SECTION FIVE

Distribution System Options

Several distribution systems can be used with DiaNorm panel radiators. Each approach has strengths and limitations. This section discusses the options and gives a step by step procedure for design.

Series Circuit Distribution Systems

The simplest concept for a distribution piping system is a series circuit that progresses from the heat source, through each radiator, and finally back to the heat source. System operation is usually controlled by a single room thermostat. An example of a series circuit of panel radiators is shown below.

Series circuits are quite limited in application due to the following considerations:

1. Because heat input to the entire building is regulated by a single thermostat, overheating or underheating of areas other than where the air temperature is sensed is likely. This is especially true when different areas experience different internal heat gains. In such situations, it is not possible to reduce the heat output of one radiator without affecting the outputs of all other radiators on the circuit.

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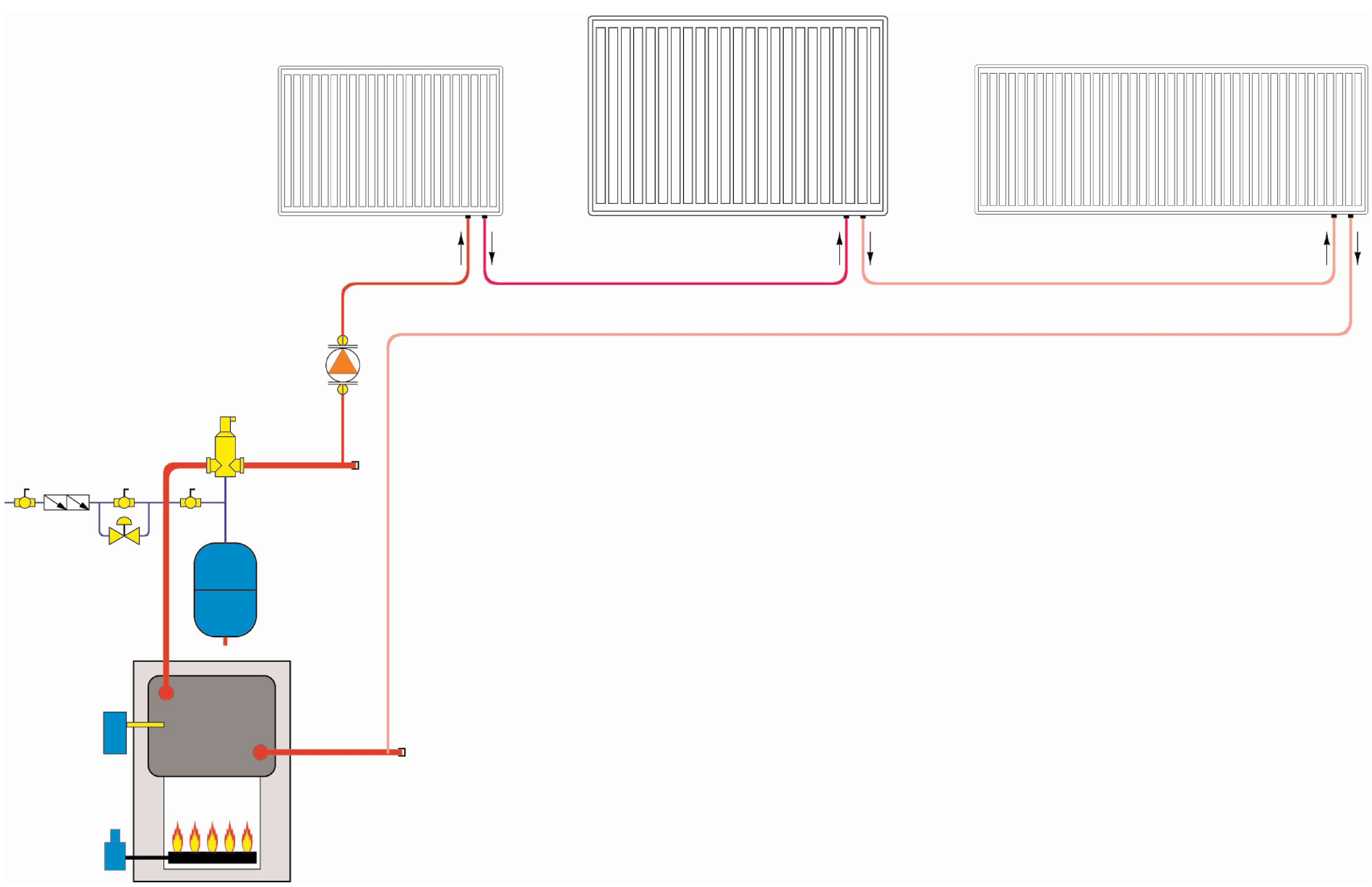

Distribution System Options

2. Radiators near the beginning of a series loop receive the highest water temperature. As flow progresses downstream, there is a drop in water temperature across each radiator. If this cascading temperature drop effect is not properly accounted for during design it could lead to undersized radiators near the end of the loop.

3. The head loss and pressure drop of all piping and panel radiators in a series loop is additive. Undersized tubing or long series loops containing several radiators can create high flow resistance that tends to reduce flow rate. This in turn reduces heat output from the radiators. The option of installing a high head circulator to overcome this effect, although possible, adds to both initial cost and operating cost over the life of the system. Because of this, high head circulators are generally not recommended for use with panel radiator systems.

Design Procedure for Series Circuits

Step 1: Determine the design heating load of each room served by the circuit. Add these loads to determine the total load on the circuit.

Step 2: Select a circuit supply temperature and a tentative circuit temperature drop at design load conditions. The circuit supply temperature is generally between 160 and 180 ºF. The circuit temperature drop should be between 15 and 30 ºF.

Step 3: Calculate the target flow rate in the circuit using the following formula:

$$f = \frac{Q}{490 \times \Delta T}$$

Where:
f = target system flow rate in the circuit (gpm)
Q = total design heating load of the circuit (Btu/hr)
ΔT = intended temperature drop of the circuit (°F) (from step 2)

Note: *The constant 490 is based on water as the system fluid. If a 30% glycol solution is used, change this value to 479. If a 50% glycol solution is used, change this value to 450.*

Step 4: Based on the target flow rate calculated in step 3, select a tube size for the circuit from the following table. This table is based on keeping the flow velocity between two and four feet per second. The lower end of this range ensures that air bubbles can be entrained and carried along by the flow. The upper end of this range keeps flow noise at acceptable levels for piping traveling through occupied spaces.

Tubing size / type	Minimum Flow rate (gpm)	Maximum Flow rate (gpm)
3/8" copper	1.0	2.0
1/2" copper	1.6	3.2
3/4" copper	3.2	6.5
3/8" PEX	0.6	1.3
1/2" PEX	1.2	2.3
5/8" PEX	1.7	3.3
3/4" PEX	2.3	4.6
3/8" PEX-AL-PEX	0.6	1.2
1/2" PEX-AL-PEX	1.2	2.5
5/8" PEX-AL-PEX	2	4.0
3/4" PEX-AL-PEX	3.2	6.4

Distribution System Options

Step 5: Calculate the *average* water temperature in the radiator using the following formula:

$$T_{ave} = T_{supply} - \frac{q_i}{490 \times 2 \times f}$$

Where:

T_{ave} = average fluid temperature in the first radiator (ºF)
T_{supply} = fluid temperature supplied to first radiator (ºF)
q_i = design heating load assigned to first radiator (Btu/hr)
f = target flow rate in circuit (gpm)

Note: *The constant 490 is based on water as the system fluid. If a 30% glycol solution is used, change this value to 479. If a 50% glycol solution is used, change this value to 450.*

Step 6: Based on the average fluid temperature in the radiator, and the heating load assigned to the radiator, select an appropriate DiaNorm radiator using the thermal performance information in section 3 of this manual.

Step 7: Calculate the head loss of the selected panel at the target flow rate using the head loss data in section 3. Assume the radiator valve is set to its full open (N) position. **Record the head loss of this radiator.**

Step 8: Calculate the outlet temperature of the radiator using the following formula:

$$T_{outlet} = T_{supply} - \frac{q_i}{490 \times f}$$

Where:

T_{outlet} = outlet temperature from the radiator (ºF)
T_{supply} = supply temperature to the radiator (ºF)
q_i = design heating load assigned to the radiator (Btu/hr)
f = target flow rate in circuit (from step 3) (gpm)

Note: *The constant 490 is based on water as the system fluid. If a 30% glycol solution is used, change this value to 479. If a 50% glycol solution is used, change this value to 450.*

Step 9: The outlet temperature from the radiator becomes the inlet temperature to the next radiator. Repeat steps 5 through 8 for the second and all remaining radiators on the circuit. Be sure to record the head loss of each radiator as it is determined.

Step 10: Based on where the radiators will be placed in the building, estimate the total length of tubing needed to connect them into a series circuit.

