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CHAPTER IV

HOT WATER HEATING SYSTEMS AND PIPING

Heat Emission of Hot Water Radiators, Temperature Drop, Different kinds of systems, Determination of Pipe Sizes, Simple Rules for Small Systems, Details of Connection.

THE feature which distinguishes hot-water heating systems from all other types is that water serves as the medium by which heat is conveyed from the heater to the radiators. Water has a large capacity for heat and for that reason it is well suited to perform the service of conveying heat.

The design of a hot-water heating system should include the radiators, the heater or heaters, and the piping system. These three subjects will be considered in the order named.

RADIATION

To proportion the radiation it is necessary to know the quantity of heat, *i.e.*, the number of B.t.u. which are lost in a unit of time by the room or space in which the radiator is to be located and which must be replaced by the heat dissipated by the radiator so that the room or space may remain at the desired temperature.

The methods of determining the heat losses from a building or part of a building are explained in Chapter I.

Knowing the number of B.t.u. which a particular radiator is to dissipate (see Chapter II), it is necessary to assume the temperatures at which the water is to enter and to leave the radiator. Having done this, it is customary to assume that the mean of these two temperatures is the average temperature of the water in the radiator. For example, if the water is to enter the radiator at a temperature of 200 deg. and to leave it at a temperature of 180 deg., it is assumed that the average temperature of the water in the radiator is 190 deg. If, in this case, the average room temperature is to be 70 deg., the average difference of the temperature of the water in the radiator and of the air surrounding the radiator is 120 deg. This temperature difference, water to air, is used as the basis for the design of the radiator.

The transfer of heat from the radiator to the surrounding space takes place partly by radiation, partly by convection, and partly by conduction. The quantity of heat dissipated by a radiator per square foot of surface, per hour, and per degree of temperature difference, water to air, is the heat dissipation coefficient of the radiator. This coefficient is generally represented by the letter k. A little reflection will convince the reader that the value of k, for a given type radiator, must decrease as the length

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This Chapter especially prepared for THE GUIDE by Prof. F. E. Giesecke, Director of Texas Engineering Experiment Station, College Station, Texas.

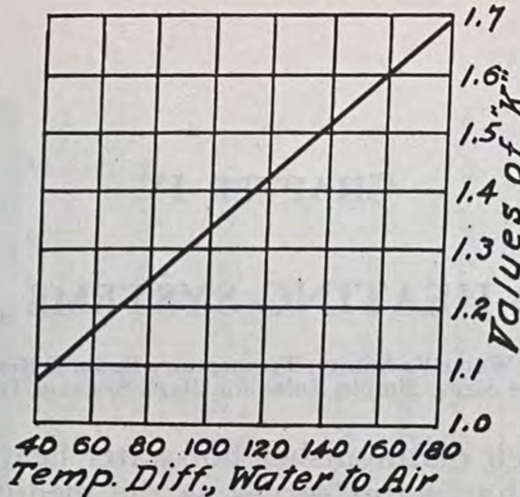


FIG. 1. HEAT DISSIPATION COEFFICIENT—*K*—OF A 38-IN., 3-COL. 20 SEC. HOT WATER RADIATOR AS DETERMINED AT THE UNIVERSITY OF ILLINOIS

of the radiator is increased, as its height is increased, as the number of columns in the radiator are increased, and as the temperature difference, water to air, is decreased. The writer conducted a series of tests in the laboratory of the Department of Mechanical Engineering, University of Illinois, to determine the values of *k* for a 38-in., 3-col., 20-sec. radiator, when the temperature difference, water to air, varied from about 55 deg. to about 145 deg., and when the water entered the radiator through the upper tapping and was discharged through the lower tapping. The results of this series of tests are shown in Fig. 1.

Using the values of Fig. 1 as a basis and assuming that the heat dissipation coefficient of a hot-water radiator varies with the height of the radiator and with the number of columns of the radiator in substantially the same manner in which the heat dissipation coefficient of a steam radiator varies, as determined by Professor Allen and other investigators, Fig. 2 shows the values of *k* for the most common types of hot-water radiators. It can be used to determine the size of the radiator when the type of the radiator to be used, the average temperature difference, water to air, and the quantity of heat to be dissipated per hour by the radiator are known.

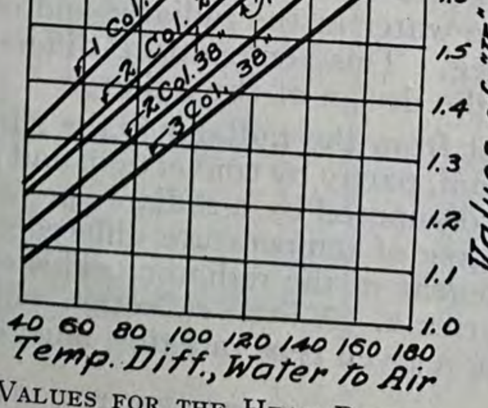


FIG. 2. SUGGESTED VALUES FOR THE HEAT DISSIPATION COEFFICIENTS—*K*—OF VARIOUS TYPES OF HOT WATER RADIATORS

An inspection of Figs. 1 and 2 shows that it is very important to maintain a high average water temperature in every radiator. For example, if a 38-in., 3-col., radiator, located in a room having a temperature of 70 deg., is to dissipate 12,000 B.t.u. per hour, a 100-ft. radiator must be selected if the average water temperature in the radiator is 160 deg., whereas we may use a 70-ft. radiator if the average water temperature is 190 deg., or a 60-ft. radiator if the average water temperature is 205 deg.

It will be shown in the discussion of the design of the pipe system, that a decrease in pipe sizes results in an increase of friction, in an increase in the difference of the temperatures of the water in the flow and return risers, and consequently, in a decrease in the average temperature of the water in the radiator.

It is evident from the preceding discussion of radiator design that any economy which may have been effected by reducing pipe sizes will be offset in part, and may be totally offset, by the increased sizes of the radiators, particularly as the cost of a hot-water heating system is frequently based on the total radiation surface.

To illustrate the use of the diagrams of Fig. 2, let it be required to find the size of the radiator to be used if 8000 B.t.u. are to be dissipated by a 38-in., 3-col. radiator when the average temperature difference, water to air, is $170 - 70$, or 100 deg. The value of k for this case, from Fig. 2, is about 1.34. The total surface required is $8000/1.34$ or 60 sq. ft.

HEATER

To determine the heater it is necessary to know the quantity of heat which is to be transmitted to the water in the heater, and whether hard coal, soft coal, gas, steam, or electricity is to be used for heating the water.

The engineer designing a hot-water heating system does not, as a rule, design the heater. He simply selects a heater suited to his needs from those available on the market. In selecting a heater for large installations, it is generally desirable to install at least two heaters, so that if one should fail the other will be available. When two heaters are installed, it may be advisable to select them of different sizes, the larger one having a capacity about 75 per cent greater than the smaller heater. If this is done, the heaters should be selected of such sizes that both may be used during extremely cold weather and the smaller or the larger during milder weather, depending on the outside temperature so that, at all times, the heating plant may be operated at a fairly high efficiency. There is frequently an advantage in having the two heaters of the same size so they may be interchangeable. This arrangement is very satisfactory, especially in the colder climates, if each heater is made of a size sufficient to carry about two-thirds of the maximum load.

PIPING SYSTEM DESIGN

To design the piping for a hot-water heating system many factors must be considered. For any given combination of heater and radiator, several different systems of piping may be designed so as to secure successful and satisfactory operation of the system.

There is only one general rule for the design of pipe systems that is applicable in all cases. It is this: *When the heating system is functioning at a uniform rate, that is when, in a given time, the radiators dissipate exactly the same quantity of heat that is delivered to the water in the heater, and when, consequently, the water in the system is circulating with a uniform velocity*, the friction head in every circuit leading from the heater to a radiator and back again must be exactly equal to the pressure head for that particular radiator, *i.e.*, to the pressure head which tends to make the water flow from the heater to that radiator and back again, along the circuit referred to previously.

