☆ Mrs J H Schaefer.

26 June 1913.

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A SERIES OF TEXTBOOKS FOR PERSONS ENGAGED IN THE ENGINEERING PROFESSIONS AND TRADES OR FOR THOSE WHO DESIRE INFORMATION CONCERNING THEM. FULLY ILLUSTRATED AND CONTAINING NUMEROUS PRACTICAL EXAMPLES AND THEIR SOLUTIONS

WATER CLOSETS
HOUSE DRAINS
SOIL, WASTE, AND VENT STACKS
TRAPS AND VENTS
DRAINAGE AND SEWERAGE
SEWAGE DISPOSAL
SOURCES OF WATER SUPPLY
WATER FILTRATION
COLD-WATER SUPPLY
HOT-WATER SUPPLY
PLUMBING INSPECTION
PLUMBING PLANS AND SPECIFICATIONS

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72

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PREFACE

The International Library of Technology is the outgrowth of a large and increasing demand that has arisen for the Reference Libraries of the International Correspondence Schools on the part of those who are not students of the Schools. As the volumes composing this Library are all printed from the same plates used in printing the Reference Libraries above mentioned, a few words are necessary regarding the scope and purpose of the instruction imparted to the students of—and the class of students taught by—these Schools, in order to afford a clear understanding of their salient and unique features.

The only requirement for admission to any of the courses offered by the International Correspondence Schools, is that the applicant shall be able to read the English language and to write it sufficiently well to make his written answers to the questions asked him intelligible. Each course is complete in itself, and no textbooks are required other than those prepared by the Schools for the particular course selected. The students themselves are from every class, trade, and profession and from every country; they are, almost without exception, busily engaged in some vocation, and can spare but little time for study, and that usually outside of their regular working hours. The information desired is such as can be immediately applied in practice, so that the student may be enabled to exchange his present vocation for a more congenial one, or to rise to a higher level in the one he now pursues. Furthermore, he wishes to obtain a good working knowledge of the subjects treated in the shortest time and in the most direct manner possible.

In meeting these requirements, we have produced a set of books that in many respects, and particularly in the general plan followed, are absolutely unique. In the majority of subjects treated the knowledge of mathematics required is limited to the simplest principles of arithmetic and mensuration, and in no case is any greater knowledge of mathematics needed than the simplest elementary principles of algebra, geometry, and trigonometry, with a thorough, practical acquaintance with the use of the logarithmic table. To effect this result, derivations of rules and formulas are omitted, but thorough and complete instructions are given regarding how, when, and under what circumstances any particular rule, formula, or process should be applied; and whenever possible one or more examples, such as would be likely to arise in actual practice—together with their solutions—are given to illustrate and explain its application.

In preparing these textbooks, it has been our constant endeavor to view the matter from the student's standpoint, and to try and anticipate everything that would cause him trouble. The utmost pains have been taken to avoid and correct any and all ambiguous expressions—both those due to faulty rhetoric and those due to insufficiency of statement or explanation. As the best way to make a statement, explanation, or description clear is to give a picture or a diagram in connection with it, illustrations have been used almost without limit. The illustrations have in all cases been adapted to the requirements of the text, and projections and sections or outline, partially shaded, or full-shaded perspectives have been used, according to which will best produce the desired results. Half-tones have been used rather sparingly, except in those cases where the general effect is desired rather than the actual details.

It is obvious that books prepared along the lines mentioned must not only be clear and concise beyond anything heretofore attempted, but they must also possess unequaled value for reference purposes. They not only give the maximum of information in a minimum space, but this information is so ingeniously arranged and correlated, and the indexes are so full and complete, that it can at once be made available to the reader. The numerous examples and explanatory remarks, together with the absence of long demonstrations and abstruse mathematical calculations, are of great assistance in helping one to select the proper formula, method, or process and in teaching him how and when it should be used.

This volume covers the subjects of water closets, house drains, soil, waste, and vent stacks, traps and vents, drainage and sewerage, sewage disposal, sources of water supply, water filtration, cold-water supply, hot-water supply, plumbing inspection, and plumbing plans and specifications. In its preparation, we have endeavored to illustrate and describe the most approved methods and modern practice. The fundamental principles underlying the design and construction of plumbing systems are carefully considered, and the theory of modern plumbing is embodied in the volume. The treatment is so broad and so practical that the master plumber is enabled to extend his field of operations, and take contracts for sewerage systems, sewage-disposal plants, water-supply systems for towns and villages, and filtration plants. The greatest amount of useful information is contained in the least amount of space. The text was prepared by practical men and constitutes the most complete and most comprehensive treatise on practical sanitary engineering that has yet been published.

The method of numbering the pages, cuts, articles, etc. is such that each subject or part, when the subject is divided into two or more parts, is complete in itself; hence, in order to make the index intelligible, it was necessary to give each subject or part a number. This number is placed at the top of each page, on the headline, opposite the page number; and to distinguish it from the page number it is preceded by the printer's section mark (§). Consequently, a reference such as § 16, page 26, will be readily found by looking along the inside edges of the headlines until § 16 is found, and then through § 16 until page 26 is found.

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WATER CLOSETS

WATER-CLOSET CONSTRUCTION

INTRODUCTION

PURPOSE AND REQUIREMENTS

1. Water closets are made in many styles, and are constructed to operate in many ways. They are made of porcelain in one piece, or partly of porcelain and partly of iron, or entirely of iron. The iron is either plain or enameled. Porcelain closets are made either plain white or in colors, and are embossed and decorated to any degree desired.

2. The duty of water closets is to thoroughly remove all excreta and paper that may be deposited in them. They must be free from odors, and must prevent the escape of drain air from the soil pipe into the building. To meet these requirements, every closet must fulfil the following conditions:

1. The water used for cleansing must be applied in such a manner that it thoroughly washes all the interior surface of the bowl.

2. The current must have sufficient force to detach all filth from the surface of the bowl.

3. The water must be of sufficient quantity to wash out all the contents of the bowl and carry it beyond the trap and into the soil pipe.

4. When the flushing operation has ceased, the closet bowl and trap must be properly filled with fresh water, the foul water being entirely removed.

3. There have been extensive changes made in the types of water closets manufactured during the last 20 years. The old styles proved unsanitary and are now condemned by health departments. They are not used in new buildings, but are yet found in many old buildings.

SINGLE CLOSETS

PAN CLOSET

4. The **pan closet,** which is now obsolete as a market article, being generally prohibited by plumbing rules and regulations, is shown in Fig. 1. It has a hopper or conical bowl to receive the excreta; the lower end is closed by a pan that is swung on a hinge by means of a lever and pull. This pan catches and retains enough of the flushing water to seal the mouth of the bowl. The porcelain bowl *a* is set on a cast-iron trunk *b* that is secured to the floor *c*. A lead safe *d* is usually set under the closet, and is erroneously connected to the closet trap by a safe pipe *e*. The copper pan *f* seals the basin and receives the excreta. When the closet handle is raised, the pan drops and takes the position shown by the dotted lines and discharges its contents into the trunk, while at the same moment a volume of foul air enters the room from the trunk. It has

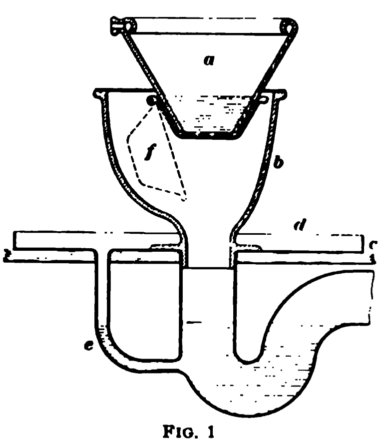


FIG. 1

many other serious imperfections too numerous to mention, and is a very imperfect apparatus. It should always be replaced with a closet of modern construction. Pan closets are universally condemned by all health authorities.

PLUNGER CLOSET

5. Construction of Closet.—The **plunger closet** is a closet condemned by health authorities, although its imper-

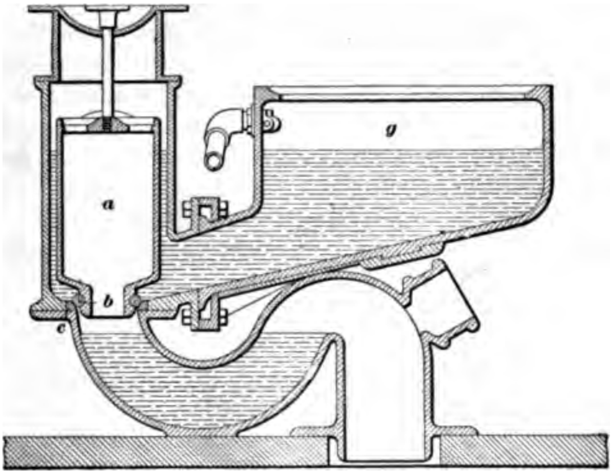


FIG. 2

fections are not so pronounced as those of the pan closet. A vertical section through a plunger closet is shown in Fig. 2. In this form, the emptying of the bowl is controlled by a valve, or plunger, *a*. This plunger is provided with a rubber ring *b*, which seats on a brass ring *c* and makes a water-tight joint with it. The plunger also acts as an overflow, because if the water rises higher in the bowl than the top of the plunger, it will flow over and down through the inside, past the valve, and into the trap.

6. The principal objection to the plunger closet is that the chamber in which the plunger works is imperfectly cleaned and becomes foul. Unless the plunger is lifted well up when emptying the bowl, pieces of paper or matches, etc. are likely to stick between the rubber ring and the valve seat and thus prevent the closing of the valve. This allows the water to leak out of the bowl, leaving it dry if the closet is supplied by a self-closing valve or by a small tank overhead. If the closet is used when the bowl is dry, the excreta will adhere so strongly that the amount of water usually furnished by the flushing apparatus will be insufficient to remove it, and, as the water again leaks away, it will remain in the bowl and become a nuisance.

If the closet is supplied by a ball-cock placed in the plunger chamber, a uniform water-line will be maintained in the bowl, and if the plunger valve should leak, a waste of water would be the result, which cannot well be detected. This kind of closet is constructed either of one piece of porcelain or partly of iron, as shown. Usually all the iron parts, including the plunger, are porcelain-lined.

This closet is practically obsolete as a market article in the United States, although it is still in use in many buildings.

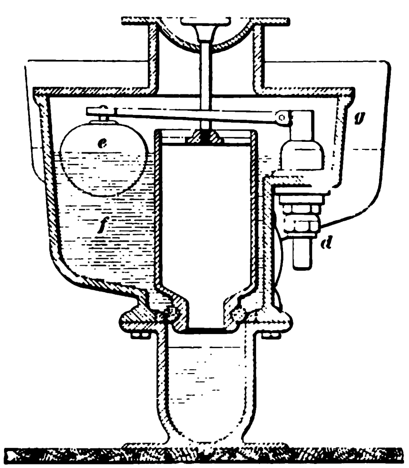


FIG. 3

7. Flushing Device. A **closet float-valve flushing device** commonly used for flushing plunger closets is shown in Fig. 3. This is a cross-section through the plunger valve, at right angles to the view given in Fig. 2, and it shows a ball-cock *d* that is controlled by the float *e*. The water rises to the same height in the chamber *f* that it does in the bowl *g*, Figs. 2 and 3, and the float is adjusted to maintain the water at the proper level.

8. Plunger closets may be flushed with water by means of a **closet spring valve** on the service pipe, which, when opened, will remain open for a short period of time and will automatically close itself after permitting a quantity of water to pass that is sufficient to properly flush the bowl. A valve designed for this purpose is shown in Fig. 4.

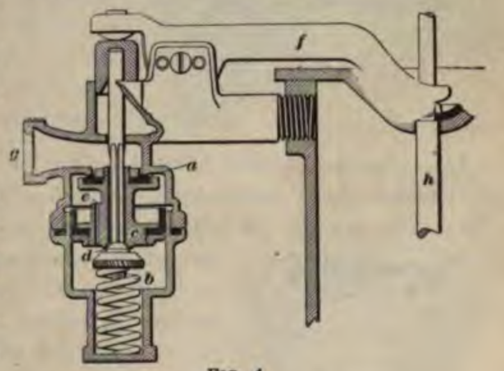


FIG. 4

The valve *a* is held up to its seat by the spring *b*. The supply water enters the space between the valve and the piston *c*. The valve spindle is loose in the valve, and has a conical head at *d* that fits in a corresponding seat in the piston *c*. A small hole *e* permits the water to pass slowly to the under side of the piston. When the valve stem is pushed down by the hand lever *f*, the valve *d* opens and allows the water in the lower chamber to escape through the central hole into the outlet *g*. The area of the piston being larger than that of the valve *a*, the water pressure drives the piston downwards until it is arrested by the valve *d*. The pressure on the opposite sides of the piston being now balanced and the lever being released, the spring *b* pushes the piston upwards and gradually closes the valve *a*. This upward motion is gradual, because the water required to fill the lower chamber must pass through the small hole *e*, and the spring is not strong enough to drive the piston upwards so rapidly as to form a vacuum behind it. The waterways in this valve should equal the area of 1-inch or 1¼-inch pipe for water-closet service. The end of the lever usually engages with the plunger rod *h* of the closet. These valves are not reliable, as they are too apt to get out of order.

9. If it can be avoided, ordinary water closets should never be supplied with water direct from city mains. Unless exposed to frost, they should in all cases be flushed from tanks.

HOPPER CLOSETS

10. **Long-Hopper Closet.**—One of the simplest forms of a water closet is shown in Fig. 5. This form, which is known to the trade as a **long-hopper closet,** and also as a **Philadelphia hopper,** has a long closet bowl curved as shown in the illustration. It is provided with a 4-inch outlet horn *a* passing through the floor, and a floor flange *b* that serves as a base to support the closet on the floor. The water used for flushing the bowl enters through the inlet horn *c*. The inlet horn of the long hopper shown in Fig. 5 is obliquely attached to the bowl, so that the water on entering the bowl will swirl around on the inside.

FIG. 5

11. A **spreader,** or **fan,** *a*, Fig 6, which is a piece of sheet metal placed over the inlet or mouth of the horn, is sometimes used to spread the water over the surface of the bowl, as shown by the arrows. The general direction of the flow is nearly horizontal.

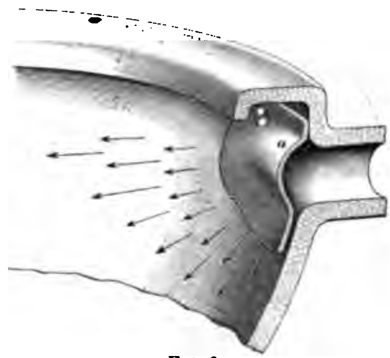


FIG 6.

12. Sometimes the rim of the closet is hollow, as shown at *a* in Fig. 7. The horn discharges into the rim, and a number of perforations on the under side of the rim permit a series of small streams to flow all over the surface of the bowl, as shown by the arrows, their general direction being downwards. This is called a **perforated flushing rim.**

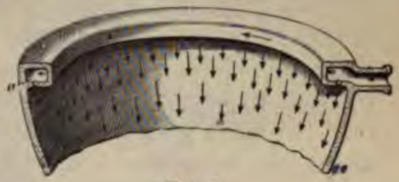


FIG. 7

13. Antifreezing Hopper Closet.—Fig. 8 shows an antifreezing closet. It is simply a long hopper set over a manhole dug about 4 or 5 feet deep and about 3 feet in

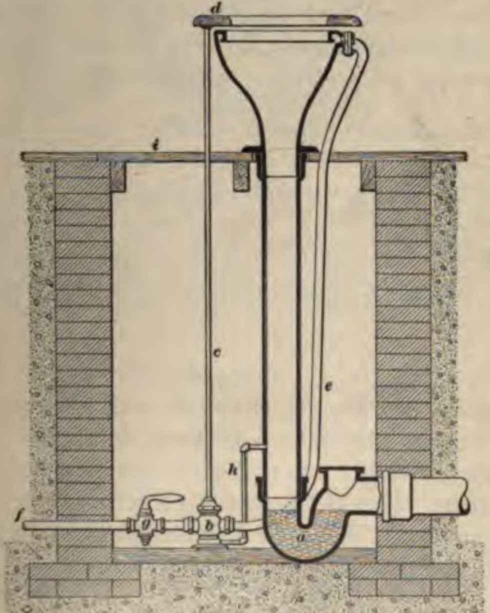


FIG. 8

diameter. The closet trap *a* and flushing valve *b* are thus located below the frost line. A rod *c* extends above the closet floor and touches the under side of the closet seat *d*, which is raised about 1 inch in front by a spring in *b* when the seat is not occupied. When the closet is being used, the seat is pressed down, which automatically opens the flushing valve *b*. Water immediately flows through *e* and flushes the closet. When the weight is removed from the seat, the closet continues to flush until the valve in *b* reaches its seat. To prevent the water from remaining in *e*, the valve *b* is provided with a small waste hole through which the water in *e* is allowed to escape through a waste tube *h* after the valve is closed. Hence the pipe *e* cannot freeze. The pipe *f* is a connection from the city mains or other source. Since the valve *b* is liable to require occasional repairs, it is necessary to place a stop-cock at *g*. A loose cover or trap door *i* is provided in the floor for access to the manhole or pit under the closet. An arrangement of this character, although not strictly sanitary, is sometimes necessarily required, and there are many in use.

14. If the supply pipe is smaller than ¾ inch, or is unusually long, it is often necessary to attach a large air chamber to store water under pressure and allow it to discharge into the bowl in a large volume when the closet is being flushed. Few of these closets are on the market. They are patented combinations and are handled as specialties.

15. A long hopper is suitable only for outdoor situations. Hopper closets are seldom supplied with enough water to keep them reasonably clean, and they should be thoroughly scrubbed periodically. A pailful of water should be occasionally thrown down the hopper to forcibly relieve the trap of the accumulation of paper and filth, which, if allowed to remain, would eventually choke it.

16. Short-Hopper Closets.—A short-hopper closet is composed of a bowl and trap above the floor, as shown in Fig. 9. This specific form is generally defined as a **short hopper and trap,** because the hopper bowl *a* is separate from the trap *b*, and they are fitted together on the job. Presumably this is the cheapest water closet on the market. The bowl is made of enameled iron or porcelain. The trap is usually made of cast iron and enameled on the inside. It is superior to the pan closet or plunger closet in every

FIG. 9

respect, and if provided with a good flushing rim and an ample supply of water at a good pressure, is a fairly sanitary fixture. The socket shown on top of the trap is for a 2-inch cast-iron vent connection to prevent siphonage of the trap.

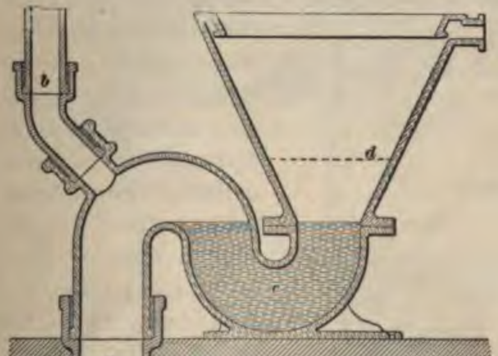


FIG. 10

17. Fig. 10 shows a section through the short hopper shown in Fig. 9. The cast-iron trap is connected to the soil pipe *a* by a calked joint above the floor and the back-vent horn is connected by a calked joint to the back-vent pipe *b*. These are good solid closet connections, and are reliable. The trap is shown filled with water at *c*. When this closet is flushed, the water-line will rise inside the bowl probably to the height of the dotted line *d*. If the water rises slowly, owing to a slow inflow of the flushing water, paper is liable to float on top and will not be driven through the trap. Hence, the flushing should be done rapidly. A 3-gallon flush delivered through a 1¼-inch flush pipe from a small tank located about 6 feet above the closet is generally sufficient to force out the closet contents each time.

18. The chief objection to the ordinary short hopper and trap is that the bowl becomes foul, because it is dry when the closet is being used. The excreta falls on the dry surface, adheres thereto, and cannot be entirely washed off with an ordinary flush.

19. The short hopper and trap closet is commonly used in workshops, cheap tenements, etc., where appearance is not an important factor.

20. Pedestal-Hopper Closets.—In Fig. 11 is shown a form of hopper closet that is usually made entirely of porcelain, and is known to the trade as a **pedestal-hopper closet,** although it is sometimes called a **combined hopper and trap.** It is provided with a flushing rim *a*, which is supplied from a flush pipe that connects to the horn *b*. A lip is formed at *c* to cause a jet of water to be ejected down into the trap, as shown by arrows. This causes the paper and solids in the closet to be driven down and quickly pass through the trap.

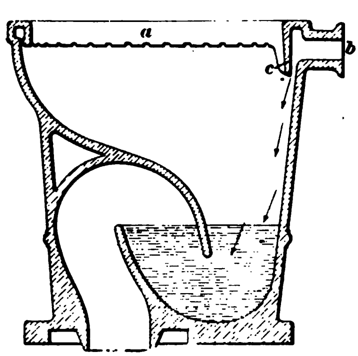


FIG. 11

This closet has the objection of having a large amount of dry fouling surface in the bowl. Pedestal-hopper closets are sometimes called **wash-down closets,** which is a misnomer, as all closets flush downwards.

21. A pedestal hopper with outlet above the floor is shown in Fig. 12. It has the least possible amount of fouling surface in the bowl. The area of water in the bowl is

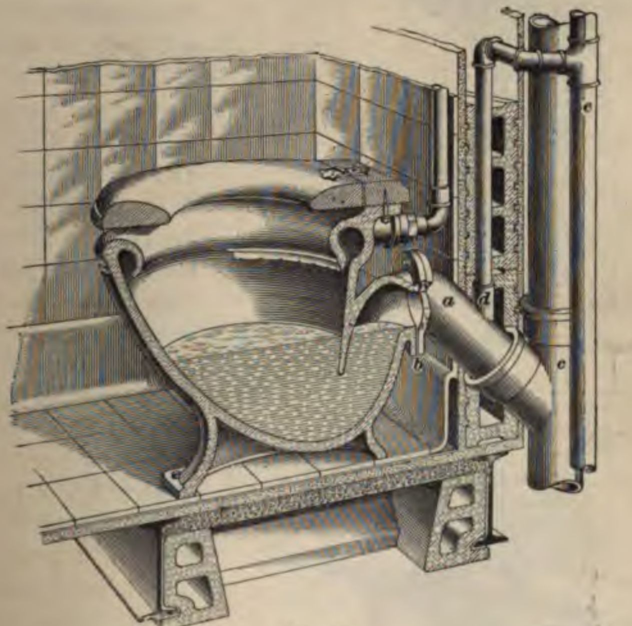


FIG. 12

large, so that solids will drop into the water. The surface of the bowl is thus protected against filth, but if the flush is weak, paper is liable to stay in the bowl. It is necessary to have a strong flush for this closet, in order to obtain perfect results. The form of trap shown is known as a **P** trap. When the trap terminates at the floor, as in Fig. 11, it is called an **S** trap. The **P** trap permits connections to be made above the floor, as shown. A special fitting *a* is used to connect the trap by means of a bolted flange joint and rubber gasket at *b* to the soil pipe *c*. A socket or tapping at *d* is furnished for a connection to the back-vent pipe *e*, which is shown connected up.

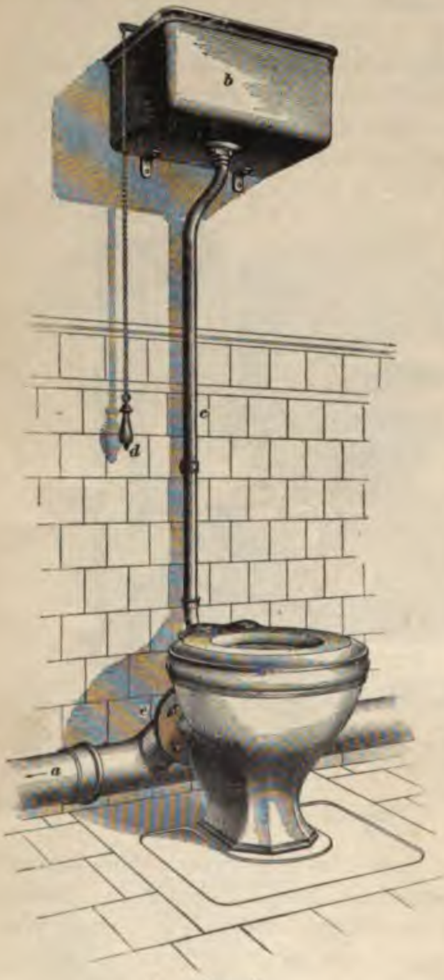


FIG. 13

22. Occasionally it is necessary to connect a row of closets to a nearly horizontal soil pipe *a*, running at the back of the closets, as shown in Fig. 13. The pedestal hopper with **P** trap is then very desirable. Fig. 13 shows how such a closet appears when connected up complete, except that the water-supply pipe to the tank *b* is not shown. The flush pipe *c* is 1¼-inch nickel-plated brass about 6 feet long. The chain pull *d*, when pulled down, operates a mechanism inside the tank *b* and allows the contents of the tank to flush the closet. In setting these closets, great care must be taken to make a perfect gas-tight joint at *e*, and also to thoroughly support the soil pipes so that they will not settle and break the porcelain.

WASHOUT CLOSETS

23. Construction.— A washout closet is shown in Fig. 14. It is composed of a bowl and trap. The bottom of the bowl has a large area and is comparatively shallow. The depth of water remaining in the bowl should be 1¼ to 1¾ inches at the deepest point.

Water is supplied to the closet bowl through the 1¼-inch flush pipe *a* and the perforated flushing rim *b*, the larger volume entering the bowl at the back. If the basin is

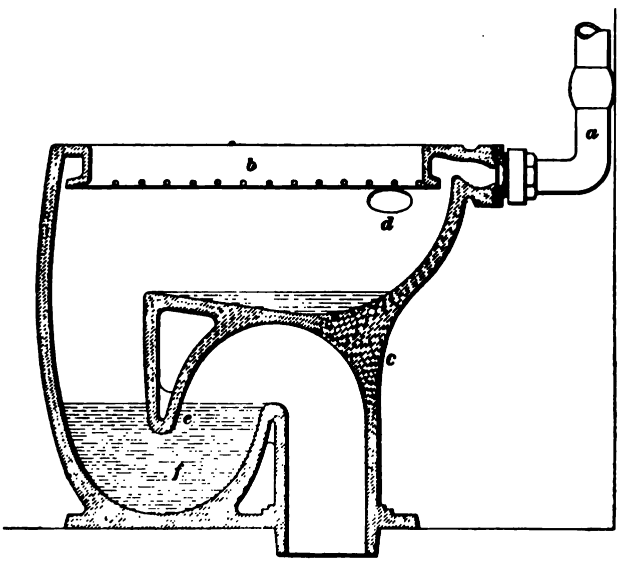


FIG. 14

deeper, the fresh water may pass under the solid excreta and fail to remove it before the flush is exhausted; and if the basin is shallower, the excreta may adhere so strongly that it cannot all be washed away without using more water than can be allowed.

The soil-pipe branch and trap was formerly ventilated by a back-vent connection made to a porcelain horn situated at *c*, but this has been dispensed with because the porcelain horn would break too easily. The bowl may be ventilated by attaching a pipe to the local-vent connection *d*. This, however, is seldom done unless the pipe can be run inside or near a warm chimney.

FIG. 15

The lip *e* forming the seal of the trap *f* should dip into the standing water in the trap not less than 1½ inches nor more than 1¾ inches. If it is submerged to a greater depth, the excreta, paper, etc. will require a larger and more forcible supply of water than can be allowed to carry them down under the lip and expel them. If the submergence of the lip is less than 1½ inches, there is danger, at times, of its failing to properly seal the trap.

The closet shown is called a **front-outlet washout water closet**; washout closets are also made with the outlet at the side or at the back, as desired. They are also constructed with the bowl separate from the trap, the bowl being of porcelain and the trap of iron. This permits the trap to be firmly calked into the cast-iron soil pipe, insuring a strong joint at that point.

24. Fig. 15 shows a front-outlet washout water closet and overhead flushing tank fitted up complete, excepting the water-supply connection to the tank. The closet has a floor connection to the soil pipe. It has no back-vent connection to the porcelain. There may or may not be a local-vent connection to the bowl; usually there is none. The closet is shown bolted down with four closet expansion bolts *a* and washers to a marble safe *b*. If the closet is set on a wood floor, the two front fastenings are usually brass lagscrews, the rear fastenings being bolts attached to a brass floor flange under the porcelain closet flange.

Fig. 15 illustrates a thoroughly sanitary fixture that gives satisfactory results if the bowl is scoured out occasionally with a scrubbing brush to remove traces of solid matter that may adhere to it.

25. Vent Connection.—Practical experience of recent years has taught the plumbing trade that the porcelain vent horns of water closets are so easily cracked, or broken off, that it is not advisable to back-vent any form of water closet from a porcelain horn. This defect has been so pronounced that many plumbing rules and regulations prohibit the use of porcelain back-vent horns.

Theoretically, a back-vent connection should be made to the top of the trap, but in practice it must be made on the metallic pipe near the floor flange connection to the closet.

26. Advantages and Disadvantages.—The washout closet is quite noisy in its operation, and the space over the trap inlet is liable to become foul. These are the principal objections to this form of closet. But, it has an advantage, which, for family use, entirely overbalances the disadvantages; namely, it holds the contents open to view for inspection, as mothers and nurses usually desire to carefully watch the passages of children. Besides, should children throw such things as dolls, etc., into a washout water closet, they can easily be observed before the closet is flushed. Such things, if dropped into other style closets, may sink into the trap and be accidentally flushed through the closet and into the soil pipe, when they may choke the closet or the drainage system. If the objection to noise is not an important factor, it is quite proper to install front-outlet washout closets for family use.

SIPHON-JET CLOSETS

27. Advantages.—The **siphon-jet closet** is a form of closet that has become quite popular. If properly flushed, it gives excellent results. It is clean, ejects the solid contents quickly, has a good depth of water into which the solids fall and thus instantly become partially deodorized, and is self-cleansing, or as nearly so as any water closet yet put in public use. With the exception of its liability to chokage, it is considered to be the best form of closet on the market. But, it must be supplied from a flushing tank that is especially constructed to discharge the proper amount of water, preferably a siphon cistern; otherwise, the siphon closet will be just as bad as, or worse than, the poorest form in use.

28. Early Form.—One of the first siphon-jet closets placed on the market is shown in Fig. 16. It clearly illustrates the general principle on which this type of closet operates.

The contents of the bowl are sucked out by the siphon, which is formed by the two tubes *a* and *b*. Some of the water that enters the flushing rim *c* rushes down the tube *d*, forming a jet that drives the water in *a* up into the space *e* and fills the tube *b*. As *b* is longer than *a*, the two passages act as a siphon until the water in the bowl falls below the lip *f*, when air enters and stops siphonage. The closet outlet horn *g* is attached to the soil-pipe branch. The back-vent pipe *h* ventilates the closet branch and prevents the bowl from being siphoned by the discharge of other fixtures into the same stack.

In the latest forms of siphon closets the back-vent horn *h* is dispensed with altogether, and instead of the back-vent

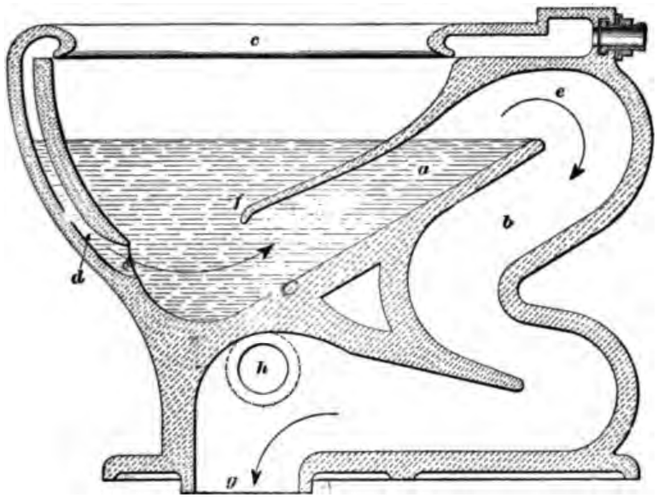


FIG. 16

connection being made to the porcelain, it is made to the soil-pipe branch under the floor and as near to the closet as possible.

29. Modern Forms.—There are now many different makes of siphon closets in the market, but, in a general way, they are all about alike. Fig. 17 shows a common modern form. The closet is composed of one solid piece of porcelain. The back strip *a* of the seat is secured to the bowl by means of lagscrews, as shown. Many seats are secured with through bolts instead. A cover *b* is shown hinged to *a*, which is very suitable for closets in private dwellings, particularly in bathrooms, but in public buildings it is seldom advisable to use hinged covers over the seats. The flush pipe *c* connects to the closet horn with a slip-joint attachment which, although water-tight, allows the flush pipe to be jarred without breaking the horn. A water channel extends down the side of the closet, as shown by dotted lines, and terminates at a $\frac{3}{8}$-inch or $\frac{1}{4}$-inch aperture *d* at the bottom of the closet; the horn also has a water channel that delivers into the flushing rim. When the closet chain is pulled, and water falls down the flush pipe, part of it flows into the bowl through the flushing rim and part of it is ejected in the form of a jet from *d*. The jet

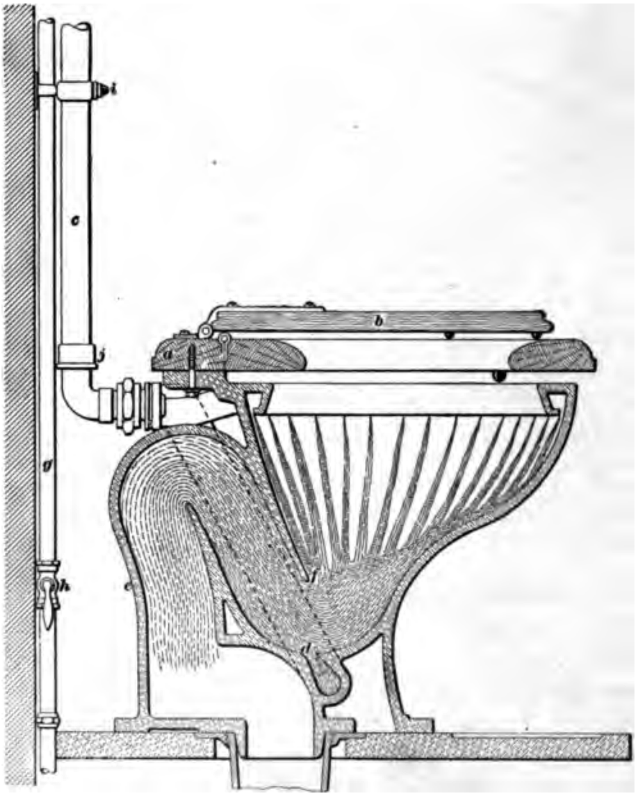


FIG. 17

throws a large volume of water from the trap into the outlet channel *e*, which acts like the long leg of a siphon, and rapidly siphons the bowl nearly empty. The illustration shows the bowl siphoned nearly empty and air being sucked in under the lip *f*, which stops siphonage.

The capacity of the flushing tank should be so arranged that the flush will stop when the bowl is filled again. The pipe *g* shown at the left of the flush pipe is a $\frac{1}{2}$-inch, nickel-plated, brass water-supply pipe for the closet tank. A stop-cock *h* is placed in it to shut off the water from the tank when repairs are required.

30. Another siphon-jet closet is shown in Fig. 18. The jet is concealed from view. It is located at the back of the

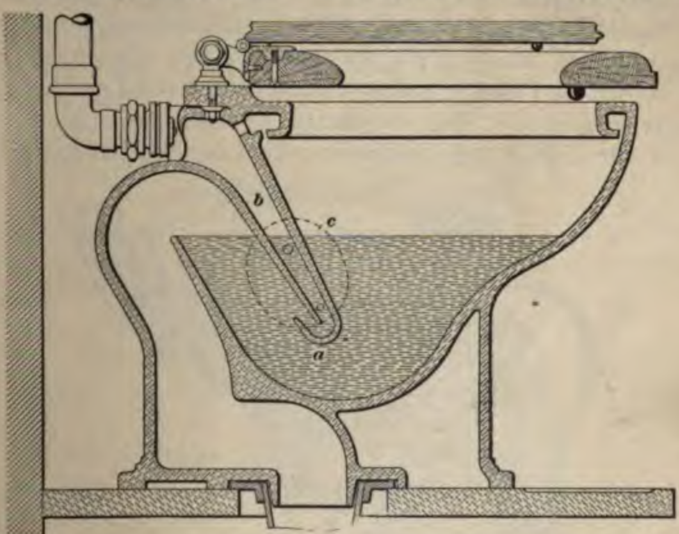


FIG. 18

lip *a* that forms the seal. The water channel *b* that supplies the jet is formed between the bowl and the inlet leg of the siphon.

31. Some siphon-jet closets are furnished with a **refilling chamber** in the form of a bulge or swelling on the side of the closet, as shown by dotted lines at *c* in Fig. 18; the two small holes shown in *b* are used to refill the seal at the lip and thus prevent drain air from coming into the building through the flushing rim or through the flush pipe if the closet seal should not be properly replaced after a siphonic discharge.

The closet seat attachment is of brass and rigidly bolted through the porcelain, which is reinforced by an extra thickness at that point. This makes a very strong and clean seat attachment, every part of which can be easily cleaned.

32. A **plain siphon closet**, or **wash-down siphon**, as it is commonly called by its manufacturers, is a cheap form of siphon closet. It has the same construction as the siphon-jet type, excepting that it has no jet to produce a quick discharge of the bowl. When such a closet is flushed, the water in the bowl simply overflows into the outlet leg, as shown in Fig. 19, and is wasted. The solid matter and paper remain at or near the surface of the water in the bowl, until the siphon leg becomes so completely charged with

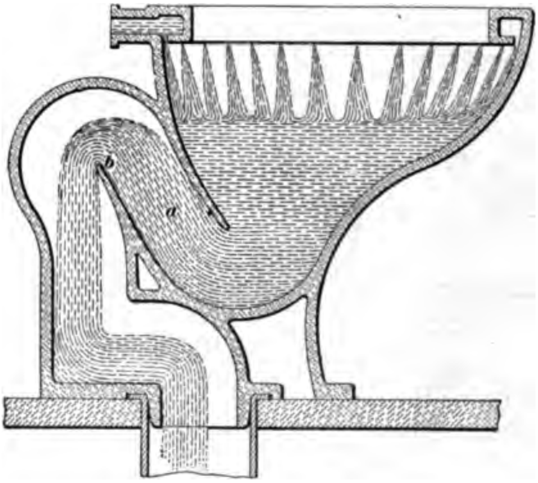


FIG. 19

water as to start siphonage, when the bowl will be emptied. But as siphonage usually does not start until the flush is nearly exhausted, solids in the short leg *a* of the siphon frequently fall back and return to the bowl. Although the flush should continue until all the contents of the bowl were thrown over the lip *b*, this form of closet would yet be defective, because most of the water leaves the closet in advance of the solid matter. In such a case, the solids ejected from the bowl remain in the house drainage system until the closet is flushed again; it is only then that the solid matter is conveyed beyond the house-drainage system.

It is different with a well-made siphon-jet closet that discharges the contents of the bowl quickly; here the latter part of the flush is used to convey the solids to the sewer. The plain siphon closet, therefore, is not to be recommended unless the closet is supplied with a quick-acting and very strong flush. When combined with a low-down tank, the ordinary plain siphon closet gives trouble by chokage and waste of water.

LOW-DOWN TANK CLOSETS

33. Low-down tank closets are becoming quite popular, because of their marked quietness in action and their adaptability to places where overhead tanks cannot be installed. They are particularly suited for spaces under stairs, etc., where there is too little headroom for ordinary tank closets, and are often placed in toilet rooms adjoining sick chambers. Fig. 20 shows a favorite arrangement. The tank *a*, which contains about 5 or 6 gallons of water, is located immediately at the back of the closet. The mechanism in the tank is similar to that in overhead tanks, the chief difference being that the flush pipe *b* is much larger. The valve in the tank is from 3 to 4 inches in diameter.

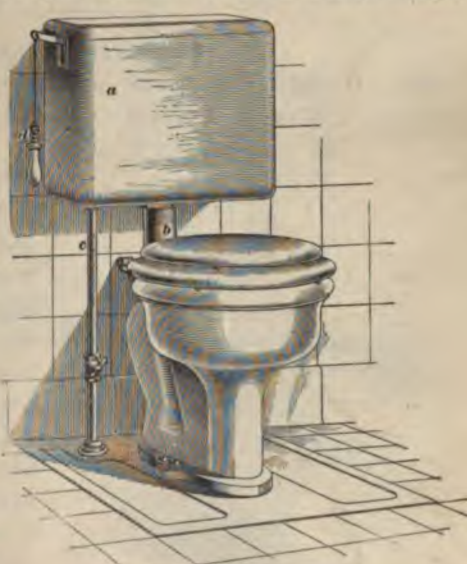


FIG. 20

34. In Fig. 20, the low-down tank is supplied with water through the bottom by a ½-inch nickel-plated brass supply pipe *c* having a shut-off valve or stop-cock attached to it above the floor for convenience in shutting off the water from the tank when it needs repairs. A chain pull *d* is used to operate the flush. A push button or other means may, however, be employed to operate the flush.

35. The chief objection to the ordinary forms of low-down tank closets is that the flush is weak, due to the low head of the flush. In attempting to overcome this objection, the closet outlet is often contracted so much that it becomes easily choked. Another objection is that a larger amount of water is required to produce a perfect flush than when the tank is high up. This also is due to lack of head for flushing.

DIRECT-FLUSH CLOSETS

36. Installation.—Direct-flush closets, i. e., those that are flushed by a direct connection to the city mains or to the general plumbing system in a building, appear to be in demand for special places or special work. The chief advantages claimed for them are the reduced cost of installation and the small amount of space they occupy. Fig. 21 shows one of these closets connected up complete. It is essentially composed of an ordinary siphon-jet closet, the horn of which is connected to a lever-handle valve attachment, as shown at *a*, and which is supplied with water from the regular house service pipes.

FIG. 21

37. Flushing Apparatus.—Fig. 22 shows, in section, the valve attachment mentioned in the previous article. It is known to the trade as the **Flushometer,** which is the name applied to it by the manufacturer. This valve is principally composed of an outer casing, an inner casing, two valves, and a lever handle. The outer casing is tapped

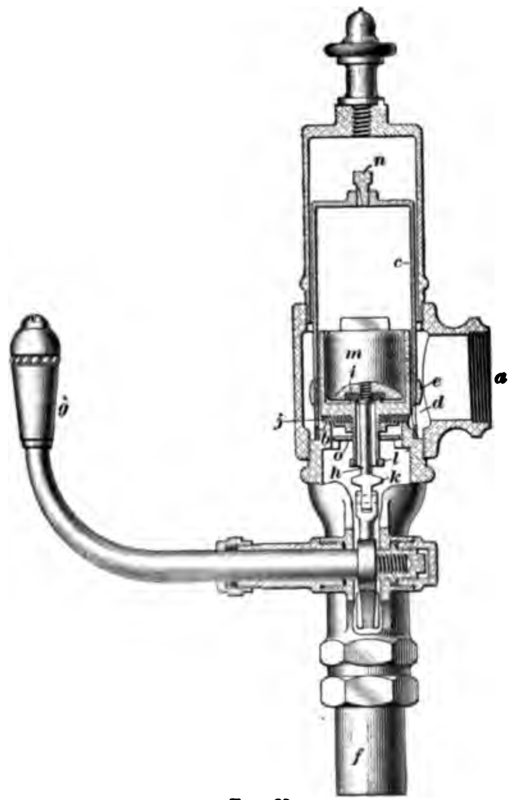


FIG. 22

$1\frac{1}{4}$ inches or $1\frac{1}{2}$ inches at *a*, to connect to an iron water-supply pipe. The outer casing above the valve seat *b* is therefore subject to the full water pressure when the closet is not in use. The inner chamber *c* is screwed over the valve seat. A number of holes (about $\frac{1}{2}$ inch diameter) are drilled all around this chamber at *d*, to allow water to flow from the outer chamber into the inner chamber; a regulating ring *e* is arranged to screw down over the port holes at *d*, and thus regulate the volume of the flush. The coupling *f* connects to the closet with a slip joint. When the handle *g* is pulled toward the closet, a lever arm raises the valve stem *h*, thus opening a small **relief valve** *i* before the large, or flush, valve *j*, is opened by a crosshead *k* engaging the hollow stem *l*. The relief valve allows water in *c* to freely escape to the closet bowl when *j* is raised quickly. When the large valve is raised off its seat, water flows freely from *a* through *f* to the flushing rim and siphon-jet channel of the closet. When the handle has been pulled over as far as it will go, the plunger *m* and the two valves are raised to the top of the chamber *c*, and the water in *c* has been displaced by the plunger. As soon as the hand is removed from the handle *g*, the relief valve closes automatically, and as the plunger fits the inner chamber closely, the large valve falls to its seat with a speed that varies with the size of the opening that allows water to enter *c* and occupy the space that the plunger is vacating as it falls.

38. To regulate the falling speed of the plunger, which also means to regulate the length of time that the closet will be flushed, a regulating screw *n* is provided; this has a tapering slot cut on the thread. By unscrewing *n*, the small water passage is increased and the duration of the flush is shortened. By screwing down *n*, the aperture is closed more and the duration of the flush is increased. To insure a refilling of the closet bowl before the flush stops, i. e., to cause the latter part of the flush to flow slowly into the closet bowl and thus refill it without danger of another siphonic action in the closet, a ring or controller *o* is loosely fitted around *l*. When the valve is raised, this allows water to come easily to the closet at first, but when the valve is raised about one-quarter of its range, the ring *o* is also raised above the level of the valve seat and the full volume of the flush goes to the closet. If this ring were omitted, the flush (from a high-pressure source) would come to the closet with such speed as to jar the fixture and make a disagreeable noise. If the flushometer is properly adjusted to suit the conditions under which it operates, a nearly noiseless and thorough flush can be obtained.

39. Flushometers are made to operate under high or low pressure, but as a rule they are not suitable for pressures less than 10 pounds by the gauge.

40. If the service pipe that supplies the closet valve is sufficiently large to insure an abundant supply of water for flushing, the form of closet shown in Fig. 21 will give satisfactory results. But, if the pipes are small and the supply not abundant, the closets will not flush satisfactorily no matter what pressure may be in the pipes. If the service pipe that supplies a building with water from a street main is ¾ inch or less, it is practically impossible to obtain a direct flush of sufficient volume and force. In such a case it is necessary to use a tank *a*, Fig. 23, in the attic or elsewhere, to supply the closets. The tank should contain from 5 to 6 gallons

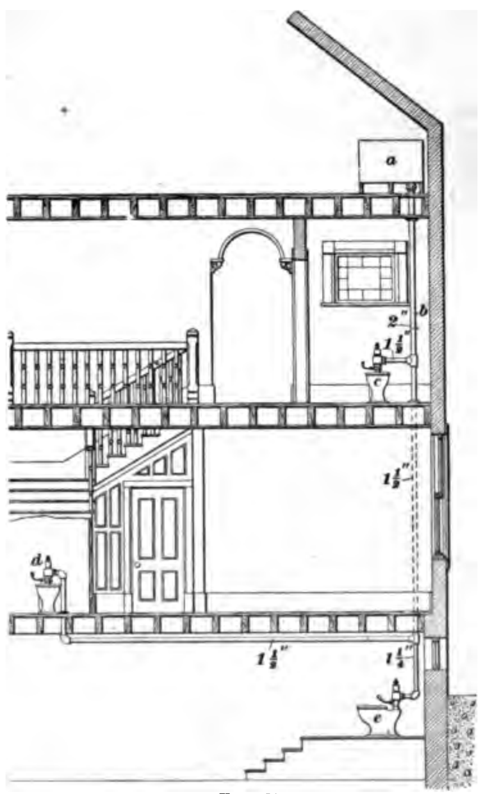


FIG. 23

of water for each closet supplied from it. A downward supply pipe *b*, whose size will depend on the number of closets that are likely to be flushed at the same time, is used to supply all the closets. In the illustration, the sizes given should produce good results.

Fig. 23 illustrates how the direct-flushing closet is particularly adapted to be placed under windows, as at *c*; under stairs, as at *d*; or on platforms where there is no headroom for an ordinary flushing tank, as at *e*.

41. If a tank is not used, and if the service pipe from the street main is small (say 1 inch or less), a **direct-flushing valve** *a*, Fig. 24, may be used in combination with an **air chamber** *b*. A $\frac{3}{4}$-inch pipe *c* connecting to the city mains delivers water into the base of the air chamber, but above the flushing valve. The street pressure compresses the air in *b*, and thus fills it with water to a height commensurate with the pressure. Thus a considerable volume of water is stored in *b* under full city pressure. The instant the handle *d* of the valve is pulled down and the flush valve opened, the water in *b* is swiftly discharged into the closet by the expanding compressed air in the chamber *b*. As soon as the air has expanded to a low pressure, the flush

FIG. 24

becomes too weak to be effective; it is useful then only to refill the bowl. Hence the necessity of a large air chamber.

Since air chambers lose air by its absorption in the water, the chambers should be occasionally replenished. Hence the tank-supply system has an advantage over the street-pressure system with air compression chambers.

42. The flushometer should take from 7 to 12 seconds to flush properly. In fitting up these fixtures, the plumber must be careful that no red lead or other cement used in making up the joints is allowed to get into the inner chamber, as this may prevent the valve falling to its seat.

43. To determine whether a flushometer can be successfully operated from a street supply, first disconnect the service pipe, then turn on the water full force and allow it to run for 10 seconds. If the volume of water discharged in that time is not equal to or greater than 5 gallons, it may safely be decided that the water supply is not sufficient for a direct flush.

PNEUMATIC SIPHON CLOSETS

44. Pneumatic siphon closets have two traps and an air chamber between. The lower trap is usually located under the floor, being separated from the closet proper. A $\frac{3}{8}$-inch or $\frac{1}{2}$-inch tube connects the air chamber to an air ejector located inside the flush pipe just under the tank. As the water falls down the flush pipe from the overhead tank to the flushing rim of the closet, it draws air from the chamber between the traps and thus starts siphonage of the bowl.

This form of closet is not so popular as the siphon-jet closet. It has the disadvantage of discharging, along with the water, the foul air from the trap chamber through the flushing rim, whence it is liberated into the rooms;

therefore, from a sanitary point of view, it is not so desirable as the siphon-jet or front-outlet washout closets. Besides, it has more parts to become choked or otherwise impaired by usage.

LOCAL-VENT CLOSETS

45. Closet Construction.—There are a large number of water closets constructed with connections for local vents, but usually the horns are too small for natural draft ventilation, being only about 2 inches in diameter. A closet especially constructed with large local-vent openings is shown in Fig. 25. Two large vent openings *a*, *a* in the form of a horseshoe are molded inside the porcelain body, a 4-inch outlet being made at the back of the closet to connect to a 4-inch local-vent pipe *b*, that runs up inside the walls against which the closet is set. The inlet openings for the local vent in the bowl are above the water-line of the bowl, and the closet is so constructed that, while being flushed, water cannot back into the local-vent openings. The local-vent pipe *b* should be continued to a permanently hot flue, and either connected to the flue or run up to and through the roof alongside of the flue in such a manner that it will be heated by the flue. This is necessary in order to insure a positive upward current in the local-vent pipe at all times.

FIG. 25

46. Venting Mechanism.—In places where it is impossible to obtain the aid of a permanently heated flue, it is necessary to insure a positive ventilation by means of mechanism. For example, a fan *a* operated by a small electric motor *b* may be used, as shown in Fig. 26, but as this is an expensive installation, it is very seldom used except in hotels or other such buildings where the local vent from a large number of closets can be connected together and joined to the fan inlet, as shown. The discharge pipe *c* from

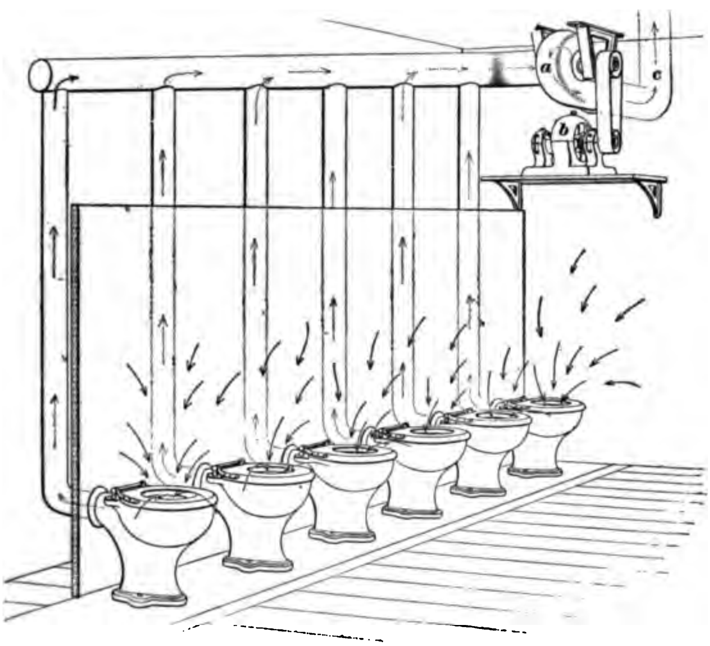


FIG. 26

the fan delivers the foul air into the outer atmosphere, preferably above the roof. Local-vent pipes may be made of No. 26 or 28 galvanized sheet iron; joints and seams should be riveted and soldered or otherwise made air-tight.

If a local-vent pipe is taken from a closet and run up through the roof away from a heated flue, there will be times when a down draft will occur. This is decidedly objectionable and renders the local-vent pipe more dangerous than useful.

47. Fig. 27 shows a sectional view of a small ventilator for local venting a closet by mechanical means; it is operated automatically, and can be connected to any closet

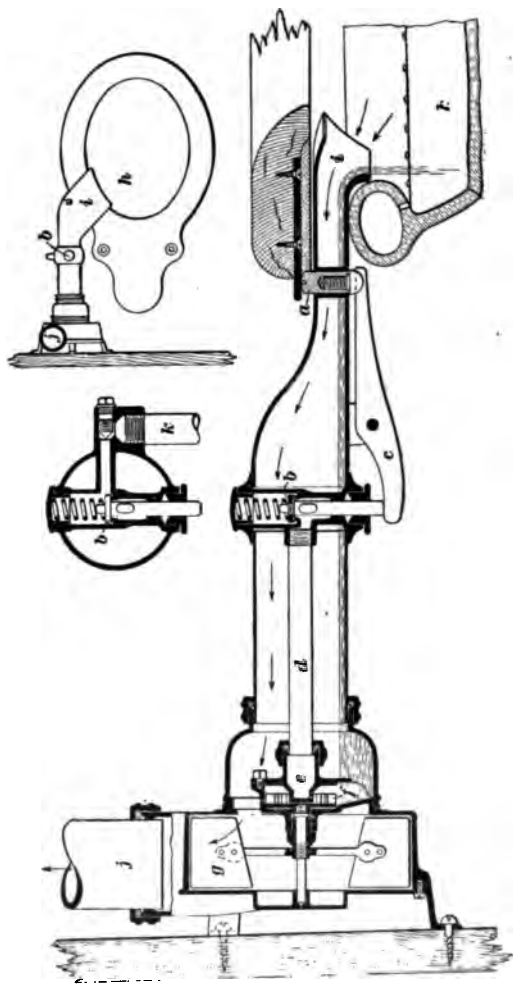


Fig. 27

having the seat attached to the bowl. When the seat is being used, the push button *a* is pressed down, opening the valve *b* by the lever *c*. This allows the water to flow through the pipe *d* into the nipple plate *e*, which has a small hole through which the water plays on the blade *f* of an impulse wheel operating the fan *g*, which is connected to the waterwheel shaft, as shown. The revolving fan draws the foul air from the closet bowl *h* through a special inlet *i* located under the seat, and ejects it to the outer atmosphere through the vent pipe *j*, as shown by the arrows. After the water passes the wheel, it flows back to the closet along the bottom of the vent tube.

48. Fig. 28 shows the ventilator connected to a low-down tank siphon-jet water closet. All parts visible have been

FIG. 28

lettered the same as the corresponding parts in Fig. 27; the water-supply pipe *k* is connected to the house service.

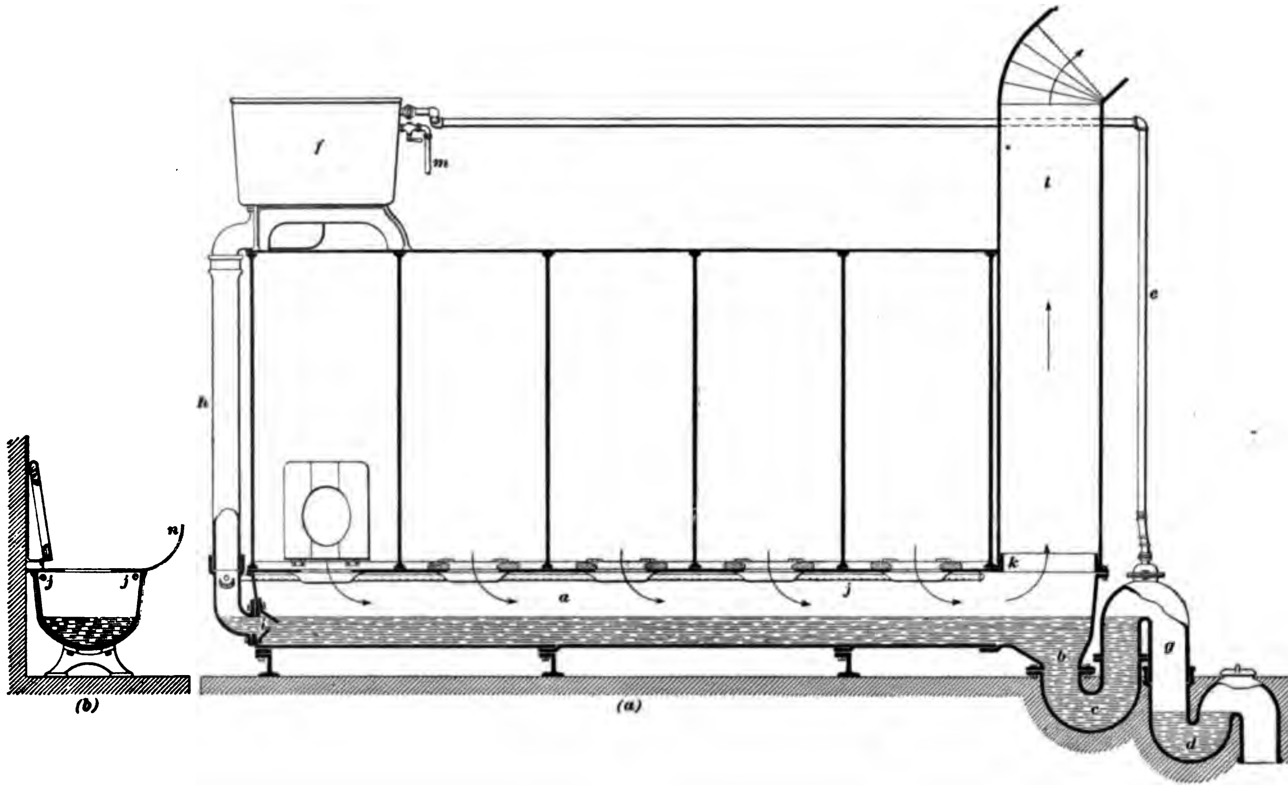


FIG. 20

WATER-CLOSET RANGES

TROUGH CLOSETS

49. A **trough closet,** or **closet range,** as it is commonly called, is simply a long narrow water-supplied trough provided with an outlet at its lower end, the trough being surmounted by a row of water-closet seats with or without partitions between them. They are used chiefly in cheap schoolhouses, barracks, workshops, etc., and for public places, such as in the streets, squares, and parks of cities, where closets receive the worst usage. If they are in charge of a janitor or other attendant, they may be provided with any suitable form of hand-flushing device. But, if there is liability of neglect in attention, they should be flushed automatically.

50. Fig. 29 (*a*) shows an automatic siphon water-closet range in common use. A cross-section through the trough is shown in detail in Fig. 29 (*b*). The trough *a* is made of cast iron, which should be enameled white inside. The bottom pitches slightly down to the discharge opening *b*. Two traps, *c* and *d*, are placed on the drain that conveys the contents of the trough to the sewer. The space between *c* and *d* is air-tight. A ¾-inch or 1-inch air pipe *e* connects with the water in the tank *f* in such a manner that when the water is being discharged from the tank a strong suction is produced that draws air from the space *g*. A large pipe *h* (usually 4-inch or 5-inch) connects the bottom of the tank to a large fan or spreader *i*, and to two perforated flush pipes *j*, *j* running the full length of the trough under the closet seats. The tank is of the automatic class, and the trough operates on the pneumatic discharge principle. Partitions are shown between the closets. The spaces between the partitions are known as **stalls.**

A ventilating extension is placed at the discharge end of the trough, and its collar *k* is fitted with a sheet-metal flue *l*, which is continued up to and through the roof, alongside or inside of a warm flue. This is a local vent that carries off odors from the trough, as shown by the arrows.

51. The operation of this apparatus is simple. Water from the city mains or house tank enters *f* through a ½-inch or ¾-inch pipe *m*, the stop-cock being regulated so that the tank will fill about once each hour or longer, according to existing conditions. At the proper time, the tank begins to discharge its contents through *h*, *i*, and *j*. At the same time a partial vacuum is produced in *g* that causes the water in *c* to immediately flow into *g* and start a siphonage of the trough. The water coming from the inlet *i* pushes all solids toward the outlet. The tubes *j*, *j* cleanse the sides of the trough. When the siphonage stops, the trap *d* retains its seal and the trough is refilled from the tank to about the level shown.

LATRINES

52. Latrines are a series of strong stoneware or cast-iron pans or closet bowls, usually porcelain-lined, connected at

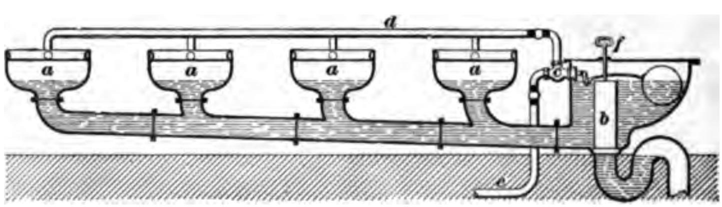


FIG. 30

their bottom by a large pipe that forms part of them and that has a gentle fall to the outlet end.

Fig. 30 shows a form that is flushed by hand. The bowls *a*, *a*, etc. are furnished with flushing rims. A plunger *b*, which also acts as an overflow, is seated water-tight in the plunger chamber. There are many different ways of flushing the bowls. The one shown is similar in principle to the method of flushing the plunger closet in Figs. 2 and 3. The valve *c* is opened or closed by the ball float falling or rising with the water in the plunger chamber, which, of course, corresponds with the water-line of the closet bowls. The branches that connect to the flushing rims of the bowls are smaller than the main flush pipe *d*. Latrines, although superior to trough closets, are not very desirable fixtures. In this particular style, the entire row must be flushed in order to cleanse any one bowl. A more sanitary arrangement can be obtained by simply using individual closets separately trapped and flushed from separate tanks overhead. Probably the greatest objection to the latrine shown here is that, should a partial vacuum be formed in the supply pipe *e*, foul air in the closet bowls may be sucked into *e* when the plunger *b* is raised and thereby contaminate the water supply to other outlets. If the latrines are arranged to be flushed from a large tank overhead, this danger will be overcome.

Latrines are used chiefly in public places, schools, railroad stations, factories, barracks, etc., and are usually under the control of a janitor.

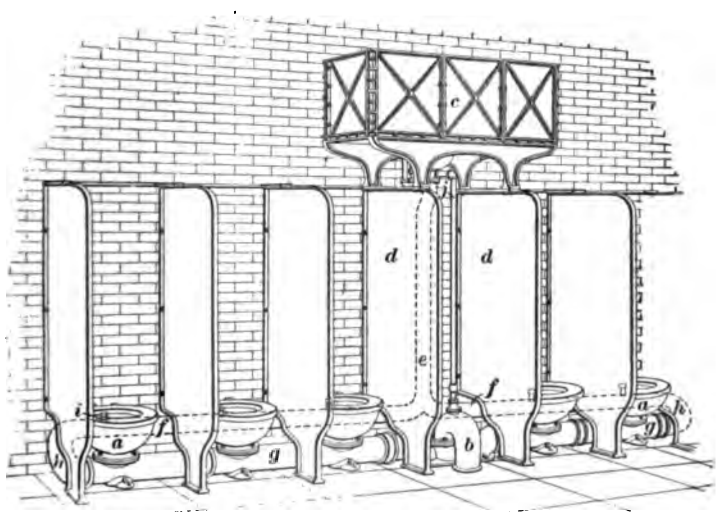


FIG. 31

53. Fig. 31 shows a set of modern automatic latrines fitted up complete. It is composed of a number of enameled cast-iron bowls *a*, *a*, etc., each furnished with a flushing rim. A double-trap pneumatic siphon arrangement similar to that shown in Fig. 29 is located at *b*. The cast-iron flushing tank *c* operates automatically, and is supported on the partitions *d*, *d*. The flush pipe branches off at its base with a twin elbow, shown by dotted lines at *e*. This splits the flush and diverts it equally to the two horizontal pipes *f*, *f*. Branches are taken from these pipes, as shown by dotted lines, to flush the bowls, and the extreme end of each pipe *f* returns and joins the higher ends of the trunk lines *g*, *g*, as shown at *h*. The return bends *h*, *h* thus flush *g*, *g*, while the smaller branches *i* flush the bowls. The air pipe *j* connects to the top of the flush pipe and acts the same as *e* in Fig. 29.

54. The dimensions best adapted to latrine stalls for schools are about 2 feet between stalls; 16 inches to top of seat; 5 feet to 5 feet 6 inches from floor to top of partitions; about 8 feet from the floor to the top of the tank; diameter of outlet, 5 inches.

55. When a set consists of 5 latrines or less, the outlet section is placed at the end. When it consists of more than 5 and up to 10 latrines, the outlet section is placed in the center, as shown. When it is desired to have more than 10 latrines in a battery, they should be set back to back in the middle of the floor This will allow 20 latrines in one battery, which are supplied from one tank over the center.

WATER-CLOSET STALLS

56. Water-closet stalls, or **closet apartments,** are usually constructed with marble partitions, nickel-plated brass fastenings, and special doors. The walls against which the closets are set are generally covered with glazed tiles, slate, or marble slabs, and the floors of the stalls are commonly of the same material. The stalls are generally arranged side by side against one of the walls of the toilet room in which they are located.

57. Fig. 32 shows marble or slate stalls in which water closets *a*, *a*, *a*, are located. These closets are flushed by tanks *b*, *b*, *b*. The stall partitions *c*, *c*, *c* and stiles *d*, *d*, *d* are

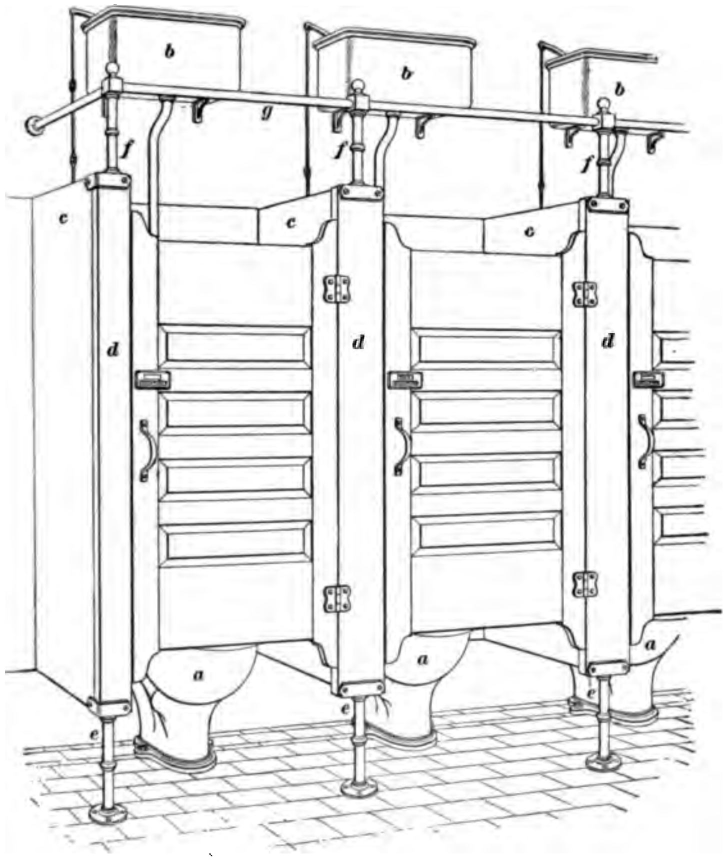


FIG. 32

separate slabs supported on nickel-plated brass legs, or standards, *e*, *e*, *e*. They are braced on top by nickel-plated brass pillars *f*, *f*, *f* and a pipe railing *g*. The dimensions of each stall are about 3 feet 6 inches wide; 5 feet 8 inches from front to rear, and 6 feet 6 inches high. These dimensions are not arbitrary, for the stalls can be made any size. The rear ends of the partitions are let into the wall about 1½ or 2 inches for support and secured with nickel-plated brass brackets. The doors are usually hinged to the stiles with spring hinges. The only locking attachment required is a bolt inside, and it is advisable that the lock be so constructed that when closed a sign will be moved on the front of the door to indicate whether the stall is occupied or not. The thickness of the marble should be at least 1¼ inches, which, if the marble is good, is sufficiently strong for ordinary service. The partitions and doors should never extend to the floor. There should be a clear space of about 1 foot for ventilation and for convenience in scrubbing the floor.

58. Fig. 33 (*a*) shows a good form of corner standard, and Fig. 33 (*b*) a common intermediate standard to sup-

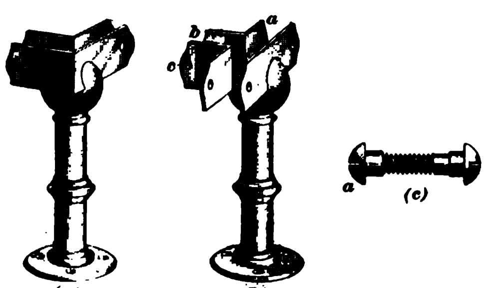


FIG. 33

port a stile with the recess *a* and a partition with the recess *b*. After the slabs are set in their respective places, holes are drilled through them to match the holes *c* in the standards and other fixings; then screw bolts, similar to that shown in Fig. 33 (*c*), are used. The part *a* is the nut. It is tapped to fit the bolt and has a half-round head with a slot in it. This makes a very neat bolt and nut for marble work.

WATER-CLOSET DETAILS

WATER-CLOSET SEATS

WALL-ATTACHED SEATS

59. Water-closet seats are given many forms, but very few of them have a proper shape. Several state boards of health have settled on the shape shown in Fig. 34 as the best form, and recommend its general use. They say: "The hole in the seat should be long from front to back, but narrow from side to side. It should never be made circular, as carpenters will do unless otherwise instructed. The proper dimensions are 11 inches by 4 inches. The edges should be moderately beveled. This shape will make the act of relief much easier and tend greatly to prevent that painful disease, hemorrhoids."

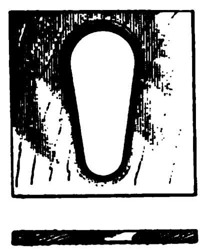


FIG. 34

60. Fig. 35 shows a **wall-attached seat** *a*, cover *b*, and back *c*. A bracket *d* is screwed to the under side of the strip *e* near each end. The brackets are then screwed to the wall at such a height that the seat will be level when it rests on the closet, and in such a position that the center of the seat will be over the center of the closet. A notch is cut in the middle of *e*, to allow space for the flush pipe *f*. The back *c* is hollow, being in the form of a box. A neat hole is cut on top of *c* to fit the flush pipe. This makes a strong seat that is independent of the closet. Being rigidly secured to the wall, the closet cannot be shaken and the floor joint consequently loosened by an ordinary use of the closet; this is an advantage. But, a disadvantage that is greater than the advantage condemns this attachment from a sanitary standpoint. There is too much woodwork in this seat to

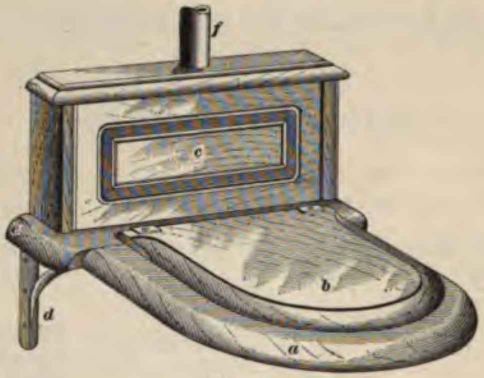


FIG. 35

become foul, and the space behind *c* is a lodging place for filth and vermin. The back *c* only makes a neat finish at the base of the flush pipe.

61. A more sanitary form of wall-attached seat is shown in Fig. 36. The seat is hinged to brackets *a*, *a* that are

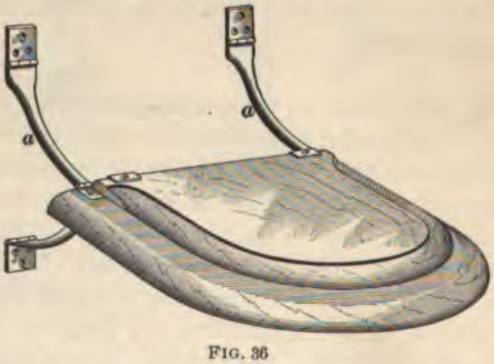


FIG. 36

rigidly screwed to the wall. This construction has a minimum amount of woodwork. The cover may or may not be used.

For public places, it is advisable to omit the cover and use only the plain seat. Covers are useful in private bathrooms, because they allow the closet to be used as a chair.

CLOSET-ATTACHED SEATS

62. A **closet-attached seat** of the common form is shown in plan in Fig. 37. It is made of hardwood, generally

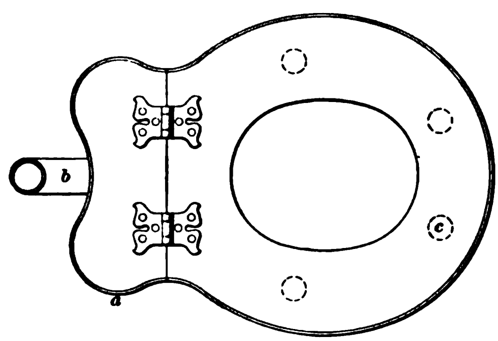


FIG. 37

oak, ash, walnut, or mahogany. The distance from the wall to the front of a closet seat varies, but is usually somewhere between 22 and 24 inches.

In Fig. 37, the back part *a* is firmly bolted to the closet, and the front part is hinged to the back part; the flush pipe *b* comes up between the closet and wall. The common form of hole in the seat is shown by this illustration; the objection to this form is that it proves uncomfortable for many people.

3. A **dished-out closet seat** is shown in Fig. 38. The dimensions are taken from one of the best and most comfortable closet seats made. The upper surface of the seat is

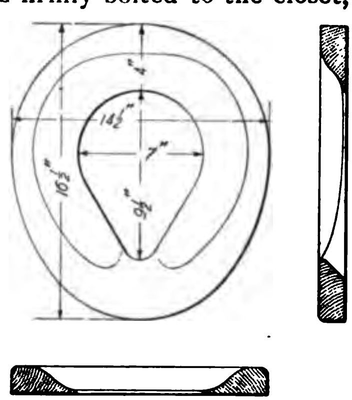


FIG. 38

nicely countersunk, or dished out. The sectional views are shown projected from the plan so that an accurate idea of the curves may be obtained.

64. Closet seats should be so made, and the grain of the wood so arranged, that the wood will not warp, sliver, or fall to pieces. Quartered oak in two or three layers crossed, or in one piece with dowels and cross-strips, seems to be the best material.

SEAT BUFFERS

65. **Seat buffers** are small cushions of rubber used to prevent the seat from striking the porcelain rim of the closet and also to prevent the cover from scratching the seat. Four buffers, or **buttons**, as they are sometimes called, should be attached to the under side of the seat, and four to the under side of the cover. A buffer should also be attached to the flush pipe if the seat or cover folds back against it. The proper location for buffers is shown by dotted circles, as *c*, in Fig. 37. A buffer *i* on a flush-pipe strap is shown in Fig. 17. Fig. 39 shows a good form of buffer. The shank is let into a hole bored in the wood, and a $\frac{3}{4}$-inch brass screw holds the buffer in its place. The head of the screw must be set well into the rubber, to prevent its striking the porcelain when the rubber is compressed.

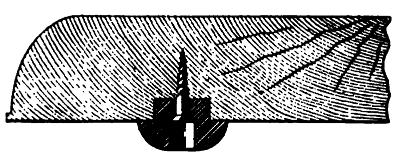


FIG. 39

WATER-CLOSET CONNECTIONS

BACK-VENT CONNECTIONS

66. Owing to the fact that rigid connections to porcelain closets invariably break the porcelain, all leading health departments forbid back-venting closets from the porcelain. Fig. 40 shows how the **back-vent connections** are usually made. A 2-inch back-vent pipe *a* is wiped to the inner curve of the 4-inch lead bend *b*, as shown. The horizontal part of the vent pipe is inclined, so that any water backed up into it may drain out into *b*. The conical top *c* on the

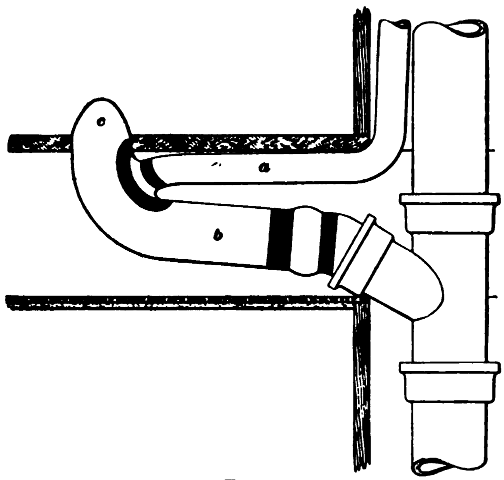


FIG. 40

bend shows how the open end above the floor is drawn in with the dresser; it is then soldered tight, so that it may successfully resist the pressure of a water test.

SOIL-PIPE CONNECTIONS

67. The **soil-pipe connection,** that is, the joint between the outlet of the water closet, or trap, and the soil pipe where it passes through the floor, as at *c*, in Fig. 40, is a matter of great importance. The common joint, which is made with putty, the porcelain flange being secured to the floor by screws, is rarely air-tight or gas-tight, although it may not leak water.

68. Porcelain closets are commonly attached by means of a brass **floor-plate joint,** as shown in Fig. 41. The soil-pipe branch *a*, if of lead, is soldered to a brass flange *b*, which is secured to the floor. A rubber gasket *c* is put between the flanges, and the porcelain closet flange *d* is screwed down on it by three or four screws or bolts, which should be of substantial size and be provided with washers, as at *c*.

The porcelain flange has but little strength and is easily broken; therefore, great care should be taken in screwing up the joint to avoid breakage.

Sometimes the lead pipe is flanged over on the floor and the porcelain flange is set on it with a bedding of putty. Such a joint will not remain gas-tight; it is worthless, and should not be allowed. The best plan is to have only the

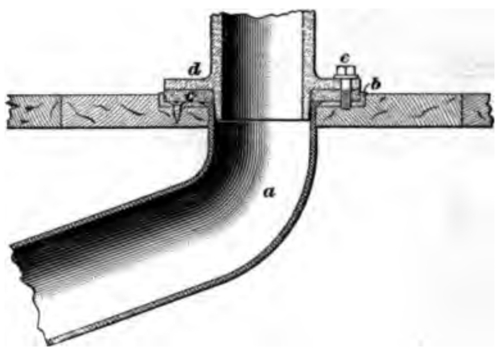
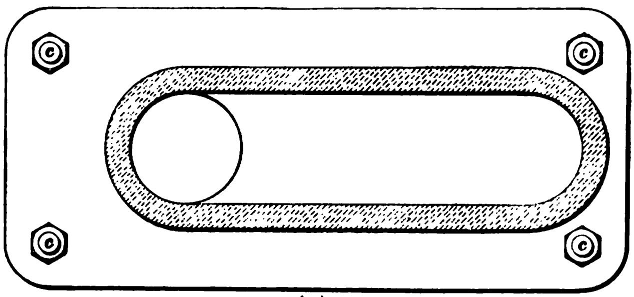


FIG. 41

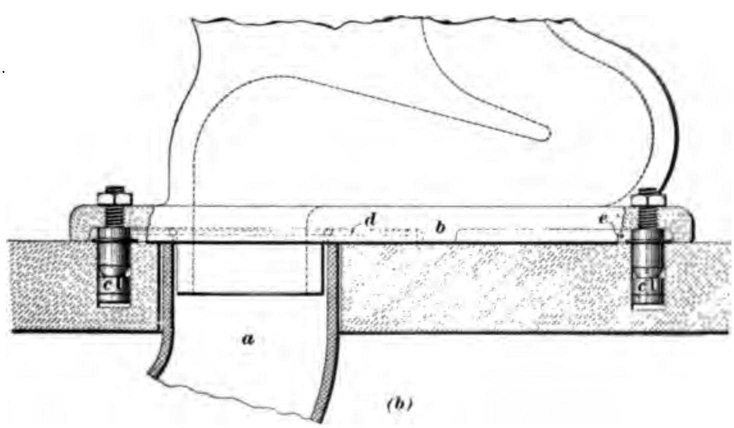
bowl made of porcelain, and to have the trap made of iron porcelain-lined or of other metal; this can then be calked into the hub of the soil pipe and a secure joint made.

The joint between porcelain and metal, which every porcelain fixture must have, should be on the house side of the seal of the trap. Joints between metal and porcelain are weak and unreliable, and should not be subjected to sewer gas. The porcelain flange shown in Fig. 41 is weak and liable to be broken if the closet receives a jar or rough usage. A closet with a strong broad base should, therefore, be selected.

69. Fig. 42 (*a*) shows in plan, and Fig. 42 (*b*) in section, a strong and secure method of setting a porcelain water closet on a marble slab. The top of the lead bend ***a*** is soldered to a brass floor flange *b*. The closet is then set temporarily and the holes are marked on the marble for the expansion bolts *c*, *c*, etc., which are located at each corner of the closet base, as shown in the plan. The closet is then removed, and the four bolt holes are drilled in the marble. The expansion bolts are next secured in position, and the



(a)



(b)

FIG. 42

closet is set permanently, a soft rubber gasket being employed, as shown at *d*, to make the joint gas-tight, and plaster of Paris, or, better still, Keene's cement, being used to fill the space *e* and thereby cement the base solid to the marble. If a porcelain closet is set in this manner, there will be no danger of the gasket joint leaking by the closet being jarred, or of horns being broken from the same cause.

70. The ordinary brass-bolted floor flange makes a good connection, but if it should ever become imperfect there is no suitable means of knowing the fact without applying a smoke test. Closet connections are the weakest points of a drainage system, and are often dangerously defective. They, therefore, require thoughtful consideration as well as very careful work in making them.

71. One of the best floor connections is shown in Fig. 43. This is a **water-sealed floor connection.** The pipe *a* is continued 1¼ inches above the finished floor, the end being rounded and free from burrs. The floor is countersunk to receive a supporting flange *b*, which is attached to the pipe. A brass flange *c* compresses the rubber gasket *d* against the porcelain when the bolts *e* are drawn up; an annular space is thus formed around the neck of the pipe *a*, which fills with water at the first operation of the closet, thus sealing the connection. If the connection leaks, this water will run out on the floor; if it does not, gas cannot escape. This connection, therefore, is self-testing.

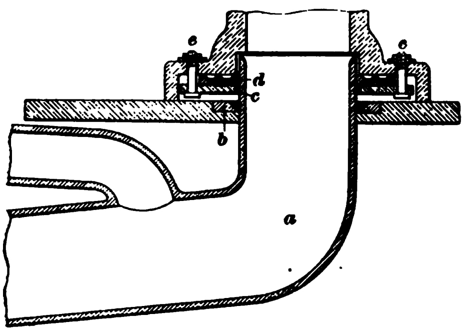


FIG. 43

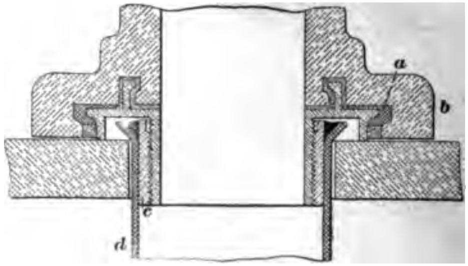


FIG. 44

72. A **threaded floor connection** is shown in section in Fig. 44. It is calked with lead at *a* and cemented into the base *b* of the closet by the manufacturer. The joint thus formed makes the brass connection equivalent to an integral part of the closet, and the porcelain is liable to break before this connection loosens. The chief advantage of this connection is its metal-to-metal bearing, which avoids the use of rubber or other gaskets.

The brass coupling, or brass ring *c*, which is threaded inside, is wiped to the lead bend *d* in such a manner that when the closet is screwed down it will sit flat on the floor and be in its exact position when the thread is screwed up tight; otherwise, the bend will be twisted in making the last turn of the closet. Lugs may be formed on the bend and secured to the floor by screws, if desired, to positively prevent the bend from being twisted.

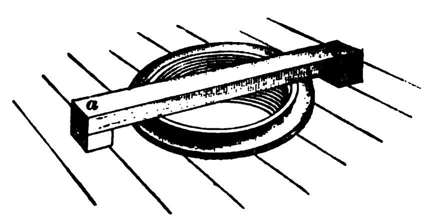


FIG. 45

73. Great care must be taken to have the face of the ring parallel with the plane of the floor; therefore, the use of a gauge, as shown at *a* in Fig. 45, is advised. The ring should be screwed up on the closet first by hand, and the front marked so that it will not be soldered in wrong.

FLUSH-PIPE CONNECTIONS

74. The **flush-pipe connection,** that is, the connection between the inlet horn and the flushing pipe, is commonly made in the older forms of closets by a screw coupling, as shown in Fig. 46. The brass nipple *a* is sometimes put in place before the porcelain is baked, and it becomes loose during the baking process. To tighten it, a locknut *b* and a rubber gasket *c* are used, as shown. This joint is rigid. If the flush pipe *d* is rigidly attached to the walls, and there is any settlement of the building after the attachment to the closet is made, or if the closet is jarred much, a great strain is brought on the coupling, which frequently breaks off the horn at *e*, *e*.

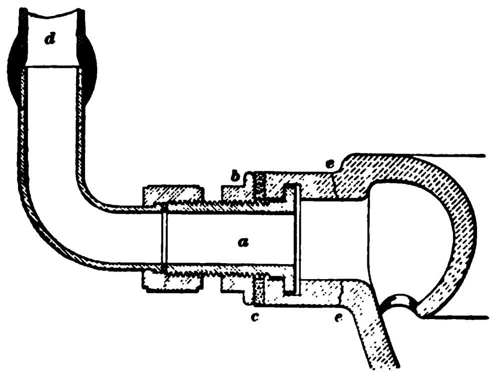


FIG. 46

75. Another way to make the connection is shown in Fig. 47. A rubber collar *a* is molded to fit the outside of the horn and the flush pipe *b*. It is secured to both by winding with copper wire at *c* and *d*. If the rubber is of good quality, this joint will be durable and will accommodate itself to any ordinary settlement of the building or jarring of the fixture.

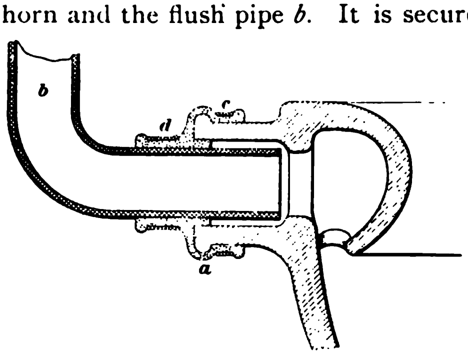


FIG. 47

Should there be danger of an extraordinary settlement, the flush pipe *b* should be connected to the horn by a rubber elbow or bend. It has been found, however, that this attachment is not durable.

76. Brass flush-pipe connections to closet horns should be made with a slip joint, as at *f* in Fig. 17. This form of joint has proved to be quite reliable for ordinarily well-constructed buildings. The strongest and presumably best form of connection, however, is that in which the flush pipe *a* enters the top of the porcelain, as in Fig. 48. A

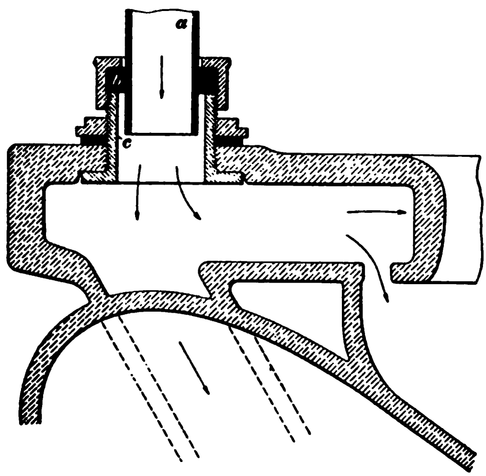


FIG. 48

thick soft-rubber gasket *b* is pressed against the flush pipe and the shoulder of the brass casting *c*, which makes the joint water-tight. The flush pipe, however, has freedom to move without affecting the strength or tightness of the joint. This form of flush-pipe connection is recommended.

FLUSHING TANKS

INTRODUCTION

77. Classification.—A **flushing tank** is a tank or cistern intended to contain or store water for the purpose of flushing, i. e., washing out water closets, urinals, slop sinks, drains, sewers, etc. A flushing tank is therefore intermittent in its action; that is to say, its contents are discharged at intervals. There are two general classes of flushing tanks: (1) that class whose discharging depends on the action of some person who may operate either a chain pull, move the closet seat, a floor treadle, a door, or some other device. The discharges from such a tank, which is called **a non-automatic flushing tank,** are irregular, according to the usage of the fixture to be flushed; (2) that class whose discharging depends on the action of the water flowing into or from the tank. This kind is automatic, discharging without the aid of any person; the discharge is at regular intervals, if the volume of the supply to the tank does not change. A tank of this class is called an **automatic flushing tank.**

78. The mechanism employed in operating flushing tanks is varied, each tank manufacturer having his own special combination of valves and levers, which is usually protected by letters patent.

79. Purpose of Flushing Apparatus.—The purpose of a flushing apparatus is to thoroughly detach and remove all excreta, etc. from a water-closet bowl, etc., and drive it through and beyond the trap. If the excreta can be driven out of the water-closet branch into the main soil pipe or main drain, it should be done, provided the water is abundant and not expensive; but it should invariably be driven out of the trap. A small stream of water, as from a ½-inch pipe, although it may have a high pressure and be spread out by means of a fan or deflector, will not clean the bowl and remove solids from the bowl and trap as well as an equivalent volume of water that is delivered with a rush through 1¼-inch pipe and is spread out by means of a flushing rim. The small stream of water will frequently fail to make the solid matter, paper, etc. dive under the lip or bend of the trap, but the larger stream causes a rush of water that drives it through very effectively.

The efficiency of a flushing apparatus can be readily tested by coloring the water in the closet bowl with ink, throwing in some pieces of crumpled paper, and then starting the apparatus. The flush may be considered satisfactory if no trace of ink or paper remains in the bowl, and if the trap and basin contain a proper quantity of clean water after the flush is over.

To secure a proper flush, a flushing tank should contain from 4 to 6 gallons of water, and it should be elevated at least 6 feet above the water-closet bowl.

NON-AUTOMATIC FLUSHING TANKS

80. Plain Flushing Tank.—A common kind of flushing tank is shown in Fig. 49. The valve *a* is pulled open by

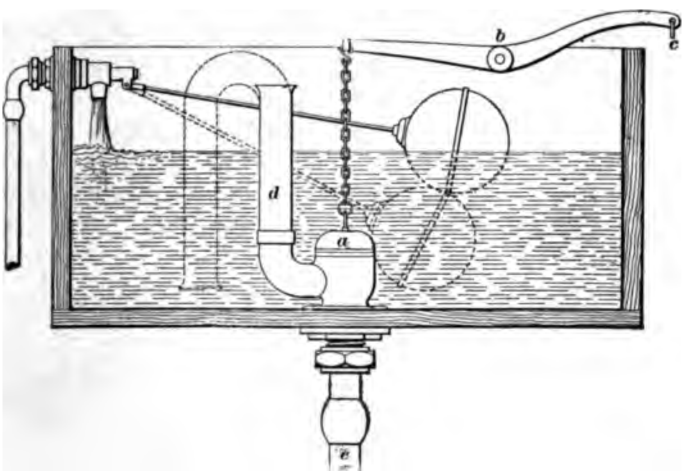


FIG. 49

means of the lever *b* and hand chain attached at *c*. The overflow *d* opens into the flush pipe *e* beneath the seat of the valve. The water rushes down the flush pipe only while the valve *a* is held open.

The amount of water sent down may be too little to do the work properly, or the water may be wasted by holding the valve open longer than is necessary. The former trouble is most likely to occur, because very few people consider the amount of water that should be delivered in a flush when they pull the chain.

81. Siphon Flushing Tank.—To remedy the defect mentioned in the preceding article, the **siphon tank** is used, which derives its name from the fact that it is emptied by siphonage. The construction of a siphon valve is shown in Fig. 50. It consists of an inner tube *a* and outer tube *b*, which are united at the top by an air-tight cap *c*. The inner tube is provided with a rubber ring *d*, which forms the valve, and is seated on the seat ring *e*. The two tubes thus form a siphon, the inner tube being the long leg. It is started into operation by lifting the valve off its seat. The water rushes down the flush pipe and draws the air out of *a* and quickly fills both *a* and *b* with water. The valve is dropped back to its seat, and the discharge continues through *a* and *b* until the level of the water falls below the lower end of *b*. Thus, if the valve be opened only a moment, or long enough to start the siphon, the tank will empty to the same point, and the same amount of water will be delivered on every occasion.

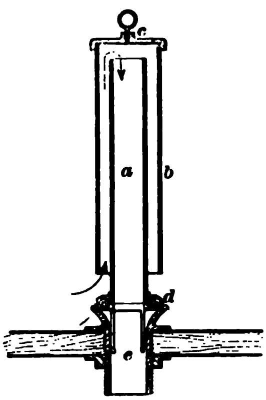


FIG. 50

The device shown in Fig. 49 can be easily modified to accomplish the same result. The overflow pipe *d* may be prolonged and bent over, as shown by the dotted lines, thus forming a siphon.

82. Service-Box Tank.—A kind of flush tank, known as a **service-box tank**, is employed either to furnish a large flush first and a smaller one immediately after, or in some other way to allow a certain volume of water to fall into the bowl and thereby refill the same after the tank valve is closed. A service-box tank, or, as some people call it, an **after-flush tank**, is shown in Fig. 51. The tank is divided into upper and lower chambers *a* and *b*. The valve *c* is made about 4 inches in diameter, and when it is opened it passes water much faster than the flush pipe *d* can discharge it. The surplus fills the chamber, or **service box,** *b*. When *c* is closed the large flush ceases and the light flow continues until the chamber *b* is emptied. The

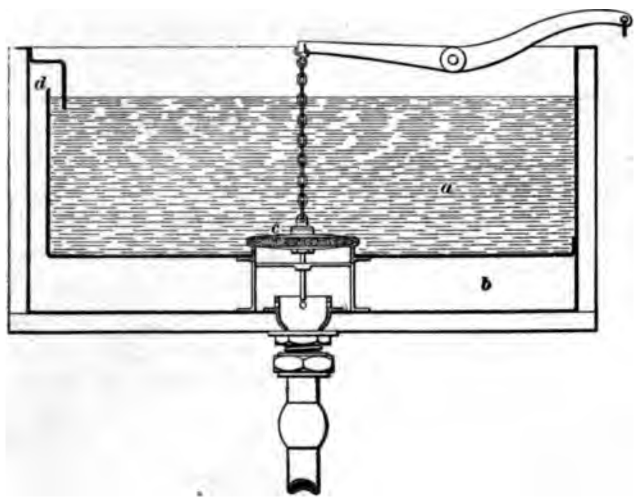


FIG. 51

overflow for the chamber *a* is at *d*. This tank may be made large enough to contain any desired number of flushes, while the ordinary siphon tank contains only one flush.

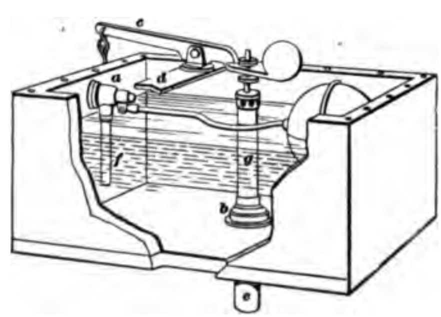


FIG. 52

83. Flushing Cisterns.—Fig. 52 shows a **plain valve cistern** commonly used for wash-down closets and hoppers. Its dimensions are about 23 in. × 12 in. × 10 in. It is provided with a ball-cock *a* and an outlet valve *b*, which is operated by a lever *c* bolted to a cross-bar *d*, the lever being worked by a chain pull. The flush pipe is shown at *e*. A deafening pipe *f* deadens the noise of the incoming water. The tube *g* forms an overflow that discharges into the flush pipe *e*. The volume of flush from this tank is irregular, depending on the time the valve *b* is held up.

84. Fig. 53 shows a **siphon cistern** particularly adapted for washout closets as well as wash downs and hoppers. Its dimensions are about 19 in. × 9 in. × 10 in. A momentary retention of the pull opens the valve *a* and starts the siphon formed by the shell *b* suspended over, and attached to, an inner standing tube that is secured to the valve, as in Fig. 50. A refilling of the bowl is obtained by a slot cut in the lower end of the siphon tube *b*, which causes the siphon to **break,** that is, to stop working gradually.

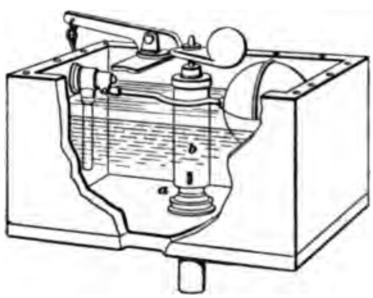


FIG. 53

85. A **refill float-valve cistern** especially suitable for siphon-jet closets and other closets requiring a refilling of the bowl is shown in Fig. 54. When the float *a* is raised, it remains buoyed up until sufficient water has passed through the closet, when it returns gradually to its seat. The pipe *b* serves as an overflow and at the same time insures an abundant refilling of the bowl. These cisterns are remarkably quiet in action. They are made in two sizes.

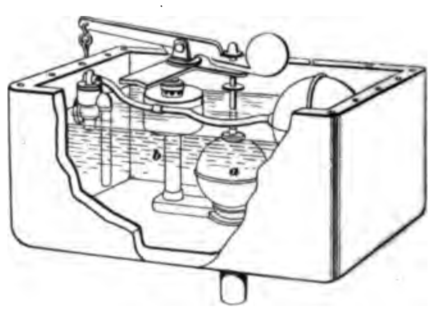


FIG. 54

86. Automatic Operating Devices.— The flushing apparatus is generally operated by means of a chain or lever pulled by hand. It can also be operated automatically by connecting it to a hinged seat or platform that sustains the weight of the person using it. The seat is counterbalanced by means of a spring or weight that holds it up off its bearings. When the seat is in use, it yields an inch or so, and by means of suitable connections to the chain *a*, Fig. 55, it opens the valve *b* and closes the valve *c*. This fills the service box *d* with water from the tank. When not in use, the seat is raised, thus closing the

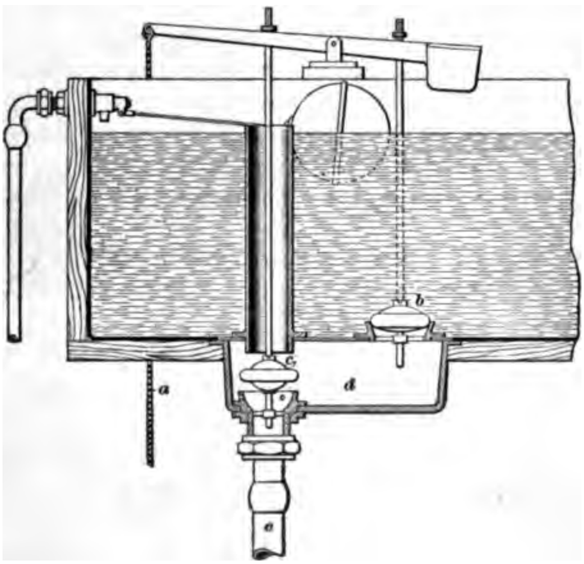


FIG. 55

supply valve *b* and opening the discharge valve *c*, the entire contents of the flushing chamber *d* are then sent quickly down the flush pipe *e*. This device is frequently used in railroad stations and other places where people are liable to go away and neglect flushing the closets. It is especially suitable where a number of closets arranged side by side are flushed from one long storage tank. Each separate flush box *d* should contain about 5 gallons of water when porcelain bowls are used.

When the water-closet space is closed by a door, an attachment may be fitted to the door that will operate the flushing apparatus every time that the door is opened.

87. Points on Installation.—Cisterns with valves away from the edges are preferable, because the wood is liable to warp and cause the locknuts to cut the copper lining.

88. The ordinary valve connection to the bottom of a tank has a leather washer between the brass flange and the copper lining. The locknut under the tank compresses the leather, and makes a temporarily water-tight joint. But, the wood shrinks and the connection is then loosened by the jarring of the valve; this rapidly produces a leak, which, however slight, soon soaks the woodwork of the tank and causes it to warp or tear apart. To avoid this common trouble, every valve flange should be soldered to the lining. If it is necessary to remove them for repairs, the solder can easily be melted with a gasoline torch.

AUTOMATIC FLUSHING TANKS

89. Tilting Tank.—Automatic flushing tanks are constructed in many different ways. They are all designed for automatically flushing urinals, etc. at regular intervals. The form shown in Fig. 56 is called a **tilting tank.** A tank *a* is divided by a partition into two equal chambers. It rocks on an axle *b*, and thus brings either chamber under the supply cock *c*. As the chamber fills, the center of gravity of the tilting tank *a* gradually changes until it passes over the axle *b*, when the tank tilts

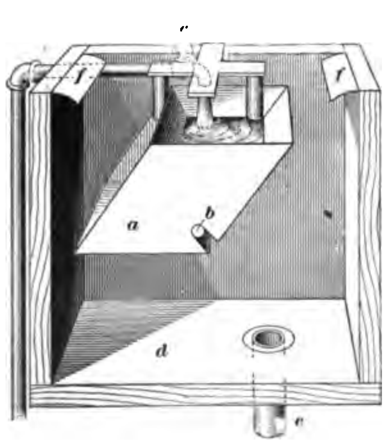


FIG. 56

over, emptying one chamber and bringing the other into position for filling. The water being emptied suddenly, a rapid flow is produced, which is well suited for flushing purposes.

Sheet-metal shields *f*, *f* prevent water from splashing over the sides when the tilting tank *a* is discharged. When a number of urinals or closets are to be flushed from the same tank, it should be deep enough to contain the desired quantity of water, i. e., from 1 to 2 gallons per urinal, and the flush-pipe opening should be provided with a siphon that can be started automatically when enough water is emptied into the receiver.

90. Automatic Siphon Cistern.—A type of automatic flushing tank that is in common use is shown in Fig. 57, and is known by the trade name of **automatic float-valve siphon cistern.** A ½-inch pipe *a* passing up through the bottom of the tank supplies water in a small stream to the tank through a common ground key cock *b* that is regulated to pass the proper quantity of water. The outlet to the tank is composed of a simple annular siphon, like that shown in Fig. 50. The outer siphon tube is surrounded

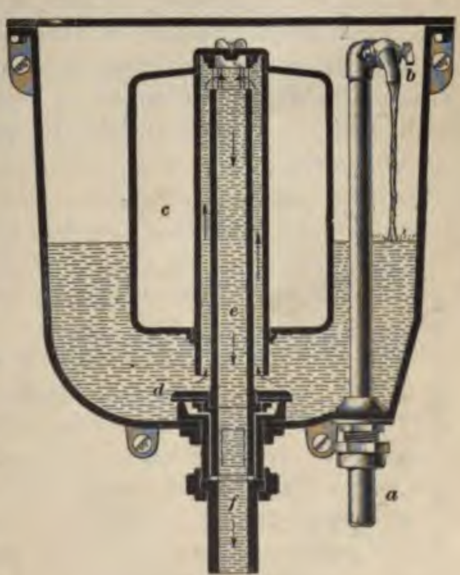


FIG. 57

by and attached to an air-tight chamber *c*. When water enters the tank, it rises slowly, because the valve *d* is closed, and continues to rise until it is about to overflow into the top of the inner tube *c*, when the buoyancy of the float will lift the siphon valve *d* off its seat and as high as it can go. The water in the tank then rushes down the flush pipe *f* to the closets or urinals. The buoyancy of the float holds up the valve until the tank is about half empty, when the siphon valve will fall on its seat and the remaining water will be discharged by siphonage. The valve will remain closed and the tank will refill slowly for another discharge; an automatic action is thus obtained.

91. Conditions Governing the Installation.—Automatic flushing tanks are desirable only when the closets are arranged in ranges or latrines for use of school children or other people that are liable to neglect flushing the closet when they have finished using it. Automatic flushing tanks are desirable for flushing urinals only when the water supply is abundant, as they waste an enormous amount of water; this makes their installation very expensive in many places. Plain overhead tanks with chain pull, or self-closing cocks working on the flushometer principle, are commonly used instead.

HOUSE DRAINS

GRAVITY-DISCHARGE DRAINS

INTRODUCTION

GENERAL DESCRIPTION

1. House drains consist of a system of nearly horizontal piping in the cellar or basement of a building, with the outlet extending through and at least 5 feet beyond the foundation walls, where it connects to the house sewer. The object of house drains is to receive the waste water and other matter discharged from the plumbing fixtures in the building. The house drains also in many cases receive the drain water from the rain leaders, yard drains, and area drains, and in some cases from the subsoil and cellar-floor drains.

In many localities, the house drain is usually placed below the cellar floor, where it is entirely covered and out of the way. When installed in this manner, great care must be exercised in laying the pipe and making the joints, and the system should be thoroughly tested with water before being covered up. Brass clean-out screws should be placed in such a position at suitable intervals that access can be had to the inside of the drain at all times without disturbing the floor or pipes. The laying of a house drain underground is necessary where cellar drains and subsoil drains are required to drain into it by gravity. It is also necessary to lay the house drain underground when laundry tubs are located in the cellars, or where there is no cellar. In some buildings, the house drain is laid in pipe ducts built for such purpose.

The top of the pipe duct is then covered with flagstone or iron covers that can be easily removed for inspection or repairs. In many cases, the house drain is placed above the cellar floor, where it is at all times open to inspection and repairs. In buildings where the cellar or basement is below the sewer line, this method must be employed in order to obtain a gravity discharge. When the house drain is located above the cellar floor, great care must be taken to securely fasten it, to prevent settlement or sagging, as any settlement in a nearly horizontal drain would cause a pocket in the pipes, which would remain partly filled with water that deposits sediment and thus tends to obstruct the drain. Suitable clean-out plugs of brass should be used in the exposed drains, the same as in the concealed drains, to facilitate cleaning. In cold climates, where the basement is exposed to extreme cold, care should be taken to protect the drain from freezing. In buildings where the house drain is above the cellar floor and it is necessary to drain the cellar or subsoil, the water must first be conducted to a suitable basin or receptacle from which it is raised by a pump or ejector to a properly connected sink or drain. All drain pipes, whether above or below the cellar floor, should be run straight and true, at a uniform inclination from the horizontal, or **fall** or **pitch**, as it is often called, of not less than ¼ inch to the foot. All branches and connections should be made with suitable fittings. Where it is necessary to pass through walls or partitions, openings should be made large enough to allow of settlement of the building without injury to the drains. In no case should tile pipes be used for a house drain, because they will not remain gas-tight.

DIVISION AND NOMENCLATURE

2. House drains may be divided into two classes, namely, *gravity-discharge drains* and *mechanical-discharge drains*. The former class includes all systems of drainage, whether subsoil drains, cellar drains, house drains, or surface-water drains, where the drainage water flows naturally, and hence without mechanical means, that is, by gravity, to its proper outlet. In other words, the drains are located above the level of the sewer or other point of disposal.

Mechanical-discharge drains consist of gravity systems of drainage connected to a receiving tank that is located at a lower level than the street sewer, and from which tank the sewage is raised to the sewer by means of pumps or compressed-air ejectors.

3. To illustrate a house-drainage system, and make clear the names of the different parts, Fig. 1 is given. The rain-water leaders are shown at *a* and *b*; they connect with the

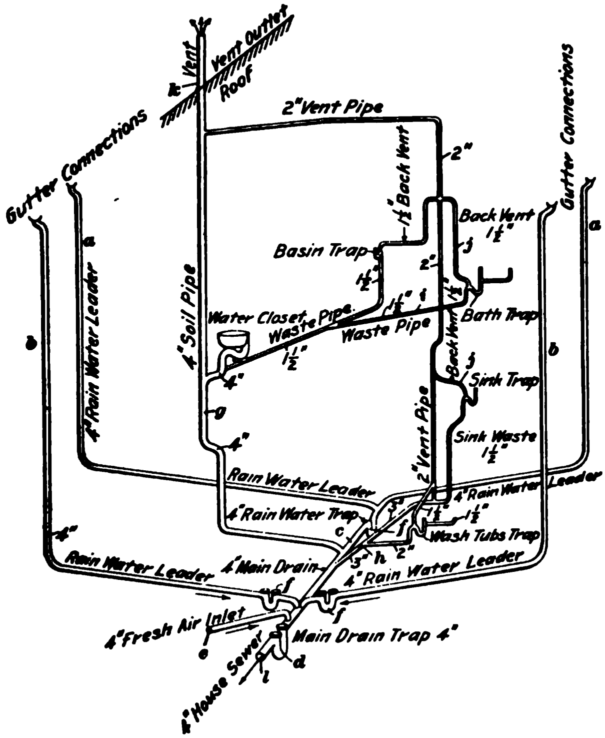


FIG. 1

house drain *c*. The main drain trap is located at *d*, the fresh-air inlet at *e*, and the leader traps at *f*, *f*. A line of soil pipe extending from the house drain up to and through the roof is shown at *g*. A waste pipe *h* takes the discharge from the laundry tubs and kitchen sink. The waste pipe from the bath-tub and wash basin is shown at *i*. Back-vent pipes are shown at *j*, *j*, which connect with the vent stack *k*. The house sewer is shown at *l*.

GENERAL PRINCIPLES OF HOUSE DRAINAGE

4. Objects and Requirements.—The object of a drainage system is to remove from a building to a sewer, cesspool, or other receptacle, all waste matter, such as soiled water, human excreta, urine, slops, etc., without permitting foul air to enter the building.

A perfect drainage system: (1) must drain perfectly toward its natural outlet, thereby carrying away and discharging into the house sewer all matter received by it; (2) must be perfectly gas-tight and water-tight to prevent damage to health or property by leakage; (3) must be properly trapped and ventilated to prevent foul air passing into the building; (4) should be constructed of suitable materials that will not crack or break on sudden changes of temperature; (5) should have joints as strong as the pipes themselves; (6) should be run straight and true, with a uniform fall, and should be securely fastened to prevent settling or swinging, and so supported as to prevent severe stresses on the connections; (7) must be large enough in all its parts to easily carry off all drainage, but not so large as not to be self-cleansing.

The flow of sewage in all drain, soil, and waste pipes in a system should be in the same general direction—toward their common outlet. When sewage flows into a pipe from a branch, it should enter at such an angle as not to interrupt or check the flow of sewage in the pipe into which it enters, but flow in harmony with it.

5. Ventilation of Drainage System.—The object of ventilation in a system of drainage is to keep the air within the pipes circulating, in through the fresh-air inlet and out through the vents above the roof, so as to remove all foul air caused by the decomposition of solids within the pipes, and to prevent unequal air pressures within the system, which would force the water seals out of the traps. This is accomplished in the first case by extending all main lines of soil or waste pipes up to and through the roof and placing a fresh-air inlet on the house side of the main drain trap. To prevent the water being forced from the traps under fixtures, one end of an equalizing pipe, called a **back-vent,** is joined to the crown of each trap, the other end being joined to a vent pipe or vent stack, which extends above the roof. By this arrangement, fresh air enters the base of the system, rises through each pipe, and is discharged by gravity above the roof.

Drain air is the air inside of the drainage system that has become vitiated by the decomposition of animal and vegetable matter within the drainage system. In a perfect system of drainage and ventilation, this foul air is constantly passing out of the system to the open air, being replaced by fresh air from the fresh-air inlets that are always supplied for that purpose. When the air outdoors is colder than the air in the house drains, the column of air in a line of pipe extending from the cellar to the roof of a building becomes warmer than a corresponding column of air outside of the building. This causes the air in the pipe to ascend and its place to be filled by air coming through the fresh-air inlet. Thus, in Fig. 1, the 4-inch soil pipe contains a column of drain air, which, as it becomes warmer, passes up and out of the opening above the roof, while air flows in through the 4-inch fresh-air inlet and through the house drain to replace it. The humidity of the air in vent stacks also aids circulation, even when the outside air is warmer than that in the building. Of course, there is not always a positive current of air flowing in the way just described. Sometimes the air is forced down the soil stack through the house drain and out of the fresh-air inlet. This can be caused by either a large flush of water being discharged into the soil pipe, filling the pipe like a plunger and forcing the air before it, or by down drafts caused by gusts of wind blowing into the mouth of the soil stack, in which case foul air will blow from the mouth of the fresh-air inlet.

DETAILS OF HOUSE DRAINAGE

MAIN DRAIN TRAPS

6. Running Traps.—There are many designs and kinds of traps for house drains, among which is the **plain running trap** shown in Fig. 2, in which *a* is the inlet end and *b*, the outlet end of the trap, while *c* shows the dip in the trap that forms the seal. The shaded portion *d* shows water, which, by settling in the dip or bend *c*, forms an effectual seal that prevents drafts of air passing from the street sewer through the house sewer into the drainage system within the house, and yet permits sewage to pass freely through to the house sewer beyond. This is the simplest design of trap, and, with some modifications, the one best suited to the purpose of a main drain trap.

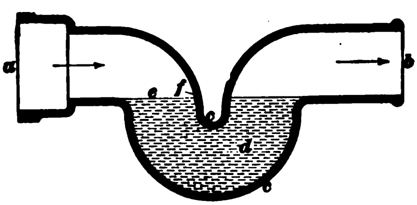
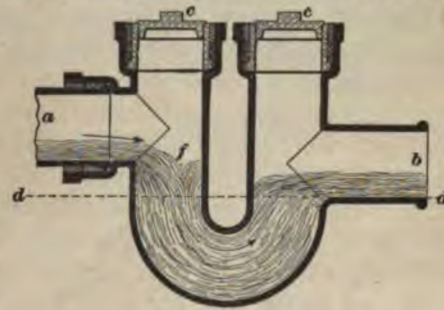


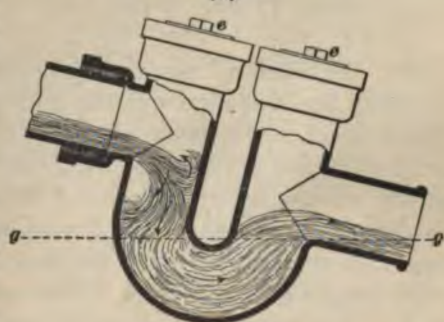
FIG. 2

7. In using the trap shown in Fig. 2, it was found that grease would float on the surface of the water at *e*, which grease being pushed by the flowing water to the wall of the trap at *f*, would adhere to it, gathering lint, paper, burnt matches, etc., until it finally choked the trap. This led to two changes being made in the construction of running traps, which are shown in Fig. 3, and which will be considered separately. It was discovered early in the history of modern plumbing that the place in a house drain most liable to stoppage was in the house trap; this naturally led to the practice of putting **clean-out openings** at suitable places in the house trap, which would permit cleaning the trap without disturbing the pipe. Fig. 3 (*a*) shows such a trap, in which *a* is the inlet, or house end of the trap, and *b*, the outlet, or street end; two hubs have brass clean-outs *c*, *c* calked into them. In case of stoppage at the trap, all that is necessary is to unscrew the brass plugs and remove the obstruction.

8. To prevent the collection of grease at *f*, Fig. 2, and also make the house trap self-cleansing, the outlet end of a house-drain trap should be made slightly lower than the inlet end. In Fig. 3 (*a*) the dotted line *d d* shows the water-line of the trap when no water is flowing through it. The water entering the end *a* falls in a cascade on paper or other floating matter on the surface of the water at *f*, thus forcing it under the dip of the trap into the house sewer. In setting the main trap, great care must be taken to set it level, so that the seal will be perfect. The correct position is shown in Fig. 3 (*a*). The drop in the inlet is such that the raising of the water-line due to the flow of the sewage does not affect the current in flowing from the house drain. Should the trap be tipped up at the inlet, as shown in Fig. 3 (*b*),



(*a*)



(*b*)

(*c*)

Fig. 3

the water will assume the position, or level, shown by the line *g g*, which will so reduce the seal that a slight pressure will force it. Should the trap be tipped backwards, so that the inlet end will be lowered and the outlet end raised, the water will assume the position shown by the line *h h*, Fig. 3 (*c*), when no water is flowing through the trap, which will so increase the depth of water in the seal of the trap that light floating matter cannot easily be washed under the dip and will remain floating on the inlet side, as shown at *i*, until a large flush of water will finally wash it under. It will also to a great extent defeat the object of making the main house trap with a lower outlet than inlet, as by raising the water to *h*, it will be on a level with the inlet pipe and water will not enter with a fall, as occurs when set as shown in Fig. 3 (*a*).

9. The object of a main house trap is to prevent foul air entering the drainage system within a building from the house sewer, street sewer, or other receptacle. The importance of thus disconnecting the house drains from the street sewers cannot be overestimated when it is considered that conditions existing in any house within a given district might become common to the drainage systems of all the other houses in that district if it were not for the main house traps. For instance, if an infectious disease breaks out in a house that is connected with the street sewer, infected matter may be carried through the drainage system of that house into the street sewer. If house traps are omitted, the infected matter may enter the drainage system of every house in the vicinity. If there should be any leaks in the drains, the infected sewer air may escape into the building, and may be a means of contagion. Independent of this, however, remains the fact that sewer gas from street mains is more poisonous than ordinary drain air, and a leak of sewer gas will vitiate the air in a building considerably more than ordinary drain air from the same leak. Besides, sewer gas is more corrosive than drain air on the metals of which a drainage system is composed.

The main drain trap should be placed as close to the wall where the drain enters the building as circumstances will permit. It should be the second fitting placed on the house drain, inside the cellar wall, and should be made of some strong metallic substance, such as iron, brass, or copper. Tile or earthenware traps should never be used inside a building.

10. Backwater Traps.—In localities where the sewer outlet is in tide water below the high-water level, it is necessary to use a *backwater valve*, also called a *tide-water trap*, to prevent the tide water backing up and filling the drain to high-water level. This is also necessary where the street sewers are so small that during heavy storms rain water backs up in the house drain from the overflowing sewers. If the building is located at a great distance from the sewer or tide-water outlet, the backwater valve should be located on the house sewer as far away from the house as possible. If the distance from the building to the outlet is short, the backwater valve may be located just outside of the main drain trap and where it will be accessible for cleaning and repairs.

11. Fig. 4 shows a **backwater valve**, in which *a* is the body, *b* is the seat, *c* is the flap that forms the seal, and *d* is an enlarged chamber for the flap *c* to swing in. The seat of the valve *b* is placed at such an angle that the flap *c* is always resting on the seat when sewage is not flowing through it. When a discharge of water flows through the pipe, the weight of the column of water opens the flap *c*, thus permitting the sewage to flow through to the sewer side of the flap, which then closes and forms a seal against back pressure. Water flowing from tide water or an overflowing sewer reaches the street side of the flap but cannot flow into the house drain.

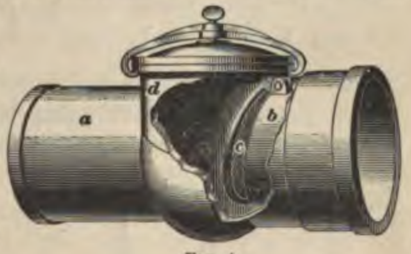


Fig. 4

12. Fig. 5 shows a **Barrett sewer and tide-water trap**, in which *a* is the sewer trap; *b*, the valve; and *c*, a brass valve seat. There are many good features about this combination trap. For instance, it does not depend on the water for a seal; the brass gate *b* that opens easily for outward discharge is closed by gravity against the raised metal

FIG. 5

seat, making a tight joint and thus rendering it impossible for backwater or air to pass through. It also possesses an inlet to the house drain well above the outlet on the sewer side of the trap, which causes a strong flow of water through the trap that is sure to keep it well scoured.

13. Fig. 6 shows a **balanced float backwater check,** which possesses the valuable feature of being open at all times except when water backs into it, when the check-valve closes automatically. The house drain connects to the inlet *a*, while *b* connects to the sewer. In a chamber *c* is located a weighted float *d* that counterbalances the check *e* and holds it open as shown when there is no backwater in the pipe. When water backs up in the house drain, however, it raises the float and closes the check, as shown by the

FIG. 6

dotted lines. A handhole *g* gives access to the chamber. A ¾-inch vent pipe is connected to *h* to permit air to escape from the chamber when it is filling with water. With this backwater check, the passage for sewage is always open in the drain. It does not stop circulation of air, and closes automatically when the water fills the pipe.

14. When fixtures are located below the high-water line in backwater systems, they should be connected to one branch of the main house drain that should be provided with a backwater check-valve to prevent sewage from overflowing from the fixtures. The remainder of the house drainage system, however, should connect direct to the sewer without a backwater valve, to allow sewage and rain water to flow to the street sewer when the head of water is sufficient to overcome the pressure in the sewer.

FRESH-AIR INLETS

15. Location.—The **fresh-air inlet** of a house-drainage system consists of a line of pipe with one end connected to the house drain on the house side of the main drain trap and with its other end opening somewhere to the atmosphere. Its object being to admit fresh air to the entire drainage system within a building, it should be of sufficient size and be suitably located to be at all times free from snow or other obstructions. The inlet end should also be so placed that when discharging foul air it will not be disagreeable or dangerous to the public or inmates of the building. There is only one place where the fresh-air inlet should join the drain, which is on the house side of the main drain trap; and it should enter a **T** branch provided for that purpose. The fresh-air pipe should never connect directly to the drain trap for two reasons, the first of which is that in cold weather the circulation of the air is more rapid through the fresh-air inlet than in warm weather, owing to the heat in the building; this would bring a strong current of air from the outside into contact with the water forming the seal in the main drain trap, which current, by absorbing heat from the water in the trap, would freeze the surface of the water at *f*, Fig. 3 (*a*), thus obstructing the drain. The second reason is that the hub on the house side of the main drain trap should be used for cleaning-out purposes.

A rule that applies equally to all non-check-valve inlets is that no fresh-air inlet should open within 15 feet of any window, door, furnace inlet, flue, or other opening communicating with the interior of a building. When possible

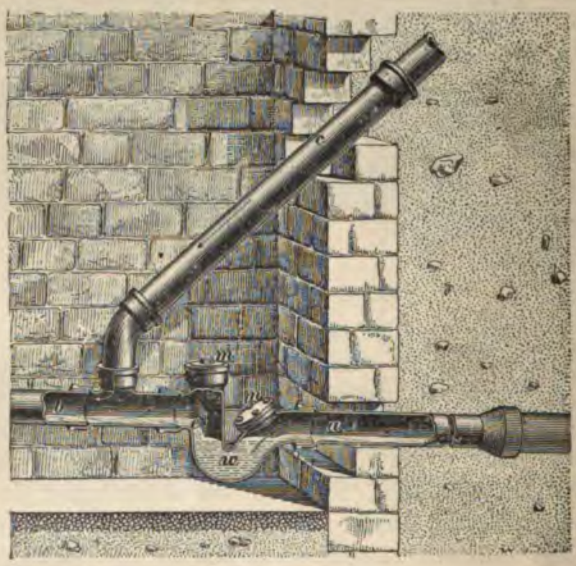


Fig. 7

to avoid it, fresh-air inlet lines should never be run in a horizontal position, but at an angle of at least 45°. This is to make sure that all dirt or refuse of any kind that finds its way into the interior of the pipe will roll or slide down the incline into the house drain and be washed away.

16. Fig. 7 shows a fresh-air inlet properly connected to the drain trap. The pipe *a* goes through the cellar wall and connects to the sewer. The main house drain *b* is a continuation of the run of the **T**, the fresh-air inlet pipe *c* having a pitch of 45° down to the **T**. Clean-outs are located at *m* and *n*. Gases generated in the space directly below the clean-out *m* will usually diffuse with the fresh-air currents, thus keeping this space ventilated.

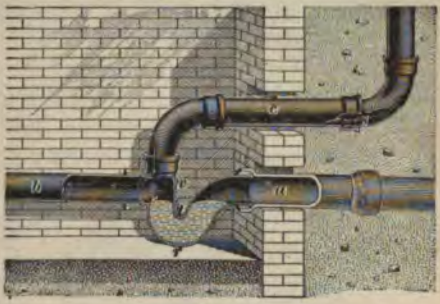


FIG. 8

Fig. 8 shows a wrong way to connect the fresh-air inlet with the house drain. Currents of air that pass in through the fresh-air inlet are deflected by the water in the trap into the house drain, but, owing to the air striking the surface of the seal, the water is liable to freeze during cold weather. Evaporation of the water in the trap also takes place more rapidly and the seal is thus liable to be lost when the system is not much used.

FIG. 9

17. Construction.—There are several forms of inlets for fresh air, each of which has some feature to recommend it. In Fig. 9 is shown a **flush wall inlet**. This is installed by running the inlet pipe *a* to and almost through the wall *b*, where a grating is fastened over it, as shown. This grating is made in two parts, namely, a frame *c* and a removable grating *d* attached to it with brass screws. The frame is calked with lead, or secured with sulphur, flush with the surface of the stone wall. This is a cheap and good form of inlet when there are no near-by windows or openings into which foul air from the inlet can blow when there are down drafts.

18. Fig. 10 shows a **curb inlet.** It is similar to the flush wall inlet, except that the pipe *a* passes clear through the foundation wall out to the box *b*, which it enters at least 4 inches from the bottom, to allow for the accumulation of sweepings and rubbish without interfering with, or obstructing, the mouth of the pipe in the box. Sometimes the curb box is made of iron, but generally it is made of bricks

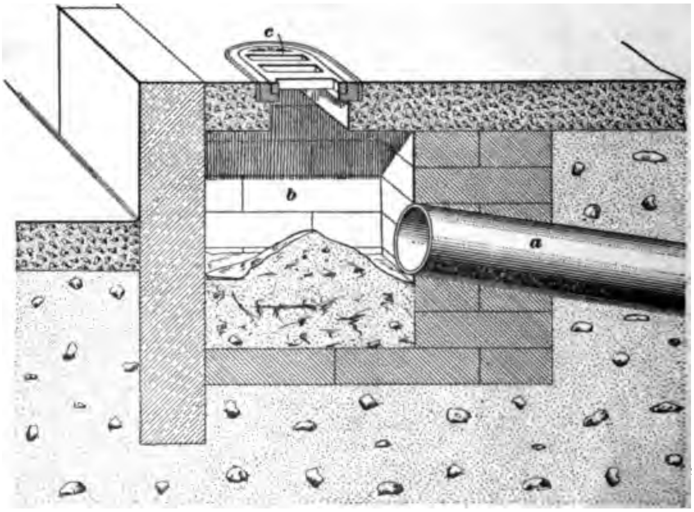


FIG. 10

cemented inside with Portland cement. The box is covered with a removable grate *c*, the area of the perforations of which should at least be equal to the area of the inlet pipe. Sometimes this grate is placed in the face of the curb a little above the street gutter to prevent dirt from being swept into it. The form of inlet shown in Fig. 10 has one good feature and many bad ones. The good feature is the distance from the house at which it discharges foul air when there is a down draft in the drainage system; this distance is seldom less than 15 feet. Among the bad features of this form of inlet are: (1) insufficient fall to the fresh-air inlet from the curb to the house drain; sweepings entering the box cannot slide down to the house drain but stay in the pipe and choke it; (2) the grating at the curb,

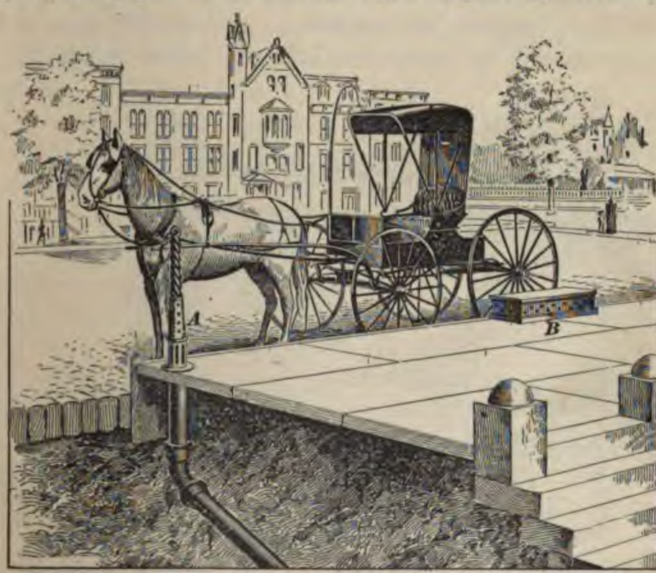


FIG. 11

whether at the side or on top of the box, is liable to be stopped with accumulated dirt, or choked with snow during winter; in cold climates the stoppage from snow may continue nearly all winter; (3) at every discharge of a large volume of water into the drainage system, or when there is a down draft, drain air issues from the openings and becomes a public nuisance.

19. Hitching-post and **stepping-block inlets** are shown in Fig. 11, in which *A* is a hollow perforated hitching post connected to the fresh-air inlet, and *B* is a hollow perforated stepping block located over the intake opening of a fresh-air inlet at the curb. These forms of inlets will not choke with dirt or snow as easily as curb inlets; otherwise, they possess all of the defects of the curb inlet. They possess the additional disadvantage of being an obstruction to the sidewalk.

20. In some localities, the fresh-air inlet is used as a rain leader or area drain to keep the pipe free from accumulations of dust, dirt, etc. When this method is used, the fresh-air inlet should be connected to the house drain by a

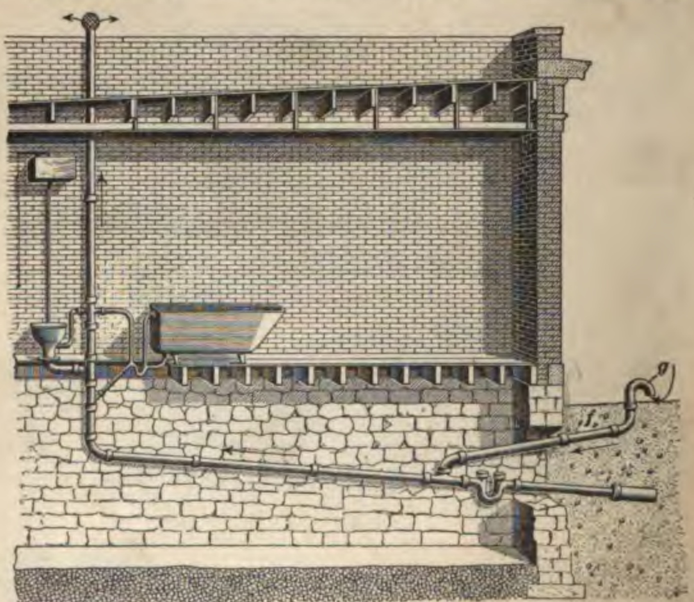


FIG. 12

Y branch, the same as a soil pipe or waste line, so that during heavy storms the flow of rain water will not back up into, or retard the flow of sewage in, the house drains.

21. In detached dwellings, it is customary to extend the fresh-air inlet away from the building about 15 feet and up through the surface of the earth about 18 inches. The end is then finished with a cowl or turned by means of a return bend, so that the opening faces the ground. Fig. 12 shows a **yard fresh-air inlet** with a return bend, *f* being the fresh-air inlet pipe and *g*, the return bend.

22. The **roof fresh-air inlet** possesses more features to recommend it than any other form, in that: (1) it is free from all possibility of stoppage from dirt or snow; (2) if dirt should enter the pipes it would fall to the house drain below; (3) it is located away from all openings into the building, and consequently cannot become a public nuisance; (4) it is not more costly for ordinary buildings in cities than any of the former systems mentioned, because masons' expenses and the taking out of building-department permits are avoided. Objections to the roof-inlet system are often made on the ground that the column of air in the fresh-air inlet pipe is equal in height to the column of air in the soil stacks, and that one column would just balance the other, and therefore there would be no circulation of air through the drainage system. If the two lines of pipe were subject to the same conditions, that objection would be well founded, but the air in the soil stacks will be warmer and more moist than that in the fresh-air inlet, which will create an up current in the soil stacks and a corresponding down draft in the fresh-air inlet stack. The causes of heat in soil pipe are many, among which are: (1) heat from the air in the buildings; (2) heat from the hot water passing through the pipes. Thus, the natural tendency of the ventilation is the same as with street and other low-lying fresh-air inlets, but whether the ventilation is up or down either stack does not matter so long as there is a satisfactory change of the air.

23. Antiblow-back valves are lightly poised check-valves that close the opening of the fresh-air inlet when there is a down draft in the system due to a heavy flush of water, or wind blowing into the soil stack above the roof, and are open to admit fresh air at all other times.

Fig. 13 shows a fresh-air inlet check-valve in section, in which *a* is the shell, *b*, *b* are two counterbalancing levers, *c*, *c* are the lever supports, and *d* is a conical disk valve made of stamped sheet brass or aluminum and provided with a flexible rubber washer *e* that is cemented to the cone valve *d*; two wire links, shown at *f*, connect the apex of the cone valve *d* with the free ends of the levers, and *g* is the seat for the valve *d*. The counterbalancing levers *b*, *b* keep the conical valve *d* lightly poised, so that a back flow of air from the house side of the fitting will close the opening, thus preventing the foul air escaping from the mouth of the inlet. When the back pressure is relieved from the valve, it will open automatically, allowing air to pass freely into the drainage system.

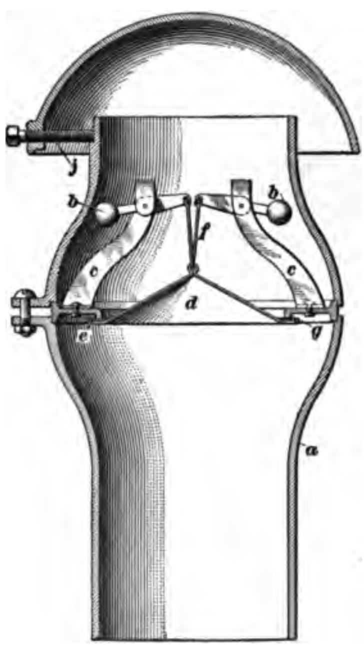


FIG. 13

24. Choice and Care. To be perfect, a fresh-air inlet must be permanent, that is, it should not possess mechanical parts that will corrode or wear away and require replacing, but when once installed should last as long as the pipe system of which it forms a part, and should not require any attention whatsoever after its installation. It should also work perfectly under all conditions and regardless of the number or size of the soil stacks and waste stacks within the building.

Antiblow-back valves are lightly constructed mechanical devices, and are liable to become useless by sticking fast or by wear. Antiblow-backs are not adapted to every building, and great care must be taken in deciding where to use them, as in many cases it is objectionable to prevent a blow-back in the air vent. For instance, consider a simple system of drainage with but one line of soil pipe extending through the roof, and a fresh-air inlet terminating with an antiblow-back valve. Should there be a large discharge of water into the soil pipe, the valve will close, thus confining and compressing the air in the system until the pressure of air becomes sufficiently strong to force the water from one of the traps near the base of the system, which, of course, is highly objectionable. When used, they should be at least 15 feet away from any opening to the inside of a building, the same as when no check-valve is used.

25. To prevent fresh-air inlets becoming useless by chokage, they may be periodically flushed with water. Fig. 14 shows an automatic system for flushing fresh-air inlets, in which *a* is the automatic flush tank and *b*, the fresh-air inlet

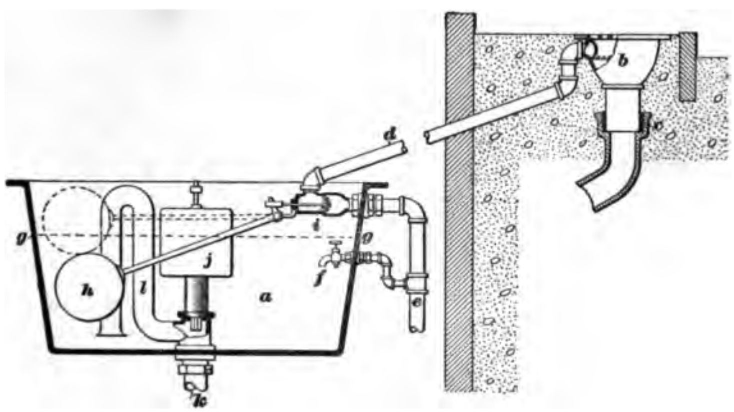


FIG. 14

hopper, which may be fitted with a flushing rim or a spreader, and a spigot end that can be calked into a hub *c*. The flushing rim is supplied with water through the pipe *d* that connects with the flush tank *a*. Water is supplied to the tank *a* through the supply *e* and the petcock *f*, which is left open, so water is running through it into the tank at all times. Water rises in the tank *a* to the line *g*, thus raising the float *h* to the position shown by the dotted lines. This opens the valve *i* and admits water to the flushing hopper *b*. At the same time water continues to flow into *a* through *f*, whereby the float *j* is finally raised. The lower end of the stem carrying this float *j* is attached to a valve closing the end of the waste pipe *k*; as soon as *j* is raised, water from the tank flows down *k* and thereby starts the siphon *l*, which promptly empties the tank. Since the float *h* is now free to descend the valve *i* closes, thereby stopping the flow of water to the flushing hopper *b*. The waste pipe *k* can discharge into a sink, laundry tub, or other fixture located in the basement, but, a better place to discharge into would be a cellar-floor drain trap, so as to keep the trap full of water and maintain a seal.

HOUSE-DRAIN INSTALLATION

26. Materials.—The material for a house drain should be some hard, strong, non-corroding substance, that will not break on being exposed to sudden changes of temperature. Copper or brass would be a good material for house drains, but the cost of the material prohibits its use for this purpose. Cast iron and wrought iron or steel are the materials generally used for drainage purposes. Steel and wrought-iron pipes are generally considered as being of the same material, there being no difference in the method of handling them. Extra heavy cast-iron pipe is generally used for good work. It may be coated with pitch, tar, or other rust preventive, or may be used uncoated. When cast-iron drains are to be buried in the ground, or laid in damp cellars, the pipe and fittings should be coated both inside and outside with pitch to keep them from corroding. When wrought-iron pipe is to be used for drainage purposes, the pipe and fittings should be well galvanized both inside and outside, or covered with a coat of pitch, tar, or asphaltum.

27. Plan and Description of House Drain.—Fig. 15 is a floor plan and elevation showing a main house drain, in which *a* is the outlet end of the house drain where it connects with the house sewer; *b* is a Y branch, the end of which is stopped with a brass clean-out plug *d*, and the branch of which turns the house drain at an angle of 45° toward the foundation wall. The clean-out opening *d* in the end of the Y branch *b* gives access to the house sewer, so that, in case of stoppage, a wire or a bamboo rod can be forced through the house sewer to the sewer in the street. At *c* is the house drain trap; *d'*, *d''*, *d'''* are clean-out plugs; *e* is the fresh-air inlet branch; *f* is a one-eighth bend that turns the

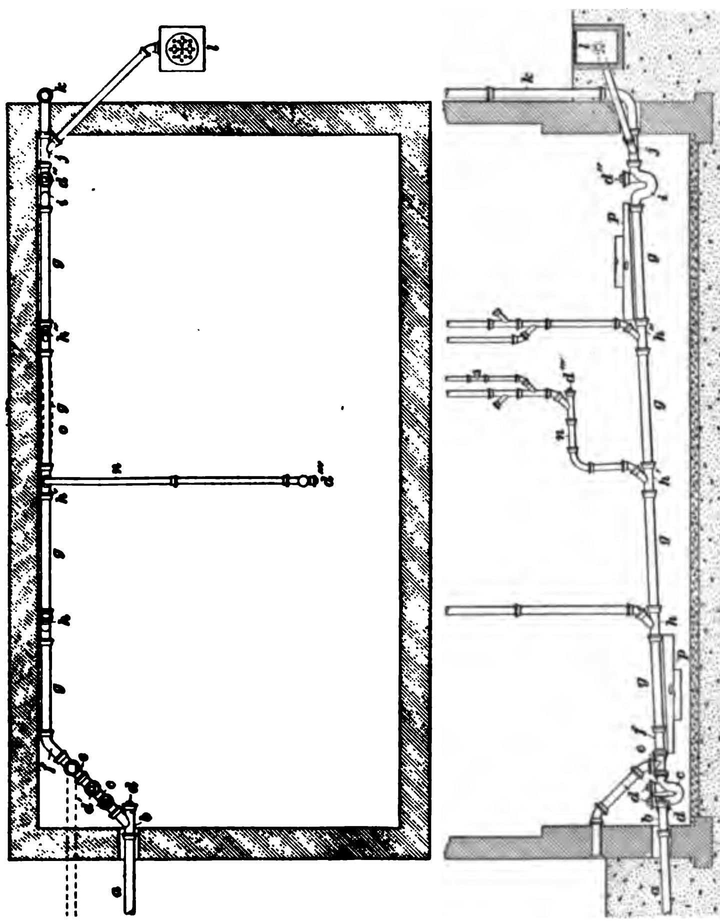


FIG. 15

house drain *g* parallel with the foundation wall along which it runs and to which it is secured. The **Y** branches for soil and waste connections are shown at *h*, *h'*, *h''*; *i* is the rain-leader trap; *j* is a **Y** branch connecting the yard drain *l* to the rain leader *k* on the house side of the trap *i*; and *n* is a Y branch for a waste-line connection.

28. Leveling House Drains.—When installing the house drain, great care should be exercised to have the bottom of the drain perfectly straight. When the drain is constructed of cast-iron pipe, straight lengths should be selected for the horizontal runs. If, however, there are no straight lengths of pipe available, the pipes should be so arranged that the bends will be at the sides of the drain and not at the bottom, where they would form a series of pockets to hold the solids that settle in them.

29. No part in the installation of a house-drainage system requires greater care than the giving of a uniform pitch or fall to the main house drain. This operation, from the use of a level in it, is usually called **leveling.** To insure perfect results, the level should be carefully tested before using, and in no case should the level be placed directly on the pipe, but always placed on a straightedge resting on the hubs. Fig. 16 shows a form of straightedge for leveling horizontal pipes, the use of which will give perfect results. It consists of a straight dry piece of soft pine 6 feet long and $1\frac{1}{4}$ inches thick. It is planed straight on the top edge *a*, at perfect right angles to the sides *b*, *b*. In the center near the top is a handhole *c*

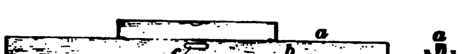


FIG. 16

for convenience in handling. The bottom edge is not parallel with the top edge *a*, but is as much deeper at one end as there would be fall in 6 feet of the pipe to be laid. Suppose that the drain pipe *g*, Fig. 15, is to be laid at a uniform fall of $\frac{1}{4}$ inch to the foot; in 6 feet of drain there would be $\frac{1}{4} \times 6 = 1\frac{1}{2}$ inches of fall. This difference of level should therefore be added to the width of one end of the straightedge. If the straightedge is 3 inches wide at one end, it will therefore be $4\frac{1}{2}$ inches wide at the other end. Should the straightedge *p*, Fig. 15, be placed on the house drain *g*, with the wide end toward the outlet of the drain pipe, the upper edge of the straightedge will be perfectly level when the drain has the required fall of $\frac{1}{4}$ inch to the foot.

30. In using a straightedge to level horizontal drain pipes, three precautions must be observed: (1) the edges of the straightedge must be made at perfect right angles to the sides of the straightedge; (2) the level must be held parallel with the straightedge; (3) the straightedge must rest evenly on the center of both hubs.

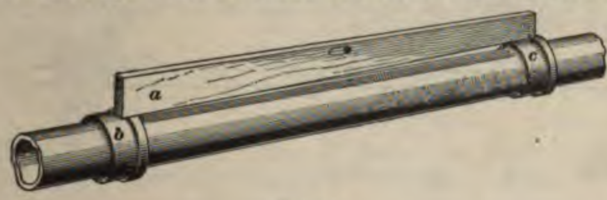


FIG. 17

The necessity of having the straightedge rest on the center of both hubs is best shown by a reference to Fig. 17, which shows a straightedge *a* resting on the hubs *b* and *c*. It will be seen that the end of the straightedge *a* is not resting on the center of the hub *b* as it should, but on the side of the hub, which, being circular, lowers the end of the straightedge *a*, thus giving a false level to the drain.

The advisability of having the top and bottom edges of the straightedge at right angles with the sides can be seen best by considering the effect produced by edges not at right angles to the sides. For the purpose of illustration, the top edge may be selected, which, as shown in Fig. 18, is planed at an inclination to the sides. If a level *a* is placed on the top edge and held parallel to the straightedge *b*, no ill effect in the indication of the level will result; but, if the level is not held perfectly parallel to the straightedge, one end of the level will be depressed and the other raised, and thus an error is introduced that in turn causes a different fall of pipe from that the straightedge was made for.

FIG. 18

31. Horizontal drain pipes should never be leveled by placing a level on a length of pipe. Fig. 19 shows a horizontal line of drain pipe *a*, *b*, *c* properly leveled but made up of crooked lengths of pipe, with the bends down. If a level is placed near the spigot end of any length of pipe, as shown at *d*, it will show an apparent fall of the entire drain toward

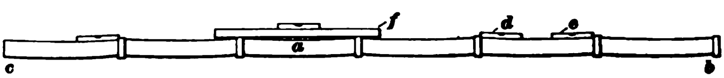


FIG. 19

the inlet end *b*. If the level is now placed at the hub end of the pipe, as shown at *e*, it will show an apparent fall toward the outlet end *c*. If a straightedge is now placed on the hubs of the drains from *b* to *c*, and the level applied, the latter will be found to be perfectly level, showing the apparent fall to be due to curves in the lengths of pipe.

When a number of fittings are so bunched together in a horizontal drain that a straightedge cannot be placed on top

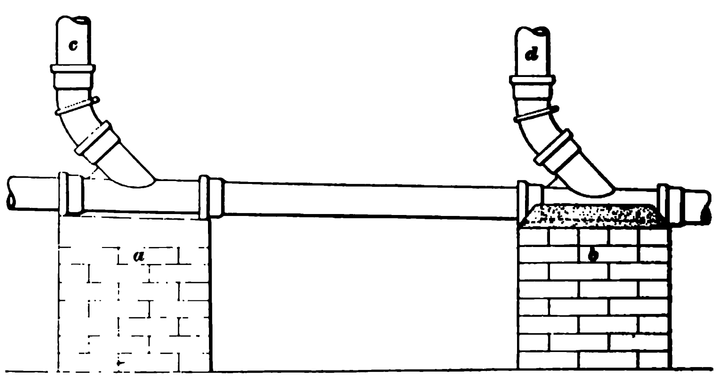


FIG. 20

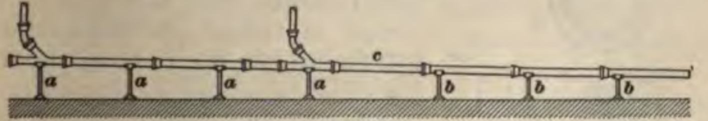
of the hubs, the straightedge can be reversed and applied to the bottom of the fittings, as shown at the left of Fig. 15.

32. Supports for House Drains.—Supports of some kind must be used for all horizontal drains to keep the pipe from settling and to support the weight of soil pipes and waste lines where they rise from the house drain. Supports are made in various forms, such as brick piers, iron-pipe rests, pipe hooks, pipe hangers, and corbels.

33. Brick piers for pipes are usually made as shown in Fig. 20, where a *stone-capped pier* is illustrated at *a* and a *cement-capped pier*, at *b*. The piers should be bonded into the foundation wall. The house drain rests on the piers at the branches of the soil stacks *c* and *d*. The piers should always be built under the stacks. Supports under a horizontal drain pipe should never be over 10 feet apart.

(a)

34. One form of an **iron-pipe rest** consists of a pipe flange, a short piece of iron pipe, and a pipe saddle. Fig. 21 (*a*) shows such a support in which *a* is a saddle tapped with a female thread; *b* is a floor flange, also tapped with a



(b)

Fig. 21

female thread; and *c* is an iron-pipe nipple threaded on both ends. The saddle and floor flange are screwed to the nipple *c*, thus forming the rest for the pipe that fits in the saddle *a*.

In Fig. 21 (*b*) is shown an application of the device just described, the rests *a* and *b* supporting the drain pipe *c*. One support must be located under each stack, the others being distributed between, as nearly equal as possible.

35. Iron pipe hooks are a poor form of support for horizontal drains, but when used should never be over 4 feet apart and should be driven into a wooden plug in the wall close to the hubs, as shown in Fig. 22 (*a*). The shanks must be long, and the shoulder *a* must not be driven in past the center line of the pipe; otherwise, the support is weakened and the pipe will sag, as in Fig. 22 (*b*).

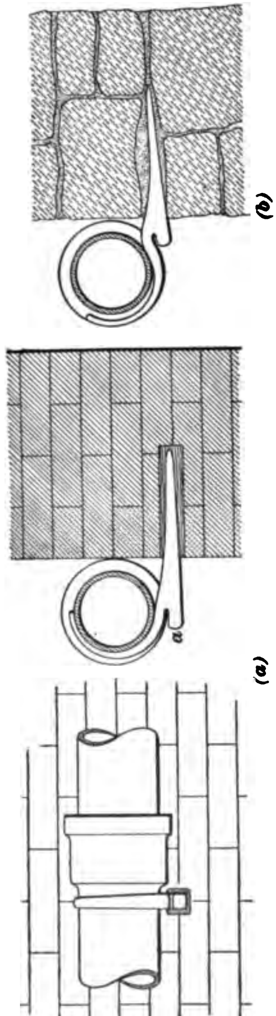


FIG. 22

36. Pipe hangers are generally used to support horizontal lines of pipe from a ceiling, but are sometimes used to secure pipe lines to a wall. Split rings or adjustable hangers are the most convenient form to use, although any other form of hanger may be used.

Fig. 23 (*a*) shows a form of split-ring hanger, in which *a* is a piece of wrought-iron pipe that screws into the half circle *b*. The clamp *c* is secured to the part *b* by the two bolts *d*, *d*, which pass through holes in the lugs *e*, *e*. The flange *f* is used in frame construction and is secured to the wooden beams by means of lagscrews passing through holes drilled through the flange. In fireproof construction, the beam clamp *g* in Fig. 23 (*b*) is used in place of the flange to fasten the hanger to the I beam.

When hangers are used as **wall supports** for horizontal drains, they may be secured to the wall in the manner shown in Fig. 24. A hole *a*, of the diameter of the iron tail-piece *b*, is drilled in the wall and at a slight angle, as shown. The tail-piece of the hanger is then driven tightly into the hole.

37. In some buildings, when the drain is located too high from the cellar floor for brick piers or iron pipe supports to be used, or where they would occupy too much space, **stone corbels** *a*, *a* can be built into the wall to support the pipes, as shown in Fig. 25. Allowance must be made, however, for the fall of the pipe toward the sewer, which should not be less than ¼ inch to the foot. Wall hooks *b*, *b* can be used to prevent the pipes from slipping off the corbels.

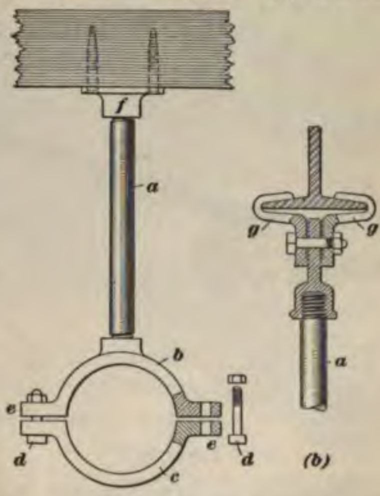


FIG. 23

38. Connections to House Drains.—All branch connections to a drain should be made at such an angle that the sewage flowing from the branch will not interfere with the flow of sewage in the drain. To secure this result, suitable fittings should be used for connecting the branch drains to the main. Connections to a drain can be either horizontal or vertical. Horizontal branches should be taken from the main drain at a slight inclination, as shown in Fig. 26, in which *a* is the drain pipe; *b*, the branch of the fitting; and *c*, a continuation of the branch.

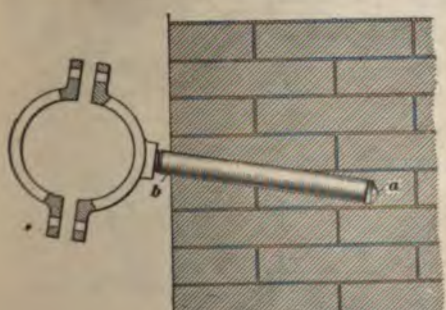


FIG. 24

39. Fig. 27 shows a top view of a **Y**-branch connection to a drain in which *a* is the drain pipe and *b* is the branch connecting to the drain *a* at an angle of 45° **in the direction of the flow of the sewage. The pipe *c* is a continuation of the branch *b*. A one-eighth bend *d* can be used to change the direction of the pipe entering the branch *b*, from at right angles to the drain *a*, as shown by dotted lines at *e*, to running parallel with the drain *a* by turning the one-eighth bend, as shown by dotted lines at *f*.**

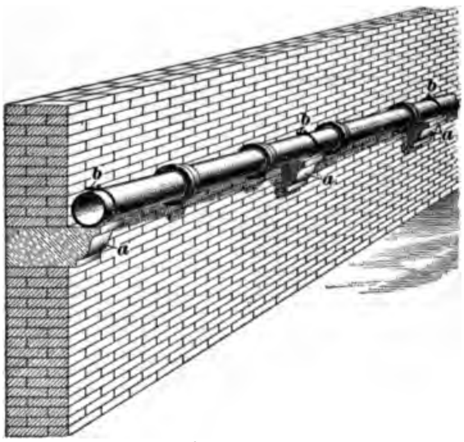


FIG. 25

Should any other angle be required between *e* and *f*, **Fig. 27, it can be secured** by elevating the branch *b*, as shown in Fig. 28, and swinging a one-eighth bend *c*, so that it will face in the direction desired.

