a 2-in. pipe for Section *KA*. The pipe sizes for the remaining eight sections and for the radiator connections can be selected in the same manner and recorded on the pipe diagram as shown.

The circulating pump for the system should be one which has its highest efficiency when it is delivering 13.8 gpm against a head of 2 ft.

If a number of heating systems are to be designed for similar conditions, *i.e.*, for a total friction head of 2 ft and a temperature drop through the radiators of 10 deg when the maximum quantity of heat is being delivered to the building, a table such as Table 2 may be prepared from the data of Fig. 4. Having this table, the pipe sizes for the system of Example 1 can be easily selected. For example, for Sections *BC* and *JK*, each supplying 54 Mbh, the equivalent pipe length of the system is 227 ft. In the table the length shown nearest to this length is 200 ft. In the 200-ft column, a 1½-in. pipe is slightly too small and a 2-in. pipe is too large. The 1½-in. pipe will therefore be selected. For Sections *CD* and *IJ*, supplying 42 Mbh, a 1¼-in. pipe is too small and a 1½-in. pipe is too large, so 1¼ in. will be selected for the flow and 1½ in. for the return line. For larger

TABLE 2. 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 2 FT AND FOR A MAXIMUM TEMPERATURE DROP OF 10 DEG[a]

1	2	3	4	5	6	7	8	9
PIPE SIZE (INCHES)	EQUIVALENT LENGTH OF PIPE (FEET[b])	EQUIVALENT TOTAL LENGTH OF PIPE IN FEET IN LONGEST CIRCUIT						
		100	150	200	250	300	350	400
		UNIT FRICTION HEAD, IN MILINCHES						
		240	160	120	96	80	69	60
½	1	*6.2* **15**	*4.8* **12**	*4.1* **10**	*3.4* **9**	*2.9* **8**	*2.6* **7.5**	*2.4* **7**
¾	2	*13.2* **18**	*10.3* **14**	*8.6* **12**	*7.3* **11**	*6.2* **10**	*6.0* **9**	*5.5* **8.5**
1	2.3	*25.0* **22**	*19.2* **17**	*16.3* **15**	*14.4* **13**	*12.5* **12**	*12.0* **11**	*11.1* **10.5**
1¼	3.0	*52.8* **27**	*40.8* **21**	*34.8* **18**	*31.2* **16**	*27.8* **15**	*26.4* **14**	*24.0* **13**
1½	3.5	*79.2* **30**	*60.7* **23**	*51.2* **20**	*45.6* **18**	*40.8* **16**	*40.0* **15**	*36.0* **14**
2	4.0	*153.8* **36**	*120.0* **28**	*104.0* **24**	*93.5* **22**	*86.4* **20**	*81.5* **18**	*73.8* **17**
2½	6.0	*250.0* **41**	*192.0* **32**	*164.5* **28**	*149.0* **25**	*139.2* **22**	*135.8* **21**	*122.5* **19**
3	6.5	*444.0* **48**	*348.0* **37**	*294.0* **32**	*270.0* **29**	*254.0* **26**	*240.0* **24**	*223.0* **22**

[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.

systems, it will be economical to operate with higher friction heads, and tables may be prepared similar to Tables 3 and 4, which are based on total friction heads of 6 and 18 ft, respectively.

Example 2. Design a direct return two-pipe forced circulation system for the layout shown in Fig. 5. For this system the length of the pipe line from the boiler to the highest radiator on the farthest riser and back to the boiler is about 250 ft. There are about 16 elbow equivalents having an equivalent pipe length of about 50 ft, so the total equivalent pipe length is about 300 ft.

Solution. The same pipe size tables may be used as those developed for the reversed return system of Fig. 3. Since this system is somewhat larger than that shown in Fig. 3, Table 3 which provides for a friction head of 6 ft may be used instead of Table 2 which provides for a friction head of only 2 ft.

Referring to the column for an equivalent total length of 300 ft for Sections *AB* and *KA*, each supplying 117.6 Mbh, it will be found that a 1½-in. pipe is too small and a 2-in. pipe is too large. Consequently, a 1½-in. pipe is selected for the flow line *AB*, and a 2-in. pipe for the return line *KA*. For Sections *BC* and *JK*, each supplying 88 Mbh, a 1½-in. pipe is only slightly too small and it is selected. The remaining pipe sizes are selected in a similar manner and recorded in Fig. 5. For a temperature drop of 10 deg, 24.5 gpm of water must be circulated. The pump to select is one which has its highest efficiency when it is delivering 24.5 gpm against a 6-ft head.

TABLE 3. 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 6 FT AND FOR A MAXIMUM TEMPERATURE DROP OF 10 DEG[a]

1	2	3	4	5	6	7	8
PIPE SIZE (INCHES)	EQUIVALENT LENGTH OF PIPE (FEET[b])	EQUIVALENT TOTAL LENGTH OF PIPE IN FEET IN LONGEST CIRCUIT					
		200	300	400	600	800	1000
		UNIT FRICTION HEAD, IN MILINCHES					
		360	240	180	120	90	72
½	1	*7.4* **18**	*6.0* **15**	*5.0* **13**	*3.8* **10**	*3.4* **9**	*3.1* **7.5**
¾	2	*15.8* **22**	*12.7* **18**	*10.8* **16**	*8.4* **12**	*7.7* **11**	*6.7* **9**
1	2.5	*30.0* **27**	*24.0* **22**	*20.4* **19**	*15.8* **15**	*13.9* **13**	*12.5* **11**
1¼	3.3	*64.8* **33**	*52.5* **26**	*44.4* **23**	*33.6* **18**	*30.0* **16**	*26.8* **14**
1½	4.0	*96.0* **37**	*76.8* **31**	*64.8* **26**	*50.1* **20**	*44.7* **18**	*40.8* **15**
2	5.0	*192.0* **44**	*153.0* **36**	*130.0* **30**	*100.1* **24**	*90.0* **21**	*78.0* **18**
2½	6.0	*300.0* **50**	*244.0* **41**	*206.0* **35**	*161.0* **26**	*144.0* **24**	*130.0* **21**
3	7.5	*550.0* **58**	*436.0* **48**	*368.0* **42**	*287.0* **32**	*249.0* **27**	*228.0* **24**

[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.