Before applying this general rule to the design of a piping system, it is necessary to assume:

1. The maximum temperature of the water leaving the heater when the outside temperature is the minimum for which the system is to be designed.
2. The drop in the temperature of the water while it is flowing through the radiator.
3. Whether the circulation of the water in the system is to be effected by gravity or by circulating pumps.
4. The arrangement of the piping connecting the heater with the several radiators.

These four preliminary steps will be discussed in the order named.

MAXIMUM WATER TEMPERATURE

For some time it has been customary to select 180 deg. as the maximum temperature of the water leaving the heater. With this maximum temperature and a temperature drop of 20 deg. through the radiator, the average water temperature in the radiator will be 170 deg. If the temperature of the room is to be 70 deg., the temperature difference, water to air, will be 100 deg. The corresponding value of k for a 38-in., 3-col. radiator is 1.34 and the heat dissipated by the radiator per square foot per hour is 134 B.t.u. A steam radiator of similar size and design and supplied with low-pressure steam will dissipate about 210 B.t.u. per square foot an hour. Under these conditions, a hot-water heating system would require about 210 sq. ft. of radiation for every 134 sq. ft. required by the steam heating system. The first cost of the hot-water system would, consequently, be considerably higher than that of the corresponding steam system. This higher first cost of a hot-water system is frequently the cause of the installation of a steam system.

If, on the other hand, 220 deg. is selected as the temperature of the water leaving the heater, the average temperature of the water in the radiator will be about 210 deg., practically the same as that in low-pressure steam radiation, and the total radiation required for the hot-water system will be about the same as that required for the corresponding steam system. The cost of the pipe system for hot water is probably a little higher than the cost of the pipe system for steam, but the cost of valves and traps for a steam system is higher than the cost of the valves for a hot-water system, so that, finally, the cost of a hot-water heating system will not be higher, and is frequently lower, than the cost of a corresponding steam heating system, if the maximum temperature of the water is selected sufficiently high.

The selection of 220 deg. as the maximum water temperature is entirely proper because the minimum outside temperature for which the heating system is designed and for which the heat losses are calculated, occurs only a few times in any one year and perhaps never in some years. Consequently, it is very seldom and in some years never necessary to heat the water to the assumed maximum temperature.

If 220 deg. is selected as the maximum temperature, it is necessary to provide sufficient pressure of the water in all radiators and in the entire pipe system so that the water will not boil at that temperature. This can be accomplished easily in all closed systems and also in all open systems. In the latter case, it is only necessary to place the expansion tank at a sufficient altitude above the highest point of the heating system. For example, if the expansion tank is located 10 ft. above the highest point in the system and if the expansion tank riser is filled with 200 deg. water when the flow risers carry 220 deg. water, the pressure at the highest point of the heating system will be about 4.2 lb. per sq. in. The corresponding boiling point is about 226 deg. and there would be no danger of boiling the water in the heating system at 220 deg.

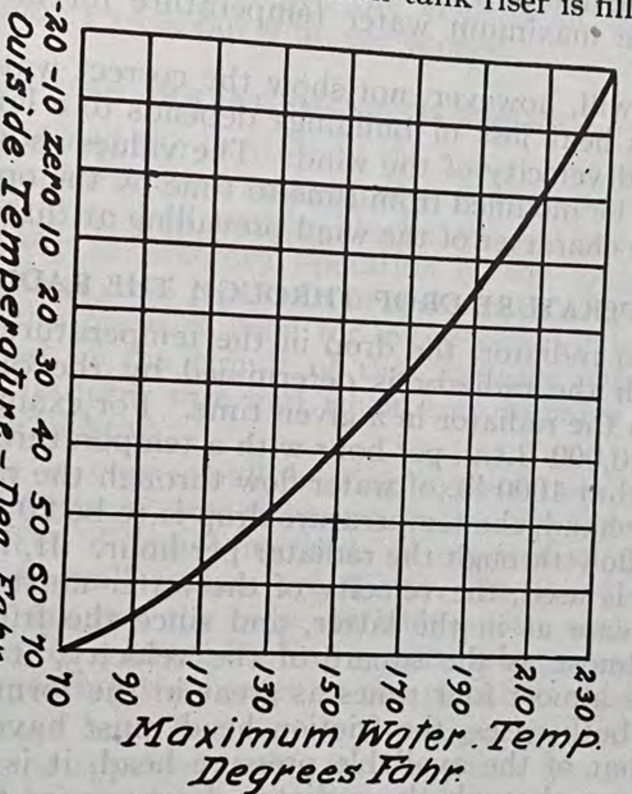


FIG. 3. AN ILLUSTRATION OF THE VARIATION, WITH THE OUTSIDE TEMPERATURE, OF THE REQUIRED MAXIMUM WATER TEMPERATURE IN THE HEATING SYSTEM

In such cases the expansion tank riser should be connected to the return main. Precautions must always be taken to prevent freezing of the water in the expansion tank or in the expansion tank riser.

Having assumed the maximum temperature of the water for the minimum outside temperature, the required maximum temperature of the water for any other outside temperature may be found as follows:

If 220 deg. is selected as the maximum temperature of the water when the minimum outside temperature is -10 deg., if the inside temperature is to be 70 deg. and the temperature drop through the radiator is to be 20 deg., if R represents the total radiation in square feet, and if it is assumed that the total heat losses are proportional to the temperature differences, inside and outside, the total heat loss will be 1.52 *R* (210 − 70) or 212.8 *R*. In this calculation, 1.52 is the value of *k* for a 38-in., 3-col. radiator. When the maximum water temperature is 180 deg., the total heat loss will be 1.34 *R* (170 − 70) or 134 *R*. Similarly, when the maximum water temperature is 140 deg. the total heat loss will be 69.6 *R*. Since a heat loss of 212.8 *R* corresponds to a temperature difference, inside to outside, of 80 deg., heat losses of 134 *R* and 69.6 *R*, correspond, respectively, to 49 deg. and 25.5 deg. of temperature differences. Consequently, the two assumed maximum water temperatures correspond, respectively, to outside temperatures of 21 deg. and 44.5 deg. From such data, a curve like that shown in Fig. 3 may be constructed and used to determine the maximum water temperature for any given outside temperature.

Such a curve will, however, not show the correct water temperatures for all times, as heat loss of buildings depends to a large extent upon the direction and velocity of the wind. The values shown by the curve must, therefore, be modified from time to time by the operating engineer according to the character of the wind prevailing at that particular time.

TEMPERATURE DROP THROUGH THE RADIATOR

For any given radiator, the drop in the temperature of the water as it flows through the radiator is determined by the quantity of water flowing through the radiator in a given time. For example, if a radiator is to dissipate 10,000 B.t.u. per hour with a temperature drop of 10 deg., it is necessary that 1000 lb. of water flow through the radiator per hour. If, on the other hand, the temperature drop is to be 20 deg., only 500 lb. of water must flow through the radiator per hour. If, in both cases, the same size pipe is used, the velocity of the water must be twice as high in the former case as in the latter, and since the friction of water in pipes varies almost as the square of the velocity, it follows that the friction head is almost four times as great in the former case as in the latter. If, in both cases, the friction head must have a fixed value—the same as that of the available pressure head, it is evident that the temperature drop through the radiator decreases as the pipe sizes are increased. It was shown above that the required size of the radiator decreases as the temperature drop through the radiator decreases.

Reducing the temperature drop through the radiator, then, decreases the sizes of the radiators but increases the sizes of the piping; in other words, it decreases the cost of the radiators but increases the cost of the piping. There is, consequently, an optimum temperature drop through the radiators for every installation which carries with it the lowest cost of installation. This optimum temperature drop can be determined by a few trial calculations. As a rule, such calculations are never made; the temperature drop is selected arbitrarily.

A temperature drop of from 20 to 30 deg. is common and generally quite satisfactory.

THE MOTIVE FORCE

Whether gravity circulation or forced circulation is to be adopted for any particular installation is generally evident from the nature of the case. In almost all residence systems and in a good many installations in larger buildings, gravity circulation is entirely satisfactory and should be adopted because its operation is much more simple and also cheaper than that of forced circulation.