40. **T**-branch connections should never be used for soil, waste, leader, or drain pipes, as the sewage backs up in the horizontal drain when flowing in from the branch *a*, as illustrated in Fig. 29 (*a*), which shows a vertical **T-branch**

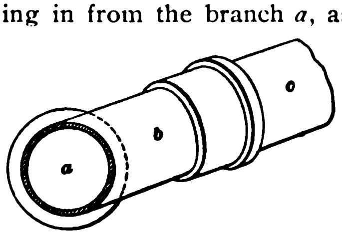


FIG. 26

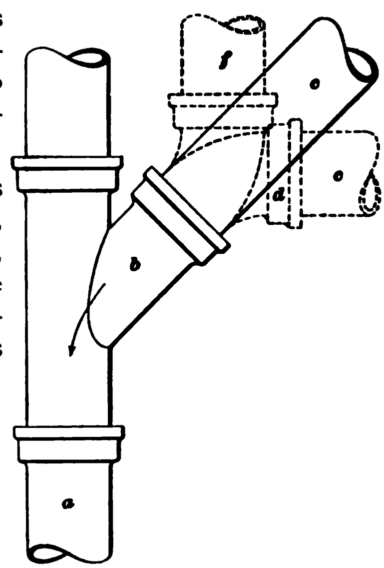


FIG. 27

connection to a horizontal drain. Sewage from the stack *a* backs up the drain *b* and deposits solids, which will soon choke this part of the drain if it is not well flushed by some other fixture.

FIG. 28

When the connections are made with a **Y** fitting instead of a **T**, the flow of the sewage is easy and in the proper direction, as shown in Fig. 29 (*b*). The sewage does not back up in the drain *b*, as in Fig. 29 (*a*).

41. In Fig. 30 (*a*) and (*b*) is shown the right and wrong way of connecting a horizontal branch to a horizontal drain at right angles to the drain. In Fig. 30 (*a*), as the sewage flows from the branch *a* into the drain, the sudden change in the direction of the flow causes the water and solids to back up in the drain, as shown at *b*, which is liable to choke the pipe at this point. This can be remedied by using a **Y** branch and one-eighth bend in making connections, as shown in Fig. 30 (*b*).

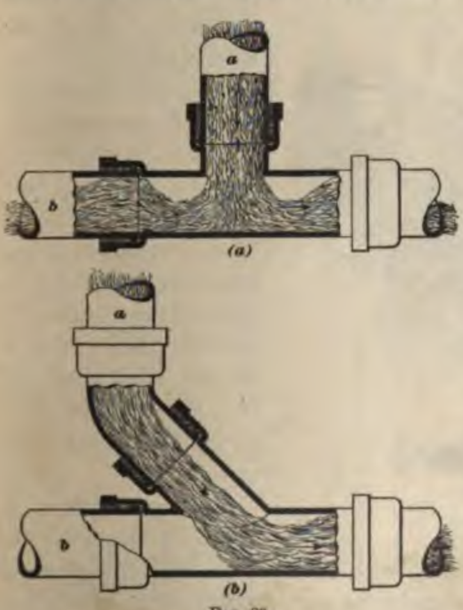
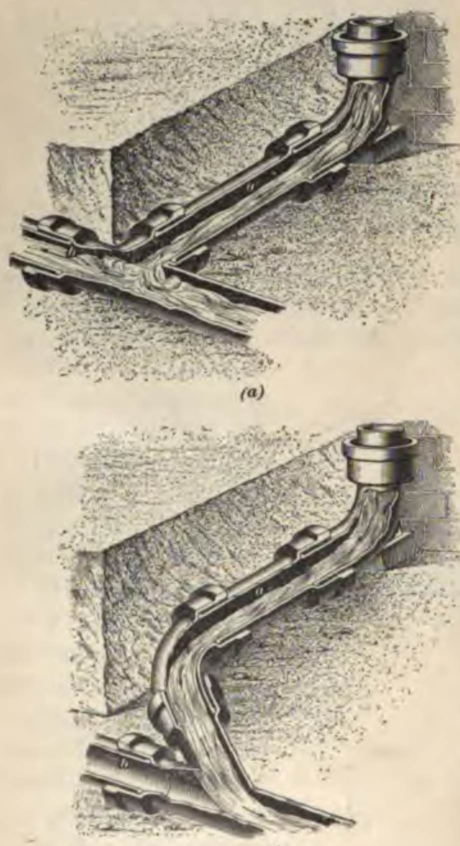


FIG. 29

42. Repairs and Alterations.—It is sometimes necessary after a drain has been installed to disconnect the pipe to put in a branch fitting or remove a defective section of pipe. To do so, the section of pipe to be removed must be melted out, broken out, or the joints picked out.

In melting out a pipe, temporary supports should be placed under the section of pipe to be removed and the water shut off from the house to prevent its trickling down the pipes; otherwise, it will be impossible to melt the lead in the hubs. A gasoline furnace *a*, Fig. 31, is placed under the pipe *b* in such a manner that the flames *c* will play on the bottom of the hub *d* until the lead is all melted out. It should then be moved successively to the hubs *e*, *f*, and *g*, melting the lead out of each hub in turn. The section of pipe between *d* and *g* can then be removed. By melting the lead out of the hubs, all of the pipe in the disconnected section is saved.


(a) (b)
Fig. 30

To disconnect a drain by breaking it, strike the hub *d*, Fig. 31, with a hammer until the hub is cracked; then insert the point of a cold chisel in the opening at the end of the hub, and drive it in until the hub is wedged apart. The spigot end of the pipe should then be broken off at *k* by striking it with a hammer. This leaves the end of the

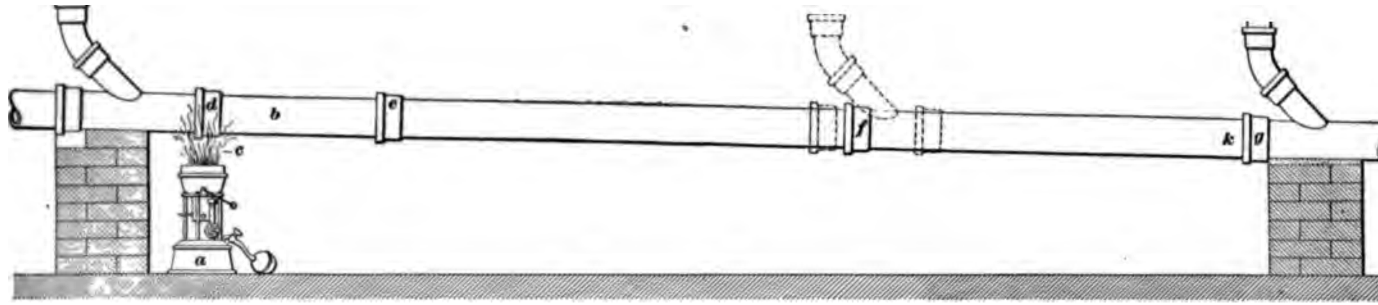


FIG. 31

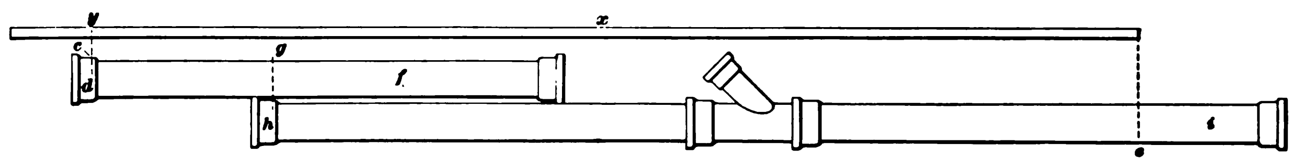


FIG. 32

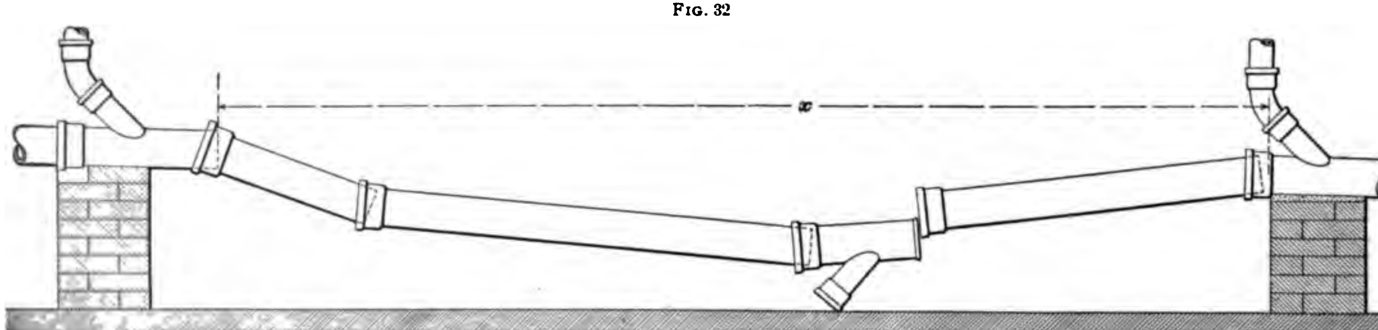


FIG. 33

pipe calked into the hub *g*, which must be cut out with a cold chisel. This method is quicker than melting the lead out of the hubs, but it destroys part of the pipe removed, and loosens the pipe and joints considerably by the jarring of the pipe due to the hammering.

The lead is picked out of calked joints with a narrow cape chisel, which is driven into the lead a short distance; the lead is then pried out by using the chisel for a lever.

43. To replace the section of pipe with the branch in its proper location, take a rod *x*, Fig. 32, and mark on it at *y* the distance *x*, Fig. 33, from the spigot of one fitting to the inside shoulder of the socket of the other fitting. Lay on the cellar floor the several pieces of pipe and the fitting, placing the fitting in its proper relative position, as shown in Fig. 32. Place the rod *x* on the section of the pipe so that

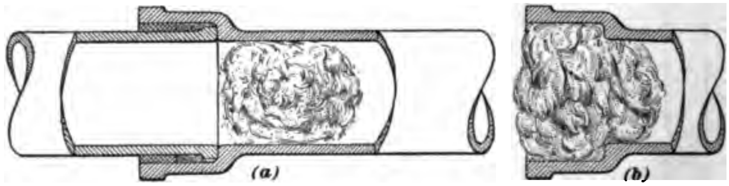


FIG. 34

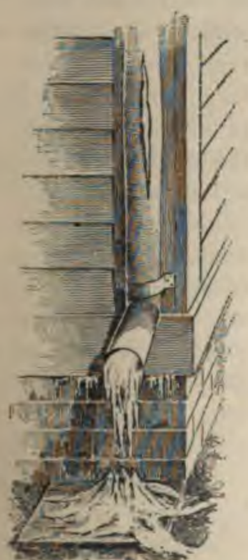
the mark *y* will be even with the inside shoulder *c* of the hub *d*. The end of the rod *x* will then rest at *e*, where the pipe *i* is to be cut off. The pipe *f* can then be marked at *g*, on a line with the inside shoulder of the hub *h*, where it is to be cut off. Both of the pipes *f* and *i* should be cut a little short of the marks *g* and *e* to allow for springing the parts back into place. Double-hub lengths of pipe should be used.

44. In replacing the sections of pipe with the new branch, the ends of the various parts are fitted together, as shown in Fig. 33, and the whole section raised to its proper position, when the proper slip to each joint will be obtained. It is lined up, secured in place, and the joints calked.

Openings to a house drain should be plugged with a wad of oakum to keep dirt from falling into the pipe. The oakum should not be placed down in the hub out of sight, as shown in Fig. 34 (*a*), where it might be forgotten and built into the line by a careless workman, but should be large enough to fill the entire hub, as shown in Fig. 34 (*b*).

RAIN LEADERS

45. Rain leaders are pipes that receive the discharge of rain water from the roof gutters of buildings and convey it to the house drain, cesspool, or other convenient point of discharge. When rain water is not stored in tanks or cisterns



(a)

(b)

(c)

FIG. 35

for domestic purposes, the leaders should be connected to the house drain, to help flush the drain and sewer and prevent the nuisance of rain water flowing about the premises. They should be large enough to carry off all rain water from the areas they drain during heavy and prolonged storms, and

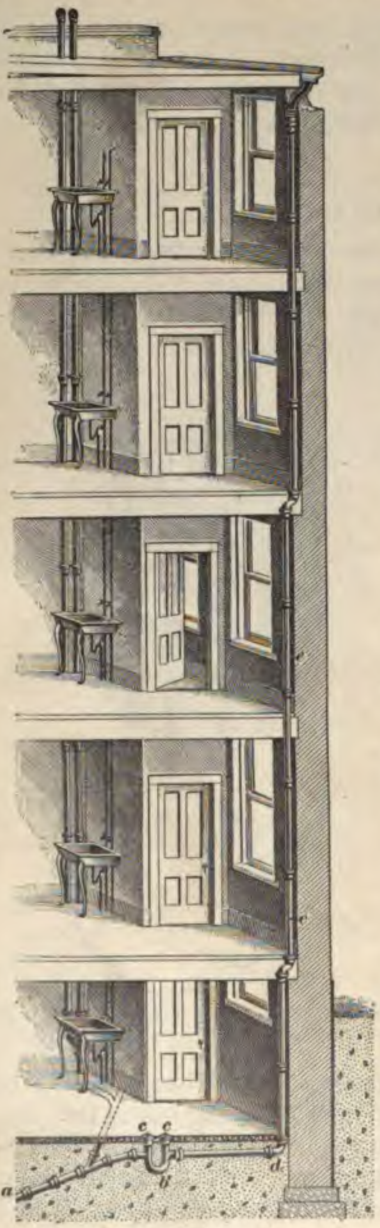


Fig. 36

should never be less than 2 inches in diameter. Roof leaders proportioned as follows have been found, in practice, to give satisfactory results: For small roofs, 1 square inch in sectional area of the leader for each 150 square feet of roof surface. For medium sized roofs, 1 square inch in sectional area of the leader for each 200 square feet of roof surface. For large roofs 1 square inch in sectional area of the leader for each 250 square feet of roof surface. When connected to house drains, leaders should be properly trapped, and in localities where there are long periods without rain, extra-deep-seal traps, provided with a brass clean-out screw, should be used.

Outside rain leaders may be made of cast-iron or wrought-iron pipe, but are generally made of sheet metal, to within 5 feet of the ground, where they connect to an iron pipe. Sheet-metal leaders are made cylindrical in section, as shown in Fig. 35 (*a*), or are made of corrugated metal, either round, as shown in Fig. 35 (*b*), or square. The difference between the two styles of pipe is the elasticity of the corrugated pipe due to corrugation. Should water freeze in the pipes, it would expand the corrugated pipe, as shown in Fig. 35 (*c*), but would not rupture the material unless repeatedly frozen. Plain cylindrical outside leader pipes invariably burst when frozen, as shown in Fig. 35 (*a*).

When rain leaders are connected to the house drain, they should be trapped with running traps having clean-outs attached, as shown in Fig. 36, in which *a* is the house drain; *b*, the leader trap; *c*, *c*, the clean-out plugs; and *d*, a long sweep; 90° bend at the foot of the rain leader *e*. When possible, two or more leaders should connect to one leader trap.

YARD AREA AND FLOOR DRAINS

46. When surface water from yards and areas around buildings is to be discharged into the house drain, care must be taken to see that the yard and area drains are properly trapped and connected to the house drain. There should be a receptacle or basin, covered with a suitable strainer, into which the surface water should drain. In warm climates, this receptacle may be square in plan and have a flat-bottomed settling basin below the outlet, as shown in Fig. 37, for silt that is carried in by the water. But, in cold climates, the bottom should be hemispherical to prevent the water in it from bursting the basin when it is frozen.

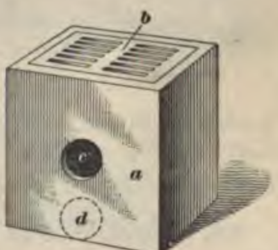


FIG. 37

The outlet from the receiving basin to the house drain should be trapped with a running trap, which should be accessible and should be provided with a clean-out plug for cleaning purposes. Where possible, the yard or area drain should connect to the leader side of a leader trap, or two or more yard and area drains may be connected to one trap.

47. Area catch basins can be made of brick and plastered inside with Portland cement, or can be made of iron, as that in Fig. 37. In either case, the top should be provided with a removable metal strainer *b*. The outlet shown at *c* is for warm climates. If flat-bottomed area catch basins are used in cold climates, the outlet should be located at the bottom, as shown by the dotted circle at *d*.

Fig. 38 shows an area drain connected to a rain leader, in which *a* is the catch basin; *b*, the leader trap; *c*, the rain

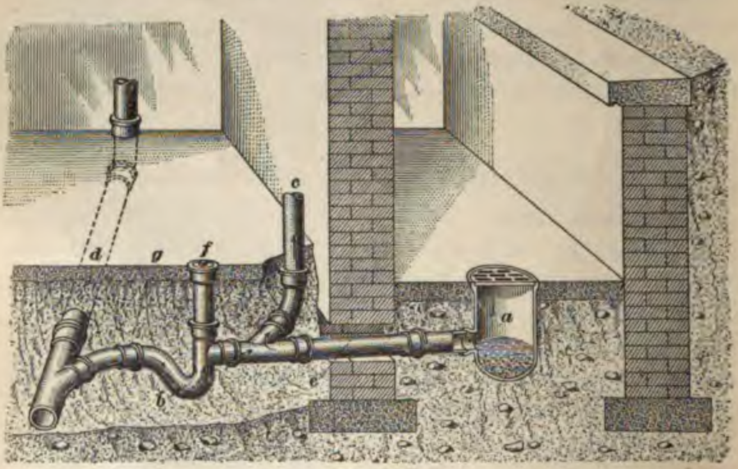


Fig. 38

leader; *d*, the main drain; *e*, the connection from the catch basin to the rain leader; and *f*, a clean-out plug, which is flush with the surface of the floor *g*.

48. Fig. 39 shows a bell trap, in which *a* is the body of the trap, *b* is the outlet, *c* is a collar around the outlet, *d* is a grating that forms the cover of the trap, *e* is a bell-shaped casting secured to the under side of the cover, and *f* is the water forming the seal of the trap. Bell traps should never be used for yard, cellar, area, or stable drains, as objections to the bell trap are many. The spigot end is so short that it cannot be calked into a hub, and this joint is therefore generally made with putty, or not made at all, and then sewer gas enters the building, as shown by the arrows. The trap cover, being removable, is soon lost or broken. Every time the top is removed, foul air blows out of the opening. Owing to the small area of the perforations in the top of the trap, a sufficient supply of water is never admitted to thoroughly flush the trap. Such a large surface of water is exposed to evaporation that the seal is soon broken, and finally the water in the trap, being so close to the surface of the ground, is frozen during cold weather.

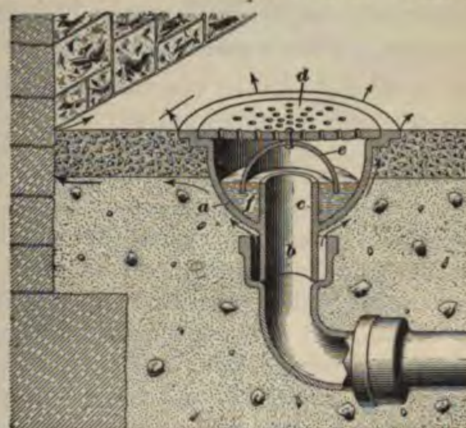


FIG. 39

49. A good form of trap to use for cellar drainage in place of the bell trap is known as the *Seiben*, and is shown in Fig. 40. It consists of an iron receptacle *a* with a removable inner chamber *b* into which dirt settles when carried in

FIG. 40

with the water through the perforated cover *c*. Water overflows from the inner chamber to the trap *d*, which is provided with a swinging flap valve *e*, to prevent sewage backing up and flooding the cellar. The check also offers a seal to the drain air should the water become evaporated from the trap. The clean-out cover *f*, being located flush with the floor, is easily accessible. The trap being under the box insures a seal when the box is cleaned out.

LOCATION OF CLEAN-OUTS

50. Clean-outs should be located at convenient points in the house drain to give access to all parts within the drain that are liable to stoppage, such as the main drain trap, all leader traps, yard traps, or area traps, where the main drain enters the building, back of all vertical lines of soil or waste branches, and at the end of all horizontal lines of drain pipe.

The proper location for clean-outs in the house drain trap is shown in Fig. 3, and for a leader trap at *d''*, Fig. 15, while Fig. 38 shows at *f* where a yard or area trap clean-out should be placed.

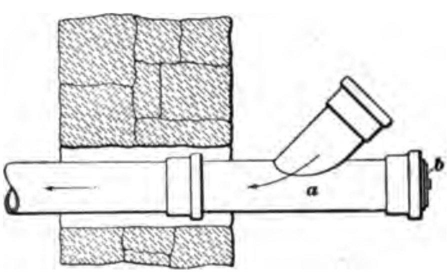


Fig. 41

Where the house drain enters a building, there should be a clean-out giving access to the house sewer. This clean-out should be the full size of the pipe, up to 6 inches in diameter, and should be located as shown in Fig. 41, in which *a* is a Y branch located just inside of the cellar wall, where the drain enters the building. When the screw-cap clean-out *b* is removed, rods can be run through to the sewer.

When clean-outs are placed in the main drain back of rising lines of soil or waste pipes, they should be calked into the branch of a Y fitting that is slightly inclined, to keep it free from deposits of solid matter. Fig. 42 shows how this connection should be made. A brass screw-cap *a* is calked into the hub of a Y branch located back of the soil-stack branch *b* on the main drain. In case of stoppage in the branch *b*, easy access is obtained through *a*.

Fig. 43 shows a clean-out located at the end of a drain, which terminates with a Y branch at the base of a soil stack. In case of stoppage in the horizontal drain *a*, the obstruction can be easily removed through the clean-out *b*.

51. When calking brass clean-out ferrules into hubs, the plug should be screwed into the ferrule; otherwise, the ferrule is liable to be bent out of shape so that the plug cannot be screwed in. The plug of a clean-out should always be well greased before being screwed permanently into place,

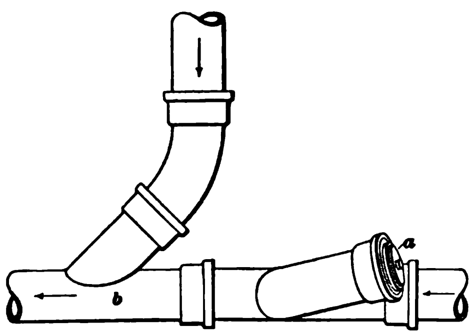


FIG. 42

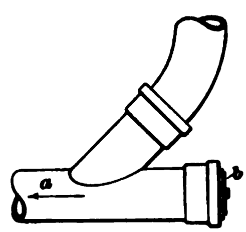


FIG. 43

and whenever removed for any cause should be greased again before replacing. Brass clean-outs should be not less than $\frac{1}{8}$ inch thick. The engaging parts of the screw-cap should have at least six threads of iron-pipe size and tapered, and should have a hub at least $1\frac{1}{2}$ inches square and 1 inch high.

OPENINGS AND DUCTS FOR HOUSE DRAINS

52. Openings in brick walls for horizontal lines of pipe to pass through should be arched over and made large enough to allow at least 2 inches space all around, as shown in Fig. 44. The exact size and locations of all pipe openings should be marked on the plans by the plumber, before the work is commenced on the foundation walls, so they can be built by the mason as the work progresses. Brick piers should also be located, and the height of each pier marked on the plans, so that they can be bonded to the walls and become part of them. In this manner a permanent pier is secured that will not settle independently of the wall nor break away from it.

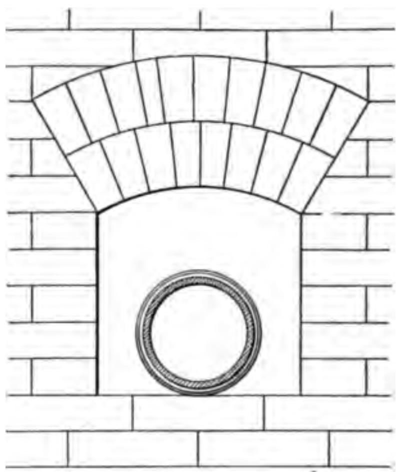


Fig. 44

Pipe ducts, in the form of trenches or tunnels, are often provided in buildings where the main drain is to be placed below the floor of the cellar. The ducts are provided with removable covers of stone or iron, which render the entire system accessible at all times for inspection and repairs. Fig. 45 shows a perspective view of a pipe duct in which the bottom *a* is made of cement concrete, the side walls *b*, *b* are built of brick, the floor *c* of the cellar is shown made of cement concrete, and the covering *d* is composed of pavement slabs, which may be removable or

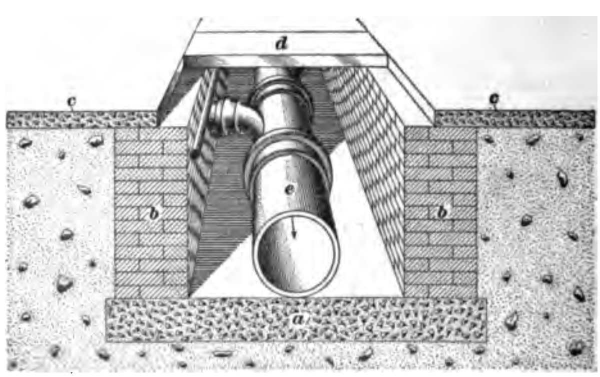


Fig. 45

provided with cast-iron manhole covers sunk flush with the finished floor. The main drain pipe *e* should run along the center of the duct, as shown.

Pipe chases or recesses are provided in the foundation walls where vertical lines of soil and waste pipes are to be run through rooms and where it is desired to conceal them. This overcomes the use of offsets at the base of the stack.

FALL AND SIZE OF DRAINS

53. Fall for Drains.—Drains should have a uniform pitch or fall throughout their length. The line of pipe must not have any part of it run level, nor should any part of it be allowed to sag below the general inclination, as thereby a pocket will be formed in which water will lie. The proper inclination or pitch to be given to drains varies with the diameter of the pipe, being greatest for the smallest diameter. The inclination should be enough to give the water a velocity of about 275 feet per minute. Less velocity will fail to carry along the solids that usually accompany the water.

The proper fall for each size of pipe is given in the following table, 1 foot of fall being allowed for the length given under each diameter:

TABLE I

FALL OF DRAINS

Diameter of drain, inches	2	3	4	5	6	7	8	9	10
Length to 1 foot of fall, feet	20	30	40	50	60	70	80	90	100

Thus, a pipe 3 inches in diameter should be laid with a minimum fall of 1 foot in 30 feet of length.

54. Diameter of Drains.—The proper diameter of the pipe to be used for a drain is a matter that requires careful consideration. The pipe should be large enough to carry off, within a reasonable time, the largest quantity of water that will ever be turned into the drain; yet, it must not be so large that the ordinary flow of water will fail to float and carry along the refuse that ordinarily accompanies the water. Thus, the quantity of water that would run properly in a 5-inch pipe would, if passed through a 9-inch pipe, be so shallow that it would not float and carry the refuse along. This may be seen by observing the difference in depth between the water in the 5-inch pipe, shown in section in Fig. 46 (*a*), and the same quantity in the 9-inch pipe, shown in section in Fig. 46 (*b*). In Fig. 46 (*a*) the solids discharged from the water closets can easily be floated and carried along with the current without even touching the pipe. Since they do not touch the pipe and are submerged in the center of the moving water, it follows that they must move forwards about as fast as the water that surrounds them. In the 9-inch pipe, however, with the same quantity of water, the solids will touch the pipe, because the water is not deep enough to properly float them. The

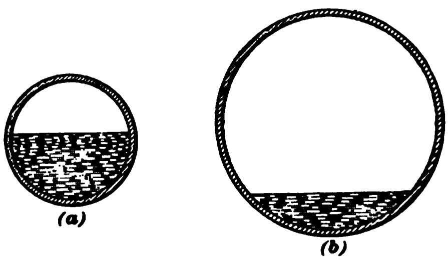


Fig. 46

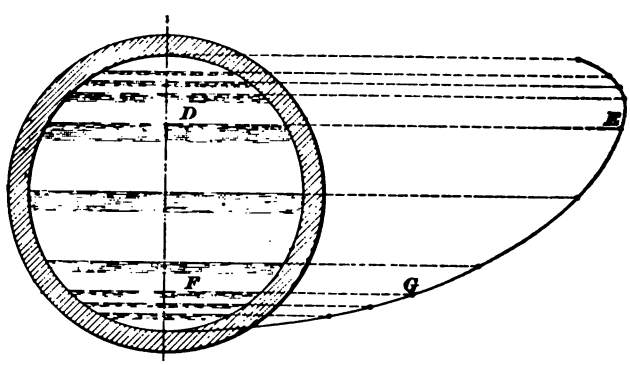
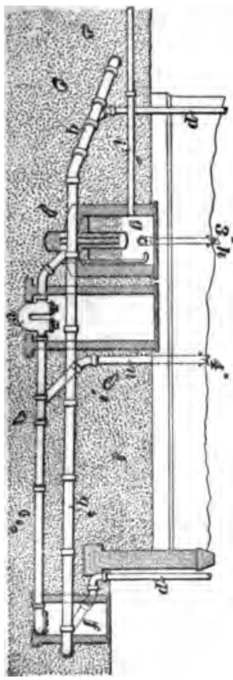


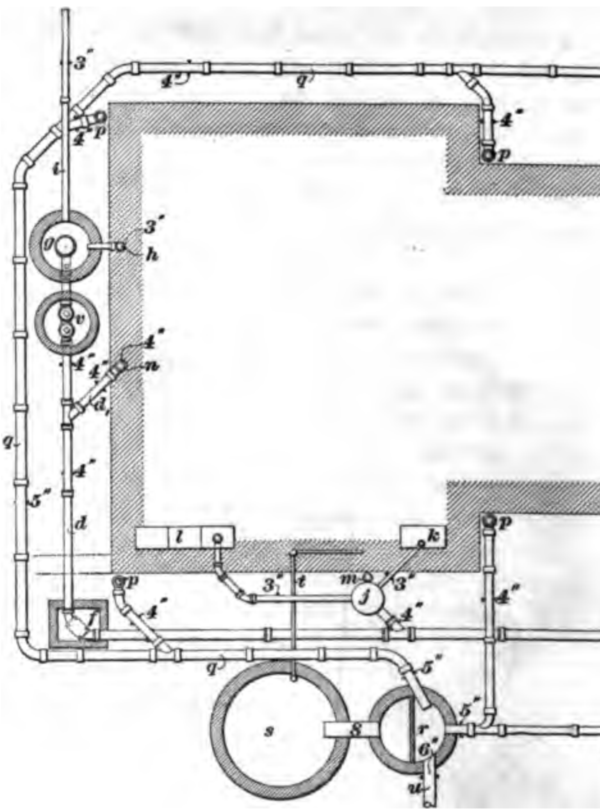
Fig. 47

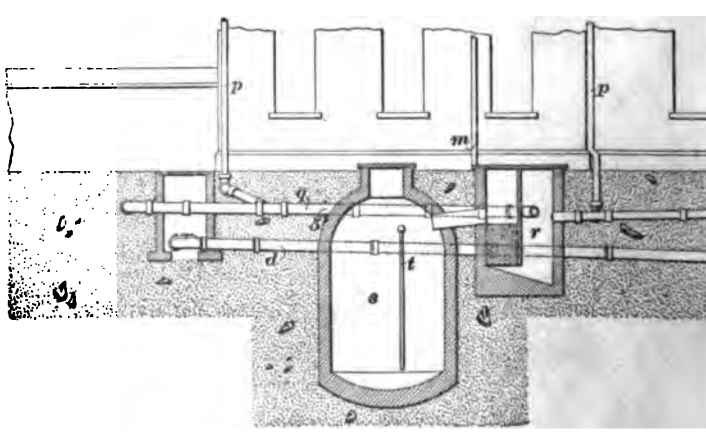
adhesion of the solids to the pipe will create such a resistance to their movement that the water will soon flow ahead and leave them behind, where they will remain until another flush comes and moves them forwards a little farther.

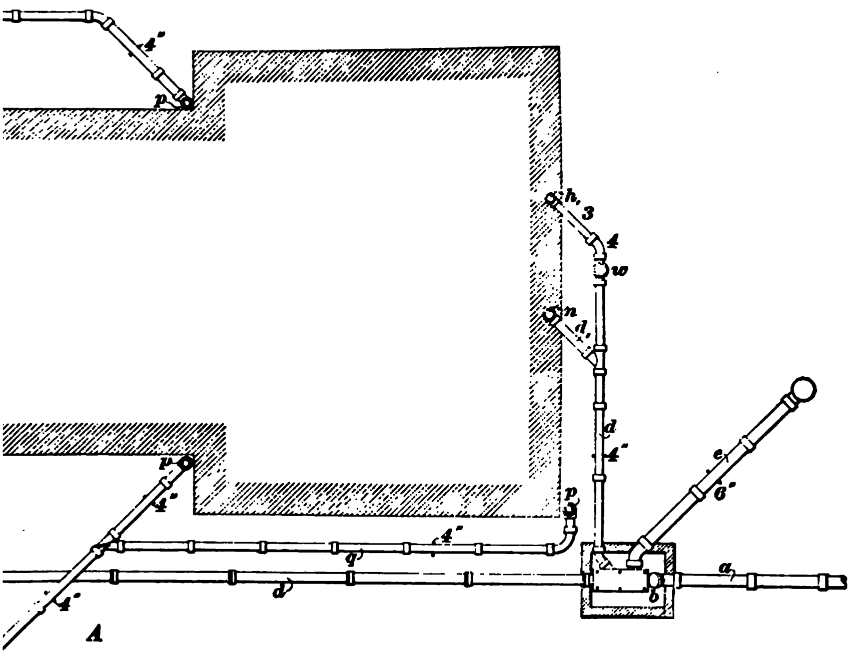
55. The velocity with which water will flow through a pipe depends on the degree to which it fills the pipe. This



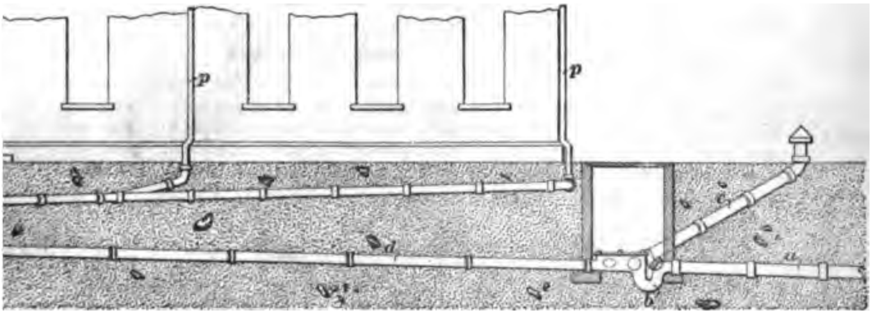
C







A



B

? 44

is shown by the diagram given in Fig. 47. If the level of the flowing water is at D, and the length of the line DE is taken to represent the velocity of the current, then the velocity of a quantity of water that fills the pipe only to the level F will be equal to the line FG. The difference is largely due to the relatively greater friction of the smaller stream, the proportion between the wet surface of the pipe and the quantity of the water being much greater at the level F than at the level D. It will be noticed that when the pipe is about three-quarters full the maximum velocity is attained.

A diameter of 4 inches is usually sufficient for a drain for an ordinary small dwelling; if the rain leaders empty into it, a 5-inch or 6-inch pipe should be used. When no rain water discharges into the house drain, a 4-inch pipe will receive the discharge from 1 to 15 fixtures; a 5-inch pipe, from 16 to 30 fixtures; a 6-inch pipe, from 31 to 50 fixtures; a 7-inch pipe, from 51 to 80 fixtures; an 8-inch pipe, from 81 to 120 fixtures; a 9-inch pipe, from 121 to 200 fixtures; and a 10-inch pipe, from 201 to 300 fixtures.

The following table shows the sizes of main drains and house sewers required to drain certain areas of roof or other impervious surfaces when the rain water empties into the drain:

TABLE II

SIZE OF HOUSE DRAINS

Diameter	Fall ¼ Inch per Foot	Fall ½ Inch per Foot
6 inches	5,000 square feet of drainage area	7,500 square feet of drainage area
7 inches	6,900 square feet of drainage area	10,300 square feet of drainage area
8 inches	9,100 square feet of drainage area	13,600 square feet of drainage area
9 inches	11,600 square feet of drainage area	17,400 square feet of drainage area

OUTSIDE HOUSE DRAINAGE

56. Fig. 48 shows, by plan and sectional elevation, a system of drainage suitable for an isolated building. Water is assumed to be scarce, and the rain water falling on the roof of the building is collected and stored in a brick and cement cistern. The sewer pipe is supposed to be very long, and to have a very slight fall toward its outlet. To keep the drains clean with a minimum expenditure of water, the waste water from some of the baths and wash basins is collected in an automatic flushing tank and discharged periodically for flushing purposes. Of course, when this is done, the bath and basin stacks must be carried separately up to and through the roof, and have no connection with the closet, soil, or vent pipes. It will be noticed that all the pipes are run immediately through the main wall and underground. This avoids running horizontal pipes in the basement or under the floors of the building, thereby reducing the danger from leaks to a minimum.

The 6-inch earthenware pipe *a* is the house sewer proper; it conveys all of the sewage from the building to a suitable outlet. The main disconnecting trap *b* is built in a brick manhole. An inspection piece into which the drains *d*, *d* discharge, and the fresh-air inlet *e* joins, delivers into the trap. A closed inspection piece is placed in the manhole *f*. An automatic flushing tank *g* is connected to the highest end. This receives discharge from the bath and basin waste *h*. The pipe *i*, led to a convenient point, is a fresh-air inlet to *g*, while *h* acts as an air-outlet. A grease trap *j* intercepts grease, etc. from the sink *k* and laundry tubs *l*, and is ventilated to the roof by a 3-inch pipe *m*, a few holes serving as air inlet being made in the cover. The branch drains d_1, d_1 connect the soil-pipe stacks *n*, *n* to the main drains. The discharge from baths and basins connected to the waste stack *k* enters the drain direct. The roof water falls in the leader or conductor pipes *p* into the stoneware rain-water pipes *q*. These pipes convey it to the filter *r*, through which it must flow before entering the cistern *s*, from whence it is drawn to the building by a pump attached to the suction pipe *t*. An overflow for the filter, that is, for the cistern, is shown at *u*. The trap *v* disconnects the flushing tank from the drains, so that when the tank is empty it will not be filled with drain air. A small air pipe, which turns over in the tank *g*, prevents an air lock between *g* and *v*. A handhole *w* is placed on the drain for easy access.

Should the water supply to this building be abundant and the roof water permitted to flow to waste, the best method would be to run all the rain-water drains into a flushing tank, and all the discharge from the several pipe stacks directly into the drainage system. If the water supply should be abundant and the pitch of the drains and sewer pipe sufficient to insure thorough cleansing with ordinary methods of flushing, that is, by the simple discharge from the fixtures, the cistern, filter, and flushing tank would be omitted. All the roof water would then deliver into the drains, the rain-water drains and leaders, of course, being trapped from the

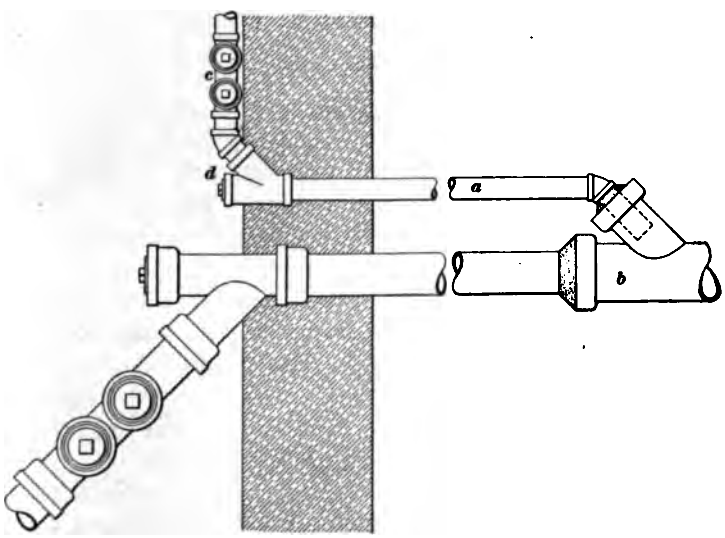


FIG 49

drainage system so that drain air or sewer gas could not flow up the rain-water leaders or conductors and be discharged into or near windows. The grease trap, however, should remain, but the laundry tubs need not deliver into it.

BOILER BLOW-OFF CONNECTIONS

57. Blow-off pipes from steam boilers should never connect with the house drain, but should enter the house sewer on the street side of the main drain trap after passing through a proper cooling tank. In the case of low-pressure heating boilers, the cooling tank can be omitted.

Blow-off connections can be made with wrought-iron or cast-iron pipe. When cast-iron pipe is used, it should be put together with rust joints or flange joints. Fig. 49 shows, in plan view, a blow-off pipe *a* connected to a house sewer *b*. A trap *c* is located on the blow-off pipe *a* inside the cellar wall, a clean-out being located at *d*. By blowing off the boiler water on the sewer side of the main drain trap, steam is prevented from entering the plumbing system in the building and thereby ruining the joints.

STABLE DRAINAGE

58. The same general rules that govern the installation of house-drainage systems, govern the installation of stable-drainage systems. The stable sewer should, if possible, connect separately with the street sewer. The drain within the building should be of cast iron or wrought iron and extend at least 5 feet outside of the foundation wall. It should be trapped with a running trap, just inside of the foundation wall, which must be accessible. It should be provided with a fresh-air inlet, and have clean-out openings located along the drain wherever it is liable to stoppage. All branches should be made with **Y** fittings, and the main lines of soil and waste pipe should extend full size up to and through the roof. Rain leaders should be properly trapped and connected to the drain, and all fixtures should be separately trapped and ventilated. The whole system becomes therefore practically the same as house-drainage work. In some localities, the stable occupies a site on the same plot of ground with the house. When such is the case, a single sewer can be run in from the street sewer and a branch taken off for either the house or the stable. Fig. 50 shows such a plan, in which *a* is the street sewer and *b* is a combined house and stable sewer. The house-sewer branch is located at *c* and the stable sewer proper at *d*. A main drain trap and fresh-air inlet is located inside the cellar wall of the house, another being located inside the cellar wall of the stable; or, if there is no cellar, it may be located outside in a manhole.

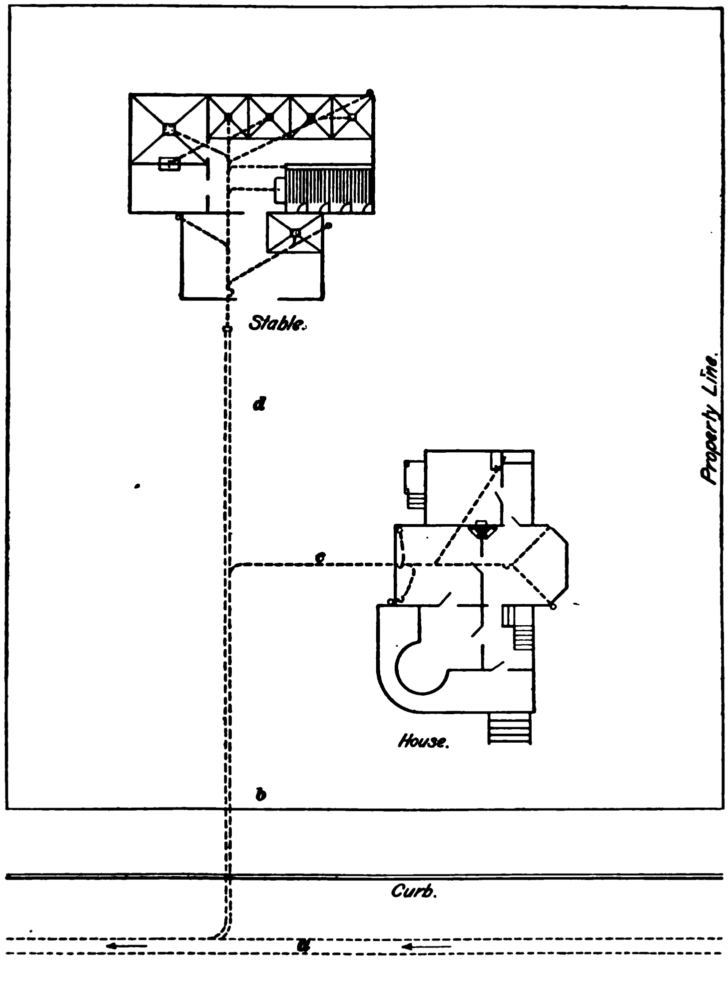


FIG. 50

59. Stall drains are made of durable hardwood planks with grooves in them draining to a gutter at the rear of the stalls. The gutters discharge into the stable drains through traps. This form of stable drain with some modification is the kind generally used.

Fig. 51 (*a*) and (*b*) shows sectional views of a stall drain made of grooved planks, in which *a* are 3-inch planks, grooved almost their entire length, as shown at *b*. The grooves *b* are deeper toward the back of the stable, as shown. Fig. 51 (*c*) is a sectional view of the stable gutter, which consists of a

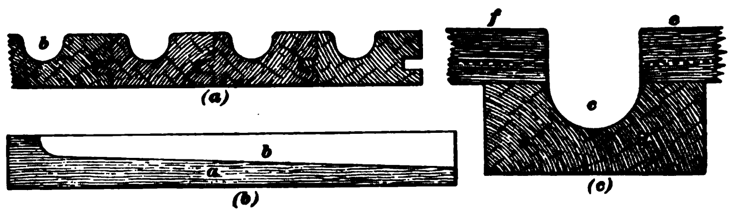


FIG. 51

groove *c* cut in a timber *d*. The groove is made deeper at the outlet end, to allow for drainage; *e* is the stall floor and *f* the stable floor, which drain into the gutter *c*. The under surface, tongue, and groove of the flooring of the stalls should be painted with asphalt or tar to keep it from rotting. The

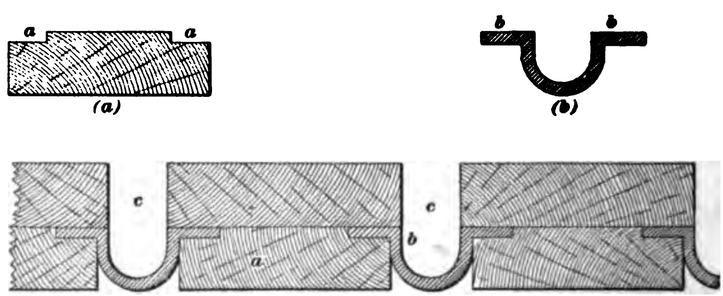


FIG. 52

flooring should be laid with a fall of about 1½ inches toward the stall gutter. Where the planking *e* and *f* rests on the gutter *d*, it should also be coated with tar or asphalt.

60. Fig. 52 shows, in section, an improvement of the grooved-plank stall drain. This drain consists of a double floor of 2-inch planks with iron channels between them.

Fig. 52 (*a*) shows the planking for the lower floor, which is rabbeted to receive the flanges *b*, *b* of the iron channel shown in Fig. 52 (*b*), and Fig. 52 (*c*) shows a section of a stall drain laid. A cast-iron gutter runs under the ends of the channels *c*, into which all drainage is discharged.

61. Fig. 53 shows a section of a stall gutter and waste connection, in which *a* is the stall drain that empties into the gutter *b* through the perforated iron cover *c*. The spigot *d* is calked into a piece of pipe without a hub from

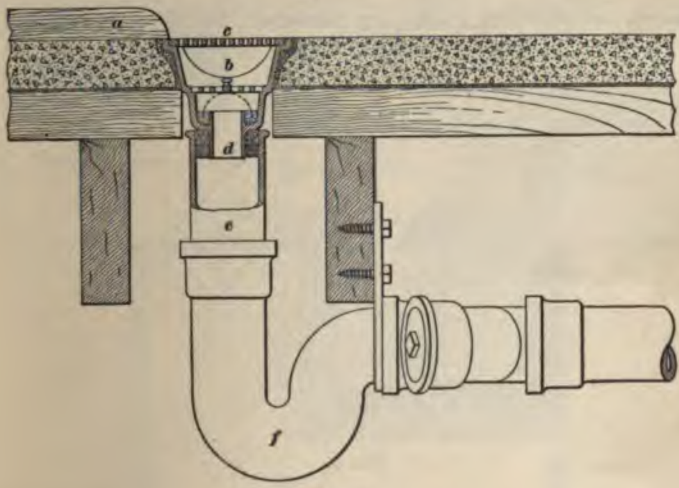


FIG. 53

the inside, as shown. The pipe *e* is then calked into the hub of the trap *f*. Traps for stall drains do not require to be ventilated. Drippings are depended on to maintain the seal in the trap. The gutters and covers are made of cast iron. The straight lengths are cast with a suitable pitch to the draining point. Various shaped fittings, such as elbows, **T**'s, and crosses, are made for changing the direction of the gutter.

Asphalt floors for stalls and stables are made by covering the floor space of the stalls and stables with a course of Portland cement concrete at least 4 inches thick, which should be graded toward the gutters. The concrete should then be covered with a layer of asphalt at least 2 inches thick.

62. Fig. 54 shows an excellent combination trap and stall chamber for stable drains. The gutter *a* may be laid with an inclination of about 1 inch for 10 feet and discharge into a trap and catch basin *b*, as shown. The solid matter will accumulate in the bottom and may be removed by lifting off the perforated covers *c* and *d*. Straw and such

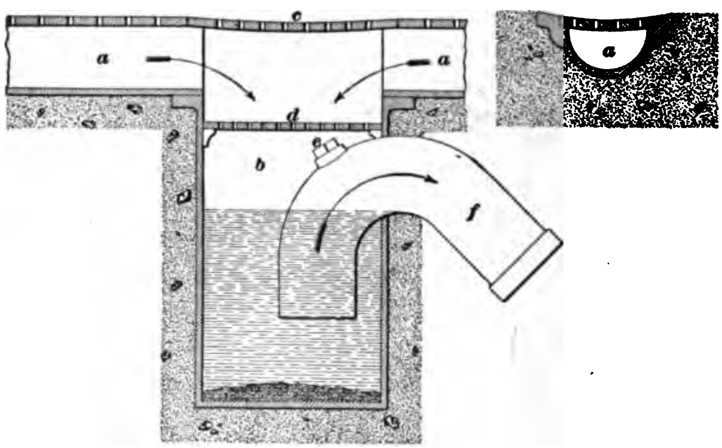


FIG. 54

matter that might pass through the floor gratings is likely to be intercepted by *d*. A clean-out screw should be provided at *e* through which rods may be inserted in case the pipe *f* becomes choked. The clean waste water from hydrants or drinking troughs should, if possible, empty into the floor gutters at their ends, so as to flush and clean them.

63. The carriage wash is a space on the carriage floor where carriages are placed to be washed. The flooring of this space slopes toward some point, generally the center, which is drained by a cast-iron catch basin and trap connected to the stable drain.

64. Fig. 55 shows a stable and carriage house. The stable contains four box stalls, four common stalls, a grooming room, and a harness room. The carriage house has a carriage wash in the corner. There is supposed to be a space of about 3 feet between the ground and the floor, in which

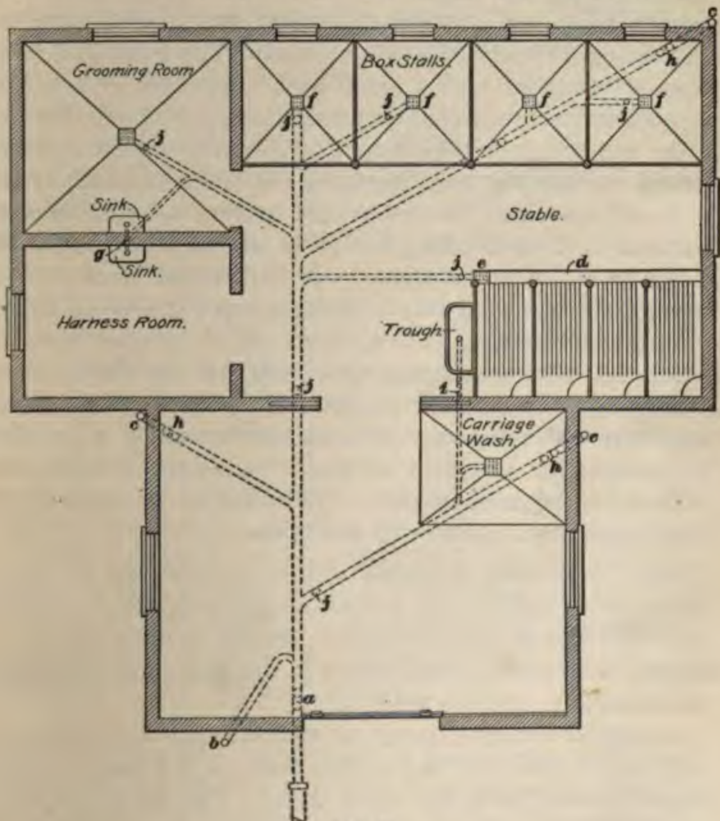


FIG. 55

the drainage pipes shown are run. They are suspended from the floorbeams, or supported on brick piers raised on the ground. A 5-inch main drain trap is located at *a*, under the carriage-house floor. A 5-inch extra heavy pipe goes through the wall and connects to a 6-inch earthenware drain underground. A 4-inch fresh-air inlet rises above the ground at *b* and terminates with a cowl. The leaders are located at *c, c*. The common stalls are provided with a stall gutter, having a perforated cover at *d*, which gutter discharges into a gutter box and trap at *e*, a clean-out being provided on the sewer side of this trap. The box stalls are provided with a catch basin and trap *f* in the center, the floor of each box stall being pitched down to this point. The grooming room also is provided with a catch basin and trap. Sinks provided with hot and cold water are located in the harness room and in the grooming room. A 4-inch stack *g* is run up to and through the roof between the sinks to ventilate the drainage system. The rain-water leaders are disconnected by traps *h, h*. A drinking trough is located at the end of the common stalls in the stable. A 2-inch vent stack *i* taken from the sewer side of the trough trap extends up to and through the roof. The carriage wash is also provided with a catch basin and trap sunk flush with the floor. Four-inch brass clean-outs are located at *j* for access to the drainage system at any point, and a suitable manhole is provided in the floor for access to all these clean-outs, because they will require frequent attention if the traps are not periodically cleaned out and flushed with the hose.

65. Drinking troughs should be provided on all the floors of a stable where horses or cattle are kept. There are two kinds of water troughs: general troughs for all the horses, or separate ones located in the stalls and sometimes automatically supplied with water.

A general watering trough should be supplied with hot and cold water; it should be properly trapped and ventilated and should connect with the stable drain. The outlet should be provided with a plug to hold the water in the trough, and it should have an overflow to the house side of the fixture trap.

WROUGHT-IRON DRAINAGE SYSTEMS

66. Pipes and Fittings.—A system of piping large buildings with galvanized or tar-coated wrought-iron or steel pipe and recessed drainage fittings, which are put together with screw threads, is now very extensively used in the larger cities, and is generally known as the *Durham* system. For the class of work in which it is used, this system has many advantages over the cast-iron pipe system, among which is the greater strength of the joints, which cannot work loose, as is sometimes the case with lead-calked joints.

All iron pipe put together with screw joints is known as *wrought-iron pipe*, although most so-called wrought-iron pipe is made of steel. The system of installation and method of handling is the same in the case of wrought-iron and steel pipes. Plain black wrought-iron pipe should never be used for a drainage system, as it corrodes and scales too quickly. The pipe and fitting should be either galvanized or tar coated.

Systems of wrought-iron and cast-iron piping are in principle the same. The method of installation only is different.

It is customary in large steel-frame buildings, fitted with the wrought-iron drainage system, for the plumber to work ahead of the bricklayers, keeping his lines one story above them. To do so, great care must be exercised in taking measurements so that the branch waste and vent pipes will come inside of the partitions where they belong. This method of working ahead of the bricklayers makes the work easier and quicker for the plumber, as there is no cutting of walls or arches in order to install the lines and branches. A suitable floor to work on is made by laying planks across the iron beams, on which a scaffold should be constructed for putting up all overhead work.

67. Fittings used on wrought-iron drainage systems are made especially for the purpose, and have a recess so that when the pipe is screwed into the fitting to the shoulder there will be a smooth continuous inner surface. The fittings are also made with easy sweep, that is, long radius curves to offer as little resistance as possible to the flow of sewage.

Types of drainage fittings with their trade names printed under them are shown in Fig. 56. Elbows are made with bends of $5\frac{5}{8}^\circ$, $11\frac{1}{4}^\circ$, $22\frac{1}{2}^\circ$, 45°, 60°, and 90°. Elbows of 45° and 90° are made from two patterns, long-turn bends and

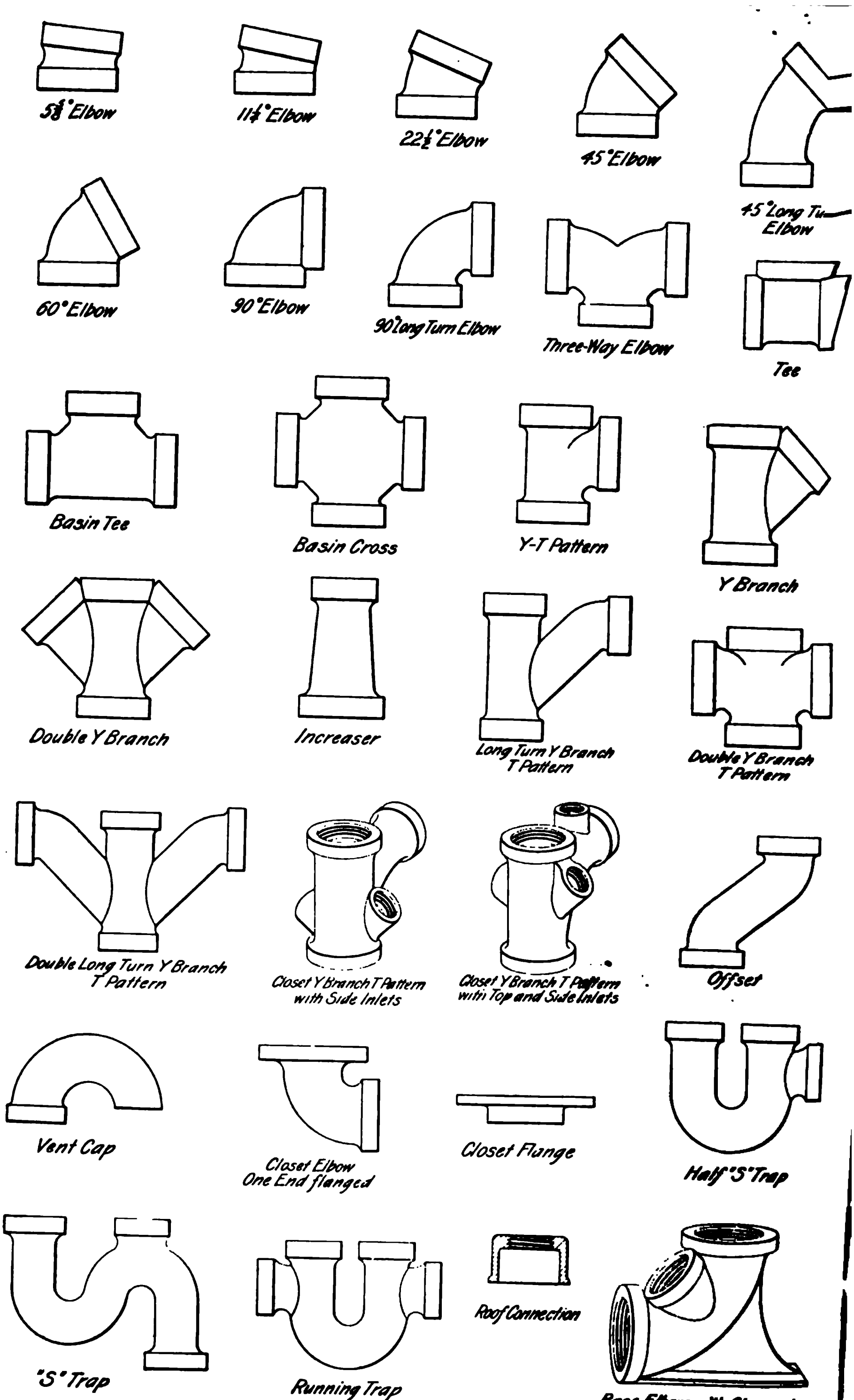

5⅝° Elbow
11¼° Elbow
22½° Elbow
45° Elbow
45° Long Tu
Elbow
60° Elbow
90° Elbow
90° Long Turn Elbow
Three-Way Elbow
Tee
Basin Tee
Basin Cross
Y-T Pattern
Y Branch
Double Y Branch
Increaser
Long Turn Y Branch
T Pattern
Double Y Branch
T Pattern
Double Long Turn Y Branch
T Pattern
Closet Y Branch T Pattern
with Side Inlets
Closet Y Branch T Pattern
with Top and Side Inlets
Offset
Vent Cap
Closet Elbow
One End flanged
Closet Flange
Half "S" Trap
"S" Trap
Running Trap
Roof Connection
Base Elbow with Cleanout

Fig. 56

short-turn bends. Long-turn bends are the most suitable for horizontal drains, although, where space will not permit their use, short-turn bends may be used. Branch fittings are made **T** pattern, **Y** pattern, and **T Y** pattern. Branch **Y** fittings are made with angles of 45° and 60°. They are made with outlets all the same size, and also with reduced branch outlets. Double **Y** fittings are made with angles of 45° and 60°, and also with reducing branch outlets. **T Y** fittings are made single and double, and from two patterns—long-turn fittings and short-turn fittings. Long-turn fittings are especially suitable for house drains, while short-turn fittings are commonly used on vertical stacks of soil and waste pipes. A convenient form of branch fitting for bathroom outlets is either the closet **Y** branch of the **T** pattern with side outlets, or the closet **Y** branch of the **T** pattern with top and side outlets. These fittings provide separate connections to the soil or waste stack for the usual bathroom fixtures, and obviate the necessity of connecting the basin and bathtub wastes to the lead closet bend. Cast offsets are convenient fittings for use where a line of pipe is to be offset 12 inches or less. Larger offsets are made with 45° or 60° bends and a piece of pipe. The vent caps are used only on fresh-air inlets and are seldom made larger than 5 inches diameter. Closet elbows and closet flanges are used for closet connections. They are only used, however, when a system is entirely of wrought iron. In most installations, lead closet connections are used. Roof connections are placed on vent pipes above the roof to prevent rain water following the pipe inside of the roof flashings. Drainage-fitting traps are made both for house drains and fixtures; they may be had in standard sizes from 2 to 8 inches in diameter. Base elbows are used at the foot of soil or waste stacks, and are provided with heavy rests to support the weight of the wrought-iron vertical stack.

68. Measurements.—For wrought-iron drainage pipes, the measurements are taken on the job, and a sketch with the measurements is sent to the shop to have the pipes cut and threaded. On small jobs, where the diameter of the largest pipe does not exceed 4 inches, and on country work, the pipes are cut and threaded on the job. Recess drainage fittings are only used on soil waste and drain pipes, common steam or water fittings being used for vent pipes.

Fig. 57 shows a main house drain of wrought-iron pipe suspended from the steel beams by the pipe hangers *a*, *a*. A scaffold made with horses *b*, *b* and planking *c* should be erected under the place where the drain is to be located, to afford a platform to work on when taking measurements and installing the pipe.

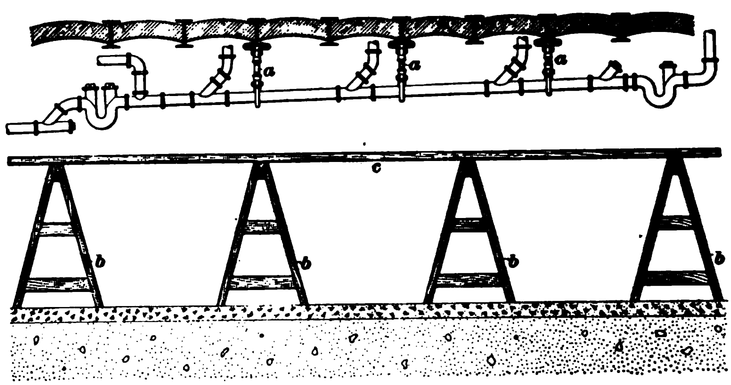


Fig. 57

Plumb-bobs should be suspended from above, where the center of the soil and waste stacks will be located, to indicate the points where the various fittings should be placed in the house drain, and if the pipes are to be cut and threaded on the job, a line drawing of the drain should be made, on which the measurements can be marked when they are taken. If, however, the diagram is to be sent to the shop, a detailed drawing should be made, showing all the fittings and having the dimensions and sizes marked thereon. A copy of this drawing should be sent to the shop and the original kept for reference.

Measurements should be made with a 10-foot rod, or when the distances are too great for a 10-foot rod, a steel tape should be used. An ordinary tape is not reliable. The distances between the plumb-lines should be measured and recorded on the sketch. These measurements represent the distance from the center of one fitting to the center of the next, and are known as center to center measurements, which may be abbreviated thus, "*c–c*."

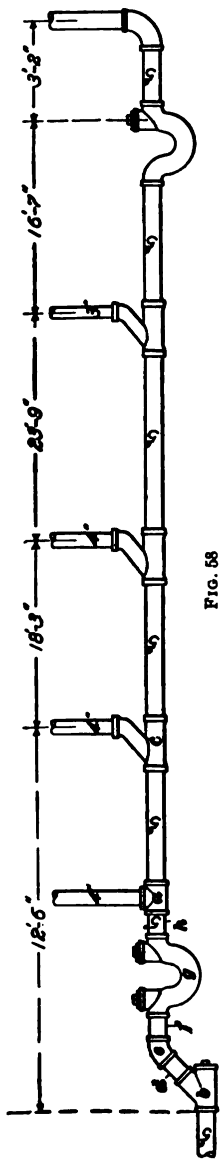


Fig. 58

69. Fig. 58 shows a working plan and measurements of a drain such as would be sent to the shop to cut and thread the pipes by. Up to the fresh-air inlet **T** *a*, no measurements have been taken, as this section of the drain will be made up as close as possible with short stock nipples and the several fittings shown. The distance from the end of the **Y** *b* to the center of the first rising line *c* is 12 feet 6 inches, so that by simply subtracting the length *a b* from the measurement 12 feet 6 inches, the length of section *a c* will be found. Suppose the distance *a b* to be 7 feet 6 inches, then the distance *a c* will be 12 feet 6 inches – 7 feet 6 inches = 5 feet.

70. Pipe Cutting and Threading From Sketch.—In getting out wrought-iron pipe, work is commenced on the outlet end of the pipe, and the fitting is screwed on the inlet end at the vise. For instance, in Fig. 58, work would commence with the **Y** *b*, into which would be screwed a short nipple *d*, and a 45° bend *e*; a short nipple *f* would next be screwed into the bend *e*, on which would be screwed the trap *g*. A nipple *h* should next be screwed into the trap *g*, on which would be screwed the fresh-air inlet **T** fitting *a*. All this work would be made up of the various fittings and stock nipples, which should be extra heavy. The first measurement to be taken would be for the section of pipe between the fittings *a* and *c*. Fig. 59 shows how a measurement is made from center to center of fittings. The fitting *a* should be screwed on the pipe *b*, and the length, 5 feet from the center of *a*, marked on the pipe, as at *c*. The fitting *d* should then be measured from the center of the fitting *e* to the shoulder *f*, against which the pipe *b* will be screwed when in place. This measurement *e f* should be deducted from the length marked (5 feet), which would show the exact place where the pipe *b* should be cut. Suppose the distance from *e* to *f* on the fitting *d* is 5 inches; then the length of pipe *b* from the center of the fitting *a* will be 5 feet less 5 inches, or 4 feet 7 inches.

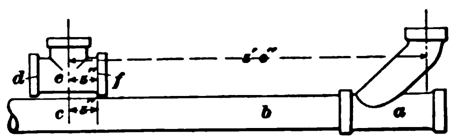


FIG. 59

Each successive piece of pipe with its proper fitting is thus measured, cut off, reamed and threaded, and the pieces marked for identification on the job.

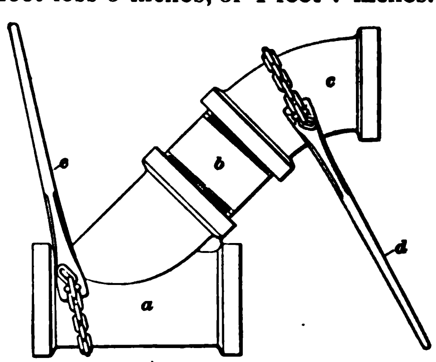


FIG. 60

71. Installation. To put together the pipe on the job, the **Y** *b*, Fig. 58, is screwed on the house drain where it comes through the foundation wall. The first four or five threads on both ends of the nipple *d* are painted with lead or graphite, one end of which is then screwed into the 45° bend *c* and the other end into branch of the **Y** *b*. Both threads are made up by hand as tight as possible, after which a chain tongs is placed on the 45° bend to screw it up while another chain tongs is put on the fitting *b* the reverse way, to keep it from turning. Screwing up the fitting *e* makes up both threads on the nipple *d*.

Fig. 60 shows the position of the chain tongs when making up the section *a c*, in which *a* is in the Y branch that connects to the house drain where it enters the building; *b*, the nipple which connects the 45° bend *c* to the branch *a*; *d*, the chain tongs used to screw up the nipple and fittings *b* and *c*; and *e* is the chain tongs that keeps the fitting *a* from turning. The whole system is put together in this manner. A short length of pipe is sometimes screwed into the branch of a fitting to

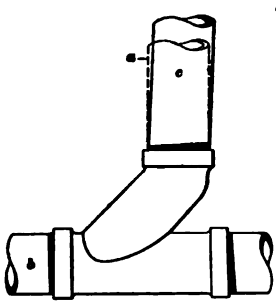


FIG. 61

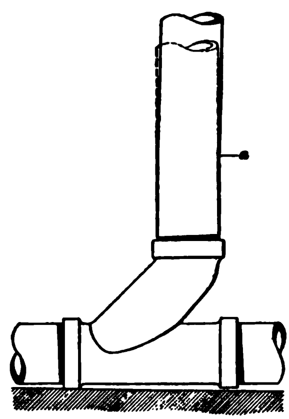


FIG. 62

keep it from turning while a threaded pipe is being screwed into it. This method is also very convenient when putting on or taking off a fitting from a piece of pipe on the floor.

72. Drainage fittings should be tapped so as to give a fall of about ¼ inch to the foot to a horizontal pipe without resorting to a crooked thread or a bend in the pipe.

Fig. 61 shows, by the dotted lines at *a*, the position of a rising line from a horizontal drain *b* when the fitting is tapped at right angles; while *c* shows the position of the pipe when the fitting is tapped to allow for a fall to the drain when the stack is plumb.

When drainage fittings are not tapped to allow for fall, a crooked thread cut on the bottom of the rising line or a slight bend in the pipe will give the required direction to the stack. Fig. 62 shows a rising line turned to a perpendicular by means of a bend at *a* in the vertical pipe. This may be necessary if the fall of the drain is greater than the tapping will allow.

Fig. 63 shows a crooked thread *a* cut on the end of a pipe *b*. The angles that can be given a pipe by the use of a crooked thread depend on the angle at which the thread is cut on the pipe. When the angle is very slight, there is nothing objectionable to this method of securing a pitch for a pipe, but if the angle is great, the thread will be cut much deeper on one side of the pipe than on the opposite, as shown at *c*, and the pipe will be weakened at this point. Crooked threads, therefore, should not be used, generally speaking.

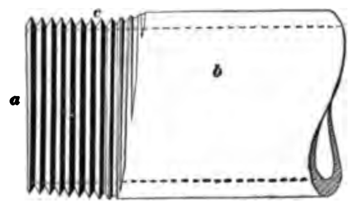


FIG. 63

73. Temporary hangers should be used to support all horizontal lines of pipe while they are being put together, and should support them in about the positions they will occupy when the work is completed. In frame buildings, temporary hangers consist of two pieces of board nailed vertically to the floorbeams and secured to a horizontal board passing under the pipes. Permanent hangers should in all cases be placed on the pipes before the temporary ones are removed. Supports from the floor, or staying, can be used in place of temporary hangers when making up pipe, but in such cases permanent hangers should be put on the pipe as the work progresses. Temporary hangers for steel structures can be made the same as for frame buildings, but with iron beam clamps to support them from the beams. A better way, however, is to put in the permanent hangers first, and place the pipe in the hangers when making it up. Hangers should be placed not more than 10 feet apart on pipe up to 4 inches in diameter, and not over 5 feet apart on larger pipes. Wherever branches are taken out of horizontal drains for rising lines, two hangers should be used, one on each side of the fitting.

The same general rules should be observed in leveling wrought-iron pipes as in leveling cast-iron pipes, with this difference, however: the straightedge need not rest on the hubs of the fittings but may be applied directly to the pipes.

SEWAGE EJECTION FROM BUILDINGS

INTRODUCTION

PURPOSE

74. Public toilet rooms, underground passenger stations, and the cellar and basement floors of large city buildings, are often below the level of the city sewer in the adjacent street. When this is the case, sewage from the fixtures in the basement cannot enter the sewer by gravity, but must be raised to it by mechanical means. The sewage from all fixtures higher than the sewer level, and the roof water, should, however, discharge by gravity into the sewer.

Different methods are used for raising subsewer drainage to the street sewer, such as pumping and compressed-air ejectment. The latter is more commonly used because the apparatus is less liable to derangement. The systems of piping are arranged so that the sewage is collected by gravity in a tank, called a **sump tank**, located lower than all fixtures or subsoil pipes to be drained. The apparatus is usually placed in a subbasement, or pit in the basement, of the building from which the sewage is to be pumped to the street sewer. The sump tanks or sewage receiving tanks and the pumps should always be in duplicate, that is to say, there should be two tanks and two pumps arranged side by side. Each unit, that is, each pump and tank, should be large enough to take care of all the sewage independent of the other. Then, one pump and tank may be disconnected for repairs without affecting the operation of the system.

PLUNGER AND CENTRIFUGAL PUMPS

75. There are two kinds of pumps that can be used for sewage ejectment: *plunger* and *centrifugal pumps*.

Plunger pumps are seldom used, chiefly on account of the leakage of sewage around the plungers, which produces foul odors; consequently, a plunger pump is not a sanitary contrivance. The leakage is caused by the sliding of the plungers out and in through the packing boxes, and as the pumps are usually out of sight in a dark place the leakage does not receive prompt attention.

Centrifugal pumps are less liable to leakage and to become inoperative by corrosion of the working parts. A centrifugal pump consists of a hollow casing in which is placed a wheel with a set of curved vanes. The wheel is rigidly keyed to a shaft or axle that extends through a packing box on one side of the casing to connect to a pulley, electric motor, or other means of motion. Fig. 64 shows two sectional views of a centrifugal pump, and clearly shows its construction. The sewage flows through the suction inlet *a* into the chambers *b*, *b* and is thus delivered to the inner ends of the vanes *c*, *c*, which are revolved by an engine or motor. The sewage, of course, revolves with the vanes and is driven outwards by the action of centrifugal force into the spiral-shaped passage *d*, which leads it to the discharge pipe connected to the outlet *e*. The pump should be below the level of the sewage in the sump tank, in order that it may always be filled with sewage; it will then start pumping as soon as it is set in motion.

PIPING

76. The subsewer system of piping, or that part of the drainage system located below the street sewer level, should be graded down to the air-tight receiving tanks, which should be made of iron, and enclosed in a water-tight iron or brick chamber placed at such a level that all subsewer soil and drain lines can empty into them. From the top of each receiving tank, a vent pipe should be extended to the street

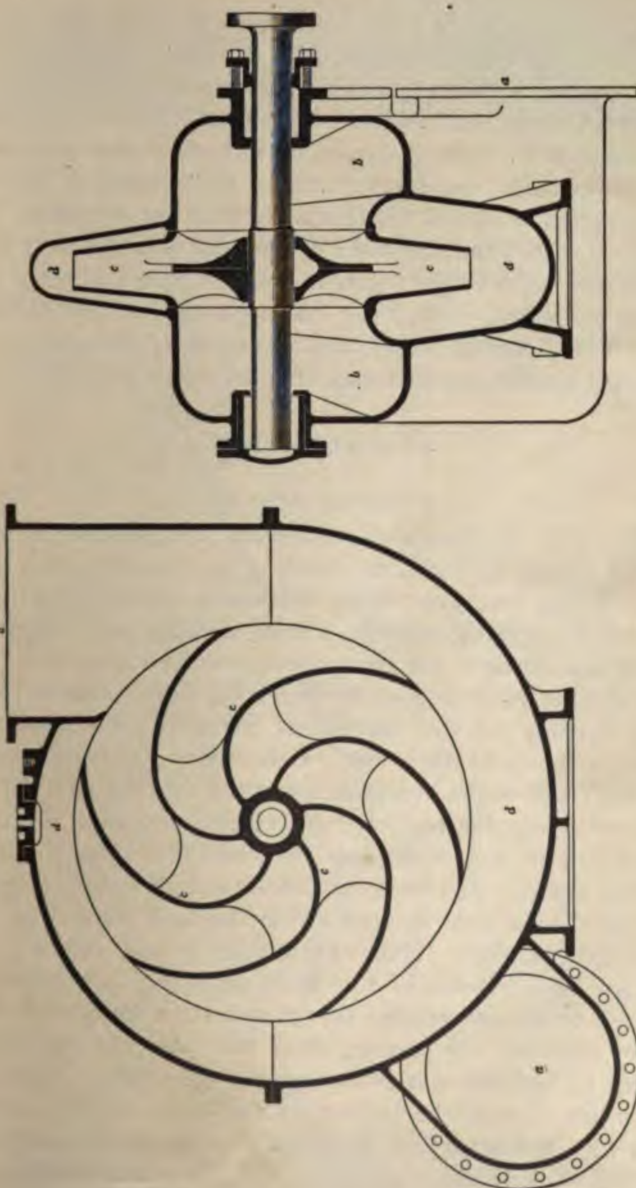


Fig. 64

curb or other suitable place to act as a fresh-air inlet to the system. The discharge pipe from the sump should run in a vertical direction as high as is necessary to obtain a gravity discharge from that point to the sewer. This allows only the water in the vertical line to drain back to the tank when the pump stops, should there be no check-valve on the discharge pipe, or should the check-valve be out of order. The vent lines from the subsewer system can join the vent lines of the house drainage system that discharge directly into the street sewer, or they can run separately to and through the roof. No main drain trap is necessary on a subsewer drainage system, as the sump tank takes the place of a trap.

INSTALLATION

PUMPING SYSTEM

77. Fig. 65 shows an apparatus for pumping sewage from a receiving, or sump, tank *a* to a sewer. The tank receives the discharge from the entire subsewer drainage system through the inlet *b*; a fresh-air inlet pipe *c* from the sump tank opens to the atmosphere near the curb. A suction pipe *d* from the bottom of the receiving tank connects to the inlet opening of the centrifugal pump *e*. The discharge pipe *f* connects to the sewer. Gate valves *g*, *g* are placed on the inlet and outlet connections to the tank to shut off the tank or pump for repairs. An electric motor *h* is direct-connected to the pump and operates it. The motor is started and stopped by an automatic switch *i* that is opened or closed by a float located inside the tank, as at *j*, or in a separate chamber. When the pump is not running, the sewage accumulates in the tank until the float is raised enough to throw over the switch and start the motor. The pump removes the sewage from the tank quicker than it comes in, and the water-line consequently falls. When the water-line is near the bottom of the tank, the float, which falls with the water-line, throws the switch back again, thus cutting off the electric current to the motor and stopping the pump. The tank then refills and the operation is repeated.

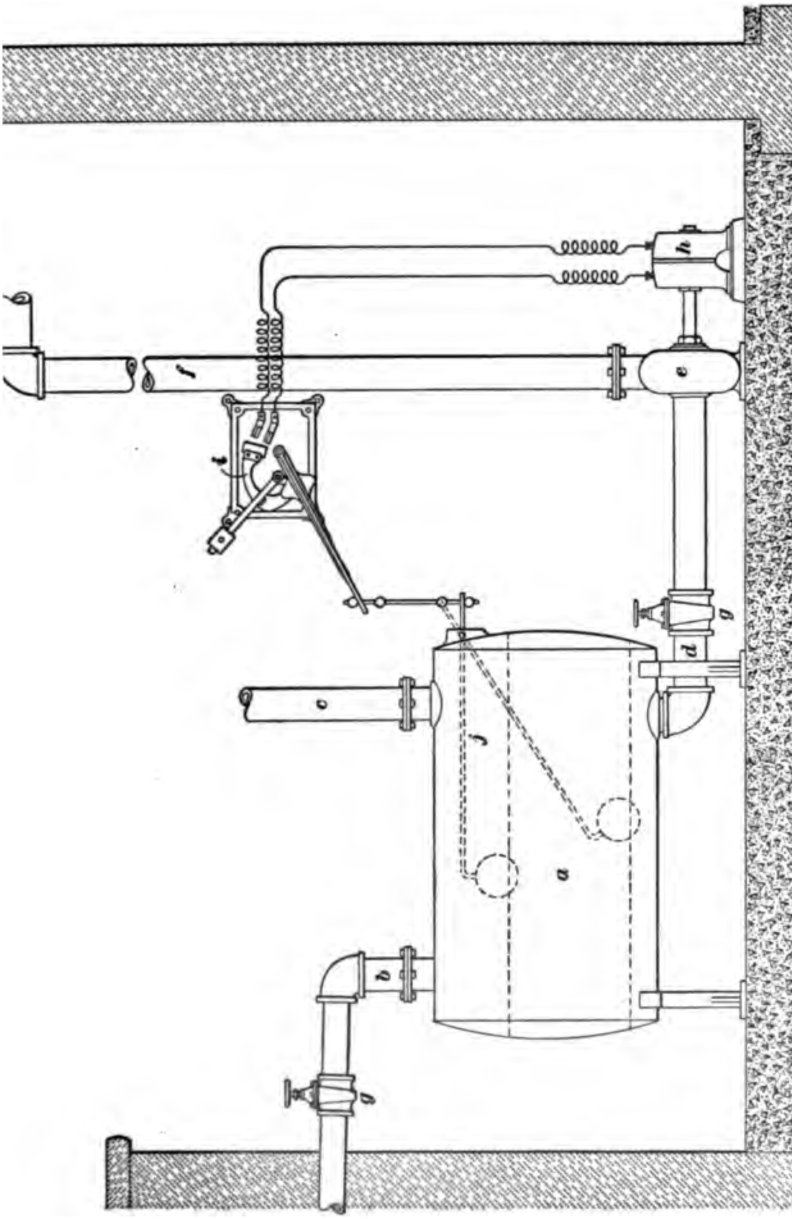


Fig. 65

78. The pump and motor should be firmly secured to a stone base, and the pipes connecting it securely fastened, to prevent vibration when the pump is operating. It is not necessary to screen the sewage when a centrifugal pump is used, because anything that enters the inlet opening to the pump can easily be discharged to the sewer. The discharge of sewage from the tank should be made automatic and certain, so that sewage cannot back up in the system through neglect of the one in charge to start the pump at the proper time. Although only one pump and one tank are shown, it is advisable to install a duplicate arrangement alongside, placing a gate valve on the inlet pipe to each tank, so that either tank can be used.

The use of pumps for sewage ejectment from buildings is not much favored by sanitary engineers at present, the method of removal by means of compressed air being preferred. When pumps are to be used, however, centrifugal pumps should be selected.

COMPRESSED-AIR EJECTION

79. General Considerations.—There are several designs of automatic ejectors for removing sewage by means of compressed air, all of which operate on the same general principle. For instance, they must all have a perfectly air-tight receiving, or sump, tank, which should be located in a water-tight chamber built of iron or brick. The sump tank must be located at such a level that all drainage from the subsewer system will flow into it by gravity. The inlet pipe must be provided with a check-valve closing when the pressure of air is applied to the tank and opening freely by the flow of sewage when the pressure is released. The tank must have a vent pipe that opens automatically to permit the escape of air after the tank has been emptied and which closes automatically when the tank is full and the compressed air is applied. There should be an apparatus to automatically open an air valve and admit compressed air when the tank is full and to automatically close the air valve when the tank is empty.

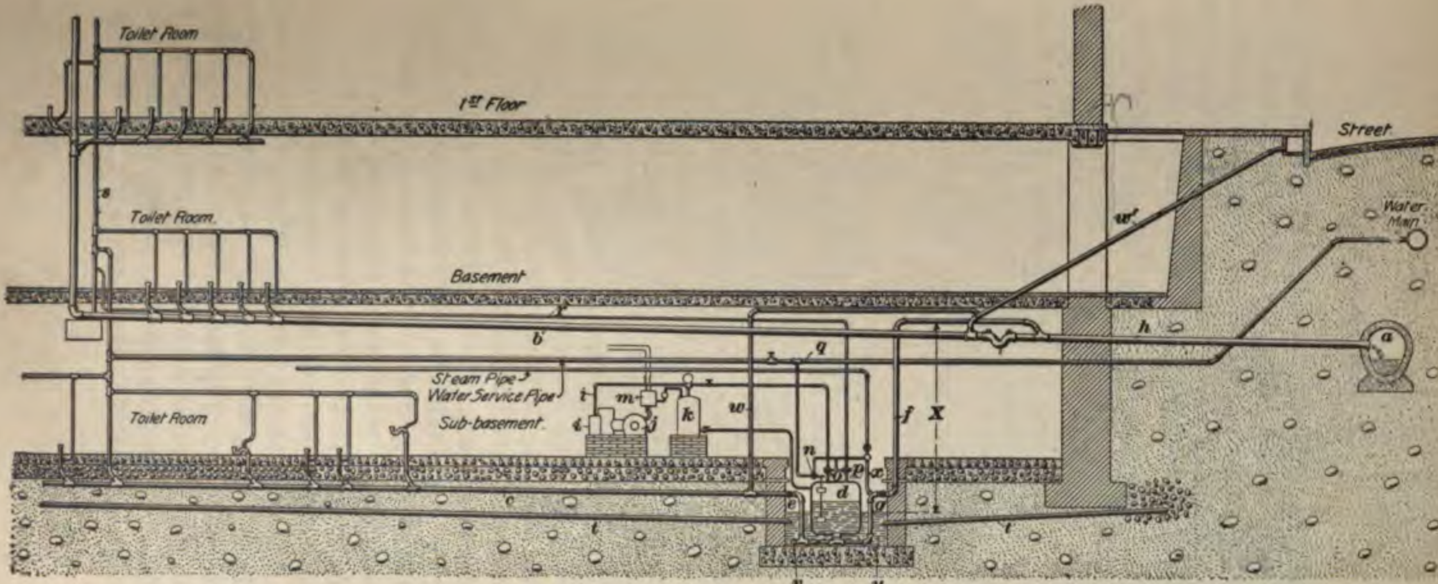

Toilet Room
1st Floor
Street
Toilet Room
Water Main
Basement
Steam Pipe
Water Service Pipe
Sub-basement
Toilet Room

FIG. 66

A check-valve should be in the discharge pipe from the tank to keep sewage in the discharge pipe from returning to the tank. An air compressor is needed to provide compressed air; also, a tank to receive and store it, and an air pipe from the air tank to the automatic valve on the sump tank. An electric or water motor is required to operate the air compressor automatically when the pressure in the air tank is lowered. The ejectors should be in batteries of two, each being of sufficient size to discharge all the sewage from the drainage system. The motors, air compressors, and air tanks should be located in the engine room or other convenient place where they are open to inspection and repairs at all times.

80. Ellis Sewage Lift.—A device that is commonly used in buildings to raise sewage and discharge it to the street sewer is shown in Fig. 66, which illustrates the general principles of this apparatus, known as the **Ellis sewage lift.** The sewer is located at *a*; the plumbing fixtures drainage in the subbasement, and the subsoil water has to be removed by an ejector or lift. The main house drain *b* is run as low as the sewer will allow, and it takes the discharge from all the fixtures above it, and also the roof water. The subbasement main drain *c* is located just low enough to take the discharge from all the plumbing fixtures located below the sewer level. The lower end of *c* discharges into the bottom of a cast-iron or wrought-iron receiver *d* through a check-valve *e*. A discharge pipe *f* having a check-valve *g* located near the receiver delivers the contents of *d* into the house sewer *h*, the connection being made on the sewer side of the main drain trap shown. An air compressor *i* operated by an electric motor *j* pumps compressed air into an air reservoir *k* through the pipe *l*. An automatic-switch regulator and rheostat are located in a casing *m*. A pipe connects the regulator with the air receiver. The pressure carried in *k* is preferably not less than 1 pound for each foot that the sewage has to be raised. Thus, if the distance *X* is 15 feet, the pressure in *k* must be not less than 15 pounds per square inch, indicated by the gauge shown on top of *k*. The apparatus will operate with a lower pressure in *k*, but the time required to discharge the contents of *d* into the sewer will be much longer and there will be a liability of the discharges from the toilet room in the subbasement filling *c* before *d* is empty.

81. The automatic discharging of *d* is accomplished by means of three automatic valves *n*, *o*, *p*. The valve *n* is a hydraulic valve having its inlet connected to the water-supply main *q* by a ½-inch pipe, and its outlet connected to the balanced valve *o* on the air-pressure pipe as well as to the balanced valve *p* on the vent pipe. These balanced valves work in opposite directions; thus, when the valve *n* is open, water under street pressure opens the valve *o* and closes the valve *p*. This allows compressed air to flow freely into *d*, press down on the surface of the sewage that has accumulated therein and thus force it up through *l* to the sewer; the vent valve *p*, being closed, confines the compressed air in *d*. As soon as the valve *n* is closed, water pressure is removed from the balanced valves and they reverse their position, that is, the valve *o* is shut and *p* is opened. This action allows the compressed air confined in *d* to escape through the vent pipe *r* to the vent stack *s*. The pressure inside *d* then becomes equal to that of the atmosphere, and sewage can flow freely from *c* to *d*.

82. The water valve *n* is operated by a stem passing through the top of the receiver, the upper end of the stem being attached to the balance lever on the valve stem and the part inside the receiver being furnished with a float near the top and a submerged bucket at the bottom. When the sewage has risen in *d* to the level of the float, the stem is raised by the buoyancy of the float and the water valve *n* is opened, allowing the air pressure to force the sewage from *d*. The water valve remains open as the tank is emptied until the water-line falls below the submerged bucket, when the weight of this bucket moves the lever of the valve *n* and shuts off the water from the balanced valve. Thus, it will be seen that the upper float opens the valve *n* and the submerged bucket closes it. The subsoil water from the foundation drains discharges by gravity through the pipes *t*, *t* into the brick sump *u*, filling this sump outside of the receiver, check-valves being placed over the mouth of the pipes *t*, *t* inside the sump to prevent rats from entering the subsoil drains. Sump water flows through the check-valve *v* into the receiver as soon as the air pressure is removed from the receiver, because the water-line in the receiver is then lower than the water-line in the sump. This check-valve automatically closes, however, as soon as the sewage in the receiver has reached the level of the water in the sump. The sump should be covered with movable iron plates laid flush with the floor; the valves *n*, *o*, *p* are usually located under these plates and on top of the receiver.

83. The advantage in having the subsoil water flow into the sump lies in the fact that should the check-valve *v* leak, the water in the sump will become slightly polluted with sewage, which can be readily detected by the engineer. If the subsoil drains were connected directly to the tank, this check-valve might leak sewage back into the subsoil drains without its being noticed, and thus saturate the soil under the building with sewage matter, which would be a dangerous condition. Should the check-valve *e* leak, sewage matter from *d* will be forced back to *c* and overflow the closets in the subbasement if the volume of leakage is sufficiently great to fill these lines while the ejector is working. Presumably the safest attachment that can be used is a sliding gate valve placed close to the check-valve *e* and another one close to *v*, both of these gate valves being operated by a rod attached to a plunger that is moved by water pressure from *n*. Thus, when sewage is being ejected the gate valves at *e* and *v* will be closed but will open automatically as soon as the pressure in *d* is relieved.

84. The ventilation of the house drainage system in the subbasement is accomplished by a fresh-air inlet pipe *w* that connects with the fresh-air inlet pipe *w′* for the plumbing system on the floors above. The back-vent connects to the fixtures of the subbasement, being connected to the vent stack *s*, as shown. In this way thorough ventilation of the subbasement plumbing can be obtained.

85. Should only one receiver be installed, it is essential to have auxiliary apparatus that will discharge the sewage while the air-pressure sewage lift, or ejector, previously described, is undergoing repairs. Otherwise should the motor, compressor, or switch require to be shut down, the tank *k* would lose its pressure and sewage would flood *d* and the basement fixtures while the repairs were being made to the machine. To prevent this, it is customary to attach a steam-jet ejector at *x* on the discharge pipe from the sump. While repairs are going on, it is then necessary only to open the gate valve on the ejector steam pipe, allowing the steam to flow through the ejector *x*. This will lift the sewage from the tank *d* into the street sewer, but will raise the temperature of the sewage presumably about 15 to 20 per cent. When the sewage has been sucked out by the steam ejector, steam will automatically be shut off from the ejector. The steam ejector, therefore, works intermittently as the tank becomes filled with sewage.

86. The discharge pipe *f* connects to the sewer side of the main drain trap to prevent steam accidentally flowing through *f* entering the drainage system, which would ruin the joints in the system throughout the building if it were allowed to blow up through the soil and vent stacks.

When two or more receivers are employed, the check-valve on one should be weighted heavier than the other, so that the receiver with the weighted check-valve will take the surplus sewage that backs up in the line while the receiver with the light check-valve is being discharged.

Should an air-pressure sewage lift work too slowly to take the drainage, it is necessary only to increase the pressure in the air tank *k*. The average job works under a pressure of about 30 to 40 pounds in *k*, which gives a rapid discharge to the tank.

SOIL, WASTE, AND VENT STACKS

INSTALLATION AND REGULATIONS

CAST-IRON STACKS

GENERAL CONSTRUCTION

1. General Directions.—**Soil and vent stacks** in frame buildings are generally made of cast iron, although wrought iron is sometimes used. Soil stacks should always be accompanied by vent stacks, which should run parallel with, and join the soil stacks, at an angle of 45°, below the lowest fixtures that discharge into them, or else continue down and connect to the house drain in the basement in such a manner as to prevent the accumulation of rust scales. The vent stacks should extend full size through the roof, or may connect with the accompanying soil stack above the highest fixtures when there are fixtures on less than six floors. Soil stacks should run vertically through the building from the house drain in the basement to a point above the highest part of the roof, where they should terminate as far away from windows, flues, or other ventilating openings as possible. The base of each stack should connect with the house drain by means of a Y branch, and should be well supported by a brick pier, or pipe rest placed under the house drain where the soil stack intersects it. Where the house drain is not directly under a rising stack of soil pipe, a long radius 90° bend with a heel rest should be used at the foot of the stack, a stone-capped brick pier being provided on which to rest the heel of the bend.

2. Location of Stacks.—Soil and vent stacks should either be exposed to sight, or located behind removable boards or panels held in place by screws or hinges. They should never be built into the walls, where they would be inaccessible, but should be left open. It is sometimes necessary to run soil and vent stacks through living rooms, where it is desired to conceal them. This can be accomplished by building a pipe chase in the wall, if of brick, or by running the pipe between the studding in frame buildings and covering the opening with a removable board. In the latter case, the partition may be built of 2″ × 6″ studding, instead of the usual 2″ × 4″ studding, in order to admit the pipe without forming a projection on the face of the wall.

Covered light shafts and air-shafts make a desirable place in which to locate soil and vent stacks, as drain air escaping from leaks will be carried out of the building without vitiating the air within, assuming that the covering is not made air-tight. Vertical soil and vent stacks should be held in place by means of pipe hooks or clamp supports, which should be placed at intervals of 10 feet or less, according to the nature of the work and the sizes of the pipes. A hook under each hub is preferable and should always be used where possible. The pipe may also be secured against the face of stone walls or to iron beams by means of wrought-iron bands.

3. Location of Stack Outlets.—Branch soil-pipe fittings for bathroom fixtures should be located sufficiently low between the floorbeams to permit all the fixtures resting on the floor to have free drainage to the soil stack. When it is not possible to locate a branch fitting between the floorbeams, the outlet must be placed either above the floorbeams or below the ceiling. When outlets for water closets are placed above the floorbeams, they necessitate the stepping up of the bathroom floor, or running the pipe on the top of the floor back of the closets, connecting the closets directly to the nearly horizontal branch. When below the ceiling, the pipes may be left exposed, or covered by a hanging ceiling.

4. In the case of kitchen-sink or wash-basin stacks, the waste and vent outlets can be located above the floor, and the hubs left protruding from the walls so that ferrules can be calked in, or the branch connections otherwise made, for instance as shown in Fig. 1, after the walls are plastered. To secure a neat finish, however, it is better to locate the waste branch between the floorbeams, and wipe a flange

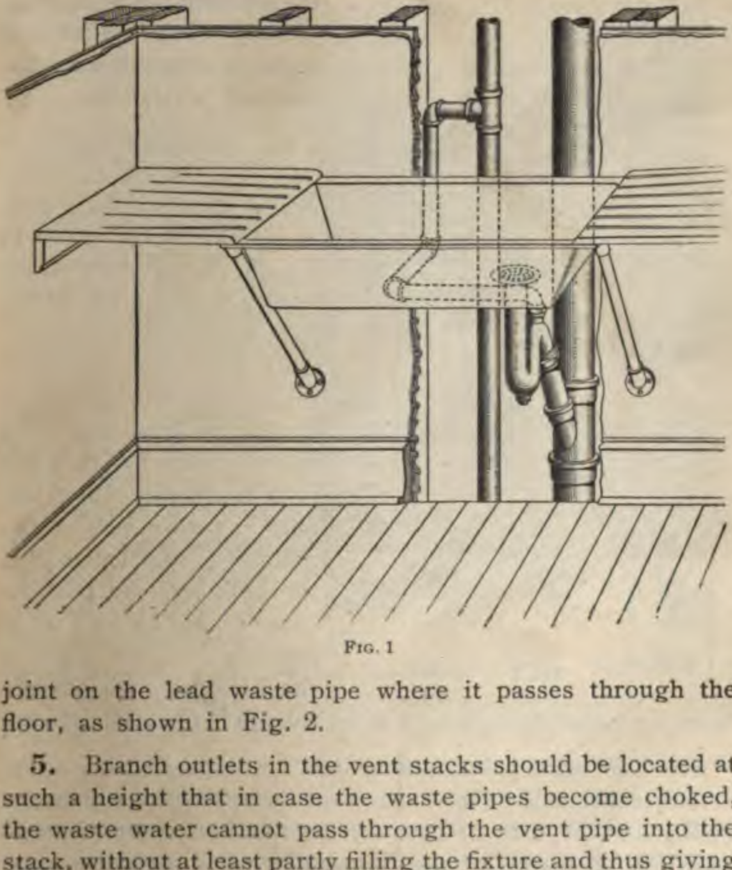


FIG. 1

joint on the lead waste pipe where it passes through the floor, as shown in Fig. 2.

5. Branch outlets in the vent stacks should be located at such a height that in case the waste pipes become choked, the waste water cannot pass through the vent pipe into the stack, without at least partly filling the fixture and thus giving notice that something is wrong. It also prevents an overflow by the discharge of water from the floor above. This is illustrated in Fig. 2. The kitchen sink *A* is connected to the waste- and vent-pipe stacks *B*, *C*. The waste stack is choked at the point *D*, and the waste water from the sinks on the floors above rises in the waste branch *E*, half fills the sink, then discharges into the vent stack *C*, and thence into the drain, to which it is connected at its base. The cause of the chokage at *D* is presumably oakum, driven into the pipe by a careless workman, which accumulates falling solid bodies until the pipe is entirely closed. Tea leaves and coffee refuse make the chokage water-tight.

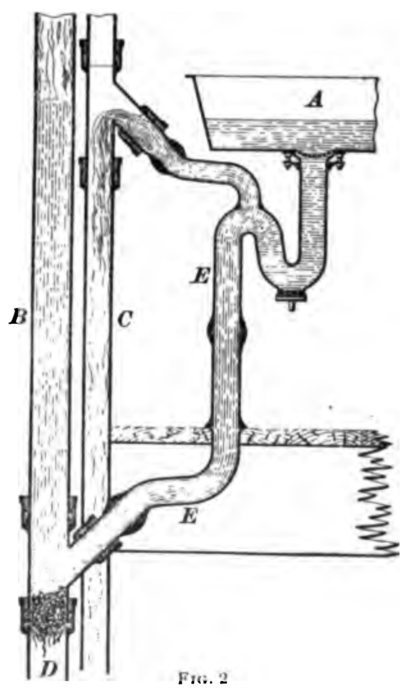


FIG. 2

6. The plumbing rules and regulations of many cities call for the back-vent connection being made at a point on the stack that is higher than the top of the fixture that it ventilates. This practice is excellent for general work, such as ordinary building and private-residence work, but it is frequently objectionable in tenement-house plumbing, particularly if the buildings are tall, because there is a liability of flooding the lower floors of the building with sewage from the upper floors in case of a chokage in the waste stacks.

7. The principal requirements for a perfect back-vent arrangement are: First, that the diameter of the pipe be sufficiently large to allow air from the outer atmosphere to flow into the crown of the trap with a volume great enough to replace water falling in the waste pipe without perceptibly decreasing the pressure in the crown of the trap. If the pipe is able to do this, it will be sufficiently large to ventilate the branch waste pipe thoroughly. Second, that the pipe at all times remain clear and unobstructed between the crown of the trap and the outer atmosphere. This can be accomplished only by arranging the pipes and connections in such a manner that foreign matter will always be excluded, and water of condensation or ice cannot close the pipe at any point. Third, that the back-vent branch in the vertical vent stack be placed neither too high nor too low.

8. Fig. 3 shows a wash basin of the ordinary type connected by a waste pipe *a* to the soil-pipe stack *b*. The vent pipe *c* connects to the vent stack *d* at too low a point. Part of the waste pipe is broken to show a chokage near the branch, and part of the back-vent pipe is also broken away at the branch on the stack *d* to show how water from the basin will overflow into the back-vent *d*. This is a bad connection, because when the waste pipe is stopped up there is nothing to indicate it. The back-vent stack is converted into a waste-pipe stack, and will sooner or later also become choked; ventilation to other fixtures in the same building will then be cut off. Care should be taken not to go to the other extreme, shown in Fig. 4, when there is any danger of chokage, unless the plumbing rules compel this form of connection. Where there are no fixtures on floors above, and where the stacks drop straight to the house drain, this

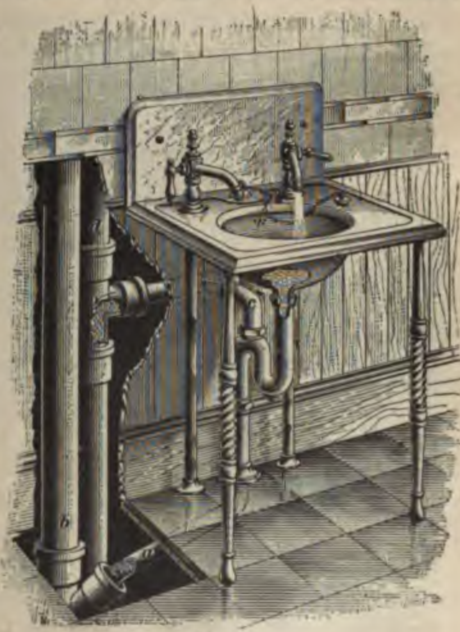


Fig. 3

manner of connecting the back-vent *c* to the vent stack *d* above the top of a fixture is not objectionable, but in buildings with fixtures on many floors, if the soil pipe should become choked at a point below the Y branch shown, the waste water from the fixtures on the floors above would collect in *b* and rise up and overflow the sink, as shown. When there is any danger of floods, such as that previously described, it is advisable to connect the back-vent pipes to the vent stacks at such points that the water may back up in the fixtures and nearly fill them, as shown in Fig. 5, before beginning to overflow into the stacks. Warning is thus given to the inmates that something is wrong.

Fig. 4

9. Special Soil and Vent Fittings. Special fittings that save time and avoid a multiplicity of joints and fittings are sometimes used to receive the fixture branches and back-vent them. They occupy less wall space than back-vents made up of ordinary pipe and fittings, which makes them especially suitable for recesses or places where there is but little space. Fig. 6 shows a stack made up with special back-vent fittings, the curves and angles of which are easy, and are in the natural direction of the water and air-currents. The easy angles of the fittings prevent them from choking with rust scales or other solids. The outlets *a*, *a* are for closet branches that are vented through the pipes *b*, *b* into the main vent stack *c*. The outlets *d*, *d* are for back-vents to other fixtures located near the stacks.

10. Offsets.—Soil, waste, and vent stacks should be run straight and vertical, if possible; but if it is necessary to make an offset in a stack, it is advisable to use two obtuse-angled bends, as *a*, *a*, shown in Fig. 7. Sharp right-angle elbows, as *b*, *b*, should not be used for this purpose. When it is necessary to make an offset so large that a long run of pipe between eighth bends will be

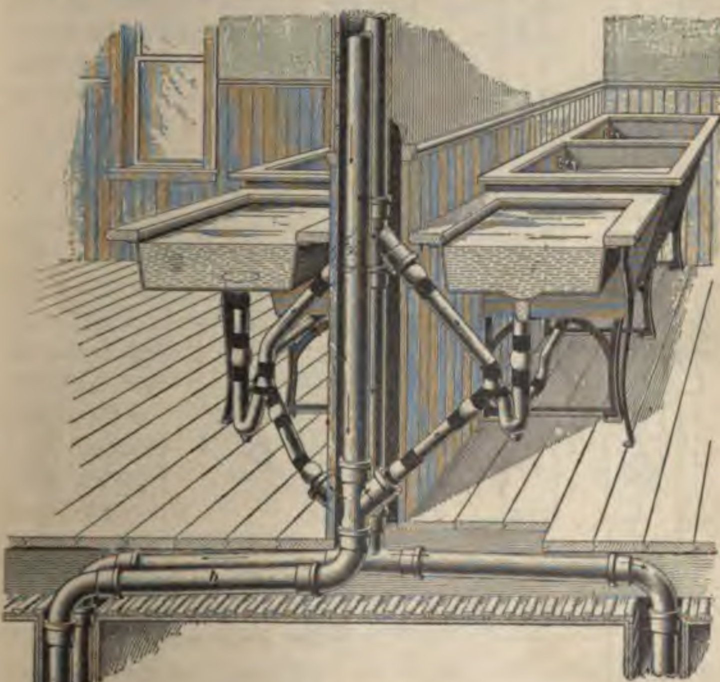


FIG. 5

objectionable, special long-sweep quarter bends should be used, the pipe between the bends having a pitch of at least $\frac{1}{4}$ inch to the foot..

All the branches to waste pipes and connections to the main drain should be made with Y branches, as shown in Fig. 8, instead of at right angles. The Y branch *a* should be inclined in the direction of the flow; that is, downwards toward a soil pipe, and upwards toward a vent pipe. By inserting an eighth bend *b* into the Y branch, the branch pipe can be connected to a vertical stack at right angles in a proper manner.

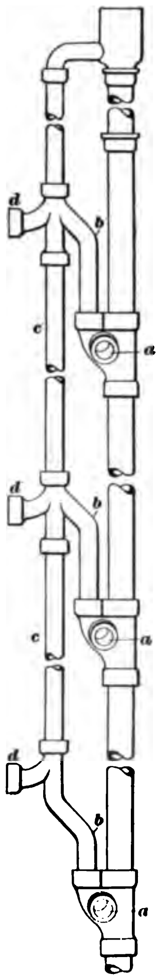


FIG. 6

11. Soil Pipes Through Roof.—All soil pipes should extend through and above the roof, thus forming foul-air outlets to the drainage system. In cold climates, the diameter of the pipe must be increased before it passes through the roof, because the warm vapor that rises in it will condense and in cold weather the outdoor end of the pipe will then become lined with ice. The formation of ice will continue until the mouth of the pipe may be choked. By enlarging the pipe, the time required to choke it is greatly prolonged. Thus, a 4-inch stack should be increased to 5 inches diameter at the roof, as shown in Fig. 9. The hub of the 5-inch piece *a* should extend above the roof to the extent shown, or slightly lower. The opening through the roof should be made water-tight by means of the flashing *b* of sheet lead. This should be extended upwards

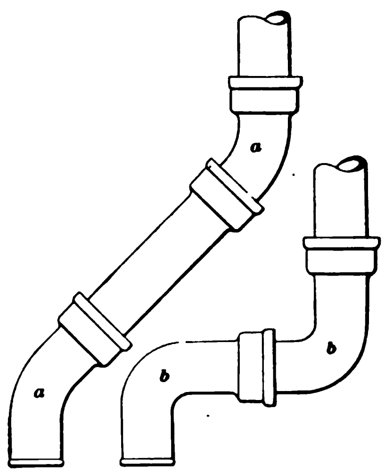


FIG. 7

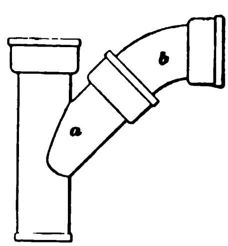


FIG. 8

under the shingles or slates *c* and be securely nailed to the roof boards. The flashing around the pipe *d* should be flanged downwards into the hub, so that when the joint is calked with oakum and lead, a perfectly water-tight joint will be made with the flashing. Care must be taken, when dressing the sheet lead into the socket, or when calking the joint, not to cut the sheet lead against the sharp edge of the socket.

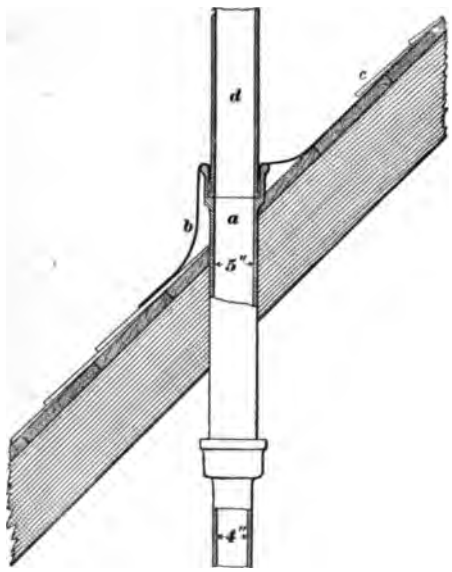


FIG. 9

12. In case a soil or vent stack is continued up through a tinned roof, the outer edge of the flange should be securely soldered to the metal roofing, the lead being folded into and calked in the socket. On tar or plastic-slate roofs, the flange should be put on and securely nailed to the roof boards. It can then be covered with the plastic roofing material by the men that lay such roofs. Where roofs are shingled, the flashing should be extended upwards under at least two courses of shingles and the lower exposed edge of the flashing secured to the shingles by short nails with large heads. Where a wrought-iron pipe passes through a roof, it can be made tight by the flashing shown in Fig. 10. This flashing consists of a sheet-metal flange *a* soldered to a tight-fitting collar *b*. The top of the metal collar extends into a recess in the coupling *c* that is screwed to the wrought-iron stack *d*; this prevents water flowing down the wrought-iron pipe from flowing inside the sheet-metal collar and thus leaking into the building. If the pipe is to be extended some distance above the roof, it can be lengthened by screwing a piece of pipe *e* into the top threads of the coupling. If the roof is not finished when the plumber has run his stacks up to the roof level, the pipe can be extended through the roof boards and the flashing slipped over the pipe into place later. If the roofing material is all on, however, the flashing should first be set in place and the pipe slipped through it from above or below and screwed into the fitting.

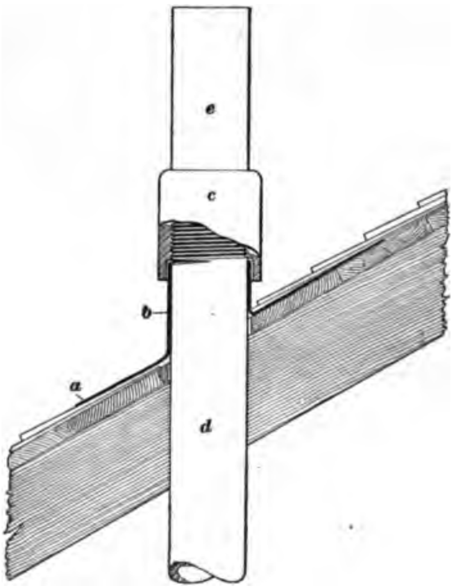


FIG. 10

13. An easy way to flash cast-iron pipe when it passes through a quarter-pitch roof is shown in Fig. 11. Into the end of the soil stack *a* is calked an eighth bend *b* so that the face of the hub will project slightly through the opening cut in the roof *c*. Sheet lead should then be slipped under two courses of shingles at the upper side of the pipe and the lead around the opening for the pipe turned over into the hub of the bend. A short piece of pipe *d* calked into an eighth bend *e* should then be calked in the hub of the bend *b* in such a manner as to turn the stack to a vertical position. This also makes a water-tight joint around the pipe. The sheet-lead flange, where exposed, should then be tacked to the shingles to prevent its being lifted at the corners by the wind.

14. Outlets Above Roof.—All vent outlets above the roof of buildings should extend above the highest part, well away from windows, flues, or other openings. They should be free from caps, cowls, or other obstructions, and should be enlarged one size at a point not less than 1 foot below the roof by a long increaser. When stacks are less than 4 inches in diameter, they should be increased to 4 inches. If a cowl or vent cap of the ordinary pattern is attached to the top of the vent pipe, as shown at *a*, Fig. 12, ice will soon be formed within the cold, exposed pipe, as at *b*, of sufficient thickness to close the airway entirely, as shown at *c*. The air passage through this form of a cowl, as it is at present placed on the market, is altogether too small, being only about ½ or ¾ inch wide, and it soon becomes so choked with ice as almost entirely, if not quite, to stop ventilation. Whether the pipe is fitted with a vent cowl or not, there will be more or less danger of chokage by frost, but the danger is greatest when cowls are used.

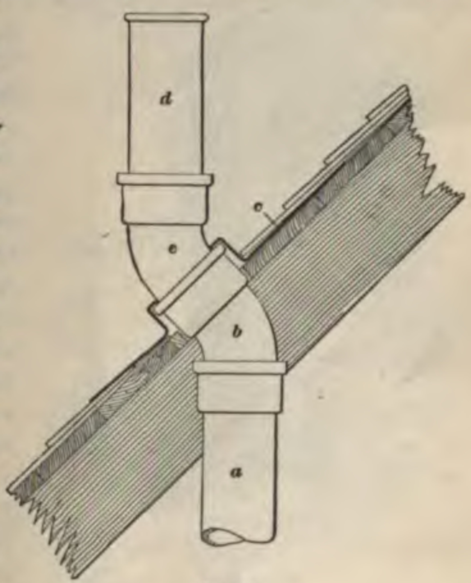


FIG. 11

In exceedingly cold parts of the country, it is best to avoid caps or cowls if possible, and use only the straight pipe *a* with an open top, as shown in Fig. 13, and it is well, even then, to protect the exposed pipe with some non-conducting material *b*, such as mineral wool or hair felt, protected against rain, snow, and wind by an impervious covering that is shown flanged on to the flat roof, and soldered down, its top being doubled over the hubs and secured water-tight by lead and oakum calking.

15. Extension of Soil and Vent Stacks.—Some plumbing regulations require that all soil, waste, and vent stacks opening above the roof be extended above the highest part of the building. This is to prevent sewer gas from entering the living rooms through crevices, between shingles or other openings of the roof, and vitiating the air within the building. Fig. 14 shows how this would occur. Wind is blowing against the house in the direction of the arrows. To shut out the wind, and at the same time have fresh air within the rooms, all windows to the windward of the house are closed while those on the sheltered side are open. Wind blowing with great force over the top of the soil stack *a* would carry sewer gas, escaping from the mouth of the stack, against the roof with such force that it would be driven through the crevices and into the attic *b*, as shown by the arrows. The diluted sewer air in the attic may pass through cracks in the ceiling *c* into the bedroom *d*, and finally pass out through the open windows at the sheltered side of the house. If the attic has an open stair leading to it, the discharge from the stack may vitiate the air in the entire building. To prevent this, the stack should be carried up inside the building to near the ridge, where it should be carried through, as shown by the dotted lines in the illustration. Wind blowing across the mouth of the pipe would then carry all sewer

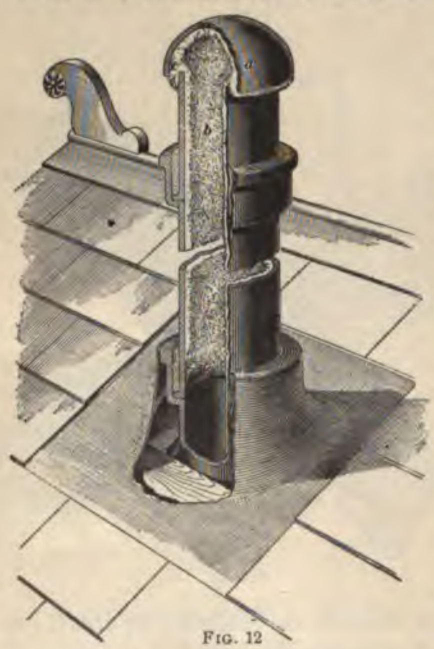


FIG. 12

gas safely away from the building, as shown by the arrows at the mouth of the dotted stack.

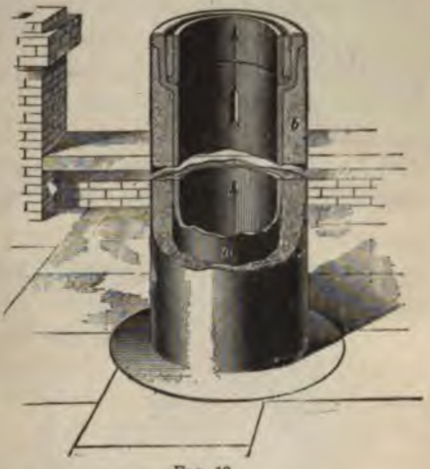


Fig. 13

16. The *vent outlets*, as the orifices of discharge may be called, since they are the outlets of the vent pipes, should be placed as far away from all windows, doors, or other openings by which the drain air may enter a building, as circumstances will allow. They should be placed, if possible, above the highest parts of the roof, so that no matter which way the wind blows, the gases will not be blown against and

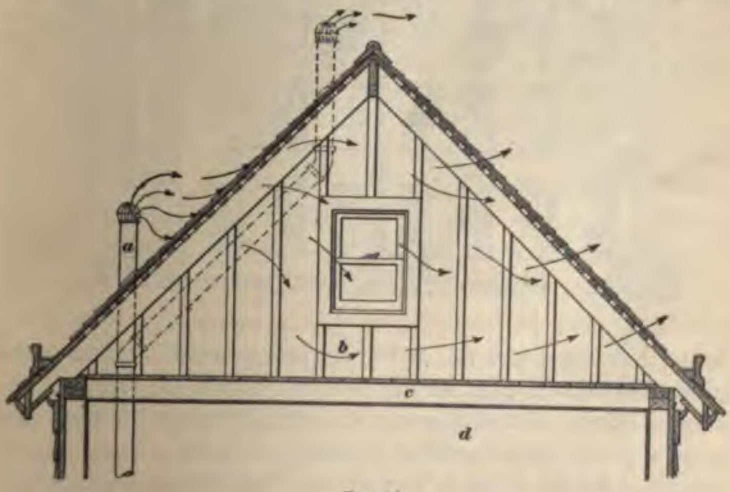


Fig. 14

into the building. If any adjoining building should be higher than the building ventilated, and be close to the vent outlet, there is danger of the foul air entering the higher building. To avoid this, the vent pipe should be run up to and above the roof of the highest building. Thus, in Fig. 15 are shown a number of vent stacks terminating at different points above the flat roofs of two tenement buildings. The vent pipe *a* is entirely too near the windows *b*, *b* in the gable end of the tall building, and drain air will certainly enter the building through these windows. This pipe should be run straight

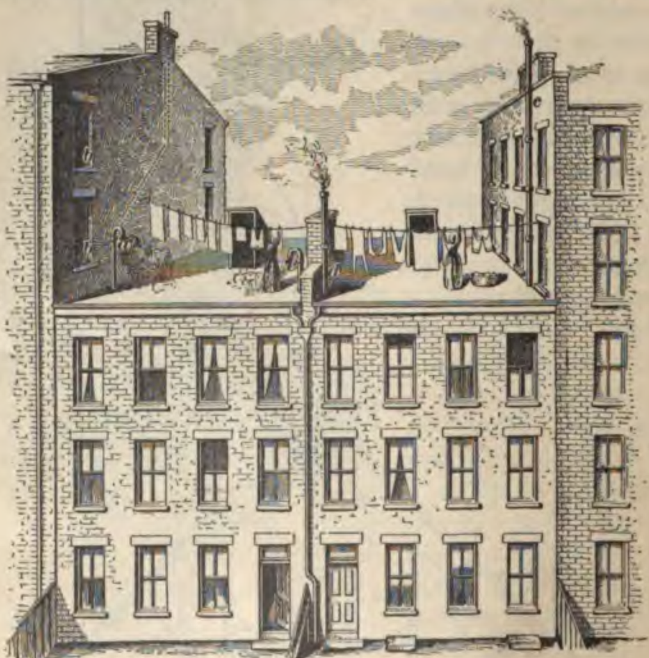


FIG. 15

up to and above the tall building, in a manner similar to the pipe *c*; or, better still, should be run above the chimney, as shown by the dotted lines. It is evident that the two vent pipes *d* and *e* cannot well be extended as high as the adjacent buildings without being out of all proportion. They are at such a distance from the gable windows, at least 15 feet, that the gases discharged from them will be greatly diluted with the surrounding air before they can reach the windows.

Still, it is better to run these pipes as high as circumstances will permit, because the natural flow of the foul-air currents being upwards, the foul air will thus be prevented from contaminating the air about the breathing line, that is, about 4 or 5 feet above the roof, unless it is forced downwards by the wind. If the vent at *a* or *e* is only 2 or 3 feet high, the gases are delivered below the breathing line, and any person near the vent may inhale poisonous gases. The paths that the gases are taking, that is, the direction in which they are wafted by the wind, are shown in the figure. Although they are shown like smoke issuing from the vent outlets, they are intended to represent the invisible drain gases. It will be seen that the woman to the left, who is hanging up clothes on the clothes line, is completely engulfed by the foul air escaping from the vent pipe *e*, while the woman to the right is not affected by the drain gases.

17. Plumbing ordinances, or the rules and regulations that usually govern plumbers and plumbing in all cities and towns of any modern pretensions, generally specify the minimum distance from the windows at which the vent outlets may be placed. The minimum distance allowed varies, of course, with the opinions of the experts that formulate the regulations, but 15 feet is usually accepted as a safe minimum standard. The plumber should always use his best judgment in selecting suitable points of discharge for drain air. He should never bind himself to the minimum distance when he can reasonably obtain safer points of discharge at a greater distance.

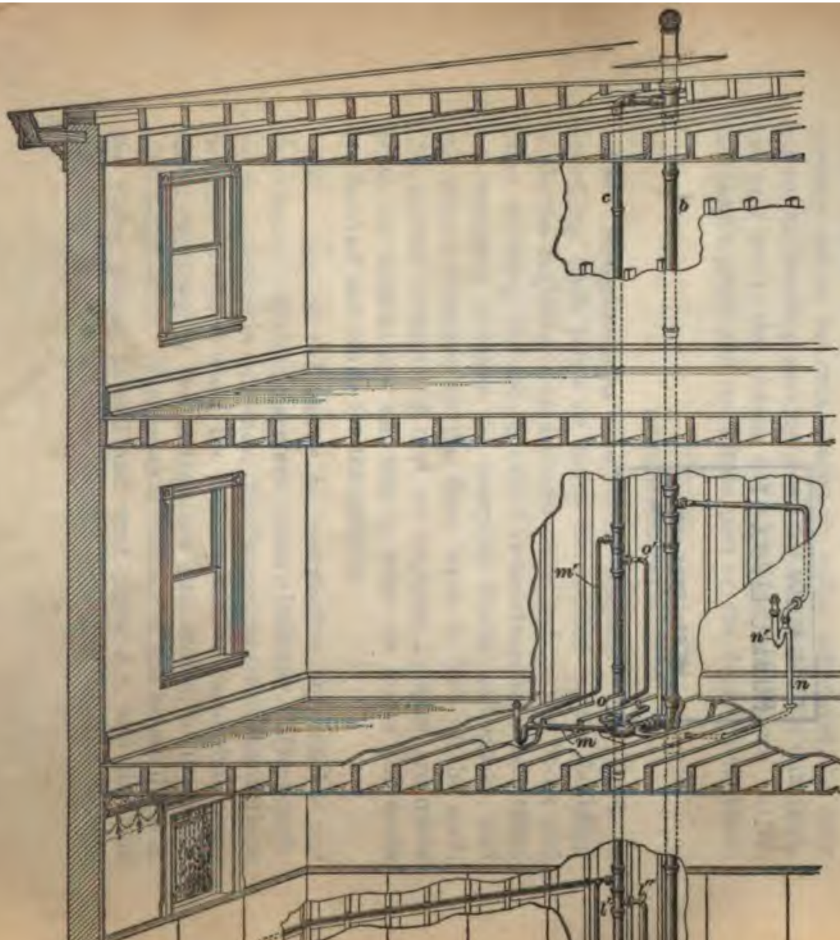
18. Soil or waste pipes should never be ventilated into sheet-metal, brick, or other flues. If a warm flue is convenient, the vent stack may be run outside but close to the flue, so that the heat of the chimney will help create a draft. When soil or waste stacks are ventilated into flues, there is always the possibility of drain air finding its way into the house through some of the openings to the flue.

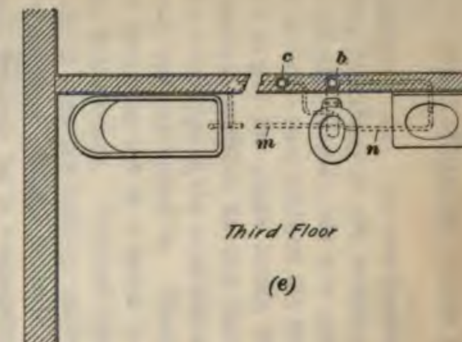
19. Pipe Chases.—Recesses in walls to receive pipes, called **pipe chases,** are left in new work by the builders for the plumber's use. In overhauling old plumbing, or while installing plumbing in old buildings, the plumber frequently has to cut pipe chases, but it is advisable to avoid the use of chases because they weaken the walls. The object of a pipe chase is to get the pipes inside the walls so that they may be concealed without having unsightly boxings projecting into the rooms, as is the case when the pipes run on the face of a wall and are boxed in. Horizontal or diagonal chases should never be cut in a brick or stone wall, because they weaken it too much. Vertical chases do not weaken walls seriously if they are built in while the walls are being laid. Even then they should be built only on the order of the architect, because he is responsible for the strength of the walls. The plumber should always receive the architect's permission before he cuts chases in walls; otherwise, he may injure the building seriously and become liable for damages. On new work, the chases for plumbing are shown on the architect's plans and constitute part of the mason's contract.

ROUGHING-IN

20. Roughing-In Cast-Iron Stacks.—The work of installing such pipes as must be erected in the building while the building is in a rough state, before the floors and other finishing is done, is called **roughing-in.** Generally, the roughing includes the complete drains and stacks, and the fixture branches to the floor level, or face of the wall. The fixture connections that are exposed to view are made when the fixtures are set, that is, after the floors and walls are finished and ready for the painter.

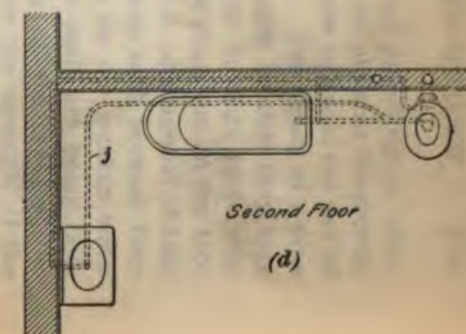
21. Fig. 16 (*a*) shows in perspective the stacks and branches of a drainage system within a building. The roughing-in is shown in full lines; the fixture traps and connections that are installed when the fixtures are set, and that come under the name of **finishing**, are also shown, to make the illustration clear. The system consists of the house drain *a*, the rising stacks of soil and vent pipes *b*, *c*, and the lead roughing for the various fixture branches on the several





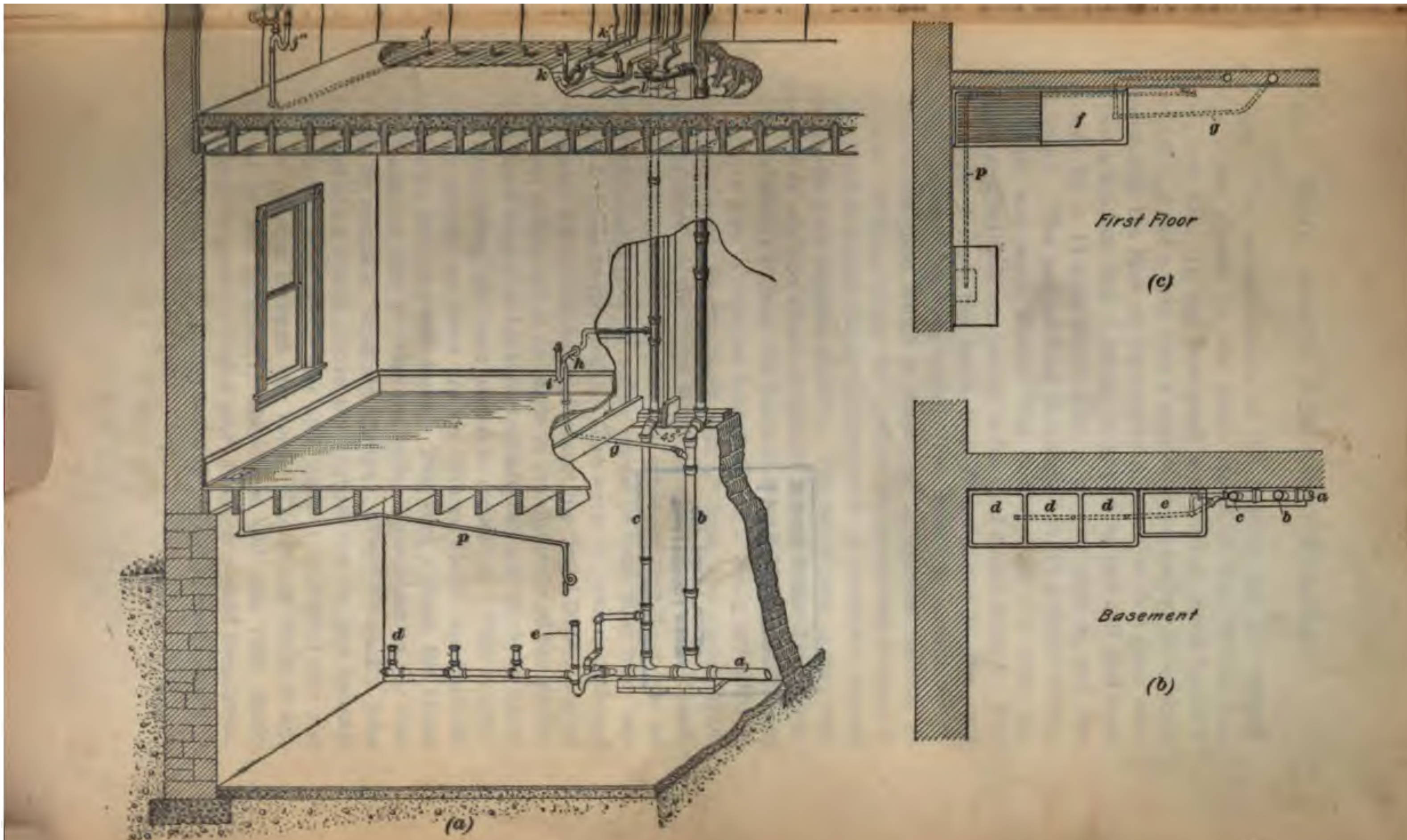
Third Floor

(e)



Second Floor

(d)


First Floor
(c)
Basement
(b)
(a)
45°

floors. The arrangements of the fixtures for the several floors are shown by the plans given in Fig. 16 (*b*), (*c*), (*d*), and (*e*). In the basement are located three laundry tubs *d*, *d*, *d* and a drip sink *e* which are connected by a brass waste into the base of the vent stack *c*. The first floor contains a kitchen sink *f*, which is joined to the soil and vent stacks by a 1½-inch waste pipe *g*, a vent pipe *h*, and the **S** trap *i*. The second floor is roughed in for a water closet, bathtub, and wash basin. The waste pipes *j*, *k* from the basin and bathtub are joined to the lead closet bend *l*. The back-vent *j'* from the basin trap *j''* is carried to the vent stack, around the side walls. The studding is notched tô receive the pipe, which is supported on wooden shelves, as shown. It has a slight fall toward the basin trap to keep it free from moisture due to condensation or overflows, should the waste pipe become choked. The waste pipe is also supported on shelves where it passes between the floorbeams. The back-vent *k'* from the bathtub trap joins the vent from the basin trap, a separate branch fitting *l'* being provided in the vent stack for the back vent *l''* from the closet bend. The fixtures on the third floor consists of a water closet, basin, and bathtub, which are so arranged that there are no long horizontal runs of either waste or vent pipe from any of the fixtures to the stacks. The waste *m* from the tub and the waste *n* from the basin intersect the closet bend *o*, but on different sides, and at an angle in the direction of the stacks. The basin trap *n'* is back-vented into the soil stack, in which a branch fitting has been placed to receive it. This connection is proper, as there are no fixtures above the basin to discharge into the soil stack. The vent *o'* from the closet bend and the vent *m'* from the bath trap connect to the vent stack by means of separate fittings. The vent stack *c* joins the soil stack *b* well above the highest fixture, just beneath the roof beams, where the soil stack is increased one size before passing through the roof. The house drain is supported in the basement, where the soil and vent stacks intersect, by means of brick piers built on a solid foundation. These support the stacks, but wall hooks or bands must be used throughout the entire height of each stack to keep them from moving sidewise.

22. Lead Roughing.—In laying out lead work for bathrooms, the work should be divided into sections that can be conveniently handled and easily placed in position without bending or twisting any of the branches. A little forethought will enable the plumber to divide the sections so that only a few joints will have to be wiped in place, and

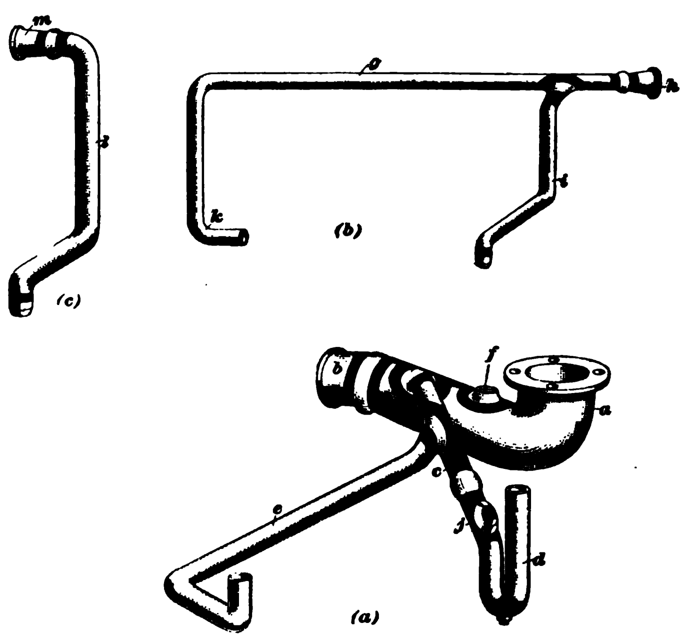


FIG. 17

those in comparatively easy positions, the other joints being all wiped at the bench.

Fig. 17 shows how the lead roughing for the bathroom on the second floor of the plan shown in Fig. 16 should be laid out and put together in sections. The section shown in Fig. 17 (*a*) is made up by beginning with the lead closet bend *a*, which is wiped to the brass ferrule *b*. The waste *c* from the bathtub trap *d* joins the side of the bend at a slight angle. The waste pipe *e* from the basin intersects the bath waste between the bath trap and the closet bend, and extends above the floor where the basin is to be located. The opening *f* in the top of the closet bend is for the back-vent from the closet. This section should be prepared and made up at the bench and then set in place to fit the other sections. The second section to be made is shown in Fig. 17 (*b*). It consists of a horizontal vent section *g* from the basin, with a ferrule *h* wiped on the end, to calk into the branch of a T fitting provided for it in the vent stack. A back-vent *i* from the bath trap is branched into the basin vent near the ferrule. The back-vent pipe for the bath trap *d* will be connected to the opening *j*. This section should be made up at the bench, then set in place, and the prepared end of the back-vent *i* is next wiped to the crown of the bath trap. The end *k*, Fig. 17 (*b*), of the basin vent is long enough to project from the wall a few inches, so that it may be flanged over and wiped to the nickel-plated back-vent of the basin trap when the finishing is done. The last section of the lead roughing to be put in, shown in Fig. 17 (*c*), consists of a 2-inch back-vent *l* for the closet bend, to which is wiped a 2-inch brass ferrule *m*. The section is then set in place and the cleaned end wiped to the closet bend at *f*, Fig. 17 (*a*). When the several sections are all in place and joined together, the ferrules should be calked into the hubs of their respective fittings, and the ends of all lead bends, pipes, or traps closed and soldered water-tight for the water test. Where lead, waste, or vent lines pass between beams, they should be supported on wooden shelves to prevent them from sagging.

23. Roughing for Batteries of Closets.—In office buildings, factories, and other buildings of a public nature, toilet rooms are generally provided on each of the several floors. They are usually located one above another, so that one line of soil pipe will take the discharge from the fixtures from all the floors, as shown in Fig. 18, which is an elevation of a plumbing system in an office building connected to a street sewer that is so small that in case of excessive storms

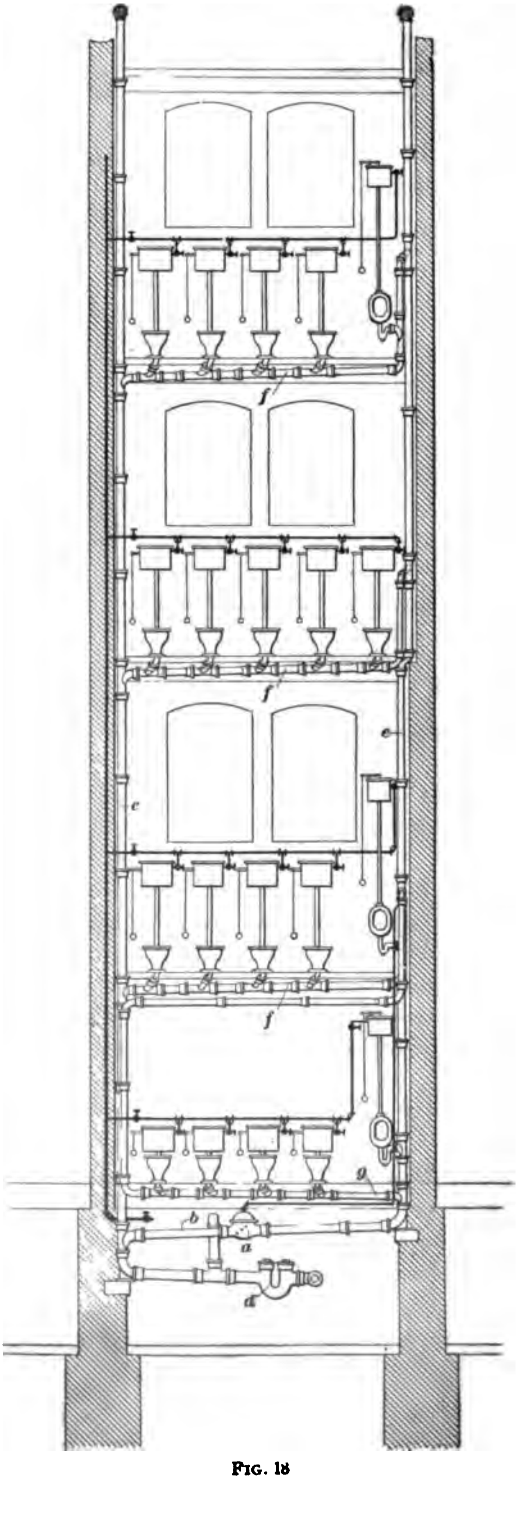


Fig. 18

it sometimes overflows. To prevent the basement of the building from being flooded by storm water backing up from the sewer and overflowing the basement fixtures, a back-water valve *a* is provided on a branch *b* of the drainage system. All fixtures located at a lower level than the surface of the street are connected to this branch on the house side of the check-valve. The branch inlets to the main stack *c* are located at so high a level that water from the sewer would overflow the manholes in the street before reaching the inlets to the stacks. Therefore, no check-valve or back-water valve is placed in the main drain *d*, to which all rising stacks connect. The fixtures on all floors above the basement can therefore be used during heavy storms, as the head of water in the stacks when it exceeds that in the sewer will discharge from the drainage system against the pressure in the sewer.

In the system of drainage shown, the soil stack is located at one side of the room and the vent stack *e* at the opposite side. The horizontal closet connections *f*, *f* cross the rooms near the ceilings, outlets being left at suitable intervals for the closets that are located on the floors above. The pipes *f*, *f* turn to a vertical direction near the vent stack along which they run and into which they are connected about 4 feet above their respective floors. This provides ventilation to the ranges of closet bends that are not otherwise ventilated. The closets on the first floor discharge into the branch *g* that is connected to the base of the vent stack, in order to wash out any rust scales or other solids that might otherwise lodge there. The fixtures are similarly arranged on the several floors, as is shown by the elevation, so that the work in the several stories is merely a duplicate of one another.

WROUGHT-IRON STACKS

SUPPORTS AND CONNECTIONS

24. Supports and Protection.—When originally designed, the wrought-iron drainage system, then known as the **Durham system**, was intended to be self-supporting, that is, supported at the base only. Suitable rests were provided at the foot of all rising stacks of soil and waste pipes and under the house drain, but no provision was made for securing the vertical stacks to keep them from swaying and vibrating. This practice, however, should not be followed. It is almost as necessary to support and steady wrought-iron pipe as cast-iron pipe; otherwise, the vibration of the stacks will sooner or later spring some of the joints and cause them to leak. Suitable iron clamps or hangers should be provided at each floor and should be secured to the iron beams or brick walls where possible.

Wrought-iron drainage pipe, when placed in cellars, should receive a protective coating of tar, asphaltum, or pure red-lead paint, to guard against the corrosive action of the moisture that will at times condense on the pipes. This is particularly so where the threads are exposed, as they present a surface that is more easily corroded through than the regular surface of the pipe.

25. Connections at Base.—Where wrought-iron stacks connect to cast-iron drains located beneath the basement or cellar floor, great care should be exercised to make a permanent connection. The usual method is to calk the end of the vertical wrought-iron stack into the hub of a cast-iron pipe or fitting, or, by means of a recessed 90° bend, turn the vertical stack to a horizontal position below the floor, and connect it to the cast-iron house drain by means of a piece of wrought-iron pipe calked into the hub of a Y fitting. When connections are made between wrought-iron and cast-iron pipe in the latter manner, the connecting section under the floor should be made of brass pipe of iron-pipe size screwed to the recess drainage bend at the base of the stack. The other end should be threaded and calked into the cast-iron pipe hub. If wrought iron is used underground, it will soon corrode and leak. A better way is to screw the vertical stack into a threaded cast-iron soil-pipe fitting, as shown in Fig. 19, and after the line is firmly screwed in place, calk the joint with lead, as shown at *a*. This will insure a tight joint, in which the lead calking cannot be loosened by ordinary usage. The threads prevent the vertical stack working loose from the fitting. If the wrought-iron stack is simply calked to a cast-iron bend, as shown in Fig. 20, the lead ring will invariably work loose, and the joint will leak drain air into the building, even though no water leaks from the joint.

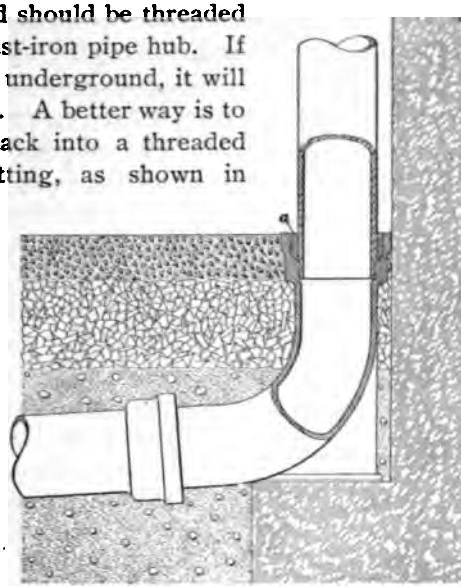


FIG. 19

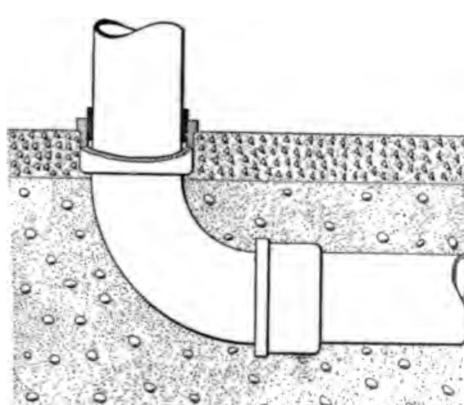


FIG. 20

26. Long-Screw Connections.—It is sometimes necessary to replace a section of wrought-iron pipe that has been removed on account of a defective fitting, or to insert a branch fitting in the line. Under such circumstances, and also when the rising stacks of soil, waste, and vent pipes are installed before the house drain is run, it becomes necessary to make final connections by means of long screw threads, sometimes called **running threads.** Flanged unions are rarely employed to make the final connections, chiefly because they require gaskets to make them tight. A right-and-left coupling may be used where the pipes will spring, but where there is no spring to the parts, special long-thread final connections should be made.

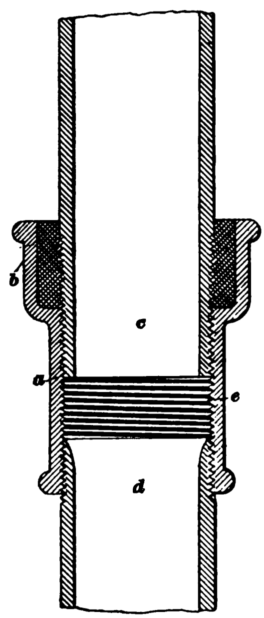


FIG. 21

Fig. 21 shows a special combination sleeve to be both screwed and calked to the pipe. A coupling *a* with a hub *b* for calking is screwed on a running, or long, thread on the stack *c* until the ends of the pipe and coupling are even. The pipe *d*, which may be a nipple, should be cut long enough to just slip in between the two sections of pipe to be joined. When the lower thread on the pipe *d* is made up, a space *e* will exist between the ends that have to be joined in the final connection. By unscrewing the coupling *a* from the pipe *c*, it will make up on the thread of the pipe *d* until that joint is tight. The coupling will then occupy the position shown in the illustration. By unscrewing the coupling from the pipe *c*, however, it leaves a slightly loose thread that would leak drain air. Therefore, to make a positively gas-tight connection, the hub *b* is calked with lead, as shown. This makes a strong long-screw connection that does not depend on a gasket for its tightness, as does the ordinary long-screw and locknut connection.

OFFSETS AND BRANCHES

27. Offsets.—In laying out Durham work, it should be arranged so as to avoid offsets in the vertical stacks. When unavoidable, however, they should be made with 45° fittings. Cast offsets or 90° bends should not be used, because rust scales or other foreign substances lodge therein and tend to obstruct them.

28. Durham System Branches.—In the regular Durham system, the branches to the fixtures are made entirely of wrought iron with flush fittings; there are no lead connections between the iron pipes and fixtures. This makes the Durham system a strictly wrought-iron pipe drainage system. The closets are bolted to floor flanges that are screwed to the iron waste pipes. All the exposed and usually nickel-plated traps of basins, sinks, wash tubs, etc. are connected to the iron pipe at the surface of the floor or wall by short pieces of nickel-plated brass pipe of iron-pipe size. There is no lead pipe on a real Durham system. It has been found, however, that while iron-pipe branches can be run in many cases and work satisfactorily, there are many places where it would be unwise to install them because of their rigidity, which has frequently been the means of breaking porcelain fixtures. For instance, a battery of porcelain pedestal wash-down water closets with back outlets are bolted up tightly to a Durham branch running above the floor at the rear of the closets. The stack settles or contracts a little; then, each closet affected by the drop of the branch will be broken at the horn, because the closets cannot drop to accommodate the change in position of the branch. In like manner, should the building settle more than the stack, or should the stack expand an undue amount by hot water falling in it, the branches would be raised and the fixtures will either be raised or broken off. For these reasons, it is customary to make the short branches of lead. If a branch is more than 5 feet long and without many changes in direction, iron pipe is generally carried to a point suitable for a short lead-pipe connection to the fixture. The reason why lead waste-pipe connections are generally used is because the lead can be bent to suit any position and forms a flexible connection that will not break the fixture if the pipes or building should settle. The branch pipe should have a good fall toward the stack to secure a rapid flow of water. The Y branch of the stack should be located as low down as practicable, and the waste pipe may be run between the floorbeams.

29. The waste pipes from baths and basins in a Durham job should be directly connected to the soil-pipe stacks, where possible, by the use of special fittings that are on the market. They should not be connected to the heels of the water-closet bends. Waste pipes of lead should not be wiped or connected at right angles but always at an angle that will favor the passage of water toward the outlets, so that the water that is being discharged from one waste pipe cannot back up into some other pipe, because it will then form deposits and may thus choke up the other pipe. Urinal waste pipes should be as short as possible. They should be well supplied with screw-caps to afford easy access to the pipe for cleaning-out purposes, as a thick slime accumulates in them.

30. Fig. 22 shows an enlarged detail of the bathroom on the top floor of the building illustrated in Fig. 16 and roughed-in with wrought-iron pipe, for a water closet, bathtub, and wash basin. A **T Y** branch *a* with a $1\frac{1}{2}$-inch side outlet on each side is provided in the soil stack *b*. This fitting provides separate connections to the stack for each of the fixtures in the bathroom. The connection for the closet is made up of a short piece of iron pipe *c* on which is screwed the 90° bend *d* to turn the branch to a vertical position, and in the proper location for the closet outlet. The closet flange *e* is connected to the bend *d* by means of an extra strong nipple, which should be of such a length that the face of the closet flange will be flush with the bathroom floor. The bath trap *f* and waste *g* are vented into the vent stack *h* through the 1½-inch back-vent *i*. The basin trap *j* and waste *k* are back-vented into the soil stack through the 1½-inch back-vent pipe *l*.

The closet bend is not back-vented in Fig. 22, although it is shown so in Fig. 16. The back-venting has been omitted in Fig. 22 to call attention to a diversity of practice that

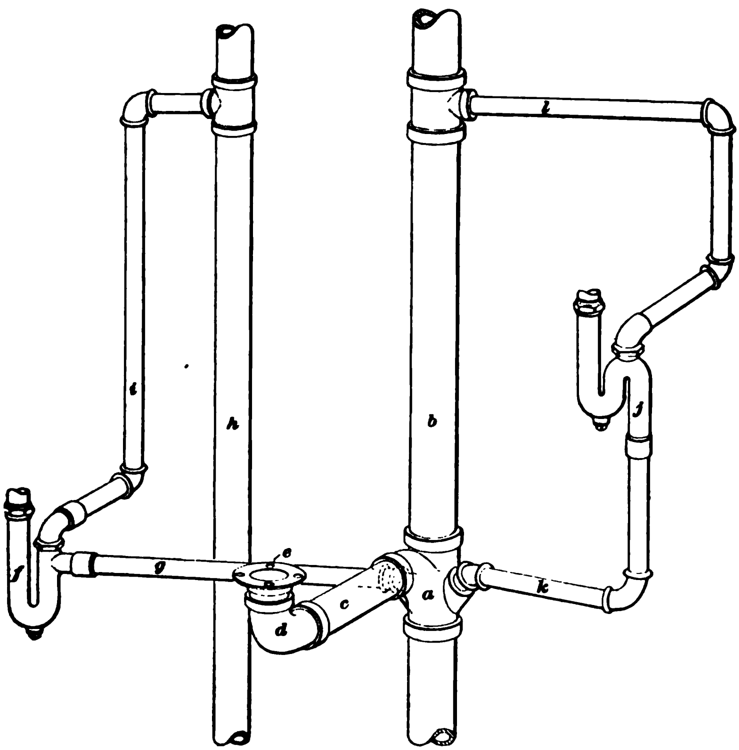


FIG. 22

exists in this respect. Some engineers claim that back-venting is superfluous for a fixture when it is the highest one connected to a soil stack; other engineers hold the opposite opinion. The safest practice is to back-vent the fixture; in any case, any existing rules and regulations governing back-venting must be complied with regardless of personal opinions.

