SECTION 9

DESIGNING MULTIPLE-LOAD HYDRONIC SYSTEMS

9-1 Introduction

There was a time when residential hydronic heating consisted of 1 to 3 zones of baseboard piped from a single boiler. Space heating was always considered the main load. Domestic hot water was sometimes provided using a tankless coil suspended in a boiler that had to remain hot 24 hours a day, 365 days a year.

Today, residential and light commercial hydronic systems are often more sophisticated than those used in larger buildings. In addition to multiple methods of space heating, these systems almost always provided domestic hot water heating. Many go further to provide snow-melting, intermittent garage heating and perhaps even warm the backyard swimming pool.

This section shows how an integrated multi-load hydronic system can be assembled. It will look at ways to configure the heat source, pipe the system and even select control strategies that allow all the loads to operate in an optimal manner.

9-2 Benefits of an Integrated Multi-load System

Hydronic systems are unmatched in their ability to merge several loads into a single "integrated system" in which a single "heat plant" supplies all loads. This approach increases the duty cycle of the heat plant relative to the individual duty cycles of several direct-fired appliances. Higher duty cycle yields higher seasonal efficiency and lower fuel consumption.

A single heat plant eliminates the need for multiple dedicated heat sources, each with their own fuel supply, ventilation, exhaust, electrical, space and maintenance requirements.

Since all heat source equipment can be located in one area, service personnel do not have to move throughout the building to access it. The mechanical room can be properly vented. The chance of carbon monoxide spillage is reduced. Should such spillage occur, there is a better chance of detecting it prior to its spread through the building.

The heat plant used in most integrated multi-load hydronic systems is one or more gas- or oil-fired boiler(s). Water in the temperature range of 180 to 200 degrees F. is produced for loads such as fin-tube convectors and domestic water heating. Medium and low temperature water for other loads is achieved by blending hot water with cooler return water using one or more of the mixing strategies discussed in section 6.

Integrated multi-load hydronic systems can also take advantage of load diversity. It's the concept that all loads in a multiple load system almost never demand full heat input at the same time. Thus, it's almost never necessary to size the heat plant equal to the total of all loads operating simultaneously at maximum output.

In the unlikely event all loads did call for maximum heating at the same time the system's controls can invoke prioritized load shedding. Heat input to lower priority loads like garage floor heating and pool heating can be temporarily interrupted so heat can be redirected to higher priority loads like domestic hot water production and space heating. When the high priority loads are satisfied, heat output is directed to making up the heat deficits of the low priority loads.

The large thermal mass of slab-type floor heating and swimming pools make boiler sizing more a matter of how much energy can be delivered over a period of several hours, rather than how much instantaneous capacity is available.

9-3 Multiple Boiler Systems

In some multi-load systems, a single boiler can supply all the loads. For larger capacity systems (or systems in which the load can change dramatically from one minute to the next) a multiple boiler system is an ideal solution.

Boilers attain their highest efficiency when running continuously. Multiple boiler systems in which each boiler is individually controlled as a "stage" of heat input encourage longer on-cycles for the individual boilers and thus higher overall heat plant efficiency. The owner is also likely to save thousands of dollars over the life of the system because of this higher efficiency. Longer duty cycles also yield longer life and reduced maintenance for components such as hot surface igniters, oil burners and relays.

Other benefits of multiple staged boiler systems

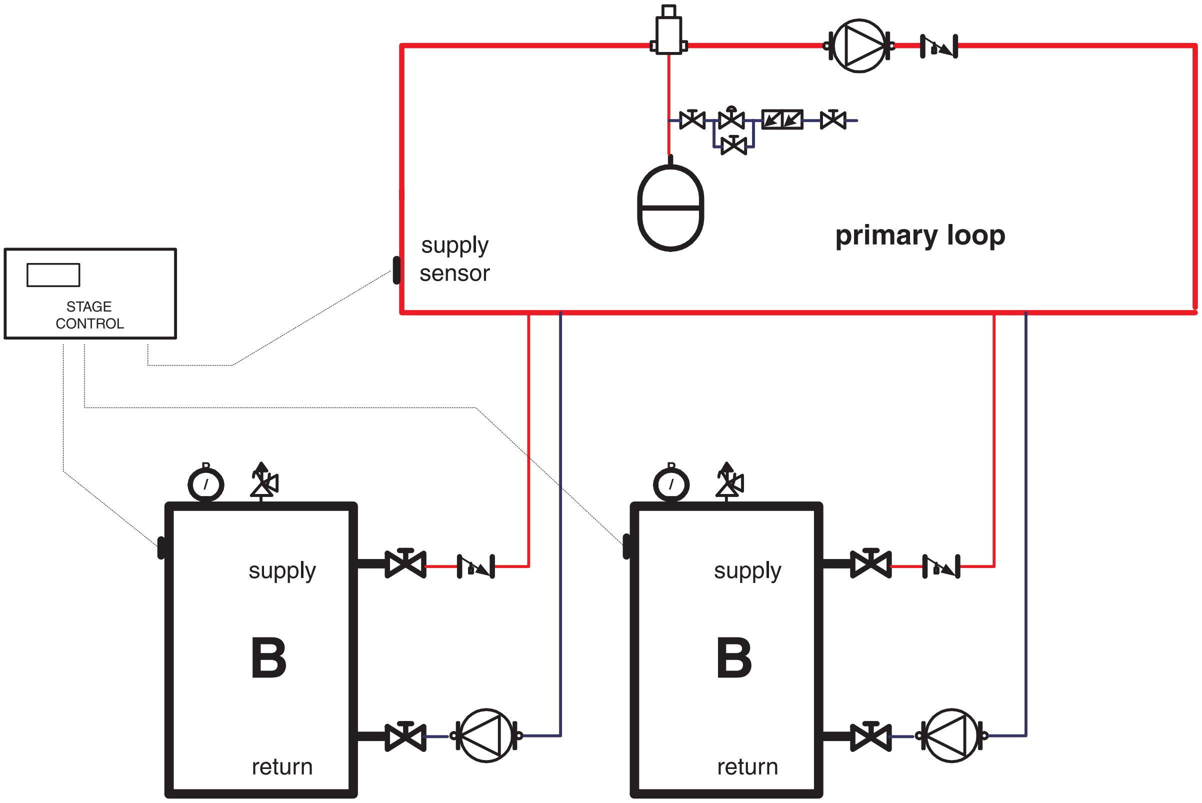


Figure 9-1

include:

- The ability to provide partial heat delivery if one boiler is down for servicing.
- The use of smaller/lighter boilers that are easier to install, especially in retrofit situations.
- The ability to place all the heat generation in one location and thus eliminate several other dedicated heat sources distributed through the building.

To achieve maximum efficiency, the multiple boiler system should be designed so heated water is NOT circulated through unfired boilers. Doing so uses the unfired boiler(s) as heat dissipaters. Although there are several possible ways to achieve this, the piping shown in figure 9-1 is considered by many to be the simplest and most efficient approach.

In this configuration, each boiler's circulator operates only when that boiler is firing. The flow check valves prevents gravity circulation or reverse flow at all other times.

This arrangement also supplies each boiler with the same (lowest possible) return temperature. The cooler each boiler operates, the higher its efficiency. System controls are configured to prevent any of the boilers from operating at temperatures low enough to cause sustained flue gas condensation.

Multiple-boiler systems are usually operated by a staging control. Such controls have the ability to determine the appropriate water temperature for the load(s) that are active at any given time, and then steer the water temperature supplied to the distribution system toward this "target" temperature.

For space heating loads the water temperature is often reset based on outdoor temperature as discussed in section 6. When the load is supplied through a heat exchanger (such as with snow melting, pool heating, or domestic water heating), the control is usually configured to deliver a high (but fixed) water temperature regardless of the outdoor temperature.

Figure 9-2 shows how a 3-boiler system can be piped to provide heat to both domestic water heating and space heating loads.

Notice the closely-spaced tees that connect the boiler

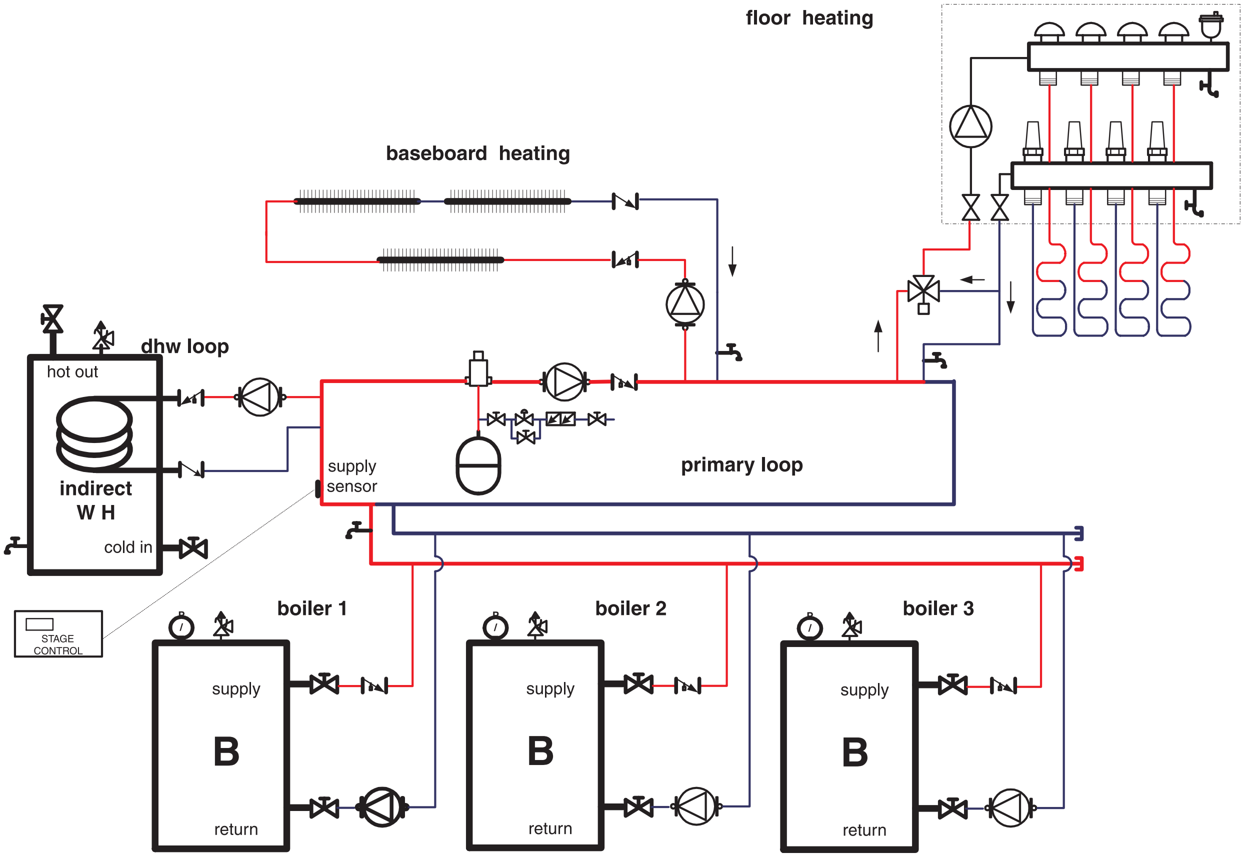


Figure 9-2

manifold piping to the distribution system. This piping arrangement allows the boiler system to “hand off” heat to the distribution system without interference between the various circulators.