For installations which are too large to function well as gravity systems and for all general heating systems which serve a group of buildings, forced circulation should be adopted.

The optimum velocity of the water in forced circulation systems is subject to calculation. As the velocity is increased, the size, and therefore also the cost, of the piping and radiation is decreased but the cost of the pump and the cost of operating the pump are increased. As a general rule, a velocity of from 6 to 10 ft. per second will be found satisfactory.

In gravity circulation systems, the velocity of the water generally varies from about 1 to about 6 in. per second.

ARRANGEMENT OF PIPING

Having determined the location of the heater and the locations of the several radiators, there are a large number of different ways in which the piping can be arranged to connect the heater and the radiators so as to secure an entirely satisfactory operation of the system, provided the radiators and the several pipes of the system are of correct size so that, in every case, the pressure head for every radiator is exactly equal to the friction head in the circuit of that radiator, when the system is operating at a uniform rate and when each radiator is dissipating its correct quantity of heat.

Fig. 4 shows a very small heating system consisting of a heater, located in the basement, two radiators on the first floor, and two on the second floor. Ten different methods of connecting the heater to the radiator for this small system are shown. It is evident that the ten methods shown are not the only methods which could be used. It is also evident that for a larger heating system, a larger number of different methods of connecting the heater to the radiators exist.

Several attempts have been made to assign distinctive names to the several methods or types of piping for hot-water heating systems. The result is not satisfactory because it is possible to have so many variations of each typical method or system of piping. The following definitions, supplemented by the illustrations of Fig. 4, will serve to describe the more common general types of piping:

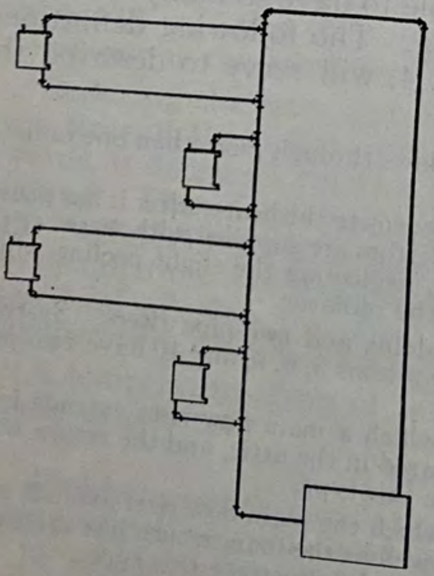
1. A *one-pipe* system is one in which the water flows through more than one radiator before it returns to the heater.

2. A *two-pipe* system is one in which all water returns to the heater after it has passed through one radiator. In a two-pipe system all radiators are supplied with water at the temperature at which the water leaves the heater, neglecting the slight cooling which takes place in the pipe leading from the heater to the radiator.

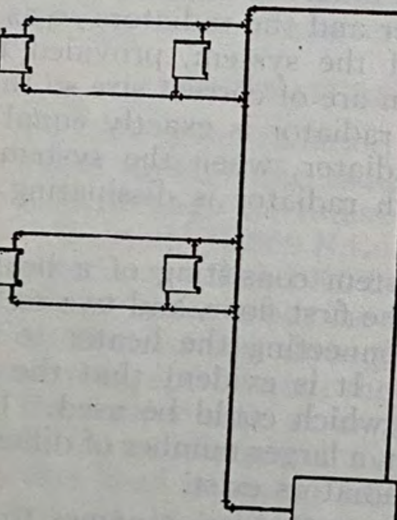
Systems 1, 2, 3, and 4 of Fig. 4 have one-pipe mains and two-pipe risers. Systems 7 and 8 have two-pipe mains and one-pipe riser. Systems 5, 6, 9, and 10 have two-pipe systems throughout.

3. An *over-head* distribution system is one in which a main flow riser extends from the heater to the attic, the distributing main is located in the attic, and the return main in the basement. Systems 7, 8, 9, and 10 illustrate this type.

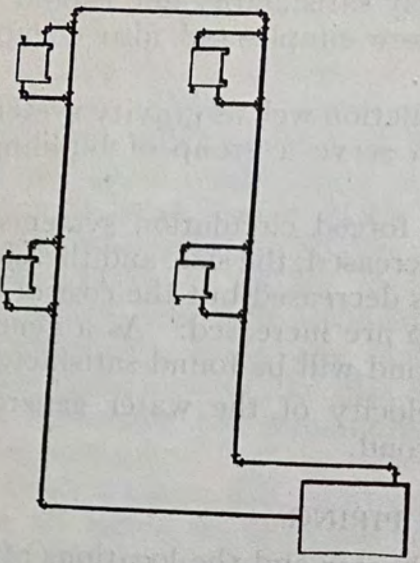
4. An *under-foot* distribution system is one in which the main flow riser extends only to the basement ceiling, and the main flow line as well as the main return line is located below the basement ceiling. Systems 1, 2, 3, 4, 5, and 6 illustrate this type.



