily reach 100 gal. This is the equivalent of a rate of 300 gal. per hour. In such a case the pump should have a minimum capacity of 300 gal. per hour.

If the source of water is weak, a large pump may pump the source dry before the pressure is high enough to throw the switch. In such a case a small capacity pump with a large storage tank is a better arrangement. With a small capacity pump the source is less likely to be pumped dry, yet the pump may store a larger quantity of water which can be drawn on at the peak demand.

Pumps designed for operation on pressure tanks are available in different weights for different pressure ranges. One should be careful to obtain a pump with a maximum pressure rating equal to or greater than the highest pressure to be handled.

Size of hydropneumatic storage tank to use. The storage tank may be of any size from 15 or 20 gal. to several hundred gallons, in capacity. The large tank requires considerable space and, unless it is buried in the ground or otherwise protected from heat, the water may become quite stale. The most common size has a 42-gal. capacity. The tank should be made of material heavy enough to hold the maximum pressure to be used.

Power available. The kind of power available will be a determining factor for the size of storage tank, and the power unit to buy.

If a *windmill* is the source of power, the storage tank should be large enough to carry the farm over ordinary periods of calm. As a rule, gravity storage tanks are best for the windmill.

If a *gas engine* is used, the storage tank should be large enough to hold a half-day's supply. A day's supply is better.

When electric power is available the *electric motor* is the most satisfactory means of powering a pump. The electric motor provides completely automatic operation. Also, cost of servicing, repairs, and operation are reduced to a minimum. The motor should be of the capacitor or repulsion-induction type and should have adequate power to drive the pump without overheating. See Job 22 for estimating horsepower.

The wiring for the motor should be large enough to supply full voltage. A motor operated on low voltage may overheat and burn up. There should be a manually operated cut out switch near the motor.

Before starting a pump, be sure that the motor is wired according to the manufacturer's instructions. Also be sure the motor and pump have been properly oiled. Turn the pump over by hand a few times to be sure that it is free.

Safety devices. The three commonly used safety devices are (1) an automatic switch for stopping the pump in case of gas-engine power and for starting and stopping the pump in the case of electric power, (2) overload and low-voltage protective device for the motor, and (3) the pressure-relief valve or "safety" valve.

The automatic switch is the primary safety device and under ordinary operating conditions prevents excessive and dangerous pressures. However, no automatic switch is proof against occasional failure. If the switch should fail, the pump may build up enough pressure to overload the motor or to blow up the tank.

To guard against overloading the motor and possibly burning it up, an overload protective device should be installed either in the automatic switch or on the motor. Also, to guard against low voltage on the motor, a low-voltage protective device should be used. These last two devices are frequently combined into one unit and installed on the motor itself.

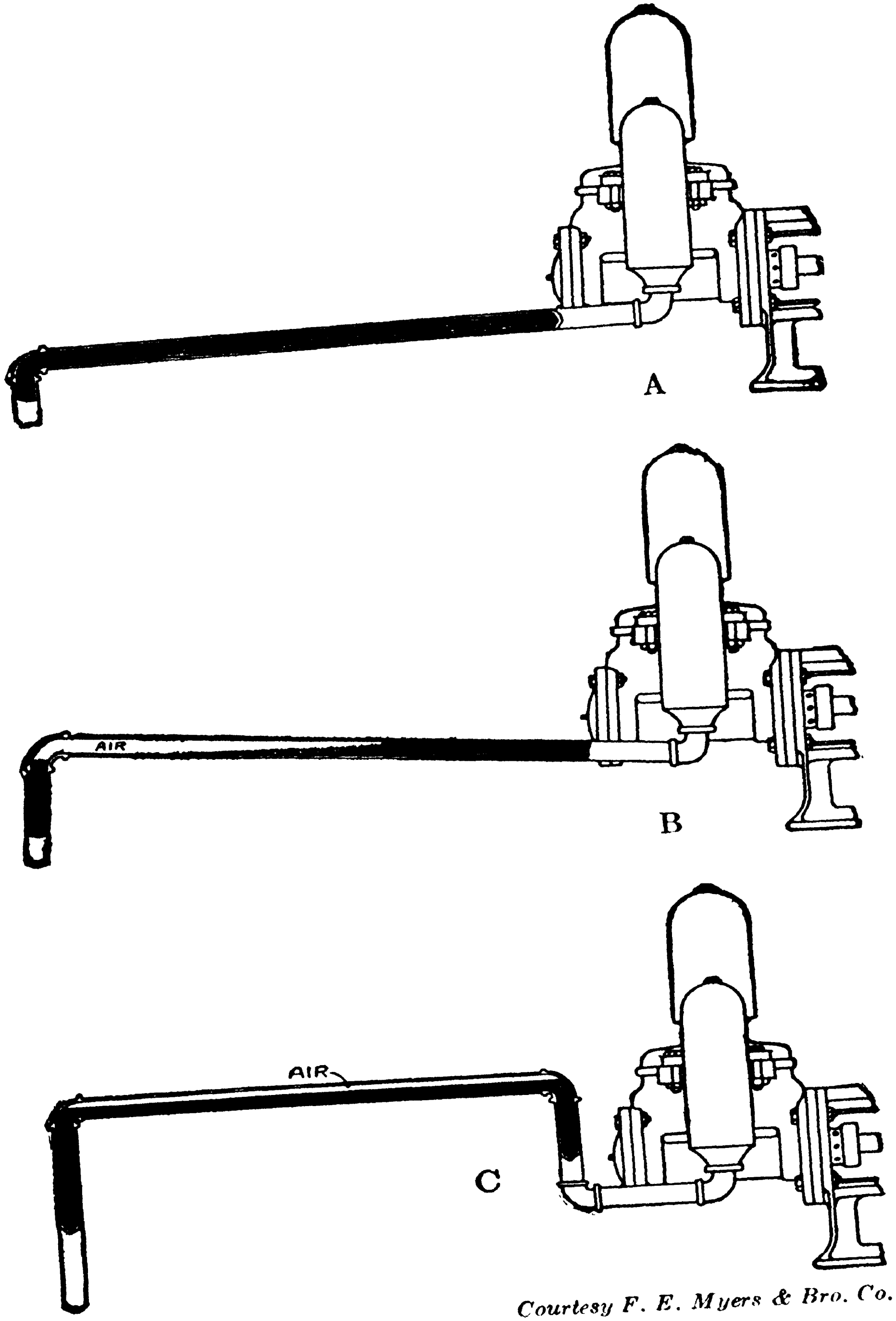
To guard against the possibility of excessive and dangerous pressures, *hydropneumatic water systems with reciprocating pumps should always have a pressure-relief valve.* This valve should be installed on the discharge pipe from the pump and should be between the pump and hand valve, as shown in Figs. 54 and 62. The pressure-relief valve should be inspected at least twice a year to be sure that it is always in working order. A pipe should be run from the safety valve back to the source of water or to a drain to avoid flooding the pump location.

Location of pump and storage tank. In general, it is desirable to have the pump and tank as close to the most-used faucets as possible. This reduces the cost of piping and prevents excessive loss of pressure due to friction. In Chapter IV a number of satisfactory locations are suggested.

Sizes and installation of pipes. In any water system it is important to install pipes large enough to permit a satisfactory flow of water. Job 15 gives instructions on how to do this.

If the suction pipe to a pump has a horizontal run, it should be graded continuously upward toward the pump, as illustrated in Fig. 87 at *A*. If the pipe has a high point, as shown at *B*, or is horizontal as shown at *C*, an air pocket may form in the pipe and cause the pump to loose its priming. This is particularly true where the suction pipe is a long one or the suction head is high. If the suction pipe is more than 10 ft. long, a vacuum chamber should be installed on the line near the pump, as shown in Fig. 54.

If the source of water is above the pump so that water flows to



Courtesy F. E. Myers & Bro. Co.

FIGURE 87.—Suction pipe installations. At *A*, a correct method, at *B* and *C*, incorrect installations.

the pump by gravity, it is best to use a small pipe or to install a hand valve in the line to cut down the flow so that the pump must "suck" a little to get water. If this is not done, the pump will not pump air and the system will, therefore, become water-logged. A water-logged reciprocating pump may become very noisy. A water-logged storage tank causes the pump to start when even a faucet is opened. If a valve is used in the suction line, it should be in good condition and should have tight packing around the stem to eliminate air leaks at that point.

If a union is used in the suction pipe, it should be of the gasket type and should be installed with a rubber gasket to eliminate air leaks. This applies for any pump.

A long vertical length of suction pipe for a shallow-well pump should not be suspended from the pump as its weight may break the housing. In a deep-well pump the size of the suction or "drop" pipe will be determined by the capacity of the pump, but should be amply large to reduce friction load on the pump and motor. If a wooden plunger rod is used, the drop pipe should be larger than for a steel rod because of the larger size of the wood rod. It is common practice to use a drop pipe of larger diameter than the cylinder to permit the removal of the valves by means of the plunger rod and without pulling the drop pipe out of the well.

If the well is quite deep, 100 ft. or more, it may be advisable to use a wooden plunger rod because it floats and will therefore be less load on the motor.

The cylinder should be located below the *low* water level if possible. If the well does not have a strong flow, it is advisable to place the cylinder within at least 22 ft. of the bottom of the well and add a 20-ft. length of pipe below the cylinder. This arrangement enables the pump practically to empty the well.

The pipe from the pump to the tank should be so graded that it can be drained.

All pipes should be as straight as possible and should be air- and water-tight.

Reducing noise. When a pump pounds, the noise is usually due to a water-logged condition, although loose parts will also cause pounding. Where there is a long suction pipe on a reciprocating pump, pounding is likely to occur unless a vacuum chamber is used. Pounding may also occur in the discharge pipe from a reciprocating pump unless the air chamber on the pump is primed with air. Water-logged conditions in the pump, discharge pipe, and storage tank can be avoided by allowing the pump to pump a small amount of air along with the water.

Centrifugal and rotary pumps have little tendency to pound because the water moves through them at a uniform speed.

Where a pump is noisy from loose or worn parts the remedy is to repair the parts.

If a water system is noisy in spite of the above precautions, the following additional remedies may be effective:

1. Insulate the pump from the floor by placing pieces of heavy rubber hose under the base.
2. Place 2- or 3-ft. lengths of stout rubber hose in the discharge pipe between the pump and tank, or between the tank and the faucets. Place the hose at an elbow if possible so that it will have a 90° bend.
3. If there is a long pipe from the tank to some remote room or to the barn, pounding may occur upon closing the faucets at the end or when cow drinking cups are released by the animals. This condition can usually be remedied by the use of rubber hose in the line and an additional air chamber on the end of the line. This air chamber must be kept charged with air to make it function properly.

Make of system to buy. There are many first-class hydropneumatic water systems on the market, any one of which will give satisfactory service. The following general rules may serve as a guide to the purchase of a satisfactory system:

1. Buy a system made by a reputable and well-known manufacturer.
2. Buy from a reliable dealer who is in a position to give adequate and prompt service.

3. Buy the type of system best suited to your own particular needs with respect to type and capacity of pump, type of power used, size of storage tank, safety features, etc.
4. Pay the lowest price that will purchase a system measuring up to the requirements of rules 1, 2, and 3.

Servicing Suggestions for Pumps and Water Systems. The modern pump of good quality will give years of satisfactory service if properly used and properly cared for.

Hand pumps need little attention except for occasional renewing of valves and plunger packing and repacking of stuffing box, if any.

Pumps that are exposed to frost should be drained after use to prevent ice from breaking the cylinder.

Power pumps of the plunger type also need new valves and new plunger leathers occasionally. Some of the centrifugal pumps have no valves or leathers to renew.

On many force pumps there is a stuffing box which should be kept water-tight and well lubricated. The packing should not be so tight as to stall the motor or score the shaft.

Pumps of all types should be lubricated according to the manufacturer's instructions.

Pump troubles. The following is a list of the more common pump troubles together with the remedies for each trouble:

PUMP TROUBLES

Symptoms	Trouble	Remedy
Pitcher Pump		
1. Handle works easily. No water delivered.	Needs priming	Pour water in top.
	or	
	Plunger leathers Worn out	Renew plunger leather.
	or	
	Hole in suction pipe	Renew suction pipe.
	or	
	Leak at base of cylinder.	Renew cylinder gasket.