Also notice the placement of the supply temperature sensor for the boiler staging control. This placement is necessary because the boiler circulators will only operate when the boilers are being “called for” by the boiler staging control. Do not place the supply sensor on the boiler manifold piping since there will be times when the boiler circulators will be off, yet a load still exists in the distribution system. Without flow through the boiler, manifold piping heat cannot be delivered to the distribution system.

9-4 Providing Domestic Hot Water

Most integrated multi-load hydronic systems supply domestic hot water using an indirect water heater. Upon a call for domestic water heating, hot boiler water is circulated through a heat exchanger built into the hot water storage tank.

One method of piping an indirect water heater is as a secondary circuit to a primary loop as shown in figure 9-3A.

If this arrangement is used, the DHW tank should be the first secondary circuit connected to the primary loop. This provides the hottest water to the tank’s heat exchanger for fast recovery.

Always install a flow-check valve in the supply line leading to the tank’s heat exchanger. This prevents the possibility of heat migration due to buoyancy forces and/or slight pressure differentials between the closely-spaced tees connecting the tank’s heat exchanger to the primary loop. It also prevents hot water in the tank from establishing a convective cooling loop when the circulators are off.

Piping the DHW tank as a secondary circuit requires hot water to flow around the entire primary loop whenever there’s a call for domestic water heating. To minimize piping heat loss, this piping arrangement should only be used for short primary loops that run within the mechanical room. Preferably, the primary loop and DHW secondary loop piping will be insulated to further reduce piping heat loss.

The system designer should also take note that if the DHW tank is not operated as a priority load, all downstream secondary circuits will receive reduced water temperature while the DHW load is operating. The heat emitters in the downstream secondary circuits should be sized to accommodate this reduced water temperature if extended demand for domestic water heating is likely to occur simultaneously with maximum space heating demand.

Another piping option for connecting an indirect water

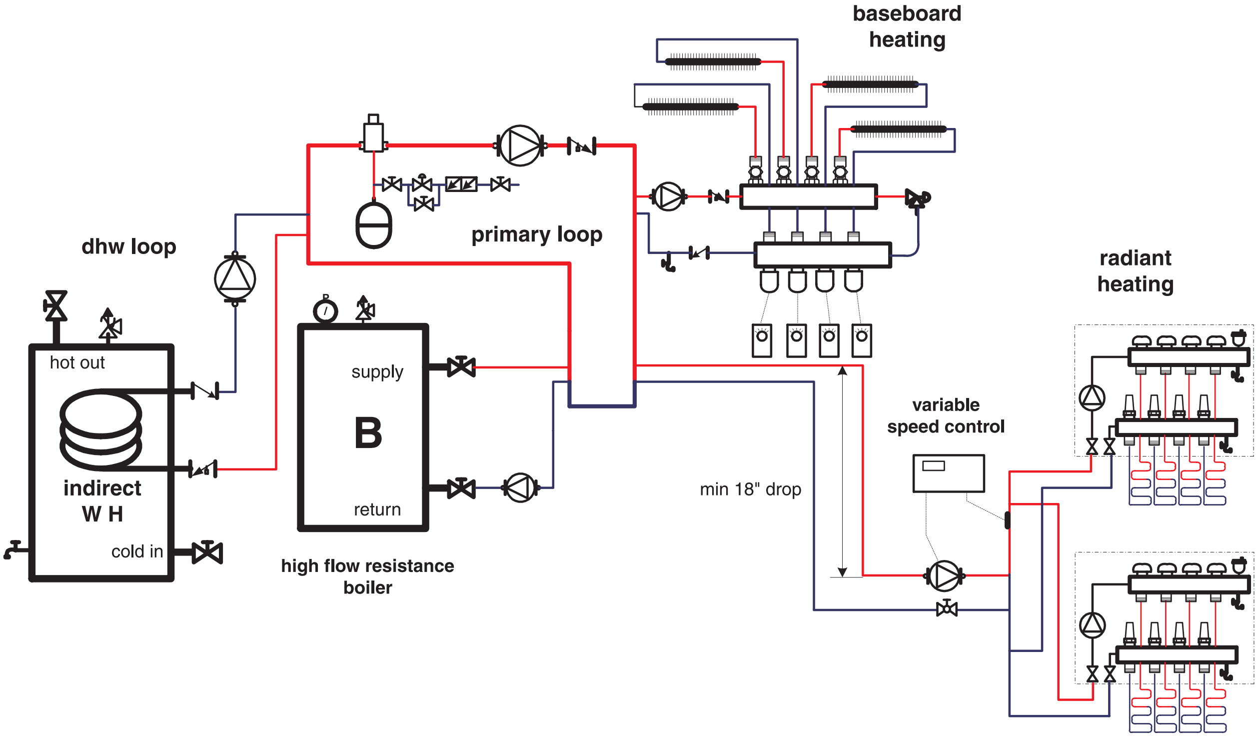


Figure 9-3A

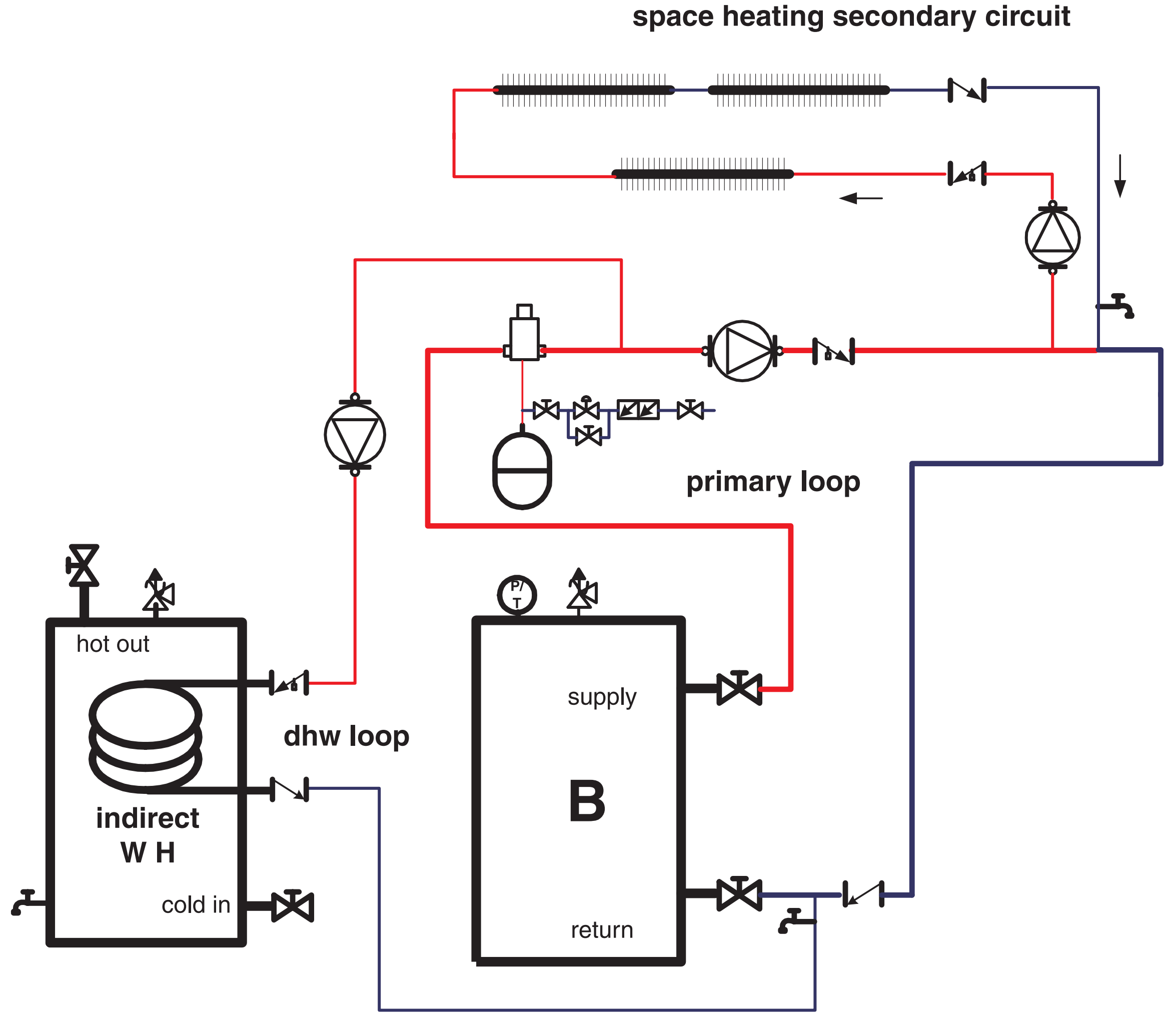


Figure 9-3B

heater into the system is shown in figure 9-3B.

The indirect water heater is now connected as a parallel circuit to the primary loop. It can operate independently of the primary loop. If the water heater is located close to the boiler and the piping circuit between the two is short, piping heat loss during the DHW cycle is minimal. Furthermore, this arrangement doesn't reduce the water temperature supplied to the primary loop should that loop be operating simultaneously with domestic water heating. Because of these advantages, the parallel piping arrangement is often preferred over piping the indirect water heaters as a secondary circuit.

9-5 Adding Space Heating Loads

Most modern integrated multi-load hydronic systems are configured around a primary/secondary piping system. The details and options available for primary/secondary piping were discussed in section 8.

The backbone of the system is the primary loop. It conveys hot water to one or more secondary circuits that, in turn, convey that water to the heat emitters. Each secondary circuit can be thought of as a subassembly that is "plugged into" the primary loop.

When the system serves several loads that operate over a wide range of water temperatures, the loads requiring the high water temperatures should be piped in near the beginning of a series-type primary loop, while those requiring lower temperatures are connected near the end. This allows the loads to accommodate the decreasing water temperature around the primary loop.

Designers should investigate the possibility of operating primary loops with temperature drops of 30 to 40 degrees F. under design load conditions, (instead of the typical 20 degrees F.). The greater the temperature drop, the lower the primary loop flow rate can be to deliver all the output of the heat source. In many cases the size of the primary loop piping as well as the primary circulator can be reduced when the loop is designed around a higher temperature drop. A smaller circulator could significantly reduce the electrical energy used by the system over its lifetime.

When designing a series primary loop, it's necessary to account for the temperature drop associated with each operating secondary circuit. Formula 8-1, repeated below, can be used for this purpose.

Formula 8-1

$$\Delta T = \frac{Q}{500 \times f}$$

Where:

ΔT = Temperature drop in the primary loop across the tees of an operating secondary circuit (deg. F)

Q = Rate of heat delivery to the secondary circuit (Btu/hr)

f = Flow rate in the primary circuit (in gpm)

500 a constant for water (use 479 for 30% , and 450 for 50% glycol)

The heat emitters in the various secondary circuits need to be sized for the water temperature available to them based on where they connect to the primary loop. The farther downstream a given secondary circuit connects to the primary loop, the lower the water temperature available to it (assuming the upstream secondary circuits are operating).

If a conventional boiler is used as the heat source, the designer should also verify that the water temperature at the end of the primary loop (when all loads are operating) is high enough to prevent sustained flue gas condensation within the boiler or its vent piping. Refer to section 5 for a more detailed discussion of this topic.

