DiaNorm Panel Radiator

Design Manual

Table of Contents

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SECTION ONE

What is a Panel Radiator?

When most North Americans hear the word "radiator" they think of large and heavy cast-iron radiators. Perhaps they envision an older building with "ugly" radiators covered with dust and taking up a large amount of floor space. Maybe they think back to times when they had seen steam hissing from radiator vents, or pipes that made sounds in the middle of the night as the system turned on. It's safe to say that most North Americans probably think of radiators as a "necessary evil" in a house - a compromise they have to make to be comfortable in winter.

Old style heavy, bulky cast-iron radiators

As in many areas of technology, the design and construction of space heating radiators has progressed immensely over the last two decades. This is especially true in Europe where hydronic heating is used in the vast majority of homes and commercial buildings.

Modern panel radiators such as those manufactured by DiaNorm are one of the most versatile hydronic heat emitter options available for homes and commercial buildings. They are a contemporary product that bears little resemblance to older cast iron radiators. They also allow for much easier installation and far superior performance. When properly selected and installed they offer unmatched comfort, convenience, and a long trouble free life.

A modern DiaNorm panel radiator

This manual shows you the latest DiaNorm panel radiators and describes how to integrate them into high performance hydronic heating systems. It will give you specific details on the strengths and limitations of various piping methods and ways of controlling the system.

By applying what is discussed you can create state-of-the-art heating systems that deliver unmatched comfort.

Advantages of DiaNorm Panel Radiators

Here are some important advantages of DiaNorm panel radiators versus other hydronic heat emitters.

• DiaNorm radiators require much less wall space in comparison to fin-tube baseboard. This reduces restrictions on furniture placement and improves appearance.

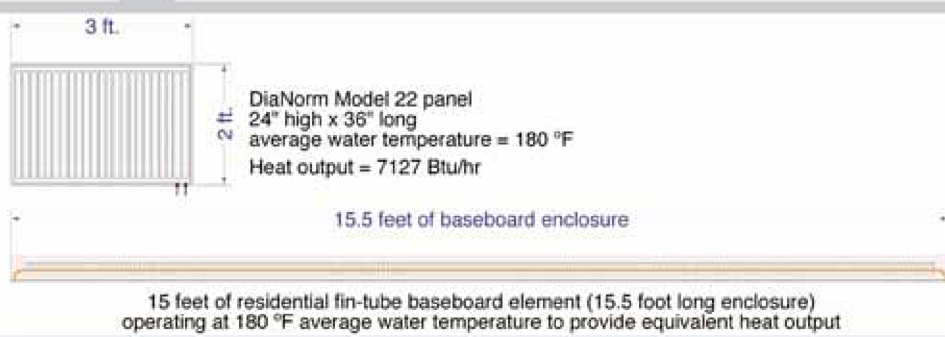
There are many installation locations where a panel radiator can be accommodated but the length of fin-tube baseboard required for equivalent heat output will not fit. There is simply not enough wall space available for the baseboard.

For example, a 24-inch high by 36-inch long model 22 DiaNorm radiator provides heat output equivalent to a residential fin tube baseboard 15.5 feet long. The size comparison is shown below.

• DiaNorm radiators contain very little water and are relatively light. This results in very low thermal mass allowing the panels to respond almost instantly to variations in room air temperature or internal heat gains.

The possibility of temperature overshoot in rooms with high internal heat gains from sunlight, lights, people, or heat generating equipment gains is far less likely relative to systems that use high thermal mass heat emitters such as radiant slab heating.

Because of their large metal and water content, cast-iron radiators are slow to respond to changes in room temperature. Lightweight DiaNorm radiators respond quickly and thus ensure better comfort.



• DiaNorm panels are wall-mounted and not affected by floor coverings. Changes in floor coverings can have a major impact on the thermal performance of radiant floor heating, but it's not an issue with panel radiators.

• DiaNorm panels can operate with a larger temperature drop than is commonly used with other heat emitters. This allows relatively small tubing to carry a substantial amount of heat to the panel.

continued on next page...

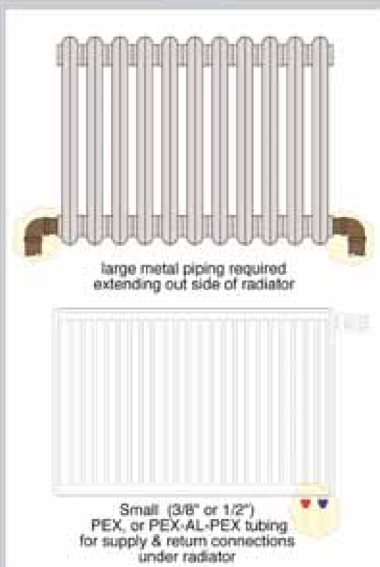
SECTION TWO

Advantages of DiaNorm Panel Radiators

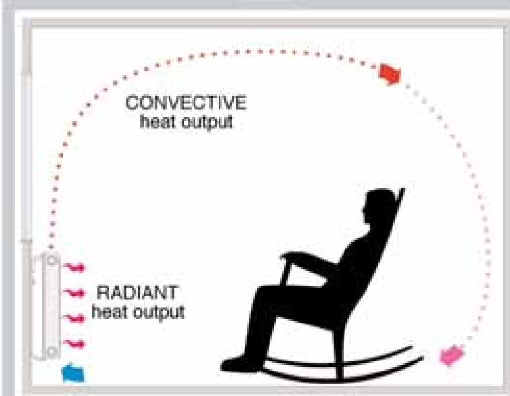
For example: A DiaNorm radiator operating with a temperature drop of 30 ºF releases about 15,000 Btu/hr for each gallon per minute (gpm) of water flow. Under such conditions, a 1/2-inch size PEX tube could supply 38,000 Btu/hr of heat flow to the radiator.

In contrast, a radiant floor heating circuit in a residential system should not operate with a temperature drop over 15 ºF to ensure acceptable variations in floor surface temperature. The same 1/2-inch tubing is only able to carry about 19,000 Btu/hr under such conditions.

There are many circumstances where 3/8" PEX or PEX-AL-PEX tubing can supply DiaNorm panel radiators. The small tubing is less expense and easier to install, especially in retrofit applications.



• **DiaNorm panel radiators release a significant portion of their heat output as radiant heat.** This improves comfort and reduces room air stratification. In contrast, fin-tube baseboard releases almost all heat by warm air convection. This can lead to room temperature stratification (e.g. warm air accumulating near the ceiling while cool air settles at floor level). Such stratification reduces comfort and increases heat loss from the room.



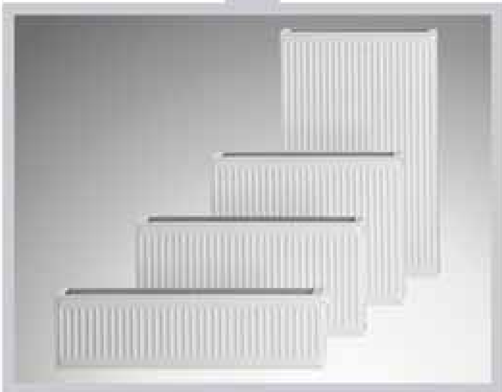
• **DiaNorm panel radiators have a high quality white powder coat epoxy finish.** This finish provides excellent aesthetics as well as high resistance to scratches or exterior corrosion when mounted in humid spaces such as bathrooms. This finish also provides an ideal base if the panels need to be painted a different color.

• **DiaNorm panels can be quickly attached to most types of walls using special spring-loaded mounting brackets.** These same brackets make it easy to detach the panel from the wall if necessary.

SECTION TWO

Advantages of DiaNorm Panel Radiators

• DiaNorm panel radiators are available in a large variety of widths and heights. This allows them to be integrated into buildings with different windowsill heights and wall widths. The narrow wall spaces often found in kitchens and bathroom can use narrow but tall panel radiators.



• Model 11 DiaNorm panel radiators are only 2.6 inches deep. The outer surface of the panel is approximately 3.7 inches from the wall surface. This minimizes the room space loss, and reduces the chance of objects or people bumping into the radiators.

• DiaNorm panel radiators have integral balancing valves. This allows the flow rate through each panel as well as the heat output to be individually adjusted. In combination with thermostatic operators, these valves allow each panel to automatically monitor the desired room temperature and respond as needed to maintain comfort. *The comfort level of each room in the building can be individually controlled.*

• DiaNorm panels can be accessorized with shelf brackets. If the owner would like a shelf above the panel for drying gloves or boots it can easily be attached directly to the radiator using optional brackets available from DiaNorm.

SECTION TWO

Advantages of DiaNorm Panel Radiators

• DiaNorm panel radiators can be easily cleaned of any internal dust. A special brush specifically shaped to match the fluted design of the panel allows the panel to be quickly and thoroughly cleaned.

• DiaNorm radiators, when properly installed, make no operating sound. Because of their design and all-steel construction, DiaNorm panels do not make the expansion sounds often associated with fin-tube baseboard as heated water begins flowing through.

• DiaNorm radiators resist denting. The design and all-steel construction of DiaNorm panel make them more resistant to physical damage than are most fin-tube baseboards. They can be applied with confidence in commercial as well as residential applications.

• DiaNorm radiators can be operated at lower water temperatures than are typical for fin-tube baseboard systems. Lower water temperatures improves the efficiency of the boiler and distribution system resulting in fuel saving. It also increases the percentage of radiant heat output from the panel. In many systems, the water temperature supplied to the radiators can be automatically controlled based on outside temperature.

• DiaNorm radiators can be easily isolated from the piping circuit. Special valves are available that allow the supply and return piping to each radiator to be temporarily turned off if that radiator ever needs to be removed for wall painting or other maintenance. In some systems these valves allow the other radiators to remain in operation while one or more panels are temporarily removed.

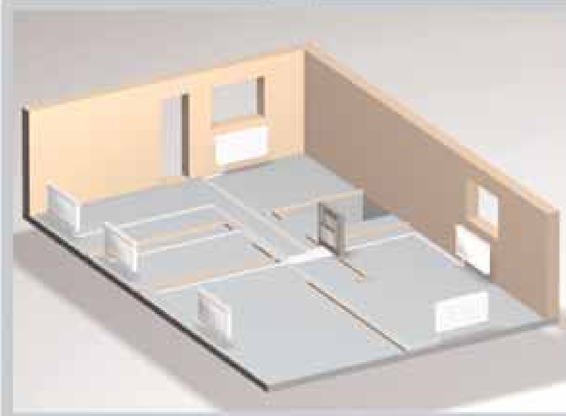
Isolation valves on supply and return piping

Advantages of DiaNorm Panel Radiators

• **DiaNorm radiators are aesthetically clean.** Their simple fluted or flush face panel allows them to match virtually any décor including both traditional and contemporary styles.

DiaNorm radiators provide a simple, clean appearance.

• **DiaNorm radiators are excellent for both new construction and remodeling.** Their lightweight, easy-to-mount construction in combination with modern piping materials such as PEX or PEX-AL-PEX tubing make them easy to install with minimal disruption of existing surface finishes.



DiaNorm radiators connected using a homerun piping system are ideal for new construction or retrofit applications.

SECTION THREE

Panel Radiators, Accessories, and Physical Data

DiaNorm panel radiators are available in a wide selection of shapes and sizes to help designers select a panel with the necessary heat output, and place that heat output within a given building space. Several accessories are also available to simplify and speed installation. This section gives physical data on DiaNorm panel radiators and accessories that help designers build efficient systems.

