6 PIPING ARRANGEMENTS

The design of a panel radiator based heating system involves selection of a piping system, pipe sizes, overall design temperature drop, required flow rates and desired type of system control. For trouble-free system operation, do not exceed the flow rates in Table 7.

Table 7: Maximum Trouble-free Flow rates and Maximum Heat Carrying Capacities

Item	Max Flow	Q (ΔT=20°F)	Q (ΔT=30°F)	Q (ΔT=40°F)	Reason
1/2" copper or PEX	1.5 GPM	15,000	22,500	30,000	Flow Velocity
5/8" PEX	2.0 GPM	20,000	30,000	40,000	Flow Velocity
3/4" copper	4.0 GPM	40,000	60,000	80,000	Flow Velocity
1" copper*	8.0 GPM	80,000	120,000	160,000	Flow Velocity
1-1/4" copper*	14.0 GPM	140,000	210,000	280,000	Flow Velocity
Diverter Valve	2.0 GPM	20,000	30,000	40,000	Flow Noise
Radiator Flow	2.5 GPM	25,000	37,500	50,000	Noise & Control

Note: Q(△T = 20°F) denotes the maximum heat load carrying capacity based on a 20°F temperature drop.

*Pipe size used for main supply/return piping in multiple one-pipe diverter valve based systems or for one-pipe systems using monoflow tees. This information is useful for sizing pipe in two-pipe distribution systems.

This chapter discusses several piping arrangements, guidelines for system design, pipe size and pump selection and fine-tuning of individual components. Heat loss (Q), water flow rate (GPM) and temperature drop (△T) through a hydronic heating system are related to each other as:

$$Q = 500 \times GPM \times \triangle T$$

This equation is used extensively for accurate sizing of radiators.

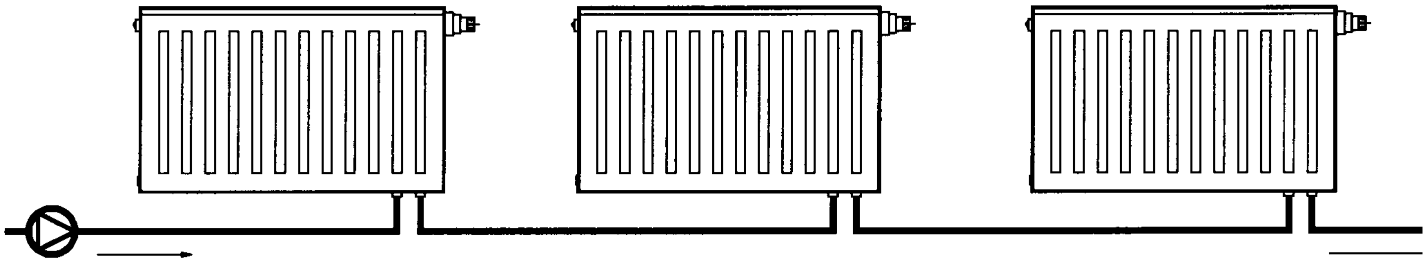
One-Pipe System Options

Figure 12 presents three different one-pipe and two-pipe arrangements. In any one-pipe system, a single pipe system connects all radiators together. Fewer materials are needed in a one-pipe system and a perimeter loop supplies water to all radiators. Since water flows possibly through all radiators and cools off along the way, it is necessary to oversize the last radiator(s) in the loop. A sizing procedure is outlined. Table 7 shows maximum Btu load on a one-pipe system based on pipe size and overall temperature drop.

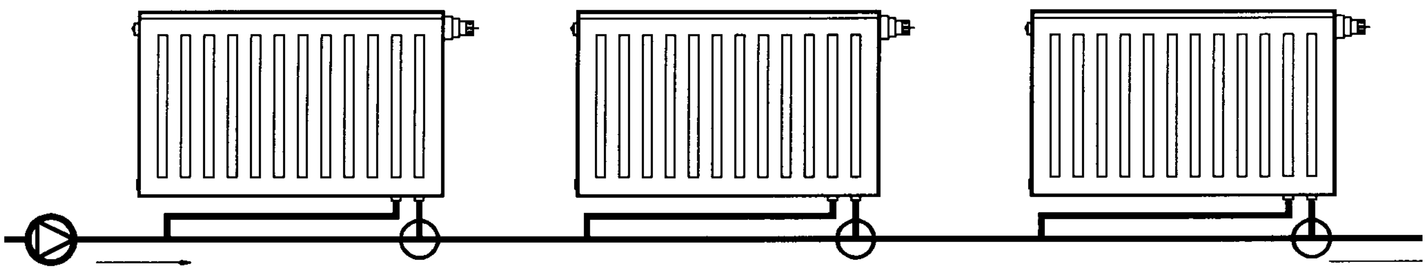
1. Series loop system.