Figure 9-4 depicts a system using a single boiler to supply radiant floor heating as well as an indirect water heater. The floor heating system consists of three manifold stations piped in parallel. This arrangement supplies the same water temperature to each manifold station (as discussed in section 8). The supply water temperature to the floor circuits is controlled by a variable speed injection mixing system.

Note that the DHW tank is connected as a parallel

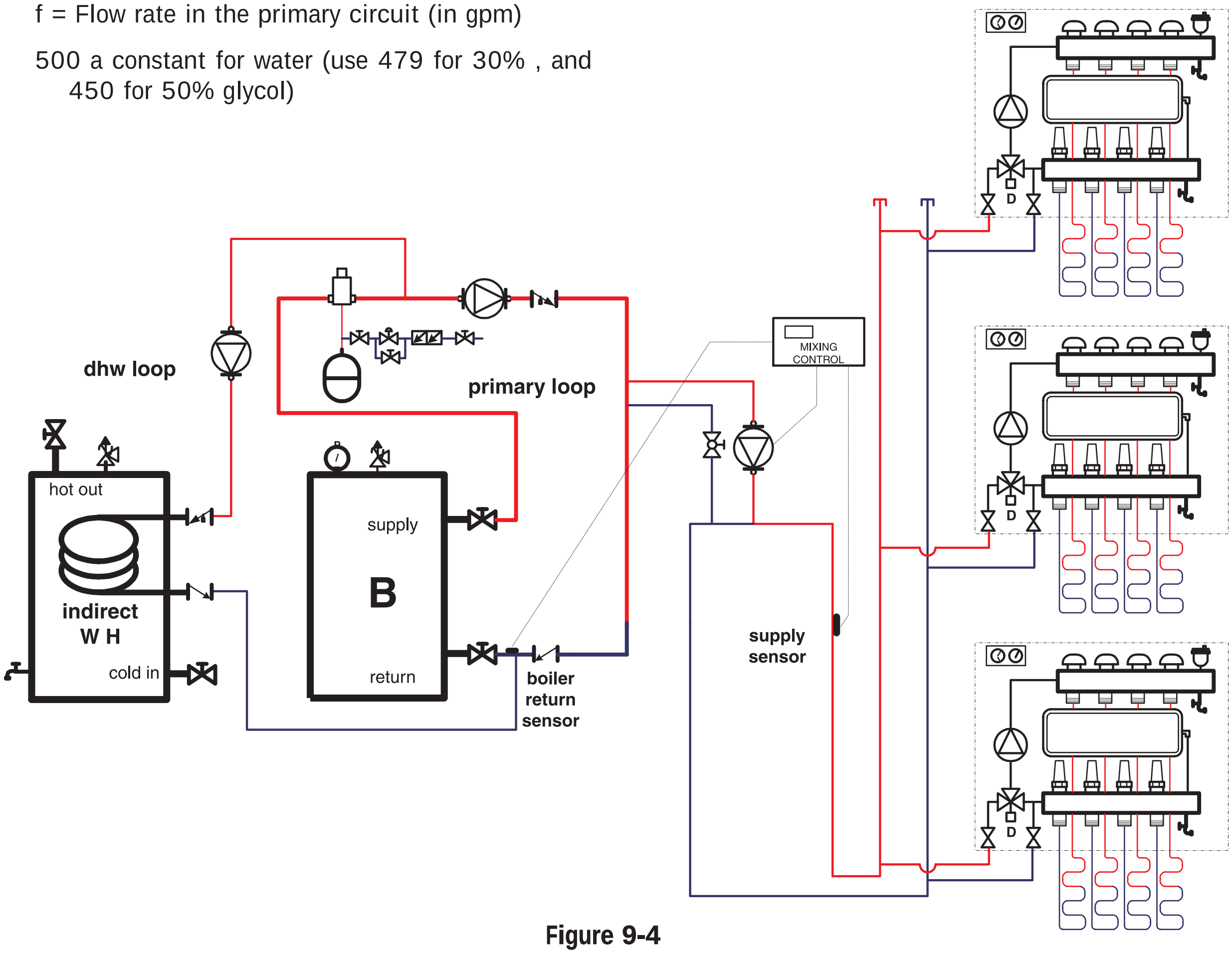


Figure 9-4

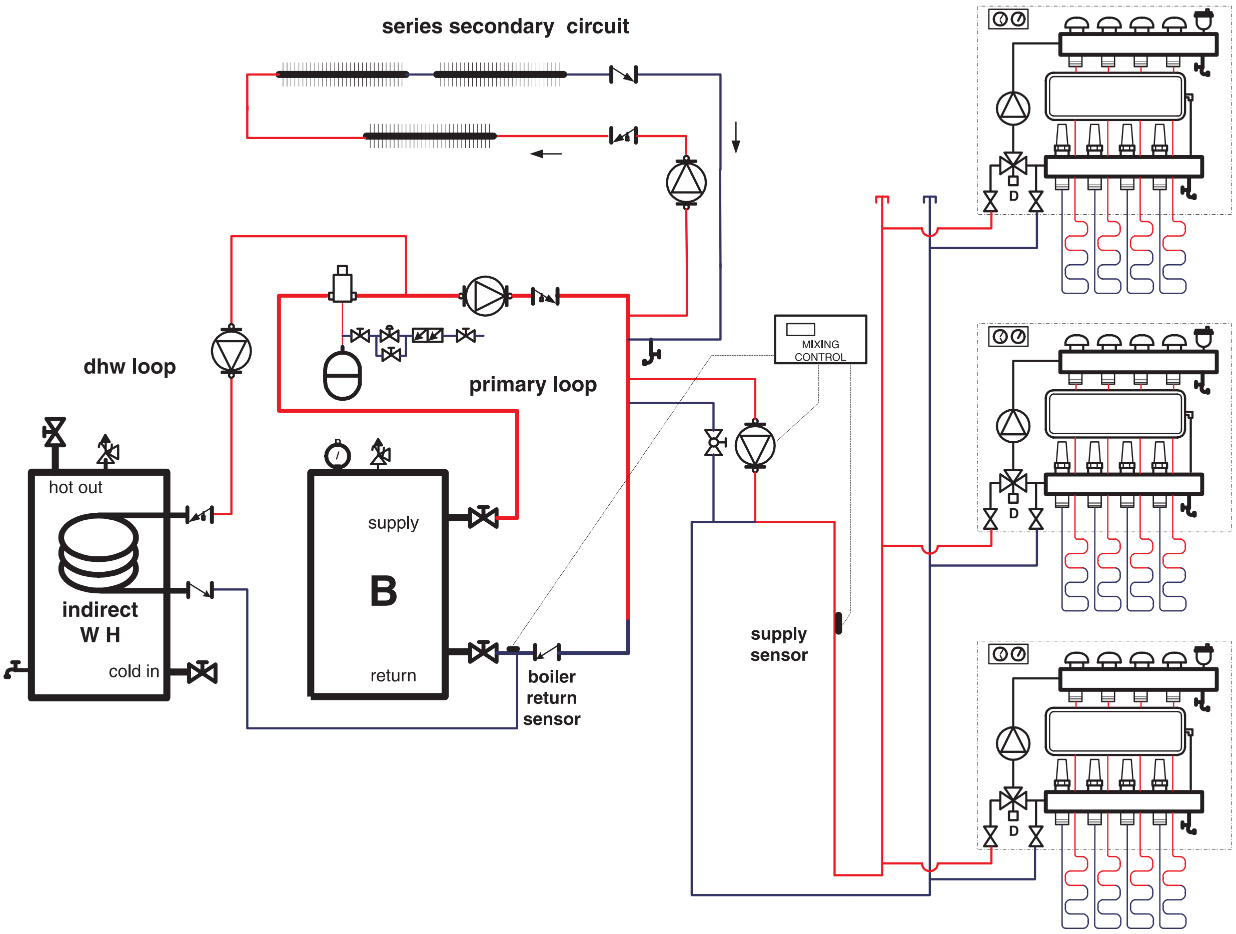


Figure 9-5

circuit to the primary circuit. Also note the locations of the temperature sensors providing feedback to the injection controller.

Figure 9-5 expands the system of figure 9-4 by adding a series of secondary circuits supplying finned-tube baseboard. Since the baseboards need to operate at a higher water temperature than the floor heating circuits, the secondary circuit supplying them is connected to the primary loop upstream of the injection mixing system.

The distribution system is further expanded in figure 9-6 by adding a heat exchanger to supply heat to a garage floor heating subsystem that will be filled with a glycol solution allowing it to be completely turned off when desired.

The temperature of the glycol solution is controlled by a variable speed injection pump that regulates the hot water flow through the "hot" side of the heat exchanger. The controller operating the injection pump monitors its own return temperature sensor located near the inlet of the boiler. When necessary, this controller reduces the hot water flow through the garage heat exchanger to prevent the cold garage floor slab from removing heat from the system faster than the heat plant can produce it.

The heat exchanger, like the DHW tank, is connected as a parallel (rather than secondary) circuit. In the event the heat exchanger and the DHW tank are allowed by the controls to operate at the same time, this arrangement makes the highest water temperature in the system available to both loads.

When the DHW tank or garage floor heat exchanger call for heat, (as evidenced by a contact closure of either a thermostat or aquastat) the boiler staging control receives a "setpoint demand." In this mode, the target water temperature leaving the boiler manifold piping is typically in the range of 200 deg. F.

When either of the space heating loads calls for heat, the boiler controller receives a "heating demand." In this mode, the target water temperature is calculated by the boiler control based on the current outdoor temperature (e.g. outdoor reset control).