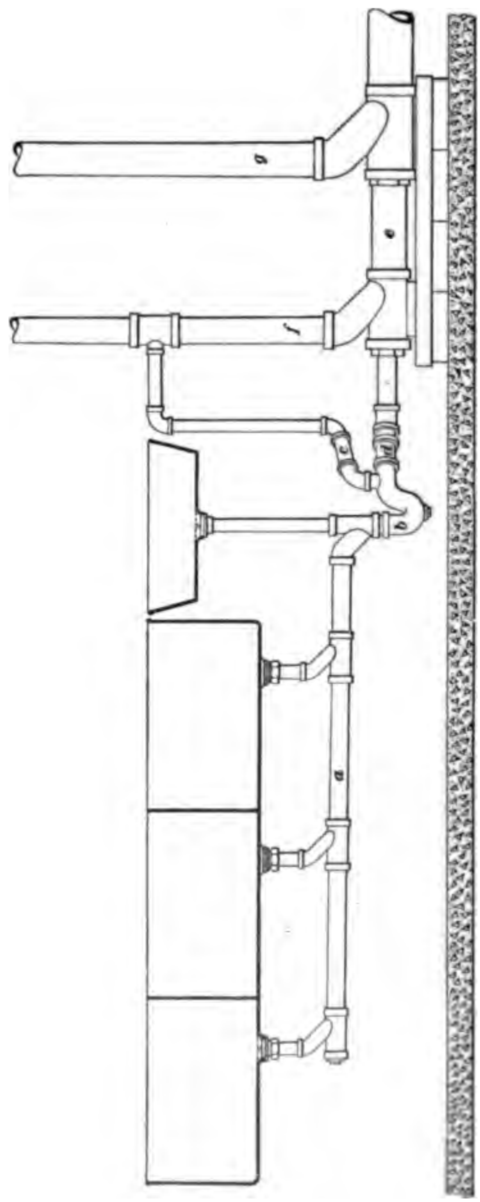


FIG. 28

31. Fig. 23 shows an enlarged detail of the wrought-iron waste connections to a set of laundry tubs and to a drip sink in the basement of the building shown in Fig. 16. The waste *a* from the laundry tubs is emptied into the sink trap *b*, which is vented through a $1\frac{1}{2}$-inch iron pipe *c*. The waste pipe *d* from the tubs and sink enters the house drain *e* at such a point as to wash out any rust or dirt either deposited at the foot of the vent stack *f* or that may back up from the soil stack *g*.

SOIL, WASTE, AND VENT STACK SIZES

SIZES OF BRANCHES AND VENTS

32. Branches.—The proper sizes of waste pipes for various fixtures are given in the following table:

TABLE I

SIZES OF SOIL AND WASTE BRANCHES

Kind of Fixture	Diameter of Pipe Inches	Kind of Fixture	Diameter of Pipe Inches
Water closet . .	4	Foot-bath . . .	$1\frac{1}{2}$
Slop sink . . .	2 to 3	Laundry tub .	$1\frac{1}{2}$ to 2
Bathtub	$1\frac{1}{2}$ to 2	Kitchen sink . .	$1\frac{1}{2}$ to 2
Wash basin . .	$1\frac{1}{2}$	Pantry sink . .	$1\frac{1}{2}$
Shower bath . .	2	Urinals	$1\frac{1}{2}$
Bidet	$1\frac{1}{2}$	Drinking fountain	$1\frac{1}{4}$ to $1\frac{1}{2}$
Seat bath . . .	$1\frac{1}{2}$		

If four or more fixtures of any one kind are connected to the same waste pipe, the branch may generally be one size larger than given.

33. Vents.—Vent branches to fixture traps should be the full size of the waste pipe up to $1\frac{1}{2}$ inches in diameter, but need not exceed 2 inches in diameter for any fixture.

The following table shows the sizes of vent pipes for wastes of different diameters:

TABLE II

SIZES OF VENT PIPES

Diameter of Waste Pipe Inches	Diameter of Vent Pipe Inches	Diameter of Waste Pipe Inches	Diameter of Vent Pipe Inches
1¼	1¼	3	2
1½	1½	3½	2
2	1½	4	2

SIZES OF STACKS

34. Soil-pipe stacks should be from 4 inches to 6 inches in diameter; their corresponding vent stacks may be one size smaller. Waste stacks are usually from 2 to 3 inches in diameter for ordinary small buildings. In flat buildings, five or more stories in height, the waste stacks may be from 3 to 4 inches in diameter, their corresponding vent stacks being one size smaller. In tall buildings, such as large office buildings, etc., where a large number of wash basins and urinals discharge into one waste stack, the stack may be from 4 to 5 inches in diameter. It is only an exceptional case that demands a larger waste stack than 4 inches. Safe and refrigerator wastes should never be less than 1 inch and need seldom be more than 2 inches in diameter. For ordinary buildings, such as small detached cottages, a 4-inch drain and main soil stack will be found large enough, even when rain water from the roof discharges into the system. For larger houses that contain not more than twenty fixtures,

TABLE III

SIZES OF SOIL STACKS

Diameter of Stack Inches	Number of Fixtures
4	1 to 27
5	28 to 70
6	71 upwards

a 5-inch drain is sufficient for both the house drainage and rain water. For ordinary office or apartment buildings where the number of fixtures does not exceed fifty, a 6-inch pipe will be found large enough. No pipe that receives the discharge from a water closet should be less than 4 inches in diameter.

In proportioning the sizes of stacks for large office buildings, hotels, etc., the sizes of pipes for the corresponding number of fixtures, given in Table III, have been found in practice to give good results.

EXAMPLE OF STACK AND BRANCH SIZES

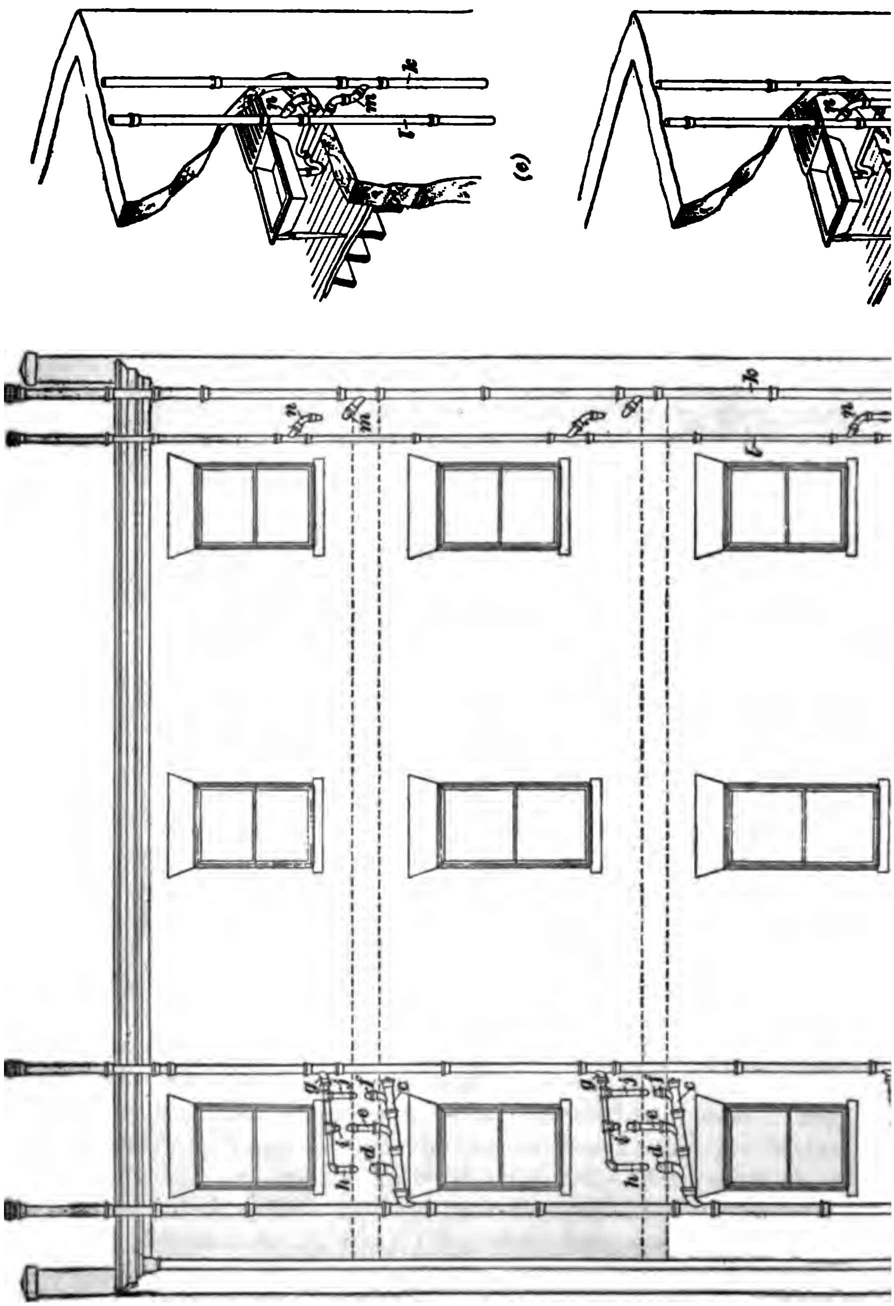
35. Fig. 24 shows an elevation of a plumbing system with the sizes of the house drain, and main vertical stacks, and fixture branches proportioned according to the foregoing tables and data. There are forty-six fixtures discharging into the line *a*, but as this is a waste stack and does not receive discharge from closets, a 4-inch waste stack and a 3-inch vent stack should be used. The stack *b* has twenty-eight fixtures discharging into it. Therefore, according to the table of soil-stack sizes, a 5-inch pipe should be used. In like manner the other sizes shown can be obtained from the tables. The sum of all fixtures on the five vertical lines is two hundred fixtures, which would require a 9-inch pipe to waste through. Therefore, the house drain should be 9 inches up to line *b*, where a 9″ × 8″ × 6″ Y branch would reduce the run to 8 inches and provide a 6-inch branch for the stack and the roof leader at *b*. Eight-inch pipe would then be continued to the stack *d*, and an 8″ × 7″ × 5″ Y would complete the reduction and provide pipes throughout proportioned to the number of fixtures discharging into them. A range of ten water closets is located on the first floor and discharge into the vent stack *e*′. It will be observed that the stack is reduced at the first floor from 6 inches to 4 inches, a 6 inch branch being taken off for the ten closets. The closets in this range are not back-vented, for which reason the pipe is made larger than called for by the table. This is a part of the system that may not meet the requirements of the plumbing rules of every city, because few of them are broad enough to embrace such unusual conditions. In a case like this it is wise to refer to the plumbing inspector for information before proceeding with the work. His duty is to make plain all problems that cannot be solved by the rules and regulations. In some cities, each of the closet bends would require to be separately back-vented, but the system shown, in which a 4-inch vent pipe connects the end of the soil pipe to a vent stack, should give satisfaction if the proper pitch is given the pipe under the closets. If there should be any doubt about the operation of the closets, a 3-inch back-vent may be attached to one of the middle closet bends to give relief should a large number of the closets be operated at the same time. Ordinarily, the arrangement shown will operate well.

EXAMPLES OF INSTALLATION

OUTSIDE STACKS

36. In warm climates, such as prevail in the southern part of the United States, soil, waste, and vent pipes with their respective branches are located on the outside of buildings, where they are always accessible and where in case of leaks any escaping drain air, by diffusing into the surrounding atmosphere, is rendered harmless.

Fig. 25 (*a*) shows the rear of a four-story and basement building fitted with an outside drainage system. The soil pipe *a* extends above the rear wall coping where it is open for ventilation. It takes the discharge from all the fixtures in the bathrooms on the several floors, except the first floor, and conducts it to the house drain underground. The vent stack [illegible] is located at the opposite side of the bathroom, so that there will be no crossing of pipes. The branches *c*, *c* are the waste connections for the several bathrooms. They take the discharge from the closets through *d*, *d*, the basins through [illegible] and the baths through *f*, *f*. The fixture traps are all vented through the back-air connection *g*, *g* and the branches [illegible] and [illegible] that drop down and pass through


(c)

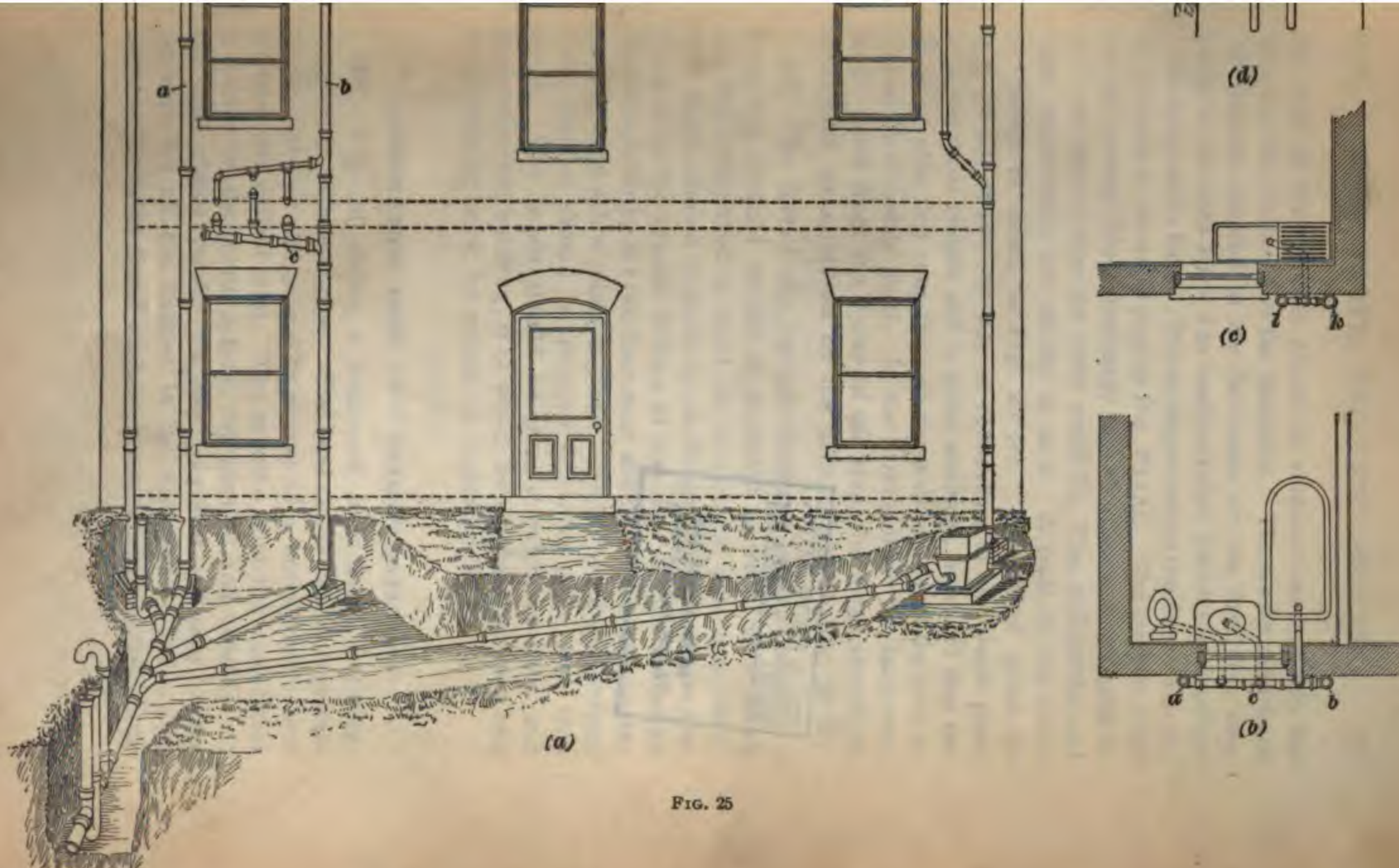


FIG. 25

the wall at their proper places to ventilate respectively the closets, the basins, and the bathtubs. The waste pipe from the fixtures located in the bathroom on the first floor connects to the vent stack *b* to wash out rust, which might otherwise lodge at its base. The arrangement of the fixtures in the bathrooms is shown in plan in Fig. 25 (*b*). The kitchen sinks on the several floors discharge into the 3-inch waste pipe *k*, and are vented into the vent stack *l*. The sink waste and vent connections are shown at *m*, *n*. A plan of the sinks is shown in detail in Fig. 25 (*c*). The detail given in Fig. 25 (*d*) shows one way of connecting up the waste pipe; it is the most simple and is quite sanitary, provided that the piece of pipe that runs through the wall and joins the trap to the stack is nearly level. If the rules call for the back-vent to be taken from the crown of the trap, the sinks should be connected up as shown by the detail given in Fig. 25 (*e*).

37. To install the outside drainage system shown, a swinging scaffold should be provided to work on, a block and fall being used to hoist the sections of pipe into place. The stacks should be made up on the ground in sections that reach from the branch fittings at one floor to and including the branch fitting for the floor next above. This necessitates calking only a few joints in place. As the work progresses, each section should be secured firmly in place with iron bands. The bands should be placed under the hubs and secured to the building, if of wood, by means of screws, and if of stone or brick, by means of expansion bolts.

COMBINATION IRON AND LEAD CONNECTIONS

38. Fig. 26 shows a bathroom in a frame building, roughed in with lead pipe. The lead closet bend *a* connects to the cast-iron soil pipe *b* by means of a brass ferrule, and a wiped and calked joint. The waste *c* from the wash basin is joined by the waste *d* from the bathtub and connects to the lead closet bend. In this way one soil-pipe outlet answers for all the fixtures in the bathroom. The waste pipes to the bathtub and wash basin are supported throughout their entire lengths by means of wooden shelves, so graded as to give the pipes a fall toward the lead closet bend. The vent pipes are made of wrought iron and are carried up between the studding of the outside wall. The branch *e* from the basin and the branch *f* from the bathtub join, by means

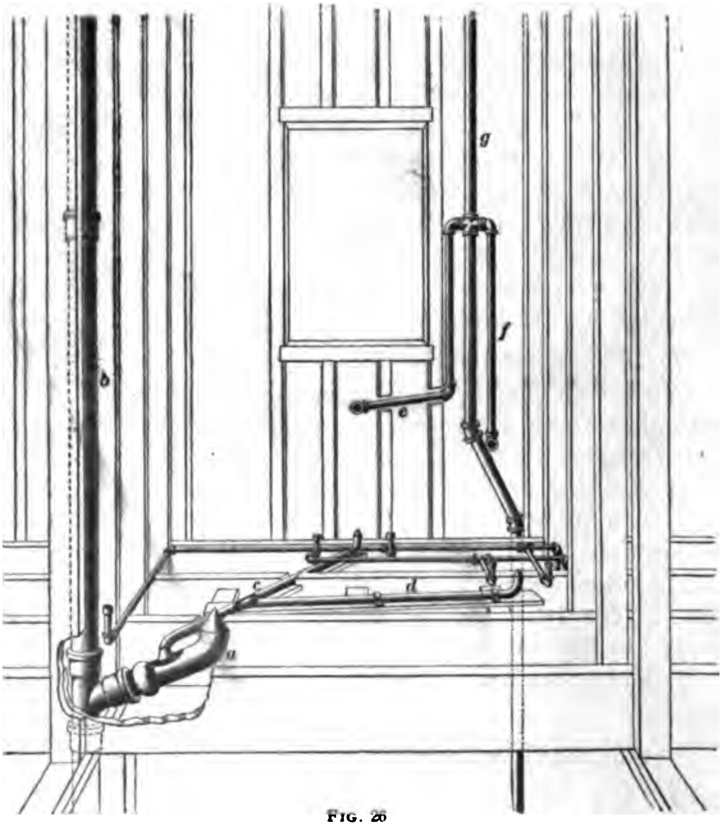


FIG. 26

of a cross, the main vent stack *g* well above the top of the fixtures. The main stack extends down to lower floors, where it vents the kitchen sink and laundry tubs, and continues up to the attic, where it crosses over and joins the main stack, or may extend up separately through the roof. The other pipes shown are the water pipes.

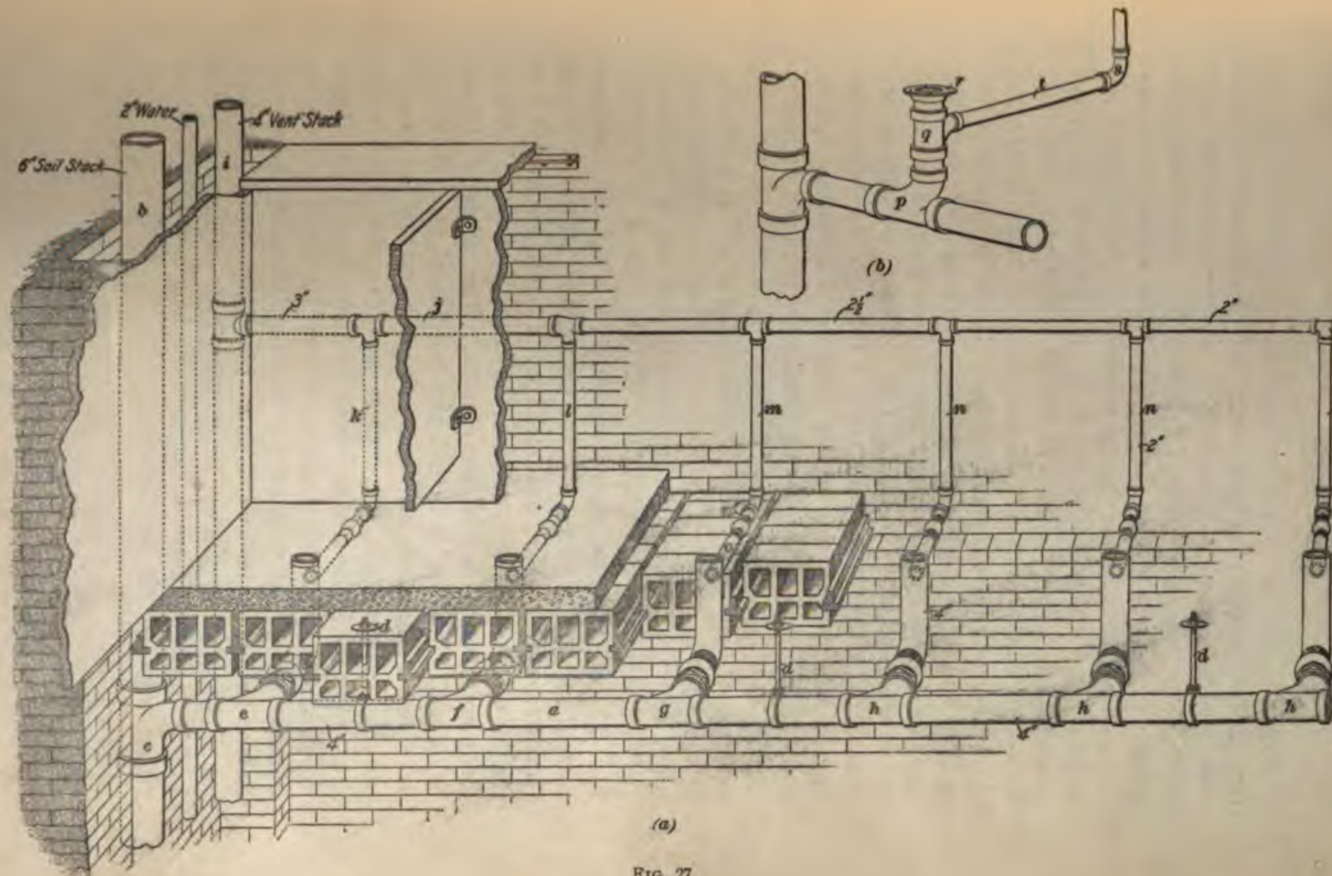
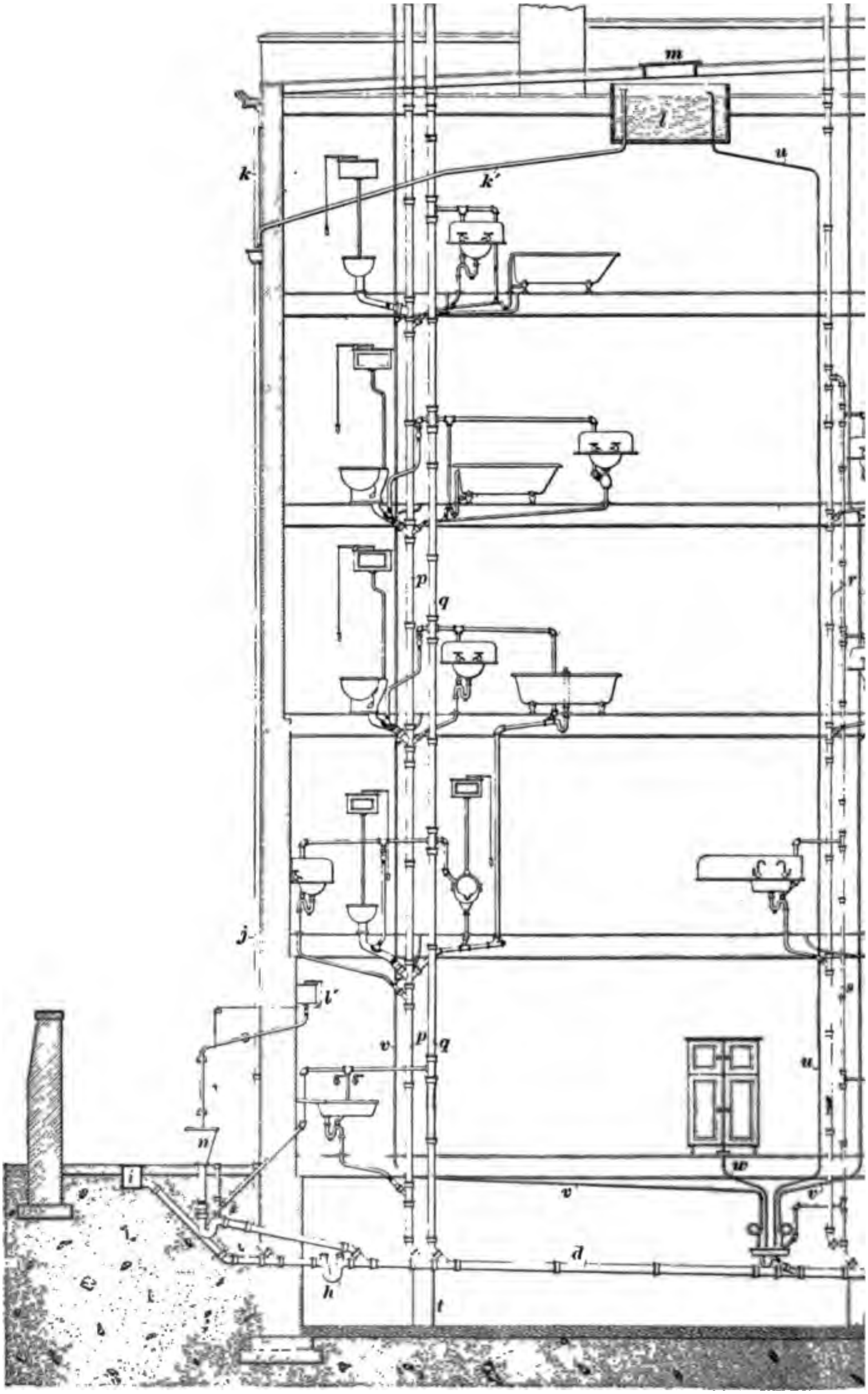
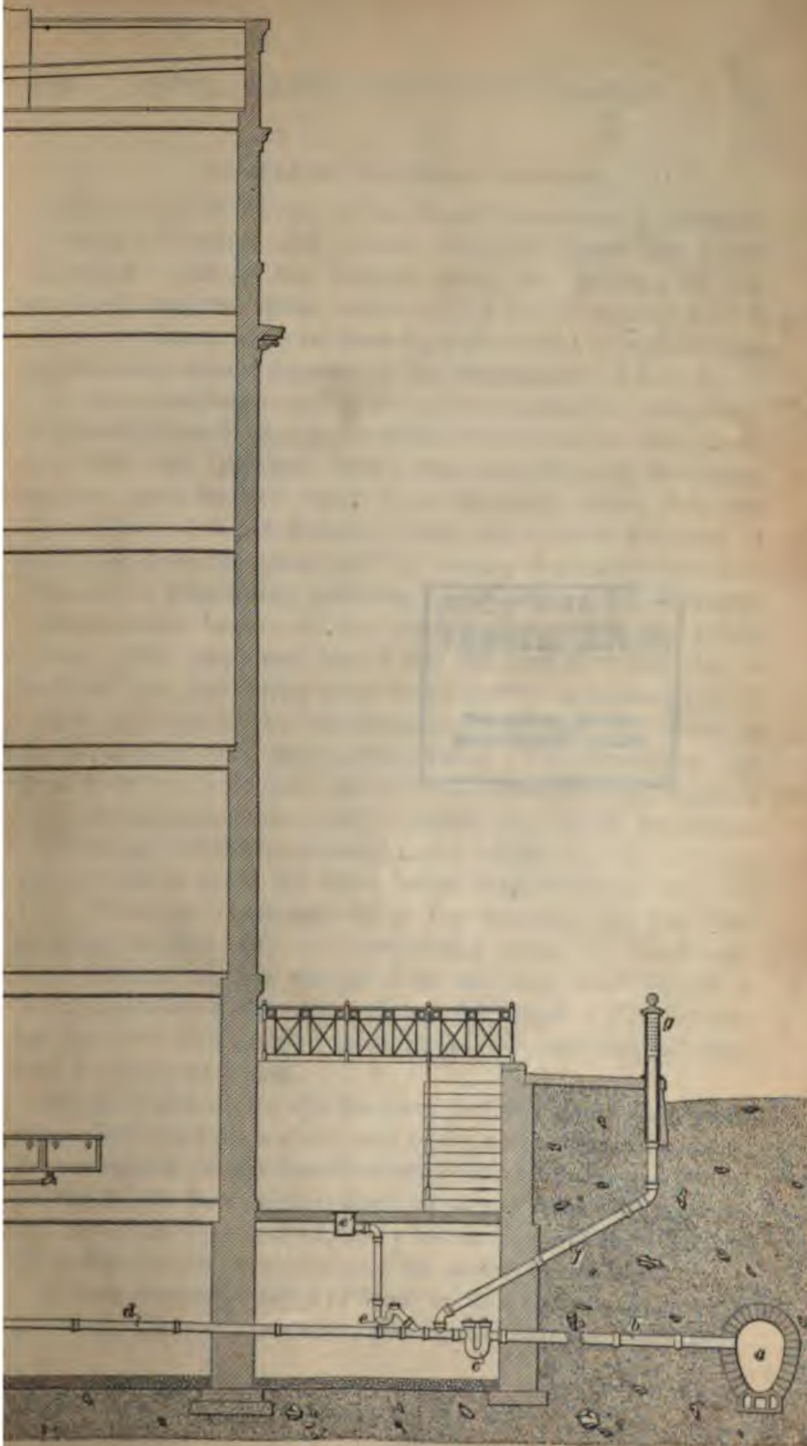


FIG. 27

39. Fig. 27 (*a*) shows, in perspective, the Durham system applied to the roughing for a tier of six water closets. The 4-inch horizontal branch *a* is connected to the soil stack *b* by means of the **TY** branch *c*. The horizontal branch is located under the ceiling, from which it is supported by means of the pipe hangers *d*, *d*. Branch **TY** fittings *e*, *f*, *g*, *h* are provided at the proper intervals for closet connections. The use of lead closet bends and short lead back-vent connections, as shown, makes a much better job than all-wrought-iron connections. These connections are flexible and should give no trouble. If, however, a strictly Durham job is specified, the connections may be made up as shown in detail in Fig. 27 (*b*). The closet bends are vented from the main vent stack *i* through the horizontal branch vent *j* and the closet back-vent branches *k*, *l*, *m*, and *n*. Short pieces of 2-inch brass pipe are used as solder nipples at *n'*. A short piece of 2-inch lead pipe is wiped to each closet bend and solder nipples *n'*, as at *o*. If a strictly Durham job is required, the horizontal branch *a* is frequently run directly under the closet outlets, and the **T Y** fittings are turned up, as shown at *p*, Fig. 27 (*b*). The 4″ × 2″ **TY** *q*, Fig. 27 (*b*), the nipples above and below it, and the iron closet-floor flange *r* are all made up together at the vise and then screwed in place, the outlet pointing to the elbow *s* at the base of the back-vent pipe that runs up at the back of the marble slabs behind the closets. The elbow *s* should be tapped right-and-left, and the horizontal pipe *t* should have one right-hand and one left-hand thread, so that it can be screwed into the fittings *q* and *s* simultaneously, thus connecting the soil and vent branches together without the use of unions. Particular care must be taken, in getting out the pipes and fittings for Durham work, to have the fixture outlets come in the exact place, because after they are in place, they cannot be conveniently changed. With lead bends it is different, because the bends can be worked either way to suit the fixture.



Fi


g
f
e
d
c
b
a

COMPLETE PLUMBING SYSTEM

40. Fig. 28 shows, in sectional elevation, a complete system of drains, soil, waste, and vent pipes for a city building. All of the sewage from the building is discharged into the street sewer *a* by a 6-inch fireclay pipe *b*, which is broken away to show that the sewer is farther from the building than it appears in the illustration. A 5- or 6-inch iron disconnecting trap *c* is placed just inside the cellar wall. A 5-inch house drain *d* is run along the face of the cellar wall. A 4-inch pipe, furnished with a deep seal trap *e* in the cellar, carries away surface water from the catch basin *e'* in the front area. A 5-inch fresh-air inlet pipe *f* takes a supply of fresh air from the street curb by means of a perforated post inlet *g*. A 4-inch deep seal trap *h* disconnects the back-area surface-water box *i* and the roof leader *j* from the house drain. The rain-water pipe *k* and the tank overflow pipe *k'* both deliver into a rain-water head on the rain-water pipe *j*.

The fixtures in the basement are a kitchen sink, a set of three laundry tubs, and a refrigerator. The fixtures on the first floor are a butler's pantry sink, a corner wash basin, a siphon-jet water closet, and a urinal, the closet and urinal both being flushed from small tanks overhead. In ordinary private-house work, the three latter fixtures would be omitted. They are connected up in the drawing only for illustration, as they may, in exceptional cases, be employed. The fixtures on the second floor are two wash basins, a Roman-shaped bath, and a siphon-jet closet. The fixtures on the third floor are two wash basins, a French-shaped bath, and a siphon-jet closet.

On the top floor, for the servants' use, is located a common enameled-iron bath, a plain wash basin, and a siphon-jet closet. A rectangular copper-lined wooden house tank *l* is also placed on the fourth floor, high enough to supply the small tank for the closet on the top floor, and a hatch *m*, about 20 inches by 30 inches, is placed on the roof for access to the tank.

A long hopper closet *n* is fitted up in a small apartment in the back area, or basement, and opens into the back area.

The tank *l'* for this closet is fitted up inside the building, and the trap is underground. This is to guard against frost, and is a common practice. A better plan is to set an ordinary closet inside the building; outside closets should never be installed in cold climates except when insisted on by the architect or owner.

The 4-inch soil-pipe stack *p* is run up full size to the roof of the building, increasing to 5 inches as it passes through the roof. The 4-inch vent stack *q*, corresponding to *p*, also increases in diameter as it passes through the roof; its base joins the house drain at an angle of 45°, so that any rust falling down may slide into *d* and thus be washed away. The 3-inch waste-pipe stack *r* is carried full size up to the roof, and increased to 4 inches as it passes through it. For purposes of economy only, the corresponding 2-inch vent pipe *s* joins *r* above the highest fixture, instead of passing separately up to and through the roof.

Brick piers *t*, *t* are built under the vertical stacks to support them. The ½-inch telltale pipe *u*, 1¼-inch safe wastes *v*, *v* and refrigerator waste *w* discharge openly into a sink in the cellar. The safe wastes are trapped by making a coil on the end of the pipe, as shown, and are carried full size up to and through the roof to prevent odors from entering any of the upper rooms through them. The vent outlets above the roof should be carried up a few feet higher than shown; they are shortened in order to avoid making the drawing too large. The waste pipe from the Roman bath on the second floor is dropped and made to flush the urinal waste; but it may join the stack *p*, if desired.

TESTING HOUSE-DRAINAGE SYSTEM

IMPORTANCE OF TEST

41. The plumbing in every building should be tested and made perfectly tight before it can be considered complete. The owner of a building should either see the plumbing tested himself or should have his representative see it done. All sanitary engineers and reputable architects include plumbing tests in their specifications. Conservative plumbing contractors test their work whether tests have been specified or not; they do this to protect their reputation for good work and to satisfy themselves that the work is correct before it is finally turned over to the owner. The plumbing rules and regulations governing the plumbing in the larger cities of the United States contain a clause that compels plumbers to test plumbing in the presence of one of the city plumbing inspectors; all plumbing done in small towns and villages not having plumbing ordinances should be tested as a matter of safety, even though the test is not compulsory.

All new jobs should receive two tests; one of the tests should be applied to the roughing before it is covered up in the building, and the other should be applied to the entire job after the fixtures are all set and the water is turned on. The latter is the more important test, because it tests the whole job, but both are necessary to accomplish the best results.

ROUGHING TESTS

42. Kinds of Roughing Tests.—There are two kinds of tests than can be applied to the roughing with satisfactory results; one is known as the *water test* and the other as the *air-pressure test*. The former is the better of the two, because leaks can be easily located by water flowing from them, and they can be quickly remedied. The water test is almost universally adopted where there is no danger of the water freezing and bursting the pipes during the test. During very cold weather, however, an air-pressure test is applied to the roughing, but much time is lost hunting for the leaks. In the water test, all outlets except the top are plugged and the piping filled with water to the top; in the air-pressure test air is pumped into the piping after all outlets have been plugged.

43. Water Test.—Plumbing rules and regulations, generally, require the water test to be applied by closing all openings to the drainage system except those above the roof, and filling the system with water until it overflows the vent stacks. When the system is filled, the cock through which water from the mains is admitted is closed. The water is allowed to stand in the stacks until the plumber has made a careful examination of every pipe and fitting in the system in a search for leaks. All leaks found having been repaired, the water having been drawn off prior to repairing, the system is again filled with water and reexamined, the examination being repeated until the plumber is satisfied that the system is tight, or until the plumbing inspector has inspected and accepted the work.

When supplying the water, it is well to fill the system slowly from the bottom and make tight all joints from the house drain up. This avoids trouble and confusion, for when a system is filled to the top a small leak near the roof will cause water to run down the stack, wetting all the hubs and thus present the appearance of all the joints leaking. When, however, the system is filled to the roof, the plumber should commence at the top and work down, making each joint tight before leaving it for another leak.

44. The purpose of the water test is: first, to ascertain whether the pipes are strong enough to resist a reasonably heavy internal pressure; second, to ascertain whether the pipes, fittings, and joints are water-tight. A good feature of the water test, if the pressure is increased to a proper point, is that any pipes that are cast very irregular in thickness, such, for example, as is often found in poor grades of cast-iron pipe, are sure to be split or burst at the thin parts. The question may be advanced: Why subject the pipe lines to heavy water pressure when it is known that a pressure above atmosphere never exists in a properly designed drainage system? The answer to this is found in the fact that iron drainage systems, if subject to moist air or drain gases, will corrode, the rust forming a scale on the exposed surface. Corrosion is the process of eating away the metal forming the pipe, and the consequent formation of rust means a corresponding thinning of the real metal.

Suppose that a pipe having a section similar to that shown in Fig. 29, is allowed to rust uniformly over its external and internal surface, say $\frac{1}{32}$ inch in depth per year. Assume that the pipe is 4 inches inside diameter, and $\frac{1}{8}$ inch thick on one side and $\frac{3}{8}$ inch thick on the other, the intention of the molder having been to cast the pipe with a uniform thickness of $\frac{1}{4}$ inch. Then, a scale of rust $\frac{1}{32}$ inch deep will be formed over the inside and outside of the pipe in 1 year; that is to say, the real thickness of the pipe at the thinnest part will then be $\frac{1}{8} - (\frac{1}{32} + \frac{1}{32}) = \frac{1}{16}$ inch. The real thickness at the opposite side will be $\frac{3}{8} - (\frac{1}{32} + \frac{1}{32}) = \frac{5}{16}$ inch. If this rate of corrosion continues for another year the resulting thickness of the real metal at these points will be $\frac{1}{16} - (\frac{1}{32} + \frac{1}{32}) = 0$ at the thin part and $\frac{5}{16} - (\frac{1}{32} + \frac{1}{32}) = \frac{1}{4}$ inch at the thick part. It will be seen that if a pipe like this one should form part of a drainage system, the thin part of the pipe may burst when a heavy pressure is applied; the presence of such a pipe can be thus detected, and it may be replaced by a sound one. If sound pipes of uniform thickness are employed throughout a drainage system, the durability of the system will be increased to the full limit. On the other hand, if defective pipes are used, the durability of the drainage system is limited to the life of the poorest part.

FIG. 29

45. It should be noted that the pressure exerted in the drainage system by the water test varies with the height of the building. Assume two vertical pipe stacks, one 100 feet high, and the other 20 feet high, each filled with water for testing purposes. The pressure at the base of the higher column of water is greater than that at the base of the smaller column. To illustrate this, refer to Fig. 30, in which the tube *a* represents the short pipe stack and *b* the long one. Suppose the sectional area of each tube to be 1 square inch, and their height to be 20 feet and 100 feet, respectively. A cubic inch of water weighs .03617 pound; consequently, the pressure on the bottom of *a* is $20 \times 12 \times 1$

× .03617 = 8.6808 pounds, and at the base of *b* is 100 × 12 × 1 × .03617 = 43.404 pounds.

Since the pressure of any layer of water in the vertical column is due to the weight of the water above, it follows that the pressure will become less as the vertical distance between the point where the pressure is to be taken and the surface of the water is decreased. This can best be illustrated by drawing a horizontal line *c d* to represent the pressure at the base, and joining *d* by a straight line to the point *e*, which represents the surface of the water, or point of no pressure. The length of any horizontal line drawn from *c e* to *e d*, such as *f g* for example, represents the pressure at any point level with the line. It is therefore evident that under the water test the top of the stack will be subject to very low pressure, while the bottom will be subject to a much higher pressure; hence, a defective pipe near the top of the stack *b* may successfully stand the test, while, if the same pipe were calked in near the bottom, it would probably be split or burst by the greater pressure.

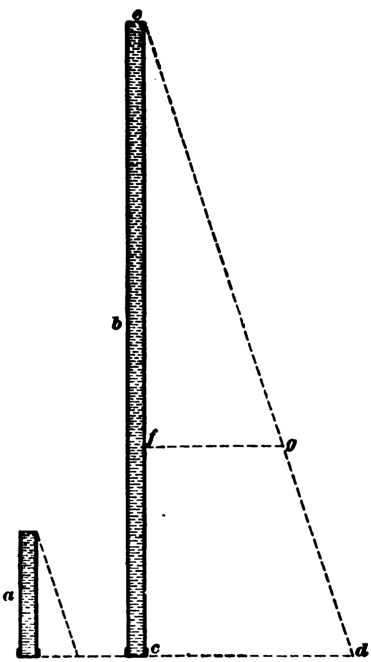


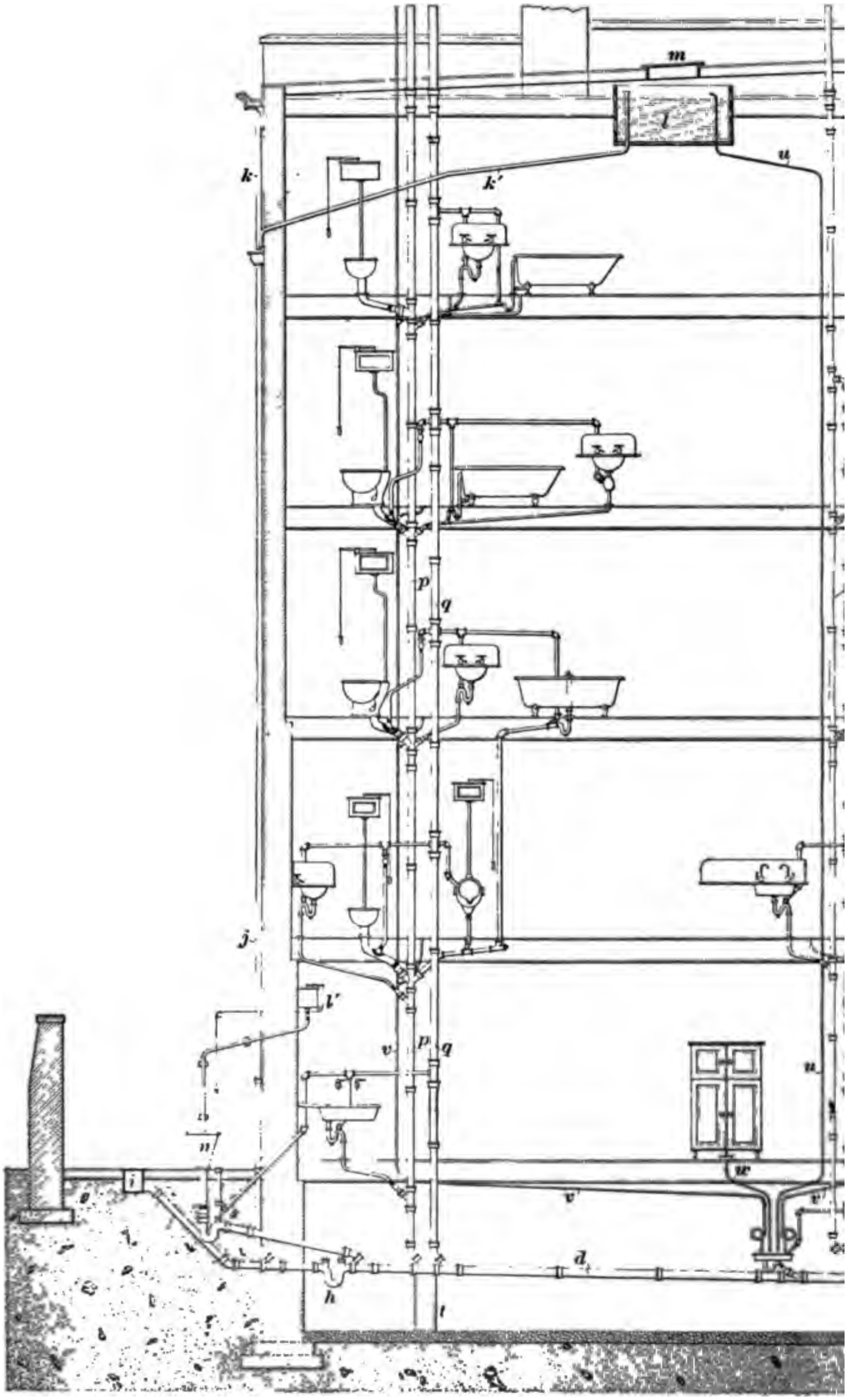
FIG. 30

46. Compressed-Air Test.—The compressed-air test is applied, after all openings are closed, by forcing air into the drainage system by means of a pump until there is a pressure of at least 10 pounds per square inch throughout the entire system. The pressure should be indicated by a mercury pressure gauge. When the column of mercury remains stationary at the highest point to which it has been raised, that is, about 20 inches for a 10-pound pressure, the system is perfectly tight. When, however, the column of mercury falls, it indicates a leak somewhere in the system, which should be located and made tight. The first place to examine for leaks is around the testing apparatus. That being tight, the testing plugs or stoppers should next be examined and made tight, after which the pipes and joints throughout the system should be examined. To locate the leaks, it is necessary to coat the stacks with soapy water and then to examine them for bubbles produced by escaping air. To find the large leaks, the stacks should be heavily coated with the soapy water, since otherwise bubbles will not be formed; furthermore, the pressure must be maintained within the system during the search for leaks. When the mercury gauge stands for 15 minutes without showing any noticeable fall of pressure the drainage system may be considered as tight.

The air-pressure test is not so desirable as the water test on account of the great difficulty in locating the leaks that exist, to some extent, in nearly all new work.

47. Testing Plugs.—Lead closet bends and lead waste pipes can be pinched together and soldered, and wrought-iron pipe openings closed by ordinary screw plugs, caps, or capped nipples. To close openings in cast-iron pipe, however, special plugs or stoppers, which can be easily removed without jarring the pipe after the system is tested, must be used.

Fig. 31 shows a malleable-iron testing plug with a large thread running spirally around the surface. The body tapers from the shoulder *a* toward the end of the plug *b*, so that it can be easily withdrawn from a hub after testing; a lug with a hole through it is cast on the top of the plug at *c*. These testing plugs are calked into the hubs to be closed. Some plugs have a hole tapped with a pipe thread through the top, into which can be screwed a nipple *d* and cock *e*. A hose may be attached to the cock to fill the drainage system with water and empty it after testing. These testing plugs can


m
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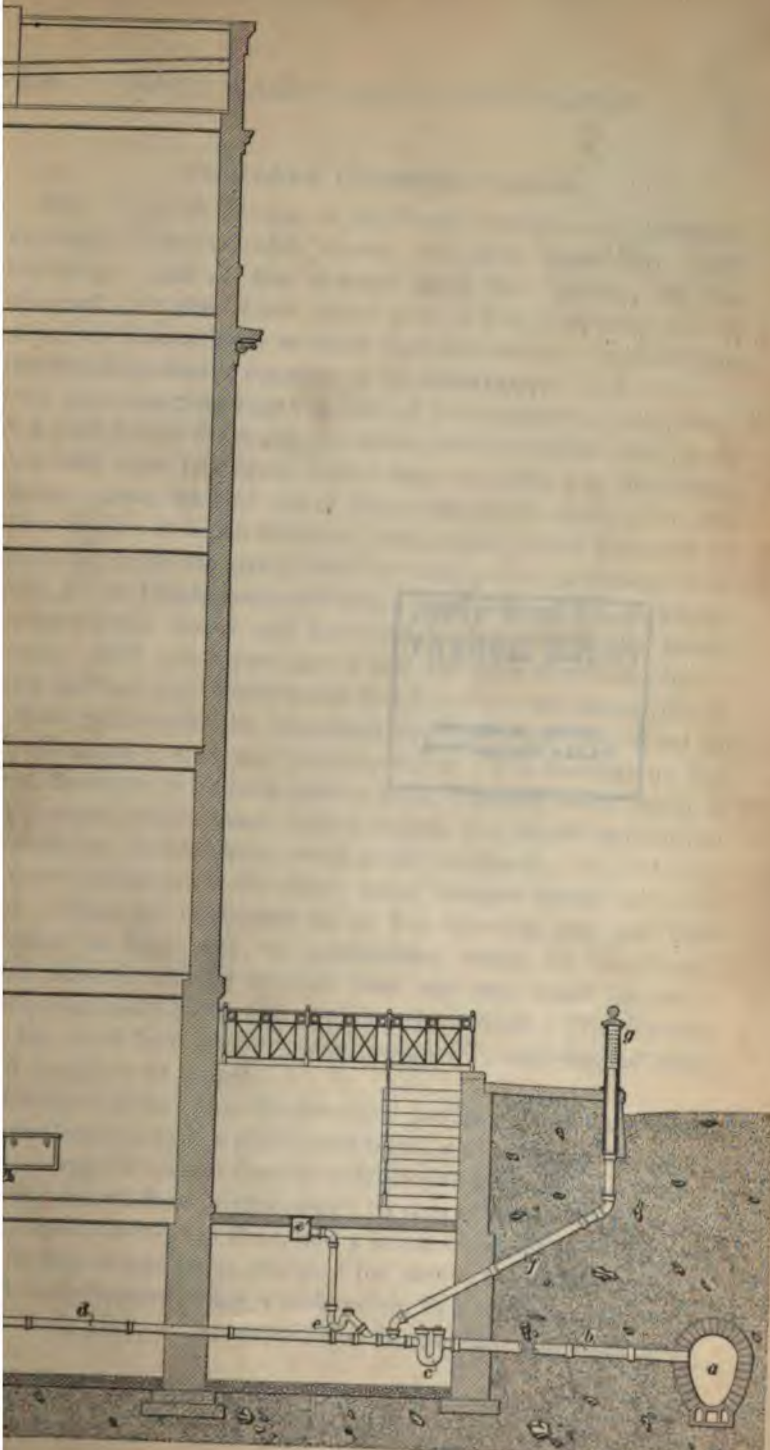
g
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d
e
c
b
a

be removed from hubs by striking them with a hammer on the top edge to loosen them, then inserting an iron rod into the opening *c* and turning the plug to the left. The lead ring can then be pried out with a bar or cold chisel. Striking the plug to loosen it sometimes starts joints in the soil pipe near where the plug is being removed; therefore, plugs of this form are not desirable when other kinds can be used.

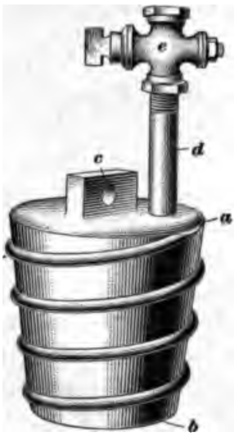


FIG. 31

48. Fig. 32 shows a testing plug that is held in place by the friction of a rubber band, under compression, bearing against the inner surface of a pipe or fitting. When avoidable, this form of testing plug should never be placed in the hub of a pipe or fitting as the large surface exposed to the pressure of water increases the liability of the plug blowing out when under pressure; it should be inserted within the pipe. This plug consists of two iron disks *a* and *b*, between which is placed a thick rubber band *c*; a piece of wrought-iron pipe *d* is bent at right angles, and the capped end *h* made long enough to prevent the plug from falling down in the pipe. On the other end is cut a thread extending from the locknut *e* to above the compression nut *f*. The dome *g* is provided to extend the distance between *b* and *f* so the body of the plug can be placed well in the pipe and the compression nut be outside of the hub convenient for operation.

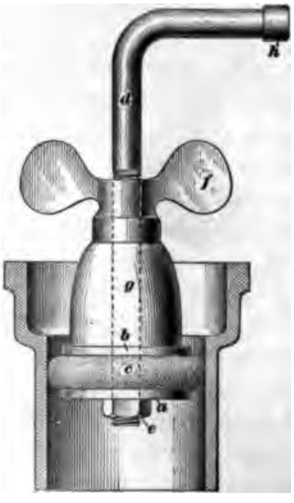
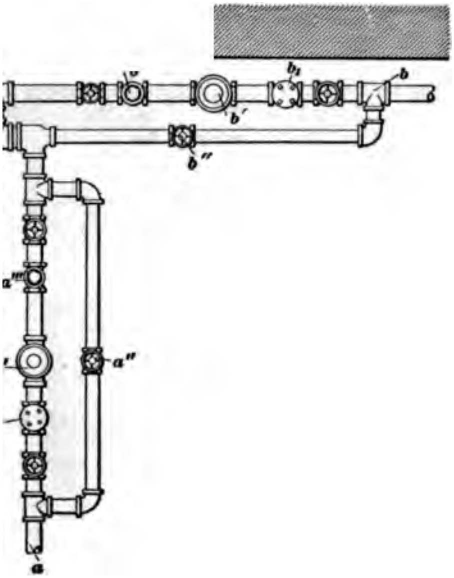
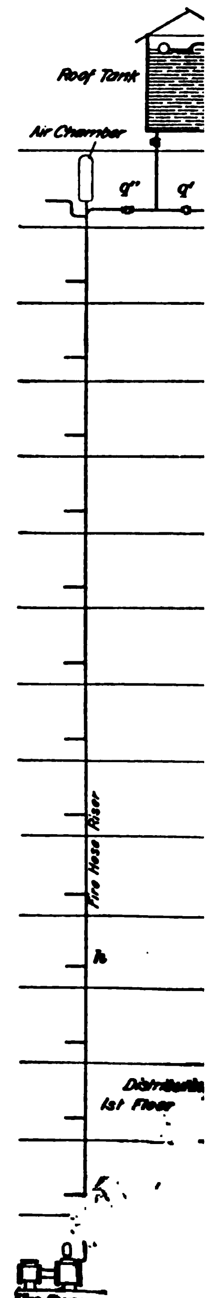
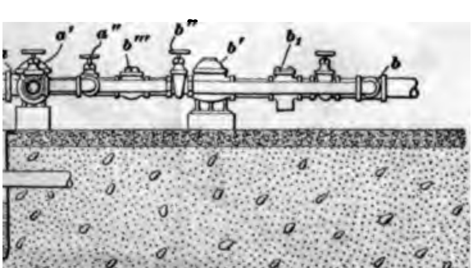


FIG. 32

By removing the cap *h* and substituting a stop-cock the system can be filled or emptied through the plug. Such


b₁
b
b′
b″
a‴
a″
a


Roof Tank
Air Chamber
q″
q′
Fire Hose Riser
h
1st Floor
Fire Pumps


a′
a″
b‴
b″
b′
b₁
b

plugs should only be used for low-pressure testing, owing to the liability of their blowing out.

49. A form of stopper that is adapted for testing under a high pressure is shown in Fig. 33, which shows an adjustable stopper made to fit different sizes of pipe. It consists of a hinged clamp *a* that hooks under the hub of a pipe or fitting, as at *b*, to prevent the pressure blowing the stopper from the hub. A disk *c*, which, when screwed down by the hollow bolt *d*, compresses a rubber gasket *e*, tightly

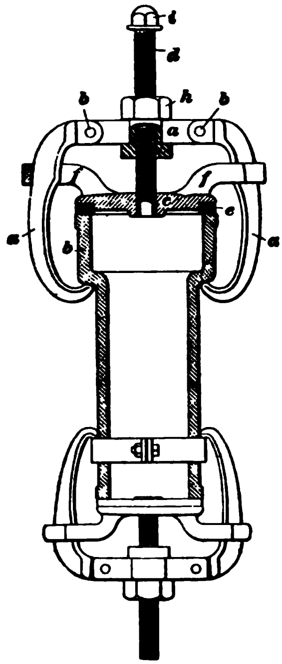


FIG. 33

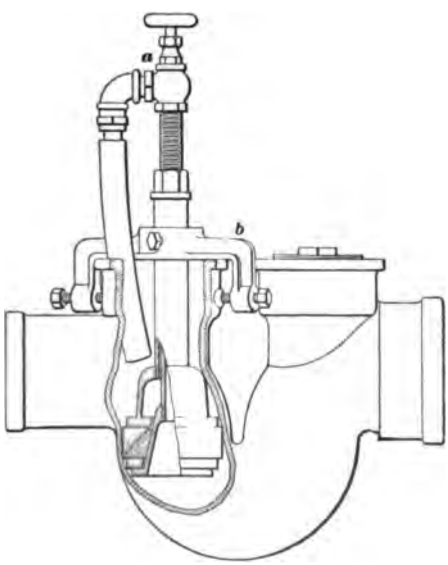


FIG. 34

closes the opening. Two arms *f*, *f* attached to the disk hold the clamp in place. The disk is raised or lowered by means of the nut *h*. The end of the hollow bolt is made tight by means of a cap *i*, which can be replaced by a stop-cock when the system is to be filled through the stopper. When a clamp-testing stopper is to be used on a spigot end, a collar must be provided to hold the clamp, as shown at the bottom of the illustration.

50. Special plugs are made to close the outlets of main-drain traps. Formerly it was difficult to close a main-drain trap connected to the sewer so that a water test could be applied to the system, but this is now easily done if a plug made especially for this purpose is used. Fig. 34 shows such a trap plug for testing, which is also provided with a valve *a* for filling and emptying the drainage system. The plug is similar to the one shown in Fig. 32, but has an extended shank and a clamp *b* for attaching it to the hub of the trap to prevent the blowing out of the plug.

FINAL TEST

51. The test by water pressure is applied only to the iron stacks, branches, and drain pipes; but in order to prove that the plumbing fixtures and their connections are gas-tight, a test should also be applied to the entire system when the fixtures are all connected up and the traps sealed with water. The pressure of such a test must be less than that required to force the trap seals. To find whether the system is gas-tight, an air test may be applied by means of a pump. All the traps are filled with water, and every opening is carefully stopped. The air pump is then connected, and a pressure about equal to that required to sustain a column of water 1 inch high is applied to the whole system. A water gauge that will show the height of a water column required to resist the air pressure may be attached at some convenient point, by which the pressure may be noted and the pumping stopped. If any of the traps blow through, or bubble, at a lower pressure than 1 inch, they should be readjusted until they will hold that pressure. If that cannot be done, the trap should be condemned and a better one should be put in its place. After the pressure is put on the system, the pump should be shut off and the water gauge should be closely watched for at least 15 minutes. If the pipes are all tight, the gauge will show no loss of pressure; but if the pressure falls, then a leak is surely indicated. To find the leak, other tests must be resorted to. Two methods are commonly employed for this purpose. One is to fill the pipes with a dense smoke, which can be seen when it escapes from the leak; this is known as the *smoke test*. The other method is to fill the pipe with some strong, pungent odor, which can be detected by smell, such, for instance, as the oil of peppermint. Care should be taken to distinguish between the oil, which is the essential oil, and the essence, which is a solution of a small portion of the essential oil in a large volume of alcohol, and is useless for this purpose.

52. The air test and the peppermint test are of little service in locating leaks, and hence the smoke test, which clearly shows the location of leaks, is generally adopted and used.

To apply the smoke test, a *smoke machine* is required. This consists of a blower that forces air into an air-tight firebox in which a fire is maintained. Usually a bunch of cotton waste that has been saturated with machine oil will furnish all the smoke required when slowly burned inside the firebox. The smoke is conducted through a flexible hose made of asbestos or rubber, or through metal pipes, to the fresh-air inlet of the drainage system, or to the most convenient branch, or open end. The ends of the branches and vent pipes should be opened to allow the smoke to displace the air and fill every part of the piping. All doors and windows should be closed, and the smoke made in starting the apparatus should be carefully prevented from entering the building through them. As soon as the smoke has filled the whole system and shows itself at all the vent openings, the plugs should be placed over these openings. The smoke pressure is then put on the system, when the smoke will ooze through the leaks and become visible, and also have a perceptible smell. It will also make its way through the traps if they are insufficiently sealed and it will come up through the water closets if they have kiln cracks or other such defects inside.

53. A convenient apparatus known as the Thomson smoke machine is shown in Fig. 35. It has a double-action bellows at the bottom and a fire-pot *b* above it. The inlet valves to the bellows are in the middle leaf, as shown, and an outlet valve is in each end leaf. When the handle *c* is operated, the bellows blows air through a three-way cock *a* into the bottom of the firebox. When the fuel on the grate *e* is ignited, the smoke blows through *b* in the direction of the arrows and passes through the outlet tube *g*, which is to be connected to the drainage system by a 1¼- or 1½-inch hose pipe. A water-jacket, which must be nearly filled with water before the fire is started, is formed around the firebox. A drum or cover *f* encloses the fire-pot and is sealed in the water. The weight of the drum is such that a pressure of about 1 inch of water column will raise it, or cause it to float in the water. A greater pressure is not required, and cannot be formed unless the drum is loaded down with weights. If the bellows is operated when the drum is floating, the result will be that the surplus smoke will escape into the atmosphere from below the drum. This prevents the trap seals from being forced by accident. When the drainage system is full of smoke and the drum floats, the cock *a* is closed and pumping is stopped.

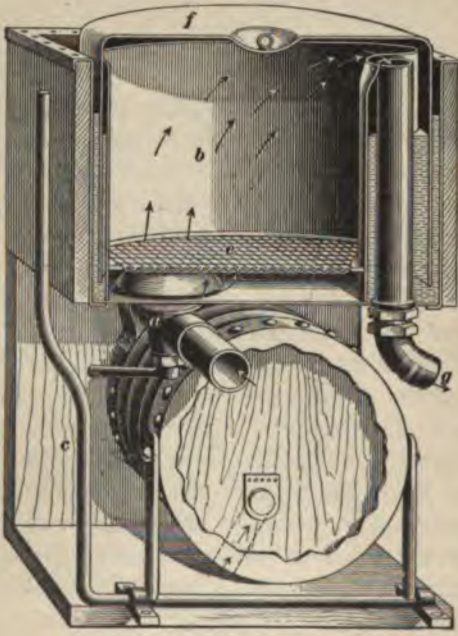


FIG. 35

If there is a leak anywhere, the drum will sink in the water and the velocity with which it falls will indicate the extent of the leak. If the drainage system is gas-tight, however, the drum will continue to float in the water. If, on an ordinary job, the drum does not show an appreciable fall in 10 minutes, the work may be passed as tight.

PLUMBING LAWS AND REGULATIONS

54. The plumbing and drainage of buildings is regulated by law in many cities and towns. These regulations establish a standard of general excellence to which all plumbers must conform. The standard thus fixed is the lowest that will be tolerated or that the public safety will permit. It is not the highest standard attainable, and does not aim to secure the best possible arrangement of drainage. The plumber should aim to supply the most perfect system of drainage and water supply that he can devise. He should not limit himself to the specific requirements of the law, but should do better, if possible.

The following verbatim copy of the regulations that are now in force in the city of New York should be carefully studied, and attention should also be given to the regulations in force in the plumber's own town or city.

RULES AND REGULATIONS FOR PLUMBING, DRAINAGE, AND WATER SUPPLY OF BUILDINGS IN THE CITY OF NEW YORK

Section 141 of the Building Code

I. The drainage and plumbing of all buildings, both public and private, shall be executed in accordance with the rules and regulations of the Bureau of Buildings for the Borough of Manhattan. Said rules and regulations, and any change thereof, shall be published in the City Record on eight successive Mondays before the same shall become operative.

Repairs or alterations of such plumbing or drainage may be made without the filing and approval of drawings and descriptions in the Bureau of Buildings, but such repairs or alterations shall not be construed to include cases where new vertical or horizontal lines of soil, waste, vent or leader pipes are proposed to be used.

Notice of such repairs or alterations shall be given to the said Bureau before the same are commenced in such cases as shall be prescribed by the rules and regulations of the said Bureau, and the work shall be done in accordance with the said rules and regulations.

II. Once in each year every employing or master plumber carrying on his trade, business or calling in The City of New York, shall register his name and address in the Office of the Bureau of Buildings in the Borough in which his place of business is located, under such rules and regulations as said Bureau shall prescribe and as hereinafter provided.

And thereupon he shall be entitled to receive a certificate of such registration from said Bureau, provided, however, that such employing or master plumber shall, at the time of applying for such registration, hold a certificate of competency from the Examining Board of Plumbers of said city.

The time for making such registration shall be during the month of March in each year. Where, however, a person obtains a certificate of competency at a time other than in the month of March in any year, he may register within thirty days after obtaining such certificate of competency, but he must also register in the month of March in each year as herein provided.

Such registration may be canceled by the Bureau of Buildings for a violation of the rules and regulations for the plumbing and drainage of said Bureau of Buildings, duly adopted and in force pursuant to the provisions of this section, or whenever the person so registered ceases to be a master or employing plumber, after a hearing had before said Bureau, and upon a prior notice of not less than ten days, stating the grounds of complaint, and served upon the person charged with the violation of the aforesaid rules and regulations.

III. After this Code takes effect, no person, corporation or copartnership shall engage in, or carry on the trade, business or calling of employing or master plumbing in The City of New York unless the name and address of such person and the president, secretary or treasurer of such corporation and each and every member of such copartnership shall have been registered as above provided. A plumber proposing to do work in a Borough other than that in which he is registered, shall present his certificate at the Office of the Bureau of Buildings in that Borough before commencing work, so that the fact of his having been properly registered may be recorded.

IV. No person or persons shall expose the sign of "Plumber" or "Plumbing" or a sign containing words of similar import and meaning in The City of New York unless each person forming such a copartnership shall have obtained a certificate of competency from the Examining Board of Plumbers, and shall have registered as herein provided.

A master or employing plumber within the meaning of this Code is any person who hires or employs a person or persons to do plumbing work.

V. The Inspectors of Plumbing in the Bureaus of Buildings of The City of New York, in addition to their other duties, shall ascertain whether the employing or master plumber having charge of the construction, repairing or alteration of any plumbing work performed in The City of New York is registered as herein provided, and if such person is not so registered, then such inspectors shall forthwith report to said Bureau the name of said plumber.

VI. The Superintendent of Buildings may present a petition to a justice of the Supreme Court or to a special term thereof for an order restraining the person so reported from acting as an employing or master plumber until he registers pursuant to the provisions of this Code. Said petition shall state that the said person is engaged in plumbing work as an employing or master plumber without having so registered, and shall be verified by the inspector making the said report.

Upon the presentation of the petition the Court shall grant an order requiring such plumber to appear before a special term of the Supreme Court on a date therein specified, not less than two nor more than six days after the granting thereof, to show cause why he should not be permanently enjoined until he has obtained a certificate of registration as herein required. A copy of such petition and order shall be served upon such person not less than twenty-four hours before the return thereof. On the day specified in such order the Court before whom the same is returnable shall hear the proofs of the parties, and may, if deemed necessary, take testimony in relation to the allegations of the petition.

If the Court is satisfied that such plumber is practicing without having registered as provided by this Code, an order shall be granted enjoining him from acting as an employing or master plumber until he has so registered.

No undertaking shall be required as a condition to the granting or issuing of such injunction order or by reason thereof.

If, after the entry of such order in a County Clerk's office in The City of New York, such person shall in violation of such order, practice as an employing or master plumber, he shall be deemed guilty of a criminal contempt of court, and be punishable as for a criminal contempt in the manner provided by the Code of Civil Procedure.

In no case shall the Bureau of Buildings be liable for costs in any such proceeding, but costs may be allowed against the defendant or defendants in the discretion of the Court.

Rules and Regulations of the Bureau of Buildings for the Borough of Manhattan for Plumbing, Drainage and Water Supply of Buildings

I

Filing ot Drawings, Descriptions, Etc.

1. Drawings and triplicate descriptions, on forms furnished by the Bureau of Buildings, for all plumbing and drainage, shall be filled in with ink and filed by the owner or architect in the said department. The plans must be drawn to scale in ink, on cloth, or they must be

cloth prints of such scale drawings, and shall consist of such floor plans and sections as may be necessary to show clearly all plumbing work to be done, and must show partitions and method of ventilating water-closet apartments.

2. The said plumbing and drainage shall not be commenced or proceeded with until said drawings and descriptions shall have been so filed and approved by the Superintendent of Buildings.

3. No modification of the approved drawings and descriptions will be permitted unless either amended drawings and triplicate descriptions, or an amendment to the original drawings and descriptions, covering the proposed change or changes, are so filed and approved by the Superintendent of Buildings.

4. The drainage and plumbing of all buildings, both public and private, shall be executed in accordance with the rules and regulations of the Bureau of Buildings.

5. Repairs or alterations of plumbing or drainage may be made without filing drawings and descriptions in the Bureau of Buildings, but such repairs or alterations shall not be construed to include cases where new vertical or horizontal lines of soil, waste, vent or leader pipes are proposed to be used.

6. Notice of such repairs or alterations shall be given to the said Bureau before the same are commenced, in such cases as shall be prescribed by the rules and regulations of the said Bureau, and the work shall be done in accordance with the said rules and regulations.

7. Where repairs or alterations ordered by the Board of Health for sanitary reasons include cases where new vertical and horizontal lines of soil, waste, vent or leader pipes are proposed to be used or old ones replaced, drawings and descriptions must be filed with and approved by the Superintendent of Buildings before the same shall be commenced or proceeded with.

8. Repairs and alterations may comply in all respects with the weight, quality, arrangement and venting of the rest of the work in the building.

9. It shall not be lawful to commence work on said plumbing and drainage or on any part thereof until the plumber who is to do the work shall sign the specifications and make affidavit that he is duly authorized to proceed with the work. Affidavit must give the name and address of owner and plumber, etc.

10. One set of specifications will be received for not more than ten houses, and then only when on adjoining lots and houses are exactly alike.

11. Written notices must be given to the Superintendent of Buildings by the plumber when any work is begun, and from time to time when any work is ready for inspection. All notices required must be sent in on blank forms furnished by the Bureau of Buildings.

II

Definition of Terms

12. The term "private sewer" is applied to main sewers that are not constructed by and under the supervision of the Department of Sewers.

13. The term "house sewer" is applied to that part of the main drain or sewer extending from a point two feet outside of the outer wall of the building, vault or area, to its connection with public sewer, private sewer or cesspool.

14. The term "house drain" is applied to that part of the main horizontal drain and its branches inside the walls of the buildings, vault or area, and extending to and connecting with the house sewer.

15. The term "soil pipe" is applied to any vertical line of pipe extending through roof, receiving the discharge of one or more water-closets, with or without other fixtures.

16. The term "waste-pipe" is applied to any pipe extending through roof, receiving the discharge from any fixtures except water-closets.

17. The term "vent-pipe" is applied to any special pipe provided to ventilate the system of piping and to prevent trap siphonage and back pressure.

III

Materials and Workmanship

18. All materials must be of the best quality, free from defects, and all work must be executed in a thorough, workmanlike manner.

19. All cast-iron pipes and fittings must be uncoated, sound, cylindrical and smooth, free from cracks, sand holes and other defects, and of uniform thickness and of the grade known in commerce as "extra heavy."

20. Pipe, including the hub, shall weigh not less than the following average weights per linear foot:

Diameters	Weights per Linear Foot
2 inches	$5\frac{1}{2}$ pounds
3 inches	$9\frac{1}{2}$ pounds
4 inches	13 pounds
5 inches	17 pounds
6 inches	20 pounds
7 inches	27 pounds
8 inches	$33\frac{1}{2}$ pounds
10 inches	45 pounds
12 inches	54 pounds

21. The size, weight and maker's name must be cast on each length of the pipe.

22. All joints must be made with picked oakum and molten lead and be made gas-tight. Twelve (12) ounces of fine, soft pig lead must be used at each joint for each inch in the diameter of the pipe.

23. All wrought-iron and steel pipes must be equal in quality to "standard," and must be properly tested by the manufacturer. All pipe must be lap-welded. No plain black or uncoated pipe will be permitted.

24. Wrought-iron and steel pipes must be galvanized, and each length must have the weight and maker's name stamped on it.

25. Fittings for vent-pipes on wrought-iron and steel pipes may be the ordinary cast or malleable steam and water fittings.

26. Fittings for waste or soil and refrigerator waste-pipes must be the special extra heavy cast-iron recessed and threaded drainage fittings, with smooth interior waterway and threads tapped, so as to give a uniform grade to branches of not less than one-fourth of an inch per foot. All fittings for wrought-iron or steel pipe must be galvanized.

27. All joints to be screwed joints made up with red lead, and the burr formed in cutting must be carefully reamed out.

28. Short nipples on wrought-iron or steel pipe, where the unthreaded part of the pipe is less than one and one-half inches long, must be of the thickness and weight known as "extra heavy" or "extra strong."

29. The pipe shall not be less than the following average thickness and weight per linear foot:

Diameters	Thicknesses	Weights per Linear Foot
1½ inches	.14 inch	2.68 pounds
2 inches	.15 inch	3.61 pounds
2½ inches	.20 inch	5.74 pounds
3 inches	.21 inch	7.54 pounds
3½ inches	.22 inch	9.00 pounds
4 inches	.23 inch	10.66 pounds
4½ inches	.24 inch	12.34 pounds
5 inches	.25 inch	14.50 pounds
6 inches	.28 inch	18.76 pounds
7 inches	.30 inch	23.27 pounds
8 inches	.32 inch	28.18 pounds
9 inches	.34 inch	33.70 pounds
10 inches	.36 inch	40.06 pounds
11 inches	.37 inch	45.02 pounds
12 inches	.37 inch	48.98 pounds

30. All brass pipe for soil, waste and vent pipes and solder nipples must be thoroughly annealed, seamless, drawn brass tubing, of standard iron-pipe gauge.

31. Connections on brass pipe and between brass pipe and traps on iron pipe must not be made with slip joints or couplings. Threaded connections on brass pipe must be of the same size as iron pipe threads for same size of pipe and be tapered.

32. The following average thicknesses and weights per linear foot will be required:

Diameters	Thicknesses	Weights per Lineal Foot
1½ inches	.14 inch	2.84 pounds
2 inches	.15 inch	3.82 pounds
2½ inches	.20 inch	6.08 pounds
3 inches	.21 inch	7.92 pounds
3½ inches	.22 inch	9.54 pounds
4 inches	.23 inch	11.29 pounds
4½ inches	.24 inch	13.08 pounds
5 inches	.25 inch	15.37 pounds
6 inches	.28 inch	19.88 pounds

33. Brass ferrules must be best quality; bell-shaped, extra heavy cast brass, not less than four inches long and two and one-quarter, three and one-half inches, and four and one-half inches in diameter, and not less than the following weights:

Diameters	Weights
2¼ inches	1 pound 0 ounces
3½ inches	1 pound 12 ounces
4½ inches	2 pounds 8 ounces

34. One and one-half inch ferrules are not permitted.

35. Soldering nipples must be heavy cast brass or of brass pipe, iron pipe size. When cast they must not be less than the following weights:

Diameters	Weights
1½ inches	0 pounds 8 ounces
2 inches	0 pounds 14 ounces
2½ inches	1 pound 6 ounces
3 inches	2 pounds 0 ounces
4 inches	3 pounds 8 ounces

36. Brass screw caps for cleanouts must be extra heavy, not less than one-eighth of an inch thick. The screw cap must have a solid square or hexagonal nut, not less than one inch high, with a least diameter of one and one-half inches. The body of the cleanout ferrule must be at least equal in weight and thickness to the calking ferrule for the same size of pipe.

37. Where cleanouts are required by rules and by the approved plans the screw cap must be of brass. The engaging parts must not have less than six threads of iron pipe size and be tapered. Cleanouts must be full size of trap up to four inches in diameter, and not less than four inches for larger traps.

38. The use of lead pipes is restricted to the short branches of the soil and waste pipes, bends and traps, roof connections of inside leaders. "Short branches" of lead pipe shall be construed to mean not more than:

5 feet of 1½-inch pipe.
4 feet of 2-inch pipe.
2 feet of 3-inch pipe.
2 feet of 4-inch pipe.

39. All connections between lead pipes and between lead and brass or copper pipes must be made by means of "wiped" solder joints.

40. All lead waste, soil, vent and flush pipes must be of the best quality, known in commerce as "D," and of not less than the following weights per lineal foot:

Diameters	Weights per Lineal Foot
1¼ inches (for flush pipes only)	2½ pounds
1½ inches	3 pounds
2 inches	4 pounds
3 inches	6 pounds
4 and 4½ inches	8 pounds

41. All lead traps and bends must be of the same weights and thicknesses as their corresponding pipe branches. Sheet lead for roof flashings must be six-pound lead and must extend not less than six inches from the pipe, and the joint made water-tight.

42. Copper tubing when used for inside leader roof connections must be seamless drawn tubing, not less than 22-gauge, and when used for roof flashings must be not less than 18-gauge.

IV

General Regulations

43. The entire plumbing and drainage system of each building must be entirely separate and independent of that of any other building.

44. Each building must be separately and independently connected with a public or private sewer or cesspool.

45. Every building must have its sewer connections directly in front of the building, unless permission is otherwise granted by the Superintendent of Buildings.

46. Where there is no sewer in the street or avenue, and it is possible to construct a private sewer to connect in an adjacent street or avenue, a private sewer must be constructed. It must be laid outside the curb, under the roadway of the street.

47. Cesspools and privy-vaults will be permitted only after it has been shown to the satisfaction of the Superintendent of Buildings that their use is absolutely necessary.

48. When allowed, they must be constructed strictly in accordance with the terms of the permit issued by the Superintendent of Buildings.

49. Cesspools must not be used as privy-vaults. Cesspools and privy-vaults must be at least twenty-five feet from any building, and should be on the same lot with the building for which its use is intended. Cesspools and privy-vaults, when constructed of brick, must be eight inches thick; of stone, twenty inches thick.

50. All cesspools and privy-vaults must be made water-tight.

51. As soon as it is possible to connect with a public sewer, the owner must have the cesspool and privy-vault emptied, cleaned and disinfected, and filled with fresh earth, and have a sewer connection made in the manner herewith prescribed.

52. All pipe-lines must be supported at the base on brick piers or by heavy iron hangers from the cellar-ceiling beams, and along the line by heavy iron hangers at intervals of not more than ten feet.

53. All pipes issuing from extension or elsewhere, which would otherwise open within thirty feet of the window of any building, must be extended above the highest roof and well away and above all windows.

54. The arrangement of all pipes must be as straight and direct as possible. Offsets will be permitted only when unavoidable.

55. All pipes and traps should, where possible, be exposed to view. They should always be readily accessible for inspection and repairing.

56. In every building where there is a leader connected to the drain, if there are any plumbing fixtures, there must be at least one four (4) inch pipe extending above the roof for ventilation.

V

Yard, Area, and Other Drains

57. All yards, areas, and courts must be drained.

58. Lodging-houses must have their yards, areas, and courts drained into the sewer.

59. These drains, when sewer-connected, must have connections not less than three inches in diameter. They should be controlled by one trap—the leader trap if possible.

60. Cellar drains will be permitted only where they can be connected to a trap with a permanent water seal.

61. Subsoil drains should discharge into a sump or receiving-tank, the contents of which must be lifted and discharged into the drainage system above the cellar bottom by some approved method. Where directly sewer-connected, they must be cut off from the rest of the plumbing system by a brass flap valve on the inlet to the catch-basin, and the trap on the drain from the catch-basin must be water-supplied, as required for cellar drains.

62. Floor or other drains will only be permitted when it can be shown to the satisfaction of the Superintendent of Buildings that their use is absolutely necessary and arrangements made to maintain a permanent water seal in the traps.

VI

Leaders

63. All buildings shall be kept provided with proper metallic leaders for conducting water from the roofs in such manner as shall protect the walls and foundations of said buildings from injury. In no case shall the water from said leaders be allowed to flow upon the sidewalk, but the same shall be conducted by pipe or pipes to the sewer. If there be no sewer in the street upon which such buildings front, then the water from said leaders shall be conducted by proper pipe or pipes below the surface of the sidewalk to the street gutter.

64. Inside leaders must be made of cast-iron, wrought iron or steel, with roof connections made gas and water tight by means of a heavy lead or copper-drawn tubing wiped or soldered to a brass ferrule or nipple calked or screwed into the pipe.

65. Outside leaders may be of sheet metal, but they must connect with the house drain by means of a cast-iron pipe extending vertically five feet above the grade level.

66. Leaders must be trapped with cast-iron running traps, so placed as to prevent freezing.

67. Rain water leaders must not be used as soil, waste or vent pipes, nor shall any such pipe be used as a leader.

VII

The House Sewer, House Drain, House Trap, and Fresh-Air Inlet

68. Old house sewers can be used in connection with the new buildings or new plumbing only when they are found, on examination by the plumbing inspector, to conform in all respects to the requirements governing new sewers.

69. When a proper foundation, consisting of a natural bed of earth, rock, etc., can be obtained, the house sewer can be of earthenware pipe.

70. Where the ground is made or filled in, or where the pipes are less than three feet deep, or in any case where there is danger of settlement by frost or from any cause, the house sewer must be of extra heavy cast-iron pipe, with lead-calked joints.

71. The house drain and its branches must be of extra heavy cast-iron, when underground, and of extra heavy cast-iron or galvanized wrought-iron or steel when above ground.

72. The house drain must properly connect with the house sewer at a point two feet outside of the outer front vault or area wall of the building. An arched or other proper opening must be provided for the drain in the wall to prevent damage by settlement.

73. If possible, the house drain must be above the cellar floor. The house drain must be supported at intervals of ten feet by eight-inch brick piers or suspended from the floor beams, or be otherwise properly supported by heavy iron pipe hangers at intervals of not more than ten feet. The use of pipe hooks for supporting drains is prohibited.

74. No steam-exhaust boiler blow-off or drip-pipe shall be connected with the house drain or sewer. Such pipes must first discharge into a proper condensing tank, and from this a proper outlet to the house sewer outside of the building must be provided. In low-pressure steam systems the condensing tank may be omitted, but the waste connection must be otherwise as above required.

75. The house drain and house sewer must be run as direct as possible, with a fall of at least one-quarter inch per foot, all changes in direction made with proper fittings, and all connections made with Y branches and one-eighth and one-sixteenth bends.

76. The house sewer and house drain must be at least four inches in diameter where water closets discharge into them. Where rain water discharges into them the house sewer and house drain up to the leader connections must be in accordance with the following table:

Diameter	Fall ¼ Inch per Foot	Fall ½ Inch per Foot
6 inches . .	5,000 square feet	7,500 square feet of drainage of area
7 inches . .	6,900 square feet	10,300 square feet of drainage of area
8 inches . .	9,100 square feet	13,600 square feet of drainage of area
9 inches . .	11,600 square feet	17,400 square feet of drainage of area

77. Full size Y and T branch fittings for handhole cleanouts must be provided where required on house drain and its branches.

no waste pipe connected between it and the fixture. Earthenware traps must have no vent-horns.

95. No sheet metal, brick or other flue shall be used as a vent-pipe.

96. The sizes of vent-pipes throughout must not be less than the following:

For main vents and long branches, two inches in diameter; for water-closets on three or more floors, three inches in diameter; for other fixtures on less than seven floors, two inches in diameter; three-inch vent-pipe will be permitted for less than nine stories; for more than eight and less than sixteen stories, four inches in diameter; for more than fifteen and less than twenty-two stories, five inches in diameter; for more than twenty-one stories, six inches in diameter; branch vents for traps larger than two inches, two inches in diameter; branch vents for traps two inches or less, one and one-half inches in diameter.

For fixtures other than water-closets and slop-sinks and for more than eight (8) stories, vent-pipes may be one (1) inch smaller than above stated.

X

Traps

97. No form of trap will be permitted to be used unless it has been approved by the Bureau of Buildings, and no masons', cess-pool, bell, pot, bottle or D-trap will be permitted nor any form of trap that is not self-cleaning nor has interior chamber or mechanism, nor any trap, except earthenware ones that depend upon interior partitions for a seal.

98. Every fixture must be separately trapped by a water-sealing trap placed as close to the fixture outlet as possible.

99. A set of wash trays may connect with a single trap, or into the trap of an adjoining sink, provided both sink and tub waste outlets are on the same side of the waste line, and the sink is nearest the line. When so connected the waste-pipe from the wash-trays must be branched in below the water seal.

100. The discharge from any fixture must not pass through more than one trap before reaching the house drain.

101. All traps must be well supported and set true with respect to their water levels.

102. All fixtures other than water-closets and urinals must have strong metallic strainers or bars over the outlets to prevent obstruction of the waste-pipe.

103. All exposed or accessible traps, except water-closet traps, must have brass trap screws for cleaning the trap placed on the inlet side, or below the water level.

104. All iron traps for house drain, yard and other drains and leaders must be running traps with handhole cleanouts of full size of the traps when same are less than five (5) inches. All traps underground must be made accessible by brick manholes with proper covers.

105. Overflow pipes from fixtures must in all cases be connected on the inlet side of traps.

106. All earthenware traps must have heavy brass floor plates soldered to the lead bends and bolted to the trap flange, and the joint made gas-tight with red or white lead. The use of rubber washers for floor connections is prohibited.

107. No trap shall be placed at the foot of main soil and waste pipe lines.

108. The sizes for traps must not be less than those given in the following table:

Traps for water-closets	4 inches in diameter
Traps for slop-sinks	2 inches in diameter
Traps for kitchen sinks	2 inches in diameter
Traps for wash trays	2 inches in diameter
Traps for urinals	2 inches in diameter
Traps for other fixtures	$1\frac{1}{2}$ inches in diameter

Traps for leaders, areas, floor and other drains must be at least 3 inches in diameter.

XI

Safe and Refrigerator Waste-Pipes

109. Safe and refrigerator waste-pipes must be of galvanized iron, and be not less than one and one-quarter ($1\frac{1}{4}$) inches in diameter, with lead branches of the same size, with strainers over the inlets secured by a bar soldered to the lead branch.

110. Safe waste-pipes must not connect directly with any part of the plumbing system.

111. Safe waste-pipes must discharge over an open, water supplied, publicly placed, ordinarily used sink, placed not more than three and one-half feet above the cellar floor.

112. The safe waste-pipe from a refrigerator must be trapped at the bottom of the line only, and cannot discharge upon the ground or floor. It must discharge over an ordinary portable pan, or over some properly trapped, water supplied sink, as above. In no case shall the refrigerator waste-pipe discharge over a sink located in a room used for living purposes.

113. The branches on vertical lines must be made by Y fittings, and be carried up to the safe with as much pitch as possible.

114. Lead safes must be graded and neatly turned over bevel strips at their edges.

115. Where there is an offset on a refrigerator waste-pipe in the cellar, there must be cleanouts to control the horizontal part of the pipe.

116. In tenement houses the refrigerator waste-pipes must extend above the roof, and must not be larger than one and one-half inches, nor the branches smaller than one and one-quarter inches.

117. Refrigerator waste-pipes, except in tenement houses, and all safe waste-pipes, must have brass flap-valves at their lower ends.

XII

118. In lodging-houses, factories, workshops and all public buildings the entire water-closet apartment and side walls to a height of six inches from the floor, except at the door, must be made waterproof with asphalt, cement, tile, metal or other waterproof material, as approved by the Bureau of Buildings.

119. In lodging-houses, the water-closets and urinal apartments must have a window opening to the outer air; if three stories or less in height they may have such window opening on a ventilating shaft not less than ten square feet in area.

120. In all buildings the outside partition of such apartment must extend to the ceiling or be independently ceiled over, and these partitions must be air-tight. The outside partitions must include a window opening to outer air on the lot whereon the building is situated, or some other approved means of ventilation must be provided. When necessary to properly light such apartments, the upper part of the partitions must be made of glass. The interior partitions of such apartments must be dwarfed partitions.

121. The general water-closet accommodations for a lodging-house cannot be placed in the cellar.

122. No water-closet can be placed outside of a building.

123. The closets must be set open and free from all inclosing woodwork.

124. Where water-closets will not support a rim seat, the seat must be supported on galvanized-iron legs, and a drip-tray must be used.

125. Every earthenware closet in all new work and in all alterations where it is not impossible to use it, because of water-pipes or other obstructions, must be set on a natural stone slab. Sand or artificial stone or tile will not be allowed.

126. All water-closets must have earthenware flushing rim bowls; "pipe-wash" bowls or hoppers will not be permitted.

127. Pan, valve, plunger, offset-washout and other water-closets having an unventilated space, or whose walls are not thoroughly washed at each discharge, will not be permitted.

128. Long hoppers will not be permitted, except where there is an exposure to frost.

129. The connection of traps must be made to main soil, waste, or vent pipes, by means of lead calked or screwed joints. Drip-trays must be enameled on both sides and secured in place.

130. In all sewer-connected occupied buildings there must be at least one water-closet, and there must be additional closets so that there will never be more than fifteen persons per closet.

131. In lodging-houses there must be one water-closet on each floor, and where there are more than fifteen persons on any floor there must be an additional water-closet on that floor for every fifteen additional persons or fraction thereof.

132. Water-closets and urinals must never be connected directly with or flushed from the water-supply pipes.

133. Water-closets and urinals must be flushed from separate cisterns on each floor, the water from which is used for no other purpose; where flushometers are used, they must be supplied from separate tanks provided for that purpose, and in no case are connections to be made direct with the water service pipe.

134. The overflow of cisterns may discharge into the bowls of the closet, but in no case connect with any part of the drainage system.

135. Iron water-closet and urinal cisterns and automatic water-closet and urinal cisterns are prohibited.

136. The copper lining of water-closet and urinal cisterns must not be lighter than ten (10) ounce copper.

137. Water-closet flush-pipes must not be less than one and one-fourth inches and urinal flush-pipes one (1) inch in diameter, and if of lead must not weigh less than two and one-half pounds and two pounds per linear foot. Flush couplings must be of full size of the pipe.

138. Latrine's trough water-closets and similar appliances may be used only on written permit from the said Superintendent of Buildings, and must be set and arranged as may be required by the terms of the permit.

139. All urinals must be constructed of materials impervious to moisture that it will not corrode under the action of urine. The floor and wall of the urinal apartments must be lined with similar non-absorbent and non-corrosive material.

140. The platforms or treads of urinal stalls must never be connected independently to the plumbing system, nor can they be connected to any safe waste pipe.

141. Iron trough water-closets and trough urinals must be enameled or galvanized.

142. In lodging-houses sinks must be entirely open, on iron legs or brackets, without any inclosing woodwork.

143. Wooden washtubs are prohibited. Cement or artificial stone tubs will not be permitted unless approved by the Bureau of Buildings.

XIII

Water Supply for Fixtures

144. All water-closets and other plumbing fixtures must be provided with a sufficient supply of water for flushing to keep them in proper and cleanly condition.

145. When the water pressure is not sufficient to supply freely and continuously all fixtures, a house supply tank must be provided, of sufficient size to afford an ample supply of water to all fixtures at all times. Such tank must be supplied from the pressure or by pumps, as may be necessary; when from the pressure, ball-cocks must be provided.

146. If water pressure is not sufficient to fill house-tank, power pumps must be provided for filling them in lodging-houses, factories and workshops.

147. Tanks must be covered so as to exclude dust, and must be so located as to prevent water contamination by gas and odors from plumbing fixtures.

148. House supply-tanks must be of wood or iron or of wood lined with tinned and planished copper.

149. House-tanks must be supported on iron beams.

150. The overflow pipe should discharge upon the roof, where possible, and in such cases should be brought down to within six (6) inches of the roof, or it must be trapped and discharged over an open and water-supplied sink not in the same room, not over 3½ feet above the floor. In no case shall the overflow be connected with any part of the plumbing system.

151. Emptying pipes for such tanks must be provided, and be discharged in the manner required for overflow pipes, and may be branched into overflow pipes.

152. No service-pipes or supplying-pipes should be run, and no tanks, flushing cisterns or water-supplied fixtures should be placed where they will be exposed to frost.

153. Where so placed they shall be properly packed and boxed in such a manner as to prevent freezing.

XIV

Testing the Plumbing System

154. The entire plumbing and drainage system within the building must be tested by a plumber, in the presence of a plumbing inspector, under a water or air test, as directed. All pipes must remain uncovered in every part until they have successfully passed the test. The plumber must securely close all openings as directed by the Inspector of Plumbing. The use of wooden plugs for this purpose is prohibited.

155. The water test will be applied by closing the lower end of the main house drain and filling the pipes to the highest opening above the roof with water. The water test shall include at one time the house drains and branches, all vertical and horizontal soil, waste and vent and leader lines and all branches therefrom to point above the surface of the finished floor and beyond the finished face of walls and partitions. Deviation from the above rule will not be permitted, unless

upon written application to and approval by the Superintendent of Buildings. If the drain or any part of the system is to be tested separately, there must be a head of water at least six (6) feet above all parts of the work so tested, and special provision must be made for including all joints and connections in at least one test.

156. The air test will be applied with a force-pump and mercury columns under ten pounds pressure, equal to twenty inches of mercury. The use of spring gauges is prohibited.

157. After the completion of the work, when the water has been turned on and the traps filled, the plumber must make a peppermint or smoke test in the presence of a plumbing inspector and as directed by him.

158. The material and labor for the tests must be furnished by the plumber. Where the peppermint test is used, two ounces of oil of peppermint must be provided for each line up to five stories and basement in height, and for each additional five stories or fraction thereof one additional ounce of peppermint must be provided for each line.

TRAPS AND VENTS

CONSTRUCTION AND INSTALLATION

TRAPS

SEWER-GAS TRAPS

1. Introduction.—Sewage is composed of water mixed with kitchen slops, grease, soap, urine, washings from stables and slaughter houses, rags, leaves, paper, human excreta, etc. The animal and vegetable matters in it rapidly decompose and generate noxious gases; the combination of these is called **sewer gas.** These gases inevitably produce sickness if they escape into a dwelling, or if they are breathed in any considerable quantity for even a few minutes. A small leak of sewer gas into a house may cause much sickness that will probably be ascribed to other causes. Many people endure a small amount of bad odor rather than send for a plumber, and are unwilling to believe that a small defect in the drainage can do much mischief.

To prevent sewer gas entering a building, *traps* and *vents* are used; these are not luxuries, but are absolutely necessary to the health of the community. A trap should be placed under each bathtub, wash basin, sink, water closet, or urinal, and to each set of laundry tubs. It should be set as close to the fixtures as possible. No trap should be placed at any point where it will check the free circulation of air through the drainage system.

2. General Description.—A trap is a device that allows the free passage, through it, of liquids and such solid matter as the liquid may carry, but prevents the passage of air or gas in either direction. The simplest form of trap, shown in Fig. 1, consists of a downward loop in a horizontal pipe. Whenever water is run through the pipe, enough will be retained to fill the bend and prevent air or gas at atmospheric pressure from passing. If the air has sufficient

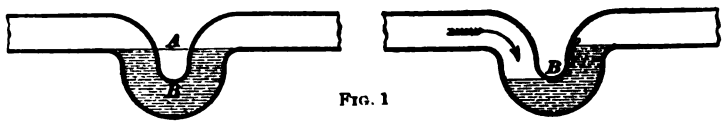


FIG. 1

pressure it may force the water down on one side of the bend and up on the other, until the air can escape past the bend *B*, and bubble upwards through the water. The difference between the level of the water when quiet, as at *A*, and the point *B*, is called the **seal** of the trap.

3. Fig. 1 shows the principle of the class called **round pipe**, or **Du Bois, traps.** The common forms of round pipe traps are shown in Fig. 2.

The trap at *A* is known as an **S** *trap*, and is used chiefly under fixtures where the waste pipe descends to the floor. A half **S** or **P** *trap* is shown at *B*; this is used chiefly to join

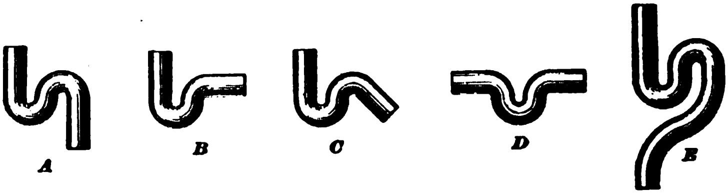


FIG. 2

fixtures to a nearly horizontal waste-pipe branch. The three-quarter **S** *trap* at *C* is used chiefly to join fixtures to a **Y** branch in a soil pipe where the distance between the trap and the branch is short. The *running trap* at *D* can only be used on a nearly horizontal waste pipe. It is often used as a bath trap, being placed under the floor. The ***hunchback trap*** at *E* is used on a vertical pipe where it is desired to have the inlet and outlet in the same straight line. It is not used as much as the other forms.

4. In some traps, as in Fig. 3, the end of the discharge pipe is submerged in water. Air or gas can pass through this trap only when under sufficient pressure to depress the water below the end of the tube.

It should be noted that a much higher pressure will be required to force gas from the cup up the tube than in the other direction, since the cup is of larger diameter than the tube, and contains a larger volume of water. For example, the area of the tube is 1 square inch, that of the cup is 4 square inches, and the height of *A B*, or the seal, is 2 inches. To blow air down the tube and through the trap requires a pressure sufficient to depress the water in the tube *C* 2 inches. As the water falls in *C* it must rise in *D*; hence, 2 cubic inches of water forced out of *C* will raise the level in *D* $\frac{2}{3}$ inch. Consequently, the passage of the air is resisted by a water column $2\frac{2}{3}$ inches high. Now, to force air in the opposite direction, or backwards, the water in *D* must be depressed 2 inches, or 6 cubic inches of water must be driven into the tube *C*. This, together with the 2 inches already there, will fill the tube to a height of 8 inches. Then, the passage of air backwards is resisted by a water column 8 inches high, or three times as much as in the forward direction.

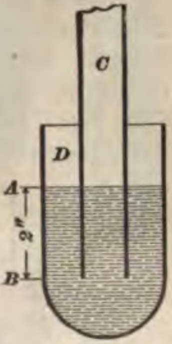


FIG. 3

5. A **bottle trap** is shown in Fig. 4. This trap is used under fixtures, such as sinks, baths, basins, or wash tubs, but never under water closets. The inlet pipe *A* is attached to the fixture, and the outlet pipe *B* joins the waste pipe *D*, of which the part *C* forms the back-vent. It is next to impossible to unseal this form of trap, although some of the seal may be lost by siphonage; from this fact it is known as an ***antisiphon trap***. The chief objections to it are that filth is liable to accumulate in the bottom of the trap and grease on the top of the water and in the chamber E, and that the water cannot be completely renewed every time the fixture is used; in other words, this trap is not self-cleansing.

6. A modification of the trap illustrated in Fig. 4 is shown in Fig. 5. This form is more direct than that shown in Fig. 4, but is more easily unsealed. However, it overcomes the danger of drain air entering the building through unseen holes in its interior, as would occur if the tube A, Fig. 4, were corroded within the chamber E. Care must be taken when attaching an overflow pipe, for instance, from a wash basin, to any form of a trap, particularly to those of the pot or bottle formation, to have the overflow properly sealed. An overflow G is attached to the body of the trap in Fig. 4.

In Fig. 5 the trap receives waste water from the fixture by the pipe A; B is the back-vent pipe and C the waste pipe.

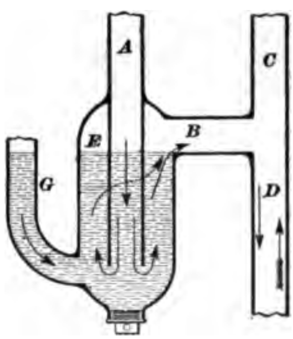


FIG. 4

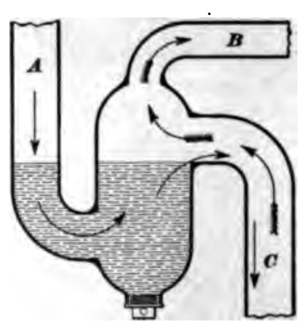


FIG. 5

The arrows with feathers show the direction of the natural air-currents in the drainage system.

Bottle traps are also known to the trade as **pot traps** and **drum traps**.

7. Traps may be divided into two classes, the ***self-cleansing*** and *non-self-cleansing*, the round pipe trap being an example of the former and the bottle, or pot trap, of the latter.

In Fig. 6 is shown a round pipe trap, and in Fig. 7, a bottle trap. The traps are shown full of water which, for the present, is supposed to be at rest. The ends *a* of the traps, or inlet ends, are supposed to be connected to the fixtures, and the outlet ends *b*, to the waste or drain pipes; consequently, the flow of water through the traps will be in the direction of the arrows. Sewer gas, or drain air, is

Fig. 6

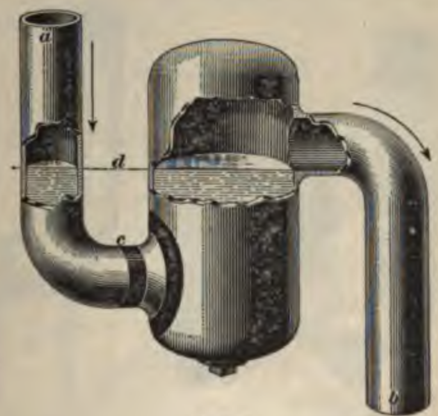


Fig. 7

prevented from entering the building through the pipe *a* by reason of the tongue *c* of the trap dipping into the water. The maximum seal is shown in Figs. 6 and 7; the water-line cannot be raised without causing a flow of water through the trap.

In order that the water-line exposed to the drain air may be level with the water-line exposed to the atmosphere, the pressures on these water-lines must be equal. If they are not equal, there will be a difference in the water levels sufficient to counterbalance the difference in pressures.

Suppose that the water seals of the traps in Figs. 6 and 7 are both 3 inches deep, and that the pressure in the pipes *b* is greater than that of the atmosphere to an extent equivalent to that of a column of water 5 inches high. The effect then will be to depress the surface of the water in the outlet end until the surface of the water in the inlet pipe is 5 inches above it, as shown in Figs. 8 and 9. This will produce equilibrium, because the atmospheric pressure on the surface of the water in the inlet, plus the pressure due to the head of water formed, will equal the pressure of the drain air on the surface of the water in the outlet end.

Since the sectional area of the round pipe trap is uniform, it follows that the loss of seal in the trap, Fig. 6, due to back

Fig. 8

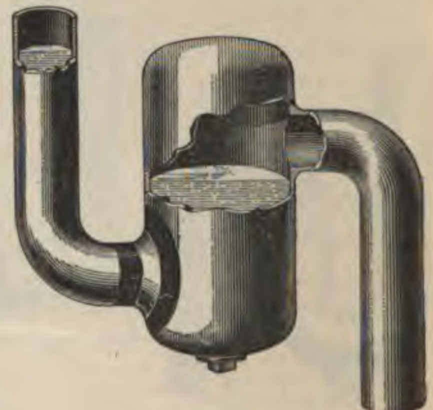


Fig. 9

pressure, is $5 \div 2 = 2\frac{1}{2}$ inches, showing that only $3 - 2\frac{1}{2} = \frac{1}{2}$ inch of a seal remains to keep back the drain air. See Fig. 8.

The loss of seal in the bottle trap, Fig. 7, is not so great, even though the same head of water has been formed in the inlet pipe. See Fig. 9. This is due to the fact that the sectional area of the pot is greater than that of the inlet tube, and, of course, in a given length of the pot, a greater quantity of water is contained than in the same length of the inlet tube; consequently, a much higher column of water must be formed in the inlet tube before the seal can become as low as that in Fig. 8.

Suppose that the sectional area of the pot of the trap, Figs. 7 and 9, is 20 square inches, then $20 \times 3 = 60$ cubic inches of water must be forced into the inlet tube before drain air can pass through the trap. If the sectional area of the inlet pipe is 4 square inches, the height of the column above the tongue must be $3 + \frac{60}{4} = 18$ inches, before the seal of the trap is forced. A back pressure of about .7 pound per square inch will be required to accomplish this.

Thus, it will be seen that to resist back pressure, traps of the pot design should be used in preference to those of the round pipe forms; but, where there is little danger of back pressure being present at any time, the round pipe trap is preferable, because it is self-cleansing.

8. In Fig. 10 is shown a **ball trap**, in which a trap is combined with a check-valve. The ball valve *c* prevents the return of either liquid or gas, and the liquid around the ball keeps the seat gas-tight. The weight of the ball is but slightly greater than that of the water displaced, so that a very slight head of water in *B* will raise the ball. This trap is particularly suitable for clean-water fixtures, such as basins or baths, which are liable to remain unused a sufficient length of time to permit the water in the trap to become evaporated and its seal consequently lost. In such a case the ball will form a nearly gas-tight joint with its seat and prevent the passage of drain air to the building. This and all other traps having the waterway restricted by mechanical appliance, such as check-valves, are liable to chokage by the accumulation of hair, small pieces of rags, sponges, and even matches.

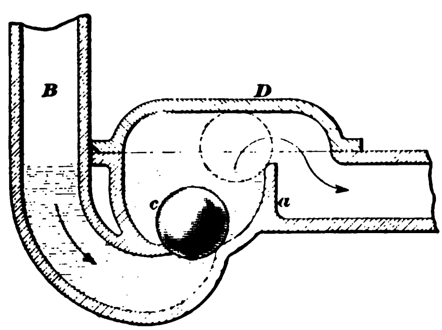


Fig. 10

The position of the ball when water passes through the trap is shown by dotted lines. It cannot enter the trap outlet pipe, as the space between the lip *a* and the handhole cover *D* is too small.

9. A **bell trap** is shown in Fig. 11. In it the seal is formed by the bell *a* suspended from the strainer *b* and dipping into a small pool of water formed by the waste outlet *c* projecting into the trap casting. The chief objections to the bell trap are: (1) It soon becomes choked by sediment lodging in the bottom, which cannot be removed without lifting off the bell. This, for the time being, permits open communication between the drains and the

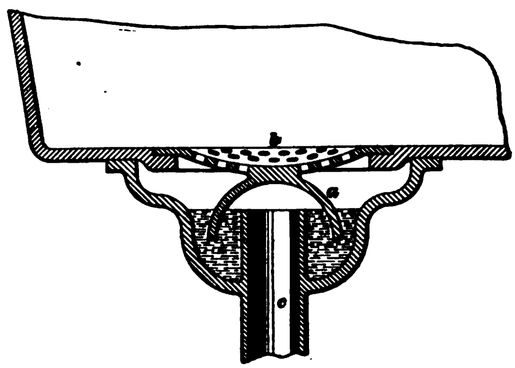


FIG. 11

building. (2) It is easily siphoned. (3) The seal quickly evaporates if the trap is not used. In fact, the bell trap has no redeeming features, and should be abolished in house drainage systems.

10. Comparisons.—The requirements of a good trap are: (1) that it shall entirely and effectually prevent the passage of any air or gas from the waste pipe into the house; (2) that it shall be so constructed that it can be readily cleaned; (3) that it shall clean itself on all ordinary occasions.

Round pipe traps usually have the same diameter throughout and freely pass nearly everything that cannot get into them; but, they are very liable to become useless through the removal of the water that seals them, by siphonage or evaporation.

The bottle trap can seldom be emptied or its security impaired by siphonage, and, as it contains a large volume of water, it will withstand evaporation for a longer time than other traps. It will clog easier than a round pipe trap, but is quite as easily cleaned when the screw plug, which is provided for that purpose, is removed. The same depth of seal forms a more effectual barrier against the back flow of gas in a bottle trap than in a round pipe trap.

The ball trap shown in Fig. 10 cannot be easily emptied by siphonage. When the water evaporates from it, the slime that coats the interior of the trap will cement the ball to its seat and make a joint that will be practically gas-tight, provided that the seat be free from shreds of cloth, hair, etc. The usefulness of the ball is very apt to be destroyed by refuse, in which case it is worse than an ordinary trap.

Traps for outdoor service, to receive surface water from courts, areas, roofs etc., should have a deep seal, from 8 inches to 1 foot, according to the warmth and length of the dry seasons.

Check-valves should not be used in place of traps, because they are very liable to be prevented from closing properly by the lodgment of refuse, such as strings, rags, paper, etc., between the valve and its seat.

All traps should have a cleaning hole. The screw plug that is used to close the hole should be of such shape and size that a wrench can be applied to it firmly and safely. Lead traps should correspond in thickness to that of the pipes they join, and brass traps should be equal in thickness to the walls of iron pipe. When brass pipe is used to connect a trap to a drainage system, it should be of iron-pipe size and the threads should be the same as for iron pipes.

11. Bath Traps.—Traps for bathtubs are generally made of lead and located below the floor of the room in which the tub is situated. The plumbing ordinances of some localities require that a round pipe trap be used for bathtubs, because round pipe traps are self-cleansing, prohibiting the use of drum traps because they are liable to become foul from the accumulation of slime on the unscoured parts. Laws of other cities require, on the other hand, that drum traps be used under bathtubs because they contain a large body of water and a deep seal, and prohibit the use of round pipe traps because of their liability of loss of seal by evaporation. Hence, in the use of traps, the plumber must be governed by the requirements of the plumbing laws of the city in which the work is to be done. Copies of the Health Rules and Regulations of any city may be had by applying to the Board of Health or plumbing inspector of the city.

12. Fig. 12 shows a round pipe trap for a bathtub waste pipe located between the bathroom floor and the ceiling below. When a closet or pantry is located below the bathroom, the clean-out screw *a* of the trap *b* may be allowed to project through the ceiling, as shown in the illustration. This permits the trap to be cleaned without disturbing the floor or ceiling, on removal of the trap screw.

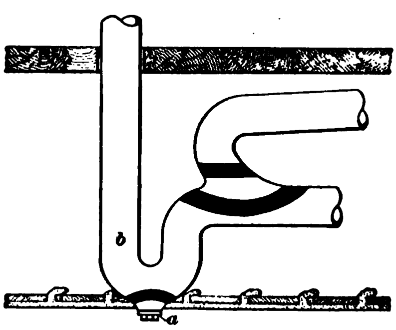


FIG. 12

13. Drum traps may be obtained from dealers in plumbers' supplies, or may be made by the plumber on the job. Fig. 13 shows a drum trap made from a piece of 4-inch drawn lead

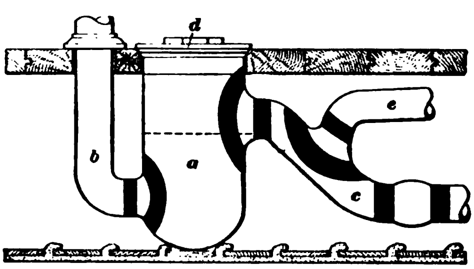


FIG. 13

pipe *a*, which forms the body of the trap. The bottom is formed by beating the end over in the form of a dome and soldering it water-tight. The inlet pipe *b* joins the body near the bottom, and the waste pipe *c* is connected near the top, thus leaving a body of water about 3 or 4 inches deep to form the seal of the trap. When set in place, the top of a drum trap for a bathtub is allowed to project through the bathroom floor, where it connects to the sleeve of a clean-out screw *d* by means of a wiped flange joint. The clean-out screw should be the full size of the body of the trap, and should be accessible, as shown.

The waste pipe is vented by the back-vent pipe *e*. The space between the ceiling and flooring in which to run the waste and vent pipes from a bath trap is usually about 10 inches. It is well, therefore, to keep the waste pipe as low as circumstances will permit, so that the vent pipe will have a good pitch down toward the trap to drain any water that might back up in it when the tub is being emptied.

14. Closet Traps.—Traps for all forms of water closets, excepting siphon-jet water closets, should be from $3\frac{1}{2}$ to 4 inches in diameter. This size is necessary to prevent frequent chokage during rough usage. Siphon-jet closet traps should preferably have the same diameter, but owing to the difficulty of producing siphonic action through large traps with an ordinary flush of water, these water closets are usually made with traps so constructed that a 2-inch ball will scarcely pass through them. These traps frequently have an elliptical cross-section.

15. Slop-Sink Traps.—Traps for slop sinks are usually made of porcelain-lined iron, or solid porcelain, and are located above the floor, where they serve as a pedestal on which to rest the sink. They are usually 3 inches in diameter. Check-valves or mechanical traps of any kind should never be used for water closets or slop sinks; they would only offer lodging places for the foul matter discharged into the fixtures, which tends to choke such traps.

16. Basin Traps.—On the better classes of work, basin traps made of cast brass, and either polished and lacquered or nickel plated, are generally used. Fig. 14 shows a brass one-half **S** trap *a* with an offset *b* for basin connection that can be lowered or raised to suit variations in the height of the basin waste outlet, due to inaccuracies in roughing in. The offset may also be swung to the right or left when the outlet to the basin is not on a line with the waste outlet *c* in the wall. The offset is made tight in the trap, at *d*, by means

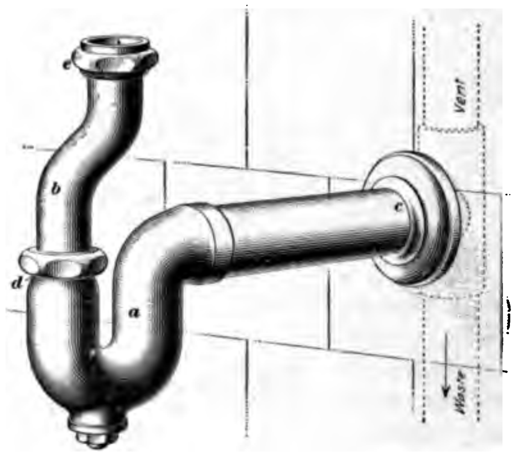


FIG. 14

of a ring packing, compressed by the union so as to form a water- and gas-tight joint. The coupling *e* is used to connect the trap to the waste spud in a basin. An escutcheon plate covers the opening in the wall through which the waste pipe extends.

17. The joints that connect the horizontal waste pipe to the trap and to the T piece, shown by dotted lines, are screwed joints. Gasket or slip joints should not be used here; they may be used, however, on the house side of the trap seal. The use of screwed joints insures permanently gas-tight joints on the sewer side of the trap.

There is a great variety of patent basin traps on the market, but the simple adjustable trap shown in Fig. 14 is quite sanitary, provided that the waste pipe is properly back-vented. Basin traps, generally, are furnished as parts of basin combinations sold complete by the supply houses.

18. Examples of Modern Commercial Fixture Traps.—For the better classes of work fixture traps are generally made of brass and are polished or nickel plated. They are made in a variety of patterns, some of which are one-half **S** traps and finish at the wall, while others are of the full **S** pattern and waste through the floor. A type of wall trap is

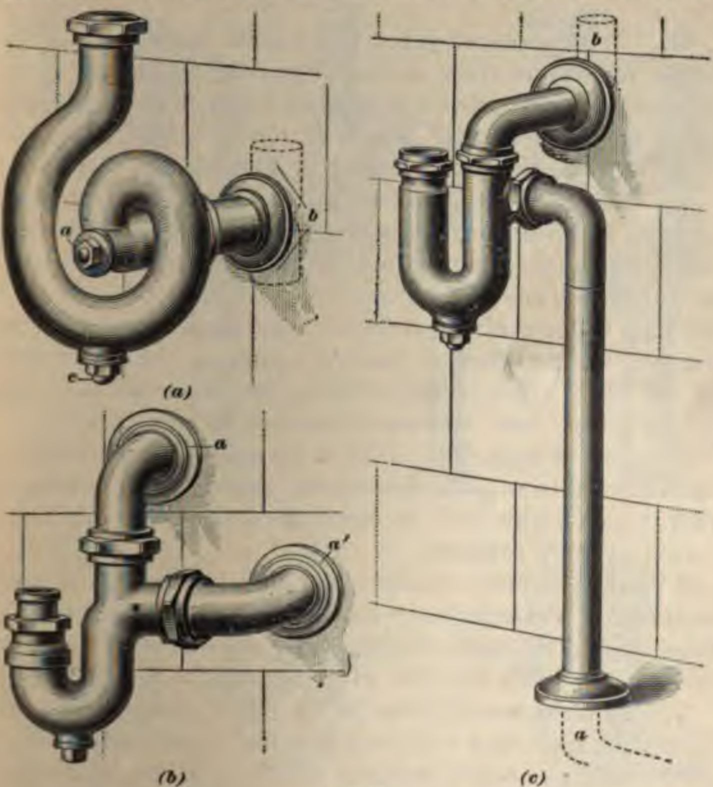


FIG. 15

shown in Fig. 15 (*a*). The vent to this trap is located back of the wall, so that no vent pipe is exposed. A clean-out screw *a* makes accessible the inside of the nearly horizontal pipe back to the waste and vent stack *b*; the clean-out screw *c* serves to empty the water from the seal of the trap and permits the dislodging of any solid matter that might lodge therein.

In Fig. 15 (*b*) is shown a one-half **S** trap with an exposed back-vent pipe; the trap and pipe extend to the wall, where they finish with escutcheons *a*, *a'*. A similar type of trap is shown in Fig. 15 (*c*), which illustration, however, shows a full **S** trap that wastes through the floor into *a* and is vented through the wall into *b*.

19. Within recent years, many cities have modified the clause relating to traps in their Plumbing Rules and Regulations, so that approved antisiphon traps can be used without being back-vented. Some of the principal antisiphon traps on the market are shown in Fig. 16.

Fig. 16 (*a*) shows a **centrifugal trap.** It is supposed to be both antisiphon and self-cleansing. The cleansing is accomplished by a rotary motion given the inflowing waste water, by the inlet being connected tangent to the body of the trap. The centrifugal force of the flowing water carries the heavier particles of foreign matter to the outer walls of the trap, where, after scouring the inner surface, they finally escape with the water through the trap outlet.

The **Bower trap,** Fig. 16 (*b*), is not only an antisiphon trap, but also contains a back-pressure valve in the form of a rubber ball. This ball prevents the seal of the trap being forced by back pressure.

Fig. 16 (*c*) shows an antisiphon trap known as the **Sure Seal trap.** An inner tube rises inside the body of the trap, as shown by dotted lines, flanges being allowed to project into the waterway at *a* and *b* to give the water a zigzag motion.

The **Sanitas trap,** shown in Fig. 16 (*d*), is one of the first antisiphon traps that was placed on the market. It depends for its ability to resist siphonic action on an enlarged chamber *a* at the side, and a partition inside to deflect the water from the trap outlet. Like the other types of antisiphon trap it is made in **S** and half **S** patterns, and may be had in rough brass, polished brass, nickel-plated brass, or lead.

In Fig. 16 (*e*) is shown a **Bennor globe trap** of the half **S** pattern. This type of trap, like the Bower trap, contains a ball to seal the pipes against back pressure.

The **Bennor bath trap,** shown in Fig. 16 (*f*), is designed especially for bathtub waste pipes. The brass body is left rough, because the trap is set under the bathroom floor, and therefore is not exposed to view. The flange and screw-cap on top are finished in nickel plate, because they are set

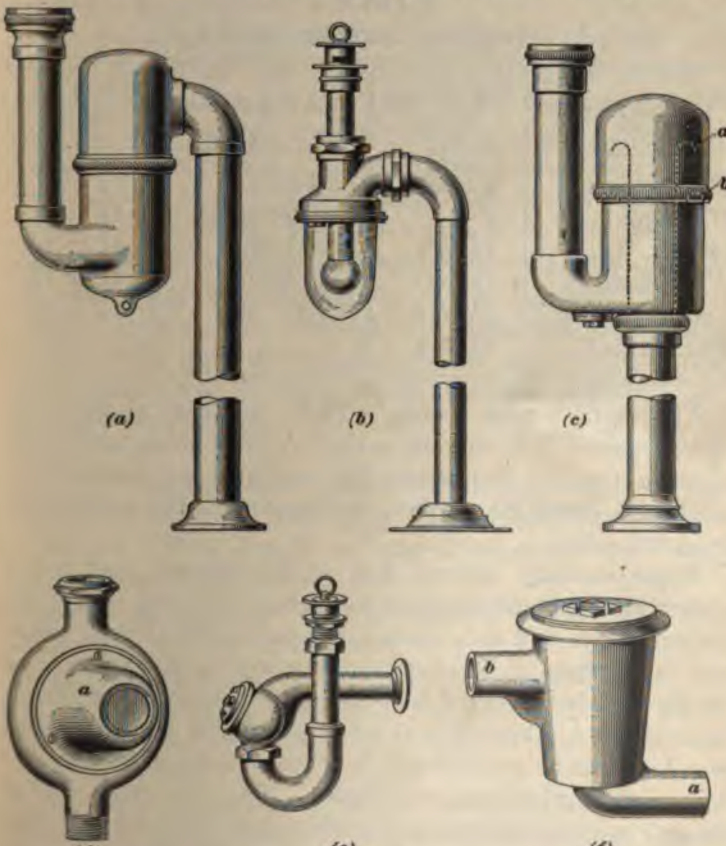


FIG. 16

flush with the floor and hence show. The inlet *a* connects with the bath, and the outlet *b* with the waste pipe. A ball that is heavier than water may be placed inside the trap to close the inlet opening against back pressure.

20. Sizes of Fixture Traps.—Traps for fixtures should correspond in size to the waste pipes with which they connect, and should be set true with respect to their water seals. The following table gives sizes of traps for different kinds of fixtures:

TABLE I

SIZES OF FIXTURE TRAPS

Kind of Fixture	Size of Trap Inches	Kind of Fixture	Size of Trap Inches
Water closet . .	3 to 4	Bathtub	$1\frac{1}{2}$ to 2
Slop sink . . .	3	Shower bath . .	$1\frac{1}{2}$ to 2
Urinal	$1\frac{1}{2}$ to 2	Seat bath . . .	$1\frac{1}{4}$ to $1\frac{1}{2}$
Wash basin . .	$1\frac{1}{2}$	Foot-bath . . .	$1\frac{1}{4}$ to $1\frac{1}{2}$
Laundry tubs .	$1\frac{1}{2}$ to 2	Bidet	$1\frac{1}{4}$ to $1\frac{1}{2}$
Kitchen sink . .	$1\frac{1}{2}$ to 2		

21. Safe-Waste Traps.—There are several things to be considered in arranging safes, the most important point, because it is one that affects the health of the occupants of the house, being the method of disposing of the waste water from the safe.

While sanitary science was in its infancy, and before plumbing rules and regulations were originated, it was not uncommon to find safe-waste pipes connected to soil, waste, and drain pipes, either directly or by means of a trap placed on the pipe between the safe and its connection to the drainage system. This method of disposing of the safe water was found to be exceedingly dangerous, and today is strictly forbidden in plumbing ordinances. The trap rapidly loses its seal by evaporation and the drain gases then freely escape into the building. Safe-waste pipes should discharge over and into a water-supplied fixture in the basement, or openly to the atmosphere at some convenient place, a swing check-valve being placed over the outlet of the safe-waste pipe.

22. Refrigerator Traps.—The plumbing rules and regulations of the different cities vary somewhat in the requirements for trapping refrigerators, because the conditions differ with the localities. Generally, however, the safe wastes from refrigerators are required to discharge over and into an open pan, or water-supplied sink in the basement, and, for easy access, be set not higher than 3 feet 6 inches above the cellar floor.

Each portable refrigerator should be trapped underneath to prevent the cold air from escaping through the waste pipe, and the ice from being thus wasted. This trap is then located over a funnel-mouthed waste pipe or a safe on the floor. The waste pipe from the funnel or safe should have a trap, usually $1\frac{1}{2}$ inches in diameter, set close to the floor. The waste pipe from this trap is run as straight as possible to a water-supplied sink, into which it discharges through a light swing flap valve over the outlet opening. As sawdust and slime will accumulate in refrigerator pipes and traps, it is necessary to attach clean-out screw-caps to them for cleaning-out purposes, at all changes in direction.

23. Trap Screws.—Brass trap screws should be placed in all fixture traps, excepting water-closet traps, to permit cleaning. They should be located below the water seal so that in case they are not perfectly gas- and water-tight the leakage of water will give notice that something is wrong. Clean-out screws should also be placed in the end of all horizontal runs of pipe to fixtures, and should be located at suitable intervals in waste pipes from kitchen sinks or other fixtures into which large quantities of greasy water are discharged.

It is good practice to place a clean-out screw in lead or iron vent pipes, within 6 inches of fixture traps, in such a position that the junction of the vent with the waste pipe may be examined and obstructions dislodged. This is of more importance in connection with the waste pipe from a kitchen-sink trap than with the waste pipes from other fixture traps, because sink waste pipes are especially liable to become choked, chiefly by grease.

In Fig. 17 a clean-out screw *a* is shown wiped to a lead back-vent pipe. Should the waste pipe *b* or the vent pipe *c* become choked, a wire or a bamboo rod can be introduced through the clean-out opening to remove the obstruction.

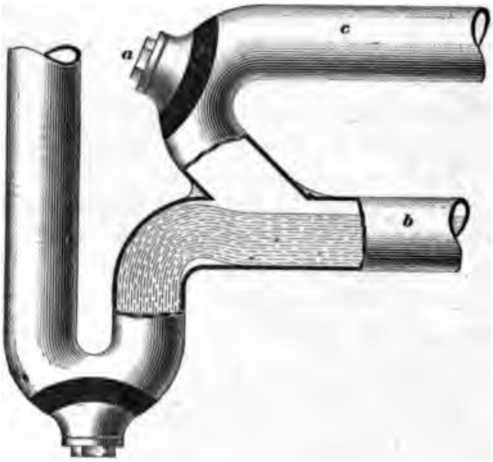


Fig. 17

The clean-out screw also provides an opening through which the junction of the vent pipe with the waste pipe can be examined to see whether the opening has become clogged with grease.

Clean-out screws with ground joints, that is, those that are made tight by an intimate metal-to-metal contact, should be used in preference to those that depend on a gasket for a tight joint, since the gasket will rot in time.

GREASE TRAPS

24. Purpose.—Grease proves very troublesome in a house-drainage system on account of its tendency to choke the pipes. While accompanied by hot water the grease is liquid and readily runs out of the sink, but as soon as it encounters the cold surface of the waste or drain pipe, it solidifies and adheres to the pipe, reducing its area and eventually choking it. Hence, it is advisable to provide means that prevent the grease entering the waste pipes. In practice the devices adopted are known as *grease interceptors*, and also as *grease traps*.

Grease traps are divided into two general classes; namely, those in which the grease is reduced in temperature until it reaches the point of solidification, by the transmission of heat from the trap to the atmosphere surrounding it; and those in which heat is transmitted from the grease and water in the trap to a colder body of water in contact with it, such, for instance, as a water-jacket around the space containing the grease and hot water. The first class may be called *air-cooled grease traps*, and the second class, *water-cooled grease traps*.

25. Air-Cooled Grease Traps.—A form of grease trap belonging to the first class mentioned in Art. 24 is shown in Fig. 18, where *a* is a fresh-air inlet, *b* is the pipe leading to the drain, and *c* is the waste pipe from the sink. The cover *d* should be large enough to readily permit the inside of the trap to be cleaned, and should be secured in position. The grease having a density less than that of water, accumulates in a layer at *e*, and if allowed to become cold, solidifies into a cake that can easily be removed.

FIG. 18

This form of grease trap is mostly used for intercepting grease from kitchen sinks in large country buildings. As the trap must be large in order to prevent the grease from entering the outlet *b*, it is usually placed underground as near the sink as possible.

26. Fig. 19 illustrates a slightly different form of an **air-cooled grease trap**, and shows its application to a kitchen sink. Water and grease, along with all other matter discharged from the sink, enter the trap *a* through the inlet pipe *b*. Solid matter, whose specific gravity is greater than that of water, will settle in the bottom of the trap, while the solids having a lower specific gravity, grease for instance, will float at *e*, and the water will pass through and out of the trap, as shown by the arrows. To prevent a direct and rapidly flowing current between the inlet *b* and outlet *c*, a solid or perforated partition may be placed between them, as shown at *i*. A 1-inch or $1\frac{1}{4}$-inch relief pipe *s* is sometimes run from the crown of the trap or pot to some safe point, so that the top of the trap may be subject to atmospheric pressure at all times; this will prevent gases from accumulating in the top of the trap to such an extent as to displace the liquid under them. Accumulations of grease and other matter can be removed through the large brass screw-cap *p*, and any chokage of the outlet pipes can be removed through a 2-inch trap screw *n*.

FIG. 19

27. It will be seen that the solidification of the grease in an air-cooled trap depends on the rapidity of the transmission of heat from the trap body to the atmosphere surrounding it. This transmission will be very slow, because the air absorbs the heat very slowly, and, of course, it will take the trap a long time to cool down. The slow transmission of heat from the water in the trap to the air is due to two causes, which are peculiar to air. The first cause is that the layer of air in actual contact with the outer surface of the trap does not move away quickly enough to allow the cold air to be brought rapidly in contact with the trap; and, as air is a very bad conductor of heat, this layer, or film, of warm air that moves slowly over the hot surface of the trap does not permit the heat to be conducted through its body to the cold air around it. The second cause is that the specific heat of air is very low, being .23751 that of water; consequently, a very large volume of air must travel over the surface of the trap and absorb the heat. Under ordinary circumstances, the trap shown in Figs. 18 and 19 will not accumulate a great quantity of grease by solidification while the grease is passing through the body of the trap; it will, however, allow the grease, which is lighter than the water, to rise to the top and remain there in a liquid state until the trap has time to cool off. To allow the grease to rise to the top, the trap body must be large, so that the velocity of flow of the liquid matter through it will be low. If the flow is too rapid, the grease will simply pass out with the water.

If a large volume of hot water flows through the trap at one discharge, molten grease is liable to be carried into the drainage system. Grease traps similar to those shown in Figs. 18 and 19 are not desirable, because the water in them soon becomes saturated with gases emitted from the decomposing solids, and hence the cleaning of such traps is exceedingly disagreeable work.

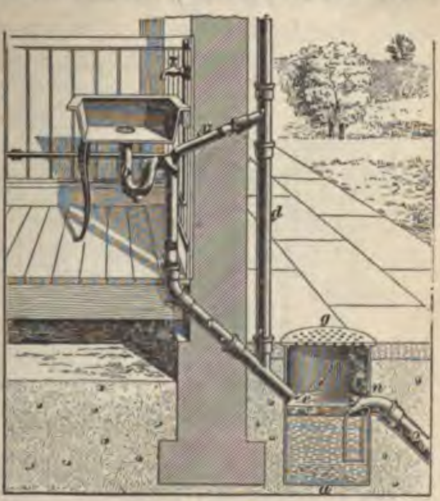


Fig. 20

28. When a grease trap is located outside of a building, it may be placed underground and joined to the sink as shown in Fig. 20, particular care being taken to guard against frost.

In this illustration, the sink is disconnected from the grease trap *a* by an ordinary round pipe **S** trap *b*, and the sink waste pipe *c* delivers above the grease *e* in the trap. To carry off any odor arising from the decomposition of matter in the trap, a pipe *d* is run up to and above the roof, the sink trap being back-vented into it, as at *v*. This prevents the seal of the trap *b* from being lost by siphonage. Fresh air enters the grease trap through perforations in the cover *g*, mixes with the gases, and carries them up the vent pipe *d*, as shown by the arrows. A trap screw *n* is placed in the outlet pipe *o*, which connects to the main house drain, or sewer.

This trap, it will be observed, depends chiefly on the power of the earth around it to conduct heat, and on the temperature of the air flowing over the grease. The trap and its pipe connections are easy of access, as the cover *g* is removable.

29. Water-Cooled Grease Traps.—Fig. 21 illustrates the construction of one form of a **water-cooled grease trap**, known also as a *chilling trap*. In this figure, *B* is the waste pipe from the sink, *D* is the pipe leading to the drain, *F* is the vent pipe, and *K* is a local vent, or air-relief, pipe.

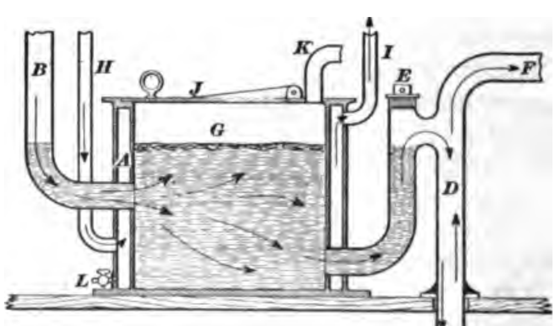


FIG. 21

The contents of the trap are chilled by means of cold water circulating through the jacket *A*. Commonly, the cold-water supply to the kitchen boiler is used for this purpose, the water entering the trap through *H* and passing to the boiler through *I*. The grease chills into a cake at *G* and is removed by opening the cover *J*. A trap screw *E* gives access to the trap outlet; a petcock *L* is used for draining the water-jacket.

The separation of the grease will be more perfect in this trap than in the one shown in Fig. 18, because the layer of grease is not disturbed by the water entering or leaving the trap. In Fig. 18, the entering water passes through the layer of grease and is liable to carry some of it along into the waste pipe.

30. A somewhat different form of trap, known as the **Tucker trap,** is shown in Fig. 22. The trap *a* is encircled by a cold-water jacket connected up to a kitchen sink and the water-supply system. Its construction is similar to that shown in Fig. 19, *b* being the inlet pipe and *c* the outlet. The internal surface of the trap can be cleaned and the grease removed by unscrewing the brass cap *p*; a similar screw-cap gives access to the outlet pipe *c*.

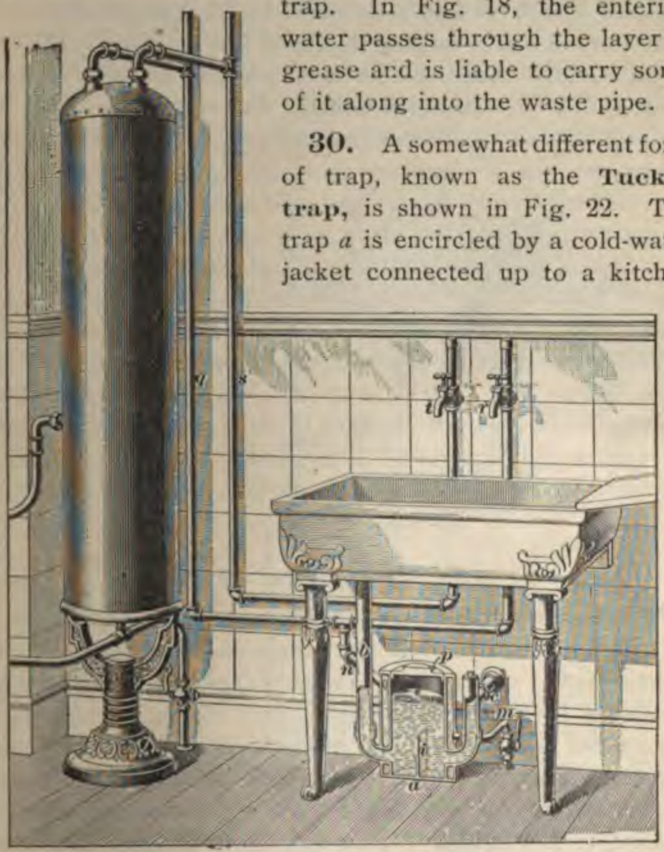


FIG. 22

The cold-water supply pipe *m*, which furnishes water from the street mains, or other source of supply, connects to the bottom of the water-jacket and leaves it at the top, as shown at *n*, before it supplies the boiler by the pipe *q*, so that if hot water is drawn from any faucets in the building, a corresponding quantity of cold water will pass through the water-jacket and act as a cooling medium for the trap. If water for drinking purposes should be drawn from the sink faucet *r*, probably it would be better to take its supply direct from the pipe *m*, instead of from *n*, as shown. It will be observed that as the trap is connected up in the figure, all water drawn from the hot-water faucet *t* and cold-water faucet *r*, or which passes through the hot-water pipe *s* and cold-water pipe *q*, must first pass around the grease and water in *a*, and thereby rapidly cool off the contents, allowing the grease in *a* to solidify quickly, and accumulate on the surface, as at *e*.

Water-cooled traps may be made considerably smaller than air-cooled traps, because the water in the jacket absorbs heat from the water in the trap much more rapidly, and, of course, the grease chills quicker. This greatly reduces the liability of grease passing into the drain pipes.

LOSS OF SEAL IN TRAPS

31. Formation of Vacuum and Plenum.—A *vacuum*, in the strict sense of the term, is a space void of matter and, consequently, void of pressure. Custom, however, has broadened the application of the term, so that it is generally understood to mean the condition existing in a space having a lower pressure than that of the surrounding atmosphere. More correctly, this condition should be called a *partial vacuum*, to distinguish it from a perfect vacuum. The latter cannot exist in nature, because it is impossible to remove all matter from a given space; the nearest approach to a perfect vacuum is found, in practice, above the mercury in a high-grade barometer.

The term *plenum* refers to the condition existing in a space having a pressure greater than that of the atmosphere; in other words, it denotes the fact that a pressure above that of the atmosphere exists in a given space.

32. It is customary to assume that there is no pressure on the walls of the drain pipes; while this assumption is usually correct, there are conditions, however, under which a partial vacuum or a plenum may exist in a drainage system, or both a vacuum and a plenum may exist at the same time in different parts of a given system. When all the fluid matter within the system is at rest, and the system is open to the atmosphere at one or more points, the pressure within the system is precisely equal to that of the atmosphere around it; but when fluids are in motion, the pressure in the several parts of the system will vary, being greater than that of the atmosphere in some parts and less in others. This will be particularly noticeable if the pipes are small, and a large volume of water flows through them.

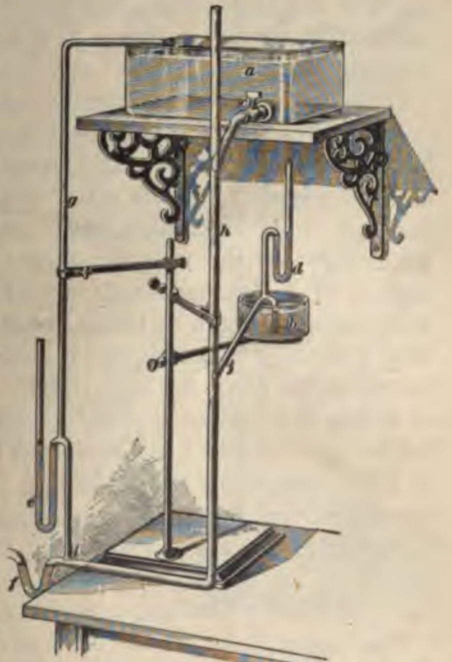


FIG. 23

To illustrate how a vacuum and a plenum can be formed in a drainage system, and how both can exist therein at the same time, consider a single apparatus like that shown in Fig. 23. The vessels *a*, *b* are filled with water, the cock *c* being closed. The traps *d*, *e*, *f* are also filled with water, and the mouth of the pipe *g* is closed air-tight with a rubber stopper. The ends of the other tubes are all open. The cock *c* is now opened to allow water to flow from *a* into *h* with a volume sufficient to fill the pipe. The immediate effect will be a compression of the air in *i* due to the weight of the column of water falling in *h*. The compression in *i* will increase until it is great enough to force the seal of the trap *f*, when the air entrapped in *i* will flow through *f* to the outer atmosphere, and *i* will become filled with water, just the same as *h*. While the air was compressed in *i*, the water in the tube *e* was forced up the outlet leg of the tube to a height corresponding with the depth of the seal *f*, and the water in *d* also rose in the outlet leg a little, but not so much as in *e*, or, perhaps, it remained practically at rest.

If the experiment is actually performed with the apparatus here described, it will be found that when the air was forced out of *i*, however, and water took its place, the water in *e* fell slightly, and the water probably fell a considerable distance in *d*; water also began to flow from *b* into *j*, thus indicating that the pressure in *j* was less than that on the surface of *b*, because fluids also flow from places of high pressure into places of lower pressure. As the water flows from *b* through *j*, the air in *j* is forced into the pipe *h*, and *j*, acting as the long leg of a siphon, soon drains the vessel *b* or draws the seal of *d*. This shows that a partial vacuum has been formed in *j*, and a plenum in *i*. The partial vacuum in *j* was caused by water flowing down *h*, carrying with it some air from *j*.

Suppose that *c* be closed, the stopper taken out of the mouth of the tube *g*, the water blown out of *d*, and *a*, *b*, *e*, and *f* be filled as before, and that *c* be then opened again.

The water from *a* will flow down *h* as before, and will draw air from *j*, but *j* cannot become a vacuum, because its top is now open to the atmosphere by means of the unsealed tube *d*. Consequently, atmospheric air will flow through *d* into *j* to take the place of that being drawn from it by the water falling in *h*. As the water falls from *h* into *i*, it simply forces the air in *i* to the outer atmosphere through the open tube *g*, and so the seal of the trap *e* is unaffected.

This, then, is a safe and positive method of preventing a plenum or vacuum within a drainage system.

33. Plenum and vacuum actually occur in some drainage systems, just as they occurred in the experiment illustrated by Fig. 23. A partial vacuum may be so high as to cause atmospheric pressure to force the seals of the traps, and so allow a quantity of the air within the building to flow into that part under a vacuum. A plenum may be high enough to cause the compressed air in the drain, or dead end, to force the seal of the trap outwards, and so allow drain air in the plenum to escape into the building. Both a vacuum and a plenum are very undesirable features in a drainage system, the latter being considerably more so than the former, because in the case of a trap forced by a plenum, foul air in the drains is positively forced into the building, while in the case of the vacuum, fresh air simply flows from the building into the drainage system. Whether traps, whose seals are forced by plenum or vacuum, will be entirely unsealed, and drain air permitted free access to the building when atmospheric pressure again prevails throughout the system, will depend entirely on the construction of the traps and the rapidity with which their seals are forced.

Fig. 24

34. Loss of Seal by Siphonage.—Probably the most common cause of traps becoming unsealed, that is, enough water being lost from the trap to permit gas from the drains to enter the building, is siphonage.

The manner in which siphonage will empty a trap sufficiently to unseal it can be shown by the aid of the experimental apparatus illustrated in Fig. 24. This apparatus consists of two vessels *a*, *b* joined by a glass tube having a petcock *c* and legs *d*, *e*, unequal in length, as shown. Close the petcock *c*, and pour water very slowly into *a*. The water-line will rise until it reaches that part of the pipe that passes through the side of *a*, when it will rise no higher, the water simply flowing through the pipe into *b*. If the pouring of water into *a* is stopped, water will soon cease to flow into *b*, and the water-line in *a* will remain level with the tube (a little higher than shown in the figure) that passes through the bung. This effect is called an overflow, the tube *d* being the overflow pipe.

If, however, a large quantity of water is suddenly poured into *a* and the water-line observed, it will be found that it will descend until it reaches the orifice of the pipe *e* that dips in *a*, a stream of water at the same time flowing into *b*. This effect is called *siphonage*, the tube *e* being the short leg and the tube *d* the long leg of the siphon, and in this instance water will be siphoned from *a* into *b*. The cause of siphonage is simply unequal pressures. The reason that siphonic action did not take place when the water was poured slowly into *a* is that the volume flowing through the tube *d* was not sufficient to fill the bore; consequently, the pressure in the top of the tube was practically equal to that on the surface of the water in *a*. When water was suddenly poured into *a*, the head thus formed forced enough water into *d* to entirely close its bore and force the air out at its lower end. With the tube thus discharging at its full capacity, the water in that part of the tube *d* below the level of the water in *a*, or the head of the siphon, caused a pressure lower than that of the atmosphere in the top of the siphon. The pressure of the atmosphere on the water in *a* simply forced the liquid up *e* and into the tube to replace that flowing from it into *b*. To prove that the action of the siphon is due to differences in pressures and that a pressure below atmosphere exists in the top of the siphon, let the petcock *c* be opened; air will instantly rush into the tube, thereby changing the pressure within the tube to that of the atmosphere. Since the pressures inside and outside the tube are now the same, the water in the short leg *e* of the siphon will be level with that in the vessel, and the water in the long leg will flow into *b*, and be replaced by the air. By introducing a sufficient volume of air into the top of any siphon, the siphonic action can be destroyed. Before siphonage can take place the outlet end of the siphon must be lower than the level of the water to be siphoned.

35. Fig. 25 illustrates one of the many cases in plumbing practice where siphonage takes place. It shows a trap *A*, of the round pipe pattern, attached to the outlet of a kitchen sink *B*, and installed in a manner common in some localities, although prohibited in all cities and towns protected by plumbing ordinances.

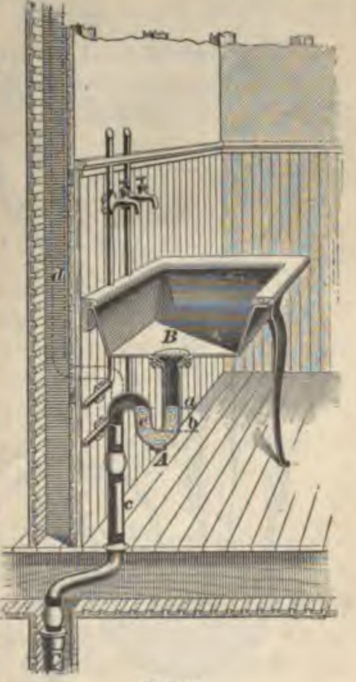


FIG. 25

The trap is shown properly sealed; the depth of the seal, which is the distance between *a* and *b*, is 2 or $2\frac{1}{2}$ inches. This forms an effective barrier to the gases in *c* and prevents their entry into the building through the sink strainer.

If a pail of water is poured into the sink, the water will flow through the trap and the waste pipe *c*, entirely filling their bore; consequently, a siphon is formed, of which *c* is the long leg, the short leg being formed by the part *e* of the trap. The instant the water leaves the sink and passes the trap, air will flow through the trap into *c*, with a loud sucking or gurgling noise, to displace the water in *c*, which flows to the outlet. Atmospheric pressure forces the water from the lower curve of *A* into *c*, just as it forced water from the vessel *a* into the tube *d* of Fig. 24, and the water in the trap will be quickly siphoned out. To prevent the siphonage of the trap shown in Fig. 25, a pipe *d*, indicated by dotted lines, should be run from the crown of the trap to the atmosphere, above the roof for instance, to prevent unequal pressures and replace with air the water flowing through *e*. The best plan is to continue the cast-iron pipe *C* up to and through the roof, joining the waste branch *c* and the air pipe, or *back-vent pipe*, as it is called, to the vertical pipe with suitable fittings and at suitable heights. This will not only prevent siphonage of the trap, but also thoroughly ventilate the piping.

36. Loss of Seal by Evaporation.—Any trap will lose its seal by evaporation of the contained water if the fixture over it is not used for a sufficient length of time. The seal of an ordinary round pipe trap will usually be broken by evaporation in about 2 weeks, although it may take more or less time to do this, depending on the state of the weather and the rapidity with which air travels over the water in the trap.

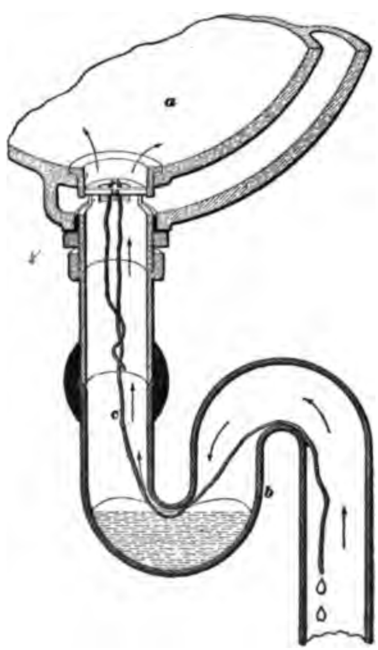


FIG. 26

When a house has to be left unoccupied for a long time, especially in summer time, it is good practice to fill all traps with crude glycerine, whose evaporation, compared with water, is very slow.

37. Loss of Seal by Capillary Attraction. Traps will often lose their seal by capillary attraction, that is, by the attraction of the molecules of a liquid for each other and a solid they are in contact with. There are many different ways in which capillary attraction can affect traps; one of these ways is illustrated in Fig. 26. A basin *a* is connected to the drainage system by an **S** trap *b*. A piece of worsted or cotton twine *c* has become caught over the strainer bars and the loose ends at first hung down in the waste pipe. Water flowing from the basin has worked the string through the trap but it cannot wash it down into the drainage system. This string by capillary attraction draws the water out of the trap until the seal is broken. The illustration shows how the water runs off the end of the string drop by drop, and it also shows how sewer gas can enter the building through the trap thus unsealed. The direction of the sewer gas is shown by the arrows. The force that lifts the water in the trap and discharges it over the outlet ridge, thus depositing it in the waste pipe, is simply that due to the attraction between the liquid and the surfaces of the many fibers in the string, and the water is siphoned out of the trap because the tail-end of the string is lower than the water in the trap.

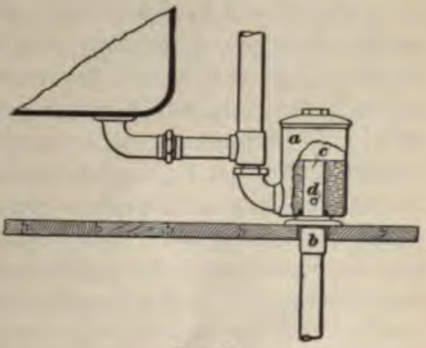


FIG. 27

38. Loss of Seal by Leakage.—Traps sometimes lose their seals by leakage. This cannot happen with all styles of traps, but only with traps that depend on an inner partition or tube for a seal. Fig. 27 shows such a trap located above a bathroom floor and connected to a bath. The seal of the trap *a* is formed by the waste pipe *b*, which continues up inside of the body of the trap, as shown. Should a hole corrode through the tubing *c*, as at *d*, the water forming the seal of the trap would leak into the waste pipe and a dangerous passage would be opened between the house drainage system and the bathroom. Danger of leakage at this point can be greatly reduced, however, by using heavy drawn copper or brass tubing for the inner tube *c*.

39. Loss of Seal by Inertia.—If a ball is dropped into a smooth round pipe trap occupying its usual position, the ball will in many cases roll through the trap, its inertia carrying it up the trap outlet leg against the action of gravity. If water is allowed to flow through a trap in a full stream and the water supply is suddenly stopped while air is allowed to freely follow the water, the inertia of the water flowing through the trap, which water may be likened to the ball previously mentioned, will carry a large part of it out through the outlet leg, and the remainder may be insufficient to seal the trap. This phenomenon is correctly known as *loss of seal by inertia*, but is often erroneously called *loss of seal by momentum*. It is particularly liable to happen in wash-basin traps of the round pipe form, and irrespective of whether they are back-vented or not. To prevent this trouble the traps should have a diameter greater than the inlets to them. For instance, a trap that has an inside diameter of 1½ inches should have a connection to the basin not greater than 1¼ inches. The higher the velocity of the water flowing through a trap and the more sudden the supply of water is shut off, the greater will be the loss of seal by inertia. To reduce the velocity of the water flowing into the trap as much as possible, the trap should be connected close up to the fixture.

40. Loss of Seal by Oscillation.—Occasionally the water in water-closet traps is seen to oscillate, that is, rise and fall in the trap inlet. This is due to variations in pressure between the air in the rooms and that in the plumbing system due principally to high winds. It is very rare that the seals are lost to a dangerous extent by oscillation.

BACK-VENTS

LOCATION OF BACK-VENT PIPE

41. The **back-vent pipe,** that is to say, the pipe that joins the trap to the outer atmosphere, either directly or by being connected to a special vent stack, does a double duty. It not only prevents the seal of the fixture trap from becoming siphoned to a dangerous extent, but also acts as a ventilating pipe that removes gases of putrefaction, or foul air, from the waste-pipe branch to the plumbing fixtures.

The back-vent pipe should always be connected to that part of the vent stack where it will give the highest efficiency; this part may or may not be the most accessible one. The methods of joining, and the points from which the back-vents should be taken, vary with existing conditions.

42. To effectively carry off the gases, the back-vent should be taken from or near the highest point of the waste-pipe branch, or in other words, from or near the crown of the trap. If it is taken from the waste pipe at a point some distance from the trap, that part between the back-vent connection and the trap will remain unventilated, and will form a *dead end;* in other words, a current of air will not flow through it, and consequently the gases accumulating in the dead end can only be removed by diffusion with the air-current as it passes from the waste pipe into the back-vent. But, ventilation by diffusion is exceedingly slow and unsatisfactory; the gases should be carried off by actual air-currents.

To effectively prevent the siphonage of a trap, the back-vent pipe should not only be connected to the trap, but should have a sectional area sufficiently large to furnish the volume of air at atmospheric pressure required to replace the water flowing through the waste pipe.

CHOKED VENTS

43. It is evident that if the back-vent pipe should become choked in any way, foul air cannot flow from the waste pipe; neither can air enter it at the proper point to prevent siphonage.

There are several ways by which back-vents may be choked, depending on the circumstances.

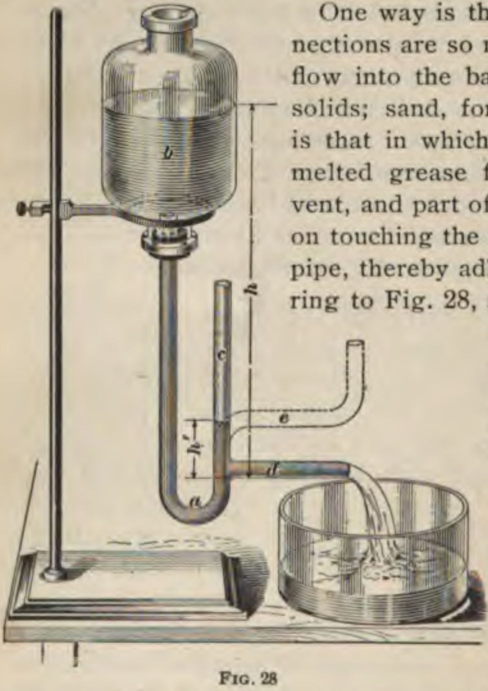


Fig. 28

One way is that in which the connections are so made that water may flow into the back-vent and deposit solids; sand, for instance. Another is that in which hot water carrying melted grease flows into the back-vent, and part of the grease solidifies on touching the colder surface of the pipe, thereby adhering to it. Referring to Fig. 28, suppose that a glass trap of the form shown at *a* is attached to a vessel *b*, the end of the trap that passes into the vessel being provided with a plug. Fill the vessel with water and pull out the plug so that the water may flow freely into and through the trap. Water, like all other matter, when in motion, tends to move in a straight line. When the water from the vessel *b* flows down the tube and reaches the bend in the trap *a*, it is forcibly deflected and made to flow around the curve; when it gets around the curve, however, it still tends to move in a straight line, but now vertically upwards. Since the tube *c* is open at the top, the water will naturally rise until it reaches a certain height in *c*, and the velocity of discharge through *d* will depend on the height, or head *h*, which again depends on the resistance to the flow through *d*. Thus it will be seen that the greater the resistance to flow through *d*, the higher will the water rise in *c*.