PUMP TROUBLES—*Continued*

Symptoms	Trouble	Remedy
2. Handle works hard and springs up after down stroke.	Suction pipe stopped up or Water too far from pump or Pump check valve stuck closed or Pump check valve not closing.	If stopped with dirt, clean out. If stopped with ice, thaw out. Place cylinder nearer water. Remove and clean check valve. Repair check valve.
3. Pump will not hold its priming.	Pump check valve not seating properly.	Repair check valve.
Simple Force Pump 1-2-3. A simple force pump may have the same trouble as outlined above for the pitcher pump. The remedies are the same also. In addition, the following trouble may occur.		
4. Leaking at the stuffing box.	Packing loose around the rod or worn out.	Tighten or renew packing.
Deep-Well Pump 1. Pump handle works easily. No water delivered.	Water level below end of suction pipe or Plunger packing worn out. or Pump check valve fails to close or is broken or Plunger rod broken.	Allow well to fill up. Renew packing. (It is usually good practice to overhaul the pump thoroughly whenever it is taken out of the well. The pipes should also be inspected for holes or breaks.) Repair check valve. Splice plunger rod.

PUMP TROUBLES—*Continued*

Symptoms	Trouble	Remedy
2. Handle springs up after down stroke.	Suction pipe plugged up below pump cylinder	Remove entire pump and clean out suction pipe. If well has filled with dirt up to suction pipe, it should be cleaned out or the pipe cut off.
	or Pump check valve fails to close	Repair check valve.
	or Pump valve fails to open.	
Horizontal Double-Acting Pump 1. Pump delivers water on one stroke only.	Valves on one end of cylinder not working properly.	Clean and repair valves.
2. Pump delivers no water.	Has lost its priming	Pour water in pump.
	or Both intake valves fail to close	Take pump apart and repair intake valves.
	or Both discharge valves fail to close	Clean and repair discharge valves.
	or Water level has dropped below end of suction pipe	Allow water to rise in well or lower the pump.
	or Leak in suction pipe	Repair leak.
	or Suction pipe stopped up	Clean out suction pipe.
	or Plunger leather dried out or worn out.	Wet or renew leathers.
3. Pump pounds badly.	Air chamber water-logged	Drain air chambers and repair air valves.
	or Vacuum chamber water-logged	Drain vacuum chamber.
	or Air chambers not large enough	Enlarge air chamber capacity.
	or Loose or worn parts.	Repair loose parts.
4. Pump will not hold its priming.	Both pump valves in bad condition	Repair valves.
	or Check valve out of order.	Repair check valve.

Pump Troubles—*Continued*

Symptoms	Trouble	Remedy
Centrifugal Pumps		
1. Pump runs easily. No water delivered.	Pump not primed	Prime pump.
	or	
	Leak in suction pipe	Renew suction line.
	or	
	Water too far below pump	Place pump closer to water.
	or	
	Packing around shaft leaking air	Tighten or renew packing.
	or	
	Pump worn out	Renew pump.
	or	
	Check valves in suction pipe not working	Repair check valves.
	or	
	Pump not running fast enough	Increase speed.
	or	
	Suction pipe or strainer plugged.	Clean suction pipe and strainer.
Diaphragm Pump		
1. Pump works easily. No water delivered.	Diaphragm leaking	Renew diaphragm.
	or	
	Check valves not working.	Repair check valves.

Water System Troubles. The following is a list of common water-system troubles together with their remedies:

Water System Troubles

Symptoms	Trouble	Remedy
Shallow-Well Automatic Water Systems		
1. Pump starts and stops frequently.	Pressure tank is water-logged.	Pump more air into tank.
	Valves in pump are leaking	Repair pump valves. If pump valves cannot be made to hold, drill a small hole through the check in the check valve and put a foot valve or good check valve on the suction line.
	or	
	Switch diaphragm may be leaking	Renew diaphragm.
	or	
	Safety valve may be leaking.	Clean and adjust safety valve.

WATER SYSTEM TROUBLES—*Continued*

Symptoms	Trouble	Remedy
2. Pump runs for unusually long periods of time.	Pump badly worn, usually leathers and valves.	Repair or renew pump.
3. Water leaks out through air valve.	Air valve core out of repair.	Renew air-valve core. On small pumps a special core with a light spring is required. The standard automobile-tire valve core has too strong a spring to admit air, especially where there is a low suction head.
4. Air blows out through faucets.	Too much air in tank.	Cut down amount of air being pumped by closing air valve on pump.
Deep-Well Water Systems		
1. Pump starts and stops frequently.	Tank water-logged or Valves in pump and check valve are leaking.	Repair air pump and pump more air in tank or close air-pump relief valve Repair pump valves.
2. Pump runs for unusually long periods of time.	Pump in bad repair or Well pumped dry.	Repair pump. Turn pump off until well fills up.
3. Water leaks out through air pump.	Check valve between air pump and water line not closing.	Repair air-check valve.
4. Air blows out through faucets.	Too much air in tank.	Open relief valve on air pump or Repair air volume control valve if one is on tank.

*Useful Facts about Water**

A cubic inch of water weighs 0.03617 lb.
A cubic foot of water weighs 62.46 lb.
A gallon of water weighs 8.355 lb.
A U. S. gallon of water contains 231 cu. in.

* Courtesy Goulds Pumps, Inc.

An English gallon of water contains 277¼ cu. in.

A cubic foot of water contains 1728 cu. in.

A cubic foot of water contains 7.4805 gal.

A "miner's inch" of water equals approximately a supply of 12 U. S. gal. per minute.

One barrel of water contains 31½ gal.

*Useful Rules**

To convert inches vacuum into feet suction, multiply by 1.13.

To reduce pounds pressure to feet head, multiply by 2.3. To reduce heads in feet to pressure in pounds, multiply by 0.434.

Friction of liquids in pipes increases as the square of the velocity.

Doubling the diameter of a pipe increases its capacity four times.

To find the area of a pipe, square the diameter and multiply by 0.7854.

Approximately, every foot elevation of a column of water produces a pressure of ½ lb. per square inch.

The gallons per minute which a pipe will deliver equals 0.0408 times the square of the diameter, multiplied by the velocity in feet per minute.

To find the capacity of a pipe or cylinder in gallons, multiply the square of the diameter in inches by the length in inches and by 0.0034.

The weight of water in a pipe of any length is obtained by multiplying the length in feet by the square of the diameter in inches, and by 0.34.

To find the discharge from any pipe in cubic feet per minute, square the diameter and multiply by the velocity in feet per minute and by 0.00545.

To find the capacity of a given tank or cistern in U. S. gallons,

---

* Courtesy Goulds Pumps, Inc.

square the diameter (in feet), and multiply by 0.7854, multiply by the height in feet and by 7.48.

To find the discharge in U. S. gallons per minute from any pipe, square the diameter in inches, multiply by the velocity in feet per second and by 2.448.

The discharge from a pipe in cubic feet per second is equal to the mean velocity in feet per second, multiplied by the area of cross-section of pipe in square feet.

Sharp angles or sudden bends in pipes cause increase in friction; consequently increase of power is necessary. Where change of direction is desired the same should be made by means of long easy curves or by using 45° ells.

CHAPTER VI

FARM PLUMBING SYSTEMS

Essential Features. A complete farm plumbing system consists of (1) the *supply plumbing*, which carries the water from the source to all the faucets, (2) the *fixtures*, such as the sink, bath tub, toilet, lavatory, and laundry tubs, (3) the *waste plumbing*, which carries the waste away from the fixtures to the sewage disposal system, and (4) the *sewage-disposal system*. Such a plumbing system is illustrated in Fig. 99.

From the standpoint of convenience, sanitation, and health a complete plumbing system is highly desirable. If funds are not immediately available for a complete installation, however, it is not necessary to wait until they are before making a start. Fortunately a plumbing system can be built up piecemeal and over a long period of time almost as economically as if it were all built at once. The conveniences of any additions can be enjoyed in the meantime.

Suggested Procedure for Installation. Figures 88, 90, 91, 98, and 99 illustrate a suggested step-by-step procedure in building a modern plumbing installation. A study of these sketches will reveal the fact that the only items discarded in the whole procedure are two hand pumps, a gravity storage tank, possibly the grease trap, and a few pieces of pipe. All these items are relatively inexpensive, and on a farm the pumps, the storage tank, and the piping may be useful elsewhere. If the water is hard and no softener is used, the grease trap should be kept in service as indicated in the insert of Fig. 99.

In a piecemeal plan of installing a complete plumbing system the order of installation of the various units is, of course, a matter of choice on the part of the owner. The following order, however, is a common one and is considered by many to provide the maximum convenience per dollar of investment.

Step 1: Kitchen Sink with Drain and Disposal System. With no plumbing at all in the house, the water must be carried in and, after it is used, must be carried out. This, of course, means considerable labor and inconvenience. Also, the temptation is strong to dispose of the waste water on the surface of the ground near the house. As the waste water is impure, its disposal on the surface is unsanitary and, therefore, may be dangerous to health.

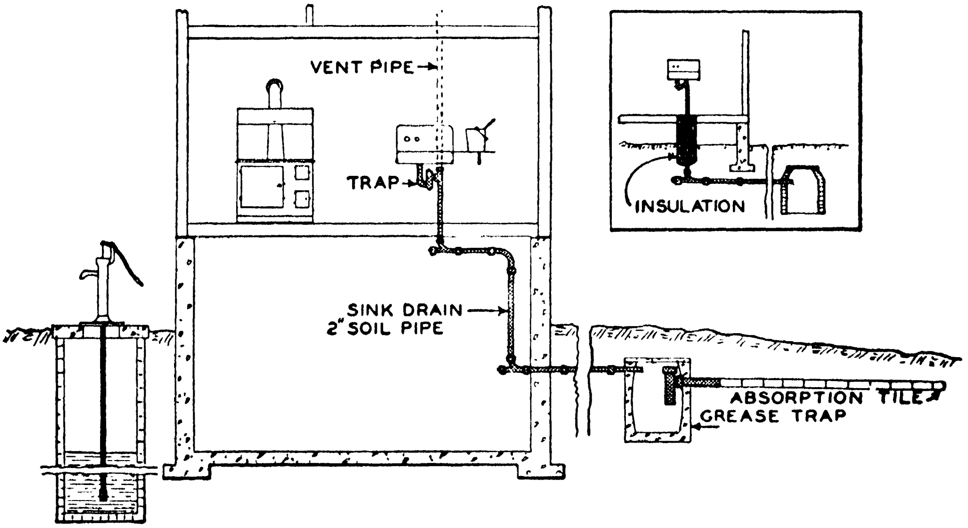


FIGURE 88.—A kitchen sink installation. The trap should be vented as shown by the dotted lines. If not vented, a non-siphoning trap should be used. The insert illustrates a method of insulating the pipe under floor and a cesspool used as an alternate disposal system suitable where the soil is porous.

A properly installed kitchen sink and disposal system will dispose of a large part of the waste water in a sanitary manner and will eliminate about one-half the labor of carrying water. Also a sink provides a convenient place to do much of the kitchen work. For these reasons the installation of a kitchen sink is the logical first step.

Figure 88 is a sketch of such an installation. The sink should be located near a window for good light and should be set at a suitable height for the person who uses it most. Laboratory studies indicate that the correct height is such that the palms of the hands can be placed on the bottom of the sink without stooping.

A trap should be installed in the waste line immediately under the sink. The trap provides a water seal in the drain pipe which prevents sewer gasses from escaping into the kitchen. It is best to have the trap vented to the roof. A vent will prevent sewer gasses from backing up through the trap, will prevent the water seal from being siphoned out, and will stop the gurgling noise so common on unvented traps. If no vent is provided, a non-siphoning trap should be used.

The drain pipe on a sink should be amply large, especially where much grease and sediment are likely to be disposed of through the drain. The pipe to the floor should be 1½ in. in diameter, and from the floor to the disposal system it should be 2 in. Clean-out openings should be provided at one end of each horizontal section of the pipe, as shown.

The drain pipe from the sink can be run to the floor or put inside the wall. When run to the floor, an "S" trap is used. When run to the wall, a "P" trap is used. When inside the wall, the floor under the sink is left clear and is easier to clean. If the drain pipe is placed in an outside wall, it should be insulated where there is danger of frost. In cold climates the water supply pipes should not be placed in an outside wall.

The drain pipe may be made of galvanized steel piping with cast-iron drainage fittings all the way to the disposal system, but it is better to use cast-iron soil pipe from the floor to the outside of the basement wall. Cast-iron drainage fittings should be used on steel drain pipes as they are less likely to cause stoppage. See Fig. 89.

From the outside of the basement wall vitrified clay sewer tile may be used if the sewer is located at a safe distance from the source of water. Where the sewer runs close to the well, cast-iron soil pipe should be used and the joints should be caulked with lead.

In cold climates, if there is no excavation under the kitchen, the drain pipe (and water pipes, if any) should be insulated as shown in the insert of Fig. 88.