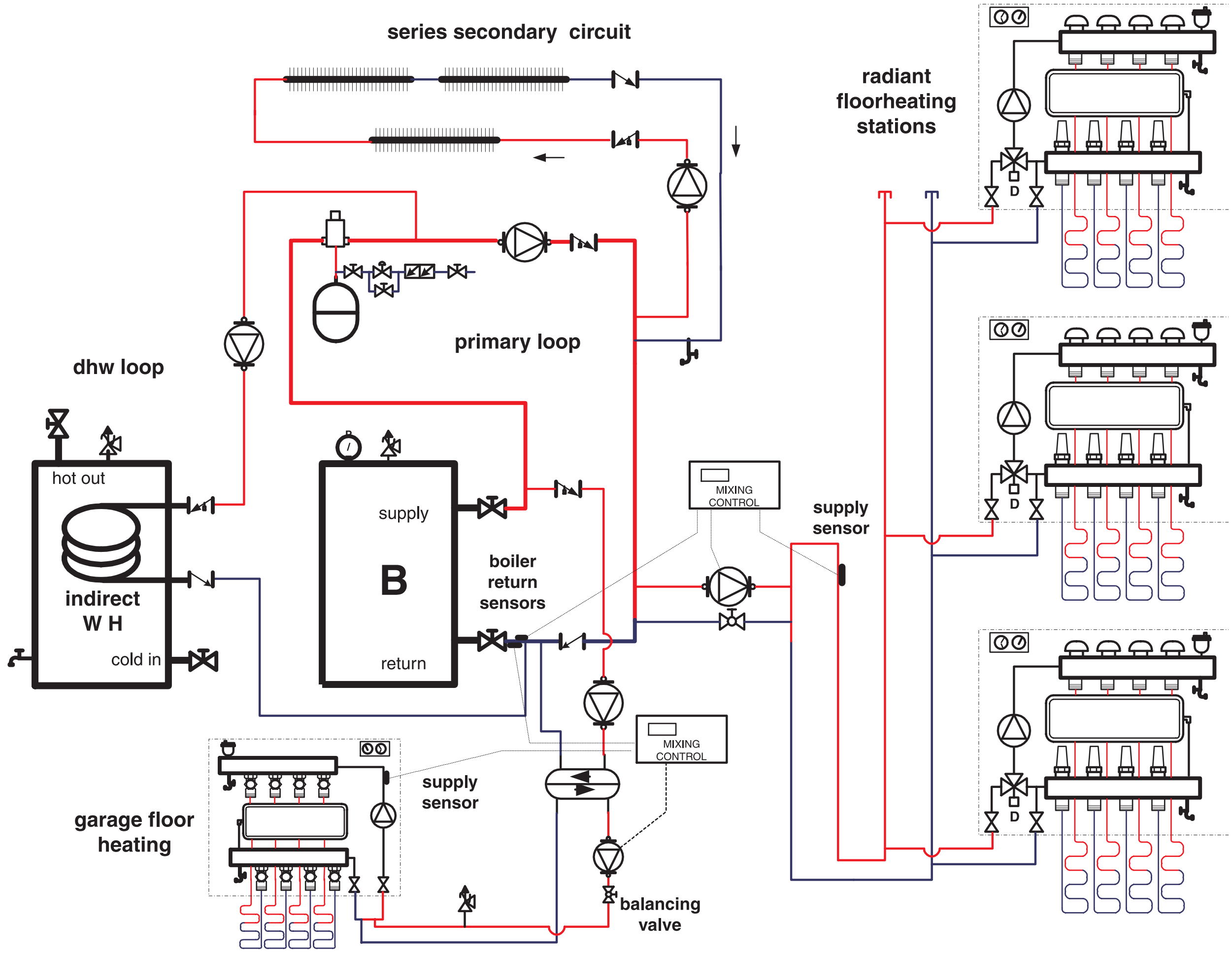


Figure 9-6

Figure 9-7 adds one more subassembly to the system. It's a secondary circuit consisting of a small circulator and homerun manifold station supplying several small heat emitters. Some of these heat emitters may be towel warmers in the building. Others may supplement the output of a heated floor in certain high load areas of the building.

The home run approach as described in section 6 allows small diameter Kitec or PEX tubing to be routed through the building structure much like electrical cable. It also allows for individual circuit control and supplies the same water temperature to each circuit.

Another modification shown in figure 9-7 is using an external stainless steel heat exchanger between the system water and a conventional hot water storage tank. A stainless steel or bronze circulator must be used between the storage tank and the heat exchanger.

This arrangement can be used in situations where the heat transfer capacity of an indirect water heater (with its own internal heat exchanger) is not sufficient to transfer the full heat output of the heat plant to the domestic hot water load. When heat transfer between the heat plant and domestic hot water load is "bottle-necked", the boiler will climb to its high limit temperature before the DHW load is satisfied and shut off during part of the cycle. As such, the heat plant is not delivering its full potential heat output rate to the load. Ensuring that this doesn't happen is important in systems that supply domestic hot water to homes with multiple bathrooms, especially those equipped with high water usage fixtures.

9-6 Summary of Design Concepts

Here's a summary of the concepts to remember when designing multi-load hydronic systems:

- Use a single "heat plant" to supply all heating loads rather than using several "dedicated" heat sources.
- Examine load diversity when sizing the heating plant. Consider the likely total heat needed by

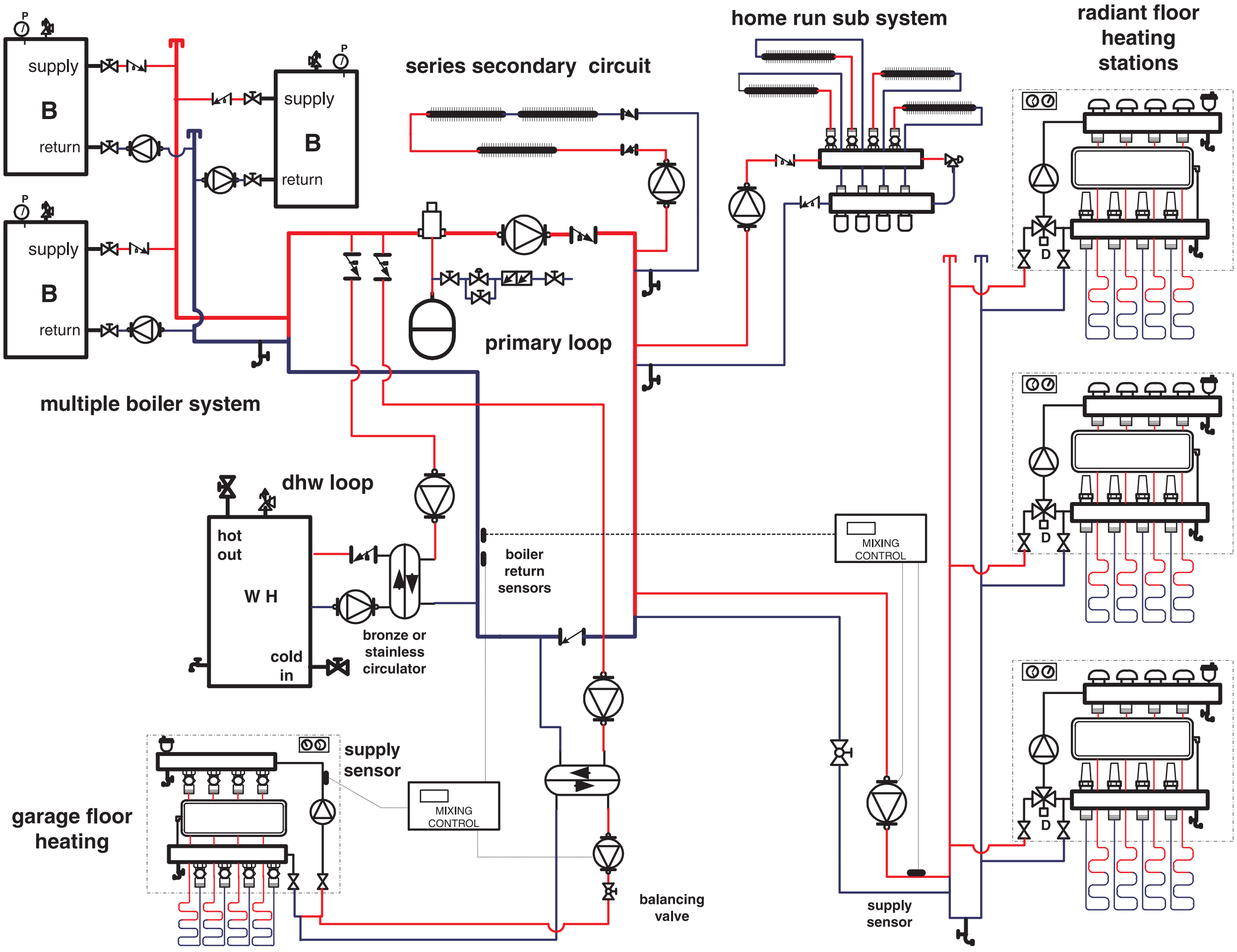


Figure 9-7

the loads over a period of several hours. Use prioritized load shedding (when necessary) to handle unusually high load requirements.

- Use a multiple boiler system rather than a single large boiler when the system has a wide range of load requirements (such as a high intermittent demand for domestic water heating).
- When using multiple boilers, configure the piping and controls so heated water is not circulated through unfired boilers.
- When using multiple boilers, connect the boiler manifold to the distribution system with a pair of closely-spaced tees to prevent interference between the boiler circulators and those in the distribution system.
- Use a series primary loop when the water supply temperatures of the secondary loads vary over a wide range.
- Connect high temperature secondary circuits near the beginning of a series primary loop, and lower temperature loads near the end.
- Use a parallel primary secondary piping when the water supply temperatures of the secondary circuits are all similar.
- To minimize piping heat loss connect the indirect DHW tank as a parallel (rather than secondary) circuit.
- To reduce pipe size, pump size and operating cost, consider designing series-type primary loops for a temperature drop of 30 to 40 degree F. under full load.
- For maximum recovery rate, ensure that the full output of the heat plant can be delivered to the water heater without the boilers reaching their high limit temperature settings. Use an external heat exchanger if necessary to ensure full heat transfer to the domestic hot water storage tank.

SECTION 10

RADIANT PIPE AND TUBING

IPEX is a leading supplier of thermoplastic piping systems, providing customers with one of the world's largest and most comprehensive product lines. Included in this offering are the two leading products for hydronic radiant heating – Kitec XPA pipe and oxygen barrier PEX tubing.

Kitec XPA and PEX tubing have each played an important role in the impressive growth of hydronic radiant system popularity in North America. Used in radiant floor heating for residential, industrial and institutional projects, radiator and baseboard hook-up, snowmelt systems and more, XPA and PEX transport liquid from heat source, to heat zone and back again.

But why choose PEX tubing for a given radiant heating installation instead of XPA pipe? The answer is really based on personal preference.

Some contractors prefer PEX tubing for staple-up applications between floor joists – stating that PEX tube is more flexible and less prone to kinking than XPA pipe. Others find smaller 3/8" diameter PEX tube ideally suited for topping pour installations where floor to ceiling height is limited or were changing the floor elevation is restricted. Some say there is no discernable difference between the two and the matter is cost. Still, others feel that XPA pipe is by far the superior pipe for hydronics.

The facts show that both PEX tubing and XPA pipe are viable products with decades of proven performance in all manner of hydronic applications. As the world's leading supplier of thermoplastic piping systems, IPEX offers industry the two leading options for hydronic pipe and tubing. In time, the debate over which is better – XPA or PEX – will sort itself out.

Kitec XPA Pipe

Great ideas are often born by merging the strengths of one product with those of another. Kitec XPA (X-linked Polyethylene Aluminum) pipe is the result of one of these great ideas. It combines the strength of metal with the longevity of plastic – and it brings some unique benefits to the hydronic radiant heating market.

XPA's aluminum core is what sets it above all other heating pipes. In combination with x-linked polyethylene and specialized adhesive layers that bond the components together, this aluminum core is responsible for most of XPA pipe's unique features and benefits.

Thanks to its aluminum core, XPA pipe is stronger than typical heating PEX tubing. XPA pipe exhibits greater long term pressure ratings (25% higher operating pressure than PEX tube), greater burst pressure resistance, greater hoop strength for resistance to crushing, greater beam strength for less sagging.

Oxygen Barrier PEX Tubing

PEX tubing is universally recognized as the most widely used radiant heating tube. Its light weight, flexibility and wide availability make it a natural choice for radiant heating applications.

IPEX offers a full range of oxygen barrier PEX tubing sizes to round out its industry leading offering of WarmRite Floor hydronic radiant heating components. PEX manifold fittings are designed to quickly and easily connect PEX tubing to the full range of standard WarmRite Floor chrome manifolds. And pre-assembled WarmRite Floor control panels accept PEX tubing as well.

In order to facilitate a technical comparison between XPA pipe and PEX tubing, the following information is arranged to show XPA details along side PEX.

