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Hot-Water Heating

PREPARED ESPECIALLY FOR HOME STUDY

By
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1082 **EDITION 1**

1082

HOT-WATER HEATING

Serial 1082 Edition 1

HEATING APPARATUS

PIPE FITTINGS AND VALVES

PIPE FITTINGS

1. The **fittings** commonly employed in steam piping are not suitable for use in connection with hot-water heating apparatus, because of the great resistance they offer to the flow of the water, due to the angles being too abrupt. The enlargements commonly made in pipe fittings are of little consequence when steam flows through them; but they retard the flow of water too much in a hot-water heating system, as the motive force of the current is small in proportion to the amount of resistance offered. Elbows for hot-water service should be made with a radius equal to five times the internal diameter of the pipe, as shown in Fig. 1. Such elbows are commonly made of wrought-iron or steel

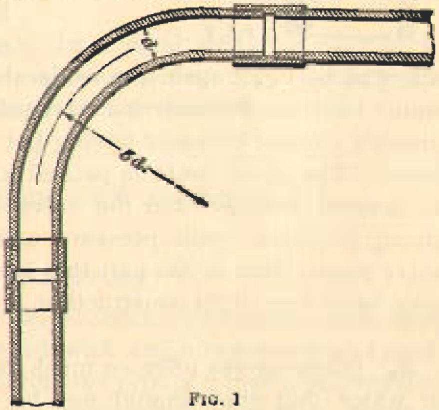

Fig. 1

pipe, bent up to shape, and, consequently, are called **bends.** When common pipe fittings must be employed, the retardation of flow due to extreme resistance may be somewhat lessened by carefully reaming out the ends of the pipe, as shown in Fig. 2.

The common screw union should never be used in hot-water piping; instead, the right-and-left coupling should always be employed. In large pipes, flanged unions may be used.

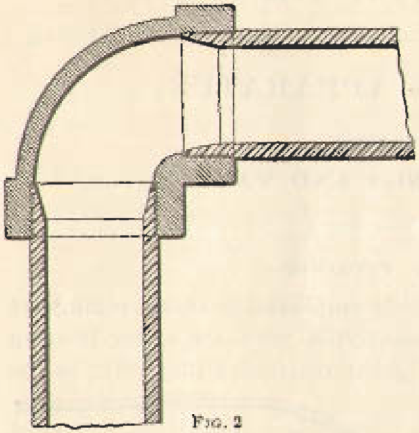

FIG. 2

VALVES

2. The essential features of **valves** used in hot-water heating are very different from those of valves employed in steam heating or in ordinary plumbing. In the latter cases, the valves must close with sufficient force to be tight against considerable pressure; but in hot-water heating, the valves are required to merely check or direct a current of water having but a very small propelling force. The stems must be packed with equal care, however, to prevent leakage, and the valve bodies must be equally strong to resist static pressure and rough usage; but the valve proper, that is, the part that serves to shut the passage, may be of very light construction.

3. Globe valves offer so much resistance to the passage of water that they should not be employed in hot-water apparatus at any point. The common angle valve offers considerable resistance, but is tolerated mainly for want of something better. It may be used as a radiator valve, but it should never be used in main-line piping, because the turn is much too abrupt.

4. Gate valves should be used exclusively in all the piping of a hot-water system. The heavy internal construction employed in steam valves may be dispensed with. A light single gate is sufficient, and the powerful operating screw required for steam or water may even be replaced by a light sliding stem and lever. Lever valves have advantages over valves operated by a wheel and screw, in that the position of the lever always indicates whether the valve is closed or open, and there is never any uncertainty about the proper mode of operating the valve.

5. To prevent the water in a radiator from freezing when the radiator is not in use, a common practice is to have a small hole (about ⅛ inch in diameter) through the valve so that a slight circulation will always be maintained in the radiator when the valve is shut. This by-pass to the valve is intended to furnish enough circulation to prevent the temperature of the radiator from reaching 32° F. when the air is near zero.

The size of the by-pass must be proportional to the size of the radiator, but in very few cases should it be more than ¼ inch in diameter.

Many radiator valves, on the general plan of a plug cock, have been designed for hot-water service, but they are usually so bulky that they are not desirable.

RADIATORS AND BOILERS

RADIATORS

6. Radiators for hot-water heating should be constructed of vertical tubes, connected with ample waterways at both top and bottom. The continuous pipe coil that is so effective in steam heating has few advantages for hot-water heating and is quite inferior to the vertical loop radiator shown in Fig. 3. The circulation in a coil will gradually stop as air collects in the upper pipes or header, but it will continue in a vertical loop radiator as long as the level of the water is above the nipple *a*, Fig. 3. If it falls below the nipple *a*, the hot water will diffuse slowly up each side of the loop, while the main circulation passes directly from the inlet to the outlet.

The connections of the loops to each other at the bottom should be no more than equal in area to the supply pipe, otherwise the resistance will be so great as to seriously impede the main circulation.

7. In the **Detroit loop radiator** for hot-water heating, Fig. 3, each loop is complete in itself and requires no base or supply chamber. The loops are connected together in any number desired by means of nipples *a*, *c*. The construction of this class of loops is often varied so that they comprise three or even four parallel tubes. They are also modified so as to form flue radiators.

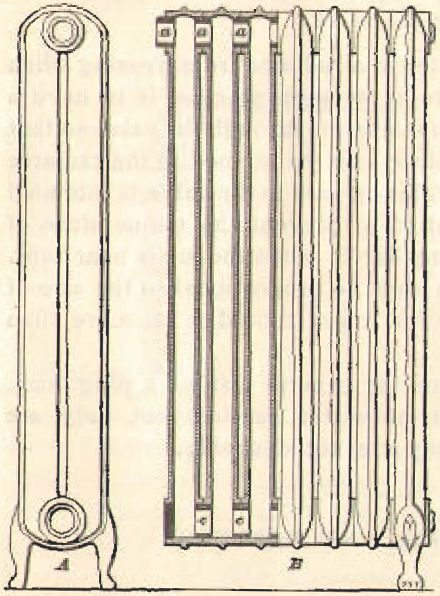

Fig. 3

8. Hot-water radiators must have two connections, one for the inlet and the other for the outlet. They cannot be operated successfully with a single connection. The supply may enter the top or bottom of the radiator, but the outlet should connect to the bottom.

In using hot-water radiators for indirect heating, particular care must be taken to prevent them from being frozen by circulation being shut off. The best preventive is simply to connect such radiators direct to the system without any controlling valves being attached to them; this will insure a constant circulation while there is a fire in the boiler.

BOILERS

9. The **boilers** used with hot-water heating systems are, in all respects, similar to the best forms of steam boilers, except that the spaces commonly reserved for steam room may be dispensed with, or may be utilized for tubes and other heating surfaces. Thus, in a common tubular boiler the entire shell may be filled with tubes.

The circulation in many parts of a hot-water boiler is apt to be much slower than in a steam boiler. The cold water enters at the bottom, and when heated passes out at the top; the general movement is, therefore, upwards, and there is only a moderate local circulation within the boiler. The local convection currents move comparatively slow, because the difference in weight of the ascending and descending parts is small, the actual working height of such local circuits seldom exceeding 2 or 3 feet. The water should pass from the inlet, over the heating surfaces, to the outlet in the most direct manner and with the least possible resistance.

10. The aids to circulation that are so commonly and successfully used in steam boilers are of little or no value in a hot-water boiler. Thus, circulating tubes can rarely be used to any advantage; and drop tubes, which add so largely to the capacity of a steam boiler, have no advantages for heating water, because there is no practicable method for maintaining a rapid circulation through them.

In a steam boiler, the depth of water is comparatively small and the circulation is greatly increased by the formation of multitudes of steam bubbles that mix with the ascending water and make it much lighter than an equal volume of the descending parts of the current. The heating surfaces in a hot-water boiler are, however, usually 40 to 60 feet, or more, below the surface of the water in the expansion tank, and the formation of steam bubbles on the heating surfaces is not desirable, because it is likely to be accompanied by loud rumblings and snapping noises. The bubbles of steam condense on coming in contact with the colder parts of the water and water hammer is the result.

11. The area of heating surface required in a hot-water boiler for a given transmission of heat is the same as in a steam boiler working at the same temperatures of water and combustion. The required areas of grates and chimney are also about the same.

The numerous varieties of hot-water boilers now on the market differ greatly in the volume of water that they contain, although they have equal heating power. A heating system that contains only a small amount of water can be heated quickly, but it will also cool quickly; while, if the volume of water is large, it will act as a reservoir of heat and will maintain a moderate temperature for a considerable time after the fire has failed.

AUXILIARY APPLIANCES

EXPANSION TANKS

12. The purpose of an **expansion tank** is to keep the pipes and other apparatus constantly full of water. The water in the heating system expands when heated, so if it fills the apparatus when cold it will overflow when hot; the expansion tank receives this overflow.

The construction of an ordinary, low-pressure, expansion tank is shown in Fig. 4. The body *a* and heads are made of wrought iron, and should be galvanized inside and out. A glass water gauge *b* is attached to show the height of the water inside. The tank is connected to the heating apparatus by an *expansion pipe c*. The top of the tank is always open to the atmosphere through the pipe *d*, which must never be closed. A connection to the cold-water house-supply pipe may be made at *e*, for convenience in filling the tank. Some expansion tanks are provided with ball-cocks, by means of which water is supplied to the tank automatically.

13. The connection of the tank to the heating apparatus must be carefully protected against frost. When this connection is frozen, the apparatus is deprived of the relief afforded by the tank, and a rupture is sure to occur in some weak parts when the water is being heated. Open communication between the expansion tank and the boiler must be maintained at all times. No stop-valve should ever be placed on this pipe, and wherever one is found it should be removed. Such a valve is liable to be closed, and thus produce disaster.

14. An expansion tank suitable for high pressure is shown in Fig. 5. It differs from the form shown in Fig. 4 mainly in its proportions, being of smaller diameter in proportion to its length; it is also made of much thicker materials. The outlet pipe is controlled by a safety valve *a*. The height of the water is shown by means of the gauge, or try, cocks *b*, *c*, *d*; glass water gauges are not suitable for high-pressure tanks, because they are apt to crack and burst, and thus allow the water to escape and damage the building.