Step 11: Calculate the head loss of all tubing in the circuit using the following formula and data:

$$H_{LT} = k \times L \times f^{1.75}$$

Where:

H_{LT} = head loss of the tubing (feet of head)
k = a number based on tubing type/size (found in table on the next page)
L = length of tubing in the circuit (feet)

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Tubing size / type	Value of k (WATER in system)
3/8" copper	0.0484
1/2" copper	0.0159
3/4" copper	0.00295
3/8" PEX	0.140
1/2" PEX	0.0374
5/8" PEX	0.0140
3/4" PEX	0.0073
3/8" PEX-AL-PEX	0.16
1/2" PEX-AL-PEX	0.0394
5/8" PEX-AL-PEX	0.0098
3/4" PEX-AL-PEX	0.00333

Step 12: Add the head loss of ALL tubing in the circuit to the head loss of ALL radiators in the circuit. This is the total head loss of the circuit.

This head loss calculated using the above data is based on water as the circuit fluid. If a 30 percent propylene glycol solution is used, multiply the total calculated head loss by 1.19. If a 50 percent propylene glycol solution is used, multiply the total calculated head loss by 1.34

Step 13: If this is the only circuit served by a circulator, that circulator should be selected based on the target flow rate (calculated in step 3), and the total circuit head loss (calculated in step 12). If there are other circuits on the same manifold, the circulator should be selected based on the total flow to the manifold and the head loss of the most restrictive circuit on the manifold.

Summary

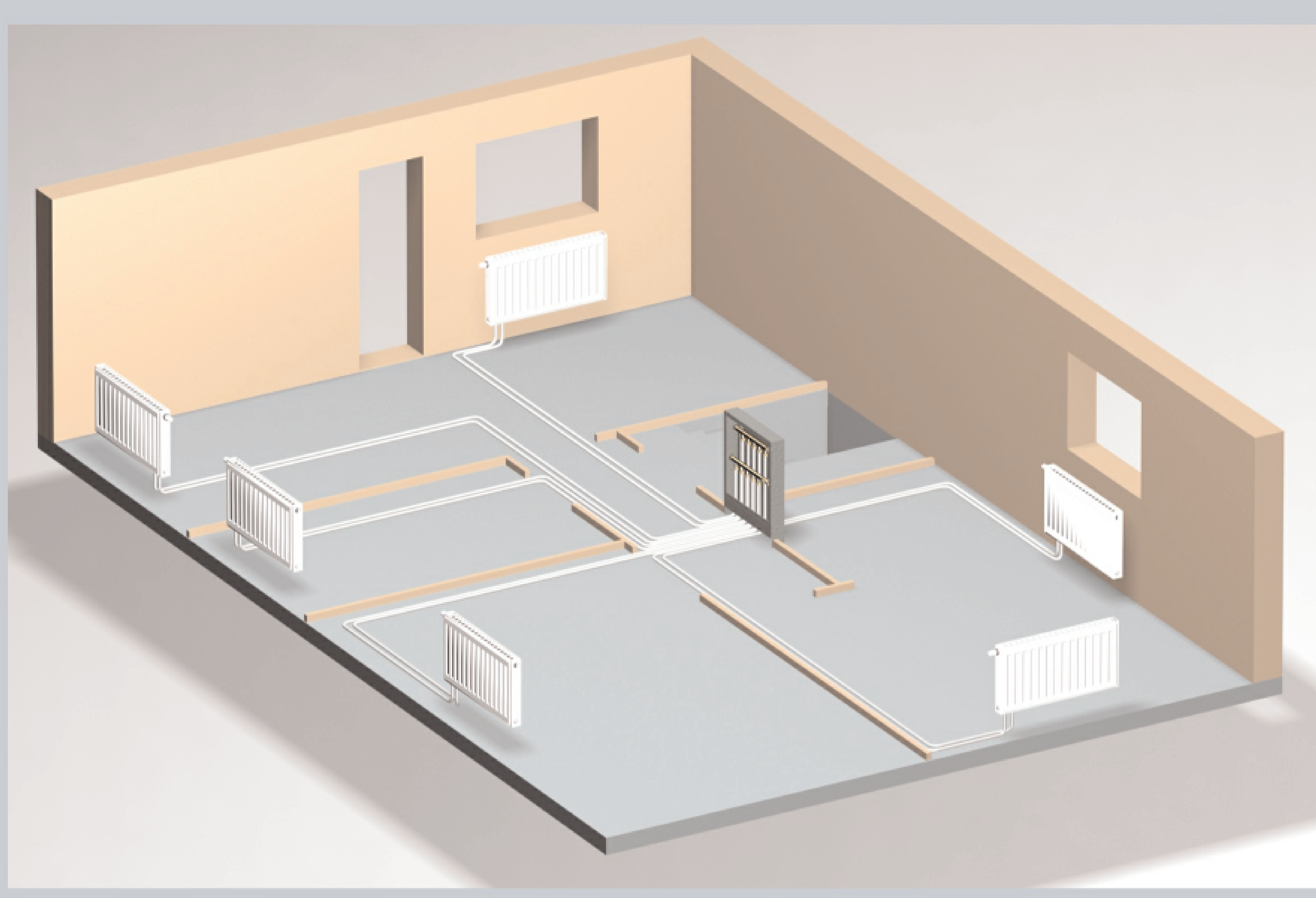
Series circuits are more difficult to design because of the sequential temperature drop effect and the possibility of high head loss. It's fair to say they are not as versatile as several of the other distribution systems to be discussed.

Distribution System Options

Homerun Distribution Systems

Many of the "classic" hydronic distribution systems were developed around the use of rigid tubing or pipe. However, over the last two decades, many designers have recognized the potential of PEX and PEX-AL-PEX tubing as universal piping materials for residential and light commercial hydronic systems. The temperature/pressure rating of PEX and PEX-AL-PEX along with their inherent flexibility offers new possibilities for piping heat emitters such as DiaNorm radiators.

One of the newest hydronic distribution systems is called a "homerun system." This simple yet elegant approach is ideally suited for use with DiaNorm radiators. The concept is shown below.



Example of a homerun distribution system

In a homerun system, a separate supply and return run of small diameter (usually 3/8" or 1/2" PEX, or PEX-AL-PEX tubing) is routed from a manifold station to each panel radiator. The small flexible tubing can be routed through framing cavities in buildings much like electrical cable. This provides a tremendous advantage over rigid tubing, especially in retrofit situations.

Home run systems also allow the heat output of each room to be individually controlled. They also deliver fluid at the same supply temperature to each radiator, which simplifies sizing.

The balancing valves on each DiaNorm radiator can be set to compensate for the flow resistances of the tubing circuit serving it.

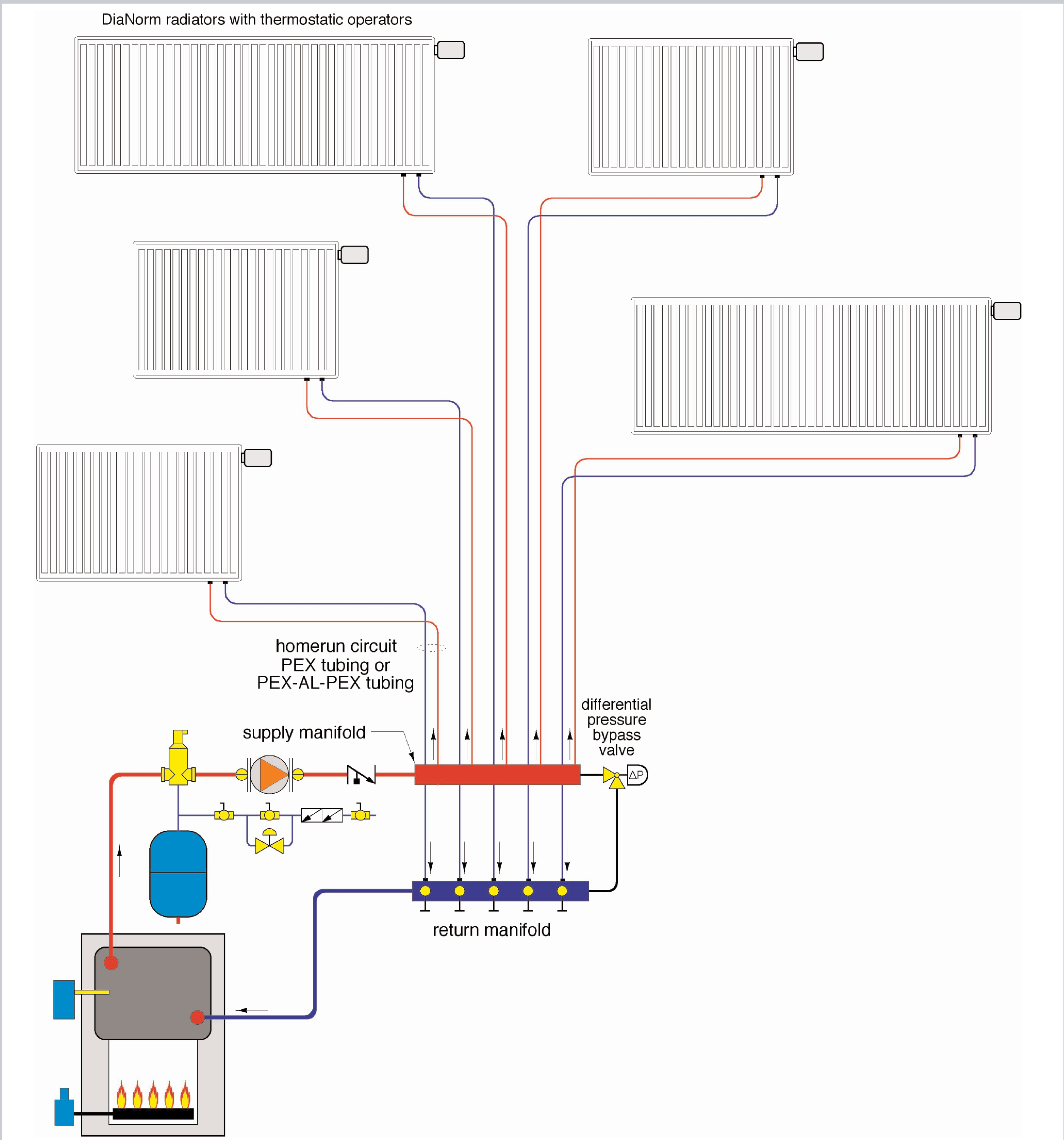
Homerun distribution systems allow several methods of zoning control. One of the simplest is to install a thermostatic operator on each radiator as shown in the schematic on the next page. These non-electric devices modulate flow through their respective radiators in response to changes in room temperature.