DiaNorm panels are produced in state-of-the-art facilities

General Construction

All DiaNorm Radiators are made of high quality 1.25mm FePO1 Steel, and finished with a white epoxy powder coating that is baked at 400 F. All panels are built under an ISO 9002 certified procedure and meet several international quality standards.

Application Stipulations

• Because of their steel construction, DiaNorm panels should only be used in closed-loop hydronic heating systems. Use in open loop systems voids the warranty.

• DiaNorm radiators are not to be exposed to pressures above 145 psi.

• The maximum differential pressure across DiaNorm radiators (inlet to outlet connection) is 14.5 psi.

• DiaNorm radiators are not for use in steam heating systems.

• The radiator inlet connection (left), and outlet connection (right) can NOT be reversed.

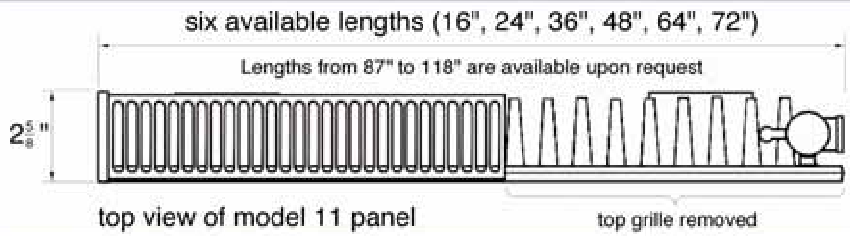
Panel shapes and sizes

DiaNorm panels are available in four heights (10", 14", 20", and 24"), and in six lengths (16", 24", 36", 48", 64", and 72"). They are also available in three depths (2-5/8", 3-3/4", and 5-7/8"). **Upon special request, DiaNorm panels are available in lengths up to 118 inches and heights up to 36 inches. Contact Heatlines, Inc. for pricing, availability, and thermal ratings.**

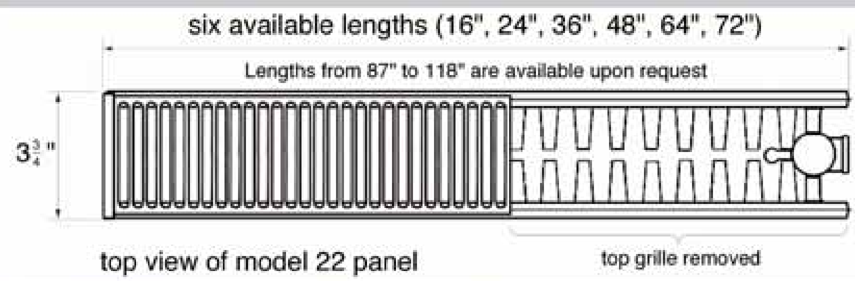
Model 11 panels (pictured next page) are 2-5/8 inches wide and available in six lengths (16", 24", 36", 48", 64", and 72"). When a thin profile is required, model 11 panels are ideal. When installed, its outer face is only 3-5/8 inches out from the wall. Model 11 panels have a single row of convective fins. They also provide a slightly higher percentage of their heat output as radiant rather than convective heat.

SECTION THREE

Panel Radiators, Accessories, and Physical Data



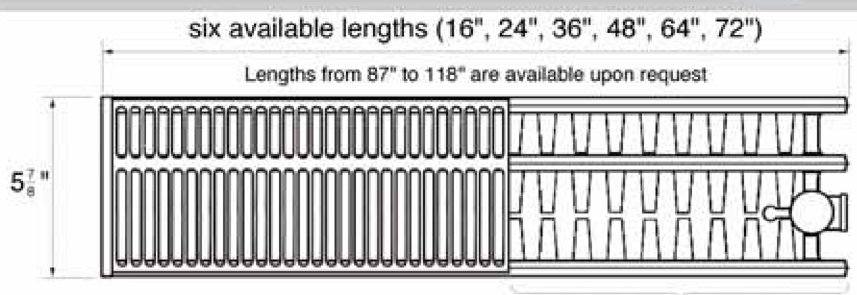
top view of model 11 panel



top view of model 22 panel

Model 22 panels are 3-3/4 inches wide and available in six lengths (16", 24", 36", 48", 64", and 72"). When space is tight and higher heat output is needed the model 22 panel is a good choice. Model 22 panels project 4-3/4 inches out from the wall surface, and have two rows of fins for higher convective heat output.

Model 33 panels are 5-7/8 inches wide and available in six lengths (16", 24", 36", 48", 64", and 72"). These panels provide the highest heat output per square foot of frontal area. Model 33 panels project 6-7/8 inches out from the wall surface, and have three rows of convective fins. They can also be floor-mounted.

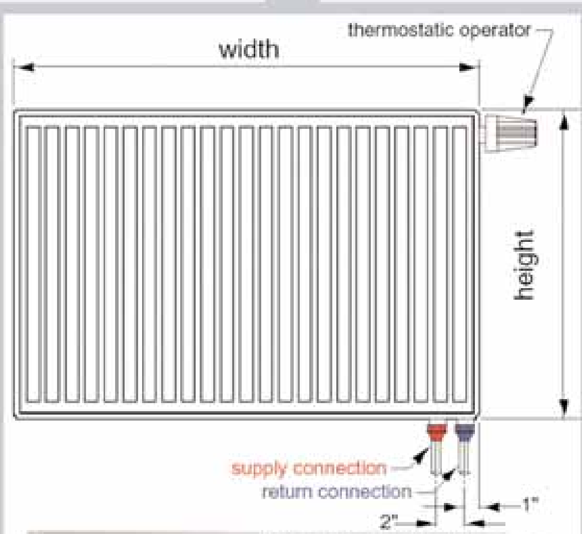


top view of model 33 panel

SECTION THREE

Panel Radiators, Accessories, and Physical Data

All DiaNorm radiators sold in North America have side-by-side supply and return connections at the bottom right side of the panel as shown below.



Assuming the radiator valve is partially or fully open, heated water enters the left (supply) connection and flows up through an internal riser tube to the inlet of the valve. After passing through the valve the flow continues onward to the horizontal manifold at the top of the panel. It then divides and flows downward through the vertical riser channels on the face of the panel. All flow is collected by the lower manifold and routed back to the outlet connection at the lower right of the panel.

The integral radiator valve maintains complete control of flow through the panel. The extent to which this valve can open can be manually set to limit heat output.

If a thermostatic operator is attached to the radiator valve, and the radiators are piped properly, the heat output of the panel is automatically adjusted to maintain a set comfort level in the room.

A thermostatic operator mounted on integral radiator valve

SECTION THREE

Panel Radiators, Accessories, and Physical Data

Accessories

Several accessories are available for DiaNorm panel radiators.

Shelf Supports

A pair of supports can be attached to the top of the radiator to support a shelf along the length of the radiator. The depth of the shelf bracket can be adjusted to accommodate shelves between 6-3/8 and 11 inches wide (depending on the model of radiator). The bracket securely tightens into the upper portion of the panel through the top grille.

Cleaning Brush

This specially shaped brush makes it easy to thoroughly clean dust from the interior of the panel. Just push the brush down through the top grille to push dust out the bottom of the panel where it can be easily vacuumed up.

Rough-in tool

This fixture allows installers to mark the exact position of piping penetrations for model 11,22, and 33 panels. It can also be temporarily connected to the supply and return piping to allow the piping system to be pressure tested and flushed prior to installing the panel radiators. Its use is illustrated later in this section.

Mounting Options

DiaNorm panel radiators can be mounted in several ways to accommodate different room conditions.

Wall Mounting

The most common mounting method is to attach the radiator directly to a wall surface. This is easily done using DiaNorm spring-loaded mounting brackets shown below.

Note: *Panel mounting brackets must mount securely to wooden framing or masonry walls. They should never be solely supported by drywall or plaster wall finishes.*

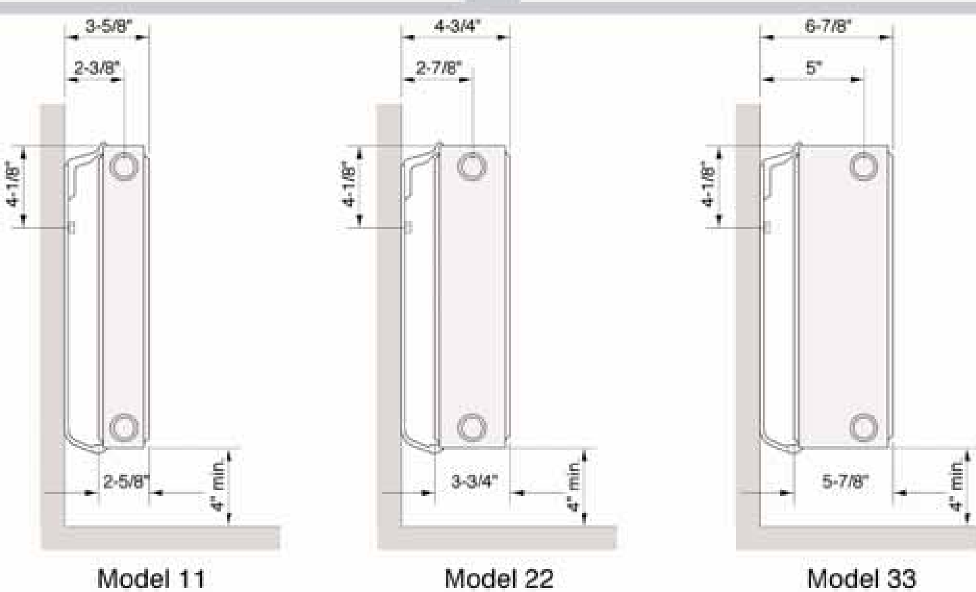
Panel Radiators, Accessories, and Physical Data

The spring-loaded mounting brackets can be attached to a radiator virtually anywhere along its length. This allows the brackets to be placed so fasteners can go directly into wooden framing. The lower portion of the bracket supports the lower edge of the panel. The upper portion of the bracket is spring loaded, and snaps securely and unobtrusively into the grille openings at the top of the panel as shown at right. The panel can be easily removed from the bracket if necessary to access the wall.

Top of spring-loaded wall bracket securely holds radiator in place. Bracket can be easily opened if panel needs to be temporarily removed from wall.

The diagram below shows the mounted dimensions for radiator types 11, 22, and 33. These dimensions are derived from metric lengths rounded to the nearest 1/8 inch. The finish wall-to-piping side port dimensions are the same as the finish wall to piping center dimensions at the bottom of the panel.

Note: Supply and return piping connections at the bottom of the radiator are spaced 2 inches center to center.



NOTE: Dimension rounded to nearest 1/8"

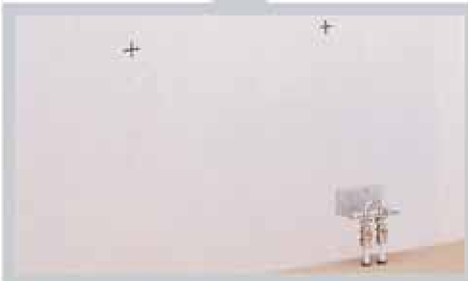
Panel Radiators, Accessories, and Physical Data

Mounting a DiaNorm Radiator to a Wall

The following sequence show how a DiaNorm radiator can be mounted to a wall using the spring-loaded mounting brackets. Piping is located and pressure tested using the rough-in bracket.