All water flows through all radiators. A thermostatic head cannot be used on any radiator as it will shut off all flow. A central thermostat is required for temperature control. Do not exceed heat loads as listed in Table 7.

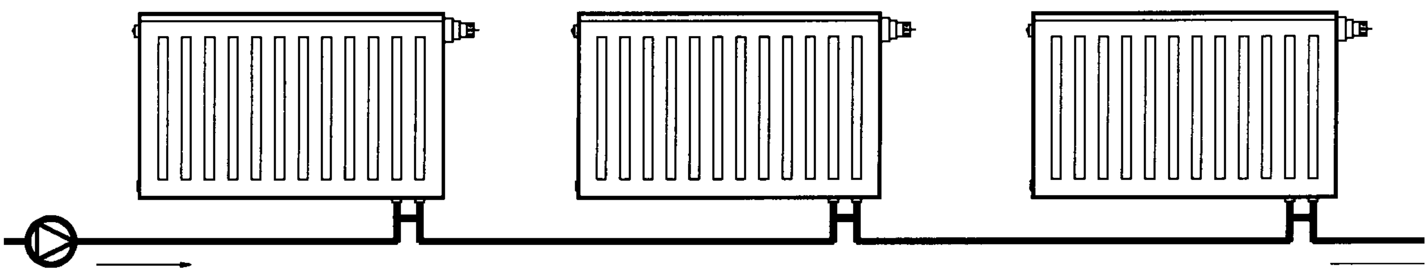
Option 1: Series Loop System



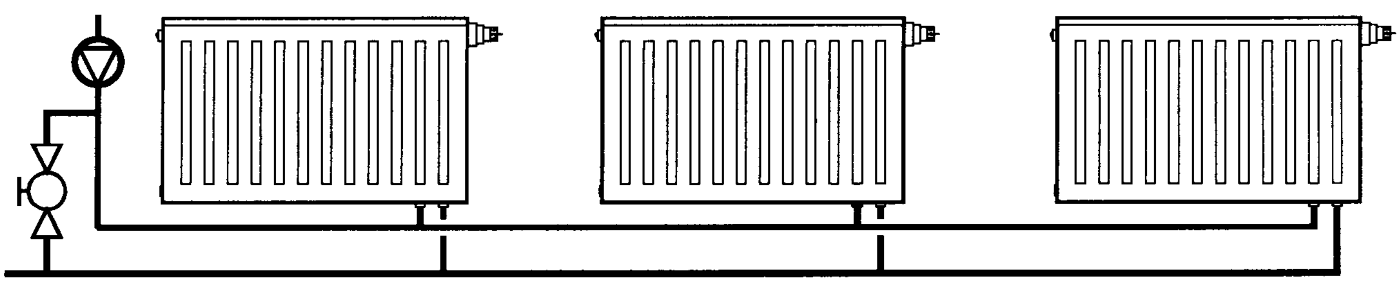
Option 2: One-Pipe System with Venturi Tees or Monoflow Tees.



Option 3: One-Pipe System with Diverter Valves



Option 4: Two-Pipe Direct Return System



Option 5: Two-Pipe Reverse Return System

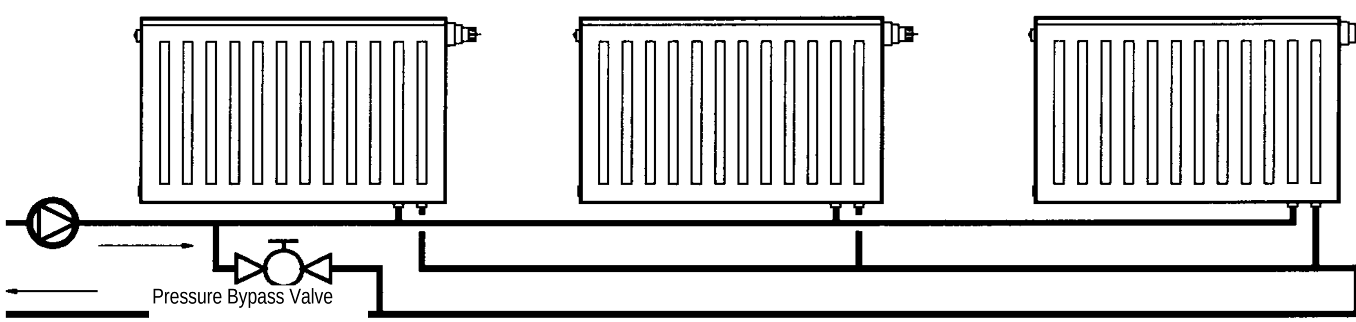


Figure 12: Radiator Piping Schematics.