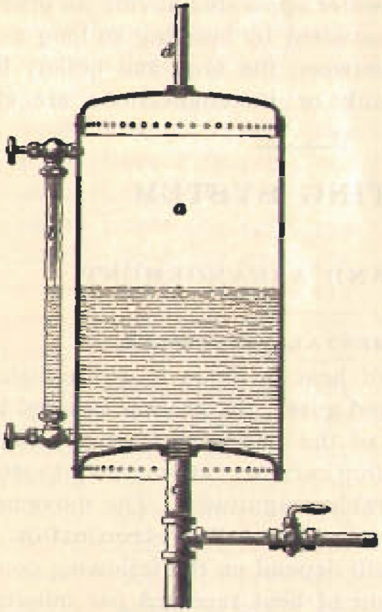

FIG. 4

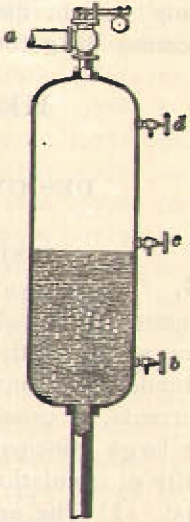

FIG. 5

15. It is very essential that a closed, or high-pressure, hot-water heating system be provided with means to prevent the accumulation of a pressure that will burst the pipes, boiler, or radiators. The expansive force of the water is practically irresistible, and unless room is provided for expansion, it will burst the apparatus. The only mode of securing safety is to provide the closed tank with a safety valve, which may be set to blow off at the pressure that steam would have at the maximum temperature desired in the apparatus. No closed tank should be installed without a safety valve. A hot-water apparatus having an open tank is absolutely safe from accident by bursting so long as open communication exists between the tank and boiler; but, if for any reason, the tank or its connections are closed, it becomes dangerous.

HEATING SYSTEM

DESIGN AND ARRANGEMENT

FUNDAMENTAL PRINCIPLES

16. The diffusion of heat in fluids is accomplished by conduction; in liquids and gases, the process is aided by the motion of the particles of the substance among themselves. The tendency of convection currents is to merge into streams, or currents, of considerable magnitude. The movement of these large principal currents is called **circulation.** The rapidity of circulation will depend on the following considerations: (1) The amount of heat received per minute on a given area of surface; (2) the extent of the heating surface in proportion to the volume of the fluid; (3) the place of application of the heat, whether at the top, side, or bottom of the mass; (4) the conductivity of the fluid.

17. The volume of water does not increase at the same rate as the temperature; the expansion has been determined by experiment, and the results are given in Table I. The increase in volume caused by heating water, or in height of

TABLE I

EXPANSION OF PURE WATER

Temperature Degrees Fahrenheit	Comparative Volume Water at 32° = 1	Comparative Density Water at 32° = 1	Weight of 1 Cubic Foot Pounds	Temperature Degrees Fahrenheit	Comparative Volume Water at 32° = 1	Comparative Density Water at 32° = 1	Weight of 1 Cubic Foot Pounds
32.0	1.00000	1.00000	62.418	135	1.01539	.98484	61.472
35.0	.99993	1.00007	62.422	140	1.01690	.98339	61.381
39.1	.99989	1.00011	62.425	145	1.01839	.98194	61.291
40.0	.99989	1.00011	62.425	150	1.01989	.98050	61.201
45.0	.99993	1.00007	62.422	155	1.02164	.97882	61.096
46.0	1.00000	1.00000	62.418	160	1.02340	.97714	60.991
50.0	1.00015	.99985	62.409	165	1.02589	.97477	60.843
52.3	1.00029	.99971	62.400	170	1.02690	.97380	60.783
55.0	1.00038	.99961	62.394	175	1.02906	.97193	60.665
60.0	1.00074	.99926	62.372	180	1.03100	.97006	60.548
62.0	1.00101	.99899	62.355	185	1.03300	.96828	60.430
65.0	1.00119	.99881	62.344	190	1.03500	.96632	60.314
70.0	1.00160	.99832	62.313	195	1.03700	.96440	60.198
75.0	1.00239	.99771	62.275	200	1.03889	.96256	60.081
80.0	1.00299	.99702	62.240	205	1.04140	.96020	59.930
85.0	1.00379	.99622	62.182	210	1.04340	.95840	59.820
90.0	1.00459	.99543	62.133	212	1.04440	.95750	59.760
95.0	1.00554	.99449	62.074	230	1.05290	.94990	59.360
100.0	1.00639	.99365	62.022	250	1.06280	.94110	58.750
105.0	1.00739	.99260	61.960	270	1.07270	.93230	58.180
110.0	1.00889	.99119	61.868	290	1.08380	.92270	57.590
115.0	1.00989	.99021	61.807	298	1.08990	.91750	57.270
120.0	1.01139	.98874	61.715	338	1.11180	.89940	56.140
125.0	1.01239	.98808	61.654	366	1.13010	.88500	55.290
130.0	1.01390	.98630	61.563	390	1.14440	.87380	54.540

20. While it is true that the total motive force increases with the size of the pipe—that is, the motive force in a pipe 4 inches in diameter will be four times that in a pipe 2 inches in diameter—it must be remembered that the 4-inch piping contains four times as much water as the 2-inch pipe, so that the force exerted and the water on which the force is exerted (in other words, the power and the resistance) are relatively the same. It is, therefore, a mistake to suppose that by increasing the size of the pipe there is secured an increase of motive force with which to overcome faults in piping, or such resistances as rise from obstructions in the form of foreign matter. Every increase in the size of pipe means an increase in the quantity of water to be moved, and there is, therefore, no motive force to be wasted in any size of piping. However perfectly the piping is proportioned and run, the margin in motive force is so narrow that extremely slight obstructions will render the apparatus practically inoperative.

21. The force available for moving the water in a gravity, hot-water, heating system may be computed by the following method: The height of the descending column should be measured from the actual top of the column (the point at which the water begins to flow downwards) to the point where the return pipe enters the boiler. The average temperatures of the ascending and descending columns should then be carefully measured. The difference in weight of columns of water 1 inch square and 1 foot high, at the actual average temperatures thus found, may be learned by using columns 4 and 8 of Table I. As these columns give the weight of the water per cubic foot, however, it is necessary to divide by 144 in order to obtain the weight or pressure per square inch for each foot in height. This difference in weight between the ascending and descending columns of water, when multiplied by the height of the columns, in feet, equals the total pressure per square inch that acts as a motive force to drive the water forwards.

EXAMPLE.—What is the total motive force per square inch in a hot-water heating apparatus, when the average temperature throughout the ascending column is 230°, and in the descending column 180°, the operative height of the descending column of water being 70 feet?

SOLUTION.—Table I shows that water at 180° exerts a pressure of 60.548 ÷ 144 = .4205 lb. per sq. in. at the base of the column for each foot of height; and that water at 230° has a corresponding pressure of 59.36 ÷ 144 = .4122 lb. per sq. in. The force available for moving the water will then be the difference in pressure multiplied by the height of the column, which is .4205 − .4122 = .0083 lb., and .0083 × 70 = .581 lb. per sq. in. at the base of the column. Ans.

In estimating the operative height of the column, any part of the system that is located above the level of the point at which the water begins to flow downwards must not be included. The elevation of the level of the water in the expansion tank above that point does not increase the motive force of the system in any degree. It serves only to increase the static pressure equally throughout the whole system. An increase of static pressure simply raises the boiling point of the contained water and thus admits of a higher temperature being given to the water in circulation.

EXAMPLES FOR PRACTICE

1. What will be the height of a column of water when heated to 200° F. from 60° F., the height of the original temperature being 24 feet? The column is uniform in cross-section. Ans. 24.92 ft., nearly

2. If 42 gallons of water is heated from 32° F. to 175° F., what will the new volume be? Ans. 43.221 gal., nearly

3. In a hot-water heating system, the ascending column averages 180° F. and the descending column 140° F.; the descending column being 45 feet high, what is the motive force, in pounds per square inch? Ans. .26 lb. per sq. in.

CIRCULATION IN RADIATORS

22. Hot-water radiators may be supplied with hot water at the top or at the bottom, but the pipe that returns the water from a hot-water radiator to the boiler should be connected to the bottom tapping of the radiator. If the hot water is introduced at the top, the circulation of the water within the radiator will be downwards in every loop or section, the sections being connected together with nipples at the top. As the water becomes cooled in the sections, it falls by gravity to the return pipe. If the hot water is introduced into the base of the radiator, it invariably ascends in the loops nearest the inlet tapping and descends in the other loops. If the radiator is short, the circulation may be up one column of each loop and down the other column; or, the direction of the circulation may be both ways in the same radiator. In any case, the general direction of the current must be from the inlet tapping to the outlet tapping. The circulation within the sections is of secondary importance and does not materially affect the efficiency of the radiator.

ARRANGEMENT OF APPARATUS

APPLIANCES REQUIRED

23. The apparatus required for warming buildings by the use of hot water is essentially composed of a water heater, often called a *hot-water boiler*, a number of radiators or other such heating surfaces, and a system of piping to connect the radiators to the water heater. An expansion tank is also employed in the system for the purpose of compensating for the expansion or contraction of the water, due to the changes in its temperature.

The boiler, or heater, is generally located in the basement or cellar of the building to be warmed, and, if possible, lower than the lowest radiators to be heated. The reason for setting the boiler low is that the hottest water always flows to the highest parts of the system, and the lower radiators, particularly if below the level of the boiler, are liable to be too cool to be efficient heating surfaces.

The piping usually consists of two systems, a **flow system**, or that which conveys the hot water from the boiler to the different radiators, and a **return system**, or that which conveys the water from the radiators back to the boiler. All the flow pipes should, if possible, pitch gently upwards toward the radiators to which they are connected, and the return pipes should have the same pitch. This will not only prevent air from accumulating at any point in the piping, but will also facilitate the circulation of the water.

Owing to the fact that water, whether hot or cold, will flow in the direction of least resistance, it is absolutely necessary that the pipes be properly proportioned to take to the several radiators exactly the volume of water required, and no more; otherwise, more water will flow through some radiators than through others, which means that some radiators will be hotter than others.