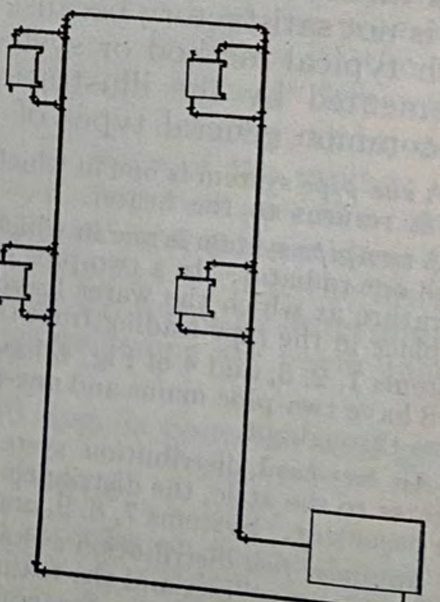
System 1



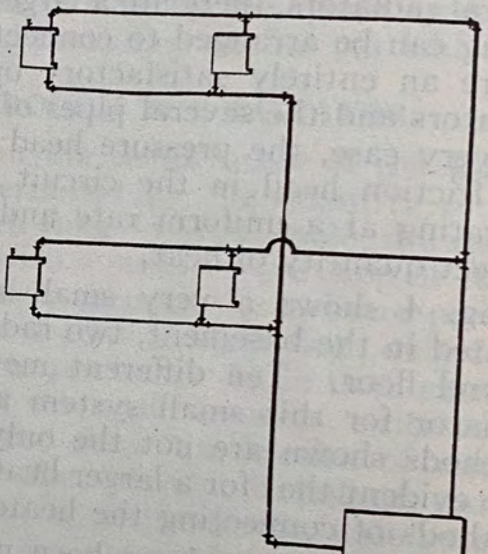
System 2



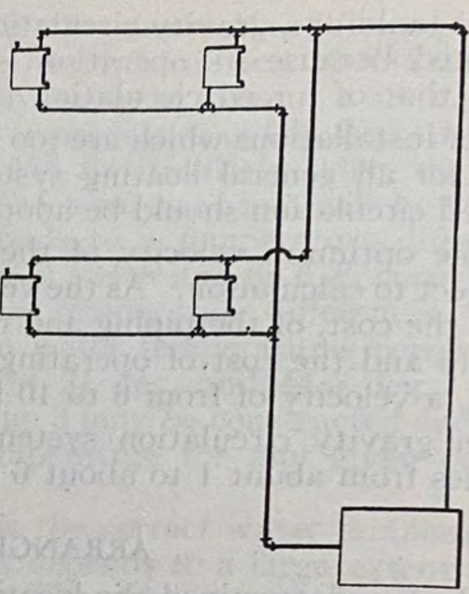
System 3



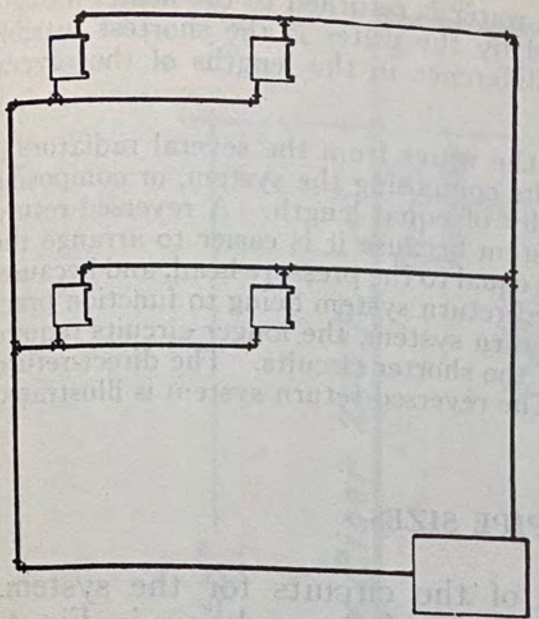
System 4



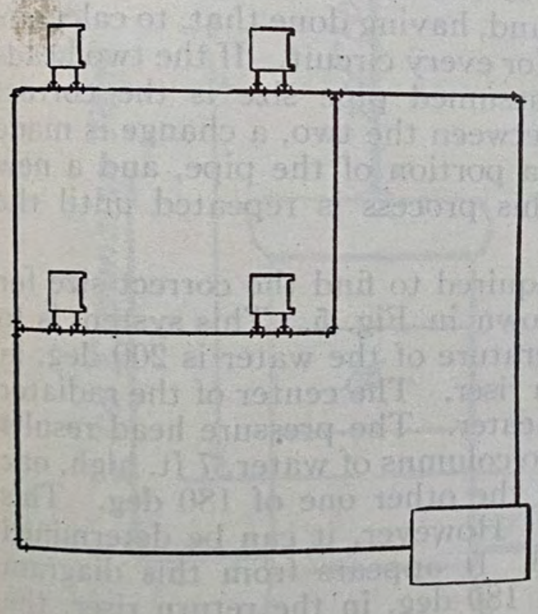
System 5



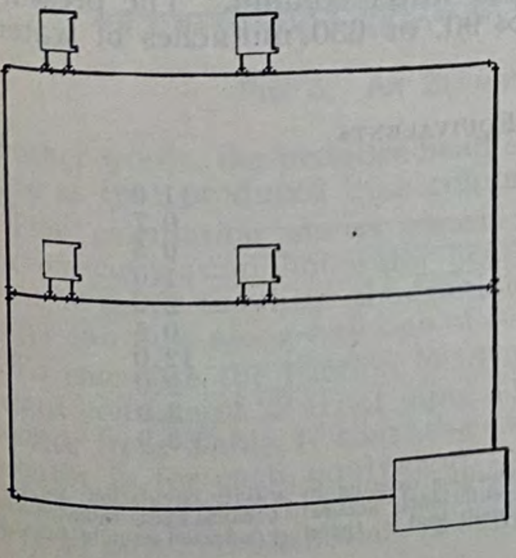
System 6



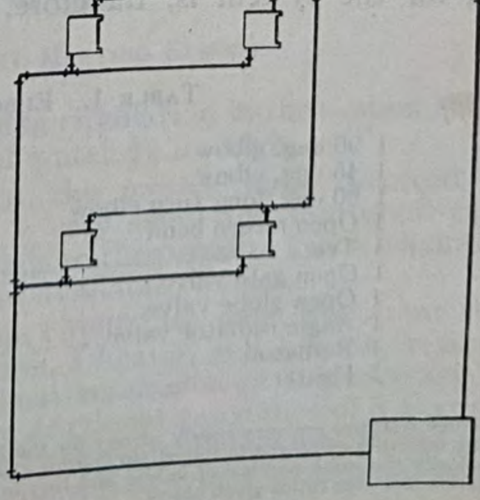
System 9



System 8



System 7



System 10

FIG. 4. TEN EXAMPLES OF A LARGE NUMBER OF PIPE SYSTEMS WHICH MAY BE USED FOR A HOT WATER HEATING SYSTEM

5. A *direct-return* system is one in which the water is returned to the heater along a direct path, so that the total distance traveled by the water is the shortest feasible distance, and so that there is a considerable difference in the lengths of the several circuits composing the system.

6. A *reversed-return* system is one in which the water from the several radiators is returned along paths arranged so that all circuits composing the system, or composing major sub-division of the system, are practically of equal length. A reversed-return system is to be preferred to a direct-return system because it is easier to arrange the circuits so that, in every case, the friction head is equal to the pressure head, and because, in starting the system, all circuits of the reversed-return system being to function practically at the same time, whereas, in a direct-return system, the longer circuits require considerably more time to begin operating than the shorter circuits. The direct-return system is illustrated by Systems 5, 7, and 9. The reversed-return system is illustrated by Systems 6, 8, and 10.

DETERMINING PIPE SIZES

Having settled on the arrangement of the circuits for the system, generally by selecting a scheme similar to one of those shown in Fig. 4, it is customary to assume the pipe sizes and, having done that, to calculate the pressure head and the friction head for every circuit. If the two heads happen to be practically equal, the assumed pipe size is the correct one. If there is a material difference between the two, a change is made in the assumed size of the pipe, or of a portion of the pipe, and a new friction head calculation is made. This process is repeated until the correct size has been found.

To illustrate the method, let it be required to find the correct size for the pipe of the elementary system shown in Fig. 5. This system is to dissipate 12,000 B.t.u. when the temperature of the water is 200 deg. in the flow riser and 180 deg. in the return riser. The center of the radiator is to be 7 ft. above the center of the heater. The pressure head results from the difference in the weights of two columns of water, 7 ft. high, one having a temperature of 200 deg. and the other one of 180 deg. This difference in weight can be calculated. However, it can be determined more easily from the diagram of Fig. 6. It appears from this diagram that for 200 deg. in the flow riser and 180 deg. in the return riser, the pressure head is 90 milinches per foot of water column. The pressure head for the system is, therefore, 7 × 90, or 630 milinches of water.

TABLE 1. ELBOW EQUIVALENTS

1 90 deg. elbow	1.0
1 45 deg. elbow	0.7
1 90 deg. long turn elbow	0.5
1 Open return bend	1.0
1 Tee	2.2
1 Open gate valve	0.5
1 Open globe valve	12.0
1 Angle radiator valve	2.0
1 Radiator	3.0
1 Heater	3.0

These relations are very nearly correct for the low velocities existing in gravity circulation; for the higher velocities employed in forced circulation, they are sufficiently accurate because every radiator has practically the same number of valves and tees in its circuit and is, therefore, affected equally by any variation from the ratios given above.