Because thermostatic valve operators are non-electric, they cannot signal for the circulator or boiler to operate as they start to open. However, the circulator can be turned on and the boiler enabled to fire whenever the outdoor temperature drops below some "heating initiation" temperature (typically about 65 ºF).

As with other systems that use valves for zoning and a constant speed circulator, home run systems should be equipped with a differential pressure bypass valve. The circulator should also have a relatively "flat" pump curve.

Homerun systems are also well suited to variable speed distribution circulators that maintain a constant differential pressure across the manifold station.

Distribution System Options



Distribution System Options

Design Procedure for Homerun Systems

Step 1: Determine the design heating load of each room served by the homerun distribution system.

Step 2: Select a fluid temperature to be supplied to the radiators under design load conditions. Common design supply temperatures for panel radiator systems range from 140 ºF to 180 ºF. The lower end of this range favors radiant heat output and provides lower radiator surface temperatures. It also increases the size of the radiator needed for a given heat output. The upper end of the range reduces radiator size for a given heat output, but may create surface temperatures higher than desired. Higher operating temperatures also decrease boiler efficiency and heat loss from the distribution piping.

Step 3: Select a target temperature drop for the homerun system under design load conditions. Suggested temperature drops for homerun systems range from 20 ºF to 40 ºF. The upper end of this range reduces the flow rate requirements and may allow smaller tubing and less powerful circulators to be used.

Step 4: Knowing the total heating load of the homerun distribution system, and the estimated temperature drop, use the following formula to estimate the flow rate into the manifold station.

$$f_m = \frac{Q}{490 \times \Delta T}$$

Where:
f_m = estimated manifold flow rate (gpm)
Q =total design heating load served by the manifold (Btu/hr)
ΔT = intended temperature drop of the circuit at design load (°F)

Note: *The constant 490 is based on water as the system fluid. If a 30% glycol solution is used, change this value to 479. If a 50% glycol solution is used, change this value to 450.*

Step 5: Calculate the flow rate through each radiator using the following formula.

$$f_i = f_m \times \left[\frac{q_i}{Q} \right]$$

Where:
f_i = flow rate through a given panel radiator (gpm)
f_m = manifold flow rate from step 4 (gpm)
Q_i = design heat output required of the individual panel radiator (Btu/hr)
Q = total design heating load served by the manifold (Btu/hr)

Step 6: Select tube sizes for each homerun circuit based on the following table, which limits flow velocity to four feet/second.

Tubing size / type	Max. flow rate (gpm)
3/8" M copper	2.0
1/2" M copper	3.2
3/4" M copper	6.5
3/8" PEX	1.3
1/2" PEX	2.3
5/8" PEX	3.3
3/8" PEX-AL-PEX	1.2
1/2" PEX-AL-PEX	2.5
5/8" PEX-AL-PEX	4.0

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Step 7: Make a sketch of the homerun distribution system and estimate the total length (supply + return) of each homerun circuit.

Step 8: Calculate the head loss of each homerun circuit. This head loss is the sum of the head loss of the panel radiator and the head loss of the supply and return tubing serving the radiator.

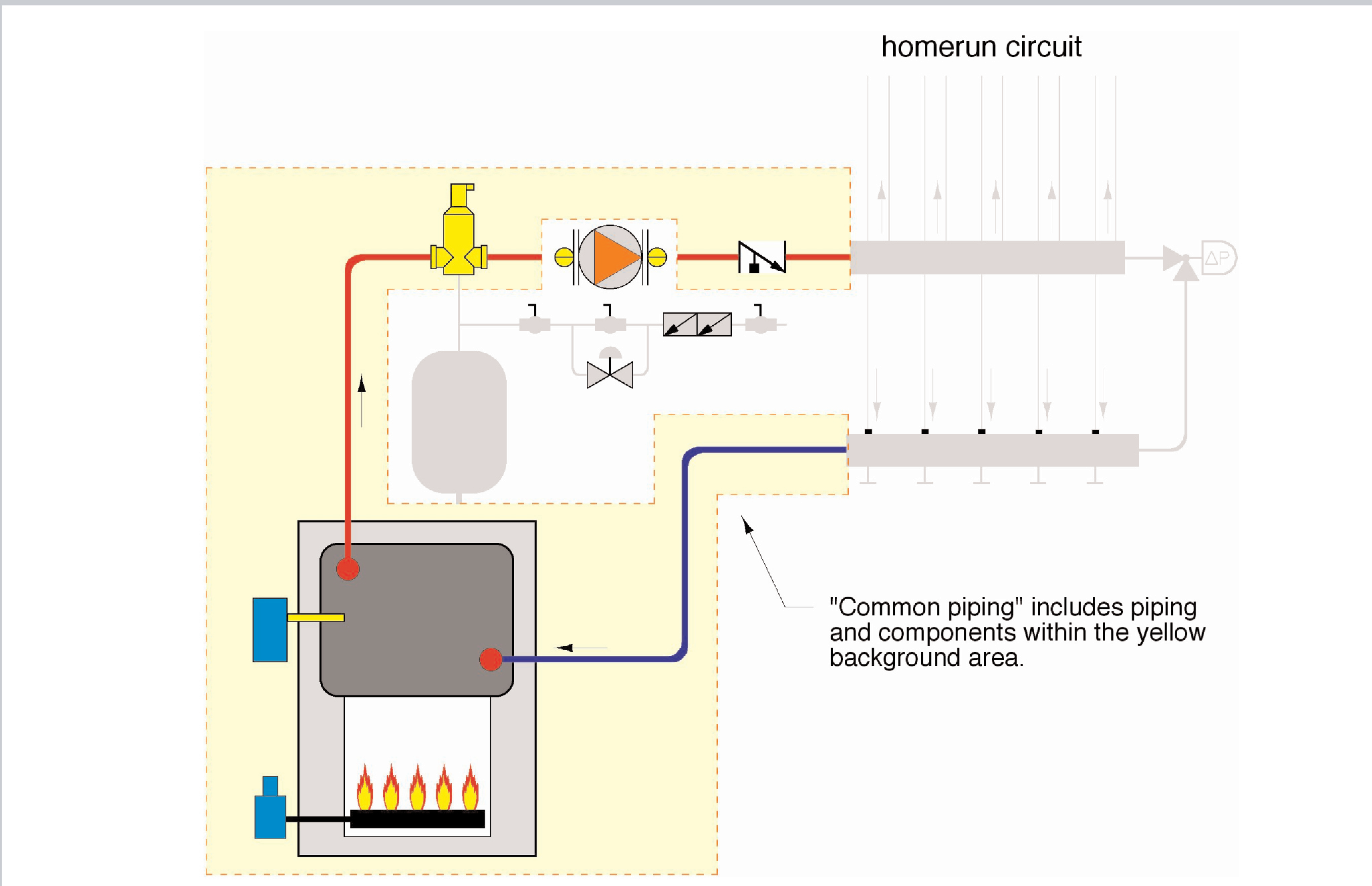
Head loss data for DiaNorm panel radiators can be found in section 3 (assume the radiator valve is in the fully open "N" position).