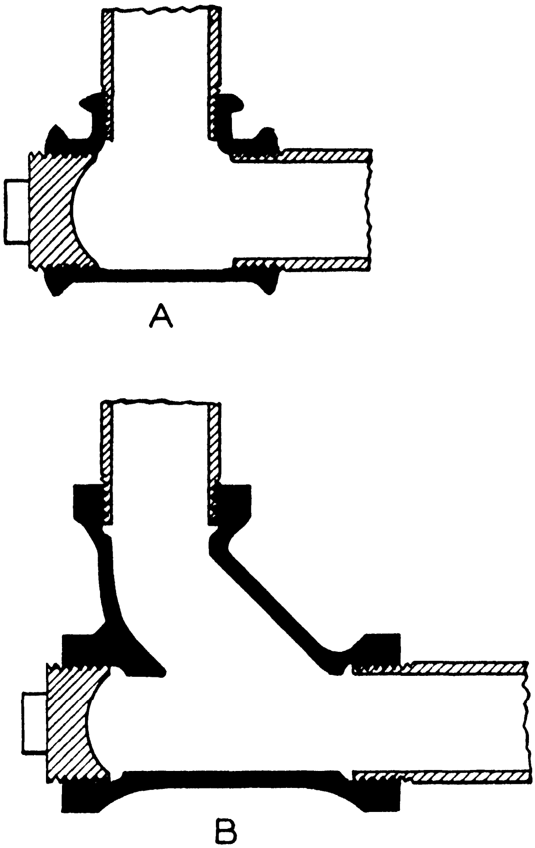


FIGURE 89.—At *A* a malleable iron fitting. At *B*, a threaded cast-iron drainage fitting. The drainage fitting offers less resistance to the flow of liquids and to the passage of solids.

If hard water is used at the sink, the drain should lead to a grease trap and then out to absorption tile. The grease trap can be made of a wooden barrel sunk into the ground, of concrete as shown here, or it can be a commercial-type metal tank.

The absorption line should be made of ordinary field drain tile.

If soft water is used and if the soil around the house is not too heavy, the drain may be discharged imto a cesspool as shown in the insert of Fig. 88.

The grease trap and absorption field or cesspool should be located on the down-hill side of the well and at least 100 ft. away if possible. See Chapter VII.

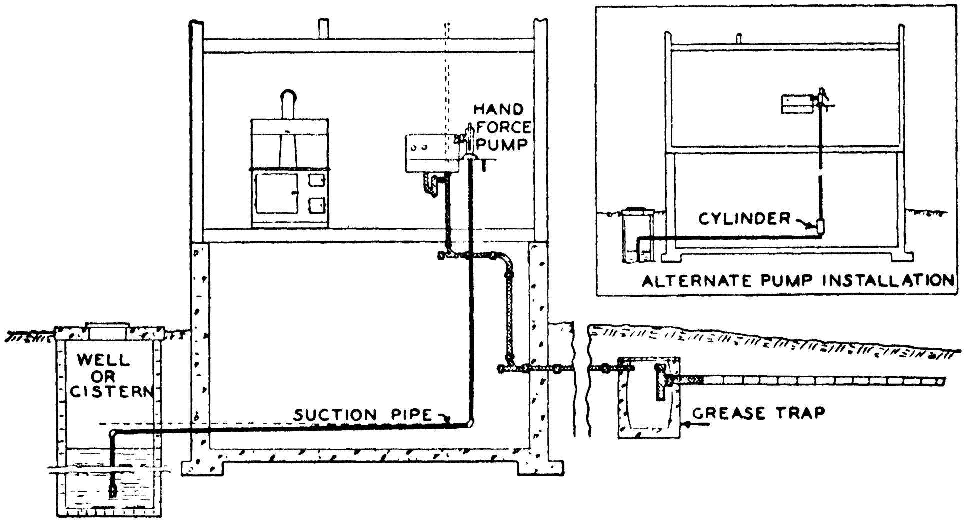


Figure 90.—The addition of a pump to Fig. 88. The suction pipe should be graded continuously downward from the pump to the well. The insert illustrates a method of installing a pump cylinder where the water is just out of reach with the cylinder installed at the sink level.

The cost of materials for such an installation will range from $10.00 up, depending upon the quantity and quality of materials used.

Step 2: Pump at Sink. The next suggested step is the installation of a hand pump at the sink, as shown in Fig. 90. This is possible, of course, only when the source of water is within 22 ft., vertical distance, of the sink. If there is a cellar or basement under the kitchen, the cylinder of the pump may be lowered as shown in the insert, to place it within reach of the water. If there is danger of frost under the floor, the suction pipe should be insulated where exposed, as shown in insert of Fig. 88.

The suction pipe should be amply large, especially so if it is quite long. A suction pipe which is too small causes the pump to work hard and limits the flow of water. Job 15 gives instructions on estimating pipe sizes.

Although a pitcher pump will deliver water at the sink, if the next step is to make the additions shown in Fig. 91, a simple house force pump with a valve in the spout and a tapped opening for a discharge pipe should be installed at this time in anticipation of the later improvements. If the plan calls for the installation as illustrated in Fig. 98 or 99 next, then the cheaper pitcher pump will do just as well.

Regardless of the type of pump installed, if there is danger of freezing in the kitchen, a pump so constructed that it can be easily drained should be used. See Figs. 28 and 29. The suction pipe should not have a check or foot valve on the end of the pipe if the pump is to be drained. Also the pipe should be graded downward all the way to the well.

The cost of materials for the pump installation will range from $5.00 up, depending upon the kind of pump and amount of piping materials used.

Step 3: Hot and Cold Running Water. The third suggested step is to install equipment to provide hot and cold running water at the sink, as shown in Fig. 91. An ordinary stock tank, or pressure tank, can be used for storage or, if there is no convenient location for a storage tank, it may be eliminated and the water forced through the pipes with the pump. The latter arrangement means, however, that the pump must be operated whenever either cold or hot water is to be drawn at the faucets. A gravity storage tank should be provided with an overflow, and, in regions of high humidity, a drip pan as shown.

Hot-water supply. The range boiler should preferably be located near the source of heat, although it is possible to locate it at some distance, as shown in Fig. 92, at *A* and *D*.

Sources of heat. The heating of the water may be done by means of wood, coal, oil, gas, or electricity.

The range boiler: installation and operation. The principle of operation of a range boiler is as follows: (Refer to Fig. 93.)

When heat is applied to the water front or the heating coil the water on the inside absorbs the heat, causing its temperature to rise. When water is heated it expands; therefore, becomes lighter per unit of volume. The lighter warm water inside the heating unit will, therefore, float on top of the cooler water. In Fig. 93, if the upper pipe *H* leading from the heating unit to the top of the range boiler is graded upward, the warm water will flow up this pipe and rise to the top of the tank. This warm water will be replaced by cooler heavier water flowing upward from the bottom of the tank through the lower pipe *C*. This circulation is known as "convection," and the force causing the circulation is the difference in weight, per unit of volume, between the two columns of water *A* and *B*, the heavier column *A*

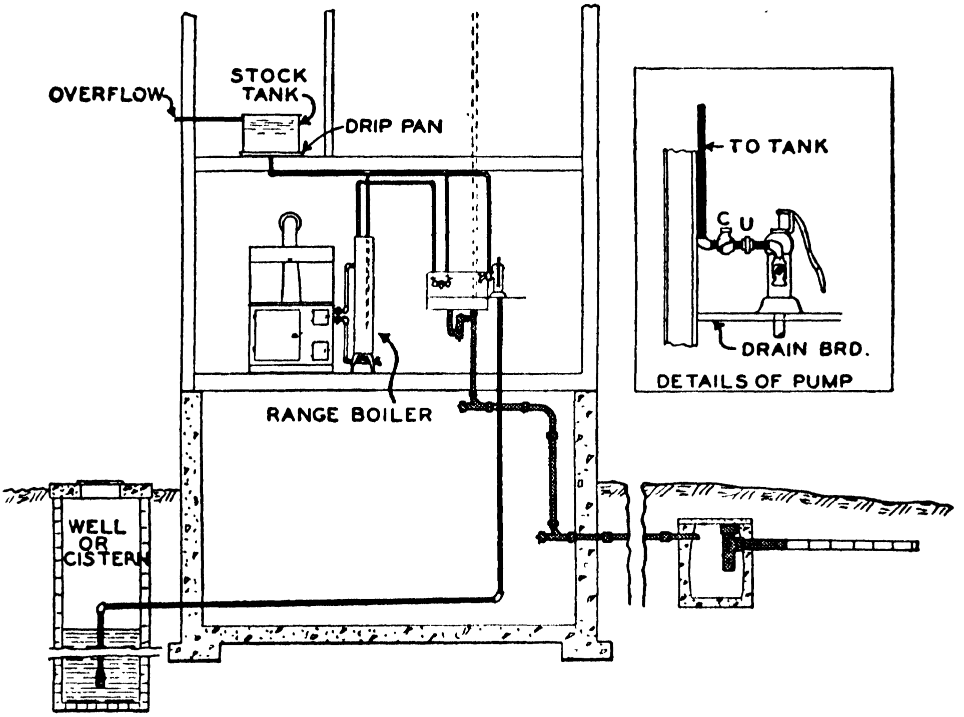


FIGURE 91.—The addition of hot and cold running water to Fig. 90. The insert illustrates details of the pump connections to the tank.

being the cooler one and the lighter column *B* being the warmer one. The circulation is continuous as long as heat is applied at the heating unit and the pipes are open.

The force causing the circulation is relatively weak, especially with a low fire. For this reason, it is important to have the circulating pipes amply large, usually ¾ in. or more; also they should be as straight as possible and free from obstructions. They should be graded continuously upward from near the bottom of the tank through the heater to near the top of the tank. A dip in the pipe, especially the upper pipe *H*, will trap the hot water and stop the circulation. Although pipe *C* may be connected at

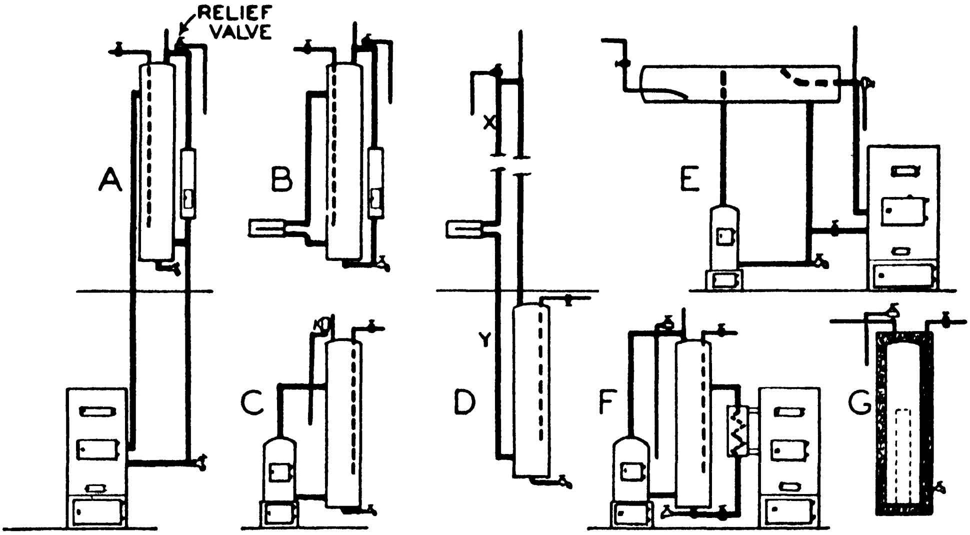


FIGURE 92.—Alternate connections for hot water supply boilers. At *A* the boiler is connected to the house-heating furnace or boiler in the basement and has a side arm heater for summer use. At *B*, a connection to the kitchen range and a side arm heater for summer use. At *C*, a connection to a hot-water supply boiler. At *D*, an arrangement for placing the range boiler below the source of heat. Vertical pipe *X* *must* be equal in length or longer than pipe *Y*. At *E*, an arrangement for a horizontal tank. At *F*, connections for an indirect heater on the house-heating steam or hot-water boiler for winter use and a hot-water supply boiler for summer use. In *E* and *F* a valve should be placed in the house-heating boiler line as shown to prevent circulation in the summer time. At *G*, an electric or gas automatic heater.

the bottom of the boiler, it is better to connect it at the side near the bottom as this leaves room at the bottom for sediment to accumulate where it will not be stirred up by the circulation. There should be a drain valve at the bottom of the boiler for flushing.

With hot water in the range boiler, when a hot-water faucet is opened the pressure on the system will cause water to flow into the boiler through the cold-water tube, thus forcing hot water out at the top of the tank to the hot-water faucet. The cold water must be discharged toward the bottom of the tank to prevent its mixing with and cooling off the hot water at the top. This is accomplished by means of a pipe inside the tank, which pipe is called the "cold-water tube."

