To secure a correct distribution of hot water among the several risers it is necessary, as previously stated, to introduce special resistances to balance the several risers, as follows:

The first riser is 80 ft nearer the boiler than the fifth riser. In order that the two may be balanced, *i.e.*, that they may operate under equal pressure heads, resistance must be added to the first riser equal to the friction head in the 80 ft of flow main from *B* to *F* plus that in the 80 ft of return main from *G* to *K*.

It will be noted from Table 3 that the unit friction head is about 240 milinches per foot. The total friction head in the flow and return mains between the first and fifth risers is therefore 160 × 240 or 38,400 milinches, or a little more than 3 ft, which must be supplied by additional resistance in the first riser to prevent its having an advantage over the fifth riser.

This resistance can be supplied by a calibrated and adjusted modulating valve or by an orifice resistor in a union. If the orifice resistor is to be used, its size may be selected from Table 5 as follows:

The lower part of the first flow riser supplies 28.8 Mbh. According to Table 3, it should be a 1-in. pipe and would have a velocity of 22 in. per second, if it were supplying 24 Mbh. Since it is supplying 28.8 Mbh, the velocity will be about 26 in. per second. From Table 5 it will be found that for a 1-in. pipe and a velocity of 24 in. per second, an 0.45-in. orifice will produce a loss of head of 37,000 milinches. For a velocity of 26 in. per second, the loss of bead will be somewhat more, probably about 43,000 milinches; the

Table 4. Capacities of Pipes in *Mbh* (1000 Btu per Hour) and Velocities of Water in Pipes in Inches per Second for Forced Circulation Systems with a Total Friction Head of 18 ft and for a Maximum Temperature Drop of 10 deg[a]

1	2	3	4	5	6	7
Pipe Size (Inches)	Equivalent Length of Pipe (Feet[b])	Equivalent Total Length of Pipe in Feet in Longest Circuit				
		200	400	600	800	1000
		Unit Friction Head, in Milinches				
		1080	540	360	270	216
½	1.0	*12.7* 32	*8.6* 23	*7.2* 18	*6.2* 15	*5.5* 13
¾	2.0	*27.5* 40	*18.7* 28	*15.1* 22	*13.7* 19	*11.5* 17
1	2.5	*55.0* 48	*36.8* 34	*30.0* 27	*26.4* 23	*22.6* 20
1¼	3.0	*122.0* 59	*81.5* 42	*66.0* 33	*58.3* 28	*50.5* 25
1½	4.0	*182.0* 66	*122.0* 46	*98.2* 37	*86.2* 31	*74.2* 27
2	5.0	*371.0* 80	*252.0* 56	*201.0* 45	*180.0* 38	*151.0* 33
2½	7.0	*598.0* 91	*407.0* 65	*323.0* 51	*287.0* 43	*240.0* 38
3	9.0	*1110.0* 107	*790.0* 76	*598.0* 60	*527.0* 51	*443.0* 44

[a]For other temperature drops the capacities of pipes are to be changed correspondingly. For example, for a temperature drop of 30 deg, the capacities shown in this table are to be multiplied by 3. The velocities remain unchanged.

[b]Approximate length of pipe in feet equivalent to one elbow in friction head. This value varies with the velocity.

difference between it and the required resistance will be about 10 per cent which is permissible, and the 0.45-in. orifice is selected.

The sizes of the orifice resistors for the second, third, and fourth risers are selected in a similar manner and found to be 0.45 in., 0.50 in., and 0.55 in., respectively.

If the design of the system of Fig. 5 is to be extremely refined, the gravity pressure heads produced by the risers should be taken into consideration. With water at 220 F and 210 F, respectively, in the risers, the gravity head is 50 milinches per foot of water column or 25 milinches per foot of flow and return pipe. The pump pressure head in this case is 240 milinches per foot of pipe, and the gravity head, being only one tenth as large as the pump head, may be neglected without serious error. This is generally done.

Temperatures of 220 F and 210 F would be used only during the coldest

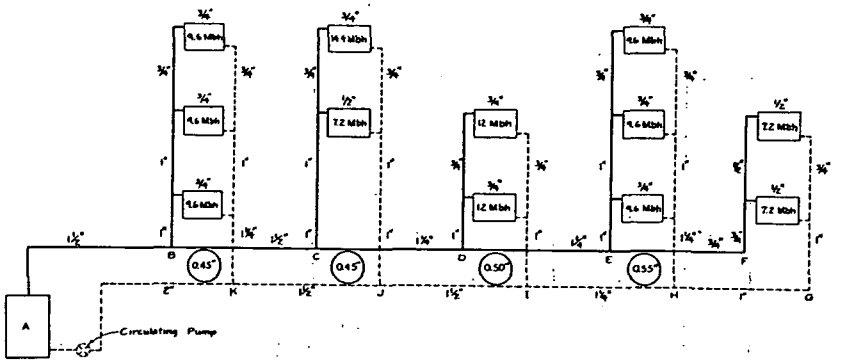

Fig. 5. A Forced Circulation Direct Return System

weather for which the system is designed. At other times the temperatures would be lower, the temperature drop smaller, and the gravity heads smaller. The pump pressure head remains constant throughout the season if the pump is operated at a constant speed and, consequently, the gravity head is generally less than one-tenth of the pump head.

Effect of Variations in Pipe Sizes

The pipe sizes for the several parts of the system selected from the tables are only approximately correct but the resulting error should be negligible as may be seen from the following study. Assume, as an extreme case, that the error in pipe size is so large that the water flows twice as fast through one of the radiators as through the others. This would make the friction head through this radiator almost four times as large as those through the other radiators. The result would be that the water, in flowing through the radiator, would cool 5 deg instead of 10 deg. The mean water temperature in the radiator would then be 217½ F instead of 215 F, and the mean temperature difference, water to air, would be 147½ deg instead of 145 deg. The heat dissipated by the radiator would therefore be about 2 per cent more than calculated. It is evident that this difference in heat dissipation is smaller than the difference