Step 1: Locate the piping riser penetrations through the floor, and mark the location for the rough-in tool on the wall. The bottom of the horizontal plate of the rough in represents the bottom of the panel radiator. Be sure the movable piping locator plate on the rough-in tool is set for the type of DiaNorm panel being mounted (e.g. model 11, 22, or 33). Mount the rough-in tool to the wall.

Step 2: Route supply and return piping to the rough-in tool. **Note: If isolation or bypass valves will be used they attach to the bottom of the rough-in tool the same way they would attach directly to the radiator connections.**



Step 3: Securely fasten the radiator mounting brackets to the wall. Remove the wall mounting plate for the rough-in tool leaving the tubing connections in place. The system piping can be pressure tested and flushed prior to mounting the panel radiator.

Step 4: Close the isolation valves and remove the piping U-bend plate. Clip the panel radiator to the wall brackets aligning the bottom connections with the upper ends of the isolation valves. Finally, connect the isolation valves to the radiator and install the PVC escutcheon plate over the tubing where it penetrates the floor.

Panel Radiators, Accessories, and Physical Data

DiaNorm panels can also be supported above the floor using the floor pedestals shown below. These supports are especially well suited for situations where the panel is mounted adjacent to glazing that extends near the floor level.

Once installed, the lower flange and vertical arm of the pedestal can be covered with a smooth white plastic collar and escutcheon plate to provide a clean and neat appearance.

Heat Output ratings

The heat output of panel radiators is dependent on several factors. The most significant of which include:

1. **Panel dimensions**
2. **Supply water temperature**
3. **Ambient air temperature**

The following tables can be used to estimate panel heat output at reference operating conditions of 190 ºF supply water temperature, 20ºF temperature drop across panel, and 68 ºF room air temperature.

Model 11	16"long	24"long	36"long	48"long	64"long	72"long
24" high	1870	2817	4222	5630	7509	8447
20" high	1607	2421	3632	4842	6455	7260
14" high	1215	1831	2748	3662	4883	5494

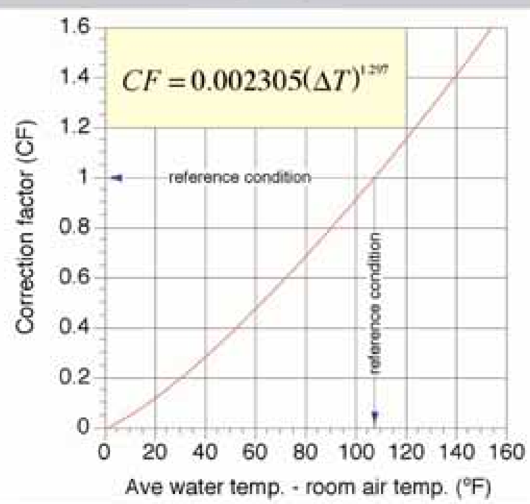
Model 22	16"long	24"long	36"long	48"long	64"long	72"long
24" high	3153	4750	7127	9500	12668	14254
20" high	2733	4123	6186	8245	10994	12368
14" high	2051	3093	4638	6182	8245	9275
10" high	1491	2247	3373	4498	5995	6745

Model 33	16"long	24"long	36"long	48"long	64"long	72"long
24" high	4531	6830	10247	13664	18216	20494
20" high	3934	5937	9586	11870	15829	17807
14" high	2968	4474	6711	8948	11932	13425
10" high	2191	3304	4958	6609	8811	9913

All outputs are in Btu/hr at reference conditions: (190°F supply water temperature, 20°F temperature drop across panel, and 68°F room air temperature).

Panel Radiators, Accessories, and Physical Data

Heat outputs can be corrected for operating conditions other than the reference conditions by finding the appropriate correction factor (CF) from the graph below.



Example

Determine the heat output of a DiaNorm model 11 panel 24" high by 48" wide operated with a design supply temperature of 160ºF, a temperature drop of 20ºF in a room with 65ºF air.

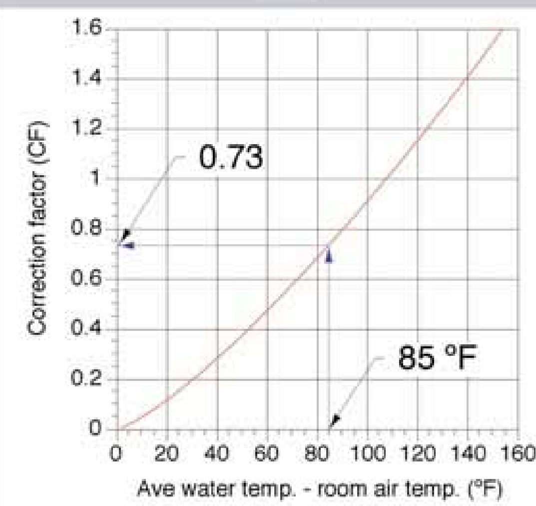
Solution

Step 1: First find the output of the panel at reference conditions (190ºF supply water temperature, 20ºF temperature drop across panel, and 68ºF room air temperature). That number is found in the model 11 heat output table (previous page): 5630 Btu/hr.

Step 2: Next, determine the *average* water temperature at the specified operating conditions by subtracting half the design temperature drop from the supply water temperature: 160 - (20/2) = 150ºF

Step 3: Find the difference between the average water temperature and the room air temperature: 150-65=85ºF

Step 4: Enter the graph at 85ºF on the horizontal axis, read up to the curve, and then over to the correction factor on the vertical axis. In this example the correction factor is 0.73



Step 5: Multiply the heat output at the reference conditions by the correction factor to get the actual heat output at the specified operating conditions: Output = 0.73x5630 = 4110 Btu/hr.

Panel Radiators, Accessories, and Physical Data

An alternative to reading the correction factor from the graph (in step 4) is to calculate it using the formula given in the upper left corner of the graph. In this case:

$$CF = 0.002305(\Delta T)^{1.297} = 0.002305(85)^{1.297} = 0.733$$

Panel heat output increases with increasing water supply temperature. Heat output also increases at lower room air temperature. Operating the panels at relatively high temperature drops (25 to 40 ºF) slightly lowers the average water temperature in the panel for a given inlet temperature. This, in turn, slightly lowers panel heat output. However, higher temperature drops also decrease flow rate requirements and may reduce the size of the distribution piping and circulator. More importantly, lower flow rates may significantly reduce the cost of operating the circulator over the life of the system.

Head Loss of Panels

The head loss of DiaNorm panels is primarily a function of the balancing valve setting. It can be calculated using the following formula (based on water as the heating fluid):

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

Where:
H_L = pressure drop through the radiator (feet of head)
f = flow rate through radiator (gpm)

The values of the constant (a) are listed in the following table based on the setting of the balancing valve:

Balancing valve setting	Value of (a)
Fully open	3.472
6	4.692
5	9.900
4	23.46
3	112.6
2	818.7
1	2918.6

If glycol antifreeze solutions are used the head loss of the panels will be higher. As a guideline, multiply the head loss using water by the following factors to estimate the head loss using glycol antifreeze solutions:

30% glycol (multiply head loss by 1.18)
50% glycol (multiply head loss by 1.34)

The pressure drop across the panels can be estimated from the head loss using the following formula:

$$\Delta P = \frac{D \times H_L}{144}$$

Where:
ΔP = pressure drop across the panel (psi)
D = density of the fluid being used (lb/ft^3) (for water at 140 ºF D = 61.3 lb/ft^3)
H_L = head loss through the radiator (feet of head)

SECTION THREE

Panel Radiators, Accessories, and Physical Data

Panel volumes

The following table lists the volume of fluid in various DiaNorm panels. The numbers are in **US gallons per foot of radiator length.**

	Height = 10"	Height = 14"	Height = 20"	Height = 24"
Model 11	N/A	0.13	0.15	0.17
Model 22	0.17	0.20	0.30	0.35
Model 33	0.26	0.33	0.44	0.52

Piping Material Options

DiaNorm panel radiators are compatible with most piping materials used in modern hydronic systems. These include copper tubing, cross-linked polyethylene (PEX) tubing, and composite PEX-AL-PEX tubing.

Type M copper

The most traditional piping material for residential and light commercial hydronic heating systems in North America is type M rigid copper water tube. It has more than adequate pressure and temperature ratings for use in residential hydronic systems. It also offers good corrosion resistance and relatively low flow resistance. It is easily joined using soft soldering.

DiaNorm panel radiators use compression fittings that allow 1/2-inch copper water tube to connect directly to the radiator inlet and outlet tappings, or to an Oventrop diverter valve if used.

Straight lengths of rigid copper tubing must be joined using fittings. In new construction, access to fittings and installation of tubing in framing areas is generally not a problem. However, in retrofit situations such access can be very difficult, especially when the framing cavities are covered with drywall or other finishes. Such installations are better handled using flexible tubing. Type L flexible copper is available and will work with the compression fittings used with DiaNorm panel radiators.

If copper tubing is used for the risers from the floor to the radiator connections, it should be of type L wall thickness for added resistance to denting. To provide a good appearance this tubing can be cleaned to a bright shine and coated with clear lacquer to preserve the bright appearance. Another option is to clean and paint the copper tubing to match the radiator or adjacent trim. The copper risers can also be covered with a white plastic sleeve available from HeatLines, Inc. In all cases, a dual escutcheon plate (available from HeatLines, Inc.) should be installed for a neat and clean appearance where the piping penetrates the floor.

Whenever copper tubing is used, there is some residual soldering flux present in the completed piping system. There may also be small chips of copper or pellets of solder. These materials can create corrosion reactions when combined with steel. For this reason, DiaNorm recommends that copper distribution systems be assembled using a rough in U-bend tool (described in the previous section) at each radiator location. This tool accurately locates the piping connections through the subfloor. It also provides a pressure tight piping U-bend that allows the system piping to be thoroughly flushed of any metal chips and soldering flux before the panel radiators are attached. This flushing prevents contaminates in the piping system from being deposited in the panel radiators.

After the system is flushed, and possibly treated with a system cleaning agent, it should be rinsed clean and partially drained. The rough-in tools can then be removed as the panels are set in place and connected to the copper tubing.

SECTION FOUR

Piping Material Options

Copper tubing must be properly supported to prevent sagging or buckling. On horizontal runs of hard temper tubing, the following maximum support spacings are suggested:

• 1/2-inch and 3/4-inch tube: 5-foot maximum support spacing
• 1-inch and 1 1/4-inch tube: 6-foot maximum support spacing
• 1 1/2-inch and 2-inch tube: 8-foot maximum support spacing

On vertical runs, copper tubing should be supported at each floor level, or a maximum of every ten feet.

A number of different supports are available for small tubing. In residential systems, horizontal piping runs are often supported by plastic coated wire hangers that allow the piping to expand and contract without creating noises. This is extremely important to keep the piping quiet as the water temperature changes.

Other hangers include "bell" hangers, and rail/clamp systems. These can be used on relatively short piping runs (ten feet or less), but should not be used on longer straight runs because they rigidly hold the tubing in place and accommodate very little thermal expansion.

The customary method of joining copper tubing in hydronic heating systems is soft soldering. The solder of choice is usually 50/50 tin/lead solder, which has a working range of 361 °F to 421 °F. Non-lead based solders such as 95/5 tin/antimony can also be used, but require higher working temperatures.

An alternative joining system for copper tubing uses a mechanical compression fitting containing elastomer (EPDM) O-rings. The tool used to compress the fittings is capable of exerting a crimping force of 35,000 pounds. This tool can be fitted with different jaws to accommodate tube sizes. Once the joint is made it cannot be taken apart.