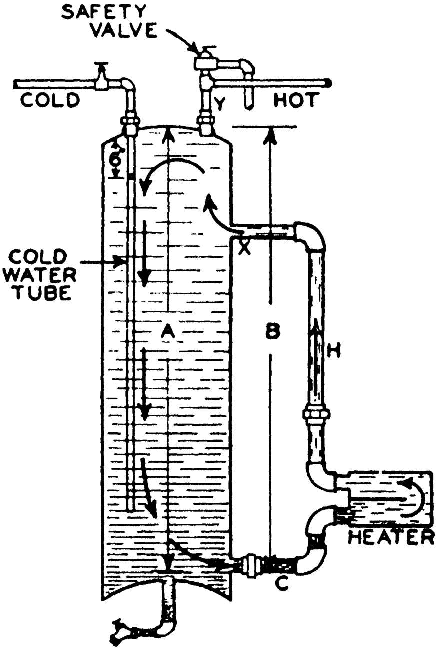


Figure 93.—Cross-section of range boiler installation showing the circulation of water. The cold-water supply pipe should have a hand valve for quickly shutting off the water pressure in case of leaks. If the boiler is connected to a pressure type of water system, there should be a safety valve on the hot-water pipe as shown.

This tube may be made of a piece of ½-in. galvanized steel pipe, but the best practice is to use copper or brass pipe. Steel pipe will corrode very quickly in hot water. This tube is screwed into the lower end of one of the range boiler unions before the union is installed. Near the upper end of the tube is a small hole, the purpose of which is to prevent siphoning of the water from the boiler. Without this hole, if the water pressure were shut off and a cold-water faucet, located below the tank, were opened the water might be siphoned out down to the end of the cold-water tube.

This would be dangerous because, as soon as the level of the water drops below the level of pipe *X*, the circulation through the heating unit will be stopped. If the fire is hot, steam will be generated which might create enough pressure to explode the tank. Such an explosion is extremely dangerous because of the high temperature of the steam and water. With a hole in the pipe, air will be admitted as soon as the water level drops to that point and the siphon will be broken. The hole is a small one (about $\frac{1}{32}$ in.) and, therefore, does not discharge enough cold water to cool off noticeably the hot water at the top. If a steel pipe is used the hole should be countersunk, as shown in Fig. 94. This will reduce the possibility of the hole's being stopped up by rust or scale.

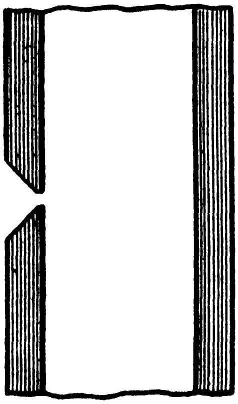


FIGURE 94.—Cross-section of steel cold-water tube showing how to countersink non-siphoning hole.

If the water is hard with "temporary hardness" (see Chapter I), lime will be deposited on the inside of the heater, the tank, and the pipes, particularly the heater and pipe *H*. The accumulation of these lime deposits will gradually reduce and eventually stop the circulation. The heating unit and the pipes must then be cleaned out or renewed.

The rate at which lime is deposited depends upon the hardness of the water and the temperature to which it is heated. Naturally the more lime there is in the water the faster it will deposit. Also, the hotter the fire the higher the rate of deposit. At temperatures of less than 150° F. the rate of deposit is negligible unless the water is excessively hard. At temperatures above 150° F. the rate of deposit accelerates rapidly. For this reason, with thermostatically controlled heaters such as automatic electric or gas heaters, where the thermostat is set at about 145° F., there is less trouble with lime deposits. There are also thermostatically controlled coal and oil heaters. A common method of heating the water with a steam or hot-water house-heating system is to use an indirect side heater, as illustrated at *F* in Fig. 92. With this arrangement the hot-water supply is heated by the boiler water, which in turn has been heated by the fire. Thus the temperature of the supply water does not go so high and less difficulty is experienced with lime. Also on some of the newer automatic house-heating boilers this arrangement makes it possible to heat the water supply with the boiler in the summer time without heating the house.

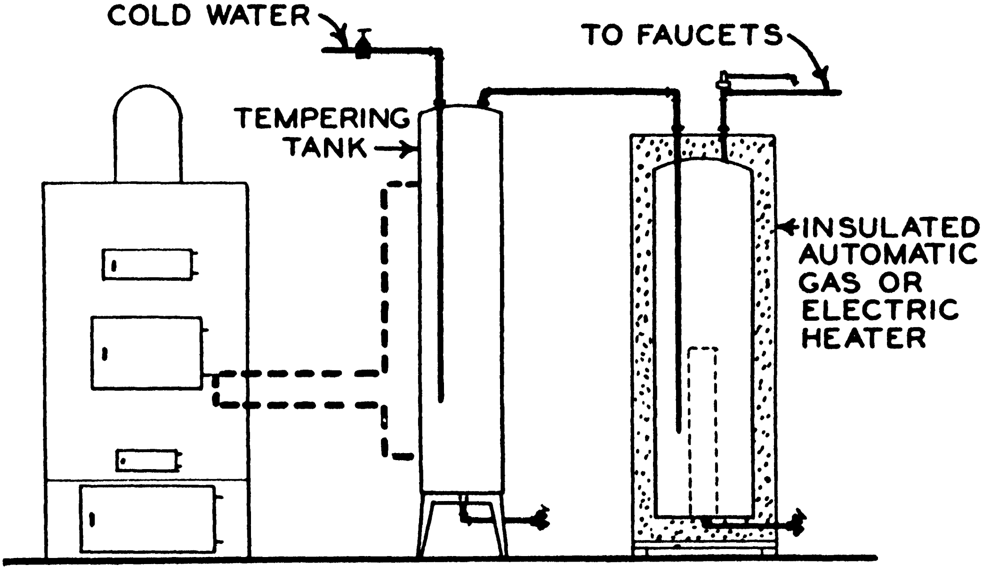


FIGURE 95.—A hot-water supply system using a tempering tank ahead of an automatic heater. The tempering tank can be connected to the furnace if desired, as is shown by the heavy dotted lines.

Tempering tank. Where an automatic electric or gas water heater is used it is common practice to install a tempering tank in the cold-water line ahead of the automatic heater as shown in Fig. 95. An ordinary uninsulated range boiler is commonly used for this purpose. There are several advantages in this arrangement. In the first place, while the water is standing in the tempering tank its temperature may be raised several degrees by the absorption of heat from the air. If the incoming water is quite cold this may effect quite a saving in the water-heating cost. In the second place, the tempering tank serves as a settling tank to remove sediment from the water before it enters the automatic heater.

If a low-cost fuel is used for house heating, a small coil placed in the furnace or boiler and connected to the tempering tank as suggested by the heavy dotted lines in Fig. 95 will help to reduce the cost of heating the water in the winter time. The water will be preheated at the coil and stored in the tempering tank from which it will flow to the insulated automatic heater when hot water is drawn at the faucet. If the temperature of the water from the tempering tank is above the thermostat setting of the automatic heater, the thermostat will not turn on. When the fire in the furnace is low, or in the summer time when the furnace is out, the thermostat will pick up the load and maintain the temperature of the water at the thermostat setting. Where automatic water heaters are used it is good practice to insulate the hot-water pipes up to the faucets.

Recirculating systems. If the hot-water pipes are long, owing to a remote location of the range boiler, and if it is desirable to have hot water at the faucets quickly, a recirculating system, such as is shown in Fig. 96, may be installed. The water circulates by convection from the top of the tank by way of the faucet back to the bottom of the tank. The circulation here is reversed from that of Fig. 93 because on the circulating pipe heat is given off rather than taken on. As the hot, lighter water flows out through the upper pipe toward the faucet, it gives off heat through the walls of the pipe to the surrounding air. The water thus becomes cooler (not cold) as it moves away from the tank. As it cools it becomes heavier and will, upon reaching the vertical section of the circulating pipe, drop downward past the faucet through the check valve and back into the bottom of the tank. From the bottom of the tank it circulates again through the heater, where it is again heated and caused to rise to the top of the tank and out through the circulating pipe. In this manner, hot water is kept flowing past the faucet at all times. The check valve in the lower section of the circulating pipe is necessary to prevent a backflow of cold water when the faucet is opened.

The pipe must be graded continuously downward from the top of the tank to the faucet and back to the bottom of the tank. Dips in the pipe will trap the water and stop circulation.

Owing to the constant loss of heat from the recirculating pipe, this system is not economical unless the water is heated by a house-heating unit such as a stove or furnace.

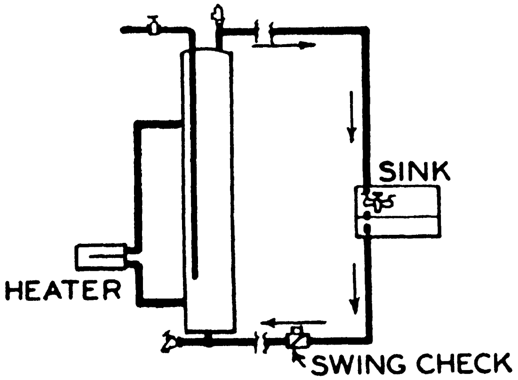


FIGURE 96.—A recirculating system for providing hot water at the faucet at all times.

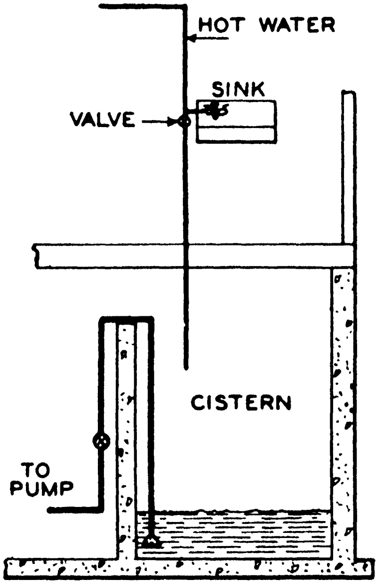


FIGURE 97.—An arrangement for conserving water at hot water faucets.

If it is necessary to economize on water, as is often the case where cisterns are used, the arrangement of either Fig. 96 or Fig. 97 may be used. If the problem is one of water economy only, the arrangement of Fig. 97 is recommended because of its simplicity and its positive action. Near the faucet a valve, preferably a self-closing valve, is installed on a pipe leading back to the cistern. When hot water is wanted the valve is opened until hot water is flowing through. The valve is then closed and the faucet is opened. In this way, the cold water standing in the pipes is drained back to the cistern instead of to waste.

All water pipes should be graded to a low point so that they can be drained.

The cost of materials for the additions of step 3 will range from $20.00 up.

Step 4: Powered Pressure System. The fourth logical step is the replacement of the hand pump and gravity tank with a powered

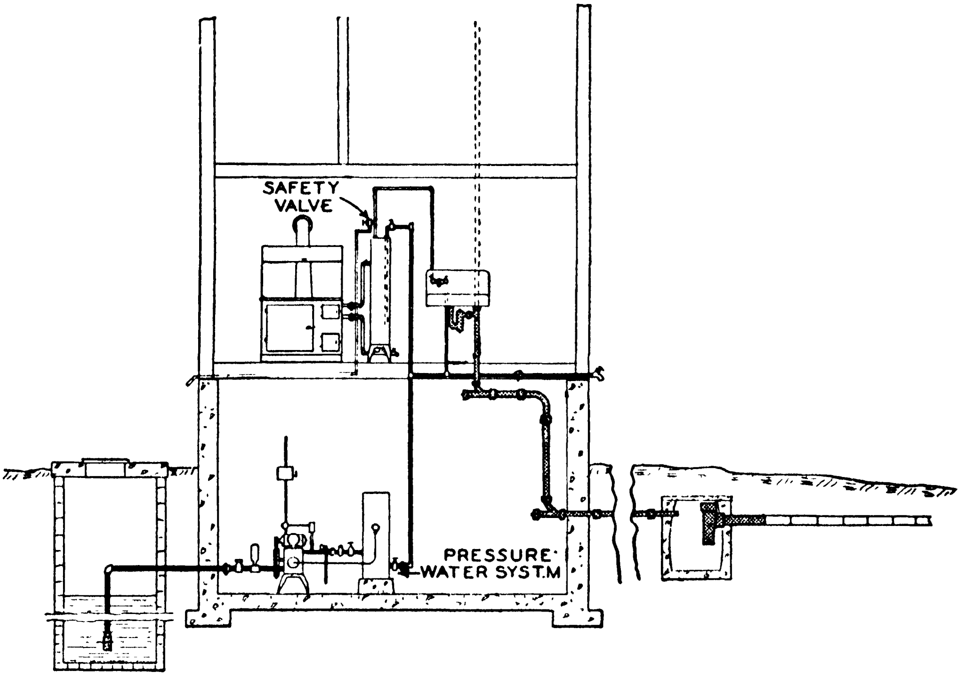


FIGURE 98.—The addition of a pressure type of water system to Fig. 91.

pressure system as shown in Fig. 98. If it is so desired, the gravity storage tank can be used with a powered pump, the engine or electric motor being controlled by a float switch in the tank. In most cases, however, the pressure tank is more satisfactory. If electricity is available the automatic electric hydropneumatic type of system is highly satisfactory.