It will be observed that if the water that rises in *c* carries grease in a melted state, part of the grease will solidify and adhere to the internal surface of *c*, forming a film of grease. The film will soon be changed into a scale, and the scale into a solid plug by the accumulation of a little grease every time such water rises in *c*.

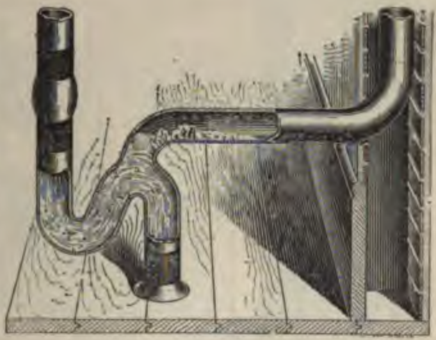


FIG. 29

If the pipe *c* should be bent over, as shown by dotted lines, so that the water will rise into the part *e*, this nearly horizontal part will soon become choked, and probably quicker than the vertical pipe *c*.

44. Back-vent pipes are very often connected to round pipe traps in the manner shown in Fig. 29, which manner it will be noticed is equivalent to that in which *e*, Fig. 28, is connected. Solids that may have accumulated in the trap while small quantities of water pass through it, may be forced up the back-vent when unusually large quantities of water pass to the drains. Such solids will accumulate, as shown at *d*, and the vent will become choked whether grease enters it or not.

CORRECT BACK-VENT PIPE CONNECTIONS

45. Probably the best method of connecting the back-vent pipe to the trap is that shown in Fig. 30, where a swan-neck or return bend *a* connects the vent pipe *d* with the outlet end of the trap. In this case the water will simply flow past the opening of the back-vent pipe without rising in that pipe, unless the base of the waste pipe *e* is restricted at some point between the back-vent connection and the cast-iron pipe

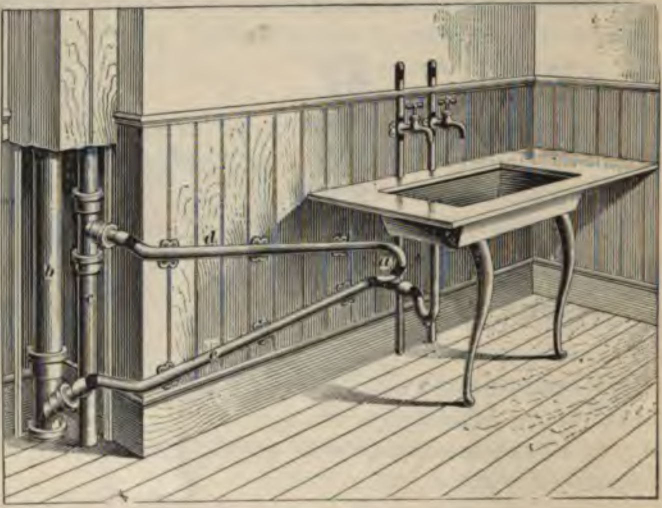


FIG. 30

stack *b*. The swanneck curve also offers little resistance to the flow of air in the piping, and consequently the ventilation of the waste pipe is satisfactory.

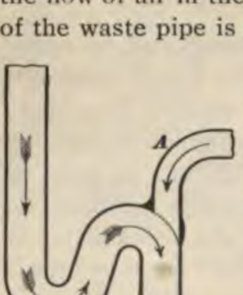


FIG. 31

If drain air is allowed to accumulate in a long branch, or dead end, the metal composing such a pipe will soon corrode and leaks will thus be formed. Lead, especially, is very susceptible to drain or sewer gases, and unventilated lead waste pipes not only soon become honeycombed with numerous small holes, but also become quite rotten and brittle. When back-vent pipes are properly applied, they not only protect the trap seals, but also prolong the life of the waste pipes.

46. The proper method of connecting the back-vent pipe to an **S** trap is shown at *A*, Fig. 31. The current of water flowing through the trap will induce a downward current of air in the vent pipe; furthermore, owing to the direction of the current, water will not enter the vent pipe, and hence no grease or other refuse will accumulate in that pipe.

47. One way to connect a vent pipe to a one-half **S** trap is shown in Fig. 32 (*a*). The waste pipe *a* connects to the

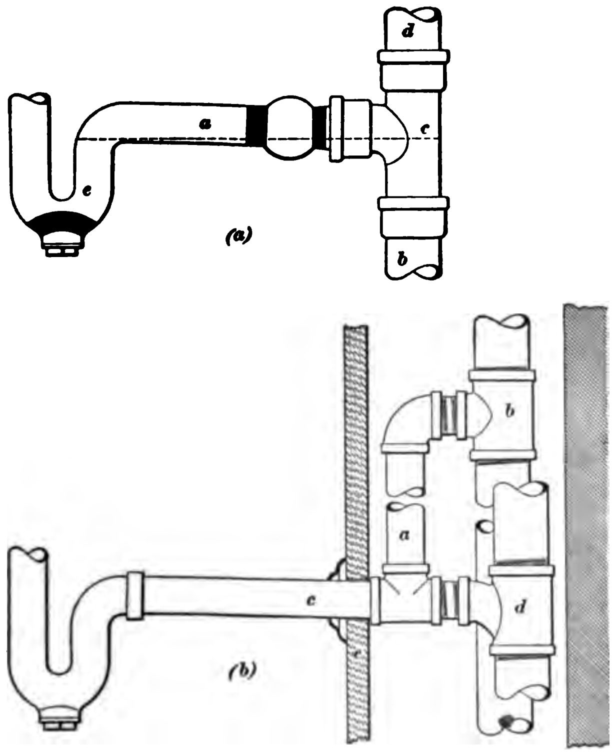


FIG. 32

waste stack *b* by means of the **T Y** fitting *c*. The continuation *d* of the vertical waste pipe forms the vent pipe for the trap *e*. This form of connection can only be used, however, when no fixture discharges into the waste pipe *b* above the branch *c*. When there are fixtures above this branch, the trap should be ventilated, as shown in Fig. 32 (*b*), in which a back-vent *a* is connected from the vent stack *b* to the waste pipe *c*, close to the vertical waste stack *d*, and back of the partition wall *e*. By this method of connection the back-vent pipe is hidden.

48. The greatest allowable distance of the vent connection from the trap depends chiefly on the pitch of the waste pipe that connects the trap with the drain stack. When the waste pipe *a* is run as shown in Fig. 33, the vent pipe *b* should connect above the water level of the trap; that is, the

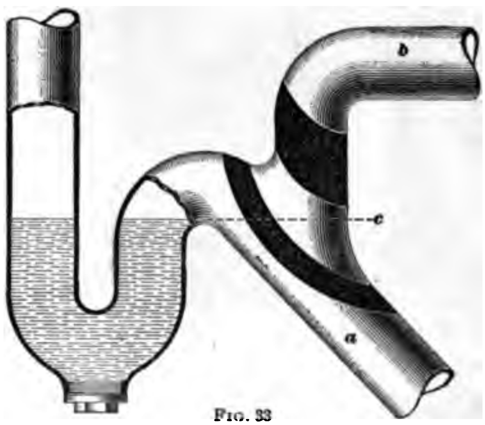


FIG. 33

center line of the back-vent pipe should not intersect the surface of the waste pipe below the horizontal plane of the water level, represented by the line *c*. Should the intersection be located below the line *c*, there is a liability of the trap being siphoned. It is evident that the nearer horizontal the waste pipe from the trap to the drainage system is laid, the farther from the trap can the vent pipe intersect it.

49. Vents to drum traps should connect to the waste pipe, as shown in Fig. 4, and not to the crown of the trap, as shown in Fig. 5, to prevent currents of air coming in contact with the water in the trap, which currents will tend to evaporate the water forming the seal.

50. It sometimes occurs that a certain fixture, such as a wash basin or a set of laundry tubs, is located in such a position that it cannot be properly back-vented without great expense. In such a case an antisiphon trap, that is, a trap embodying the principle shown in Fig. 4, may be employed, although it is better practice to properly back-vent regardless of expense.

51. When a fixture is located in the center of a room, the extending of a back-vent pipe to the ceiling is inadvisable, because it will be unsightly and in the way. The trap for a fixture so located may be back-vented in the manner shown in Fig. 34. The vent *a* from the trap *b* should be carried up

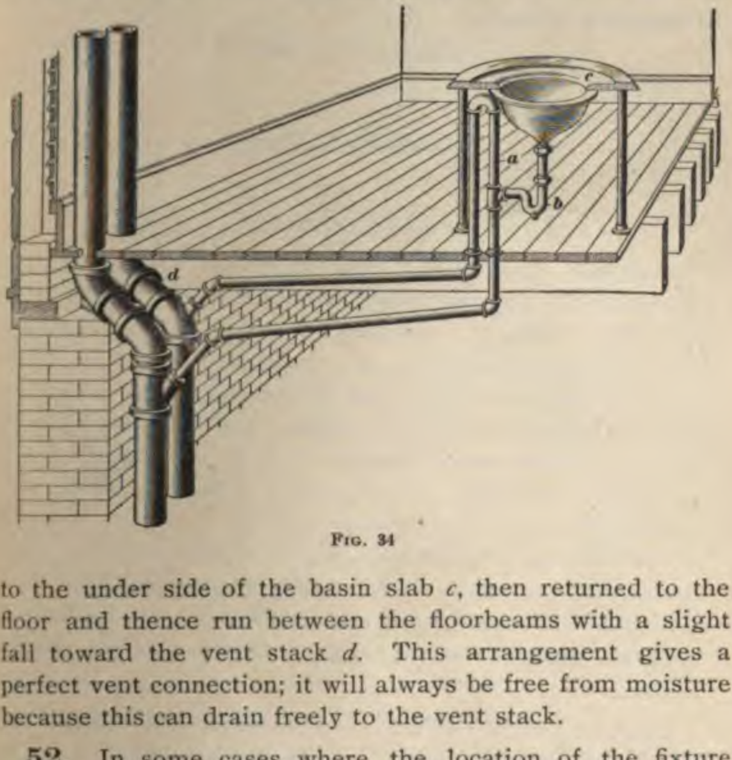


FIG. 34

to the under side of the basin slab *c*, then returned to the floor and thence run between the floorbeams with a slight fall toward the vent stack *d*. This arrangement gives a perfect vent connection; it will always be free from moisture because this can drain freely to the vent stack.

52. In some cases where the location of the fixture renders the installation of a back-vent pipe difficult and expensive, a device called an **antisiphon back-vent,** which is a light check-valve sealed by mercury, is applied to the crown of the trap. The check-valve is arranged to open when the pressure in the crown of the trap becomes less than that of the atmosphere, admitting air in that case and thus stopping siphonage. The valve will close and be sealed by the mercury when sufficient air has entered the trap. An antisiphon back-vent may not only be rendered useless, but also become dangerous, in many ways. For example, the valve may stick, or the mercury be lost or stolen; the gas in the drains will then flow through the valve into the building. Hence, most sanitary engineers are opposed to the use of antisiphon back-vents, preferring to install proper vent pipes irrespective of cost.

DRAINAGE AND SEWERAGE

DRAINAGE

STORM DRAINAGE

INTRODUCTION

1. Drainage and Sewerage.—In sanitary engineering, the subjects of drainage and sewerage are so intimately associated as to be almost inseparable. In general, however, it may be stated that, while the subject of sewerage refers principally to the removal of excremental or human refuse and other waste matter common to human habitations, the subject of drainage properly relates to the removal of storm water from the surface and subsoil. All water given by rain storms may, without impropriety, be called **storm water.** This name, however, is commonly applied to the water from rain storms that does not soak immediately into the ground nor evaporate, but that flows away over the surface, through natural channels or through artificial conduits.

2. Municipal Drainage.—In rural districts, the drainage may be for the purpose of reclaiming and improving low-lying lands, in order that they may be utilized for agricultural purposes. The drainage systems constructed within the limits of municipalities are not commonly for this purpose, however, but for the purpose of removing the storm water from the surface, where it would cause more or less injury to habitations and inconvenience to the inhabitants, and from the subsoil, where it would become a menace to health.

3. In municipalities, the storm water is generally removed by means of drains or sewers constructed for the purpose. The storm water is sometimes conveyed wholly by the street gutters and in open conduits without entering the sewers, but such practice is not common; in most cases, it is led into the sewers by the most direct routes. The latter method of removing the storm water, being the more common and popular and by far the better, will be the method considered here. In some cases, the storm-water drainage is conveyed in a system of conduits separate from that in which the sewage is conveyed; that is, the drainage system and the sewerage system are entirely separate. In other cases, the drainage and sewage are removed by the same system of conduits; that is, the drainage system and sewerage system are combined in one system. The latter system is the more common.

4. A system of drainage should be adequate for the prompt removal of the rainfall from the surface during violent storms, including also such animal and vegetable refuse as will necessarily be removed with the storm water. If this is accomplished, and the drains are located at sufficient depth, efficient drainage will be provided for the subsoil.

5. In designing a system of sewers for the purpose of drainage, the principal conditions that must be considered will usually be as follows:

1. The area, physical outlines, and general topographical features of the district to be drained must be considered with reference to the natural flow of water on its surface, in order that the sewers may be located as nearly as possible in the natural drainage channels.

2. The rainfall on the district must be considered with reference to the maximum intensity of precipitation during a period of time sufficient to completely charge the sewer.

3. The general character, condition, and slope of the surface must be considered with reference to the proportion of the rainfall that will probably reach the sewer during the time of its maximum flow.

4. The geological character of the district must be considered with reference not only to the depth to which it may be desirable to provide efficient subsoil drainage, but also with reference to the difficulties to be encountered in the practical construction of the sewer.

5. The location of the outlet of the sewer must be considered with reference to the final disposition of the drainage.

These various conditions, however, are not wholly independent of one another, and the consideration of any one of them will usually involve some consideration of certain features of the others.

PHYSICAL OUTLINE OF DRAINAGE DISTRICT

6. Elevated Location.—The physical character of the district should be carefully studied. If the location of the district be near a summit or quite elevated, with the surface sloping in such a manner as to afford ample channels of natural drainage, the problem of artificial drainage will be very simple. In such case, the lines of drainage sewers are located along such routes as most nearly follow the natural drainage channels, leading to such natural outlet as may be available. It will often be found that the positions, directions, and grades of the streets will be influenced to some extent by the natural channels of the drainage.

7. District Without Natural Outlet.—If the drainage district be situated in a valley not having a good natural drainage outlet, the problem of drainage will be much more serious than in the case just mentioned, and the expense of the construction of the system greatly enhanced. If the drainage is to be discharged into a running stream passing through the town or estate, the drainage should be delivered to the stream at a point *below* the territory drained, whatever may be the direction of the natural drainage. This

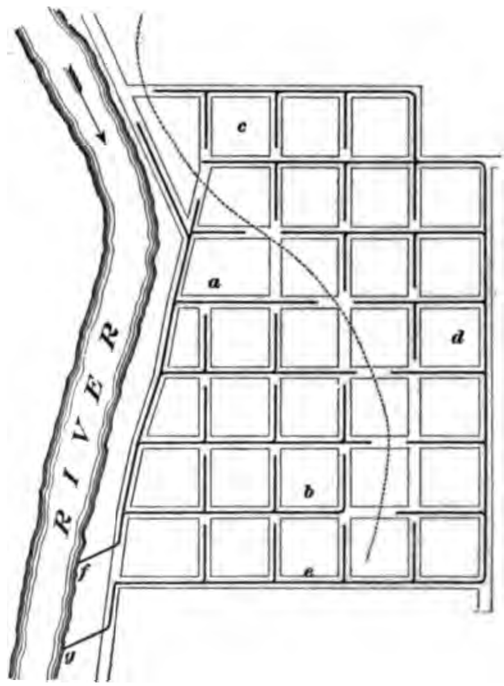


FIG. 1

may require inconvenient and circuitous courses for the sewers, as well as deep excavations. A case of this nature is represented in Fig. 1. As there shown, the town is situated on the bank of a stream. A crest of elevated ground, in the position indicated by the dotted line, separates the town into practically two drainage districts. The outlet for the district *a b* is at *f*, while the drainage from *c* passes around by the circuitous course *de* and is discharged at *g*. The drainage from *c* could not pass by a direct course to the outlet without an extremely deep excavation through the high ground.

8. Low-Lying District.—If a drainage district be very level and at a very slight elevation above tidewater or above the river into which the drainage is to be discharged, the discharge sewer must be carried to the lowest point within the district. This will then be the chief controlling condition, and it may even be necessary to resort to pumping in order to provide sufficient fall for the drainage to cause it to flow to the outlet. In such cases, the drainage is conveyed to tanks, located at the lowest points, and then pumped to a sufficient height to flow to the outlet.

Such conditions will often control the depth at which drains can be located. For the purpose of removing the storm water, it is not generally necessary to locate the drains at any great depth below the surface, but for the purpose of subsoil drainage, it is necessary to locate them as deep as it may be desired to drain the subsoil.

9. Subsoil Drainage.—The subject of subsoil drainage is very important. If the entire district to be drained is built up and paved, the amount of rainfall reaching the subsoil will be so small, comparatively, that it usually need not be taken into consideration. But, if a portion of the district consists of grassy lawns, wooded tracts, or unpaved streets, the amount of rainfall reaching the subsoil will be very considerable, and provision must be made for its removal. This will especially be the case when the subsoil is quite permeable and has below it an impervious stratum; the necessity for drainage will be further increased if the formation be such as to produce springs in the subsoil. The water having no opportunity to escape, the subsoil will be continually soaked with stagnant water, a condition having a very injurious effect on the health of the inhabitants. If the formation is such that the water will be continually in motion and flowing away, the injurious effect will not be nearly so marked, but stagnant water is an enemy of life and should be very thoroughly removed. Hence, it is seen to be very important that efficient subsoil drainage should be provided.

RATE OF RAINFALL

10. Measurement.—In determining the required capacity for a storm-water sewer, one of the most important conditions to be considered is the maximum rate of rainfall; that is, the maximum rate of precipitation for any given number of minutes. A knowledge of this condition will enable us to determine the amount of storm water reaching the sewer during a storm continuing for a period of time sufficient to completely charge the sewer. Rainfall is measured in inches. Thus, by 6 inches of rain is meant a sufficient quantity to cover the surface fallen on to a depth of 6 inches, provided it all remains on the surface where fallen. If a vessel were placed out in the storm, it would be filled to a depth of 6 inches.

11. Records of Rainfall.—For the purpose of proportioning drains and sewers, the records of rainfall are quite incomplete. Records of daily, monthly, and yearly rainfall are numerous; but however valuable such records are for some purposes, they have little value for the purposes of designing sewers. The records of storms, as generally reported, give the total precipitation for the entire storm and, possibly, the duration of the storm, but they do not usually give the maximum rate of the precipitation. The average rate of precipitation throughout the storm can be obtained by dividing the total precipitation by the duration of the storm. But this will seldom, if ever, be the maximum rate of precipitation; for, as is well known, the greatest intensity of the rainfall is attained only during certain short periods of the storm's duration. It is often the case that a rain storm will continue through several hours with a very uneven intensity, being sometimes a mere drizzle and again a veritable downpour. Evidently, the total precipitation of such a storm will bear no relation to its maximum rate. A storm that will precipitate 6 inches of rain in 12 hours may precipitate 3 inches in 2 hours or possibly 2 inches in 30 minutes. The average precipitation during the entire storm would then be at the rate of $\frac{6}{12} = \frac{1}{2}$ inch per hour, while the precipitation during the 30 minutes, $= \frac{1}{2}$ hour, of maximum rainfall would be at the rate of $\frac{2}{\frac{1}{2}} = 4$ inches per hour. For these reasons, records of the maximum rate should be taken.

12. Violent Storms.—In cases of violent and excessive downpours, a small portion of the storm water can be conveyed in the surface gutters, thus to some extent relieving the sewers, by temporarily affording additional provision for the storm water; hence, no serious damage will usually result if at rare intervals the rate of precipitation be such as to give a flow somewhat in excess of the actual capacities of the sewers. It is not customary, and is not generally considered necessary or even desirable, to design drainage systems with capacities sufficient for the prompt removal of the entire rainfall from excessive storms by means of the sewers alone. Storms giving an excessive precipitation occur only at long intervals and are of short duration. The excess of storm water, above that which can be conveyed by the sewers, can usually be taken by the surface gutters until the storm subsides, so that but little, if any, damage will result. Further, sewers with capacities sufficient to meet the conditions of excessive storms would not be advantageous as conduits for the ordinary flow.

13. Chief Condition to be Considered.—A locality subject to long-continued drizzling rains may have a large annual rainfall, while short heavy rains may occur in localities having a much smaller annual rainfall. It is generally this maximum rate, or rapid downpour, during a reasonably short period, that most severely taxes the capacity of a as 70 per cent. of the rainfall. But evaporation does not take place to any extent while rain is falling, and for practical purposes it may consistently be assumed not to occur during the maximum flow of storm water. Hence, this condition may be wholly neglected.

19. Percolation.—The proportion of the rainfall that soaks or percolates into the ground will vary according to the nature of the soil; it will be much greater in sandy or peaty soil than in ordinary soil, and will be very much smaller in clay. Under favorable conditions, the percolation in ordinary soil may be 30 per cent. of the rainfall; in chalk, it may be nearly 40 per cent., while in sand or gravel, it may be over 80 per cent. But during a short and rapid downpour of rain the percentage of percolation will be much smaller. Also, if the conditions are such as to afford a prompt and rapid flow of the water over the surface, the percentage of percolation will be small. A large portion of the water that soaks into the ground may reach the sewer or watercourse farther down; but this will occur after the lapse of considerable time, and not during the maximum flow of the storm water.

In the design of sewers, however, we do not deal with the conditions of evaporation and percolation except indirectly. They need be considered only so far as they affect the amount of storm water reaching the sewer, with which we have to deal directly.

20. Conditions Affecting the Flow of Storm Water. The proportion of the rainfall that reaches the sewer varies according to the area, slope and condition of the surface, and the nature of the subsoil. Wooded tracts, cultivated lands, or those covered by luxuriant vegetation retain a greater portion of the rainfall, and are longer in yielding up what they do not retain than smoothly cut lawns or areas devoid of vegetable growth. The latter will therefore give the greater flow. The amount of flow is also affected by the nature of the soil. Loose, porous soils, as sand or loam, readily drink in a large proportion of the rainfall, while hard-packed and impervious soils, as clay and cemented material, take in much less of the rainfall and give much greater surface flows. Steep slopes throw off a much greater proportion of the rainfall than flat areas, and carry it more quickly to the channels of flow. Hence, a hilly country will not only yield a greater proportion of the storm water than a level country, but will also deliver it to the sewers much more quickly. Frozen ground may give a surface flow practically equal to the rainfall; in connection with melting snow, it may considerably exceed the rainfall.

21. Flow of Storm Water From Built-Up Districts. The conditions just noticed refer principally to suburban districts. In closely built-up districts, with paved streets, the proportion of storm water carried to the sewers and the rapidity with which it will be conveyed to them are both greatly augmented. The greater portion (often the entire portion) of the surface on which the rain falls consists of paved streets and courts, walks, and the roofs of buildings, all of which offer nearly impermeable surfaces to the rainfall, which the systems of surface drains, troughs, and gutters quickly convey to the sewers. As a result, a large portion of the rainfall is promptly delivered to the sewers, which will be severely charged by short storms having a high rate of precipitation.

22. Ratio of Storm Water to Rainfall Found to be Constant.—Gaugings of sewers during the flow of storm water indicate that, after the ground has become saturated, the ratio of storm water to rainfall is practically constant for a given district, which is a quite important condition; that is, after saturation, the percentage of rainfall reaching the sewer is practically the same for all rates of precipitation. In the case of roofs and well-paved areas, the effect of saturation is slight. As previously noticed, the ratio of the storm water to the total rainfall depends largely on the character and condition of both the surface and subsoil.

Gaugings sufficient to definitely establish this ratio for different conditions of surface have never been made. Such reliable information as is available concerning the subject will be briefly noticed.

23. Professor Baumeister, a German authority, states that "for drainage purposes, the ratio of the storm sewage to the total precipitation can be assumed to be the same as that existing between the impervious and the total area." In this statement the word "impervious" has an absolute significance; that is, wholly or fully impervious. Area not fully impervious should be reduced to an amount of impervious area proportionate to its impermeability.

24. Mr. E. Kuichling, of Rochester, N. Y., a well-known hydraulic engineer and an eminent authority on storm-water sewerage, gives the percentages in the following table as representing the relations of the impervious surface to the total drainage area, assuming the relations to vary according to the density of the population. These values were obtained from an extended analysis of the conditions found in such cities as Buffalo, Rochester, and Syracuse. The percentages in the last column should be used as the ratios of storm water to total precipitation.

TABLE I

RELATION OF FULLY IMPERVIOUS SURFACE TO TOTAL AREA ACCORDING TO DENSITY OF POPULATION

Average Number of Persons Per Acre	Percentage of Fully Impervious Surface			
	Roofs	Improved Streets	Unimproved Streets, Yards, Etc.	Total
15	8.4	3.3	3.0	14.7
25	14.0	7.0	4.3	25.3
32	18.0	10.2	5.0	33.2
40	22.5	14.7	5.4	42.6
50	28.0	19.0	5.6	52.6

25. According to Knauff, the maximum quantity of storm water reaching the sewer, in percentages of the rainfall, is as follows:

On flat roofs...	40 to 50 per cent.
In courts and squares......	50 to 70 per cent.
On steep roofs.............	60 to 80 per cent.

These percentages are probably rather low for small areas.

26. In London, it has been found from gaugings of the sewers, that from 53 to 94 per cent. of the rainfall flows away as storm water.

SUBSOIL DRAINAGE OF BUILDINGS

NECESSITY OF DRY CELLARS

27. It frequently happens that water is discovered while excavating cellars and for the foundations of buildings. Since it is essential for cellars to be free from water and dampness, in order that the buildings may be habitable and wholesome, it becomes necessary to provide means for removing the water from underneath the foundations and the cellar floor. Probably the greatest objection to damp cellars is the fact that cellar air will pass up through the floors, walls, and partitions and thereby not only cause a damp atmosphere in the living and sleeping rooms of the building, but also actually vitiate the air, since the odors of damp cellar air are due to the decomposition of vegetable and organic matter from many sources. Rheumatism and malaria are often the evil effects of damp cellars; typhoid or typhus fever the probable effects of contaminated cellar air.

DISPOSAL OF SUBSOIL WATER

28. Introduction.—The disposal of subsoil cellar drainage water is often a matter of great difficulty, particularly when the drainage is intermittent. It frequently happens that the drains are dry during the summer and winter months, and that they only convey the water during the spring and fall. When such conditions exist, particular care must be taken to avoid the evaporation of water in traps, that may disconnect the subsoil drains from any sewer or house drain into which they may discharge.

29. Gravity Disposal.—Fig. 2 shows how subsoil water may be discharged by gravity into the house drainage system. In order to accomplish this, the sewer must be

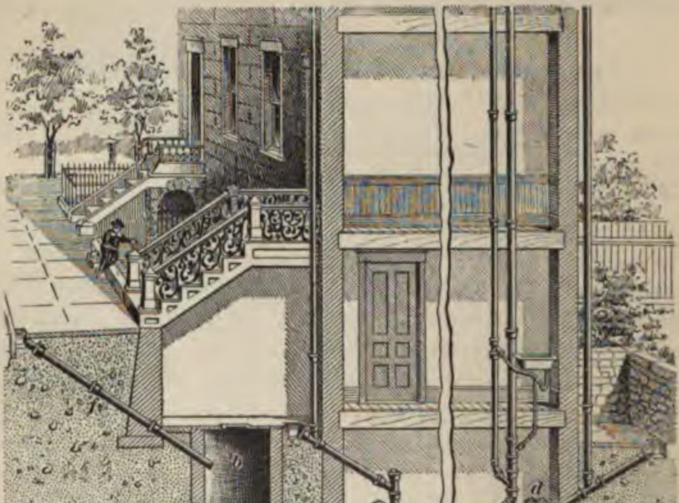


FIG. 2

lower than the subsoil drains. The main disconnecting trap *a* is set in a vault *b* furnished with a concrete floor. The main house drain *c* joins the trap on the house side of the seal. Roof water and back-area water enter the drainage system through the trap *d*, and the other trap in the basement takes front area and roof water. Water about the footings of the walls flows through a 3-inch or 4-inch perforated earthenware pipe *e*, and discharges on the concrete floor of the vault *b*, a very light flap valve being attached on its outlet end. The vault is fitted with a tight cover, and fresh air enters it through the fresh-air inlet pipe *f*, and flows into the drainage system through the trap inlet, being delivered to the atmosphere above the roof of the building by the vertical pipe stacks.

This arrangement has many good features. For instance, there is no danger of drain air entering the subsoil drainage system; neither can sewage matter that might accumulate in the vault, should the sewer connection *g* or the trap *a* become choked, enter this system, because the check-valve on the mouth of *e*, if properly fitted, will prevent it. Many plumbers simply place a trap between the subsoil drainage and the house drainage systems, trusting to a constant stream of subsoil water to maintain a seal in the trap; but this alone is not sufficient protection.

The subsoil drains are inaccessible, and should they at any time be charged with sewage, which will certainly be the case if the street sewer becomes flooded, sewage will back up the subsoil drains and contaminate the ground under the building. Particular care should be taken to guard against this danger, and a check-valve, a ball trap, or a backwater trap of some description should always be used. If a check-valve is used, a separate trap is very suitable as a positive safeguard against the entrance of drain air or sewer gas. On the best work, a water-sealed trap combined with a check-valve is used. Probably one of the best forms of subsoil drainage traps is that which has a deep seal and a float arranged in such manner that the float will automatically rise and shut off the subsoil drains from the house drain when house sewage backs up in the trap, and that will descend with the water of the trap, and shut off the subsoil drains from the house drain before the seal is lost by evaporation.

30. Forced Disposal.—Should the cellar floor be below the sewer level, or at least so nearly level with it that the subsoil water cannot be removed by a gravity system of drainage, it becomes necessary to use some convenient force to raise the water to a point from which it may flow by gravity into the sewer.

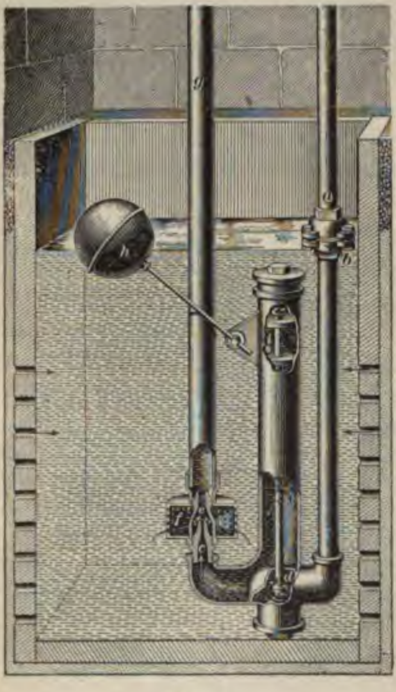


FIG. 3

Common hand pumps can be employed for this work, but they require too much labor and attention, and consequently are not suitable machines. If a building that is affected in this manner has a bountiful supply of water at a pressure of, say, 30 pounds or more per square inch, a simple automatic cellar drainer may be used to raise the subsoil water.

Fig. 3 shows one of these machines in detail. It is set in a small pit below the cellar floor, and into this pit the subsoil water may drain. The drainer is connected to the cold-water supply pipe by means of a pipe *a* that is furnished with a flanged union *b*, inside of which is a close-meshed strainer, which prevents any grit from entering the machine with the water. The pressure-water passes through the valve *d* and issues from the nozzle *c* in a fine stream, about $\frac{1}{16}$ inch in diameter. This jet enters the larger cone *e* and forces the pit water, which enters this cone through the perforations, up into the outlet pipe *g*, which delivers into an open fixture, as a safe-waste sink in the cellar, for instance. The perforated hood, or strainer, *f* prevents any chips, or other matter that may be floating in the pit, from entering and choking the cone *e*.

The jet of water, the force of which raises the subsoil water from the pit, is governed by a simple device that opens the valve *d* when the pit is about full of water and closes it when the pit is nearly empty. The machine is thus automatic and intermittent in action.

The valve *d* is provided with a hollow stem of sufficient diameter to nearly fill the valve orifice. The water, after passing over the edge of the valve disk, enters slots in the bottom of the stem and emerges from small holes farther up the stem, as shown by arrows. This arrangement prevents the valve from chattering on its seat, and allows it to fall by its own weight when slightly opened. When the water rises above a certain level in the pit, the float *h* operates a finger *i* that pushes down on the lower disk attached to the valve stem, and thus opens the valve and starts the machine. As the water falls in the pit, the float falls with it, and the finger *i* rises slowly, engaging with the upper disk, raising the stem and closing the valve.

The machine will start itself when the water is high enough in the collecting pit, and will continue to eject water until the pit is nearly empty, that is, until the float has reached the downward limit.

SEWERAGE

SEWERAGE SYSTEMS

INTRODUCTION

31. Necessity of Sewerage.—**Sewage** is composed of water mixed with kitchen slops, grease, soap, urine, washings from stables and slaughter houses, rags, leaves, paper, human excreta, etc. The animal and vegetable matters in it rapidly decompose and generate noxious gases, the combination of these being called **sewer gas.** These gases are poisonous and will inevitably produce sickness if they escape into a dwelling, or if they are breathed in any considerable quantity by those that have weak constitutions or that are susceptible to disease.

A small leak of sewer gas in a house may cause much sickness that will probably be ascribed to other causes. Many people will endure a small amount of bad odor rather than incur the expense of sending for a plumber, and are unwilling to believe that a small defect in the drainage can do much mischief. But, the plumber must protect people against their own ignorance and cupidity in this matter.

It is clear, from the nature of sewer gas, that traps and vents on the drains are not luxuries, but are absolutely necessary to the health of the community.

32. Effect of Efficient Sewerage.—Evidence in regard to the salutary effect of efficient sewerage and drainage of cities on the health of the inhabitants is abundant and need not be given here. The experience of a large number of cities could be cited to show the marked reduction in the death rate resulting from the construction of sewerage systems; but the benefits of sewerage are now so well known as to make such proofs unnecessary. There is no longer any question in regard to why sewers and drains should be built; the only question at present is how shall they be built.

33. Necessity of Pure Air.—One of the principal conditions requisite to health is that the air we breathe shall be pure. The air in the vicinity of human habitations may be maintained pure by promptly removing those things that pollute it, such as decaying matter, noxious gases, and all conditions favorable to the development of disease germs.

34. Deleterious Matter Requiring Removal.—Besides the prompt removal of all water from the surface and subsoil, which is accomplished by efficient drainage, all garbage, street sweepings, solid kitchen and factory waste, decaying vegetable matter, and other dry refuse should be promptly collected and removed, and all excremental or human waste and liquid refuse should be removed by an adequate system of sewerage. By such means, the putrefying matter, stagnant water, and dampness, which not only generate disease germs but also make their continued existence possible, are effectually removed. The soil is thus rendered dry and wholesome and the air is purified.

SYSTEMS OF REMOVAL

35. Classification.—The different methods employed for the removal of excremental and liquid waste may be divided in three general classes, namely: the *direct-removal system*, the *pneumatic system*, and the *water-carriage system*.

36. Description.—The principal methods of **direct removal** are the *pail system* and the *dry-earth closet*. In the former system the excrement is caught in a pail or other vessel, and at stated intervals is transferred to and removed by carts. In the latter system, dry, powdered earth, or ashes, is added to the excreta in sufficient quantities to absorb the moisture and deodorize the entire mass until it can be removed. There are various modifications to both these systems of direct removal, all of which give results more or less satisfactory and also involve features more or less objectionable.

37. The **pneumatic systems** generally consist essentially of systems of air-tight pipes, through which the excremental matter is forced by atmospheric pressure, the air being exhausted from the pipes by large air pumps. Such systems are intended for the removal of only such portion of the wastes as is most valuable for fertilizing purposes. Separate conduits are provided for liquid wastes. These systems, though disposing of only a portion of the refuse, require costly machinery, and are also expensive to operate.

38. The *Shone system* employs compressed air for the purpose of raising sewage. The sewage flows through pipes by gravity, in the usual manner, until it reaches the lowest level practicable or desirable for it. At such a point the sewage flows into a large iron tank, called a *pneumatic ejector*, from which, when full, it is forced into pipes at a higher level by means of compressed air automatically applied. This appliance is especially valuable in cities where sufficient fall to the outlet of the sewers cannot be obtained. In such cases, it can often be advantageously substituted for pumps for raising the sewage to the required elevation. This is not of itself a distinct pneumatic system, but is more properly considered as a special expedient of the water-carriage system.

39. The **water-carriage system** for the removal of sewage is by far the most popular. It is thoroughly efficient and requires only a comparatively inexpensive conduit to convey all the sewage. It will not be necessary to discuss here the merits of this system of sewerage; the statement that it is the system universally employed in America, and quite generally used in all civilized countries, will be sufficient, and therefore, only the water-carriage system of sewerage will be considered.

SEWERS

SEWER CONSTRUCTION

40. Classification.—There are two general classes of sewer systems for cities, towns, or villages; namely, the *separate sewer system* and the *combined sewer system.*

41. Separate Sewer System. — The separate system consists of two sets of drains, one to convey to a suitable and safe point of discharge all the excreta and all water

FIG. 4

that, whether used for drinking, washing, or other purposes, is returned in a foul state as sewage. This pipe should be laid water-tight. The other drain is used only to carry away to some convenient watercourse all the rain or storm water falling or flowing on the sewered districts. This drain need not be water-tight if the soil in which it is laid is wet, as it will thus drain the land when storm water is not flowing through it.

42. A cross-section of a street showing the sewer conduits as sometimes arranged in the separate system is shown in Fig. 4. In this figure *a* is the sewage conduit and *b* is the storm-water conduit, while *c* and *d* are pipes that convey the storm water from the catch basins *e* and *f* to the storm-water sewer *b*. The catch basins receive the storm water from the street gutters through the street openings *g* and *h*. The pipes *i* and *j* are respectively for gas and water.

43. The volume of sewage from any town or city is practically a known quantity. It is nearly equal to the water consumption, if roof and storm waters are excluded. The volume of sewage changes slightly with the hours of the day, more flowing during the day than during the night. The sewage pipe should not be too large, but should be proportioned to the work it will have to do. Less fall will be required for it than for one that carries storm water combined with sewage, as there is no grit and sand to be washed forwards.

44. Combined Sewer System.—The combined system is that in which the roof and storm water is conveyed to a suitable point of discharge by the sewers that convey the sewage from the buildings. The uniting of the two is claimed to be an advantage, since the storm water flushes the drains admirably. Such sewers, if made large enough to carry off the heaviest rainfalls, are much too large for dry seasons. A small, shallow, sluggish stream of sewage will then flow through them, and solid matter is liable to accumulate, putrefy, and evolve sewer gas. If the sewers are constructed too small or have too little fall, they will fill up during heavy storms, and the water will back up into the basements.

45. The shape that should be given to a sewer depends on the nature of the flow through it. If the quantity of liquid is fairly constant, a circular sewer or pipe may be used. If the flow is variable, as is always the case where storm waters are to be disposed of, the sewer should be egg-shaped.

46. Brick Sewers.—For circular sewers of diameters not greater than 30 inches, vitrified pipe is the best material. Larger sewers are commonly made of brick. The

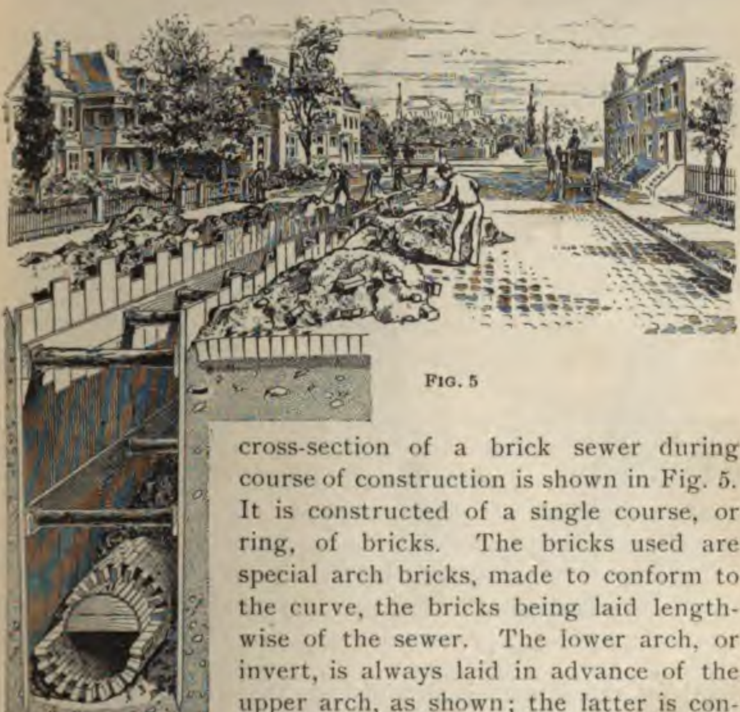


FIG. 5

cross-section of a brick sewer during course of construction is shown in Fig. 5. It is constructed of a single course, or ring, of bricks. The bricks used are special arch bricks, made to conform to the curve, the bricks being laid lengthwise of the sewer. The lower arch, or invert, is always laid in advance of the upper arch, as shown; the latter is constructed over a temporary wooden arch *a* called a **center,** or **form,** which is held in place by wooden blocks (not shown), that rest on the invert. The thickness of a brick sewer under ordinary conditions may be approximately determined by allowing one ring of bricks for each three feet diameter. The bricks should be soaked in water and then bedded in place, using a mortar composed of equal parts of Portland cement and clean sharp sand. The joints at the inner surface of the sewer must be neatly and smoothly faced. The house sewer should discharge into the street sewer a little above the center of the latter.

47. Fig. 5 also illustrates a system of **bracing** for preventing the caving in of the sides of the trench. This form of bracing is used only when the ground is very soft and quick to slide.

48. The proper form to be given to an **egg-shaped sewer** is shown in Fig. 6. The upper part is a semicircle, having the diameter d. The total height h is made equal to $1\frac{1}{2}d$. The bottom curve has a radius r, which equals $\frac{1}{4}d$. The sides are curved to a radius r_1, which equals the height h.

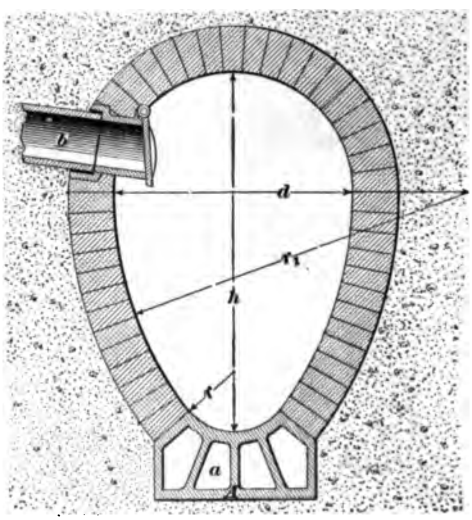


FIG. 6

The special advantage presented by this form is that with a minimum quantity of water a maximum depth can be obtained, and that as the depth of the stream is diminished, the wetted perimeter, which is the friction-producing factor, is reduced proportionately.

The invert block A must be set on a **solid unyielding** foundation. It is made of terra cotta, **salt-glazed on its** inside face. The spaces a within the block **may be used** to drain the land. They form continuous channels to the sewer outlet.

The house drain *b* should join the sewer above the line *d*, as shown. If there is danger of water backing in the sewers, the mouth of *b* should be protected by a light hinged flap valve, as shown.

49. All sewers and drains should have open communication with the atmosphere at some point, so that air may freely pass out and in to accommodate changes in volume of the liquid flowing through them, these openings serving as reliefs for the escape of drain air should tidal water back into the drains and sewers. The ordinary practice is to have a few holes in the manhole covers on the main, or trunk, lines.

Some sewerage systems are furnished with ventilating shafts located at their extreme highest ends. These insure a constant current of air through the system if the air in the shaft is warmer than the atmosphere. The natural ventilation of sewers and all underground drains is a current of air traveling toward their lower end, or outlet, during hot weather, and toward the ventilating shaft during cold weather, unless otherwise affected by prevailing winds, etc.

50. Pipe Sewers.—For pipe sewers, the trench can be excavated as deep as to about the center of the pipe by common laborers, below which depth it should be shaped to receive the pipe by men trained to the work. It should be so shaped that the pipe will be supported entirely on its cylindrical part (where it is of uniform cross-section), a recess being formed to receive the socket and cement joint for each length of pipe, which recess should be afterwards filled with well-packed sand. The pipe should be carefully laid with socket end toward the summit; this should be done by one trained man, who should have a helper when laying large pipe. The joints should also be cemented by one man, who should be well trained to the work. The earth should then be carefully packed around the pipe, previous to filling in the trench; it should be packed with especial care around all **Y** branches, the ends of which should be temporarily closed by special caps. The **Y** branches, to which the houses will be connected, should be generally located about 25 feet apart along both sides of the sewer, and a record of their exact positions should be carefully kept.

51. Bracing the Trenches.—In most cases, where the depth is not great, the sides of the trench will stand without protection. In some soils, however, there will be great tendency to caving, and it will be necessary to protect the sides of the trench from caving by means of timber work and braces. This is a matter to be looked after principally by the contractor, as on him devolves all the risks of the undertaking. It is, nevertheless, a matter over which the engineer should keep a general oversight, as the lives of the workmen may be endangered and the work greatly delayed by accidents due to lack of, or insufficient, protection to the banks of the trench during the construction of the sewer.

52. The banks of sewer trenches are commonly protected by means of a temporary framing of planks and timbers, known as **sheet piling.** Sheet piling consists essentially of a row of planks, having their lower ends sharpened, driven vertically along each bank; these are braced by means of braces extending across the trench. If the trench is deep, the planks that sustain the bank can generally be placed horizontally with advantage for about the upper 4 feet of the trench, then driven vertically for the portion below. This is quite plainly shown in Fig. 7.

The horizontal planks may generally be in the ordinary marketable lengths, 16 feet being commonly a convenient length. These planks should be 2 inches thick. A length of about 7 feet is generally to be preferred for the vertical planks, or **piles,** which may generally be 1 inch thick, if sufficiently supported. One row of such piling, in connection with the horizontal planking, will be sufficient for a depth of 8 or 9 feet. For greater depths, two or more rows of piling must be driven, each row being on the inner side of the next row above, as shown in Fig. 7. The planking and piling is held in position by horizontal and vertical timbers,

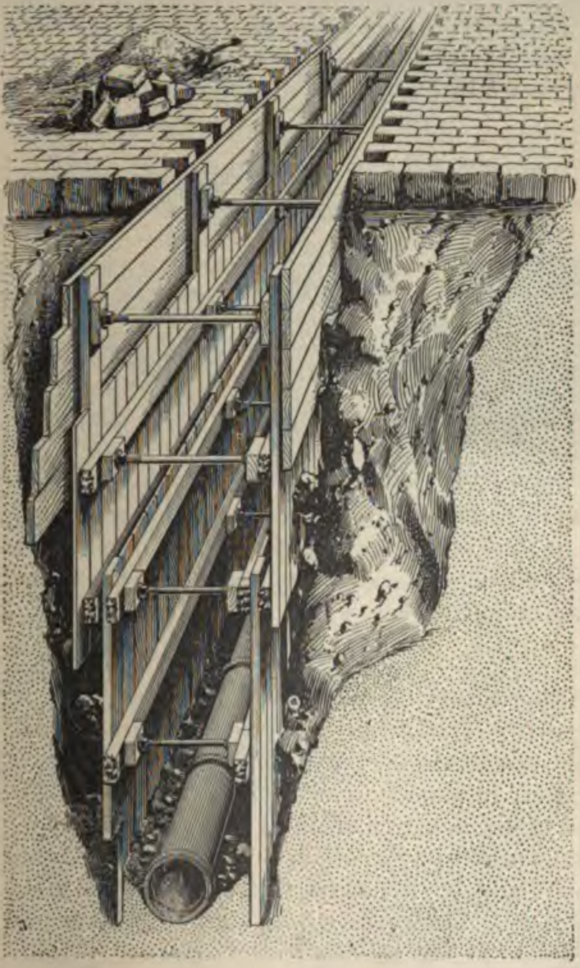


FIG. 7

generally of about 3 in. × 6 in. cross-section, which are in turn held in place by the cross-braces.

53. The cross-braces used are sometimes timber shores. These, however, must be cut to length and driven into place. They often become loose, when they must be wedged or replaced by longer shores; furthermore, shores used once cannot generally be used a second time. Much better cross-braces are afforded by the iron screws, or **adjustable braces,** shown in Fig. 7, and also shown in detail in Fig. 8.

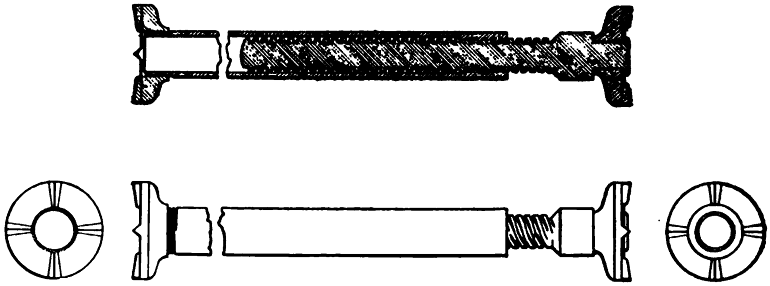


FIG. 8

These screws can be used any number of times, can be adjusted to fit any width of trench within reasonable limits, can be quickly put in place and removed, or tightened without jarring. Considerable experience is required to put in place, and remove, sheet piling quickly and without damage to the material.

54. Combined Trench and Tunnel Excavations. It frequently occurs that deep trenches must be excavated in hard, compact soil of a clayey nature. Plumbers then often resort to a mode of excavating that is partly tunneling, the object being chiefly to avoid the expense of removing all the earth under which the sewer is to be laid; also, to avoid the cost of bracing; furthermore, to prevent the destruction of trees, paths, etc., that may be on the sewer line.

Fig. 9 (*a*) shows two men laying an earthenware sewer *a* on the bottom of such a trench. The line of the sewer is first staked off. Then the ground is opened at intervals along the line, as at *b*, *b*, etc. These holes are made oval,

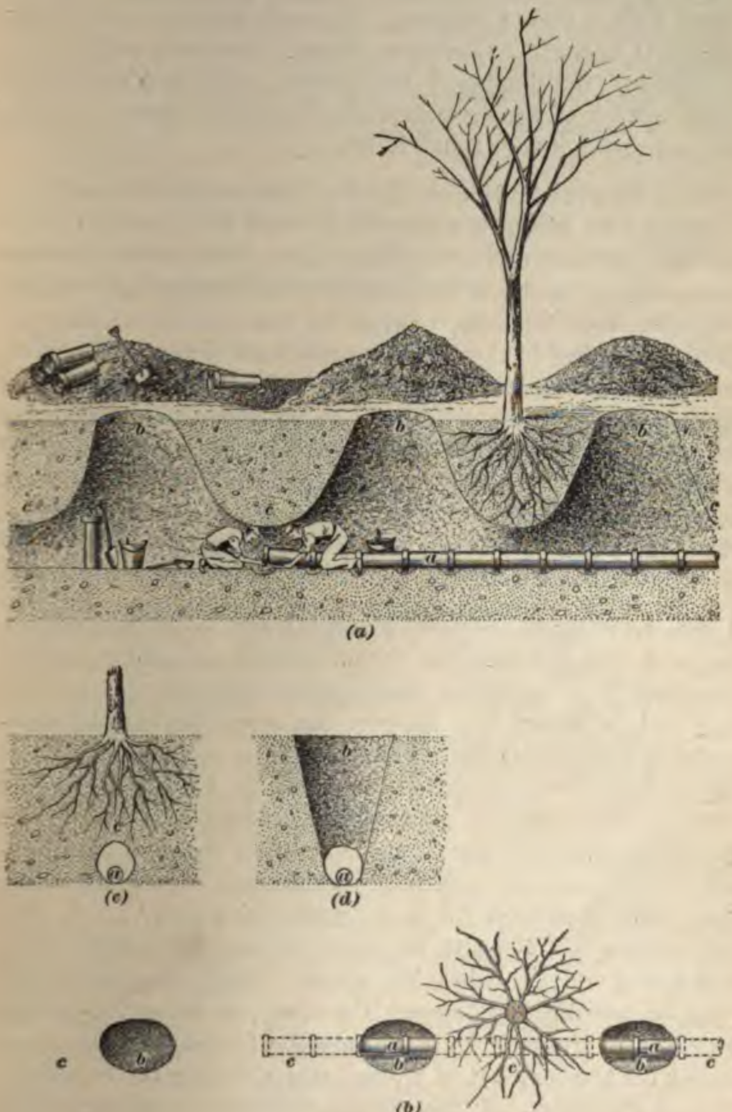


FIG. 9

as shown in the plan given in Fig. 9 (*b*), each being dug down to the trench bottom. Tunnels are now cut under the parts *c*, *c*, etc., which are allowed to remain and act as braces for the banks of the trench. Fig. 9 (*c*) shows a cross-section of the tunnel, while Fig. 9 (*d*) shows a cross-section through the trench holes.

55. The method of excavating just described must not be employed where the ground is loose and liable to cave in, since serious accidents may occur. It is used in cases where the ground will be positively self-sustaining. Many valuable trees have been saved by this method of excavation. In filling in this trench, great care must be taken to first pack the earth well into the tunnels, to prevent the parts *c*, *c*, etc. from collapsing when the ground becomes loosened by frost and affected by freshets. It is considered a good plan to flood the trench with water after the tunnels have been packed and before the holes *b*, *b*, etc. are filled in. The water will settle the earth and make it very compact in the tunnels.

56. Artificial Sewer Foundations. — It sometimes happens that the material encountered in excavating sewer trenches is so unstable that special expedients must be resorted to in order to support the sewer during the construction and until the earth filling can be tamped around it. When the material encountered is very treacherous quicksand, it will be generally necessary to support the sewer on piles or timbers, while in other and less treacherous soils it may be sufficient to excavate somewhat below the grade line and fill in to grade with gravel. A tile underdrain laid beneath the sewer is very advantageous in quicksand and water-bearing strata. This secondary drain may be laid directly beneath the sewer, or somewhat to one side of the trench. This will also be found very advantageous for the removal of subsoil water during the construction of the sewer. It may be constructed of ordinary drain tile 2, 3, or 4 inches in diameter, according to the amount of subsoil water.

57. Velocity of Flow in, and Fall of, Sewers.—The velocity of the flow in sewers and drains should not be less than 2 or 3 feet per second, nor higher than 4 or 5 feet per second, if the sewers are built of brick and convey storm water. If there is much sand or grit in the sewage, a velocity of 6 feet or more is liable to wear away the brickwork.

The fall of brick sewers should be about 1 in 240 if possible, though with frequent flushing 1 in 600 may be permitted. When it is less than this, solid matter will deposit and must be removed by manual labor.

58. Size and Capacity.—The final and most important question to be decided, in designing a system of sewers, is the question of size. This question can be decided much more satisfactorily for sewers that are to convey only sewage proper than for those that are to convey storm water also.

The aggregate yearly discharge of house sewage from built-up residence areas is greater than the entire volume of storm water that ordinarily reaches the sewers during the same period. Yet the sewer capacity required for ample house drainage is about $\frac{1}{40}$ that commonly given to storm-water sewers for like areas. This is due to the fact that the discharge of storm-water sewage may be very excessive for short periods of time and nothing at all for quite long periods, while the discharge of house sewage is reasonably constant. The capacity of the sewer must be sufficient to provide for the maximum rate of discharge.

The maximum rate of discharge must always be carefully considered. This maximum rate is so great for storm-water sewers that it is not considered necessary to provide additional capacity for the domestic sewage in sewers of the combination system. For sewers of the separate system, the required capacity may be materially greater in a manufacturing than in a residence district. This is due to two reasons. First, the daily quantity of sewage from a manufacturing district may be considerably greater than from a residence district of the same size, and, second, the entire daily sewage from the manufacturing district may be discharged during a few hours, while that from the residence district will generally be distributed through the greater part of the 24 hours.

The waste of water is generally more nearly constant than its legitimate use. Consequently, the greater the percentage of water wasted, the more nearly uniform will be the discharge of sewage and the less will the maximum exceed the average discharge. These and all similar conditions must be carefully investigated and considered, as relating to each particular case, and the required capacities of the sewers must be determined accordingly.

TABLE II

CAPACITY OF CIRCULAR SEWERS FLOWING FULL

Diameter of Pipe in Inches	Slope, or Head, Divided by Length of Pipe						
	1 in 40	1 in 70	1 in 100	1 in 200	1 in 300	1 in 400	1 in 600
5	.456	.344	.288	.204	.166	.144	.118
6	.762	.576	.482	.341	.278	.241	.197
7	1.170	.889	.744	.526	.432	.372	.304
8	1.700	1.290	1.080	.765	.624	.540	.441
9	2.370	1.790	1.500	1.060	.868	.750	.613
10		2.400	2.010	1.420	1.160	1.000	.820
11		3.120	2.630	1.860	1.520	1.310	1.070
12		4.000	3.350	2.370	1.930	1.670	1.370
15			6.180	4.370	3.570	3.090	2.520
18			10.210	7.220	5.890	5.100	4.170
20			13.650	9.650	7.880	6.820	5.570
22			17.710	12.520	10.220	8.850	7.230
24				15.800	13.000	11.230	9.170
26				19.730	16.000	13.960	11.390
28				24.150	20.500	17.070	13.940
30				29.080	24.750	20.560	16.790

To use the above table, first compute the volume of water in cubic feet that requires to be removed per second during the heaviest rainfall. Next, under the proper sewer grade in the table find the discharge nearest to the computed amount to be removed; then, by following to the left column, the diameter of pipe required is found.

59. To accurately proportion sewers for large districts, it is necessary to use very complicated formulas and to make elaborate surveys. This is the work of the municipal, civil, or sanitary engineer rather than that of the plumber. Since, however, plumbers are occasionally called on to lay large sewers for suburban districts or country estates, Table II, taken from Kent's Mechanical Engineers' Pocket Book, is given. In this table the discharge is given in cubic feet per second.

EXAMPLE.—The total roof area of buildings whose storm water is to be removed is 80,000 square feet. The total area of the corresponding back yards, pavement, and macadam road is 40,000 square feet. The fall of the sewer is 1 in 100. The rainfall being 4 inches, 75 per cent. of which will reach the sewer, what should be the size of the sewer pipe?

SOLUTION.—The total area of the surface to be drained is 80,000 + 40,000 = 120,000 sq. ft. 75 per cent. of 4 = 3 in. of rainfall = .25 foot. Therefore, the volume of water to be removed per second $= \frac{120{,}000 \times .25}{60 \times 60}$ = 8.3 cu. ft. Referring to the table, in the column headed 1 in 100, and in the left-hand column, we notice that an 18-inch pipe delivers 10.21 cu. ft. per second. This size of pipe is chosen, since the next smaller size, 15-inch, is too small. If a 17-inch pipe could be obtained, it would be large enough to safely carry the storm water.

60. Sewer Branches.—House connections are made to pipe sewers by means of a special **Y branch.** This fitting is shown in Fig. 10, by a top view and side elevation. It consists, essentially, of a length or cylinder of sewer pipe intersected by a cylinder of smaller diameter, the angle of intersection of the axes of the two cylinders being about 30°. The branch can be turned either to the right or left. Until a house connection is made to a Y branch, the end of the branch is closed by a **cap, or stopper,** the general form of which is shown at *c* in the figure. For making the house connections to brick sewers, a piece of pipe corresponding to the smaller

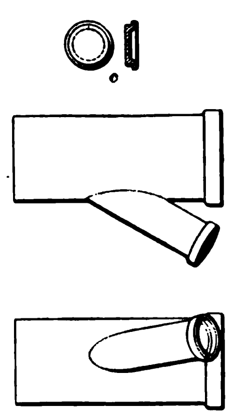


FIG. 10

cylinder of Fig. 10 is used. This piece of pipe, called a **branch,** or **slant,** is built into the upper arch of a brick sewer just above the springing line, or line along which the upper arch and invert join. The form of the branch and manner in which it is built into the side of a brick sewer is shown in Fig. 11, which illustrates a longitudinal section and view of the bottom of both sewer and branch.

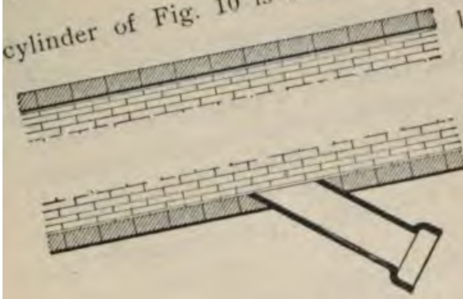


FIG. 11

61. Curves.—House connections entering sewers are often required to turn quite sharply. Special curves are

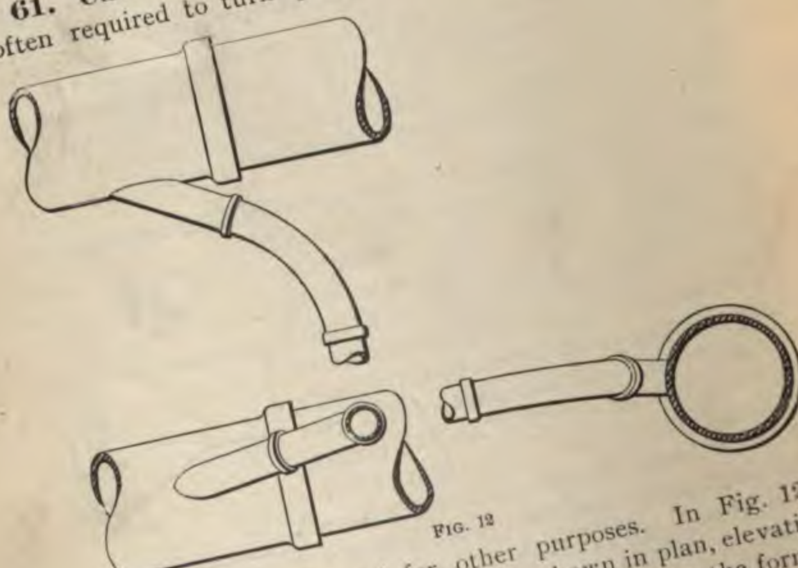


FIG. 12

required for this and for other purposes. In Fig. 12 a ... connecting curve are shown in plan, elevation, ... shows clearly not only the form of ... position for making it

62. Tees.—Pipes having somewhat the form of the letter **T** and, from the similarity, called **tees** or **T's**, are used for certain purposes in the construction of sewers. It is not a proper connection for branches, as it produces too abrupt a change in the direction of the current, causing eddies and deposit. It is, however, a good fitting for certain purposes, such as lamp holes, handholes, and flushing-out openings, where a hose may be applied for the purpose of flushing a section of the sewer.

63. Handholes.— Sections of sewer pipe having a detachable piece, as shown in Fig. 13, are sometimes laid at intervals along a pipe sewer. Such sections are commonly called **handholes,** although the name is more properly applied to the opening. They afford a means of removing obstructions from the sewer without breaking the pipe. When used, they are laid at intervals of about 100 feet along the sewer. As, however, house connections are not usually made to all the **Y** branches laid for that purpose, the unused **Y** branches may be made to serve the same purpose as handholes by simply removing the cap, or stopper.

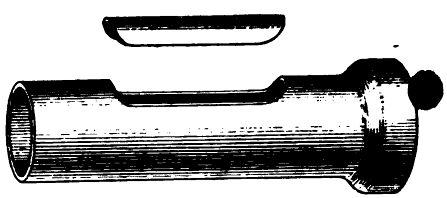


FIG. 13

64. Junctions.—Substantially the same fitting as the **Y** branch is used for the junction of two lines of pipe sewers. The relative sizes of the branch and main pipes are varied to suit different requirements, and the form is also somewhat varied. Where two branch sewers join a main sewer, a double **Y** branch, as shown in Fig. 14, is employed. In pipe sewers and all sewers too small to be entered, the curves for the junctions should be entirely within, or accessible from, the manholes.

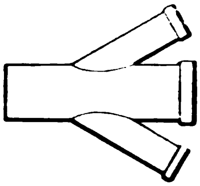


FIG. 14

The junctions of brick sewers are sometimes quite difficult of construction. The radii of the connecting curves should be as great as practicable, generally from about 10 to 50 feet, according to the size of the sewer, the longer radii being for the larger sewers; the sewers should, when possible, connect tangentially.

65. Manholes.—Where two or more sewers unite, an opening leading to the surface of the street should be constructed for the purpose of affording access to the sewer. Such openings are called **manholes.** A manhole is shown in Fig. 15. It is here shown as constructed at the junction of three pipe sewers, but the construction will be substantially the same for any case. Manholes are constructed of brick; they may be directly over the sewer or somewhat to one side, as circumstances may require. In America, however, they are generally constructed directly over the sewer. The walls should be 8 inches thick and plastered on the outside with cement mortar. The foundation and bottom of the manhole should be formed of concrete, which should be brought up to a level with the bottom of the sewer. The bottoms of manholes should be carefully made to conform to the shape of the sewer. The top of the manhole should be covered with a perforated cast-iron cover, the top of which should be on a level with

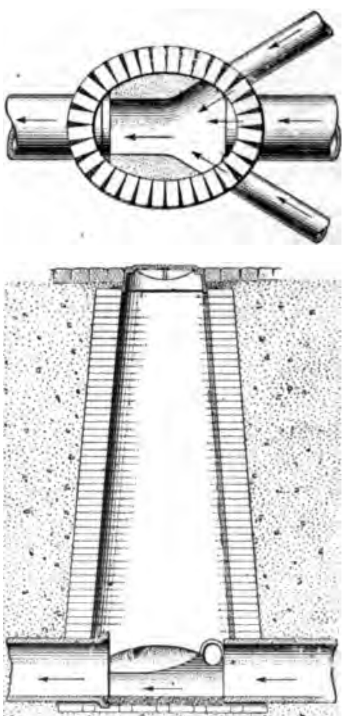


FIG. 15

the surface of the street. In some cases, a dust pan is hung below the cover

66. Manholes should be constructed at all junctions (except house connections) at the upper ends of curves, and, where the distance between such points is great, at occasional street intersections. In general, they should be constructed at all points where it may be desirable to have access to the sewer for the purpose of inspection, repairs, the removal of obstructions, or for any other purpose. They afford a means for making the connections between pipe sewers that cannot be satisfactorily connected by the ordinary **Y** branch, as is often the case with large pipe sewers. In such cases, all the tributary sewers discharge into the manhole, to which an outlet is afforded by the main sewer. Manholes also serve to ventilate the sewers. It should be stated, however, that the construction of manholes adds materially to the cost of a sewer and they should not be constructed more frequently than necessary.

67. Lamp Holes.—For pipe sewers, where the distances between manholes is considerable, the means of observing the condition of the sewer at intermediate points may be afforded by what are called **lamp holes.** A lamp hole is formed by placing a **T** in the line of the sewer and carrying a vertical pipe, or stand pipe, to the surface, as shown in Fig. 16. The sewer may be examined by means of a lamp lowered through the vertical pipe. The lamp hole may stop just beneath the pavement, and its top may be covered with a light casting, or it may be carried nearly to the surface and its top protected by a cast-iron frame having a heavy cover, as shown in the figure.

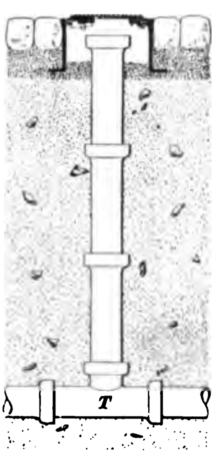


FIG. 16

If the lamp holes are carried to the surface and covered with perforated cast-iron covers, they will assist materially in the ventilation of the sewer. Lamp holes can be cheaply constructed; they afford means for inspecting the condition of pipe sewers, but do not give access to the sewer for cleaning or removing obstructions.

68. Catch Basins.—For the purpose of admitting storm water to the sewers, **catch basins** are placed at street corners, and sometimes, if the block be long, at intermediate points also. Catch basins are built in various forms, most of which consist of a chamber or basin into which the storm water flows directly from the street gutters, having an outlet into the sewer from a point at some distance above the bottom. By this arrangement, a large portion of the coarsest and heaviest of the matter suspended in the storm water will not enter the sewer, but will settle to the bottom of the catch basin and be there retained. In order to prevent sewer gas from entering the catch basin (from which it would escape in the vicinity of the sidewalk and be very objectionable), the outlet to the sewer is given such a shape as to form a trap.

69. The common form of catch basin in the United States is shown in Fig. 17. It is generally built of brick, but is sometimes built of concrete, or of earthenware pipe. In the figure, *o* is the opening for admitting the storm water from the gutter; *t*, the trap to the outlet leading to the sewer *s*; *w*, the surface of the water, and *m*, the deposit of mud and sedimentary refuse; *c* is a cast-iron cover to an opening in the top of the catch basin, through which the deposited mud and refuse may be removed.

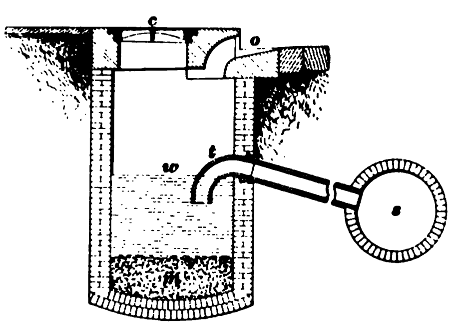


FIG. 17

It is important that catch basins should be perfectly water-tight, in order to maintain the water surface at or very near the level shown in the figure. This is necessary, in order both to cover the deposit of mud and prevent it from giving off disagreeable gases and to seal the trap against the escape of sewer gas. The water level in street catch basins should be from 2 to 3 feet below the street surface and the total depth of the basin should be generally from 6 to 8 feet, in order to avoid freezing. The construction may be varied in detail to suit circumstances.

70. Sewage Lifts.—In order that the sewers shall not become clogged, the sewage must flow with sufficient velocity to keep the sewers clean. This requires that the sewers shall be laid to grades having sufficient inclination to induce the required velocity. In low-lying districts, such grades are not always available without requiring the sewage to be pumped or otherwise lifted; in other words, the available fall to the outlet is not enough to convey the sewage, and the expedient of allowing the sewage to flow to a low point in the system, and there lifting it to a higher level from which it will flow to the outlet, must be resorted to.

71. Fig. 18 shows a sewage lift that is commonly used. In this device compressed air is applied to lift the sewage, which flows by gravity through the inlet *a* and is admitted to the large chamber or reservoir *r*. When full, the pressure of the sewage lifts the small bell *d* that operates a valve and admits compressed air into the reservoir through the pipe *e*. This increases the pressure in *r* and forces the sewage out through the outlet *b*. When the chamber is empty, the air valve is closed and a vent hole to *r* is opened by the weight of the small bucket *c*, which is always full of sewage. A check-valve opening toward the reservoir is placed at the foot of the inlet pipe opening, and another check-valve that opens toward *b* is placed at the foot of the outlet pipe *b*. These check-valves prevent sewage in *r* from entering *a* when the air pressure is on, and the

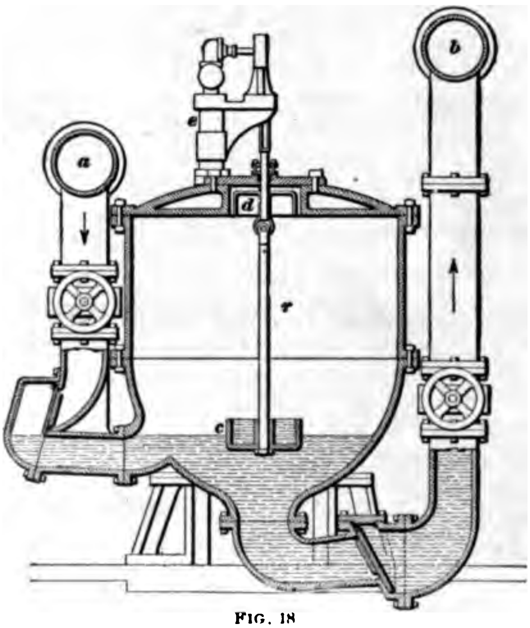


FIG. 18

sewage in *b* from backing into *r* when the pressure is off.

SANITARY REQUIREMENTS OF SEWERAGE

72. Necessity for Flushing and Ventilating.—In order to form some idea of the great amount of gas constantly generated in a sewer, it is only necessary to observe the column of vapor rising from a manhole on a frosty morning, or to get a smell of the same on a warm day. This gas is given off by decomposing sewage, which gets stranded in considerable quantities during the shallow flow of dry weather, and more or less of which adheres to the sides of the sewer at all times. Fresh sewage is not very offensive, but after rapid decomposition has begun in sewage, immense quantities of sewer gas are liberated. It is, therefore, evident that, in order to so far as possible prevent the generation of sewer gas, the sewers should be frequently and thoroughly flushed, washing out the accumulations of decomposing sewage. The generation of sewer gas is largely prevented by keeping the sewers clean. This sewer gas, which is constantly generated in sewers, must escape. Ventilation of the sewers is of great importance. The air in sewers should never be stagnant, but should be kept constantly in motion, being allowed to escape at certain points in the system and renewed at others. By thus maintaining the circulation, all impurities will be more or less oxidized, instead of collecting in putrefying masses, and the air in the sewer will not generally contain injurious gases in great quantity.

73. Means of Ventilation.—The efficient ventilation of a system of large sewers is a difficult problem, and up to the present time it has not been satisfactorily solved. Some of the highest authorities that have investigated the matter have concluded that the most effective expedient is to ventilate through manholes and air inlets in the middle of the street. This is highly objectionable on account of the disagreeable odors, but is perhaps as free from danger as any cheap method of ventilation that can be employed. Ventilation by manholes is reasonably effective with air-currents in either direction.

74. Methods of Flushing.—The flushing of sewers may be accomplished in various ways. One of the simplest methods is to dam up the sewage by gates in the sewer until it is nearly or quite full, then, by opening the gates, allow the sewage to escape with a strong, full current, washing out the accumulations of solid matter. In order to avoid holding the sewage until it backs up into cellars and basements, the gates used should not reach quite to the top of the cross-section of the sewer. This simple method of flushing cannot be applied to the upper ends of sewers, where other expedients must be resorted to.

75. Automatic Flush Tanks.—Sewers may be kept reasonably clean by regular flushing with clean water. This may be accomplished by means of automatic flush tanks located at all dead ends and various other points along the sewers. The requisites for an automatic flush tank are: certainty of action, rapidity of discharge, simplicity, ease of inspection, durability, and economy both in first cost and maintenance. Many forms of automatic flush tanks have been invented, not all of which will meet the above requirements for the usual conditions. Automatic flush tanks may be classified as *tilting tanks*, *siphon tanks*, and *valve tanks*.

76. Tilting tanks are hung on horizontal axes, and each tank is so formed that, as it fills, its center of gravity becomes changed until equilibrium is destroyed, and the tank tilts over and empties itself. When empty its own weight restores it to its former position.

77. Siphon tanks, when they become filled to the desired point, discharge by means of siphons. They differ somewhat in construction, but chiefly in the device employed to start the siphon.

78. Valve tanks discharge by means of valves that are generally operated by balls floating on the surface of the water.

79. Complicated mechanism is very undesirable in a flush tank. For simplicity of construction, the siphon tanks are generally to be preferred.

80. A simple form of an automatic flush tank is shown in Fig. 19. It consists of a large chamber *c* into which water is slowly admitted by an ordinary faucet *f*. The tank empties through the siphon *s*, at the bottom of which is hung a small cast-iron tilting basin *b*. As the tank fills, the water gradually rises through the free, or ascending, leg of the siphon until it overflows down the descending leg, filling the tilting basin. As the basin fills, its center of gravity becomes changed until it tilts over to the position shown by the dotted lines, lowering the surface of the water in the

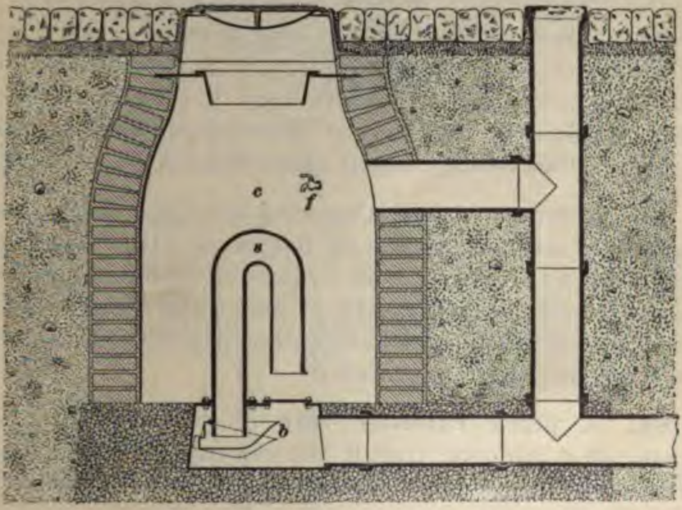


FIG. 19

basin about 1 inch. This produces sudden rarefaction in the siphon and brings it promptly into full action. When the discharge ceases the basin tilts back to its former position.

81. Capacity of Flush Tanks.—Flush tanks should have discharging capacities equal to those of the sewers into which they discharge; for the separate system, they are commonly constructed with capacities ranging from about 125 to 250 gallons. They should discharge automatically once, or at most twice, during each 24 hours. For thorough flushing, the tank should generally be so located as to give a head, in feet, equal to from one-half to three-quarters the diameter of the sewer in inches. The head required by this rule could not, however, be readily obtained for the large sewers of the combined system. It may be stated that the problems of both ventilating and flushing are much simplified in the separate system.

SEWER TRAPS

82. A sewer trap is a bent pipe or other device that is so constructed as to allow sewage to flow freely, but will not allow sewer gas to pass through it. There are many different kinds in use, but the following will suffice to give a clear understanding of their construction.

83. A **mason's trap** is made of brick and cement, and sometimes also of pieces of flagstone. It is so called because it was formerly built by masons. Although a number of mason traps are still in use, their construction is strictly forbidden by sanitary authorities, because they are foul, non-self-cleaning chambers.

84. A **plain running trap** is shown in Fig. 20. Although it is a good trap if the velocity of the sewage is reasonably high (5 feet per second or more), yet when the

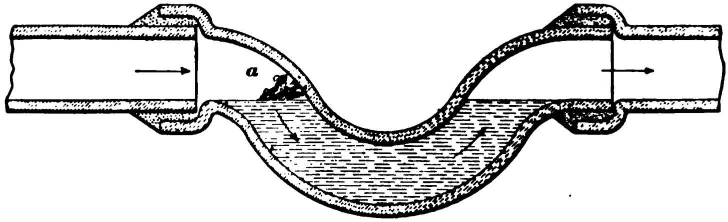


Fig. 20

sewage velocity is low, the foul matter will accumulate at *a* because the inlet and outlet of the trap are about level. Another objection is the lack of a handhole for access to the trap.

85. Fig. 21 shows a **running trap with clean-out.** It is substantially the same as that shown in Fig. 20, except that a handhole is provided at *a* for cleaning-out purposes. As this handhole branch soon becomes filled with grease and other

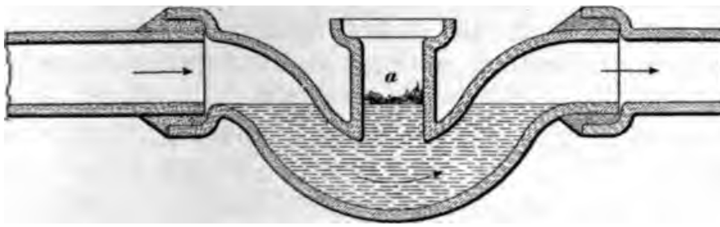


FIG. 21

foul matter, it forms a fouling chamber that is not desirable.

86. A **Buchan's trap** is shown in Fig. 22. It is a self-cleaning trap provided with a clean-out opening *a* that may

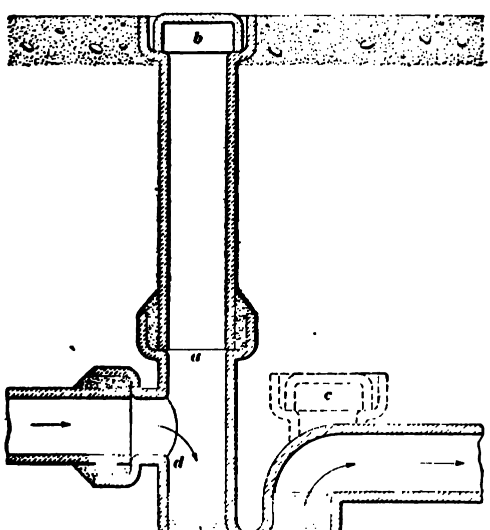


FIG. 22

be continued above the ground and used as a ventilator, or it may be capped, as at *b*, and used only as a handhole. These traps can be had with a handhole at *c*, as shown by dotted lines. One of the best features of this trap is the cascade that is formed at *d* by having the inlet lip 2 or 3 inches higher than the outlet. This cascade drives down all matter in the trap, causing it to dive under the tongue *e* and thus escape to the outlet, as shown by the arrows.

87. For underground sewerage work the traps are usually made of vitrified earthenware. All traps used on sewers should be circular in cross-section, experience having shown that if given this form they are almost entirely self-cleansing; that is, they are cleaned by the liquid in the sewage; the seals should not exceed 2 inches.

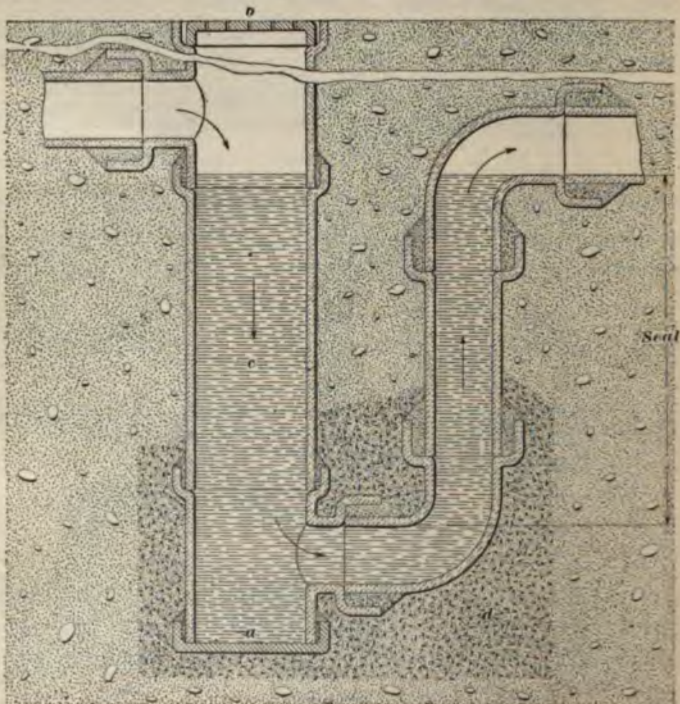


FIG. 23

88. Traps for storm-water drains must necessarily have deep seals to allow for the inevitable loss of seal that occurs during dry seasons. The ordinary sewer traps having seals of 3 inches or less are not suitable for storm-water traps. As there does not appear to be many specially deep seal traps on the market, we show by Fig. 23 how a safe and satisfactory deep seal trap can be made from ordinary pipes and fittings. A cap *a* closes the end of the lower T. A grating or dead plate may be used at *b*, as desired. The seal of this trap will be about 3 feet if a full length of pipe is used at *c*. If the trap is made of glazed earthenware pipes, the lower fittings should be imbedded in concrete *d*, as shown. This will, under ordinary circumstances, prevent leakage at these fittings and a consequent loss of seal. If there will be any heavy traffic over this trap, or if the first cost is not a hindrance, it is advisable to make it out of cast-iron pipe and fittings to prevent it from being broken or made leaky.

HOUSE CONNECTIONS TO SEWERS

89. General Directions.—The house sewer connection, or that part of the general sewerage system that connects the house plumbing system to the city sewer, cesspool, settling tank, or other place of disposal, is usually made of vitrified earthenware pipe, if the ground is old and has already settled down and become compact. If, however, the ground is loose, that is, filled in, or made, ground then cast-iron pipe should be used instead. If earthenware sewer pipe is laid in made ground, it usually becomes cracked and broken by the settling of the ground. The pipe should always be run straight from the house wall to the branch or spur on the sewer. If any rocks or boulders are encountered in digging the trench, they should either be removed or cut away so as to insure a straight run.

90. Main Drain Trap.—If the **intercepting trap,** or **main drain trap,** is located on the house sewer line under the ground, it should be set in a manhole, if possible, as shown in Fig. 24, so as to be easily accessible in case of chokage or for testing purposes. The trap *a* has a 1½-inch or 2-inch seal. On the sewer side of the trap is located a brass screw cap *b* for access to the sewer pipe *c*, which connects with the public sewer or other place of disposal. This allows cleaning rods to be pushed through *c* to clear any obstructions that may exist beyond the trap *a*. An inspection and cleaning-out chamber or handhole should also be provided on the house side of the trap, as at *d*, so that the

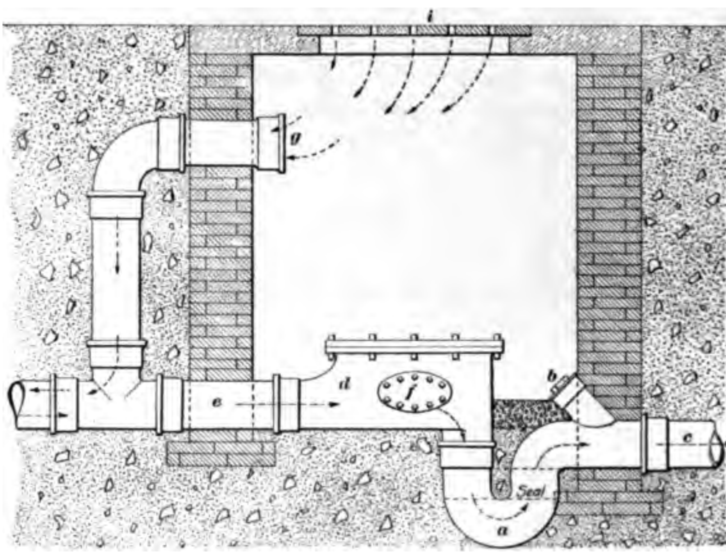


FIG. 24

pipe *e* between the trap and the house may also be inspected or cleared if desired. A branch may be connected to *d* by removing the flange *f* and bolting on a branch fitting instead. A branch taken from the top of *e* and extended into the manhole with an open end, as shown at *g*, is called the **fresh-air inlet**, because it allows fresh air to enter the drainage system, as shown by dotted arrows. The cast-iron plate *i* finishes flush with the ground and is perforated to admit air to the manhole.

91. Another form of intercepting trap is shown in Fig. 25. It is simply a running trap *a* with two handholes *b* and *c*, each of which is continued up full size to the ground, and capped flush with the ground by means of brass screw-cap ferrules *d* and *e*. Into the inlet hub of the trap is calked a T, the branch of which is continued up above the ground line and surmounted by a ventilator or hood *f* that forms the fresh-air inlet for the house drainage system. If the hood *f* were calked on *d*, and the pipe *d b* thus used as a fresh-air inlet, the cold air falling through *b* would be liable to freeze the water in the trap *a* during the night, when little or no sewage is passing through the trap.

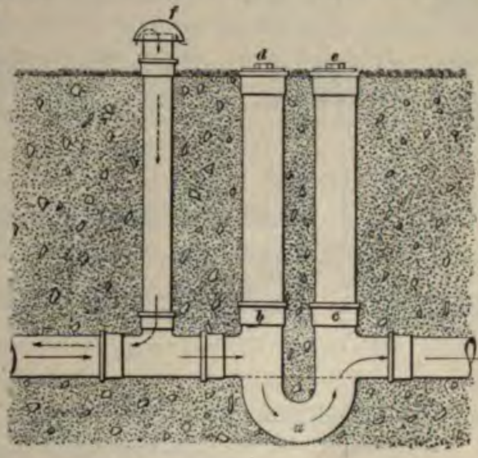


FIG. 25

92. Locating Hole in Cellar Wall for Sewer Connection.—It is necessary for the plumber to know the exact location of the hole in the cellar wall where the sewer connection will enter the building. Sometimes this must be determined before the cellar walls are built, so that the builder may leave the hole in the wall at the proper height. This is better than cutting the hole after the walls are built. To locate the hole exactly, the plumber should call on the city engineer, examine the sewer map of the district, and from it determine the depth of the sewer below the grade line of the street, or the curb, or any other fixed object. He must then determine how high above the flow line, or bottom of the sewer, he will be required to make his connection. Or, he may go down the two nearest manholes in the street and take measurements himself, as explained below.

93. Fig. 26 (*a*) shows a 36-inch brick sewer *a* running along Park Avenue. A building *b* is being erected facing

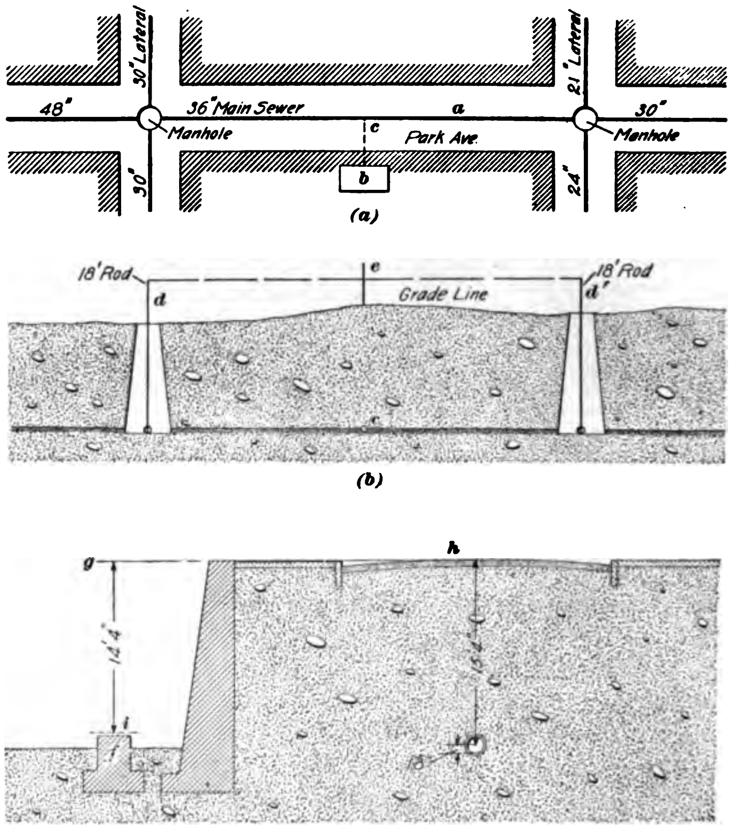


FIG. 26

Park Avenue, and the sewage from *b* will enter the main sewer at the point *c*. Manholes are located at the street crossings where the lateral sewers join the main, or trunk, line on Park Avenue. The sewer *a* is straight from manhole to manhole, which can be determined by lowering a lamp at one manhole and looking through from the other. But, the street grade is not uniform between the manholes. Therefore, the depth of the sewer at *c* below the street grade cannot be determined by merely measuring the depth of the manholes. To obtain this depth, a rod, say 18 feet long, should be held upright in each of the manholes, as at *d*, *d'*, Fig. 26 (*b*). A third party should hold a rod immediately over the point *c*, as shown at *e*. A sight line, shown dotted, should then be taken by the eye from tip to tip of the rods *d*, *d'*. A slide should be moved up and down the rod *e* till it is exactly on the sight line. The distance from this slide to the surface of the street is then noted. Let us suppose it is 14 inches. Now, as the rods *d*, *d'* each stood on the sewer bottom while the measurements were taken, and as the sewer between the two manholes is straight, it follows that the distance from the street grade to the sewer bottom at the point *c* = 18 feet − 1 foot 2 inches = 16 feet 10 inches. But, as the sewer has an inside diameter of 36 inches, and as the house sewer cannot join it below the arch, it follows that the bottom of the house sewer must enter the main sewer at a point at least 1 foot 6 inches above the main sewer bottom, or 16 feet 10 inches − 1 foot 6 inches = 15 feet 4 inches below the street grade over the point *c*. The bottom of the hole in the cellar wall should be a little higher than this to allow a proper pitch down to the street sewer. Suppose the distance of the cellar wall from the sewer to be 50 feet; a pitch of 1 foot in that distance will be sufficient to insure good drainage. The bottom of the hole, therefore, should be located 15 feet 4 inches − 1 foot = 14 feet 4 inches below the surface of the street over the point *c*. To mark off the hole at the cellar wall, it is only necessary to run a level line from the street grade over the point *c* to a point over the cellar wall *f*, as shown at *g*, *h* in the cross-section in Fig. 26 (*c*). Then 14 feet 4 inches are measured downward and the position of the bottom of the hole is marked off, as at *i*.

If surveying instruments are used, the holes can be located easier and quicker. The method given shows how they can be located without instruments.

DEFECTS IN SEWER CONSTRUCTION

94. Chokage of Drains and Sewers.—The causes of chokage of drains and sewers are numerous. Some drains become choked at regular intervals due to slow accumulations of grease and sediment discharged into them. Other obstructions, however, work into the drain through defective joints or cracks. Chokage by grease can be avoided by the use of proper grease traps attached to the waste pipes of the kitchen sinks and laundry tubs. Chokage by sediment can be avoided by giving the drain or sewer a pitch that will produce a velocity of flow sufficient to wash the sediment and other solids forwards. If the proper pitch cannot be obtained, a flushing tank should be constructed at the highest end of the drain and allowed to discharge into it automatically and at regular intervals, perhaps once or twice in 24 hours. This will wash out the contents of the drain.

95. Defective Joints.—Defective joints are probably the most common cause of chokage in earthenware drains. Fig. 27 shows one of them. The spigot end *a* should have been raised until the axis of the pipe was in line with that of the other. This would prevent the cement, of which the joint is made, being pushed through, as at *b*, and dripping on the bottom of the pipe, as at *c*, thereby forming an obstruction to the flow of the sewage.

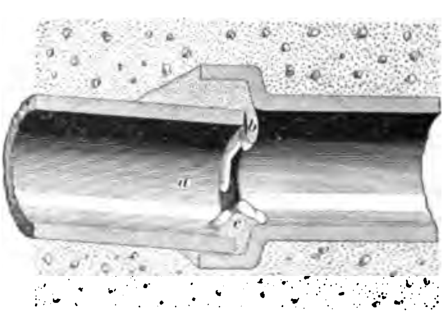


FIG. 27

96. Fig. 28 shows how a drain or sewer may become choked with sand and gravel. The workman has failed to cement the bottom of the joints. The liquid sewage flows out at some of the joints, as at *a*, and forms a current under

FIG. 28

the pipe that carries sand and mud with it. If this water enters the pipe at any of the other open joints, as at *b*, *b*, the sand will accumulate in the pipe at *c* or elsewhere and ultimately choke it at the nearest place where the pitch is not great enough for the sand to be washed forwards.

FIG. 29

97. Fig. 29 shows how a drain *a* may be choked by tree roots if the joints are not carefully cemented. The roots, particularly those of the willow tree, grow toward water. Their delicate extremities will enter a sewer pipe through very small holes, as shown at *b*, *b*, etc., ultimately choking the pipe by the growth of small fibrous roots, as at *c*, which shows the roots inside the pipe. To avoid this, the joints must be thoroughly cemented all around.

98. Sewers Not Water-Tight.—Sewers in the vicinity of wells must be made perfectly water-tight and of durable material. Earthenware is not sufficiently reliable for this purpose. Iron pipe, preferably extra-heavy cast iron, should be used. If sewers leak in the vicinity of wells, the water supply is very liable to become poisoned by being mixed with the leaking sewage. The sewage soaks down through the ground until it reaches the body of water from which the well is supplied. The safe distance for an earthenware sewer pipe from a well depends on the formation of the ground. In some cases 100 feet is quite safe, while in other cases 300 feet may not be safe. It is safest always to use iron pipe where there is any doubt.

99. Evil Effects of Small Sewers.—If sewers are made too small to freely remove all the surface water and sewage that flow into them, they fill up during heavy rain storms. The pressure due to the hydraulic head thus created forces sewage back into the branches that connect the houses to the sewer, causing the sewage to overflow into cellars through floor strainers, water closets, or laundry tubs. To prevent this trouble, it is advisable to place backwater traps or check-valves on lines that may be flooded by sewage. Care, however, must be taken to see that the rain-water leaders are connected to the sewer side of these check-valves; otherwise, roof water from the building itself will overflow the fixtures and flood the cellar.

100. Fig. 30 shows how a building may be protected against sewage matter backing up into the house drains and overflowing the fixtures that may be located in the cellar or basement. We will assume that the street sewer *a* is too small. The storm water flows into it from the street gutters so rapidly that the sewer becomes entirely filled with

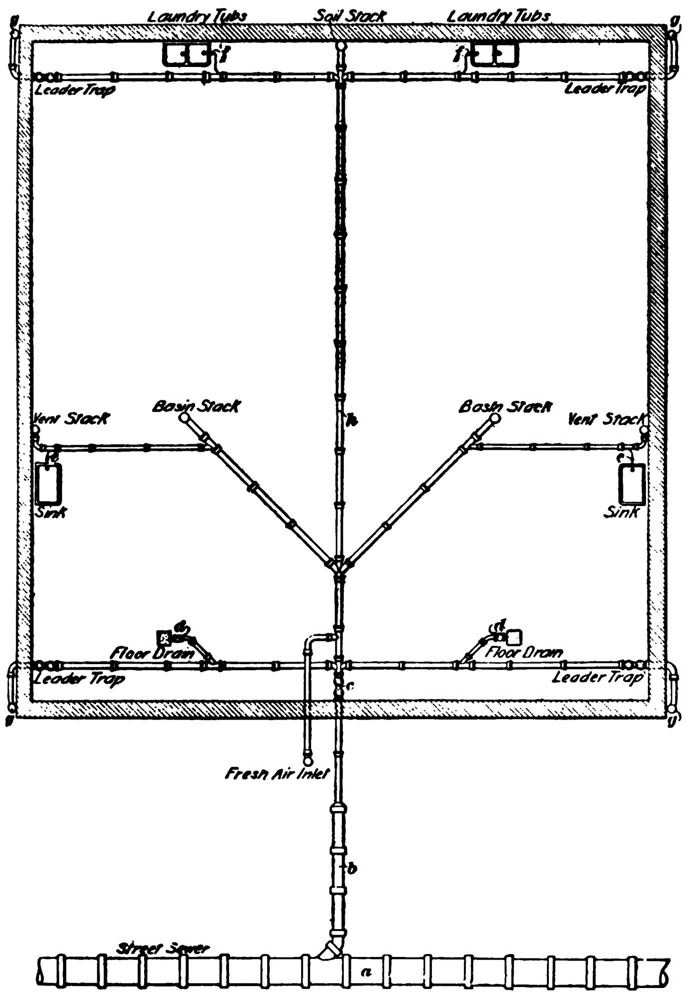


FIG. 30

water; and pressure of water from street gutters and roof leaders of the neighboring buildings causes the contents of *a* to back up the house sewer *b*, flow through the main drain trap *c*, and escape into the building from the lowest opening. In Fig. 30, which shows a plan of the pipes in the cellar of an ordinary double house, are shown six places where sewage may escape and flood the cellar, namely, two sets of laundry tubs, two sinks, and two floor strainers. As the floor strainers are lower than the other openings, the sewage would gush up through them first. To avoid this, a check-valve may be located at *d*, *d*, or it may constitute part of the trap. If the floor strainers are properly protected by check-valves, the next trouble will come from the sinks and tubs; they will fill up with sewage and overflow on the floor. The sinks, being lower than the tubs, will overflow first. To prevent this trouble, the waste pipes of these fixtures must also have check-valves at the points *e*, *e* and *f*, *f*. Then, the nuisance will remain remedied until the valves get out of order or choked up.

It is a mistake to try to economize by using only one check-valve for the whole house, and placing it on the main line, at or near the main drain trap, because, while it may keep back sewage from the city sewer, the roof leaders *g*, *g* and the discharges from the other pipes in the building would certainly flood the cellar. The back pressure of the sewage in *b* would hold the check-valve so tightly closed that the sewage in the main drain *h* would not open it until the storm was past and the sewers relieved.

SEWAGE DISPOSAL

METHODS OF DISPOSAL

CESSPOOLS

INTRODUCTION

1. The disposal of sewage matter from buildings is accomplished in various ways, but chiefly by the following methods: By discharging direct into the main street sewer; by discharging into cesspools; by discharging directly or indirectly into the sea, lake, or river in close proximity to the building; by septic tank systems; by chemical precipitation.

2. **Cesspools** are receptacles sunk below the surface of the ground for the purpose of receiving the sewage, but they are so liable to foul the soil for many yards in every direction that they should not be employed if it can be avoided. They should be located so that the liquid leaching from them into the surrounding soil will not contaminate the water supply or enter the cellar of the house. By **leaching** is meant the separation of the liquid from the solid sewage matter by percolation. Cesspools should not be made air-tight; they should have a vent pipe discharging a safe distance from the house. A running trap having a fresh-air inlet, so that a current of fresh air will pass through the drain at all times, should be placed on the drain near the cesspool.

If there is no danger that the drinking water may be contaminated, the cesspool may be excavated, in a circular form, from 8 to 12 feet in diameter, and to a depth sufficient to reach an absorbent stratum. In sandy or gravelly soil, such a cesspool will dispose of waste liquids of the house for a long time; however, in the course of years, the earth around it becomes permeated by the solid matter in the sewage and a new cesspool should be dug.

In clayey soil, no leaching or absorption of the sewage by the soil takes place, and the cesspool fills up like a tight cistern and overflows. The simplest way of getting rid of the sewage in such a case is to pump it out and dispose of it as a fertilizer in the garden or on meadow land.

LEACHING CESSPOOLS

3. In order that the sewage may properly filter away after being discharged into the cesspool, it should be built in ground composed of gravel, loose stone, or coarse sand.

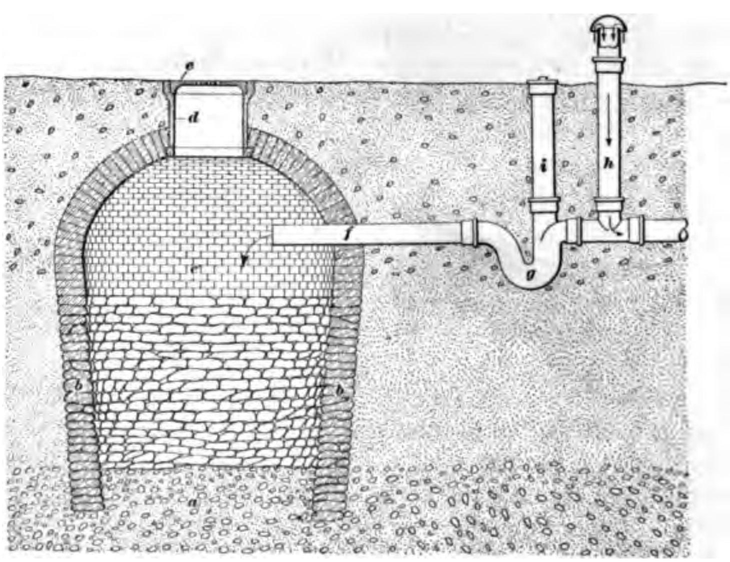


FIG. 1

Fig. 1 shows an ordinary **leaching cesspool** built in loose sandy soil and gravel. The bottom of the cesspool extends about 1 foot into the gravel, as shown at *a*. The side walls *b*, *b* are built of stone without mortar. The top is arched over with bricks laid in mortar, as shown at *c*. A 20-inch glazed tile pipe *d* is used for the manhole, which is provided with a cast-iron cover *e* having perforations through which air is admitted. The inlet pipe *f* should extend inside the cesspool far enough to prevent the sewage matter falling on the wall of the chamber and closing the crevices between the stones. Gases from the cesspool are prevented from entering the house drain by the running trap *g*, while the pipe *h* serves to supply the drain with fresh air. A clean-out cap is placed in the upper end of the pipe *i* for access to the trap.

4. Leaching cesspools, when newly built, effect some purification and filtration of the household wastes; but when they have been a long time in service the pores of the soil become clogged and the soil gradually becomes saturated with sewage matter, which undergoes a slow process of decomposition. Gases are thus generated and given off at the surface. For this reason cesspools should be located as far as possible from all dwellings. The use of leaching cesspools involves the risk that the liquid that seeps into the soil may reach some subterranean fissure or stratum, along which it moves and finally empties into some spring or well. Outbreaks of typhoid fever, caused by drinking water contaminated in this manner, have often been traced to leaching cesspools.

5. The size of a leaching cesspool will depend on the nature of the soil, the number of fixtures to be discharged into it, and the number of people occupying the house. For an ordinary two-story dwelling, if the cesspool is made in loose soil, it may be from 4 to 6 feet in diameter and 6 to 10 feet deep. If, however, the soil is composed of clay and sand, it should be made at least 1 foot larger each way.

TIGHT CESSPOOLS

6. A simple form of cesspool sometimes used in clayey soil where the liquids will not filter away, or in loose soil where it is not desirable to pollute the soil with sewage, is so similar to that shown in Fig. 1 as not to require a separate illustration. The construction differs only in that the tight cesspool is built of bricks laid in cement mortar. The inside is finished with a coat of Portland cement to make it water-tight. The cover is made of cast iron and perforated. When tight cesspools become filled, it is necessary to pump the sewage into barrels, dump it on farm land, and plow it under.

Tight cesspools should be made with great care, to avoid any possibility of leakage, and should be located as far from dwellings as possible. The dimensions of tight cesspools may be about the same as those of leaching cesspools built in sandy soil. A tight cesspool should be thoroughly disinfected each time it is emptied.

7. A good form of tight cesspool, shown in Fig. 2, consists of two compartments, the one being an intercepting or settling chamber *a*, and the other a liquid chamber *b*. The compartments are made circular in plan, the walls of each chamber being 8 inches thick and built of hard-burned bricks laid in hydraulic cement mortar. The floors and walls are finished with a strong coating of cement; both chambers are made perfectly water-tight, and arched over as shown. The manholes *d*, *d* are carried to the surface of the ground, and provided with tight-closing cast-iron covers *e*, *e* fitted into pavement slabs *f*, *f*. The chambers *a* and *b* are connected by a 4-inch overflow pipe *g* of extra-heavy soil pipe, which extends about 2 feet below the surface of the water in the chamber *a*, to prevent the scum from being drawn into the overflow pipe; the sewage enters the settling chamber through the house sewer *i*. A pipe for ventilating the chambers is shown at *h*, which should terminate at a point where the odor will not be objectionable.

8. The separation of the liquid and solid matter facilitates the disposal of both. The liquid can be pumped out and used to sprinkle and irrigate the lawn or garden. The solid matter can be removed and put under the soil as fertilizer. The size of the chambers depends on the size of the house, the number of occupants, number of fixtures, and the amount of water used daily. For an ordinary residence containing two bathrooms, laundry tubs, etc., the intercepting chamber *a* should be about 4 feet inside diameter, and 5 feet deep from the overflow *g* to the bottom of the chamber. The chamber *b* should be about 6 feet inside diameter, and 8 feet

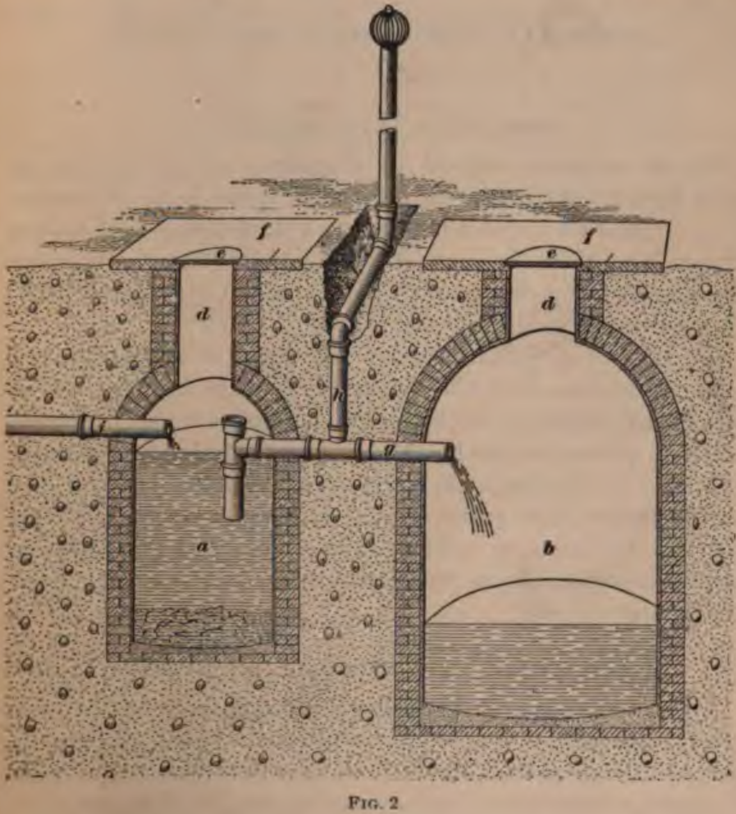


FIG. 2

deep from the overflow line to the bottom of the chamber. The sizes of the chambers should, however, be modified to meet the requirements of each case.

The principal objections to this form of cesspool are: First, if it is built moderate in size, and absolutely tight, as it should be, it requires considerable attention and expense; second, if, on the other hand, the dimensions are made large to avoid frequent cleaning out, the danger arising from stagnant sewage is increased. The cesspool should be cleaned and disinfected at frequent intervals.

DISPOSAL INTO BODIES OF WATER

DISCHARGE INTO STREAMS

9. A common method of disposing of sewage is to discharge it into a near-by stream or other body of water. This method of disposal is convenient and cheap, and, under proper conditions, is permissible, provided that the sewage discharged forms only a small percentage of the total volume of water into which it is discharged.

Where a large volume of running water is available, suburban residences may discharge their sewage into it without danger of polluting the water, as a large volume of water tends to dilute and purify the stream, rendering the sewage innocuous. However, sewage from villages and estates should not be discharged directly into small streams, as the water may become so polluted as to wholly unfit it for the use of those persons below them who depend on the stream for their water supply.

DISCHARGE INTO THE SEA OR LAKES

10. The discharge of sewage directly into the sea or a lake is apparently an easy way of disposing of it. However, this plan is not always a good one, as much unpleasantness is frequently experienced by the floating sewage matter returning to the shore with the tide, or by the action of the currents, wind, or waves, thus rendering the beach useless for bathing and other purposes. If a bathing beach adjoins the sewer outlet, it is advisable to intercept the solids and sludge in the sewage, and thus allow only the liquid sewage to discharge into the water. If it is desired to still further purify the liquid sewage before it enters the stream or lake, it can be effected by a chemical treatment in which the solids are precipitated to the bottom by mixing chemicals with the liquid sewage in the tank. The chemicals precipitate not only the solid matter, but also a portion of the matter held in solution. Various chemical processes are employed, a large number of which have been patented. The effluent from sewage clarified by any process of chemical precipitation, is, however, far from being pure water, and is liable to decompose after being discharged. Moreover, the addition of the chemicals used is more or less deleterious to the water. This method of purification is not of itself sufficient where the effluent is to be discharged into a stream from which a water supply is obtained. Chemical treatment is principally resorted to in the sewage-disposal plants of cities.

APPLICATION TO THE SOIL

METHODS

11. Applying sewage to the soil is one of the most satisfactory and effectual means of disposal, provided that the sewage is applied to the top earth where it can be absorbed by vegetation, and that the volume of the sewage is not enough to flood the ground.

There is a wide range of methods and materials employed in the design and construction of those sewage-disposal systems in which the effluent is discharged into the soil. The main object to be attained is to furnish sufficient oxygen to oxidize the organic matter suspended in the effluent.

Two general methods of sewage disposal by application to the soil are in use. The one method is called **broad irrigation,** and also **surface irrigation,** and is the process of discharging the effluent broadly over the surface of the ground; the other method is called **subsurface irrigation,** and is the process of distributing the effluent below the surface of the ground. In either case, the sewage should not be applied in such large quantities as to saturate the soil.

SURFACE IRRIGATION

12. The most satisfactory and effectual means of sewage disposal, combined with purification, where sufficient land can be procured, is surface irrigation. It includes a variety of methods that differ in detail; all consist, essentially, in applying the sewage in such a manner and quantity as to irrigate and fertilize the soil for the growth of vegetation. This appears to be the most natural and economic method

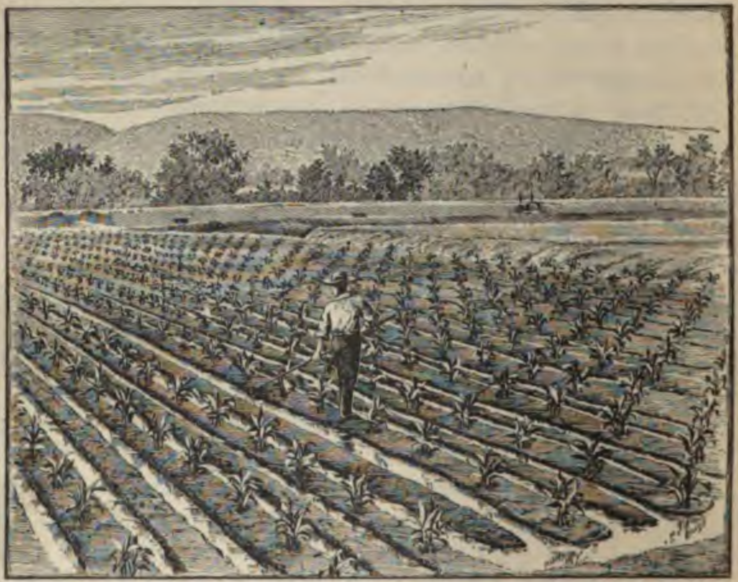


FIG. 3

of sewage disposal and purification, involving the familiar processes of decomposition and growth under natural conditions, and it utilizes, by irrigation and fertilization, the full economic value of the sewage. As the amount of sewage that can be applied to a given area, however, without being detrimental to the growing crops, is limited, this method requires extensive areas; hence, the name, broad irrigation.

13. An illustration of an irrigation field is shown in Fig. 3. A large number of ditches are dug, and corn or other species of vegetation is planted in the ground between the ditches. The sewage effluent is allowed to flow into the ditches at intervals, and thus to irrigate the ground. In order that renewed supplies of oxygen may enter the soil to maintain the oxidizing processes, the application of sewage, commonly spoken of as the *dose*, must be intermittent.

14. The sewage is flooded on ground that has been prepared for the purpose and thoroughly underdrained, and is filtered by passing downwards through the soil to the drains. The filtration is not merely mechanical, however, but is largely a chemical process. While the soil, to some extent, acts as a mechanical filter in straining out portions of the solid matter, the purification is chiefly a chemical change, involving oxidation and nitrification, brought about largely through the agency of micro-organisms, called **bacteria**, contained in the sewage. By *nitrification* is meant the act of slowly oxidizing the nitrogen contained in organic matter. It is thus seen that sewage contains within itself the means of its own purification, and, when the proper conditions are present, virtually becomes its own purifier. Under the favorable conditions afforded by intermittent filtration, purification is effected by the bacteria; and these minute organisms having performed their important work, finally succumb to the action of the oxygen and wholly disappear.

SUBSURFACE IRRIGATION

15. The porous soil near the surface has power to destroy the organic substances in sewage, rendering them innocuous by the aid of the oxygen contained in the pores of the soil, and by vegetation, as the roots of grass and shrubs take their nourishment from the organic matter. The liquid sewage contains more or less organic matter; the liquid, in passing through the soil, is clarified to a large extent by filtration. One of the principal objects to be considered in discharging sewage effluent into subsurface drains

absorption by the earth is to have the discharge dis-
uted uniformly to prevent flooding any one section of
ground. Aside from the efficiency of a sewage-disposal
stem, it is of great importance, when located in the
cinity of buildings, that all parts of the process should
e free from offense, both to the eye and nostril.

SEPTIC TANK SYSTEM

DESCRIPTION OF APPARATUS

16. The **septic tank system** of sewage purification and disposal is a process by which the raw sewage from a building, or a number of buildings, is conveyed to a set of collecting tanks and stored there until the solids have settled to the bottom and the floating material has gathered at the top, and a septic action has more or less purified the liquid between the sediment and the floating scum. The term *sepsis*, from which *septic* is derived, means putrefaction, or decomposition of animal or vegetable matter accompanied by fetid odors. The septic action, or putrefaction, is produced by a germ growth, which is encouraged, as much as possible, by burying the tanks underground and preventing the liquids becoming chilled.

The condition of darkness, no air-currents, and a moderate heat caused by decomposition and fermentation, develop a large mass of minute organisms known as **anaerobic bacteria.** The chemical action thus developed causes a large portion of the sewage to pass off in the form of gases, a small portion remaining in the tank as sludge. The effluent flows from the tank practically without odor. The septic process is continuous and requires no attention except the occasional removal of the sludge. The effluent from the tank, being practically odorless, can ordinarily be discharged into an open ditch, or stream, that is located at a point lower than the outlet from the tank, or it may be run through farmer's tile pipe and used to irrigate a lawn or garden if the ground is located lower than the outlet.

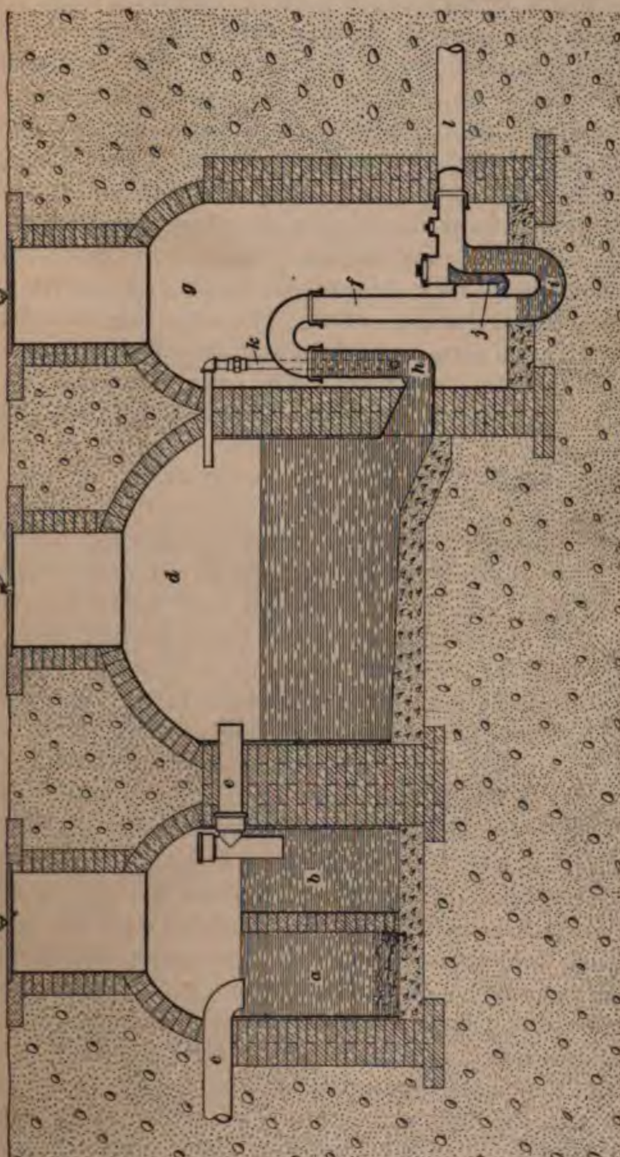


FIG. 4

17. Fig. 4 shows a septic tank suitable for a large building or country estate. It is composed of three compartments built of brick and cement mortar, and made water-tight. The left-hand compartment is the raw-sewage receiving chamber, the middle compartment is the effluent or liquid-sewage collecting chamber, and the right-hand compartment is a manhole in which is built an automatic siphon, to siphon out the liquid from the middle chamber and discharge it through the outlet pipe, shown. This pipe is continued to the disposal field, river, sea, brook, creek, or whatever point may be selected for its outlet. The receiving chamber is divided into two parts, *a* and *b*, by a brick wall that terminates at the overflow line, as shown. The sewage enters *a* through a 5-inch drain pipe *c*, which turns down and extends about 1 inch below the surface of the water so as to prevent air from the chamber entering the house drain. If the pipe extends too far below the surface, grease will accumulate and obstruct the drain; but, if it extends only slightly below the water level, the flow of sewage from an ordinary house will keep the pipe clear. The division wall holds back most of the solid matter and scum; the liquid portion flows into the compartment *b*, over the top of the wall in a thin sheet, in such a way as not to disturb the contents in *b*. The agitation caused by the inflowing sewage being confined to the chamber *a*, the solids suspended in the liquid contents of the chamber *b* settle quietly to the bottom. The liquid overflows from *b* into the collecting or discharge chamber *d* through a 4-inch pipe *e*, which extends deep enough into the water to prevent the scum or solids on the surface from being carried into the discharge chamber. The chamber *d* should be large enough to hold about 12 hours' sewage supply; it is provided with an automatic siphon *f* located in a separated chamber *g*, which location renders the siphon accessible for repairs. The siphon shown is known to the trade as the **Rhoads-Williams siphon**; the connection to the tank is made funnel shape so as to take the inflow readily. The action of the siphon depends on the sudden releasing of compressed air between the inflow *h* and the deep trap *i*. When the water rises sufficiently in *d* to compress the air in *f* enough to force the water in the blow-off trap *j* to the bottom of the seal, the water is blown from *j* into the sewer pipe *l* and the air pressure in *f* is suddenly released; the water in *d* then rushes suddenly into the siphon, bringing it rapidly into action and thus emptying the chamber *d* through *l*. When the chamber *d* is nearly emptied, the siphonage is gradually broken by the admission of air through the pipe *k*.

Since the solid matter is held in the settling chamber, it is not ordinarily found necessary to clean out the discharge chamber; although the putrid sewage contains more or less fine matter, this is not sufficient in quantity to interfere with the action of the siphon or the proper action of the absorption drains.

18. There are other forms of septic tanks on the market, among which may be mentioned the **Nelson septic tank,** which is a continuous flow tank. This is made oblong with a rounded top; the bottom of the tank is placed about 5 feet below the frost line. The sewage from the building passes slowly through the tank and, after undergoing a decomposition of the organic matter, is discharged through a pipe to a point of disposal best suited to the existing conditions. The process in this, as in other septic tanks, is to hasten the natural decomposition and to liquefy all animal and vegetable matter as quickly as possible. The more that the solids are thrown into solution, the less will be the formation of sludge in the tank. The sewage thus freed from the solid matter passes from the tank in a continuous flow.

19. A form of siphon tank in common use for septic tank systems employs the **Miller automatic siphon,** and is shown in Fig. 5. The tank consists of two parts: A receiving or settling chamber *a*, and a liquid, or discharge, chamber *b*, in which the siphon is located. The siphon consists of two parts: A discharging limb, or deep-seal trap, *c* and the intake bell *d*, which is placed over the long leg of the siphon and held in place by its own weight. The sewage flows into the settling chamber through the pipe *e* at a point near the surface of the water, as shown. The liquid overflows into the discharge chamber *b* through the trapped pipe *f*. The water gradually rises above the edge of the bell *d* and compresses the air within the long leg of the siphon; the trap being filled with water, the air is prevented from escaping. As the water rises in the tank, the confined air gradually forces the water out of the trap until a point is reached when the air is just about to escape under the lower bend *j*. Since the difference of the water level in the two legs of the trap equals the difference of the levels between the water in the tank and the water within the bell, the column of water in the short leg *g* has practically the same depth as

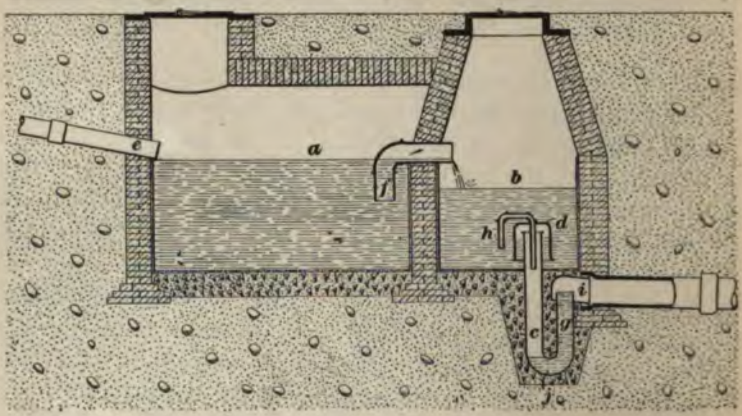


FIG. 5

the head of water in the tank, above the level at which the water stands in the bell. The two columns of water balance each other at a certain fixed depth in the tank, but as soon as this depth is increased by further supply of water, however small, a portion of the air confined in the long leg is forced around the lower bend. By its upward rush in the short leg *g*, this air carries with it a portion of the water, thus destroying the equilibrium, and the siphon is brought into full action, drawing the water out of the tank until it nearly reaches the bottom of the bell *d*, when the siphonage is slowly broken by the admission of air through the pipe *h*.

The operation is then repeated. The free projection *i* of the short leg of the trap allows the instantaneous escape or falling away of the heaved-up water. If the discharge mouth *i* were formed as an ordinary bend the siphon would not work, although the confined air rushed around the lower bend, for the reason that the heaved-up water would have no means of instantaneous escape, and, therefore, the equilibrium would not be sufficiently disturbed to set the siphon in operation. It will thus be seen that the action of the siphon depends not only on the escape of air, but also on the sudden reduction of pressure by the counterbalancing column of water in *g*.

ABSORPTION DRAINS

20. The pipe leading from the house to the tank and from the tank to the filter bed, or other point of outlet, may be of glazed tile, the joints being well cemented. The fall of the main drain from the tank, after coming within 20 feet of the absorption tile, should not be more than 1 inch in 25 feet. The absorption lines should have a fall of not more than 1 inch in 50 feet. If a greater fall is given, the sewage may be carried to the far end of the line, and, if the line is long, the sewage is liable to break out at the surface. The absorption drains are made of ordinary field tile 3 inches in diameter and 1 foot in length. They are laid in tile gutters,

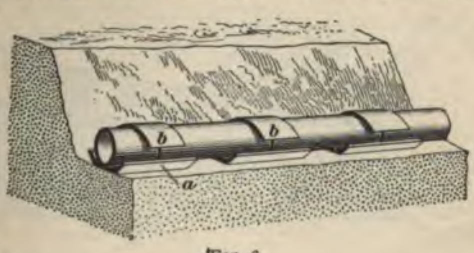


FIG. 6

as shown at *a*, Fig. 6; a ¼-inch space is left between each section of tile, the space being protected from the entrance of earth by a loose-fitting cover or cap *b*. The gutter and cap are made of a larger radius than the outside of the absorption tile, so that practically the whole joint is available for the escape of sewage into the ground. The gutters are laid about 12 inches under the surface of the ground.

21. The amount of absorption tile required in a reasonably porous soil is about 1 foot for each gallon of water discharged from the chamber. If the soil is heavy, the length of the tile must be increased.

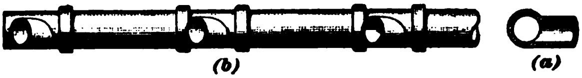


FIG. 7

Clayey soil is not suitable for subsurface irrigation, and should not be used, but when no better soil can be obtained, at least 3 feet of tile drain should be provided for each gallon in the tank.

22. In designing the absorption bed, the tile can be run in one continuous line, or a number of short lines may branch off from the pipe leading from the tank by using eccentric Y branch fittings, as shown in Fig. 7, placed about 3 feet apart.

STEPPED TRUNK LINES

23. When it is necessary or desirable to arrange the disposal field on a hillside, the distributing main, or trunk

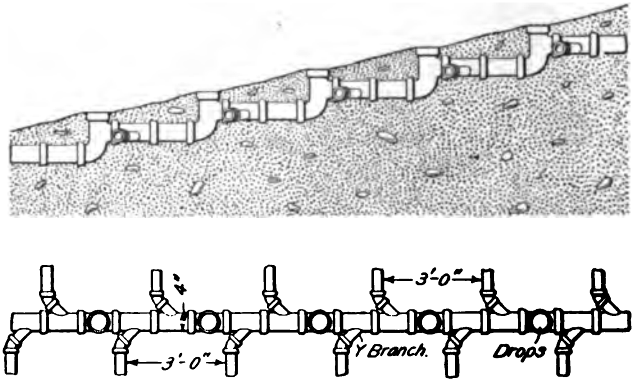


FIG. 8

line, where the field tile branches are taken off, cannot be laid to follow the natural surface of the ground, because at each discharge of the siphon the sewage would flow with great force directly to the lower end of the bed and burst through the ground. This difficulty can be overcome by stepping the drain, as shown in Fig. 8, by the use of special drops. The drops are of vitrified tile pipe made in one piece, having a hub and spigot ends. Between the drops are placed special drainage fittings or branches, which are made right-and-left. The bottom of the 3-inch branches for receiving the absorption tile are on the same level as the bottom of the trunk line itself. Thus, water flows as easily into the upper branches that supply the upper rows of field tile as it does into the lower branches, and a uniform distribution of effluent to all the field-tile lines is insured.

DISPOSAL FIELDS

24. Figs. 9 and 10 show two methods of applying a system of piping according to the variation of the ground. In Fig. 9, a septic tank located at *a* receives the sewage from the drain *b* leading from a large house. The irrigating or disposal field is located on a flat plot of ground. A 4-inch main drain *c* extends from the tank through the center of the bed, having extending from it, at intervals of about 3 feet,

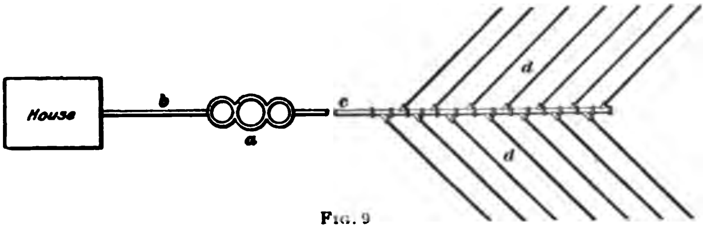


FIG. 9

Y branches, as shown, from which run lateral lines *d*, *d* that are made of 3-inch field tile laid 10 or 12 inches below the surface of the ground, supported on tile gutters, and covered with about 6 inches of stone, which permits a large volume of air to immediately attack the sewage, throwing off therefrom hydrogen and nitrogen, the nitrogen being absorbed by the roots of plants in the soil above. The surface being level, the branches are run straight, as shown.

25. In Fig. 10, the flush tanks receive the sewage from the house *a*; the house sewer *b* runs in a direct line to the septic tank *c*. At the point *d*, the main drain turns at an angle and has three outlets to be used alternately, the first, *e*, communicating with the parallel drains *f*, *f* at the bottom of the field; the second, *g*, runs parallel with *e* and feeds the two absorption drains *h*, *h*; the third, *i*, connects to the three lines *j*. These lines are made shorter, but they have the same aggre-

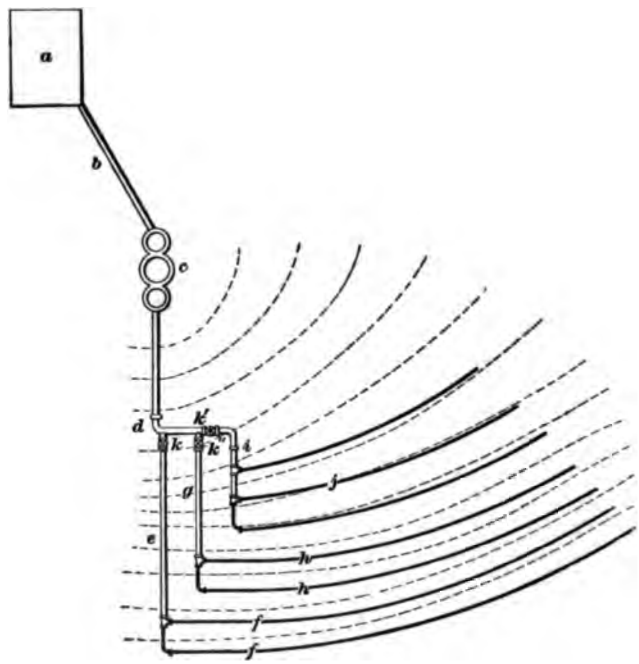


Fig. 10

gate length as the lines *h* and *f*. The house is located on a knoll or hill. The pipes are carried around the hill, to conform with the contours of the ground, in such a manner as to obtain the required downward inclination, that is, fall. The dotted lines show where the surface of the ground would be intersected by imaginary horizontal planes 1 foot apart; these lines serve to show which way the ground is inclined. The flow of sewage to each system of absorption drains is controlled by the gate valves k, k', k''. The septic tank can be placed any desired distance from the building, and the field may be located any distance from the septic tank when a proper fall can be obtained.

FIG. 11

26. A modification of the system shown in Fig. 10 consists in making the absorption tile larger and of horseshoe shape, and laying it in trenches filled with broken stone or coarse gravel. The capacity of the tile and the space between the stone should be large enough to receive the full contents of the tank. Figs. 11 to 13 show, in cross-section, horseshoe tiles laid in trenches and filled in with stone.

FIG. 12

27. In Fig. 11, the ground is of a porous and absorbing nature, and has a gradual incline, as shown. In Fig. 12, the under soil *a* is heavy and non-absorbing, and nearly level. The entire field is underdrained at *b*, *b*. The absorption bed *c* is made of gravel; low ridges *d*, *d* are formed over the tile, as shown. Purification takes place in the porous and well-ventilated material of the absorption bed. The clarified water sinks into the underground drains *b*, *b*, and is conducted to some convenient point of discharge. This arrangement is used for filtration of the effluent rather than for irrigation.

28. Fig. 13 shows, in cross-section, a filter bed located on a hillside. As the soil is composed of impervious material, such as clay, the surface is covered with coarse sand and gravel *a*. The bed is divided into sections by clay banks *b* underneath the gravel at the foot of each

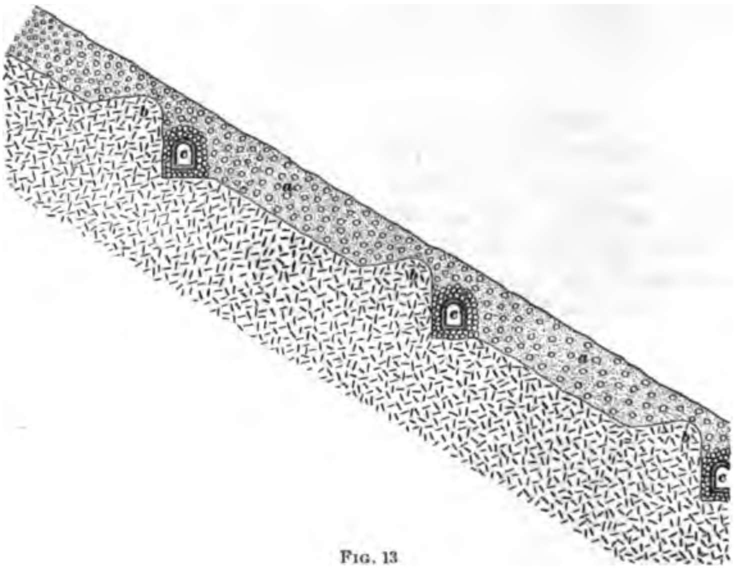


FIG. 13

section. The sewage is delivered into the tile and stone drains *c*, *c* at the upper part of each section, and thus becomes purified before it reaches the bank below, or is held by the bank until disposal by evaporation or by subsurface drains similar to those shown at *b*, Fig. 12.

29. Fig. 14 shows a subsurface sewage-disposal system for a number of buildings, in which there are a large dwelling, a house for the superintendent, several small cottages, shops, barns, etc.; also, a railroad depot. As the wells located

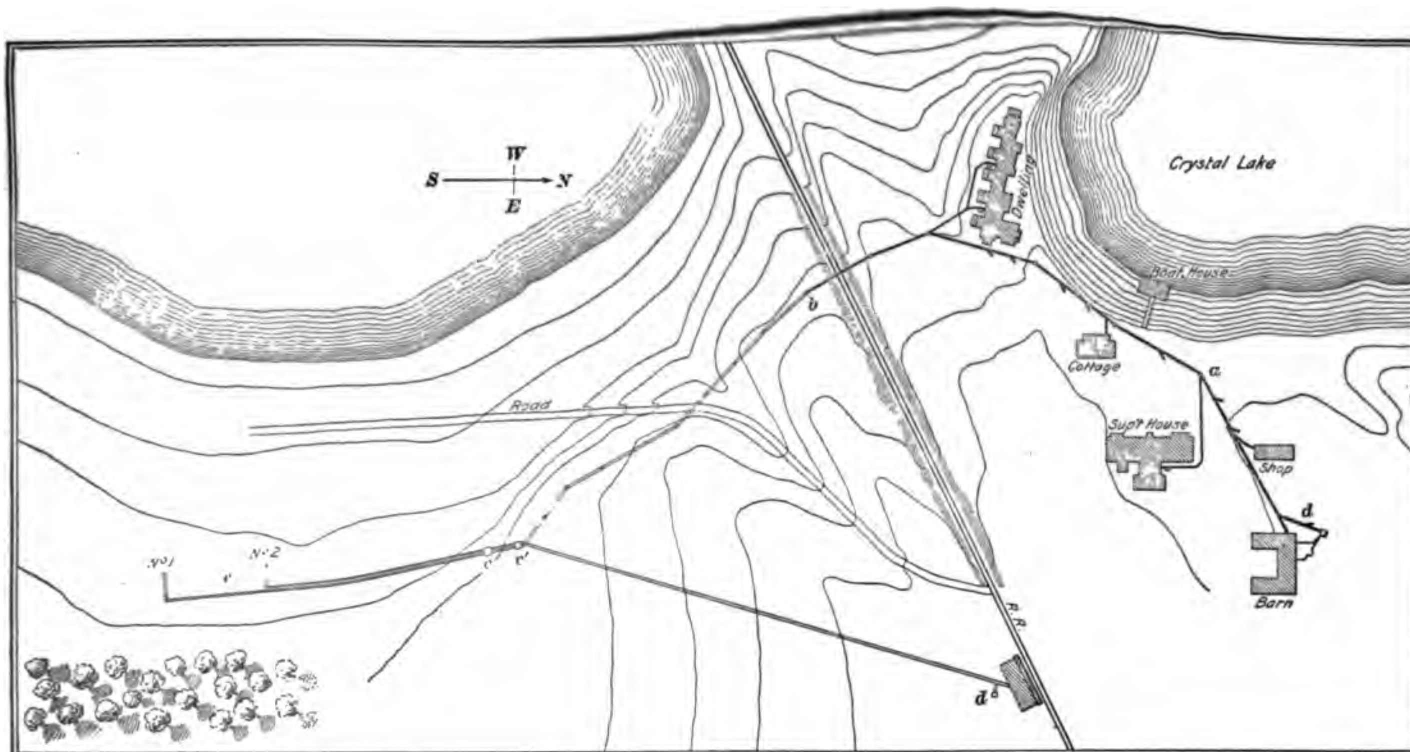

Crystal Lake
Dwelling
Boat House
Cottage
Sup't House
Shop
Barn
a
b
d
W
S
N
E
Road
R.R.
No 1
No 2

FIG. 14

near the superintendent's house supply the estate with water, the sewer, indicated by the heavy solid line *a*, near the buildings is made of extra-heavy 6-inch cast-iron pipe with calked joints. From the depot, and at a point *b* near the railroad, the pipe is continued to the disposal fields with glazed tile having the joints carefully cemented; this continuation is indicated by double light lines.

There are two disposal fields, marked *No. 1* and *No. 2*, each being supplied by a separate pipe joining the valve chamber *c*. The sewers are provided with manholes and lampholes at all changes in direction, to permit thorough inspection and ready removal of obstructions. The upper ends of the two sewer lines are supplied with washout connections at *d*, *d*, which are brought to the surface and sealed with a brass screw. By removing the screw, the sewer can easily be flushed with water from a fire-hose as often as required. The septic tank and two discharge tanks are located at *c′* from which the sewage is automatically discharged into subsurface irrigation beds, located on flat land at *e*. This land is composed of coarse sand and is located about 300 feet from the septic tanks. The disposal beds are laid out in duplicate, and the delivery to each bed is provided with gate valves, so that the dose can be turned on either bed at will. The valves in the valve chamber at *c* are so arranged that both tanks can be discharged into either pipe leading from the tanks to the disposal fields. By operating the valves in the chamber *c* and the valves at the disposal fields, the sewage can be discharged into either bed or distributed evenly under the entire surface of all the beds. The sewage is first turned into one-half of disposal field *No. 1*, Fig. 14, for 1 week; it is then turned into the other half of field *No. 1*, from there to one-half of field *No. 2*, and thence to the other half of field *No. 2*. With this arrangement of the beds and valves, each bed is allowed a period of rest, thus preventing the fields becoming saturated by the sewage.

30. Fig. 15 shows details of the tanks and the valve arrangements as they may be used in the system shown in

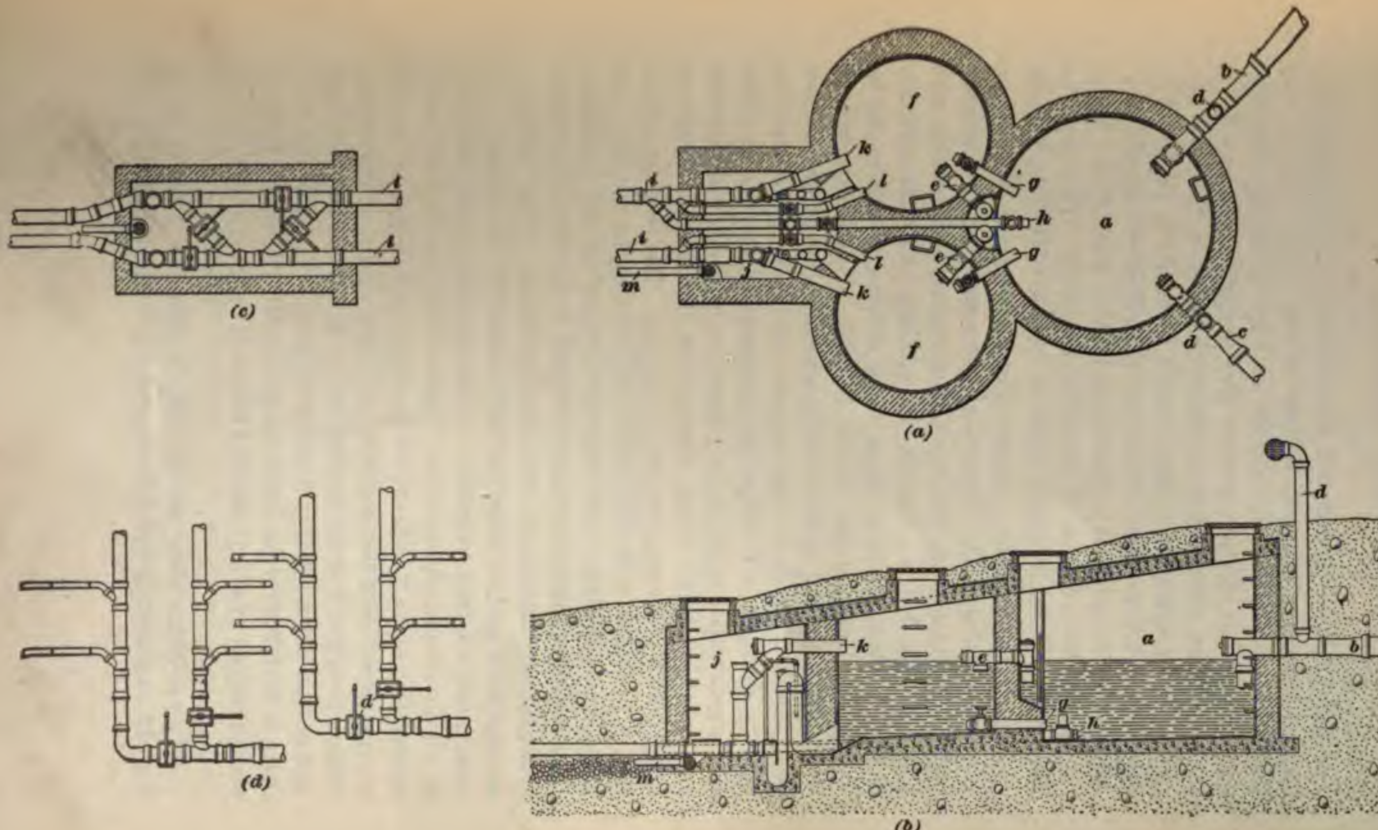


FIG. 15

Fig. 14; the tanks are shown in plan at (*a*) and longitudinal section at (*b*). The general construction is the same as that previously described and shown in Fig. 4, the chief difference being that this is a double arrangement. Sewage from the buildings enters the settling chamber *a* through the pipes *b* and *c*, a fresh-air inlet *d* being attached to each. The settling chamber is fitted with two 6-inch overflow pipes *e*, *e*, one leading to each of the discharge tanks *f*, *f*, which are sometimes called *flushing tanks* or *siphon chambers*. The depth of the water is from 3 feet to 3 feet 6 inches. Near the bottom of the settling chamber are two 3-inch pipes *g*, *g*, with a gate valve on each. These are used for emptying the settling tank into the siphon tanks when necessary. There is also a 3-inch pipe *h* that connects the settling chamber with the siphon discharge pipe *i*, so that the settling chamber can be drawn off direct to the disposal fields. But, to prevent *h* from being choked with the sediment that lies at the bottom of *a*, the inlet is taken from a point about 1 foot above the bottom through a **T** and nipple, turned up as shown. The settling-chamber ends of the pipes *e*, *e* are located in a recess or pocket, a screen being placed over the recess to prevent large solids from entering the pipes *e*, *e*. The settling chamber is provided with two manholes with tight covers; iron steps are built into the wall for access to the chamber. Each siphon chamber is provided with a perforated or ventilating cover, and steps are also provided. Two siphons, one for each siphon chamber, are located in the siphon manhole *j*, and a 6-inch overflow *k* connects each siphon chamber to the discharge pipes of the siphons. Each siphon chamber is connected by a 3-inch drain pipe *l* and gate valve to the discharge pipes from the siphons. All the drain, or emptying, valves are placed in the siphon manhole, and in case of leakage in this manhole it is drained separately by a 3-inch floor drain *m* that discharges into a blind drain. The concrete roofs are supported by steel rails, or I beams, as shown in Fig. 15 (*b*).

31. A plan view of the valve chamber located at *c*, Fig. 14, is shown in detail in Fig. 15 (*c*). The 6-inch pipes *i*, *i* are the discharge pipes from the siphons at the septic tank. They run through the valve chamber, which is built of brick, and are continued as straight as possible to the disposal fields. These pipes are cross-connected in the chamber and valved with four sliding-stem gate valves in such a manner that either or both of the siphons can discharge into either or both of the pipes that run to the disposal fields, according as the gates are opened or closed. In case of leakage into the chamber, it can be emptied through a 3-inch emptying pipe that discharges into a blind drain.

32. A detailed drawing showing the valves at the inlets to the disposal beds is shown in Fig. 15 (*d*). These valves are all quick-closing sliding-stem gate valves, which are better for such work than screw stem valves, because they work under a very low pressure and frequently must be closed quickly. The valves *c*, Fig. 15 (*d*), control field *No. 1*, and the valves *d* control field *No. 2* in Fig. 14.

The siphons are so arranged that they flush about every 12 hours, operating alternately every 6 hours. When one siphon is emptying, the other is about half filled.

CONTACT BEDS

33. Principles.—It is frequently necessary to purify the sewage effluent much further than it is possible to do in the septic tanks before the effluent can be allowed to discharge at the point of disposal. This is often necessary when the sewage enters a lake or creek. The principle of operation of the system used in that case is to aerate the sewage effluent and thus oxidize the putrescible matter that may still remain in the liquid. The oxidation is accomplished by the contact of the sewage with air. To properly accomplish the contact, the sewage liquid is allowed to flow into beds of broken stone that contain air. The liquid usually remains in the bed from 8 to 10 hours and is then drawn off and discharged at the desired point of disposal. The stones are then allowed to become aerated again while another contact bed is put into service. As the time for the contact is an important matter, it follows that the intervals of time between the discharges must be regular; hence, the siphon used to drain the contact beds should not only be automatic, but should go into action regularly at a stated time.

34. Time Siphon.—Fig. 16 (*a*) shows a plan view and Fig. 16 (*b*), a sectional view of one section of a filter bed provided with an automatic siphon, of the kind mentioned in the preceding article, for discharging the contents of the bed. This type of siphon is called a **time siphon.** The tank *a* is made water-tight and filled with granular material, to which the sewage is exposed for the purpose of producing bacteriological effect; the sewage is discharged from the septic tank (which should be located at a higher level) into *a*. The chamber *b* and the tank *a* are connected by a drain tile or underdrain *a'* laid at the bottom of the tank. This pipe allows the liquids to flow freely into *b*; this chamber is emptied by the automatic siphon shown, which, at the same time, draws all the liquid from the tank *a*. The siphon shown in Fig. 16 is composed of an intake bell *c*, the mouth of which is located near the bottom of the tank as shown, and a discharge leg *c'*, through which the sewage is discharged when the liquid seal in the trap is broken. The intake bell *c* surrounds the upper end of the long leg *c'*. The operation of the siphon is similar to that of the one shown in Fig. 5, excepting that instead of being automatically started by the head of liquid in the tank *b*, it is started by the head of liquid in a separate tank containing the time siphon *d*. The liquid is retained in the tank *b* a certain time after the tank is filled. The siphon in the tank *b* is so proportioned that the highest practical level of the liquid in *b*, in the usual operation of the system, will not start this siphon without the aid of the auxiliary siphon *d*. The operation of the auxiliary, or timing, siphon *d* is as follows: As the tank *a* gradually fills with sewage, the level of the liquid rises in *b* and consequently in the bell *c*. The air that is confined between the liquid and the trap thus prevents the discharge of the tank until the siphon *d* is set in operation.

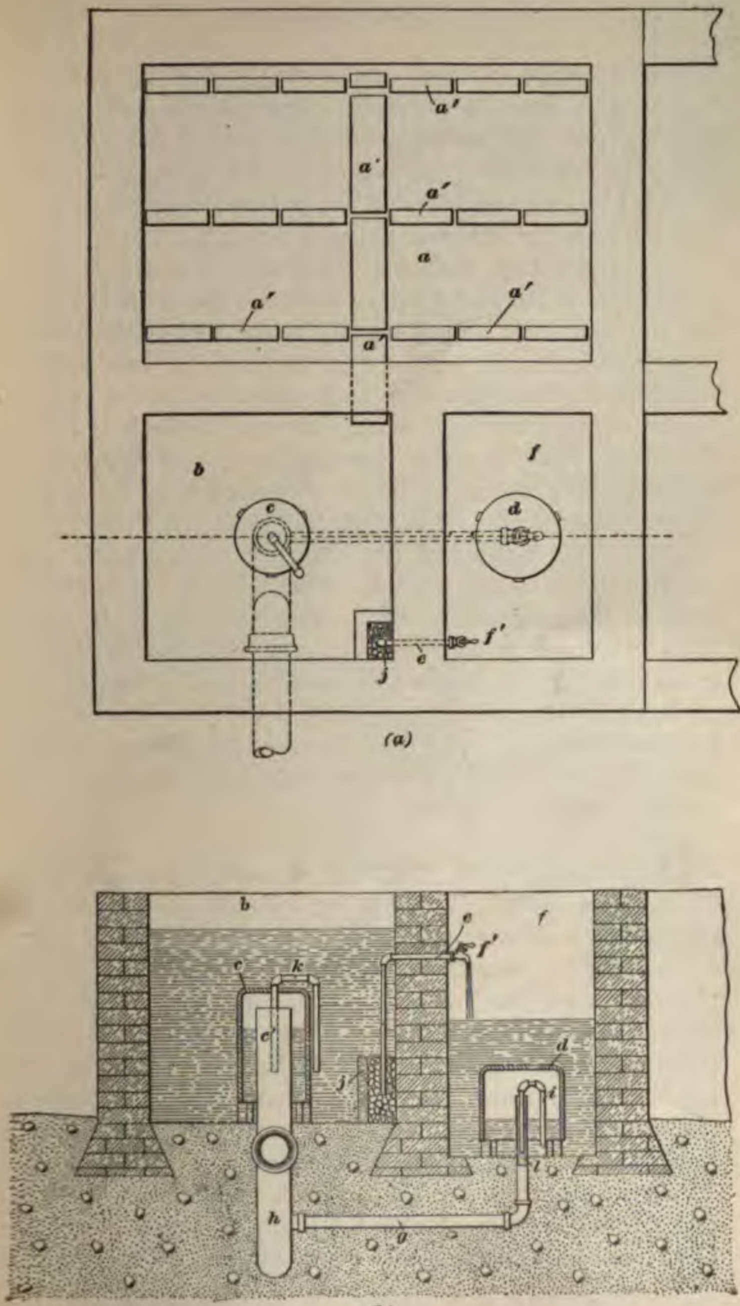


FIG. 16

When the liquid in *b* rises above the level of the pipe *e*, the liquid flows into the chamber *f* through this small pipe *e*, which is provided with a valve *f'* to control the flow of the liquid and the time required to fill the chamber *f*. Thus, the tank *a* may stand filled for a time, depending on the volume of water allowed to pass through *e* into *f*.