Small air valves, automatic, or otherwise, are attached to the highest points of the several parts of the system, usually on or near the tops of the radiators, to allow air in the system to escape, and thus prevent a stoppage of circulation by air locks.

EXPANSION TANKS

24. The object of using an expansion tank in a hot-water heating apparatus is simply to have a receptacle into which the water in the heating system may expand when heated. If an open expansion tank is used, the expansion of the water takes place without any perceptible change in the pressure throughout the system. If a closed tank is used, however, the water in expanding will compress the air in the tank, thereby increasing the pressure throughout the system and raising the boiling point of the water; for instance, the boiling point of water at the sea-level pressure of 14.7 pounds is 212° F., while the boiling point of water subject to a gauge pressure of 60 pounds per square inch is about 307° F.

25. To compute the size of an expansion tank, it is first necessary to find the capacity of the heating apparatus, and then how much the water will expand when heated from 46° F. to the highest temperature possible for the pressure to which the water will be subjected. When the tank is open, it is customary to calculate on a maximum temperature of 212°, although the temperature of the water in the heater may be much higher, due to the pressure corresponding to the hydrostatic head; that is, to the depth of water between the expansion tank and the boiler. When the tank is closed, the amount of expansion is usually calculated from 46° F. to the boiling point at a pressure equal to the highest pressure that will ever exist in the expansion tank.

The amount of expansion for a given system, that is, the change in volume of the contained water, is calculated by the rule in Art. **17** and this should be the minimum capacity of an expansion tank. Thus, suppose that the capacity of the water heater, the piping, and the radiators is 300 gallons, and that an open expansion tank will be used. Then, by Table I, the relative volumes at 46° and 212° are 1 and 1.0444, respectively. Applying the rule in Art. **17**, the expansion is $300 \times (1.0444 - 1) = 13.32$ gallons, which should be the minimum capacity of the tank.

Having computed the actual volume required for the expansion of the water, the additional space for air may be readily found. The pressure of steam having a temperature of 350° is about 135 pounds absolute. Air must be compressed to about one-ninth of its original volume to produce that pressure; therefore, the space for air, above high-water mark, should be one-ninth of that allowed for the expansion of the water.

The dangers pertaining to the use of the hermetically sealed tank are so great that their use is unjustifiable. In all cases where a closed tank is employed, a proper safety valve should be attached.

26. A common and simple method of proportioning an open tank to a heating apparatus is to make the tank capacity 5 per cent. that of the apparatus. This is done on some of the best work and gives good results.

The size of the closed tank depends considerably on the highest temperature at which the water is to be kept. For example, an apparatus to be run at a temperature of 300° F. should, for safety, have a closed tank whose capacity is 10 per cent. of that of the heating system; for 400°, 16 per cent.; and for 500°, 25 per cent. of that of the entire apparatus.

27. The expansion tank should be so placed in the building as to be accessible and in view at all times, say in the hallway of the top floor. It must be thoroughly protected from frost, and must be placed at a point higher than the top of the highest radiator; in fact, it must be the highest point of the system.

28. Expansion tanks are often furnished with a ball-cock that allows water to flow into them when the water-line descends too low. The ball-cock maintains a practically uniform water level in the tank for the several temperatures; that is to say, a water-line near the top of the gauge for high

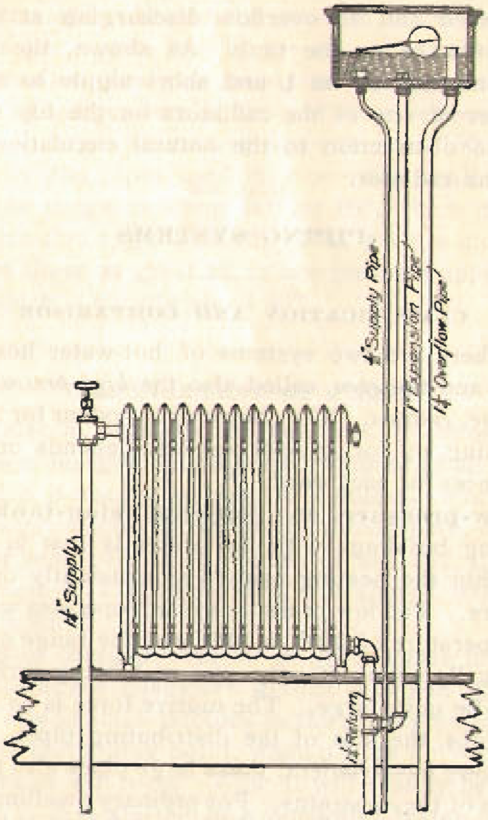

Fig. 7

temperatures, at the base of the gauge for low temperatures, and water-lines between these points for intermediate temperatures. This prevents the necessity of running in a little water at intervals by the use of the stop-cock *g*, Fig. 3, to compensate for evaporation, etc.

29. Fig. 7 shows a frequently used method of making connections to the expansion tank, which in this illustration is of the horizontal flush-tank pattern, with automatic ball-cock feed and an overflow discharging at some convenient point below the tank. As shown, the expansion pipe is connected by an **L** and short nipple to a **T** in the return riser of one of the radiators on the top floor, thus offering no obstruction to the natural circulation of water through the radiator.

PIPING SYSTEMS

CLASSIFICATION AND COMPARISON

30. There are two systems of hot-water heating; viz., the *closed*, and the *open*, called also the *high-pressure*, and the *low-pressure, systems.* The choice of a system for any particular building or for special service depends on the local circumstances in each case.

The **low-pressure,** or **open-expansion-tank, system** of warming buildings with hot water is that in which the water within the heating system is constantly open to the atmosphere. The low-pressure system operates with a maximum temperature of 210° or 212° and the range of temperature is usually about 20°; the area of heating surfaces must, therefore, be quite large. The motive force is so small that, in large jobs, the size of the distributing pipes and mains becomes very inconvenient; these large pipes also add greatly to the cost of the apparatus. For ordinary dwellings, the low-pressure system has substantial advantages: it is not liable to damage by explosion or by neglect; it can be operated by any person capable of maintaining a proper fire in the boiler; and, if properly erected, it is not liable to get out of order.

31. The **closed-tank,** or **high-pressure, system** is that in which the hot water within the heating system is not open to the atmosphere, but is enclosed in an air-tight apparatus, much the same as water is enclosed in an ordinary steam boiler. In the high-pressure system, the temperature of the water may be anything from 212° to 400°, or even more, for heating purposes. Where there is no objection to high temperatures and the accompanying risks, it may be used in preference to the low-pressure system. It requires strong boilers and radiators, the pressure at 250° being about 121 pounds per square inch by the gauge, but the apparatus is much smaller than that used for low-pressure heating. The range of temperature at the radiators between the inlet and outlet is large, amounting sometimes to 150° or more; consequently, the pipes used may be quite small. Usually, however, the range is about 50° or 60°, which means that the radiators also may be small. This gives a motive force about three times as great as in low-pressure apparatus, the range in which is usually about 20°.

ARRANGEMENT OF PIPING

32. Water at ordinary temperatures, if exposed to the air, is always charged with a certain amount of air and other gases, which it seems to hold in solution. For example, distilled water, when exposed to the atmosphere, will absorb about 4 per cent. of its own volume of air; and, if placed in an atmosphere of carbon dioxide, will absorb 100 per cent. of its own volume.

When water charged with air or other gases is increased in temperature, the gases are gradually driven off from the liquid and rise in small bubbles to the surface until the water has reached the boiling point, when all the air will be liberated and steam will form. Now, it will readily be seen that when a fire is first started in a hot-water boiler, air will be liberated from the water and will rise to the highest points of the heating apparatus, where it will accumulate and form *air locks*, if it cannot escape to the atmosphere. This matter must be carefully considered in constructing hot-water heating apparatus, because the motive force is so small that it may be easily neutralized and the circulation stopped by an air lock of comparatively small size. Air always collects in all high places, such as the tops of radiators, the upper ends of vertical pipes, etc., and these points should always be provided with air vents.

33. All horizontal supply, or flow, pipes should be inclined upwards on a uniform grade, so that the air will readily flow into the risers. The air in the pipes will then pass into the expansion tank and escape into the atmosphere or into the radiators. If this cannot be done, an automatic air vent of sufficient capacity must be attached to the piping at the highest point.

In many cases, air pockets may be vented advantageously by attaching a small pipe to the top of the pocket, and extending it to the top of the house, at least as high as the top of the expansion tank, leaving it open to the atmosphere, preferably over the expansion tank. This makes a reliable vent, but the special pipe cannot always be permitted. Care must be taken to keep it from freezing, because there is no circulation through it.

34. A bubble of air lodged in a pipe will obstruct the flow of water through it, to the same extent as a block of wood or metal of the same size. Thus, in Fig. 8, if the bubble *a* occupies two-thirds of the area of the pipe, the remaining third only is available for the passage of water. Although the air is very elastic and light, it occupies space just as positively as any solid substance. The bubble can be dislodged only by a much stronger current of water than can usually be found in a hot-water heating apparatus. The best remedy for air lock in a pipe is to straighten the pipe. Whether the bend that holds the air is long or short, or whether it occurs in the flow or return pipes, is of little consequence, because the effect is the same in all cases.

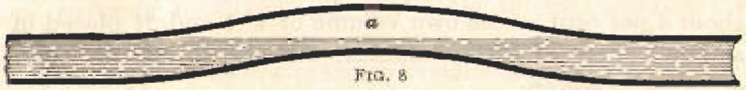

FIG. 8

35. A bubble or small air lock in a local circuit will, in many cases, completely stop the circulation. Thus, when several radiators are so connected to the same supply and return mains that each is on a local and practically independent circuit, the force that impels the water through them is so nearly alike in each that the impediment caused by an air bubble lodged in one of the connections is usually sufficient to stop the flow through that circuit and to divert all the hot water into the other circuits.