The job of installing such a water system is discussed at length in Chapter V.

When a pressure tank is used, a safety valve should be installed on the hot-water pipe near the boiler as shown. The best type of safety valve is one which has a lever for testing. The valve should be tested frequently to make sure that it is in working order. A discharge pipe should be run from the valve to a drain or through an outside wall.

The cold-water supply pipe to the boiler should have a hand valve near the tank, as shown, to shut off the water pressure in case of leaks or to repair faucets without shutting off the cold-water supply.

The cost of materials, including the pump and tank, for the additions illustrated in Fig. 98 will range from $50.00 up.

Step 5: Bathroom and Sewage Disposal System. The fifth, and final, step is the installation of bathroom fixtures and a sewage-disposal system, as shown in Fig. 99. A laundry tub may be included if desirable.

It is possible to install bathroom fixtures one at a time but it is not so practical because of the necessity of tearing up floors and walls to install the drains. It is an advantage to complete the job immediately once it is started.

It may be seen by reference to Figs. 98 and 99 that the bathroom equipment and sewage-disposal system have simply been added to the installation of Fig. 98. In Fig. 98 the sink drain is shown connected to the soil stack. If the water is hard it would be well to leave the sink drain connected to the grease trap, as shown in Fig. 98, and then connect the grease trap to the septic tank as shown in the insert of Fig. 99.

The construction of a soil stack, the installation of drain pipes to the soil stack, and the setting of bathroom fixtures are jobs which require considerable skill and should not be undertaken by an inexperienced person without very careful planning and preparation. It is safer and, in the long run, may be cheaper to have an experienced plumber do at least this part of the work.

The choice of bathroom fixtures is a matter of personal taste and price. There is a wide price range on such merchandise, but it is usually poor economy to buy the cheapest.

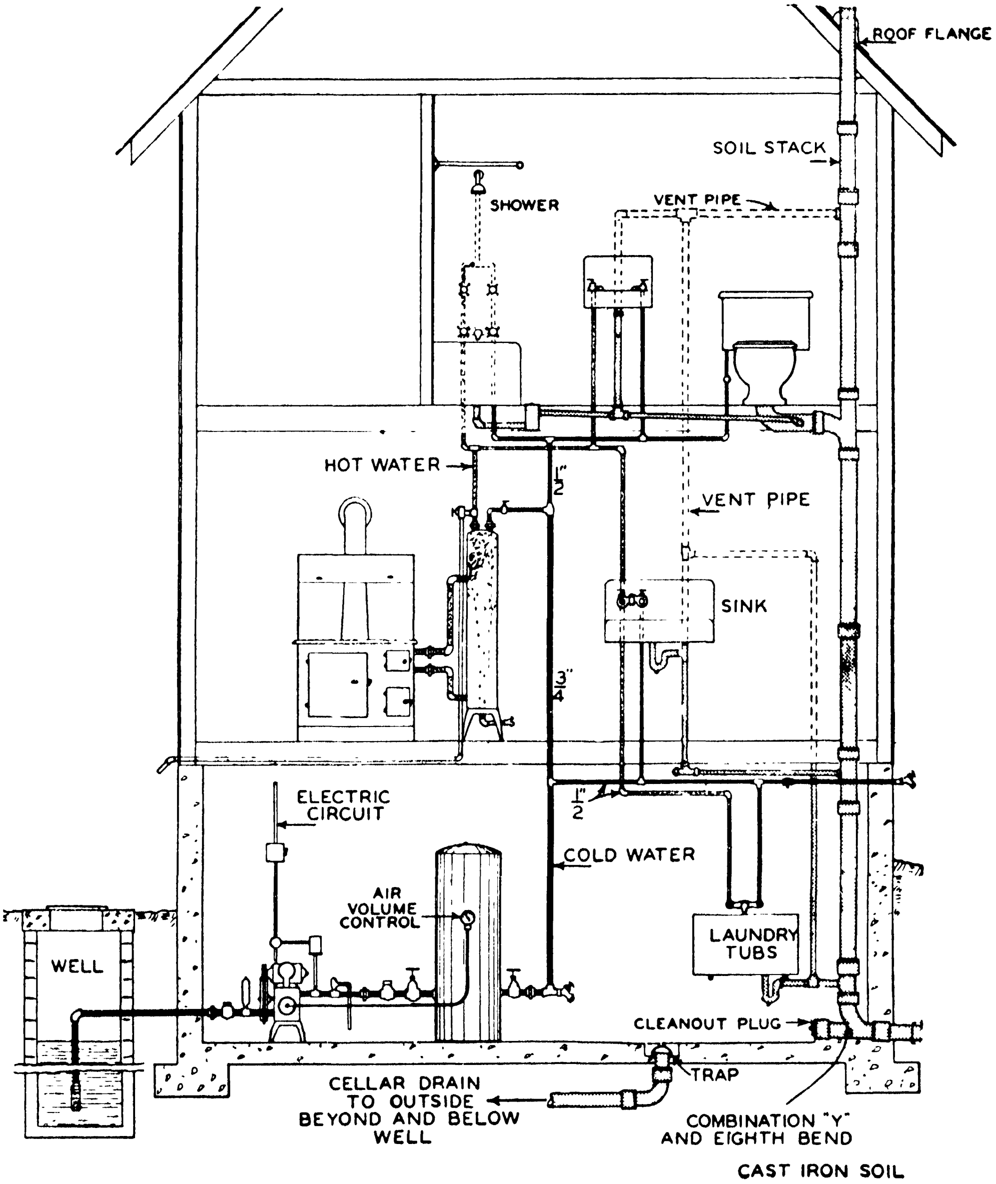
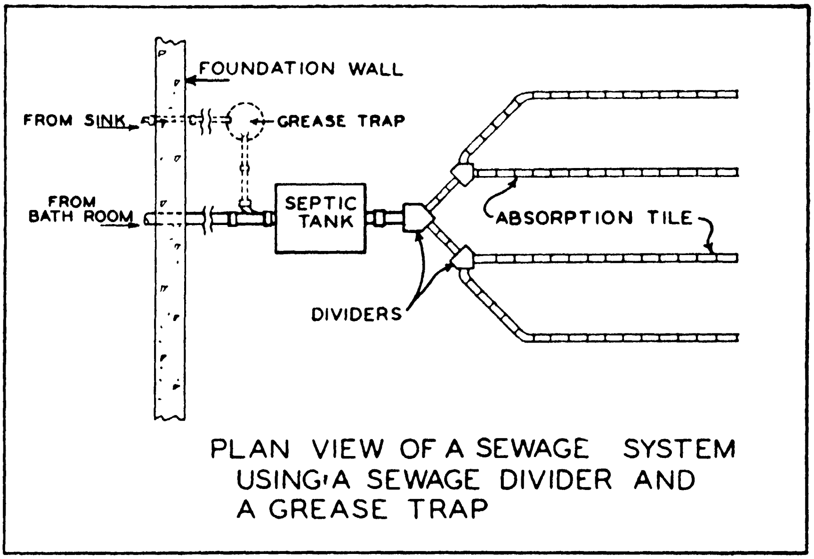


Figure 99.—A bathroom, a laundry tub, and a sewage system added to Figure 98. This completes a plumbing system suitable for a farm, village, or suburban home. The insert on page 259 shows how the grease trap may be left in service and a method of arranging the absorption field where there is not room to run it out in a straight line. An outside trap vented to the surface as shown in dotted lines is required in some localities.

For a first-class job, the drains from all fixtures should be vented, as shown, or at least equipped with non-siphon traps. The following sizes should be used for the various drains: for the toilet, 4 in.; for the bath tub, 1½ in.; for the lavatory, 1½ in.; for the sink, 1½ in. (to the floor), 2 in. from the floor to stack. Galvanized steel pipe with galvanized drainage fittings may be used, but lead pipe or cast-iron soil pipe are better.



PLAN VIEW OF A SEWAGE SYSTEM USING A SEWAGE DIVIDER AND A GREASE TRAP

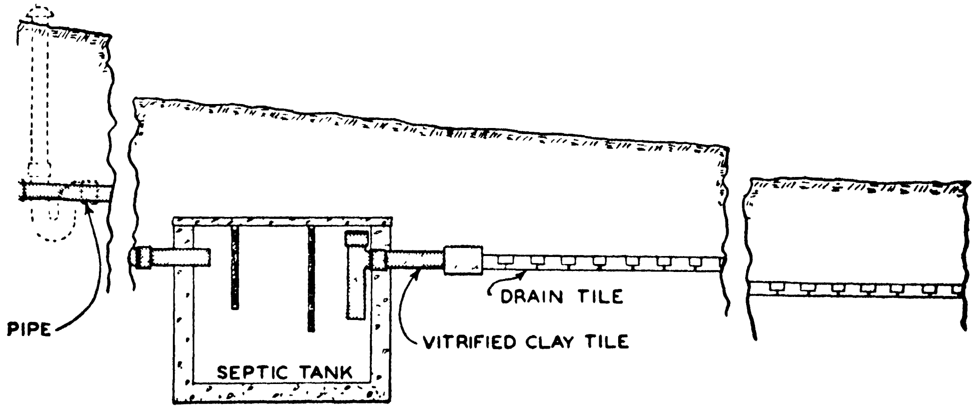


FIGURE 99—(*continued*).

The soil stack should be 4-in. cast-iron soil pipe. The sewer should be cast iron at least to the outside of the foundation.

The construction of the sewage-disposal system is discussed in detail in Chapter VII.

The cost of materials for the additions of step 5 will range from $100.00 up, depending upon the quantity and quality of materials used.

Total Cost. On the basis of 1939 prices, the total cost of materials for the entire installation as outlined here would range from $185.00 upward. This total does not include the cost of labor.

Plumbing Materials. In plumbing materials, as in most other types of merchandise, there is a wide range of quality and of price. As a rule it is poor economy to buy low-quality material. It is sometimes difficult for the inexperienced to distinguish quality merchandise. Up to a certain point, however, price is a fairly good indication of quality. The price ordinarily increases with the quality of materials and workmanship used in manufacturing. The thing to avoid is an increased price due to some extra gadget or trick designs which in no way add to the life or usefulness of the merchandise. In other words, buy durability and utility first and extra gadgets as fancy and funds permit.

It is possible to buy good used plumbing materials, especially plumbing fixtures, at prices considerably below the cost price new.

Supply Plumbing Materials. Materials used for supply plumbing are (1) galvanized steel pipe with malleable iron fittings, (2) galvanized copper-bearing steel pipe with malleable iron fittings, (3) wrought-iron pipe with malleable iron fittings, (4) copper tubing, either hard-tempered or soft-tempered, with flanged, compression-type, copper fittings for soft copper and solder copper fittings for hard copper, and (5) brass pipe with brass fittings. All valves are either solid brass or have brass or stainless steel inserts for working parts so that corrosion will not destroy their usefulness. Faucets are also made of brass and for use on fixtures are usually chromium-plated. Metal handles on faucets are less likely to be broken than porcelain handles.

Of the piping material, the cheapest is galvanized steel pipe with malleable iron fittings. A steel pipe of good quality which has a heavy coat of galvanizing will last for many years. Galvanized copper-bearing steel pipe is more expensive but lasts longer.

Wrought-iron pipe is used relatively little in residence plumbing because of the high cost.

In recent years copper tubing, both hard-tempered and soft-tempered, has been used extensively for supply plumbing, especially in well-constructed buildings. Copper under ordinary water conditions does not corrode and will, therefore, last a life time. In addition copper tubing is easier to install than steel piping. In old buildings the soft copper can be fished through partitions and under floors with a minimum of cutting. Also fewer fittings are necessary. By use of copper-to-iron fittings copper tubing can easily be joined to steel pipe. Although copper tubing is more expensive to buy than steel piping, the labor cost is considerably less. Therefore, at the 1939 price of copper, the cost of copper plus labor is not a great deal more than the cost of a good grade of steel pipe plus labor. It is advisable, however, to investigate, if possible, the effect of local water on copper before using it, because in some localities the water has a corrosive action on copper, which is objectionable, if not injurious to health. Where the water has no effect on it, copper is recommended for use in well-constructed and permanent buildings, particularly so long as the present low price differential between copper and steel exists.