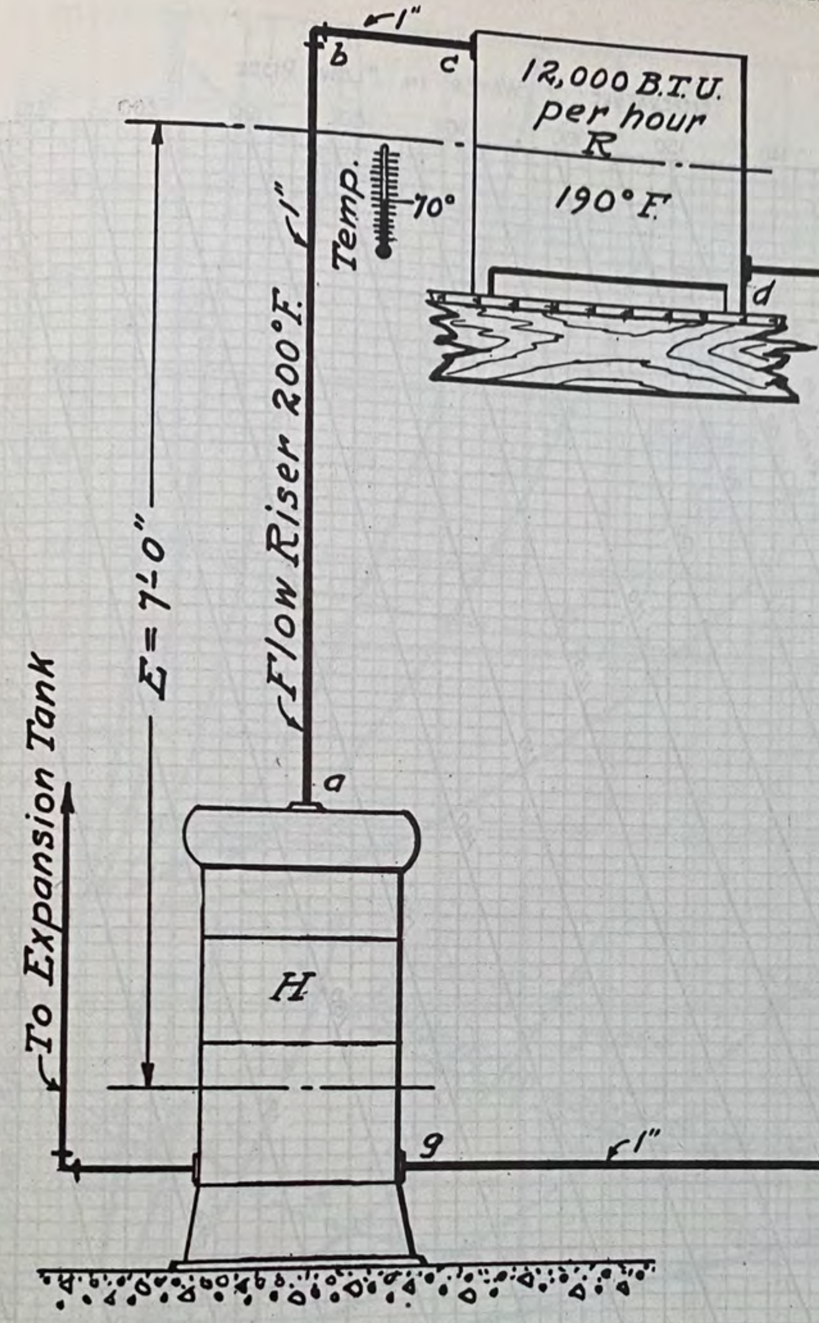


FIG. 5. AN ELEMENTARY HEATING SYSTEM

In other words, the pressure head causing circulation in the system is the same as that produced by a column of water ⅝ in. high.

This calculation shows clearly that the motive force involved in gravity circulation hot-water heating is very small and that great care must be taken to adjust the friction heads to the pressure heads when the water can flow along any one of several available circuits.

To calculate the friction head in the circuit, we note, first, that the circuit consists of 22 ft. of pipe, 3 elbows, 1 heater, and 1 radiator; and, second, from Table 1, that the frictional resistance of 1 heater and 1 radiator is, for each, equivalent to the frictional resistance of 3 elbows. Consequently, the friction head of the entire circuit is equal to that in 22 ft. of pipe and 9 elbows. Assuming, now, that 1-in. pipe is to be used,

