it will be found that a 1 in. pump will deliver 7 gpm against a head of 4½ ft (54,000) milinches).

Since the main from A to O has an equivalent length of 150 ft (100 ft actual length plus 50 percent added for friction loss in fittings), the main may be sized for 54,000/150 = 360 milinches per foot.

From Table 2 by interpolation at 360 milinches friction loss and at 20 deg drop, a 1 in. pipe would supply 62,600 Btu per hour, and a 1¼ in. pipe would supply 131,600. Since the 1 in. pipe is too small, a 1¼ in. pipe will be used.

Since the 1¼ in. pipe offers less than 360 milinches resistance per foot, the velocity of water will increase until the output of the pump and the friction loss are in equilibrium at some point on the pump performance curve, for instance, at 10 gpm and a head of 4 ft or 48,000 ÷ 150 = 320 milinches per foot of pipe. The friction loss in the main between flow and return connections to radiators will be assumed to be 320 milinches per foot.

In determining sizes for the piping from the main to any radiator, the resistance in the radiator circuit such as B-C (which has a load of 9 Mbh) is made equal to the

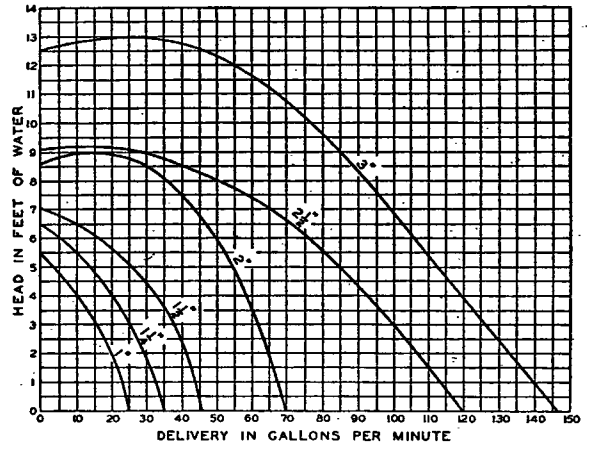

FIG. 12. PERFORMANCE CHART FOR CIRCULATING PUMP

resistance in the main from B to C which, if there are 3 ft of main between connections, is 3 × 320 = 960 milinches. If the total equivalent length of the radiator circuit determined by use of Table 1 is 32 ft, the radiator circuit B-C will be sized for a friction loss of 960 ÷ 32 = 30 milinches per foot, for which in Table 2 a ¾ in. pipe is found to supply 8550 Btu per hr, and will be considered ample.

Other radiator circuits such as D-E, F-G, etc., can be sized in a similar manner.

Two-Pipe Gravity System (with Reversed Return)

Example 5: Select pipe sizes for the two-pipe gravity system shown in Fig. 13. The center plane of the highest radiator is 8 ft above the center plane of the boiler. Assume a 180 F flow temperature and a 150 F return temperature.

Solution: The piping should be sized so that the frictional resistance at the desired rate of flow is equal to the available circulating head.

From Fig. 1 at 180 F flow and 150 F return temperature, the available head is 118 milinches per foot of height or 8 × 118 = 944 milinches total for the highest radiator. The longest circuit from boiler to radiator and back to boiler must therefore have a resistance of 944 milinches. The longest circuit (see Fig. 13) is A-D + D-H + H-N containing 38 ft of pipe and, if 50 percent is added for equivalent length of fittings, the equivalent length is 57 ft.

The circuit should then be designed for a friction loss of 944 ÷ 57 = 16 milinches per foot (approximately). The pipe size may be found from Table 2 at 16 milinches per foot, but since the temperature drop is 30 deg, find pipe size corresponding to 20/30 of actual load for each section as follows:

Section	Load Mbh	Size of Pipe for 16 Milinches per Foot	Section	Load Mbh	Size of Pipe for 16 Milinches per Foot
A-B	58	1½	G-H	11	1
B-C	31	1¼	H-K	19	1¼
C-D	20	1¼	K-L	25	1¼
D-E	16	1	L-M	31	1¼
E-F	6	¾	M-N	58	1½

Piping to the radiators may be sized from Table 2 for the same resistance, 16 milinches per foot, but since the temperature drop is 30 deg, find pipe size corresponding to 20/30 of actual load for each section as follows:

Radiator	#1	#2	#3	#4	#5	#6
Load, Mbh	11	8	6	6	24	3
Pipe size, In.	1	¾	¾	¾	1½	¾

A hot water heating system will adjust its rate of flow until the friction loss balances the available head. It is therefore self-correcting in regard to small errors made in selection of pipe sizes.

Two-Pipe Forced Circulation System

Example 6: Select pipe sizes for the two-pipe forced circulation reversed return system having a total load of 159 Mbh shown in Fig. 14. Assume a difference of 20 deg in supply and return water temperature. The total equivalent length of the longest circuit is 180 ft. The gravity circulating head due to difference in temperature may be disregarded in design.

Solution: The water to be circulated is 159,000 ÷ 20 = 7950 lb per hr or $\frac{7950}{60 \times 8}$ = 16.5 gpm. From a pump performance chart such as Fig. 12 it is found that 16.5 gpm will be delivered by a 1 in. pump against a 3 ft head (36,000 milinches) or a 1¼ in. pump against a 4.5 head (54,000 milinches).

The longest circuit, including the supply and return main and the longest radiator circuit, is 120 ft and, if 50 percent is added for friction loss in fittings, the equivalent length is 180 ft. If the 1 in. pump is used, the piping will be sized for 36,000/180 = 200 milinches per foot, resulting in selection from Table 2 of a 2 in. main for the Section A-B which supplies 159 Mbh. The large difference in pump and main size, as well as the low velocity resulting from the 200 milinch per foot friction loss, indicates that the 1¼ in. pump should be considered. The design friction loss, if the 1¼ in. pump is used, can be 54,000/180 = 300 milinches per foot and, at this friction loss, Table 2 will indicate the pipe sizes for the various sections in Fig. 14 as follows:

Supply			Return		
Section	Mbh	Pipe Size, In.	Section	Mbh	Pipe Size, In.
A-B	159	1½	J-K	16	¾
B-C	91	1¼	K-L	28	¾
C-D	75	1¼	L-M	42	1
D-E	63	1¼	M-N	54	1
E-F	49	1	N-O	75	1¼
F-G	37	1	O-P	91	1¼
G-H	16	¾	P-Q	159	1½

The radiator circuits may also be sized for the same friction loss, 300 milinches per foot, using Table 2 as follows:

Radiator	#1	#2	#3	#4	#5 and #6	#7
Load, Mbh	16	12	14	12	21	16
Pipe size, In.	¾	¾	¾	¾	1[a]	¾

[a] Where circuit divides, use ¾ in. branch to #5 and ¾ in. to #6 radiator.