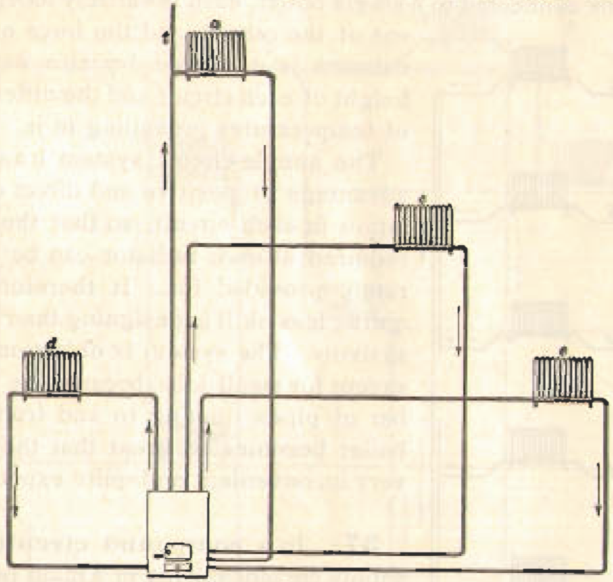

FIG. 9

The manner of fitting up and connecting pipes for hot-water service is substantially the same as for steam heating. The expansion of the pipes by heat must be provided for by using spring pieces, etc. in the same manner.

PIPING CIRCUITS

36. Simple and Compound Circuits.—A pipe circuit in which the water flows directly to a radiator through a single pipe without branches, and returns to the boiler through another direct and special pipe, as shown in Fig. 9, is called **a simple circuit.** Although a large number of such circuits may be connected to a single boiler, each is entirely independent of the others, and the force of circulation is governed by the actual height of each circuit and the difference of temperatures prevailing in it.

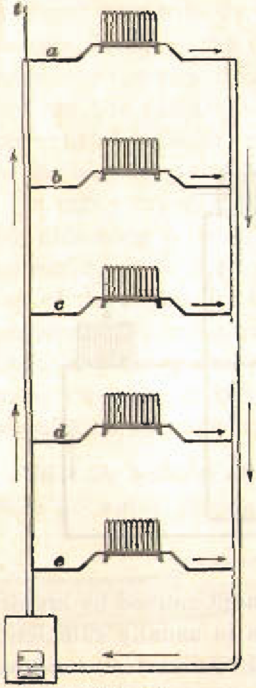

FIG. 10

The simple-circuit system has the advantage of positive and direct circulation in each circuit, so that the heat required at each radiator can be accurately provided for. It therefore requires less skill in designing than other systems. The system is objectionable, except for small jobs, because the number of pipes running to and from the boiler becomes so great that they are very inconvenient and quite expensive.

37. In a **compound circuit,** the supply current moves in a main pipe of comparatively large dimensions, commonly called the *flow main*, and the return currents proceed to the boiler through a similar pipe called the *return main*. These mains are connected by a number of small branches, each of which makes a direct circuit between the flow and return mains. The radiators are connected to these branches, usually one on a branch, sometimes more.

Compound circuits are arranged in many ways, most of which are variations of the two systems shown in Figs. 10 and 11. In Fig. 10, the mains are vertical. and the branches

are substantially horizontal. In Fig. 11, the mains are horizontal and the radiators are attached to vertical branches or drop risers. In the former case, the effect of rapid cooling at any one radiator is to decrease the average temperature of the return main; and as all the radiators are connected to the same mains, the effect is divided and distributed over the entire system. In the latter case, each radiator is independent, and the rapidity of the circulation through it will depend on the amount of cooling that occurs at that point.

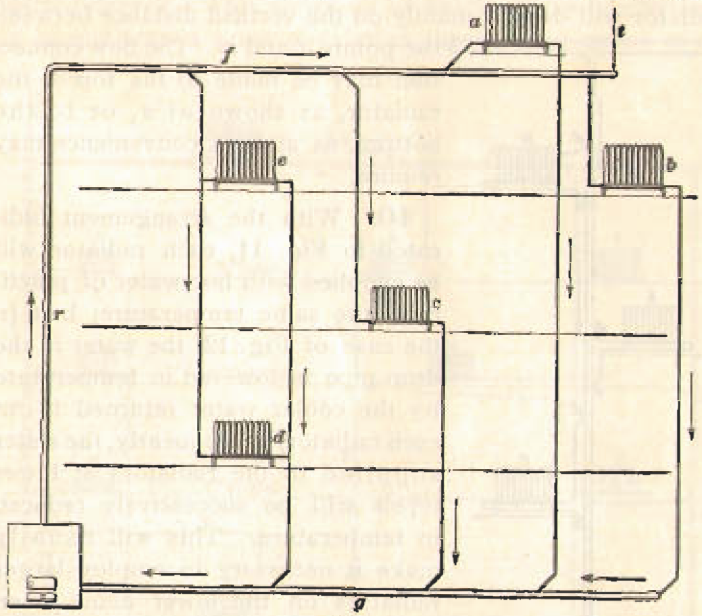

FIG. 11

38. In Fig. 11, the radiators *c* and *d* are supplied from the same **drop riser,** and both are connected to the same return pipe. The circulation through the upper radiator will always be good, but while this continues in operation the lower radiator may be unable to get any hot water owing to the fact that the pressure of the cool water in the return between *c* and *d* overbalances that of the hot-water column in the flow connection to *d*, and prevents its flowing through the radiator. This trouble can be remedied by providing it with a separate return to the main *g*, thus making it independent of the upper radiator.

39. Another method of operating a radiator on a drop riser is shown in Fig. 12. The flow connection to the supply pipe is made at one level and the return is connected into the same pipe at a lower level. The circulation through the radiator will depend mainly on the vertical distance between the points *d* and *e*. The flow connection may be made to the top of the radiator, as shown at *a*, or to the bottom, as at *b*, as convenience may require.

40. With the arrangement indicated in Fig. 11, each radiator will be supplied with hot water of practically the same temperature; but in the case of Fig. 12, the water in the drop pipe is lowered in temperature by the cooler water returned from each radiator; consequently, the water supplied to the radiators at lower levels will be successively reduced in temperature. This will usually make it necessary to employ larger radiators on the lower floors when this system is employed.

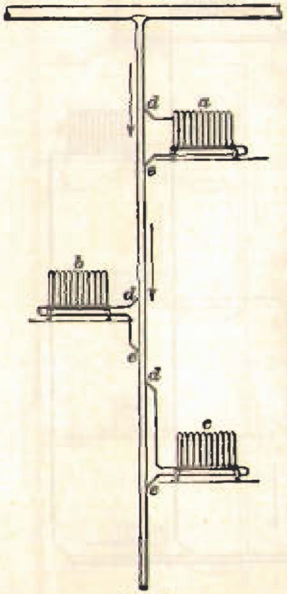

FIG. 12

41. Open and Closed Circuits.—There is quite a difference of opinion regarding the true meaning of the terms *open* and *closed circuits*. The terms and their meanings as adopted here, may seem contrary to local usage, but they coincide with the meanings of the same words as applied in the electrical profession, and therefore will help to prevent confusion or misunderstanding.

In the plans shown in Figs. 10 and 11, the flow and return mains are connected only by the radiator branches, and there is no way of maintaining a flow of water through them when

the radiators are shut off. This arrangement of mains is called an **open circuit.**

When all the radiators, except one or two, are shut off, the amount of circulation is likely to be too small to keep the water in the mains at a proper working temperature. Then, when the other radiators are opened for use, considerable time must elapse before the whole system heats to the desired degree. This slowness of heating may be obviated by keeping up a good circulation through the mains at all times, regardless of the radiators, by connecting the flow and return mains by a pipe *k*, as shown in Fig. 13. This arrangement is called a **closed circuit.** The connection should be as large as the extreme ends of the flow and return mains which it connects. As long as a proper fire is maintained in the boiler, an active circulation will go on in the mains and the water will be always at the maximum temperature, so that any or all of the radiators may be promptly supplied with hot water as soon as the valves are opened.

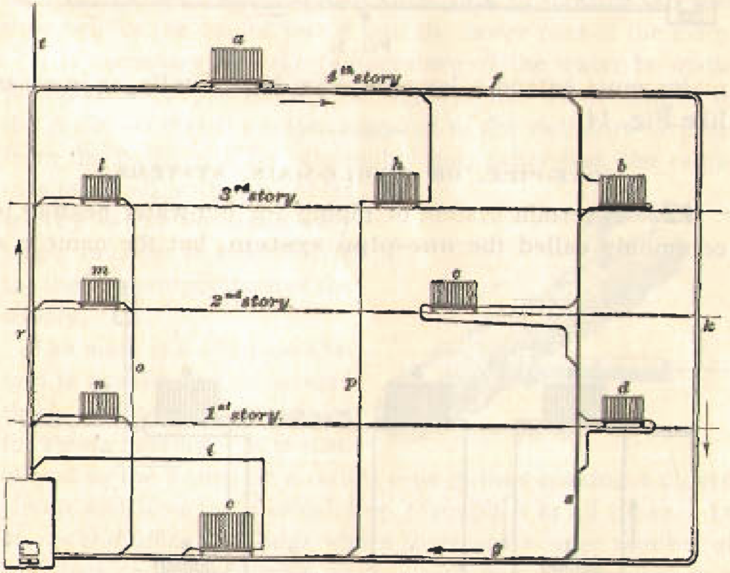

FIG. 13

The closed circuit is desirable for all situations where the simple or single circuit, Fig. 9, is not used, and is adapted to high buildings as well as low ones. It is superior to all others in long low buildings of one or two stories, where the mains must extend a long distance horizontally, as in cases like Fig. 14.

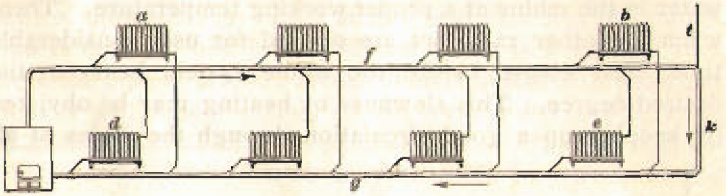

FIG. 14

ONE-PIPE, OR SINGLE-MAIN, SYSTEMS

42. A certain system of piping for hot-water heating is commonly called the **one-pipe system**, but the name is a misnomer. While it is practicable to operate a steam-heating system with a single main and with single connections to the radiators, it is wholly impracticable to do so with hot water. Hot-water radiators must have two connections. The overhead system represents the nearest approach that can be made to a one-pipe system of hot-water distribution, the flow branches and return branches of the radiators being connected to the same drop riser as in Fig. 12, or radiator branch connections may be made to the same main substantially as shown in Fig. 15. In the latter system, the main is of unusually large diameter, so that it acts as a reservoir, and the movement of the current through it is comparatively slow. The risers are tapped into the top of the main, and the returns are connected into the side or bottom, so that they deliver the cooled water into the lower part of the main.