Although the fittings for this type of system are more expensive than standard (solder-type) fittings, the time required for joint preparation is considerably shorter. The tube ends still require reaming to remove any burrs due to cutting. However, no mechanical cleaning or fluxing is required. This reduces the installation cost of the pressed joint system relative to that of a soldered joint.

All of the piping systems discussed in the next section of this manual can be constructed using copper tubing.

PEX Tubing

Cross-linked polyethylene tubing, commonly known as PEX tubing, is also an excellent choice for piping DiaNorm panel radiator systems. PEX tubing has proven itself a reliable alternative to metal piping in many hydronic systems worldwide.

PEX tubing meeting ASTM F876 standards in nominal sizes of 3/8-inch, 1/2-inch, and 5/8-inch can be connected directly to DiaNorm panel radiators using compression fittings available through HeatLines, Inc.. Tubing meeting the ASTM F876 standard has a temperature pressure rating of 180 ºF at 100 psi and 200ºF at 80 psi. These ratings are more than sufficient for typical panel radiator applications.

Piping Material Options

Example of 1/2-inch size PEX tubing

Only "barrier-type" PEX tubing meeting the DIN4726 standard for oxygen diffusion should be used with DiaNorm panel radiators. Such tubing is manufactured with an EVOH oxygen diffusion barrier that reduces oxygen entry through the tubing wall to acceptable levels.

PEX tubing is sold in continuous coils ranging from 150 to more than 1,000 feet in length (depending on diameter and manufacturer).

One of the biggest advantages of PEX tubing is that long circuits can be installed without joints or fittings. This, along with the fact that small diameter PEX tubing can easily be formed and bent by hand make it a good choice for both new and retrofit installations.

PEX tubing expands significantly more than copper tubing when heated. While this does not harm the tubing, it does allow the possibility for expansion "ticking" sounds if the tubing is not properly installed. To eliminate expansion noises PEX tubing must be installed so that it can freely expand without rubbing tightly against the other materials. One horizontal runs, small diameter PEX tubing should be supported every 24 to 30 inches to prevent excessive sagging when operating at higher temperatures. Use plastic support clips or sleeves that allow the tubing to slide back and forth as it heats and cools.

PEX tubing with nominal inside diameters of 5/16", 3/8", 1/2", and 5/8" can be connected directly to the inlet and outlet connections of the radiator, or to an isolating valve or bypass valve using the "Euroconus" fittings shown below (available from HeatLines, Inc.)

Euroconus fittings are used to connect PEX tubing to radiator or valves attached to radiator.

Composite PEX-AL-PEX Tubing

Another type of tubing that's well suited for panel radiator systems is called composite PEX-AL-PEX tubing. It consists of three concentric layers bonded together with special adhesives. The inner and outer layers are PEX. The middle layer is longitudinally welded aluminum.

Example of 1/2-inch size PEX-AL-PEX tubing

Piping Material Options

Like PEX tubing, PEX-AL-PEX is supplied in continuous coils up to 1000 feet long. In the smaller sizes, PEX-AL-PEX tubing is easily shaped by hand, and can readily be "snaked" through closed framing cavities in retrofit applications.

The PEX-AL-PEX tubing commonly used in hydronic heating systems conforms to the standard ASTM F1281. The aluminum layer in the tubing provides a very tight oxygen diffusion layer.

PEX-AL-PEX tubing has slightly higher temperature and pressure ratings than PEX tubing. Tubing that meets the ASTM 1281 standard is rated for 180 ºF at 125 psi, and 210 ºF at 115 psi. Again, these pressure temperature rating are more than sufficient for panel radiator systems.

One significant difference between PEX and PEX-AL-PEX tubing is that the latter tends to retain the shape to which it is formed. This is due to the structural characteristics of the aluminum layer. This can be a significant advantage in retrofit applications where the tubing must be "snaked" through closed framing cavities. It also allows the tubing to be straightened to improve appearance.

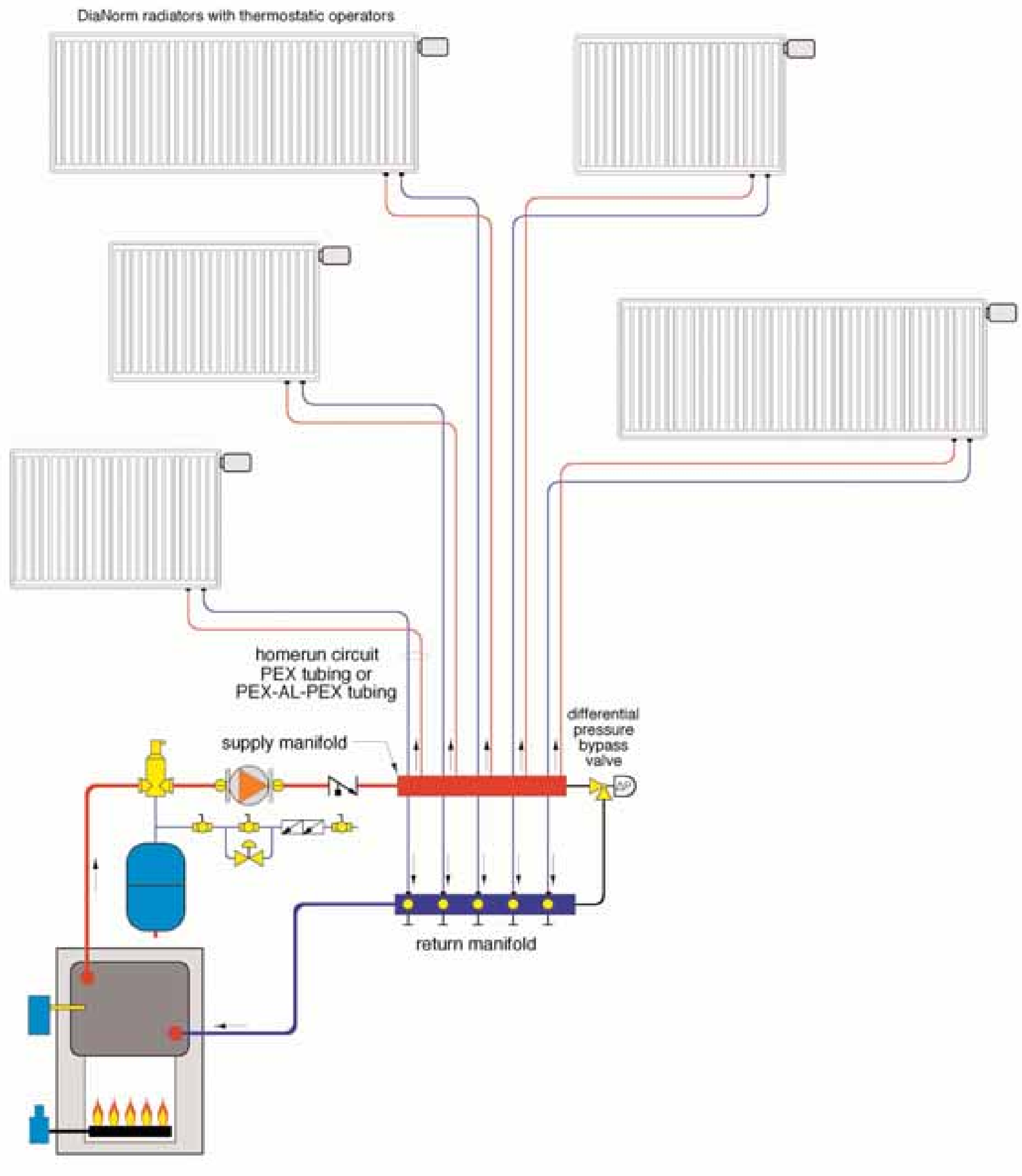
The aluminum layer also reduces the expansion movement of PEX-AL-PEX tubing relative to PEX tubing. PEX-AL-PEX tubing should also be installed to allow space for expansion movement without the tubing rubbing tightly against other materials. Attention to these details will produce a quiet system.

When PEX-AL-PEX tubing is used, it can be connected to DiaNorm panel radiators using R20 Euroconical insert fittings supplied by the tubing manufacturer.

One of the best distribution piping systems for combining PEX or PEX-AL-PEX tubing with DiaNorm panel radiators is called a homerun system. This system, discussed in detail in section 4, uses separate lengths of tubing for supply and return to each panel. All circuits begin and end at a manifold station. A piping schematic for this approach is shown on the next page.

R20 Euroconical fittings are used to connect PEX-AL-PEX tubing to radiator or valves attached to radiator.

Piping Material Options



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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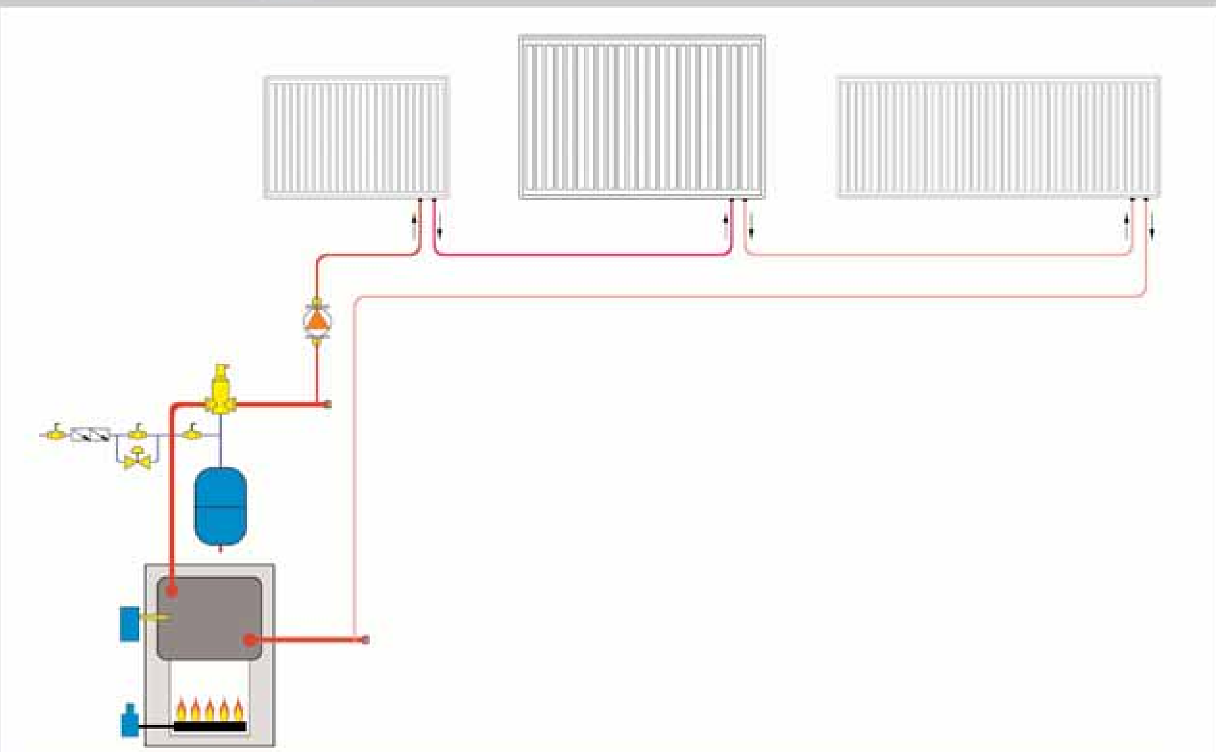


SECTION FIVE

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

SECTION FIVE

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)

Distribution System Options

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

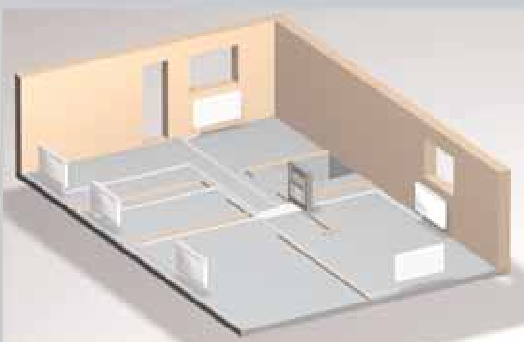
Series circuits are more difficult to design because of the sequential temperature drop effect and the possibility of high head loss. It's fair to say they are not as versatile as several of the other distribution systems to be discussed.