During the time that the chamber *f* is being filled, the liquid rises in the bell *d* and compresses the air in the siphon and the connecting pipe *g* leading to the trap *h*; the pressure thus produced in the siphon *d* continues to increase until it is sufficient to overcome the back pressure in the principal siphon in the chamber *b*, when the water in the long leg *l* of the time siphon is forced into the trap *h* of the principal siphon. After the water has been forced from the long leg of the siphon *d*, the pressure is sufficiently increased in the trap *h* to break the seal and start the main siphon, which empties the chamber *b*; at the same time, the time siphon *d* empties the chamber *f*, discharging into the main siphon. The siphonage is broken slowly by air entering the vent tubes *k* and *i*; this insures the trap remaining sealed when the siphons stop working. The inlet end of the pipe *e* is protected by a strainer *j* that prevents solid matter clogging the cock *f'*; the clogging of this cock would change the time elapsing between flushes.

35. Example of Multiple Contact Beds.—Fig. 17 illustrates a contact plant having separate contact beds, and an automatic discharging device for controlling the flow of sewage and to direct it alternately into each bed. In this plant there are four beds, of which three beds, marked *a*, *b*, and *c*, respectively, are shown. The fourth bed and the partition wall between it and the bed *c* have been omitted in the illustration, in order to show the construction of the beds and the automatic controlling devices. Each bed is made of brick and cemented water-tight; the walls are laid about 30 inches high, and the area of each bed is great enough to contain the sewage of about 6 hours' duration after being filled with broken stone to a depth of from 20 to 24 inches.

The sewage flows by gravity from the septic tank *d* through the inlet sluice *e* over the weir *f* inside the bell *g*, and then over the weir *h* into the inlet locking chamber *i*, compressing the air in the air bell *j* shown by dotted lines. As the sewage water rises in the locking chamber, the air pressure in *j* is communicated through the pipe *k* to an inverted bell over the outlet-gate weir *l*. The air pressure depresses the water in the bell, thereby lowering the water level below the outlet-gate weir *l* and thus preventing the flow of sewage from the bed. When the chamber *i* is full, the sewage overflows into the contact bed *c*.

When the contact bed is full, the sewage overflows into the locking chamber *m*, displacing the air in the air bell *n*. This air passes through the air pipe *o* to the top of the bell of the inlet sluice *g*, closing it. At the same time, air in the small air bell *p* is displaced and passing through the air pipe *q* releases the closed sluice gate in the filter bed *b*, unlocking the inlet and allowing *b* to take sewage from *e*. The sewage remains in the filter bed *c* until the timing chamber *r* has been filled through the timing cock *s*, shown dotted, which is set to give the desired time of contact. When the air in the small bell *t* is sufficiently compressed, it unlocks the seal of the outlet sluice and the effluent is discharged either to the river through the sewer pipe *u*, or to secondary contact beds in case a higher degree of purification is desired than can be obtained in the primary beds shown. The outlet sluice of *c* remains open until the three other contact beds have been filled, when the small bell in the inlet locking chamber of the last bed filled blows the seal of the release trap *v*, thus relieving the air pressure and again admitting sewage from *e* to *c*. The air supply to *n* is maintained through uncovering its bottom edge, the chamber *m* being siphoned empty through the siphon *w* every time the liquid is drained from the contact bed. The compressed air in the bell *g* cannot escape through *n* when *m* is empty, because the pipe *o* dips into the water on the sluice side of the plate *f*. The pipe *x* leading from the release trap *v* connects to the top of the bell *g*. The pipe *y* connects the inlet end of the release trap to the bell in the inlet locking chamber of the bed that is not shown.

36. In the illustration, the bed not shown may be assumed to be in contact, that is, full; the bed *c* receives the flow of sewage and is filled nearly to the locking level; the bed *b* has been resting and aerating and is ready to receive its next dose; the bed *a* is also resting empty, the sewage not removed at the first flow draining slowly through the outlet sluice that remains open until the next filling.

SOURCES OF WATER SUPPLY

NATURAL SOURCES

INTRODUCTION

GENERAL INFORMATION

1. The sources of potable water supply may be broadly divided into *natural* and *artificial sources*, the dividing line between the two not being sharply drawn, however. Custom classifies wells, springs, streams, rivers, lakes, and rain as natural water-supply sources, and limits the application of the term artificial source to large reservoirs built by the hand of man, the reservoirs drawing their supply from the natural sources.

A supply of potable water can be, and in a few instances is, produced on a small scale by the distillation and subsequent aeration of water normally unfit for drinking, cooking, and other domestic purposes, such as sea-water; a water supply thus obtained is, truly speaking, an artificial one.

Reservoirs, when the topographical and other conditions permit it, are located above the level of the city, town, village, or buildings they supply, in order that the water drawn from these may flow through the mains by gravity; in many cases, however, reservoirs must be located at such a low elevation that the water must be pumped from them to its destination. Whenever possible, the location of a reservoir is also so chosen that it will receive its water supply from the natural sources by gravity; should conditions prohibit such a location, the water must be pumped from its source to the reservoir.

In cases where it is necessary to pump the water to a city, etc., either from a reservoir or from natural supply sources, it is the usual practice to have the pumps deliver their water into one or more stand pipes erected in suitable locations. These *stand pipes* are simply vertical cylindrical tanks open at the top and of a height depending on the maximum pressure required in the distributing mains; the water flows by gravity from the stand pipes into the mains. The employment of stand pipes relieves the distributing mains of the undue pressure and stresses they are liable to be subjected to at times if the pumps delivered the water directly into the mains.

WATER-SUPPLY CONTAMINATION

2. The necessity for securing a good wholesome supply of water and safeguarding it in every possible way to maintain its purity, cannot be overestimated when it is considered that drinking water is the source of most of the disease epidemics now prevalent. Numerous instances can be cited where epidemics of cholera, typhoid fever, and malaria were traced directly to an infected water supply.

3. Spring waters, also artesian-well waters, usually come from a great distance and have lain in the ground for a considerable period of time; filtration of the waters through the earth, together with the germicidal action of time, usually clears such waters of all impurities, except certain harmless minerals dissolved from the strata through which they have percolated. Almost invariably such waters furnish a wholesome water supply.

4. Well waters, particularly in densely populated districts, should always be regarded with suspicion, and, if cesspools or outhouse privies are conditions of that neighborhood the waters should not be used unless a chemical and bacteriological examination has shown the waters to be wholesome; even then it is better not to use the waters, for as long as the source of danger exists there is a liability of the pollution working its way to the wells and contaminating the waters.

5. Lake and river waters are seldom free from contamination. Cities, villages, and country dwellings along the shores may pour their sewage into the waters, and the surface washings from the adjacent territory is added to the filth of the already polluted stream or lake. Formerly it was believed that running water purified itself and that a few miles below a source of pollution the water would be fit for use again; investigation, however, has disproved this hypothesis. It is now known that running water only affects a partial clarification by dilution, and that within 20 miles of the source of contamination slow-running river water should not be used, while with swift-current rivers the minimum limit should be 30 miles. Even then waters from an acknowledged contaminated source should not be used without previous filtration. Lake waters are clarified much quicker than river waters; in still lake waters, free from currents, the range of pollution is usually confined to the vicinity of the sewer outfall. Sedimentation is the chief factor in clearing lake water of sewage. The large particles fall to the bottom, and in falling carry with them smaller particles with which they come in contact, thus effecting a still further clarification.

6. From whatever source water is derived, it should never be adopted for domestic supply without first being subjected to a chemical and bacteriological examination. When an examination of water is to be made it is better for the analyzing chemist or his assistant to collect the samples himself, and every opportunity should be given him to study the conditions surrounding the source of supply, as it will enable him to more intelligently interpret the analysis on which is based his report.

If samples of water are to be sent to a chemist for analysis, great care should be exercised to see that the collecting vessels are thoroughly sterilized before they are filled with water. It is customary to use for sample jars, jugs of glazed earthenware or glass bottles of 1-gallon capacity, sealed by glass stoppers. Accompanying the samples should be a minute report of the conditions surrounding the water at the time of obtaining the samples.

7. Shallow wells are liable to contamination in many ways; the principal sources of contamination, however, are leachy cesspools, privy vaults, and defective sewers. Fig. 1 shows how a well can be contaminated from a leachy cesspool. The cesspool *a* is extended down to a porous stratum of sand also pierced by the driven well *c*. The walls of

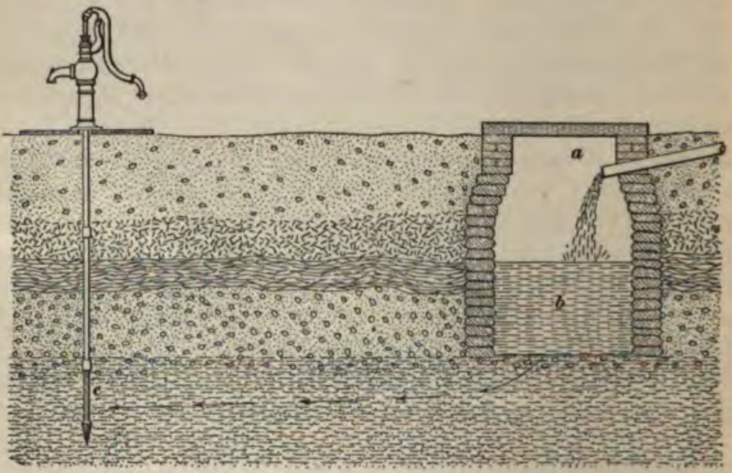


FIG. 1

the cesspool are lined with stones laid without mortar, so that sewage at *b* can escape to the soil and the liquid portions leach away. But in doing so they follow the natural slope of the stratum to the well and are pumped out again in a diluted form in the water drawn for domestic use.

8. Wells are sometimes contaminated by sewage from defective sewers passing near by. When necessary to run sewers close to wells, cisterns, springs, or other sources of water supply, the sewer should be constructed of iron pipe, and the joints made perfectly water-tight. Another source of contamination of wells is around the top; they are often covered with planking laid with wide cracks between the board. Filth of various kinds is then washed into the well by the waste water from the pump. The top of a well should be elevated above the surrounding earth and should be covered with a broad flat stone, so that all waste water from the pump will be carried some distance away and cannot again enter the well without passing through several feet of earth.

When it is suspected that a well is being contaminated from a cesspool or privy vault, the truth can be determined by emptying into the suspected source of contamination a large quantity of salt water. If within a reasonable length of time, varying from a few hours to a few days, depending on the distance of the well and density of the ground, the well water shows, by taste or by chemical examination, an amount of chlorine over the normal it will be almost conclusive evidence that the suspected well is being contaminated.

SUPPLY FROM WELLS

OPEN SHALLOW WELLS

9. Country buildings and institutions are seldom so situated that water mains can be conveniently extended from the nearest city system to them. Therefore, in the absence of a spring, stream, or lake on or near the premises, resort is usually had to wells for the supply of water. The simplest form of well is an **open shallow well,** shown in section in Fig. 2. It consists of a circular pit *a* dug vertically into the earth several feet below the level of ground water. Its sides are usually lined with stones *b* or brick laid dry (that is, without mortar) and the top is covered water-tight with a flagstone *c* or arched over with brick laid in cement mortar. The earth should slope from the mouth of the well to prevent surface water entering and contaminating the water.

In localities where ground water is low, being more than 12 feet from the surface, shallow wells usually provide a wholesome supply of water if there are no cesspools or privy vaults near to contaminate them. Where the ground water is high and the soil saturated with water, sufficient filtration does not take place before the surface water reaches the well, and water from shallow wells in such localities, while abundant, may not be wholesome.

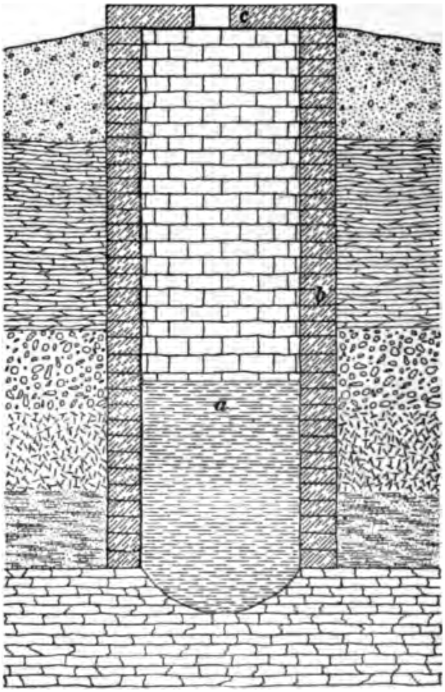


FIG. 2

OPEN DEEP WELLS

10. The only real difference between open deep wells and open shallow wells is the greater depth the former must be extended to tap water-bearing strata. **Deep wells** are usually lined above the water level with curved bricks to withstand the pressure of the earth and prevent the walls from caving in. Wells of a greater depth than 25 feet may be considered as deep wells; when less than 25 feet deep they are shallow wells. Both open deep wells and open shallow wells derive their supplies principally from rain water that falls in the immediate neighborhood and percolates through the porous strata to the water vein.

ARTESIAN WELLS

11. An **artesian well**, in its true sense, is a spouting well bored down to a deep-water vein within which there is sufficient water pressure to force the water out at the surface.

The term artesian well is also applied to any deep well that is bored through an impervious stratum to a water-bearing stratum below the impervious one.

The supply of water for artesian wells is usually derived from a distant source and conducted between impervious strata of rock or clay to the point of interception. In Fig. 3 is shown an artesian well *a* that derives its water from a porous stratum *b* outcropping on the farther side of a mountain range. Water falling there on the stratum *b* becomes confined between the impervious strata *c* and *d*, and at various points of the stratum *b* has a hydrostatic head, depending on the local conditions, the maximum head being in each case

FIG. 3

the vertical distance to the overflow line *e*. When the porous stratum is tapped by a well below the overflow line, as at *a*, water flows from the mouth of the well, or if confined in a tube will rise to the level of *e*. If a well were bored to the porous strata at *f*, water would rise in the pipe but would not overflow. Strictly speaking, only a flowing well can be called an artesian well, but the term is generally used to designate all wells that derive their water from a distant source through the water veins that run under strata of clay, hard pan, or rock.

Artesian wells may be shallow or deep, the depth depending entirely on the formation of the ground.

BORED WELLS

12. Wells that are to be extended to a great depth in the earth, or that are to be sunk through rock, are usually bored and the walls lined with iron pipe. A **bored well** is shown in Fig. 4. When the casing *a* has been extended to the water-bearing stratum sought, a dynamite cartridge is sometimes exploded at the bottom of the well to excavate the cavity, or reservoir, *b*. This is resorted to, however, only when the water-bearing stratum is so dense that water does not percolate through it sufficiently fast to supply the pump. The casing pipe *a* forms the wall of the well only. It is never used as a suction pipe for the pump. The pump *c* containing the pump bucket is lowered inside the casing *a* to near the water, and has a suction pipe *d* fitted at its lower end with a strainer *e* and a foot-valve. The pump rod *f* is located inside the discharge pipe *g*. Since the pump is generally of the single-acting type, it is advisable to fit a large air chamber *h* to the discharge pipe. To inspect, renew, or repair the pump parts, the pump, etc. must be raised out of the casing.

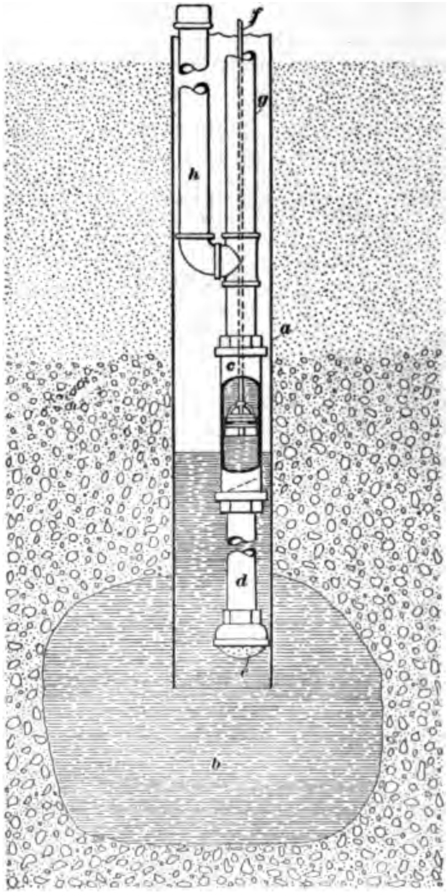


FIG. 4

In Fig. 4 the plunger of the pump works inside the barrel, or cylinder, *c*, the valve that holds up the water being at *d*. This pump will freeze and burst if exposed to frost.

Bored wells have been carried to a depth of over 6,000 feet.

DRIVEN WELLS

13. A good type of well for loose soils is shown in Fig. 5; it is known as a **driven well.** This type of well consists of a suction pipe *a* driven into the earth until the *driven-well point b* reaches ground water or taps a water-bearing stratum of gravel or sand. The points cannot be driven through solid rock, and only with great difficulty through hard pan. Considerable trouble is experienced in driving wells through soil that contains stones and boulders. In loose sandy soil, the wells can be driven to a depth of 75 feet, and under favorable conditions they can be driven even deeper, while in a more dense soil 50 feet might be the limit. A driven-well point is a perforated piece of pipe covered with a fine-mesh brass-wire screen, which is protected from being torn off by a perforated sheet-brass covering. The perforated pipe is screwed into a cast-iron point. This driven-well point is driven into the ground at

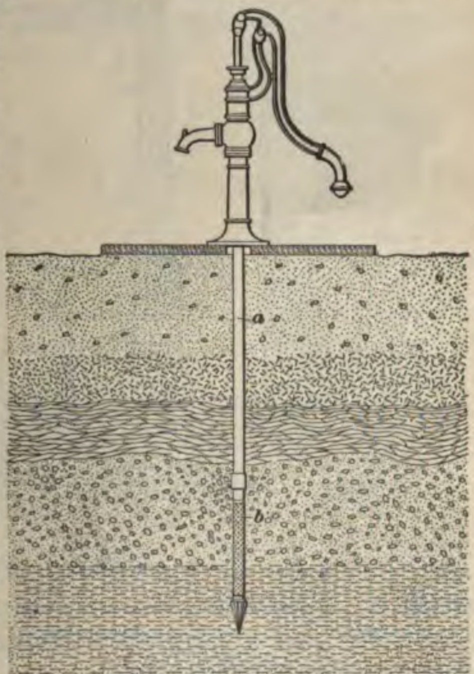


FIG. 5

the place the well is to be located. A short length of pipe is then screwed to the threaded end and the point is driven until the second piece of pipe is almost level with the ground; another piece of pipe is then screwed on and driven downwards. This operation is repeated until the point reaches the desired depth. The pipe is driven by the blows of a sledge hammer, a cap having first been screwed to the

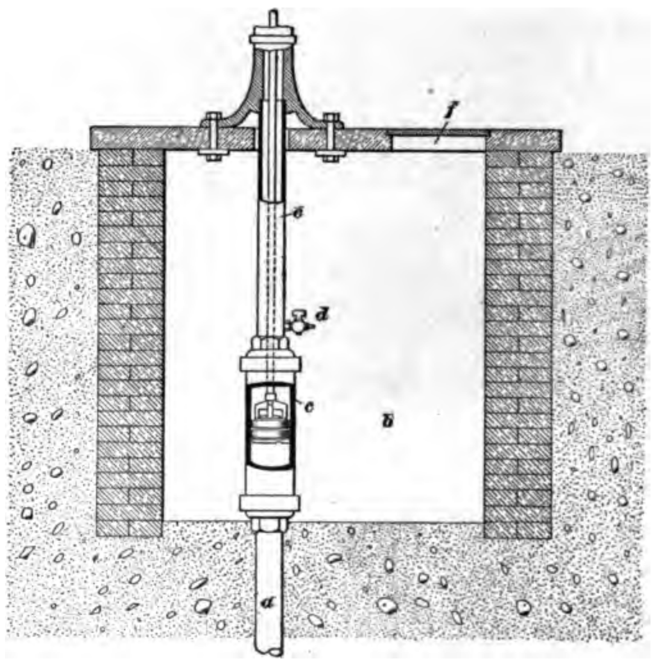


FIG. 6

end of the pipe and a piece of wood placed on the cap to receive the blows, to prevent battering the end of the pipe out of shape.

14. An **antifreezing pump** is one that cannot be frozen, and is therefore suitable for outdoor service in cold climates. In this type the piston and pump cylinder are located in a pit under the discharge end of the pump, as shown in Fig. 6. The suction pipe *a* terminates at the bottom of the pit *b*. The pump cylinder *c* is screwed on *a* and must be located deep enough to be away from frost, usually 4 or 5 feet. A petcock *d* is tapped into the side of the discharge pipe just above the cylinder. This cock is kept closed during summer and the water consequently stays up in the discharge end, but during winter it is opened and then drains water from the discharge pipe *e* when the pump is not being worked. The bottom of the pit being porous, the waste water soaks away freely. A manhole plate *f* is placed in the pit cover for access to the pit.

15. When a greater supply of water is required than can be furnished by one driven well, a battery of wells may be driven, as shown in Fig. 7. Each well *a* should be con-

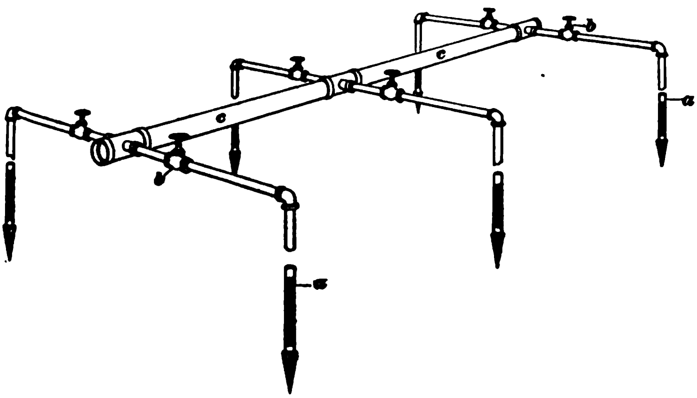


FIG. 7

trolled by a valve *b* placed close to the main suction pipe *c*, so that any well in the battery can be cut out for alterations or repairs. The wells should be spaced at least 20 feet apart, so as to be outside the zone of influence of one another. Driven wells are usually made of galvanized iron and the pipes are seldom over 2 inches in diameter, being usually 1¼ inches or 1½ inches. The method shown in Fig. 7 is commonly used in connecting large pumps to driven wells.

SUPPLY FROM SPRINGS

GRAVITY SUPPLY

16. A wholesome and abundant supply of water can usually be obtained from a spring when there is one located on the premises. This water is usually obtained from a source similar to that of artesian wells; in place of flowing from a bored opening in the earth, however, spring water follows a fissure to the surface, where it bubbles forth.

All spring waters are not suitable for domestic purposes. Some are so strongly alkaline that they cannot be used at all; others are saline and, while suitable for bathing and for flushing fixtures, cannot be used for potable or culinary purposes. Waters from sulphur springs are useless for domestic purposes, and some waters are so hard that they cannot be used.

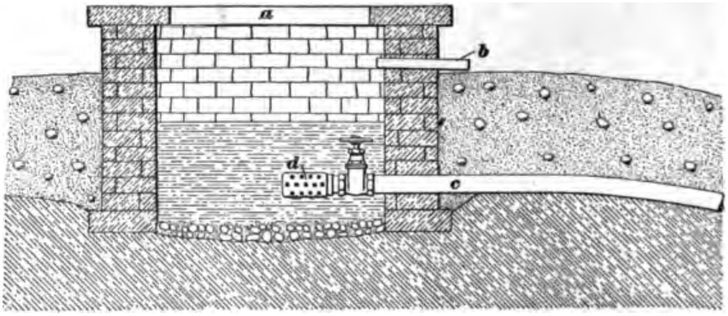


FIG. 8

17. In order that spring water may be piped to a building, there should be constructed at the springs a reservoir that will store sufficient water to balance fluctuation due to unequal drafts at different hours of the day.

The manner of constructing a storage reservoir at a spring is shown in Fig. 8. The wall *a* confines the springs, and, when water is not being drawn, it rises to the level of the overflow pipe *b*. The house-service pipe *c* enters the reservoir near the bottom, and is provided with a large perforated strainer *d* to prevent the entrance of anything but water to the service main.

If the spring is at such an altitude that the head will cause excessive pressure in the building, or if the consumption of water nearly equals the supply, a storage tank should be provided at the building. This not only reduces the pressure of water in the distributing system of pipes in the building, but will also store the night flow of water from the spring, which will be required during the day. To protect the spring from contamination by leaves, birds, animals, or people, a house should be built to enclose it. Besides protecting the spring from contamination, the house will also help to prevent the water from freezing during winter or becoming warm during summer. If the house is made dark inside, it will prevent, or check, the growth in the water of Algæ or other disagreeable forms of water vegetation.

SIPHONIC SUPPLY LINES

18. It is always advisable to run water pipes from springs so that they will pitch toward the building the entire length of the line. This allows air to escape from the piping at the spring. It frequently happens, however, that a hill is located between the spring and the building.

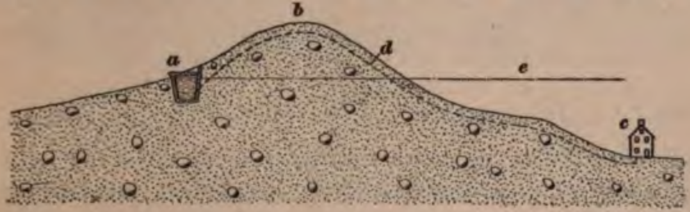


FIG. 9

If it will cost too much to dig deep enough through the hill to give the pipe a gradual pitch to the building, then it is necessary to lay the pipe in the form of a siphon, and hence the part at the hill will be higher than the water in the spring.

Fig. 9 shows a **siphonic supply line** that conveys water from the spring *a* over the hill *b* and down to the building *c*, the underground pipe being shown by the dotted line *d*. The dot-and-dash line *e* is an imaginary line drawn level with the surface of the water in the spring. The greatest height that the pipe *d* can be run above *e* is from 25 to 30 feet, according to the height of the spring above sea level. Generally, it is not advisable to make this distance

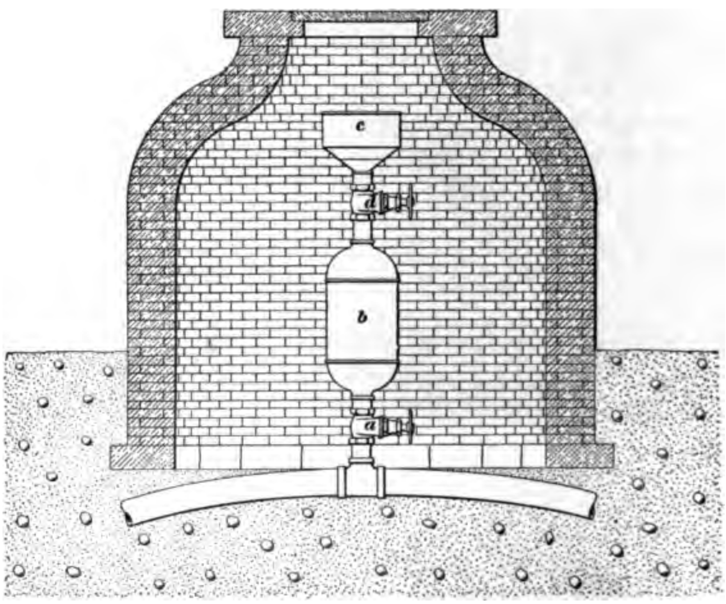


FIG. 10

more than 25 feet, because the pressure of the water at the highest point is so low that air readily enters the pipe and breaks siphonage.

The actual head that produces the water pressure in the building is the vertical height between *e* and the building, and in computing the volume of water that will be discharged at the building this is the head that must be considered.

If the air is not removed from the pipe it will impede, and finally stop, the flow of water. The system is then said to be ***air bound***, or, the siphonage is said to be ***broken***.

The discharge end from a siphon line should be submerged in water in the tank or reservoir it supplies. This will prevent air entering the mouth of the pipe when the service is not flowing full. To start a siphon, the pipe must first be filled with water; this may be done by filling the pipe through a valve at the highest point in the line, or the air may be forced from the line with water by an ordinary house pump. If the pipe line is not perfectly air-tight above the level of the line *e*, air will enter the pipe, accumulate at the highest point, displace the water, and prevent a flow of water through the line. It does not require much air to fill the bore of the pipe, and a very small leak will stop siphonage entirely in a few days. To extend this time, an air accumulating chamber may be used, if it is impossible to find the leak and remedy it.

An air chamber suitable for siphon lines is shown in Fig. 10. The manner of operating it is as follows: The valve *a* is closed and the chamber *b* filled with water through the funnel *c*. The valve *d* is then closed, the valve *a* is opened, and the air chamber is ready for service. As air accumulates in the top of the siphon line it displaces water from the chamber until it is entirely empty. The chamber must then be filled again with water. Air chambers should be located within manholes, for easy access and to protect them from frost. Lead pipe is less liable to air leakage than iron pipe, and in this respect is more suitable for siphon lines.

SUPPLY FROM STREAMS, RIVERS, AND LAKES

SUPPLY FROM STREAMS

19. The manner of supplying buildings with water from small streams depends greatly on the size of the stream and whether the stream dries up during periods of prolonged drought. If a stream occasionally dries up, a reservoir should be provided in which to store sufficient water to maintain a good supply during droughts. When, however, the stream can be depended on always to furnish an adequate supply no reservoir will be required. To guard against damage from ice, flood, or fish, the intake from a small stream that is free from mud should be located as shown in Fig. 11. The intake strainer *a* should be placed in a clean perforated keg *b*, sunk below the bed of the stream *c*. A strainer so

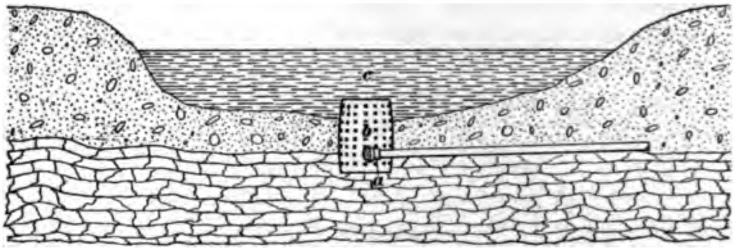


FIG. 11

located will not only be safe from frost and floods, but it will be well supplied with water as long as any flows through the stream.

20. The usual manner of building a reservoir is shown in Fig. 12. The sides of the reservoir are built at an angle, or slope, of 1 foot on the vertical run to at least 2 feet on the horizontal run. The bottom and sides are puddled with about 12 inches of good clay to make the reservoir water-tight, and the sloping sides are covered with brick or concrete pavement to protect the walls from the abrasion of ice. An overflow *a* formed with good solid masonry is generally made

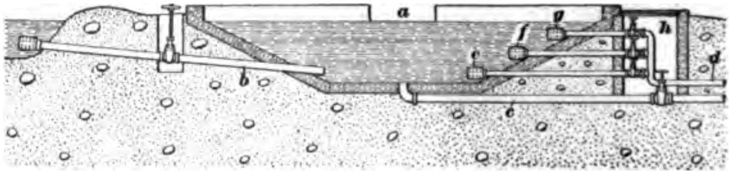


FIG. 12

large enough to discharge four times the quantity of water that can enter the inlet pipe *b*. This extra capacity allows for the probability of the overflow sometimes being partly filled with ice. An emptying pipe *c* connects with the bottom of the reservoir and discharges into the stream at a point lower down. This pipe should be of large capacity, so that the reservoir can be quickly emptied and cleaned.

The supply main *d* from the reservoir to the buildings is provided with three intake strainers, *e*, *f*, and *g*, so that by manipulating the valves shown in the manhole *h* water can be drawn from different levels in the reservoir.

SUPPLY FROM RIVERS

21. Water supply from rivers, while generally inexhaustible in quantity, is not always of the best quality. This, to a certain extent, can be remedied by carefully selecting the point of intake. One manner of locating an intake is shown in Fig. 13. With this method, the supply of water is not obtained from the river proper, but from an infiltration gallery *a* built parallel with the river *b*, so as to intercept ground water flowing toward it. The advantages

FIG. 13

of locating the intake *c* in this manner are: (1) that the water is purified by passing through the soil; (2) the water is not liable to be contaminated by sewage deposited in the river; and (3) the intake cannot be damaged by frost or flood.

When a water supply is taken directly from a river, the intake should be placed above the buildings, to avoid the surface drainage from about the premises that will enter the river, even if the sewage does not. Care should be taken to locate the intake at that point which will give the purest water at all times. It should be placed in a good strong crib of masonry that is capable of withstanding torrents and ice; and the crib should not be placed in an eddy or in shallow water at one side of the river, since matter in suspension is apt to collect there. Should there be an enlargement that may be likened to a lake or pond in the river near the buildings to be supplied, the crib should be located below rather than above it, unless there is danger of additional pollution at that point. The intake strainer

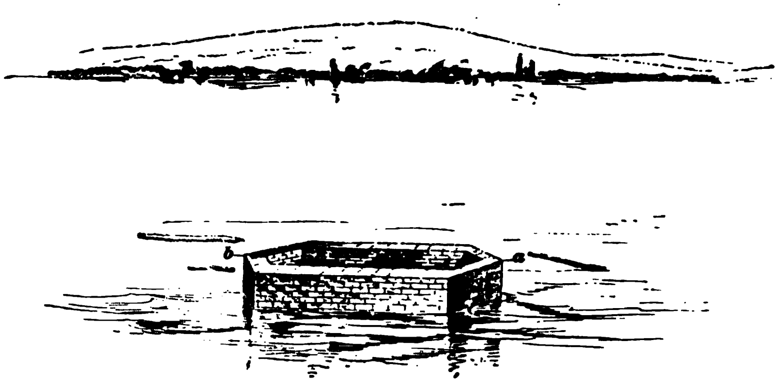


FIG. 14

should be at least 2½ feet below the lowest surface of the water and at such an elevation above the bottom that sand or silt cannot enter the suction pipe.

22. That portion of a suction pipe that extends into the water can be made up and lowered into place from rafts anchored on the river. If the suction pipe is of small diameter, wrought-iron pipe may be used, as it is sufficiently flexible to allow for the spring incident to lowering the pipe to the river bottom. If, however, the suction pipe is of large diameter, a pipe with flexible joints should be used; this allows the pipe to adjust itself to the river bottom without undue stresses on any part of the line, and permits it being made up on rafts and lowered into place.

23. A crib in which to locate an intake is shown in Fig. 14. The ends *a* and *b* point, respectively, up and down stream. The upper end is pointed so as to offer but slight resistance to floods or floating ice and afford but a small lodging place for logs, trees, and other floating matter; it also prevents the formation at this point of sand or mud bars. The down-stream end is pointed so as not to form eddies, which would retain mud and floating material coming within its influence.

24. Cribs should be built of brick or stone masonry laid in Portland cement, or, they may be made of Portland-cement concrete. Openings should be left in the walls on the lower end and sides, below water level and extending to near the river bed. The inlet openings should be fitted with sliding screens to keep out fish and other matter. Sometimes, cribs are covered and pumping machinery is installed in a house built over the crib. It is the more common practice, however, to install the pumping machinery in a pump house built on the river bank; the pumps then take the water from the crib and pump it into a reservoir, stand pipe, or directly into the mains, as conditions require.

SUPPLY FROM LAKES

25. Water supply from lakes must be selected with great care, since the water is liable to contamination by people living on its shores. If a city disposes of its sewage into the lake, additional care must be exercised to locate the intake at the point least liable to contamination from the sewage. The proximity of picnic grounds, burial grounds, drives, and cultivated fields must also be considered as possible sources of contamination, and the intake located as far as possible from such places.

The supply from lakes should be taken from deep water subject to currents. It is desirable to place the intake at the lower end of a lake near the outlet, as the shallow still water is usually at the upper end. The intake should be placed in or near the channel and on the side of the main current opposite to the outlet of any sewers, or the mouth of polluted streams, discharging into the lake. When a spring that feeds the lake is convenient, the intake should be extended to the bottom of the lake near the spring hole.

ROOF-WATER SUPPLY

ADVANTAGES AND DISADVANTAGES

26. In many localities, the ground water from wells is so impregnated with minerals as to render it unfit for domestic purposes. In other localities, where the ground water is *hard*, that is, contains carbonates or sulphates of lime, it may be used for some domestic purposes, but is very unsatisfactory for laundry work and bathing. Under such conditions it is customary to construct cisterns in which to store rain water, and connect the cisterns so that they will fill from the water that falls on the roofs of the buildings. In many cities that are supplied with hard water from the city mains, cisterns are installed and the rain water from the roof stored, so that the buildings can be supplied with both hard and soft waters.

Buildings that are to be supplied with rain water should be provided with roof gutters to confine the water, and leader pipes to convey it to the storage tank. When a house tank is located in an attic, the leader pipe may be run from the roof gutter direct to the house tank, and an overflow pipe extended from the house tank to an underground cistern, so that water overflowing the house tank during rain storms will not be wasted. This method of filling the house tank with water saves pumping, but is open to the objection that the dirt is washed from the roof during the first part of a storm and discharged immediately into the house tank without an opportunity for sedimentation to clarify it. The amount of street dust that is blown on a roof and afterwards washed into a cistern is much greater than is commonly supposed; excrement of birds, fallen leaves, and mossy growths also add their impurities to the waters collected from this source. In the vicinity of manufacturing cities, various products of combustion and of industrial waste are added to the other impurities on a roof and are washed off during the first part of every storm. This dirt gathers on the bottom of the cistern, and is apt to contaminate the water by the decay of some of its constituents.

UNDERGROUND CISTERNS

27. Rain Leaders.—The leaders that conduct waters from buildings to **underground cisterns** should be constructed of some material that will not affect the waters flowing through them. Iron pipes are quickly corroded by rain water, and then give off a red oxide of iron that discolors clothes and stains kitchen and tableware. Lead pipes are slightly dissolved by rain water, and then give off a poisonous solution of lead salts. The best material for underground rain leaders is salt-glazed earthenware pipe laid with Portland-cement joints.

Fig. 15

To allow water from the roof surface to run to waste during the first 5 or 10 minutes of a storm, and also to turn water off when the cistern is full, a **leader cut-off**, shown in Fig. 15, is generally used. When the disk *a* is in the position shown in the illustration, rain water from the roof is turned into the branch *b*, which discharges to waste. After the roof is sufficiently cleansed by the rain, the wire handle *c* is raised parallel with the leader pipe and locked in the clamp *d*. The disk *a* is then in an upright position and confines the water to the leader *e*, which discharges into the cistern.

28. Construction and Capacity of Cisterns.—Underground cisterns for the storage of rain water are usually made of brick laid in Portland cement, and plastered on the inside with a good coat of Portland cement $\frac{3}{4}$ inch thick.

An overflow pipe from a cistern should never connect to a cesspool or sewer. If it cannot discharge to the atmosphere, it is better to have no cistern overflow but provide a cut-off, so that when the cistern is full all surplus water can be run to waste.

Where rain water is depended on as the only source of supply, the cisterns should be large enough to store sufficient water to tide over the longest period of drought likely to prevail in that locality. Should the locality be subject to rains only during certain seasons of the year, cisterns should be made sufficiently large to store all the water that falls on the roof surface during such periods. If the average rainfall during the rainy season is known, then the capacity of a cistern can be determined by multiplying the area of roof surface, in square feet, to be drained by the average rainfall, in feet, during the rainy seasons. Thus, if the average rainfall is 12 inches, that is, 1 foot, and the roof of a building is 40×60 feet, the required capacity of cistern is $40 \times 60 \times 1 = 2{,}400$ cubic feet.

29. Aeration of Cistern Water.—Water standing in a cistern stagnates and sometimes gives off offensive odors, due to the decomposition of organic matter carried into the cistern by the rain water. Could the water be thoroughly stirred and aerated daily, it would be more fit for the uses to which it is put. A simple means of aerating the water is by using a special form of pump, known as an **aerating pump,** for pumping the water from the cistern; this type of pump mixes air with the water being pumped. There are many forms of aerating pumps in use, of which the most common are the so-called *bucket*, or *chain*, *pumps*. These have little cup-shaped buckets attached to an endless chain that passes around and is operated by a sprocket wheel. The lower loop of the chain passes under a pulley wheel and the ascending leg of the chain passes through a tube. When the handle is turned, the ascending buckets in the tube raise water to the level of the spout, where it overflows. The buckets and chain in descending carry air into the water and thus help to keep it fresh. The buckets are so constructed that, when righted for the ascent, the air is released from them, and in rising to the surface both aerates and agitates the water. Pumps of this description can also be advantageously used to aerate the water in cisterns from which the house supply is pumped into a house tank.

30. Cleaning of Cisterns.—No matter how careful an attendant might be to see that the first part of all storm water falling on a roof is run to waste, a considerable amount of organic matter will, in course of time, be carried into the cistern, where, after enough has accumulated, it will impart a disagreeable taste and odor to the water. For this reason cisterns should be thoroughly cleaned at certain intervals of time to keep the stored water as pure and wholesome as the source of supply and conditions of storage will permit. Where cistern water is depended on as the only source of supply, two or more cisterns should be used, so that one can be cleaned while water is stored in the others.

ARTIFICIAL SOURCES

STORAGE RESERVOIRS

OUTDOOR RESERVOIRS AND TANKS

31. Tanks and reservoirs that store water for country institutions and large suburban residences are usually located outside of the main building, and in cold climates are housed by themselves. When the reservoir is at such an elevation that excessive pressure will be exerted in the distributing pipes, a distributing reservoir is usually located at a lower level to relieve the system of the excessive strain. When a distributing reservoir is installed, a by-pass is usually constructed around it, so that in case of fire the pressure of water from the impounding reservoir can be turned into the distributing system.

Reservoirs should be sufficiently large to store enough water to tide over the greatest period of drought likely to prevail in that locality. If, however, a reservoir is supplied from a clear stream that never runs dry, it need only be large enough to store a few weeks' supply. If, on the contrary, the stream is muddy or carries much matter in suspension, two reservoirs should be constructed, each of sufficient capacity to store water for several weeks' supply; then, while water is being drawn from one reservoir, sedimentation will take place in the other.

32. Underground basins or reservoirs are usually built of brick laid in Portland cement, or of Portland-cement concrete. The roofs are made of elliptical groined arches resting on columns of masonry spaced about 14 feet apart. Generally, one or more manholes *a*, Fig. 16, are built into

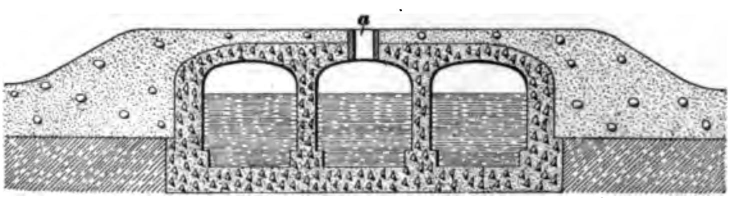


FIG. 16

the top of the reservoir; these serve as vent openings and also permit entrance to the reservoir for cleaning, inspection, or repairs. In place of manholes, ventilators are sometimes used. The top of the ventilator should be protected against the entrance of insects or other foreign matter by a fine-mesh wire screen.

33. Outlet connections to small reservoirs are usually made as shown in Fig. 17. An upper flange *a* of the outlet pipe *b* finishes flush with the reservoir bottom, so that an extension piece *c* can be attached to extend the outlet above the mud and sediment on the bottom. The pipe *b* is well bedded in concrete *d* to hold it rigidly and make a water-tight joint around the pipe. The outlet is protected by a wire basket or strainer *e* secured to the opening of the pipe.

34. Outdoor tanks are usually made sufficiently large to hold 2 days' supply of water. However, in localities remote from repair shops, if but one pump is depended on to fill the tank, a larger storage capacity should be provided to tide over periods of breakdown. When water from the tank is also used for fire protection, additional storage capacity must be provided. It is better practice, however, to supply fire lines directly from the pump, as greater pressure can thus be obtained than from a storage tank at the ordinary elevation.

Tanks should be placed reasonably close to the buildings to be supplied and, when possible, should be located on high ground, but sheltered from strong cold winds.

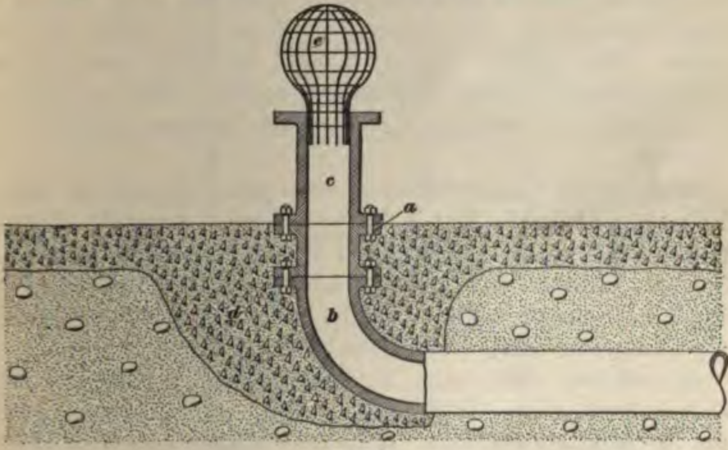


FIG. 17

35. In cold climates, pipe connections to tanks must be protected from frost; this is usually accomplished by enclosing them in a wooden boxing and packing the boxing well with some non-heat-conducting materials. Sometimes the entire space inside of a water tower is enclosed in woodwork and used for a tool house. In severe climates, this enclosure is heated by steam or other means to prevent the water freezing and bursting the pipes. The pipes leading from the tank to the ground should be wrapped with two or three thicknesses of hair felt and then covered with a sewed-on canvas jacket, which in turn is given two coats of paint; the piping finally should be incased in an air-tight wooden box.

STEEL TANKS

36. Steel storage tanks are made in many sizes and shapes to suit different locations and conditions, and can be obtained either square, rectangular, or cylindrical in form. The sizes and shapes most commonly used are listed and usually kept in stock by manufacturers.

Steel tanks are made of large sheets of steel riveted together; owing to their shallow depth and consequent low pressure, which seldom exceeds 5 pounds per square inch, the seams are all single-riveted, and the only reenforcing braces used are those around the top edge of the tanks. The greatest stress on steel tanks of this type is on the bottom; hence, they should be firmly set on a level floor, which will uniformly support the bottom and prevent bulging.

Screwed pipe connections to steel tanks should be made by means of spuds, that is, tapped flanges, securely riveted to the tank shell; these make a strong connection. When, however, a connection must be made to a steel tank already in place, it can be made by means of a running thread on the pipe, the joint being made tight by gaskets and locknuts.

In ordering steel tanks, a sketch should accompany the order, showing the location and size of tapping of the spuds for the pipe connections. The tank maker will then rivet the spuds in their proper places.

STEEL STAND PIPES

37. The usual form of steel tank for large water supplies is shown in Fig. 18; this type is known as a **stand pipe.** It is cylindrical in form, open at the top, and is made of wrought-iron or steel plates riveted together.

Metal plates for stand pipes have not only to withstand the bursting pressure due to the hydrostatic head, but they must also be strong enough to withstand the additional stress due to wind pressure. For this reason stand pipes are made of much thicker plates than would be required for a uniformly supported horizontal tank subject to the same internal pressure. The top edges of stand pipes are reenforced by a heavy angle iron riveted to the plates.

The thickness of metal for stand pipes depends on their diameter and height, whether the stand pipe will be exposed

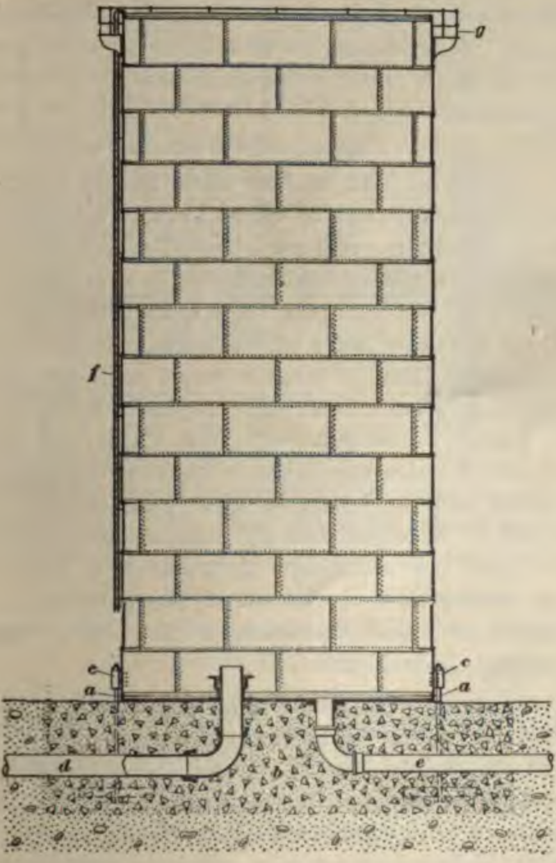


FIG. 18

to winds, the velocity of prevailing winds, and the action of the stored water on the metal plates. Under average conditions metal plates of the thicknesses given in Table I are sufficient:

TABLE I

THICKNESS OF PLATES FOR STAND PIPES

Height of Stand Pipe Feet	Thickness of Lower Plates Inch	Thickness of Upper Plates Inch
75	$\frac{3}{8}$	$\frac{1}{4}$
75 to 150	$\frac{1}{2}$	$\frac{1}{4}$
150 to 200	$\frac{3}{4}$	$\frac{3}{8}$

38. Tornadoes and violent wind storms are the most destructive forces that stand pipes have to withstand. During severe gales the pressure of wind on plane surfaces at right angles to the wind is sometimes as great as 40 pounds per square foot, but owing to the wind striking a cylindrical surface, the resultant force of the wind against a stand pipe is only about one-half of what it would be if the stand pipe were square and one side at right angles to the wind.

When empty, stand pipes are least stable, and under the force of severe gales are liable to shift their position or tip over, unless well anchored to their foundations. Anchorage is usually accomplished by bedding anchor bolts *a, a*, Fig. 18, into the stand-pipe foundation *b* and securing them to the bottom of the stand pipe, as at *c, c*. With stand pipes of small diameter, anchor bolts should be spaced about 3 feet apart.

39. Connections to stand pipes are usually made at the bottom of the tank. Sometimes the pump pipe *d*, Fig. 18, serves as the supply pipe to the distributing system, and a separate pipe *e* connected flush with the bottom of the stand pipe serves to empty the tank or occasionally wash out the sediment. Valves located in a manhole underground and near the stand pipe should be placed on both the supply pipe and the draw-off pipe. Overflow pipes are sometimes provided for stand pipes, but in recent practice they are omitted altogether. The height of water in a stand pipe is usually indicated by a pressure gauge located in the pump room. In addition to the pressure gauge an electric telltale is sometimes installed; this rings a bell in the pump room when water rises above or falls below certain levels in the stand pipe. A ladder *f* should be provided on all stand pipes to give access to the platform usually placed on top.

The greatest stress on stand pipes is due to internal pressure, and affects the vertical seams most. Hence, the vertical seams are usually double-riveted, while the horizontal seams are single-riveted. The lap of the sheets for a single-riveted joint is about three times the diameter of the rivets, and the lap for double-riveted joints about five times the diameter of the rivets. The size of plates generally used is 5 feet by 6 feet, or 5 feet by 9 feet.

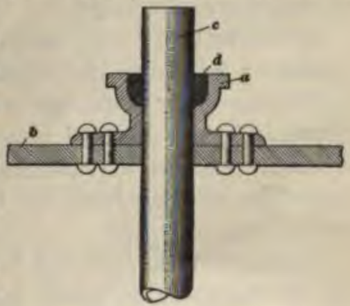


FIG. 19

The manner of securing anchor bolts to a stand pipe requires careful attention. A wrought-iron lug should be securely fastened to the stand pipe by means of rivets. The free end of the anchor bolt passes through a hole in the lug and is secured on top by a nut.

40. Connections to stand pipes are usually of large diameter and made with cast-iron pipes. This necessitates the use of a special connection fitting, made as shown in Fig. 19. A flanged hub *a* is securely riveted to the bottom plate *b*; the pipe *c* is then slipped through the hub and the joint *d* made tight by calking it with oakum and soft pig lead.

CAST-IRON TANKS

41. Cast-iron tanks are made in sections, and the sections are bolted together to form a tank. These sections are made of uniform size, so that a tank can be enlarged by adding sections to it, or it may be diminished in size by taking some sections away. This type of cast-iron tank is shipped knocked down from the factory, with the various parts numbered, so that it can be put together in place by inexperienced workmen. The joints are made up with a paste or cement furnished by the manufacturers, and are bolted firmly together with bolts and nuts. Cast-iron tanks are very heavy, and hence their bottoms should rest firmly and evenly on a solid floor or platform. The rectangular forms of tank are made up of plain sections, with reenforcing cross-braces cast on each section to stiffen them; the top edge is usually stiffened by a strip of metal that extends around the entire edge.

Cylindrical cast-iron tanks are also built up of sections. Tanks of this form can be added to in height only, because to increase their diameters would require plates of different curves. The individual plates for cylindrical tanks are not cross-braced, but the flanges that form the joints are reenforced by brackets, and the top edge of the tank is finished with a ring of metal.

Connections to cast-iron tanks can be made to bosses cast on the sections, or spuds may be bolted or riveted to the tanks. Cast-iron tanks are not used as extensively as steel tanks, because they are more expensive and are more liable to breakage. They are used chiefly in places where steel tanks would corrode too rapidly.

WOODEN TANKS

42. Most tanks used for storing water for suburban homes and country institutions are made of wooden staves bound together by iron hoops or bands.

Where the surrounding land is level the tanks are usually placed on a platform *a*, Fig. 20, elevated by a tower *b* above the level of the highest fixture to be supplied. When water from the tank is to be also used for fire protection, the tank is elevated to a much higher level than it would be for domestic supply only. A ladder *c* extends from near the ground to the top of the tank; the projecting floor of the tower forms a balcony for workmen to stand on while constructing the tank and tightening the hoops. A guard

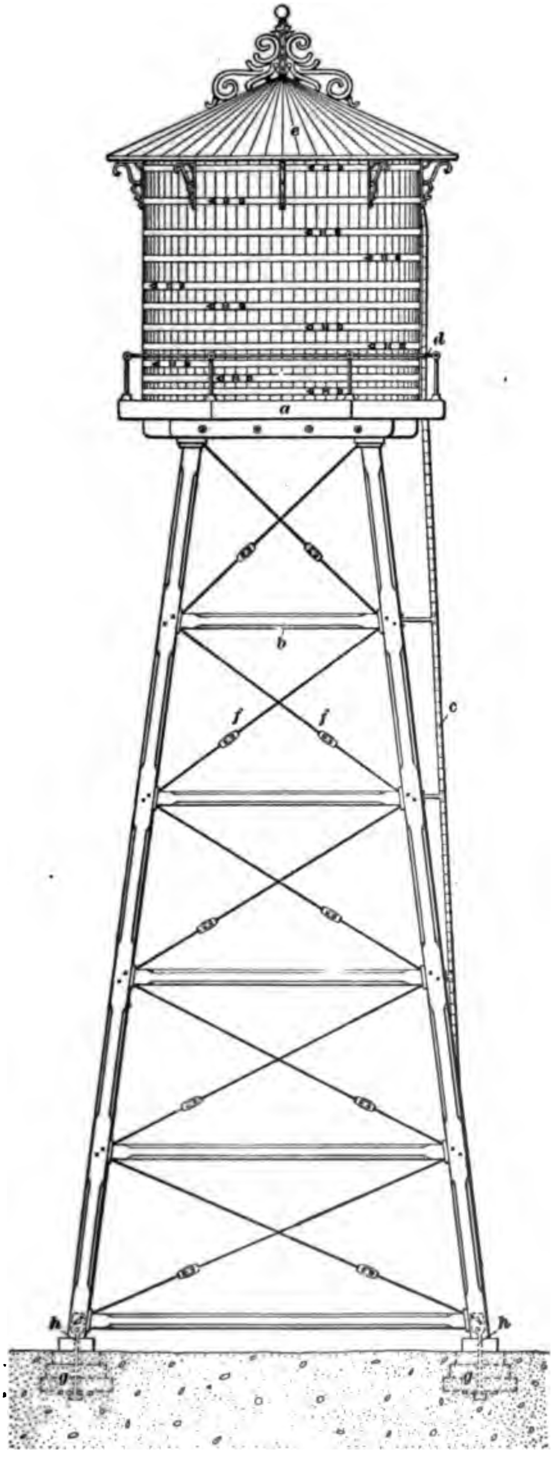


Fig. 20

rail *d* extends all around the platform balcony, and the tank is roofed over by a cover *e*. The tower is stiffened against wind pressure by tie-rods *f*, *f*, which are secured to metal sockets on the upright posts. The lower ends of the upright posts rest on brick, stone, or concrete foundations *g*, *g*, to which they are anchored by the anchor rods *h*, *h*, which should extend to the bottom of the foundation walls, below the frost line.

Tank towers are also made of steel framework, the general arrangement of the members of the structure being the same as shown in Fig. 20.

43. The hooping of a wooden tank is the most important part about its construction, for on the strength of the hoops depends the safety of the tank. There should be sufficient strength in the hoops to not only hold the pressure of water, but to allow a factor of safety of not less than four to one; in other words, if the tensile strength of the metal is 40,000 pounds, the hoops furnished should be of such a number and size that when properly spaced on the tank no more than 10,000 pounds stress per square inch of section will come on any hoop. As the greatest pressure in a tank is near the bottom and decreases toward the top, hoops should be spaced closer near the bottom to withstand the increased pressure. On the cheaper tanks, hoops are made of band iron with the ends riveted together, and are tightened by driving them down toward the spreading bottom of the tank; with the better classes of tanks, flat-iron hoops are used and tightened by means of hoop adjusters drawn together by bolts and nuts.

In recent years round hoops have been much more generally used than flat hoops. Round hoops are several times as thick as flat hoops of equal weight, and consequently there is several times the thickness of metal to rust through before the hoops give out. Moreover, since the corrosion of hoops is principally from the under side, where the band bears on the staves, the point of attack is materially lessened in the round hoops, since only a small part bears on the tank.

Furthermore, almost the entire surface of round hoops can be examined and painted, whereas, after flat hoops have been put on a tank they can be painted only on one side. As threads are cut on round hoops for the locknuts at the draw lugs, the strength of the hoops must be based on the size at the bottom of the threads, and, therefore, the total weight of the round hoops required for any tank must be considerably more than would be necessary in flat hoops for the same tank.

44. Outside tanks should be roofed over to protect the waters from contamination by dust, birds, or insects, and to

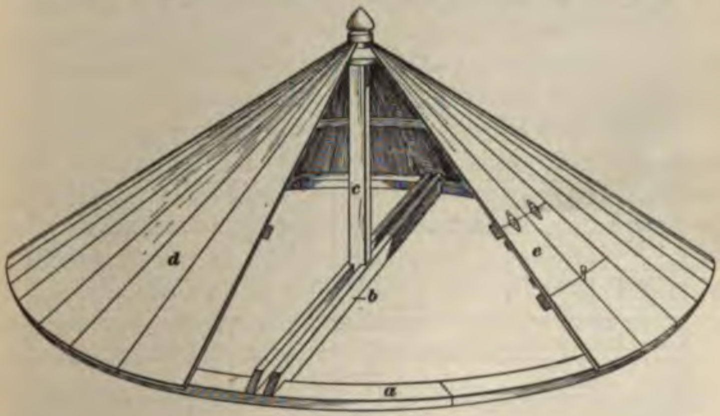


FIG. 21

check the formation of ice. The roofs may be either flat or pitched, the latter being preferable on account of the better appearance and greater cleanliness.

The construction of a pitched roof is shown in Fig. 21. A plate *a* rests on and is secured to the top edge of a tank. A cross-beam *b* supports the center post *c*, which forms the apex of the roof and affords a bearing for the upper end of the roof boards *d*. A hinged door is provided at *e* to afford access to the tank.

45. The thickness of wooden staves for tanks depends on the diameter of the tank. Thus, stock sizes up to 8 feet in diameter have $1\frac{1}{2}$-inch staves. Tanks from 8 to 20 feet in diameter have 2-inch staves, and all tanks with diameters larger than 20 feet may have 3-inch staves.

46. Wooden tanks are sometimes fitted with an indicator gauge and float, so that from the engine room the engineer in charge can see the depth of water in the tank. The manner of fitting up an indicator gauge is shown in Fig. 22. A gauge board *a* with a white background is fastened to the

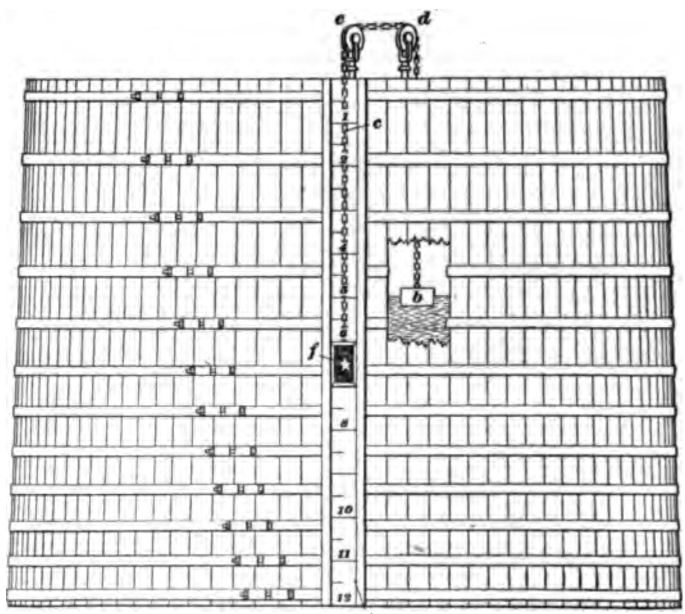


FIG. 22

outside of the tank. The board is laid out with black lines to indicate feet and fractions of a foot, and the feet marks are indicated by black figures 3 inches high. A galvanized-iron or copper float *b* inside of the tank rises and falls with the level of water, and thus by means of a chain *c* and pulleys *d* and *e* raises or lowers the sliding weight *f* to correspond with the height of water in the tank.

MAINS

47. Underground distributing pipes should be placed below the level of frost and should be so valved and graded that any branch can be cut out and drained. If the pipes are of wrought iron with screwed joints, and require to be drained and left empty during cold weather, provision should be made for expansion and contraction, so as not to spring any of the joints and cause them to leak. In sandy soil, provision for expansion should be made every 500 feet; while in clayey soil, expansion should be provided for every 300 feet. The usual method of allowing for expansion of underground pipes is to offset the line at certain distances and cover the spring piece of each offset with a wooden box or brick culvert sufficiently large to permit a movement of $\frac{1}{2}$ inch for each 100 feet length of the pipes. If the pipes are laid below the frost line and remain full of water all winter they are usually laid to suit the ground. Joints in cast-iron pipe are flexible to a certain extent, and each joint compensates for the expansion and contraction of the pipes, which may therefore be laid in straight lines of indefinite length. For pipes up to 2 inches in diameter, wrought-iron pipe is generally used; larger pipes are usually of cast iron.

48. The water pressure in city mains is seldom constant, and often varies considerably from the normal pressure. This is due to excessive draft at factories, slaughter houses, and other places where large quantities of water are used during the day.

In localities where the pressure in street mains is irregular, a tank should be provided and a pump installed to pump water from the city mains into the tank for use when the pressure is low. The pump used for this purpose need not pump water from a specially provided suction tank, but may connect directly to the service pipe of the building.

49. Sometimes water supplies from city mains are subjected to pounding noises, caused by water hammer, due to defective pumping machinery at the pumping station or to hydraulic elevators operating directly from the city supply. It is beyond the province of the plumber to remove the cause of water hammer in city mains. He can modify its effect in the house system, however, by installing large air chambers at suitable points of the distributing system to absorb some of the shock.

PUMPS

HAND PUMPS

50. Pitcher Spout Pumps.—The simplest form of pump used to supply water for domestic purposes is a **pitcher spout pump**; this can be used to supply water only to the fixture to which it is attached. It cannot raise water to a greater height than its own level and is usually placed at the end of a kitchen sink to supply water to that fixture. This form of pump is never used to fill house tanks, as it is not suited to that purpose. Its use is limited to country or suburban residences, where a kitchen sink and possibly a bathtub constitute the plumbing fixtures in the building. The greatest height a pump of this type will lift water depends on its elevation above sea level. Theoretically, at sea level it should raise water 34 feet, but in practice the height it will raise water is found to be about 28 feet.

The valves of a pitcher spout pump are located in a cylinder that forms the barrel of the pump; consequently, as the valves raise and hold the water, the pump and suction pipe always remain full of water unless precautions are taken to empty them after use. As the precaution of emptying the pump and suction pipe after use is liable to be forgotten, pitcher spout pumps that are located in exposed places in cold climates should be protected from frost by placing the valves in a cylinder located below the level of frost and providing a drip hole above the valve cylinder in the pump pipe, through which the water in the pump and pipe can drip back into the well or cistern.

Two or more pitcher spout pumps are sometimes connected to one suction pipe. When so connected the main suction pipe should be sufficiently large to supply water to all the pumps when they are operated simultaneously, and each branch to a pump should be provided with a stop-cock, so that water will not run from all the pumps when only one is operated. This method of installing pumps, however, is very unsatisfactory, and when the extra cost of stop-cocks is considered it is doubtful if the slight saving would justify such an installation in place of providing a separate suction pipe for each pump.

Two suction pipes are sometimes connected to one pump. This is usually done to permit either well or cistern water being drawn from the same pump; the change from one to the other is accomplished by means of a three-way cock placed close to the pump.

51. Force Pumps.—When it becomes necessary not only to lift water from a well or other source of supply, but also to elevate the water to a higher level, where it may be stored for distribution, **force pumps** must be installed. When force pumps are used in deep wells, the valve cylinders are placed in the well just above the level of water. By so locating the valve cylinders, the valves can be repaired without removing the pump from the well, since a workman can be lowered on a seat by means of a block and fall, and repair the pump in place. Pump pipes in deep wells should be securely fastened to cross-braces placed at intervals of about 10 feet to prevent vibration of the pipe.

Force pumps are provided with air chambers placed immediately above the valve cylinders. In ordinary house pumps, the air chamber is pear-shaped and forms part of the pump. In deep-well pumps, however, the air chamber usually consists of a capped length of iron pipe connected to the pump pipe just above the valve cylinder and extended upwards parallel with the pump pipe.

52. To fix a pump in place, a workman is frequently required to descend into the well. All deep excavations in the earth are liable to become partly filled with carbon dioxide, which is fatal to animal life and kills by suffocation. Therefore, before entering a well the air should be tested by lowering a lighted candle or lamp, on a wire or cord, to the surface of the water. If the flame burns badly or goes out, it indicates that gas is present in a dangerous quantity, and

FIG. 23

the workman should not go down until the air is pure. The accumulation of the gas is quite irregular, and depends to some extent on the pressure of the air, as shown by the barometer. Sometimes a well that is free from gas on a certain day will accumulate enough gas during the night to be dangerous the next morning.

POWER PUMPS

53. Hydraulic Rams.—If a stream of good water, having a fall of 5 feet or more in a hundred feet, flows within a reasonable distance of the premises, a hydraulic ram may be used to pump water into a suitable house tank. The manner of connecting a ram is shown in Fig. 23. The ram *a* is located in a masonry pit *b*, where it should be protected from frost by banking earth around the walls. The drive pipe *c* from the source of water supply, which in the figure is a dam made in the stream, is connected to the inlet tapping of the ram, and the discharge pipe *d* is extended in a trench to the house, where it supplies a tank located in the attic. The level of a ram should be at least 2 feet below the level of the inlet to the drive pipe, and in cold climates the drive pipe, the ram, and the discharge pipe should be protected from frost.

54. Drive pipes for hydraulic rams should be of wrought iron or brass to withstand the hammering of the water column, which would soon destroy lead pipes. They should be about 40 feet long, to provide sufficient weight of water in the driving column to operate the ram. If two or more rams are used, each must have its own independent driving pipe, but they may all discharge into the same delivery pipe. If angles or bends are necessary in any of the pipes, they should be made by bending the pipes to as large a radius as practicable. Angles should not be made with ordinary pipe fittings, because of the frictional resistance they offer to the flow of water. To facilitate repairs, each drive pipe and each delivery connection should be provided with a straight-way or gate valve.

Double rams are in the market; these can be operated by a stream of dirty or impure water, but will take pure water from some other source and elevate it to the point desired.

55. Hot-Air Pumps.—Pumps driven by the expansive force of heated air are usually well adapted for domestic water-supply purposes, as they require very little attention and use but little fuel. Care must be taken to avoid overheating them and to keep them properly lubricated. If the engine is of the vertical type, the engine-house roof must be made high enough to permit the removal of the pistons by means of a block and tackle. There should be a hitch in the roof large enough to allow the pump rods and tubes to be lifted out of the well.

56. In Fig. 24 is shown a sectional view of the **Ericsson hot-air engine.** This engine is chiefly used for driving low-pressure pumps, and may be obtained with the fire-chamber adapted to any kind of fuel. The type shown is

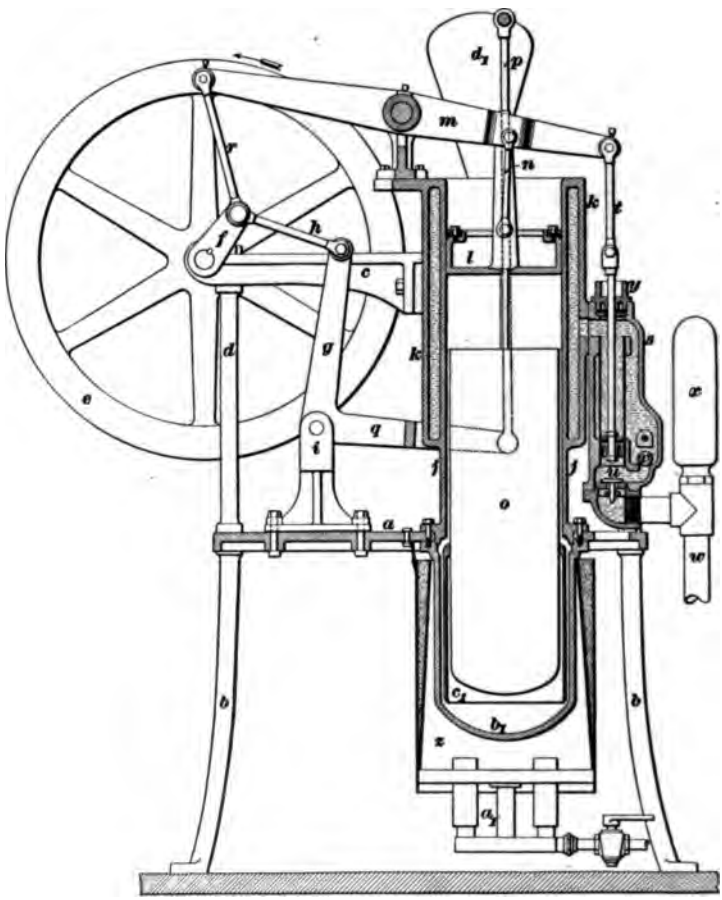


FIG. 24

designed to use gas as a fuel, and is very suitable for use in city buildings where city gas is easily obtained, or in suburban or country buildings having their own gas-making machines.

The engine is placed on a solid rectangular frame *a*, supported by four wrought-iron legs *b*, *b* solidly bolted to the floor. A cast-iron bracket *c* and a wrought-iron post *d* support a flywheel *e*, which has a crank *f* keyed to its shaft. The arm *g* of the bent lever, or bell-crank, whose fulcrum is *i*, is attached to *f* by means of a connecting link *h*. A cast-iron cylinder *j*, having a water-jacket *k* around its upper part, has the closely fitted main piston *l* connected to an overhead lever *m* by connecting links, as *n*. The cylinder also has a loosely fitted transfer piston *o*; this piston is connected to a rod *p* that branches out over the walking beam *m*, and passing down outside of the water-jacket connects to the arm *q* of the bent lever, as shown by dotted lines. One end of the walking beam is connected to *f* by means of a link *r*; the other end connects with the piston rod of a pump chamber *s*, bolted to the water-jacket by means of a brass link *t*. The form of pump shown is usually furnished with the engines, being especially designed for them. The pump is single-acting, and the plunger moves in a brass cylinder within the pump chamber *s*, as shown. The foot-valve *u* is simply a disk of rubber held in place by a brass bolt. The outlet or discharge valve *v* is a cylinder of rubber resting loosely on a rectangular seat. The suction pipe *w* is connected to the source of water supply, which may be a shallow well, cistern, or city water main. It is customary to place an air chamber *x* on the pipe *w*, and near the pump. A brass gland and nut at *y* holds the pump-rod packing in place. The furnace *z* is composed of a double thickness of heavy sheet iron having insulating material between, and is fitted with a sheet-iron pipe to convey the products of combustion to some convenient chimney. In the figure, the furnace is shown fitted with atmospheric gas burners a_1 of the Bunsen type. A lever-handle stop-cock is attached to the gas supply pipe, and a screwed union is placed on the pipe between the burner and the stop-cock, so that the burner may be taken out at any time. The cast-iron heater b_1, which is a cylinder with an elliptical lower end, hangs in the combustion chamber or furnace, and is supported by bolts that attach it to the upper cylinder *j* by an air-tight joint. Another cylinder, or sleeve, c_1 is suspended within b_1 in such a manner that communication is had between the spaces above and below the transfer piston.

57. When the heater is sufficiently hot (its working temperature, of course, varying with the work the pump has to do, but usually a dull red heat), the flywheel is revolved by hand once or twice to start the engine. When at work, the heater b_1 is kept at a dull red heat. Referring to the illustration, the piston *l* is very near the lower end of its stroke, and the transfer piston *o* has made about one-third of its upward stroke. As it approaches *l*, the air between them is driven downwards between *o* and *j* into the space underneath. This air passes over the red-hot surface b_1, and is quickly heated and expanded. The pressure that results from the expansion drives the piston *l* upwards and rotates the flywheel. About the time that *l* reaches the middle of its stroke, the transfer piston starts downwards and quickly displaces the air in the hot lower end of the cylinder, driving it into the upper and cold end. As the air comes in contact with the water-cooled surfaces of the cylinder, it parts with its heat to the water and contracts correspondingly. The pressure decreases sufficiently to permit the flywheel to return the piston to the lower end of its stroke without stopping, and to move the transfer piston, thus shifting the cooled air into the heater again. The pressure of the air within the cylinder thus rises and falls once during each revolution. It will be seen that the air, when expanded by the heat of the fire, in forcing the piston *l* upwards, also raises the pump plunger, which forces a certain quantity of water through the water-jacket and into the delivery pipe connected to it. A copper air chamber d_1 is attached to the delivery pipe near the water-jacket, and forms a cushion to receive sudden shocks that might otherwise burst the outer shell, or jacket.

It will be observed that all the water raised by this engine must pass through the water-jacket and do duty as a cooling medium. To stop the engine, it is only necessary to shut off the gas.

When it is necessary for the pump to raise water to a height greater than 100 feet, such as is often the case in country buildings, a double-cylinder hot-air engine is most commonly used. With this class of engine, coal is generally used as the fuel, although furnaces can be had that will burn any kind of fuel.

58. In Fig. 25 is shown a **Rider compression pumping engine,** especially designed for pumping against high pressures. Although having two cylinders, its principles of action are nearly the same as those of the Ericsson, already explained. The compression piston *a* extends into the base of the engine, and closely fits the cylinder *b* as well as a sleeve suspended from it, which extends to about ½ inch from the bottom, as shown. An air space, in the form of an annular passage, is provided between this sleeve and the cooler, or water-jacket, *c*. The power piston *d*, which fits the cylinder *e* closely, extends down into the heater *f*, and closely fits the top of a sleeve suspended from *e*, which sleeve extends into the annulus of the heater, as shown. Annular air passages are formed around the power piston and the sleeve. The air space with the heater communicates with the space enclosed by the water-jacket *c* by means of a regenerator *g*, fitted with a number of thin plates held apart about ⅛ inch. The pistons *a* and *d* are connected to a flywheel and shaft by means of cranks *h*, *h* and connecting-rods *i*, *i*. An arm bolted to the top of the compression piston connects with the plunger rod of the pump. A snifter valve *j*, whose action is similar to that of a vacuum valve, furnishes air to the interior of the compression chamber, if at any time the pressure therein becomes less than that of the atmosphere. Double cup leathers at *k*, *k* make the pistons air-tight around their tops. Any leakage of air at these packings or elsewhere is compensated for by a supply of air through *j*. The furnace pot of this engine is lined with thick firebrick, and a 6-inch or 7-inch smoke pipe

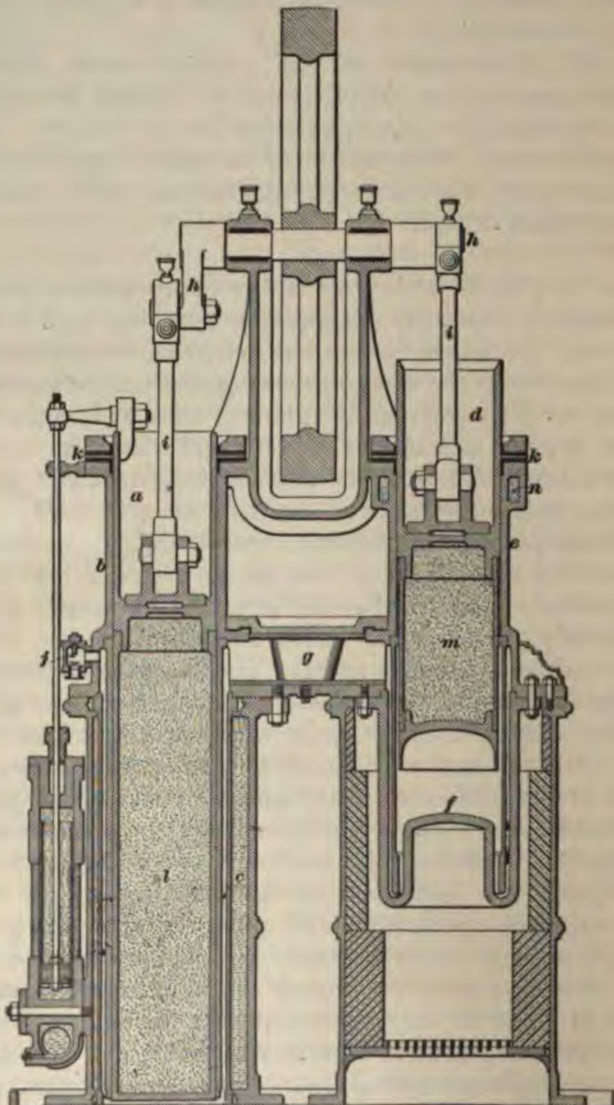


FIG. 25

taken from the back of the combustion chamber if coal is used as the fuel. In operation, the heater is maintained at a low red heat. When the parts are in the position shown, the greater part of the air is in the heater and is expanding, thus driving the piston *d* upwards. During the last half of its upward stroke, it is assisted by the pressure that acts under the piston *a*. By the time that the piston *d* has reached the middle of its downward stroke, the plunger *a* has risen to the top of its stroke, and the greater part of the air has been driven through the regenerator into the cooler. The pressure rapidly falls and permits the flywheel to drive *d* to the bottom of its stroke. Meantime, *a* comes half way down and compresses the charge of air. As *a* continues to move downwards, *d* begins to rise, and the transfer of the cooled air to the heater begins. Thus the pressure rises and falls within the engine during each revolution. In the passage of the hot air from the heater to the compression cylinder, a large amount of heat that has been absorbed and retained by the regenerator plates is transmitted to the air on its passage back to the heater. Thus it will be seen that the regenerator is a device increasing the economy of the engine. The pumps used in this class of engine are double-acting.

59. The lower parts *l* and *m* of the pistons, which are subjected to high temperature, are filled with non-combustible non-conducting material. The packings *k* on top of the cylinder *e* are kept at a low temperature by a water collar *n*, through which a stream of water is allowed to flow while the engine is working. The water-jacket *c* is connected to *n* by a ¼-inch iron pipe having a stop-cock in it to regulate the flow. The surplus water passing through *n* is usually allowed to go to waste; it is only a very small stream, forming a mere fraction of the quantity of water delivered by the pump.

Care must be taken when oiling these hot-air engines not to allow oil to flow into the cylinders, as it soon becomes baked hard and fast, and finally stops the engine by jamming the pistons. These engines must be set on a solid foundation, preferably a concrete floor, and the base should be bolted to the floor. They must also be perfectly plumb, so that the pistons, which are very heavy, will bear equally all around. Care must be taken also to avoid overheating the cylinders; they are liable to crack if they are heated too highly or unevenly. These engines are specially adapted for high-pressure pumping where unskilled labor is employed to run them.

60. Quimby Screw Pump.—In Fig. 26 is shown a rather peculiar but highly efficient form of rotary pump, which type is characterized by the absence of valves in the water end. The particular form of pump illustrated is known as the **Quimby screw pump.** There are two shafts *a*, *a* side by side and connected by the gears *b*, *b*. Each shaft carries a right-hand and a left-hand screw, and

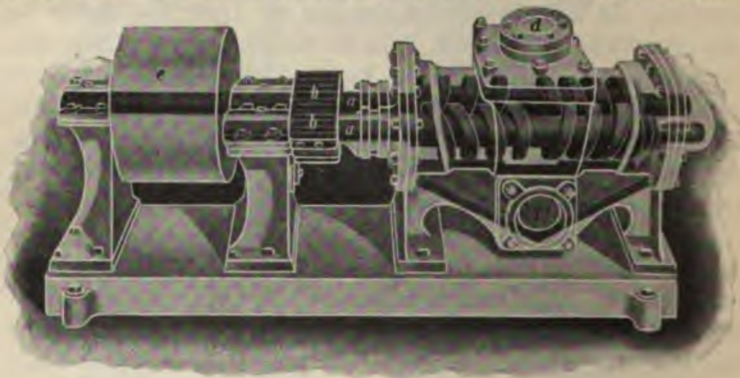


FIG. 26

the right-hand screw of one shaft meshes with the left-hand screw of the other shaft. The water coming through the suction pipe attached at *c* flows through passages in the casing to the outer ends of the screws, and is drawn toward the center by the revolving screws, from whence it is discharged through *d*. The screws closely fit the pump casing and are a close running fit on each other. Since the screws are right-handed and left-handed and the course of the water is

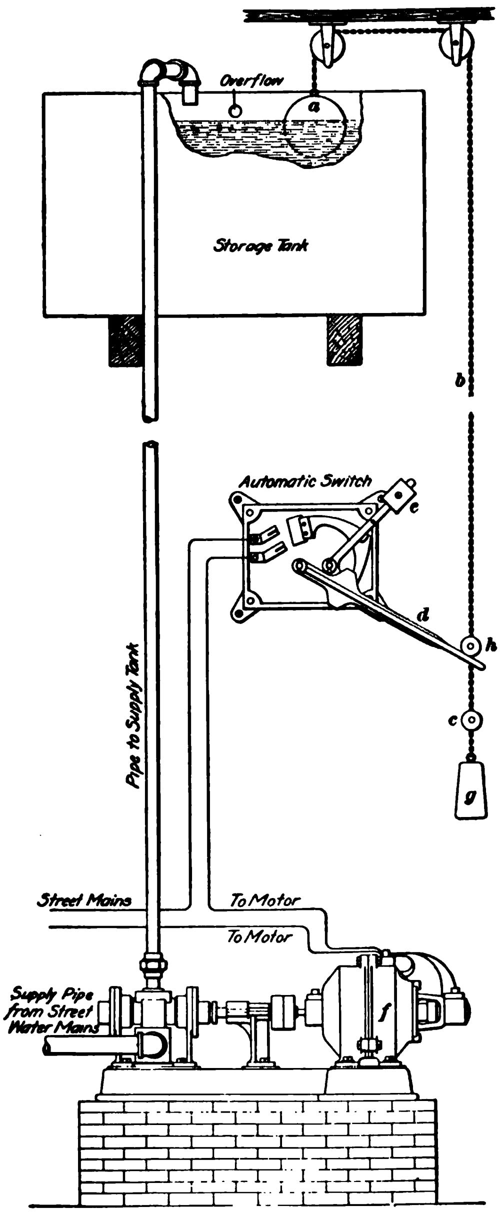

Overflow
a
Storage Tank
b
Automatic Switch
e
d
h
c
g
Pipe to Supply Tank
Street Mains
To Motor
To Motor
Supply Pipe from Street Water Mains
f

FIG. 27

toward the center from the ends of the four screws, there is no end thrust. The pump may be driven by a belt placed on the pulley *e*, or an engine or an electric motor may be connected directly to it.

61. Screw pumps for house service are usually connected to a direct-connected electric motor and are so fitted that they operate automatically. The manner of connecting a

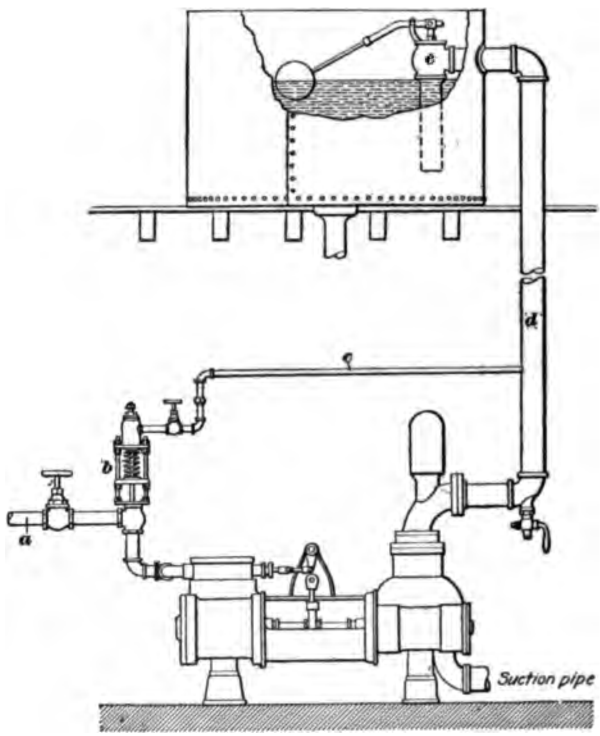


Fig. 28

Quimby pump to operate automatically is shown in Fig. 27. The pump is controlled by the float *a* that rises and falls with the level of water in the tank. When water in the tank is low, the weighted float raises the weighted chain *b* until the disk *c* trips the lever *d*, thus throwing over the contact bar *e* of an automatic switch to close the circuit and turn the electric current on to the motor *f* that operates the pump. As the tank fills with water, it raises the float, and the counterweight *g* pulls down on the chain until the disk *h* trips the lever *d* back again, thus shutting off the current and stopping the pump.

62. Electrically driven pumps, particularly those of the plunger type, should be provided with a rheostat, or starting box, to turn the current on to the motor slowly. This will start the pump easily and develop the maximum speed gradually. Should the current be turned on full at once and the pump thus suddenly started, the pounding due to instantly starting in motion a large column of water might

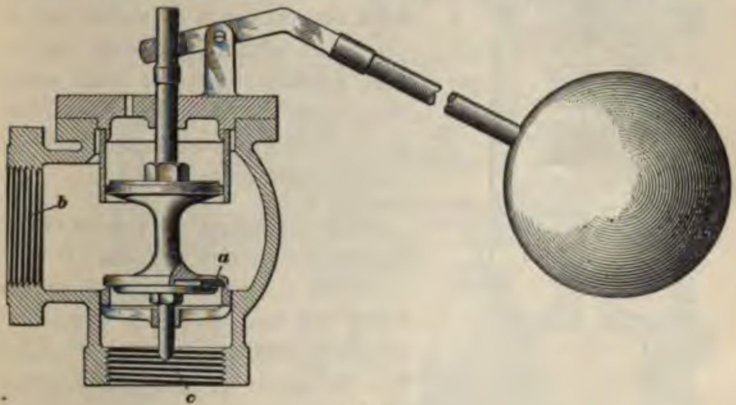


FIG. 29

injure the working parts of the pump. Some starting boxes are provided with attachments to automatically cut out the motor in case it is overloaded or underloaded.

63. Steam-Pump Control.—Steam pumps for tank work are sometimes controlled automatically; a common method of control is shown in Fig. 28. The steam pipe *a* is provided with a regulating valve *b* that is connected by the pipe *c* to the pump discharge pipe *d*. The discharge pipe is fitted, in the tank, with a balanced float valve *e* that closes when the tank is full of water, thus compressing water in the pipe. This pressure in the pump discharge pipe is transmitted through the pipe *c* to the regulating valve, which it closes, thus cutting off the supply of steam and stopping the pump. When the water level in the tank is lowered, the float falls with it, thus opening the balanced valve and relieving the pressure on the regulating valve, which is opened immediately by a spring and starts the pump again.

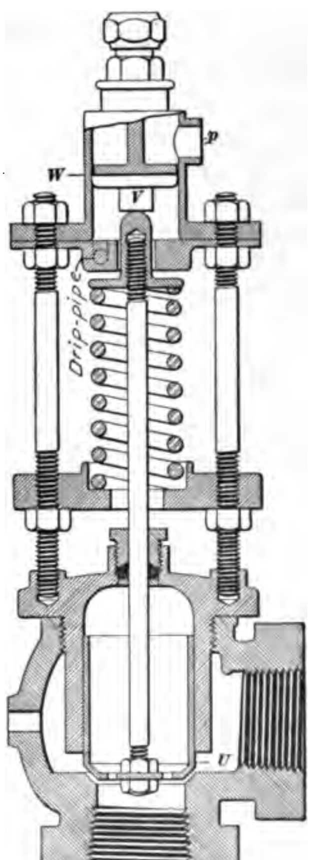


FIG. 30

64. A sectional view of a balanced float valve is shown in Fig. 29. The valve, as the name implies, is balanced and closes with the pressure of water. It is provided with a soft disk seat *a* that effects a perfect seal when the valve is closed. The inlet port of valve is at *b* and the discharge outlet at *c*.

65. A Ford regulating valve is shown in Fig. 30. It consists of a spring-actuated steam valve *U* and a water piston *V* moving in a little cylinder *W* under the influence of the water pressure. By properly adjusting the spring, the steam valve can be made to close when the water pressure on the piston *V* exceeds a certain required amount. The regulating valve should be placed in the steam supply pipe in a vertical position between the steam chest and an ordinary throttle valve. The oil cup should be placed so as to allow the oil to pass through the regulating valve. The pipe connecting the pressure tank with the regulating valve should be provided with a globe valve and a union next to the valve, in order that the cap may easily be removed for repacking the piston *V*. A drip pipe should be connected with the bottom of the cylinder *W*.

66. Fire-Pumps.—An Underwriters' steam-driven fire-pump, with connections that are self-explanatory, is shown in Fig. 31. This pump should be located so as to be easily accessible and at the same time safe from damage by fire or from other causes. To be ready for instant service, a steam pressure of at least 50 pounds should at all times be maintained on the steam pipe to the pump. When the lift is over

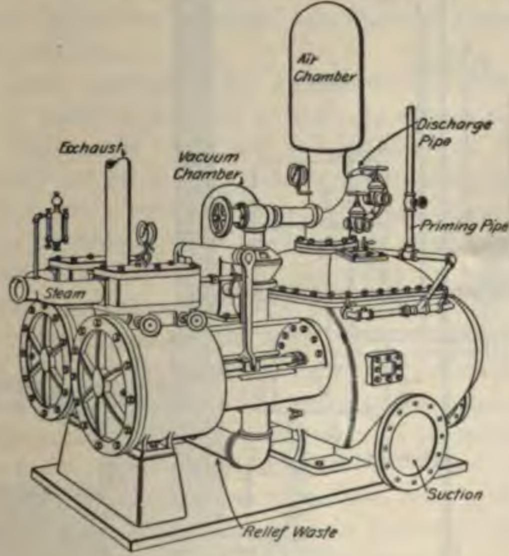


FIG. 31

5 feet, the suction should be provided with a strainer, foot-valve, and priming pipe. The reservoir, cistern, or tank from which a fire-pump derives its supply should be of sufficient capacity to supply water for at least 1 hour when the pump is running at its maximum speed.

67. Water Lifts.—A pump that is operated by water pressure is often called a **water lift**. Such pumps are used principally in localities where the city water is extremely hard, and are there used to pump cistern water to the various plumbing fixtures. In cities where the pressure of city water is not sufficient to supply fixtures located on the upper floors

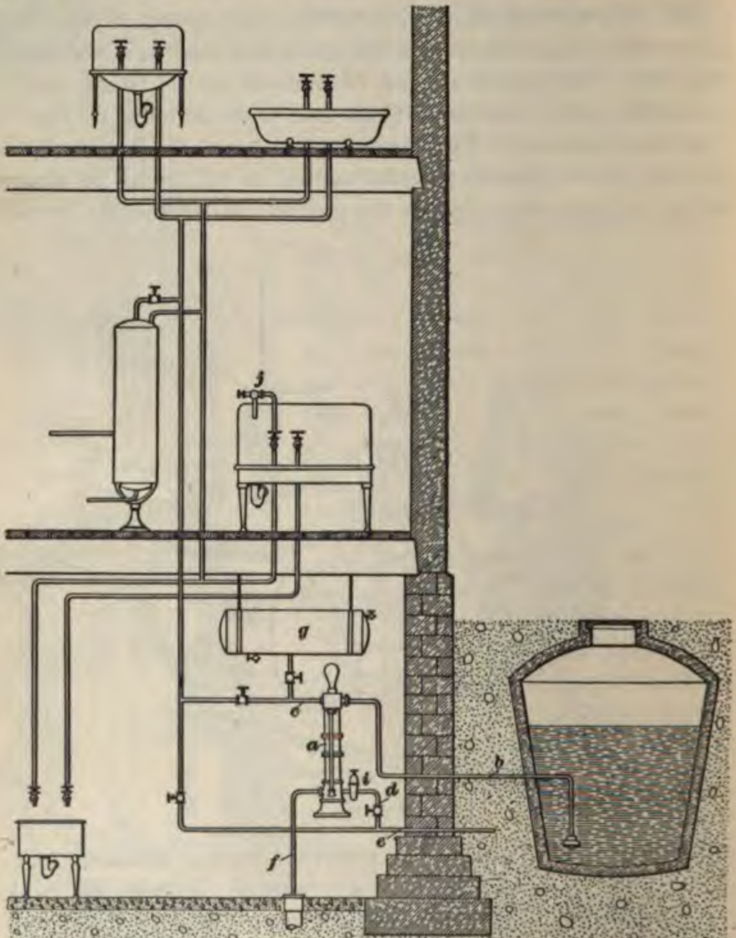


FIG. 32

of buildings, water lifts are sometimes used to increase the pressure, or to fill a house tank from which fixtures on the upper floors are supplied. A type of water lift frequently used is shown connected up completely in Fig. 32. The lift *a* is composed of two cylinders placed in line with each other. The upper cylinder contains the pumping mechanism, which takes cistern water through the suction pipe *b* and forces it into the plumbing system through the discharge pipe *c*. The lower cylinder of *a* contains the driving mechanism, or motor, for the pump, and is supplied with water under city pressure through the branch pipe *d* taken from the main service pipe *e*; the waste water from the motor goes to waste through the sewer connection *f*. A pressure regulator is located at *i* which can be set to maintain any desired pressure in the plumbing system.

The lift is located in the basement or cellar, where it should be securely fastened to prevent vibration. The discharge pipe of the water lift should be fitted with a large air chamber, which may take the form of a compression tank, as *g* in Fig. 32, in which air is confined and compressed, thus providing an elastic force to distribute water when a faucet is opened. The compression tank may be located in any convenient place about the premises; usually, however, it is located in the basement or cellar, thus relieving the upper floors of the building of its weight and removing the possibility of damage to walls and ceilings from leaky seams or a sweating tank. In place of a compression tank in the basement, an open house tank is sometimes provided in the attic, and the discharge pipe fitted with a ball cock to shut off the water when the tank is full, thus stopping the lift from operating. The lift is equivalent to a check valve that prevents the increased volume of water due to expansion from backing into the cistern; therefore, a safety valve is located over the sink, as at *j*, and no stop-cock should be placed between this valve and the kitchen boiler.

WATER FILTRATION

MODES OF PURIFICATION

INTRODUCTION

IMPURITIES IN WATER

1. The greater part of the water consumed in cities for drinking and cooking purposes, although falling from the clouds quite pure in the form of rain, becomes contaminated on its way to the reservoirs, and often in the reservoirs themselves. Not only does the pure rain water absorb mineral impurities as it travels down the hill or mountain sides, but it often becomes highly impregnated with mud, decayed vegetation, and even with the excrement from sheep and cattle. When these highland streams reach the reservoir, they are often so turbid as to be nearly as dark as stale ale. Most of the matter held in suspension settles on the bottom of the reservoir, and the water, when allowed to stand, ultimately becomes fairly clear before it enters the main pipe lines. A reservoir may, however, become so turbid after a heavy shower that it is a common occurrence for the muddy water to enter the street mains and be drawn from the faucets; hence it is not unreasonable to expect water companies to build large filtering beds at their reservoirs, so that all foreign matter held in suspension by the water will be intercepted at the filters before the water enters the street mains.

2. The impurities that occur in ordinary waters are of two kinds: mechanical, or those held in suspension by the water, and chemical, or those held in solution. The mechanical impurities are mud, leaves, vegetation, fish, frog spawn, insects, insects' eggs, etc. The chemical impurities are solutions of minerals, putrescent animal matter, albuminous slimes, etc. The leachings from privy vaults and drains are usually the most harmful poisons that get into the water supply. The mechanical impurities are far less dangerous, being easily seen and easily removed.

Nearly all mechanical impurities can be removed by filtration through sand or other suitable material, but the danger lies mainly in the matter held in solution, which is invisible. Mineral poisons can be neutralized by the use of chemicals, and sometimes by heating and settling or by distillation. The organic poisons from sewage, etc. can be entirely removed only by distillation, but a careful repeated filtration through sand and bone charcoal will, in most cases, improve the water sufficiently to make it suitable for drinking and cooking purposes. Bone charcoal is often employed as a filtering medium, because it exerts a chemical action on the organic matter in the water, and renders it inert or harmless. The charcoal, however, gradually becomes saturated and clogged with the refuse, and loses its value as a purifying agent. Therefore, it must be renewed at intervals.

Bone charcoal is hard and dense; when its pores become clogged with refuse it can be restored to usefulness only by reburning. There is no practicable way by which this can be done on a small scale. Unless the air is carefully excluded during the whole process, the material will be consumed, like other charcoal, and will be destroyed.

Charcoal that is made from wood has little or no value for the purpose of effecting satisfactory filtration.

AERATION OF WATER

3. Water that has grown stale by standing may be greatly improved, and be made suitable for drinking purposes, by the process called **aeration**, provided that it has not been otherwise polluted. Aeration may be accomplished in several ways: the water may be squirted into the air in fine streams; air may be forced through the water in fine bubbles; or, air and water together may be shaken up or otherwise agitated. The object to be obtained in every case is to expose the water to the action of the air to the greatest practicable extent.

In the process of aeration, the water absorbs a considerable quantity of air and is thereby greatly improved in appearance and taste. The air has a mild oxidizing effect, which is sufficient to destroy a small amount of vegetable matter and render it harmless. But this purifying influence is very limited in extent, and is of no use whatever for removing or destroying the germs of putrefaction, fermentation, and disease that are imparted to the water by sewage or house drainage. These germs can be killed only by boiling, and in the case of certain disease germs even boiling is insufficient; they can be completely destroyed only by fire.

The process of aeration is thus adapted only to the purpose of freshening water and rendering it more palatable, and is not serviceable for actual purification.

In all apparatus designed to aerate water, care must be taken to thoroughly exclude all dust from the air, because dust is very apt to carry with it many kinds of germs which give rise to putrefaction and disease. Dust must be kept out of food and drinking water.

FLOW OF WATER IN FILTRATION

4. In all varieties of filters, the velocity of the water passing through them should be low enough to permit the finest sediment to be deposited on the surface of the beds of filtering material. Otherwise, in treating muddy water, it will retain a muddy color.

The velocity of the water passing through a filter bed of bone charcoal should be low, so that the water may be in contact with the charcoal as long as possible, the chemical changes in the impurities thereby being made more complete.

The beds of filtering material gradually become clogged by the accumulation of refuse on the surface of the bed and on the grains of sand or charcoal; the flow of water is thereby checked and the usefulness of the apparatus is greatly impaired. This can be remedied by reversing the direction of the flow of water at suitable intervals of time. The accumulations can thus be washed away and be run to waste, and the filter can be operated almost continuously.

A filter in which the flow of water cannot thus be reversed should not be employed, because the care and trouble that will be required to keep it in good working order will be so great as to lead almost certainly to neglect. A filter that is neglected is likely to become foul, and thus give rise to the very danger that it was intended to prevent.

There are so-called filters that are made to screw on the nozzle of an ordinary faucet. They consist of a cup having a filling of bone charcoal or other filtering material, and they operate only as strainers, to hold back the insoluble impurities that are carried by the water. They do not purify the water except in a mechanical way. The bone charcoal has no purifying effect on it, because it passes through far too rapidly for any chemical effect to take place.

Filters should be kept full of water. They should not be allowed to become dry, nor be exposed alternately to water and to air. Alternate wetting and drying of putrescible matter greatly hastens putrefaction and increases the growth of disease germs, etc. A filter that is thus operated is liable to become a source of poison instead of a protection against it.

In cities and towns having a water supply that is liable to become muddy at times, dwellings should be supplied with a filter, located in the basement. All the water that enters the house should pass through the filter. This will prevent the kitchen boiler from filling with mud, and will insure clean water throughout the building.

SLOW SAND FILTRATION

DETAILS OF FILTERS

5. Rain-Water Filter.—The mode of constructing an ordinary filter, suitable for rain water, etc., is shown in Fig. 1. The body of the filter is built of brick, laid in mortar composed of Portland cement mixed with an equal volume of clean sharp sand, and it is divided into two chambers by means of a partition slab *a* of slate or flagstone. The bottom

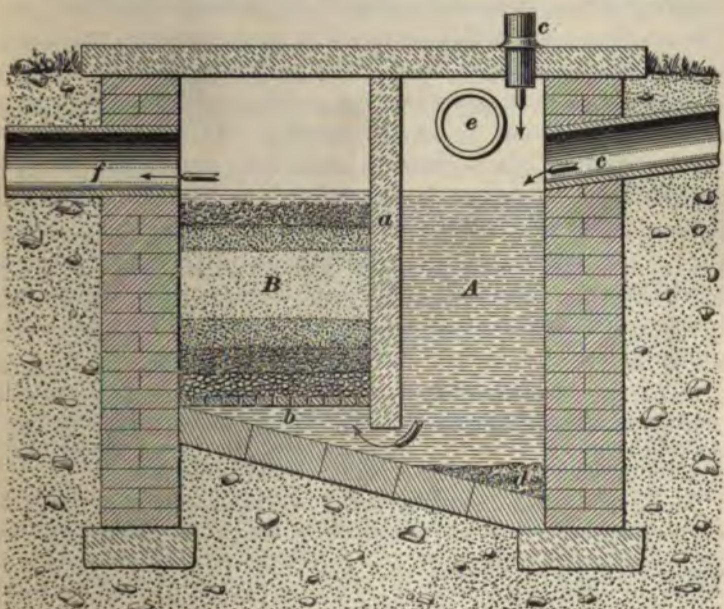


FIG. 1

of the chamber *A* is provided with a low place or pocket *d* in which sediment may gather, and from which it may be removed by the garden pump or other convenient means. The chamber *B* is fitted with a perforated bottom *b*, on which is placed a course of gravel, and then clean sand, nearly up to the level of the discharge pipe *f*. It is topped with gravel. The rain water enters the chamber *A* through the pipes *c, c* and deposits any solids that may accompany it in the pocket, as shown at *d*. It then flows upwards through the sand in the chamber *B*, which clarifies it. The chamber *A* is also provided with an overflow pipe *e*, so that if the filter becomes choked with dirt the water will not acquire sufficient head to force the dirt through the filter; it also acts as an overflow for the cistern into which *f* delivers.

6. Size of Filter Bed.—In **slow sand filtration**, the movement of the water is downwards through a bed of sand and gravel to a system of underdrains beneath the filter bed. The application of water to the filter is continuous, maintaining a permanent water level, and the rate of filtration should be automatically regulated to that giving the highest purifying efficiency, as found by experimenting with the water to be purified. With comparatively clear lake water, the rate of filtration for 24 hours is sometimes as high as 7,000,000 gallons per acre of filter surface, or 1,446 gallons per square yard, while with turbid water the rate of filtration for 24 hours rarely exceeds 2,000,000 gallons per acre, or 413 gallons per square yard, and averages about 1,600,000 gallons per acre, or 330 gallons per square yard, of filter surface.

EXAMPLE.—A sanitarium is supplied with water from a reservoir constructed especially for its own use. The maximum volume of water that will be used in 24 hours is 50,000 gallons. How many square yards of filter-bed area are required if the raw water is turbid?

SOLUTION.—If the water is turbid, 1 square yard of filter-bed area will pass an average of 330 gallons in 24 hours. Therefore, the area required is $\frac{50,000}{330} = 151.5$ sq. yd. Ans.

7. Cleaning the Bed.—Slow sand filtration is simply a straining process in which suspended or insoluble matter in the unfiltered or **raw water** is largely or entirely removed, while hardness, organic matter, and color are only slightly removed.

The efficiency of a filter depends largely on the fineness of the filtering medium. When the sand in the bed of a filter is supplemented by a fine layer of sediment on the surface of the sand, the efficiency of the filter is increased and continues to increase with the growth in thickness of the sediment layer until it becomes too thick and fine for sufficient water to pass through. When the surface clogging reaches such a stage, the water must be drawn off from the filter and the sediment and top layer of sand removed by scraping for a depth of about 1 inch.

The length of time required for a sediment layer to become so thick as to require cleaning depends on the kind of water to be purified and the rate of filtration. Thus, with excessively turbid water the filter beds will probably require cleaning once each week, while with comparatively clear water the periods between scrapings might exceed 60 days. It has been found in practice that for average waters the average length of time between scrapings is about 20 days.

8. **General Construction.**—In order to provide for an uninterrupted supply of pure water while a filter bed is being scraped or the filter is being repaired, two or more filters are usually provided, each of which has a capacity sufficient to supply the daily consumption of water. When the raw water is extremely muddy, or holds large quantities of matter in suspension, three or more filters should be provided.

When slow sand filters are constructed in wet land, the site should be provided with a system of subsoil drains to prevent the ground water from rising to and mixing with the pure water in the filter underdrains. Also, the sides and walls of the filter should be well **puddled** with clay, that is, lined with clay in the form of a thick paste, or otherwise made water-tight. If the ground water from the subsoil drains cannot be discharged by gravity, it may be gathered in a sump and discharged by mechanical means into the nearest watercourse or sewer.

Filters are made water-tight in various ways. The simplest method employed is to puddle the bottom and sides of the filter with clay. In some cases, the bottom and sides of a filter are paved with stones or bricks on top of the clay, and in most cases the sloping sides are paved to protect them from the abrasion of ice. In all puddled or paved filters, the sides are sloped from 2 to 3 feet on the horizontal run to each foot in height.

The best type of open filters have the bottom and sides constructed of concrete or masonry. The walls are carried up vertically, with a ledge, 4 inches wide and a little above

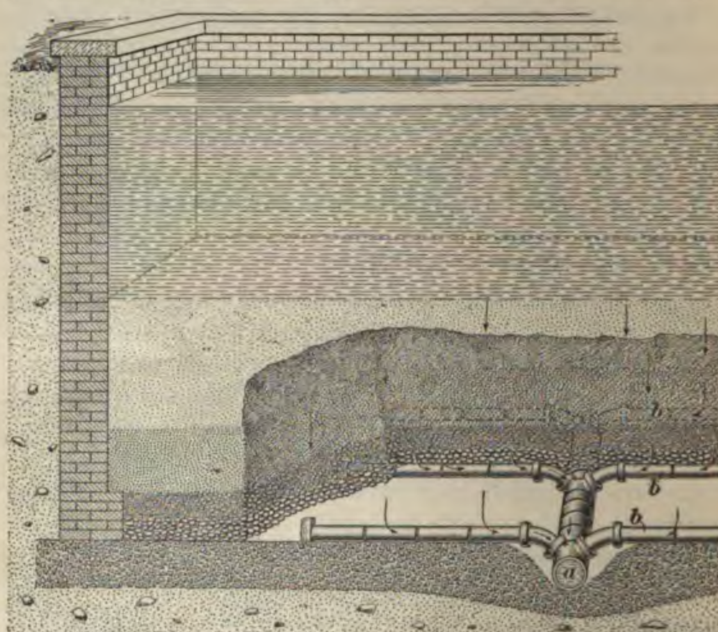


FIG. 2

the gravel, for the sand to rest on and form a closer joint than it would with the vertical walls.

The shape of a filter depends on local conditions; the usual shape is rectangular, although no good reason can be given why a filter should not be made any other shape. The depth averages about 10 feet, proportioned as follows: 6 inches for underdrains, 1 foot for depth of gravel, 4 feet for maximum depth of sand, and 4 feet 6 inches for depth of water.

9. Underdrains.—The underdrains are a series of agricultural, or field, tile pipes that are placed on the bottom of the filter to collect the water that filters through the filter bed. These drains have open joints and may be perforated. The trunk line of the main drains connects to the discharge pipe from the filter.

There are two principal systems of underdrains used with slow sand filters. The first system, which is shown in Fig. 2, consists of a main trunk line or pure-water collector *a*, into which is connected a system of branch drains *b*, *b*, *b*, spaced about 30 feet apart in large filters occupying 1 acre or more in space, and from 5 to 10 feet apart for small filters, such as the plumber or sanitary engineer frequently has to build. Each drain is extended to within about 4 feet of the filter wall, the end being closed with a stone. If the pipes are not perforated, the joints between the pipes must be left open for the entrance of the filtered water. The spaces between the drains are filled with broken stones, as shown in Fig. 2, to provide an easy passage for the filtered water, which flows downwards through the sand bed, as shown by the arrows. In a system of this description, the pipes should be large enough to carry off easily the greatest amount of water that is filtered. The branch lines for small filters may be of 4-inch pipe, and the trunk lines of 6-inch or 8-inch pipe. For large filters, the branch underdrains may be of 6-inch or 8-inch pipe, and the collector of twice the area of the discharge pipe.

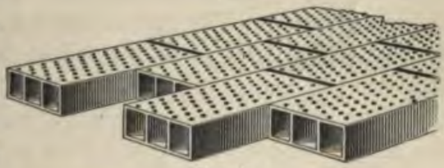


FIG. 3

10. The second system of underdrains, shown in Fig. 3, consists of a flooring of hollow perforated tile covering the entire filter bottom. These drains are laid with slightly open joints, and the gravel layer is placed on top of the tile, the perforations being small enough to prevent the gravel falling through into the underdrains. With this system of underdrains, the tile collectors are generally extended to the walls of the filter. A better method, however, is to end the drains a few feet from the walls and fill the space with sand, so that water passing down the inner surface of the walls of the filter will have a slight lateral movement through the sand from the filter walls to the underdrains. This precaution will insure a purification of any raw water that might pass through cracks or joints in the filter walls, or through imperfect contact between the walls of the filter and the filter bed, or through any other imperfections or defects that might develop around the walls of the filter.

11. Details of Filter Bed.—The bed of a slow sand filter suitable for general purification purposes is shown at the left in Fig. 2. It consists of a layer of fine sand about 4 feet thick supported by a bed of gravel about 1 foot thick and resting on the underdrains. The largest gravel stones are placed on the bottom and smaller sizes are placed on the first layer, the last layer on top being of very fine gravel. A bed of sand 4 feet thick is not necessary for perfect filtration, but the thickness of the bed gives stability to the filter and reduces the possibility of raw water breaking through to the underdrains. It also allows of repeated scrapings of the bed, for cleaning purposes, without replacing any sand. When the sand has been reduced by repeated scrapings to 12 inches in thickness, the water should be drawn off from the filters, an extra deep layer of sand removed, and the sand that has previously been removed should be washed and returned to the bed. The filter should then be filled by allowing water to rise from the underdrains until it covers the surface of the sand about 6 inches, after which raw water can be admitted through the inlet.

The coarse gravel at the bottom of a filter bed has no effect in the process of purifying the water, but acts only as a porous stratum through which the pure water passes to the underdrains. The graduated sizes of gravel or sand that are interlaid between the coarse gravel and the fine sand bed on top are used only to prevent the fine filter sand from washing down and clogging the gravel bed.

12. The size of sand used for filter beds varies from the finest obtainable to the coarsest kind. The sand must all be sifted, and deposited in consecutive layers, the coarsest at the bottom and the finest at the top, because the filtration is downwards. The practical objection to the use of very fine sand is that it clogs much quicker than coarse sand, and requires more frequent scrapings. The coarse sand, on the other hand, allows the sediment to penetrate deeper, and the extra sand that must be removed in scraping will offset the more frequent cleanings of the fine sand. In practice, for average waters, a sand $\frac{1}{75}$ inch in diameter has been found to give the best general results. For comparatively clear lake or reservoir water, a fine sand of about $\frac{1}{150}$ inch in diameter can be used, while a coarse sand of about $\frac{1}{64}$ inch in diameter will probably be found best for turbid river waters.

Filter sand should be free from clay, loam, vegetable matter, or lime. Clay or loam will cement the grains of sand together and cause subsurface clogging of the filter. Vegetable matter will contaminate the bed, and lime sand in sufficient quantities will harden the water. Vegetable matter, loam, and clay can be removed by washing, and, if sand perfectly free from all impurities cannot be procured from a sand bank or river bed, it should be washed before being used. If the amount of lime in the sand is not excessive, it may be used, as the degree of hardness will decrease with age, but if pure soft water is wanted, sand containing lime should be rejected.

13. A simple test for lime in sand is to wet the sand with hydrochloric acid; if it gives off a gas it indicates the presence of lime, the amount of which can be judged by the quantity of gas given off and the appearance of the samples after the test.

14. To insure a uniform rate of filtration throughout the filter bed, it is necessary to so deposit the sand that it will have a uniform density and depth. This cannot be done by laying it in thin layers, or in one layer spread over the entire surface of the filter bed. The best way to deposit the sand is in two or three layers, the full width of the filter, each layer being laid continuously across the filter the full thickness of its bed. Planks should be placed for the workmen to walk on, and the surface of the sand should be well raked when the planks are removed.

15. Care should be taken in placing the gravel around the underdrains to bury the lateral drains under at least 6 inches of gravel, and fill the space between the drains to the same depth. The gravel should stop about 3 or 4 feet from the side walls, and the space should be filled with sand to compel the water from around the walls of the filter to flow through sand to the underdrains. The gravel should be well packed down and settled before the sand is placed, to prevent disturbing the sediment layer on top of the fine sand by a subsequent settlement of the gravel.

The part of a filter most likely to afford a passage for unfiltered water is in or around the vertical walls. To guard against this many expedients are resorted to in order to insure filtration of the water that passes at such points. Stepping the walls and stopping the underdrains 3 or 4 feet from the filter walls have already been mentioned. Other precautions that are found effective are sanding the walls or washing them with a coat of Portland cement. It is not good practice to plaster stone or brick walls with cement below the water-line, as cement sometimes adheres in spots only, and water entering to the back of the plaster through a crack can then work its way unfiltered to the bottom of the filter bed.

Brick or stone walls or piers are not as suitable as concrete for the construction of filters below the water level. There is seldom a good joint between the mortar used and the brick or stone, and unfiltered water entering a joint can follow down to the bottom of the filter and thence to the underdrains. The walls preferably should be of solid concrete.

16. Raw-Water Inlets.—Inlets for the admission of raw water to slow sand filters are made to operate both automatically and by hand. A simple form of inlet is shown in

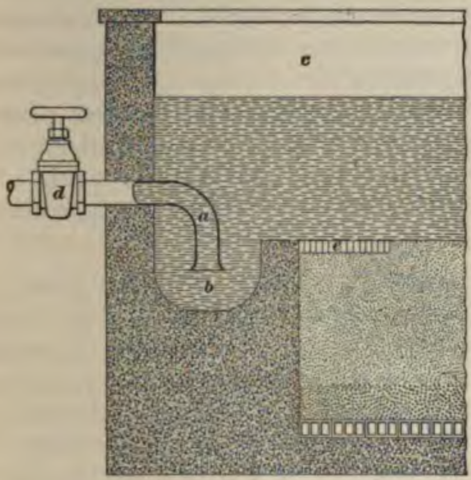


FIG. 4

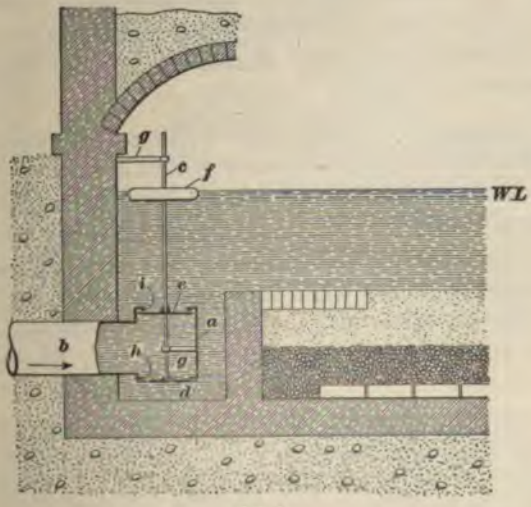


FIG. 5

Fig. 4. It consists of a 90° bend *a* that turns into a masonry chamber *b* on the inside of the filter *c*. This is a hand-operated inlet. The rate of flow to the filter is controlled by partly closing or opening the valve *d*. By paving the surface of the filter bed around the inlet chamber with brick, as shown at *e*, it is protected from being washed away. This form of inlet requires constant attention to prevent a fluctuating water level in the filter, which will cause a corresponding variation in the rate of filtration.

17. To prevent fluctuations in the filter water level, automatically regulated inlets may be used. Fig. 5 shows a simple form of **automatic inlet regulator.** It consists of a vertical cylinder *a* attached to the inlet pipe *b*. A vertical rod *c* to which two disks *d*, *e* and a float *f* are attached, passes through the cylinder. The rod *c* is held in position by the guides *g*, *g*. When the water in the filter reaches the high-water level, the float raises the two disks against the seats *h*, *i*, thus shutting off the water. When the water in the filter is lowered, the float descends, thus opening the valve for the admission of raw water. In this manner, an almost constant water level is maintained, the fluctuations rarely exceeding 6 inches vertically.

18. Filling a Filter.—When filling a filter after the beds have been scraped, the water should at first be admitted through the underdrains until the sand is covered to a depth of at least 6 inches, and then water may be admitted through the raw-water inlet. This practice prevents the disturbing of the sand that occurs when an empty filter is filled entirely through the raw-water inlet. The supply to the underdrains is taken, when filling the filter, from the filtered-water storage tank by a pump that is usually electrically driven. If there are two or more filters, a by-pass valve on a pipe connecting the underdrains may be opened, when the filtered water from one filter will rise through the bed of the other filter; the installation of a pump is thus avoided.

19. Controlling the Filtration Rate.—The rate of filtration in slow sand filters is regulated in three ways.

In the first method, the rate of filtration depends on the rate of consumption. The pure-water reservoir is built on a level with the filter and the water in the two compartments is practically on the same level. When the consumption of water is light, the rate of filtration is low. When the consumption of water is excessive, as may be the case during certain hours of the day, the rate of filtration is correspondingly increased, and the water that has passed through the filter is then liable to be quite impure.

20. The second method of control, the principle of which is shown in Fig. 6, involves operation by hand, and is entirely independent of the rate of consumption. Pure water enters the **effluent chamber** *a* from the filter *b* through the underdrain *c*. The term effluent, often used in hydraulic

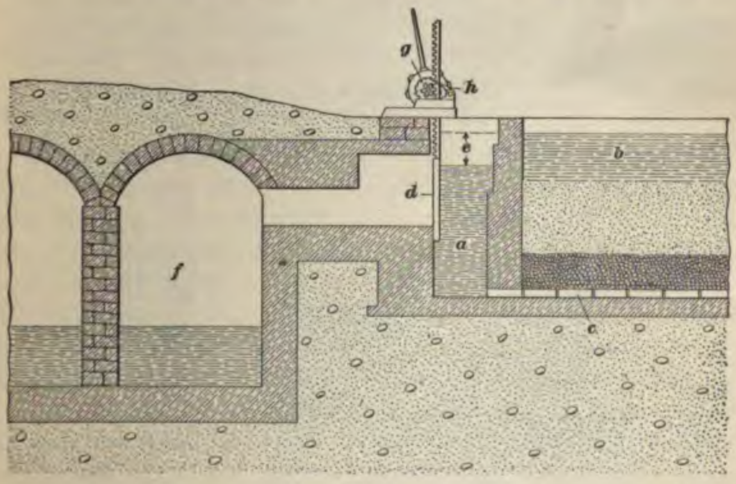


Fig. 6

engineering, means an outflow of liquid, as water. When the sand bed is clean and the water passes through with but slight resistance, the weir, or gate, *d* is raised to decrease the head *e* that forces the water through the sand. As the surface of the filter bed becomes clogged with sediment, a greater head is necessary to force the required amount of water through, and the weir is consequently lowered. When the weir has been lowered to such a level that the head, or the difference between the level of the water in the filter and the level of the water in the effluent chamber is 6 feet, the filter must be emptied and the filter bed cleaned. Any further loss of head is liable to cause a break in the sand and allow unfiltered water to pass through to the underdrains. The filtered water that passes over the weir from the effluent chamber is collected in the pure-water reservoir *f*, which is located at a lower level than the filter. A crank operating a rack and pinion serves to raise and lower the weir; a ratchet wheel *g* and dog *h* locks it in place.

21. In the third method, the rate of filtration is regulated automatically and independently of the rate of consumption, as shown in Fig. 7. The float *a* is attached to a telescopic cylinder, or joint, *b*, which moves up and down over the pipe *c* as the water in the effluent chamber *d* fluctuates. The telescopic joint is open near the top to serve as an outlet for the

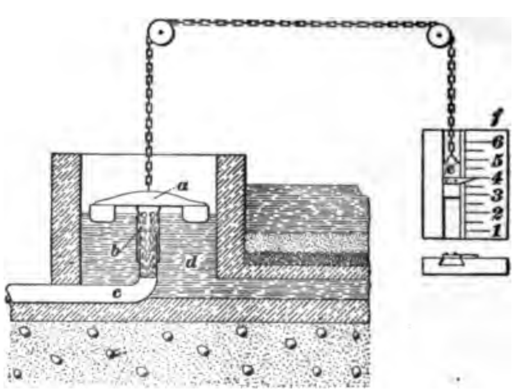


Fig. 7

water. When the filter bed is new and the rate of filtration rapid, the telescopic joint and float are automatically raised by the water that rises in the effluent chamber. As the surface of the filter bed becomes clogged, the float and outlet are automatically lowered by the fall of water in the effluent chamber, but, as the outlet openings in the side of *b* are maintained at a fixed distance below the float, a uniform rate of filtration is maintained. The rate can be increased by weighting the float so as to lower the outlet openings, and conversely the rate can be decreased by attaching a counterweight *e* to the chain to raise the outlet. In the latter case, the counterweight may be used as a gauge to register the loss of head by attaching the scale *f* and an indicator arm, as shown.

22. Covering of Filters.—When open filters are used in cold climates, ice forms over the entire surface of the water, and, if there are but two filters that operate alternately, ice must be removed from one and the bed scraped while the other filter is supplying water. The scraping of filter beds in freezing weather is generally followed by decreased efficiency in the filter, and to obviate such evil, as well as to avoid the expense of removing ice, enough filter beds are sometimes supplied to tide over periods of excessively cold weather without scraping the filter beds.

23. Most of the slow sand filters are built without protection from the weather, and while this practice is generally safe in warm climates where ice does not form on the surface of the water during winter, there are certain conditions under which covered filters are advisable even in warm climates. When the supply is derived from ground water or from other sources that contain much mineral matter, the water should be filtered and stored in the dark to prevent the development of objectionable water vegetation, known as **Algæ**, that rapidly clogs the surface of the filters and also imparts a disagreeable taste and odor to the water. So rapidly does vegetation develop in some ground waters that the periods between scrapings of filter beds are thereby reduced by one-half, and so thick and matted are some of the growths that they can be rolled up like a carpet.

24. In climates where the temperature remains below the freezing point for long periods, and a thick layer of ice forms on all exposed waters, it is advisable to cover filters, both for hygienic and economical reasons. The formation of ice on the surface of water in a filter does not of itself affect the purity of the effluent; but by injuring the walls or scraping the sediment layer of the filter bed it might be the cause of raw water passing through to the underdrains without adequate purification. Also, the efficiency of open filters is greatly reduced for a short period after scraping, owing to raw water passing through cracks in filter beds due to freezing of the sand.

25. Filters may be covered with arches of masonry or wooden roofs, according to the requirements in each particular case. In warm climates, where a roof is used only to darken the reservoir and prevent the growth of Algæ, a wooden construction will be quite suitable, but in cold climates where the object of filter covers is chiefly to prevent the formation of ice on the water, the cover should be made of masonry and the top covered with several feet of earth. Arches, either domed or elliptical in shape, and built of brick, hollow tile, or cement concrete, are generally used. The cost of constructing covered filters of masonry average about 50 per cent. more than the cost of constructing open filters under similar conditions. However, the saving in the cost of operating covered filters in cold climates will more than offset the extra first cost, and they are preferable for all localities where the mean January temperature is below 30° F. In any case, the valves and all operating parts must be housed in for protection.

26. Settling Basins.—When a water supply is obtained from a river that carries a large amount of clay or loam in suspension, settling basins are usually provided to affect a partial **clarification**, that is, the clearing of the water, by allowing it to stand until part of the suspended matter has settled to the bottom. Twenty-four hours has been found a sufficient period of time to allow for **sedimentation**, that is, settlement. Most of the particles that settle at all will do so in that time; a longer storage might allow the growth of Algæ and in other ways cause the water to deteriorate rather than improve in quality. Three settling basins are generally built, each with a storage capacity for 24-hours' supply of water. One of the settling basins can then be filled while the suspended matter in another is settling, and water from the third is being delivered to the filter beds.

When the river from which water is obtained is so affected by tides or other causes that at certain hours of the day the raw water is better than during other hours, openings to the settling basins should be made sufficiently large so that the entire daily supply can be admitted during the short period of time when the water is at its best. The openings to the settling basins should be protected by suitable gratings to prevent the entrance of large floating objects from the river.

The proportion of suspended matter removed in 24 hours by sedimentation averages about 60 per cent. of the particles held in suspension. The heavier particles are drawn to the bottom by the force of gravity, and in settling they carry with them such light particles as they come in contact with, thus affecting a further clarification of the water.

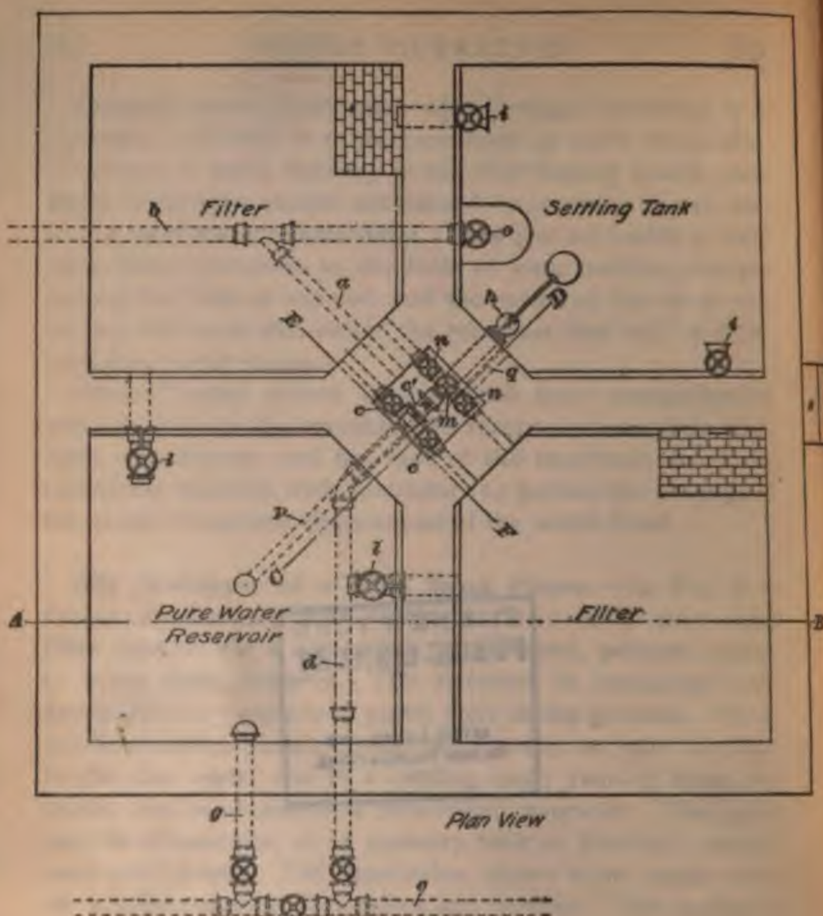
The frequency of cleaning settling basins depends on the amount of water used, the proportion of suspended matter, and the depth of mud provided for in the settling basin. Where muddy water is to be treated, usually a depth of 4 feet is allowed for the deposit of mud; when that limit is reached the water is drawn off and the settling basin cleaned. The mud is removed in barrows or buckets and the sides and bottom of the basin are washed with water from a hose attached to hydrants placed around the sides of the basins for that purpose. The mud and water from the washings are carried out through a mud-valve toward which the bottom of the basin slopes.

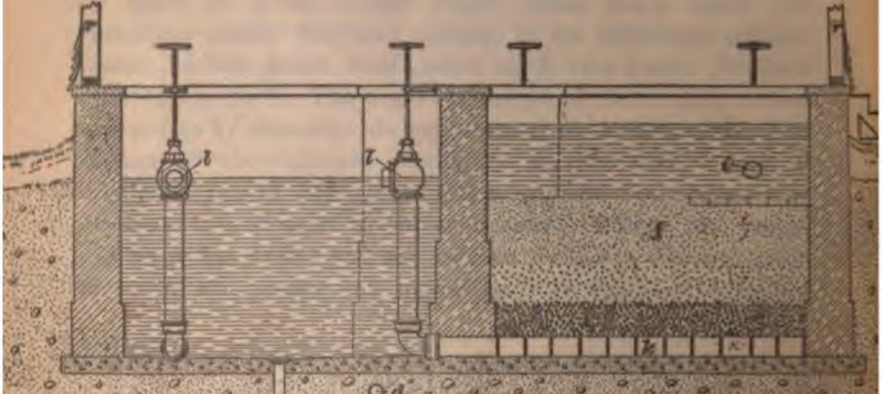
27. Pure-Water Reservoirs.—At all filtration plants pure-water reservoirs should be provided to store a supply of water to compensate for the hourly fluctuations due to an irregular consumption.

Filtered water deteriorates with storage; therefore, it is desirable to deliver it to the consumer as soon as possible. To insure a quick delivery to the distributing mains, pure-water reservoirs should not exceed in capacity 25 per cent. of the daily water consumption. It is also advisable to build pure water reservoirs in the form of long narrow passages having the inlet at one end and the outlet at the other end, so that the water that enters the reservoir first will be delivered first to the mains.

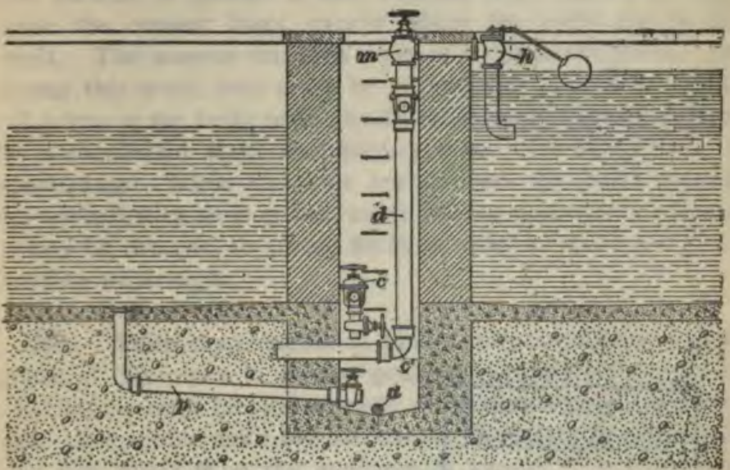
Filtered water should be protected from contamination while in storage, by covering the reservoir to exclude dust, light, and insects; and the roof of the reservoir should be plentifully supplied with ventilators to permit the passage of air to suit the hourly fluctuations of the water level.

28. Example of a Slow Sand Filter.—In Fig. 8 is shown a plan and four sectional views of a slow sand filter suitable for a sanitarium, large hotel, private estate, or other such property. The structure is composed substantially of a square tank partly sunk in the ground. There are four compartments inside the square, as may be seen in the plan view: one is a settling tank; two of them are filters; and the fourth is a pure-water reservoir. The walls may be of concrete, or of masonry built in Portland cement with solid joints. The illustration shows stone walls built on a solid concrete foundation and bottom. The partition walls are also of stone, all the walls being about 2 feet thick. The bottom concrete is about 8 inches thick. This may be made of good broken stone, clean sharp sand, and first-class quality Portland cement, in the following proportions: Broken stone, four parts; sand, two parts; Portland cement, one part. The concrete should be thoroughly mixed and put in by men who are accustomed to lay concrete. The surface of the concrete should be finished with 1 inch of Portland cement and clean sharp sand in the proportions of about two of sand to one of cement. Before this finishing layer has finally set, the surface should be smoothed by throwing on cement and troweling it in well, and bringing

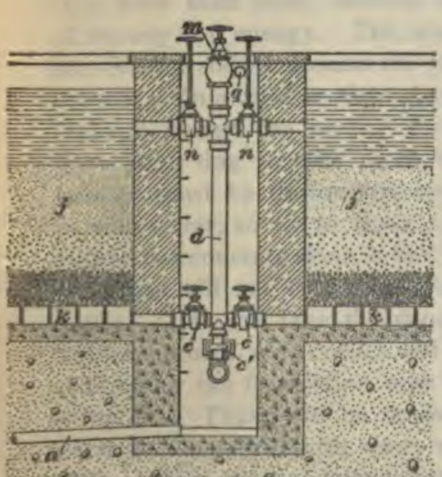




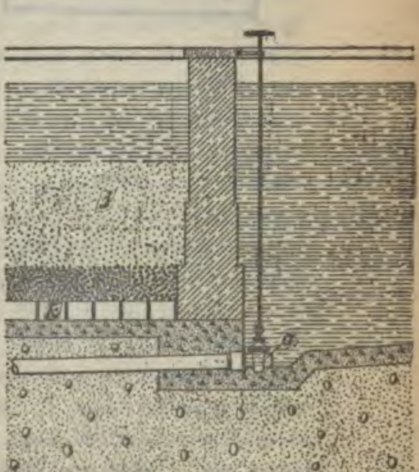
Section through AB



Section through C D



Section through E.F.



Section at O

the surface up to a smooth water-tight finish. After the concrete bottom and foundation have set for about a week and become hard, some empty cement bags should be laid over the surface to protect it, and a plank floor should be laid over the cement bags, except where the walls are to be built. The masons can then proceed to build the walls. In doing this work, they must be exceedingly careful to make all joints in the body of the walls solid, using cement mortar in a semiliquid state, and driving it in well; this is called **grouting.** When the walls are finished, the joints should be rubbed with an iron bar, made for the purpose and called a **key** by masons, to a hard finish in order to make the joint surface water-tight.

29. While the concrete is being laid, the plumber must place all his pipes in proper position, and prop them up so that they cannot be shifted while the concrete men are working. He should take his measurements from the plans and get the levels from the engineer in charge of the work to be sure that the pipes will be in their correct places. It will spoil the walls to cut holes through them for the pipes after they have been built; besides, it is a needless expenditure of money and energy. The mason must be careful to pack the cement solidly around the pipes and grout them in with cement a little thicker than cream, so that there will be no leakage around the pipes. Furthermore, the trenches that have been dug for the pipes that run under the concrete bottom must be thoroughly tamped and the earth slushed in with water, so as to make it compact around the pipes before the concrete floor is laid; otherwise, the earth around the pipes will not be as solid as the natural earth and will settle. This will take the support from under the concrete bottom, which will crack, and by then allowing water to leak under the foundation may cause serious damage to the structure. There will be no danger of such damage if the earth is slushed in with water and made to settle solidly in place before the concrete foundations are laid. The pipes underneath the concrete must be extra-heavy cast iron, with perfectly calked joints, so that they will not become corroded or otherwise defective within a period of at least 50 years. They will probably last longer if there is no unusual corrosive action between the earth and the pipes. Of course, the fixtures and tanks can be arranged separately instead of being grouped together as shown. It is customary to keep them separate in large plants, but in small plants, such as are required for private residences, hotels, etc., they may be grouped together and enclosed in one building.

30. The square shown in the center of the plan is a pit about 3 feet square and 14 or 15 feet deep, in which a number of valves are placed. The drain pipe *a* removes any leakage that may enter the pit through the walls or through the valves and discharges this waste water through the pipe *b* to a point above the ground outside the building. As the bottom of the valve pit is lower than the bottom of the filters, the latter can be drained and emptied into the pit through the valve c'. In the sectional view through *E F* will be noticed a straight pipe joining the bottom of one filter with the bottom of the other filter and having two valves *c*, *c* on the pipe. There is a branch between these valves that turns down with another valve c' attached thereto. This valve drains the cross-pipe into the pit. Thus either filter can be drained into the pit through the valve c'; or, either filter can supply water to the other filter by opening the valves *c*, *c* and closing the valve c'. The pipe *d* is the raw-water supply pipe from the water main *e* that runs underground outside of the building. There is a by-pass valve *f* located on the water main between the branch to the pipe *d* that supplies the filters and the branch to the pipe *g*, which is the pipe that delivers pure water into the main. That portion of the main at the right of *f* is consequently full of raw water, while that portion at the left of the valve *f* contains filter water when the valve *f* is closed. Should it be necessary to shut down the filter plant for repairs, or to give a greater supply of water in case of a fire, the by-pass *f* can be opened and the valves on *g* and *d* closed. These valves are placed close together for convenience in such an emergency. The raw water passing through *d* enters the settling tank through a ball cock *h*, the outlet of which is below the surface of the water and discharges in a horizontal direction so that the inflow will not disturb the mud that has settled in the bottom of the tank. A diffuser that will spread the incoming raw water and prevent agitation of the water in the settling tank would be a better device. The supply to the filters is obtained by the settling tank overflowing into them through the gate valves *i*, *i*. Water percolating down through the sand bed *j* flows through the underdrain *k* and up through the discharge valves *l*, *l* into the pure-water reservoir, from which it is drawn by the pipe *g* and delivered to the buildings. To make repairs to the ball cock *h*, the water can be shut off from the settling tank at the angle valve *m*, and the supply to the filters can be furnished temporarily by opening the gate valves *n*, *n*, which of course must be regulated so as not to overflow the filters. This must be watched while the ball valve is not in operation. The settling tank can be drained empty through a gate valve *o* located at the bottom of the settling tank, which grades toward this point from all sides. The other filter can be emptied for cleaning purposes by opening the necessary valves in the pit, including the valve c', and it can be filled again through the underdrains, previous to turning in the raw water, by closing c' and opening the valves *c*, *c*, both of which should be closed as soon as the water is 6 inches above the sand bed. To prevent the raw water that flows into the filters through *i* from corroding the surface of the sand, a number of bricks are laid on the sand where shown. The bottom of the pure-water reservoir grades down to the center where the waste pipe *p* is run to the bottom of the valve pit, a gate valve being attached inside the pit. To prevent raw water from overflowing the settling tank and filters by an accident to the ball valve, and thereby entering the pure-water reservoir, the settling tank should be furnished with an overflow discharging into the valve pit. The overflow, shown at *q*, should have an area equal to twice that of the ball valve.

If it is desired, the valve *o* may also be placed inside the valve pit, and the settling tank allowed to discharge therein. The dimensions of the different parts will, of course, vary with existing conditions, such as water pressure, the volume of water to be filtered, etc., but the general type of apparatus shown is well adapted to conditions where about 1,000 persons have to be supplied. By running both filters at the same time, 2,000 persons could be supplied, but this is not advisable, because one filter should rest while the other one is in service. It will thus be ready for service when the other is ready to be cleaned.

31. The walls of the wooden house over the filter plant are shown at *r*. The general appearance of the housing can be varied to suit the architectural requirements of the vicinity. In any case, however, the walls and roofs must be built so as to prevent the water from freezing. A hatch should be fitted in the roof over the settling tank for light and ventilation when desired. The hatch may be operated by a rope and pulleys. There should be no hatch over the pure-water reservoir. The door of the reservoir house is located at *s*. It should not be located near the pure-water reservoir, because the traffic should be along the walls of the settling tank instead of along the walls of the pure-water reservoir. The tops of the partition walls are 2 feet wide, which is enough for the men to remove the sand and mud with wheelbarrows. All the valves in the valve pit should preferably have the stems extended above the walls, so that in case of accident, or chokage of the waste pipe *b* with a consequent flooding of the valve pit, any valve can easily be operated from the walls.

The valves on the main are placed outside the building for two reasons: (1) because it is not advisable to build the filter plant over the main; and (2) because they should be easy of access should the keys of the filter house be lost. A portable housing over the valve wheels can easily be removed in the event of fire.

The ground should be graded from the walls of the building, as shown in the section through *A B*. In fact, it is frequently advisable to bank the earth to a point at least 2 feet above the water-line, to prevent the moisture in the walls from freezing and cracking the joints. Should the water ever become so cold that there is danger of freezing, a small stove can be placed on the wall heads with a smoke pipe passing through the roof, but it should not be necessary to resort to this precaution if the house is well built.

MECHANICAL FILTRATION

INTRODUCTION

32. Mechanical filtration is a straining process in which a sediment layer is artificially produced by the use of coagulants. Clarification of water can be effected by passing it without coagulants through a mechanical filter; but, when perfectly pure water is desired, coagulants are used.

Coagulation consists of forming a jelly-like layer on the surface of a sand bed by means of chemicals, which are mixed with the raw water. The coagulant generally used is sulphate of alumina, that is, common alum. When added to water, it decomposes into its component parts, sulphuric acid and alumina; the sulphuric acid combines with lime or any other base present in the water, while the alumina forms a flaky precipitate that gathers together and holds whatever suspended matter it encounters.

There are two kinds of mechanical filters: gravity and pressure. *Gravity filters* are open to the atmosphere at the top and the water percolates through the filter bed by gravity. *Pressure filters* are closed water-tight vessels, in which the water is forced through the filter bed by the full hydraulic pressure of the service pipe. The gravity filters must be located higher than the fixtures supplied, while the pressure filters may be, and usually are, located in the cellar or basement.

The method of filtration is the same in gravity as in pressure filters. Raw water enters the filter at the top, passes

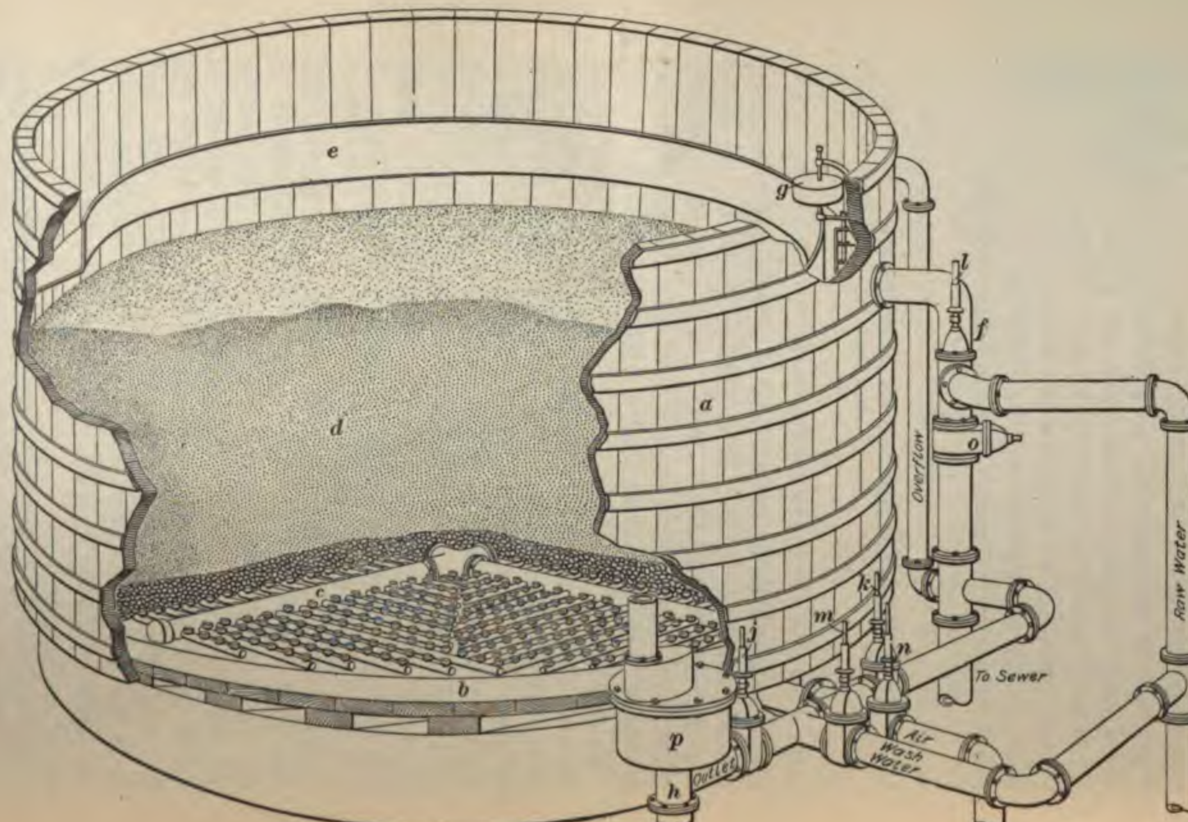

e
g
l
f
a
d
o
Overflow
Raw Water
c
k
m
j
n
To Sewer
b
Air
Wash
Water
p
h
Outlet

FIG. 9

down through a bed of sand, and is collected by a system of underdrains below. Mechanical filters will purify from 100,000,000 to 200,000,000 gallons of water per acre of filter surface, or from 2,295 to 4,590 gallons per square foot of filter surface, per 24 hours; this rate is from 50 to 100 times that obtaining in slow sand filtration.

MECHANICAL GRAVITY FILTERS

33. Continental Filter.—A **mechanical filter** of the gravity type is shown in Fig. 9. It consists of a wooden tank *a* having its bottom lined with a layer *b* of Portland cement; a system of underdrains, as *c*, rests on the cement. The main underdrains have a large number of branches, each of which is provided with a number of perforated nozzles, as shown. A thick layer *d* of sand serves as the filter bed; the trough *e* is an overflow to carry off the wash water when the filter is being cleaned. The operation of the filter is as follows: Water enters through the pipe *f* and its height is automatically regulated by the float *g* inside the tank. The water flows downwards through the sand to the underdrains and is conducted through the pipe *h* to a pure-water tank. The filter bed is cleaned by closing the valves *j*, *k*, and *l*, and alternately forcing water and air through the sand from the underdrains. Water is first admitted through the valve *m* to stir up the bed and thoroughly loosen the dirt, which is floated to the surface by the water and carried over into the trough *e*. The valve *m* is then closed and compressed air admitted through the valve *n* to further agitate the water and aerate the bed. The valve *o* on the waste pipe leading to the sewer is used for flushing the sewer, and is normally kept closed. A regulating device *p* having a valve and float inside, insures a constant rate of filtration through the sand. When the filter is in operation, the valves *l* and *g* are open and all other valves are closed. Detailed instructions regarding the operation of the filter are usually furnished by the maker; these instuctions should be framed and hung up near the filter.

34. When muddy water is to be purified, separate settling tanks are provided and a coagulant admitted to the raw water before it enters the settling tank. If a coagulant is

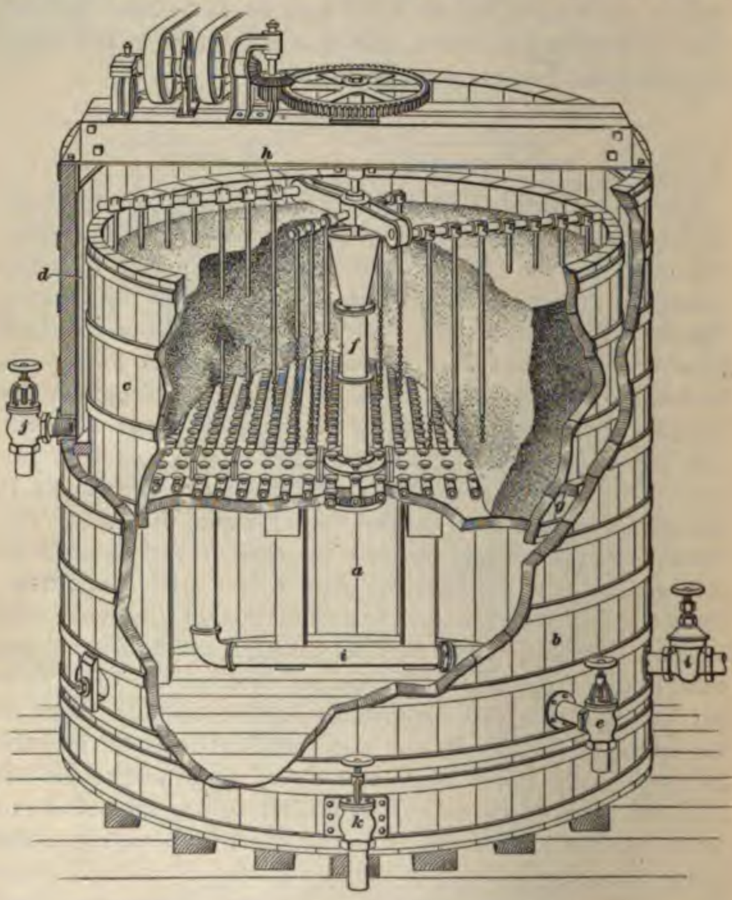


FIG. 10

used in connection with the apparatus shown in Fig. 9, the alum chamber should be attached to the pipe *f*.

35. In a pressure filter of the Continental type, the principles of construction and operation are the same as those of a gravity filter. The only difference is in the containing tank, which is a horizontal steel cylinder that will withstand a heavy internal pressure. The cylinder usually lies horizontally, the pipe connections being made at the end.

36. Jewell Filter.—Fig. 10 shows a gravity type of the **Jewell filter.** It differs from the Continental filter principally in the location of the settling chamber and the method of washing the filter bed. The settling basin *a* occupies the lower half of a large tank *b*, in which is placed the filter *c*. An annular space *d* is left between the filter and the containing tank for the overflow of water when the filter is being cleaned. Coagulated water enters the settling basin through the pipe *e* and rises to the filter through the stand pipe *f*. The strip *g* between the filter and the large tank prevents raw water from rising in the space *d* and overflowing the filter. Air is not used in cleaning this type of filter, but an iron rake *h* is revolved to stir up the sand while water is forced up through the bed from the underdrains. The settling chamber is drained through the valve *k*. The filtered water from the underdrains is drawn off through *i*. The overflow water, while the filter is being washed, is drawn off from *d* through *j*. The gearing, belts, and pulleys shown on top of the tank are used to rotate the prongs and thus stir up the sand while it is being washed.

PRESSURE FILTERS

37. A **pressure filter** is one in which the full water pressure comes on the filter bed, which, thérefore, must be enclosed. There are many kinds of pressure filters on the market, but in a general way the principle of filtration is about the same in all.

Fig. 11 shows what is known as the Jewell pressure filter. It differs from the gravity type bearing the same name, chiefly in the casing. The gearing *a* in this and other large filters is operated by power, a belt being attached to the pulley *b*; in small filters the rake *c* is revolved by hand, a crank being used instead of the pulley.

The filter shown is suitable for filtering the water supply for large hotels, office buildings, etc., where power can easily be obtained. The smaller filters are used chiefly in residences, etc. In the filter connections shown, raw water enters through the pipe *d* and is fed to the bottom of the casing through the valve *e*, the valve *f*, which is on the drain pipe,

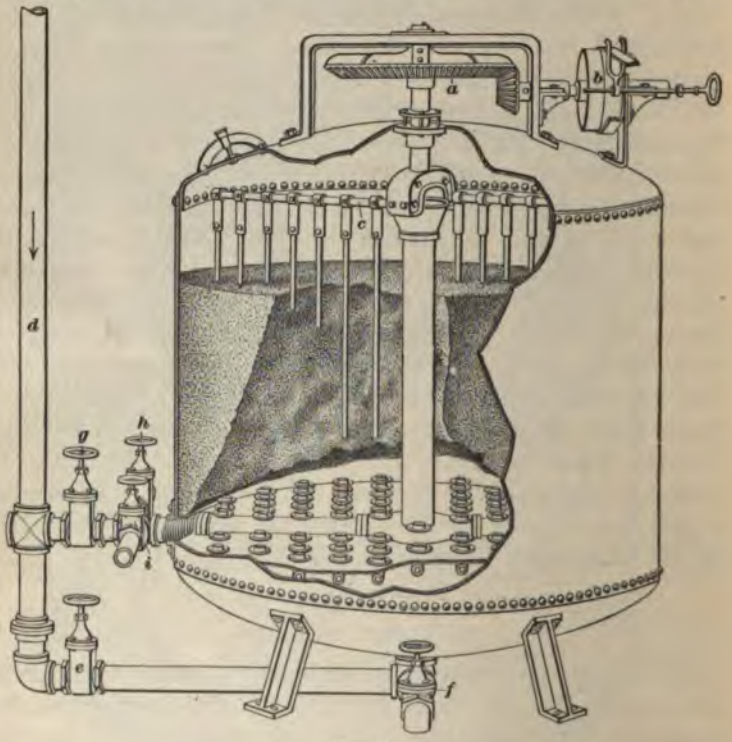


FIG. 11

being closed. The by-pass valve *g* is closed while filtered water is being passed to the building. The valve *h* connects the header of the underdrains to the building and is the filtered-water valve. The valve *i* connects the same header to the sewer or other suitable place where water can be discharged to waste after the filter bed has been cleaned and before the filtered water is turned on in the building. The names of the different valves shown are as follows: *e*, raw-water, or inlet, valve; *f*, sediment, or drain, valve; *g*, by-pass, or filter-washing, valve; *h*, filtered-water, or outlet, valve; *i*, filtering to waste valve. Care must be taken to have the connections made rightly, since otherwise the filter cannot be operated correctly.