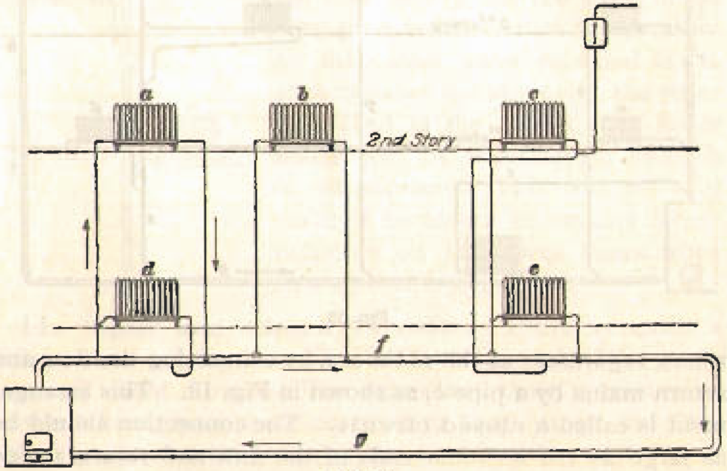

FIG. 15

It is necessary that the temperature of the water be maintained at a proper degree throughout the whole length of the main, so that the water supplied to the radiators farthest from the boiler will be reasonably hot; otherwise, the radiators supplied with the cooler water must be made very large, in order to compensate for the low temperature of the supply.

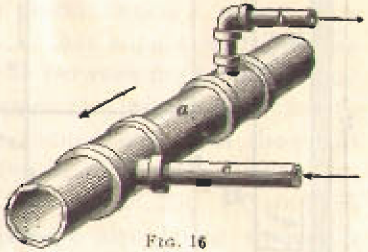

FIG. 16

The main in a one-pipe system is usually carried around the basement walls exactly as for steam heating. It is connected to the boiler by a return pipe *g*, thus making a closed circuit and insuring a circulation through it at all times. In stores and office buildings where there are a large number of radiators on a single-main circuit, each being controlled by a different person, the advantage of having the circuit closed is of great importance. This system has no apparent advantages, except that in some cases it is cheaper to install. The circulation in each radiator depends solely on the actual height of its individual return column, and the system as a whole is sluggish in operation.

In the one-pipe system, the connections for a radiator are made substantially as shown in Fig. 16, the main current moving through *a* in the direction of the arrow, *b* being the flow connection and *c* the return. The object here is chiefly to take the supply of hot water from the top of the main and return the cooler water into the bottom.

43. One of the disadvantages of the single-main, or continuous-circuit, system of hot-water heating is that the lack of a uniform temperature throughout the circuit necessitates proportioning the radiators so as to provide for differences in heating power at different points in the main, which should be arranged so as to secure the advantages of a divided instead of a continuous circuit.

44. Whenever it is possible to do so, it is an advantage to install the single-main system with multiple, or spit, circuits as indicated by a plan view in Fig. 17, which shows the piping system for a small one-story library. This not only permits the use of a smaller piping but reduces the temperature drop, thereby insuring greater uniformity of temperature throughout the whole building. Supply and return connections may be taken from special fittings, thus reducing the expense of installation as compared with systems

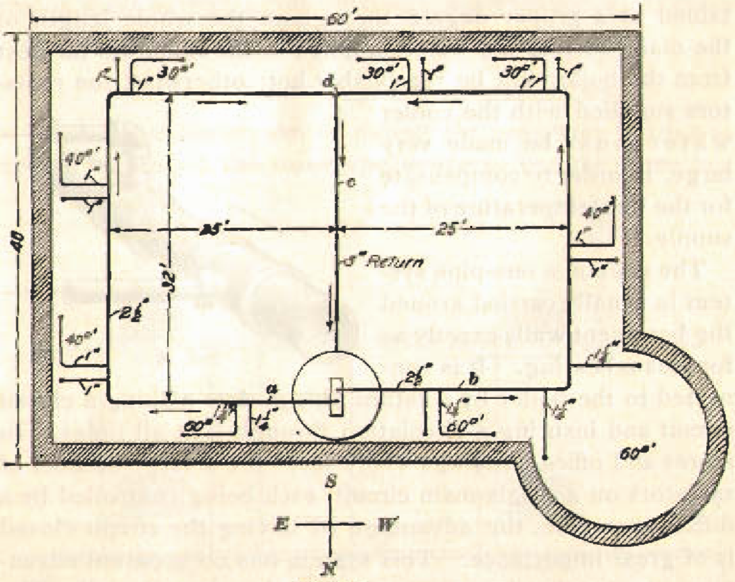

FIG. 17

wherein the connections are made as shown in Fig. 16. In arranging the mains as shown in Fig. 17, the highest points are at the riser connections nearest the boiler. The separate main pipes *a* and *b* run in opposite directions around the cellar, to be connected into the return *c* by means of a long-turn twin elbow at *d*, where the main drops to or below the cellar floor and from thence is carried to the boiler.

45. In the **overhead system** of hot-water heating, shown in Fig. 18, a single main riser *a* is carried directly upwards from the boiler to the attic, proper provision being made for expansion; the riser usually supplies two opposite branches *b*, *b* of smaller diameter, as shown. When the piping can be so arranged, it may be run beneath the top floor, as shown, with the top-floor radiator connections taken from the branch mains, the radiator valves being placed in the return connections. From the branch mains *b*, connections are taken for the drop risers *c*, *c'* that supply the radiators on the floors below. Connections between the drop riser and radiators may be made as shown at the left of Fig. 18 with the radiator valve in the return connection, or as shown at the right, with the radiator valve in the supply connection. In some cases, two drop risers, as *c'* and *c''*, Fig. 18, are used for each line of radiators, this case also being shown in Fig. 11, the supply riser being reduced in size at each radiator connection and the size of the return riser being correspondingly increased.

46. With the overhead, or drop, system of hot-water heating, no air valves are necessary, except when the system is arranged as shown in Fig. 18, when the radiators on the top floor should be equipped with air valves for venting the air that would escape through the expansion tank if all the radiators were served by drop risers. One of the advantages of the overhead system of distribution is that it provides no opportunity for one radiator to rob another of its supply of hot water, but all radiators work together harmoniously, so to speak. The water that passes through one radiator must flow through the one below it whenever the radiator valve is open. To preserve the greatest possible difference in temperature between the ascending and descending columns of water, the riser main and the horizontal mains taken therefrom to supply the drop risers should always be well covered with some good pipe covering, but the drop risers should not be covered.

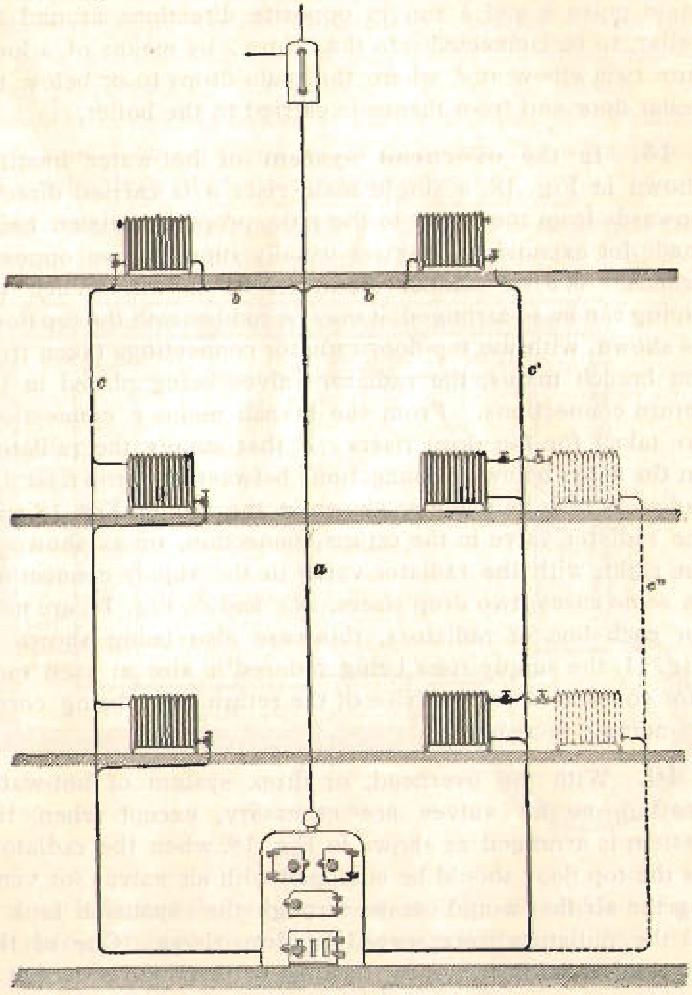

FIG. 18

47. Expansion tank connections may be made by running a 1-inch pipe from a bushing in the long-turn cross at the top of *a* in Fig. 18, or the expansion pipe may be attached to the return end of one of the radiators on the top floor, in case such an arrangement would be more convenient. The overhead system is well adapted for use in large residences where the heating of the first floor is accomplished by means of indirect radiation, the amount of which should be 50 per cent. in excess of the amount of direct radiation that would be required to heat the first-floor rooms.

TWO-PIPE SYSTEMS

48. An illustration of the **two-pipe system** of hot-water heating is presented in Fig. 19. The hot water flows from the boiler through the supply mains and risers *a*, *a'* to the radiators *r*, *r*, whence it returns to the boiler through the risers *c'*, *c'* and return mains *c*, *c*. Both flow and return mains pitch upwards from the boiler, as shown. Provision for expansion of the water is provided by the expansion tank *o*, which is connected with one of the return mains near the boiler, as indicated.