Kitec XPA Pipe

Dimensions in inches

Nominal Size	Average I.D.	Average O.D.	Weight lb / 100 ft	Volume U.S. gal / ft
3/8	0.346	0.48	4.7	0.005
1/2	0.500	0.63	6.8	0.009
5/8	0.631	0.79	10.1	0.016
3/4	0.806	0.98	13.7	0.025
1	1.032	1.26	23.0	0.040

Dimensions in mm

Nominal Size	Average I.D.	Average O.D.	Weight g / m	Volume l / m
9	8.8	12.2	69	0.063
12	12.5	16.0	101	0.113
16	16.0	20.0	150	0.201
20	20.5	25.0	203	0.314
25	26.0	32.0	341	0.500

PEX Tubing

Dimensions in inches

Nominal Size	Average I.D.	Average O.D.	Weight lb / 100 ft	Volume U.S. gal / ft
3/8	0.346	0.500	4.1	0.005
1/2	0.485	0.625	5.4	0.009
5/8	0.584	0.750	8.1	0.014
3/4	0.681	0.875	10.2	0.019
1	0.875	1.125	16.9	0.030

Dimensions in mm

Nominal Size	Average I.D.	Average O.D.	Weight g / m	Volume l / m
9	8.8	12.7	61	1.063
12	12.3	15.9	81	0.111
16	14.8	19.0	121	0.174
20	17.3	22.2	152	0.236
25	22.2	28.6	252	0.372

XPA pipe is easily shaped by hand, Keeps its shape

XPA pipe loops can be easily shaped by hand to a radius of 5 times the pipe O.D. And thanks to the aluminum core XPA pipe maintains the shape that you bend it to – this is of great benefit when installing radiant heating loops especially when compared to PEX tubing. Larger pipe sizes may require a bending tool to achieve the minimum radius shown.

When uncoiled, PEX tubing tries to revert back to its smaller coil size. This makes installation somewhat more challenging and requires PEX tube to be secured at closer intervals in order to maintain its installed position. As well, PEX tubing is less malleable than XPA pipe and therefore has larger allowable bending radii than XPA.

Nominal Pipe Size		XPA Pipe Min. Bend Radius		PEX Tubing Min. Bend Radius	
in	**mm**	**in**	**mm**	**in**	**mm**
3/8	9	2.5	64	3.0	76
1/2	12	3.2	81	3.8	97
5/8	16	4.0	102	4.5	114
3/4	20	5.5	140	7.0	178
1	25	6.5	165	9.0	229

Oxygen permeation

Unlike barrier PEX tubing with its externally applied oxygen barrier XPA pipe houses an aluminum oxygen barrier permanently in between layers of plastic. This means that damage due to installation and construction is avoided making the oxygen barrier a permanent and reliable component of your heating system.

XPA pipe limits oxygen permeation to 0.006g/m^3/ºC/day, 25 times better than the acceptable standard.

PEX tubing has its EVOH oxygen barrier located on the outside of the tubing. This layer limits oxygen permeation to minimum acceptable amount of 0.10 g/m^3/ºC/day.

XPA Pipe – built in safety against ground source contaminants

That same aluminum core that provides such an excellent and permanent oxygen barrier, acts as a first line of defense against ground source contamination such as termiticide. IPEX XPA pipe can be buried directly below grade and in the slab without fear of ground source contamination.

PEX tubing should be treated as a thermoplastic piping material in relation to its permeability. Thermoplastic systems including PEX should not be used if ground source contamination is a threat.

Low Expansion and Contraction

The coefficient of linear expansion for XPA pipe is very similar to copper – 1.3 x 10-5 in./in./ºF (0.23mm/10m/ºC). As an example, one hundred feet of XPA pipe with a 10ºF rise in temperature will expand only 0.156 inches.

PEX tubing on the other hand has a linear expansion / contraction 7 times greater than XPA pipe. One hundred feet of PEX tubing expands and contracts at a rate of 1.1 inches per 10ºF change in temperature.

The following charts provide a quick reference for expansion / contraction of 100 feet (30.5m) of Kitec XPA pipe and PEX tubing.

Approximate linear expansion / contraction of 100 feet of XPA pipe

ºF ºC	20ºF (-7C)	40ºF (4C)	60ºF (15C)	70ºF (21C)	80ºF (27C)	100ºF (38C)	120ºF (49C)	140ºF (60C)	160ºF (71C)	180ºF (82C)	200ºF (93C)
in	-0.80	-0.48	-0.16	**100.0’**	+0.16	+0.48	+0.80	+1.12	+1.44	+1.76	+2.08
mm	-20	-12	-4	**30.5m**	+4	+12	+20	+28	+36	+44	+52

Approximate linear expansion / contraction of 100 feet of PEX Tubing

ºF ºC	20ºF (-7C)	40ºF (4C)	660ºF (15C)	70ºF (21C)	80ºF (27C)	100ºF (38C)	120ºF (49C)	140ºF (60C)	160ºF (71C)	180ºF (82C)	200ºF (93C)
in	-5.5	-3.3	-1.1	**100.0’**	+1.1	+3.3	+5.5	+7.7	+9.9	+12.1	+14.3
mm	-140	-84	-28	**30.5m**	+28	+84	+140	+196	+252	+308	+364

Less head loss than equivalent PEX tube

The following table provides a head loss comparison between Kitec XPA Pipe and PEX Tubing. The larger I.D. of XPA is clearly evident in the following table. Detailed flow rate tables for various heating mediums and temperatures are included in the Appendices.

	XPA Pipe Pressure Loss per 100 feet - psi					PEX Tubing Pressure Loss per 100 feet - psi				
Flow Rate GPM	**3/8"**	**1/2"**	**5/8"**	**3/4"**	**1"**	**3/8"**	**1/2"**	**5/8"**	**3/4"**	**1"**
0.1	0.11	0.02	0.01	0.00	0.00	0.11	0.03	0.01	0.01	0.00
0.2	0.45	0.05	0.02	0.01	0.00	0.45	0.06	0.03	0.01	0.01
0.3	0.92	0.16	0.03	0.01	0.00	0.92	0.18	0.04	0.02	0.01
0.4	1.52	0.26	0.09	0.01	0.01	1.52	0.30	0.13	0.06	0.01
0.5	2.24	0.39	0.13	0.04	0.01	2.24	0.45	0.19	0.09	0.03
0.6	3.08	0.54	0.17	0.06	0.02	3.08	0.62	0.26	0.12	0.04
0.7	3.61	0.70	0.23	0.07	0.02	3.61	0.81	0.34	0.16	0.05
0.8	4.58	0.89	0.29	0.09	0.03	4.58	1.03	0.42	0.20	0.06
0.9	5.66	0.97	1.36	0.11	0.03	5.66	1.15	0.52	0.25	0.08
1.0	6.84	1.17	0.43	0.14	0.04	6.84	1.39	0.63	0.30	0.09
1.2	9.48	1.62	0.52	0.19	0.06	9.48	1.92	0.77	0.42	0.13
1.4	12.50	2.14	0.69	0.24	0.08	12.50	2.54	1.02	0.49	0.17
1.6	15.90	2.72	0.88	0.28	0.10	15.90	3.22	1.29	0.62	0.19
1.8	19.60	3.36	1.08	0.34	0.12	19.60	3.98	1.60	0.76	0.23
2.0	23.70	4.06	1.31	0.41	0.13	23.70	4.81	1.93	0.92	0.28
2.5	35.50	6.06	1.96	0.61	0.19	35.50	7.18	2.88	1.38	0.41
3.0	49.20	8.41	2.71	0.85	0.26	49.20	9.96	3.99	1.91	0.57
3.5	-	11.10	3.58	1.12	0.34	-	13.10	5.27	2.52	0.76
4.0	-	14.10	4.55	1.43	0.44	-	16.70	6.70	3.20	0.96

	XPA Pipe Pressure Loss per 100 meters - kPa					PEX Tubing Pressure Loss per 100 meters - kPa				
Flow Rate L / min	**9mm**	**12mm**	**16mm**	**20mm**	**25mm**	**9mm**	**12mm**	**16mm**	**20mm**	**25mm**
0.39	2.41	0.55	0.22	0.08	0.03	2.41	0.97	0.30	0.16	0.06
0.78	10.2	1.11	0.43	0.16	0.06	10.2	1.93	0.59	0.32	0.12
1.17	20.7	3.61	0.65	0.25	0.09	20.7	2.90	0.89	0.48	0.18
1.56	34.3	5.97	1.95	0.33	0.12	34.3	7.74	2.85	1.38	0.24
1.95	50.7	8.82	2.88	0.91	0.15	50.7	11.4	4.22	2.03	0.62
2.33	69.7	12.1	3.96	1.26	0.39	69.7	15.7	5.8	2.80	0.85
2.72	81.7	15.9	5.18	1.65	0.51	81.7	20.6	7.6	3.66	1.11
3.11	104	20.1	6.55	2.08	0.64	105	26.0	9.6	4.63	1.41
3.50	128	21.9	8.05	2.55	0.79	128	32.0	11.8	5.69	1.73
3.89	155	26.5	9.68	3.07	0.95	155	38.5	14.2	6.84	2.08
4.67	215	36.7	11.9	4.22	1.31	215	52.9	17.5	9.41	2.86
5.45	283	48.4	15.6	5.53	1.71	283	63.3	23.0	11.0	3.75
6.22	360	61.5	19.9	6.24	2.16	360	80.4	29.2	14.0	4.21
7.00	44	76.0	24.5	7.71	2.66	444	99.2	36.1	17.3	5.20
7.78	537	91.8	29.6	9.31	3.19	537	120	43.6	20.9	6.28
9.73	802	137	44.2	13.90	4.25	802	179	65.1	31.2	9.37
11.70	1110	190	61.4	19.30	5.89	1110	248	90.3	43.2	13.0
13.60	-	251	81.0	25.40	7.77	-	327	119	57.0	17.1
15.60	-	319	103	32.30	9.87	-	416	151	72.5	21.8

Larger inside diameters

XPA pipe has larger inside diameters than the comparable nominal size PEX tubing.

Nominal Size in	Nominal Size mm	XPA Pipe Actual I.D. in	XPA Pipe Actual I.D. mm	PEX Tubing Actual I.D. in	PEX Tubing Actual I.D. mm
3/8	9	0.346	8.8	0.346	8.8
1/2	12	0.500	12.7	0.485	12.3
5/8	16	0.637	16.2	0.584	14.8
3/4	20	0.806	20.5	0.681	17.3
1	25	1.032	26.2	0.875	22.2

Rates of Thermal Conduction

Due to its aluminum and plastic construction, XPA pipe has a greater rate of thermal conduction than does PEX tubing. The following chart defines values for both XPA and PEX.

Nominal Pipe Size in	Nominal Pipe Size mm	XPA Pipe BTU/h/ft/ºF ºF	XPA Pipe W(m.ºC) ºC	PEX Tubing BTU/h/ft/ºF ºF	PEX Tubing W(m.ºC) ºC
3/8	9	0.329	0.570	0.290	0.502
1/2	12	0.457	0.791	0.377	0.653
5/8	16	0.578	1.000	0.454	0.785
3/4	20	0.725	1.255	0.530	0.917
1	25	0.927	1.605	0.681	1.179

High pressure ratings

IPEX XPA pipe provides 25% greater long term pressure rating than typical PEX tubing. XPA is rated for continual service of 200 psi at 73ºF and 125psi at 180ºF. PEX tubing is rated for continual service of 160 psi at 73ºF and 100psi at 180ºF. XPA also offers excellent resistance to quick burst conditions as shown in the following table.