38. Large horizontal-cylinder pressure filters are frequently used instead of vertical-cylinder filters. They have the advantage of a very large filter bed, but they have the disadvantage of not being ordinarily provided with rakes for stirring up the sand during the cleaning process. The pipe connections to the horizontal-cylinder pressure filters are usually made at the end of the cylinder, and are valved and by-passed in substantially the same manner as is shown in Fig. 11.

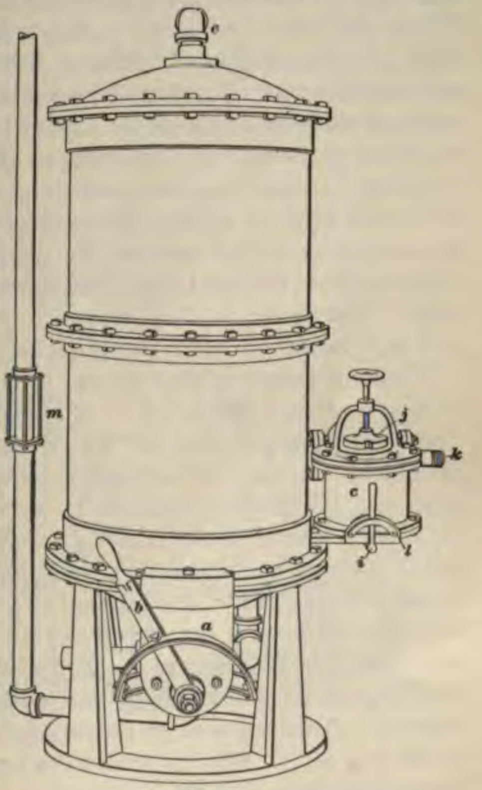


FIG. 12

39. A **Loomis pressure filter** is shown in front elevation in Fig. 12. A feature of this type is the operating valve that takes the place of the numerous separate valves that would otherwise be required. The lever guide *a* is fitted with a registered dial marked "By-Pass," "Filtering," "Filtering to Waste," and "Washing Filter Bed." This plainly marks the stations of the lever during the different operations of the filter. When the lever *b* is at the station marked "Filtering," the water passes down through the filter and is purified, and filtered water can be drawn at the fixtures. When the filter bed is dirty the lever is moved along the dial to the station "Washing Filter Bed"; this action reverses the flow of water and washes the accumulated sediment up and out of the filter. After it is cleaned the lever is moved to the station "Filtering to Waste," when the flow of the water is again reversed and the water again filters down. When the lever is at this station the filtered water is allowed to escape for a few minutes, or until the wash water is all removed from the sand, when the discharge will become quite clear. The lever is then moved to the station "Filtering" and pure water is again supplied to the building.

When necessary to shut off the filter to renew the sand bed or make repairs, the lever is moved to the station marked "By-Pass." This cuts off the water from the filter, and establishes direct communication between the water service pipe and the house distributing system. Coagulant, such as alum, is stored in the tank *c*, from which it is automatically fed to the raw water entering the filter. During the process of cleansing the filter, the current of water lifts the filter bed bodily and forces it through a cutting plate located over the sand bed, thus tearing the matting of sediment to shreds and breaking up the filter bed so that each grain of sand can be washed. A wire screen or perforated confining plate located at the top of the filter prevents the sand from being washed away with the sediment.

40. A view of the under side or bottom of the filter shown in Fig. 12 is given in Fig. 13. The under side of the registered dial is shown at *a*. The lever handle *b* operates a combination cock *c* having numerous water passages. Raw water from the inlet pipe *d* passes through *c*, and either flows into the top of the filter through *e*, is by-passed to the building through the outlet pipe *f*, or washes up through the filter bed, according to the position of the lever *b*. The pipe *g* is the waste pipe through which the mud on the filter bed is washed to the sewer. This is the same pipe that is shown in Fig. 12 rising at the left of the filter, a section *m* of which is made of glass so that the turbidity of the water can be examined.

In Fig. 13, *h* is the under side of the coagulant chamber shown at *c* in Fig. 12; the pipe *e* in Fig. 13 is the same pipe that is shown at *e* in Fig. 12. This pipe connects the combination cock to the top of the filter.

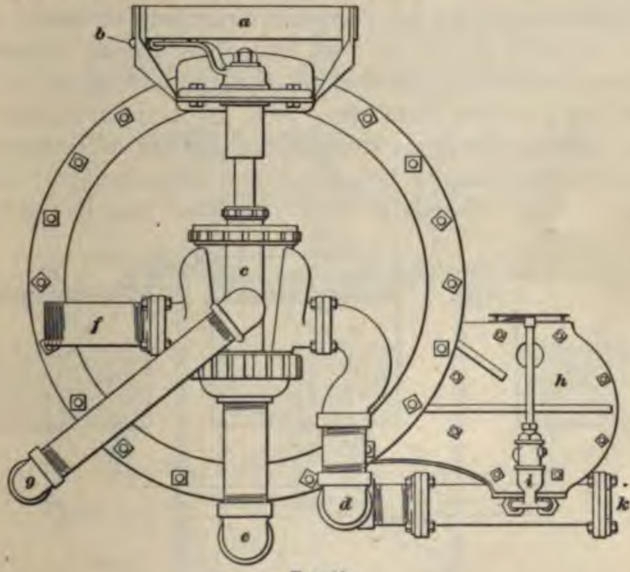


FIG. 13

41. When pressure filters are used, a storage tank should, if possible, be provided for the pure water, to insure a nearly uniform rate of filtration. All pressure filters should also be connected to the house supply by means of a by-pass, so that water can be drawn direct from the service pipe when the filter is cut out for repairs; or, better still, duplicate filters may be used, so that either may be used while the other is shut off.

Pressure filters are seldom used for municipal purification plants. Owing, however, to the facility with which they can be connected to the service pipe of any building furnished with a municipal supply, they are used almost exclusively for the filtration of water in private and public buildings. Also, they are extensively used for manufacturing purposes, where clearness of water is more important than freedom from bacteria.

COAGULATING APPARATUS

42. Coagulator for Gravity Filters.—An apparatus frequently employed for applying coagulant to water in a gravity filter is shown in Fig. 14. Two mixing chambers *a*, *a'* are provided so that the solution can be prepared in one while being drawn from the other. A certain amount of alum, sufficient to prepare a definite amount of solution, is placed in the crates or boxes *b*, *b'* and a fine spray of water blown over it. The water is so regulated that by the time

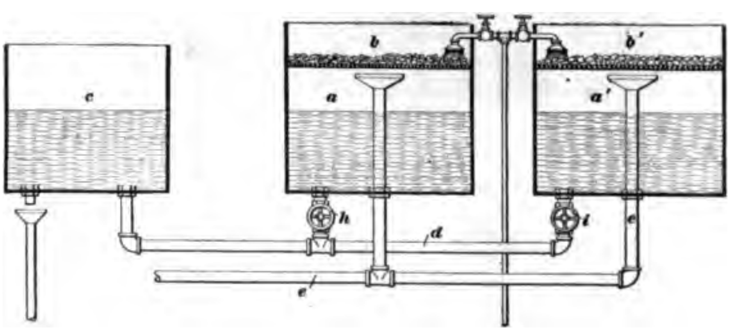


FIG. 14

the tank is filled all the alum will be dissolved. The solution drops from the bottom of the alum box into the mixing chamber, where it should be kept agitated by a stirring device or by forcing compressed air through it from the bottom. The solution passes from the mixing tanks to the measuring tank *c* through the pipe *d*. The overflow pipe *e* prevents the liquid overflowing the tanks *a*, *a'*. The application of the solution to the water in the filter is regulated by increasing or decreasing the size of the opening in *b*; or, the opening may remain unchanged and the charge of coagulant regulated by changing the strength of the solution. The pipe conveys the coagulant to the raw water entering the filter. The valve *h* is used to cut out the tank *a* while the solution is being prepared in it, and the valve *i* is provided to cut out tank *a′* when *a* is supplying the solution.

43. Coagulator for Pressure Filters.—Fig. 15 gives a sectional view of a simple type of coagulant tank for use with pressure filters, and serves to illustrate the principle governing the application of such tanks to pressure filters.

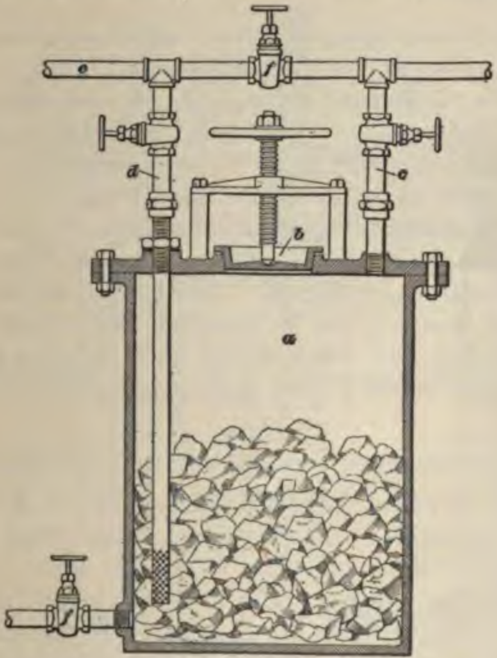


Fig. 15

A quantity of alum is placed in the tank *a* through the handhole *b*. A small stream of water is then admitted through the inlet pipe *c*. The water passes through the alum, dissolves it, and the solution flows through the outlet pipe *d* into the raw water flowing to the filter through *e*. To cause this apparatus to operate automatically, a greater pressure is required in the inlet pipe than in the outlet; a difference of ½ pound to the square inch is sufficient. This is produced by throttling the valve *f* on the service pipe between the two branches to the measuring tank. The valve *f* serves as a blow-off to clean the tank. The objection to this arrangement is that there is no way of measuring directly how much coagulant enters the service pipe. The proper amount of coagulant has to be determined by trial, adjusting the supply by slight increases until the filtered water becomes perfectly clear.

44. The flow of coagulant from special coagulant tanks, such as are shown at *c* in Fig. 12 and *h* in Fig. 13, is directly controlled by a graduated valve *i*, Fig. 13, that regulates the amount of flow. The handhole *j*, Fig. 12, is used for charging the tank *c* with alum. The raw-water pipe is connected to *k*, part of the water passing through the coagulant tank and part passing directly into the filter. The best forms of alum tanks are provided with a graduated gauge for the operating lever, as *l* in Fig. 12. This lever is set at the first notch of the gauge when the alum charge is fresh, and is moved up notch after notch as the alum solution weakens, which is shown by the filtered water appearing less pure.

EXAMPLE OF COMBINATION FILTER CONNECTIONS

45. Fig. 16 shows, in horizontal section and elevation, a method of connecting up two filters so that either or both may be used at the same time. They are supposed to be connected by the pipes *a* and *b* to a coil placed in an ice chest. The pipe *a* feeds the coil, and *b* is the cold water discharge from the coil. The ice chest is supposed to be located at the right of the illustration. The service pipe *c* connects with the city main or tank supply, as the case may be. The pipe *d* is the filtered-water supply pipe to the building. The combination gauge *e* has two indicators, one of which indicates the pressure in *c*, and the other that in *d*. When filtered water is being drawn in the building, the pressure in *d* becomes reduced because of the resistance to the

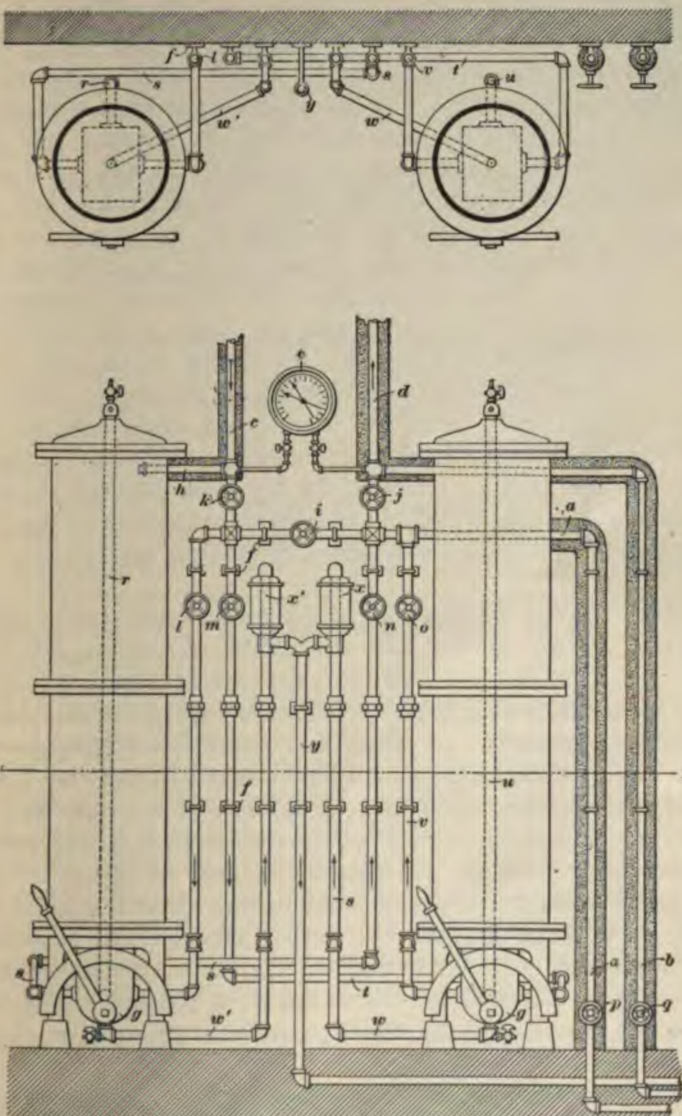


FIG. 16

flow of the water through the filters as it flows from *c* to *d*. The difference in pressure as indicated by the gauge will change with the amount of water drawn and the amount of sediment in the filters. If the filters have been neglected and are clogged, a great difference in pressure will be noticed on the gauge when the faucets supplied by *d* are opened; when the filters are clean, the difference will be slight. Thus, not only the pressure of the water can be read on the gauge, but also, approximately, the condition of the filter bed. Most of the pipes shown in the illustration are placed against the wall, and the filters stand out from the wall about 6 or 8 inches. As shown on the plan, the pipes are held from the wall with ring plate hangers *f*. The water filters downwards, but when being washed the water flows upwards. A combination valve *g* is located at the base of each filter and is operated by the lever handles shown. The pipe *h* is a blind end and terminates at the back of the left filter to give the work a balanced or uniform appearance.

46. To operate both filters and the ice chest, the by-pass valves *i*, *j* are closed and the valves *k*, *l*, *m*, *n*, *o*, *p*, *q* are opened. The raw water entering through *c* is thus compelled to take the following route: It enters through *k* and is divided into two currents at the cross; one current goes through *l* to the valve *g* and thence up the pipe *r* at the back of the filter and entering the top passes through the filter, and *s* and *n* into the pipe *a*, where it joins the discharge from the other filter, both passing through *a* to the ice chest. The other raw-water current that enters through *c* and splits at the cross under the valve *k* passes through the valve *m*, through *t*, to the combination valve *g*, under the right-hand filter, up *u*, and in at the top of the filter, passing through it and out through the combination valve at the bottom, then through *v* and *o* into *a*.

The filters are washed through the waste pipe *w* and *w'*, sight glasses being arranged at *x* and *x'* so that the quality of water washed through the waste pipe can be examined. The sight glasses discharge into a waste pipe *y* that connects with the drainage system, and through which all sediment and wash water from the filters is discharged.

To operate both filters without sending the filtered water through the ice chest, the valves *i, p*, and *q* are closed and *j, k, l, m, n, o* are opened.

To operate the right-hand filter and to use the ice chest, the valves *k, m, o, p, q* are opened and *l, n, i, j* are closed.

To by-pass both filters and the ice chest, or, in other words, to draw raw water through *d*, close *l, m, n, o, p, q* and open *k, i, j*.

It will be seen that by this arrangement of the connections shown, any part of the apparatus, including the ice chest, can be thrown out of service or put into service independent of the other parts, or they can all be put together or in any required combination.

The pipes *a, b, c, d* are covered with pipe covering. It is necessary to cover the pipe *b*; it is not absolutely necessary to cover *a* and *c*, because the pipe *b* contains the ice water while the temperature of the water in *a* and *c* is normal. They are covered chiefly for appearance, but may be left bare if desired.

47. In making combination connections between apparatus, a number of valves are necessary. It is advisable to place these valves symmetrically, and in a general way lay out the work so that when it is finished it will appear neat and workmanlike. It is a very easy matter for a plumber to fit up the filters and ice chest and cross-connections so that they will ordinarily work all right; the very best mechanics take pride, however, not only to fit up the pipes and valves so that the apparatus will work satisfactorily, but also to have the whole job appear symmetrical and neat.

COLD-WATER SUPPLY

COLD-WATER STORAGE

GENERAL PRINCIPLES

PROPERTIES OF WATER

1. Solvent Action of Water.—Most waters, particularly those that are soft, exert a solvent action on minerals and metals with which they come in contact. When brought in contact with iron pipes, soft waters corrode them, forming a red oxide of iron commonly known as *iron rust*. When large quantities of iron oxide are present in water, it renders the water unfit for domestic use, owing to the disagreeable taste imparted to the water, and also owing to the reddish color and consequent liability of staining clothing and vessels with which the water is brought in contact. Water will also corrode lead, brass, and zinc, and then form compounds that are poisonous. Unfortunately, the presence of these poisons in water cannot be detected by color, but only by taste or chemical tests. Water does not affect tin.

The water that exists in common soil is usually mixed with a small percentage of vegetable and mineral acids originated by the decomposition of leaves and minerals; it is more or less destructive to metal pipes that are laid underground unless they are coated with asphaltum or some other protective covering.

The solvent action of water usually increases both with heat and pressure, although heat will sometimes change the character of the water and thus reduce its solvent action.

Steam is very destructive to lead pipe, but it is harmless to brass or iron pipe, unless mixed with air. Lead and zinc, when exposed to water, frequently have a coating formed on their surfaces that protects them from further corrosion.

Hot water, if it be pure and free from gases or air, will not attack pipes of iron, brass, or lead to an extent sufficient to poison the water or render it unfit for cooking purposes, unless it should be allowed to stand in the pipes for a few hours before being drawn off.

2. Absorption of Gases in Water.—Gases are soluble in water, but in different proportions. Pure water at atmospheric pressure and ordinary temperature absorbs an amount of air equal to 4 per cent. of its own volume; of sulphureted hydrogen, 4 per cent.; and of carbon dioxide, 100 per cent. The absorptive capacity is doubled by an increase of 15 pounds in pressure.

The relative volume of gas absorbed varies, in all cases, directly as the pressure and inversely as the temperature. Thus, if the pressure is increased, the water will absorb more gas, and if the water is heated it will absorb correspondingly less gas. Water is said to be *saturated* when it has in solution all the gas that it can hold. If water is saturated with gas and the pressure is reduced or the temperature is raised, the capacity of the water to hold the gas is reduced, and some gas will be liberated. Thus, if water that is under pressure and saturated with air is allowed to flow from a faucet, it will appear milky, because the air is liberated in a great number of fine bubbles that slowly rise to the surface, and the water ultimately becomes clear.

A lower pressure usually exists at the end of a line of piping, or in the vicinity of faucets while water is flowing from them, than at the street main. This reduction of pressure will, if the water be saturated, liberate more or less gas. If air chambers are properly located they will receive this air or gas and utilize it to reduce shocks caused by a sudden stoppage of the water. On low-pressure systems, the water is frequently saturated with air, or nearly so; but this seldom occurs in high-pressure systems, because in these the absorbing capacity of the water is very great on account of the pressure having been increased over that to which the water was subjected in the reservoir. For example, suppose that water in a reservoir under an absolute pressure of 15 pounds (a gauge pressure of zero pounds, approximately) is saturated; that is, contains 4 per cent. of air. Let this water flow into street mains under a gauge pressure of 75 pounds (90 pounds absolute pressure). The absorptive capacity of the water in the street mains, if the water is free from air, is $\frac{90 \times .04}{15} = .24 = 24$ per cent.; but since the water already carries the 4 per cent. of air absorbed in the reservoir, it can only absorb $24 - 4 = 20$ per cent. more air. If this water encounters a supply of air under pressure, as in an air chamber, it will soon absorb it and thus the air chamber will become useless.

MEASUREMENT OF WATER

3. Measuring Pressure.—Water pressure is measured in pounds per square inch above atmospheric pressure by means of a pressure gauge. For pressures of about 100 pounds or less, an ordinary steam-pressure gauge may be used; but for higher pressure, particularly if the apparatus is subjected to sudden shocks, especially made hydraulic gauges should be used.

In Fig. 1 is shown the construction of a pressure gauge adapted to the measurement of either steam or water pressures. It consists of a tube *a* of elliptical cross-section that is filled with water and is connected at *b* with a pipe leading to the vessel containing the liquid whose pressure it is desired to find. The other end *c* is closed, and is attached to a link *d*, which is, in turn, connected with a rack *e*; this rack gears with a pinion *f* on the index pointer *g*. When the elliptical tube is subjected to pressure, it tends to take a circular form of cross-section, and as a whole it straightens out slightly, throwing the free end out a distance proportional to the pressure. The movement of the free end is transmitted to the pointer by the link, rack, and pinion, and the pressure is thus indicated on the graduated dial.

The pressure of water in the plumbing in any building or part of a building supplied from city mains cannot be computed exactly from the vertical height of the reservoir above the building, because the water in the mains is constantly flowing to supply a demand at factories, stores, dwellings, etc. in other parts of the city or town, and the pressure is

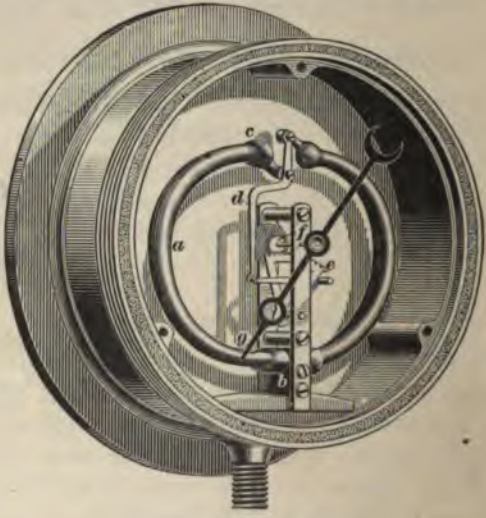


FIG. 1

always lower than that corresponding to the actual head; consequently, a pressure gauge must be used to ascertain the actual pressures at the several points.

The height that water will rise in a building, the gauge pressure, in pounds per square inch, being known, may be computed by the following rule. Although this rule gives the height to which the water will rise, it is advisable to have a surplus head of at least 10 feet above the highest fixture supplied from this pressure, so as to obtain a suitable velocity of discharge.

Rule.—*Multiply the gauge pressure by 2.3; the product will be the height, in feet.*

EXAMPLE.—A pressure gauge attached to a service pipe in the cellar of a building indicates a pressure of 23 pounds. To what height will the water rise in the plumbing system within the building?

SOLUTION.—Applying the rule, $23 \times 2.3 = 53$ ft., nearly. Ans.

4. Measurement of Volume.—Water is measured and sold by volume. The usual unit of measurement for water is the gallon, which in the United States contains 231 cubic inches; the imperial, or British, standard gallon contains 277.12 cubic inches. In some localities the unit of measurement is the cubic foot. Water flowing through pipes is measured by special apparatus called **water meters,** of which there are many types on the market.

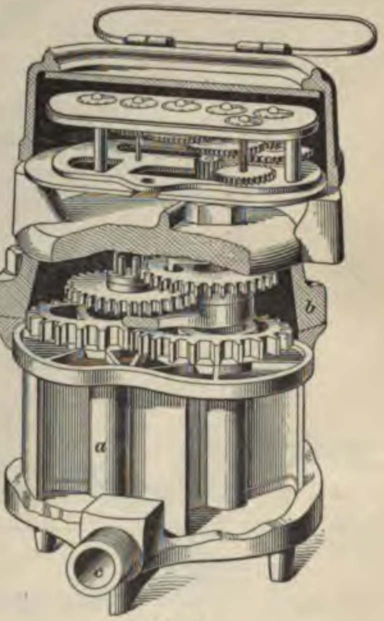


FIG. 2

5. The Worthington water meter belongs to the **reciprocating piston** type; it has two cylinders side by side, with reciprocating pistons therein. The water in flowing through the meter pushes the pistons to and fro; each piston stroke represents a definite quantity of water passing the meter. The movement of the pistons is registered by a suitable mechanism on a dial graduated to read directly to gallons, or cubic feet.

6. The type of water meter shown in Fig. 2 is a **rotary piston meter;** this has two revolving pistons, as a, provided with wings that roll together in such a manner that no water can escape past them without being measured. The elliptical gears in the chamber *b* prevent the pistons *a* from becoming locked. Each revolution of the pistons allows a certain amount of water to pass, and the registering apparatus in the top chamber is so constructed that it will show the gross amount in cubic feet. The meter is attached to the pipe by a coupling connection at *c* and by a corresponding connection on the opposite side.

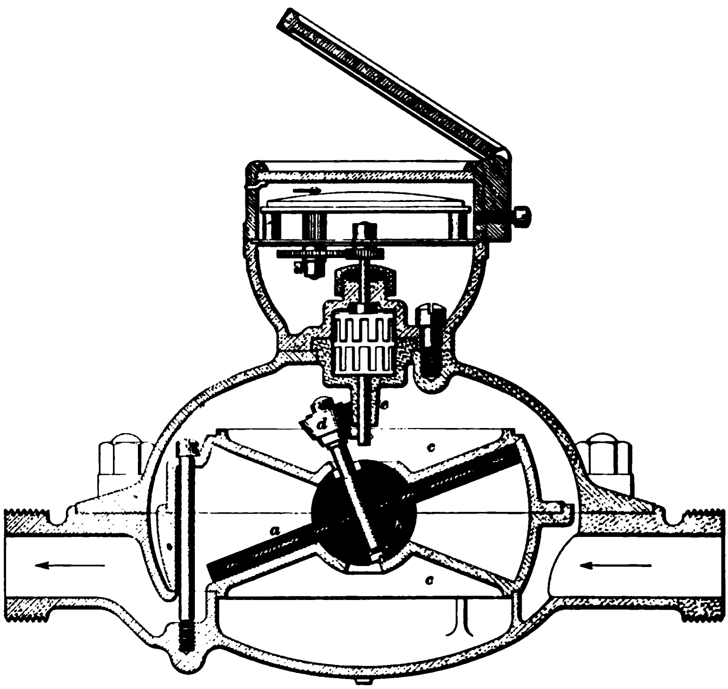


FIG. 3

7. A **disk meter** is shown in Figs. 3 and 4. The disk *a*, Fig. 3, is attached to a central ball *b* that rocks in suitable bearings in the top and bottom heads *c*, *c*, which are conical; the sides of the chambers in which the disk moves are truly spherical. A top view of the disk and working chamber is shown in Fig. 4. The water enters at *a*, Fig. 4, and passes out at *b*, the outlet being divided from the inlet by a partition *c* which extends from the upper to the lower head, and from the ball to the side of the chamber. The disk is slotted to fit over this partition. The roller *d*, which touches the stud *e*, central with the spherical chamber, compels the disk to always touch the upper and lower heads. Since the heads are frustums of cones, and since the disk is a flat plate, it follows that the latter is in contact with the upper heads only along a single line. Referring to Fig. 3, which is a section taken through the outlet port *b*, Fig. 4, let the disk be depressed until it occupies its lowest position in front of the inlet port; then the disk will touch the upper head

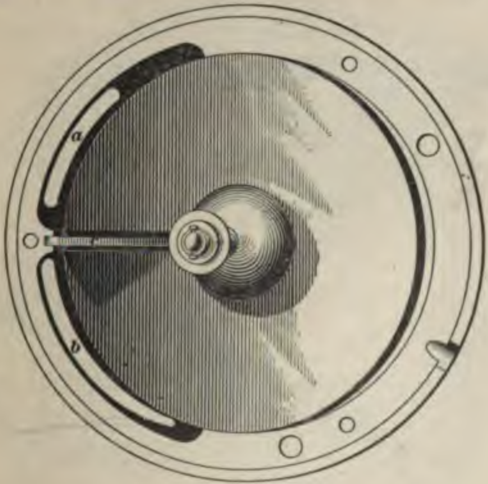


FIG. 4

just about opposite the partitions, Fig. 4. The inflowing water fills the space from the inlet port to the line of contact of the disk with the upper head; it tends to force the disk from the latter. But since the roller *d* prevents this, the disk gyrates; i. e., rolls along the conical surfaces of the heads. As the disk keeps on rolling, it soon opens the outlet port, the momentum of the water on the under side of the disk forcing the water on the upper side of the latter out into the outlet port. The disk is now, in reference to the inlet port, in its highest position; hence, touches the lower head just about opposite the bridge *c*, Fig. 4. The inflowing water now tends to force the disk from under the head; but, since this cannot take place, the disk gyrates in the same manner as before. Thus, it is seen that at alternate gyrations the inflowing water is above and below the disk; hence, the outflowing water is discharged alternately above and below the disk. Each gyration of the disk displaces the entire contents of the chamber, and this quantity is registered, in cubic feet, on the dials above.

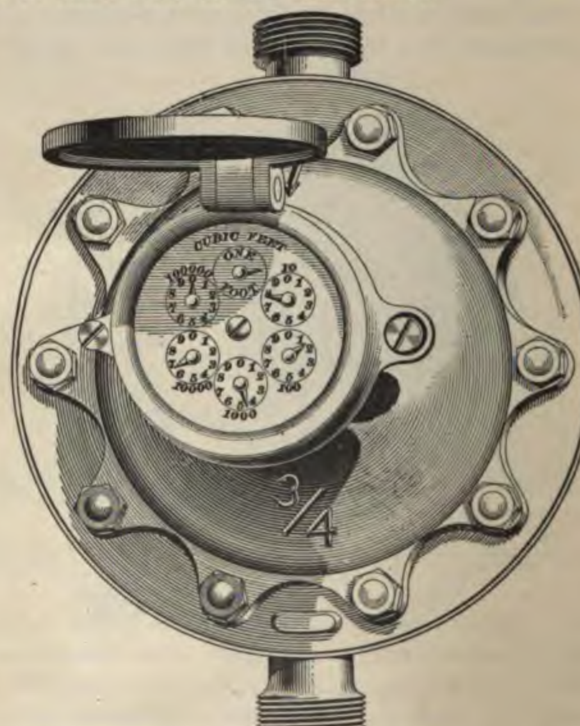


FIG. 5

8. Meters should be so placed that their dials can be seen readily. The method of reading dials, the ordinary arrangement of which is shown in Fig. 5, is about the same in all kinds of meters. The figure to be taken is always the one that the pointer has last passed, and not the one it is approaching. The figure that is indicated on the dial marked *10* must be put down first; that is, in the units place. To the left of it put down the figure indicated on the dial marked *100;* to the left of that put down the figure indicated on the dial marked *1000*, and so on. Thus, the dials in Fig. 5 indicate 6,417 cubic feet. The small dial marked *one foot* indicates only fractions of a cubic foot. To find the quantity of water that has passed through the meter in any certain time, subtract the previous reading from the later one.

9. Great care must be taken to protect the meter, by means of a fine strainer, from the entrance of fish, sand, etc. The principal working parts of ordinary water meters are usually made of hard rubber, which is quickly destroyed by hot water. If there is any danger of hot water flowing back from the boiler to the meter, its working parts should be made of brass or bronze, or a check-valve should be placed on the house side of the meter. If a check-valve is used, a safety valve must be fitted to the kitchen boiler to prevent the accumulation of an undue pressure due to the expansion of the water. The requirements of a good meter are that it shall measure accurately all the water that flows through it, whether it passes as a very small stream or is of the full capacity of the pipe. The working parts should be durable, so that the accuracy of the meter may be maintained for a long time. The meter should offer as low a resistance to the flow of the water as possible. It should always be set level, to secure proper operation of the working parts, and should be placed on the main service pipe, close to the point where it enters the premises, with a waste cock or valve on the side next to the mains, so that the water may be drained from the meter when desired. An air chamber of suitable size should be attached to the inlet side of the service pipe close to the meter, to absorb all the shocks that occur in the pipes. Red or white lead should not be used in screwing up joints in meter connections, or the pipe that joins the meter to the source of water supply, because some of this substance is liable to reach the interior working parts and clog their movements. All meters should be carefully protected from frost.

10. The accuracy of a water meter may be tested by weighing the water that passes through it. Several tests should be made, drawing the water slowly in some tests and as rapidly as possible in others. An ordinary barrel will hold about 5 cubic feet, or between 350 and 400 pounds of water, and is of convenient size to hold water for this purpose.

MOVEMENT OF WATER

11. Water Hammer.—The shock that is felt in a pipe when the flow of water through it is abruptly stopped, is called **water hammer.** It is very destructive to piping and fixtures, because a shock that is caused at one point is felt throughout the entire line of pipe, and damage is inflicted on everything connected with it. The term water hammer is also applied to the loud humming noise frequently made by water pipes when the faucet is opened, and also to the rumbling and snapping noise made by kitchen boilers and hot-water pipes.

The cause of the trouble is quite different in the several cases. In the first case, the movement of the entire column of water from the faucet to the main is suddenly arrested. The water having no elasticity will not compress and thus momentarily absorb its own momentum; consequently, the momentum of the entire moving column of water is expended on the pipes and cocks. If they were sufficiently elastic, the momentum of the water would be absorbed quietly and without noticeable shock, but as they are very inelastic, a heavy blow results. If the pipes are capable of stretching or yielding, every shock will slightly enlarge them. In the course of time the enlargement will result in numerous leaks. If a lead pipe has a thin or weak spot in it, the pipe will swell out and finally burst at that point.

The remedy for water hammer is to use on the pipes air chambers that will cushion the shocks, and to use slow-closing faucets, such as compression bibs.

The trouble in the second case is usually due to interference of the currents of water within the pipe, which frequently occurs at the point where a branch is taken off, and is very liable to occur in a long line of pipe of small diameter in which the velocity of flow is high. A very similar sound is caused by the dancing or chattering of a valve on its seat. The hammering results from the momentary checking and starting of the water column, which is repeated with great rapidity. This action is similar to that of a hydraulic ram, and is very destructive to piping.

The hammering noise usually heard in a kitchen boiler is due to the formation of steam in the waterback. The bubbles of steam travel toward the boiler until they encounter water that is cool enough to condense them, which occurs usually at the coupling at the side of the boiler. The condensation is nearly instantaneous, and the volume of the condensed steam or water being only a fraction of that of the live steam, a vacuum is formed. Water rushes into this space from all directions, and there being nothing present to cushion the blow, the particles of water collide with great force. This trouble is most liable to occur when the water in the boiler is heated nearly to the boiling point and the circulation through the waterback is sluggish.

A rumbling noise is sometimes heard in the boiler when a hot-water faucet is opened. This is due to the fact that the water is heated up to the steaming point, and as soon as the pressure is reduced, as occurs by opening the faucet, steam is instantly liberated in the boiler, or is formed in the waterback.

12. Air Chambers.—In order to cushion the shocks that accompany the sudden stoppage or irregular movements of the water within pipes, **air chambers** are used on them. For many purposes these consist merely of a dead end of pipe filled with air, and so arranged that the air will not escape, or be carried away, by the current of water. Air chambers of larger capacity are used on pumps and hydraulic rams, not only to ease off the shocks of the water column but to equalize the flow of the water, which would otherwise be intermittent. All natural water carries in solution some air or gas that is easily disengaged from the water by a change of temperature and by a decrease in the pressure. Thus, at many points in a system of water pipes, air is liberated in the shape of small globules, or bubbles. These collect at the high points in the system, or in the dead ends of pipe; hence, the air chamber should be placed near the ends of the pipes, or at the highest point.

Under high pressures, air chambers are nearly useless, because the water will absorb the air from them, but the absorption can be retarded in the larger air chambers attached to pumping machinery by pouring a little olive oil, or other sweet oil, into the chamber. The oil floats on the water and forms an air-tight partition between the water and the air, but it must be renewed at intervals. Another means of retaining the elasticity of the air chamber is to fill it with soft rubber balls, either hollow or solid. These, however, will be destroyed by hot water.

13. Air Locks.—Trouble is often caused in low-pressure water-supply systems by air becoming trapped in a supply pipe and stopping the flow of water; this stoppage is known by the name of **air lock.**

The effect of air locked in water pipes may be illustrated by bending some ½-inch glass tubing and connecting it to a glass cylinder, as shown in Fig. 6, and then slowly filling the cylinder with colored water. Water will rise slowly in the columns *a* and *b*, the water-lines of which will be precisely level with that in the cylinder until the column *a* is entirely filled. By continued pouring into the cylinder, water will overflow *a*, trickle down the inside surface of *c*, and gather in the bottom of the columns *c* and *e*. Thus far the water-lines in the cylinder and *b* will remain level with that in *a*. Air is now locked in the column *c* by water above and below it, and the pressure of this air is equal to that of the atmosphere. As water continues to flow into the cylinder, it rises in the tubes *e* and *c*; but since, when rising in *c*, it compresses the air contained in this column, it must also rise in *e* to form a head that will cause the compression in *c*. Thus, while the water rises but slightly in *c*, it will continue to rise in *e* until it reaches the top, when it will overflow and trickle down the internal surface of the column *f*, just the same as it trickled down *c*. During the process of filling the column *e*, water in the cylinder and in the column *b* will rise a distance equal to the vertical height of *e*. Continued pouring of water into the cylinder will cause the water in *a* to overflow into *c*, *e* to overflow into *f*, and a consequent head to be formed in the

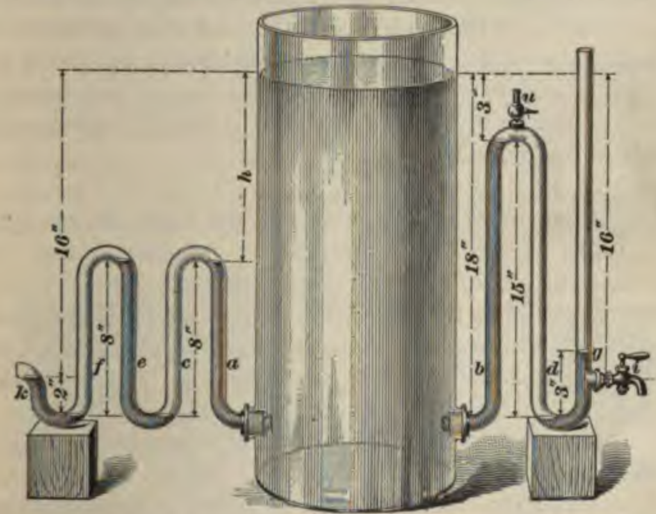


FIG. 6

column *k*, until the cylinder is filled to a point about 2 inches from the top, as shown; the head in *k* will correspond to the increased head in the cylinder.

In order to obtain a complete and thorough understanding of the cause of this phenomenon, the pressures at the several points of the apparatus should be considered. It is evident that the pressures are in equilibrium because all the fluid is in a static condition; it requires unequal pressures to cause a flow. Suppose that the depth of the water in the cylinder, above the inlet opening to the tubes, is 18 inches. The vertical height of the columns *a*, *c*, *e*, and *f* is 8 inches, and the height of the column *k* is 2 inches, as marked in the figure. The pressure on the top of the column *a* is equal to that due to the head *h*, which is 18 − 8 = 10 inches.

Assuming that the air in *c* has no weight, the pressure at the base of *c* is equal to that on top of *a*. The pressure on top of *e* is, therefore, equal to the pressure due to the head *h* minus that due to the head in *e*, which will be 10 − 8 = 2 inches. Since the air in *f* has practically no weight, it follows that the pressure in the base of *f* must also equal that due to a head of 2 inches, and this head is obtained in the column *k*. Hence, a hydrostatic head of 18 inches in the cylinder is resisted by three smaller heads or water columns *a*, *e*, and *k*, which, if placed on top of one another, would cause a vertical head of 8 + 8 + 2 = 18 inches, equal to that in the cylinder.

14. Again refer to the tubing to the right of the cylinder. While water was rising in the cylinder it also rose in *b*, and the water-lines remained constantly level until *b* overflowed into *d*; that is, when the water in the cylinder was 15 inches above the inlet orifice to *b*. The water overflowing into *d* soon closed the return bend at the base, locked the air in *d*, and rose to a height of 3 inches in *g*, which is open to the atmosphere as shown, and would rise no higher when the head in the cylinder was 18 inches. The 15-inch head in *b* and the 3-inch head in *g* precisely counterbalance the 18-inch head in the cylinder. If a cock *i* is tapped into *g* at a point 1 inch below the water-line in *g*, and, consequently, 16 inches below the water-line of the source of supply, and this cock is opened while everything is in equilibrium, water will flow from *i* very slowly, because the effective head causing a flow from the cylinder to *i* is only 1 inch, even though the apparent head is 16 inches. If the small petcock *n* at the top of *b* be now opened, the air in *d* will immediately escape to the atmosphere, because the pressure in *d* is greater than that of the atmosphere by about 3 inches of water column. Water in the cylinder will then flow freely into *d* to replace the air, and when *u* is closed, water will rise in *g* to a level with that in the cylinder. This will now give the full effective head in *g*; the water will flow from *i* under a greater pressure and, consequently, with a greater velocity, which is equivalent to a correspondingly greater volume discharged in a given time. If the air be extracted from the tubes *f* and *c* by vent cocks or air-relief pipes attached to the top of the upper curves, or if the air be forced out of the open end by pouring water rapidly into the cylinder, water will flow from the orifice of the column *k* with a velocity corresponding to a 18 − 2 = 16-inch head in the cylinder.

15. A practical illustration of an air lock in a plumbing system, as it applies to tanks or other vessels depending on one another for their supply, is shown in Fig. 7. The tank *A*, which supplies water to the plumbing fixtures in a building, is filled with water by a pump, through the delivery pipe *a*, and is fitted with a cold-water distributing pipe *b*, expansion

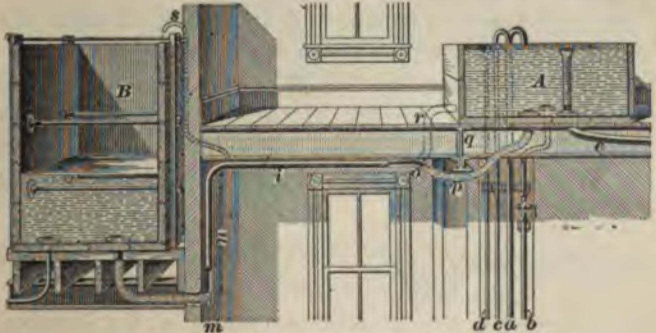


FIG. 7

pipe *c*, telltale *d*, and standing-waste overflow *e*. Suppose that extensions have been made to the building and more plumbing has been installed. The tank *A* is then too small to store the proper amount of water to supply the entire building for a reasonable length of time without comparatively frequent refilling; hence, another tank *B* is installed. This second tank is set at such a height that its top is level with the top of *A*, and it is supplied with water by a communication pipe *i* that joins the bottom of each tank, as shown. This is done to overcome installing a separate delivery pipe, a telltale pipe, and an overflow pipe for the tank *B*, the supposition being that when *A* is filled by the pump, the tank *B* will also fill up; this it certainly would do if air did not become locked in the pipe *i*.

From what has been said regarding the formation of air locks, it will be seen that the pipe *i* will become air locked between the points *m* and *o*, because of the pocket *p* that has been made in order to clear the lower flange of a steel beam *q*, and the loss of head in *B* will equal the vertical height of the air column, as represented by the distance *n*. There are several ways by which this air lock may be avoided; that is, by which the air in the pipe may freely escape to the atmosphere, and the pipe *i*, consequently, be permitted to fill with water. One method is to make a connection to the side of the tank *A*, as shown by dotted lines at *r*, instead of to the bottom; another method is to leave the bottom connection as it is and fit a small air relief pipe *s*, shown by dotted lines, the upper end of which is bent over the tank and the lower end joined to the highest point of the air-bound part of *i*. Either of these simple changes will effect a permanent remedy, and the water-line in *A* will then always be level with that in *B* when no water is being drawn from either of the tanks.

16. There are many ways by which house plumbing becomes air bound, but the effects of the air accumulations are chiefly observed in low-pressure systems, as, for instance, in those systems that are supplied with water by house tanks. The reason of this is that the pressure due to the head between the air locks and the tanks is usually too low to force the air out of the pipes. It is different, however, when the system is under high pressure, because then the pressure is usually sufficient to force the air out of the pipes along with the water.

17. A common cause of air lock in a building is that in which a lead hot-water pipe is run over the floorbeams for a considerable distance, and where the pipe is not supported uniformly throughout its length. A good example of this is shown in Fig. 8. The tank *a* feeds the boiler and the plumbing fixtures, the pipe *b* being the cold-water distributing pipe, and *c* the hot-water distributing pipe. The hot-water and cold-water pipes that supply the wash basin *d* are run under the floor in notches cut in the joists, and, being unsupported between the joists, have sagged, as at *e*. If the

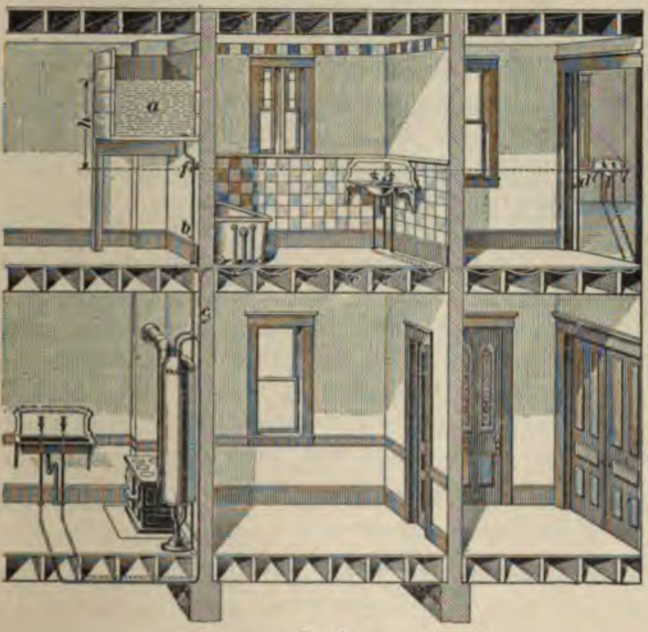


FIG. 8

water be now shut off by closing the stop-cock *f* under the tank, and the cocks at the basin *d* and at the kitchen sink be then opened to drain the pipes, the pipe *e* will be emptied, or nearly so, and air flowing in through the open cocks at *d* will replace the water that leaves *e*. Of course, a certain quantity of water will remain in each pocket or lower curve in *e*, but each upper curve will be full of air. When the water is again turned on by opening *f*, owing to the low pressure and the resistance, frictional and otherwise, the water will not flow through *e* with sufficient velocity to force the air out of the upper curves; consequently, air is locked in each curve and the pipe is thus air bound.

Suppose that the head *h* is 4 feet and that there are thirty air locks in *e*, each lock being equivalent to a loss in head of 2 inches; then, water will not flow into the basin *d*, because while the apparent head is 4 feet, the loss of head due to air locks is $\frac{30 \times 2}{12} = 5$ feet. It will thus be seen that the water will rise in the pipe under the basin *d* only to a height of 1 foot below the basin cock; it will, however, flow all right from the cocks of the other fixtures.

In order to remove the air from *e*, it will be necessary to apply a pump to some suitable point of the system and force water through *e*. This will force out the air along with the water, and thus subject the basin *d* to the full benefit of the head *h*. Or, if a pump is not at hand, the air may be forced out of *e* by opening and suddenly closing the bath cocks. This latter method will cause a temporary increase of pressure in *e* every time the bath cock is suddenly closed, and will force the locks one at a time. The use of the pump is, however, to be recommended for such troubles, because it is positive, and will force every particle of air from the pipe, while the other method will not.

STORAGE TANKS

TANKS FOR GRAVITY SUPPLY

18. General Considerations.—In most cities supplied with city water the pressure on the street mains is sufficient at all times to supply water to all buildings. When such is the case, house tanks are seldom used, both on account of the expense of installation and because water drawn from a tank is never so cool nor so fresh as water drawn directly from street mains. Water-supply systems to many cities, however, cannot be depended on for a pressure that will always be great enough to cause the water to rise in the buildings and supply the highest fixtures. In such cases it is necessary to use tanks in which a quantity of water may be stored, so that when the city pressure fails there will be enough water in the tank to supply the building until the pressure returns.

The type of tank generally used for this purpose is an open tank located above the level of the highest fixture to be supplied. In this type of tank the water is subject only to atmospheric pressure and falls to the fixtures by the force of gravity alone; hence, they are called **gravity supply tanks.**

Gravity supply tanks may be located in the attic of a building, on the roof of a building, or on a separate water tower outside of a building. In small detached cottages and city residences the house tank is usually located in the attic, and when possible is placed directly over the bathroom, so as to simplify the system of piping and economize materials.

In placing a tank in a building, the plumber or engineer must carefully examine the building under the tank to see if the partitions come over one another, and that the stresses due to the load of the tank are transmitted straight down to the cellar floor. If the tank is not set over strong partitions, the ceiling of the room under the tank will invariably sag and the plaster will crack, and probably fall down; or, if the tank is extremely heavy, it may break through the floor.

19. Materials for Tanks.—The materials of which tanks should be made differ with the locality, the kind of water used, and the location of the tank. Round cedar or cypress wood tanks made of staves hooped together are commonly used outside, as on roofs or elevated on trestles. Round steel tanks are extensively used for both inside and outside locations. Wood tanks used inside of buildings are usually rectangular in form and lined with 6-pound sheet lead or 16-ounce sheet copper, tinned on the inside.

20. To determine whether lead or copper will make the better lining for any particular tank, examine some tanks that have been used for storing the same kind of water, to see what effect, if any, the water had on their linings. If this cannot be done, it is considered good practice to send a sample of the water to an analyst, who will advise as to the best kind of lining for the water under consideration.

If it is found that the solder in the seams becomes rotten, no solder should be exposed to the action of the water. In lead-lined tanks, this is easily accomplished by burning the seams. In small copper-lined tanks, the seams should be soldered at the back; but, to protect the soldered seams of large copper-lined tanks it is necessary to paint the entire inner surface with two or three coats of shellac varnish, or with a paint that will withstand the action of the water.

21. Sheet copper, well and heavily tinned on its inside surface, is very well adapted for lining tanks to contain soft water. A block-tin coating is insoluble in most waters, but it is just as soluble as lead or zinc in others. The results obtained by the use of tinned copper for soft-water tanks are so satisfactory, however, that this metal is almost universally employed for such work.

22. Lead forms an excellent lining for tanks that store what is called *hard water*, which means water that contains sulphates or carbonates of lime or magnesia, because a thin insoluble crust of either a sulphate or a carbonate is formed on the inner surface of the lead, and protects the lead from further action of the water.

If a lead-lined tank is employed for storing soft water, such as rain water, or even mineral or spring waters containing certain salts, such as nitrates and chlorides, the water will have a dissolving influence on the lead, and is, therefore, liable to become contaminated.

23. Tanks made of impervious materials, such as porcelain, glass, slate, stoneware, etc., are also used for storing *drinking* water. The slabs of which these tanks are made are usually made water-tight at the seams with red and white lead putty and are held in position by staybolts, which bind the opposite sides and resist the water pressure.

24. Construction of House Tanks.—Plumbers are expected not only to line tanks with sheet metal, and thereby make them water-tight, but also to design them and oversee their construction; therefore, the subject of designing and constructing rectangular wooden tanks will be treated rather extensively, as this form of tank is generally used inside of buildings.

25. Unlined rectangular wooden tanks are difficult to keep water-tight; consequently, they are usually lined with sheet metal. In a lined tank the wooden sides and bottom have only to support the sheet-metal lining and resist the hydrostatic pressure, but are not required to be water-tight. It should be remembered that the pressure on the sides of a tank depends wholly on the length of the tank and the depth of the water, and is not affected by the width of the tank, while the pressure on the bottom depends on its length, width, and the depth of the water. Thus, with an equal depth of water, a tank 1 inch or less in width will have exactly the same bursting pressure on its sides as one 10 feet or more wide and of the same length. To compensate for the increase in pressure with increase in depth, the sides and bottoms of rectangular wooden tanks should be built of planking proportioned to the depth of the tank; thus, for tanks less than 3 feet deep, 1½-inch planks should be used; for tanks from 3 to 6 feet deep, 2-inch planks should be used, and for tanks deeper than 6 feet, 2½-inch planks should be used. The outside of tanks should be well supported with cross-braces spaced about 3 feet apart for tanks 3 feet deep, 2½ feet apart for tanks between 3 and 6 feet deep, and 2 feet apart for tanks of greater depth.

26. Two methods of bracing the sides of a rectangular tank are shown in Fig. 9. The sides are prevented from bulging outwards by vertical posts *a* and a_1. In the method illustrated at the left of the figure, the posts *a* are secured in position by mortise-and-tenon joints *c* to the horizontal timbers *d*, *d*, and are wedged tight by wooden wedges *e*, *e*. This bracing is not so strong as that which ties the post a_1, which is held in position at the top and bottom by wrought-iron bolts, or rods, *b*, *b*. The lower rod should be stronger than the top rod. All the bracing timbers must run crosswise with the planking *g*, *g*, and fish-plates, or large iron washers, *f*, *f*, should be used to prevent the nuts from sinking into the wood. The ends of the tank, like the sides, must be sup-

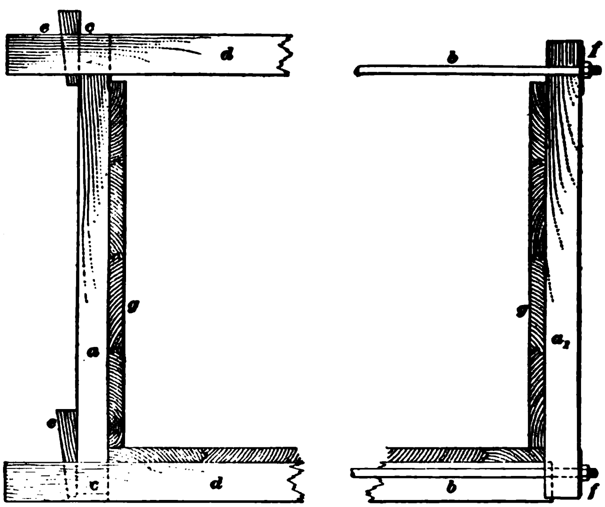


FIG. 9

ported by posts and tie-rods. The bottom tie-rods will necessarily pass through the sills. These must never be notched to pass the rods, but holes for that purpose should be drilled along the center line of the timber, making the holes $\frac{1}{4}$ inch larger than the rods, for convenience in pushing them through.

27. A large open house tank is shown in Fig. 10; it is 8 feet long, 5 feet wide, and 4 feet deep. The planking is white pine 2 inches thick and free from knots. The planking of the ends is let into the side planking about $\frac{1}{2}$ inch, as shown at *a*, and the sides are held together by iron tie-rods *b* and braces, side posts, or stiffeners, *c*, *c*, the lower ends of which are secured by mortise-and-tenon joints into the timbers *d*, *d*, etc., which also support the bottom planking of the tank. Particular care must be taken when cutting the sills *d*, *d* to allow enough of the timber to project beyond the mortise hole to form a good, unyielding abutment for the tenon, or the wedge, as the case may be. Although a brace is not absolutely necessary to prevent the ends of the tank, in this case, from bulging, it is better to use one at each end, as

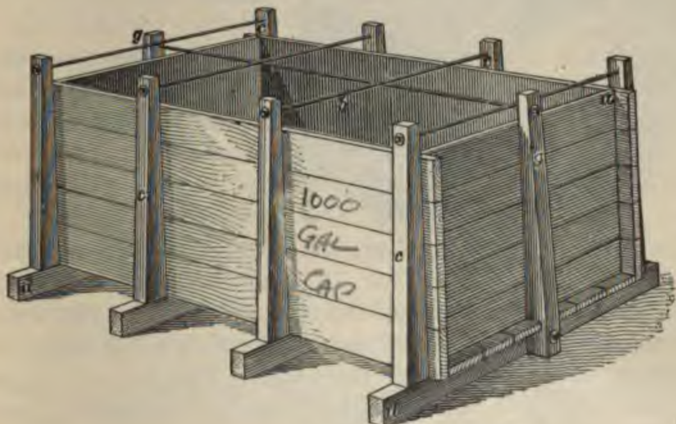


FIG. 10

shown at *g*, *g*, so that the ends, like the sides, will be practically unyielding. These braces are drawn together by iron tie-rods above and below the tank, the lower rod running through holes drilled in the neutral axes, or middle of the timbers, *d*, *d*.

Should the tank be over 5 feet deep, it becomes necessary to tie the braces together at suitable points in their length, so as to avoid the use of too heavy braces. This is accomplished by running tie-rods entirely through the tank, and protecting them from the action of the water by slip tubes wiped to the tank lining.

28. Small tanks that require to be neatly made and strongly built can be made as shown in Fig. 11 when they do not exceed in size 4 feet by 3 feet by 2 feet deep. Their sides *a*, *a* and ends *b*, *b* can be joined together at their corners by dovetailed joints, which are reenforced by nails, shown by dotted lines. The sides and ends are then carefully squared and the bottom is spiked on, the nails being shown by dotted lines. These nails, or spikes, prevent the lower parts of the sides and ends from spreading, and, consequently, preserve the lining.

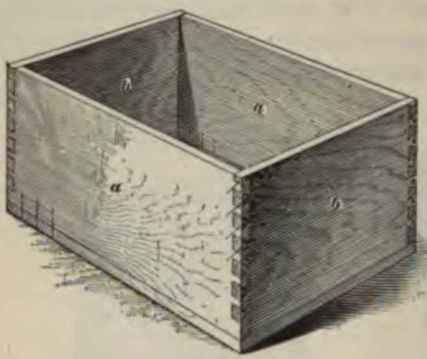


FIG. 11

29. When a wooden house tank is filled with water, it tends to bulge outwards, and when it is emptied it returns nearly to its original shape. There is usually more injury done to lead tank linings by the opening and closing of angles and sharp curves, when the sides and ends of the tank yield under the pressure, than is done by corrosion. This is due to the fact that lead has little elasticity, and, consequently, cannot successfully withstand repeated bending at the same point.

Fig. 12 shows a section of a wiped seam in the bottom angle of a lead lining. It clearly illustrates why lead lining in a poorly made tank will not long remain water-tight unless a constantly uniform water level is maintained. The view is supposed to be taken at about the middle of the tank, because this is the place where the side *a*, if unsupported, will spread out most. When the tank was made, the lowest side plank *a* was spiked

FIG. 12

closely against the bottom plank *b*, and, of course, the lining was put in to fit snugly into the angles and then wiped in position. As the tank filled with water, the pressure on the side became too great for the spikes to resist; hence, they were drawn out to the extent shown, and the plank *a* bulged outwards about $\frac{1}{4}$ inch. The lead lining, however, fitted snugly against the woodwork, and, when the plank *a* bulged outwards, offsets were formed along the edges of the solder *c*, as shown at *d* and *e*, which weakened the metal at those points. Notwithstanding this defect, the lining would last a reasonable length of time if the offsets in the metal did not change their shape. If, however, the side *a* should spring back to its original form when the tank is emptied, or should the lining change much in temperature, and thereby cause the offsets to compensate for the expansion and contraction of the sheets, the metal along the edge of the wiping would soon become brittle to a certain extent, a crack finally being formed along the edges of the wiping.

30. Repairs to metal-lined tanks are frequently tedious to make because of the difficulty in finding leaks. Generally, however, they are on the bottom and often at the seams. If the lining shows signs of pinholes or serious corrosion, it is advisable to reline the tank at once, without attempting to patch it.

31. Open steel tanks are usually made from steel plates, $\frac{1}{8}$ inch to $\frac{1}{4}$ inch thick, riveted together and calked so as to be made water-tight. Such tanks are usually rectangular in shape, although almost any design can be obtained on a special order.

Steel tanks should be set on a flat, solid platform to prevent the bottom seams being strained by the sheets bulging with the pressure. To prevent corrosion, steel tanks should be painted both outside and inside with two coats of paint, composed of pure red lead, pure boiled linseed oil, and just enough white lead worked in to give the paint a body and prevent the red lead from settling to the bottom of the paint pot. Then, after the tank has been set and all pipe connections made, the inside should be painted with one coat of asphaltum.

32. Connections to Tanks.—The pipe connections to house tanks may be made in different ways. Fig. 13 shows a lead-lined tank with the several connections that are most commonly made in practice. The soldered seams at *a* and *b* and the solder dots, or bull's eyes, *c*, *c* are all wiped. An oval funnel-mouth overflow is wiped to the side at *d*. This overflow may discharge through the roof or may be carried

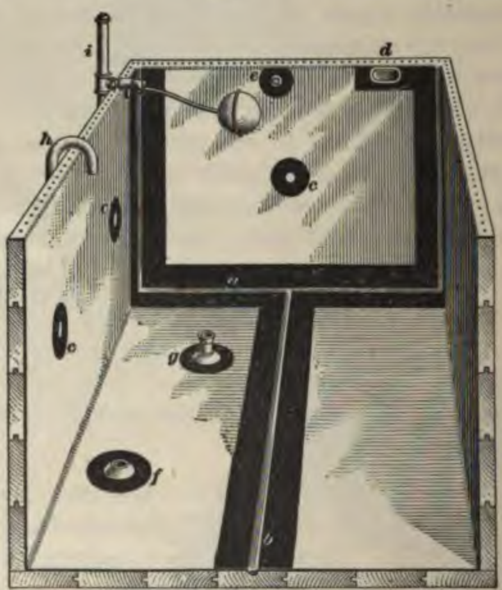


FIG. 13

down and discharge into a water-supplied fixture, such as a safe-waste sink in the basement. A telltale pipe $\frac{1}{2}$ inch in diameter is wiped to the side of the tank at *e*, a point about $\frac{1}{2}$ inch below the level of the bottom of the overflow opening. This telltale is used only when the tank is supplied by a pump, and is intended to indicate when the tank is full. The lower end of the telltale pipe discharges openly into a plumbing fixture near the pump. When the tank is full, water flows down the telltale pipe and is seen by the person at the pump; or, the telltale may be used to automatically stop the action of a power pump. The pipe shown passing up through the bottom of the tank and wiped at *f* supplies the kitchen boiler with cold water; generally, this pipe is also allowed to supply cold water to the plumbing fixtures; this method gives satisfaction provided that the tank is refilled as soon as it becomes empty. But, in cases where the pumping is liable to become neglected, a separate pipe may be run to supply cold water to the plumbing fixtures, allowing the inlet end to be about 6 inches above the bottom of the tank, as shown at *g*. Water then fails to flow from the cold-water faucets before the supply to the boiler is stopped, and helps to prevent trouble due to steam being formed in the boiler. The pipe *h* shown turning over the top of the tank with a gooseneck bend is the discharge pipe from a pump. If the water makes too much noise in falling into the tank from *h*, a deafening pipe may be used. This is simply a pipe one or two sizes larger than *h*, the upper end of which is slipped about 2 inches over the discharge end of *h*, the lower end resting on the bottom of the tank. A number of large holes are cut in the deafening pipe, commencing about 6 inches above the bottom, through which the water will flow to the tank. The slip joint at the top must be sufficiently loose to allow air to freely flow into *h* and prevent the water in the tank from being siphoned back to the well through the pump, should the pump valves leak.

33. Tanks above roofs are usually elevated a few feet in order that connections may conveniently be made underneath, and that the tanks may be protected from frost by suitable casings. Tanks in sheltered positions are usually set on flat floors, with the pipe connections leading from their sides.

The usual manner of supporting and connecting a house tank above a flat roof is shown in Fig. 14. The tank *a* is supported by two 8-inch I beams *b* resting on walls of the building, wooden beams *c, c* being placed between the bottom of the tank and the top of the I beams in order that the bottom edge *d* of the tank may come clear of the I beams. The supply pipe *e* enters the tank through the bottom and extends to above the water level, where it is secured to the

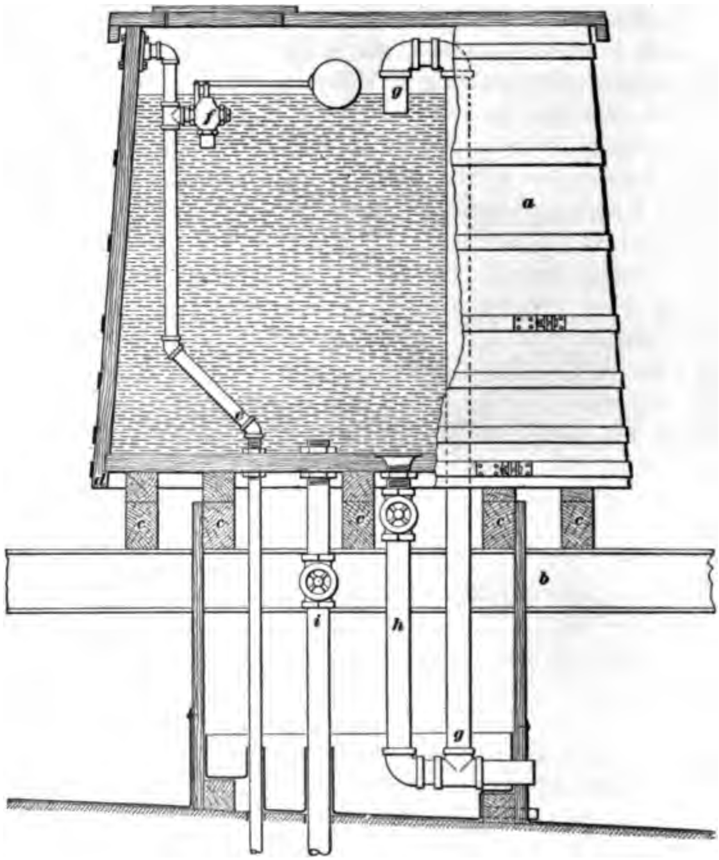


FIG. 14

side of the tank. A ball-cock *f*, connected to the supply pipe near the top, controls the supply of water to the tank and automatically shuts it off when it reaches a certain level. An overflow pipe *g* discharges on to the roof, and its inlet dips into the water to prevent currents of air from circulating through the pipe. An emptying pipe *h* connects to the overflow pipe, or may discharge independently on to the roof. The supply pipe *i* to the building enters the bottom of the tank.

34. Connections to steel tanks should be made by the use of tapped flanges, commonly called **spuds**, riveted to the tank shell as shown in Fig. 15. The spud *a* is tapped to receive an iron pipe *b* and is riveted to the tank body *c* as shown. A sketch giving the exact location and size of these tappings should always be sent to the factory where the tank is to be built.

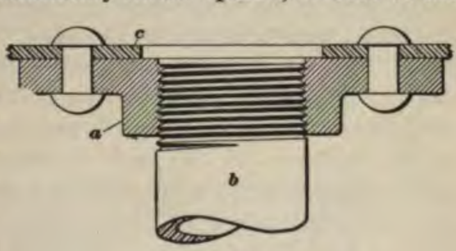


FIG. 15

35. Should it be necessary to make a pipe connection to a steel tank at a point where there is no spud, the connection can be made as shown in Fig. 16. A long thread is cut on the end of the pipe *a*, and a locknut *b* is screwed on the pipe. A gasket *c* is then slipped over the thread and the end pushed through the tank; another gasket *d* is now slipped over the thread and the locknut *e* solidly screwed down. This joint is liable to leak because of the vibration of the pipe, and is not as good as that shown in Fig. 15.

FIG. 16

Connection to the bottom of the tanks should always be made with an offset, to give a spring piece under the tank that will compensate for vibration or a settling of the pipe or the tank.

36. Every open supply tank should be provided with an overflow pipe to remove surplus water that may be discharged into the tank, and thus prevent it from overflowing. Ball-cocks frequently leak and do not shut off when the tank is full. Pumping may even be continued after a tank is full, through neglect of the party at the pump, or failure in operation of a pump governor.

The size of an overflow pipe depends on the quantity and character of the supply to the tank; in any case, it must be larger than is actually required to remove the volume of supply. If roof leaders discharge into a tank, the overflow should be at least one size larger than the combined areas of the leaders. If the tank is supplied by a ball-cock or pump discharge pipe, the overflow should have a sectional area at least six times the sectional area of the supply pipe, because the velocity of the supply stream may be considered to be at least six times as great as the velocity of the water flowing through the overflow pipe. Thus, a $\frac{3}{4}$-inch ball-cock, which has a nominal sectional area of about .5 square inch, should be accompanied by an overflow having an area of $.5 \times 6 = 3$ square inches, which nearly equals a 2-inch pipe. A $\frac{1}{2}$-inch ball-cock may be accompanied by a $1\frac{1}{4}$-inch or $1\frac{1}{2}$-inch overflow, the latter size being used if the water pressure is over 75 pounds per square inch. The mouth of an overflow should always be funnel-shaped to enable a large volume of water to enter freely at a low velocity.

37. Standing overflows are made funnel-shaped, like a long horn, the inlet mouth being about twice the diameter of the base. A ground brass plug and socket connects the overflow to the waste pipe at the bottom of the tank. When it is desired to empty the tank the overflow horn is pulled out, the sediment is stirred up, and the contents allowed to drain away through the overflow waste pipe.

38. In buildings that are supplied with separate systems of piping for different classes of fixtures, as is sometimes the case in localities where water is scarce, the different supplies from the tanks are connected as shown in Fig. 17. The pipe *a* that supplies the least important class of fixtures, such as lawn and street sprinklers, extends to near the high waterline of the tank, so that when water is scarce it will be cut off from these fixtures first. The pipe *b*, which supplies the class of fixtures next in importance, such as water closets, bathtubs, etc., is the next highest pipe and the second one to be cut off when water in the tank is low. The pipe *c* is the next in importance. It supplies the kitchen sink and laundry tubs and is the third system to be deprived of water when

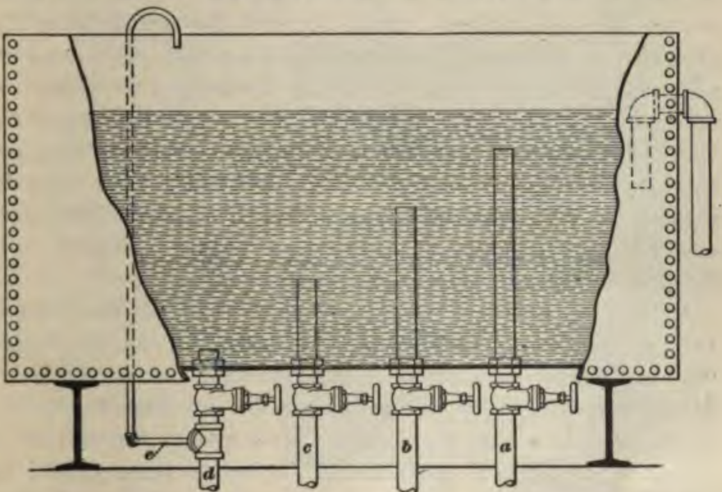


FIG. 17

water in the tank is low. Pipe *d* is the most important supply of all. It is the cold-water supply to the hot-water boiler and is the very last pipe from which the supply is cut off.

If it is desired to vent each supply line so that the air will flow into a line and allow the water to be drained out when the valve under the tank is closed, a ½-inch or ⅜-inch pipe may be connected under the valve and run up over the tank as shown at *e*. Each of the pipes *a*, *b*, *c*, and *d* may be provided with a pipe like that at *e*.

39. Supply to Tanks.—In many cities, the water pressure is sufficient to raise the water above any of the buildings, while in others it can perhaps rise only to the second or third stories of some of the buildings. It will be well for the plumber to ascertain just how high the water will rise before he commences any of the plumbing work, because the system of piping, or the method of supplying and distributing the water, that is best adapted for the building will depend chiefly on the height to which the water will rise. This height can be ascertained only by applying a pressure gauge to the main, or service, pipe and computing the vertical height of a column of water required to counterbalance the pressure indicated, which is done by multiplying the pressure, in pounds per square inch, by 2.3; or, it may be approximated by comparison with the height to which the water will rise in adjoining buildings. If it is found that the water will not rise high enough to supply the plumbing fixtures on the top floor at all times, a storage tank must be placed somewhere, usually above the roof or immediately under it, to contain a supply of water for the building, or at least for that part to which the water will not rise.

In many localities, however, water will rise and supply the top floors of a building during the night, but not during the day. This is due to larger quantities of water being drawn from the street mains during the day than during the night, and is called an *intermittent supply*. When such a condition as this is encountered, a house tank should be located at a convenient point above the highest fixture. The tank should be large enough to hold a 3-days' supply of water for the building. To save the labor and expense of pumping water to the tank, the service pipe should be large, so that when the pressure comes on during the night the tank will fill and be ready to supply the building in the morning.

40. There are several methods of connecting up a tank to the street service and the house distributing pipes, but the most common, and probably the best, is simply to extend the service pipe from the street main up to the tank, taking off as many branches as can safely be supplied at all times by street pressure. When the water pressure increases in the mains, water will rise through this pipe and overflow into the tank, where it will remain until drawn off at the house fixtures. To prevent the tank from overflowing during the night, the flow into the tank should be governed by an automatic regulator, as a ball-cock, for instance. This plan, of course, necessitates running two lines of pipe, the one being an inlet to, and the other an outlet from, the tank.

Fig. 18 shows how one of the lines can be dispensed with, the other line being made to do the work of both. The tank *a* is supposed to be in the attic or on the top floor. The pipe *b* joins it to the city main, a check-valve being placed on *b* at a height that will depend on the lowest pressure likely to prevail at any time. This main check-valve opens toward the tank. Two other check-valves *c*, *d* are attached at the tank end of the rising line *b*. The check-valve *c* allows water to flow from the tank into *b*, but prevents a flow from *b* to the tank, while *d* allows water to flow from *b* into the tank, but prevents any air or water from entering *b* through the ball-cock *e*. The operation of this arrangement is as follows: When the street pressure is high enough, water will rise in *b* until it flows through *e* into the tank, and then all the fixtures in the building will draw their supply direct from the street through *b*. When the street pressure is not sufficient to raise water to the tank, water

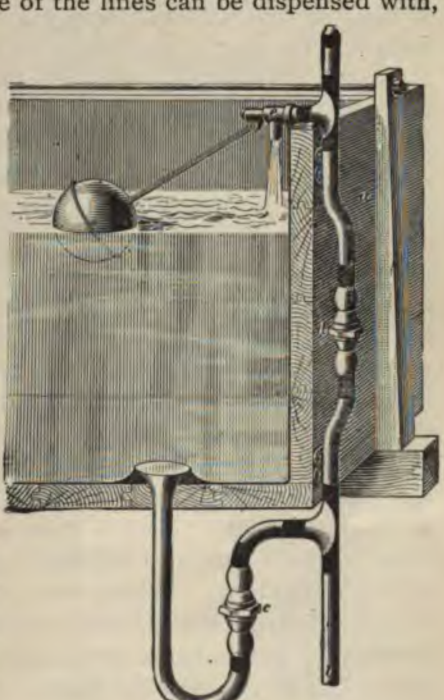


FIG. 18

will flow from the tank through *c* to *b* to supply all fixtures that take their supply from points between the main check-valve on the riser and the tank.

41. Tanks are sometimes installed in buildings that could be supplied directly from the city mains. This is done to provide a temporary supply of water in case the water is shut off from the street mains, and also to relieve the distribution system of the stresses inseparable from a high-pressure supply. To supply the tank with water under such conditions, the service pipe from the street should be run up to the tank and terminate with an air chamber on top, as at *i*, Fig. 13, a ball-cock being connected to it and screwed down to the top of the tank as shown. The tank will thus be kept full by the ball-cock, which works automatically. The spherical ball float shown at the end of the lever rises and falls with the surface of the water in the tank. Should the noise of the water falling into the tank from the ball-cock be undesirable, the noise can be practically stopped by the use of a deafening pipe. An expansion pipe from the highest point of the hot-water distributing pipe that supplies the plumbing fixtures with hot water from the kitchen boiler may be run up to and bent over the top of the tanks, as may also any pipe used to remove air from a trapped part of the water-pipe system. Should it be desired to run roof water directly into a tank, the roof leader pipe may discharge over the top of the tank. In such a case the overflow *d* should be a size larger than the roof leader discharge pipe, and the funnel mouth of *d* should be twice the sectional area of *d* to prevent the tank from overflowing during a heavy rain storm.

42. Size of Tanks.—The size of house tank required to store water for a building depends on the number of inmates to be supplied and the daily quantity of water required for each person. It is found in practice that the daily quantity of water required per person varies with the character of the building. For instance, a larger quantity of water per person would be used daily in a hotel, where the inmates spend the greater part of the 24 hours, than would be used in a school building, where the students spend but a few hours of the day. The following table of quantities of water required for different classes of buildings is compiled from experience. The volume of water required per day for purposes other than ordinary usage at the plumbing fixtures, such, for example, as water motors, care and watering of stock and cattle, carriage washing, lawn sprinkling, etc., should be added to that found by using Table I.

TABLE I

APPROXIMATE WATER CONSUMPTION

Kind of Building	Number of Gallons per Inmate per Day
Ordinary dwellings, tenements, and flats	20
Apartment houses and mansions	25
Hotels	30
Office buildings	15
Ordinary schools	10

The actual amount of water required for each person, child or adult, in a private residence has often been estimated at 25 gallons per day. This amount is used approximately as follows:

Drinking	1 quart
Food	1 quart
Washing dishes and cooking utensils	1 gallon
House cleaning	2 gallons
Washing clothes	3 gallons
Toilet purposes	5 gallons
Bathing and water closets	13½ gallons

A horse will drink about 7 gallons of water per day, and will need 4 gallons for washing.

A carriage will require from 9 to 16 gallons for washing.

A cow will drink 5 to 6 gallons per day.

Tanks supplied from city mains need not be larger than is required to hold a 2-days' supply. Those that depend on one pump and are not near a city, should contain at least 1 week's supply, if water is taken from a well or some other such source. Those that depend on rain only for their supply should hold at least 1 month's supply, or more, depending on the frequency and duration of rain.

43. Protection of Tanks.—In arranging an open tank for the storage of water that will be used for drinking and culinary purposes, it is essential that sanitary conditions exist in and around the tank. Dust and vermin must be prevented from entering the tank, and the space where the tank is located should be ventilated so that the air around the tank will be pure. The tank should in all cases be provided with a close-fitting cover, the top of which may be provided with a large opening covered by a fine-mesh woven brass screen to afford ventilation to the tank.

44. Protection against frost must be considered in making tank connections. Fig. 19 shows how the cold-water supply connection may be made to a copper-lined tank in a cold attic. A round-way stop-and-waste cock *a* has its inlet end wiped to the tank lining an inch or two above the bottom. The cock should be driven in to fit the wood tightly. The outlet end may be wiped to a lead supply pipe, as shown, or be screwed to an iron or brass pipe with a spring piece to take any stress off the lining. The pipe is covered with hair felt *b* and a canvas jacket, which may be sewed or secured with copper wire. A wooden box having a hinged cover *c* is fitted around the cock, and the space is filled in with sawdust or mineral wool. By connecting the cock close to the tank, the water may be shut off and the pipes drained while the tank remains full. All exposed pipes that cannot be boxed in may be covered with hair felt 1 or 2 inches thick, the felt being covered with canvas; or, special pipe coverings may be used.

A tank located outside, or on top of a building, should be provided with a wooden housing to protect it from frost and from the heat of the sun. Care must be taken in locating a tank to avoid the vicinity of soil pipes and vent pipes and all other possible sources of contamination by foul air.

45. Tank Safes.—When copper-lined or lead-lined tanks have been in service a number of years they frequently leak. During warm, humid weather the moisture in the atmosphere

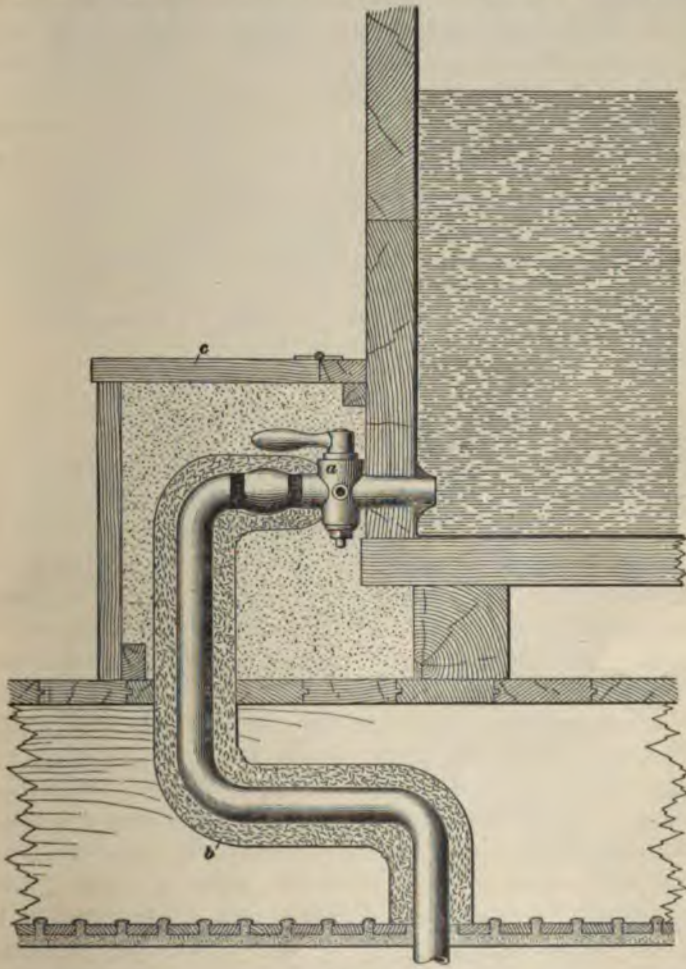


Fig. 19

condenses on the sides of steel tanks and drips off the bottom; tanks inside buildings should therefore be provided with sheet-metal safes laid under them to catch leakage and condensation drips, and thus prevent the buildings from being damaged by water. The safes should be made of 14-ounce or 16-ounce sheet copper, or 4-pound to 6-pound sheet lead. The edges all around should be turned up at least 3 inches and protected by being nailed to the top of a wood fillet, or against the walls. If possible, the upstand of the safe should project at least 3 inches beyond the sides and ends of the tank. A safe-waste pipe, 1¼ inches for small tanks and 1½ inches for large tanks, should connect the safe to a safe-waste sink in the cellar, or a slop sink, if such is conveniently located in the building. This pipe should discharge openly over and into the fixture, a flap valve being placed over the mouth of the pipe. The end connecting to the safe should be protected by a convex brass grating soldered over its open mouth.

TANKS FOR PNEUMATIC SUPPLY

46. Construction and Location.—A new method of supplying water to buildings has recently been introduced to the trade and is now extensively used. It consists of closed chambers in which air and water are confined under a pressure more than sufficient to raise water to the highest fixtures supplied. Then, when a faucet is opened the compressed air in the top of the tank expands and forces the water out of the tank and through the open faucet. Compressed-air pressure, that is, pneumatic pressure, being used as the force to supply water to the fixtures, this class of storage tanks is known as **pneumatic tanks.** With this method of supply a storage tank may be located at any convenient place about the premises. Generally, however, it is placed in the ground, or in the cellar, where it is out of the way and can be kept cool. In order that a pneumatic tank may operate satisfactorily, it must be perfectly air-tight; otherwise, the air will escape, its pressure will be lost, and the water, consequently, will not flow from the tank.

47. Pneumatic tanks are made of wrought iron or steel, and should be cylindrical in form. The thickness and size of the plates, rivets, and other parts are usually determined by the manufacturer. The plumber orders the tank of a certain capacity or cubical contents, or, better still, of a certain length and diameter to suit the location. He should accompany the order with a sketch, showing the location and sizes of the pipe tappings, etc., and specify that the tank be

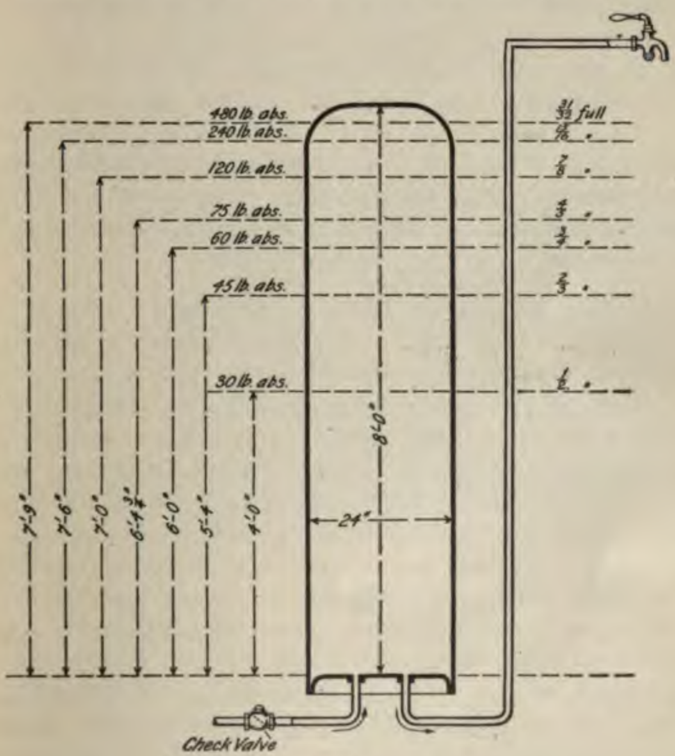


FIG. 20

required to successfully withstand a water test at a pressure equal to at least three times the maximum working pressure. Thus, it is known that the water pressure in a certain building will vary from 40 to 100 pounds per square inch, the maximum working pressure is 100 pounds, and the tank should be tested by filling it with water and then pumping up a pressure of 300 pounds or more. This should be done by the plumber before connecting up the tank.

If a pneumatic tank contains air at atmospheric pressure and water is pumped into it, the absolute pressure resulting in the tank will be inversely as the volume of the air. Thus, when the tank is half full of water the pressure will be equal to about 30 pounds per square inch. When three-quarters full the pressure will be about 60 pounds, etc., as shown in Fig. 20, where the tank is 8 feet high. When the pressure varies between 45 and 75 pounds absolute, that is, between 30 and 60 pounds by the gauge, the tank is between two-thirds and four-fifths full if air has not escaped. Any working pressure within these limits gives good results in buildings four stories and less in height, the tank being in the basement.

48. Advantages of Pneumatic Supply.—Tanks of the pneumatic type have many advantages to recommend their use. Among them are: the water stored in them is free from contamination by dust and dirt; the water is cooler than water from open gravity tanks during hot weather; the tank can be located in the cellar or any convenient place, and it is not necessary to reenforce the building to support one; leakage from the tank will not damage a building when the tank is in the cellar, or buried in the earth.

The disadvantages are: the air will escape from the tank no matter how well it is made; even though the tank were perfectly air-tight, the air would slowly be lost by absorption in the water, and the air must, therefore, be renewed periodically. This is done as far as possible by attaching to the pump an air compressor that at each stroke of the pump forces a proportional amount of air into the tank to maintain the air supply. When the water is drawn from the tank, the pressure decreases directly as the volume of the air is increased; this means that an irregular pressure will exist in the plumbing system.

49. Operation of Pneumatic Water Supply Systems. All pipe connections to a pneumatic tank must be made at the bottom. The seams and manhole plates should also be located at the bottom, so that if they leak the water and not the air will escape.

The construction and operation of a pneumatic supply are shown in Fig. 21. An air-tight steel tank *A* is connected to a pump in a well. The inlet pipe *a* connects to the delivery pipe *b* of the force pump shown, and an outlet *c* is led to the house to be supplied with water. A check-valve *d* prevents the water in *A* from flowing back through *b*

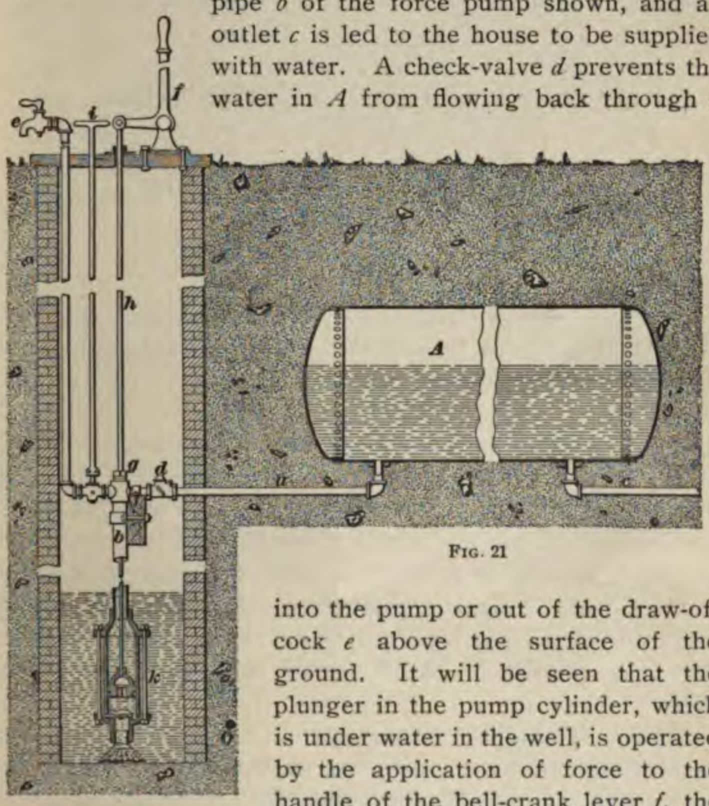


Fig. 21

into the pump or out of the draw-off cock *e* above the surface of the ground. It will be seen that the plunger in the pump cylinder, which is under water in the well, is operated by the application of force to the handle of the bell-crank lever *f*, the fulcrum of which is solidly bolted to a platform over the well. The pump shown is single-acting, and it raises water with the up strokes of the plunger. A stuffingbox at *g*, through which the plunger rod *h* moves, makes a water-tight joint. A stop-and-waste cock on the pipe that supplies *e* can be operated by a **T**-handled key *i*. This is used in winter to shut off the water from *e* and drain its supply pipe below the frost line. A small air pump (not shown) may be attached so that each stroke of the pump plunger forces a proportional amount of air into the tank to keep it charged.

To obtain satisfactory results from a pneumatic pressure tank it is necessary to pump water into it frequently and also to maintain a correct volume of air in the tank.

COLD-WATER DISTRIBUTION

SUPPLY FROM HOUSE TANKS

MATERIALS

50. Lead and galvanized wrought iron are the two materials most used for water-supply pipes, although brass pipes and tin-lined wrought-iron pipes are sometimes used.

Lead pipe is best suited for low pressures and where hard water is used; galvanized wrought-iron pipe is generally used for high-pressure work, and tinned brass pipe or tin-lined iron pipe should be used for conducting water that dissolves lead or zinc. Lead pipe varies in weight and thickness, and in practice should be selected of sufficient strength to withstand at least double the working pressure to which it will be subjected. Lead pipe runs quite uniform as regards quality. The grade known as *AAA* is used extensively for underground service pipes.

Wrought-iron pipe varies greatly in quality. Most of the so-called wrought-iron pipe now on the market is actually made of steel, although it is frequently sold as wrought-iron pipe. The only practical difference between wrought-iron pipe and steel pipe is that steel pipe is sometimes harder to cut and thread than wrought-iron pipe, and is not so easy to bend into coils or offsets. Galvanized pipe is very extensively used on all plumbing systems of the ordinary class where economy in first cost is a consideration.

Brass pipe is made in stock lengths of 12 feet, although special lengths can be made to order. It may be had tempered hard, soft, or medium. For plumbing and steam work, the medium, or **regular temper,** as it is termed, is the best. This tubing is just sufficiently annealed to make it bend easily without cracking. It is advisable when ordering brass pipe always to state for what it will be used. This information will greatly assist the dealer or manufacturer in determining what kind of pipe will give best results. Where brass pipe is exposed in bath or toilet rooms it usually is nickel plated. Brass pipe is used extensively on all first-class plumbing work, particularly in private residences and other buildings that are not erected as investments. When subject to much hard usage and consequent cleaning, however, polished brass pipe or white metal pipe will be found to wear longer and give better results, because it has the same color throughout the entire thickness. The brass soon shows through nickel plating and thus disfigures the work.

DISTRIBUTION SYSTEMS

51. Water-supply systems for buildings should be so proportioned that an ample supply of water at low velocity can be had at all the fixtures. Generally speaking, the pressure of water within a building should not exceed 40 pounds per square inch. In very high buildings, however, it is sometimes necessary to carry great pressure at the lower floors in order to have sufficient pressure to supply fixtures on the upper floors. If these buildings are fifteen stories and upwards in height, intermediate tanks are used to supply from eight to ten floors and thus maintain a moderate pressure. In such cases, by-passes are usually so arranged that the lower floors of a building can be supplied from any of the upper tanks.

52. When buildings are supplied from gravity storage tanks, the mains that descend from the tank may be reduced in diameter as various distributing branches are taken off. This is done to economize in the cost of the installation and to prevent the flow of water at the faucets on the upper floors from being reduced by the flow at the lower floors. An example of such reduction is shown in Fig. 22. The vertical distributing main is reduced in size from $1\frac{1}{2}$ inches, where the top branches are taken off, to $\frac{3}{4}$ inch, where the lowest branch is taken off. The reason that this reduction in size is permissible is that water flowing from the tank *A* tends to fall to the bottom of the vertical line of pipe, and flow out of the lowest branch. Although the vertical line is decreased in size as it descends, it still follows that owing to the greater head there is a greater pressure on the lower branches than on the higher ones; and, to compensate for this difference in pressure, the sizes of the branches on the different floors may be decreased as they descend. Thus, in Fig. 22, the top branch is 1 inch and the lowest one is $\frac{1}{2}$ inch. By this system of distribution a nearly uniform supply of water can be given to each floor in a high building.

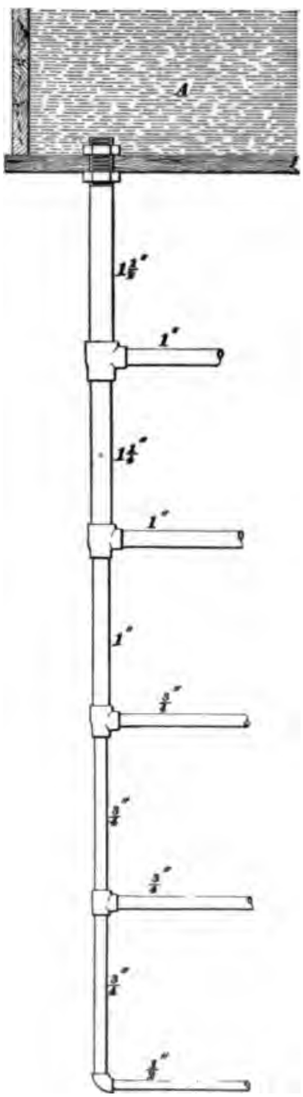


Fig. 22

53. Pipes that rise from a service pipe in the basement and ascend to the upper stories usually should not be reduced in diameter until the last branch is reached, because the pressure grows less as the height increases, and to secure a satisfactory flow on the upper floors, the pipes must be large in diameter. Even if the head is so great that there is plenty of pressure at the upper floors, yet, if the pipes are reduced in diameter, there will be a liability of a lack of water at the upper floors due to water being drawn from the faucets in the lower stories. If a faucet in the basement be opened, for example, the flow from a faucet on the top floor that happens to be open at the same time will be checked, or even stopped, according to the size of the service main.

54. Horizontal distributing mains may be reduced in size in a manner similar to that shown in Fig. 23. However, should the distributing branch enter at the opposite end, so that the pantry-sink branch would be taken off first,

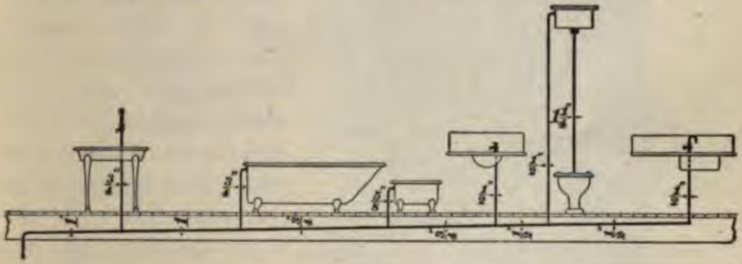


FIG. 23

then it would be reduced only one size, that is, from 1 inch to $\frac{3}{4}$ inch, because its extreme end must equal that of the sink branch. It is better to have the distributing mains a little too large than too small, as the annoyance of one faucet robbing another will then be avoided.

55. The separate system of distribution is resorted to only in localities where water is scarce, or where the tank is not automatically filled and is liable to become emptied. In this system, separate distributing mains are installed for different classes of fixtures, the supply for the least important class being taken from near the top of the tank, so that water will be cut off from that class first when water is scarce; supplies for the other classes of fixtures are taken from nearer the bottom of the tank in proportion as they are more or less important, or separate tanks may be used for the separate systems, although this is seldom done because of the increased cost.

ARRANGEMENT OF STOP-COCKS AND VALVES

56. All stop-cocks in a building should be neatly arranged and grouped together as much as possible, both for convenience and appearance. Fig. 24 illustrates how they may be neatly arranged over a kitchen boiler, a safety valve being attached at *e*. The pipe *a* is the cold-water supply pipe, which connects directly with the street mains. The pipes shown connected to *a* are cold-water pipes, *b* being the inner tube of the boiler. The pipes connected to the pipe line *c* at the right are for the distribution of hot water from the boiler to the fixtures. No stop-cock or other form of shut-off should be placed between the safety valve *e* and the boiler. A stop-cock is placed on the branch that supplies the boiler with cold water; this will, in appearance, balance the safety valve and allow the boiler and hot-water system to be shut off while the entire cold-water supply to the house remains in service. The safety valve has lugs cast on it, so that it

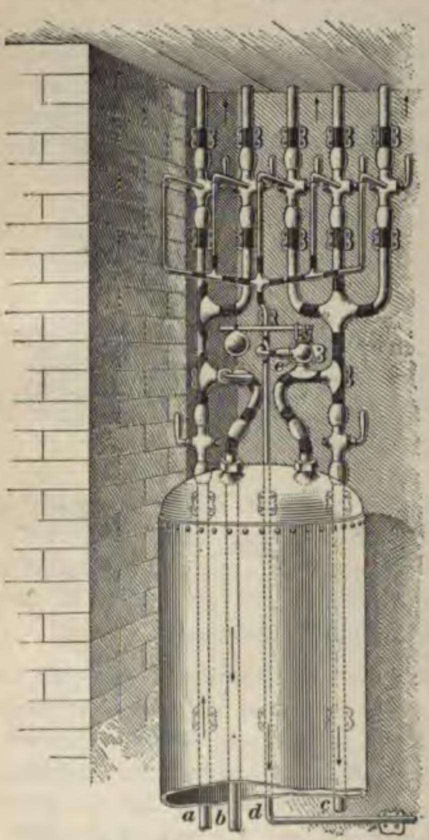


FIG. 24

may be fastened to the wall as shown. This prevents its weight from bending the lead pipes. Its blow-off coupling is wiped to a ½-inch or ⅜-inch lead waste pipe *d*, the lower end of which delivers openly over and into the kitchen sink. The upper end of *d* is continued above the valve and receives the small ¼-inch or ⅜-inch waste pipes from the stop-and-waste cocks, as shown. The same general appearance can be obtained with brass, copper, or galvanized-iron pipe.

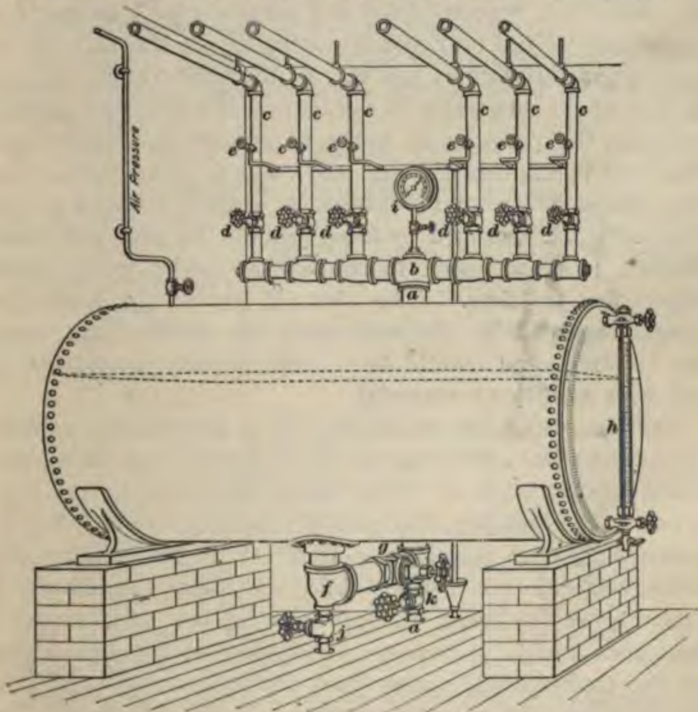


FIG. 25

57. In large buildings the service pipe from the street main is usually connected to a valve header, from which branch connections to the different lines of pipes are made. Sometimes the valve header is so connected to a storage tank that air is locked in the top of the tank, which then serves as an air chamber to absorb shocks and equalize the flow; this method is shown in Fig. 25. The service pipe *a* connects to the valve header *b* near the center. Branches *c*, *c* are taken off for the various distributing lines; each distributing line is controlled by a valve *d* and is provided with an emptying valve *e* to empty all water from the distributing pipe when the controlling valves are closed. The waste pipes from the several emptying valves are connected together and discharge into a water-supplied sink or other receptacle. A branch *f* from the service pipe *a* connects to the bottom of the tank and is controlled by the valve *g*. A water-gauge glass *h* at the end of the tank shows the proportion of air and water in the tank, and a pressure gauge *i* indicates the pressure of water, in pounds per square inch. The tank is emptied through the valve *j*. The valve *k* controls the water supply for the entire system. Every service pipe, where it enters a building, should be provided with a shut-off cock, or valve, to control the entire water supply within the building. The shut-off should be located as close as possible to the wall where the service pipe enters the building, and should be of the most approved pattern and best quality of material.

The apparatus shown in Fig. 25 is particularly valuable in cases where a building is supplied from a small main in which the pressure is high. While the water is not being drawn in the building, the tank is subjected to the full street pressure. When more water is drawn in the building than the small main can supply, the extra water needed will be drawn from the tank; the pressure in the tank gradually decreases while this occurs. As soon as the heavy draft on the tank ceases, water from the street main will enter the tank and the pressure therein will run up again. This tank, therefore, operates as a pneumatic storage tank.

SIZES OF WATER PIPES

58. Sizes of Service Pipes and Branches.—The proper diameters of pipes for cold-water supplies depend on several conditions, which are: the number and size of faucets likely to be discharging water at the same time; the pressure or head of water; the length of the pipe.

If the pipe is crooked and contains numerous bends or angles, due allowance must be made for the resistance arising therefrom. A pipe of small bore having great length is liable to be noisy, if the pressure is great, being subject to singing noises and water hammer. This defect may be avoided by using a pipe of larger diameter, thus reducing the velocity of the moving water.

All service pipes that supply fire-hydrants without the intervention of storage tanks should be at least 3 inches in diameter.

TABLE II

SIZES OF COLD-WATER MAINS

Diameter of Mains Inches	Number of Fixtures Mains Will Ordinarily Supply	
	Low Pressure	High Pressure
3/4	10	15
1	15	25
1 1/4	25	50
1 1/2	50	75
2	75	125
2 1/2	150	200
3	200	300
4	300	600

The sizes of mains given in Table II are commonly used in buildings where the pipes are not of great length. If the pressure is less than 30 pounds per square inch, the system may be rated as low pressure, and if above 30 pounds, as high pressure. Judgment must be exercised, however, in using the table, as there are conditions under which larger sizes of pipes would be desirable, and other conditions under which smaller pipes may be used. For instance, in a building where the probabilities are that most of the fixtures

TABLE III

SIZES OF COLD-WATER BRANCHES TO FIXTURES

Supply Branches to	Diameter in Inches	
	Low Pressure	High Pressure
Bath	$\frac{3}{4}$ to 1	$\frac{1}{2}$ to $\frac{3}{4}$
Basin	$\frac{1}{2}$	$\frac{3}{8}$ to $\frac{1}{2}$
Water-closet flush tank	$\frac{1}{2}$	$\frac{1}{2}$
Water-closet flush valve	1 to $1\frac{1}{4}$	$\frac{3}{4}$ to 1
Sitz or foot-bath	$\frac{1}{2}$ to $\frac{3}{4}$	$\frac{1}{2}$
Kitchen sink	$\frac{5}{8}$ to $\frac{3}{4}$	$\frac{1}{2}$ to $\frac{5}{8}$
Pantry sink	$\frac{1}{2}$	$\frac{3}{8}$ to $\frac{1}{2}$
Slop sink	$\frac{5}{8}$ to $\frac{3}{4}$	$\frac{1}{2}$ to $\frac{5}{8}$
Urinal	$\frac{5}{8}$ to $\frac{3}{4}$	$\frac{1}{2}$ to $\frac{5}{8}$

TABLE IV

SERVICE PIPE SIZES FOR FLUSHOMETER VALVES

Number of Flushometer Valves											Diameter of Pipe Inches
Water Pressure, in Pounds per Square Inch											
10	15	20	30	40	50	60	70	80	90	100	
			1	1	1	2	4	4	4	5	1
1	1	1	2	2	2	3	5	5	5	6	$1\frac{1}{4}$
2	3	3	3	4	4	6	6	7	7	7	$1\frac{1}{2}$
4	6	6	7	7	8	8	9	9	12	14	2
6	8	8	10	10	12	14	5	16	18	18	$2\frac{1}{2}$
7	8	10	13	14	15	16	7	18	20	22	3
11	14	16	19	21	24	28	3	34	37	40	$3\frac{1}{2}$
25	28	32	40	48	56	64	70	75	78	80	4
40	45	50	60	70	80	90	00	110	120	130	$4\frac{1}{2}$
60	70	80	100	120	140	160	180	200	220	240	5
100	125	150	200	250	300	350	400	450	500	550	6

will be used at the same time, the largest size mains should be used, while if only comparatively few fixtures will be used simultaneously, a smaller size main may be used.

The sizes of supply branches to fixtures for high-pressure and low-pressure systems can be found in Table III.

59. Size of Service Pipes for Direct-Flush Valves. Direct-connected flush valves are now extensively used in place of overhead tanks to flush water closets, urinals, or slop sinks. They may be supplied with water direct from the street service, or, as is generally the practice, from a special tank in the attic. They are made to operate under high or low pressures, but as a rule are not suitable for pressures less than 10 pounds. The sizes of rising mains required under different conditions are as given in Table IV, provided that the length of the pipe does not exceed 1,000 times its diameter.

SUPPLY FROM STREET MAINS

CONNECTIONS TO MAINS

60. Water mains are usually tapped and the service connection made while the water pressure is on. This is accomplished by means of a special tapping machine that drills and taps the pipe, and screws in the corporation cock without permitting water to escape. When the corporation cock is screwed into the water main, the machine is removed, and the service connection can then be made. Tapping of service mains is usually done by an employe of the water company or city that owns the plant.

61. Fig. 26 shows two methods of connecting a galvanized-iron service pipe to a cast-iron street main. The service pipe *A* is connected to the street main *B* by the brass corporation cock *C*, forming a straight connection at right angles to the main. This makes a cheap but unsatisfactory connection; if the ground is of such a nature that the heavy main *B* can settle, the ends of the cock *C* are liable to be broken off; also, if the service pipe *A* is long and rigid, it will exert stresses on *C* that may ultimately break the connection. A more reliable connection is that by which the service pipe *D* is joined to the main. A corporation cock *E* is screwed into a hole drilled and tapped in the main in the same manner as *C*, and *E* is joined to *D* by means of a lead-pipe offset *F* wiped to a brass solder nipple *G* and to a

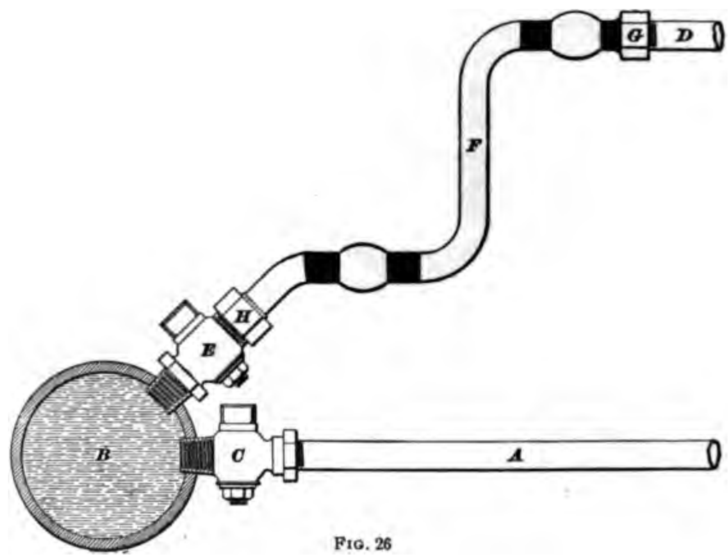


FIG. 26

ground coupling and ring, or union *H*. The lead pipe will easily bend with any change of position due to settlement or change of temperature of *D*. Double *A* or *AAA* lead pipe should be used for this connection, according to the water pressure and the nature of the earth in which the pipe is laid.

62. Where the service pipe to a building is larger than a common corporation cock can supply, and the main cannot be cut to allow the insertion of a special branch fitting, it is advisable to screw a number of corporation cocks into the main and connect them all to a special breeches piece or multiple-branch increaser, as shown in Fig. 27. The branch increaser shown at *a* tapers from the full size of the service pipe *b* down to the size of the largest corporation cock allowable by the waterworks authorities. The branches taken from the increaser project at an angle of about 45° and should be so arranged that the current from any one will not affect the flow from any of the others. The lead pipes *c*, *c* connect to the top of the main *d*, each piece of lead pipe being a bend.

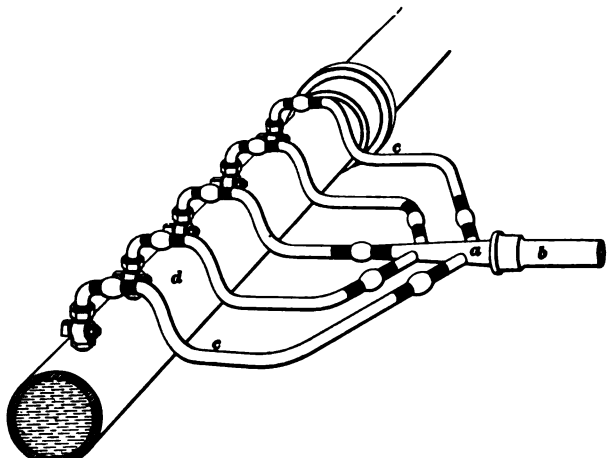


FIG. 27

The sum of the sectional areas of the branches should be a little greater than the sectional area of the service pipe, in order to compensate for the frictional resistance of the water as it flows through them. This will allow the service pipe to deliver water at its full capacity, which is necessary if it supplies fire-hydrants.

63. In large office buildings, hotels, and in public institutions, where an uninterrupted supply of water is necessary, two service pipes should connect the building with the street mains. Each service pipe should be large enough to supply the entire building with water, and each should connect to a different water main, and they should be cross-connected in the building, so that in case water is cut off from one street main an adequate supply can be obtained from the other.

64. Where a service pipe passes through a foundation wall, allowance should be made for probable settlement of the wall, and a space of 2 inches or more should be left on all sides of the pipe. A good practice is to build into the wall a thimble of iron pipe two or three sizes larger than the service pipe.

65. A street washer is simply a branch taken from the water-pipe system for the purpose of furnishing water for washing streets and sidewalks, sprinkling lawns, etc. The connection, if remote from the building, is usually taken from the service pipe at a suitable point underground. A stop-and-waste cock, or valve, is placed on the street-washer branch below the frost line, and is operated by a rod terminating near the surface of the ground, usually within a cast-iron box with a hinged cover. The orifice of discharge is provided with a hose nipple, and the shut-off cock is drained to a point below the frost line when the cock is closed. If the street washer is near the building, the connection is made to the main in the cellar, the stop-and-waste cock also being located in the cellar.

66. Corrosion of service pipes takes place in soil that, owing to its chemical composition, attacks the metal and decomposes it. Corrosion may be prevented by protecting the service pipe from contact with the earth or with waters that have percolated through the soil, by covering the pipe with a good coat of asphalt, or other good pipe covering, while the pipe is hot.

Electrolysis is caused by currents of electricity using water pipes for return conductors while following the path of least resistance, whence they escape back to the dynamos. Electricity does not cause damage, however, where it passes along a pipe; it is only where the current leaves the pipe that electrolysis takes place.

Electrolysis is the cause of serious pittings of water pipes in large cities where electricity is extensively used. Its prevention, however, is more within the province of the electrical engineer than the plumber, and those in charge of electric stations can prevent it only by providing suitable return conductors to their dynamos.

67. The size of the corporation cock that may be attached to a street main is usually determined by the water department. The diameter of the service pipe should not be governed by the size of the corporation cock, however, but should be determined solely by the requirements of the building and the available pressure. If the quantity of the water required is very large, the water authorities will, on due presentation of the facts, usually allow a larger connection to be made to the water mains.

68. A valve or stop-cock, with waste outlet, should be placed in the service pipe either at the curb of the sidewalk or just inside the cellar wall; when placed at the curb, such a cock is generally called a **curb cock.** Care should be taken to set the cock so the waste outlet will allow the water to escape only from the house side of the cock. Stop-cocks located at the curb should be enclosed in tight iron curb boxes, having covers flush with the sidewalk, that will keep out surface water, snow, and dirt. The service pipe and curb cock should be placed far enough underground to escape damage from frost.

CAPACITY OF SERVICE PIPES

69. The capacity of water service pipes of various sizes under different pressures, when subject to various back pressures, may be found in Table V, which was computed by

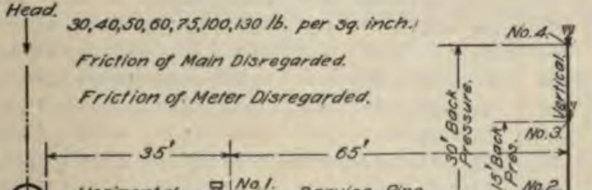


FIG. 28

Mr. Kuichling for the Thomson Meter Company. Table V gives the discharge capacity of service pipes under conditions indicated in the diagram, Fig. 28. Condition No. 1 represents a discharge at the meter in the cellar; No. 2, the discharge at the rear wall of an ordinary cellar; No. 3, the discharge about

TABLE V

DISCHARGE FROM SERVICE PIPES

Condition Indicated in the Diagram	Pressure in Main Pounds per Square Inch	Discharge, in Cubic Feet per Minute, Delivered From Pipe Under Conditions Indicated in Diagram, Fig. 28. Nominal Diameters, in Inches, of Iron or Lead Service Pipes								
		½	⅝	¾	1	1½	2	3	4	6
No. 1	30	1.10	1.92	3.01	6.13	16.58	33.34	86.16	173.85	444.63
No. 1	40	1.27	2.22	3.48	7.08	19.14	38.50	101.80	200.75	513.42
No. 1	50	1.42	2.48	3.89	7.92	21.40	43.04	113.82	224.44	574.02
No. 1	60	1.56	2.71	4.26	8.67	23.44	47.15	124.68	245.87	628.81
No. 1	70	1.74	3.03	4.77	9.70	26.21	52.71	139.39	274.89	703.03
No. 1	100	2.01	3.50	5.50	11.20	30.27	60.87	160.96	317.41	811.79
No. 1	130	2.29	3.99	5.28	12.77	34.51	69.40	183.52	361.91	925.58
No. 2	30	.66	1.16	1.84	3.78	10.40	21.30	58.19	118.13	317.23
No. 2	40	.77	1.34	2.12	4.36	12.01	24.59	67.19	136.41	366.30
No. 2	50	.86	1.50	2.37	4.88	13.43	27.50	75.13	152.51	409.54
No. 2	60	.94	1.65	2.60	5.34	14.71	30.12	82.30	167.06	448.63
No. 2	75	1.05	1 84	2.91	5.97	16.45	33.68	92.01	186.78	501.58
No. 2	100	1.22	2.13	3.36	6.90	18.99	38.89	106.24	215.68	579.18
No. 2	130	1.39	2.42	3.83	7.86	21.66	44.34	121.14	245.91	660.36
No. 3	30	.55	.86	1.52	3.11	8.57	17.55	47.90	97.17	260.56
No. 3	40	.66	1.15	1.81	3.72	10.24	20.95	57.24	116.01	311.09
No. 3	50	.75	1.31	2.06	4.24	11.67	23.87	65.18	132.20	354.49
No. 3	60	.83	1.45	2.29	4.70	12.94	26.48	72.28	146.61	393.13
No. 3	75	.94	1.64	2.59	5.32	14.64	29.96	81.79	165.90	444.85
No. 3	100	1.10	1.92	3.02	6.21	17.10	35.00	95 55	193.82	519.72
No. 3	130	1.26	2.20	3.48	7.14	19.66	40.23	109.82	222.75	597.31
No. 4	30	.44	.77	1.22	2.50	6.89	14.11	38.63	78.54	211.54
No. 4	40	.55	.97	1.53	3.15	8.68	17.79	48.68	98.98	266.59
No. 4	50	.65	1.14	1.79	3.69	10.16	20.82	56.98	115.87	312.08
No. 4	60	.73	1.28	2.02	4.15	11.45	23.47	64.22	130.59	351.73
No. 4	75	.84	1.47	2.32	4.77	13.15	26.95	73.76	149.99	403.98
No. 4	100	1.00	1.74	2.75	5.65	15.58	31.93	87.38	177.67	478.55
No. 4	130	1.15	2.02	3.19	6.55	18.07	37.02	101.33	206.04	554.96

on the first floor; No. 4, the discharge about on the third floor of an ordinary building.

DETAILS OF INSTALLATION

70. Pressure-Reducing Valves.—Fig. 29 shows a pressure-reducing valve *a* in a basement, connected to a service pipe *b* near where the service pipe enters the building. The pressure gauge *c* indicates the pressure in the service pipe on the street side of the reducing valve, and the gauge *d* indicates the pressure of the water on the house side of the valve. The gauge *d* will indicate whether the valve *a* is

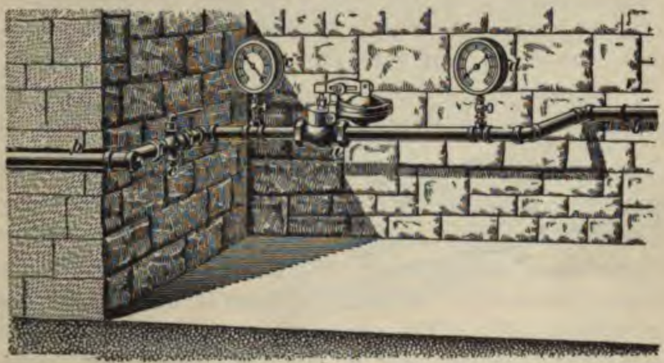


FIG. 29

tight or leaking. If the valve leaks, even a trifle, the gauge *d* will soon indicate a pressure nearly or quite equal to that indicated by *c*, when no water is being drawn from the faucets in the building, and thereby give notice that the pressure-reducing valve requires attention. The stop-cock shown at *e* is of the stop-and-waste form, and is used to shut off the water from the entire building.

71. Service Pipes.—The main service pipe in the cellar should be run in an exposed and accessible location, where it will be out of the way. A good place to locate it is near the cellar ceiling, or alongside a blank wall. When located below the cellar floor, service pipes should be placed in pipe ducts arranged to render the pipes readily accessible for connections or repairs.

All distributing mains within a building should grade to some point where the water can be drained from the system when the supply is shut off. Water service mains should be well supported throughout their entire length, and should be run straight, true, and at uniform grades.

The hangers used to support water pipes are of the same general patterns as those used to support steam pipes, with the single exception that expansion hangers are not required for cold-water pipes.

Where pipes pass through walls and partitions, sleeves should be set in the walls to prevent expansion and contraction of the pipes from cracking the plastering; escutcheons, or floor and ceiling plates, should also be used on walls, floors, and ceilings to conceal the space around the pipes.

72. Covering Pipes.—Cold-water pipes exposed in warm, humid places are liable to gather moisture from the atmosphere, or *sweat*, as it is generally termed. This can be prevented by covering the pipes with some non-conducting substance to insulate the pipes from the surrounding atmosphere. Wool-felt sectional covering with a canvas jacket and asphalt lining is commonly used, the covering when finished being given two coats of paint. Hot-water pipes are often covered to prevent loss of heat from radiation; this is seldom done in small dwelling houses, but should be done in places where the hot-water mains are large, as in hotels and apartment houses.

73. Rising Mains.—The vertical pipes that rise from horizontal mains in the cellar to supply water to the distributing branches on the upper floors of a building are called **rising mains**. They should, when possible, be exposed to view or located behind removable boards where they will be accessible for repairs. When choosing a location for rising mains care should be exercised to select a place that affords the best protection against danger from frost. Rising lines should be well supported throughout their entire extent by suitable hangers placed at proper intervals under the fittings, if possible. Iron pipe may be supported either by pipe hangers or by galvanized-iron straps, spaced about 10 feet apart. Lead pipe should be supported by lead tacks soldered to the pipe and secured to the pipe board by screws. On vertical lead pipes, tacks should be spaced from 18 to 30 inches apart, the exact distance being determined by the size of the pipe and the temperature of the water that flows through it.

74. Supporting Lead Pipes.—When lead pipes run in a horizontal position on a side wall they should be supported by strips of cove or quarter-round molding nailed to the pipe board, as shown in Fig. 30. If iron or brass straps are used to hold lead pipe in place, the edges of the straps will cut into and weaken the pipe; hence, the use of straps on lead pipe should be avoided.

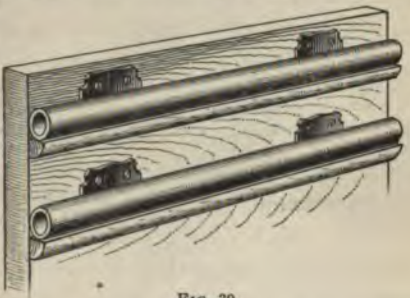


FIG. 30

75. Distribution Branches.—At each floor distribution branches are taken off from the rising mains to supply the groups of fixtures, and each fixture in the group in turn is supplied through a branch taken from the distributing branch. Each distributing branch where it is connected to the rising main should be provided with a valve or cock to shut off the supply of water from the group of fixtures, and where the cost is not prohibitive valves should also be placed on each fixture branch.

When possible to do so, distribution branches should be run exposed in rooms and not concealed in partitions or under floors. Frequently, however, it becomes necessary to so conceal the pipes, under which circumstances, if they are located over valuable ceilings, they should be placed in lead or copper-lined safe boxes, to prevent condensation or leaks from spoiling the ceilings or walls.

76. Notching Floorbeams.—When it is necessary to run a pipe under the flooring, it should be run parallel with the floorbeams, if possible. If that cannot be done, notches of sufficient depth to admit the pipe must be cut across the beams. The notch should be made near the end of the beam, and should never be made at, or anywhere near, the middle of the beam.

The strength of a floorbeam is not in direct proportion to its depth, but varies with the square of the depth. Thus, a beam 10 inches deep is four times as strong as a beam 5 inches deep and of the same thickness. For example, in Fig. 31 the strength of a certain beam 10 inches deep, without a notch, and loaded at the middle is 100 pounds. When a notch $1\frac{1}{4}$ inches deep is cut in the middle of the beam, as at *A*, the depth is reduced to $8\frac{3}{4}$ inches, and the strength is

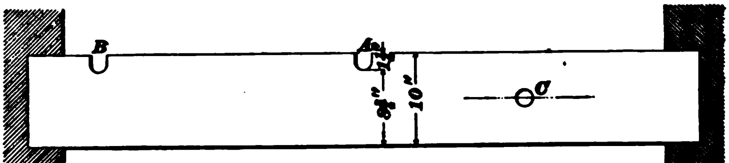


FIG. 31

reduced in proportion to the square of the depth, or to $76\frac{1}{2}$ pounds, which means a loss of $23\frac{1}{2}$ per cent. of the total strength. The same notch may be cut near the end, as at *B*, with a very slight loss of strength, unless some very heavy weight rests on the beam close to it. A hole of the same diameter may be bored through anywhere along the center line of the beam, as at *C*, without perceptible loss of strength, provided that the diameter of the hole does not exceed about one-seventh the depth of the beam.

While the notching of floorbeams in the middle may not always weaken them to such an extent as to make them unsafe, yet it is almost certain to seriously impair the stiffness of a floor, and might spoil it.

FIRE-LINES

77. Stand pipes for fire-lines are now installed in most large buildings. In some cities this protection against fire is a requirement of the building laws.

The stand pipes consist of lines of 3-inch or 4-inch pipe extending from the basement or cellar to the top floor of the building, with valves in the corridors of each floor. Usually a branch of the stand pipe extends through the front wall of

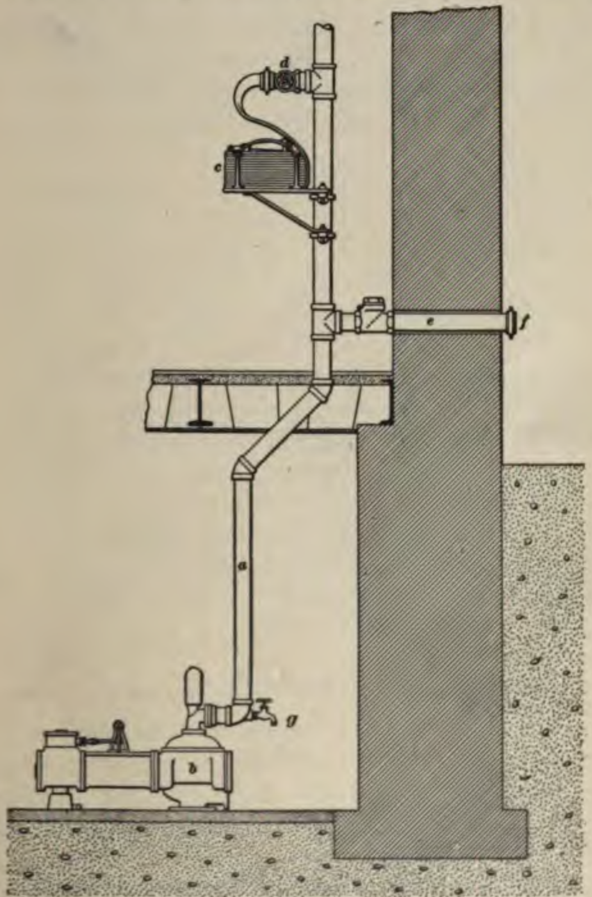
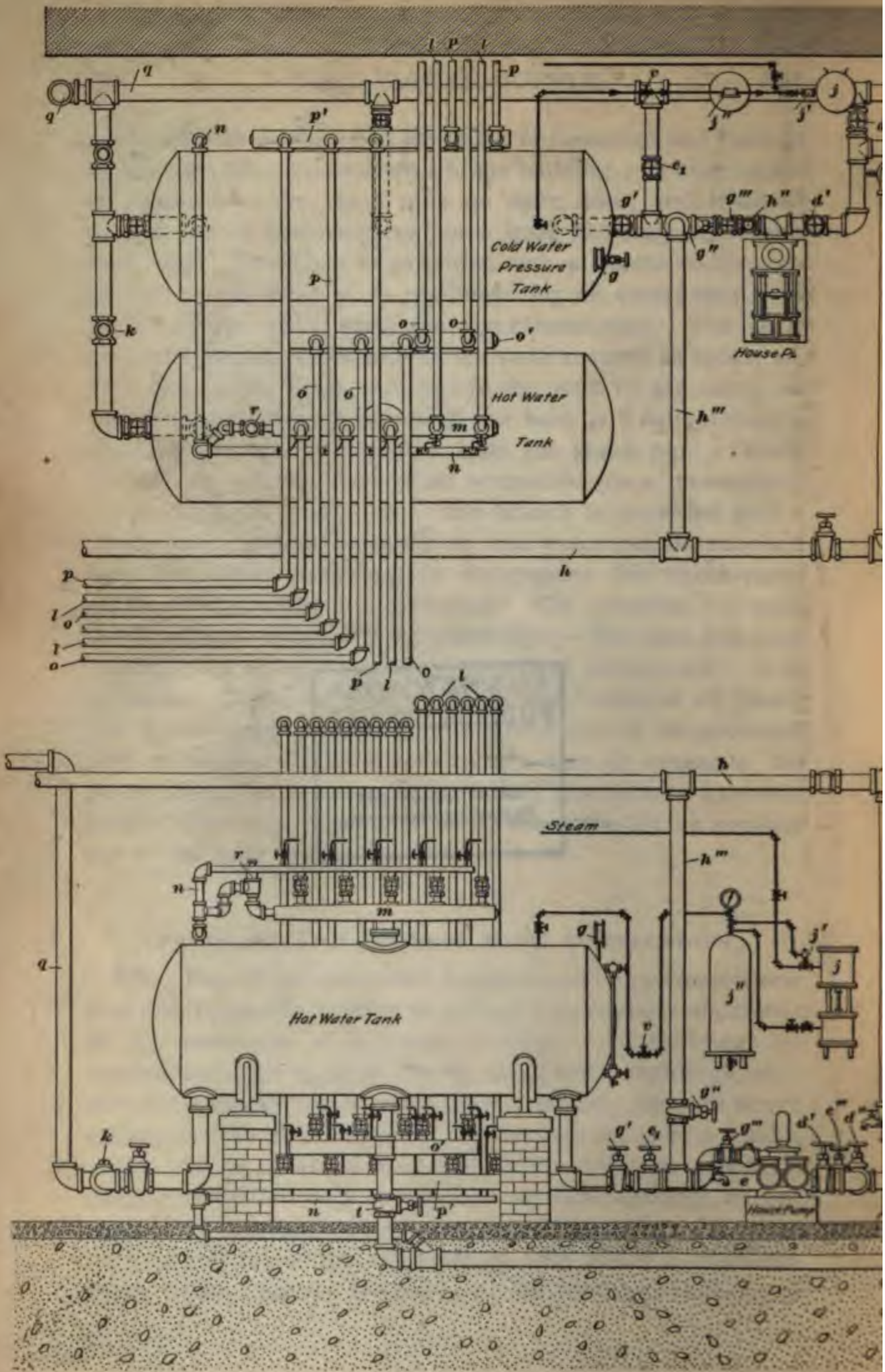


FIG. 32

the building, where it terminates with a check-valve and hose coupling, so that connection can be made with fire-engines, or hose from hydrants. The manner of installing fire-lines is shown in Fig. 32. A 4-inch galvanized-iron stand pipe *a* connects with a pump *b* in the cellar or basement and extends up through the various stories of the building. A hose rack *c* is clamped to the stand pipe on each floor, and from 50 to 100 feet of Underwriters' linen hose is neatly folded on each rack. The hose is provided with a nozzle and is connected to the valve *d*, in readiness for an emergency. In place of hose racks, reels are sometimes used. The reels may be clamped to the pipe in the same manner as racks, or, as is sometimes done, attached to the stem of the valve, so that the operation of unreeling the hose will automatically open the valve. A branch *e* from the stand pipe extends through an outside wall in an accessible place, convenient for attaching a hose to it. The branch is provided with a check-valve opening inwards, so that water can be supplied from the street hydrants, or fire-engine; this check-valve closes when the pump is operating. The coupling *f* is used for attaching the hose to the stand pipe. The cock *g* is used to empty the stand pipes after they have been in use. If it is desired to keep up pressure in the stand pipes at all times, the steam throttle valve to the pump should be provided with an automatic regulator that will turn on steam to the pump when the pressure in the stand pipe falls to a certain point. Thus the pump will work automatically as soon as any of the hose lines are in use.

PRESSURE AND SUCTION TANK CONNECTIONS

78. Fig. 33 (*a*) shows the apparatus and pipe connections that are frequently used in installing water-supply apparatus in the basement of a large building. All buildings of importance, such as large hotels, large office buildings, etc., should be supplied with water taken from two different street mains, so that if the water should be shut off in one main a supply can be obtained from the other. Thus there is little danger of the building at times being without water, except when the whole waterworks system is inoperative. It is not necessary to meter the supply from both street mains separately unless they are the mains of different corporations, in



Cold Water
Pressure
Tank
Hot Water
Tank
House Pu.
Steam
Hot Water Tank
House Pump

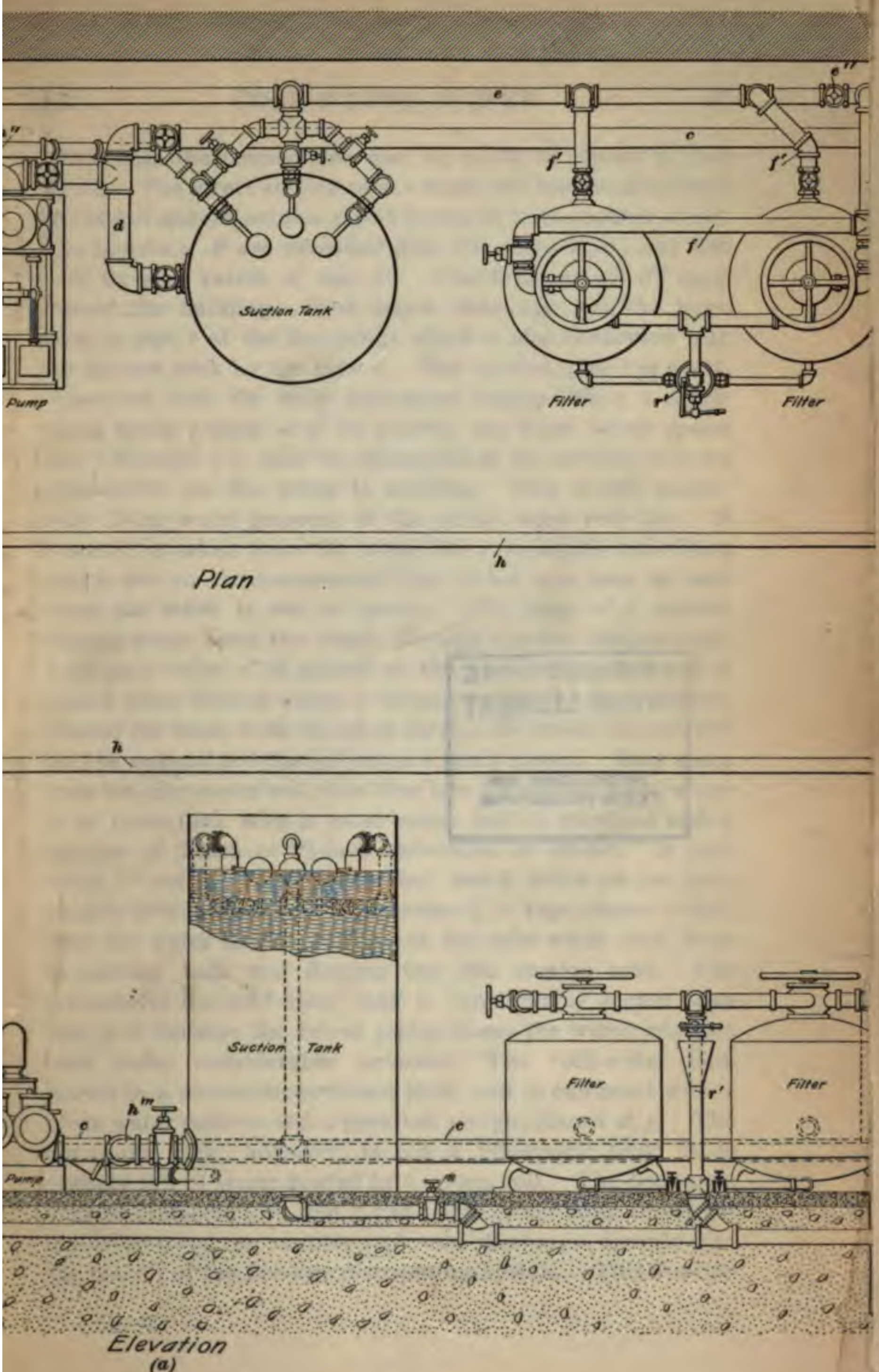

Plan
Suction Tank
Pump
Filter
Filter
Elevation
(a)
Suction Tank
Filter
Filter
Pump

FIG. 33

which case the connections may be made as shown in this figure. The street service pipe *a* leads into the building from one street and the service pipe *b* comes in from another street. The meters a', b' are provided with fish traps a_1, b_1, and also with by-pass valves a'' and b''. Check-valves a''', b''' open toward the building. Both mains discharge into the large suction pipe *c* of the fire pump, which is also connected with the suction tank by the pipe *d*. The suction pipe *c* is cross-connected with the main cold-water supply line *e*, a check-valve being placed at e' to prevent air from being drawn into *c* through *e* in case the ball-cocks at the suction tank are open while the fire pump is working. This would happen only if the water pressure in the street were very low. A branch *f* is taken from the main line *e* to supply two filters which are so cross-connected that either one may be used when the other is out of service. The pipes f', f' convey filtered water from the filters through *e* to the suction tank. A by-pass valve e'' is placed on the main house line and is closed when filtered water is being run into the suction tank. Should the filters both be out of service, however, the valve e'' may be opened and the valves on *f* and f' closed. Raw water from the city mains will then flow into the suction tank, which is an open tank with a loose cover and is provided with a number of 2-inch or 2½-inch ball-cocks, as shown. A gate valve e''' on the main house line, which valve on the plan view is hidden by the air compressor *j*, is kept closed to prevent the water under pressure in the cold-water tank from by-passing back and flowing into the suction tank. The pressure in the cold-water tank is considerably higher than that in *e*, because the house pump forces the water into this tank under considerable pressure. The cold-water tank shown is a pneumatic-pressure tank, and is equipped with a glass water column and a pressure gauge, shown at *g*. The hot-water tank, however, is not a pneumatic tank; it is entirely full of water heated by a steam coil. The fire pump is cross-connected, so that it can pump either from the street mains or from the suction tank and discharge directly into the main *h* of the fire-line distributing system. This fire-line is extended up to a tank on the roof, as shown in the diagram, Fig. 33 (*b*), the pressure in *h* being maintained considerably higher than that in the plumbing pipes. The pressure at the pumps will vary according to the height of the building. A pressure of about 50 pounds per square inch may be maintained in the fire-line at the top floor to secure sufficient force for fire-hose there. A check-valve h'' is usually placed on the fire-pump discharge pipe. The fire pump is provided with a regulator (not shown) attached to the piping *h* and to the steam pipe that supplies the pump, so that when the pressure falls slightly in the fire-lines the pump will start up automatically and increase the pressure again to the desired point, when the pump will be shut off automatically. In this way a nearly constant pressure is maintained in the fire-line. An air compressor, which may be driven by an electric motor or by steam power, is shown at *j*. The illustration shows a steam-driven device that is supplied with a regulator j'. This compressor supplies air under a suitable pressure for the pneumatic-pressure tank. The fire-line is cross-connected with the plumbing system by the pipe h'''. In the event of the house pump being thrown out of service the fire pump may temporarily be used in its place by opening the valve g''.

79. While the plant is in ordinary operation the valve on *d* is closed and the fire-pump suction pipe is open directly to the street main. The valve d' on the house-pump suction pipe to the suction tank is open, while d'' is closed. In the case of a fire, the fire pump will operate automatically as soon as water is drawn off, and the pressure consequently falls. The house pump can be put in service to help the fire pump by closing the valve g' and opening the valve g'', the valve e_1 already being closed and the valve g''' being open. Should the house pump get out of order, and if there is no duplicate house pump provided, the fire pump may temporarily be allowed to take water from the suction tank to supply the plumbing system with pure water through the pipe h'''. Although only one house pump is shown in the plant it is advisable on important work to have two of them cross-connected.

80. The hot-water tank is supplied at the bottom from the cold-water tank through the pipe provided with the check-valve *k*. The hot-water supply pipes *l*, *l* which distribute hot water to the different parts of the building are taken from the manifold *m*, a gate valve and drip valve being attached to each line, as shown. The drip valves empty into a waste pipe *n*, which in turn discharges to the sump. The return pipes *o*, *o* from the different parts of the building drop down at the back of the hot-water tank, and connect with the manifold o' located between the tanks. Each one of these lines is furnished with a gate valve and a drip valve, the latter being connected to the waste pipe to drip the lines when repairs are to be made.

The cold-water pipes *p*, *p* which supply different parts of the building are taken off the header p' at the back of the cold-water tank. In some places the conditions are such that this arrangement cannot be used, and frequently it is advisable to bunch all the pipes and valves together symmetrically on what is known as a *pressure board*, labeling and tagging every valve. The arrangement shown will, however, give satisfaction, and is very easily understood and controlled by the engineer in charge. The pipe *q* from the house tank on the roof is connected as shown in the diagram, Fig. 33 (*b*), and has a check q' opening from the tank back to the building. Thus the tank on the roof will always be full of water and will act as a reserve to supply the building should the basement supply fail. The check-valve q'' in the diagram prevents the water in the fire-lines from flowing into the roof tank, but in the event of a fire in which the fire pump cannot hold up a pressure in the fire-lines greater than that corresponding to the height of the roof tank, the check q'' will open and supply the fire-hose from the roof tank.

81. A pop safety valve *r* is located on the header of the hot-water tank and is set so that any excessive pressure, such, for instance, as may occur through the expansion of the water in the tank while being heated, and because of the presence of the check-valve *k*, will be released; the surplus water will flow to waste through the pipe *n*.

82. The air compressor *j* pumps not only into the cold-water tank, but also into a storage tank *j''*, from which air under pressure may be drawn for various purposes, such as blowing dust from machinery, etc. The regulator *j'* on a lowering of the air pressure opens the steam supply to the air compressor, thus starting it. When the pressure has run up to the point the regulator has been set for, the regulator automatically shuts off the compressor steam supply. As long as the compressor is delivering air into the cold-water tank, the valve *v* in the discharge pipe is kept wide open. When compressed air is required only for cleaning purposes, etc., the valve *v* is closed; the compressor then delivers into the storage tank *j''*, from which the compressed air is conveyed to the point of delivery through piping and flexible hose. A separate valve is placed close to the cold-water tank in the air delivery pipe, to permit this pipe to be taken down for repairs, or the valve *v* to be repaired without letting the air out of the cold-water tank.

83. The pipe *r'* provided with a funnel on top is intended to receive the waste from the filters, discharging it into the sump. The emptying pipes from the filters connect into this waste pipe. The valve *s* is used to empty the suction tank into the sump. The valve *t* is used to drain the hot-water tank, and a similar valve (not shown) is used to drain the cold-water tank. Drips from the pump, etc. may also go into the sump.

ICE-WATER SUPPLY

METHODS OF COOLING WATER

84. It is customary in public and semipublic buildings to install one or more drinking fountains and to supply them with filtered and cooled water. When there is only one fountain in a building, the problem of cooling the drinking water is usually solved by building a small ice chest at the back of the fountain and placing in the box a pipe coil made of block tin, through which the water circulates and cools before reaching the faucet. An arrangement of this character is shown in Fig. 34. The box *a* is lined with sheet lead or sheet copper, and the coil *b* is placed firmly on the bottom of the tank so that it cannot easily be damaged by the weight of ice. From 10 to 12 feet of ½-inch pipe coil is usually sufficient for a fountain of this kind.

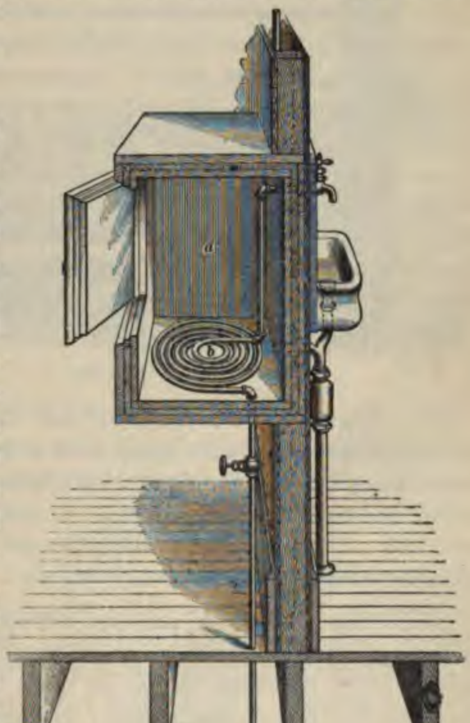


FIG. 34

85. When several drinking fountains are installed in a building, it is both cheaper and better to provide one large ice box and cooling coil at some convenient point and pipe the cold water through a system of pipes from the tank to the several fountains. A box and coil for this purpose are shown in Fig. 35. A coil of pipe *a* is placed on the bottom of a riveted-steel water-tight ice box or tank *b* and is connected to the drinking-water supply in such a manner that all water drawn at the drinking fountains must first pass through the coil. The water in the coil of pipe is cooled by placing ice in the tank; the ice melts and surrounds the coils with ice water, thus lowering the temperature to the desired degree. The tank is provided with an emptying pipe *c* and an overflow pipe *d* that enters the side of the box at a high enough level to retain a sufficient depth of water in the box to submerge the coils and float the ice. The overflow pipe should extend to near the bottom of the tank to draw off water from that point, as it is usually a little warmer at the bottom than near the top. A rack *e* of wood protects the coil from injury from the ice.

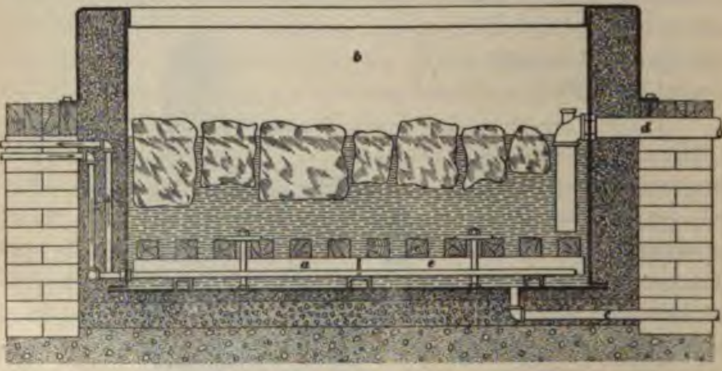


FIG. 35

86. The best material for ice tanks is boiler plate, although wooden boxes lined with copper or sheet lead are sometimes used. Iron or steel tanks are better able to withstand the hard usage incident to depositing ice in them, and are not affected by the damp to so great an extent as wooden tanks.

87. The size of an ice box depends on the number of drinking fountains for which it must cool water and the temperature to which the water must be lowered. A good temperature for drinking water is from 45° to 50° F., and allowing for a rise of temperature of 10° in passing from the cooler to a drinking fountain, the temperature of the water in the ice box should be from 35° to 40° F. To secure this temperature space enough should be allowed in an ice box to hold at least 50 pounds of ice for each drinking fountain. Greater economy, however, is obtained in the operation of the plant by making the ice box large enough to hold a daily supply of ice amounting to from 100 to 150 pounds for each fountain. In this manner the temperature of the entire enclosure will be lowered and the ice melted more slowly.

88. The ice box should be thoroughly insulated from the atmosphere by at least 6 inches of asbestos fiber, charcoal, or other equally good non-conductor of heat, well packed into an annular space provided at all sides and below the bottom of the tank.

Circulating coils for ice boxes should be made of block-tin pipe or tinned copper pipe, coiled or bent to the desired shape. Owing to the length of time water might stand in the coil, lead or iron pipe should not be used for this purpose, although tin-lined iron, lead, or brass pipe would not be so objectionable.

To properly cool enough water for all the fountains, allowance should be made in the coil for at least 10 feet of $\frac{3}{4}$-inch pipe for each fixture supplied. The coldest water is obtained when the ice is allowed to rest on the pipe coil, but this is frequently considered too cold for wholesome drinking.

METHODS OF DISTRIBUTION

89. The two systems of distribution for supplying ice water to drinking fountains are the *direct system* and the *circulating system*.

In the **direct system,** the ice chest is located in the basement, cellar, or other convenient part of the building; a supply main is taken from the cooling coil, and branches are extended from the main to the various drinking fountains. In this method of supply, the water in the distributing pipes remains stationary when water is not being drawn. Hence, it heats, and considerable water must frequently be drawn from a faucet before cold water is obtained.

With the **gravity circulating system** the ice tank is located in the attic or on some floor above the highest drinking fountain, and a circulating pipe is returned from the lowest fixture to the cooling coil, so that water from the coil will circulate to the lowest drinking fountain and back again to the ice box to be cooled. This system of cold-water circulation is shown in Fig. 36 (*a*). With this system, however, the difference in temperature between the columns of water in the supply pipe and circulation pipe is so small that circulation at its best will be but feeble; therefore, to increase the circulation and make it positive an injector nozzle *a* is inserted in the circulation pipe at the point where

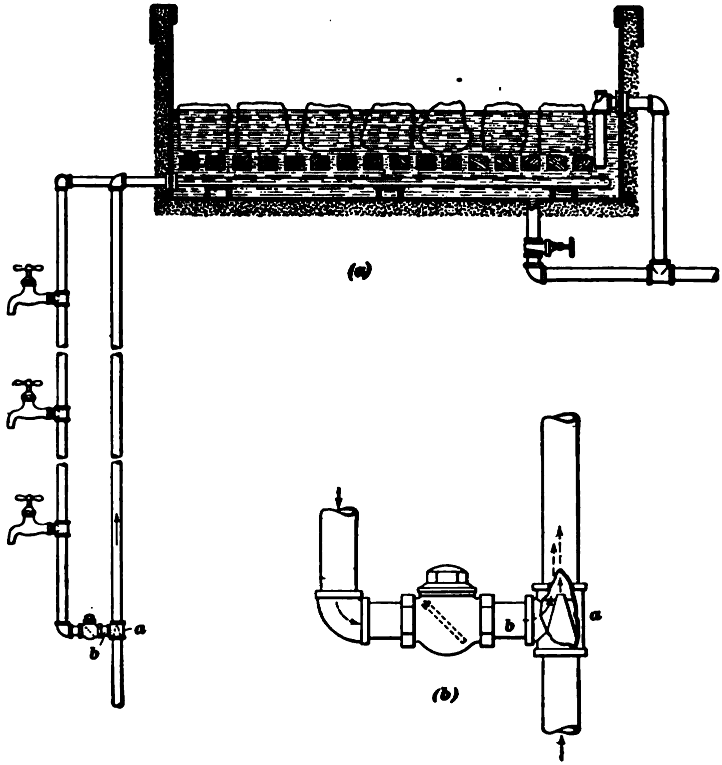


FIG. 36

the cold-water supply to the tank joins. When a faucet is opened to draw water at a fountain, water flowing through the injector nozzle tends to create a vacuum in the pipe at *b* and thus causes water to flow from the supply pipe into the circulation pipe, thereby insuring a positive circulation. A light swing check-valve *c* prevents water from flowing the reverse way. A detail of the injector nozzle and check-valve is shown in Fig. 36 (*b*). If the water pressure is 50 pounds per square inch or over, the nozzle may be $\frac{1}{4}$ inch in diameter, the piping being $\frac{3}{4}$ inch; if the water pressure is below 50 pounds per square inch, the nozzle should be from $\frac{3}{8}$ to $\frac{1}{2}$ inch in diameter, the piping being $\frac{3}{4}$ inch.

The chief objection to a gravity circulation system is that on account of the tank requiring to be located high up, all ice must be raised through the building to the tank.

90. When circulation has to be provided between an ice tank in the basement and a number of fountains on the upper floors, it can be obtained to a limited extent by using an injector nozzle. The most reliable method, however, is to attach a small pump to the circulation pipe and thus give a forced, positive circulation. This is usually done in very large buildings where the drinking water is cooled by a refrigerating machine.

91. In very large buildings containing twelve or more drinking fountains, or in buildings where the temperature of the water must be reduced to 40° F. or less, it is usually more economical to employ a refrigerating machine instead of an ice box. The machine should be capable of producing from 2 to 4 tons of ice in 24 hours; that is, its ice-making capacity should be from 2 to 4 tons.

HOT-WATER SUPPLY

WATER HEATING AND STORAGE

WATER HEATING

CIRCULATION OF WATER

1. **General Principles.**—When a body of water is increased in temperature, it expands and, consequently, occupies more space; when decreased in temperature, it contracts and occupies less space. The smaller the space a given weight of water occupies, the greater is the density of the water; and the greater the space the same weight of water occupies, the less dense will be the water. Suppose that a given volume of water at the bottom of a large body of water in a vessel is raised in temperature and hence has its density decreased. Since the attraction of the earth, that is, the force of gravity, is less on a given volume of the warmed water than on the same volume of cold water, the cold water sinks to the bottom and displaces the warm water, which rises to the top. If a small volume of water near the bottom be heated continuously, the warmed water will rise in a stream and cold water will flow in continuously to take its place, become heated, and rise, in turn. This flow of water is called **circulation**, and since it is due to the action of the force of gravity, it is spoken of as **gravity circulation;** a circulation of water due to this cause is also called **natural circulation**, to distinguish it from a circulation induced by mechanical means, as a pump, and known as **forced circulation.**

2. Suppose that a vessel is partly filled with water and that heat is applied to the center of its base by a flame, as shown in Fig. 1. Heat from the flame is absorbed by the bottom of the vessel, and conducted to its inner surface, from which it is transmitted to the nearest portion of water. This portion, being increased in temperature, becomes less dense, and, consequently, rises toward the surface. The water that takes its place, in turn, becomes heated and also rises. The water at the top is cooled by coming in contact with the atmosphere. The particles of water touching the sides of the vessel become cooled by the transmission of heat from them through the metal to the outer atmosphere. Hence, the particles of water touching the sides will descend more rapidly than those some distance from it, and the circulation within the water will, in general, be about as shown by the arrows for the case illustrated. Circulation within an undivided volume of water, as in the vessel of Fig. 1, is called **local circulation.**

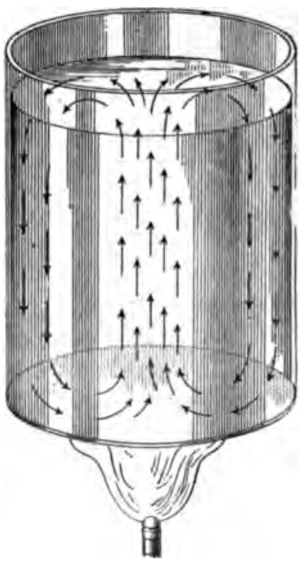


FIG. 1

The transmission of heat through a liquid, by a motion of its particles, is called **convection.**

3. Suppose a **U** tube to be connected near the top by a cross-pipe having a water-tight valve *a*, Fig. 2, attached. If this valve is closed and cold water is poured into the loop until the surface in the tube *b* is at the dotted line *c*, the surface of the water in the tube *d* will be at the dotted level line *c*. The surface of the water in one tube will be level with the surface of the water in the other tube, because the temperature of the water will be the same in both tubes. If the valve *a* is opened, the water will not flow from one tube into the other, because no hydrostatic head will be present to produce a current. Suppose that the valve *a* is closed and that heat is applied to the base of *d* by a flame, as shown; the water in *d* will become heated, and will occupy a greater space. Hence, the surface of the water in the tube *d* will rise from its original level *c* to a new level, as *e*. It will be noticed that while the columns of water in *b* and *d* are equal in weight, they are unequal in height, the warmer column being the higher one. If the valve *a* is now opened, the pressure due to the head of water between the levels *c* and *e* will cause water in the top of *d* to flow through the horizontal tube into *b*. The head of water between the levels *c* and *e* is known as the **circulation head.** While the pressure due to the circulation head is very low, it is sufficient to overcome the friction of the water against the inner surface of the tubes and to cause a free flow of water into *b*. Weight is thus transferred from *d* to *b*, *d* becoming a little lighter and *b* a little heavier. The two columns of water no longer balance; hence, *b* sinks and *d* rises. The cool water from *b* passes into the base of *d* and absorbs the heat. The water is thus expanded, its weight is diminished, and it is crowded upwards by the cooler and heavier water coming in beneath it, that is, a circulation is established. The rapidity of the circulation will depend on the difference in temperature, that is, the difference in weight of the two columns *d* and *b* and the various resistances.