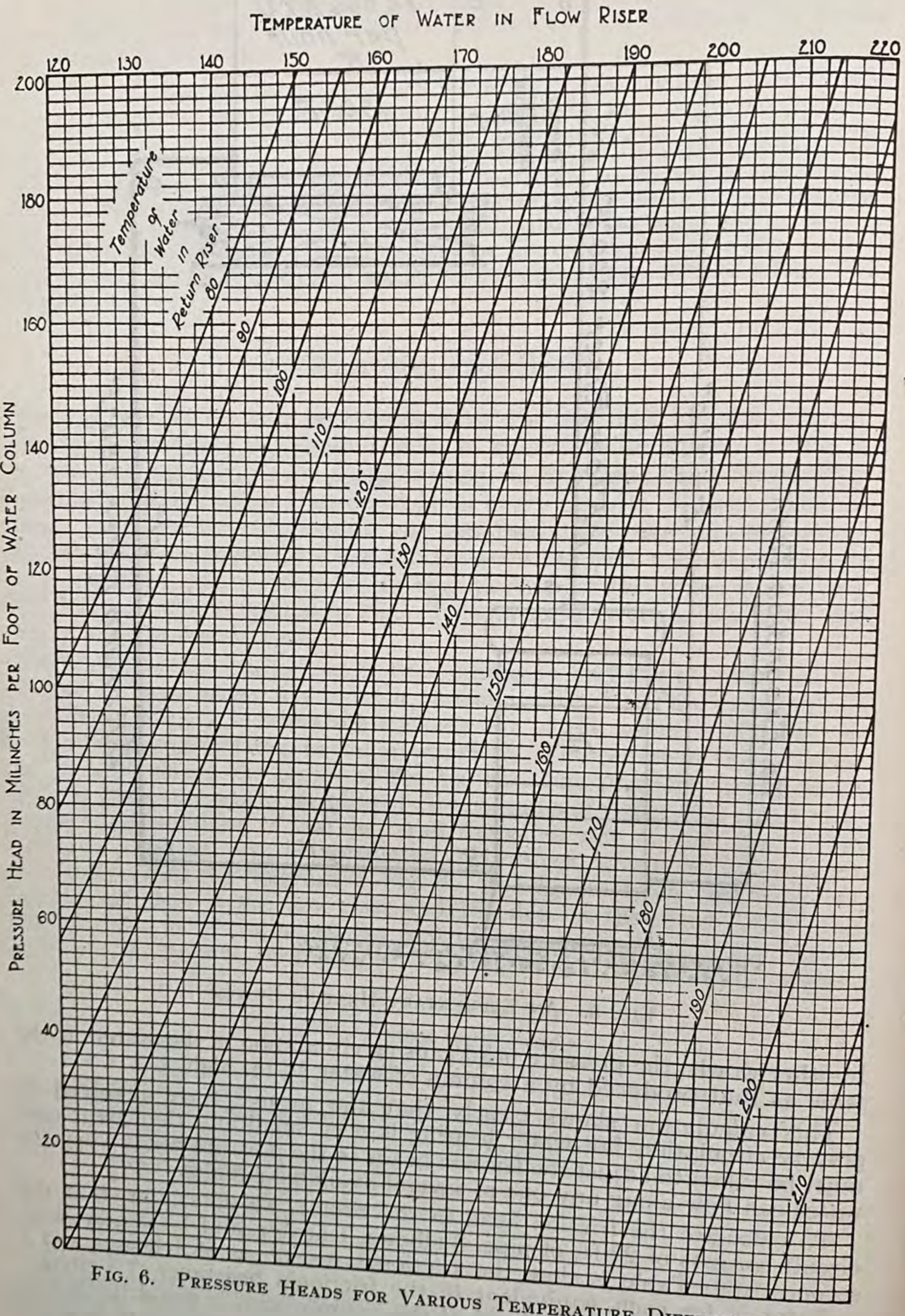


FIG. 6. PRESSURE HEADS FOR VARIOUS TEMPERATURE DIFFERENCES

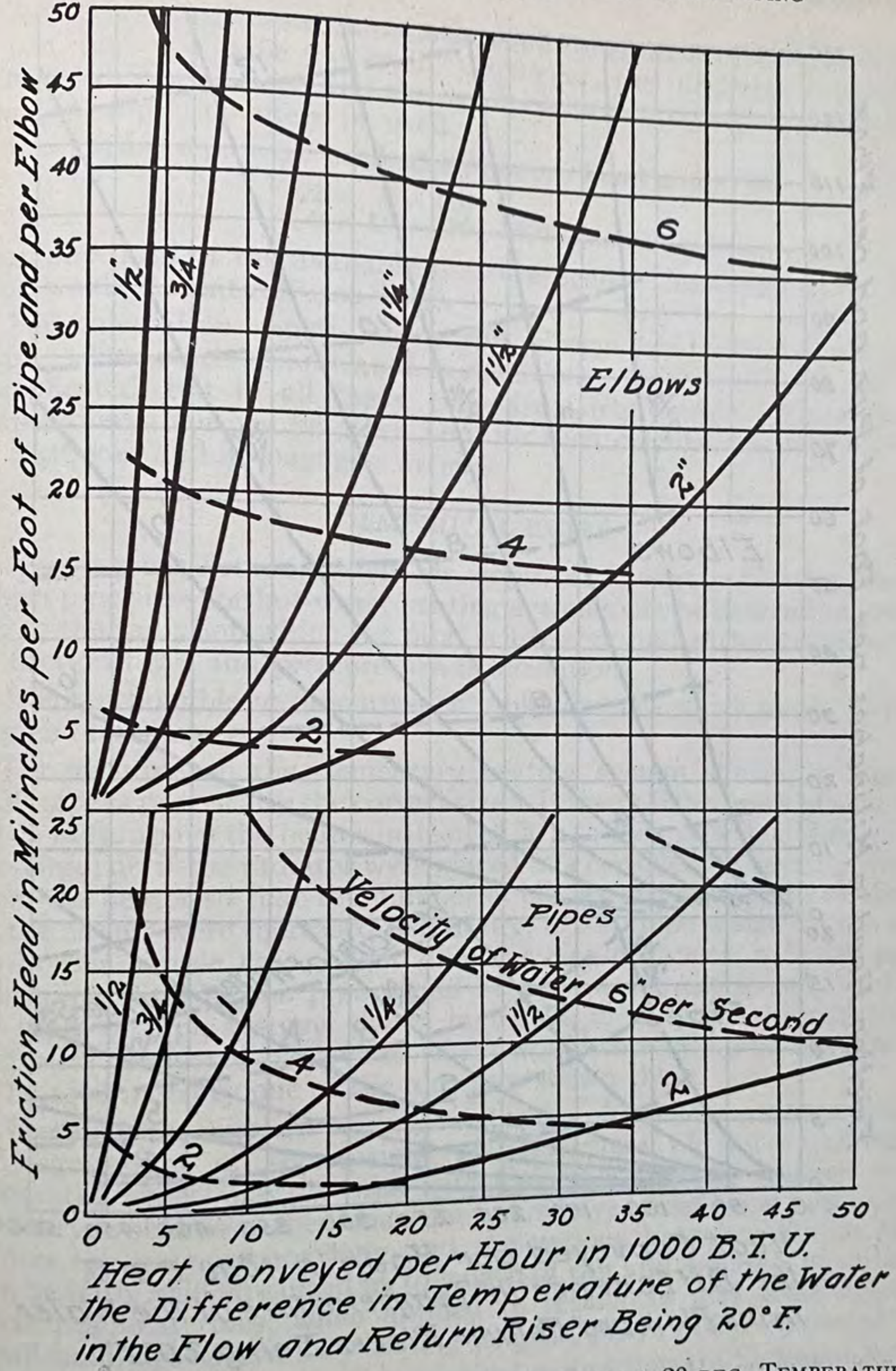


FIG. 7. FRICTION HEADS, IN PIPES AND ELBOWS, FOR A 20 DEG. TEMPERATURE DIFFERENCE OF THE WATER IN THE FLOW AND RETURN LINES

the friction heads in the pipe and in the elbows can be calculated by known formulae, or, they can be determined more readily from the diagrams of Figs. 7 and 8. It will be noted from Fig. 7, that for a 1-in. pipe, for 12,000 B.t.u. per hour, and for a temperature drop of 20 deg., the friction head is 18 milinches per foot of pipe and 35 milinches

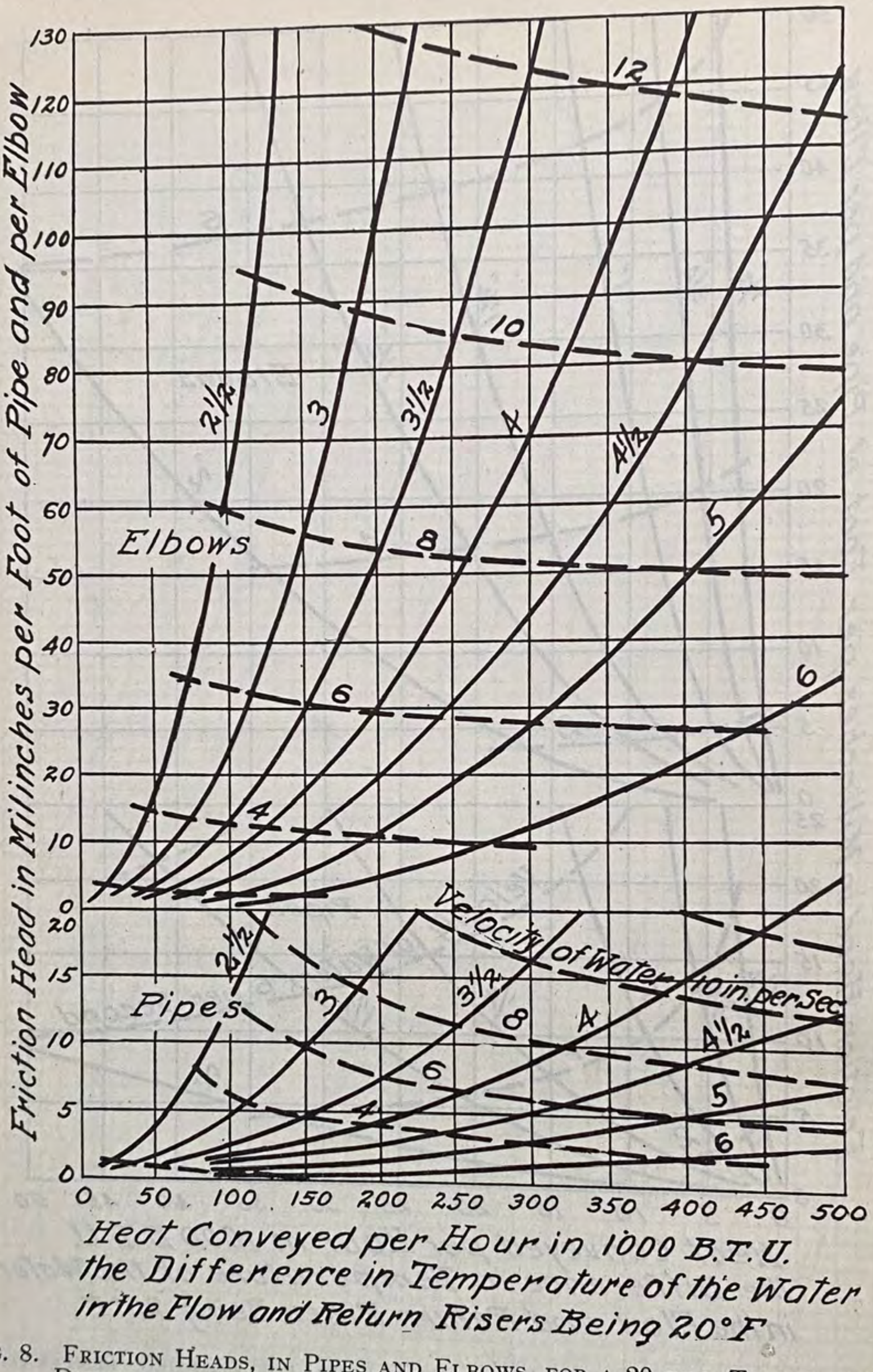


FIG. 8. FRICTION HEADS, IN PIPES AND ELBOWS, FOR A 20 DEG. TEMPERATURE DIFFERENCE OF THE WATER IN THE FLOW AND RETURN LINES

per elbow. Incidentally, we note also that the velocity will be about 5 in. per second.

The total friction is, therefore,

$$\begin{array}{r} 22 \times 18 = 396 \\ 9 \times 35 = 315 \end{array} \quad 711 \text{ milinches.}$$

As this is slightly more than the available pressure head of 630 milinches, a 1-in. pipe is a trifle too small. However, the difference between the calculated friction head and the available pressure head is so small that the 1-in. pipe can safely be used.

If a 1¼-in. pipe were used, the pressure head would be

$$\begin{aligned} 22 \times 5 &= 110 \\ 9 \times 11 &= 99 \end{aligned}$$

209 milinches, or less than one-third of the available pressure head. Consequently, a 1¼-in. pipe would be entirely too large.

The calculation shows how easily friction head calculations can be made. For more complicated installations, the calculations are more complicated, but in all cases, they are fairly simple. More detailed instructions than can be given here for such calculations may be found in textbooks and in magazine articles.