49. The two-pipe system shown in perspective in Fig. 20 is sometimes called the **parallel system**, because the flow and return pipes are run throughout the building substantially parallel to one another. In this illustration, the flow pipes are shown by solid lines and the return pipes by dotted lines. The boiler is located in the cellar as usual. From the two tappings on the upper header are run the flow mains *a* and *b*. The main *a* is split into two mains *c* and *d* by a twin elbow. The return mains are all run on the same horizontal plane and parallel with their respective flow mains, except the return main *e*, which is run under the main *a* so that a twin elbow and 45° offset can be used at the point *f* to raise the mains *g* and *h* to the horizontal planes of the mains *c* and *d*. The branches to the risers and the first-floor radiators are taken off midway between the top and the side of the flow and return mains, by the use of a reducing **T**, a short nipple, and a 45° elbow at each branch. The radiators *i*, *i* are supposed to be located on the first floor and circulation to them has been favored by making their connections directly to the main or taking them from the top of the riser connections at the cellar ceiling. The radiators *j*, *j* are located on the second floor, *k*, *k* on the third floor, and *l*, *l* on the fourth floor. Gate valves are shown located in the mains *g*, *c* to shut off that circuit; gate valves are also located in the mains *d*, *h*, and on *b* and its corresponding return to shut off these circuits. The expansion tank *m* is provided with a pipe continued up through the roof and bent over in the form of a return bend. The bottom of the expansion tank is connected to the vertical part of the flow main *a*, directly over the boiler. Many fitters connect the expansion pipe to the return manifold. The advantage of connecting the expansion pipe as shown is this: If the gate valves on the mains are closed for repairs and the fire is not properly drawn from the heater, steam generated in the heater will

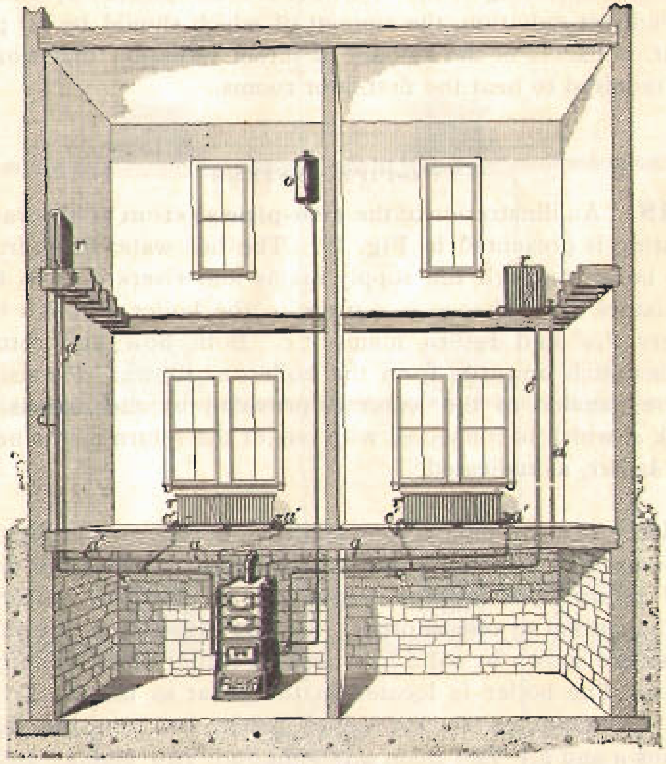

Fig. 19

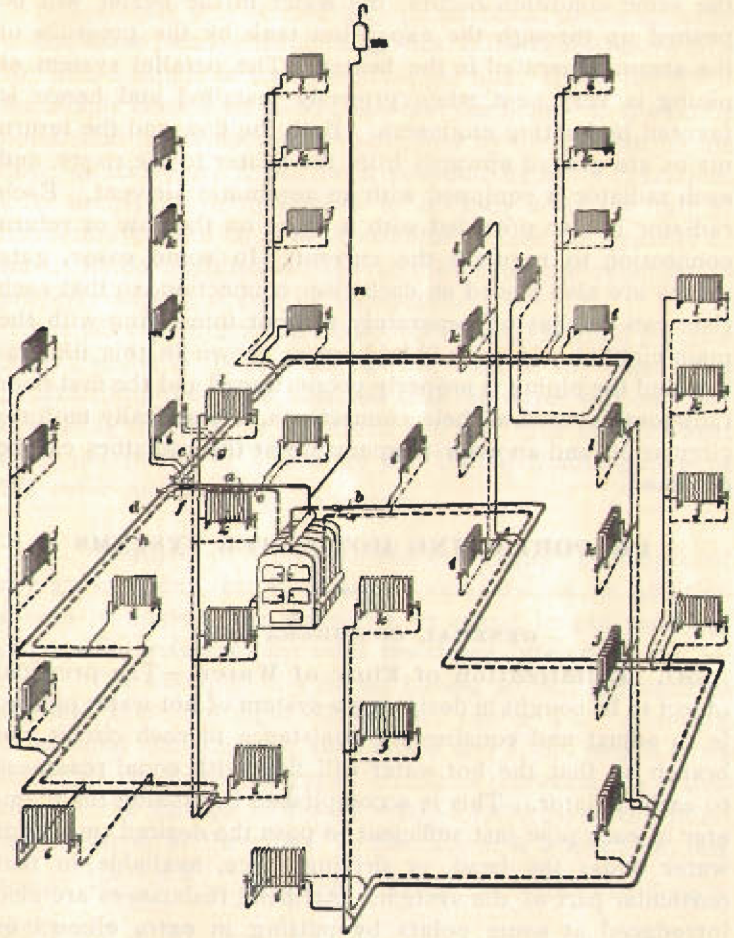

Fig. 20

pass up through the expansion pipe *n*, through the tank *m*, and escape above the roof without emptying the heater. If the pipe is connected to the bottom of the heater, and if the same condition occurs, the water in the heater will be pushed up through the expansion tank by the pressure of the steam generated in the heater. The parallel system of piping is very neat when properly installed and hence is favored by heating engineers. Both the flow and the return mains are graded upwards from the heater to the risers, and each radiator is equipped with an automatic air vent. Each radiator is also provided with a valve on the flow or return connection to regulate the current. In some cases, gate valves are also placed on each riser connection, so that each riser can be shut off separately without interfering with the main circuits. It work is laid out as shown in this illustration and the piping is properly proportioned and the first-floor radiators favored at their connections, a practically uniform circulation and an even temperature at the radiators can be obtained.

PROPORTIONING HOT-WATER SYSTEMS

GENERAL CONSIDERATIONS

50. Equalization of Flow of Water.—The principal object to be sought in designing a system of hot-water piping, is to adjust and equalize the resistance in each circuit and branch so that the hot water will flow with equal readiness to each radiator. This is accomplished by making the diameter of each pipe just sufficient to pass the desired amount of water under the head, or driving force, available in that particular part of the system. Artificial resistances are also introduced at some points by putting in extra elbows or bends; valves are sometimes used for the same purpose.

An ordinary low-pressure system requires larger pipes than a high-pressure system, because the difference in temperature of the flow and return is less, and the driving force is consequently smaller.

51. Temperature Drop.—The water must fall in temperature while passing through the radiator, in order to emit heat. The rate of emission per hour being the same, the fall of temperature will be inversely proportional to the quantity of hot water passing through. Thus, if the temperature falls 10° with a supply of 100 cubic feet per hour, it will fall 20° if the supply is reduced to 50 cubic feet per hour. It should be noted that the temperature multiplied by the volume of the flow, or its velocity, will be a constant figure. Therefore, it is necessary to determine in advance what the fall of temperature shall be at each radiator, before the quantity of water to be supplied or the size of the pipe required to properly supply it can be computed.

The fall of temperature commonly allowed in good practice is 20°, while 35° is regarded as the limit in any case. For general purposes, it is assumed that the water will cool 20° in passing through the radiators, and will thus emit 20 heat units per pound or 166 units per United States gallon of 231 cubic inches.

52. Length of Circuit.—In estimating the length of any given circuit, for purposes of computation, an addition should be made to the measured, or actual, length sufficient to equal in resistance the total resistance offered by the fittings. For example, in a circuit having an actual length of 300 feet, there are eight elbows and twelve **T**'s. Allowing 70 nominal diameters for each elbow and **T**, the length to be added to the actual length of circuit to represent the resistance of the fittings is $8 + 12 \times 70 = 1{,}400$ times the nominal diameter of the pipe. In the case of a 4-inch pipe, this equals $\frac{1{,}400 \times 4}{12} = 467$ feet, making the estimated length $300 + 467 = 767$ feet.

The actual length of a circuit is always understood to be the actual distance traveled by the water in going from and returning to the boiler, or the connection at the main.

When the water flows through pipe coils, the actual distance traveled must be ascertained and included in the estimate of length of the circuit, and full allowance must be made for each return bend. It is found, by experience, that the ordinary flow and return connections from a radiator to the risers or mains, which have an aggregate length of about 10 feet, and include six ordinary elbows or their equivalents, will present about the same resistance to the flow of water as a plain, straight pipe from 50 to 100 feet long. Therefore, in computing the friction in a circuit, from 50 to 100 feet should be added to the actual length for each ordinary radiator connection.

53. Height of Circuit.—The horizontal pipes on the upper floors of a building, and also the risers leading thereto, may be made smaller in diameter than those on the lower floors, because the driving force that impels the water increases with the height of the circuit, as previously explained. The proper size of the pipe having been determined for a given service on the first floor, the diameter for equal service on higher floors, the temperatures remaining the same, may be found by multiplying by the following factors:

	SECOND STORY	THIRD STORY	FOURTH STORY	FIFTH STORY
Factors . .	.87	.8	.76	.73

No factors are given for heights above the fifth floor, or about 50 feet, because the decrease for the succeeding stories is so small that it is of little practical account.

The area of heating surface that may be supplied by a pipe of given diameter will increase as the circuit is made higher. If the area of radiating surface known to be right for a given size of pipe on the first floor is taken as 1, the areas on the upper floors will increase in the following order:

SECOND STORY	THIRD STORY	FOURTH STORY	FIFTH STORY
1.41	1.72	1.98	2.24

54. Heat-Emissive Capacity of Hot-Water Radiation.—Owing to the fact that air circulates less rapidly over hot-water radiators because of the comparatively low temperature of the radiating surface, the heat emission per square

foot of surface per degree difference of temperature is less than with steam-heated surfaces. The rate of emission varies with the temperature of the water, being approximately, in British thermal units, as given in Table II, which also gives the temperature that the radiating surface should have in order to meet the requirements imposed by varying weather conditions.