FIG. 2

4. A single tube *a*, Fig. 3, having a partition *b* will operate the same as the two tubes of Fig. 2 when heat is applied at one side. But, if the partition is removed, the upward and downward currents will mingle and interfere, thus retarding the circulation. The circulation in a tube without a partition will be very slow and uncertain if the tube is small in diameter.

If the divided tube is laid in a horizontal position, the circulation will still take place, but at a much slower rate. If no partition is present, the circulation will be very slow and imperfect.

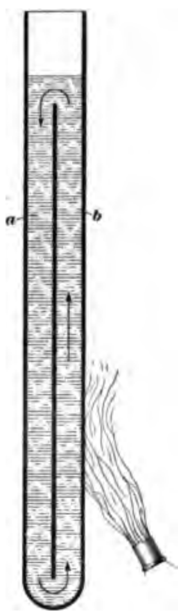


Fig. 3

5. The circulation of water in a pipe system used for cooling purposes depends on a change in the density of the water by cooling instead of by heating. The ice or refrigerating liquid should be applied near the top of the descending column; the material that is to be cooled should be allowed to touch only the ascending column, and, if possible, be placed at its base. In this way the greatest possible difference in density of the ascending and descending columns will be obtained.

6. Water must be heated from below and cooled from above. It conducts heat so poorly that the heating or cooling depends very largely on circulation. A liquid, like mercury, that conducts heat readily, can be heated from any direction.

7. Circulation Between Separate Vessels.—If the water has to be warmed by a source of heat some distance from the vessel, the water is usually warmed in a separate heater adjacent to the source of heat and discharged into the other vessel, from which cold water passes to the heater. So-called **circulation pipes** convey the water from one vessel to another. The simplest arrangement of the apparatus is shown in Fig. 4. The heater *C* is located directly over the source of heat, a gas flame in this instance, so that it will be subjected to the direct heat of the fire, and is connected by pipes *D* and *E* to the vessel. The water will then receive heat from the flame, be thus made less dense, ascend in the **flow pipe** *E*, and enter the vessel.

Cold water enters C through the **return pipe** D to replace that leaving it through E. A continuous circulation is thus maintained between the vessel and the heater C, the currents flowing in the direction of the arrows. This simple apparatus illustrates the manner in which water for washing and other purposes is heated in modern residences, the heater C being usually placed in the kitchen range and adjacent to the fire; the vessel at the left in Fig. 4, which forms a reservoir for the storage of hot water, is located near the kitchen range and is then called a **kitchen boiler,** and also a **range boiler.**

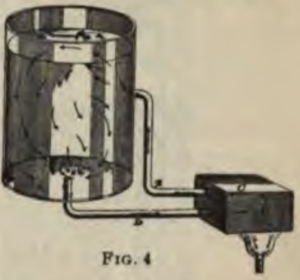


FIG. 4

8. The velocity of the circulation, and hence the time required to heat the water in the boiler, depends on the difference in the mean density of the flow and return columns, their vertical heights, and the resistance to the flow by friction, obstructions, etc. The greater the difference in density between the columns, or the greater their vertical heights, the greater will be the velocity of circulation; and the less the difference in density of the columns, or the less their vertical heights, the lower will be the velocity of the circulating currents. To reduce friction, sharp bends, contractions, and enlargements of the circulating pipes should be avoided; their presence will greatly retard the velocity of the circulation.

9. Fig. 5 illustrates an actual installation of hot-water heating apparatus, in which the circulation takes place as explained in conjunction with Fig. 4. The boiler, shown in section, receives hot water from the heater B, commonly called a **waterback,** and stores the hot water until it is drawn off at the faucets. This method of connecting a kitchen boiler to the kitchen range, and to the plumbing system, is the one most commonly employed in the United States of America. The boiler is fed with cold water from the street main by the pipe D. The boiler being filled with water, the fire is started in the range, and the water in *B*, which is in direct contact with the fire, is thus heated; but, as it is heated it rises in the pipe *E*, the same as it would if it were in *E*, Fig. 4, and heat were applied to *C*, Fig. 4. The heated water from *B* enters the side of the boiler at *F*, and

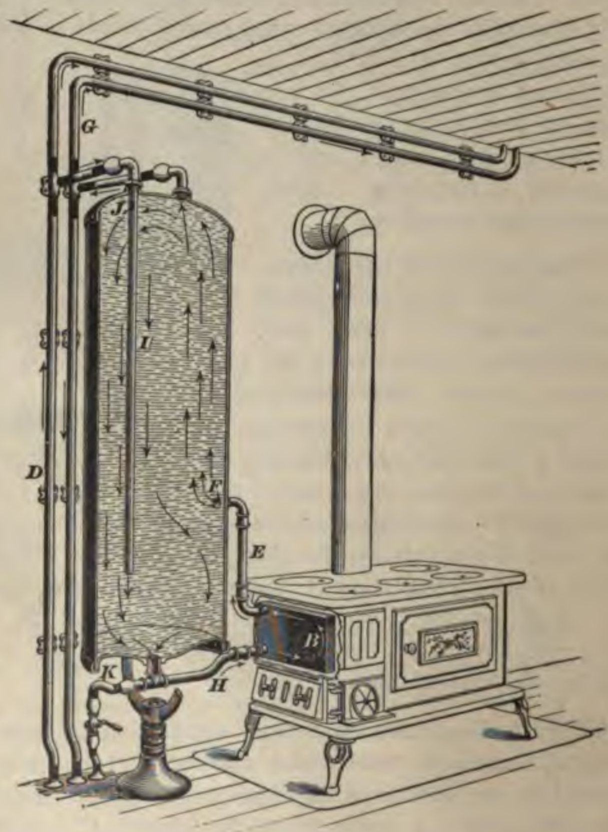


FIG. 5

immediately rises toward the top, where it remains until drawn off at a faucet through the pipe *G* or is displaced by warmer water. The coldest water is always at the bottom of the boiler and the hottest at the top. For this reason, the pipe *G*, through which the hot water is drawn, is always connected to the top of the boiler, and the pipe *H*, which supplies the water heater *B*, to the bottom. Cold water is fed to the boiler through an inner tube *I*, which should reach down inside the boiler to a point about 3 inches above the level of the water heater. The reason for this is that should there be a partial vacuum formed within *D*, such, for example, as may be caused by fire-engines pumping water from the city mains, there will never be danger of siphoning the water in the boiler to a point below the water heater. As an additional precaution, a small vent hole *J* is usually drilled at the top of the tube to admit air to *D*; this, normally, will prevent the boiler being siphoned below the level of the vent hole. Should the vent hole become stopped up by any means, the fact that the inner tube *I* ends above the level of the waterback will insure the retention of the water in the waterback should any siphonic action take place.

10. Boiling Point of Water.—The point at which water boils varies with the pressure, but the temperature at which the formation of steam begins does not increase in the same ratio as the pressure. Thus, water boils under atmospheric pressure at sea level at 212°; under 10 pounds gauge pressure at 238°, which is an increase of 26° temperature for 10 pounds increase of pressure. From 50 to 60 pounds pressure the temperature rises from 297° to 307°, or about 1° for each pound of pressure. From 100 to 110 pounds pressure the temperature rises from 337° to 344°, or about 7° for each 10 pounds of pressure.

Table I shows the boiling point of water (that is, the temperature of steam) under different absolute pressures, above and below atmospheric pressure; also, the volume of steam at a given pressure compared with the volume it will occupy when condensed, that is, changed to water, and cooled to the point of maximum density (39.2° F.).

Water cannot be heated to a higher temperature, under a given pressure, than that named in the table. If the temperature be increased the pressure will be increased; conversely, a lowering of the pressure involves a decrease of

TABLE I

BOILING POINTS OF WATER

Pressure Above Vacuum Pounds per Square Inch	Temperature Degrees Fahrenheit	Ratio of Volume of Steam to Volume of Equal Weight of Distilled Water at Temperature of Maximum Density	Pressure Above Vacuum Pounds per Square Inch	Temperature Degrees Fahrenheit	Ratio of Volume of Steam to Volume of Equal Weight of Distilled Water at Temperature of Maximum Density
1	102.018	20,623	46	275.704	563.0
2	126.302	10,730	48	278.348	540.9
3	141.654	7,325	50	280.904	520.5
4	153.122	5,588	52	283.381	501.7
5	162.370	4,530	54	285.781	484.2
6	170.173	3,816	56	288.111	467.9
7	176.945	3,302	58	290.374	452.7
8	182.952	2,912	60	292.575	438.5
9	188.357	2,607	62	294.717	425.2
10	193.284	2,361	64	296.805	412.6
11	197.814	2,159	66	298.842	400.8
12	202.012	1,990	68	300.831	389.8
13	205.929	1,845	70	302.774	379.3
14	209.604	1,721	72	304.669	369.4
14.69	212.000	1,646	74	306.526	360.0
15	213.067	1,614	76	308.344	351.1
16	216.347	1,519	78	310.123	342.6
17	219.452	1,434	80	311.866	334.5
18	222.424	1,359	82	313.576	326.8
19	225.255	1,292	84	315.250	319.5
20	227.964	1,231	86	316.893	312.5
22	233.069	1,126	88	318.510	305.8
24	237.803	1,038	90	320.094	299.4
26	242.225	962.3	92	321.653	293.2
28	246.376	897.6	94	323.183	287.3
30	250.293	841.3	96	324.688	281.7
32	254.002	791.8	98	326.169	276.3
34	257.523	748.0	100	327.625	271.1
36	260.883	708.8	105	331.169	258.9
38	264.093	673.7	110	334.582	247.8
40	267.168	642.0	115	337.874	237.6
42	270.122	613.3	120	341.058	228.3
44	272.965	587.0			

the temperature. The temperatures of the water and of the steam that is in direct contact with it are always equal. The water, however, may vary several degrees in temperature in various parts of the boiler, owing to the loss of heat by radiation or cooling.

11. Expansion of Water.—The change in volume, that is, the amount of expansion or contraction, of a given quantity of water due to heating it from one temperature to another can be found by the aid of Table II, which gives the

TABLE II
EXPANSION OF WATER

Temperature Degrees Fahr.	Comparative Volume Water at 32° = 1	Comparative Density Water at 32° = 1	Weight of 1 Cubic Foot Pounds	Temperature Degrees Fahr.	Comparative Volume Water at 32° = 1	Comparative Density Water at 32° = 1	Weight of 1 Cubic Foot Pounds
32	1.00000	1.00000	62.418	135	1.01539	.98484	61.472
35	.99993	1.00007	62.422	140	1.01690	.98339	61.381
39.1	.99989	1.00011	62.425	145	1.01839	.98194	61.291
40	.99989	1.00011	62.425	150	1.01989	.98050	61.201
45	.99993	1.00007	62.422	155	1.02164	.97882	61.096
46	1.00000	1.00000	62.418	160	1.02340	.97714	60.991
50	1.00015	.99985	62.409	165	1.02589	.97477	60.843
52.3	1.00029	.99971	62.400	170	1.02690	.97380	60.783
55	1.00038	.99961	62.394	175	1.02906	.97193	60.665
60	1.00074	.99926	62.372	180	1.03100	.97006	60.548
62	1.00101	.99899	62.355	185	1.03300	.96828	60.430
65	1.00119	.99881	62.344	190	1.03500	.96632	60.314
70	1.00160	.99832	62.313	195	1.03700	.96440	60.198
75	1.00239	.99771	62.275	200	1.03889	.96256	60.081
80	1.00299	.99702	62.240	205	1.04140	.96020	59.930
85	1.00379	.99622	62.182	210	1.04340	.95840	59.820
90	1.00459	.99543	62.133	212	1.04440	.95750	59.760
95	1.00554	.99449	62.074	230	1.05290	.94990	59.360
100	1.00639	.99365	62.022	250	1.06280	.94110	58.750
105	1.00739	.99260	61.960	270	1.07270	.93230	58.180
110	1.00889	.99119	61.868	290	1.08380	.92270	57.590
115	1.00989	.99021	61.807	298	1.08990	.91750	57.270
120	1.01139	.98874	61.715	338	1.11180	.89940	56.140
125	1.01239	.98808	61.654	366	1.13010	.88500	55.290
130	1.01390	.98630	61.563	390	1.14440	.87380	54.540

volume of a given weight of water compared with the volume of the same weight at 32° F., taking the latter volume as 1. The change in length or height of a given body of water, due to heating or cooling, can be readily found from the change of volume. In practice, the heated water is usually confined in round vessels of uniform cross-section, as pipes, for instance. Then, with such vessels, the change in length or height is found, in inches, by dividing the change of volume, in cubic inches, by the cross-sectional area of the confining vessel, in square inches.

Rule I.—*To find the new volume of a quantity of water at a given temperature, multiply the original volume by the comparative volume, taken from Table II, at the new temperature. Divide the product by the comparative volume, taken from Table II, at the original temperature.*

Rule II.—*To find the change in volume of a given quantity of water, due to a change of temperature, take the difference between the new volume found by rule I and the original volume.*

EXAMPLE 1.—A vertical cylindrical vessel contains 40 United States standard gallons of water which is heated from 62° F. to 200° F. What is the new volume of the water, in cubic inches?

SOLUTION.—The original volume is $40 \times 231 = 9{,}240$ cu. in. By Table II, the comparative volume at 62° = 1.00101, and at 200° = 1.03889. Applying rule I,

$$\text{new volume} = \frac{9{,}240 \times 1.03889}{1.00101} = 9{,}589.66 \text{ cu. in.} \quad \text{Ans.}$$

EXAMPLE 2.—What is the change in volume of the water mentioned in example 1, under the conditions there stated?

SOLUTION.— $9{,}589.66 - 9{,}240 = 349.66$ cu. in. Ans.

EXAMPLE 3.—If the vessel mentioned in example 1 is 18 inches in diameter, how much will the water rise therein under the conditions stated in that example?

SOLUTION.—The cross-sectional area of the vessel is $18^2 \times .7854 = 254.47$ sq. in. The change in volume of the water being 349.66 cu. in., the increase in height is $\frac{349.66}{254.47} = 1.37$ in. Ans.

FIRE-HEATED WATER HEATERS

12. Waterbacks.—A so-called **waterback** is generally used for heating water for domestic purposes, and is located inside the kitchen range, forming one side of the firebox. The waterback is an iron casting having two passages cored therein, and has at one end two tapped holes, one for each passage, for either $\frac{3}{4}$-inch or 1-inch pipe, according to size. While this form of water heater is most generally called a waterback, there are many places where its name changes with its position in the firebox of the range. For example, when the water heater is located at the side or front of the range, it is often called a *water front*.

A waterback is shown in section in Fig. 6. The casting *a* is the heater. Its flat sides are tied together by a partition *b*, which also compels the water to circulate through the entire length of the casting. The pipe *c* supplies the heater with cold water, usually taken from the bottom of the kitchen boiler, and is called the *return pipe* to the waterback. The pipe *d* receives hot water from the heater and delivers it to the boiler, where it is stored ready for use.

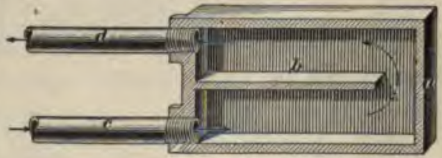


FIG. 6

13. A waterback, since it has water inside and fire outside, is exposed to severe internal strains, and hence, for safety, the metal must be much thicker than is required to merely resist the water pressure. Waterbacks are usually designed to resist a pressure, when cold, of 700 pounds per square inch, but in constant use they are sometimes overheated and weakened, or are eaten away by internal corrosion, and if an extraordinary pressure is then brought to bear within them, they will explode with disastrous effect. To prevent this occurrence, they should be inspected periodically, and replaced by new ones when their condition arouses doubt of their safety.

The size of a waterback is measured by its heating surface, in square inches, reckoning only that side which is exposed to the fire. On an average, about 100 square inches of external heating surface is sufficient for a 40-gallon boiler where water is supplied under pressure from the street main, or a 50-gallon boiler where water is pumped by hand to a tank at the top of the house.

The quantity of water heated, the time required to heat it, and the quantity of water consumed, vary in every case; hence, the size of a waterback that should be placed in a range depends on the plumber's judgment. A large boiler requires a large waterback, and a small boiler a small one. A large boiler combined with a small waterback results in a scarcity of hot water, although the combination may give plenty of luke-warm water. A large waterback combined with a small boiler results in boiling hot water, and rumbling, snapping, and cracking noises that are caused by the formation of steam.

14. Incrustation in Waterbacks.—In localities where the water supply is hard, a deposit of lime forms on the interior walls of a waterback, as shown in Fig. 7, and accumulates until the passageway for water is completely choked. The period of time in which a waterback will become completely obstructed with lime, depends on the degree of hardness of the water and the amount of water heated. In some localities, a waterback will become choked in from 4 to 6 weeks if no means are employed to prevent the incrustation. When a waterback becomes completely stopped with lime so that water cannot circulate through it, the

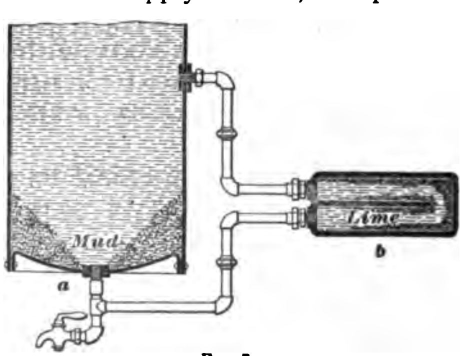


FIG. 7

waterback must be removed from the range and cleaned. If it is not cleaned, steam will be generated in the waterback and force its way back to the boiler, where the steam bubbles on encountering cold water, will collapse with a rattling, snapping sound that is quite alarming. Finally, the metal of the waterback will become overheated and its tensile strength greatly weakened thereby.

To clean a waterback, the water must, first of all, be shut off from the boiler and the water therein drawn off. This is done by opening the blow-off cock at the bottom of the boiler and opening a hot-water faucet at some fixture to open the boiler to the atmosphere, since if air is not admitted to the boiler the water will not run out. If the opening of a hot-water faucet fails to start the water in the boiler, the hot-water supply-pipe coupling on top of the boiler should be uncoupled to let in air. When the boiler is empty, the connections to the waterback should be unscrewed and the waterback removed from the range. It is then ready for the actual work of cleaning. This is done by pounding the waterback with a hammer to loosen the scales; a long slender chisel is then used inside to break up the incrustation, and detach any particles that adhere to the sides. As the incrustation is loosened, it should be removed by turning the waterback so that the openings point downwards, and dropping it on a plank to jar out the loosened lime.

In some cases, the lime incrustation is so baked to the sides of the waterback that it is necessary to cut it out with acid. Hydrochloric acid, commonly called muriatic acid, is generally used for this purpose. It is poured into the waterback and allowed to cut and weaken the incrustation so that it can be removed in the manner already described. A waterback that has been cleaned with acid should be thoroughly cleansed with water before being replaced in the range.

15. The incrustation of waterbacks by lime can be checked to a certain extent by chemically treating the water before it enters the waterback. Fig. 8 shows a device for automatically feeding the chemical to the water. The chemical used in this apparatus, which depends on the character of the water, is prepared in the form of a salt, and furnished by the manufacturer of the apparatus. The salt is placed in the chamber *a* through the handhole *b*, and is then thoroughly

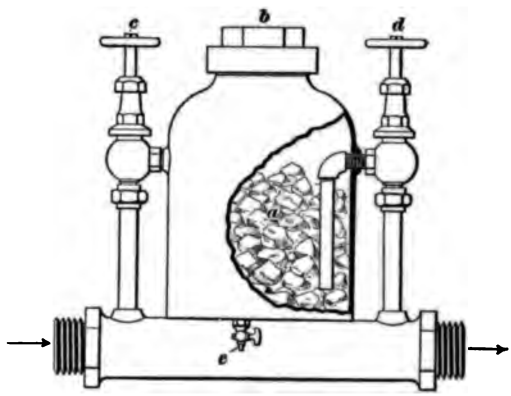


FIG. 8

moistened; the two valves *c* and *d* are now opened and the apparatus is ready to feed automatically the chemical to the water circulating from the boiler to the waterback. The petcock *e* is used to draw off sediment from the chamber. The apparatus is placed on the circulating pipe from the boiler to the waterback. It should never be placed on the flow pipe from the waterback to the boiler, as the lime would then deposit in the waterback before the chemical was mixed with it.

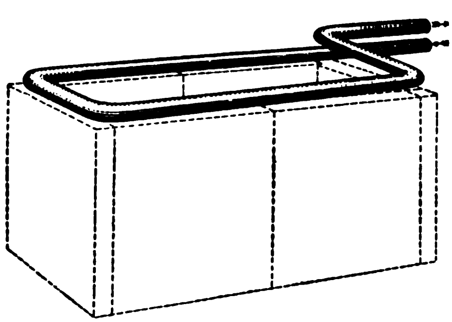


FIG. 9

16. Firebox Coils. In place of a waterback, a pipe coil, shown in Fig. 9, is occasionally used for heating water for domestic purposes. The coil is usually made of a copper tube, $\frac{3}{4}$ inch internal diameter and about $\frac{1}{8}$ inch thick, and is placed on the inner edge of the firebricks, as shown. A heating coil like that shown is safer than a waterback, because it contains only a small quantity of water, and hence an explosion will not be very violent; on the other hand, owing to its limited heating surface it will heat only a small quantity of water. Furthermore, a heating coil will be choked by incrustation much faster than a waterback. These considerations render the use of heating coils inadvisable except under conditions especially favorable to them, and hence they are seldom installed.

17. Special Water Heater.—In places where large quantities of hot water are required for domestic purposes, as in hotels, clubs, and bath houses, sufficient heat cannot be obtained from the kitchen range, and hence special heaters, which can be obtained in the open market, are installed. One form of such a heater, heated by a coal fire, shown in Fig. 10, consists of a hollow annular casting or ring *a*, between the walls of which water is heated by the fire and hot gases. Water from a storage tank enters the water space of the heater near the bottom through the return circulation pipe *b*. It is heated by the fire, rises to the top of the heater, and passes through the flow pipe *c* to the storage tank, thus establishing a circulation.

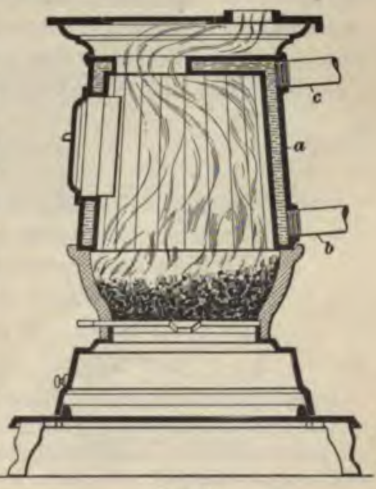


FIG. 10

The connections to fire-heated water heaters are usually of 1¼-inch pipe for a 100-gallon boiler, 1½-inch pipe for a 200-gallon boiler, and 2-inch pipe for a 300-gallon boiler.

18. The size of a water heater to do a given amount of heating may be approximated by calculating the grate surface it should have, by the following rule. Before this rule can be applied, it is necessary to estimate the probable combustion rate per square foot of grate surface. Experience indicates that the combustion rate averages 3 pounds of coal per square foot of grate surface per hour in small heaters under usual conditions; in large heaters a combustion rate of $4\frac{1}{2}$ pounds of coal may safely be figured on. Where a large heater receives constant attendance, the figure given may be much exceeded; it is wise, however, to figure on the usual combustion rate to provide for contingencies, such as poor coal, poor attendance, etc. The amount of heat transferred to the water per pound of coal must also be estimated; in practice, this amount has been found to average about 8,000 British thermal units per pound of coal burned.

Rule.—*To find the grate surface required for a water heater, in square feet, multiply the weight of water to be heated per hour, in pounds, by the required temperature rise, in degrees Fahrenheit. Divide this product by 8,000 times the estimated coal consumption per square foot of grate surface per hour.*

Or,

$$G = \frac{Wt}{8{,}000\,C}$$

where G = grate surface, in square feet;

W = weight of water per hour, in pounds;

t = difference between initial and final temperature of the water, in degrees Fahrenheit;

C = combustion rate per square foot of grate surface per hour.

EXAMPLE.—What grate surface is required for a water heater that is to heat 1,000 United States gallons of water per hour from 50° to 180°, the combustion rate being estimated at $4\frac{1}{2}$ pounds per hour per square foot of grate surface?

SOLUTION.—The weight of water is $1{,}000 \times 8.3 = 8{,}300$ lb. Substituting values in the formula given,

$$G = \frac{8{,}300 \times (180 - 50)}{8{,}000 \times 4\frac{1}{2}} = 30 \text{ sq. ft., nearly. Ans.}$$

STEAM-HEATED WATER HEATERS

19. Construction and Installation.—The hot-water supply for large buildings, hotels, etc. is sometimes heated by steam, the installation of the system being about as shown in Fig. 11. A horizontal boiler *A* is shown, but a vertical one can be used equally as well. The steam is taken in at the valve *C*, and after passing through the coil *D* of brass or copper pipe, passes off, in the form of water, through the pipe *E* to a steam trap. The coil should be inclined so that the steam which is condensed within the tubes will flow, by gravity, toward the exit *E*. The cold-water supply pipe is shown at *B*, the hot-water supply pipe to the fixtures at *F*, and the return pipe from the fixtures at *G*.

The supply of steam for heating the coil may be shut off at times, or may be withdrawn during the summer. In that case, an auxiliary heater must be provided; this may be arranged as shown in Fig. 11. It consists mainly of a furnace chamber that is surrounded by a cast-iron water-jacket *H*. The cool water flows down the pipe *J* and, becoming warmed in the jacket *H*, flows upwards through the pipe *I*, thus maintaining a constant circulation.

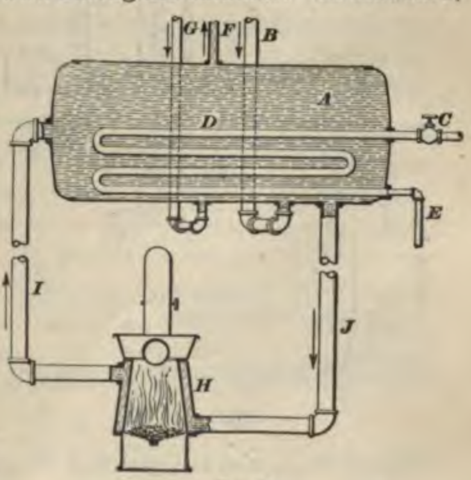


FIG. 11

Steam coils in tanks for heating water generally use exhaust steam from engines; a live steam connection is usually provided, by which live steam can be turned on in case the engines are shut down. The amount of coil heating surface used in large tanks is about 1 square foot for every 15 gallons of capacity of the tank; or, what is equivalent, 1 lineal foot of 1-inch pipe for every 5 gallons in the tank.

20. A method of installation utilizing steam from an ordinary house steam-heating system as an auxiliary means of heating the water in a kitchen boiler, is shown in Fig. 12. Two pieces of 2-inch pipe *a* and *b* are screwed together to form the letter **L** and a ¾-inch brass or copper tube is placed inside, as shown by dotted lines. The top end of this tube is connected to a ¾-inch or 1-inch pipe *c* that connects to the top of a steam main. The lower end of the inner tube connects to a return main by a ¾-inch pipe *d*, at a point below the water-line *w. l.* of the steam boiler. An automatic air vent is located at *e*. The space around the inner tube, enclosed by the 2-inch pipe, is connected to the hot-water pipe over the boiler, and to the bottom of the boiler, as shown. The steam attachment for heating the boiler is thus separate from, and independent of, any other heating attachments. It will operate automatically and without attention. When the steam boiler is fired, steam will rise in *c*, and the pressure will force the air out of the inner tube through the vent *c*. As the steam fills the inner tube, it will rapidly impart its heat to the water in the 2-inch pipe, and the condensed steam will flow by gravity back to the boiler through *d*. The hot water in the 2-inch pipe being less

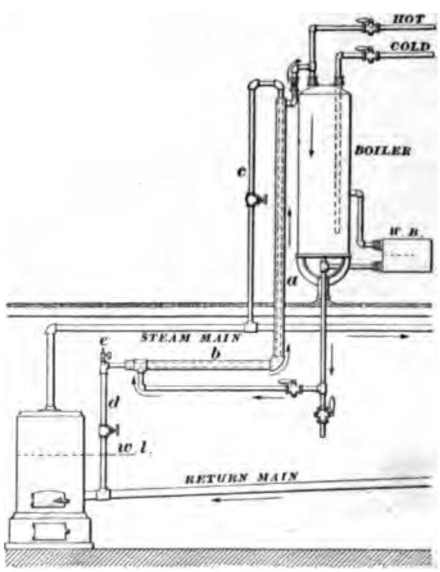


FIG. 12

dense than that in the boiler, will rise and flow into the top of the boiler, while cold water will flow from the bottom of the boiler to take its place, as shown by the arrows. The length of the inner tube should be at least 8 feet for a 40-gallon boiler in an ordinary house.

21. Heating Surface of Steam Coil Heaters.—The theoretical amount of heating surface required in a steam coil to heat a certain quantity of water in a given time, can be found by dividing the total number of British thermal units required to heat the water by the number of British thermal units given off in a given time, per square foot of heating surface, in the coil. It has been found in practice that 1 square foot of heating surface in a steam coil made of pipe about $\frac{1}{8}$ inch thick will transmit in 1 hour 300 British thermal units if the pipe is of copper, and 200 British thermal units if the pipe is of wrought iron, for each degree of temperature difference between that of the steam and surrounding water. From these considerations the following rule has been derived, in which an allowance of 25 per cent. has been made for contingencies:

Rule.—*To find the heating surface required to heat a given weight of water per hour by a steam coil, multiply 1.25 times the weight of water, in pounds per hour, by the required rise in temperature of the water, in degrees Fahrenheit. Divide the product by the product of 300 for copper pipe, or 200 for wrought-iron pipe, and the difference between the temperature of the steam and the average temperature of the heated water. The quotient will be the required heating sunface, in square feet.*

Or,
$$S = \frac{1.25\ Wt}{f(T - t_a)}$$

where S = heating surface of steam coil, in square feet;
W = weight of water, in pounds per hour;
t = temperature rise of water;
f = 300 for copper pipe, and 200 for wrought-iron pipe;
T = temperature of the steam;
t_a = average temperature of the water.

It should be noted that by the term average temperature of the water is meant one-half the sum of the temperatures at entering and leaving the heater.

EXAMPLE.—How many square feet of heating surface will be required in a copper steam coil to heat 200 United States gallons of water per hour from 50° to 190° F., the steam having a temperature of 240° F.?

SOLUTION.—Since a United States gallon of water weighs 8.3 lb., the water to be heated per hour is $200 \times 8.3 = 1{,}660$ lb. The temperature rise is $190 - 50 = 140°$ F. The average temperature of the water is $\frac{190 + 50}{2} = 120°$ F. Substituting in the formula corresponding to the rule, $S = \frac{1.25 \times 1{,}660 \times 140}{300 \times (240 - 120)} = 8$ sq. ft., nearly. Ans.

HOT-WATER STORAGE

CONSTRUCTION OF HOT-WATER BOILERS

22. The reservoir for the storage of water heated by some form of a water heater is usually called a **boiler;** for domestic use, these boilers are made either of copper, thoroughly tinned on the inside, or of galvanized iron. They are commonly set in a vertical position, but when circumstances require it they can be set horizontally. The usual construction of a boiler is shown in Fig. 5; referring to that illustration it will be seen that the boiler consists of a cylindrical shell closed by heads riveted thereto. Suitable bosses tapped with standard pipe threads are provided for the necessary pipe connections. The boiler shown is *single;* boilers are also made double, one within another, to suit places where the water is supplied from two sources at different pressures, and where one water heater must heat the water for both boilers. Iron boilers are galvanized after they are riveted together. The interior of a boiler can be examined by pushing a lighted candle inside and looking through the pipe holes.

23. Boilers that are constructed with a single line of rivets in the longitudinal seam are called **single-riveted**

boilers, and are suitable for pressures lower than 40 pounds, by the gauge. Those having two lines of rivets in zigzag or alternate order are called **double-riveted boilers**, and are suitable for pressures greater than 40 pounds per square inch. A single row of rivets is sufficient to secure the head or the bottom. The boilers known as **standard**, which are generally single-riveted, are usually tested by the makers under a hydrostatic test of 150 to 200 pounds per square inch; and extra heavy boilers, which are generally double-riveted, are tested to 250 pounds by the gauge.

24. The size of boiler to be placed in a residence cannot be found from theoretical considerations. Experience shows, however, that a 40-gallon boiler is usually sufficient for a house having one bathroom, one sink, and a set of wash tubs. If there are two bathrooms, a 50-gallon or 60-gallon boiler should be used. It is good policy to have the boiler a little too large rather than too small, particularly if the water pressure is low.

25. Safety valves are not necessary when the boiler is connected directly to the street mains or draws its water supply from a house tank, because the expansion of the water in the boiler will then force the surplus water into the supply pipe. When there is a check-valve or a pressure-reducing valve in the cold-water supply pipe, however, a safety valve must be placed in the hot-water supply pipe or on the boiler; this valve should be so located that the surplus water discharged from it will flow into a sink or some other convenient place.

A vacuum valve should be attached to copper boilers if they are likely to be emptied and to have at times a partial vacuum formed inside, to prevent the pressure of the atmosphere crushing the thin shell. A boiler that is supplied with an expansion pipe needs neither a vacuum valve nor a safety valve.

26. The usual stock sizes and capacities of galvanized-iron range boilers are given in Table III.

27. When the capacity of the hot-water reservoir exceeds, say, 200 gallons, it is customary to call it a **hot-water tank.** Large hot-water storage tanks are generally suspended from the overhead beams by means of iron bands. Sometimes, however, they rest on cast-iron saddles placed on the floor or on brick piers.

Storage tanks are most generally used in large apartment and tenement houses, and similarly used buildings; their capacity is usually based on the number of families to be supplied,

TABLE III

CAPACITY OF RANGE BOILERS

Capacity U. S. Gallons	Length Feet	Diameter Inches	Capacity U. S. Gallons	Length Feet	Diameter Inches
18	3	12	48	6	14
21	3½	12	52	5	16
24	4	12	53	4	18
24	3	14	63	6	16
27	4½	12	66	5	18
28	3½	14	79	6	18
30	5	12	82	5	20
32	4	14	98	6	20
35	5	13	100	5	22
36	6	12	120	6	22
36	4½	14	120	5	24
40	5	14	144	6	24
42	4	16	168	7	24
47	4½	16	192	8	24

and is as follows: For from 10 to 15 families, from 22 to 25 gallons capacity per family; for from 15 to 20 families, 20 to 22 gallons capacity per family; for from 20 to 25 families, 18 to 20 gallons capacity per family; for from 25 to 30 families, 16 to 18 gallons capacity per family. The capacities given have in practice been found to be ample if no laundry work is done. Should laundry work be done, however, the capacity per family should be made at least 50 per cent. larger, on account of the great demand for hot water on wash days.

CONNECTIONS TO HOT-WATER BOILERS

28. Usual Connections to Vertical Boilers.—A very common method of connecting up vertical range boilers is shown in Fig. 13. The cold-water pipe *X* should enter at the top of the boiler and end at the line *a b*, which should be about 3 inches above the level of the waterback *W. B.* When the water is shut off from the house, the water is likely to be drawn out of the boiler by the opening of a faucet in the cellar, or even through the waste outlet of the stop-cock on the service pipe. The pipes *X*, X_1 then act as a siphon, and draw out the water until its level falls to the end of the pipe X_1. If X_1 extend to the line *c d*, the waterback will be drained, which is dangerous. Unless the fire is

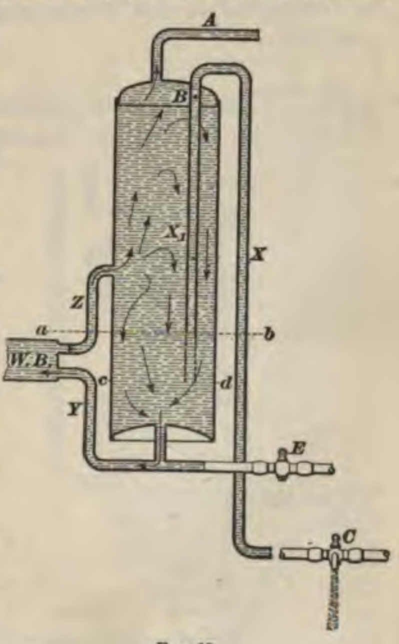


FIG. 13

drawn, the waterback will become overheated, and when the cold water is turned on it will be very liable to crack or explode. All danger from siphoning can be avoided by drilling a small hole, about $\frac{1}{8}$ inch, in the inner tube X_1, as at *B*. The hot-water pipe *A* is connected at the extreme top part of the boiler. The direction of the circulation is shown by the arrows. Connections are made to the waterback *W. B.* by two pipes *Y* and *Z*. The pipe *Y* should be connected to the bottom of the boiler, and should be inclined upwards toward the waterback. The pipe *Z* receives the hot water from the waterback, and should be inclined upwards toward the boiler. This pipe is usually connected to a side tapping located near the middle of the boiler, as shown, and should be at least ¾ inch in nominal diameter for a 40-gallon, or 1 inch for a 60-gallon, boiler. A blow-off cock, to remove mud and sediment, should be provided, as at *E*. This may empty into a sink, or may be connected to the waste pipes on the house side of the trap seal.

29. If the boiler is connected to the waterback in the manner just described, considerable time elapses before the water in the boiler is heated sufficiently to allow hot water to be drawn from the faucets. To get hot water without delay after starting a fire in the kitchen range, the connections are frequently made as shown in Fig. 14. The hot-water pipe *Z* from the waterback is connected directly to the hot-water distributing pipe *A*, a connection to the top of the boiler being made at the junction of *A* and *Z*. Then, the hot water from the waterback may flow directly to the fixtures, or into the boiler when the fixtures are not in use.

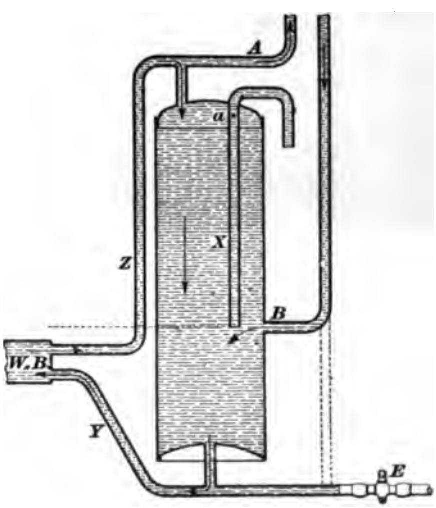


FIG. 14

To prevent cooling of the water in the hot-water supply pipe, the water therein should circulate constantly between the faucets at the fixtures and the boiler; hot water can then be obtained quickly at the faucets. To obtain the needed circulation, a return pipe *B*, Fig. 14, must be used. This pipe is joined, by branches, to the hot-water supply pipe near each fixture, and should be one or two sizes smaller than the supply pipe. The return pipe should, if possible, enter the boiler at the side and a little above the top of the waterback; it is not always satisfactory if it is connected to the extension of the pipe *Y*, as shown in dotted lines. If the return pipe is connected to *Y*, cold water from the bottom of the boiler is liable to flow up the return pipe on the opening of a faucet and mix with the hot water before it reaches the faucet, thus cooling the supply.

30. Top-and-Side Connection to Vertical Boilers. Probably the best way to connect a range to an upright boiler is shown in Fig. 15. The flow pipe from the waterback *W. B.* connects to the side of the boiler as well as to the top. The advantage of this connection is that the hot water from the waterback will flow immediately to the top of the boiler when there is water in the main hot-water distributing pipe *a*. When the stop-and-waste cock in the cellar on the cold-water supply pipe *b* is closed, and the water drained out of *a*, the hot water from the waterback will flow freely into the boiler through the side tapping; that is, circulation between the range and the boiler is not impeded by shutting

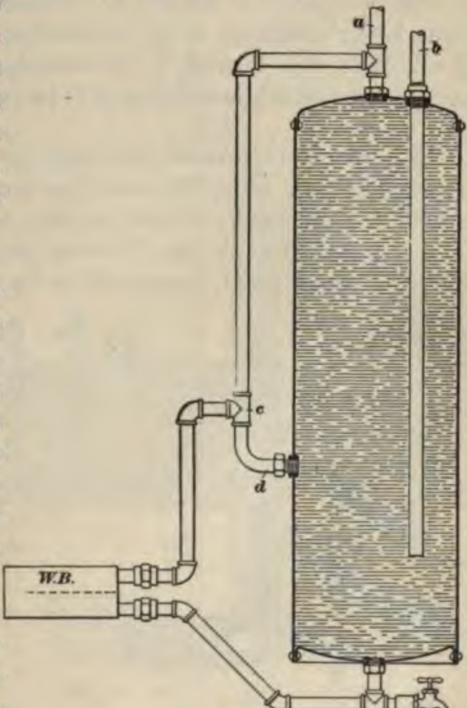


FIG. 15

off the water supply from the house. If the side connection is not made in addition to the top connection shown in Fig. 14, the water will boil in the waterback and produce steam, accompanied by very disagreeable sounds, whenever the cold-water supply is shut off from the boiler and the hot-water supply pipe *A*, Fig. 14, is drained below the **T** at which the flow pipe *Z* joins.

The position in which the **T** *c*, Fig. 15, is placed, permits a bent boiler coupling to be connected to the side tapping of the boiler; this insures a circulation of water through the top connection while the pipe *a* is full of water.

31. Connections to Horizontal Boilers.—In places where there is no space available for the installation of a boiler in a vertical position, it may be placed horizontally. The connections to the fixtures and waterback may be made in many ways, one of which is shown in Fig. 16. In

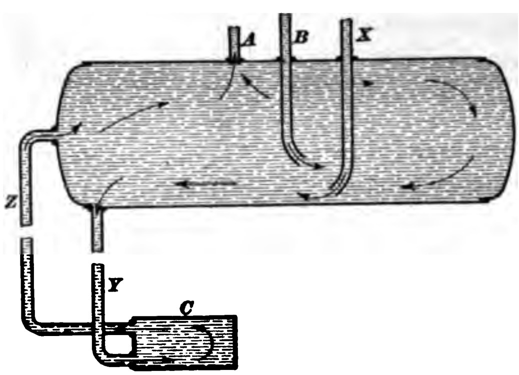


Fig. 16

the illustration, *A* represents the hot-water supply pipe; *B*, the return pipe; *X*, the cold-water supply; *Y* and *Z*, the connections to the waterback *C*. The waterback should be at a lower level than the bottom of the boiler. The arrows show the direction of the circulation. The boiler may be supported on brackets or may be suspended by bands from overhead floorbeams. Small horizontal boilers are usually suspended immediately over the kitchen range. The use of the return pipe *B* insures hot water at the fixtures as soon as a faucet is opened; if this feature is considered unnecessary, the return pipe and its fixture branches are omitted.

32. Connections to Double Boilers.—When the water to be heated is supplied from two sources, double boilers are employed; usually one part of these boilers receives water from the street main, while the other is supplied from a tank. The two boilers are combined in one structure, as shown in Fig. 17. The boiler *B* that is fed from the tank and sustains the higher pressure is placed inside the low-pressure boiler *A*. The inner boiler is heated by the water in the outer one; both are thus heated by one waterback or heater.

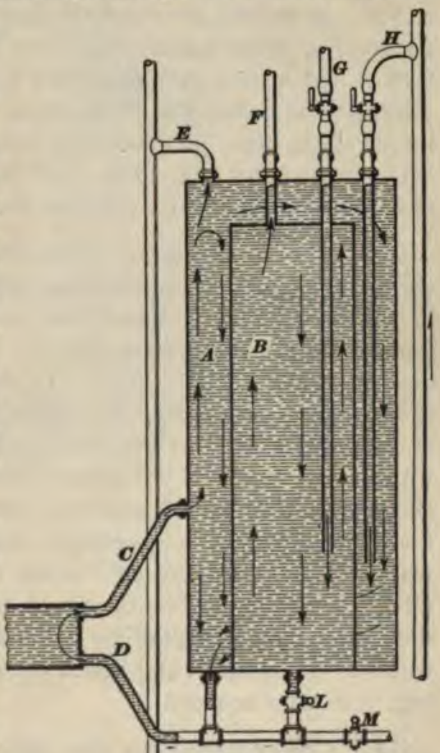


FIG. 17

If the inner boiler should be emptied while the outer one is full, it might collapse in consequence of the external pressure; therefore, care must be taken to empty the outer boiler first at all times, or, better yet, to arrange the blow-offs so that both boilers will be emptied at the same time. The inner boiler should always be filled first. The connections to each boiler are made in the same manner as for an ordinary vertical boiler, the flow pipe *C* entering the side, and the return pipe *D* the bottom, of the outer boiler. The hot-water supply pipe *E* of the street-pressure system supplies the lower stories of the building; the upper stories have a tank-pressure system and are supplied with hot water through the pipe *F*. The cold-water supply pipe *H* is connected to the street main, and the cold-water supply pipe *G* to the house tank. A blow-off, or sediment, cock *L* is used for emptying the inner boiler, and a similar cock *M* for the outer boiler. It should be noted that, with the cocks placed as shown, the inner boiler cannot be emptied without opening both *L* and *M*, and thus emptying both at the same time; this prevents the possibility of an excess of pressure in the outer boiler at the time of emptying, which excess would tend to collapse the inner one. The inner boiler should be of copper, and should be thoroughly tinned both inside and outside.

33. The conditions under which double boilers may be installed are present in buildings situated where the pressure in the street mains is insufficient to force water to the upper floors, and the hot water supplied to the whole building is heated by the kitchen range. In that case, the lower floors are supplied with water by street pressure, and the upper floors from a tank at the top of the building, to which the water is pumped. If a double boiler is installed under these conditions, only the hot and cold water required for the upper floors requires to be pumped; should a single boiler be installed, however, the cold water for the upper floors and all the water to be heated would have to be pumped. It is thus seen that by installing a double boiler the amount of water to be pumped, and hence the power required for pumping, is greatly reduced.

34. Connections to Gas Heater, Kitchen Range, and Furnace.—A kitchen boiler is sometimes connected to the waterback of a kitchen range, to a gas water heater, and to a coil or water ring in a house-heating furnace in the cellar. Then, in summer, when the kitchen range is not in use, the water can be heated by the gas heater; at other times, the kitchen range can be used for heating the water; and in winter, the coal furnace will also heat water. This combination should be so installed that either two or all three of the heaters can be used on occasions when there is an extraordinary demand for hot water. The usual connections for a heater combination such as is described, are shown in Fig. 18, in which *a* is the cold-water supply pipe to the house; *b*, the cold-water supply pipe to the boiler; *c*, the hot-water supply pipe for the house; *d*, the return pipe, insuring hot water to appear promptly at the fixtures when a faucet is opened. The heater in the furnace is connected by the flow pipe *e* to the side of the boiler; the flow pipes *f* and *g* from the gas heater and kitchen range connect to *c* at the top of the boiler, as shown. The cold water flows to the three heaters through the pipes *h*, *i*, and *j*, joined to the pipe *k* connected to the bottom of the boiler. With the piping installed in the manner shown, any one of the three heaters can be used independently of the others, any two heaters may be in service at the same time, or all three heaters may be employed in heating water. The sediment cock *l* is placed at the lowest point of the pipe system, where it will drain the boiler, the heaters, and the pipe connections to the boiler.

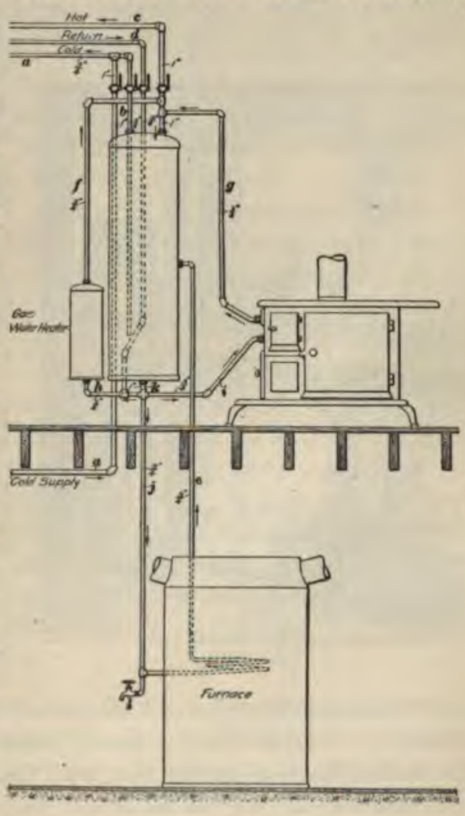


FIG. 18

35. Connections to Laundry Stove and Kitchen Range.—When a set of laundry tubs is supplied with hot water from the kitchen boiler, very often the waterback of the kitchen range cannot heat the water quickly enough to supply the increased demand on wash days, while the building may be well supplied with hot water on ordinary occasions. Then, if the heating surface of the waterback is increased so as to heat the water quickly enough to supply the demand when the laundry tubs are in use, it is generally too large for the ordinary daily usage. To overcome this trouble, many buildings are furnished with a separate water heater, and often with a separate boiler, to supply the laundry with hot water. These auxiliary attachments may be connected with the usual hot-water heating and distributing portion of the plumbing system, but if they are intended to be operated independently of the kitchen boiler, they may be fitted up and connected directly to the laundry distributing pipes, which then have no connection with the boiler in the kitchen.

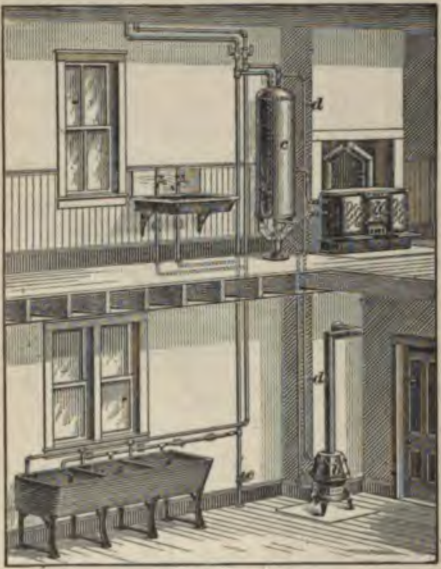


FIG. 19

In Fig. 19 is shown a simple method of connecting a laundry stove and kitchen range to one boiler. One waterback is located in the kitchen range *a*, and another, or a pipe coil, is located in the laundry stove *b*. In this arrangement it is assumed that the boiler *c* is large enough to hold the quantity of hot water required during wash days, and that the waterback in *a* is not able to heat enough water. The waterback, or coil, in *b*, consequently, is only intended to assist that in *a* during times of exceptional demand for hot water. The waterback in *a* is connected to the side and bottom of the boiler in the usual manner, as shown. The flow pipe *d* of the laundry-stove water heater connects at the top of the boiler to the hot-water supply pipe.

36. Since the rapidity of circulation between the range and the boiler depends chiefly on the vertical height of the flow pipe, it may seem more proper to connect *d*, Fig. 19, to the side tapping of the boiler and to connect the flow pipe between *a* and *c* to the top of the boiler, so as to increase the circulation between the kitchen range and the boiler without injuring the circulation between *b* and *c*. Such a method of connection would furnish more hot water in a given time, and in this respect it would be better than the method shown in the drawing. It has the peculiar disadvantage, however, which is more pronounced than any advantage gained, that if the water is shut off at the stop-and-waste cock *e*, water may be siphoned from the boiler until the boiler water-line reaches the small vent hole in the boiler tube. Circulation between the range and boiler will then be cut off, because the water in the flow pipe that joins the hot-water distributing pipe at the top of the boiler in the assumed method of connection will not be able to rise high enough to enter the boiler. Steam will then be generated in the waterback and disagreeable hammering and snapping noises will be created.

37. It is bad practice, when connecting two or more waterbacks to one boiler, to place stop-cocks or stop-valves in the circulation pipes for the purpose of allowing each waterback to be cut out of service for repairs without affecting the other. While this object is accomplished thereby, the danger of a waterback explosion is introduced, which may happen if the stop-cocks of one circuit are closed by accident or through ignorance while the corresponding waterback is subjected to heat and contains water. On general principles, stop-cocks must not be placed between ranges and boilers.

38. Connection of Two Boilers to One Waterback. Fig. 20 shows how two or more boilers may be connected to one waterback when a separate hot-water distributing line is taken from the top of each boiler. The waterback tapping should be 1 inch. The flow branch to the nearest boiler is made by a 1″ × ¾″ × ¾″ reducing **T**, so that the 1-inch current will be split, and thus caused to flow into both boilers. The return pipe is increased at the nearest boiler with a similar fitting. The flow pipe from the top tapping of the waterback must pitch upwards toward both boilers, since otherwise the water will not circulate. To equalize the temperature of the two boilers they may be connected with two equalizing pipes, one connecting the top of one boiler to the top of the other boiler, and the other pipe connecting the bottom of one boiler to the bottom of the other boiler. Generally speaking, it is better to use a single boiler of the required storage capacity rather than two small ones.

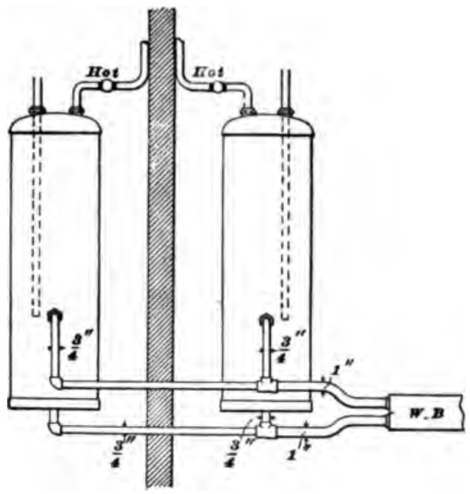


FIG. 20

39. Connection of One Boiler to Several Ranges. Fig. 21 shows how four waterbacks *W. B.*, *W. B.* may be connected to a boiler so that a positive and efficient circulation can be secured between each waterback and the boiler. The arrows show the direction of the currents. The pipes are reduced in size as they extend from the boiler, which will prevent the waterbacks farthest from the boiler from being "short-circuited" by those nearest the boiler; that is to say, the circulation will take the shortest course between boiler and waterback if the piping is all one size, but if it is proportioned as shown, a good circulation will take place in each waterback.

In case the side tapping of the boiler is too low, or in case the ranges are set too far apart and the proper head for circulation cannot be obtained, the hot-water flow pipes may be connected to the top of the boiler, as shown by the dotted lines; or, the boiler may be raised so that a satisfactory head may be secured for a circulation to a side opening.

40. Connections for Boiler in Cellar.—Fig. 22 shows part of a building in which the hot-water boiler *a* is

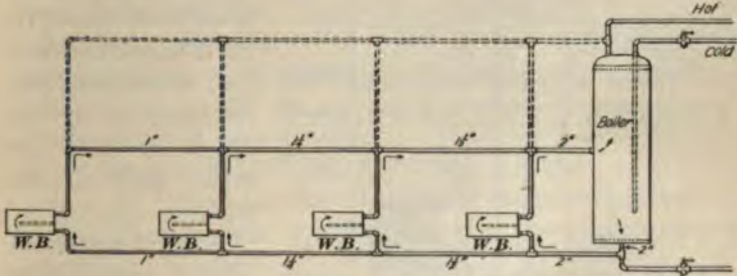


FIG. 21

located in the basement, and heated from the waterback in a range on the floor above. If the boiler and the range are connected by two pipes dropping directly from the range to the boiler, circulation will not take place between these points, because the hot water will remain in the waterback and the cold water in the boiler. There will be no force present to raise the cold water to the waterback, and so displace the hot water and cause it to flow down to the boiler. The water will simply remain in the waterback until part of it is converted into steam, when, by the enormous expansion of the water so changed to the gaseous state, the greater part of the hot water will be forced down in the pipes that connect the waterback to the boiler, and the waterback then being full of steam, instead of water, will soon become overheated. Such a condition is usually made manifest by snapping or hammering and rumbling sounds.

In order to obtain a force sufficient to cause the hot water to descend to the boiler, and thereby secure a circulation between the boiler and the range, the flow pipe *f* is extended vertically upwards as far as the circumstances will allow, then returned and dropped downwards to the boiler, as shown by *e*. The vertical height of the loop should be at least twice the vertical distance between the waterback and the bottom of the boiler in order to insure good circulation.

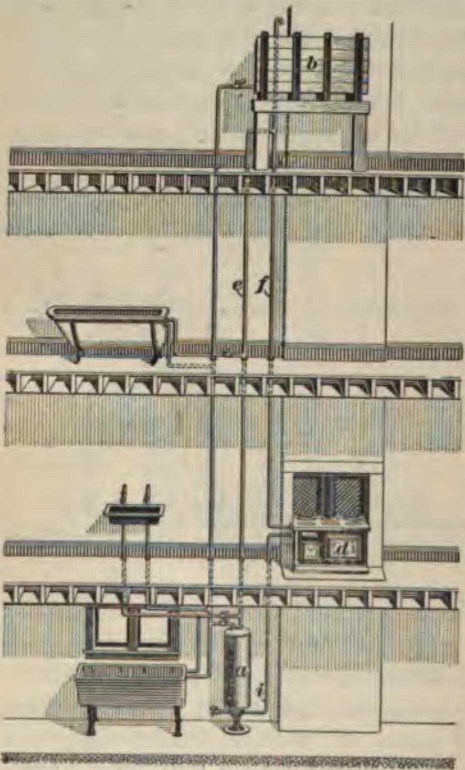


FIG. 22

When a system of piping similar to that shown in Fig. 22 is employed, particular care must be taken to arrange the piping in such a manner that the waterback cannot be accidentally drained by shutting off the water and draining the branches for repairs. It should be so arranged that the hot water may be shut off from the fixtures without interfering with the range circulation. This can be easily accomplished by placing stop-cocks where shown in the figure.

In Fig. 22 the cold-water supply is shown as derived from a tank; the arrangement of the connections between the boiler and waterback will be the same, however, if the cold-water supply is taken from a street main, except that the loop will rise only to the highest fixture to be supplied with hot water, the branch to the fixture being taken from the highest point of the loop to draw off continuously any air that may accumulate there.

41. Connections to Hot-Water Tank in Attic. Occasionally, the owner of a building objects to the presence of a boiler in the kitchen, and demands that it be located in the attic. In that case, the connections between the hot-water tank and waterback may be made as in Fig. 23, which shows a case where the cold-water supply is obtained from a tank at the top of the building. The hot-water tank *a* is located on the top floor below the house tank *b*, which is joined to *a* by a cold-water feedpipe *c*. The waterback in the kitchen range *d* is joined to *a* by the flow pipe *f* and return pipe *e*. When the cold-water supply is obtained from a house tank, as in the case illustrated, an overflow pipe *g* should be attached to *a* and deliver openly into *b*; this pipe permits the water to expand freely when heated.

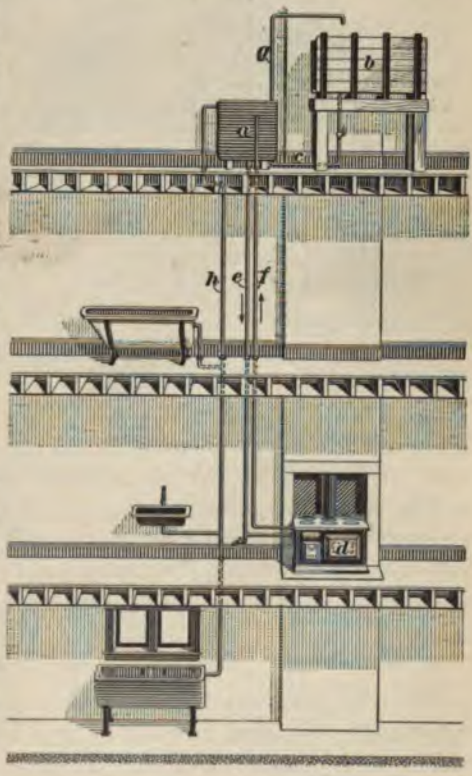


Fig. 23

42. Connections to Radiators Heated From Kitchen Boiler.—If a waterback is large enough, and if the kitchen range is fired sufficiently during extremely cold weather to give the proper amount of heat in the rooms, it is quite practicable to connect radiators to a kitchen boiler. Fig. 24 shows the way the connections may be made so that the circulation to the radiators *R*, *R* will be independent of the water-supply system, and will not affect the distribution of hot water through the building, whether the radiators are in operation or not. The arrangement shown favors the distribution of hot water to the plumbing fixtures rather than circulation to the radiators in the room, it being assumed that the heating of the rooms over the kitchen is a matter of less importance than the supply of hot water for domestic purposes. The circulation to the right-hand radiator can be increased by dropping the return pipe into the kitchen before connecting it to the other return pipe.

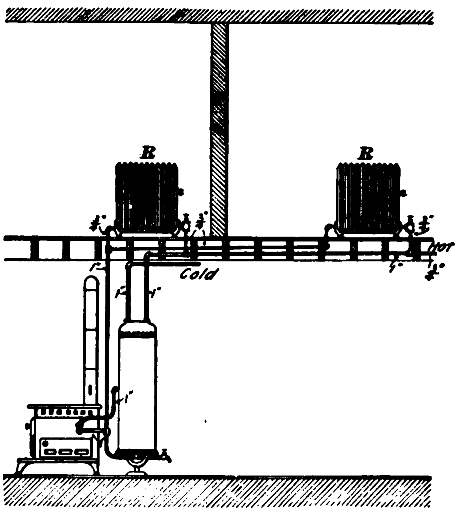


FIG. 24

DETAILS OF HOT-WATER BOILER INSTALLATION

43. Expansion Pipes.—An expansion pipe is a pipe, open at the top, that extends from a kitchen boiler to a cold-water supply tank at a higher elevation and empties into the tank. The pressure within the boiler is determined by the height of the surface of the water in the tank above it, and the boiling point of the water will correspond to that pressure. The expansion pipe serves the double purpose of acting as a safety device, preventing the accumulation of steam pressure, and permitting expansion of the heated water. Since the water in the hot-water pipes and expansion pipe is warmer than that in the supply pipe from the tank to the boiler, the level of the water in the expansion pipe will be higher than the surface of the water in the tank. Advantage may be taken of this circumstance to keep the temperature of the water in the boiler below its boiling point. For example, the water when heated to the desired temperature will stand several inches higher in the expansion pipe than in the tank. The end of the expansion pipe is then carefully cut down to that level, so that if any increase in temperature occurs, the consequent expansion will cause the water to overflow. The weight of the column of hot water will then no longer balance the cold supply column, and cold water will come down into the boiler and displace the hot water, driving it up the expansion pipe until the temperature falls to a point where the columns will balance. Thus, in some buildings, the temperature of the water in the boiler may be kept from exceeding a desired maximum, regardless of the pressure; and, the formation of steam within the boiler may be prevented, so long as the cold-water supply is maintained constant. Expansion pipes are not applied to hot-water systems supplied directly from the street mains; the water in such systems is allowed to expand back into the mains.

44. Boiler Tappings.—Kitchen boilers kept in stock are usually tapped with two 1-inch openings in the top of the boiler, one 1-inch opening in the bottom of the boiler, and one 1-inch opening in the side about one-third to one-half of the distance from the bottom to the top of the boiler. Special tappings can be had to order in any part of the boiler, or handholes can be provided on special order. When ordering special tappings in a boiler, to avoid mistakes the order should be accompanied by a sketch showing the location and sizes of the various openings.

45. Boiler Coverings.—Boilers may be covered with wooden lagging, composed of strips of pine or hardwood,

$1\frac{1}{2}$ inches to 2 inches wide, $\frac{3}{4}$ inch or more in thickness, tongued and grooved, and confined by brass or galvanized-iron bands. This will prevent the large waste of heat that occurs from radiation, and which goes far to make the kitchen uncomfortably warm.

Copper boilers may be nickel plated. This not only reduces the amount of heat lost by radiation, but prevents the boiler from becoming stained green with verdigris. When boilers are located in cellars or other places where the prevention of heat radiation is of more importance than the appearance of the boiler, they may be covered with a coating of asbestos cement, or a layer of hair felt can be put over the boiler and then covered with a canvas jacket neatly sewed on.

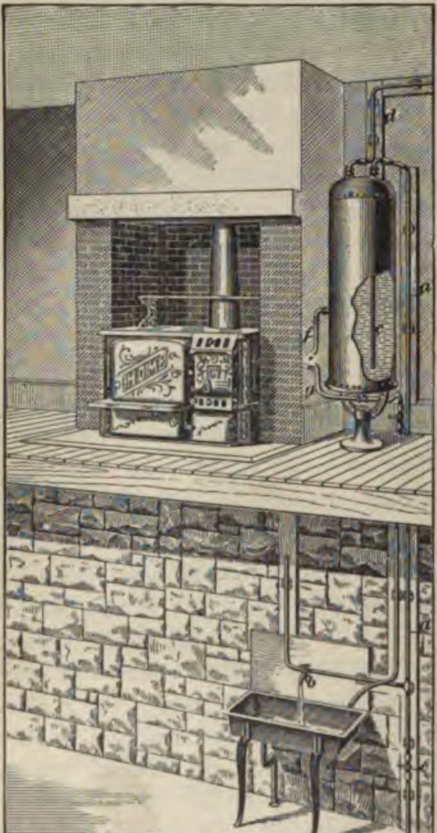


FIG. 25

46. Siphonage of Kitchen Boilers. The manner in which a boiler and a waterback may be emptied by siphonage will be explained with the aid of Fig. 25. The pipe *a* supplies cold water from the street main to the kitchen boiler as shown, and a branch, with a faucet *b* on it, supplies cold water to the basement sink. The cold water enters the boiler at a point below the level of the waterback in the range, by means of an inner tube *c*. The pipe *d* furnishes hot water to fixtures at another part of the building. If the pipe and the boiler are full of water, and the cock *e* is closed while *b* is opened, the pipe *a a* will form the long leg of a siphon and *c* will be the shorter leg; there will then be a tendency to siphon water from the boiler into the sink, through *a* and *b*, if the pressure of the atmosphere is permitted to bear on the water in the boiler. This it will do if any hot-water faucet at the fixtures above is opened. The air pressure will then extend through *d* into the boiler and force the boiler water up the inner tube *c* into *a*, whence it will flow, by gravity, into the sink below. If the tube *c* is air-tight, siphonic action will continue, under these circumstances, until the water in the boiler falls to the bottom of the inner tube, when air will enter *c*, and so break the siphon. Since the bottom end of *c* is lower than the waterback, which is connected to the boiler by the flow pipe *f* and return pipe *g*, the waterback becomes emptied by siphonage.

Suppose that the cock *e* is of the stop-and-waste pattern. Then, if *e* is closed, the waste hole will be opened at the same time, and if a faucet on the hot-water supply pipe is opened, the boiler will be siphoned through the waste until air can enter *c*. To prevent the water from becoming dangerously low in the boiler, a small hole should always be drilled through *c* near the top of the boiler; the siphonage will then stop as soon as the water level in the boiler has fallen to the level of the hole, which stops the siphonic action by admitting air to the short leg of the siphon.

47. Sediment Chambers.—Kitchen boilers of the ordinary pattern are sometimes provided with sediment chambers intended to receive foreign matter in suspension in the water. The chamber consists of a pocket *a*, Fig. 26, connected by a narrow opening *b* to the bottom of the boiler. The circulation pipe *c* from the boiler to the waterback is taken from a tapping in the side of the pocket. This prevents the mud or sediment from accumulating rapidly in the pipe connecting the pocket to the waterback. The sediment settles in the pocket, from which it should be removed occasionally by opening the blow-off cock to wash it out. If this is not done, sediment will accumulate in the pocket and ultimately choke the return pipe to the waterback.

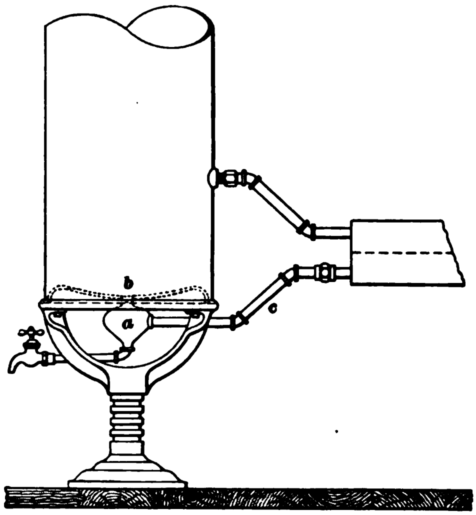


FIG. 26

48. Regulating Temperature of Water.—Hot-water tanks that are heated by steam coils can have the temperature of the water regulated automatically so as to maintain an even temperature. A form of regulator extensively used, shown in Fig. 27, consists of two rods made of metals with different coefficients of expansion, enclosed in a tube *a*, and so adjusted that when the temperature of the water reaches a certain degree the expansion of the metal will open the valve *b*, thus permitting the water to pass from the tank to a diaphragm valve *c*, which closes and shuts off the supply of steam from the coil. When the water in the tank cools sufficiently, the rods contract and shut off the supply of water from the diaphragm valve, which opens again to admit steam to the coil.

The petcock *e* at the lower end of the drip pipe is opened just a little so that while the pressure is on the diaphragm a small stream of water will flow into the funnel-mouthed branch of the drain pipe. When the valve in the regulator is closed so that the boiler-water pressure does not come on the diaphragm the pressure of the water remaining in the drip pipe becomes reduced by the small escape opening of the drip cock *e*. A spring between the diaphragm and the valve body will push the valve open when the tank pressure is off the diaphragm.

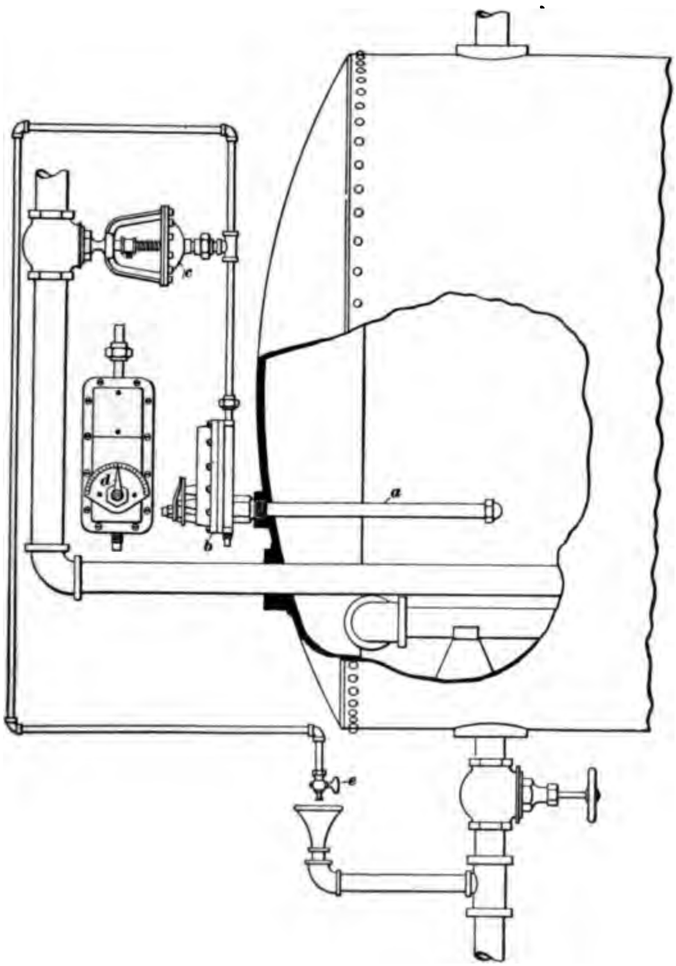


FIG. 27

The temperature at which the water is to be maintained can be regulated by the adjuster *d*, which increases the temperature of the water when its pointer is turned to the left and maintains a lower temperature when the pointer is turned to the right.

The proper location for the regulator, when applied to a tank heated by a steam coil, is at a distance of a few inches above the coil. If the boiler is heated by a coal fire, the regulator should project into the tank at a height of a few inches above the bottom, or into the return pipe, the diaphragm being attached to the damper in the smoke pipe and the draft damper to the ash-pit. Or, a hot-water damper regulator, such as is used on hot-water heating boilers for house-warming purposes, may be used.

HOT-WATER DISTRIBUTION

PIPING

MATERIALS USED FOR PIPES

49. Hot-water connections may be made of lead, brass, copper, or galvanized iron; plain iron pipe is unsuitable. The choice will depend on the pressure and on the appearance desired; also, on the character of the water, and its action on the metal. In all cases where the water corrodes the metals named, pipes should be used that have an interior coating of glass or porcelain, or are lined with pure block tin.

50. Lead pipe is very smooth on the inside, and of all piping offers the least resistance to the flow of water owing to the absence of short-turn fittings. It is easily bent to suit any situation, and easy curves are readily made. Lead pipe is not suitable to withstand high pressures because of its low tensile strength, nor to withstand high temperatures on account of its low fusing point and tendency to sag from its own weight when heated. It is also unsuitable for underground pipes, because some soils corrode it externally and gradually destroy it.

Lead varies greatly in quality. The pure lead is soft and pliable, and will not tear or crack as quickly as a harder and more impure lead while being worked into bends, etc. The hardness varies according to the kind and quantity of other metals mixed with it, and a hard, tenacious lead will stand more tensile stress than a soft lead. Therefore, no reliable estimate can be formed of the actual strength of lead pipe. It will bend under pressure without breaking, and is, therefore, desirable for connections to fixtures that are liable to change their position, in consequence of the settling or rocking of the building, provided that the water pressure is not excessive.

51. Brass and copper tubings are smooth inside, and are made in several thicknesses. For distributing the water supply in buildings, iron-pipe size brass or copper tubing is the only kind that should be used, as it will withstand the highest water pressures normally found in street mains. The peculiar advantage of brass and copper tubings is that pure water will not corrode them to an appreciable extent, nor will they be distorted by hot water in the same manner as lead pipe, owing to their superior elasticity. Copper tubing, owing to the high ductility of the material, is better than brass tubing, being less liable to split in service; its high price prohibits its extensive use, however, and hence it is employed only in the very best of work where first cost is a minor consideration.

52. Galvanized-iron pipe is the kind of pipe most generally used for cold-water and hot-water distribution, and will withstand the highest water pressures found in practice in street water mains. It endures the corrosive action of moist earth and water fairly well, but not as well as brass or copper pipe. Galvanized-iron pipe, like brass and copper pipe, must be put together with screw joints. The short bends and sharp angles, incident to this mode of connection, cause much friction and impede the flow of water.

SIZE OF HOT-WATER PIPES

53. The proper diameter of pipes that are to supply hot water depends on several considerations: (1) The number and size of faucets that are likely to be discharging water at the same time. (2) The pressure or head of the water. (3) The length of the pipe. If the pipe is crooked, making numerous bends or angles, due allowance must be made for the resistance arising therefrom. A small pipe having great length is likely to be noisy, if the pressure is great, being subject to singing noises and water hammer. The defects may be avoided by using a larger pipe, thus reducing the

TABLE IV

SIZES OF HOT-WATER MAINS

Number of Fixtures Low Pressure	Number of Fixtures High Pressure	Size of Main Inches
10	15	$\frac{3}{4}$
15	25	1
25	50	$1\frac{1}{4}$
50	75	$1\frac{1}{2}$
75	125	2
150	200	$2\frac{1}{2}$
200	300	3
300	500	4

velocity of the moving water. It is well to have the distributing mains a little too large rather than too small; the annoyance of one faucet robbing another, that is, not delivering a full stream of water while some other faucet is open, will then be avoided.

54. The diameters of hot-water mains may be based on the number of fixtures supplied, and may be as given in Table IV. When conditions are such that there is likelihood of a large number of fixtures being in use at the same time, the size of pipe given in the table may be increased one size.

If the pressure in the street main is less than 30 pounds per square inch, the hot-water distributing system may be ranked as a low-pressure system, and if the water pressure is higher, as a high-pressure system.

Horizontal pipes may be reduced in diameter as various branches are taken off. This is done only to economize in the cost of pipe.

55. In office buildings, dwelling houses, apartment houses, etc., the branches leading from the hot-water mains to the various fixtures are generally short, and may then have the sizes given in Table V. If the branch pipes are very long, it is well to make each one size larger than is given in the table.

TABLE V

SIZE OF HOT-WATER BRANCHES TO FIXTURES

Supply Branch to	Size of Branch in Inches Low Pressure	Size of Branch in Inches High Pressure
Bath cock	$\frac{3}{4}$ to 1	$\frac{1}{2}$ to $\frac{3}{4}$
Basin cock	$\frac{1}{2}$	$\frac{3}{8}$ to $\frac{1}{2}$
Sitz or foot-bath	$\frac{1}{2}$ to $\frac{3}{4}$	$\frac{1}{2}$
Kitchen sink	$\frac{1}{2}$ to $\frac{3}{4}$	$\frac{1}{2}$ to $\frac{3}{4}$
Pantry sink	$\frac{1}{2}$	$\frac{3}{8}$ to $\frac{1}{2}$
Slop sink	$\frac{1}{2}$ to $\frac{3}{4}$	$\frac{1}{2}$ to $\frac{3}{4}$

HOT-WATER DISTRIBUTING SYSTEMS

DETAILS

56. Circulation to Fixtures Below Level of Boiler. It is a difficult matter to pipe a building so that hot water can be drawn instantly at fixtures located at a lower level than that of the boiler. To get results fairly satisfactory in this respect it is necessary to form a loop by running the hot-water pipe as high as possible before descending to supply the lowest fixtures. A good example is shown in Fig. 28, where laundry tubs are located in the basement of a house supplied with water from a tank in the attic. The hot-water distributing pipe forms a loop, the flow pipe of which connects to the top of the boiler. A ½-inch relief, or expansion, pipe is located at *a*, which must be the highest point of the loop. This allows air to escape from the loop, which would otherwise become air-locked. A stop-cock is placed at the base of the relief pipe, as shown, which may be checked down to a very small opening if it is necessary to prevent air from being sucked in through the relief pipe while hot water is being drawn through the fixtures. A check-valve fitted with a very light swinging valve is attached to the return pipe of the loop to prevent cold water in the bottom of the boiler from being drawn at the hot-water faucets of the tubs. Care must be taken not to use a heavy check-valve here, for the force of the circulation is not great enough to lift a heavy check.

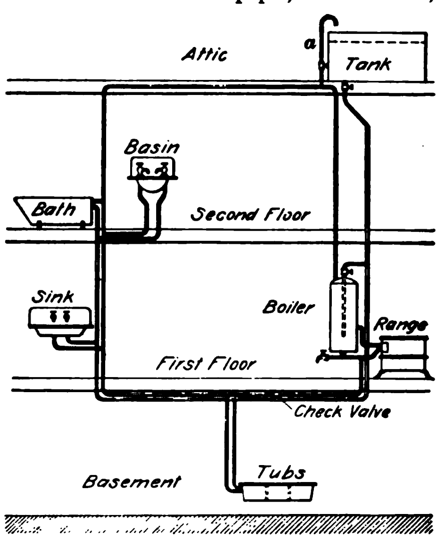


FIG. 28

When the house is supplied with water under pressure from the street main, no relief pipe is fitted to the highest part of the loop, because the pressure is sufficient to dislodge any air that may be entrapped in the loop.

57. Grouping of Stop-Cocks.—In hot- or cold-water distribution, it is a very good practice to control the various distributing branches from the same point, such as above the boiler or at the back of the kitchen sink. The waste tubes of the stop-and-waste cocks can then be joined to one waste pipe that discharges into the kitchen sink or other convenient place of disposal.

The advantages gained by supplying each line with a stop-cock are threefold. First, if a leak develops in any line of pipe, water will not have to be shut off from the entire water-supply system, but only from the line of pipe in which the leak occurs. Second, by closing a stop-and-waste cock and opening all the hot-water faucets at the fixtures supplied by that line of pipe, the water will all drain out of the pipe into the kitchen sink. The advantage of grouping the stop-cocks together is that in case of a leak the right one to shut off can be located without loss of time, while if the stop-cocks are scattered throughout the building much damage might be done to the walls and furniture before the right stop-cock could be found.

58. Covering Hot-Water Pipes.—It is advisable always to cover hot-water supply and circulation pipes with some good non-conducting pipe covering to prevent loss of heat by radiation, and also to prevent them from warming the water in cold-water pipes that may be placed near them. Any steam-pipe covering is suitable for covering hot-water pipes, because sweat does not gather on them. Cork, or wool felt lined with asphalt paper are better adapted for cold-water and ice-water pipes.

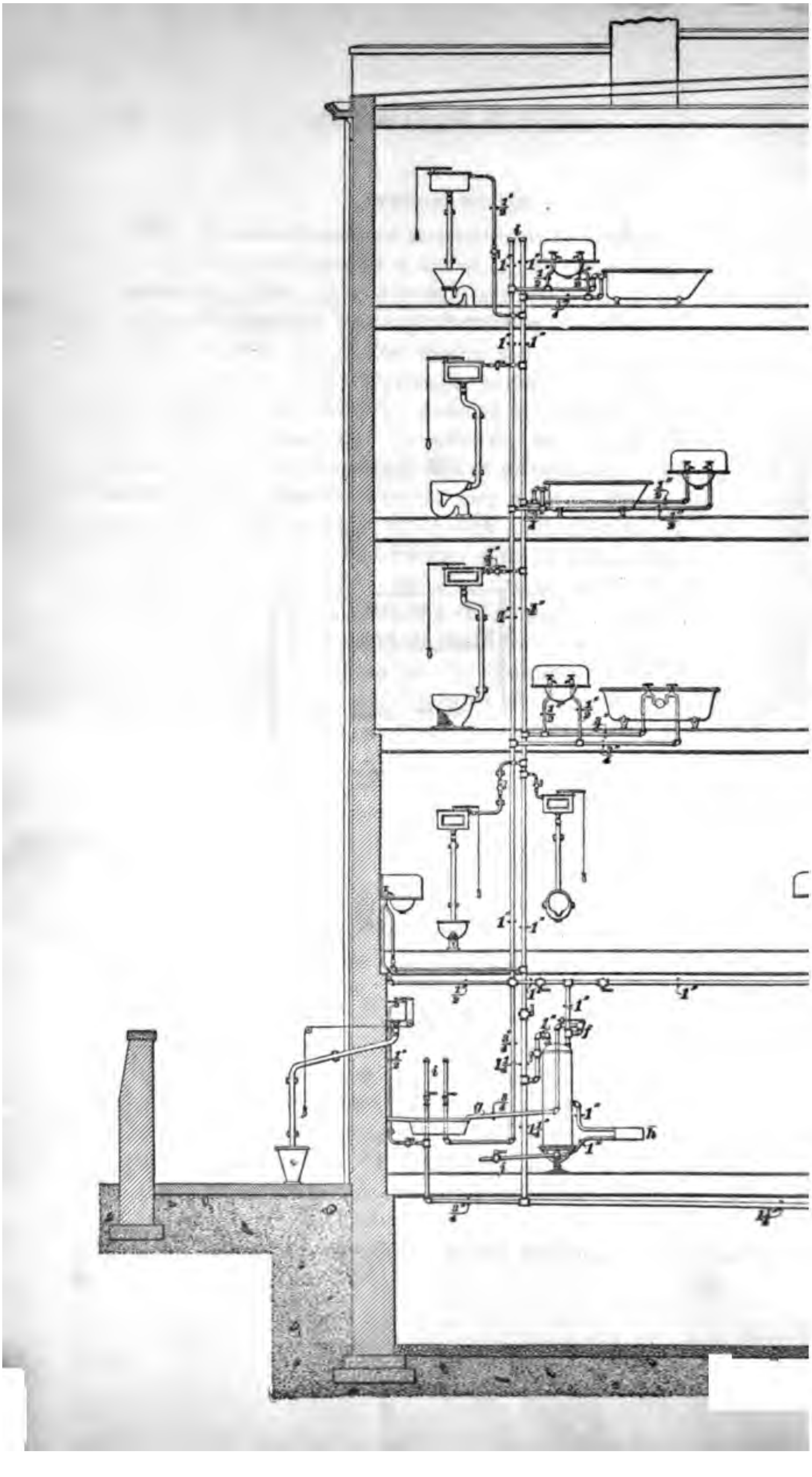
59. Expansion of Hot-Water Pipes.—When running hot-water supply pipes, provision should always be made for the expansion and contraction due to the variation of the temperature of the water. If this provision is not made, the joints are liable to become leaky by the enormous stresses to which the lines of piping will sometimes be subjected. Hot-water pipes should never be embedded in concrete; if they should be, the expansion will either crack the concrete or burst the pipes. When it is necessary to pass pipes through concrete, a little tunnel or duct should be formed to receive the pipe, which can then freely expand or contract.

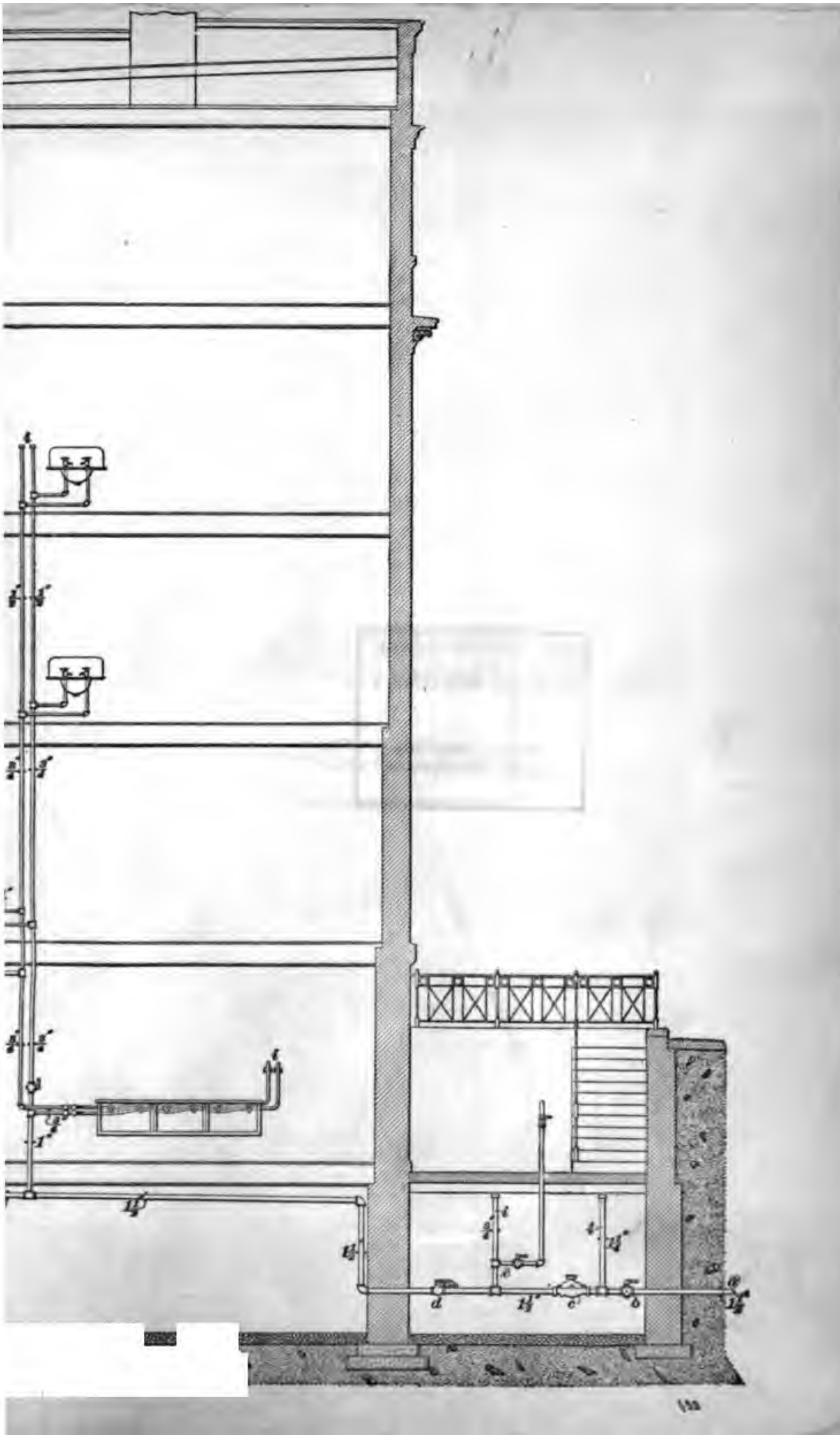
INSTALLATION

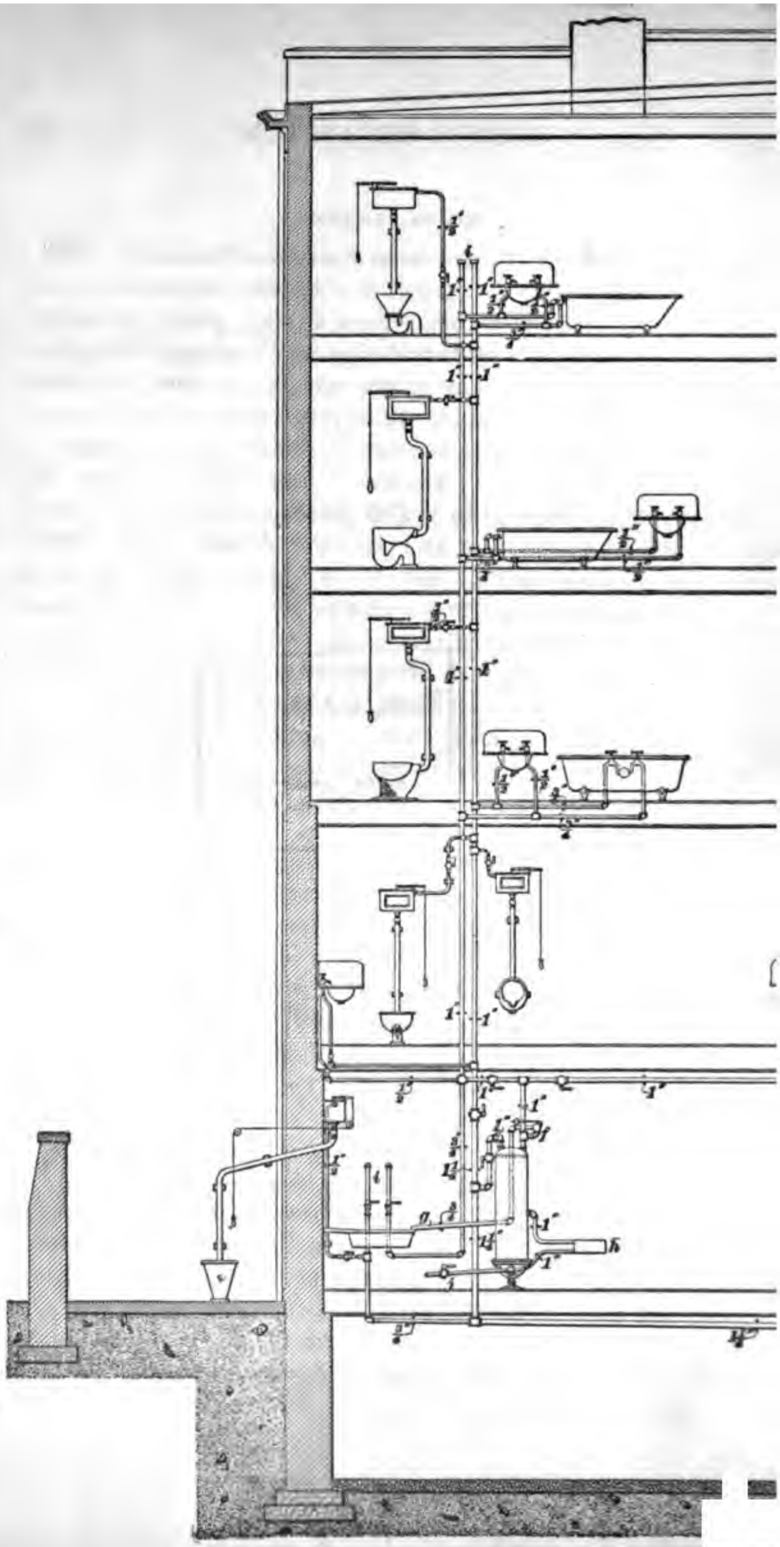
60. Street-Pressure Water-Supply System.—Fig. 29 gives a sectional view of a building, showing fixtures and a system of piping for the supply and distribution of hot and cold water, the supply being taken from the city mains. The minimum pressure in the mains must be more than that required to just raise water to the highest fixtures. With this system of piping, when the water is shut off the street mains the entire building will immediately be without water, the boiler, of course, remaining full, if unsiphoned. The street-service pipe *a*, which joins the city main to the pipes in the building, has a stop-and-waste cock *b* attached to its end just inside the cellar. A water meter *c*, fitted with an air chamber near its inlet, indicates the quantity of water used in the building. The pressure in the street mains in this particular case is supposed to be too great for safety or comfort, if applied to the plumbing in the building; consequently, a pressure-reducing valve *d* is placed on the house service pipe just beyond the pipe *e*, which supplies a hose bib in the front area with water under the full pressure of the main. The stop-and-waste cock shown on this pipe *e* shuts off and drains it during cold weather.

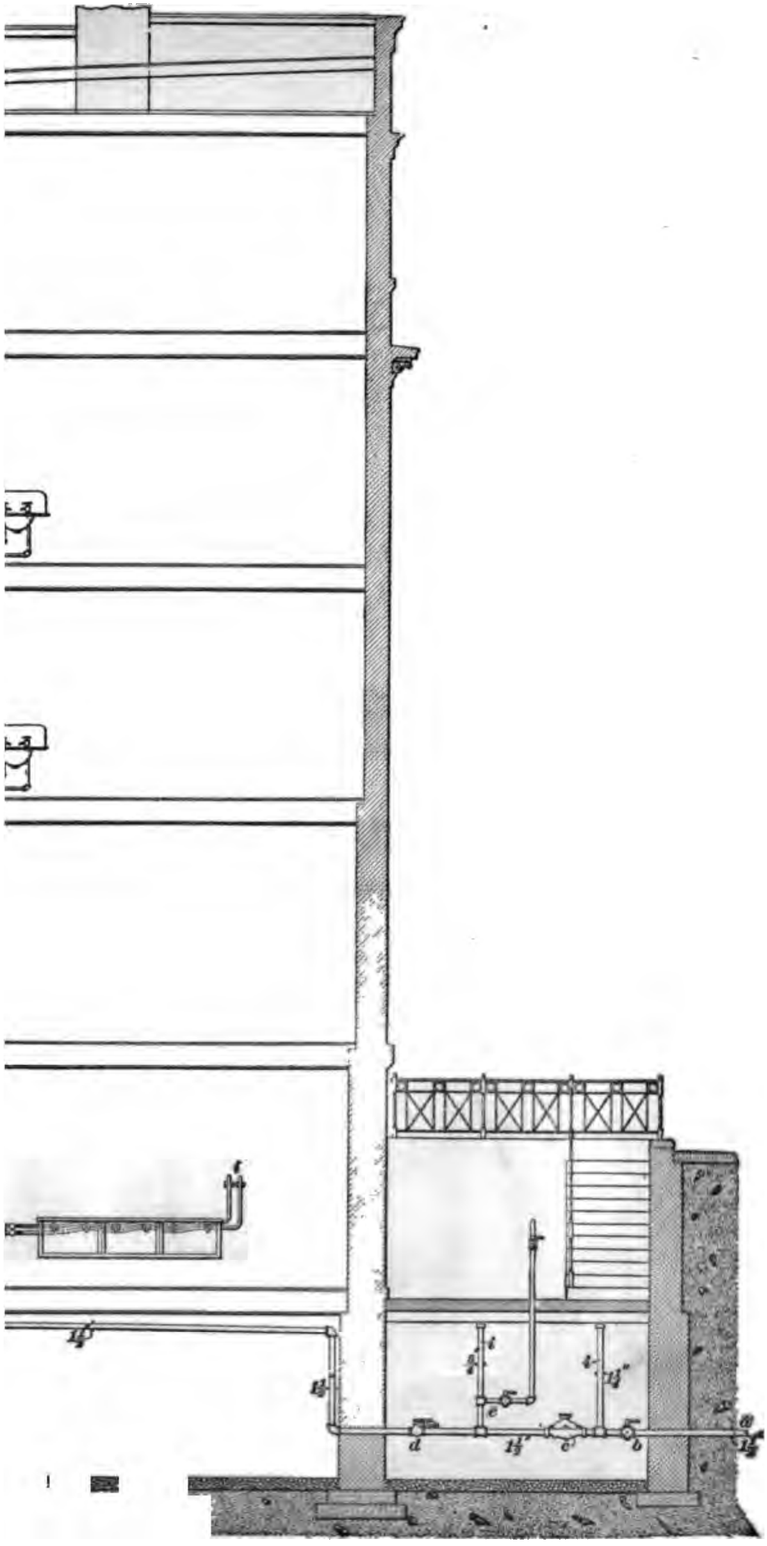
Suppose that the average main pressure is 95 pounds by the gauge, and that this pressure, by the use of *d*, is reduced to a constant pressure of 45 pounds in the cellar of the building; then the size of the pipes may be approximately as marked on the illustration. The hot and cold distributing pipes are of galvanized iron or brass, and some of the branches shown are of lead. They may, however, be all of brass or all of galvanized iron.

Since the pressure-reducing valve is similar to a check-valve, in that it prevents water to expand back into the mains, a safety valve *f* is placed on the boiler, and a pipe *g* leads any water discharged from *f* into the kitchen sink. Lever-handle stop-and-waste cocks are placed on the most important parts of the system to facilitate shutting off sections for repairs, etc., without shutting off the entire building. Each closet

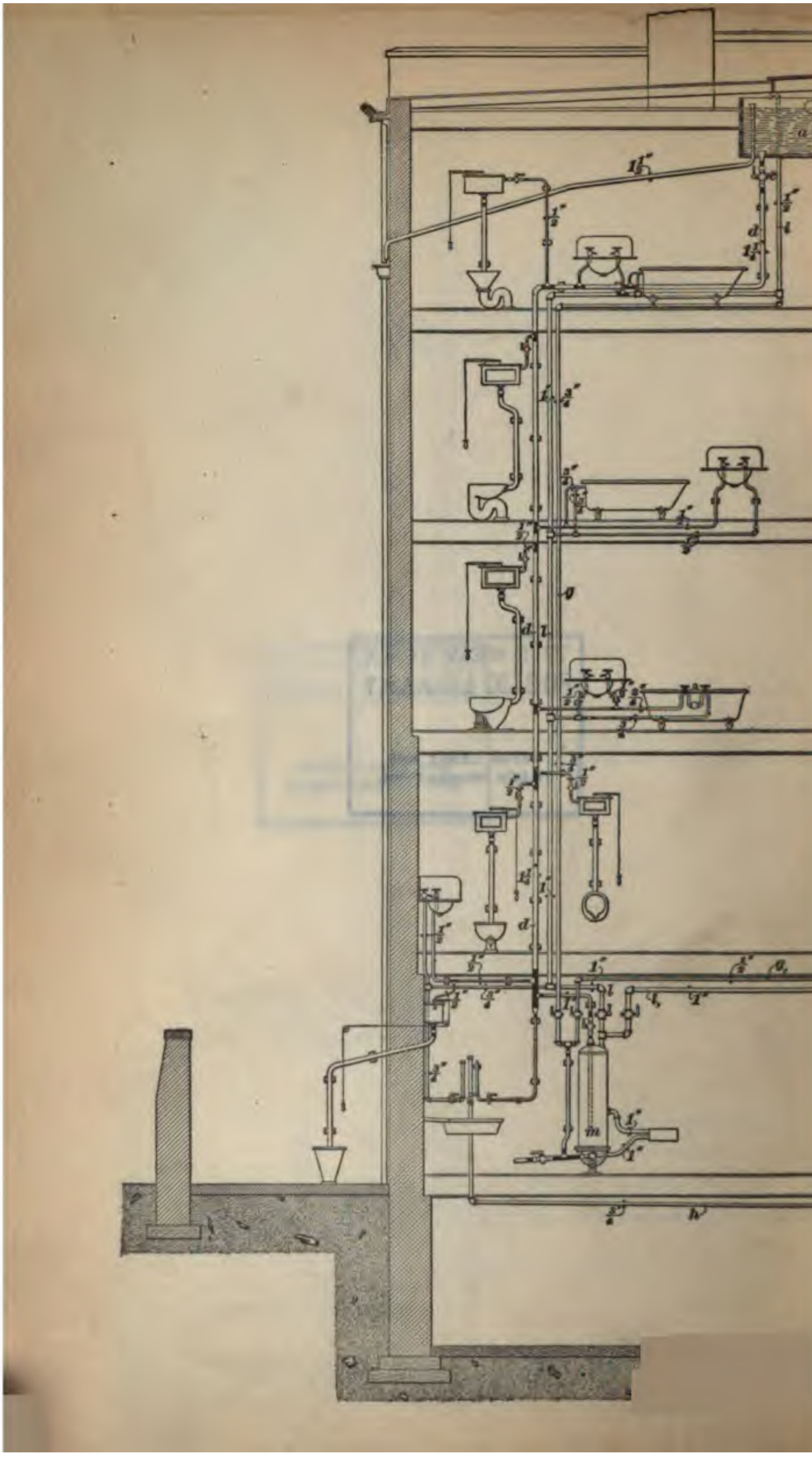


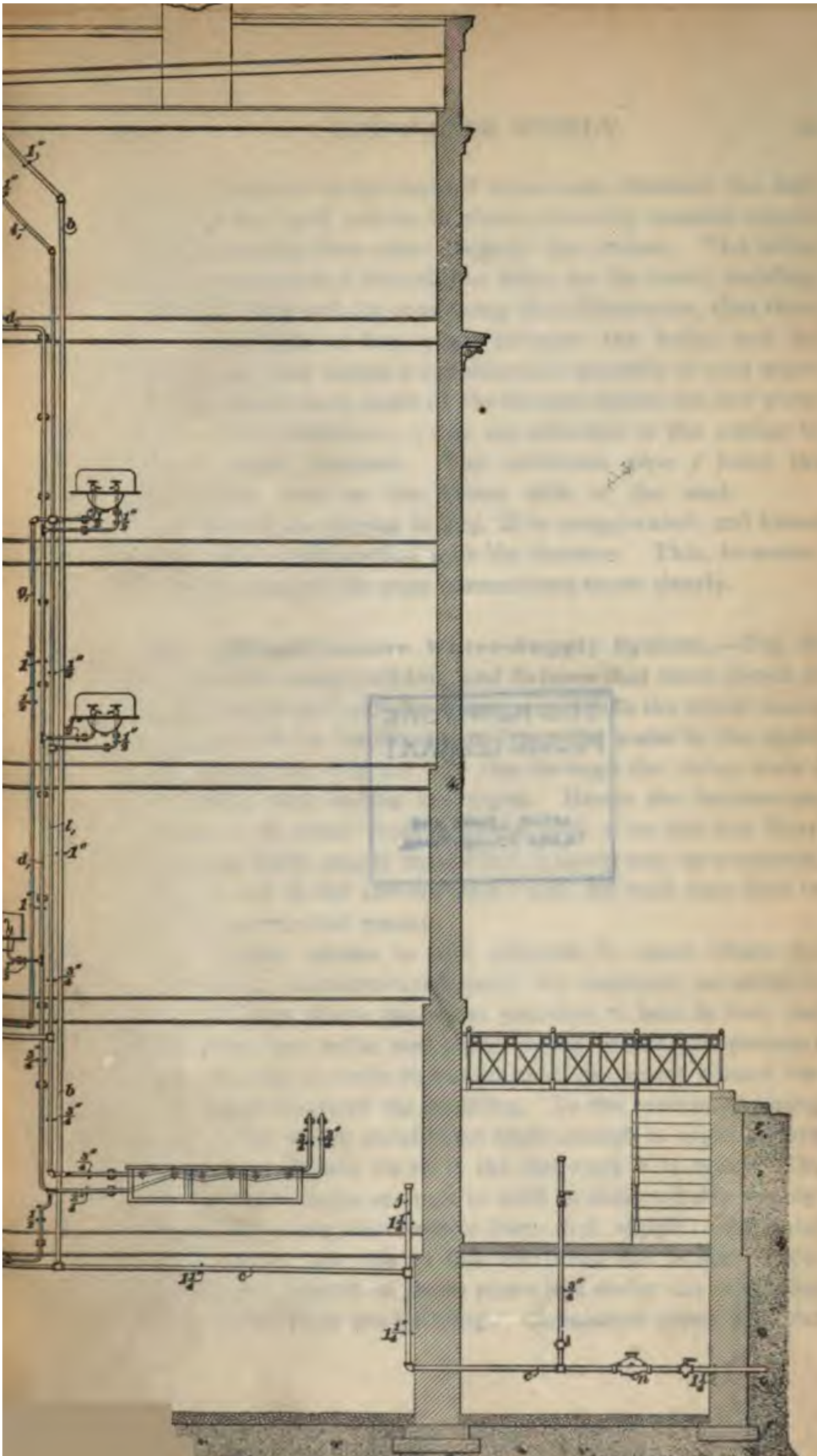






d
e
c
b





§ 52

tank is arranged to be shut off separately, because the ball-cocks or the tank valves in them generally require repairs more frequently than other parts of the system. The boiler and the waterback *h* furnish hot water for the entire building. It will be observed, by consulting this illustration, that there is no circulation of hot water between the boiler and the fixtures, and that hence a considerable quantity of cold water must be drawn from some of the fixtures before the hot water flows. Air chambers *i*, *i*, etc. are attached to the piping to prevent water hammer. The sediment pipe *j* joins the kitchen-sink trap on the house side of the seal.

The size of the piping in Fig. 29 is exaggerated, and hence appears out of proportion with the fixtures. This, however, was done to show the pipe connections more clearly.

61. Tank-Pressure Water-Supply System.—Fig. 30 illustrates the same building and fixtures that were shown in Fig. 29, but in this case the water pressure in the street mains is assumed to be insufficient to force the water to the upper floors during the day but will rise through the rising main *b* and fill the tank during the night. Hence the fixtures are supplied with water from a house tank *a* on the top floor. In case the night supply should fail, a pump may be connected either to *b* or to the service pipe *c* and the tank may thus be filled by mechanical means.

The system shown is well adapted to cases where the water supply is intermittent, such, for example, as occur in towns or cities where the water pressure at best is low, and where factories, mills, and other works lessen the pressure during the day to such an extent that the water cannot run to the upper floors of the building. In the system of piping shown, if the water should rise high enough at night to flow into the tank, it may do so if the ball-cock *k* is open. The tank should be large enough to hold at least a 2-day supply.

Two cold-water distributing lines d, d_1 supply cold water to the fixtures; the one to the left feeds the boiler. Stop-cocks *e* and *f*, placed on these pipes just under the tank, shut off the water from the building. Circulation pipes g, g_1 run from the upper ends of the hot-water distributing pipes l, l_1 to the boiler m, to insure a supply of hot water at the upper fixtures as soon as the faucets are opened.

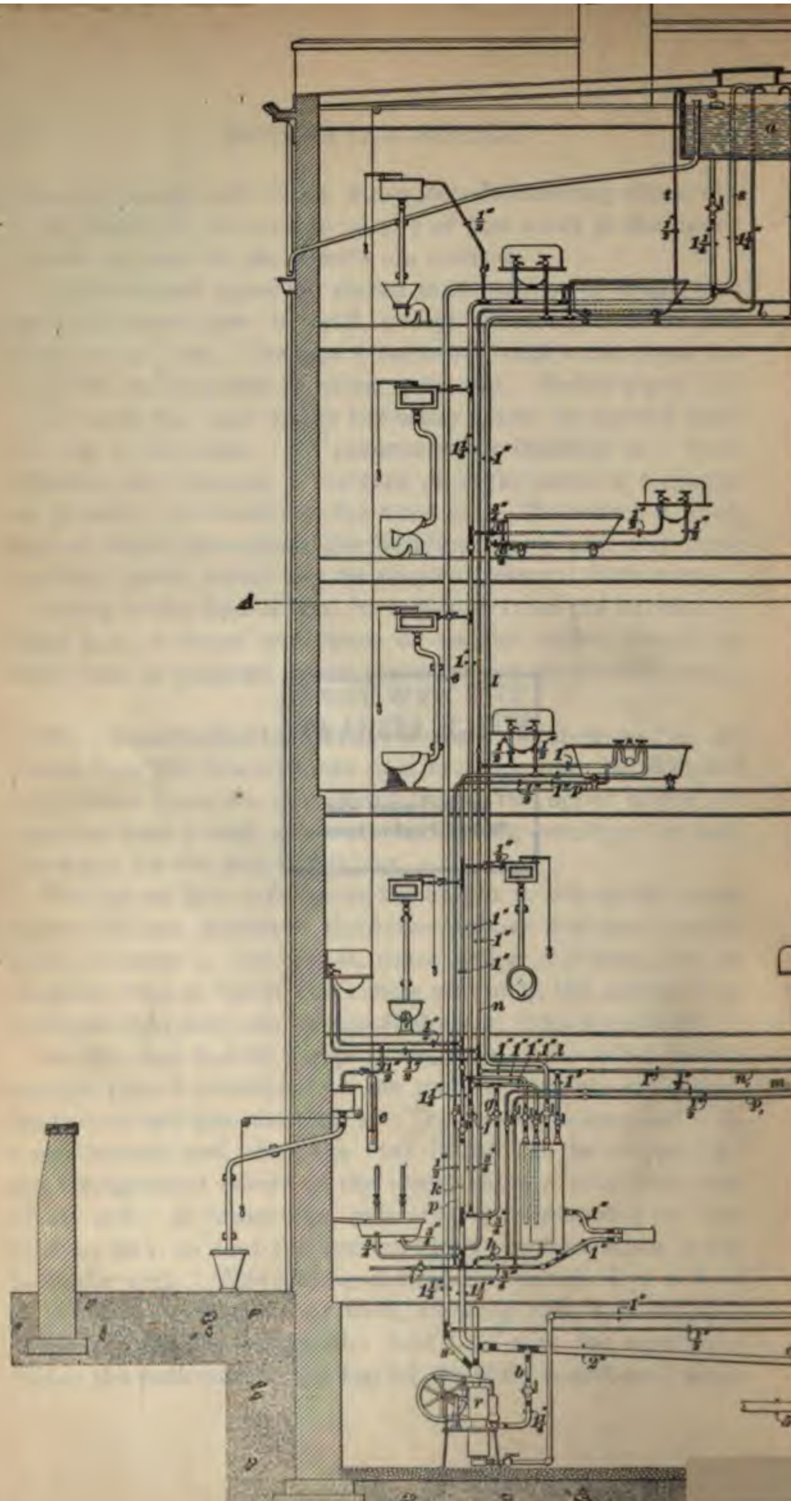
The hot-water pipes are shown made of iron or brass, and the cold-water pipes of lead, except those from the main, which are of iron. The pipe h furnishes fresh water from the main for cooking and drinking purposes. Relief pipes i, i_1 taken from the tops of the hot-water pipes are turned over the top of the tank. To prevent water hammer in c from affecting the ball-cock in the tank or in the meter n, a special air chamber is attached to the main at j. To secure a good flow of water throughout the building, the pipes may have the sizes given, which are the nominal internal diameters.

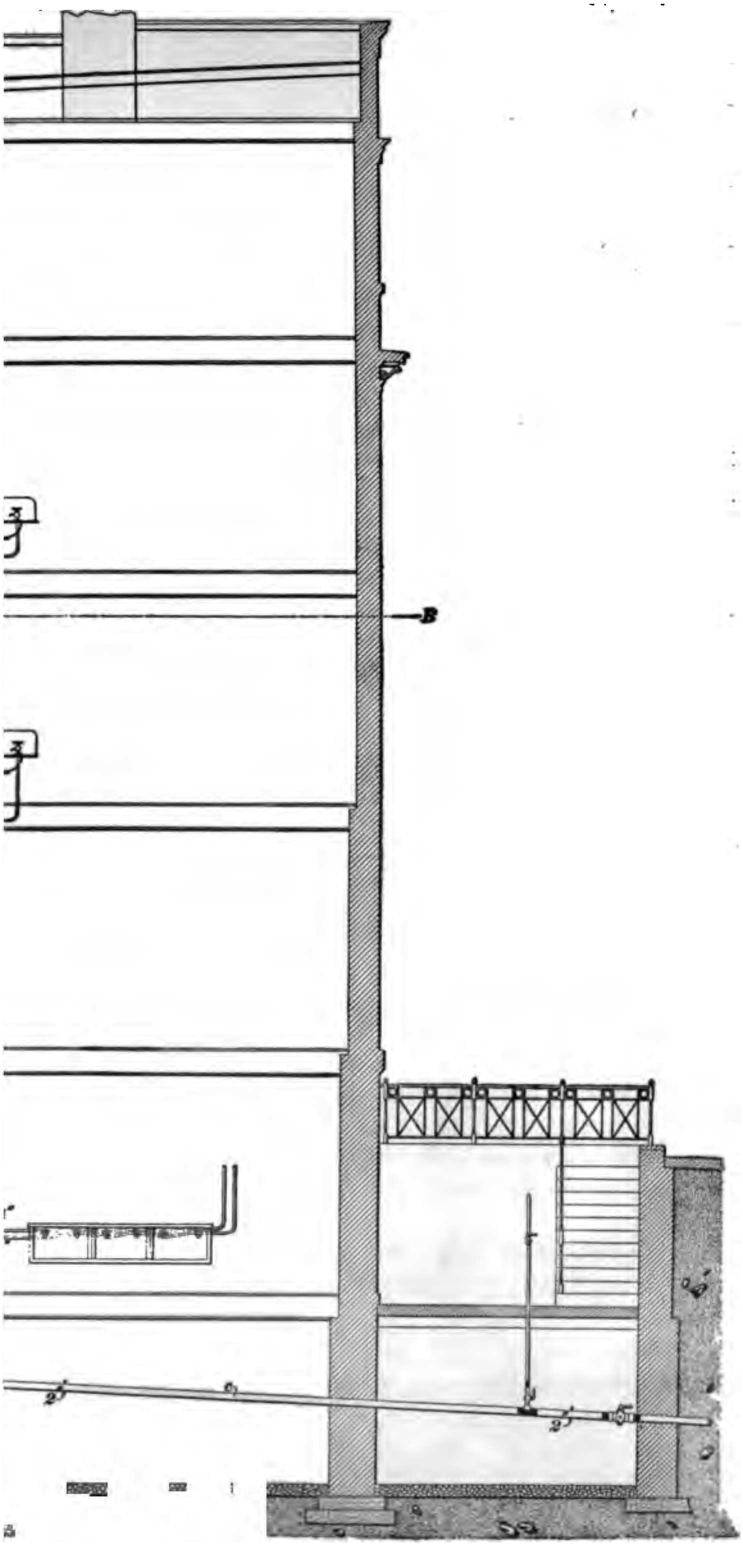
Owing to the loss of heat by radiation from the circulation pipes g, g_1, a larger waterback or smaller boiler should be used than is required when there are no circulation pipes.

62. Double-Boiler Water-Supply System.—Fig. 31 shows how the lower floors of a building may be supplied with water from the city mains, while the upper floors are supplied from a tank, one waterback being employed to heat the water for the entire building.

The dotted line $A B$ shows the height to which the street water will rise; therefore, the fixtures above that are supplied from the tank a. Of course, those below $A B$ may also be supplied from a, but to economize pumping, the piping is so arranged that they can be supplied direct from the street.

An Ericsson hot-air pumping engine r in the cellar has its suction pipe b connected to the main c; its delivery pipe s leads over and into the tank a. The engine is supplied with a gas burner, and when the tank is full can be stopped by the arrangement shown at the wheel valve d over the basement sink. A water-line indicator e is placed over the kitchen sink, so that the servants may see how much water is in the tank. This sliding indicator is attached to a float in the tank by a chain or wire, working over two pulleys. When the tank is empty, the float falls with the water and raises the indicator to the top of the slide board, and when





B

filled again the indicator falls toward the bottom. The slide board is graduated in feet and inches, and if the indicator is regulated properly it will indicate very accurately the depth of water in the tank. The illustration also shows hot-water circulation pipes to the fixtures, except to the kitchen sink and laundry tubs, the branches to which are short. Circulation to these fixtures may be obtained by dropping the return pipe below the boiler level, and connecting the branches to the returns. If such connections are made, however, there will be danger of relatively cold water being drawn from the bottom of the boiler along with hot water from the flow pipes, unless check-valves are used on the returns near the boiler. Some plumbers object to check-valves on returns, and, consequently, connect these fixtures as shown.

The check-valve *f* will permit water to flow from the outer boiler or street main to the inner boiler, when the pressure in the inner boiler is less than that in the outer one, but will prevent any water in the inner boiler from passing out again.

A lever-handle stop-cock *g*, when opened, will feed the outer boiler and all the fixtures on the lower floors with tank water. Of course, when this cock is opened, the valve on the street service pipe must be closed, since otherwise the tank water would flow back to the street mains. If the cock *g* is used much, a swinging check should be placed on the main service pipe *c*.

The sediment cock for the inner boiler is shown at *h*, and for the outer boiler at *i*.

The waterback is connected to the outer boiler in the ordinary manner, and heats water for the entire building. The telltale *j* flows into the pan of the automatic shut-off valve *d*, so that when the tank is full, the telltale will fill the pan with water, the weight of which will close the valve and stop the engine.

The rising main supplies cold water to the outer boiler, kitchen sink, and fixtures on the first and second floors above, except the water closet on the second floor, which is supplied from the tank, because it is too near *AB*. The hot-water supply to the third and fourth floors, or the

filled again the indicator falls toward the bottom. The slide board is graduated in feet and inches, and if the indicator is regulated properly it will indicate very accurately the depth of water in the tank. The illustration also shows hot-water circulation pipes to the fixtures, except to the kitchen sink and laundry tubs, the branches to which are short. Circulation to these fixtures may be obtained by dropping the return pipe below the boiler level, and connecting the branches to the returns. If such connections are made, however, there will be danger of relatively cold water being drawn from the bottom of the boiler along with hot water from the flow pipes, unless check-valves are used on the returns near the boiler. Some plumbers object to check-valves on returns, and, consequently, connect these fixtures as shown.

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tank-pressure hot water, flows through *l* to the top floor, where an expansion pipe is taken off its highest point and led over the tank. This pipe continues and drops to supply the wash basin to the right on the third floor. It is then continued back to the boiler by the return pipe *m*. The hot-water supply to the basement and first and second floors flows through *n* and n_1, the end of *n* being run up to and over the tank to serve as an expansion pipe and air vent. The pipes *p*, p_1 permit circulation of the street-pressure hot-water supply. If desired, a small pipe may be run from the hot-water supply branch *q* up to and over the top of the tank to carry off any air that may accumulate in *q* and stop circulation. The pipe *t* acts only as a relief pipe, and may or may not be used.

In this illustration it is assumed that the street water will not at any time have sufficient pressure to rise into the tank; otherwise, the expansion and relief pipes would be omitted, or carried considerably above the tank, to prevent the temporarily increased main pressure from forcing hot water into the tank.

63. Storage-Tank System.—Fig. 32 shows in front elevation and end elevation a horizontal hot-water storage tank *a* and its installation, connected up in a neat and symmetrical manner. The tank is suspended by two wrought-iron cradles *b*, *b* that are supported on iron-pipe frames put together with common stock fittings, as shown. The flanges at the base of the frame are set on the floor and the top of the rear frame is calked to the wall, as shown at *c*. Cold water can be supplied to the boiler either from the street mains through the pipe *d*, or from a house tank through the pipe *e*, according to the requirements of the building and the condition of the street pressure, a check-valve *f* being placed on the rising main *d*. The water is heated during winter by a steam coil, shown by dotted lines inside of the tank. During summer, when steam is not available in the building, the water is heated by a coal fire in the heater *g*. A distributing manifold *h* is located over the tank, the hot-water

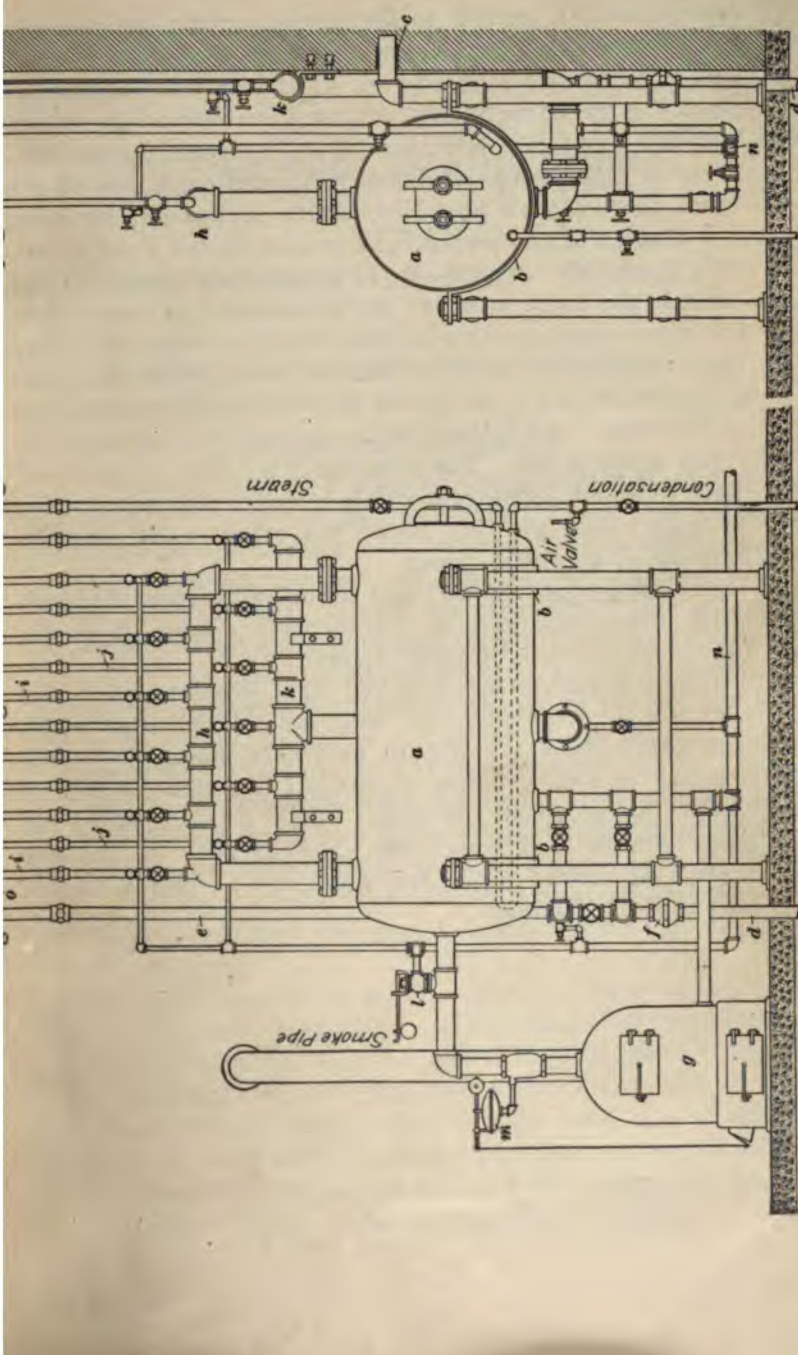


FIG. 32

flow pipes *i*, *i*, leading to the fixtures taking their supply from this manifold, each being separately valved and dripped above the manifold, as shown. The return or circulation pipes *j*, *j* are connected in the same manner to the return header *k*. A safety valve located at *l* prevents the accumulation of an excessive pressure due to the expansion of the water, there being a possibility of the pressure rising from this cause, since a check-valve *f* is used on the supply pipe. This check-valve is necessary to prevent a discharge of the water in the house tank into the street main at times when the street-main pressure is less than the pressure in the house pipes. A damper regulator *m* regulates the combustion of the fire in the heater according to the temperature of the water, and is intended to prevent the formation of steam in the heater. The drip pipe *n* is continued to a floor drain trap and discharges openly into it. This pipe carries off water from the drip cocks, the safety valve, and the blow-off, or emptying, pipes.

The rising pipes are run under the ceiling at equal distances apart, being supported by bar hangers *o* hung from the ceiling at intervals of about 8 feet.

The arrangement shown in Fig. 32 is particularly adapted for use in apartment houses, small hotels, and other buildings where steam is not used for power purposes. If the plumber, in making boiler connections like those shown, is careful to line up all the valves neatly in rows, fit up the pipes straight and equidistant, and to have no crooked threads or marred pipes, the work will be typical of the best modern practice.

PLUMBING INSPECTION

INSPECTION OF NEW WORK

DUTIES OF PLUMBING INSPECTOR

INSPECTION OF PLANS

1. The first duty of a plumbing inspector in relation to the work in any new building located within his jurisdiction is to examine carefully the plans and specifications submitted for approval to see that they conform to all the requirements of the plumbing code. Should the plans and specifications for any reason not conform to such requirements, they should immediately be disapproved and notice of such disapproval, stating the reason for such action, should be served on the owner, architect, or plumber that submitted the plans.

Under no consideration should plans and specifications be returned to the party that filed them, but corrections in the form of amendments should be added to the plans and specifications until they conform to all requirements of the code. By this method of procedure, a complete record of the entire transaction, showing the various stages of negotiations, is kept.

When defective plans or specifications have been amended, they should again be examined, and if unsatisfactory a second notice of disapproval should be sent to the party filing them. If, on the other hand, the plans and specifications both conform to all requirements of the plumbing code, they should be approved, and notice of such approval sent to the proper party. This notice of approval usually serves as a permit, and is a license to the contracting plumber to proceed with the installation according to the approved plans and specifications.

2. Pending approval of plans and specifications, the inspector may keep watch on the building where the work is to be installed to see that no work is done by the plumber without approval of the department. Should the work be installed and finished without the knowledge or approval of the department it would require a lawsuit to cause alterations to be made. The lawsuit would consist of a condemnation proceeding, which would place on the department the burden of proof to show that the work was unsanitary—sometimes a very difficult matter to prove. Should, on the other hand, a contractor be discovered installing work, the plans for which have not been approved by the proper authorities, an injunction proceeding will restrain him from finishing it until such time as all conditions have been complied with.

INSPECTION OF THE WORK

3. Periodical Examinations.—When the work of installing a plumbing system has been commenced, the inspector should make periodical examinations of the work to see that no deviation from the plans and specifications are made. Should it be necessary, at this stage of the installation, to change the layout of work to avoid some unforeseen obstacles, or should some extra fixtures be required as an afterconsideration, the inspector should see that amendments to the plans and specifications, covering the alterations, are submitted to and approved by the proper authority, before permitting that portion of the work to be installed.

4. Common Defects of New Work.—The defects of installations most frequently observed and that must be carefully looked for by the plumbing inspectors are split hubs; sand holes in pipes or fittings; light-weight cast-iron pipe and fittings; low vent connections to vent stacks; light-weight lead pipe, traps and bends; light-weight ferrules; and T-branch connections to soil or waste pipes.

Where the Durham system of piping is used, the inspector should see that the ends of all pipes, before they are screwed into fittings, are reamed to remove the burr formed by cutting the pipe; and, that fittings are flush fittings. Also, he should see that the entire drainage system is well supported to prevent settlement of the stacks, and that all offsets are made with bends of easy curves.

It should be ascertained beyond any possibility of doubt that all drain pipes have a suitable pitch toward their natural outlets, and that the sizes of the pipes actually installed coincide with the sizes of pipes marked on the approved plans. It should further be ascertained that all soil stacks and waste stacks are carried full size up to and through the roof, and that the outlets terminate well away from windows, doors, chimneys, flues, or other openings to the building. The inspector should examine the vent stacks to see if they intersect the accompanying soil stacks or waste stacks below the inlet from the lowest fixture. He should further be sure that the vent stack is again connected to the accompanying soil stack or waste stack above the highest fixture, or else extends separately through the roof.

Fixture traps should be examined to see that they are set true with respect to their water seals, and that they are properly vented by a branch pipe extending from near the crown of the trap to the main vent stack.

The fresh-air inlet should be examined to see that it is properly connected to the main house drain, and that the outlet is properly protected from obstruction and located a suitable distance from windows or doors. In fact, the entire work must be inspected to see that it is built in accordance with the plans, specifications, and the plumbing code.

5. Changes.—Should the contractor, without filing an amendment to the plans and specifications, deviate from the work as approved by the department, or should inferior materials be used in place of those specified, it becomes the duty of the plumbing inspector, on discovering such alterations or deviations, to notify the department of such violation of the code. The inspector's report on violation should state that he has examined the premises described and has found thereon a violation of section ____ of the plumbing code, and should then state in detail what omission or commission constituted the violation.

6. Violations of Plumbing Code.—A blank form of report on violations as used by the New York City Department of Buildings, and that can be modified to suit the requirements of any department, is as follows:

REPORT OF VIOLATION TO SUPERINTENDENT OF BUILDINGS

THE CITY OF NEW YORK,

BOROUGH OF MANHATTAN, ____________ 190

TO THE SUPERINTENDENT OF BUILDINGS FOR THE BOROUGH OF MANHATTAN.

SIR:—I respectfully report that I have examined the premises and building situated on the ____________ of the lot on the ____________ side of ____________, commencing about ____________ feet from the ____________ corner of ____________

and ____________

and known as No. ____________

and find existing thereon a violation of Section ____________

of the * ____________

as follows: ____________

____

____

____

____

____

____

____

____

*Insert Building Code or Tenement House Act, as the case may be.

said building being________________

building________and________stor ________in height,

________feet front,________feet rear,________

feet deep, and________feet high, and occupied or intended

to be occupied as________________

________________and located in the Borough of Manhattan,

in The City of New York________________

Owner________________

Residence________________

Place of Business ________________

Person superintending the work,________________

Address________________

Condition of work (how far progressed)________________

____

Plan No.________New Buildings of 190

Plan No.________Alterations of 190

Lessee________________

Residence________________

Place of Business________________

Agent________________

Residence________________

Place of Business________________

Architect________________

Residence________________

Place of Business________________

Builder________________

Residence________________

Place of Business________________

________________*Inspector*,

________ *District*

7. On notice from an inspector that a violation of the plumbing code exists on certain premises, the Superintendent of Buildings should cause to be served on the contracting plumber installing the work a notice that such violation exists, together with an order to remove the cause of violation forthwith, under penalty of incurring the punishment prescribed by the code. Such notice to remove a violation should be served by an official or employe of the department, and may be served personally on the contracting plumber, or by leaving a copy at his place of business. A blank form of notice, suitable for this purpose, follows:

NOTICE TO REMOVE VIOLATION

THE CITY OF NEW YORK,

BOROUGH OF MANHATTAN, ______________ 190

To ____

____

____

You will please take notice that there exists a violation of the Building Code at the premises hereinafter described, in that

____

____

____

____

____

____

____

____

The building and premises to which this notice refers are situated on the ________________ of the lot on the ________________ side of ________________ commencing about __________ feet from the ____________ corner of ____________________ and ____________________________, and known as Number ____________________ said building being ____________ story ________________ building, about __________ feet front, __________ feet rear, __________ feet deep, and __________ feet high, and occupied or intended to be occupied as a ________________ and located in the Borough of Manhattan, in The City of New York.

By the commission of the said violation you have incurred a penalty of Fifty Dollars.

Should you fail to comply with this notice within ten days after the service thereof, you will incur a further penalty of Two Hundred and Fifty Dollars.

You are hereby required to remove said violation forthwith, or legal proceedings will be commenced against you.

____

Superintendent of Buildings for the Borough of Manhattan

8. Having served the notice to remove a cause of violation, the process server should then certify on the back of the *original* notice that he has served a copy of same and state whether the service was a personal one or had been made by leaving a copy at the contractor's place of business. Such an indorsement should be attested by a duly authorized notary public.

A copy of a notice of service follows:

NOTICE OF SERVICE

STATE AND CITY OF NEW YORK, } *ss.:*
COUNTY OF __________ }

____

of said City and County, being duly sworn, says that he is an officer and employe in the Bureau of Buildings of The City of New York,

Borough of Manhattan; that he is over twenty-one years of age; that on the ________ day of ______________ 190 ,

at ____________________

in the Borough of ____________________

in said City, he served the within notice upon ____________________

therein named, by delivering to and leaving with ____________________

personally, a true and correct copy thereof, and that he knows the person so served as aforesaid to be the same person mentioned and described in the said notice.

Deponent further says that the said ____________________

then and there stated to deponent that he was the ____________________

of the building described in the said notice.

Sworn to before me, this ________
day of ____________ 190 ,

Notary Public, ____________ *County*.

Viol. No. ______
(ORIGINAL)

9. When a notice to remove a cause of violation is served on a contractor, and he refuses or neglects to obey its mandate, the case leaves the jurisdiction of the Building Department and becomes a matter for the courts to settle. If, on the contrary, the plumber removes the cause of violation, then, on notice to the Building Department, an inspector will make another examination of the condemned portion of work, and if found satisfactory will make a final report to the superintendent of the condition of the work, together with a recommendation to dismiss the violation.

The final report may be made on a blank similar to the following:

FINAL REPORT ON VIOLATION

THE CITY OF NEW YORK,

BOROUGH OF MANHATTAN, ______________ 190

In the matter of the violation of law on building ______________
____
______________ } Final Report.

TO THE SUPERINTENDENT OF BUILDINGS FOR THE BOROUGH OF MANHATTAN.

Sir:—I respectfully report that I have examined the building herein described and find that the violation thereon has been removed as follows: ______________

____
Inspector

On the outside of such report the following record and recommendation should be indorsed:

THE BUREAU OF BUILDINGS

OF THE CITY OF NEW YORK

BOROUGH OF MANHATTAN

Nature ____________________________

____

____

No. ____________

Report of Examinations, Etc.—General Violations

Premises ____________________________

____

____________________________ *Owner*

	190	
		Report of Inspector__________
		Notice served by__________
		Notice posted by__________
		Sent to Corporation Counsel
		Violation removed
		Final Report of Inspector
		________________

THE CITY OF NEW YORK, ______________ 90__

TO THE SUPERINTENDENT OF BUILDINGS FOR THE
BOROUGH OF MANHATTAN.

Sir:—The requirements of the law ______________

having been complied with, I recommend that this

case be ______________________________

____

____

____
Inspector

Approved ______________________ 190__

____
Superintendent of Buildings
for the Borough of Manhattan

Case dismissed ______________________ 190__

See Report on last page.

____
Superintendent of Buildings
for the Borough of Manhattan

10. Witnessing Tests.—When the Building Department receives notice that a drainage system is filled with water and ready for the inspector to examine, it is its duty to have an inspector examine and pass upon the work within 48 hours from receipt of such notice. Should the inspector refuse or neglect to make an examination within the prescribed time, the plumber may have the work examined by some other competent person, and then withdraw the water from the lines and proceed with his work.

11. When about to witness a roughing test, the inspector should first ascertain whether it will be a water test or a compressed-air test. If it is a water test, he should have the entire drainage system filled until water overflows the stacks above the roof; then, beginning at the top, he should work downwards, examining carefully every line of pipe, keeping a sharp lookout for rust, tallow patches, and tar patches, that might conceal split hubs, sand holes, or other defects in the pipe or fittings. When the system is perfectly tight, he should have the water drawn from the system in his presence and can then judge from the volume of water whether the system was completely filled.

12. When witnessing an air test, the inspector should first examine and test the pressure gauge to prove its accuracy, and see that it has not been calibrated to register a greater pressure than is actually on the system. Where doubt exists as to the accuracy of a pressure gauge and no means are available for testing its accuracy, the inspector should require a mercury gauge to be substituted for the spring gauge. The air in the system should then be compressed in the presence of the inspector, who can judge from the length of time required to pump up the pressure whether the entire system is being filled. When a pressure of 10 pounds is indicated by the gauge, the pressure is sufficient for the purpose of a test, and if the indicating hand of the gauge remains stationary for 20 minutes the system can be considered tight. The test, however, does not end there. The inspector should now carefully examine the system to see that leaks have not been made tight with pitch, tar, rust preparations, or other temporary makeshifts that might soon give way and permit the system to leak. He should further satisfy himself by loosening testing plugs in various parts of the system that pressure is on all the stacks and branches.

13. Where the plumbing code requires that "after the completion of work, when water has been turned on, the system shall again be tested with a peppermint test or a smoke test," the inspector should insist on the smoke test being applied. Peppermint tests, in a strict sense, cannot be considered tests, inasmuch as they disclose only large leaks in a system. They do not create an internal pressure, and when they disclose the presence of a leak it is only by indicating to the sense of smell that there is a defect somewhere in the system—the precise spot is not disclosed. Smoke machines, on the contrary, maintain a pressure within the system that discloses the most minute leak, and smoke issuing from the defects indicates the exact location.

When a smoke test is applied, the inspector should see that all traps are sealed with water and that all outlets above the roof are left open until smoke issues from them. The outlets should then be tightly plugged to prevent further loss of smoke or escape of pressure, and the system pumped full of smoke until it sustains a pressure equal to at least a 1-inch column of water. If this pressure remains unchanged for 5 minutes the system may be considered tight.

14. Reports of Inspection to Department.—Besides the reports on violations, a plumbing inspector should, as the work progresses, make several other reports to the Building Department. Each report should be based on a personal examination of the premises and should state the amount of work that had been installed since the last inspection of the premises and whether the work conformed to the specifications. His first report should be made as soon as work is commenced on the plumbing contract; it should be indorsed on the application for permit and may be similar to the following.

REPORT OF INSPECTOR AS TO COMMENCEMENT OF WORK

THE CITY OF NEW YORK,

BOROUGH OF MANHATTAN, ____________ 190

TO THE SUPERINTENDENT OF BUILDINGS FOR THE BOROUGH OF MANHATTAN.

Sir:—I beg to report that the work of plumbing and drainage herein described was begun on the ______ day of ______ 190

Respectfully submitted,

____________ *Inspector,*

________ *District*

Following the report as to commencement of work, the inspector should supplement it with a detailed description of the number and kinds of fixtures to be installed, size and number of house drains, material and manner of trapping drains, number of soil waste and vent stacks, in short, everything appertaining to the plumbing work. This report must in all respects tally with the original specifications in the description of materials, sizes of pipes, location and direction of stacks and branches, number and location of fixtures, number of buildings and purposes for which they are to be used, together with all other information that has a bearing on the sanitary aspect of the plumbing work. Should there be any discrepancy between the two reports, it then becomes the inspector's duty to examine carefully the premises to ascertain wherein the difference lies, and if any deviation in the installation has been made from the specifications as originally filed, a notice of violation should be served on the contractor to prevent him proceeding further with the work without complying with the original plans and specifications, as follows:

Plan No.________ {New Buildings / Alterations} 190__

Location________________________

In all cases Inspectors will furnish the following information without regard to the information given in the application and plans on file in the Bureau:

1. Number of Buildings ____________________

2. How occupied at present ____________

3. Fixtures—what kind and where located:

	Water Closets (How many)	Urinals (How many)	Wash Basins (How many)	Bathtubs (How many)	Wash Tubs (How many)	Sinks (How many)
Yard						
Cellar						
Basement						
First Story						
Second Story						
Third Story						
Fourth Story						
Fifth Story						
Sixth Story						
Seventh Story						
Eighth Story						
Ninth Story						
Tenth Story						
Eleventh Story						
Twelfth Story						
Thirteenth Story						
Fourteenth Story						
Fifteenth Story						
Sixteenth Story						
Seventeenth Story						
Eighteenth Story						
Nineteenth Story						
Twentieth Story						

4. School sinks (how many)

5. Describe water closets

6. Describe urinals ____

7. Describe wash basins

8. Describe bathtubs (state brand of same)

9. Describe wash tubs (state brand of same)

10. Condition of school sinks and where do they waste?

11. **House drains—State number for each building ________________**

Diameter________inches. Material ________________________

12. **Area shaft, court, and yard drains—Material ________________**

Diameter________inches. How trapped? ________________________

13. **Cellar drain—Material ____**

Diameter________inches. How trapped?________________________

14. **How are the sewage and drainage of the buildings disposed of?**

Public or private sewer?____

15. **House sewers—State number for each building________________**

Diameter________inches. Material ________________________

Where connected?____

16. **House traps—Material ______________________________________**

Diameter________inches.

17. **Fresh-air inlets—State number for each building ______________**

Diameter________inches. Material ________________________

Location of inlet____

How are they protected against obstructions?________________

____

18. Soil pipes—Number in each building ____________________________

Diameter________inches.

Number extending above roof in each building____________________

Diameter and material of outlets and branches up to traps________

____

19. Waste pipes—Number in each building __________________________

Diameter________inches.

Number extending above roof in each building____________________

Diameter and material of outlets and branches up to traps________

____

20. Vent pipes—Number in each building __________________________

Diameter ________inches.

Number extending above roof in each building____________________

Diameter and material of outlets and branches up to traps________

____

21. **Material of soil, waste, and vent pipes** ______________________

22. **How are all the above soil, waste, vent, and other pipes supported?** ______________________

____

23. **How are the floors of water-closet apartments made waterproof?**
______________________ **base** ______ **inches high.**
Material ______________________

24. **How are present water-closet apartments ventilated to the external air?** ______________________

____

25. **Is the building supplied with water?** ______________________

26. **Is a pump necessary?** ______________________

Special Fixtures

27. **Describe any special fixtures or work** ______________________

____

____

____

Remarks

28. **Give a general description of plumbing work as same exists at present** ______________________

____

____

____

____
Inspector

Dated ______________________ **190** ___

15. When the work of installing plumbing in a building is completed and the final test has been made, these facts should be certified to the Department of Buildings in the form of a final report. Such report should be indorsed on the original detailed specifications, and may be as follows.

FINAL REPORT

THE CITY OF NEW YORK,

BOROUGH OF MANHATTAN, __________________190

TO THE SUPERINTENDENT OF BUILDINGS FOR THE BOROUGH OF MANHATTAN.

Sir:—I beg to report that the work of plumbing and drainage herein described was completed on the _______ day of ______________ 190 , and that said work was carefully examined by me and found to conform in all respects to the approved plans and specifications and the rules and regulations of the Bureau of Buildings for the Borough of Manhattan.

Respectfully submitted,

____________________________________ *Inspector,*

__ *District*

16. An inspector should file a weekly report stating what work he has done during the week. The chief object of this report is to gather data for statistics showing the number of inspections that are made weekly, monthly, and annually, in each inspection district. Incidentally it is a check on the inspector, as his reports should show a certain average for each week of the year. This average, however, cannot be wholly depended on, as during various months the amount of work in any inspection district might vary considerably, and when the demands for inspection are numerous it is reasonable to suppose that more inspections will be made than in periods when work is scarce. On the other hand, when an inspector has ample time to perform his duties, it must be expected that a more thorough examination will be made of all work he inspects.

Weekly reports are not supposed to state in detail the condition of work in premises inspected, but should state the number of violations placed on work and briefly state the reasons for such action; also, it should state the number of inspections made, the dates of such examinations, the number of plans examined, final examination made, and anything of an unusual nature that falls under the inspector's observation while engaged in the discharge of his duties. A form for such a report follows.

WEEKLY REPORT

The Bureau of Buildings of The City of New York

FOR THE BOROUGH OF MANHATTAN

THE CITY OF NEW YORK,
BOROUGH OF MANHATTAN, ______ ____________190

TO THE SUPERINTENDENT OF BUILDINGS FOR THE BOROUGH OF MANHATTAN.

Sir:—I have the honor to report for the week ending__________190 as follows: In respect to plumbing and drainage of buildings for the ______________inspection district.

	Tenements	Misc.	Total
New buildings begun			
New buildings finished and final reports filed			
New buildings in course of construction at date			
New buildings containing plumbing at date			
Alterations begun			
Alterations finished and final reports filed .			
Alterations in course of construction at date			
Alterations containing plumbing at date . .			
Slip alterations begun			
Slip alterations finished and slip turned in .			
Slip alterations in course of construction at date			
Slip alterations containing plumbing at date			
Buildings reported in violation of plumbing law			
Buildings reported in violation of tenement-house law			
Buildings in which violations of plumbing law were removed			
Buildings in which violations of tenement-house law were removed			
Buildings on which violations of plumbing law are outstanding			
Buildings on which violations of tenement-house law are outstanding			
Number of inspections under plumbing law			
Number of inspections under tenement-house law			
Number of other inspections			
Total			
Total of all inspections			

REMARKS

Respectfully submitted,

____
Inspector

17. The final report of a building inspector, while certifying to the department that the work has been completed according to the requirements of the building code, cannot be construed as a final acceptance of the work by an owner or as a certificate of acceptance from any architect. The plumbing inspector certifies only that the sanitary portion of the work is in accordance with the code, and not that workmanship and materials are all that the plumber's contract require him to furnish.

When work under a contract is completed, the contracting plumber should so notify the architect in writing and request an examination of the work and a certificate of acceptance.

DUTIES OF PLUMBER

REGISTRATION AND LICENSE

18. Where the laws of a city or state require it, a contracting plumber should pass an examination, secure a license, and register with the Department of Buildings his name, home address, and place of business. On registering his name and address, the department will issue to him a certificate of registration similar to the following:

Office of the Borough President of the Borough of Manhattan
IN THE CITY OF NEW YORK

The Bureau of Buildings for the Borough of Manhattan
Office, No. 220 Fourth Avenue
S. W. Cor. 18th Street

Certificate of Registration of Master Plumber

Certificate No.______

When issued ______

Name ______

Residence ______

Shop ______

______
Superintendent of Buildings for the Borough of Manhattan

19. Contracting plumbers are usually not permitted to open streets, make connections to street sewers, or tap water mains until they have secured from the proper authority, generally the Department of Highways, a yearly license to perform such services. As a condition precedent to issuing a license, the department in authority, in some cities, requires that the applicant furnish a suitable bond to indemnify them for any judgments rendered against the city for damages or injuries sustained due to opening or obstructing the street by the licensee. A bond for this purpose may be furnished either by friends of the plumber, or, as is more generally the case, by a surety company authorized to act in that capacity within the state. To act as bondsmen, individuals must be owners of real estate, the value of which is equal to at least twice the face value of the bond.

To secure a bond from a surety company, the plumber files with the company an application for a bond, stating the name of applicant, residence, place of business, amount of bond required, purpose of the bond, and giving the names and addresses of several references who can certify as to the responsibility of the applicant. If the references given prove satisfactory, on payment of a fee of about $10 per thousand, the bond will be executed.

COMPLIANCE WITH RULES

20. The bond required of a licensed plumber is generally a guarantee that he will comply with all rules and laws of the Building Department and Board of Health. Should he not do so proceedings may be instituted against him to have his license revoked.

Before proceeding with the installation of new work or with alterations of old work, the contracting plumber should file, or cause to be filed with the Department of Buildings, plans and a detailed description, or specifications of the work to be installed, and should wait for the approval of the department before commencing operations. A blank form of specifications follows.

SPECIFICATIONS OF WORK

OFFICE OF THE

Borough President of the Borough of Manhattan

In The City of New York

The Bureau of Buildings for the Borough of Manhattan

Office, No. 220 FOURTH AVENUE

S. W. Corner 18th Street

Plan No.______________ N. B. / Alt. 190 Filed______________________ 190

NOTICE.—The approval of this application is in accordance with section 4 of the Building Code, to wit: "Any approval which has been issued by the Superintendent of Buildings pursuant to the provisions of law, but under which no work has been commenced within one year from the time of issuance, shall expire by limitation."

Application is hereby made to the Superintendent of Buildings for the Borough of Manhattan, of the City of New York, for the approval of the plans and specifications herewith submitted for the Plumbing and Drainage of the building herein described. The applicant agrees to be governed by the rules and regulations of the Bureau of Buildings for the Borough of Manhattan, and to comply therewith and with every provision of law, whether herein specified or not.

Date______________________________ 190

____

(*Sign here.*)

Location ______________________________

Number of buildings ________ Description of buildings ______________

______________________________ Front or rear of lot ____________

How occupied ____________ Dimensions of each building ____________

Dimensions of each lot ____________ Feet front ________ Feet deep ______

Owner ______________________ Address ______________________

Architect ______________________ Address ______________________

Plumber ______________________ Address ______________________

	Cellar	Basement	First Story	Second Story	Third Story	Fourth Story	Fifth Story	Sixth Story	Seventh Story
Number of families on each floor									

How will the sewage and drainage of the buildings be disposed of?

____

If other than a public sewer, describe same ______________________

____

____

House sewers—State number for each building ______________

Diameter ____ inches.

Material ______________________ Fall per foot ____ inch.

Where connected? ______________________

House traps—Material ______________ Diameter ____ inches.

Fresh-air inlets—State number for each building ____________

Diameter ____ inches.

Material ______________ Location of inlet __________

How will they be protected against obstructions? __________

____

House drains—State number for each building ____________

Diameter ____ inches.

Material ______________________ Fall per foot ____ inches.

Area, shaft, court, and yard drains—Material ______________

Diameter ____ inches.

How trapped? ______________________

Cellar drain—Material ______________ Diameter inches.

How trapped? ______________

How will the yard, area, shaft, court, and cellar drains be protected against obstructions?

Catch basins—Where located? Material

How will they be made water-tight?

Dimensions, ______ × ×

Subsoil drains—Material Where connected?

Floor, stable, and stall drains—Material Diameter inches.

How trapped?

How arranged to maintain a permanent water seal in subsoil, floor, stable, and stall drain traps?

Material of soil, waste, and vent pipes________________

Soil pipes—Number in each building________ Diameter______inches.

Number extending above roof in each building____________

Diameter and material of outlets and branches up to traps________

Waste pipes—Number in each building______ Diameter______inches.

Number extending above roof in each building____________

Diameter and material of outlets and branches up to traps________

Vent pipes—Number in each building________ Diameter______inches.

Number extending above roof in each building____________

Diameter and material of outlets and branches up to traps________

Refrigerator waste pipes—State number in each building________

Diameter______inches.

Material______________ Will they extend through roof?______

Roof drainage—State number of outside leaders______ Material______

Diameter______inches Diameter of traps______inches.

State number of inside leaders______ Material____________

Diameters__________ Diameter of traps______inches.

How will all the above soil, waste, vent, and other pipes be supported?

____

How will the floor of water-closet apartment be made waterproof?

______________base______________inches high.

Material________________________

Safes—Material____________ Where located?____________

Diameter and material of safe waste pipe______________

Drip trays—Material____________ Where located?__________

Water-closet cisterns—Material________ Dimensions,___×___×___

Diameter and material of supply pipe____________inch______

Diameter and material of flush pipe____________inch______

House tank—Material____________ Dimensions,___×___×___

Where located?________________________

Overflow pipe, where discharged?__________________

Emptying pipe, where discharged?__________________

Telltale pipe, where discharged?__________________

Pump—Is a pump necessary?____________________

Where will it be located?____________________

State character of same?____________________

Other fixtures—what kind and where located:

	Water Closets (How many)	Urinals (How many)	Wash Basins (How many)	Bathtubs (How many)	Wash Tubs (How many)	Sinks (How many)
Yard						
Cellar						
Basement						
First Story						
Second Story						
Third Story						
Fourth Story						
Fifth Story						
Sixth Story						
Seventh Story						
Eighth Story						
Ninth Story						
Tenth Story						
Eleventh Story						
Twelfth Story						
Thirteenth Story						
Fourteenth Story						
Fifteenth Story						
Sixteenth Story						
Seventeenth Story						
Eighteenth Story						
Nineteenth Story						
Twentieth Story						

Describe water closets____________________

____

Describe urinals____________________

____

Describe wash basins______________________________________

____

Describe bathtubs (state brand of same) ________________________

____

Describe wash tubs (state brand of same) _______________________

____

Describe sinks____

____

Water supply—will all fixtures be water supplied?________________

Give general description and character of same________________

21. The following attested statement should accompany the detailed specifications and may form part of them:

*Plan No.*____________*190*__ *Filed*____________*190*__

To the Superintendent of Buildings for the Borough of Manhattan, of the City of New York.

As required by law, the accompanying plans and detailed statement of specifications of the plumbing and drainage proposed to be put in the building described below is hereby submitted for your approval:

Location of Buildings

__________side of ____________________________________

__________feet____________of ___________________________

Street or avenue number__________________________________

Number of buildings?__________New or old buildings__________

Front or rear of lot? ________ Any other building on lot________

How to be occupied?_____ If old, how was building occupied_____

Size of lot_______ feet front________feet rear________feet deep

Owner ____

Address of Owner_______________________________________

Architect____

Address of Architect ___________________________________

STATE AND CITY OF NEW YORK, } ss.:
COUNTY OF NEW YORK

____

being duly sworn, deposes and says, that he is a duly registered plumber in the Borough of Manhattan, City of New York, residing at

______________________________ Borough of _______________

and with shop at ____________________ Borough of _______________
that he is duly authorized by the owner as given above to do the plumbing work as set forth in this detailed statement of specifications, and shown on accompanying plans, and hereby stipulates that all laws, ordinances, rules and regulations governing plumbing and drainage shall be complied with, whether specified herein or not.