2. One-pipe system with monoflow tees.

Monoflow tees are used to divert some water from the main loop into each radiator. Use one monoflow tee on the return if the radiator(s) are located above the main loop; use two monoflow tees if the radiators are installed below the main loop. Place the tees in the main loop to each radiator at least 12" apart.

Thermostatic heads on each radiator provide very easy means for individual temperature control. The system can be operated off a central thermostat or with constant circulation using an outdoor reset system.

Size the main loop based on the selected temperature drop (20°F, 30°F, or 40°F) and heat load. Make sure to oversize the last radiators properly, especially when using an overall temperature drop of 30°F or 40°F.

3. One-pipe system with diverter valves.

This arrangement is similar to using monoflow tees except that now each radiator is equipped with a diverter valve. Secondly, the total loop flow can NOT exceed 2 GPM because of possible noise at greater flow rates. The bypass adjustment in the diverter valve can be used to throttle down the flow through the first radiators and increase flow through the last radiators in the loop to make up for the drop in loop temperature.

Thermostatic heads on each radiator provide an easy means for individual temperature control. The system can operate off a central thermostat or with constant circulation using an outdoor reset system. Follow Table 7 for pipe sizing (either 1/2 " copper or 5/8 " PEX).

4. Multiple one-pipe systems.

Options 2 and 3 above can be installed in a multiple loop fashion where several one-pipe systems are connected between a common supply and return manifold. Assure adequate flow in all piping systems when using monoflow loops and/or diverter valve loops. Isolation and balancing valves are recommended on each loop for service and flow control.

A properly sized pump operating on constant circulation can supply water to all loops. A single Grundfos UP15-42 or equivalent can handle up to 3 diverter valve loops; use a Grundfos UP26-64 or equivalent for 4 to 6 loops. Size the main piping for the combined flow in all branches, following the guidelines in Table 7.

Refer to the Pressure Drop Diagram on page 31 for estimating the pressure drop through each radiator when using monoflow tees. Use the Pressure Drop Diagram on page 30 for a one-pipe system using diverter valves. Use the approximate flow rate through the radiator and flow setter valve setting to read off the pressure drop. Size the circulator based on total flow and overall system pressure drop.

Thermostatic heads are required in this arrangement for individual temperature control.

Design Procedure for One-Pipe System with monoflow tees or diverter valves.

1. Select radiator hook-up sequence.
2. Determine individual heat loads.
3. Determine linear footage of wall space available for each radiator.
4. Compute the required heat load per foot for each room.
5. Select system temperature drop $\triangle T$ = 20, 30 or 40°F and maximum supply temperature.
6. Compute the total heat load (Q) in the loop by adding the individual heat loads.
7. Determine loop flow rate from total heat load (Q) and selected $\triangle T$ as:

$$GPM(loop) = Q / (500 \times \triangle T)$$

8. Compute the supply temperature for each room based on the supply temperature and heat load of the previous room and the total loop flowrate (GPM) as:

$$\text{New Supply Temp} = \text{Previous Supply Temp} - (Q_{room})/(500 \times GPM)$$

9. With the supply temperature computed in Step 8 and the linear heat load in Step 4, refer to Figures 9, 10 and 11 to find the required radiator size. Use the same $\triangle T$ value in reading from the curves in Figures 9-11 as the selected value in Step 5.

In case more than one radiator is to be installed in a room, size all radiators based on the above procedure.

Table 8: Radiator Sizing Sheet: One Pipe System

1	Select Room Sequence	Room 1	Room 2	Room 3	Room 4
2	Heat Load per Room (Btu/hr)				
3	Available Wall Space (ft)				
4	Minimum Required Heat Load per linear ft (Btu/ft)				
5	Select system ΔT Max Supply Temperature	ΔT = ________°F Supply Temp (Room 1) = Max Supply Temp = ________°F			
6	Total Heat Load (Btu/hr)	Q = ________Btu/hr			
7	Total Loop GPM	GPM(loop) = Q / (500 x ΔT) = ________ GPM			
8	Supply Temp per room	________°F*	________°F	________°F	________°F
9	List possible radiator model(s) and sizes from Fig.'s 10, 11 & 12				

*This entry is always equal to the maximum supply temperature.