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.

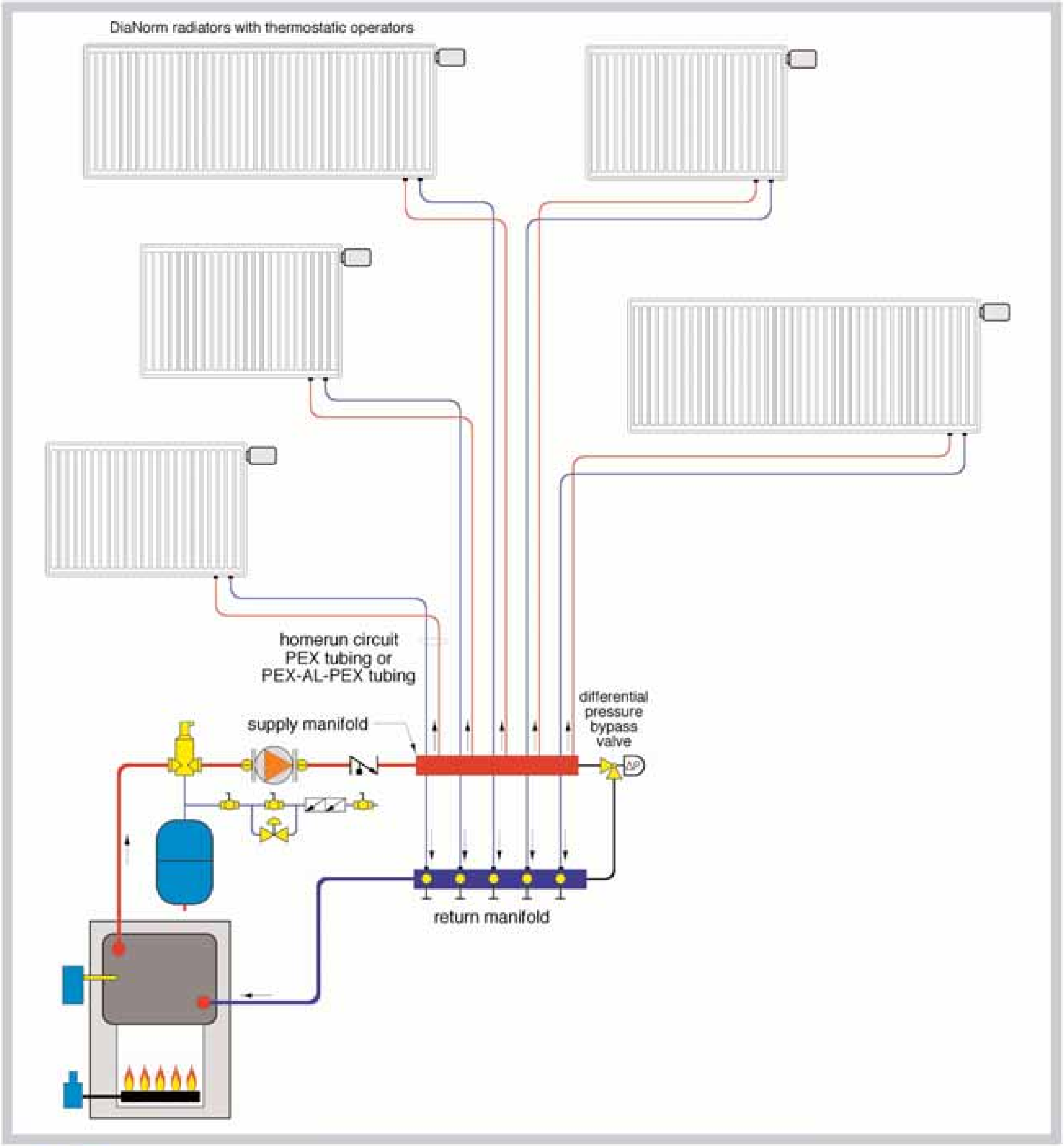
Because thermostatic valve operators are non-electric, they cannot signal for the circulator or boiler to operate as they start to open. However, the circulator can be turned on and the boiler enabled to fire whenever the outdoor temperature drops below some "heating initiation" temperature (typically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

SECTION FIVE

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 °F to 180 °F. 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 °F to 40 °F. 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

SECTION FIVE

Distribution System Options

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.

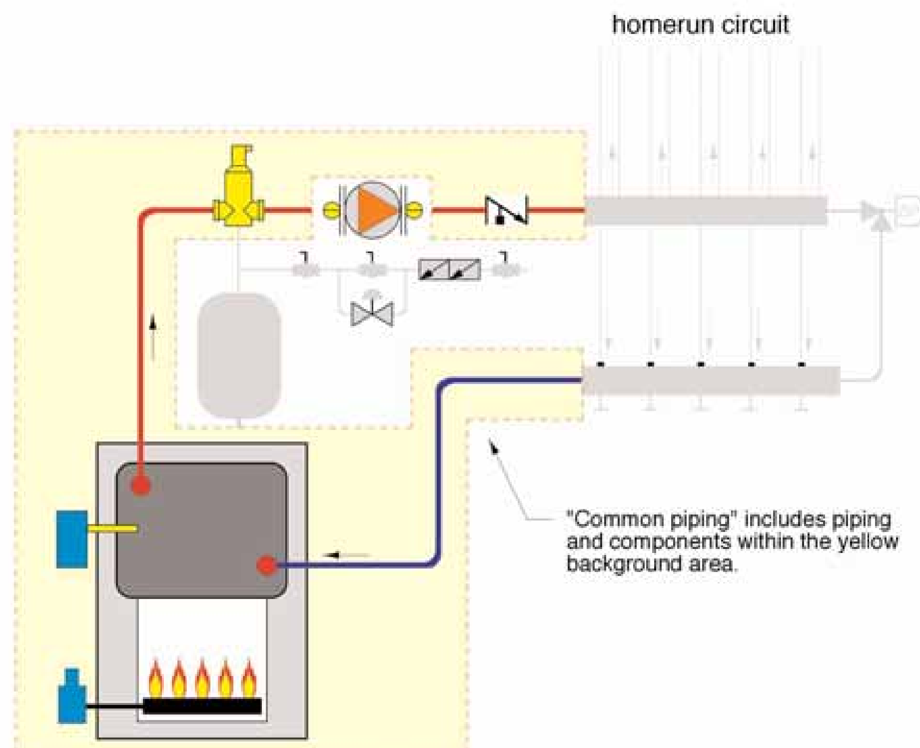
Head loss data for DiaNorm panel radiators can be found in section 3 (assume the radiator valve is in the fully open "N" position).

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)



Distribution System Options

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.

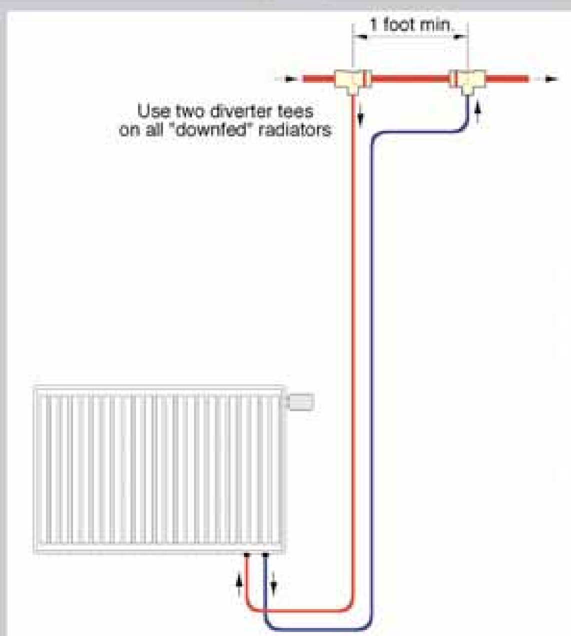
When no heat is needed at a radiator, the thermostatic operator on that radiator is closed. This blocks any flow through the branch circuit. As the room cools the thermostatic operator begins to open allowing flow of heated water through the radiator.

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.



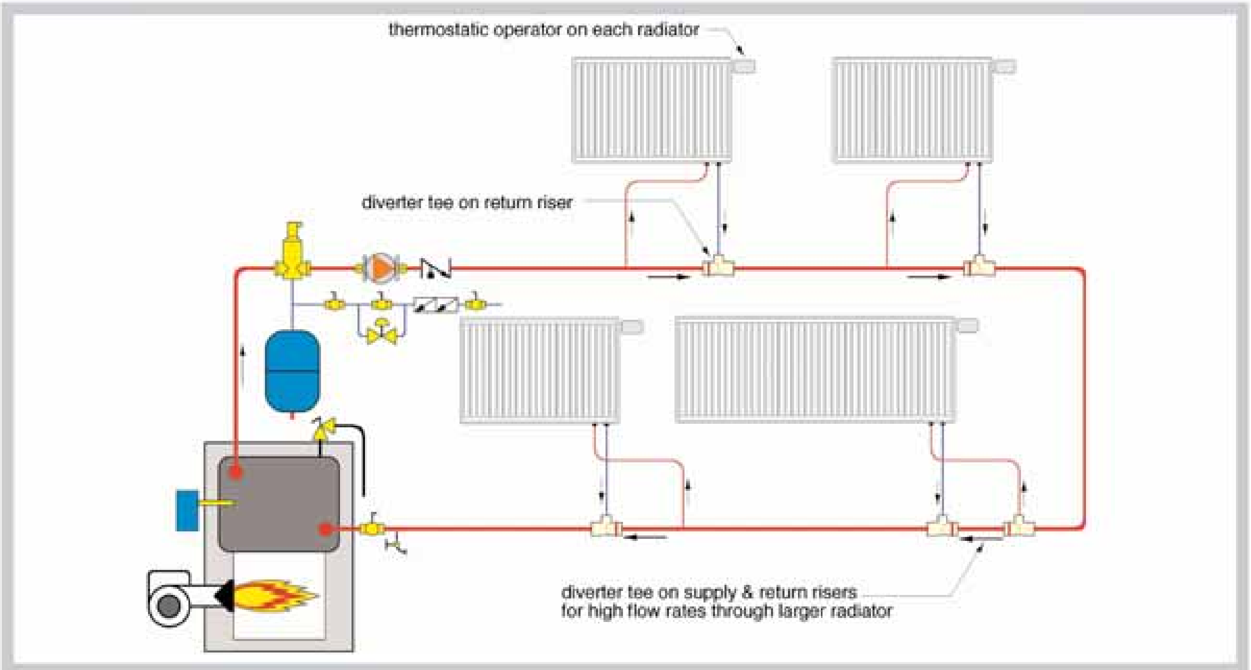
When installing diverter tees it is critically important that the tee is installed in the correct flow direction. The red band on the outside of the tee should always be as shown on the piping schematics.