Quick Burst Pressures – XPA Pipe

	3/8" (9mm)	1/2" (12mm)	5/8" (16mm)	3/4" (20mm)	1" (25mm)
Quick Burst 73ºF (23ºC)	1160 psi (8004kPa)	1015 psi (7003kPa)	1005 psi (6935kPa)	825 psi (5693kPa)	790 psi (5451kPa)
Quick Burst 180ºF (82ºC)	750 psi (5175kPa)	685 psi (4724kPa)	655 psi (4520kPa)	550 psi (3795kPa)	535 psi (3692kPa)

Resistance to damage from freezing

Good installation practice dictates protection against freezing for piping systems. However, in the event that freezing does occur, XPA pipe does provide a level of safety against pipe burst when installed in open free air conditions. Tests show that IPEX XPA pipe may take up to 5 freeze thaw cycles before failing. Compared to traditional metal pipes XPA provides you with more built in peace of mind.

When encased in concrete however, the extreme forces of freezing water against cured concrete leave little chance for any pipe including XPA to survive. Care must always be taken to avoid freezing of hydronic piping installed in slabs.

Flame Spread and Smoke Ratings

XPA pipe has a Flame Spread Rating of 5 and a Smoke Development Rating of 5 as per third party testing to ULC-S102.2. This allows it to be used in high-rise construction as well as in return air plenums and vertical shafts. Check with the local authority having jurisdiction.

PEX tubing also meets certain building code guidelines for use in combustible construction – contact your IPEX representative for more details.

Firestopping XPA Pipe

XPA pipe has been tested and listed with various firestopping materials in accordance with CAN/ULC S115-M95, ASTM E81 and UL 1479. Approved and listed firestop materials are available from 3M (CP 25WB or Silicone 2000), PFP Partners (4800 DW) and Johns Manville (Firetemp CI).

In the event that XPA pipe must penetrate a fire rated wall, these firestop materials may be used to maintain the assembly rating. IPEX XPA pipe and firestop products must be installed in accordance with the individual product listing to ensure proper performance. Contact IPEX for detailed instructions.

Electrical Properties

Although XPA pipe contains an aluminum core, its joining systems are not designed to conduct stray current. In consideration of electrical grounding XPA pipe is considered to be a thermoplastic piping system and should never be used to ground.

PEX tubing too should be treated as other thermoplastic piping systems are in that it must not be used to ground electrical systems.

XPA Pipe and Fitting Standards

IPEX manufactures and carries third party certification on XPA pipe to the following standards:

CAN / CSA B137.9
Standard for Crosslinked Polyethylene / Aluminum / Crosslinked Polyethylene Composite Pressure Pipe Systems

ANSI/ASTM F1281
Standard Specification for Crosslinked Polyethylene / Aluminum / Crosslinked Polyethylene (PEX-AL-PEX) Pressure Pipe

These standards include requirements for pipe sizes, dimensions, workmanship, quality control, burst and sustained pressure performance and more.

ANSI / ASTM F1974
Standard Specifications for Metal Insert Fittings for Polyethylene / Aluminum / Polyethylene and Crosslinked Polyethylene / Aluminum / Crosslinked Polyethylene Composite Pressure Pipe

This standard includes requirements for IPEX K1 compression style fittings and K2 crimp style fittings. The standard outlines acceptable fitting materials, dimensional requirements, short term burst and long term pressure ratings, etc.

Mechanical and Building Code Compliance

XPA pipe and fittings are recognized and included in the National Plumbing and Building Codes of Canada as well as in the National Hydronic Standard of Canada.

In the United States XPA pipe and fittings are included in the Uniform Mechanical Code and the International Plumbing, Mechanical and Residential Codes.

PPI TR-4
PPI Listing of Hydrostatic Design Bases and Maximum Recommended Hydrostatic Design Stresses for Thermoplastic Pipe Materials

IPEX XPA pipe is listed with PPI for the following pressure and temperature ratings:

200psi at 73ºF   125psi at 180ºF

ANSI / NSF 14
Plastics Piping System Components and Related Materials Product Certification Listing

IPEX holds NSF certification on its XPA pipe for potable water applications and radiant floor heating in residential and commercial construction, including manufactured housing.

PEX Tubing Standards

IPEX offer CTS SDR-9 PEX tubing manufactured and third party certified to the following standards:

CAN/CSA B137.5
Standard for Crosslinked Polyethylene Pressure Tubing Systems

ASTM F876
Standard Specification for Crosslinked Polyethylene (PEX) Tubing

ASTM F877
Standard Specification for Crosslinked Polyethylene (PEX) Plastic Hot and Cold Water Distribution Systems

PPI TR-4
PPI Listing of Hydrostatic Design Bases and Maximum Recommended Hydrostatic Design Stresses for Thermoplastic Pipe Materials

IPEX PEX tubing is listed with PPI for the following pressure and temperature ratings:

160psi at 73F   100psi at 180F

ANSI / NSF 14
Plastics Piping System Components and Related Materials Product Certification Listing

IPEX holds NSF certification on its PEX tubing for potable water applications and radiant floor heating in residential and commercial construction, including manufactured housing.

Mechanical and Building Code Compliance

PEX tubing is recognized and accepted in all model codes across North America including the National Plumbing Code of Canada, the National Hydronic Standard of Canada, the Uniform Mechanical Code, the International Plumbing, Mechanical and Residential Codes, and by BOCA and SBCCI.

SECTION

11

HYDRONIC SNOW AND ICE MELTING

11-1 Introduction:

IPEX hydronic heating products can be used to provide snow and ice melting on all types of exterior areas including:

- Driveways
- Walkways
- Parking areas
- Steps
- Wheelchair access ramps
- Patios
- Decks
- Roofs

On specialized commercial and industrial properties, hydronic snow melting has been used for the following applications:

- Car washes
- Hospital emergency entrances
- Toll booth areas
- Loading docks
- Helicopter landing pads
- Security gate areas
- Other areas that must be kept free of snow and ice

11-2 The Benefits

Hydronic snow and ice melting offers many benefits over traditional methods of snow removal. They include:

- The capability of providing fully automatic/unattended snow removal whenever required.
- The ability to remove snow without creating banks or piles that subsequently cause drifting, and often damage surrounding landscaping.
- The elimination of sanding.
- The elimination of salting and its potential damage to landscaping and the surrounding environment.
- Less pavement damage due to frost action, chemical deterioration due to salting, and physical damage from plowing. The latter is especially important when paving bricks/tiles are used.
- Cleaner interior floors because sand and salt are not tracked in
- Because all snow and ice is removed, the possibility of slips, falls or vehicular accidents is greatly reduced, especially on sloped pavements. This reduces liability, especially in public areas.
- Improved property appearance during winter.
- The ability to use almost any fuel or heat source to provide the energy required for melting.

11-3 System Classifications

There are several possible approaches to designing a hydronic snow and ice melting system. They vary in both the rate of heat delivery to the surface being melted, and the type of controls used to initiate and terminate the melting operation.

Over the last few decades the design of snow and ice melting systems has been somewhat loosely classified as follows:

Class 1 systems:

This class of system is generally accepted as sufficient for most residential walkway and driveway areas. The rate of heat delivery to the surface in generally in the range of 80 to 125 Btu/hr/square foot depending on location. Class 1 systems often allow a layer of snow to accumulate during a heavy snowfall, especially if the system is manually controlled and starts from cold. This snow layer is actually beneficial because it acts as an insulator between the heated pavement surface and the outside air reducing both evaporation and convective losses. Evaporation of the melt water requires much higher heat input.

Class 2 systems:

Generally accepted as sufficient for most retail and commercial paved areas that must be kept clear of accumulating snow during a heavy snow fall, although the pavement will often remain wet. The rate of heat delivery to the surface in typically in the range of 125 to 250 Btu/hr/square foot, depending on location.

Class 3 systems:

Used for high priority areas such as helicopter pads, toll plazas, sloped pavements in parking areas, pavements adjacent to hospital emergency rooms. Class 3 systems are designed with the ability to melt all snow as fast as it falls and quickly evaporate the melt water from the surface. They generally require heat delivery rates of 250 to as high as 450 Btu/hr/square foot.

Design Output, Btu/hr/sqft

City	Class I System	Class II System	Class III System
Albuquerque, NM	71	82	167
Amarillo, TX	98	143	241
Boston, MA	107	231	255
Buffalo – Niagara Falls, NY	80	192	307
Burlington, VT	90	142	244
Caribou – Limestone, ME	93	138	307
Cheyenne, WY	83	129	425
Chicago, IL	89	165	350
Colorado Springs, CO	63	63	293
Columbus, OH	52	72	253
Detroit, MI	69	140	255
Duluth, MN	114	206	374
Falmouth, MA	93	144	165
Great Falls, MT	112	138	372
Hartford, CN	115	254	260
Lincoln, NB	67	202	246
Memphis, TN	134	144	212
Minneapolis – St. Paul, MN	95	155	254
Mt. Home, ID	50	90	140
New York, NY	121	298	342
Ogden, UT	98	216	217
Oklahoma City, OK	66	81	350
Philadelphia, PA	97	229	263
Pittsburgh, PA	89	157	275
Portland, OR	86	97	111
Rapid City, SD	86	102	447
Reno, NV	98	154	155
St. Louis, MO	122	152	198
Salina, KS	85	120	228
Sault Ste. Marie, MI	78	144	213
Seattle – Tacoma, WA	92	128	133
Spokane, WA	87	127	189
Washington, D.C.	117	121	144

(Permission to use data authorized by ASHRAE)

The major distinction between these classes is in the rate of heat delivery to the area being melted. The following table gives suggested heat delivery rates for all three class of snow melting systems in several locations.

11-4 Tubing Installation Guidelines

This section shows suggested construction details for installing Kitec tubing in various snow melting applications. These details have been carefully developed to ensure good performance of the system. In some cases, local design practices and code requirements may require them to be modified.

Drainage considerations

It is crucially important that all melted pavement areas be detailed for proper drainage of melt water. The heat delivery rates used with Class 1 and 2 systems assume that most of the melt water will be drained from the surface (as a liquid) rather than evaporated. The latter method of moisture removal requires considerably more heat input.

Failure to provide proper drainage can allow melt water to accumulate at low points in the pavement, or where the melted pavement adjoins non-melted areas. When the system turns off, this standing water can quickly turn to dangerous ice. Pavements must be sloped to drains capable of routing the melt water to a drywell, storm sewer, or other discharge (check local codes) without it freezing in the process. Drainage piping should not run through the heated thermal mass because the cold water will rob heat from the system. Instead, drainage piping should be routed beneath the underside insulation where it is protected from freezing. Keep in mind that a shallow drainpipe running through unheated soil can quickly fill with ice and be very difficult to thaw. One method of ensuring the drainage system does not freeze is to install a dedicated drain heating circuit of Kitec tubing alongside the drainage trench, receptor and piping.

Trench drain systems are often used at the lower elevations in melted pavements. If the pavement slopes toward a building, be sure the melt water can be collected before it can flow into the building. Likewise, be sure melt water running down a pavement toward a street will be collected by a drain before it contacts the unheated pavement.