Example: One-Pipe System Lay-out

Design a one-pipe system for a second floor with individual room temperature control:

Description	Heat Load	Window Size	Hook-up Sequence
Bathroom:	3,000 Btu	1-2 ft wide	first
Master bedroom:	9,000 Btu	2-4 ft wide	second
Bedroom:	6,000 Btu	1-3 ft wide	last
Bedroom:	4,000 Btu	1-3 ft wide	third

Solution:

1. Complete the Radiator Sizing Sheet to find minimum size radiator.

2. Select control strategy and size piping and pump using Table 7.

Table 9: Radiator Sizing Sheet: One-Pipe System

Step 1-4: See Table above.

1	Select Room Sequence	Bathroom	M. Bedroom	Bedroom #2	Bedroom #3
2	Heat Load per Room (Btu/hr)	3000	9000	6000	4000
3	Available Wall Space (ft)	2	8	3	3
4	Minimum Required Heat Load per linear ft (Btu/ft)	1500	1125	2000	1333
5	Select system ΔT Max Supply Temperature	ΔT = 30 °F Supply Temp (Room 1) = Max Supply Temp = 180 °F			
6	Total Heat Load (Btu/hr)	Q = 22,000 Btu/hr			
7	Total Loop GPM	GPM(loop) = Q / (500 x ΔT) = (22,000)/(500 x 30) = 1.47 GPM			
8	Supply Temp per room	180 °F*	176 °F	164 °F	156 °F
9	List possible radiator model(s) and sizes from Fig.'s 10, 11 & 12				

* This entry is always equal to the maximum supply temperature.

Step 5: Assume temperature drop (△T) = 30°F, maximum supply temperature = 180°F.

Step 6: Add all heat loads from row 2 and enter in Step 6.

Step 7: Compute flow rate in the one-pipe system in GPM.

Note: The flowrate can not exceed 2 GPM when using diverter valves. Using a larger △T lowers the GPM.

Step 8: Here we must compute the supply temperature for each room. Start with the first room and compute each supply temperature step by step as shown here.

Supply Temp(1) = 180°F
Supply Temp(2) = 180 - 3000/(500 x 1.47) = 176°F
Supply Temp(3) = 176 - 9000/(500 x 1.47) = 164°F
Supply Temp(4) = 164 - 6000/(500 x 1.47) = 156°F

Step 9: Now with each value computed in steps 4 and 8, locate those values in Figures 9 through 11. The output curve located directly above that point identifies the minimum size radiator required. Use the 18°F△T curves if designing for a 20 to 30°F temperature drop, use the 36°F△T curves if designing for a 40°F drop.

Results:		Output/ft	Radiator Models
Bedroom	Supply Temp = 180°F	1500 Btu/ft	#22 20" or #33 14"
M. Bedroom	Supply Temp = 176°F	1125 Btu/ft	#11 24" or #22 14"
Bedroom #2	Supply Temp = 164°F	2000 Btu/ft	#22 24" or #33 20"
Bedroom #3	Supply Temp = 156°F	1333 Btu/ft	#22 24" or #33 14"

The bold faced models are stock radiators, fit in the available wall space and provide sufficient heat. Use 5/8" PEX and diverter valves (or: 3/4" copper main line with 3/4" x 3/4" x 1/2" monoflow tees) with thermostatic heads on all radiators for individual room control. Place a thermostat in the bathroom or master bedroom or run constant circulation. Use a Grundfos UP15-42, a Taco 007, or equivalent pump with a balancing valve to throttle the flow. Noise may otherwise develop in the diverter valves.

Two-Pipe System Options

Figure 12 on page 23 illustrates two common two-pipe configurations:

1. Two-pipe system with direct return.

2. Two-pipe system with reverse return.

Benefits of two-pipe systems:

1. Each radiator is supplied with the same temperature water maximizing radiator output.

2. No limit to the number of radiators on a two pipe system loop; the supply and return mains must be sized for maximum flow. Follow the guidelines in Table 7 for sizing the supply and return runs. Use 1/2” copper or PEX tubing to connect radiators to main runs.

3. Individual radiator control is easily done using thermostatic sensor heads. Use constant circulation with outdoor reset control for optimum system performance. A central thermostat can be used for on/off control; however, thermostat location governs overall system control and may override individual room control.