The head loss of supply and return tubing can be estimated using the following formula and table (table on next page).

$$H_{LT} = k \times L \times f^{1.75}$$

Where:

H_{LT} = head loss of the tubing (feet of head)
k = a number based on tubing type/size (found in table page 35)
L = length of tubing in the homerun circuit (supply and return) (feet)
f = flow rate through the circuit (step 5) (gpm)



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Tubing size / type	Value of k (WATER in system)
3/8" copper	0.0484
1/2" copper	0.0159
3/4" copper	0.00295
1" copper	0.000845
1.25" copper	0.000324
3/8" PEX	0.140
1/2" PEX	0.0374
5/8" PEX	0.0140
3/8" PEX-AL-PEX	0.16
1/2" PEX-AL-PEX	0.0394
5/8" PEX-AL-PEX	0.0098

Note: *The head losses calculated using the above formula and data are based on water as the system fluid. If a 30 percent propylene glycol solution is used, multiply the values in the table by 1.19. If a 50 percent propylene glycol solution is used, multiply the values in by 1.34*

Step 9: Once the head loss of each circuit is calculated, determine the circuit with the greatest head loss and record this value.

Step 10: Calculate the head loss of the "common piping" supplying the manifold that supplies the homerun circuits (see drawing on page 34). Use the same formula and table data from step 8. Once the head loss of the common piping is determined, add it to the head loss of the tubing circuit from step 9. This is the design head loss of the system.

Step 11: Select a circulator having a pump curve that passes through or slightly above the operating point defined by the total flow rate found in step 4 and the design head loss found in step 10.

Summary

Homerun distribution systems are ideally suited to panel radiator systems. They allow individual heat output control of each panel, and provide the same supply water temperature to each panel. They are easily fabricated using PEX or PEX-AL-PEX tubing, and are well suited to both new and retrofit applications.

Distribution System Options

Diverter Tee Distribution Systems

Another distribution system option that can be used with DiaNorm radiators is called a diverter tee system. A piping schematic of this approach is shown on the next page.

A diverter tee (also commonly called a Monoflo® tee after the B&G trademark brand) contains a specially shaped venturi insert that creates a pressure differential as flow passes through the straight path (run) of the tee. This pressure differential is used to divert a portion of the flow entering the tee out through a branch circuit connected to the side port of the tee.

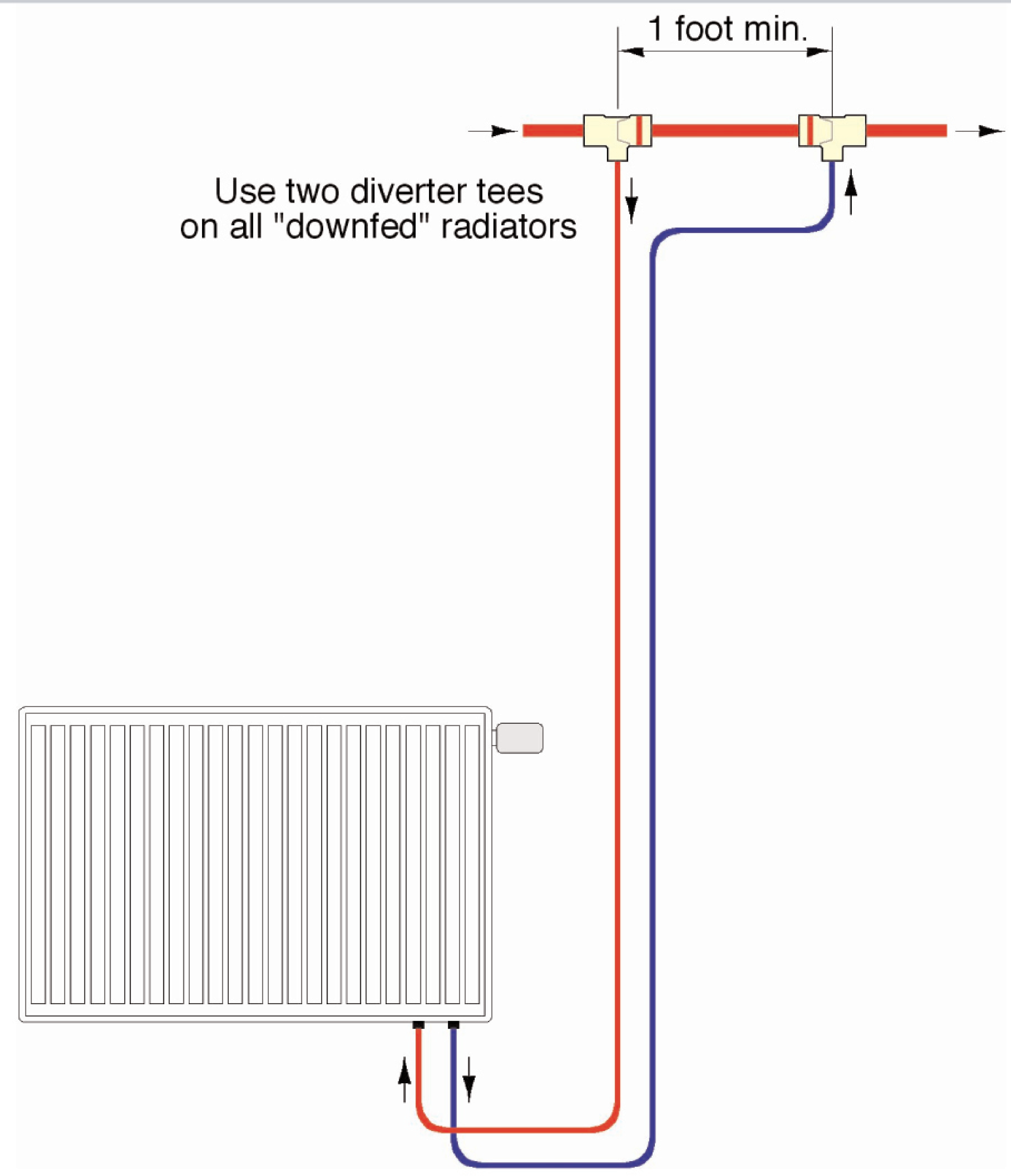
When no heat is needed at a radiator, the thermostatic operator on that radiator is closed. This blocks any flow through the branch circuit. As the room cools the thermostatic operator begins to open allowing flow of heated water through the radiator.

Diverter tee systems allow the heat output from each radiator to be individually controlled.

When two or more panel radiators are used to heat a large room they can be connected into a reverse return parallel group as shown on the next page and controlled as if they were a single radiator.

When the branch circuit has a high flow resistance, it is common to install two diverter tees - one on the supply side of the branch circuit and the other on the return side. The "push /pull" effect created by the two tees working together induces a greater flow rate through the branch circuit.

It is also common to use two diverter tees when the radiator is located several feet below the main piping. This helps overcome the buoyancy effects associated with forcing hot water to flow downward.



When installing diverter tees it is critically important that the tee is installed in the correct flow direction. The red band on the outside of the tee should always be as shown on the piping schematics.

If thermostatic operators are used on each radiator, the distribution circulator must operate continuously during the heating season. This can be done several ways.

If the system has a boiler reset control, it can be used to turn on the circulator and enable