55. Radiating Surface Required.—The amount of hot-water radiation required for heating dwellings of ordinary construction when the temperature of the radiating surface is 160° F. may be found, approximately, by means of the following rule, which applies to the ordinary two-pipe system:

TABLE II

HEAT EMISSION OF HOT-WATER RADIATORS

Outside Temperature Degrees Fahrenheit	Required Temperature of Radiating Surface to Maintain Rooms at 70° F.	Temperature Difference Between Radiating Surface and Air in Rooms	Total Heat Emitted per Square Foot of Radiating Surface per Hour	Heat Emitted per Square Foot of Surface per Hour per Degree Difference of Temperature
−10	212	142	282	2.00
0	200	130	234	1.80
10	190	120	204	1.70
20	180	110	176	1.60
30	160	90	135	1.50
40	150	80	118	1.48
50	140	70	102	1.45

Rule.—*Multiply the exposed wall surface by .25 and add the actual glass surface to the product, taking the surfaces in square feet. Multiply the sum by .63 to determine the amount of direct radiation required on the first floor; for the second floor, multiply by .59; and for the third floor, by .56.*

Or, $R = (.25\,w + g)\,c$

in which R = direct radiation, in square feet;

w = exposed wall surface, in square feet;

g = glass surface, in square feet;

c = .63 for first floor, .59 for second floor, .56 for third floor.

EXAMPLE.—How much radiation is required for a first-story, a second-story, and a third-story room having 268 square feet of exposed wall surface and 72 square feet of glass surface? The rooms are to be heated by the two-pipe hot-water heating system.

SOLUTION.—Applying the rule,

$R = (.25 \times 268 + 72) \times .63 = 87.57$ sq. ft. for the first-floor room. Ans.

$R = (.25 \times 268 + 72) \times .59 = 82.01$ sq. ft. for the second-floor room. Ans.

$R = (.25 \times 268 + 72) \times .56 = 77.84$ sq. ft. for the third-floor room. Ans.

56. For the single-pipe overhead system, the amount of hot-water radiation may be approximated as follows:

Rule.—*Multiply the exposed wall surface by .25 and add the actual glass surface to the product, taking the surfaces in square feet. Multiply the sum by .71 for the first floor to determine the direct radiation; by .63 for the second floor; and by .56 for the third floor.*

Or, $R = (.25\,w + g)\,c$

in which R = direct radiation, in square feet;

w = exposed wall surface, in square feet;

g = glass surface, in square feet;

c = .71 for first floor, .63 for second floor, .56 for third floor.

EXAMPLE.—With the overhead system of heating, how much direct radiation is required for a first-story, a second-story, and a third-story, room having 328 square feet of exposed wall surface and 81 square feet of glass surface?

SOLUTION.—Applying the rule,

$R = (.25 \times 328 + 81) \times .71 = 115.73$ sq. ft. for the first-floor room. Ans.

$R = (.25 \times 328 + 81) \times .63 = 102.69$ sq. ft. for the second-floor room. Ans.

$R = (.25 \times 328 + 81) \times .56 = 91.28$ sq. ft. for the third-floor room. Ans

57. Ratio of Radiating Surface to Space Heated. For ordinary dwellings having average wall and glass exposures, with the open-tank or low-pressure system of hot-water heating and direct radiation, Table III gives ratios of radiating surface to space heated such as may be employed when an approximate determination of the amount of radiating surface required is desired.

Where semidirect radiation is employed, the radiating surface should be increased as least 25 per cent.; while for indirect radiation, there should be 50 per cent. more surface than would be required for heating by direct radiation. In proportioning flues for indirect hot-water heating, allow 1.5 square inches of flue area for each square foot of radiating surface in the indirect stack for the first floor, and 1.25 square inches area for the flue to the second floor and for cold-air duct to stacks.

TABLE III

RATIO OF DIRECT HOT-WATER RADIATING SURFACE TO SPACE HEATED

Character of Space to be Heated	Ratio of Radiating Surface to Cubic Space Heated
Living rooms, one side exposed	1 to 32
Living rooms, two sides exposed	1 to 30
Living rooms, three sides exposed	1 to 28
Sleeping rooms	1 to 30–40
Hall and bathroom	1 to 20–30
Schoolrooms and offices	1 to 30–50
Factories and stores	1 to 50–70
Auditoriums and churches	1 to 80–100

58. Hot-Water Boiler Ratings.—The manufacturers of hot-water boilers rate these boilers by stating the number of square feet of direct radiating surface that they will supply, all uncovered pipes being figured as direct radiation. Average practice is to base the rating on a consumption of

4 pounds of coal per square foot of grate surface per hour, assuming a heat transmission of 8,000 British thermal units per pound of coal burned to the water in the boiler, and a temperature of 170° F. at the radiator.

A careful comparison of the rating of many boilers has shown that 1 square foot of grate surface, on which 4 pounds of coal is burned per hour, is rated as capable of supplying about 206 square feet of direct radiating surface or 137 square feet of indirect radiating surface with sufficient hot water to maintain the radiating surfaces at 170° F. With these figures as a basis, Table IV has been deduced; with the aid of this table, the grate surface for any hot-water boiler at various coal-consumption rates and temperatures of radiating surface can be found; it is also possible to determine what amount of radiating surface a given boiler will be adapted for under conditions differing from those under which it was rated, and what coal consumption will be required for a given set of conditions.

TABLE IV

RELATIVE CAPACITIES OF HOT-WATER BOILERS

Temperature of Radiating Surface	Factor for		Combustion Rate
Degrees Fahrenheit	Direct Radiation	Indirect Radiation	Pounds per Square Foot per Hour
212	28.3	18.8	7.3
200	34.0	22.3	6.0
190	39.3	26.0	5.3
180	45.5	30.0	4.5
170	51.5	34.3	4.0
160	59.3	39.5	3.5
150	67.8	45.0	3.0
140	78.5	52.3	2.6

59. To find the grate surface, proceed as follows:

Rule.—*Divide the radiation, in square feet, by the product of the hourly combustion rate per square foot of grate and the factor corresponding to the kind of radiation and temperature, the factor being taken from the second or third column of Table IV. The quotient will be the grate surface, in square feet.*

Or,

$$G = \frac{R}{Cf}$$

where G = grate surface, in square feet;
R = radiating surface, in square feet;
C = hourly combustion rate per square foot of grate;
f = factor taken from Table IV.

Example.—What grate surface is required for a hot-water boiler that is to keep 1,200 square feet of direct radiation, inclusive of piping, at 140° F., with an hourly combustion rate of 4.5 pounds per square foot of grate?

Solution.—By Table IV, $f = 78.5$. Applying the rule,

$$G = \frac{1{,}200}{4.5 \times 78.5} = 3.4 \text{ sq. ft., nearly. Ans.}$$

60. To find what radiation can be supplied by a boiler under a given set of conditions, apply the following:

Rule.—*Multiply the grate surface, in square feet, by the hourly combustion rate per square foot of grate, and by the factor taken from Table IV, corresponding to the temperature and kind of radiation. The product will be the radiating surface, in square feet.*

Or,

$$R = GCf$$

in which the letters have the same meaning as in the formula in Art. **59.**

Example.—What amount of indirect radiation can be supplied by a hot-water boiler having a grate surface of 5.6 square feet, when burning 3 pounds of coal per square foot of grate per hour and keeping the radiating surface at 200° F.?

Solution.—By Table IV, $f = 22.3$. Applying the rule,

$$R = 5.6 \times 3 \times 22.3 = 374.6 \text{ sq. ft., nearly. Ans.}$$

61. The hourly combustion rate per square foot of grate can be approximated as follows:

Rule.—*Divide the radiation, in square feet, by the product of the grate surface, in square feet, and the factor, taken from Table IV, corresponding to the kind and temperature of radiating* *surface. The quotient will be the combustion rate per hour per square foot of grate.*

Or, $$C = \frac{R}{Gt}$$

in which the letters have the same meaning as in the formula in Art. **59.**

Example.—Approximately, what should be the combustion rate in a boiler having a grate 6 square feet in area and supplying 1,500 square feet of direct radiation to keep the radiating surface at 190° F.?

Solution.—By Table IV, $t = 39.3$. Applying the rule,

$$C = \frac{1{,}500}{6 \times 39.3} = 6.3 \text{ lb., nearly. Ans.}$$

62. Size of Chimney.—The required size of chimney flues for ordinary installations of hot-water heating apparatus may be found in Table V, which gives the smallest size that should be used for a given amount of radiation. A chimney flue smaller than 8 by 10 inches should never be used.

TABLE V

CHIMNEY DIMENSIONS FOR HOT-WATER HEATING

Square Feet of Direct Radiation	Required Dimensions of Chimney Inches	Square Feet of Direct Radiation	Required Dimensions of Chimney Inches
375	8 × 10	1,350	12 × 12
450	8 × 12	1,500	12 × 12
600	8 × 12	1,800	12 × 12
750	9 × 12	2,100	12 × 14
900	9 × 12	2,400	12 × 14
1,050	10 × 12	2,700	12 × 16
1,200	10 × 12	3,000	12 × 16

EXAMPLES FOR PRACTICE

1. Suppose that a pipe of a certain diameter will supply 194 square feet of radiation on the first floor; how many square feet of radiation will the same size of pipe supply on the fifth floor?
Ans. 435 sq. ft., nearly

2. A first-story room having 124 square feet of exposed wall surface and 30 square feet of glass surface is to be heated by a two-pipe system of hot-water heating; how much direct radiation is required for the room?
Ans. 38 sq. ft., nearly

3. Suppose that the room in example 2 is to be heated by the one-pipe overhead system; how much direct radiation will be required?
Ans. 43 sq. ft., nearly

4. If 600 square feet of direct radiation, inclusive of piping, is to be kept at 150° F., what grate surface should the boiler have for the usual combustion rate of 4 pounds of coal per square foot of grate per hour?
Ans. 2.2 sq. ft., nearly

5. A hot-water boiler has a grate surface of 3.2 square feet. Burning 4 pounds of coal per hour, how many square feet of direct radiation can be kept: (*a*) at 140° F.? (*b*) at 170° F.? (*c*) at 200° F.?