Copper tubing is available in three grades, designated as K, L, and M. Grade K, made of heavy-gauge, soft-tempered copper, is used for underground piping, suction pipes for pumps, and for high pressures. Grade L, made of medium-guage, soft-tempered copper, is the "standard" grade for indoor supply plumbing. Grade M, made of hard-tempered copper, is used for indoor supply plumbing. It is sold in straight 20-ft. lengths instead of coils as is the soft copper.

Flanged-type fittings are used with the soft copper, grades K and L, and solder-type fittings are used with the hard copper, grade M.

Owing to the smoothness of the inside of copper tubing and copper fittings, it is sometimes possible to use one size smaller than would be required in steel pipe. For example, where ½-in. steel pipe would be required ⅜-in. copper might be used.

Plumbing fixtures. Plumbing fixtures are made of porcelain enameled sheet iron, porcelain enameled cast iron, vitreous china, and some of the stainless metals, such as Monel metal. All toilet bowls are made of vitreous china. The cheapest fixtures are those made of enameled sheet iron. They are light but fairly durable if used carefully. The most commonly used material is porcelain enameled cast iron. Cast iron is very rigid, and, therefore, will stand harder usage without cracking the enamel. There is a wide range in quality of enamels. Some are so soft that strong soap will discolor and disintegrate them; others are highly resistant to heat changes, acids, cleaning compounds, and even mechanical injury.

Solid vitreous porcelain fixtures are very durable except for breakage. This material is not recommended for sinks and bath tubs.

Waste-plumbing materials. Materials used for waste plumbing are (1) cast-iron soil pipe, (2) galvanized steel pipe, (3) galvanized wrought-iron pipe, (4) black wrought-iron pipe, (5) lead pipe, (6) brass pipe, (7) copper pipe or tubing, and (8) vitrified clay sewer tile.

Of these materials cast-iron soil pipe is most common. Soil pipe is available in three grades: standard, medium, and extra heavy. For long service use the extra-heavy grade, especially in the soil stack and sewer line.

Galvanized steel, or wrought-iron pipe, is frequently used on fixtures to the floor line.

Lead is often used for toilet bends and waste pipes in concealed places and in basements.

Brass and copper pipe are seldom used for waste plumbing except in expensive houses.

Vitrified sewer tile is used underground on the outside of buildings.

Waste fittings on plumbing fixtures, including exposed traps are usually made of chromium-plated brass.

CHAPTER VII

FARM SEWAGE-DISPOSAL SYSTEMS*

Advantages of Sewage Disposal Systems. To safeguard the health of the farm family, and for convenience, the farm home should have some sanitary means of sewage disposal. This includes the disposal of both wastes from the kitchen and of human excrement.

Many communicable human diseases can be spread from person to person through contact with human excrement or through the medium of animals, flies, and insects which carry the diseases to food and clothing of other people. Also, improper sewage disposal may cause contamination of the drinking-water supply and thus spread disease.

A safe and sanitary sewage-disposal system is one which absolutely prevents contact with human feces, either by persons, animals, or flies, and which does not in any way contaminate the water supply.

Types of Sewage Disposal Systems. There are a number of approved methods of sewage disposal applicable to the farm home. It is the purpose of this chapter to describe some of the most common sewage-disposal systems and to offer suggestions on their construction. The systems discussed here are as follows:

1. Septic tank with absorption tile.
2. Septic tank with cesspool.
3. Septic tank with underdrained absorption field
4. Septic tank with covered sand filter.
5. Cesspool.
6. Outdoor toilets.

*** Much of the information contained in this chapter was obtained from the N. Y. State Dept. of Health through the courtesy of Mr. C. A. Holmquist, Director of the Division of Sanitation.**

The type of system to install is determined largely by the character and topography of the soil at the location and by the degree of convenience which can be afforded.

1. *Septic Tank with Absorption Tile.* The most satisfactory system from the standpoint of both sanitation and convenience is the *complete waste-plumbing system* including a septic tank and absorption-tile field, such as is illustrated in Fig. 99, Chapter VI. With this system the sewage is covered and is away from direct contact at all times. If properly located with respect to the water supply, this system will prevent contamination of the drinking water.

Location. The septic tank should be located as far as is practical from the water source and on the down-hill side. This is to insure against pollution in case of a leak in the tank. Twenty to thirty feet is a satisfactory distance from the house, although the topography of the land and the location of the water supply may require a greater or lesser distance.

For best operation the septic tank should be so located with respect to the house that the sewer pipe from the house will have a grade of ⅛ in. to ½ in. to the foot. A grade less than ⅛ in. per foot will not maintain a rate of flow high enough to carry solids and the sewer may become stopped up. A grade of more than ½ in. to the foot will produce such a high velocity of discharge into the tank that turbulence may occur, causing solids to be carried out of the tank with the effluent. The accumulation of these solids in the absorption tile will eventually stop them up.

If the septic tank must be located where the land slopes steeply away from the house, it is best to locate the tank close to the house and let the steep grade come after the septic tank rather than before. The top of the tank should be at least 1 ft. under ground for frost protection and to provide enough soil for vegetation to grow over it.

The sewer pipe from the house to the septic tank should be carefully laid to avoid leaks. If the sewer passes within 100 ft. of the water source, cast-iron soil pipe should be used and the joints should be caulked with oakum and lead. If the sewer is more than 100 ft. from the water source and is on the down-hill side, vitrified bell-sewer tile may be used and the joints may be sealed with good cement mortar or bituminous joint compound.

The absorption-tile field should be located with the same precautions used in locating the septic tank or cesspool. The absorption-tile field should be large enough to take up all liquids without at any time saturating the soil. Under average soil conditions allow 500 sq. ft. of area per person using the system.

Operation. The operation of a complete sewage system, such as is shown in Fig. 99, Chapter VI, is as follows:

1. Waste materials from the bathroom, kitchen, and laundry flow from the fixtures through the traps and drainage pipes to the "soil stack." In the soil stack they flow downward to the sewer pipe and into the septic tank.

2. Because of the large size of the septic tank the speed of the sewage is reduced at this point so that it remains in the tank for a day or longer, depending on the size of the tank. In the tank the sewage is acted upon by anerobic bacteria, which thrive without air. This bacterial action breaks up a part of the solids into liquids and gasses. The gasses escape through the sewer and through the soil, while the liquids join the effluent of the tank and flow to the absorption tile. In this way the amount of solids remaining in the tank is greatly reduced.

The solids remaining in the tank will be divided.The heavier solids will sink to the bottom as sludge while the lighter ones will float to the top, forming a thick scum and seal.

The accumulated solids in the tank should be removed every four or five years, or more often if necessary. These solids should be buried in a trench or pit. In no case should they be emptied into a stream or buried near a water source.

Suggestions on construction. Good materials should be used in the drainage *plumbing* and they should be installed with care. Leaky drain pipes spoil plaster and produce insanitary conditions in the house. Also, improperly installed drains may continually give trouble which is due to stoppage. All traps should be vented as shown in Fig. 99, or non-siphoning traps should be used. Drainage fittings should be used rather than supply plumbing fittings.

The soil stack should be made of at least 4-in. cast-iron soil pipe and should extend through the roof for at least 12 in. Convenient clean-outs should be provided in both the drain pipes and the soil pipes. Floor drains should *not* be connected to the septic tank but should be led off by a separate drain to an open ditch, or discharged into a "dry well," as shown in Fig. 99. Down spouts from the roof should *not* be led into the septic tank.

The *sewer pipe* from the outside of the foundation wall to the septic tank may be either cast-iron soil pipe or vitrified sewer tile, or both, of at least 4-in. inside diameter. All joints in cast-iron soil pipe should be caulked with oakum and lead, as directed in Job 18. Joints in vitrified sewer tile should be sealed with cement mortar or bituminous joint compound. To lay sewer pipe start at the septic tank and lay toward the house with the bell end of each tile pointing toward the house. See Job 21.

Septic tanks made of water proofed and reinforced concrete are the most durable. Ready-made septic tanks of steel or concrete are available on the market, and are, in general, fairly satisfactory if care is taken to obtain the proper size. Manufacturers of such devices sometimes recommend sizes too small for the job which they are supposed to do. The following sizes are recommended here: See Table VII.

In general, the tank should have a capacity of at least 50 gal. per person using the system and never less than 300 gal. total. The length should be at least twice but less than three times the width. See Fig. 19–2. The depth should be 4 to 6 ft.

For building of a septic tank, see Job 19.

The absorption tile. The liquid discharge from a septic tank may be disposed of by means of a cesspool if the soil is open and the water table is 8 ft. or more from the surface. A safer and more common method of disposal, however, is through a field of

TABLE VII

DIMENSIONS OF SEPTIC TANKS*

No. of Persons	Inside Dimensions			Outside Dimensions		
	Width	Length	Depth	Width	Length	Depth
5 people or less....	3′	6′	4′6″	4′	7′	5′
8 people.........	3′	7′	4′6″	4′	8′	5′
10 people.........	3′	8′	4′6″	4′	9′	5′
12 people.........	4′	8′	4′6″	5′	9′	5′

* In part from Cornell Ext. Bulletin 48, "Sewage Disposal for Rural Homes."

absorption tile, as shown in Fig. 99. The tile used may be ordinary field drain tile 3 in. or 4 in. in diameter.

The absorption-tile field should be located at a safe distance from the water supply, preferably 100 ft. or more, and on the down-hill side. Neither surface drainage nor seepage from the tile should drain toward the water source.

The size of the tile field varies with the type of soil and the number of people served.

In coarse, gravelly, soil where the liquid is readily taken up, less tile length is needed than in heavy loam soils. Table VIII shows the tile length for various soils recommended by the New York State Department of Health, Division of Sanitation.

A proportionate reduction in the lengths of tile required per person when the sewage flow is less than 50 gal. per capita per day may be made.

If there is doubt relative to soil conditions, the lengths of tile to be provided should be determined by the percolation test described below.

Percolation Test

Dig a hole 1 ft. square and of a depth equal to that at which it is proposed to lay the tile drain. Fill with water to insure thor-

TABLE VIII

LENGTH OF TILE RUNS PER PERSON UNDER VARIOUS SOIL CONDITIONS

Nature of Soil	Approximate length of 4-inch tile required when the sewage flow is 50 gal. per capita per day
	Feet per person
Clean coarse sand or gravel	12
Fine sand or light loam	20
Fine sand with some clay or loam	30
Clay with some sand or gravel	80
Heavy clay	Unsuitable

Courtesy N. Y. State Department of Health.

ough moistening of the soil and allow the water to seep away. Then while the bottom of the hole is still moist fill to a depth of 6 in. and observe the time required for the water level to fall 1 in. The approximate length of tile required per person, based upon a trench about 1 ft. wide and a sewage flow of 50 gal. per capita per day, is given in Table IX.

If the sewage flow is less than 50 gal. per capita per day, some reductions in the lengths of tile required per person may be made. Proportionate reduction in lengths required is also permissible if trenches wider than 12 in. are used.

The absorption tile should be laid in a single line if there is room enough. No single line, however, should be more than 100 ft. in length. A common procedure for large systems is to run two or more lines as shown in insert of Fig. 99. At points where the line branches, dividers are used to divert the liquid equally to the various lines.

To facilitate the proper bacterial action around the absorption tile the flow should be intermittent. For small households the normal flow will be intermittent. In large households the flow may be continuous, in which case there should be two ab-

TABLE IX

APPROXIMATE LENGTH OF TILE PER PERSON BASED UPON A PERCOLATION TEST

Time for Water to Fall One Inch (Minutes)	Approximate length of 4-inch tile required when the sewage flow is 50 gal. per capita per day
	Feet per person
1	12
2	15
5	20
10	30
30	60
60	80
Over 60	Unsuitable

Courtesy N. Y. State Department of Health.

sorption fields and a switch provided in the line so that the sewage can be diverted alternately from one field to the other.

The trench for the tile should be 20 to 30 in. deep and about 1 ft. wide. The bottom of the trench should be carefully graded to secure the proper flow. In porous soil the grade should be steeper than in heavy loam. In porous soil make a grade of $\frac{1}{16}$ to $\frac{1}{8}$ in. per foot. In heavy loam use a grade of $\frac{1}{32}$ to $\frac{1}{16}$ in. per foot. The bottom of the trench should be filled with coarse gravel or broken stone to a depth of at least 2 in. This will help to distribute the liquid evenly from the tile joints.

Field tile should be laid carefully end to end with a space at the joints of about $\frac{1}{8}$ in. The top of each joint should be covered with a piece of tar paper as described in Job 21, to prevent backfill dirt from entering the tile. After the tile is laid, it should be covered with 4 to 6 in. of gravel. The trench should be backfilled with earth on top of the gravel.