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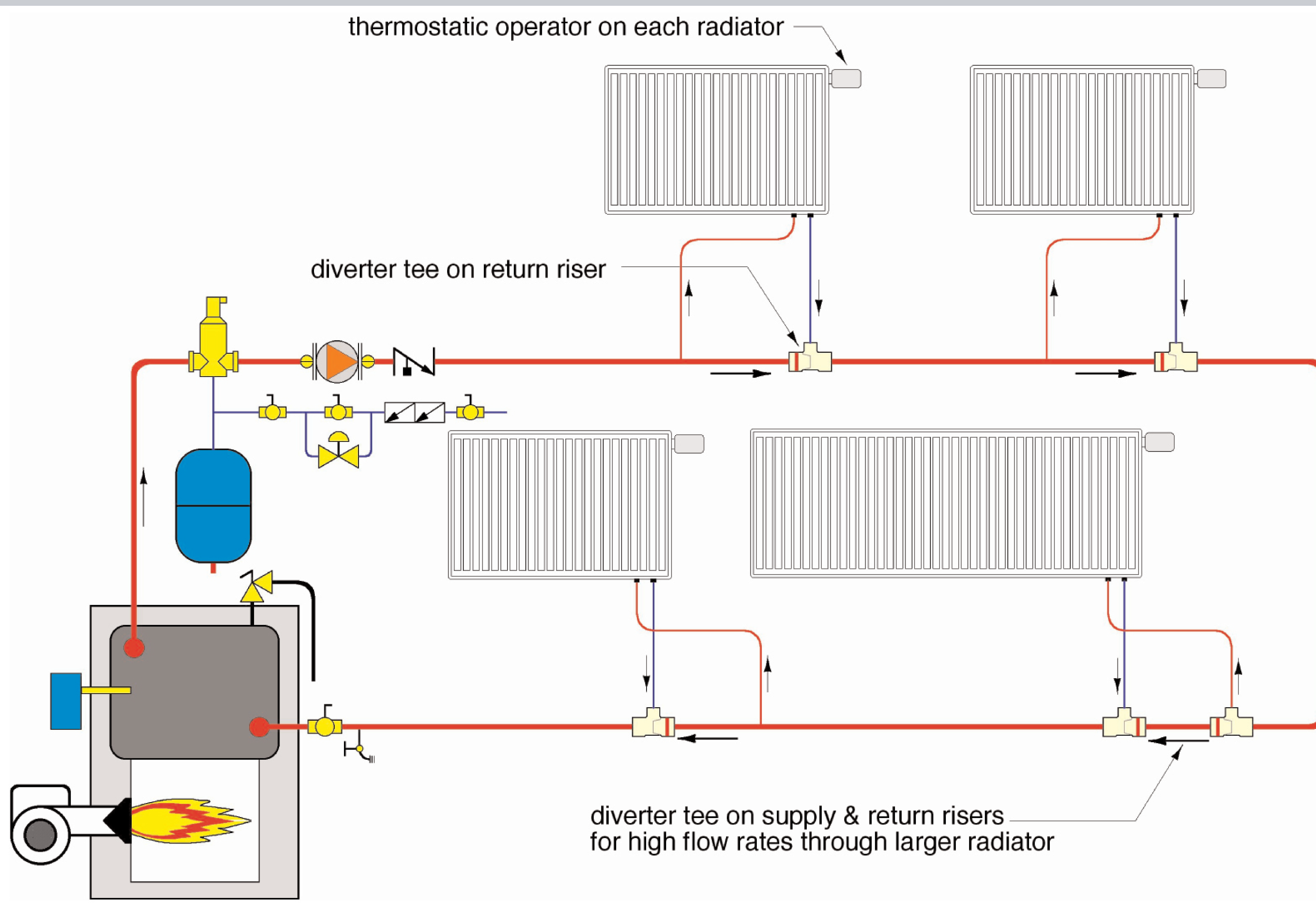
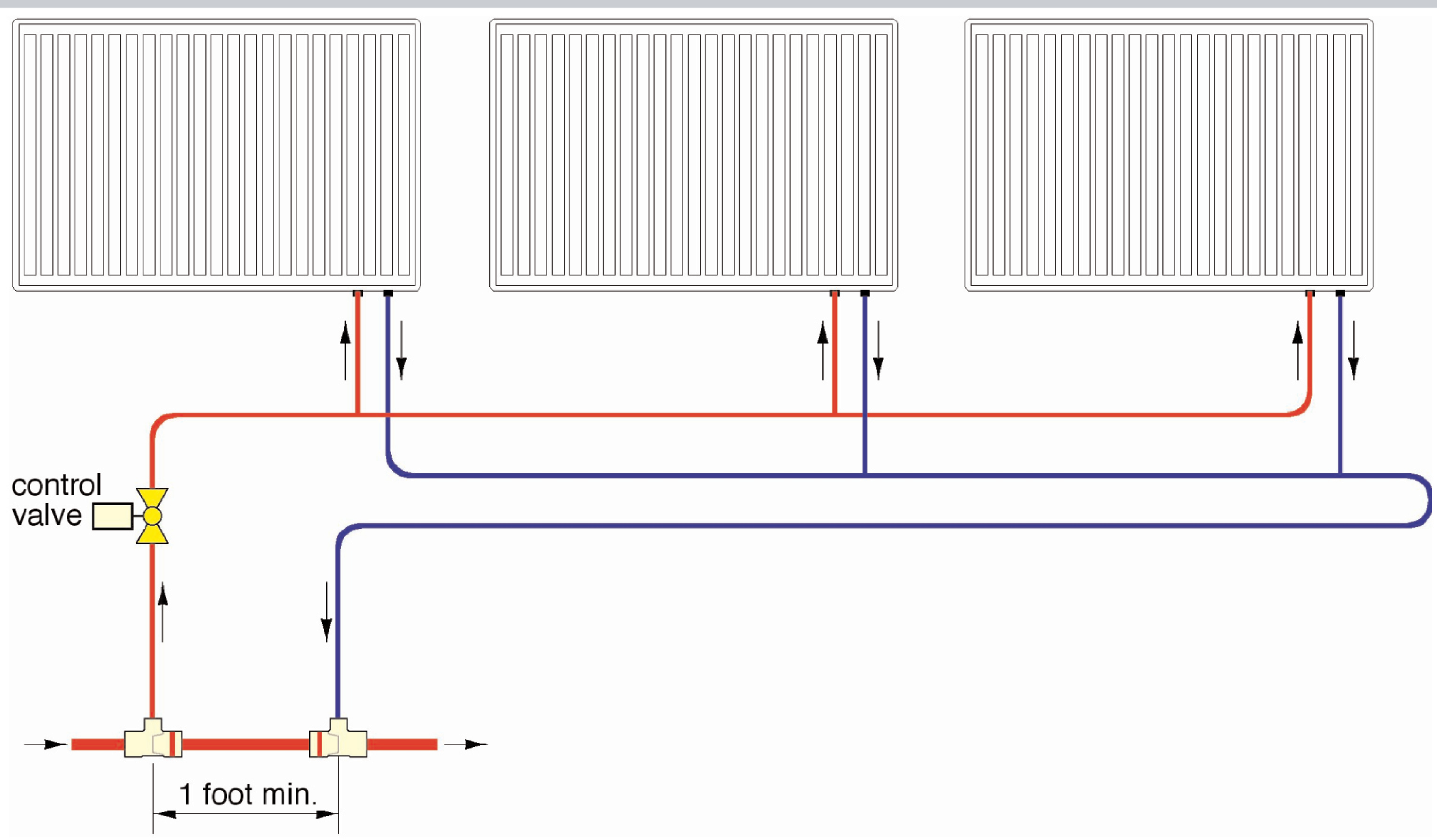


Example of a diverter tee distribution system

Multiple radiators served by a pair of diveter tees



Distribution System Options

the boiler to fire whenever the outdoor temperature drops below a preset "heat initiation" temperature (typically 60 to 65 ºF).

Another option is to use a temperature setpoint control to turn on the circulator and allow the heat source to operate below a given outdoor temperature.

With nearly continuous circulation during the heating season, it's important to insulate the main distribution piping circuit to minimize uncontrolled heat output.

Design of Diverter Tee Systems

As is the case with series circuits, it's necessary to account for the drop in fluid temperature around the piping circuit when sizing each panel radiator. The farther downstream the radiator is, the lower its inlet water temperature

Step 1: Determine the design heating load of each room served by the circuit. Add these loads to determine the total load on the circuit.

Step 2: Select a circuit supply temperature and a tentative circuit temperature drop at design load conditions. The circuit supply temperature is generally between 160 and 180 ºF. The circuit temperature drop should be between 15 and 30 ºF.

Step 3: Calculate the target flow rate in the main circuit using the following formula:

$$f = \frac{Q}{490 \times \Delta T}$$

Where:

f =target system flow rate in the main circuit (gpm)

Q =total design heating load of the circuit (Btu/hr)

ΔT = intended temperature drop of the circuit (°F) (from step 2)

Note: *The constant 490 is based on water as the system fluid. If a 30% glycol solution is used, change this value to 479. If a 50% glycol solution is used, change this value to 450.*

Step 4: Based on the target flow rate calculated in step 3, select a copper tube size for the main circuit from the following table. These flow rates are based on keeping the flow velocity between two and four feet per second. The lower end of this range ensures that air bubbles can be entrained and carried along by the flow. The upper end of this range reduces flow noise to acceptable levels for piping traveling through occupied spaces.

Tubing size / type	Minimum Flow rate (gpm)	Maximum Flow rate (gpm)
3/4" copper	3.2	6.5
1" copper	5.5	10.9
1.25" copper	8.2	16.3
1.5" copper	11.4	22.9
2" copper	19.8	39.6

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Step 5: Calculate the average water temperature in the radiator using the following formula:

$$T_{ave} = T_{supply} - \frac{q_i}{490 \times 2 \times 0.3 \times f}$$

Where:

T_{ave} = average fluid temperature in the first radiator (ºF)
T_{supply} = fluid temperature supplied to first radiator (ºF)
q_i = design heating load assigned to first radiator (Btu/hr)
f = target flow rate in circuit (gpm)

This formula assumes the flow rate through the radiator is approximately 30 percent of the main circuit flow rate.