Ans. (*a*) 1,005 sq. ft.
(*b*) 659 sq. ft.
(*c*) 435 sq. ft.

SIZE OF PIPES

63. Mains.—Table VI shows the area of radiating surface, in square feet, that may be supplied with hot water by two-pipe mains of a given size and of uniform diameter throughout their whole length, the radiators being located on the first floor. For higher floors, a larger amount of radiating surface can be supplied by mains of a given size; to find this amount, multiply the value taken from these tables by 1.41 for the second story, 1.72 for the third story, 1.98 for the fourth story, and 2.24 for the fifth story. The tables given are based on a fall of temperature of 20° F., and a height of circuit of about 10 feet.

To use Table VI, estimate the length of the circuit, and enter the column headed by the nearest length of circuit. Run down this column until the nearest radiation is found; the proper pipe size is then found on the left. When the choice lies between two sizes of pipe, it is usually better to err on the side of safety, that is, to select the larger pipe.

Example.—What size of mains is required for a two-pipe system to supply 900 square feet of direct radiation, the circuit being 370 feet long?

Solution.—Referring to Table VI, the nearest length-of-circuit column is 400 ft. Following this column down, and consulting the

TABLE VI

DIRECT RADIATION SUPPLIED BY TWO-PIPE HOT-WATER MAINS

Nominal Diameter of Pipe Inches	Total Estimated Length of Circuit, in Feet									
	100	200	300	400	500	600	700	800	900	1,000
	Square Feet of Radiation Supplied									
1	50									
1¼	90	64								
1½	140	98	85	70						
2	250	176	153	125	113	103	95			
2½	360	256	220	180	162	148	137	126	119	112
3	540	385	329	270	243	221	205	189	178	167
3½	750	533	458	375	338	308	285	263	248	233
4	1,000	710	610	500	450	410	380	350	330	310
4½	1,400	980	854	700	630	574	532	490	462	434
5	1,800	1,278	1,098	900	810	738	684	630	594	568
6	2,700	1,917	1,647	1,350	1,215	1,107	1,026	945	891	837
7	4,000	2,840	2,440	2,000	1,800	1,640	1,520	1,400	1,320	1,240
8	5,400	3,850	3,290	2,700	2,430	2,210	2,050	1,890	1,780	1,670
9	7,200	5,112	4,392	3,600	3,240	2,952	2,736	2,520	2,376	2,232
10	9,600	6,800	5,800	4,800	4,300	3,900	3,600	3,400	3,200	3,000

left-hand column, it is seen that 900 sq. ft. can be supplied by a 5-in. pipe. Ans.

64. In proportioning mains for the single-main, or one-pipe, system of hot-water heating, satisfactory results on circuits under 200 feet in length will ordinarily be obtained by making the diameter of the main, in inches, not less than .16 times the square root of the direct radiation supplied, in square feet.

Example.—With a single-main system, what size of main is required to supply 400 square feet of radiation, the circuit being 190 feet long?

Solution.—Size of main = $.16\sqrt{400} = 3.2$ in. In practice, a 3½-in. pipe would be used. Ans.

65. For single-pipe system mains, where the circuit is longer than 200 feet, Table VI may be consulted and the size of main there given increased one size.

Example.—With a single-pipe system, what size of main is required for a circuit 900 feet long and supplying 600 square feet of direct radiation?

Solution.—By Table VI, a 5-in. main is used. Then, by the statement in this article, use a 6-in. main. Ans.

66. Branches.—When the various branch pipes are of different sizes, recourse must be had to calculation to find the size of main capable of supplying these branches. To save this calculation for the most common cases, Table VII has been prepared.

67. Risers.—Table VIII shows the area of direct radiating surface, in square feet, that can properly be supplied at various elevations by risers of a given diameter. The radiators are supposed to be connected by ordinary short connections having a total length of about 10 feet. Each story corresponds to a height of about 10 feet.

There is a practical limit to the vertical length of risers that can be used to advantage, especially in the smaller sizes of pipe. If a small riser is extended to a great height, the friction of flow becomes excessive and the quantity of water delivered will be much smaller than it would be with less

TABLE VII

RELATIVE SIZE OF MAINS AND BRANCHES

Size of Mains Inches	Size of Branches That Mains Will Supply
1	Two ¾"
1¼	Two 1"; or one 1" and two ¾"
1½	Two 1¼"; or one 1¼" and two 1"
2	Two 1½"; or one 1½" and two 1¼"
2½	Two 1½" and one 1¼"; or one 2" and one 1¼"
3	One 2½" and one 2"; or two 2" and one 1½"
3½	Two 2½"; or one 3" and one 2"; or three 2"
4	One 3½" and one 2½"; or two 3"; or four 2"
4½	One 3½" and one 3"; or one 4" and one 2½"
5	One 4" and one 3"; or one 4½" and one 2½"
6	Two 4" and one 3"; or four 3"; or ten 2"
7	One 6" and one 4"; or three 4" and one 2"
8	Two 6" and one 5"; or five 4" and two 2"

TABLE VIII

DIRECT RADIATION SUPPLIED BY RISERS

Diameter of Riser Inches	Floor on Which Radiation is Located					
	1	2	3	4	5	6
¾	18	25				
1	36	50	62	71		
1¼	65	92	112	128	145	
1½	100	141	172	198	224	244
2	180	253	309	356	403	439
2½	260	366	447	515	582	634
3	370	521	636	732	828	902
3½	540	761	928	1,069	1,210	1,318
4	720	1,015	1,238	1,425	1,612	1,756

height. The limits for the various diameters are about as follows:

Diameter, in inches	¾	1	1¼	1½	2
Height, in feet	20	30	45	60	80

If a riser is diminished in diameter toward the top and the height of any given size of the riser exceeds that prescribed above, a larger size should be used. For instance, if the last proposed extension of the riser is ¾ inch, and the height of this proposed ¾-inch extension is over 20 feet and under 30 feet, a 1-inch pipe should be used.

68. Radiator Connections.—Table IX gives the area of radiator surface, in square feet, that is adapted to connections having the diameter given, for service on the first floor; that is, at an elevation of about 10 feet above the level of the return connection to the boiler. If the area of heating surface exceeds the amount given, the fall of temperature will exceed 20°, and if it is less, the fall will be less correspondingly. If the connections are long or crooked, less heating surface can be operated, or a larger drop in temperature will occur.

TABLE IX

SIZE OF RADIATOR CONNECTIONS

Direct Radiation				Indirect Radiation	
First Floor		Second Floor			
Pipe Size Inches	Surface Square Feet	Pipe Size Inches	Surface Square Feet	Pipe Size Inches	Surface Square Feet
¾	0 to 18	¾	0 to 24	1	0 to 24
1	18 to 40	1	24 to 54	1¼	24 to 50
1¼	40 to 70	1¼	54 to 94	1½	50 to 80
1½	70 to 120	1½	94 to 160	2	80 to 120

When the length of the circuit through the radiator connections exceeds 100 feet, allowing for friction of elbows, etc., use the next larger pipe size for circuits up to 300 feet in length, and for longer circuits use pipe two sizes larger than would be required for the ordinary, or short, radiator connections.

EXAMPLES FOR PRACTICE

1. In a single-main system having a circuit 180 feet long, what should be the size of the main if 400 square feet of direct radiation is to be supplied? Ans. 3½ in.

2. If 300 square feet of direct radiation is located on the second floor of a residence, what size of riser is required? Ans. 2½ in.

3. What should be the size of the connections for a 100-square foot radiator located on the first floor? Ans. 1½ in.

HOT-WATER HEATING

Serial 1082 Edition 1

EXAMINATION QUESTIONS

Notice to Students.—*Study the Instruction Paper thoroughly before you attempt to answer these questions.* **Read each question carefully and be sure you understand it;** *then write the best answer you can. When your answers are completed, examine them closely, correct all the errors you can find, and* **see that every question is answered;** *then mail your work to us.*

(1) Are the fittings commonly employed for steam work suitable for hot-water heating apparatus? Give reason.

(2) What are the principal requirements of valves employed in hot-water heating, and how do they differ from those used in steam heating?

(3) Is it considered good practice to use globe valves in a hot-water system? Give reason.

(4) What provision should be made in hot-water radiator valves to prevent the water in the radiator from becoming frozen when the valve is closed?

(5) What must be considered in connecting up an expansion tank in regard to stop-valves and frost?

(6) On what does the velocity of circulation depend?

(7) A hot-water heating system contains 200 cubic feet of water at 55° F.; how much will the water expand if the water is raised to 200° F.? Ans. 7.702 cu. ft.

(8) What is understood by motive force, as applied to a hot-water heating system?

(9) What is the total motive force, per square inch, in a hot-water heating system, the average temperature in the ascending column being 200° F. and that in the descending column 160° F., the operative height of the descending column of water being 30 feet? Ans. .189 lb. per sq. in.

(10) What is the object of using an expansion tank in connection with a hot-water heating system?

(11) What is the minimum size of an expansion tank required to provide for the expansion in a heating system containing 500 gallons of water?

(12) Describe briefly the difference between the open and closed system of hot-water heating.

(13) Explain how it is that air gathers at the highest points of a hot-water heating system.

(14) To what extent will an air lock affect the circulation in a hot-water apparatus?

(15) Describe briefly the simple-circuit system of hot-water heating.

(16) Describe how the flow and return branches to the radiators are connected to the main in a one-pipe hot-water system.

(17) It is found that a 2-inch pipe is the proper size to supply a radiator on the first floor; what size of pipe will be required to supply the same radiator on the fourth floor?

Ans. $1\frac{1}{2}$ in.

(18) With a two-pipe system of hot-water heating, how many square feet of direct radiation will be required on the first floor for a room containing 325 square feet of exposed wall surface, and 80 square feet of glass surface?

Ans. 101.6 sq. ft.

(19) What grate surface will be required in a boiler that is to supply 1,500 square feet of direct radiating surface, including piping, at 160° F. burning 5 pounds of coal per square foot of grate surface per hour? Ans. 5.06 sq. ft.

(20) What size of main will be required to supply 900 square feet of direct radiation on a one-pipe circuit system, the length of the circuit being 160 feet? Ans. 5 in.

Mail your work on this lesson as soon as you have finished it and looked it over carefully. DO NOT HOLD IT until another lesson is ready.