If the only place for the absorption tile is on a steep grade, the tile may be laid as shown in Fig. 100 or Fig. 101.

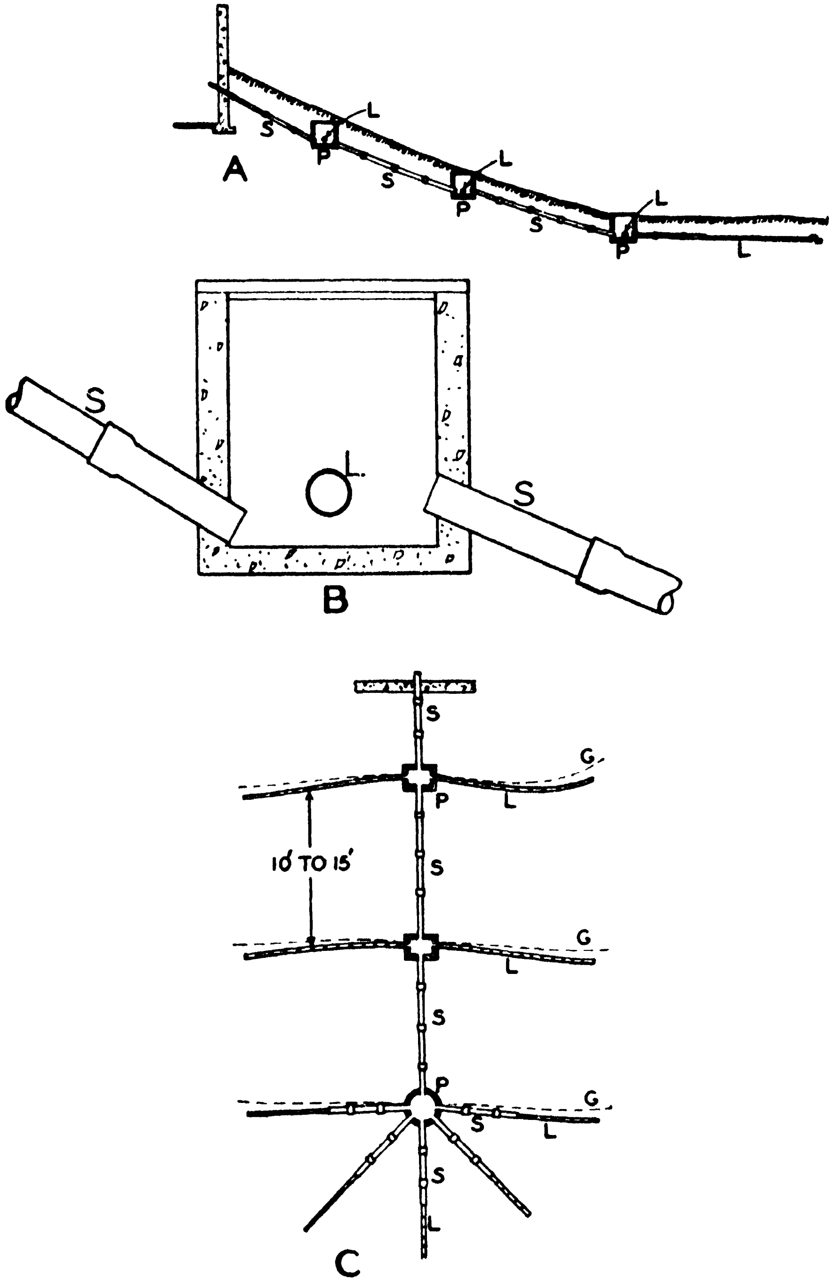


FIGURE 100.—Sewage distribution on a steep grade by means of a series of diverting pits. At *A* is a profile of the system. At *B* is a cross-section of a diverting pit. At *C* is a plan view. The letter *S* indicates a bell and spigot sewer, *L* indicates drain tile, *P* indicates the diverting pits, and *G* the contour line.

The length of service of an absorption tile field depends upon (1) the care with which it is made, (2) the character of the soil in which it is laid, (3) the care given the septic tank, and (4) the amount of grease and lime in the water.

With any septic tank a certain portion of the solids will find their way into the drain tile, but if the tank is cleaned frequently the amount of these solids will be reduced to a minimum and tile will serve for many years. However, if the tank is neglected or if there is an excessive amount of grease in the sewage, the tile may fill up quickly. If the tile fills with solids it will be necessary to dig it up and clean it out or to build a new absorption field.

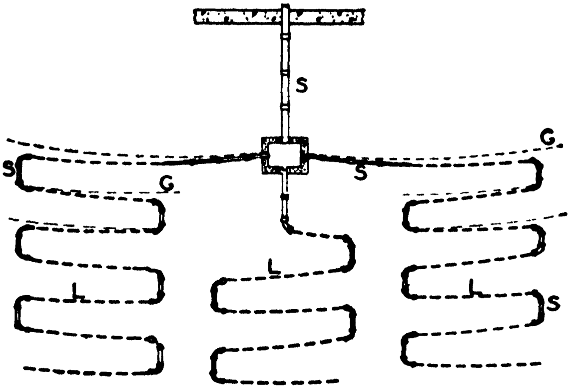


FIGURE 101.—A method of sewage distribution on a steep grade using one diverting pit and turning the drain tile by means of sewer pipe. The letter *S* indicates sewer pipe, *L* indicates drain tile, and *G* indicates contour lines.

2. *Septic Tank with Cesspool.* Where the soil is moderately porous and there is plenty of room to locate the sewage-disposal system at a safe distance from the water supply, an effective and economical arrangement is to construct a cesspool to receive the effluent from the septic tank. Suggestions on the construction of a cesspool are given in Job 20.

A cesspool after a septic tank may be preferable to absorption tile under certain soil conditions. If the top 2 or 3 ft. of soil are heavy clay, the soil will be unsuitable for absorption tile. In such a case a cesspool which extended through the clay into porous strata below, if any, would be more effective. Also, where space is too limited for an absorption-tile field, the cesspool may be used.

3. *Septic Tank with Underdrained Absorption Field.* Where the soil condition is such that neither an ordinary absorption field nor cesspool will be adequate yet the soil is porous enough to allow some seepage, the absorption field can be underdrained as shown in Fig. 102. The discharge from the underdrain should, if possible, go into a large stream. A health officer should be consulted before any such discharge is arranged.

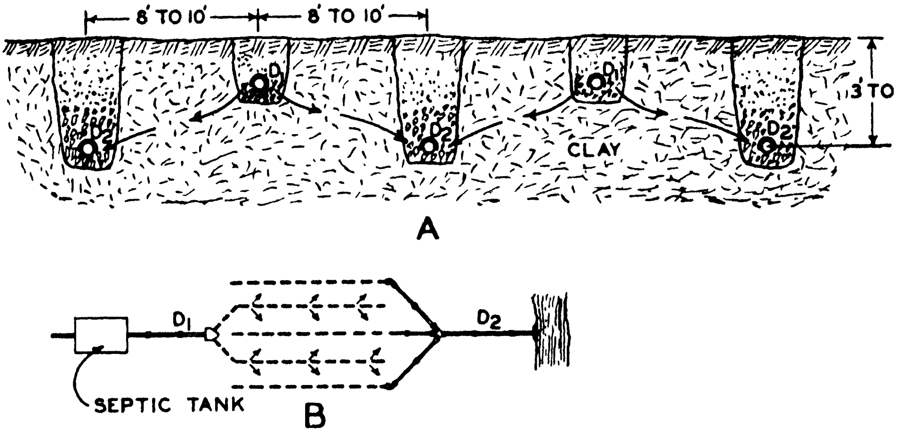
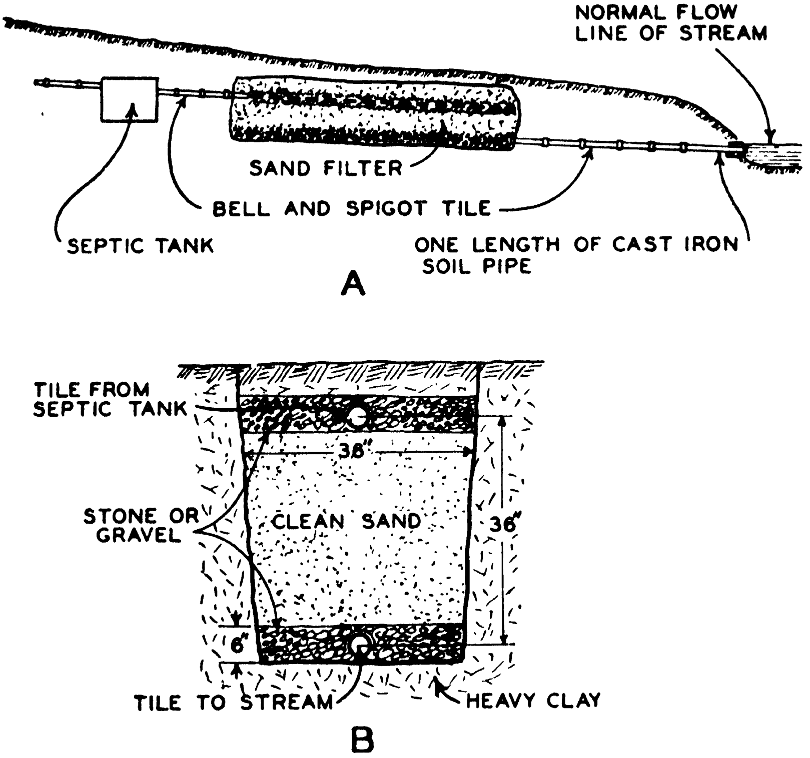


FIGURE 102.—A method of constructing an absorption field with underdrains. At *A* is a cross-section view. The shallow Tile D_1 leads from the septic tank and the deeper Tile D_2 is the underdrain tile for carrying the water out to a stream. At *B* is shown a plan view of the system.

4. *Septic Tank with Covered Sand Filter.* In regions where the water table is close to the ground surface or where the soil is heavy and impervious, or where both of these conditions exist, absorption tile or cesspools may not be able to dispose of the septic tank effluent. In such places covered sand filters may be used to treat the effluent so that it may be discharged into sur-

face drainage, such as a stream. Before any such discharge is arranged for, the local health officer should be consulted.

Location. The covered sand filter should be located with the same care as absorption tile. The filter should be at a safe distance from the water source, and the filtered liquids should be discharged into as large a stream as is available. As the effluent from the filter may contain disease germs, it should in no case be discharged into a small stream which supplies drinking water.



Courtesy N. Y. State Dept. of Health.

FIGURE 103.—A covered sand filter for sewage disposal where the natural soil is not suitable for absorption tile. At *A* a profile view; at *B* a cross-section view.

Construction features. Figure 103 illustrates the essential structural features of a covered sand filter. The filter may be constructed in a long trench or in a rectangular pit. The trench or pit should be about 4½ ft. deep. In the bottom is placed 6 in.

of coarse gravel or broken stone. In this gravel or stone is placed the under drain tile, which should discharge into a stream as shown at *A*. About 3 ft. of clean sand should then be placed on top of the bottom gravel. On top of the sand is placed another 6 in. of coarse gravel or broken stone. In this layer of gravel is placed the drain tile carrying the effluent from the septic tank. The top of the joints should be covered with tar paper. Over the top layer of gravel or stone is earth backfill.

If the filter is rectangular, the drain tile on top and in the bottom of the filter should be branched just as in an absorption field.

The sewer pipe from the septic tank to the drain tile over the filter and from the drain tile under the filter should be made of vitrified bell-sewer tile. The end of the sewer leading from the filter should be set in cement as shown and should be located below the normal water level. One length of cast-iron soil pipe should be placed at the stream end of the drain.

Operation. The effluent from the septic tank is distributed over the top of the filter by the top drain tile and by the coarse gravel or stone. As the liquid filters down through the sand, solids and some of the impurities are filtered out. The remaining liquid flows into the bottom drain and out through the sewer to the stream.

Although a well-constructed filter operated in conjunction with a well-cared for septic tank will normally give many years of service, the solids will eventually clog the filter. When this occurs the top soil should be removed and the clogged portion of the filter taken out. Any sand and gravel thus removed should be replaced by fresh material. If the filter is deeply clogged it may be better to abandon it and construct a new one.

5. *Cesspool.* Where the soil is quite porous and there is no danger of pollution of the drinking water a cesspool alone can be used to dispose of the sewage. As shown in Fig. 20–1, a cesspool is essentially a walled-up hole in the ground into which the

sewer pipe empties and from which the liquids seep away through the soil.