***Note:** The constant 490 is based on water as the system fluid. If a 30% glycol solution is used, change this value to 479. If a 50% glycol solution is used, change this value to 450.*

Step 6: Calculate the outlet temperature from the downstream tee where the return riser from the radiator rejoins the main circuit using the following formula:

$$T_{outlet} = T_{supply} - \frac{q_i}{490 \times f}$$

Where:

T_{outlet} = outlet temperature from the downstream tee (ºF)
T_{supply} = supply temperature to the radiator (ºF)
q_i = design heating load assigned to the radiator (Btu/hr)
f = target flow rate in main circuit (from step 3) (gpm)

***Note:** The constant 490 is based on water as the system fluid. If a 30% glycol solution is used, change this value to 479. If a 50% glycol solution is used, change this value to 450.*

Step 7: The outlet temperature from the downstream tee becomes the inlet temperature to the next radiator. Repeat steps 5 through 6 for the second and all remaining radiators on the circuit.

Step 8: Sketch a pipe routing path for the circuit that accommodates both the building construction and placement of the panels. Think about where it will be possible (or not possible) to route the piping under floors, through partitions, etc. in order to access each radiator.

Step 9: Once the pipe routing has been determined, estimate the length of the main circuit as well as the number of elbows and other fittings or valves it may contain.

Step 10: Count the total number of diverter tees in the main piping circuit. Add the following equivalent length of tubing (for each diverter tee) to the total length of straight tubing and total equivalent length of fittings in the main circuit.

Size of main pipe	Equivalent length of each diverter tee
3/4-inch	70
1-inch	23.5
1.25-inch	25
1.5-inch	23
2-inch	23

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Step 11: Estimate the head loss of the main circuit using the formula below.

$$H_L = k \times L \times f^{1.75}$$

Where:
H_L = head loss of the circuit (feet of head)
k = a number based on tubing type/size (found in Table below)
L = total equivalent length of main circuit (tubing + fittings) (feet)
f = flow rate through main circuit (gpm)

***Note** that L is the total equivalent length of the main circuit including all straight piping, as well as the equivalent length of the fittings, valves, and diverter tees.*

Tubing size / type	Value of k (WATER in system)
3/4" copper	0.00295
1" copper	0.000845
1.25" copper	0.000324
1.5" copper	0.000146
2" copper	0.0000397

***Note:** The head losses calculated using the formula and data above are based on water as the system fluid. If a 30 percent propylene glycol solution is used, multiply the calculated head loss by 1.19. If a 50 percent propylene glycol solution is used, multiply the calculated head loss by 1.34.*

Step 12: Select a circulator with a pump curve that passes close to the point representing the target flow rate in the main circuit (determined in step 3) and the associated circuit head loss calculated in step 11.

Summary

Diverter tee systems improve upon series circuits by allowing the option of individual control of each panel radiator. However, as in a series circuit there is a temperature drop in the main piping circuit each time it passes an active radiator. Proper design must account for this temperature drop.

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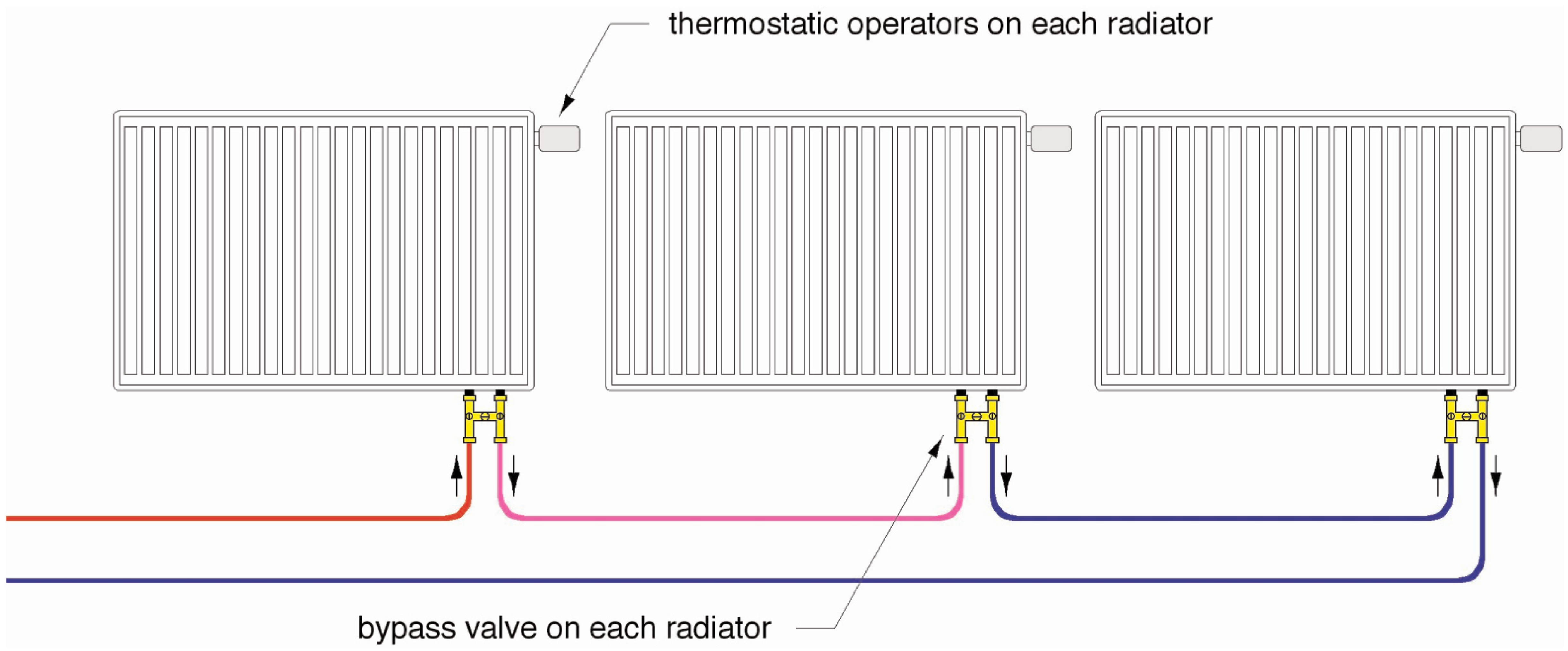

Bypass Valve Distribution Systems

A unique adaptation of the diverter tee concept has been developed for DiaNorm panel radiators. This approach is called a bypass valve distribution system.

This approach relies on a special valve that attaches to the bottom inlet and outlet connections of the radiator as shown below.

This valve provides several functions, the most important of which is to allow the flow of heated water to bypass the radiator when the thermostatic operator on that radiator is partially or fully closed.

Instead of passing through the radiator, flow passes through the horizontal portion of the valve connecting the supply and return ports. In effect, this valve allows the heated water to do a "U-turn" through the valve rather than pass through the radiator when the thermostatic operator is closed.

Unlike a diverter tee, which has a fixed pressure drop characteristic, this valve has an adjustable bypass characteristic that allows the pressure drop to be precisely set for the needs of the radiator.

When this valve is used with DiaNorm radiators equipped with thermostatic radiator valves, the piping system appears to be a simple series circuit as shown at the top of the page.

The Oventrop bypass valves supplied with DiaNorm radiators also provide the capability to isolate the radiator on both the supply and return piping. Once the panel is isolated, unions at the top of the valve can be opened to quickly disconnect the panel from the piping. This allows the radiator to be easily removed if the wall behind needs painting.

Distribution System Options

Design Procedure for Bypass Valve Systems

Stipulations:

• The maximum number of panel radiators on a bypass valve circuit is four.

• The maximum circuit flow rate when using bypass valves is 2.0 gpm.

• The tubing used to connect bypass valves must be 1/2" copper, 1/2" PEX, or 1/2" PEX-AL-PEX.

Step 1: Determine the design heating load of each room served by the circuit. Add these loads to determine the total load on the circuit.

Step 2: Select a circuit supply temperature and a tentative circuit temperture drop at design load conditions. The circuit supply temperature is generally between 140 and 180 ºF. The circuit temperature drop should be between 20 and 40 ºF.

Step 3: Calculate the target flow rate in the circuit using the following formula:

$$f = \frac{Q}{490 \times \Delta T}$$

Where:
f = target system flow rate in the circuit (gpm)
Q = total design heating load of the circuit (Btu/hr)
ΔT = intended temperature drop of the circuit (°F) (from step 2)

Note: *The constant 490 is based on water as the system fluid. If a 30% glycol solution is used, change this value to 479. If a 50% glycol solution is used, change this value to 450.*

Step 4: Verify that the target flow rate in the circuit does not exceed 2.0 gpm. If it does, either reduce the number of radiators on the circuit (and hence the total circuit load), or consider increasing the circuit's design temperature drop.