Requirements of two-pipe system:

1. Two main distribution pipes are needed; one for the supply to the radiators and a second pipe for the return to the boiler.

2. A pressure actuated bypass valve (Part No. 3L602502 for a 3/4" Danfoss valve) connected between supply and return mains is necessary on constant circulation systems with thermostatically controlled radiators to prevent dead-heading the pump. This bypass valve is not needed on thermostat controlled systems if the radiators are not equipped with thermostatic sensor heads.

Design Procedure for Two-Pipe System

1. Determine individual heat loads.

2. Select desired overall temperature drop of systems ($\triangle T$); i.e. 20°F, 30°F or 40°F.

3. Compute loop flow rate GPM from: $GPM = Q/(500 \times \triangle T)$

4. Use Figures 9-11 or the Conversion Factors in Table 6 to determine output of radiator models in case of lower supply temperatures.

5. Use the Pressure Drop Chart on page 31 as a guide to set the flow setter valve for each radiator to ensure proper flow through each radiator. Adjust flow setter valves as needed based on system performance. Close down the flow setter on “hot” radiators by dialing in a lower setting on the adjustment ring, or adjust the flow setter to a higher setting for “cool” radiators.

6. Size piping based on system flowrate; size circulator based on flowrate and overall system pressure drop.

Example 2: Two-pipe System Lay-out

Design and select a two pipe panel radiator system with the following requirements:

Room Description	Heat loads	No.&Size of Windows		Required Btu/ft
Walk-in closet	2,000		none	
Bathroom	5,000	1	2 ft wide	2,500
Bedroom#1	8,000	2	3 ft wide	1,333
Bedroom#2	10,000	2	4 ft wide	1,250
Master Bedroom	12,000	2	4 ft wide	1,500
Total Load:	37,000 Btu/hr			

System Parameters: Maximum Supply Temperature: 194°F
Thermostat in master bedroom for on/off control.

Solution: Two-Pipe System Lay-out

1. If sufficient space is available for radiators, select radiators based on required heat output and desired style. Select radiators from Table 3 since the system temperature is similar to those listed in Table 3.

If the radiators must be sized for the available window space, determine the minimum needed model radiator based on the required Btu/ft for each room from Figures 9, 10 and 11 with a 194°F supply temperature. Use the same supply temperature for each radiator in a two-pipe system.

2. Select an overall temperature drop of 20°F.
3. Compute system flow rate as: GPM = Q/(500 x $\triangle$T) = 37000/(500 x 20) = 3.7 GPM
4. Combine all information in tabular form as shown in Table 10.

Table 10: Radiator Option Determination Chart: Two-Pipe System

Room Description	Heat Load	Btu/ft	Selected models	No. and Length of Radiator	Flowsetter Valve Number
Walk-in closet	2,000		#11 20x24, #22 14x16	1	3 - 4
Bathroom	5,000	2,500	#22 24"	1 x 2 ft	6 - 7
Bedroom #1	8,000	1,333	#11 24" or #22 14"	2 x 3 ft	5 - 6
Bedroom #2	10,000	1,250	#11 24" or #22 14"	2 x 4 ft	6 - 7
Master Bedroom	12,000	1,500	#22 14"	2 x 4 ft	7 - N

5. *Balancing the system*
Initial settings of flow setter valves will help to ensure proper flow through all radiators. Keep in mind that this is only a starting point and that the system may require further adjustment based on the heating characteristics of the structure.

Procedure for setting the flow-setter valves.

5a. Identify the largest radiator. In this case it would be the master bedroom radiator (#22 14” x 48”). The setting for this radiator should be “N”. This radiator will have the highest pressure drop and requires that the flow-setter valve be full open.

5b. Using the Pressure Drop Chart on page 31, find the output for this radiator (at selected △T) at the bottom of the chart. Based on 6,000 btuh at a 20°△T the flow rate for this radiator is .6 GPM. Follow the .6 GPM line vertically until you intersect the N setting. Reading across to the left you will see that the pressure drop for this radiator is approximately 12 in. wc or 1ft/hd.