EMPIRICAL RULES

A very great demand exists for empirical rules or tables by means of which pipe sizes for hot-water heating systems can be determined according to the radiation which the pipe is to serve and without the necessity of friction head and pressure head calculations.

It is not possible to prepare such tables or rules which would have any degree of accuracy.

For example, in the elementary heating system shown in Fig. 5, a 1-in. pipe is practically the correct size. If the radiator were placed about 10 or 14 ft. above the heater instead of 7 ft., a 1-in. pipe would be entirely too large; or, if the radiator were placed at a considerably greater distance from the heater so that the number of elbows and the length of the pipe of the circuit were increased materially, a 1-in. pipe would be too small. So in this simple case, under different circumstances, a ¾-in. pipe, a 1-in. pipe, or a 1¼-in. pipe would be the correct size to select. In the 10 types of pipe systems shown in Fig. 4, it is quite evident that no empirical rule could be devised which would correctly give the pipe sizes to be used in every one of the ten cases shown there.

There are a number of empirical rules, however, contained in the catalogue data of the various manufacturers of hot-water heating apparatus which may be used with success if properly applied to such ordinary problems as these manufacturers have found them applicable to. Where the runs are not long and the various branches of the system can be fairly well equalized as to length of run and amounts of radiation, these practical rules, when applied to residences and other relatively small buildings of ordinary ceiling lengths, prove quite successful.

There are also a number of practical suggestions, to be found in these data, as to piping details and different kinds of connections.

GRAVITY HOT WATER HEATING[1] FOR SMALLER INSTALLATIONS

In the average small hot-water heating system such as is used for bungalows, cottages and even the modest sized home or residence, it is

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[1] Compiled by H. L. Alt, Philadelphia.

TABLE 2. AREAS OF STANDARD SIZE PIPES OF STANDARD WEIGHT

Nominal Size of Pipe Inches	Area of Pipe Sq. In.
⅜	0.192
½	0.305
¾	0.533
1	0.863
1¼	1.496
1½	2.038
2	3.356
2½	4.784
3	7.388
3½	9.887
4	12.73
5	19.99
6	28.89
8	50.04
10	78.84
12	113.10

not usually the case to find much attention given to complicated formulae and curves; this is for the reason that the saving on installations involving only a few hundred dollars is so small as not to justify elaborate engineering calculation besides which the work itself is generally installed by a competition contractor and no funds are available for which a proper designer could be employed. As a general rule the contractor himself does all the designing which is necessary and he doesn't want to be bothered with any complication which can in any way be avoided.

Probably the simplest way of determining hot-water pipe sizes in the ordinary small gravity system is the old method of taking the area of each radiator connection or valve and adding these areas together where the lines join, making the area of combined line practically equal to the sum of all the areas which the line supplies.

Thus if a pipe is feeding three radiators, one with a ¾-in. connection, one with a 1-in. connection and the third with a 1½-in. connection the sum of these areas is as follows:

1 in.	0.863 sq. in.
1½ in.	2.038
¾ in.	0.533
	3.434 sq. in.

Referring back to the table it will be found that the pipe which has practically the same area is a 2-in. pipe which has an area of 3.356 sq. in.

For jobs of somewhat larger character where too much refinement is

TABLE 3. SQUARE FEET OF RADIATION ALLOWABLE ON RISERS UP TO 100 FT. HEIGHT

NOMINAL PIPE SIZE INCHES	DISTANCE ABOVE THE BOILER IN FEET									
	10	20	30	40	50	60	70	80	90	100
¾	40	50	60	70	80	90	100	110	120	130
1	70	80	90	100	110	120	130	140	150	160
1¼	110	120	135	150	160	175	185	200	210	225
1½	180	185	210	230	250	265	285	300	315	330
2	300	350	400	500	575	625	700	775	825	900

unnecessary but at the same time closer results than that given in the above are desired, the table given below which takes into the consideration the height of the riser available to circulate the line may be recommended.

The risers are then connected up to the mains on the basis of allowing a factor for each size of pipe and then adding these factors to obtain the factor corresponding to the proper size of basement main. These factors are as follows:

TABLE 4. FACTORS FOR VARIOUS SIZES OF PIPE IN GRAVITY HOT WATER HEATING

Nominal Size of Pipe Inches	Factor
¾	5
1	10
1¼	20
1½	30
2	60
2½	110
3	175
3½	260
4	380
5	650
6	1050
8	2250
10	-------
12	-------

Thus, if the three radiators previously considered were set and sized as follows; the ¾-in. radiator with 20 sq. ft., and located 40 ft. above the boiler; the 1-in. radiator with 40 sq. ft. and set 20 ft. above the boiler and the 1½-in. radiator with 75 sq. ft., and set 10 ft. above the boiler all being on the same riser, the riser size would be as follows:

Riser for 20 sq. ft. radiator 40 ft. above	¾ in.
Riser for 40 sq. ft. radiator 20 ft. above	¾ in.
Riser for 75 sq. ft. radiator 10 ft. above	1¼ in.

To combine into one riser take the factors and add;

¾ in.	5 factor
¾ in.	5
1¼ in.	20
Total	30

and the factor 30 is equivalent to a 1½-in. riser.

Even if these radiators had all been placed on the first floor (or 10 ft. above the boiler), the riser size of 1½-in. would still have been sufficient for the three or their equivalent in one radiator. This indicates that the method of combining valve areas gives about one pipe size larger than when more accurately figured.

AIR SEALED OR CLOSED HOT WATER SYSTEMS[2]

For many years the closed system of hot-water heating in some form has been used successfully abroad, but there has been little thought given to and no research work done in connection with the air sealed system in this country, so that available data is meagre. For design

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[2] Prepared from data submitted by R. H. Feltwell, Philadelphia and H. A. Thrush, Peru, Ind.