Step 5: Calculate the average water temperature in the first radiator using the following formula:

$$T_{ave} = T_{supply} - \frac{q_i}{490 \times 2 \times f}$$

Where:
T_{ave} = average fluid temperature in the first radiator (ºF)
T_{supply} = fluid temperature supplied to first radiator (ºF)
q_i = design heating load assigned to first radiator (Btu/hr)
f = target flow rate in circuit (gpm)

Note: *The constant 490 is based on water as the system fluid. If a 30% glycol solution is used, change this value to 479. If a 50% glycol solution is used, change this value to 450.*

Step 6: Based on the average fluid temperature in the radiator, and the room load assigned to the radiator, select an appropriate DiaNorm radiator using the thermal performance information in section 3 of this manual.

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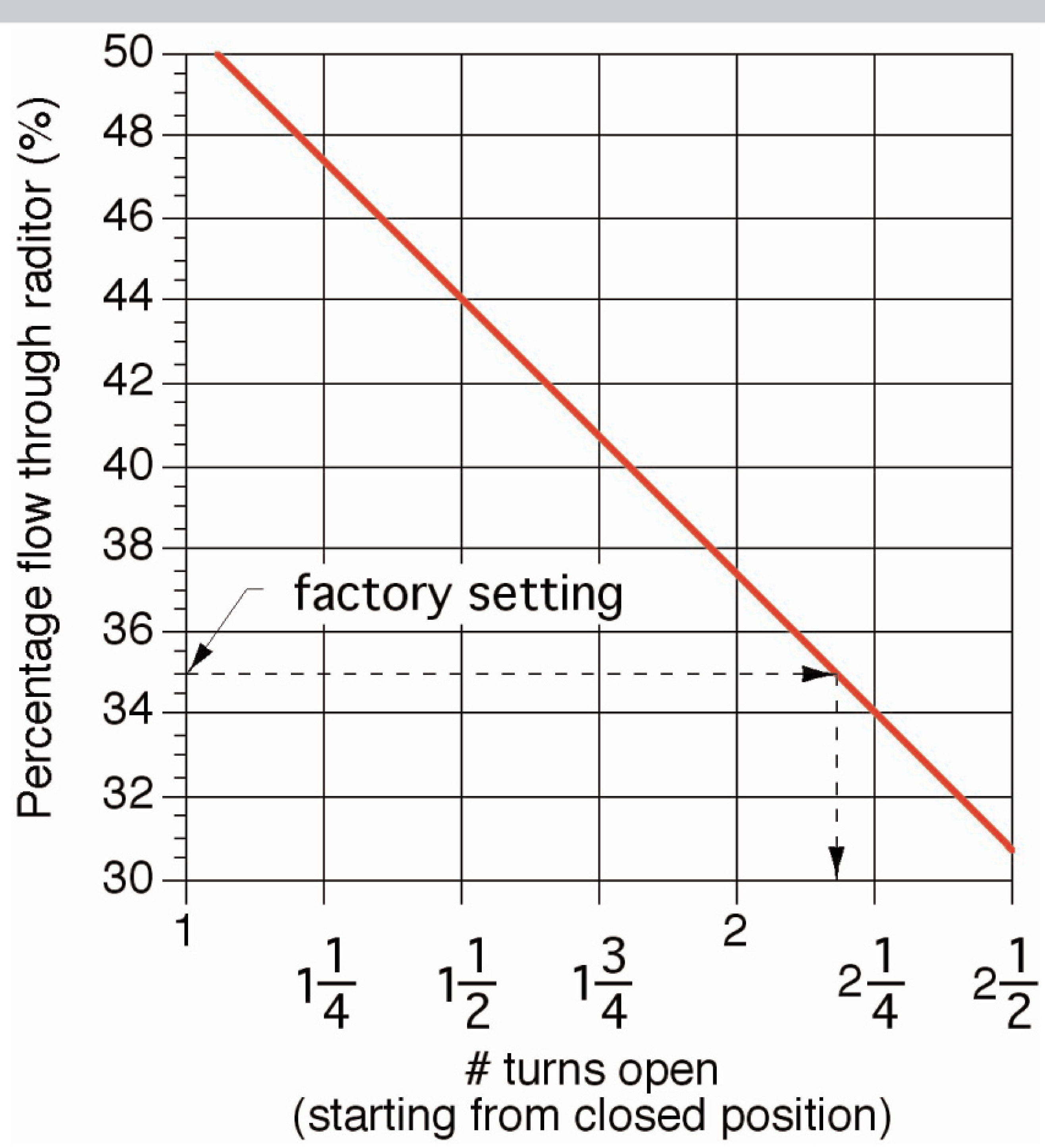
Step 7: Calculate the percentage of the circuit flow that should pass through the radiator using the following formula:

$$\% f_i = \left[\frac{q_i}{Q_T} \right]$$

Where:
$\%f_i$ = percentage of system flow rate through the radiator (%)
q_i = design load of the radiator (Btu/hr)
Q_T =total design heating load served by the circuit (Btu/hr)

Step 8: Based on the percentage of flow through the radiator, determine the stem setting of the bypass valve from the following graph. Note: The stem setting is the number of turns open starting from the fully closed position. Be sure to record it for this radiator.



Step 9: Use the following formula to determine the head loss of the radiator / bypass valve combination based on the circuit flow rate and the percentage of flow through the radiator. Record the head loss for this radiator.

$$H_L = c \times (f)^2$$

for 50%: c = 1.1862
for 45%: c = 1.0591
for 40%: c = 0.9422
for 35%: c = 0.7524
for 30%: c = 0.6778

Step 10: Calculate the outlet temperature of the radiator using the following formula:

$$T_{outlet} = T_{supply} - \frac{q_i}{490 \times f}$$

Where:
T_{outlet} = outlet temperature to the radiator (ºF)
T_{supply} = supply temperature to the radiator (ºF)
q_i = design heat output of the radiator (Btu/hr)
f = target flow rate in circuit (from step 3) (gpm)

Note: The constant 490 is based on water as the system fluid. If a 30% glycol solution is used, change this value to 479. If a 50% glycol solution is used, change this value to 450.

Step 11: The outlet temperature from this radiator becomes the inlet temperature to the next radiator. Repeat steps 5 through 10 for the second and all remaining radiators on the circuit. Be sure to record the head loss of each bypass valve/radiator as it is calculated.

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Step 12: Based on where the radiators will be placed in the building, estimate the total length of tubing needed to connect them into a circuit.

Step 13: Calculate the head loss of all tubing in the circuit using the following formula and data:

$$H_{LT} = k \times L \times f^{1.75}$$

Where:
H_{LT} = head loss of the tubing (feet of head)
k = a number based on tubing type/size (found in Table below)
L = length of tubing in the circuit (feet)
f = target flow rate through the circuit (step 3) (gpm)

Tubing size / type	Value of k (WATER in system)
1/2" copper	0.0159
1/2" PEX	0.0374
1/2" PEX-AL-PEX	0.0394

Step 14: Add up the head loss of ALL tubing in the circuit and ALL radiator/bypass valves. This is the total head loss of the circuit.

This head loss is based on water as the circuit fluid. If a 30 percent propylene glycol solution is used, multiply the calculated head loss by 1.19. If a 50 percent propylene glycol solution is used, multiply the calculated head loss by 1.34

Step 15: If this is the only circuit served by a circulator, that circulator should be selected based on the target flow rate (calculated in step 3), and the total head loss (calculated in step 14).

If there are other circuits on the same manifold, the circulator should be selected based on the total flow to the manifold and the head loss of the most restrictive circuit.

Summary

Bypass valve systems allow the simplicity of a series loop piping while still retaining the ability to individually control the heat output of each radiator. They are an excellent choice for circuits of up to four radiators. The Oventrop bypass valves used in this system also allow each radiator to be isolated and temporarily removed if necessary.