Sworn to before me this __________ }
day of ________________ 190__ } __________________________

____
Commissioner of Deeds, City of New York

22. When a contracting plumber wishes an inspection made of any work that he has installed, he should so notify the department and state the location of the buildings. A blank form of request furnished by the department for this purpose follows:

APPLICATION FOR INSPECTION

THE CITY OF NEW YORK,

BOROUGH OF MANHATTAN, ________________ 190

TO THE SUPERINTENDENT OF BUILDINGS FOR THE BOROUGH OF MANHATTAN.

No. 220 4th Avenue

Sir:—An inspection of the plumbing and drainage _______________

____

____

_______________ _______

of the buildings situated at__________________________

____

____

in the Borough of Manhattan is requested.

Plumber________________________

Address________________________

Borough of____________________

Plan No.__________B, 190__

☞Notice for inspection to be made on this blank.

INSPECTION OF OLD WORK

INTRODUCTION

COMPLAINTS AND REPORTS

23. When a building is unsanitary, and the owner will not place it in a sanitary condition, the tenant may enter a complaint with the Board of Health, whose duty it then becomes to inspect the premises. The inspection of plumbing work in old buildings is beyond the authority of plumbing inspectors, unless alterations or repairs are being made to the drainage system; hence, when the plumbing work in an old building is believed to be in an unsanitary condition, complaints must be made to the Department of Health, which has full jurisdiction in the matter. On receiving from a citizen a complaint, stating the cause for apprehension and the location of the premises complained of, the Department of Health will cause a sanitary survey of the premises to be made, and if the premises or plumbing system is found to be in an unsanitary condition, will require them to be put in order.

24. It is of the utmost importance to the owner of a building that he have his plumbing work examined by one who is neither prompted by fear nor actuated by the hope of gain in formulating his report. Unfortunately, some contractors when called on to test their own work will conceal defects, if any exist, for fear that admitting their existence would cause them to lose future work of the owners. A sanitary engineer, not being influenced by such motives, is free to ascertain the true state of affairs, and can report conditions just as he finds them, together with an unbiased recommendation of what should be done to put the premises in a sanitary condition.

25. Plumbing work in buildings should be annually tested and inspected by sanitary engineers or reputable plumbing contractors, and whatever defects are found in the plumbing systems should be repaired without delay. By thus annually examining and repairing a plumbing system it will be kept in good condition, and hence will never be a menace to the health of the inmates of the building. Furthermore, the cost for maintenance of plumbing work will not be so great when it is annually inspected as when no work is done toward discovering and repairing leaks until the entire system is out of repair. An examination of a plumbing system by a sanitary engineer should not be confined to the plumbing within a building, but should include a careful sanitary survey of the entire premises, with a view to ascertain: The source of water supply, and its proximity to cesspools, privies, or other possible sources of contamination; the method of sewage disposal and disposal of rain and surface waters; the drainage of stables and of the subsoil; the conditions of the cellar; the quantity of the water supply; damp, unventilated cellars; and everything else that might exert a salutary influence on the health of the inmates.

COMMON DEFECTS OF OLD WORK

26. Among the defects most commonly discovered in old plumbing systems may be mentioned: By-passes around fixture traps; fixtures that are double-trapped; vent pipes improperly connected to fixture traps; vent stacks connected to chimney flues or to ventilating shafts; safe or refrigerator waste pipes connected to the drainage system; traps placed at the foot of soil or waste stacks; fixtures that are not trapped; traps that are not vented; tile house drains with leaky joints; unventilated soil stacks and waste stacks; insufficiently supported house drains, stacks, and branches; no fresh-air inlet; no main drain trap; saddle hub connections to soil and waste pipes; leaky joints in soil pipes, and waste and vent pipes; inaccessible drain traps; T-branch connections to soil and waste pipes; rain leaders used for soil or waste pipes; vent outlets opening near windows, doors, or other openings to a building; cowls or caps attached to vent outlets above the roof; boiler blow-off connected to the drainage system on the house side of the main drain trap; and, the blow-off pipe from high-pressure boilers connected to the drainage system without first passing the water through a cooling tank.

INSPECTION OF PLUMBING SYSTEM

INSPECTION OF ABOVE-GROUND SYSTEM

27. General Procedure.—The sanitary engineer should carefully examine the plumbing system within the building to see that a sufficient supply of water is obtainable at all the fixtures; that the house tank is protected from dust and vermin and that it is kept clean; and that all pipes in cold places are properly protected from frost. He should further see that all lines of pipes are well supported; that the waterback is properly connected to the range boiler; that the waterback is not partly choked with deposits of lime; and that there are no pounding or humming noises in the supply pipes when faucets are opened. As a sanitary engineer's examination of a plumbing system progresses, he should make note of the location and nature of defects discovered, so that a description of them can be embodied in his report to the owner, together with recommendations for their repair.

28. Smoke Test.—When a sanitary engineer has a smoke test applied to a drainage system, he should see that no undue preparation of the system has been made for the test. The system having been in daily use, all fixture traps and drain traps, if properly installed, should be sealed with water; if they are not sealed, that fact should be ascertained and the cause discovered. If care were taken to seal the traps before applying a test, the fact that the traps were not sealed would not be discovered under ordinary conditions.

If, while the smoke test is applied, a drainage system leaks so badly that pressure cannot be maintained, temporary repairs should be made, so that sufficient pressure can be pumped up to develop most of the leaks. This can be done in nearly all cases by closing the large leaks with putty or clay; if this is done the location of each large leak should be noted in writing, since otherwise one or more of these large leaks may be forgotten when permanent repairs are made.

When the pressure in a drainage system supports the smoke machine float or water-column gauge for 5 minutes, the system may be considered tight and the test discontinued; up to that time search should be continued for the leak or leaks that caused the float or water column in the gauge to fall. These leaks are sometimes so small as to be almost beyond detection; they may be merely a sponginess in the iron, or very slight leaks in the calked joints of the soil pipe through which smoke oozes so slowly as to be almost invisible.

INSPECTION OF UNDERGROUND SYSTEM

29. Locating Cesspool.—Leaching cesspools are sometimes capped with a flat stone and covered with earth to the level of the surrounding ground. After many years, the location of such cesspools may be forgotten, and before a sanitary engineer can examine their condition he must first find their location. To locate a covered cesspool, the engineer would naturally look first in that part of the premises where, from the contour of the ground and general surface indications, his judgment tells him he would be likely to place it. Having judged the approximate location of the cesspool he should then carefully examine the surface of the ground in that locality, keeping a sharp lookout for mounds of earth, overflow pipes, vent pipes or anything else connected with a cesspool that would show to him its exact location. If there are no surface indications of the location of a cesspool, he should judge the approximate location, and then with the aid of an iron bar sound the locality for the stone cover. If the cover is not too far below the surface of the ground, its exact location can be determined by a hollow sound when the iron bar strikes it.

When all other means of locating a cesspool fail, its location can be determined by means of a smoke test, provided that the main drain trap is not located near the cesspool. The smoke test may be applied to any part of the house sewer outside of the main drain trap, and in a few minutes thereafter smoke will be seen rising from the earth above the cesspool.

30. Locating Underground Trap.—Drain traps are not always made accessible, and sometimes their exact location is unknown. Usually, however, the approximate location of underground traps can be determined from the location and direction of the fresh-air inlet. When the drainage system is not provided with a fresh-air inlet, a more difficult problem confronts the sanitary engineer, who then has no visible signs to guide him in his search.

If the main drain trap is not located inside of the cellar wall, it would next be assumed that it was located in the house sewer just outside of the foundation wall, and a trench should be opened down to the house sewer at this point. If the main drain trap is not located there, it may then be assumed to be near the cesspool, which should be located, and by digging down to the sewer on the house side of the cesspool, the main drain trap will doubtless be found. Frequently it can be located by running rods through the drain until they reach the trap.

31. Locating Unsealed Dead Ends, and Dummy Vents.—In many old buildings, fixtures have been removed and the unused waste and vent pipes left in place. Sometimes through carelessness or neglect the ends of these unused pipes are left open, or if of lead, are only partly closed by beating the ends together, or if of iron, by filling the hubs with putty, cement, or wooden plugs.

In new buildings soil, waste, and vent stacks have been found extended only to the topmost fixtures, where they were plugged and dummy vents extended through the roof to give the appearance that all lines of soil and waste pipe are vented. It is the business of a sanitary engineer when examining plumbing systems to discover these defects and report them to the owner.

32. Both unsealed dead ends and dummy vents can be discovered by means of the smoke test. When a smoke test is applied to a drainage system, and no smoke issues from the vent stacks above the roof, it is a very good indication that the vent stacks are not connected to the system; in other words, they are what are known to the trade as *dummy vents.* Whether or not a suspected vent pipe is a dummy can be detected by dropping a pebble down the vent pipe and noting the sound, and also by reflecting sunlight by means of a mirror into the vent pipe and noting where the pipe terminates. If both of these means fail to convince the examining engineer, the alternative is to tear off some lath and plaster where the pipes are concealed in the attic and thus ascertain their exact condition. If concealed dead ends of pipe are unsealed, this condition will be evidenced by smoke escaping from the unsealed ends and working into rooms when the smoke test is applied.

33. Leaks Under Cellar Floors.—In old buildings where tile house drains have been installed in the ordinary manner it is quite certain that many of the joints leak; as this leakage has doubtless been taking place for many years, it is quite probable that the soil under the entire cellar floor is saturated with sewage. The existence of this state of affairs must be ascertained, and a remedy pointed out, by the sanitary engineer. Usually, where the tile house drains leak, that fact is perceptible to the sense of smell, a musty odor pervading the cellar when the windows are closed. If doubt exists, however, a smoke test applied to the house drain will demonstrate the existence and location of such leak. When it is known that tile drains run under cellar floors, they should be condemned whether leaks can be demonstrated or not; for, while they might apparently be tight at that particular time they may develop leaks at some future time, and sewer gas escaping therefrom would vitiate the cellar air. Cellar floors, unless made of asphalt, do not offer a seal to the passage of sewer gases.

34. If underground drains are laid with leaky joints, the sewage escaping therefrom for a considerable period of time will saturate the soil for many yards on all sides of the drain. This leakage is more serious in its effect than would at first appear, for part of the escaping sewage may be carried by the ground water to nearby wells or other sources of water supply, while the gases of decomposition arising from the polluted soil might contaminate the air in the vicinity of the building. When the surface of the ground above leaky drains is frozen, or when paved with materials that are impervious to air, the gases of decomposition escaping from the leaks follow the path of least resistance, which is usually along the pipe trunk into the cellar of the building. If the leak is near the cellar wall but outside of it, the sewage frequently works back under the drain and flows into the cellar through the hole in the cellar wall.

In city streets, sewer gas from street sewers, and illuminating gas from street mains, sometimes escape, and, as the surfaces of many streets are paved with impervious materials through which the escaping gases cannot pass, the gases frequently flow into the cellars of buildings through pipe openings in the foundation walls, where they mix with and vitiate the cellar air. In tall buildings with light shafts and air-shafts extending from basement to roof, or with open stair and elevator shafts, these shafts act like chimney flues, and draw the sewer gas and illuminating gas into the building in large quantities. Even the ordinary two- or three-story buildings will draw gases in from under the street, but in such buildings the odors are not so noticeable except during winter. To remedy such cases, it is necessary to cement all holes and cracks in the cellar walls and floors, and if possible to ventilate the cellar. The air in bedrooms is frequently vitiated by the introduction of air from cellars. The cellar air passes through hollow partitions, follows pipe lines, or escapes up the stairway to the bedrooms above. This is more likely to happen when the air in the cellar is vitiated by illuminating gas, the specific gravity of which is about one-half of that of the air. This tendency of cellar air to vitiate the air in a building can be observed by sprinkling oil of peppermint in the cellar and noting how quickly the odor will be observed in most of the rooms in the building. Since impure cellar air will vitiate the air of an entire building, it is the duty of a sanitary engineer, when making a sanitary survey of a building, to carefully examine the cellar, giving especial attention to the cellar walls and floors.

SAMPLE REPORT

35. The following sample report of a sanitary engineer will serve to guide other sanitary engineers or master plumbers in preparing a report to an owner:

MODEL CITY, PA., December 18, 1905.

JOHN H. BURNS, ESQ.,
314 West St.,
Model City, Pa.

Dear Sir:—I hereby report that, at your request, I have this day made a sanitary inspection and test of the four-story brick residence, outbuildings, and premises located at No. 314 West Street, this city, and beg to state that I found the premises to be in a sanitary condition, with the following exceptions, which are accompanied by recommendations for repairs and improvements:

1. The garbage cans are at present located under the dining-room windows. They emit foul odors and draw flies; they should be removed to rear of lot. These cans should be washed out and dis-

infected once each week with a solution of one tablespoonful of carbolic acid to one pail of water.

2. The back yard grades down to the rear foundation wall of the residence, and hence storm water enters the cellar. The ground should be filled in around the foundation walls and graded back 10 feet from the building. Place a 4-inch drain, and a catch basin at the lowest point to remove the surface water.

3. The manure pit at the stables is open, emits disagreeable odors, and draws flies. This pit should be closed by an air-tight hinged cover in two halves, and should be provided with a galvanized chute to stable.

4. The stable is so constructed that the horses have no ventilation. The air cannot be changed except by a window that, if opened, will allow a draft on the horses. A No. 26 galvanized-iron flue measuring 1 foot by 2 feet should be run from the ceiling of the stable up through the roof, and should be provided with a damper and operating chain, and a cowl. A corresponding flue measuring 2 feet by 1 foot should be installed near the feed-chutes, the upper end terminating with a register 5 feet above the floor, the lower end being continued to the outer air. This will properly ventilate the stable.

5. There are traces of backwater marks on the cellar walls, which lead me to believe that water from the city sewers backs up into the cellar during heavy rain storms. This belief is corroborated by your butler, who states that he saw water boiling up through a grating in the cellar floor during the heavy rainfall of June 28th, and some of the other servants have observed the same results during other heavy rainfalls. This is due to the city sewer in West Street being unable to remove the storm water quick enough to prevent a back pressure in your private sewer. As the backwater contains more or less sewage, it is positively dangerous to have it contaminate the cellar. A sewer check-valve should be applied at the floor drain; another should be applied to the laundry tubs in the cellar, and the water closet in the cellar should be removed and the opening closed.

6. A vent pipe on top of the building at No. 312 West Street discharges foul air directly under and within 5 feet of the nursery window on the third floor. As this is a menace to health the owner of said building should be notified of same, so that he may at his own expense and in accordance with the building laws of this city, run the said vent pipe up against your wall and terminate above your roof, or otherwise remove the vent.

7. The rain-water leader from the rear porch is not trapped; during the test smoke came out at the roof and entered the rear bedroom window. Sewer gas can enter as freely as the smoke; therefore, this leader should be trapped.

8. Smoke entered the cellar freely through the floor drain. The water seal was evaporated. This seal can be assured and the present

trap made safe by running a $\frac{1}{4}$-inch tube from the flush pipe of the nearest water closet to the floor drain trap.

9. Smoke escaped into the siphon jet water-closet bowl in the toilet room on the second floor. There is a kiln crack at the top of the siphon that cannot be seen. It cannot be repaired; therefore, a new water closet should be installed in its place.

10. The connection of the basin waste to the bath waste on the third floor is defective, inasmuch as sewer gas is forced into the room through the bathtub when the basin is filled with water and emptied quickly. To remedy this, it is necessary to lift part of the bathroom floor, and make a new connection between the basin waste and the bath waste, which connection should be in the form of a Y. It is also necessary to connect the crown of the bath trap with a $1\frac{1}{4}$-inch back-vent pipe to the back-vent pipe from the basin. This will entail cutting into the partition back of the wash basin.

11. The water pressure on the premises varies from 60 pounds during the day to 125 pounds per square inch during the night, and as the ball cocks of the closet tanks make disagreeable singing noises during the night I recommend that a "Jones improved" pressure regulator be applied on the service pipe and set to reduce the pressure to 40 pounds in the cellar, a safety valve being placed on the hot-water pipe over the boiler and set to blow off into the sink at a pressure of 50 pounds per square inch.

12. There are seven leaks in the drainage and vent pipes, as follows: One at the floor joint of the water closet on the third floor—to remedy this the closet will have to be reset; four at the calked joints where marked with white chalk in basement—these should be calked rigid; one under the roof flange of the 3-inch vent stack—to repair this remove the flange, recalk the joint, and then replace roof flange; one in the kitchen-sink iron waste pipe, where a hole has been cut to remove stoppage in the pipe and has been covered over with putty—to remedy this, cut out the piece and insert a clean-out fitting with screw cap.

The cost of making the above enumerated repairs and improvements is approximately Three Hundred and Seventy Dollars ($370), inclusive of all trades.

Respectfully submitted,

JOHN SMITH, Sanitary Engineer.

The preceding report is a simple one for a building where but little work is required to put it in a sanitary condition. In such a case it is usually advisable to give the work to a reputable plumber on a time-and-material basis. But, in cases where the changes and improvements are numerous and extensive, the cost will be sufficiently high to justify the engineer in making plans and specifications and in obtaining bids from plumbing contractors, should the owner decide to remodel the work in accordance with the engineer's report.

36. When the engineer sees that the building cannot be made thoroughly sanitary without a complete overhauling of the plumbing system, he should try to have the owner witness the test and see for himself how the sewer gas can permeate the building. Then the report should be submitted, enumerating the defects in a general way and ending with a recommendation regarding the improvements. In the recommendation the approximate cost should be stated, and it may be suggested that plans and specifications be made and bids solicited. An arrangement should be made whereby the sanitary engineer will be employed to prepare the plans and specifications, receive bids and close the contract, superintend the overhauling, test the work when finished, and finally accept the job and turn it over to the owner. The sanitary engineer in this respect is the duly authorized agent of the owner, and must be respected as such.

37. Should a master plumber be called in by an owner to make a sanitary inspection and test, he may perform his duties along the lines of the sanitary engineer. Indeed, he then becomes the sanitary engineer and must attend to the interests of the owner, who has thus placed confidence in his ability and integrity to intelligently determine and honestly report the exact condition of the premises from a sanitary point of view.

The master plumber can make arrangements with the owner to prepare plans and specifications and the owner may use them for obtaining competitive bids for the work, but the master plumber who furnishes the plans and specifications should be remunerated for same, whether he is awarded the contract or not. Should the contract be awarded to another bidder, then the master plumber who has prepared the plans and specifications may be asked to inspect the work on completion to see if it is installed according to his plans and specifications, and should witness the final test.

If the building is located within the jurisdiction of a city plumbing inspector, the owner may relieve the master plumber who prepared the plans from inspecting and testing the work, as the city plumbing inspector is expected to attend to this. Should, however, the services of the master plumber who prepared the plans be retained to inspect and to test the premises upon completion of the work, he must be very careful to make a just and honorable inspection and test. He must realize that, as far as this particular job is concerned, he is not a contractor, but is a sanitary engineer who has assumed the responsibility of designing a plumbing system and superintending its construction to a finish, and is being paid for his learning and ability along this line. Many plumbing contractors are entrusted with this class of work. For instance, a city gentleman is building a country house a long distance from his city home. He has confidence in the ability of the plumbers who do business in the village near his country estate to erect a good plumbing system according to plans and specifications, but he cannot depend on their ability to design the right kind of a system. He, therefore, employs his city plumber to make plans and specifications for the plumbing and drainage work, and incidentally asks him to present a bid for the work. Usually the bid of the city plumber is very much higher than the bid of the local plumber, and the latter is awarded the contract, while the city plumber is asked to inspect and to test the work on completion, and receives pay for this.

PLUMBING PLANS AND SPECIFICATIONS

PLANS AND ESTIMATES

PLANS

PREPARATION OF PLANS

1. Building plans on which are marked the work to be performed by the plumbing contractor are called **plumbing plans;** to an estimator they are provided to guide him in computing the cost of installing the plumbing system. When plans are properly drawn, the estimator can readily distinguish and count the fixtures and other apparatus to be installed. Also, by measuring the piping drawn or indicated on the plans, he can arrive at a close approximation of the amount of pipe of various sizes and the number and kind of fittings that will be required. After the contract is awarded, the plans serve as a guide to the contractor when installing the work and insure a better job than would likely be the case if the layout of the system were left entirely to the contractor. In addition to serving as a guide for the estimator and contractor, the plans form part of the plumbing contract and, as such, should clearly show, or indicate, the entire system of plumbing within the building; for, in case of a dispute as to the amount of work to be performed, the deciding factor will undoubtedly be the plans; because, while the specifications and plans are generally construed together, the specifications only describe the quality of the goods to be used while the plans show the quantity, extent, and layout of the work.

2. Plumbing plans are generally prepared, either directly or indirectly, by the architect. In large cities, a sanitary engineer employed by the architect usually prepares the plumbing plans and specifications and superintends the installation. Some architects, however, instead of employing a sanitary engineer, retain a consulting sanitary engineer to prepare the plans and specifications for plumbing installation, which requires special knowledge of sanitation. Either method will insure the owner a perfectly sanitary job, well and economically laid out, and will secure the competition of reliable plumbing contractors, who, while possessing the capital, might not have the requisite ability to properly design a large plumbing installation and write the specifications. Architects in smaller cities, and some architects in large cities, do not employ or retain a sanitary engineer but depend on what suggestions they can get from contracting plumbers to help them lay out the plumbing work. Such a course of procedure is unsatisfactory for many reasons. It places the architect under an indebtedness to the contractor, who, unless paid for his services, will expect a preference in the bidding. It is unfair to the owner who thus indirectly pays more for unprofessional services than would be required to fee a sanitary engineer, without the assurance of an equally good job. To the contracting plumber this method is unsatisfactory, because he risks his standing as a contractor when he undertakes the duties of an engineer and fails; for, no matter how honest and sincere he may be, he might not possess sufficient technical knowledge to design a plumbing system satisfactorily.

SAMPLE PLANS

3. In Figs. 1 to 5 are reproduced, to a small scale, the plumbing plans for a large detached residence. Fig. 1 shows, in plan, the basement of the house and the general

arrangement of drain pipes and basement fixtures. There are twenty plumbing fixtures in this building, and under ordinary conditions, a 4-inch main house drain would be sufficiently large to take care of the sewage properly. However, in addition to sewage, this drain must take care of rain water from the roof, so that up to the point where the first two principal branches are taken off, the house drain is made 5 inches in diameter.

4. On the first-floor plan, Fig. 2, are shown the rising lines of soil, waste, and vent pipes run in partitions. The stacks are indicated by small circles, and their sizes are printed alongside. For convenience in reference, the stacks are lettered consecutively from *A* to *E*. Stack *A* is a 2-inch waste pipe from the kitchen sink; from this stack, above the level of the sink, a vent pipe is extended to the cellar to back-vent the laundry tubs, and a branch from this vent is connected to the kitchen-sink trap. Stack *B* takes the discharge from fixtures on three floors: the servants' water closet and drip sink in the basement, the butler's sink on the first floor, and the servants' bathroom on the third floor. A vent stack accompanies this soil stack and is connected to it above the highest fixture in the bathroom and below the branch vent to the servants' closet in basement. This vent stack serves as a back-vent for the several fixtures on the three floors. Stack *C* is from the bathroom over the kitchen and the slop sink in the adjoining room on the second floor; as it takes the discharge from a water closet, this soil stack is made 4 inches in diameter. Stack *D* takes the discharge from a water closet and lavatory located under the stairway on the first floor. As this stack receives the discharge from a water closet it, likewise, is made 4 inches in diameter. Stack *E* is 4 inches in diameter. It takes the discharge from the bathroom over the dining room and from a lavatory in the adjoining chamber.

5. The second-floor plan is shown in Fig. 3. In this plan are shown continuations of the soil, waste, and vent stacks, and the general arrangement of the fixtures in the bathroom; there is also indicated the layout of the soil, waste, and vent pipes to the different fixtures.

6. The third-floor plan is shown in Fig. 4. On this plan are indicated the various vent stacks, the arrangement of fixtures in the servants' bathroom, and the layout of soil, waste, and vent pipes for the fixtures.

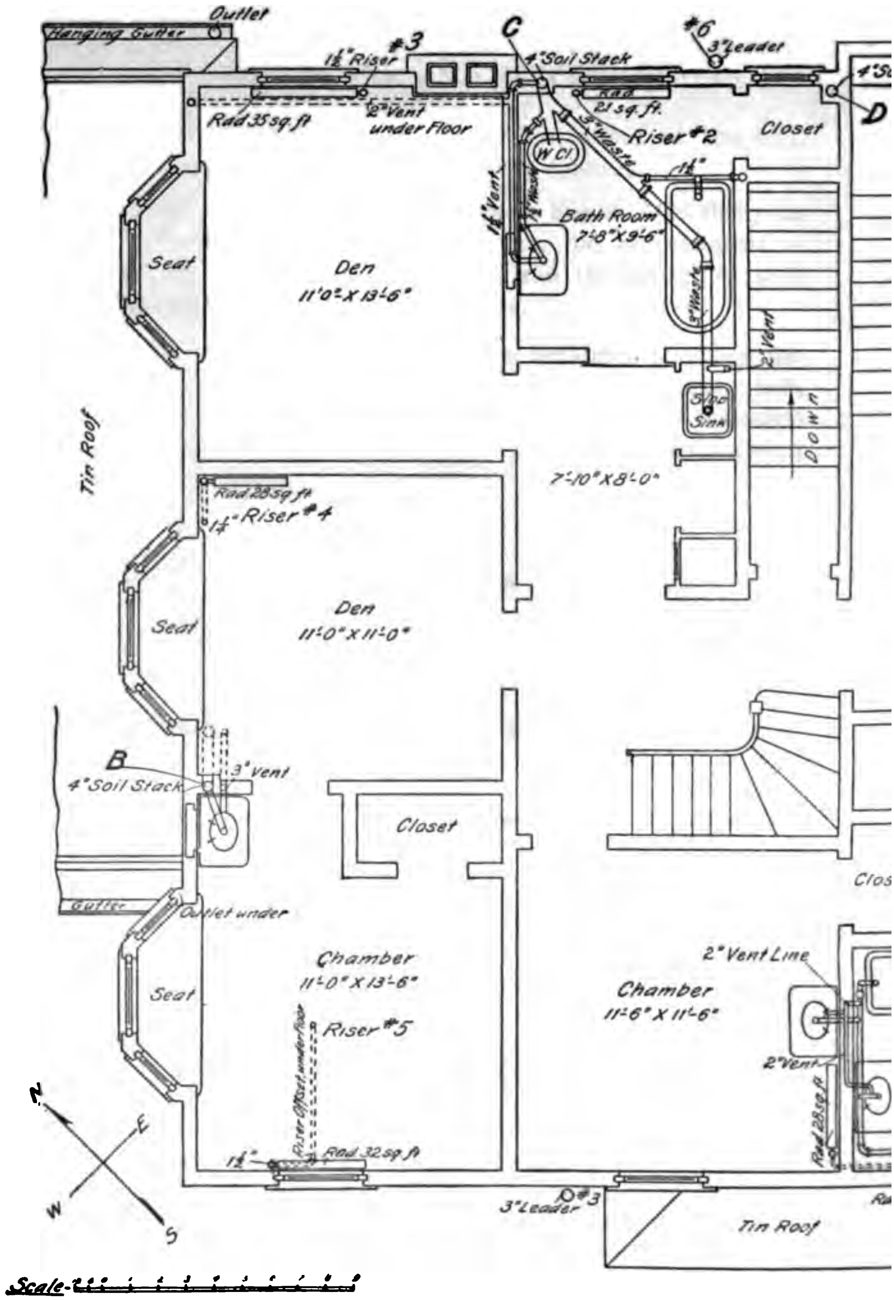
7. A sectional elevation of the building, showing the plumbing system, is given in Fig. 5. The house drain, soil, and waste stacks, also the soil and waste pipes, are indicated by heavy solid lines, while the vent stacks and branch vent pipes, are indicated by dotted lines.

ESTIMATES

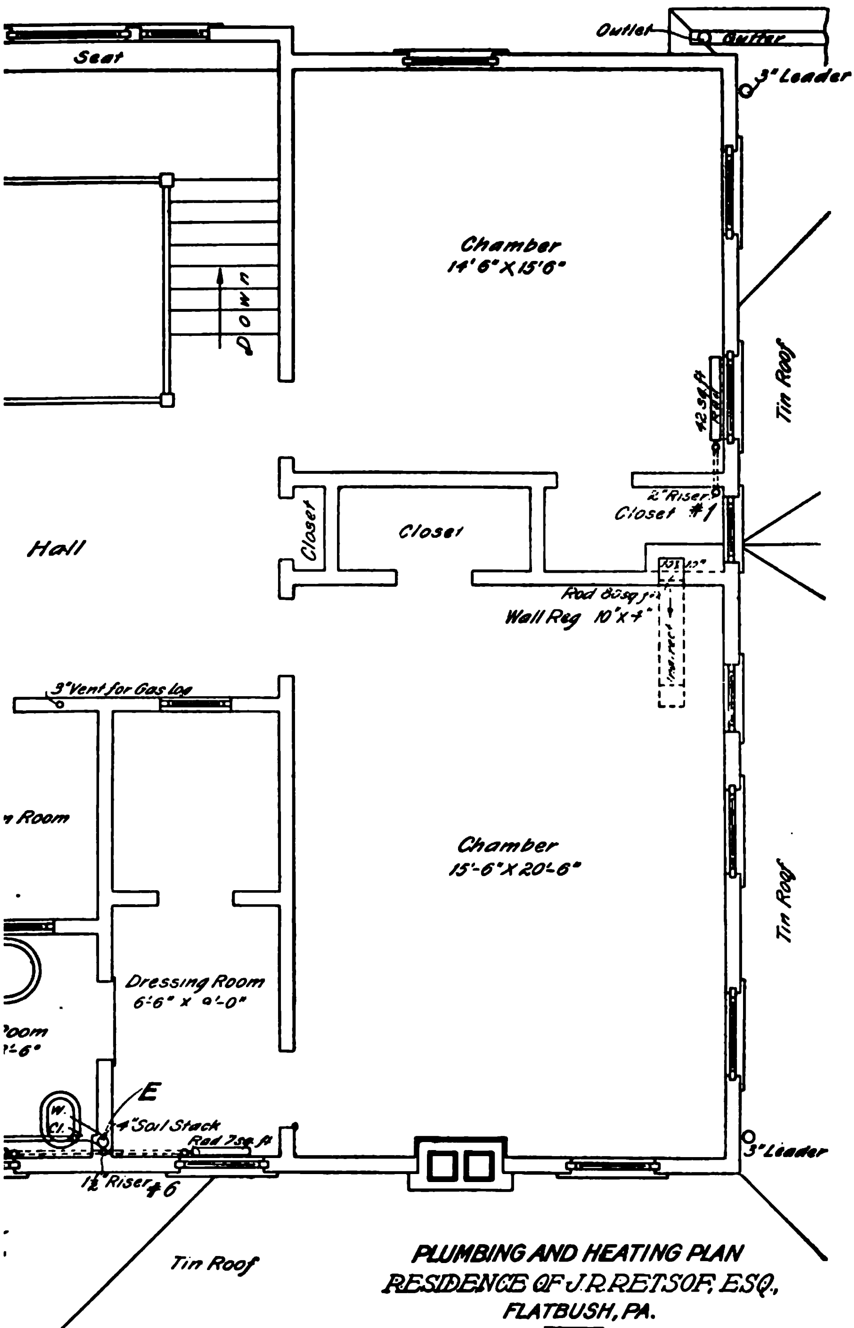
PRINCIPLES OF ESTIMATING

8. Introduction.—The art of estimating is very important both to the architect and to the contractor—to the latter, in that he must employ some systematic method of estimating in order to carry on his business successfully; and to the former for the reason that he should at all times be able to estimate the cost of work that he designs. The science—for such it is—of fixing a price on a piece of work must be based on an extended experience. With a little practice any one can learn to take off the quantities of materials and obtain their net cost, but only a person of large and varied knowledge of the business can accurately estimate the time and labor required to complete the work.

9. There are no standard or definite rules on estimating that hold good everywhere, for the plumbers of each locality have their own ideas and customs in regard to the subject; this fact, together with the difference in cost of labor in various parts of the country and the fluctuations in the market prices of materials, requires, as before remarked, that the clever estimator shall be a man of long and varied experience

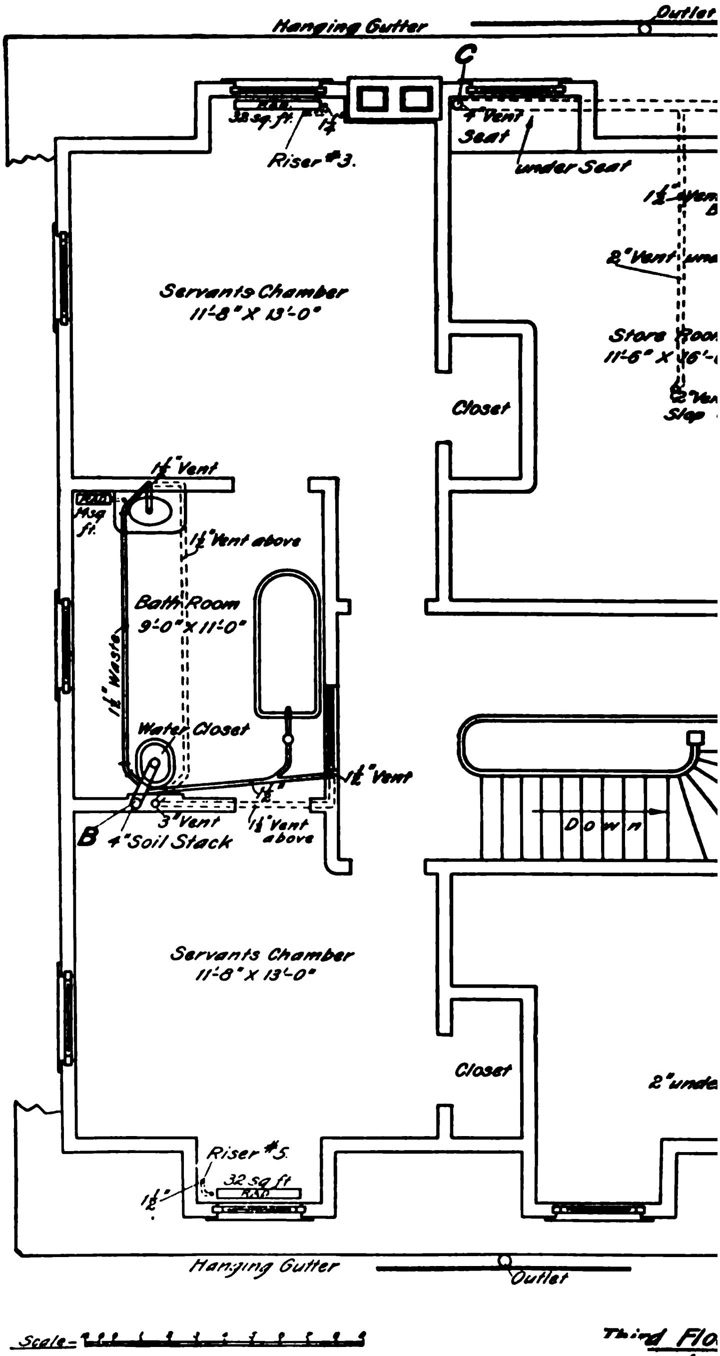


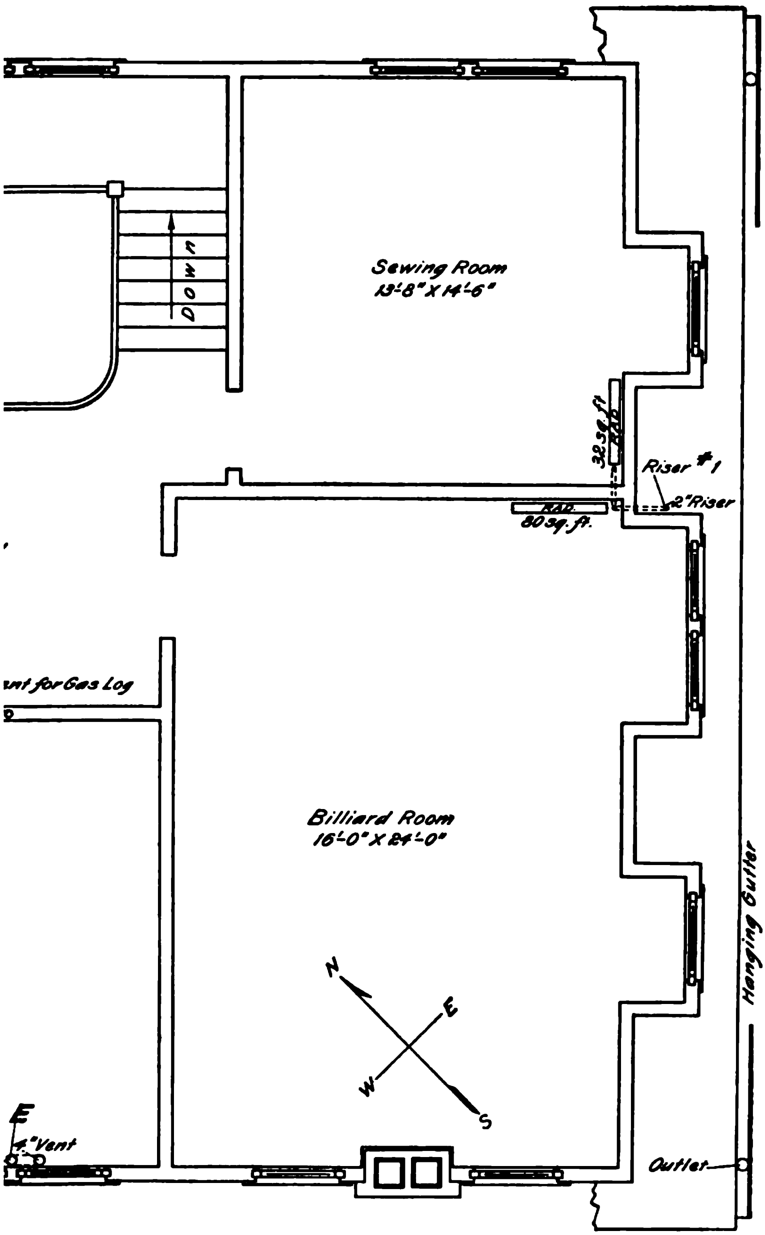
Second Floor Plan
(Scale ¼ in. = 1 ft.)



PLUMBING AND HEATING PLAN
RESIDENCE OF J.R.RETSOF, ESQ.,
FLATBUSH, PA.

No. 104 ... John Scott, Arch. Jos. Hawley, Eng. DATE..........


Hanging Gutter
Outlet
C
38 sq. ft.
Riser #3.
4" Vent
Seat
under Seat
Servants Chamber
11'-8" X 13'-0"
Closet
Store Room
2" Vent
1½" Vent
1½" Vent above
Bath Room
9'-0" X 11'-0"
1½" Waste
Water Closet
1½" Vent
3" Vent
1½" Vent above
B
4" Soil Stack
Down
Servants Chamber
11'-8" X 13'-0"
Closet
Riser #5.
32 sq. ft.
Hanging Gutter
Outlet
Scale
Third Floor



PLUMBING AND HEATING PLAN
RESIDENCE OF J.R. RETSOF, ESQ.
FLATBUSH, PA.

No. 105.. John Scott, Arch. Jos. Hawley, Eng. DATE..........

in the business. There are, however, certain practical suggestions that will materially assist in taking off quantities, and in valuing the labor required for any plumbing contract. These will be given farther on.

10. The prime considerations in making an estimate are time and accuracy; to these ends the estimator must systematize his efforts and endeavor to do a maximum amount of work in a minimum amount of time, but not at the expense of accuracy, which is the most important factor, and which is insured only when the figures are carefully checked. The estimator should, therefore, while avoiding too great refinements in calculation, aim at correctness rather than speed in doing work. Very frequently do the effects of haste and inaccuracy in estimating the cost of work become evident when it is too late to remedy the errors, which result sometimes in the financial ruin of the contractors who trust too implicitly in the estimator's figures.

A record should be kept of all estimates made, as this kind of information is most valuable, and establishes a precedent on which to base subsequent estimates, as well as a check on the work at hand.

11. Schedule.—The drawings and specifications for an installation are the guides that an estimator must follow in making his computations. All measurements necessary for calculating the quantity of the materials required are obtained from the drawings; and all information in regard to the character of the workmanship and quality of materials to be used is furnished by the specifications.

In compiling a schedule, there are three stages to the operation: (1) Taking the dimensions for each material; (2) computing and collecting the quantities; (3) estimating the cost. In carrying out the first of these steps, each subdivision should be considered in the order in which it will be executed.

The third step—estimating the cost—may be subdivided into cost of labor and cost of material. The latter can be definitely fixed by an examination of lists giving current prices of materials, while the former must be based on a fixed rate of wages per day for the various classes of workmen.

12. In estimating the cost of plumbing work, the possibility of overlooking important items can be reduced to a minimum by providing a schedule of materials such as might be used in the installation of all classes of plumbing work, and using that schedule to check the list of materials taken from a plan. A convenient form of schedule or blank for estimating is given on the opposite page.

13. Taking-Off Quantities.—Plumbing work and materials may be estimated as outlined in the following paragraphs:

Measure all horizontal pipes from the plans and vertical pipes from the sectional elevations.

Commence at the sewer outlet, and measure the main sewer line forwards to the building, and then measure the horizontal branches.

Measure the vertical soil, waste, and vent stacks to their terminations above the roof, and the waste-pipe branches to the fixtures on the several floors.

Itemize the several pipes in the different kinds and classes.

Estimate all earthen pipe by the lineal foot and allow for Portland cement in the joints.

Estimate all trenching by the lineal foot, allowing for the depth of the trench, nature of the soil or rock to be cut through, and interference from water or other causes.

Estimate all digging for sewage disposal beds by the cubic yard.

Estimate all cast-iron pipe by the lineal foot, allowing for each joint $\frac{3}{4}$ pound of lead for each inch in diameter of the pipe.

Estimate wrought-iron pipe by the lineal foot, inclusive of couplings.

Estimate brass, copper, and lead pipe by the pound.

Estimate all traps, bends, branches, increasers, reducers, and other fittings separately, except such special brass

Estimate No. ______ ______________ **Location**

For ______________________________

____

Architects

Date ______________ **19**____

			Estimated Cost		Actual Cost	
		Bathtubs				
		Bathtub trimmings				
		Lavatories				
		Lavatory trimmings				
		Closets				
		Closet trimmings				
		Urinals				
		Urinal trimmings				
		Sinks				
		Sink trimmings				
		Laundry tubs				
		Range boiler				
		Boiler fittings				
		Soil pipe				
		Soil-pipe fittings				
		Sewer pipe				
		Sewer-pipe fittings				
		Wrought-iron pipe (galvanized)				
		Malleable-iron fittings (beaded and galvanized)				
		Lead pipe				
		Lead goods—ferrules, sheet lead, etc.				
		Pig Lead				
		Oakum and putty				
		Solder				
		Brass goods (solder nipples, clean-outs)				
		Valves				
		Stop-and-waste and stop-cocks				
		Bibbs				
		Nickel-plated bibbs				
		Rubber goods				
		Labor				
		Board				
		Fare				
		Freight and cartage				
		Incidentals				
		Inspection				
		Extras Net cost				
		Profit				
		Estimate				

fixtures, traps, and connections as are included in the cost of the fixtures. Do not figure lead bends that are smaller than 2 inches in diameter.

Estimate on brass-ferrule connections at all points where lead pipe joins cast-iron pipe.

Estimate on all solder joints (wiped), allowing 1 pound of solder for every inch inside diameter of the pipe.

For street supply, allow for permits, corporation tapping, and curb box.

Measure the service pipe from street main to cellar and allow for a stop-and-waste cock inside the cellar wall.

Measure all branches for the several fixtures on the different floors, to the lawn hydrants, etc.

Itemize separately all stop-cocks, pipe tacks, straps, hangers, etc.

Estimate, by the pound, all water-pipe fittings less than 1½ inches in diameter.

Estimate on a kitchen boiler, sediment cock, and range connections; and also faucets for all fixtures other than those that are included in the costs of the fixtures.

Estimate on garden hydrants and lawn sprinklers, and allow a stop-and-waste cock in the cellar for each.

Measure lead tank linings, in square feet, and estimate by the pound, allowing 1 pound of solder for every 2 feet of seams.

Allow 2 feet of lead pipe to connect iron pipe to the house tank, and for stop-cocks close to tank. Provide for telltale and overflow pipes for the tank. Estimate copper lining for tanks in square feet and by the pound, allowing 1 pound for each square foot.

If there are iron, slate, glass, or cedar tanks, figure them separately.

Estimate each fixture separately, and include traps, faucets, waste, vent, and water connections to walls or floors. When the sewer is long and has but little fall, figure on using a grease trap for the kitchen sink. Estimate the labor by allowing for each item of work a sufficient length of time for an ordinary workman to perform the work. This can best be done by estimating separately the labor for the drainage system, water-supply system, and setting of fixtures.

PROPOSALS

14. When the total net cost of a proposed installation has been ascertained, the profit is added and the price for which the contractor is willing to do the work thus determined. A formal proposal to do the work for that amount should be submitted to the owner or architect. If the terms of payment and general conditions to be observed are stated in the specifications the proposal, known also as the *bid*, may be worded something like the following:

NEW YORK CITY, September 16, 1904.

To GEORGE B. HILL,
1492 Columbus Avenue,
New York City.

Dear Sir:—We propose to furnish all materials and perform all labor, according to the plans and specifications dated August 18, 1904, for the plumbing in the residence you are about to erect at 231 Jefferson Street, this city, for the sum of three thousand, two hundred and fifty-six dollars ($3,256). This offer is for immediate acceptance only.

Respectfully submitted,
GROVE & SONS.

When the conditions in the specifications are not full and complete, or for other reasons are not satisfactory to the contractor, and he desires to enter into a formal contract with the owner he should insert in his proposal a clause something like the following: "In case of acceptance of this proposal, a formal contract to be entered into." An acceptance of the proposal then is not binding on the proposer until a formal contract is signed.

15. A complete record should be kept of every estimate submitted, and the proposal should be followed up by the estimator until the contract is finally awarded. The record should state the amount of the proposal, to whom submitted, and the date. It should state the date, hour, and place of the award, and if the award is not made at the time and place agreed on, the date and place to which it is postponed should be recorded. Finally, when the contract is let, the name of the party to whom it is awarded, the amount of the winning bid, together with a record of all competing proposals should be entered. A convenient place to make or keep such a record is on the back of the detailed estimate and the entries may be made similar to the following:

RECORD OF ESTIMATE

For ________ Submitted to ________________ Date ________

Contract to be awarded ________________

Award postponed to ________________

Name of Estimators	Amount of Estimates	
Grove & Sons	3,256	Awarded contract
Smith & Roos	3,420	
Griffeth & Co.	3,210	
Hewison Bros.	2,866	Lowest bidders

Remarks:

SPECIFICATIONS

SPECIFICATIONS FOR RESIDENCE PLUMBING

PURPOSE AND REQUIREMENTS

16. Plumbing specifications are written descriptions of materials to be supplied and work to be performed in installing a plumbing system. In the preparation of plumbing plans, the general layout of the system, and the location and character of fixtures and apparatus can only be indicated; hence, to clearly define the grade and finish of goods, and describe details that are not shown or indicated on the plans, requires a written description embodying all necessary information. To serve the purpose for which they are intended, specifications must be full and complete in all details, leaving nothing to be assumed that can and should be described or explained. Each and every clause in plumbing specifications should be so clearly worded that a person having a reasonable knowledge of plumbing can construe it in only one way. Ambiguity in specifications of any kind is to be avoided, as it leads to misunderstandings and consequent delays and often lawsuits.

A careful study and critical examination of the plans and specifications here presented is advised. These plans and specifications have been selected because they have been actually used, and the work done according to them is in successful operation.

SPECIFICATIONS

17. In the following specifications are described, in detail, the various conditions to be observed, the class of fixtures to be installed, and the extent of work to be performed, when installing the plumbing indicated on the plans represented by Figs. 1 to 5.

Specifications of materials and workmanship relative to the plumbing for a residence proposed to be erected on Clay Avenue near Gibson Street, Flatbush, Pa., for J. R. Retsof, Esq., of said city, in accordance with drawings and specifications prepared for the same by John Scott, architect, and Jos. Hawley, sanitary engineer. Flatbush, Pa., June 30, 1904.

GENERAL

Duties of Contractor.—The contractor will be required to give his personal superintendence to the work, furnish all materials and transportation of same, and all implements and appliances necessary to duly complete the work specified and in accordance with a fair and reasonable interpretation of the drawings and specifications combined. He shall procure and pay for all permits and licenses required for the fulfilment of his contract, in accordance with the laws, rules, regulations, and ordinances of the city of Flatbush, and he shall perform all his operations so as to conform to the existing plumbing rules and regulations.

Supervision.—The work will be under the general supervision of the architect and sanitary engineer, whose decision as to the true meaning and intent of the drawings and specifications will be final and conclusive. The architect or his engineer will have the power to inspect the work at any time and reject any materials or work unsuitable or not in accordance with the drawings and specifications, and to cause their removal from the premises without delay at the expense of the contractor should he refuse to remove the same immediately.

Drawings.—The plumbing drawings consist of the following sheets:* No. 1, plan of the plumbing in the cellar and underground drainage; No. 2, plan of the plumbing on the first floor; No. 3, plan of plumbing on second floor; No. 4, plan of plumbing on third floor; No. 5, elevation of the plumbing system. All necessary general and detailed drawings will be furnished and the work must be done in strict accordance therewith.

Gas Supply, Water Supply, Drainage Disposal.—The gas supply will be taken from a 4-inch gas main in Clay Avenue. The water supply will be taken from a 4-inch water main also in Clay Avenue. The drainage will discharge into a 12-inch sewer on Costello Court.

PLUMBING FIXTURES

Servants' Closet.—Furnish and fit up complete where shown in the basement one plain, substantial, siphon-jet closet with strong oak seat hinged to the bowl, and strong, durable, overhead tank lined with 16-ounce copper and fitted with strong approved high-pressure ball-cock; flush pipe is to be of nickel-plated brass, at least $\frac{1}{16}$ inch thick; or, furnish the closet with a Kenney flushometer valve as directed, the supply pipe to be of galvanized iron.

Safe-Waste Sink.—Furnish and fit up complete where shown in the cellar one 20″ × 14″ × 6″ plain cast-iron safe-waste sink supported on cast-iron legs and wasted through a 1½-inch cast-iron trap and pipe to the floor. Back-vent this trap with galvanized-iron pipe. Supply water to this sink through a ½-inch finished brass compression and hose bib with stuffingbox.

Laundry Tubs.—Furnish and fit up complete where shown in basement one set of three Mott's Colonial wash tubs of best quality solid earthenware glazed natural yellow, free from cracks and flaws of any description, Plate 908 R. Tubs are to be fitted with a suitable strong ash frame and attachments are to be provided for a wringer; the tub cocks are to be over the tubs. Waste these tubs through a 2-inch brass waste pipe and trap into the base of a 2-inch vent line, and supply the tubs with hot and cold water through ¾-inch galvanized-iron pipes and nickel-plated flanged Fuller cocks; the standards for the tubs are to be strong, heavy bronzed cast iron, and the tubs are to be rigidly attached to the walls.

* The drawings referred to as No. 1. No. 2. etc. are represented by Figs. 1, 2, etc. respectively.

Butler's Pantry Sink.—Furnish and fit up where shown in butler's pantry one strong copper-lined tinned square pattern butler's pantry sink, with rounded corners and flat bottom, with substantial wooden casing, the copper to be at least 16 ounce. Waste this sink through a $1\frac{1}{2}$-inch nickel-plated brass trap, properly back-vented. Supply the sink with hot and cold water through a suitable nickel-plated brass double pantry cock, the sink to be provided with a rubber plug and a strong nickel-plated brass chain.

The drain board and woodwork around the sink to a height of 12 inches is to be neatly covered with pure block tin $\frac{1}{16}$ inch thick, and neatly worked in place so that the nails will not be visible. This block-tin work must be done very neatly; it must hug the wood snugly and be smooth and perfect when completed.

Kitchen Sink.—Furnish and fit up where shown in kitchen, one Mott's Colonial solid-porcelain sink, 36 inches by 23 inches, Plate 831 R, with natural buff glaze. Support the sink on a strong iron frame rigidly secured to the wall at the back and resting on two neat bronzed iron legs in front, and provide a back 18 inches high and patent ash drain boards hinged with telescope leg. Waste this sink through a 2-inch approved cast-iron porcelain-lined grease trap and 2-inch waste pipe. Back-vent the trap with $1\frac{1}{2}$-inch pipe. Supply the sink with hot and cold water through $\frac{3}{4}$-inch pipe and $\frac{3}{4}$-inch nickel-plated Fuller cocks, the cold-water cock being threaded for hose.

Reception Hall.—Furnish and fit up in the reception hall one first-class quality approved Hajoca plain vitreous china siphon-jet water closet, with a properly countersunk seat strongly made of selected solid mohogany and hinged to the bowl. Flush this closet with a nickel-plated Kenney flushometer or with best-quality mahogany-finish copper-lined low-down tank combination as directed.

Wash Basin.—Furnish and fit up where shown in the reception hall one Regal porcelain corner lavatory as shown in Plate 151 L, Haines, Jones, & Cadbury Co.'s catalog. The lavatory is to be of the best-quality vitreous china, Class A, and 20 inches on the side. Secure the slab rigidly to the wall with suitable supports. Do not use the center leg. Waste the basin through a $1\frac{1}{4}$-inch nickel-plated brass trap and waste pipe to the wall. Supply the basin through $\frac{1}{2}$-inch nickel-plated brass supply pipes for hot and cold water. Use Hajoca basin cocks with "Hot" and "Cold" china name plates.

Second-Floor Toilets.—Furnish and fit up where shown two Hajoca siphon-jet water closets, plain and neat and thorough in action, made of vitreous china, first-class quality. Flush these closets through Kenney nickel-plated brass flushometer valves and regulating cocks. Each closet is to be provided with a strongly made solid mahogany countersunk seat attached to bowl, same as is specified for the reception hall; or, furnish and fit up a low-down flush tank lined with 16-ounce copper and furnished with a suitable high-pressure ball-cock and solid-mahogany casing, all of first-class quality as may be directed.

Furnish and fit up where shown two standard porcelain-enameled cast-iron bathtubs of first-class quality complete as shown in Plate 53 S of the Standard Sanitary Manufacturing Company's catalog S, free from cracks, flaws, or other imperfections, baths to be 5½ feet inside, with a 4-inch roll rim, and must bear guarantee against cracking of the enamel and other defects. The exterior finish is to be ivory-white with gold bands. These tubs must be perfect in every respect. Waste them through suitable brass traps with 4-inch nickel-plated brass screwcap flush with the floor.

Wash Basins.—In each bathroom and in the bed chamber over the dining room, furnish and fit up one Regal porcelain lavatory, complete as shown in Plate 143 L of Haines, Jones, & Cadbury Co.'s catalog. Waste each basin through a 1¼-inch nickel-plated brass trap to the wall. The slab of each basin is to be 30 inches by 22 inches, the quality is to be Class A, and they must be perfect in every respect, with neat straight lines, clean-cut moldings, and perfect glaze, each basin to be provided with Regal porcelain legs, and Fuller basin cocks with porcelain name plates marked "Hot" and "Cold."

In the bed chamber adjoining the den on the second floor, furnish and fit up complete one solid-porcelain right-hand corner basin with back and end, the slab to be 30 inches by 22 inches, and of the same general type and quality as the Regal basin previously specified for the toilet rooms. Use one porcelain leg for this basin. Waste the basin through a standing waste properly trapped and supply with hot and cold water through Fuller basin cocks with "Hot" and "Cold" china name plates.

Slop Sinks.—Furnish and fit up where shown on the second floor one 22″ × 18″ × 12″ roll-rim Mott's Colonial slop sink, with bronzed iron trap standard and nickel-plated strainer, and 18-inch back as shown in Plate 812 R. Supply this with hot and cold water through a nickel-plated compression double faucet. The trap standard is to be a half **S** trap.

Servants' Bathroom.—Furnish and fit up where shown one cast-iron enameled 5′ 6″ bath of the ordinary plain pattern, with plain plug and chain and combination cock inside the bath, same as in Plate 19 S, Standard Manufacturing Company's catalog S, without exterior finish.

Furnish and fit up in servants' bathroom one porcelain-enameled flat-back iron basin in one piece, with nickel plated Fuller cocks, rubber plug and chain, nickel-plated trap, and brackets complete.

Furnish and fit up in servants' bathroom one plain durable siphon-jet water closet, with Kenney flushometer or plain-oak low-down flush tank, copper lined, as directed. The seat is to be of oak and attached to the bowl.

Kitchen Range.—The kitchen range will be furnished by the owner. The gas range will be furnished by the owner. The plumbing contractor will be required to make connections between these ranges and the kitchen boiler with brass piping.

Kitchen Boiler.—The contractor will furnish and fit up in the kitchen where shown one 60-gallon galvanized-iron extra-heavy best-quality range boiler tested to 250 pounds.

Refrigerator.—The refrigerator is to be furnished and set in position by the owner. The plumber will be required to connect the refrigerator with the safe-waste sink in the cellar, providing a check-valve on the mouth of the safe-waste pipe over the sink and cleanouts wherever necessary to insert rods for cleaning-out purposes; a copper pan 1 foot square of 16-ounce copper with 1½-inch upstand is to be located under the refrigerator outlet and is to be connected with 1½-inch lead pipe and brass strainer at the floor line.

DRAINAGE SYSTEM

Main House Drain.—The contractor will furnish and lay in a straight line between the rear of the building and the sewer in Costello Court a 6-inch salt-glazed vitrified sewer pipe. This pipe must be laid on a solid natural bottom. The joints are to be made with Portland cement and clean sharp sand in the proportions of half and half. The lines must be laid perfectly true and the interior swept out clean as it is laid. Place the main drain trap under the cellar floor just inside the rear wall. Take off a 4-inch fresh-air inlet from the house side of the main drain trap and run it through the rear wall, terminating above the grade line where directed with a suitable vent cap. All the drainage work shown in the cellar plan is to be extra-heavy cast iron with calked joints and supported on natural earth bottom. A hatchway will be left in the floor for access to the space underneath. Brass screw-cap clean-outs must be placed at all points on the drainage and waste-pipe system where it is necessary to obtain access to any line. The base of each soil stack must be supported solidly on a brick pier to be built by the owner for that purpose. The drain, soil, waste, and vent stacks having a diameter greater than 2 inches are to be of extra-heavy cast-iron pipe with strong calked joints. Those having a smaller diameter are to be of galvanized-iron pipe and are to have easy-sweep flush fittings; no wrought-iron pipe is to be used under the cellar floor. All the vents and branches on the drainage and ventilation system must have easy-sweep flush fittings. All vent stacks less than 4 inches that pass through the roof are to be increased in diameter at such a place and in such a manner as required by the city ordinance; all soil, waste, and vent stacks are to be rigidly secured with wall hooks or other approved fastenings. All lead branches to closets or other fixtures are to be connected to the cast iron with heavy brass ferrules and wiped joints; all lead pipe used on the drainage system is to be equal to 7-pound sheet lead in thickness; all nickel-plated waste pipes are to be connected to lead branches with wiped joints concealed by heavy nickel-plated brass flanges; the vent pipes intersecting the roof are to be flashed with 6-pound sheet lead. The location and the proper height to which the vent pipes will be run shall be directed on the job; the top of each vent pipe is to be protected with an approved woven-wire ball screen. All the waste connections and vent connections exposed to view under the fixtures are to be nickel-plated brass and all are to be provided with suitable brass floor and wall plates.

Leaders.—The leaders from the roof down to a point about 5 feet above the ground, or where directed, shall be furnished and installed by the sheet-metal contractor. The plumber will continue the extra-heavy cast-iron leader drain up to and above the ground to receive these leaders, leaving them plumb and neat and in true alinement for the leaders. The leader traps are to be located under the cellar floor where shown and provided with brass screw-cap clean-outs; the leader drains outside the building are to be of cast iron.

WATER-SUPPLY SYSTEM

Main Line.—From the street main in Clay Avenue run a 1¼-inch extra-heavy, galvanized-iron service pipe into the cellar through the front wall. Cover this pipe with a heavy coat of R. I. W. paint to prevent corrosion. Obtain and pay for a 1¼-inch tapping to the street main. Connect the corporation cock to the galvanized service pipe with 1¼-inch **AAA** lead pipe and brass solder-nipple connections. Place a stop-cock and a curb box at the curb. Run the service pipe line at least 5 feet below the ground and finish with 1¼-inch plugged **T** inside the cellar. On the house side of the **T**, place 1½-inch gate valve, with a drip cock on the house side of the valve. On the house side of this drip cock place a 1½-inch Kieley pressure-reducing valve. Place a suitable pressure gauge on the house side of the pressure-reducing valve and set the valve so that it will hold up 30 pounds per square inch pressure in the building independent of street variations. On the street side of the pressure-reducing valve, take off a ¾-inch galvanized-iron pipe, run same to supply a ¾-inch hose bib to be located where directed for lawn sprinkling purposes, and place a ¾-inch roundway stop-and-waste cock on this line in the cellar. Continue from the pressure-reducing valve with a 1½-inch galvanized-iron water main to the several risers. Leave a plugged **T** where directed to supply a steam boiler in the future. Run a 1-inch branch to the laundry tubs, a ½-inch branch to the safe-waste sink, a ¾-inch branch to the butler's pantry sink, a 1¼-inch branch to the reception-hall lavatory, a 1¼-inch branch to each toilet room containing flushometer valves. Take off ¾-inch branches to all baths, and ½-inch branches to all basins. Place a gate valve on each branch to each toilet room and a drip cock on the house side of each gate valve. Place a gate valve or roundway stop-and-waste cock on all branch lines from both the hot and the cold main distributing lines to control any part of the building without shutting off any other part, where directed. Valve each closet tank and hot and cold supply to basins separately. Run all the pipes in the cellar neatly along the cellar ceiling, supporting them rigidly with suitable tinned pipe straps and screws. Use beaded malleable-iron fittings all through the job for the water supply pipes; all threads must be clean-cut. Grade all cellar pipes down to the several drip cocks, and make provisions for all the pipes to be easily drained without traps.

Safes.—Lay a 14-ounce soft-rolled copper pan under the entire floor of the bathrooms over the dining room and over the den, making an upstand all around and back of the baseboard. Properly lock all seams and solder same water-tight. Run a 1¼-inch waste pipe from the second-floor safe to the cellar ceiling. Run a 1¼-inch waste from the third-floor safe to the cellar ceiling over the sink. Test these safes by filling them with water after the roughing is all in.

BOILER CONNECTIONS

Set the boiler on a strong galvanized-iron stand where directed. Connect it to the coal range with 1-inch semiannealed brass tubing and to the gas range with ¾-inch semiannealed brass tubing. Leave a plugged T at the top and another at the bottom of the boiler for future connection to a steam water heater. From the top of the boiler, run a 1-inch hot-water distributing line, branching off to the bathroom over the dining room and return with a ½-inch circulation pipe. Connect the circulation pipe to the bottom of the boiler with a ¾-inch connection, placing a swing check and stop-cock on the line where directed. From the 1-inch hot-water distributing main at the kitchen ceiling, run a ¾-inch branch up to the bathroom on the third floor and return with ½-inch pipe, which will join the ¾-inch circulation pipe from the bathroom over the dining room. Place a stop-cock on both the hot and circulation branches to control both bathrooms. From the top of the boiler, run a ¾-inch hot-water pipe to supply the bathroom over the kitchen without providing for circulation. Run a ½-inch hot-water supply pipe along the cellar ceiling to the vestibule basin without providing for circulation. Place a gate valve on the cold-water supply above the kitchen boiler and a gate valve on each main line running from it. Run a ¾-inch sediment pipe from the kitchen boiler to the safe waste sink in the cellar. On top of the kitchen boiler place a ½-inch safety valve of approved make of the spring pop pattern. Discharge the safety valve into the sediment pipe and load the safety valve to blow off at 40 pounds per square inch.

All the pipes for supplying both hot and cold water throughout the entire building are to be the best quality galvanized iron, except where specified otherwise. All the fittings are to be strong malleable-iron galvanized beaded fittings or brass beaded fittings.

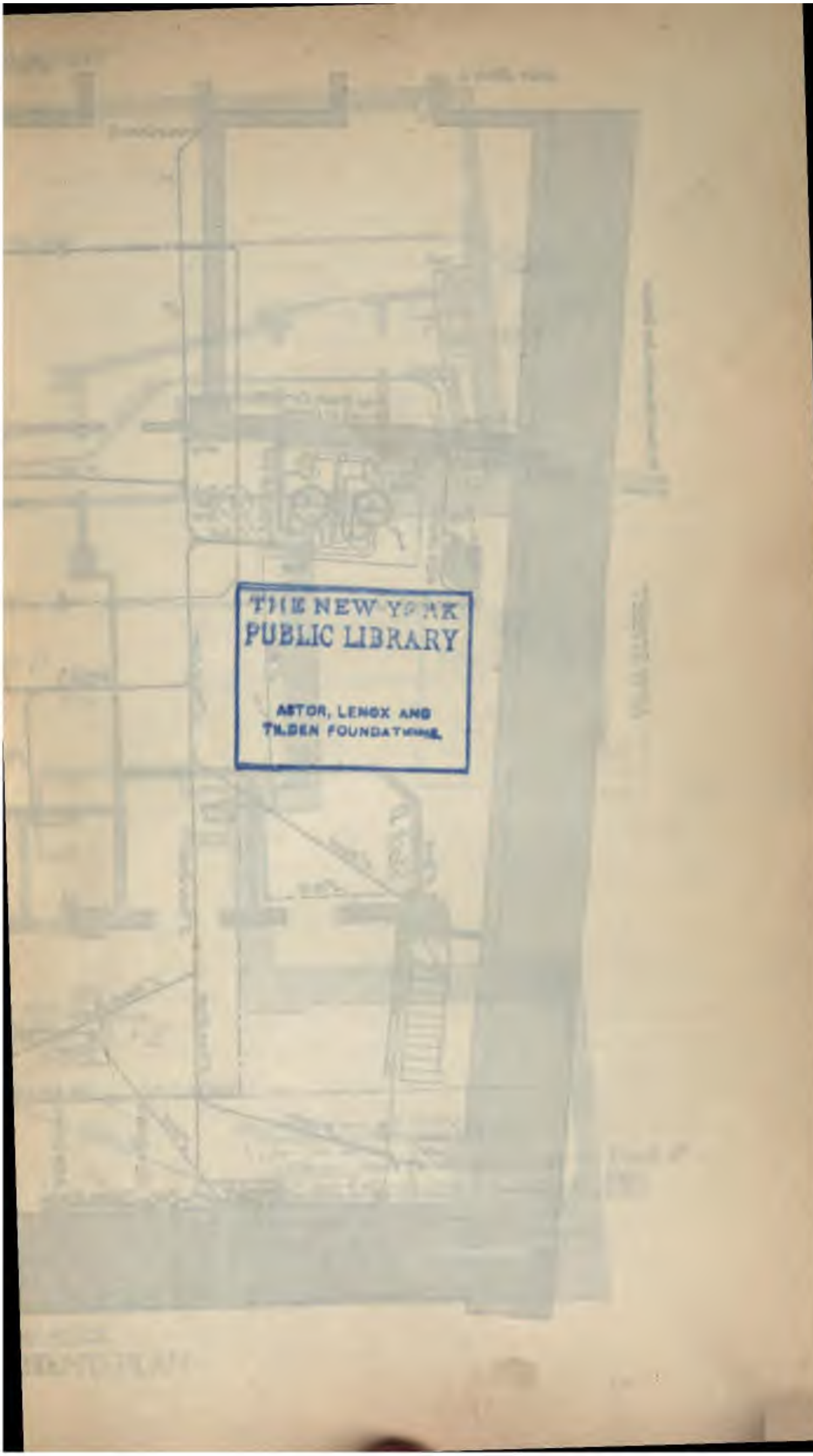
Galvanized-iron ring-plate hangers are to be used where the pipes run along finished ceilings or against finished walls. All hot-water and cold-water pipes exposed to view under the fixtures are to be of nickel-plated brass, iron-pipe size, finishing at the floor or walls, as the case may be, with heavy brass nickel-plated flanges; all hot-water pipes are to be graded so as to pitch back to the boiler and are to be provided where necessary with drip cocks, so that every pipe can be emptied easily.

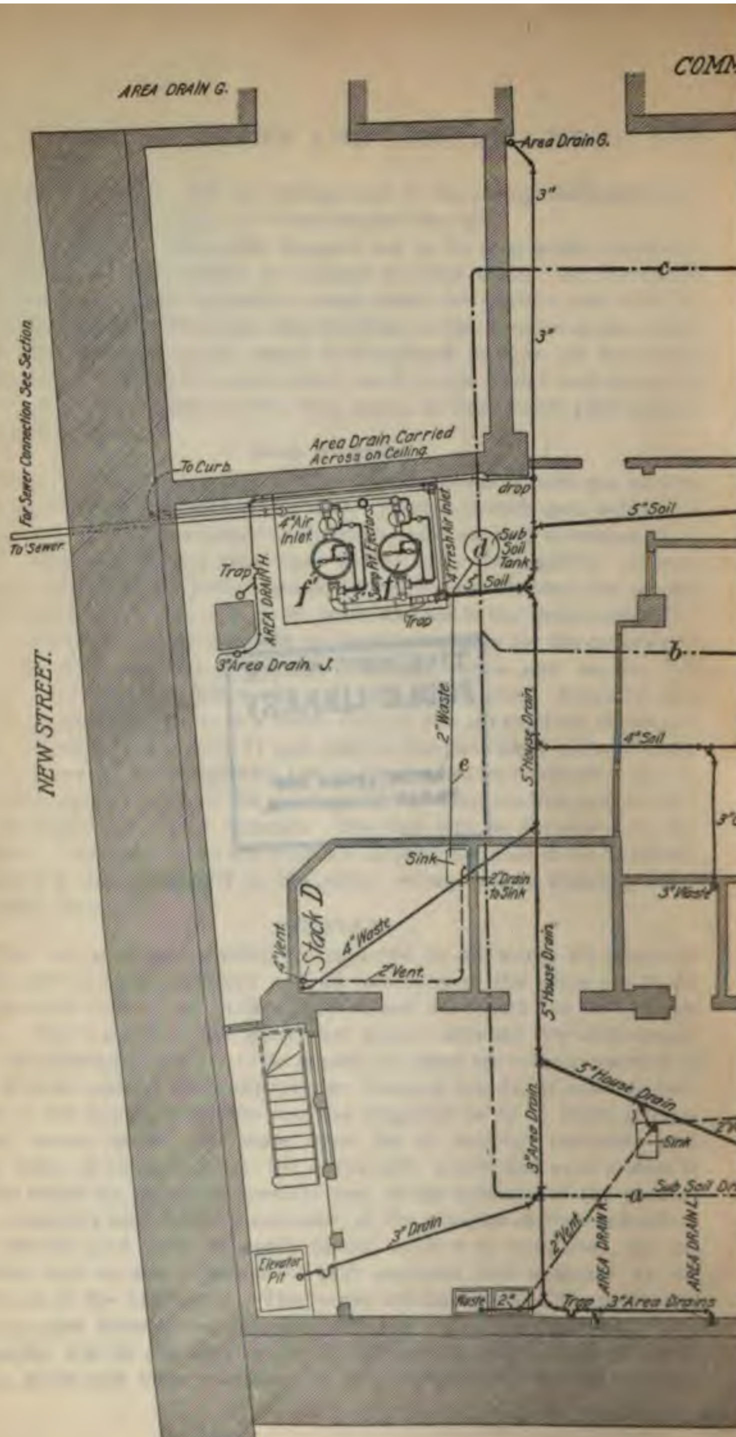
GAS PIPING

From the 4-inch gas main on Clay Avenue, run a 1½-inch gas service pipe in through the front cellar wall. Place a 1½-inch gate valve just inside the wall, and another at the curb, with an iron extension curb box. Drip this service pipe back to the main, if possible. If not, place a drip cock and pocket inside the cellar wall. Protect the service pipe with a heavy coat of R. I. W. paint and fill in the trench carefully. The contractor will be required to furnish and pay for the tapping of the gas main and the connection. He will obtain and set the gas meter. Connect this meter with a 1½-inch **D** lead pipe. Run a 1½-inch gas pipe from the meter to a point beyond the connections to the gas logs. Then continue with 1¼-inch pipe to the gas range in the kitchen and connect up the range and the gas water heater complete. Run a ¾-inch gas pipe to each of the gas logs in the reception hall and connect to the logs complete as directed. The logs will be furnished by the owner. There will be no gas used for lighting purpose in the building. Leave a ¾-inch plugged **T** at the cellar ceiling, where directed, for a laundry stove.

FINALLY

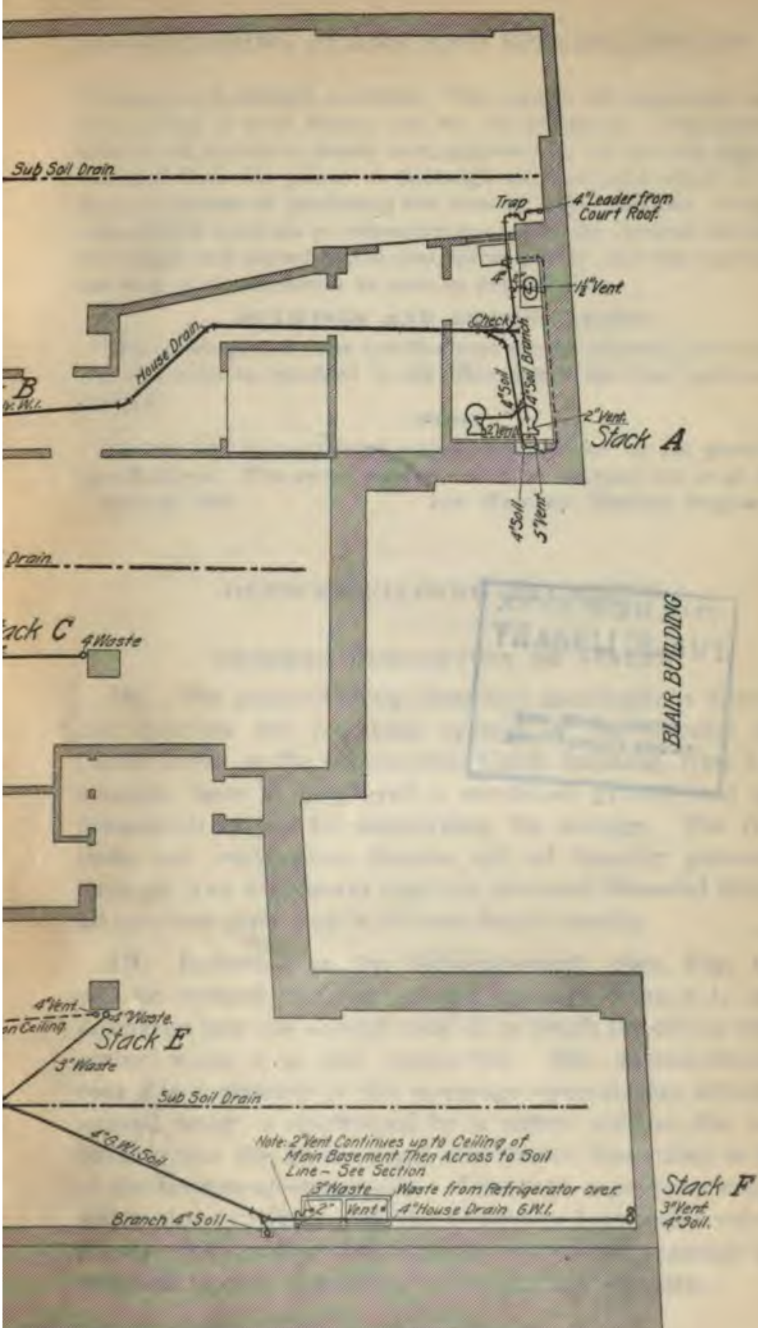
The city ordinances must be respected in all work; all cast-iron pipes are to be extra heavy and all junctions of the same are to be made with oakum and molten lead calked flush with the face of the hub. The weights of the pipes must accord with the city ordinances; all the soldered joints are to be wiped; all pipes are to be supported in the firmest manner with appropriate hangers, bands, or other fastenings to be approved by the sanitary engineer so as to effect strong, neat, secure work. All pipes must be of uniform thickness and free from all imperfections; the entire soil, waste, and vent system is to be tested by the water-pressure test, in the presence of the plumbing inspector and sanitary engineer, at the expense of the contractor; the whole work is to be again tested, after it is completed, by the smoke test in the presence of said inspector and engineer at the expense of the contractor. The owner will furnish and fit up all necessary pipe boards and planking for the pipes and fixtures. The plumber will be required to pay for all permits and furnish all materials, tools, and labor necessary to duly complete his work and leave





COMM
AREA DRAIN G.
Area Drain G.
3"
c
For Sewer Connection See Section
To Sewer
To Curb
Area Drain Carried
Across on Ceiling
drop
5" Soil
4" Air Inlet
Sump Air Ejectors
4" Fresh Air Inlet
Sub Soil Tank
d
5" Soil
Trap
AREA DRAIN H.
3" Area Drain J.
b
NEW STREET.
2" Waste
e
5" House Drain
4" Soil
3" G.
Sink
2" Drain to Sink
3" Waste
Stack D
4" Vent.
4" Waste
2" Vent.
5" House Drain
5" House Drain
Sink
3" Area Drain
a
Sub Soil Drain
3" Drain
2" Vent
AREA DRAIN K
AREA DRAIN L
Elevator Pit
Waste
2"
Trap
3" Area Drains
·TH

ABLE BUILDING



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the same in a finished condition. The owners will execute all necessary cutting of walls, beams, etc. for the plumbers. The workmen must be all first-class, steady men, approved by the sanitary engineer, who will have the power to discharge any workman whom he may deem incapable of producing the class of work required. Preparations for the wo^rk are to commence as soon as the contract shall have been made and signed by the contracting parties, and the erection of the work is to commence as soon as practicable.

DRAWINGS AND SPECIFICATIONS

The drawings and these specifications are the property of the architect and must be returned to his office before the final certificate is granted.

BIDS

No bid will be considered unless accompanied by the plans and specifications. The owner reserves the right to reject any or all bids.

June 30, 1904. Jos. Hawley, Sanitary Engineer.

OFFICE-BUILDING PLUMBING

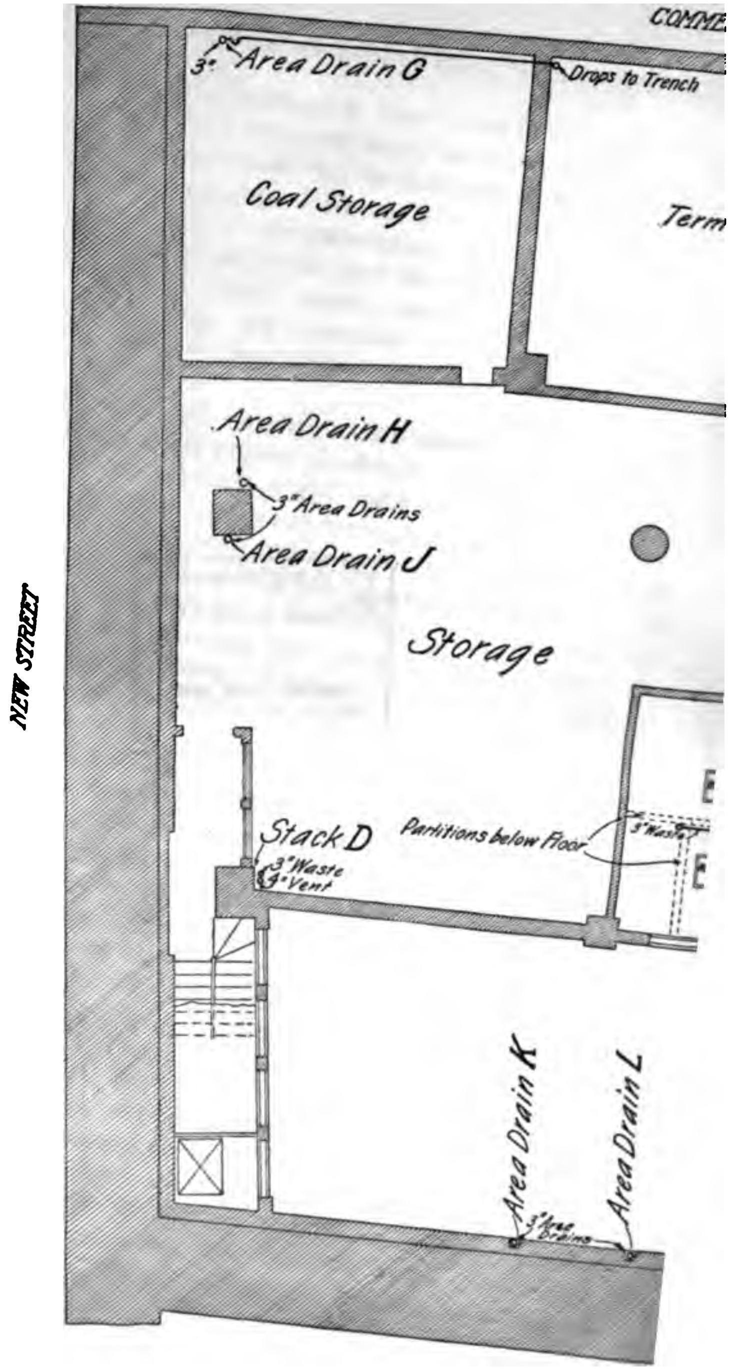
GENERAL DESCRIPTION OF SYSTEM

18. The accompanying plans and specifications illustrate and describe the plumbing system in the recently completed annex to the Commercial Cable Building, New York, wherein there is employed a combined gravity and compressed-air system for discharging the sewage. The rising lines and connections thereto are of heavily galvanized wrought iron with heavy cast-iron recessed threaded fittings; all cast-iron pipe used is of extra-heavy quality.

19. Referring to the third-basement plan, Fig. 6, it will be noticed that the subsoil drainage lines *a*, *b*, and *c* discharge into the subsoil tank *d*, to which the 2-inch refrigerator waste *e* is also connected. The subsoil-drainage tank *d* is connected to the sewerage system, into which the subsoil water is discharged by a siphon ejector, the water passing into the house drain and thence into either or both of the sewage ejecting tanks f, f' through a properly trapped waste pipe provided with the necessary back-water valve to prevent sewage from backing into the subsoil drainage lines and tank in case of accident to the sewage ejectors.

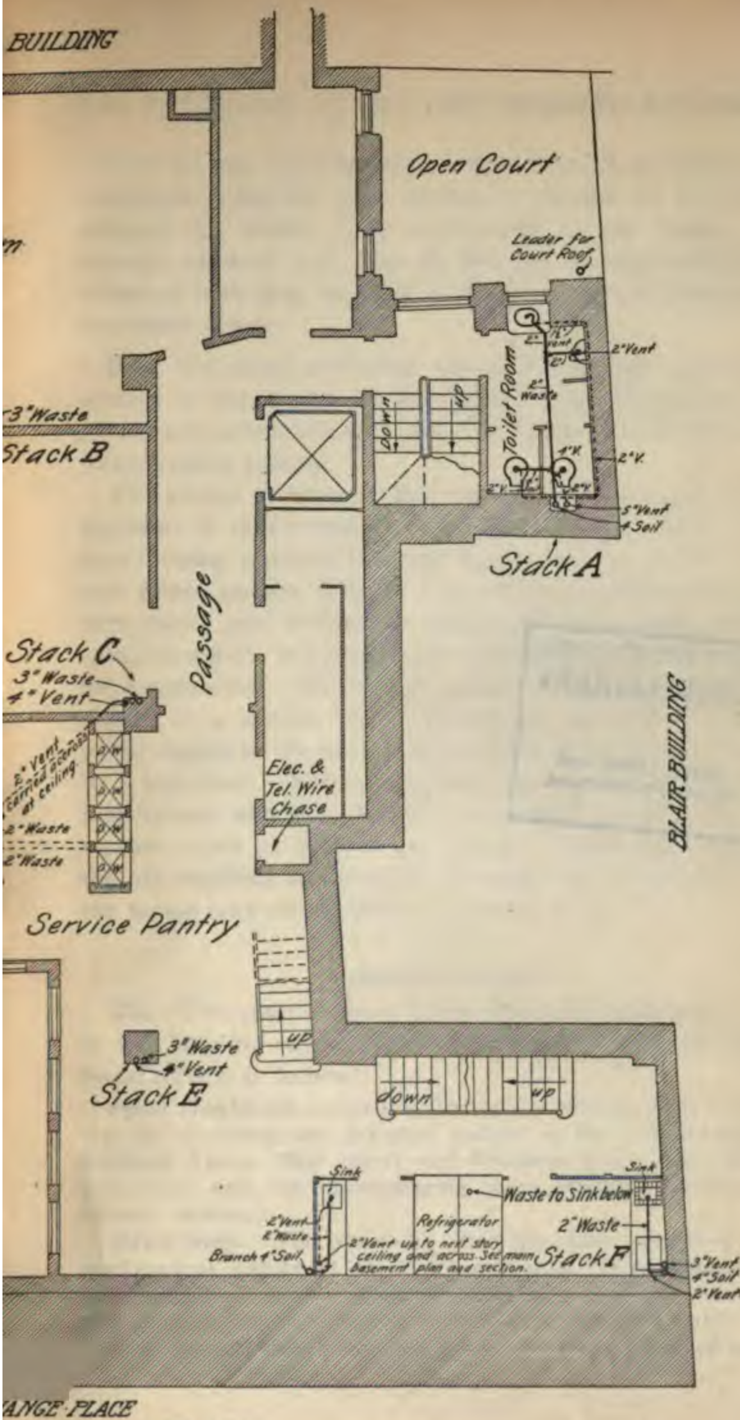
As is frequently necessary in large office buildings having several stories below the street level, the house-drainage system is arranged in two sections, the discharge from one section being effected by gravity, while that from the other is accomplished by the use of compressed-air sewage ejectors *f*, *f'* located in the sump pit in the third basement. As shown on the third-basement plan, various waste pipes, soil pipes, and area-drain pipes are connected into the 5-inch house drain that discharges through the ejectors in the sump pit.

20. As indicated on the main-basement plan, Fig. 8, the main drain of the gravity discharge section of the house drainage system runs along the south wall of the old building and discharges by gravity through a running trap into the 7-inch house sewer, and thence into the New Street sewer. The house drain of the gravity discharge system also receives the discharge from a portion of the plumbing system in the new building (see stack *A*, Fig. 12), the main drain being carried along the wall in an easterly direction to a point opposite the toilet rooms in the eastern side of the new building, where it is run through the south wall of the old building, across the court of the new building in the channel iron shown in detail in the main-basement plan, Fig. 8, and thence through the court wall, just beneath the ground-floor toilet room in the new building, as indicated on the sectional view, Fig. 12, showing the various rising lines of the plumbing system. From the ground floor to the roof, all the waste from the toilet-room fixtures on the stack *A* is discharged through this gravity system, which also receives the discharge from the rain-water leaders, as indicated at the left of Fig. 12. The soil and waste line for the fixtures below the ground floor on stack *A*, Fig. 12, is connected into the vent line above the highest waste fixture on the lower line, as shown, and continued upwards to the roof. The vent lines are connected at the bottom with the soil and waste lines below the lowest fixtures, the waste of the nearest fixture being connected above the bend. The waste from stacks *B*, *C*, *D*, *E*, and *F*, the location of which is



NEW STREET
COMME
3" Area Drain G
Drops to Trench
Coal Storage
Term
Area Drain H
3" Area Drains
Area Drain J
Storage
Stack D
3" Waste
4" Vent
Partitions below Floor
3" Waste
Area Drain K
Area Drain L
3" Area Drains

SECO



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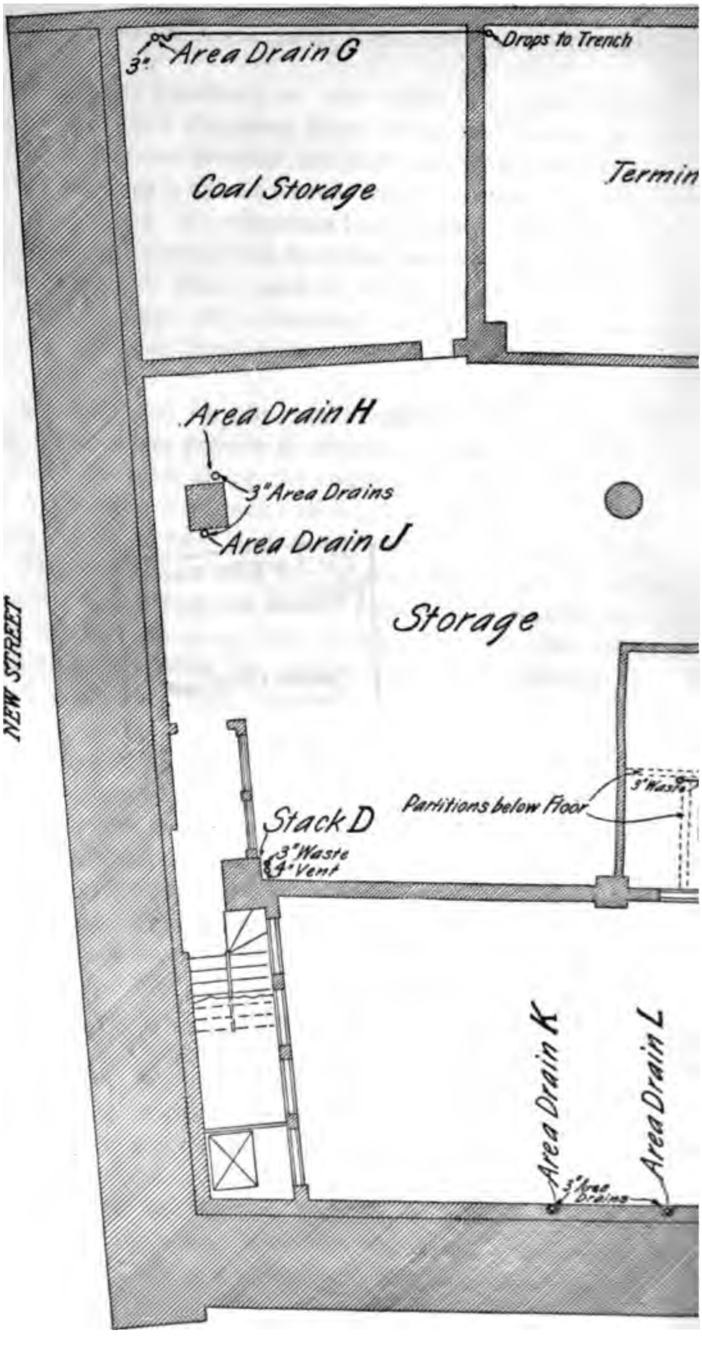
3"
Area Drain G
Drops to Trench
Coal Storage
Termin
Area Drain H
3" Area Drains
Area Drain J
Storage
NEW STREET
Partitions below Floor
3" Waste
Stack D
3" Waste
4" Vent
Area Drain K
Area Drain L
3" Area Drains

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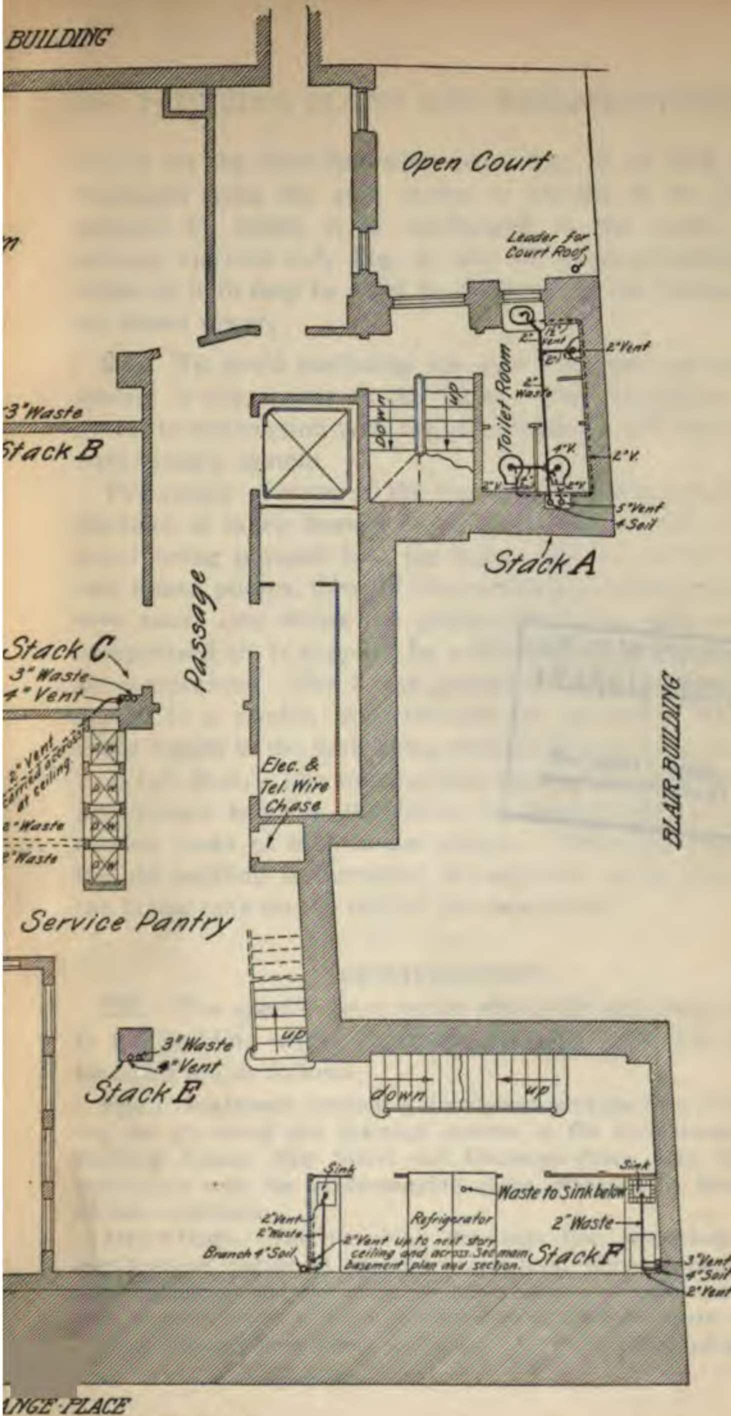

BUILDING
Open Court
Leader for Court Roof
Toilet Room
2" Vent
2" Waste
4" V.
2" V.
5" Vent
4" Soil
Stack A
Down
up
3" Waste
Stack B
Passage
Stack C
3" Waste
4" Vent
2" Vent carried across at ceiling
2" Waste
2" Waste
Elec. & Tel. Wire Chase
BLAIR BUILDING
Service Pantry
up
3" Waste
4" Vent
Stack E
down
up
Sink
Waste to Sink below
Sink
2" Vent
2" Waste
Branch 4" Soil
Refrigerator
2" Vent up to next story ceiling and across. See main basement plan and section.
2" Waste
Stack F
3" Vent
4" Soil
2" Vent
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shown on the third-basement plan, Fig. 6, as well as the discharge from the area drains, is carried to the sewage ejectors by which it is discharged to the sewer. The sewage ejectors f, f', Fig. 6, are so cross-connected that either or both may be used in discharging the sewage into the street sewer.

21. To avoid confusing the pipe lines the water-supply system is not shown on the plans. The description here given, in conjunction with the specifications, will explain the water-supply system.

The supply of water to the various plumbing fixtures and fire-lines is taken from a large house tank on the roof, the water being pumped into the house tank by one or both of two house pumps, directly over which are located two pressure tanks into which the pumps discharge and to which compressed air is supplied by a Westinghouse steam-driven air compressor. The house pumps are independently connected to a suction tank beneath the basement floor, the water supply to the tank being controlled by a valve operated by a ball float. The water-supply main to the suction tank, just before entering the latter, is cross-connected to the suction pipes of both house pumps. The water supply for the old building is furnished through the supply pipe from the house tank on the roof of the new annex.

SPECIFICATIONS

22. The specifications under which the plumbing system in the building whose plans are given in Figs. 6 to 13 was installed are as follows:

Specifications covering materials and workmanship for installing the plumbing and drainage systems in the Commercial Cable Building Annex, New Street and Exchange Place, New York, in accordance with the accompanying plans prepared by Howells & Stokes, architects:

Drawings.—The plumbing drawings that accompany these specifications consist of the following plans: third-basement plan, showing subsoil, leader, and house-drain lines; second-basement plan; first- or main-basement plan; ground-floor to third-floor plan; fourth-floor to fifteenth-floor plan; roof plan. All these plans indicate the location of soil, waste, and vent stacks. There is also presented a sectional elevation corresponding to the layout indicated on the third-basement plan and showing various soil, waste, and vent stacks and attached fixtures. The drawing entitled Gravity House Drain and Ejector Discharge Pipes (Fig. 13) is a sectional elevation showing the course of the stack *A*, also the connections between the sewage ejectors in the sump pit and the New Street sewer.

Scope of Work.—Included under the plumbing contract will be the complete installation of the plumbing and drainage system, to include all sewerage from all fixtures throughout the building, the drainage of all roof water, areas, etc., the proper venting of all lines, and the furnishing and setting of all fixtures and other work, as may be more particularly called for and shown on the plans, sections, elevations, and in these specifications.

Toilet for Workmen.—The plumbing contractor is to furnish and set at some convenient point in the building, at as early a date as possible, toilet connection, with the necessary hopper, seat, enclosure, etc. for the convenience of the workmen of this building. This toilet is to be kept in a perfectly clean condition and is to be supplied with running water, and is to be cleaned out, disinfected, and removed whenever requested by the architects. Provide one toilet on the first and eighth floors.

Materials.—The cast-iron pipe used is to be extra heavy throughout. All fittings are to be extra heavy and of standard make.

The wrought-iron pipe used is to be of extra-heavy manufacture and of the proper sizes, as called for, and is to be heavily galvanized throughout. Fittings for wrought-iron pipe are to be extra-heavy cast-iron recessed-and-threaded drainage fittings.

Lead pipe is to be of the grade known as D.

Brass pipe is to be thoroughly annealed seamless drawn brass tubing of standard iron-pipe gauge. Fittings on brass pipe are to be heavy cast-brass fittings, to be recessed and threaded where necessary.

Valves.—All valves used throughout the work are to be of the standard Fairbanks or Jenkins Bros. manufacture.

Joints.—All joints between cast-iron pipes are to be made up with spun oakum and pig lead. The pipe is to be set concentric and the joints are to be thoroughly filled and calked until the same are tight.

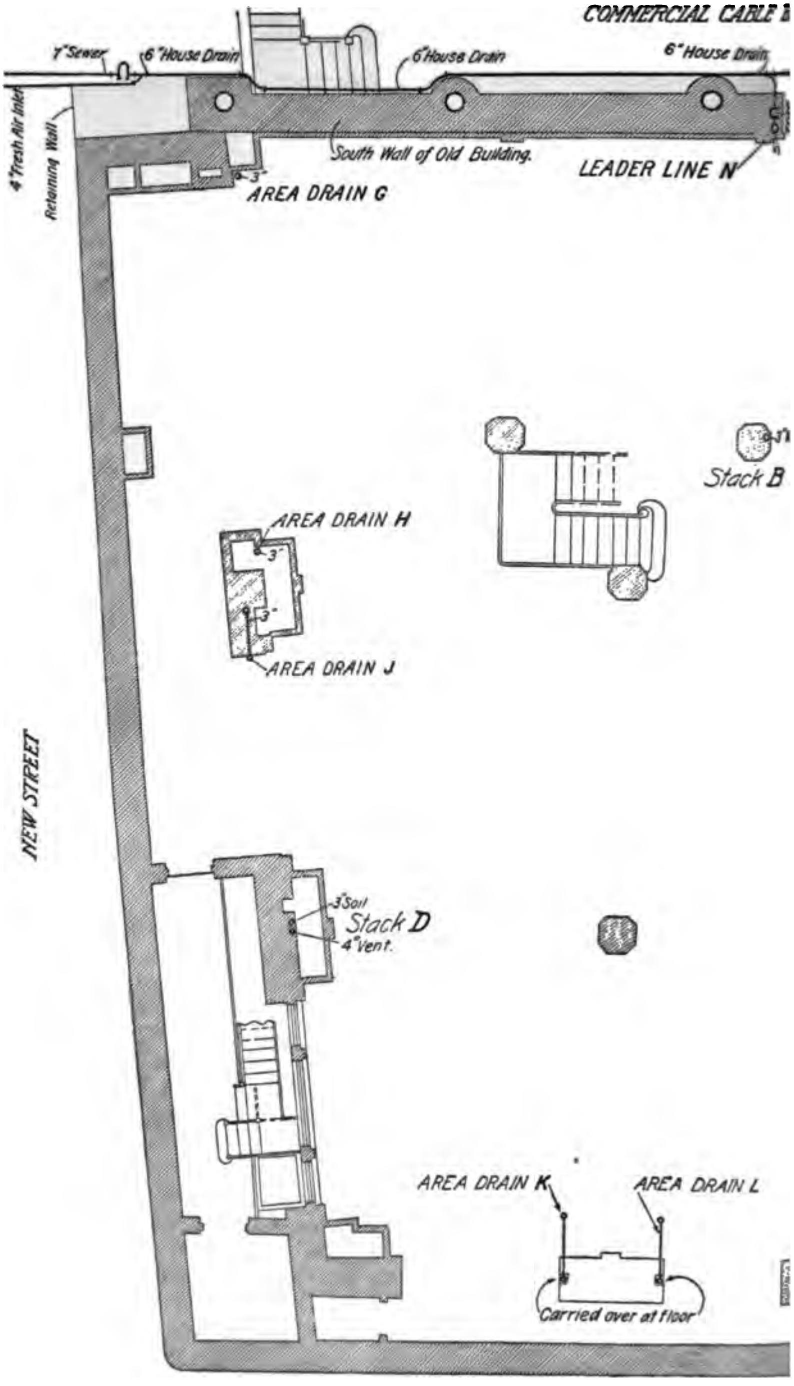
All joints in galvanized wrought-iron pipe are to be made up with threaded connections in red lead.

All joints between lead pipe are to be wiped solder joints.

All joints between lead pipe and iron pipe are to be made with long heavy proper-sized brass ferrules thoroughly calked into the iron pipe and a wiped solder joint between the brass ferrule and the lead pipe.

All joints in brass pipes are to be screwed joints made up with white lead.

Slip joints beyond the trap seals will not be accepted.



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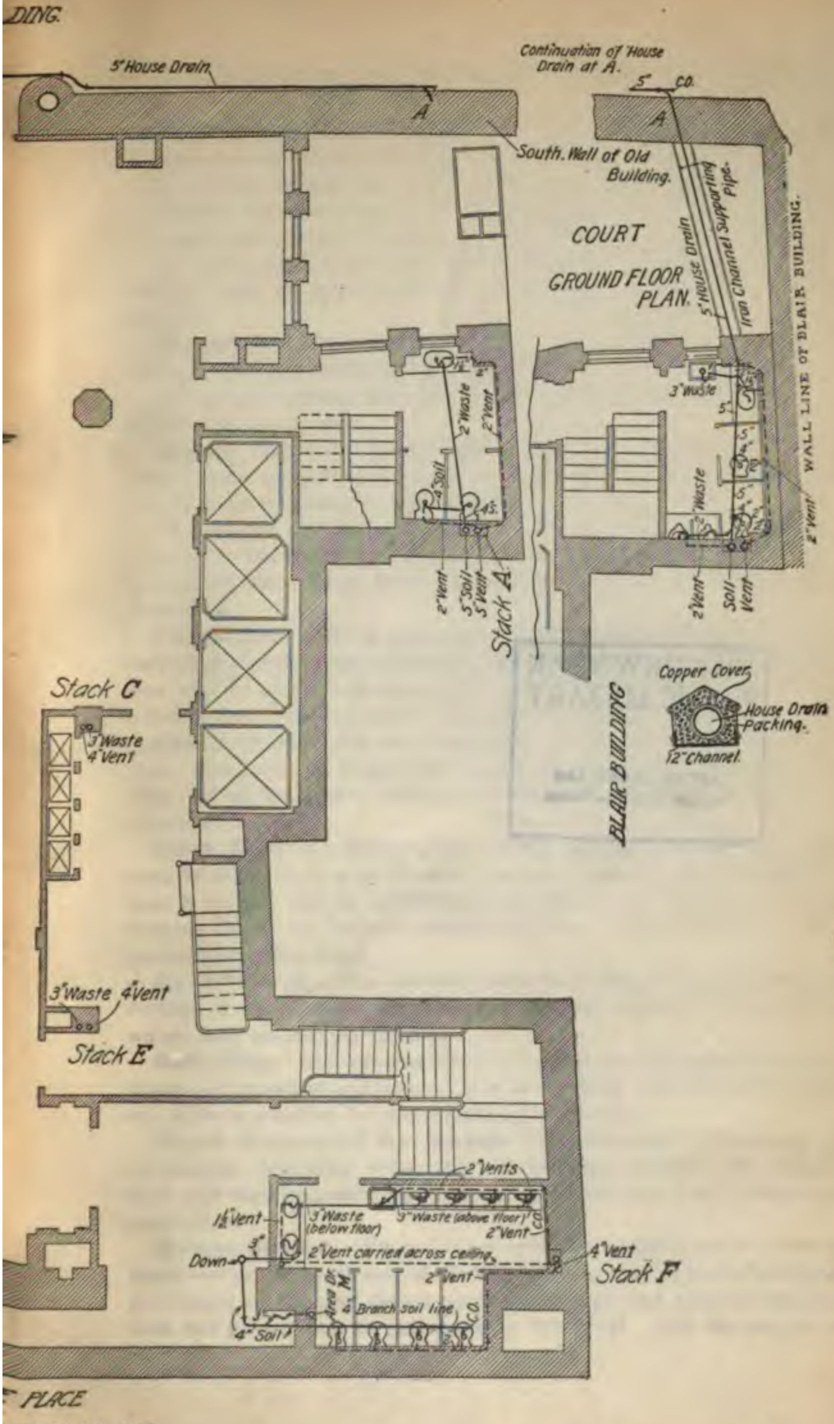

PLACE

MENT·PLAN·

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Piping.—All piping shall be run as direct as possible, substantially as shown on the plans, avoiding unnecessary bends and outlets.

No piping, whether so drawn on the plans or not, shall be run so as to interfere with the proper installation of the work of other contractors, and such piping shall be altered to run as directed by the architects.

All sewer and drain pipes are to have a uniform fall of ¼ inch to the foot, and all other pipes are to be properly pitched in a uniform manner.

Hangers.—All horizontal runs of piping shall be supported on wrought-iron adjustable hinged hangers.

All vertical piping shall be supported on adjustable hinged pipe bands of wrought iron.

Exposed piping in finished rooms shall be hung and supported on hinged pipe hangers and supports of the same material as the piping and shall be secured in a neat manner.

All hangers and supports shall be of the pattern, and spaced, as directed by the architects, and any special hangers or supports required to support the piping shall be furnished and set by the plumbing contractor.

Thimbles.—Where pipes pass through walls, floors, or partitions, they shall pass through adjustable telescope thimbles of either wrought-iron pipe or galvanized-iron pipe, properly flanged and to be at least ½ inch larger than the outside diameter of the pipe.

Clean-Outs.—All clean-outs shall be provided with brass screw-caps. All running traps shall have two clean-outs. The foot of all lines and all changes in direction of the house drain shall be provided with clean-outs.

Roof Joints.—Where pipes extend through the roof, the joints shall be made tight with 16-ounce copper, flanged out on to the roof at least 8 inches, and be carried up the pipe to the first joint; the cap flashing is to be calked tightly into this joint, and all is to be guaranteed waterproof.

Excavating.—The plumber shall do all the excavating inside and outside of the building for the house sewer, house drains, and the water- and gas-supply piping.

Refilling.—All trenches shall be refilled with clean earth in 12-inch layers and puddled and tamped in place, and all repairing of the street, etc. is to be paid for by the plumbing contractor.

Work Executed by Mason Contractor.—The sump pit, excavation, retaining walls, and the trenches beneath the basement floor and their retaining walls will be excavated and built by the mason contractor.

House Sewer.—From the inside of the retaining walls of the first basement at the south end of the old building run an extra-heavy cast-iron sewer of the size shown on the drawings and connect the same, with the proper fall, to the sewer in the street. Into the end of this cast-iron sewer calk, in a first-class manner, the end of the galvanized wrought-iron main house drain pipe from the new building.

House Trap.—On the house drain line, just inside of the retaining wall, on the horizontal run of pipe leading to the street, furnish and install an extra-heavy running trap, to be of extra-heavy galvanized iron and to have two threaded brass clean-out screws.

Air Inlet.—Connect the house trap on the house side by means of a proper size galvanized wrought-iron pipe. Carry this inlet up to the sidewalk and have it end in a brass grating set in the sidewalk, with a suitable frame.

House Drain.—Continue the house drain, as above called for, with proper rise, in an easterly direction along the south wall of the old building until the same is opposite the toilet rooms in the eastern side of the new building. At this point turn the drain south and through the south wall of the old building, across the court of the new building on the channel iron hereinafter called for, rising sharply, and enter the court wall where shown, just beneath the floor of the ground-floor toilet room in the new building. From this point continue as specified under Rising Lines. All waste from the fixtures of the toilet rooms, from the ground floor to the roof, will be carried out through this gravity system. All fixtures below the ground floor and all office fixtures will discharge through the sewage ejector as hereinafter called for. The soil line for the fixtures below the ground floor is to be continued up to and above the roof, forming the vent line for the fixtures above the ground floor and is to have a separate vent throughout the basement stories, properly cross-connected to the vent above-mentioned and above the highest waste fixture of the lower line.

Sump Tank.—In the sump pit below the floor of the third basement, furnish and set two heavy wrought-iron riveted tanks, having a capacity of 100 gallons each, to be circular in form, to have flanged bottoms and tops, and all to be made of iron ½ inch thick, and to be put together in a thoroughly first-class and workmanlike manner; joints of the tanks are to be double-riveted and calked until air-tight, and tested to withstand 200 pounds pressure per square inch.

These tanks are to be provided with all the necessary riveted flanged connections, flanged manholes, etc. and are to be installed in accordance with the Ellis system of sewage ejection and are to be properly connected by means of galvanized-iron pipe of the size shown on the drawings; the outlet is to be taken from the bottom of the tank and is to be carried up vertically to the third-basement floor, thence horizontally under the coal-bin tracks into the old building, and is to rise vertically to a point 4 feet above the level of the house drain, as above mentioned, and then by means of a return bend is to be connected to the house drain.

Where the vertical run from the sump tank changes its direction to the horizontal, place a cleanout T with a screw-cap on the back side in all cases.

Steam Connection.—From the top of the sump tanks furnish and set a proper size steam connection, with check-valve, to be thoroughly secured to the tank and properly valved and to be run through the subbasement of this building to a point near the house pumps, to which the steam mains from the present Commercial Cable Building steam plant will be brought. Make a proper connection to the same with long-turn bends.

Compressed Air.—Furnish and set complete, where directed in the basement, two electrically driven air compressors; each is to be capable of compressing at least 15 cubic feet of free air per minute and maintaining a pressure of 35 pounds. Each compressor is to be provided with an unloading device and is to be arranged to work entirely automatically. Compressors are to be valved and cross-connected so as to work together or separately and so that either or both can be used on the air tank for the sewage lift. Put checks on the air pipe to the sewage air tank and arrange them so that there is no possibility for air to return to the compressors.

Furnish and set where shown, near the air compressors and hung from the ceiling by galvanized-iron hangers, or supported on galvanized-iron stands from the floor, an air-receiver tank 5 feet long by $2\frac{1}{2}$ feet in diameter, made of $\frac{1}{4}$-inch steel shell, $\frac{3}{16}$-inch heads, all double-riveted, strongly braced and stayed, and warranted to stand 150 pounds per square inch working pressure; the tank is to be provided with riveted flanged inlets and outlets, safety valve, pressure gauge, valved emptying pipe, manhole plate, guard and gasket complete. Make all connections with the compressors and the receiving tank with proper-sized pipe and provide all valves, checks, etc. complete.

Water System.—The water system is to be properly connected with the water system of the building, and is to be properly valved, check-valved, and all to be arranged to work automatically to discharge the sewage from the tanks into the sewer with the least possible amount of water.

Fixtures.—The sump-pit tanks are to be provided with the necessary governing valves, wheel gate valves, on both inlet and discharge pipes, of proper size, and one No. 2 Ellis automatic sewage lift, guaranteed to discharge not less than 200 gallons per minute for each tank. The working of this sewage ejector is to be satisfactory and reliable and all is to be installed under the direction of The Ellis Company and operated under a steam pressure of 100 pounds per square inch.

From the sump tanks on the building side, and properly connected to the same with clear-way check-valves, run underneath the basement floor and other places where so shown proper sewerage lines having $\frac{1}{4}$ inch drop to the foot, all to be galvanized wrought-iron pipe. All changes of direction are to be made with Y fittings, with cleanouts in the end of the Y's.

Rising Lines.—The rising lines of the waste, soil, and vent lines shall be of galvanized wrought-iron pipe connected to the house drain with Y fittings and extended through the roof.

The bottom of the vent lines shall be connected to the soil and waste stacks below the lowest fixture and the waste of the nearest fixture shall be connected to same above the bend. Lines less than 4 inches in diameter shall be increased to 4 inches below the roof and continued 4 inches in size throughout the same to a point 6 feet above the roof.

Fixture Branches.—Fixtures are to be connected to the waste, soil, and vent stacks through the following size branches of galvanized wrought-iron pipe:

	Waste Inches	Vent Inches
Water closets	4	2
Wash basins	2	1¼
Wash trays	2	1¼
Sinks	2	1¼
Slop sinks	3	2

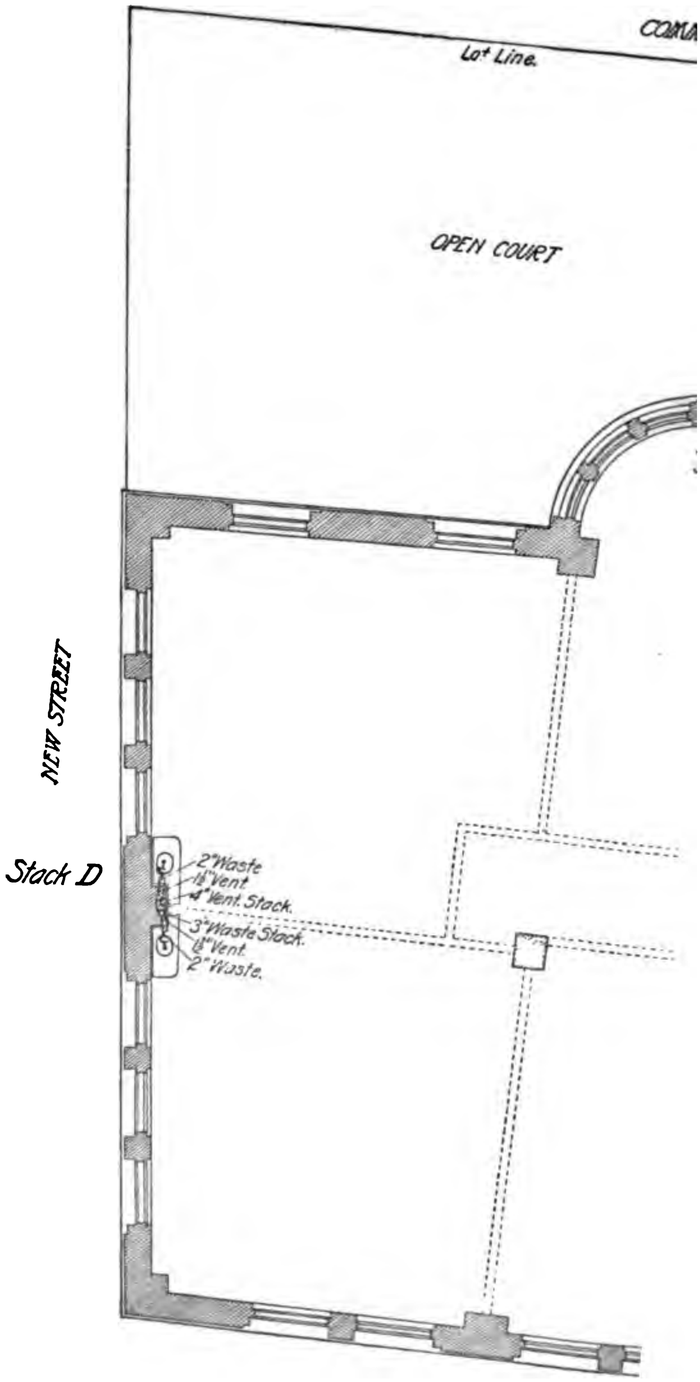
Fixture Connections.—The basin, sink, and wash-tray traps shall be screwed directly into the galvanized wrought-iron pipe.

The water closets shall be connected to the soil lines with brass screw floor flanges and 4-inch lead bends. These bends are to be as short as possible and the vents to the closets shall be connected to the top of the lead bend below the floor line.

Leaders.—Furnish and set where shown on the drawings galvanized wrought-iron leaders, to be of the size shown. At the roof end, they are to have a brass expansion-joint connection to allow of the soldering of the copper leader to the same.

The water from the pent-house roof will empty on to the main roof. The main-roof water will be taken down in one leader on the north side and this leader will empty on to the roof of the court over the ground-floor corridor. The roof of the fourth-story extension will be drained in a copper leader called for under "Roofing Work" and will empty on to the roof of the ground-floor corridor. The roof of the ground-floor corridor will be drained into one leader on the north side and this will continue down vertically below the ground-floor level and will then pass through the wall of the old building and connect to the house drain at this point. The roof of the court over the third basement will be drained by a leader connected to the third basement toilet-room drainage lines. All leaders will be trapped at the foot of each before they enter the drainage systems by means of a running trap with a cleanout.

Leader in Old Building.—In the south wall of the old building where the door on the ground floor connects the corridors, there now exists an old leader which must be cut off above



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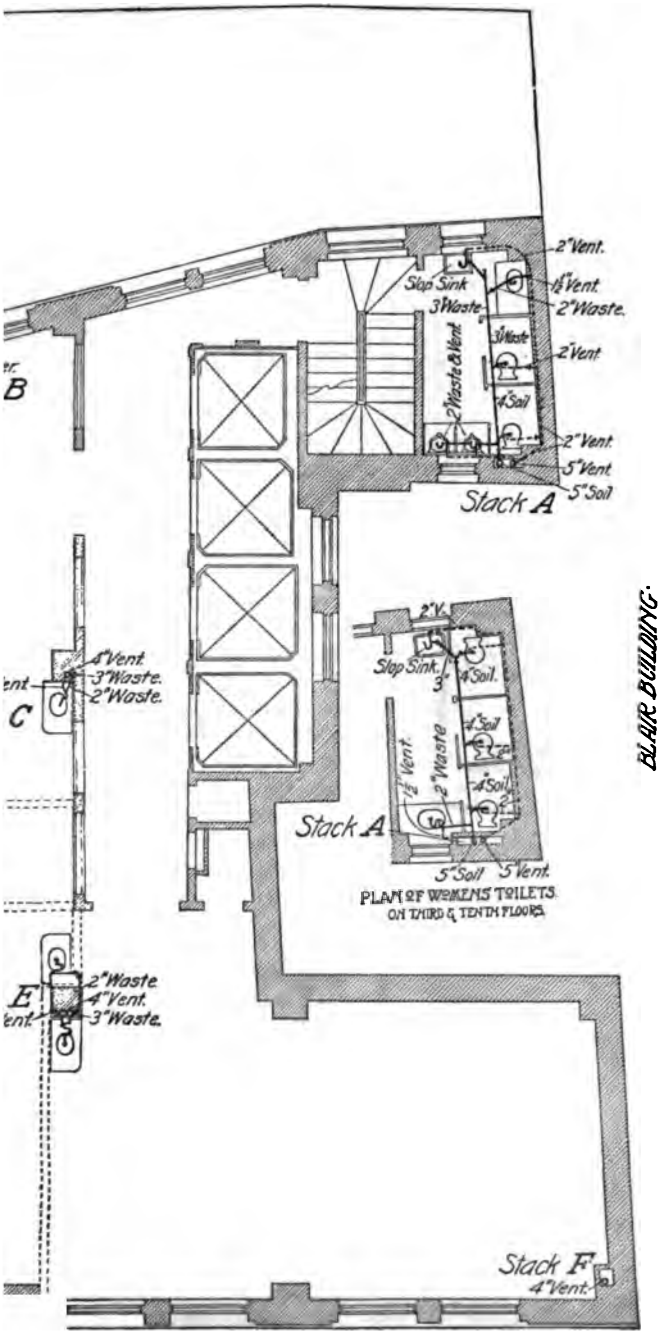

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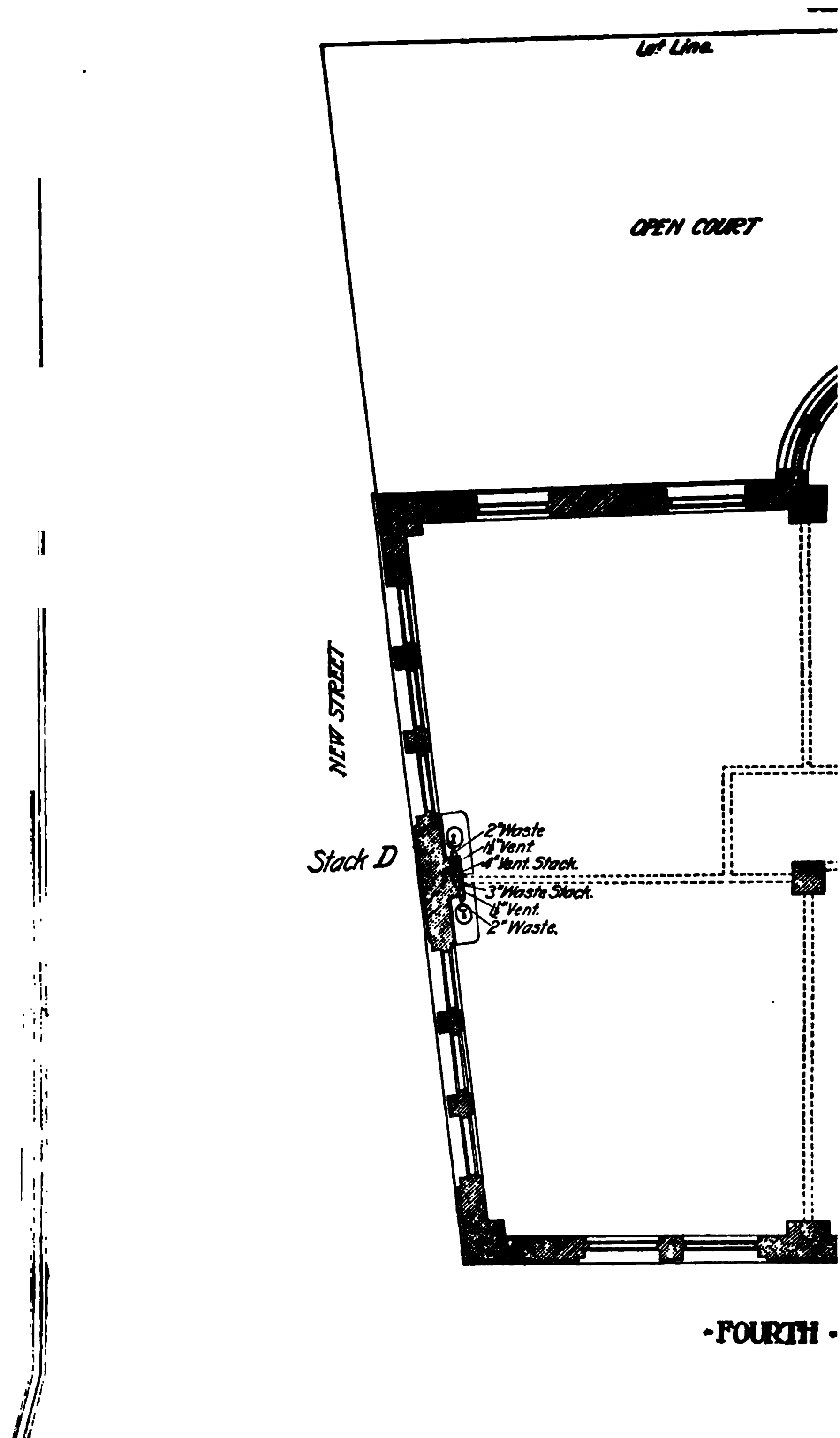
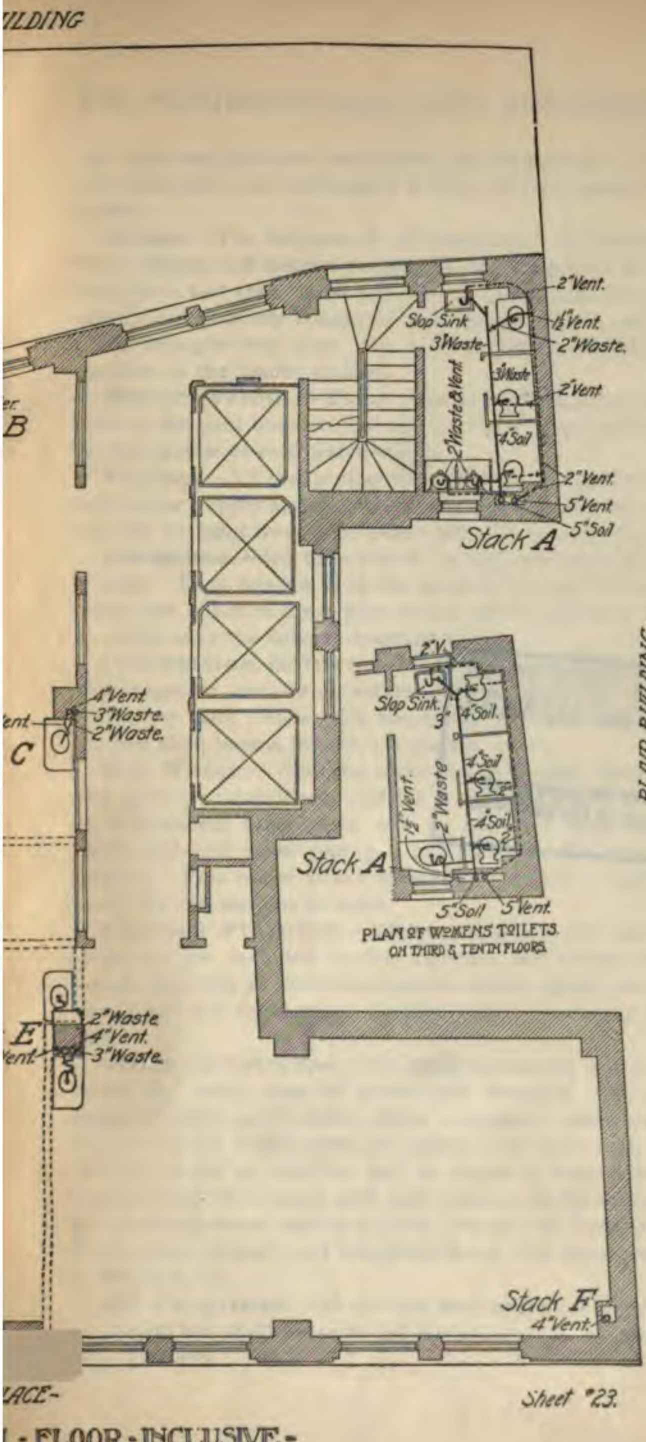
Sheet #23.

- FLOOR - INCLUSIVE -



Lot Line.
OPEN COURT
NEW STREET
Stack D
2"Waste
1½"Vent
4"Vent Stack.
3"Waste Stack.
1½"Vent.
2"Waste.

·FOURTH ·


ILDING
2"Vent.
Slop Sink
1½"Vent.
3"Waste
2"Waste.
3"Waste
2"Vent
2"Waste & Vent
4"Soil
2"Vent.
5"Vent.
5"Soil
Stack A
B
C
E
4"Vent.
3"Waste.
2"Waste.
2"Waste.
4"Vent.
3"Waste.
2"V.
Slop Sink.
3"
4"Soil.
4"Soil
4"Soil
2"Waste
1½" Vent.
Stack A
5"Soil
5"Vent.
PLAN OF WOMENS TOILETS.
ON THIRD & TENTH FLOORS.
BLAIR BUILDING:
Stack F
4"Vent.
LACE-
Sheet #23.
-FLOOR-INCLUSIVE-

the door and run over horizontally far enough to avoid the doorway and then down and back again horizontally to connect with its original outlet.

Areas.—The bottoms of all areas shall be provided with square brass frames and hinged perforated brass covers with brass cesspools without a bell trap, to be soldered to the copper work in the window areas, and properly connected and trapped to a proper-sized galvanized wrought-iron pipe, the same to be connected in the proper manner to the leader system.

Water System.—The contractor shall pipe the building from the tank in the pent house to the various fixtures throughout the building for the system of cold-water supply.

Piping.—All the piping throughout for both the hot- and the cold-water supply system, where the same is concealed, shall be galvanized wrought iron, with heavy galvanized cast-iron fittings.

Branches.—No fixture is to be supplied with less than a $\frac{3}{4}$-inch branch. Each branch is to be properly pitched to drain back to the main and a $\frac{1}{2}$-inch drain pipe with a valve is to be run from the main to empty over the subsoil-drainage sump.

Circulation Return.—Each hot-water line shall be provided with separate circulation return carried back and connected to the boilers or tank inside with emptying valves. All branches to the fixtures shall have a branch circulation return.

Hot Water.—Only the sinks of the kitchen, the sinks of the service pantry and scullery, and the wash basins and slop sinks of the main-basement toilet room will be supplied with hot water. Hot-water and cold-water piping is to be run to the range boiler in the kitchen. This boiler is not included here, but all piping will be run ready for connections to same.

Kitchen Fixtures.—Kitchen, scullery, and service-pantry fixtures are not included in this contract, but waste, vent, and water-supply pipes for all the above fixtures, where shown, are to be included herein and will be installed complete, ready to connect fixtures to same later.

Office Lavatories.—All office lavatories are to have exposed waste and vent lines of galvanized wrought iron, and are to be supplied with cold water from concealed galvanized-iron pipes. Care is to be taken with all piping that same may be erected as close to walls as possible and to make a neat job. All exposed piping other than waste and vent pipes is to be nickel-plated brass. All galvanized-iron piping is to be bronzed, as hereinafter called for. Throughout ground and basement floors this piping will be conceald in columns, etc.

Air Chambers.—In no case shall any pipe terminate at a valve or faucet, but shall be provided with a vertical air chamber of sufficient capacity.

Control of Piping.—In addition to the control previously specified, each fixture and each group of fixtures shall be controlled with valves in such a manner that each fixture may be cut out without interfering with the supply of any other fixture.

Sill Cocks.—Run ¾-inch pipe to two sill cocks where directed. At the sidewalk, the sill cocks shall be of brass, with hose connection, and controlled with a removable key.

Testing Drainage System.—When all the traps are set and the drainage and vent piping is completed, the ends of the piping shall be temporarily plugged and the system filled with water, as directed by the architects.

Testing Water-Supply System.—The entire system of hot-water and cold-water supply piping shall be filled with water and a pressure of 150 pounds to the square inch developed.

Retesting.—Should any leaks or defects develop under the test these shall be made good and the system retested, and the operation shall be repeated until the entire system is made tight, and all damage caused by leaks or other defects shall be made good by the plumbing contractor.

Finishing.—Where exposed pipes pass through walls, floors, partitions, marble, or wood work, they shall have cast brass flanged escutcheons, the same to have nickel-plated finish and the same to be on both sides of the floors, walls, or partitions.

All exposed piping throughout the entire building above the second basement will be nickel-plated brass pipe, except where otherwise noted.

All exposed piping not otherwise covered shall be cleaned of all oil, grease, dirt, and scale and given a coat of sizing and aluminum bronze.

No water pipe is to be run on outside walls, and all water piping exposed to the action of frost is to be covered, where necessary, with hair felt and jacketed with canvas sewed on. All other exposed metal work, including tanks, is to be painted with three coats of lead and oil paint.

Fire-Lines.—Furnish and set where directed, throughout all floors, including basements and roof connection, fire-lines of the size pipe as indicated or required, the same to be of galvanized wrought iron, with all the necessary fittings of extra-heavy cast iron. On each floor, at a height of about 7 feet from the floor, leave an outlet and extend the same in a neat manner through the wall, exposed piping to be nickel-plated brass, and leave connection for the attachment of a 2½-inch hose. On each floor furnish and erect a hose reel, to be firmly secured to the wall and supplied with 75 feet of rubber-lined first-quality linen hose, the same to have all necessary brass couplings, to be supplied with a brass fire-nozzle, and to be properly attached to the fire-line and also to be properly valved with a heavy nickel-plated brass valve. The supply for this fire-line is to be taken from the tank

on the roof and is to be run to the sidewalk level where directed, and is to have a heavy polished-brass Siamese fire-connection having standard New York Fire Department thread, and the line is to have a check-valve at the foot.

Hose Reel.—Hose reel is to be a Star swinging hose reel, to be made of nickel-plated brass in all parts, to be thoroughly secured to the wall by means of expansion bolts, and to be of the manufacture of John Simons & Co., of New York City.

Pipe Support.—Where the main soil pipe crosses over the court on the east side, furnish and set a 12-inch 20-pound channel to carry this pipe. This channel is to be set on the flat, flanges up, and is to have riveted to each flange one $\frac{1}{4}'' \times 12''$ steel plate to form a box. All this work is to receive three coats of lead and oil paint, both inside and outside. The channel is to rest on the brickwork of the walls for a distance of at least 12 inches. All cutting in connection with this is to be done by the owner.

When pipe has been set in this channel it is to be securely packed on all sides with mineral wool until the box is full. Over this box furnish and set a 16-ounce copper-pitched roof, same to extend down the sides and to be strapped under the bottom of the channel. This roof is to be so arranged as to be removable, and is to be water-tight, and all necessary flashing in the walls is to be included.

Subsoil Drainage.—The plumbing contractor is to furnish and install a subsoil drainage system beneath the floor of the third basement and also beneath the bottom of all trenches. The pipe is to be 4 inches in diameter, non-vitrified round subsoil drainage tile, without hubs, is to be laid with uniform grade, and the joints are to be covered on the top only with a flap of heavy tarred roofing felt. The drainage pipe is to be filled in around the sides of the tile and over the top of the same to a depth of about 3 inches with medium-sized gravel. All subsoil drains shall be run where shown and discharge into the sump tank, which is to be located in the same pit with the ejector tanks, and is to be placed low enough to receive the drainage from the three subsoil lines.

The tank is to be built of $\frac{3}{8}$-inch steel plates riveted together, 2 feet in diameter and 10 feet deep, and is to be sunk 6 feet below the floor of the third basement. This tank is to have a horizontal flange, at least 12 inches wide all around, riveted to same 12 inches under the basement floor. This flange is for the purpose of permitting a water-tight joint to be made with waterproofing at the basement level.

The subsoil tank is to be provided with an internal suction pipe extending upwards inside of the tank, coming out near the top, and then emptying into the sewage system below the basement floor. This waste is to have a trap, a vent, and a check-valve properly set on same.

Refrigerator Waste.—In the refrigerator room, the plumbing contractor is to install a brass floor trap, with removable brass strainer, to be properly trapped, and the trap is to empty over a sink that is to be placed on the exterior wall of the refrigerator, which in turn is to be connected with the sewerage system. All is to be complete in all respects.

Drips.—The drip from all machinery, overhead steam lines, drainage of water pipes, or other drip drainage coming in connection with the plumbing work is to empty over the same sink as the refrigerator waste.

House Tank.—In the pent house of this building, the plumbing contractor is to furnish and set a house tank, the same to be made of $\frac{7}{16}$-inch steel plates, double-riveted, with all joints calked and the tank to be guaranteed absolutely water-tight and air-tight under a pressure of 200 pounds per square inch. The tank is to be circular in form, with dished heads; it is to be 6 feet in diameter and 18 feet long. It is to have all necessary cast-iron flanges for inlet connection, discharge connection, and overflow connection riveted to the same, and also necessary gaskets, and necessary flanged manhole opening and cover, with gasket. The tank is to be properly supported on wrought-iron supports secured to the structural steelwork of the building, and is to be raised at least 18 inches from the floor.

The tank is to have a 4-inch overflow pipe, with the necessary gate valve on the same, the overflow pipe to empty on the roof of the building.

The tank is to be provided at the proper level with water-gauge connections, these connections to be of brass and the water glass to be at least 1 foot long, with the proper drainage and control valves on both the inlet and the outlet. The glass is to be of heavy steam water-gauge manufacture.

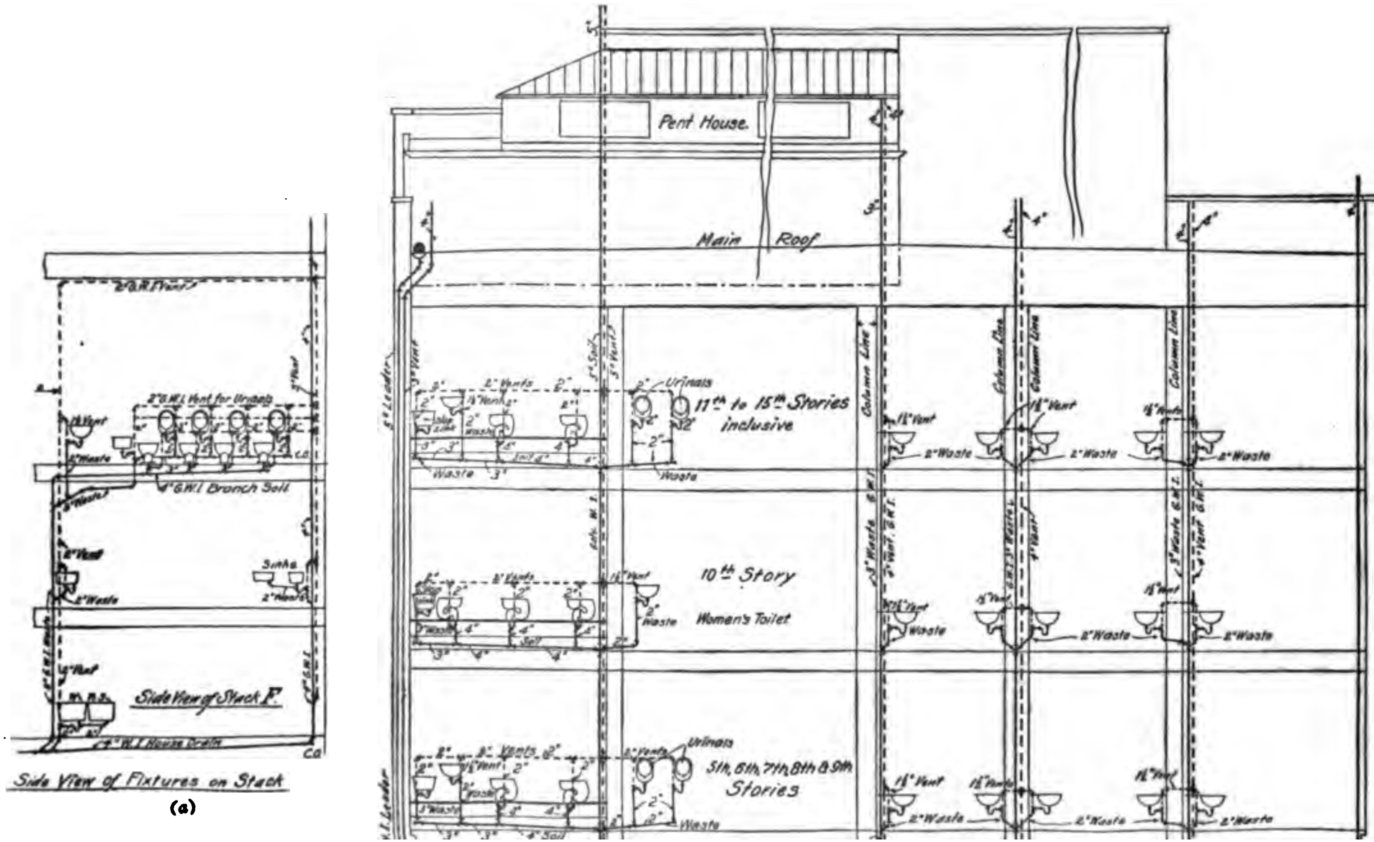
This tank is also to be provided with the proper size relief valve of approved manufacture. This valve is to be so arranged that the pressure may be altered by means of a spring, and all parts are to be made of bronze. The relief valve is to be connected in a proper manner to the overflow pipe.

From this tank carry the proper size of supply pipe down to, and connect the same to the pressure tanks in, the basement. Also, this tank is to be cross-connected by means of a proper size galvanized-iron pipe above the water-line in both the pressure and the house tanks.

This tank is also to be connected, by means of a proper size pipe, with the top of the fire-line, with a check-valve in the same.

This tank is also to be connected with the proper size supply pipe for distributing the water through the entire building.

This tank is also to have a ball float on the inside of the tank, the same to be properly connected by means of electrical connections to the exterior of the tank. This float is to be arranged to denote the level of the water, both when the tank is full and when the same is nearly empty, and the electrical connections are to be carried to the



Side View of Fixtures on Stack

(a)

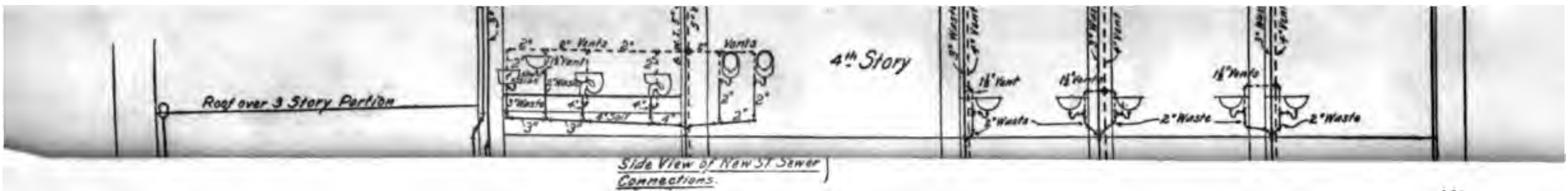

Roof over 3 Story Portion
2" Vents
Vents
4th Story
3" Waste
4" Soil
1½" Vent
1½" Vents
2" Waste
Side View of New St. Sewer Connections.

FIG. 12

§ 64

third basement of the old building, where the same will be within easy access of the engineer. Also install telltale bells and arrows to denote above.

House Pumps.—Furnish and erect where shown on the plans two 10″ × 6″ × 10″ house pumps, the same to be driven by steam, to be of Worthington manufacture, and to be capable of raising 250 gallons of water per minute under a head of 250 feet. The pumps are to be properly connected to the steam mains, which will be brought to this point by the steam contractor, and are also to be properly connected to the exhaust, which pipe will also be brought to this point by the steam contractor. The pumps are to be of the best manufacture, and are to have a capacity fully 25 per cent. in excess of the above requirements.

The pumps are to be connected in a proper manner by means of proper size pipes to the suction tank and also to the pressure tanks, which are to be installed directly over the pumps. The piping is to be provided with all necessary check-valves and controlling valves.

These pumps are to be set on foundations that will be furnished by the mason contractor, and are to be left in complete working order and guaranteed to perform the work required of them and are to be provided with all necessary petcocks, packings, holding-down bolts, sight-feed lubricators, etc., complete.

The pumps will be tested as to their capacity, and the strokes must not exceed 100 per minute for the above work with steam pressure at 125 pounds per square inch.

Air Pump.—Furnish and set near the house pumps, and connect to the air pipe that forms the cross-connection from the pressure tanks to the house tank, by means of galvanized-iron pipe, one Westinghouse automatic steam air compressor. Steam is to be taken from the main feeding the house pumps, and is to exhaust into their exhaust pipe. All feed and exhaust pipes are to be properly valved and dripped. The air compressor is to have its steam and air cylinders properly packed and provided with sight-feed lubricators and all necessary petcocks. The compressor is to have a capacity for raising the air pressure in the pressure tanks to 200 pounds per square inch and shall have an automatic shut-off valve to close off the steam when the required pressure has been reached. The compressor will operate under a steam pressure at the boilers of 125 pounds per square inch and will be tested accordingly.

Pressure Tanks.—Over each pump, hung from the ceiling or supported from the floor by means of galvanized-iron pipe supports, furnish and erect a $\frac{7}{16}$-inch metal pressure tank, to be $2\frac{1}{2}$ feet in diameter, 8 feet long, ends to be dished, all joints to be double-riveted and calked, all to be guaranteed air-tight and water-tight, and to be tested with a pressure of at least 200 pounds to the square inch; each tank is to be provided with the necessary flanged openings, properly threaded and riveted to the same; all openings are to have the necessary gaskets; each tank is to be provided with a water gauge similar to that specified for the house tank. Each pressure tank is to be connected, as above mentioned, to the pumps, and is also to be connected to the supply main of the house tank, and is to be connected to the foot of the fire-line, and is also to be cross-connected with an air pipe to the house tank, as above mentioned.

The flanges on all pipes of the plumbing work that come, or that join, to the flanges of pipes brought to this point by the steam contractor, are to be made strictly to match the above flanges, and this contractor is to make the connections between these flanges, providing the necessary bolts, gaskets, etc.

Suction Tank.—Furnish and set a suction tank in the floor at the side of the pumps. The same is to be square in shape, to be made of $\frac{5}{16}$-inch steel, all joints to be double-riveted and calked, tank to be approximately 7 feet wide, 10 feet long, and 8 feet deep, to have cover riveted on the same, to have all necessary flanged openings, flanges to be made of cast iron, to be properly threaded, and to be properly riveted and calked, with all necessary gaskets and manhole and cover to the tank.

Furnish galvanized-iron suction pipe from the bottom of the tank to the pumps, each pump being connected independently; also make connections from the present water supply of the old Commercial Cable building by means of a proper size pipe, being of the full diameter of both inlets of old building. On the end of this supply pipe furnish and set a valve, all portions of which are to be made of bronze, the same to be worked automatically by means of a ball float in order to shut off the supply of water when the tank becomes full.

The water main feeding this suction tank is to be cross-connected to the suction pipes of both pumps before it enters the suction tank, and is to be properly check-valved.

The supply pipe from the house tank is to be brought down full size to the third basement, and is there to be connected in a proper manner to the piping of the present building wherever required, and is also to be carried full size through into the old Commercial Cable building, where the plumber is to make proper connections with the old water system in order to furnish the old building with water from the new house tank.

Changing Water Mains.—The plumber is to disconnect and remove all the present 4-inch water mains in the present building in the space immediately in front of the boilers, and is to raise the mains to a point near the ceiling where the same will clear all steam pipes. In this new line the plumber is to provide and leave all necessary T's, and is to cap such as are to feed the injectors to the boilers. This piping to the injectors is to be done by the steam contractor. All necessary T's for cross-connection to the new building are to be left and

the old water mains are to be connected to the new water mains in a proper manner.

Old Sump Pump.—The plumbing contractor is to disconnect and remove the old sump pump, which is located in the old building. He is to replace the same on the new foundations, which will be in a different situation from the present, and is to make all proper connections between the pump and the sump pit and the pump and the discharge pipes, and the pump and the steam connections, and also the exhaust connections.

All water connections other than the above are to be made in order that the pump may perform all operations to which it is now put.

Old House Pumps.—The plumber is to disconnect and remove both of the present house-tank pumps, removing all steam, exhaust, and other pipe connections, the same to be delivered to the owners in all parts.

Old Pressure Tank.—In the subbasement of the old building, the plumbing contractor is to remove the present pressure tank, the same to become the property of the owners; he is also to remove all connections to the same, making all new connections as above specified.

The contractor is to run a water-line along the side wall of the boiler room for supply to the automatic return pumps. Remove the connections to the present return pumps.

Time.—All alterations to the plumbing work or other work done by the plumber in the present Commercial Cable building, are to be performed at such times and in such manner as the architects may direct, and in no case are these alterations to interfere with the operation of any of the present machinery until the new machinery has been placed in position and in running order, and in all respects the plumbing contractor is to work either day or night at such times as will not affect the operation of the present system, which is to be overhauled.

Kitchen Fixtures.—The plumbing contractor is to run the connections to the kitchen fixtures of the proper sizes, but the fixtures and their traps are not included. The connections will be left at a point 6 inches above the floor line and will be capped.

Metal for Marble.—The plumbing contractor is to furnish nickel-plated brass standards, angles, border strips, floor flanges, etc., of approved make, for the full and complete support of all marble or slate work in connection with the toilet room, the standards etc. to be 2 inches in diameter, to have all necessary screw fittings, etc. and to be set in accordance with Plate 274 F of the Meyer Sniffen catalog of 1900.

Gas Piping.—The building plans* show all pipe throughout for gas, with outlets as shown. All pipes shall be of the best quality

* The plans referred to are not reproduced here.

heavy black iron, in no case less than ½ inch in diameter, with heavy malleable-iron fittings. The main is to be carried from the present building, down through the third basement, across into the old building, and to a point where the gas connections enter the old building in the area on the New Street side. At this point this contractor is to install a proper size meter, with all necessary connections, and is to have all necessary work in their line performed by the gas company furnishing service.

The pipes are to be firmly secured in position and properly drained to the point of entrance and provided with an emptying cock at the lowest point. All outlets shall be properly plugged and capped, and the caps left on at the completion of the work.

All pipe is to be put together with red lead, and all is to be screwed up tight.

The entire system shall be thoroughly tested with either an air force pump or a mercury gauge, the test to consist of a half-hour duration with a drop of not more than $\frac{1}{16}$ inch.

All work shall be done in conformity with the regulations of the city and the gas company, and shall be left perfect and satisfactory to the architects. All pipes are to be run to the outlet boxes of the electric work and are to be strongly supported to carry the fixtures.

All gas piping is to receive one coat of red lead and oil after the same has been tested. Each story is to be valved at the floor in order that the same may be controlled independently, and all other necessary valves are to be placed on this system.

Drawings.—The plumbing contractor is to furnish drawings for the approval of the architects showing all systems of piping, the layout of all pump work, sump, subsoil, and other work in the above specifications, and no work is to be performed until the approval of the architects has been received. The architects reserve the right to make any changes in the location and direction of pipes or fixtures as they may see fit, provided they do not change the cost of the work.

Cutting and Repairing.—All cutting and repairing is to be done by the owner.

In General.—All of the above testing will be done under the supervision of the New York Building and Sanitary Inspection Company's men. This is to include the water test, the test of hot-water and cold-water supply, and the final test, and the expense of all tests and also all expenses necessary to secure the certificate of approval of the above-named company are to be paid by the plumbing contractor. The certificate is to be delivered to the architects on the completion of the work.

The plumbing contractor is to furnish all the above fixtures, and such labor and materials as may be necessary in conjunction with the above work to make the same complete in all respects.

Painting.—All the above tanks, engines, pumps, piping, etc. are to be painted with two coats of lead and oil paint.

Water Closets.—All water closets are to be plain, strong, vitreous-china siphon-jet water closets, with 10-gallon round-cornered oak tank, with Puritan valve and Birkery ball-cock, top supply, nickel-plated brackets, nickel-plated link chain with solid metal pull and one-piece wall guide, No. 1 oak seat and cover with nickel-plated hinge, 1½-inch nickel-plated flush pipe and adjustable offset connection, and strong brass floor flange and bolts, with porcelain caps. All is to be approved by the architects.

Wash Basins.—All wash basins are to be 15″ × 19″ oval vitreous-china basins with nickel-plated Vigilant waste with solid metal handle, nickel-plated adjustable offset trap with nipple and escutcheon, and nickel-plated supplies to wall, with controlling valves, and push button self-closing basin cocks. All is to be approved by the architects.

Urinals.—All urinals are to be strong, vitreous-china siphon-jet urinals with No. 7 round-cornered oak tank, nickel-plated clover brackets, nickel-plated link chain with solid metal pull and nickel-plated one-piece wall guides, nickel-plated pipe, and nickel-plated inlet and outlet connections. All is to be approved by the architects.

Slop Sinks.—All slop sinks are to be of white porcelain, measuring 20 inches by 16 inches by 12 inches, with three-quarter roll rim, with plain porcelain back, class B, with bronzed-iron trap standard and brass floor flange and bolts, and ¾-inch nickel-plated Vigilant compression cocks.

Marble Work.—All marble work in connection with the water closets, urinals, and slop sinks herein mentioned will be done by the marble-work contractor.

All marble work in connection with the above-mentioned lavatories is to be supplied and set by the plumbing contractor and is to be white Italian 1¼ inches thick, with molded edges and dished top, with aprons ⅞ inch thick by 6 inches deep, supported on No. 1 offset nickel-plated brass legs, substantially as shown on Plate 110 F of the Ronalds & Johnson Co.'s catalog. All marble work is to be strongly secured to the walls and put together with plaster of Paris and brass clamps.

All backs, end slabs, etc. will be formed by the wainscoting, except in offices, where back or end slabs ⅞ inch thick by 16 inches high will be provided.

Fixtures.—The plumber is to furnish and set complete the following fixtures hereafter described. Unless otherwise called for, they are to be of the best of their respective kinds, and before final acceptance, they are to be thoroughly cleaned and adjusted. In the roughing-in of the work care must be taken in spacing the fixtures so that they will make the best possible appearance when set. All exposed supply pipes are to be nickel-plated brass and are to be provided with nickel-plated brass wheel-handle controlling valves.

LIST OF FIXTURES

Location	Closets	Lavatories	Slop Sinks	Urinals	Sinks
Third basement	2	1	1		1
Second basement . . .	2	1		1	
Main basement	6	3	2	4	
Ground floor	2	1	1	2	
First floor	2	7	1	2	
Second floor	2	7	1	2	
Third floor	3	7	1		
Fourth floor	2	6	1	2	
Fifth floor	2	6	1	2	
Sixth floor	2	6	1	2	
Seventh floor	2	6	1	2	
Eighth floor	2	6	1	2	
Ninth floor	2	6	1	2	
Tenth floor	3	6	1		
Eleventh floor	2	6	1	2	
Twelfth floor	2	6	1	2	
Thirteenth floor	2	6	1	2	
Fourteenth floor	2	6	1	2	
Fifteenth floor	2	6	1	2	

Kitchen, scullery, and service-pantry fixtures are not included in this contract.

Materials and Workmanship.—All materials and workmanship are to be of the best throughout and suitable for the needs to be supplied.

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