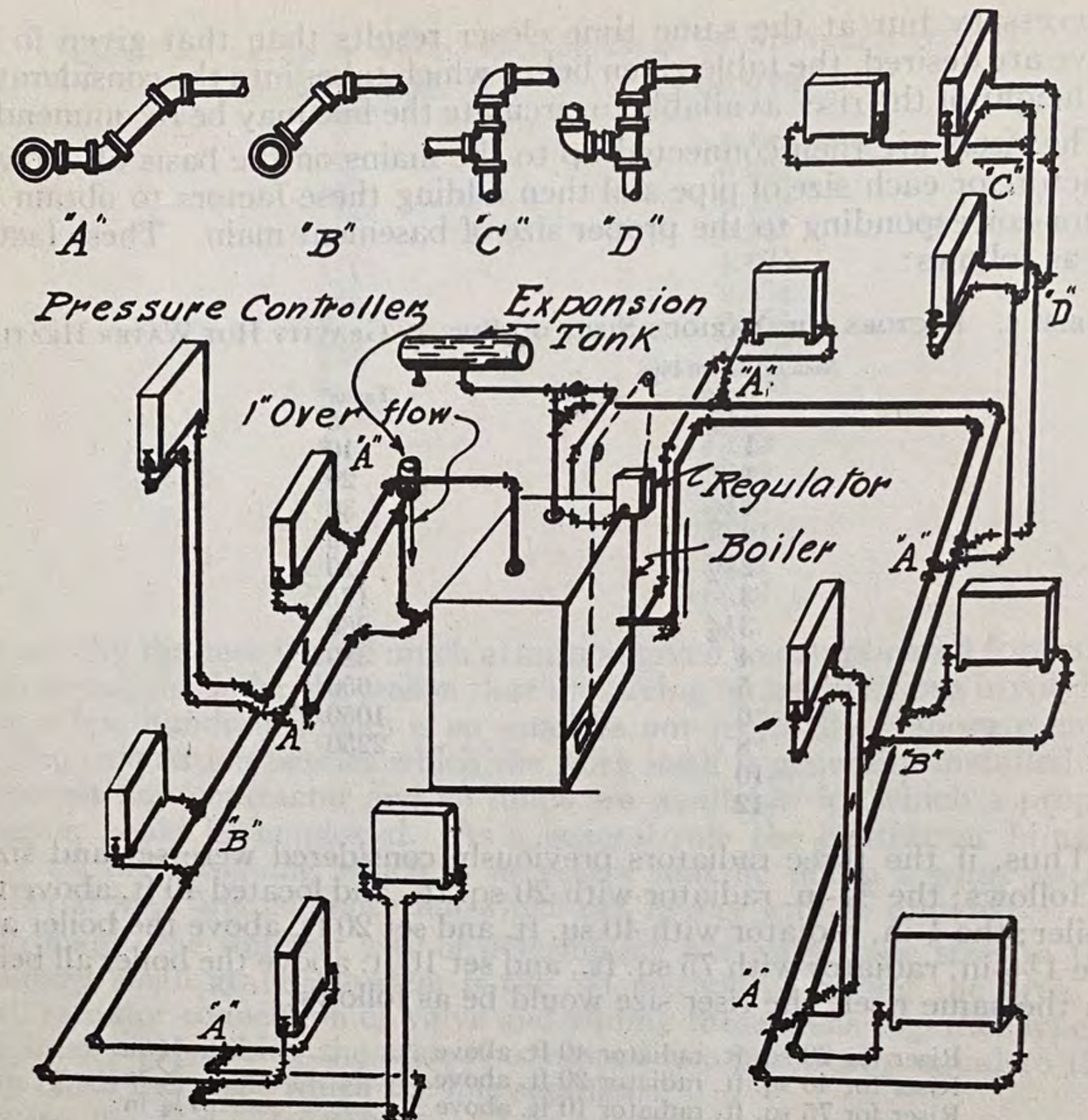

FIG. 9. PIPING CONNECTIONS FOR CLOSED HOT WATER HEATING SYSTEMS

work the engineer, architect or heating contractor, finds little on pipe sizes, etc.

Due to the more rapid circulation of water in an air sealed system 50 per cent more radiation can be supplied than by a gravity connection. Therefore the rules as set forth by F. E. Giesecke, N. S. Thompson and C. A. Fuller in their books on hot-water heating can be used to advantage by adding 50 per cent to their formula for house heating. The following table would then be applicable for air sealed hot-water system.

TABLE 5. PIPE SIZES AND CONNECTIONS FOR CLOSED SYSTEMS

	Amount of Radiating			
PIPE SIZE INCHES	FIRST FLOOR	SECOND FLOOR	THIRD FLOOR	FOURTH FLOOR
½	30	40	50	60
¾	60	75	90	110
1	110	120	135	150
1¼	165	180	200	225
1½	270	290	315	350
2	450	525	600	750

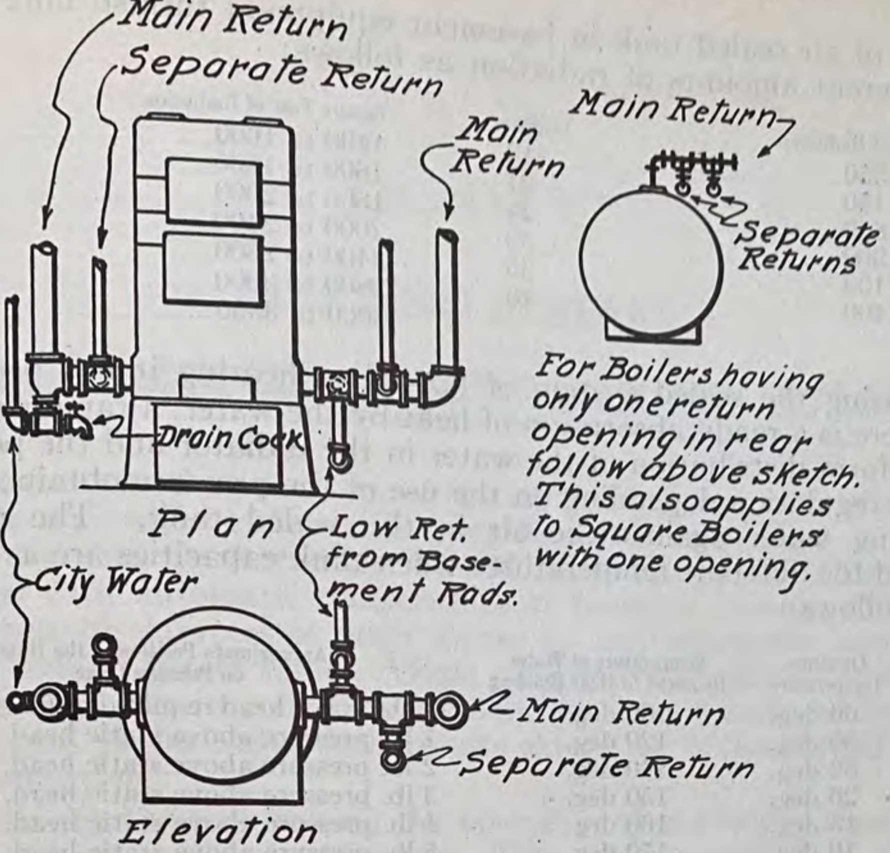

FIG. 10. CONNECTING SEPARATE RETURNS TO BOILER

The piping layout should be designed to conform to the best engineering experience of the engineer. It is not necessary except on very small mains to continue the mains full size to the end for they should end two sizes larger than the last radiator they supply. In all cases mains should end in the first floor radiator. Where a riser extends beyond the last first floor radiator the line running out to it should be treated as a lateral. See plan Fig. 9.

In each case the lateral leading from the main need be no larger than the radiator valve it supplies but care should be exercised that allowance is made for the proper distribution of the water to the radiators. Connections as shown in plan Fig. 9 are recommended, the *B* connection being used on all first floor radiators except right at the boiler where the *A* connection can often be used to advantage. The *C* connection is used on upper floors on the same level to supply two or more radiators from one riser and the *D* connection is used on risers feeding more than one floor and the style of connection should be used on the different floors of a building where it is desired to extend to a floor above.

The area of mains both flow and return must equal or exceed the total area of the valve sizes they are to supply. It is recommended that nearby radiators to the boiler have separate returns and that these returns enter the boiler as shown in Fig. 10.

Many sealed systems of hot-water heating do not function properly on account of lack of air in the air sealed expansion tank. Tank sizes should conform to the amount of water contained in the heating system, and are based on 12½ lb. of water to the gallon, for tank capacity. The makers of air sealed tank in basement equipment furnish tank sizes for the different amounts of radiation as follows:

Square Feet of Radiation	Gallons
250 to 350	18
350 to 450	21
450 to 650	24
650 to 900	30
900 to 1100	35
1100 to 1400	40
1400 to 1600	54
1600 to 1800	60
1800 to 2000	70
2000 to 2400	80
2400 to 2800	90
2800 to 3000	110
3000 to 3500	120

By using the sealed system of hot-water heating it has been found that there is a ready absorption of heat by the water, a rapid circulation and uniform distribution of the water in the radiator and the possibility of close regulation depending on the use of the pressure obtained by the expanding water against the air in the sealed tank. The pressures obtained for different temperatures when tank capacities are as outlined are as follows:

OUTSIDE Temperature	Temperature of Water Required to Heat Building	Approximate Position of the Hand on Pressure Gage
60 deg.	100 deg.	At the static head required to fill the system.
50 deg.	120 deg.	1 lb. pressure above static head.
32 deg.	140 deg.	2 lb. pressure above static head.
20 deg.	150 deg.	3 lb. pressure above static head.
15 deg.	160 deg.	4 lb. pressure above static head.
10 deg.	170 deg.	5 lb. pressure above static head.
0 deg.	180 deg.	6 lb. pressure above static head.
−10 deg.	190 deg.	7 lb. pressure above static head.
−20 deg.	200 deg.	8 lb. pressure above static head.
−25 deg.	210 deg.	9 lb. pressure above static head.
−30 deg.	220 deg.	10 lb. pressure above static head.

The table also gives the outside temperature and the corresponding boiler temperature of the water in the radiators necessary to warm to 70 deg., when radiation is figured on the basis of heating rooms to 70 deg.