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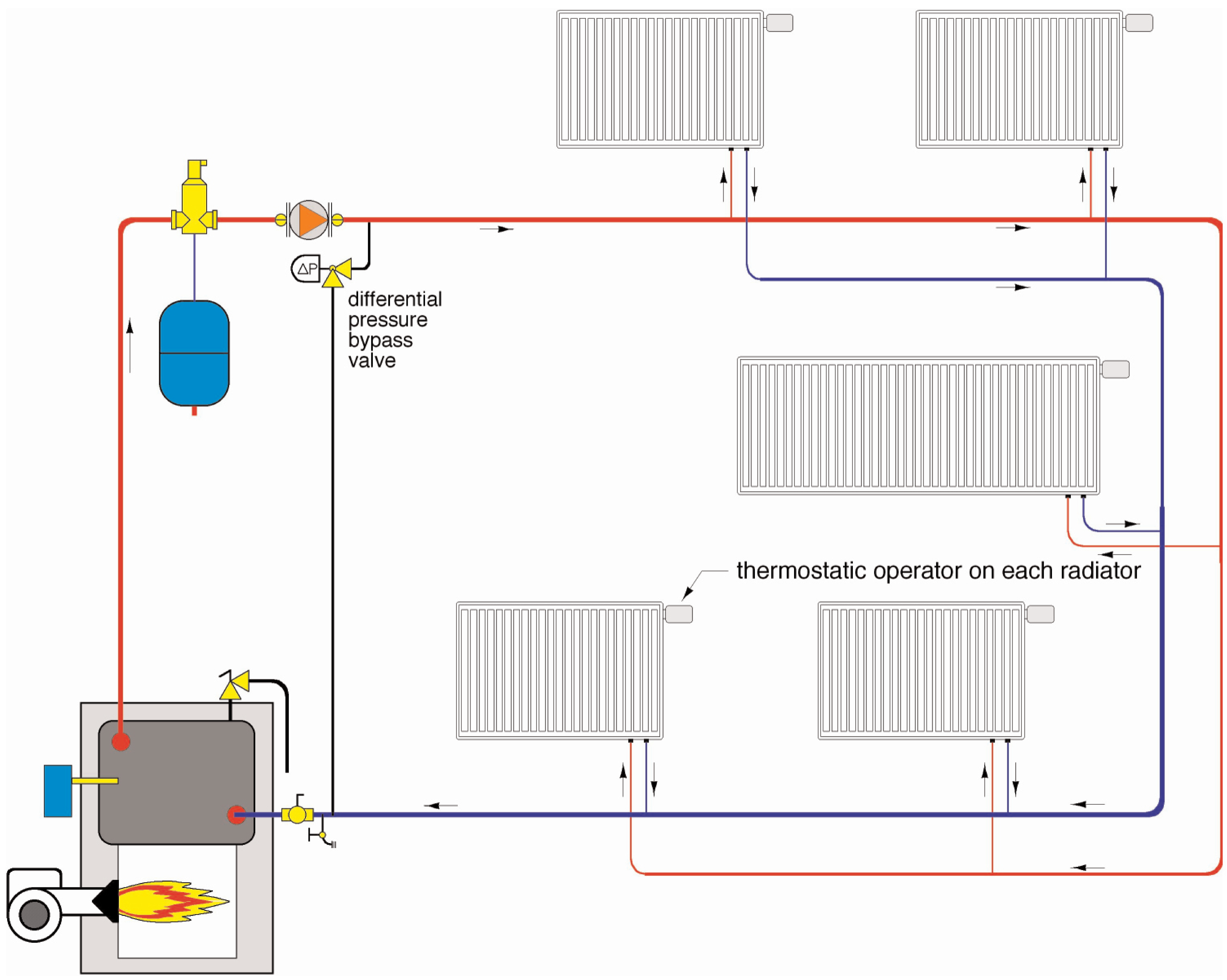

2-Pipe Reverse Return Distribution Systems

Another piping method that can be used with panel radiators is called a 2-pipe reverse return system. The concept is shown above.

Notice that the radiator closest the circulator along the supply main is the farthest from the circulator along the return main. Likewise, the farthest radiator on the supply is the closest on the return. This arrangement helps naturally balance flow rates through the system.

Reverse-return systems usually requires different pipe sizes in various parts of the system. The supply main gets progressively smaller as one moves away from the circulator. The return main gets progressively larger as one moves toward the circulator. The concept is to keep the flow velocity at or below 4 ft/sec to prevent flow noise in all areas of the distribution system.

The ideal arrangement for a 2-pipe reverse return system is where the supply and return piping is routed around the perimeter of the area to be heated.

If all branches of a reverse-return system had identical flow resistance, and all pipe size changes in the supply and return mains were

continued on next page...

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symmetrical, each branch will operate at the same flow rate. Systems like this are very uncommon. Because of this, the balancing valves on DiaNorm radiators can be used to ensure the proper flow through each panel.

Like a homerun system, 2-pipe reverse return systems deliver the same water temperature to each radiator. This eliminates the need to account for temperature drops as in series loop or diverter tee systems. It also lowers the required system supply temperature, which can improve boiler efficiency.

A differential pressure bypass valve should be used to prevent excessive differential pressure across the circulator under partial load conditions. These systems are also excellent candidates for variable speed distribution circulators.

Design Procedure for 2-pipe Reverse-Return Systems

Step 1: Determine the design heating load of each room served by the circuit. Add these loads to get the total load on the circuit.

Step 2: Select a tentative supply temperature for the system at design conditions. For a circuit supplied by a conventional boiler the supply temperature is often selected in the range of 140 ºF to 180 ºF.

Step 3: Select a tentative temperature drop for the system under design load conditions. Temperature drops of 20 to 30ºF are typical for these systems.

Step 4: Knowing the total heating load on the circuit, and the estimated temperature drop, use the formula below to estimate a target system flow rate

$$f_T = \frac{Q}{490 \times \Delta T}$$

Where:
f_T = estimated target system flow rate in the circuit (gpm)
Q = total design heating load served by the circuit (Btu/hr)
ΔT = intended temperature drop of the circuit (°F)

Note: *The constant 490 is based on water as the system fluid. If a 30% glycol solution is used, change this value to 479. If a 50% glycol solution is used, change this value to 450.*

Step 5: Select panel radiators based on the design heating loads of each room and the heat output information for DiaNorm radiator given in section 3.

Step 6: Sketch a tentative piping layout for the heat emitters selected and their placement in the building.

Step 7: The design flow rate through each radiator can be estimated using the following formula:

$$f_i = f_T \times \left[\frac{q_i}{Q} \right]$$

Where:
f_i = estimated flow rate through a given radiator (gpm)
f_T = estimated system flow rate (from step 4) (gpm)
q_i = design heat output of a given radiator (Btu/hr)
Q = total design heating load served by the system (Btu/hr)

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Step 8: Pipe sizes can now be selected based on keeping the flow velocity in all pipes between 2 and 4 ft/sec.

Tubing size / type	Minimum Flow rate (based on 2ft/sec)(gpm)	Maximum Flow rate (based on 4 ft/sec)(gpm)
3/8" copper	1.0	2.0
1/2" copper	1.6	3.2
3/4" copper	3.2	6.5
1" copper	5.5	10.9
1.25" copper	8.2	16.3
1.5" copper	11.4	22.9
2" copper	19.8	39.6
3/8" PEX	0.6	1.3
1/2" PEX	1.2	2.3
5/8" PEX	1.7	3.3
3/4" PEX	2.3	4.6
1" PEX	3.8	7.5
3/8" PEX-AL-PEX	0.6	1.2
1/2" PEX-AL-PEX	1.2	2.5
5/8" PEX-AL-PEX	2	4.0
3/4" PEX-AL-PEX	3.2	6.4
1" PEX-AL-PEX	5.2	10.4

Step 9: Sketch a system diagram showing the expected flow rates (as calculated in step 7) present in all piping segments.

Step 10: Calculate the head loss of each branch. This is the sum of the head loss of the panel radiator and the head loss of the tubing and fitting serving the radiator. Head loss data for DiaNorm panel radiators can be found in section 3 (assume the radiator valve is in the fully open position).

The head loss of branch tubing can be estimated using the following formula and table.

$$H_{LT} = k \times L \times f^{1.75}$$

Where:
H_{LT} = head loss of the tubing (feet of head)
k = a number based on tubing type/size (found in table below)
L = length of tubing in the circuit (feet)
f = flow rate through the circuit (step 5) (gpm)

Note: *The head losses calculated using the formula and data are based on water as the system fluid. If a 30 percent propylene glycol solution is used, multiply the calculated head loss by 1.19. If a 50 percent propylene glycol solution is used, multiply the calculated head loss by 1.34*

Tubing size / type	Value of k (WATER in system)
3/8" copper	0.0484
1/2" copper	0.0159
3/4" copper	0.00295
1" copper	0.000845
1.25" copper	0.000324
3/8" PEX	0.140
1/2" PEX	0.0374
5/8" PEX	0.0140
3/8" PEX-AL-PEX	0.16
1/2" PEX-AL-PEX	0.0394
5/8" PEX-AL-PEX	0.0098

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Step 11: Identify the branch with the highest head loss.

Step 12: Calculate the head loss of the supply and return piping from the return tee of the branch identified in step 11 all the way around the system and back to the supply tee of that branch, as shown in the diagram on the next page.

Step 13: Add the head loss of the branch identified in step 11 to the head loss of the supply and return piping determined in step 12. This is the design head loss of the system.

Step 14: Select a circulator with a pump curve that passes close to the point representing the target flow rate determined in step 4 and the associated design head loss determined in step 13.

Summary

2-pipe reverse systems allow the heat output of each radiator to be individually controlled. They also supply the same fluid temperature to each radiator. The majority of the piping is likely to be copper tubing or other rigid tubing rather than the flexible PEX or PEX-AL-PEX used in homerun systems. A differential pressure bypass valve should be used to prevent excessive differential pressure across the circulator under partial load conditions. These systems are also excellent candidates for variable speed distribution circulators.

SECTION FIVE

Distribution System Options