A cesspool is an especially dangerous source of pollution of drinking water because large quantities of sewage are disposed at one point. This means that seepage of raw sewage may extend for a much greater distance underground than from absorption tile. Also the bottom of the cesspool may be very close to the water table, in which case the pollution may follow the underground water for many rods to pollute even neighbors' wells and springs.

Seepage from cesspools may also find its way into deep fissures in bed rock and thus be carried hundreds of yards to water sources. For these reasons extreme care should be taken in locating a cesspool. As a rule, in small communities where houses are close together, the cesspool should *not* be used if the people are dependent upon near-by wells and springs for drinking water.

Construction features. Unless used after a septic tank, cesspools work best when constructed in two units, as shown in Fig. 20–2. The first unit serves to collect the solids, and the second unit to leach away the excess liquids. With this arrangement the cesspool will last longer than will a single unit.

The inside diameter of a cesspool should not be greater than 6 ft. and in no case should the bottom extend below the level of the water table. The wall should be laid up with stones, brick, or tile, and without mortar. The top of the wall should be drawn in so that a cover can be placed over the top. A large flat stone or a concrete slab may be used for a cover. The cover should be at least 12 in. below the surface of the ground so that grass will grow over the top to conceal it. The wall should be carefully laid to prevent collapse.

Size. The size of pool needed is determined by (1) the number of people served and (2) the type of soil in which it is located. The effective leaching area is that of the vertical wall up to the sewer. The bottom is not effective as it very soon becomes clogged with sediment. To calculate the effective leaching area in square feet, multiply the diameter in feet by three times the height of the vertical wall up to the sewer line. The effective leaching area for the cesspool in Fig. 20–1 would be 5 × 3 × 4 = 60 sq. ft.

The following table from the N. Y. State Department of Health may be used as a guide to the leaching area required under different soil conditions.

TABLE X

LEACHING AREA OF CESSPOOLS UNDER VARIOUS SOIL CONDITIONS

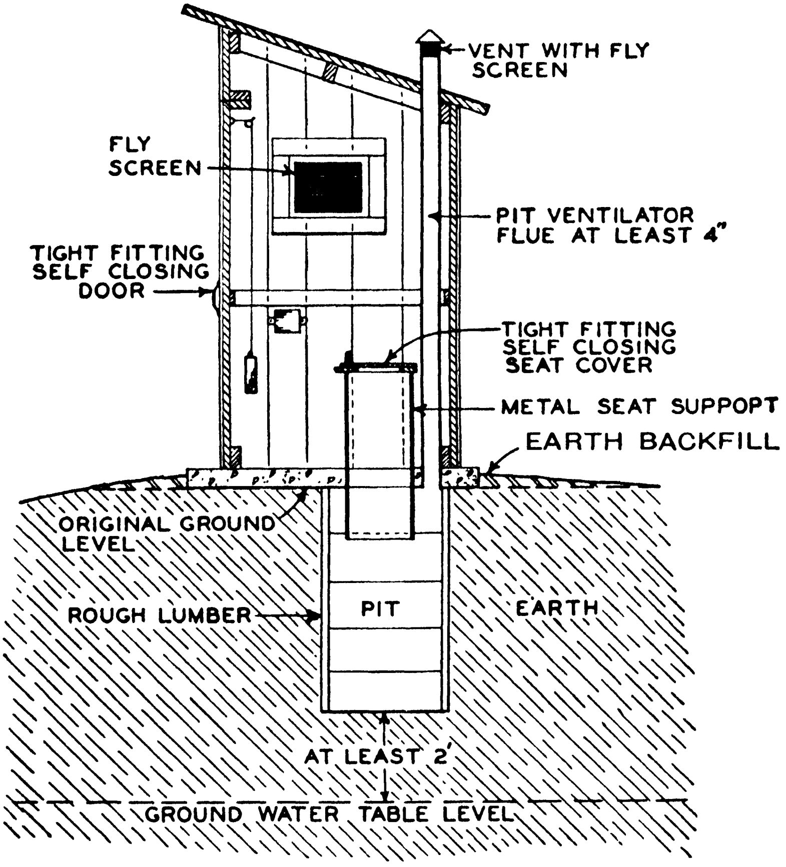
Character of Soil	Effective leaching area per person required where sewage flow is 50 gal. per capita per day
	Square feet
Clean coarse sand or gravel	10
Fine sand or light loam	15
Fine sand with some clay or loam	22
Clay with considerable sand or gravel	40
Clay with small amount sand or gravel	Generally unsuitable
Heavy clay	Unsuitable

Courtesy N. Y. State Department of Health.

In a cesspool solids will accumulate as in a septic tank. Therefore, the cesspool should be cleaned occasionally and the solids disposed of in a safe place, preferably underground. In time the soil around the pool may become clogged with solids in spite of periodical cleaning. In such a case the best remedy is to abandon the old pool and construct a new one.

6. *Sanitary Outdoor Toilets.* Where a sewage-disposal system consisting of a septic tank or a cesspool cannot be provided some other sanitary means of disposing of human excrement should be used. There are several types of outdoor toilets which

are suitable. The following types are in common use: (1) the sanitary pit privy; (2) the concrete vault privy; (3) the septic privy; (4) the removable receptacle privy; and (5) chemical toilets.



Courtesy N. Y. State Dept. of Health.

FIGURE 104.—A sanitary pit privy.

The sanitary pit privy. Where the soil is coarse and sandy and where the water table is 7 or 8 ft. below the surface the sanitary-pit type of privy is probably the most satisfactory. Good drainage from the pit is essential to insure proper decay of solids and to reduce objectionable odors.

The pit privy should be very carefully located with respect to the water supply. It should be at least 100 ft. distant from a well or spring and on the down-hill side. If conditions are such that these precautions cannot be taken, then the concrete vault privy or chemical toilet should be constructed.

The pit should be about 5 ft. deep and, if possible, the bottom should be at least 2 ft. above the ground water table, as shown in Fig. 104. The pit should be lined with concrete or boards to prevent cave in. The structure over the pit should be well constructed and made fly-proof. A counter-weight or some other means should be provided for keeping the door closed and the seat covers should be chocked so that they cannot be left open. Both the building and the pit should be ventilated as indicated.

When the accumulated solids in the pit are within 1½ ft. of the top of the pit they should be removed and buried in a safe place, or the building should be placed over a new pit. The new location should be chosen carefully as has been suggested above. The old pit should be covered with about 2 ft. of earth.

A quantity of lime or mixture of lime and dry soil should be kept in the building at all times for scattering over the solids in the pit. Frequent application of lime to the solids will greatly reduce odors.

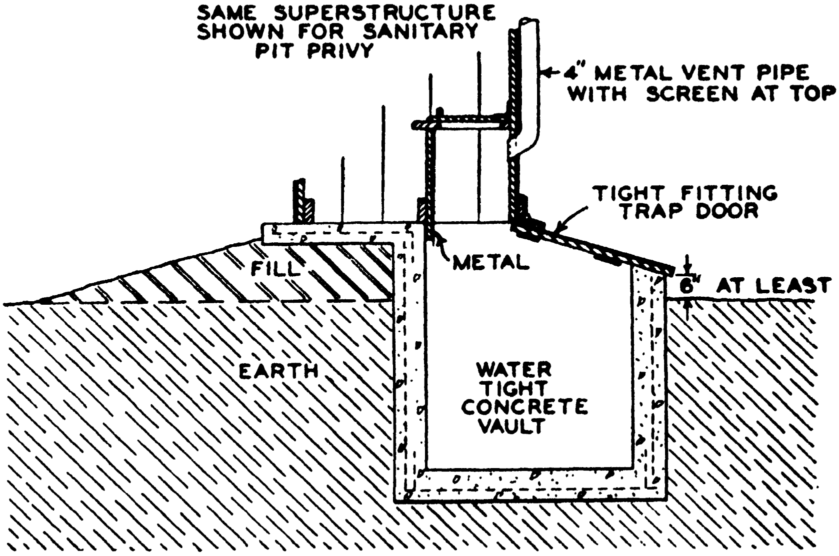
The inside of the building should be scrubbed occasionally and otherwise kept clean.

The concrete vault privy. In locations where the soil is heavy and impervious or where the water table is close to the surface or where there is not room to establish the sanitary-pit type of privy at a safe distance from the water supply, the concrete vault privy may be used. However, because of the possibility of leaks, the vault should be at least 50 ft. distant from the water source and should be on ground which slopes away from the water source.

The vault should be constructed of reinforced concrete, as shown in Fig. 105, and should have a capacity of 3 cu. ft. per person served. The top of the vault should extend 6 or 8 in. above the ground level and should be banked up to divert surface water away from the vault.

A trap door should be provided, as shown, for convenience in cleaning. The structure over the vault should be of the same type suggested for the sanitary-pit privy. The contents of the vault should be frequently sprinkled with lime to reduce odors. The vault should be cleaned when about two-thirds full. The contents of the vault should be buried at a safe distance from the water source.

The septic privy. The septic privy is similar in construction to the concrete vault privy except a drain tile is provided to carry liquids off into porous soil.



Courtesy N. Y. State Dept. of Health.

FIGURE 105.—A concrete vault privy.

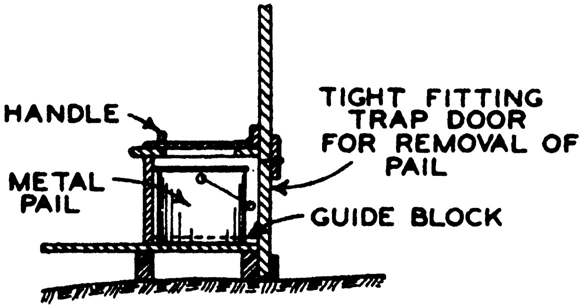
Owing to the nature of the drain from the vault it is a very dangerous source of pollution of water sources and for this reason should be located with extreme care.

No chemicals such as lime are added to the contents of the vault as they would interfere with the bacterial action on the solids. The bacterial action is necessary to reduce the solids to a minimum as in the case of the septic tank. It is from this bacterial action that the name "septic" privy is derived.

Water must be added to the contents of the vault of the septic privy to make up for evaporation losses and to insure a flow through the drain tile. About 2 gal. a day should be sufficient.

Due to the danger of water pollution and to the unpleasant odor of a septic privy it is perhaps the least desirable of all the outdoor toilets described here.

The removable receptacle privy. The removable receptacle privy consists of a building having a seat under which a metal receptacle is placed as shown in Fig. 106. The receptacle is emptied at frequent intervals, the contents being buried at a safe distance from the water supply.



Courtesy N. Y. State Dept. of Health.

FIGURE 106.—A removable receptacle privy.

This type of privy is used in camps, at summer cottages, and at other places of temporary residence.

The chemical toilet. The chemical toilet, if properly cared for, is probably the safest of all the outdoor toilets. Its chief dis-. advantage is the cost of the chemicals necessary for its proper functioning.

The chemical toilet should be located with the same precautions recommended for the water-tight vault type of privy, especially if the tank is buried in the ground. If the tank is to be set on a floor or on the surface of the ground and is left accessible for inspection, it can be placed quite close to the water supply and close to an occupied building. Care should be taken, however, to see that the toilet is in good working order at all times.

There are a number of ready-made chemical toilets on the market. They are easy to install and if operated according to instructions will give satisfactory results.

BIBLIOGRAPHY

BEHERENDS, F. G., *The Farm Water Supply.* Cornell Extension Bulletin 50, Cornell University, Ithaca, N. Y.

GODFREY, EDWARD S., JR. *Rural Water Supply and Sewage Disposal.* New York State Dept. of Health Bulletin 26, New York State Dept. of Health, Albany, N. Y.

RIFE RAMS & PUMP WORKS. *Manual of Information on Rife Rams.* Rife Rams and Pump Works, Waynesboro, Va.

RILEY, H. W. and MCCURDY, J. C. *Sewage Disposal for Rural Homes.* Cornell Extension Bulletin 48, Cornell University, Ithaca, N. Y.

SEARS, ROEBUCK & CO. *Instructions for Installing Plumbing Systems.* Sears, Roebuck & Co., Chicago, Ill.

SEARS, ROEBUCK & CO. *Plumbing, Heating and Water Supply Bulletin.* Sears, Roebuck & Co., Chicago, Ill.

WARREN, GEORGE M. *Farm Plumbing.* U. S. D. A. Bulletin 1426. U. S. D. A. Washington, D. C.

WARREN, GEORGE M. *Sewage and Sewerage for Farm Homes.* U. S. D. A. Bulletin 1227, U. S. D. A., Washington, D. C.

WARREN, GEORGE M. *Simple Plumbing Repairs.* U. S. D. A. Bulletin 1460, U. S. D. A., Washington, D. C.

Trade Literature on Pumps, Water Systems, Plumbing Supplies, and Sewage-Disposal Equipment.

INDEX