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

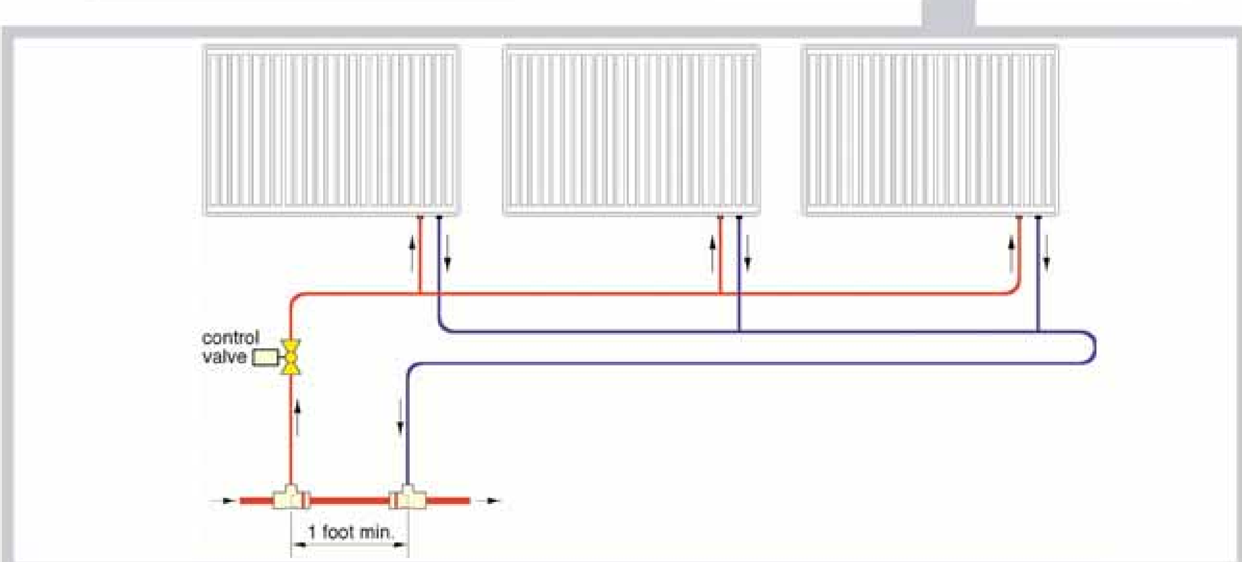
continued on page 38...

Distribution System Options



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 °F).

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 °F. The circuit temperature drop should be between 15 and 30 °F.

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

Distribution System Options

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

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

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

Distribution System Options

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

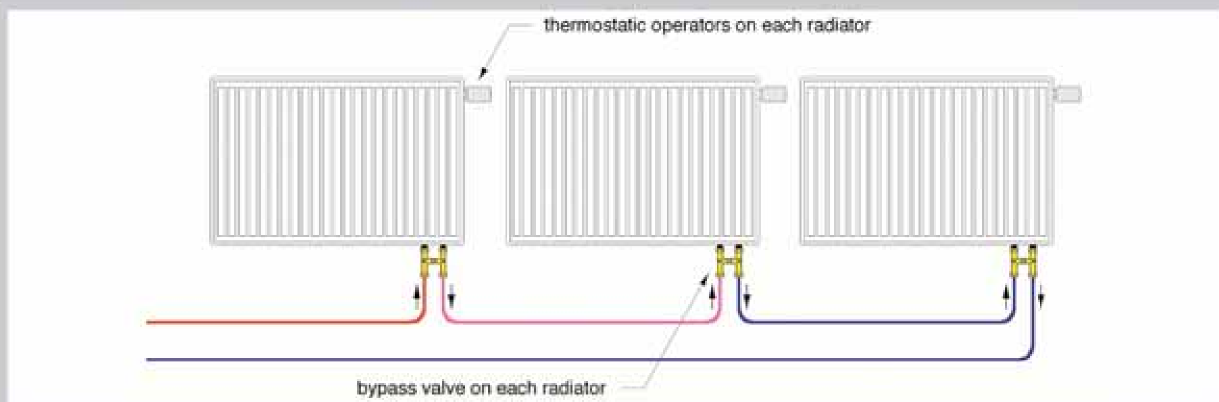
Note: *The head losses calculated using the formula and data above are based on water as the system fluid. If a 30 percent propylene glycol solution is used, multiply the calculated head loss by 1.19. If a 50 percent propylene glycol solution is used, multiply the calculated head loss by 1.34.*

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.

Distribution System Options



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 (ºF) (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.

SECTION FIVE

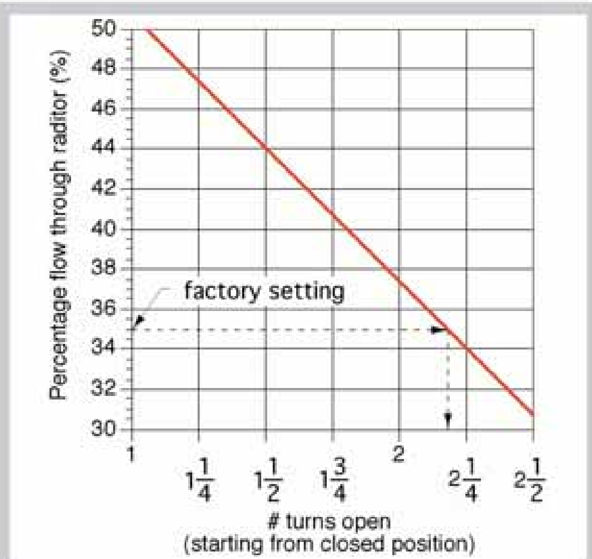
Distribution System Options

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.

DiaNorm RADIATORS

SECTION FIVE

Distribution System Options

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

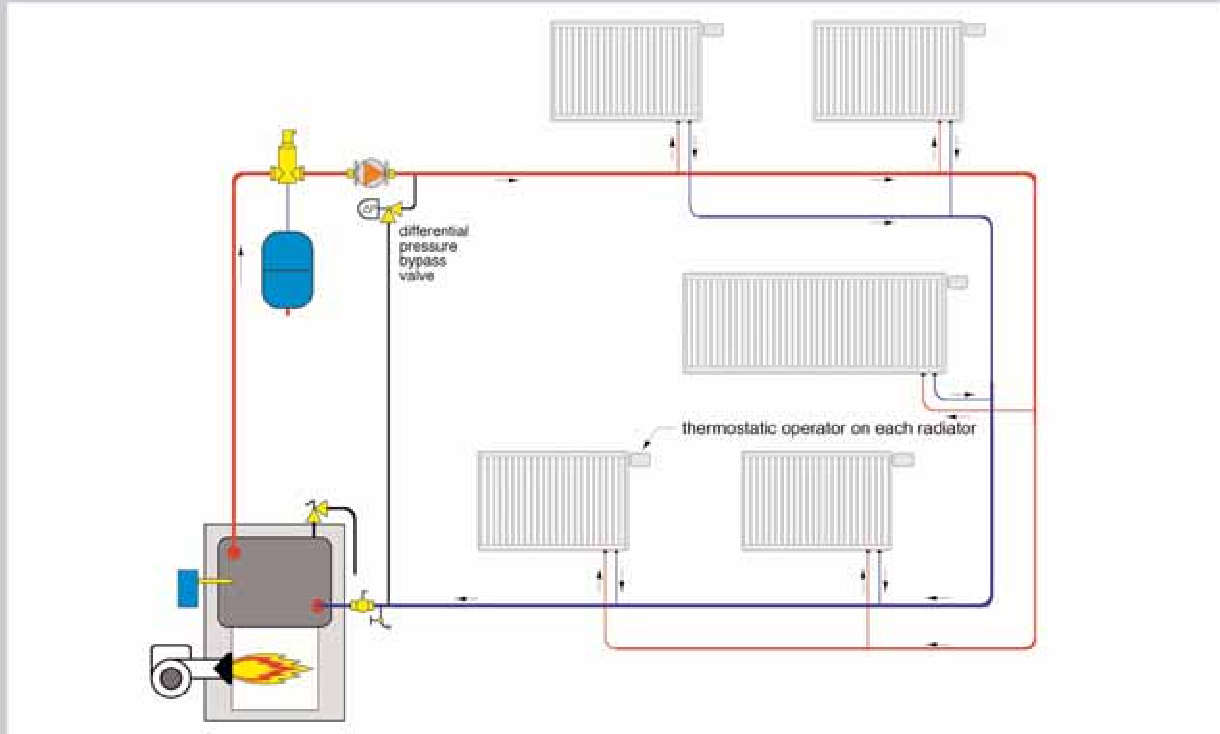
Step 15: If this is the only circuit served by a circulator, that circulator should be selected based on the target flow rate (calculated in step 3), and the total head loss (calculated in step 14).

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.

Distribution System Options



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...

Distribution System Options

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 °F to 180 °F.

Step 3: Select a tentative temperature drop for the system under design load conditions. Temperature drops of 20 to 30°F 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)

Distribution System Options

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

SECTION FIVE

Distribution System Options

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.

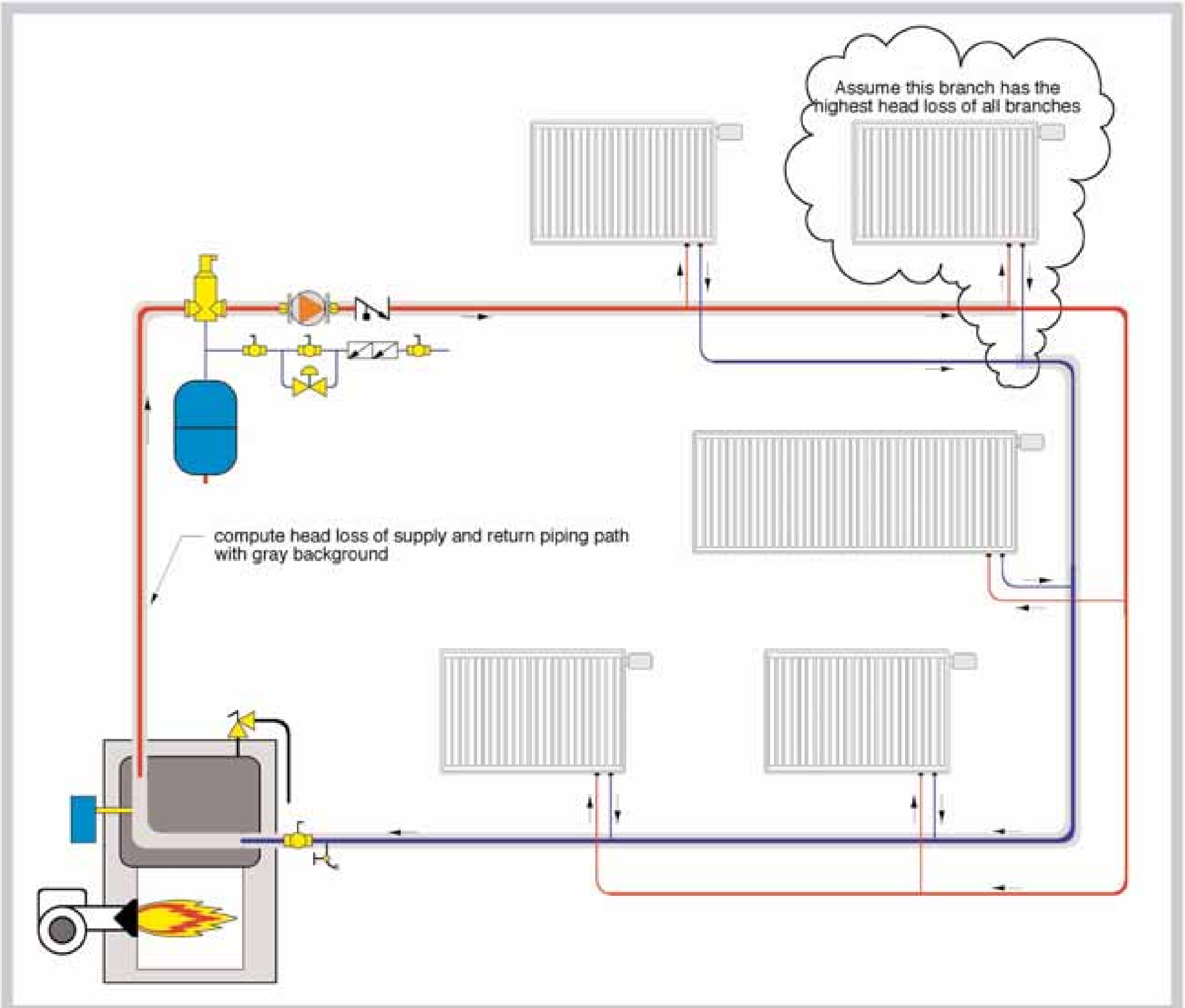
Step 13: Add the head loss of the branch identified in step 11 to the head loss of the supply and return piping determined in step 12. This is the design head loss of the system.