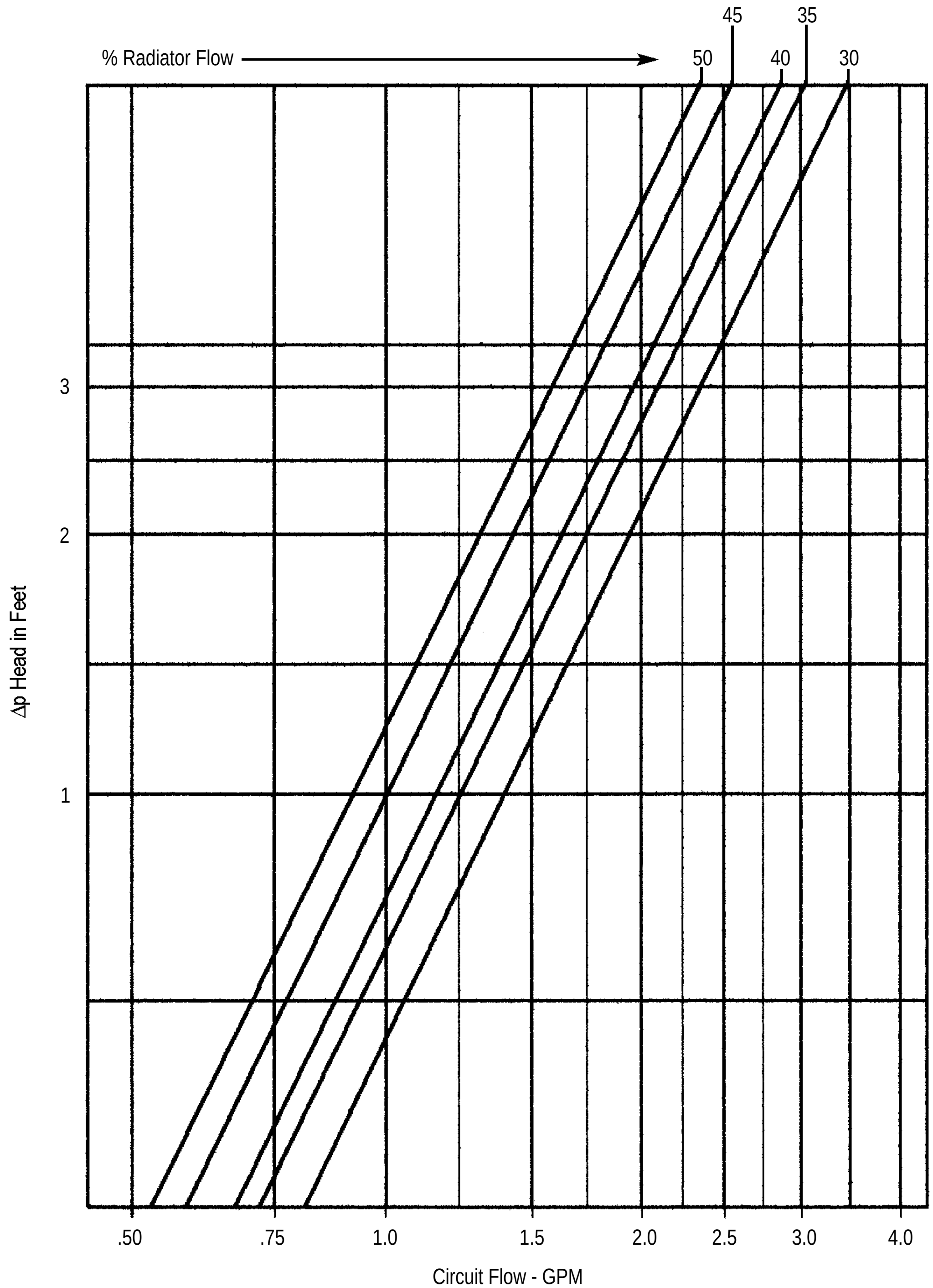
5c. Draw a horizontal line across the diagram at 12 in. wc.

5d. Select the next radiator. Identify its btuh output, locate this figure at the bottom of the chart as you did for the first radiator. At the corresponding flow-rate, move vertically on chart until you intersect the horizontal line that you drew indicating 12 in. wc. Find the appropriate flow setting. If the setting value is between two settings, say 3 and 4, then simply set the valve between 3 and 4.

5e. Repeat step 4 for remaining radiators.

6. Use guidelines in Table 7 to size main piping. In this case, use 3/4” copper mains with 1/2” copper (or PEX) to/from each radiator. Install a thermostat in master bedroom. Size circulator based on total flowrate and install balancing value for flow control.

Pressure Drop Diagram: One-Pipe System with Diverter Valves



Pressure Drop Diagram: Two-Pipe System or One-Pipe with Monoflo w Tees.