Figure 11-2 shows some examples of pavement drainage concepts.

Be sure to discuss drainage provisions with those responsible for its installation as soon as possible in the planning stages of the system.

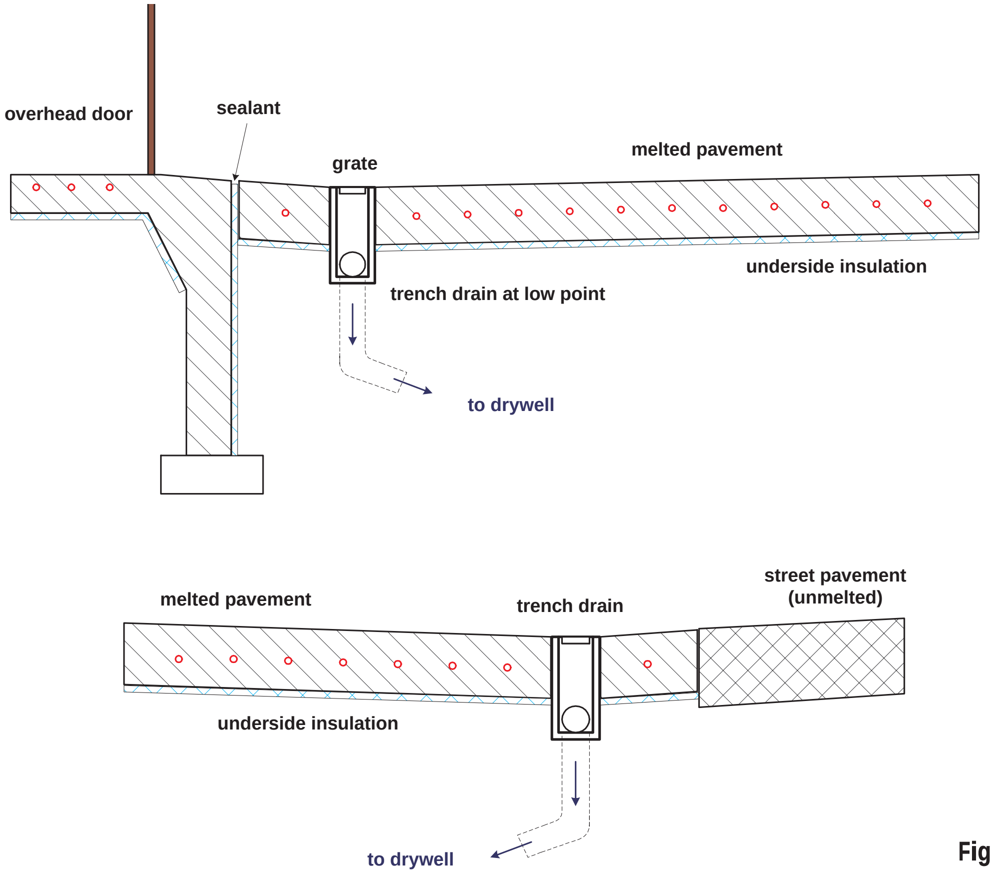


Figure 11-2

Evaluating Sub-surface Conditions:

When planning a snow melting system, the designer should always evaluate the soils under the area to be melted. Failure to address subsoil problems can lead to unanticipated conditions that will not only damage the pavement, but could also severely damage the tubing.

If the local water table is within 3 feet of the surface, it has the potential to greatly increase downward heat loss from the melted pavement. Such situations require proper subsoil drainage to lower the water table. A properly detailed “French drain” constructed around the perimeter of the paved area is a typical solution.

If bedrock is present under the area to be melted, it’s imperative to slope or channel the rock surface so any water percolating down from the melted surface can be drained away. Otherwise, the bedrock may pond water under the melted pavement. It’s also crucial to install a minimum of 1 inch of extruded polystyrene insulation to reduce heat conduction to the bedrock.

Low percolation soils containing high amounts of clay or silt retain moisture in winter. When these (saturated) soils freeze, the expanding ice crystals create powerful forces that can easily crack and heave pavements upward. If such soils are present, the base layer of the pavement system should consist of 6 to 9 inches of #2 size crushed stone. The soil surface beneath the stone layer should be sloped so any water reaching the stone layer can be collected and drained away. The stone layer should also be tamped to form a flat surface for the insulation board installed above it.

When pavements are to be placed over areas of disturbed or otherwise unstable soil, a geotextile fabric should be incorporated into this base layer. This very strong non-deteriorating fabric helps spread high loads over larger areas to prevent eventual depressions in the pavement. Such depressions could eventually damage embedded tubing.

Remember—no snow melting system can make up for poor pavement design. Be sure to involve knowledgeable professionals in the pavement planning process.

Installation Procedure for Concrete Pavements

Figure 11-3 shows the material assembly used for a typical snowmelting system in a concrete driveway or walkway.

When the local soil has good drainage characteristics, the base layer generally consists of 6 to 9 inches of compacted gravel. Moisture that may eventually percolate down to this layer will pass through into the subsoil below. In some cases, a geotextile fabric will be incorporated into this base layer to further stabilize it.

In cold climates or projects where the pavement will be held at an “idling” temperature near freezing, it is cost effective to install a layer of extruded polystyrene insulation over the compacted gravel base. This insulation greatly reduces downward heat loss from the pavement. It also shortens the response time of the system when melting is required, especially in cold climates where the system doesn’t idle the slab.

A thickness of 1 inch (R-5) is usually adequate. Be sure the rigid board insulation lies flat against the compacted gravel base at all locations so the pavement is fully supported when loaded.

The compressive stress rating of the insulation should be selected to match loads that may be imposed on the pavement. A 25 psi rated insulation board is the minimum rating for pavements subject to light vehicular traffic. If heavier (truck) traffic is anticipated insulation with a compressive load rating of 40 to 60 psi should be considered. Insulation manufacturers can provide guidance on the proper compressive stress rating for a given pavement application.

Welded wire fabric (WWF), or a grid of rebar is now installed over the insulation. Be sure to overlap all sheets of WWF by at least 6” and tie them together with wire twist ties.

The Kitec tubing can now be secured to the steel reinforcing using wire twist ties spaced 48 to 60 inches apart.

Tube spacing should never exceed 12 inches. Wider spacing can result in uneven melting patterns that may not completely clear the pavement of snow before the melting operation is shut off. Nine inch tube spacing is recommended in most cases. In areas with high snow fall rates, high average wind speeds or situations where a cold (non-idled) slab needs to be brought up to temperature quickly, 6 in. spacing should be used. Section 11-6 discusses tube spacing issues in more detail.

Tubing circuits should be planned so as not to exceed the maximum lengths given in section 11-6. The warmest portion of the circuit should generally be routed in the areas with the highest melting priority. For example, the tire track area of a typical driveway would usually have a higher melting priority than the edges of the driveway. Don’t install tubing closer than 6 inches to the edge of the pavement.

Figure 11-3

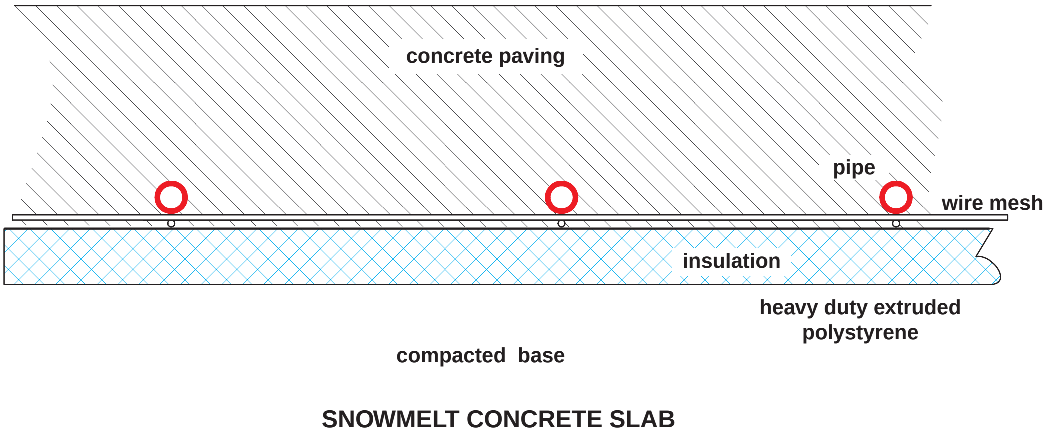


Figure 11-3A

Figure 11-4 shows a typical tubing layout for a residential driveway based on use of 5/8" Kitec pipe.

It is highly recommend that the designer make an accurate tubing layout drawing for each project before installation begins. CAD generated tubing layouts allow the designer to check circuit lengths, determine the total amount of tubing needed and provide the installer with an easy to follow plan.

Once installed, all tubing circuits should be pressure tested using compressed air at 75 psi for a minimum of 24 hours prior to placing the concrete.

Be sure to cap all circuit ends until they are connected to the manifold to prevent construction dust and moisture from contaminating the system.

The tubing and reinforcing steel should be supported or lifted during the pour so the top of the tubing is 1.5 to 2 inches below the finish surface of the slab. Tubing depth is more critical in a snow melting applications than in radiant floor heating. Leaving the tubing at the bottom of a typical 6" exterior slab significantly increases the response time of the system when melting is initiated. It also increases the required fluid temperature and downward heat loss.

The tubing should be protected with sleeving wherever it crosses a full control joint location in the slab. The tubing depth should be sufficient to ensure that sawn control joints will not harm the tubing, no sleeving necessary. In locations where the tubing passes from the paved area through a foundation wall, the installation must be detailed to prevent damage to the tubing should the pavement shift up or down.

Air entrained concrete with a minimal 28 day compressive stress rating of 4000 psi is often specified for exterior slabs.