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.

Distribution System Options



Water Temperature Control Options

Achieving smooth and accurate heating from any hydronic heat emitter requires good water temperature control. This section discusses several options for water temperature control that can be used with DiaNorm panel radiators.

Setpoint Water Temperature Control

The "standard" method for regulating the water temperature supplied to a hydronic distribution system is called setpoint control. This is usually done using a high limit aquastat on the boiler.

Upon a demand for heat from a room thermostat, the distribution circulator is turned on. If the water temperature inside the boiler is less than the setpoint temperature minus a differential 5 to 10 ºF, then the burner is also turned on.

If boiler heat output exceeds the rate of heat dissipation by the distribution system, which is often the case, the boiler water temperature steadily increases.

If the boiler water temperature reaches the temperature to which the high limit aquastat is set, the boiler's burner is turned off. However, flow through the distribution system continues as long as there is a demand for heat from a room thermostat.

When this flow has removed enough heat from the boiler to lower its temperature by the differential setting the burner is restarted.

For example, if the high limit aquastat is set for 180 ºF and has a 10 ºF differential setting, the burner is turned off if the water temperature leaving the boiler reaches 180 ºF, and turned back on when this temperature drops to 170 ºF. Circulation through the boiler and distribution system continue as long as a room thermostat demands heat.

Although this method of control is simple, it does have several limitations including:

1. The water temperature supplied by the boiler is always hot enough to provide the "design" rate of heat output from the panel radiators. This rate of heat output is only needed on the coldest day of the year. At all other times the rate of heat output from the panel radiators can be less, and could be attained with lower boiler water temperture. Unfortunately, with setpoint control this will not take place. Operating the boiler at the highest required water temperature regardless of the heating load reduces its efficiency and increases fuel usage.

2. Because boiler water temperature remains high at all times, the system controls tend to "short cycle" at low load conditions. Heat is delivered to the rooms in "pulses" rather than a smooth continuous process. Occupants are notice this cycling operation, and generally not be pleased with it.

3. Since the water temperature is higher than necessary most of the time, heat output must be restricted by turning the flow through the panel radiators on and off. This can create rapid temperature changes in piping that may cause expansion sounds. This is especially true if the distribution piping system has not been detailed to properly accommodate expansion movement. Such noise, although generally harmless to system components, is annoying and of concern to building occupants.

continued on next page...

Water Temperature Control Options

4. High water temperatures also decrease the control capability of thermostatic radiator valves (TRVs) because the valves are forced to operate with very limited stem travel during partial load conditions. Under such conditions, the TRVs tend to act more like on/off devices.

Variable Water Temperature Systems

Setpoint control systems do not provide an ideal match between the heat output of the panel radiators and the room heating load. One of the ways to improve this match is through variable water temperature control. As the outdoor temperature decreases and the building's heating load increases, the water temperature supplied to the radiators increases and so does their heat output. When such a control system is properly set, heat output from the panel radiators accurately matches the heat loss of the rooms they serve. Flow through the distribution system will be almost continuous under such conditions.

The most common way of varying the water temperature supplied to the panel radiators is based on outdoor temperature and called outdoor reset control. When properly executed, outdoor reset control is like cruise control for the heating system. It allows just the right amount of heat to be released from the panel radiators to match the current heating load.

There are several benefits associated with outdoor reset control including:

• Stable indoor temperature: When outdoor reset control is properly applied, the water temperature supplied to the panel radiators is just warm enough to satisfy the prevailing load conditions. Rooms don't undergo noticeable changes in temperature, as is the case when heat input is cycled on and off using setpoint control.

• Near-continuous circulation: Because the water supplied to the panel radiators is just warm enough to meet the prevailing load, the distribution circulator remains on most of the time. This reduces the perception of on/off cycles and uses the thermal mass of the distribution system to smoothen heat delivery.

• Reduced Expansion Noise: The combination of near-continuous circulation and very gradual changes in water temperature minimizes expansion noises from the distribution piping. During a heating season, the piping and panel radiators still experience thermal expansion movement similar to that in systems not using outdoor reset control. However, with outdoor reset control the movement takes place over days rather than a few seconds (as is often the case when setpoint control is used). Piping expansion noise is much more noticeable in systems where rapid changes in temperature occur.

• Reduced Thermal Shock: The use of outdoor reset control reduces the possibility of thermal shock to both the heat source and the distribution system. Hot boilers are less likely to receive "slugs" of cold water from zone circuits that have been inactive for several hours.

• Indoor Temperature Limiting: If water is supplied to the panel radiators at design temperature regardless of the load, occupants can set the thermostat to a high setting, and simply open a window or door to control overheating. Although this sounds like an odd approach to comfort control, it is often

Water Temperature Control Options

done in rental properties where tenants don't pay for their heat. When the water temperature is controlled by outdoor reset control, the water is just hot enough to meet the prevailing load with the windows and doors closed, and thus discourages this practice.

• Reduced Energy Consumption: Outdoor reset control has demonstrated its ability to reduce fuel consumption in both residential and commercial buildings. The exact savings will vary from one project to another. Conservative estimates of 10 to 15% are often cited.

Implementing Outdoor Reset Control

There are two ways of implementing outdoor reset control in hydronic systems.

1. **Boiler Reset Control**
2. **Mixing Reset Control**

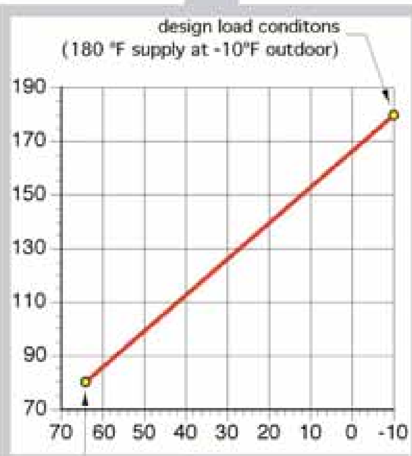
Boiler Reset Control

Boiler reset control regulates the temperature supplied by the boiler. The warmer it gets outside, the lower the water temperature supplied by the boiler (and vice versa). Boiler reset controllers are set up to follow a specific relationship between outdoor temperature and boiler supply temperature. This relationship is usually given in the form of a graph as shown at right.

The line shown on the graph is called a reset line. It shows the relationship between outdoor temperature and the corresponding water supply temperature from the boiler.

The heating designer can specify the slope of the reset line. The line shown puts the boiler supply temperature at 180 °F when the outdoor temperature is -10 °F. This is the design load condition, and is represented by the upper point on the line. The other end of the line shows a heat initiation condition with a water supply temperature of 80 °F when the outdoor temperature is 65 °F.

To find the water temperature supplied by the boiler at other conditions first find the outdoor temperature along the horizontal line, go straight up to the reset line, and then left to the vertical axis to read the water temperature.
Boiler reset control is largely responsible for



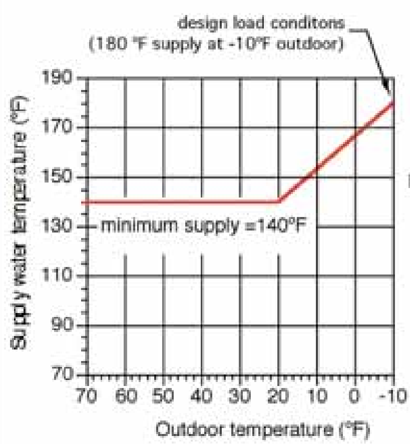
the energy savings mentioned as one of the benefits of outdoor reset control. These saving are mostly the result of lower heat losses from the boiler. If boiler reset is used as the sole means of water temperature control to the panel radiators it also improves comfort, especially during partial load conditions.

Boiler reset is limited when used with a conventional gas- or oil-fired boiler. If the water

steps continued on next page...

Water Temperature Control Options

returning in the boiler is allowed to drop too low, flue gases will condense within the boiler and its venting system. Such condensation can severely scale and corrode both the boiler and vent connector. To prevent this, most boiler reset controllers have an adjustable minimum supply temperature setting. The controller does not allow the boiler to operate below a specified minimum temperature regardless of outdoor temperature. An example of a reset line with a minimum supply temperature setting of 140 °F is shown below.



Example of a reset line with a minimum supply temperature of 140°F

Notice how the lower portion of the sloping line has been "truncated" by the minimum supply temperature setting.

With the minimum water temperature setting, the water temperature supplied to the panel radiators is higher than necessary during low load conditions. Building overheating is prevented by slowing or stopping flow through the panel radiators.

In a system where each panel radiator is equipped with its own thermostatic valve operator flow is reduced as necessary to limit heat output. A differential pressure bypass valve would prevent the circulator from operating at excessively low flows and high differential pressure under such conditions. If the system used electrical thermostats instead of thermostatic valves, the circulator would cycle on and off to regulate heat output under low load conditions.

