

through a particular heating unit is equal to the capacity of that unit divided by the capacity of the total radiation circuit multiplied by the total temperature drop of the circuit.

4. Since the temperature of the water supplied to heating units in the series-loop system cannot be regulated, it is advisable to provide dampers in the cabinets containing finned pipe or baseboard radiation to permit adjustment of the heat delivery by each unit. Valves or adjusting fittings, if used in the water circuit, would affect the performance of the entire loop and would not be a satisfactory means of controlling the heat output of the units.

Certain disadvantages of the series loop-system are:

1. The difficulty of making suitable provision for adjustment and balancing of the system.
2. The total circulating head required may be excessive.
3. The design of the system may be more difficult than for one-pipe or two-pipe main systems.

Example 3: A series loop system is to be designed for the residence used in *Examples 1 and 2* for two-pipe and one-pipe design. No heat will be supplied to the basement. The total heat loss equals 45,500 Btu. Baseboard type radiation having a rating of 0.5 Mbh per linear foot at an average temperature of 190 F, is selected as the radiation used. The radiation is constructed with $\frac{3}{4}$ -in. pipe. A 20 deg design temperature drop will be used.

Solution: For a 45.5 Mbh load 4.55 gpm must be circulated for a 20 deg temperature drop. For a single looped main the measured length equals 140 ft. The approximate equivalent length equals 140×1.5 or 210 ft. If the $\frac{1}{4}$ -in. pump, Fig. 9, were initially selected, it would develop a 6 ft head at 4.55 gpm delivery. For an available head of 6 ft and an equivalent length of 218 ft (nearest to 210 ft) Table 1 shows that only 3 gpm will circulate through the $\frac{3}{4}$ -in. main. A larger, and more costly pump may be tried. The 3-in. pump Fig. 9 has 12.7 ft available head at 4.55 gpm delivery. Using 12 ft available head and 250 ft equivalent length as the nearest available values Table 1 indicates that a flow of 4.3 gpm at a velocity of 2.6 fps will be established through $\frac{3}{4}$ -in. main. However, because of cost, appearance and temperature drop considerations, this may not be desirable.

If the system is divided into two loops, as shown in Fig. 11, a smaller pump may be used and the system temperature drop decreased.

The $\frac{1}{4}$ -in. pump at 6 ft head for 4.55 gpm is again selected for preliminary sizing of piping.

The measured supply main length plus the length of the longest loop circuit is 106 ft. The equivalent length equals 106×1.5 or 159 ft. For 6 ft available head and 160 ft equivalent length, Table 1 indicates that the friction loss would be $3\frac{3}{4}$ ft per 100 ft or 450 mi per ft. At this friction loss the supply main would be of 1-in. size for a flow of 7 gpm (which is more than the required 4.5) and the $\frac{3}{4}$ -in. looped main would deliver 3.7 gpm (more than the required 2.25 gpm). Because the flows are more than required, the system temperature drop would be less than 20 deg. A smaller pump could therefore be used if desired.

The pipe sizes should be recalculated at the design flow rates as follows:

SECTION	HEAT LOAD MBH	DESIGN FLOW GPM	PIPE SIZE IN.	FRICTION LOSS FT/100 FT	PIPE LENGTH FT	FITTINGS		TOTAL EQUIV. FT	PRESS DROP FT
						No. and Type	Equiv. FT		
AB	45.5	4.55	1	$1\frac{3}{4}$	36	2 elbows 2 gate valves 1 flow valve 1 boiler	5.0 2.5 50. 7.5	101	1.77
BCA	22.5	2.25	$\frac{3}{4}$	$1\frac{1}{2}$	70	8 elbows 1 cock 2 tees @ 50%	13.6 1.7 13.6	99	1.5
Total									3.27

The total system head loss equals 3.27 ft for a flow of 4.55 gpm and the $\frac{1}{4}$ -in. pump is a satisfactory selection.

If desired, the actual design temperature drop can be determined. Because the pump head at 4.55 gpm is greater than 3.27 ft, the flow in the system will increase until pump head and flow equal system pressure drop and flow. Construction of a system curve, as described under centrifugal pumps, shows that for the system with the pipe size selected and with the $\frac{1}{4}$ -in. pump, equilibrium will be reached at 6 ft head and 6.2 gpm flow. The actual temperature drop for design conditions would then be $\left(\frac{4.5}{6.2}\right) \times 20$ or 14.5 deg, approximately.

Combination Systems

Three types of systems have been illustrated namely; one-pipe, two-pipe reversed-return, and series-loop. Actually the design for a particular building may be a composite of two or even all three of these types of systems. For example, a two-pipe reversed-return system of distribution may be used with a number of one-pipe loops in a single building such as an apartment house, or a two-pipe reversed-return system may be used with a main riser at each end of a building with a series-loop system used to serve the space on each floor of the building. In any case, it is well to bear in mind the principles of design involved in each particular type of system for that portion of the installation where it is used.

Adjustment of Flow and Capacity

Where the heating elements and piping are properly sized and arranged a hot water system is, to a large extent, self-adjusting. This is so because the mean temperature of the water flowing inside the heating unit is the most important factor in determining its output. If the flow of water is within 5 to 15 percent of the correct value for a given heating unit, the difference in mean temperature will not exceed one or two degrees and, consequently, the effect on heat output will be negligible. However, the limitations of commercial pipe sizes and pipe arrangement sometimes result in flow rates considerably different than those required to develop the proper output of the heating units. A means of adjusting the heat output of heating elements and branch circuits must be provided in the system to correct these effects.

Adjusting means may be necessary due to the type of system, for example, the two-pipe system using direct return mains. In this system the water flow circuits are hydraulically unbalanced, because the water for the first heating load taken off the main is the first to be returned. As a result, the first heating unit will receive a much greater flow than is required to develop its rated output. The flow through the last heating unit can be so low that practically no heat is delivered. The poor distribution of flow in the direct return system can be corrected by the installation of orifices or of adjusting fittings or valves, by means of which the system is balanced after it is placed in operation. In some cases, proper flow distribution can also be established by careful pipe size selection. That is, the piping can be sized so that the pressure drop through each piping circuit is the same at the design flow rate.

These troubles are minimized by the reversed-return system, Fig. 8. In this system the water for the first heating load taken off the main is the last to be returned, and all circuits are of approximately equal length. Proper hydraulic balance is therefore easily obtained and the system is inherently self-adjusting. While the reversed-return piping circuit is much preferred, in some large installations a saving in pipe can be effected by use of a direct-return system.