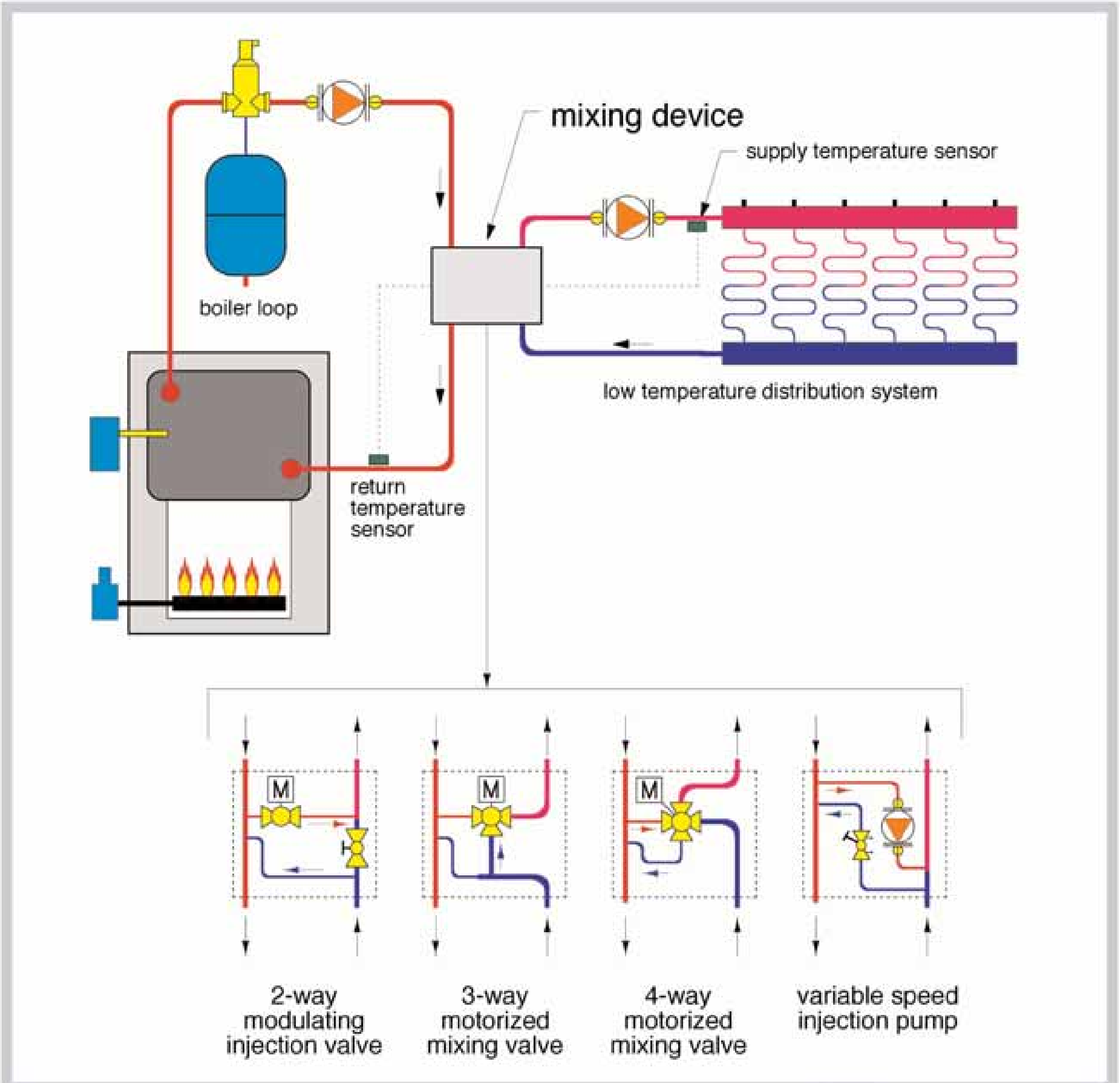
Mixing Reset Control

Mixing reset control requires a mixing device such as a 2-way, 3-way, or 4-way mixing valve, or a variable-speed injection pump. These options are shown in the diagram on the next page. A temperature sensor downstream of the mixing device provides continuous feedback to the mixing device allowing it to adjust the supply temperature very close to the target value calculated based on the reset line.

Mixing reset control allows the water temperature supplied to the panel radiators to range from a set maximum value at design load conditions, all the way down to the room air temperature. This is called "full reset" because the reset controller can operate the mixing device to produce a water temperature anywhere along the reset line.

Most mixing reset controllers also measure the temperature of the water returning to the boiler. If this temperature drops below a preset minimum, the mixing device decreases hot water flow into the mixing point allowing the boiler to quickly recover to a temperature where flue gas condensation will not occur.

Water Temperature Control Options

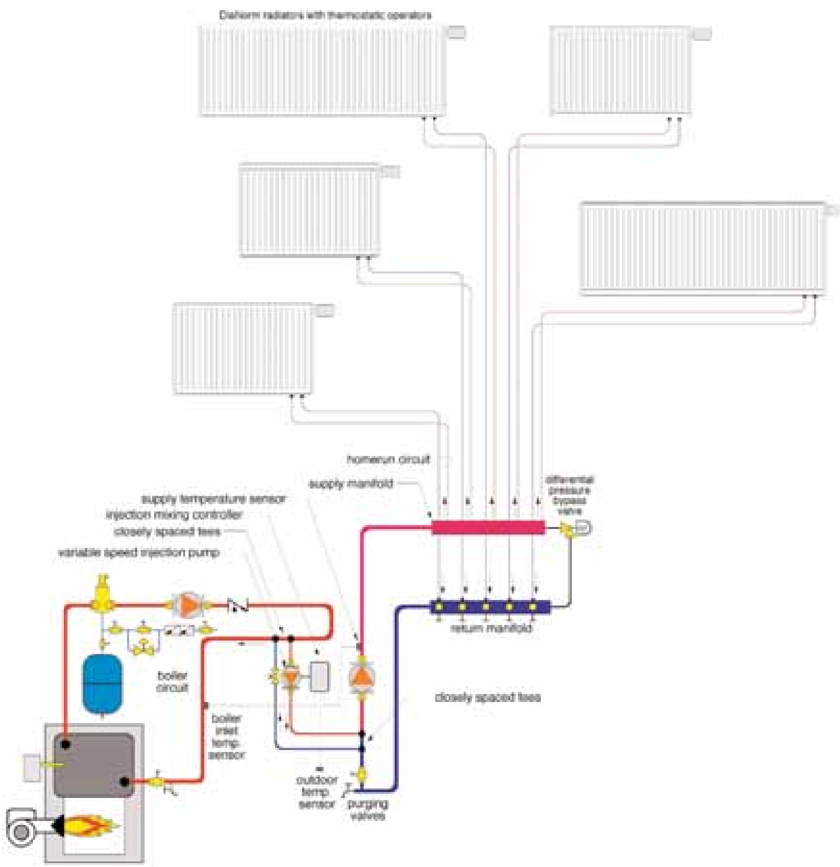


Four mixing options suitable for providing mixing reset control.

Water Temperature Control Options

The figure below shows a homerun distribution system supplying several DiaNorm panel radiators. The temperature of the water supplied to the manifold is regulated by a variable speed injection pump. The reset line of the injection mixing controller has been set to provide 160 ºF water to the manifold at design load when the outdoor temperature is -10 ºF. The water temperature is reduced to 80 ºF when the outdoor temperture is 65 ºF. Thermostatic radiator valves are provided on each panel radiator to allow individual room temperature adjustment and prevention of overheating due to internal heat gains.

It is possible to use **both** boiler reset and mixing reset in the same system. The boiler supply temperature decreases as the outside temperature increases, as does the water temperature supplied to the panel radiators. Such systems increase seasonal boiler efficiency as well as provide the ideal supply water temperature for optimal comfort.

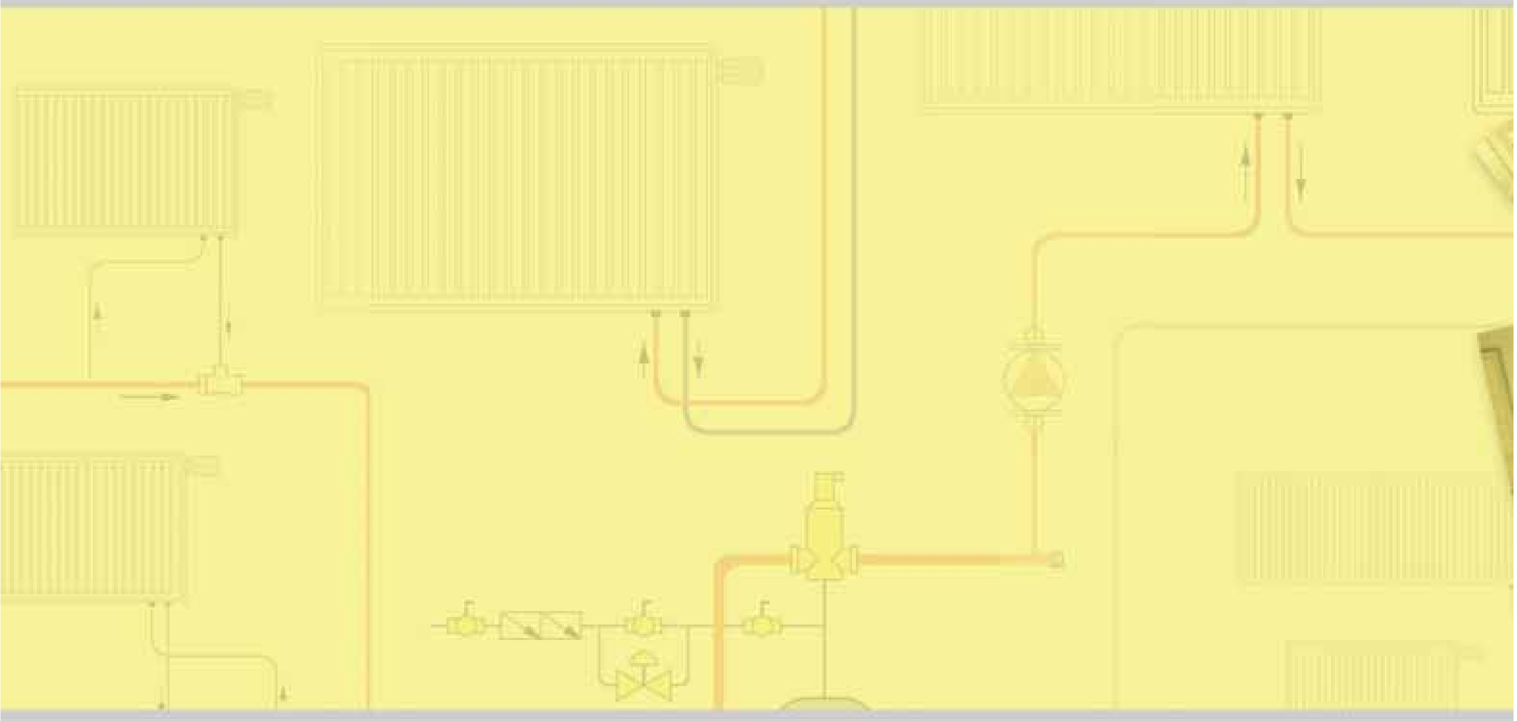


This manual is dedicated to the memory of Thomas Walsh Senior, founder of Rood Utilities in Auburn NY. Tom, who passed away in 2004 at the age of 82, was an innovator in hydronic heating. He recognized the advantages of applying state-of-the-art products and systems, and enthusiastically shared his passion for hydronic heating with countless others over 52 years in the industry.

"Senior," as he was often called, was an ardent supporter of panel radiators and even retrofitted his home with them. He was also instrumental in having this manual produced.

Those who knew Tom remember him as passionate about his work, as well as an incessant learner and educator. He created a training facility at Rood utilities in 1964, and used it to teach modern hydronics to thousands of heating technicians over the years. At an age when others had long since retired Tom was still hard at work sharing his knowledge with the next generation of heating professionals.

Tom leaves a legacy for others in the hydronic heating industry to follow. He would revel in knowing this manual will help others provide the same uncompromising comfort he sought for his customers.



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