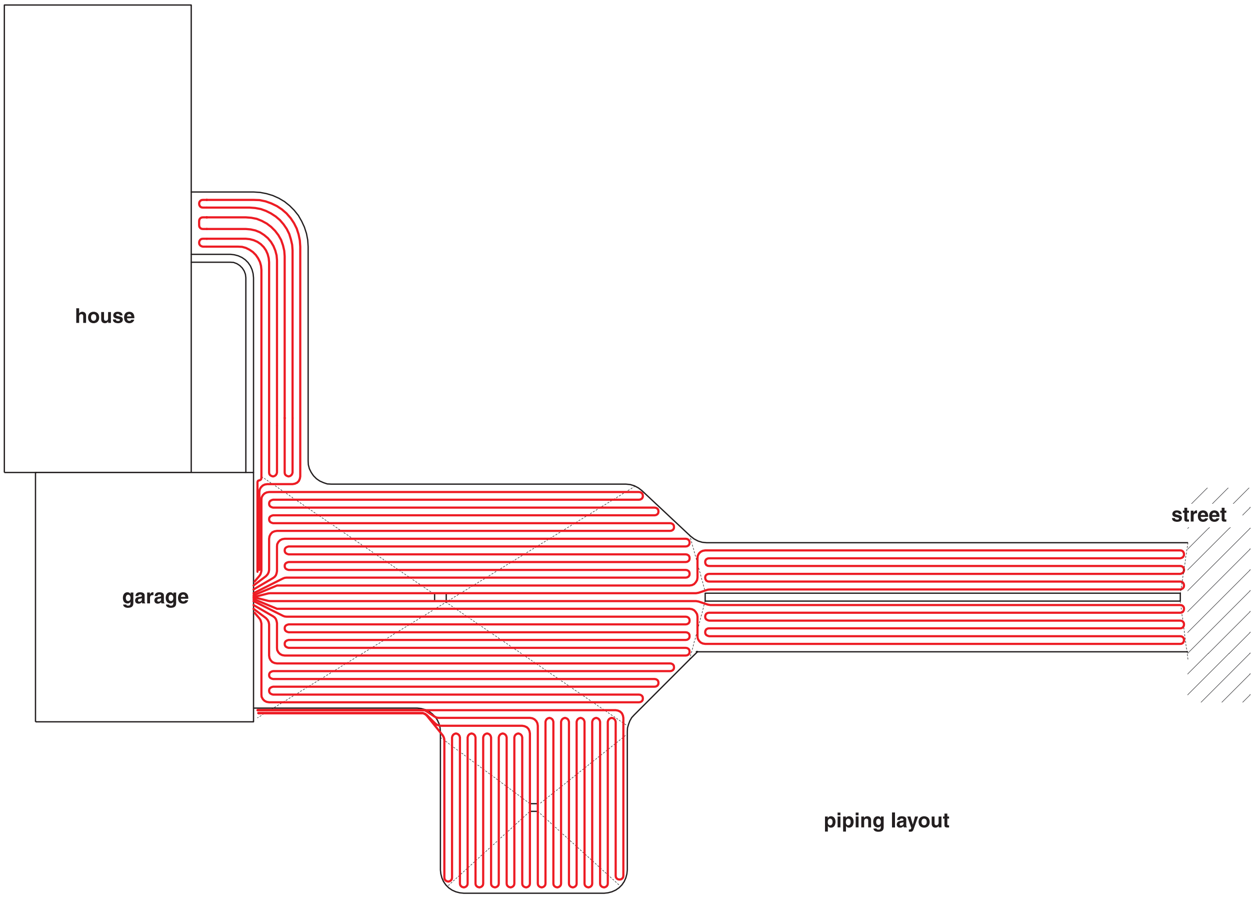


Figure 11-4

Installation Procedure for Asphalt Pavements

Figure 11-5 shows the material assembly used for a typical snow melting system in asphalt paved driveways or walkways.

The subgrade and insulation under an asphalt driveway or walkway is prepared the same as for a concrete pavement. A mat of welded wire fabric (WWF) is then laid out over the insulation. All sheets of the WWF

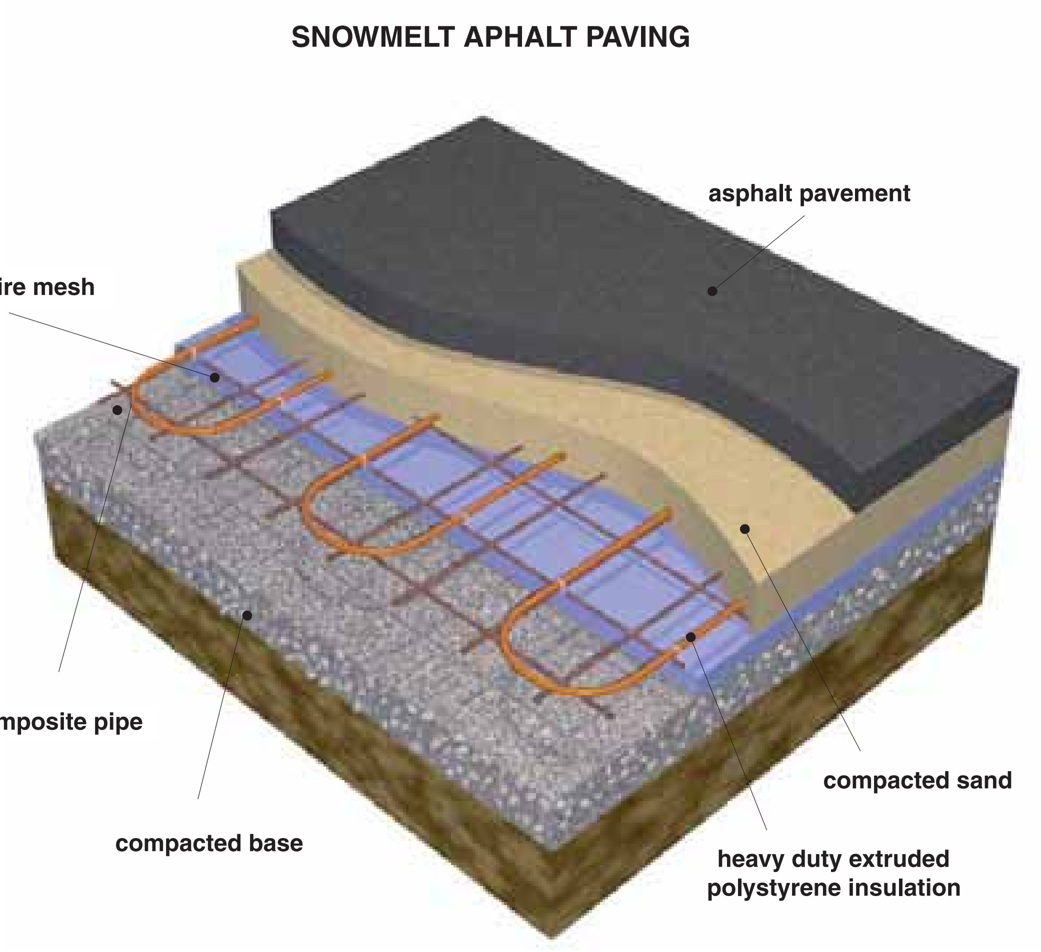
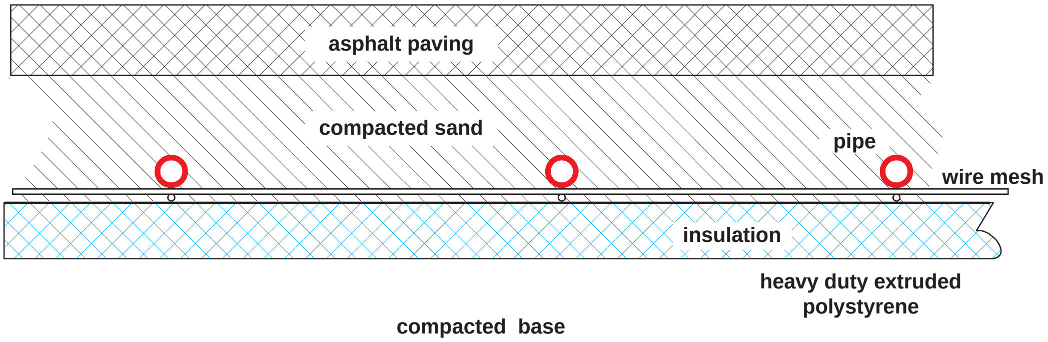


Figure 11-5



SNOWMELT ASPHALT PAVING

Figure 11-5A

should be overlapped 6 inches at their edges and tied together with wire twist ties. The tubing is unrolled and secured to the WWF with wire twist ties spaced 48 to 60 inches apart.

After pressure testing the circuits a 3 to 4 inch deep layer of sand or stone dust is placed over them. The sand/stone dust layer protects the tubing from the hot asphalt (250-350 degrees F.). After the WWF and tubing have been placed, the sand/stone dust should be uniformly and thoroughly soaked with water to settle the particles around the tubing and provide a stable base for the asphalt.

Kitec (PEX-AL-PEX) pipe is especially well suited to this application because its low coefficient of expansion minimizes dimensional changes of long tubing runs as the system cycles between warm and cold.

When placed, asphalt paving can be as hot as 350 degrees F. It should never be placed directly on Kitec or PEX tubing. However, when the tubing is embedded in the layer of sand/stone dust as described, the hot asphalt can be placed without damaging to the tubing.

Installation Procedure for Surfaces Covered with Paving Stones

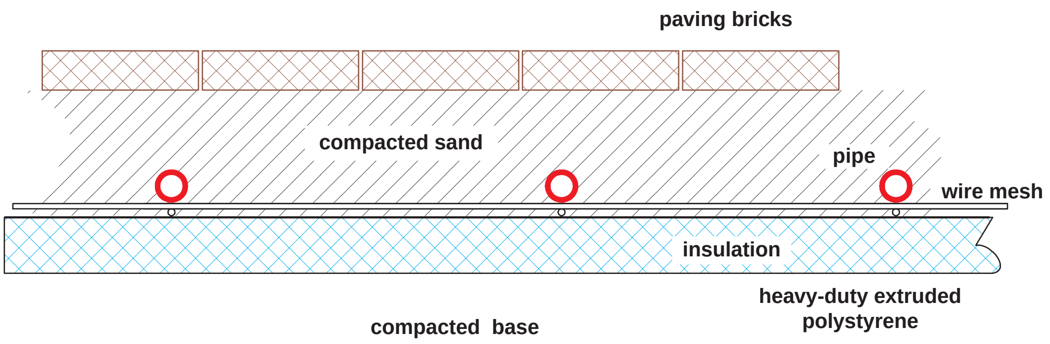
Pavements consisting of loosely laid (non-mortared) paving bricks or tiles are easily damaged by conventional methods of snow removal and therefor well suited to hydronic snow melting.

Figure 11-6 shows the material assembly used for a typical snow melting system for an area finish with paving bricks or stone.

Unlike concrete or asphalt, paving bricks allow water to seep down between individual units. This water cannot be allowed to accumulate under the pavers because subsequent freezing can cause the pavers to heave upward.

In areas with low permeability soil, the base layer below the insulation should be detailed for efficient drainage. A 6 to 9 inch deep layer of #2 crushed stone placed over a slightly sloping grade allows vertical drainage of water. The crushed stone base layer must itself be drained to either a drywell or other suitable

Figure 11-6



SNOWMELT PAVING STONES

Figure 11-6A

discharge area. The crushed stone layer should also be tamped flat before the rigid insulation is placed over it.

Drainage detailing is still recommended since the rate of melt water (or rainwater) accumulation may at times exceed the rate at which water can weep downward between the pavers.

Extruded polystyrene insulation is impermeable to water. To allow water drainage, nominal 1/2" gaps should be left between adjacent sheets of insulation. Alternatively, several sheets of rigid insulation can be stacked and drilled to form a grid of 1 inch diameter holes space 12 inches apart. In either case, the holes or slots must be covered with strips of water permeable "filter fabric." This allows water to drain through without carrying the fine particles of sand or stone dust with it. Avoid creating drainage situations where flowing water could form channels through the sand/stone dust layer beneath the pavers. Such channels could lead to voids that may eventually cause some pavers to sink.

A mat of welded wire fabric (WWF) is laid out over the insulation. All sheets of the WWF should be overlapped 6 inches at their edges and tied together with wire twist ties. The tubing is then unrolled and secured to the WWF with wire twist ties spaced 48 to 60 inches apart.

After the tubing circuits have been pressure tested, the tubing and WWF should be covered with 3 to 4 inches of sand or stone dust. After the WWF and tubing have been layered the sand layer should be uniformly and thoroughly soaked with water to settle the sand or stone dust around the tubing and provide a stable base for the pavers.

11-5 Controlling Snow Melting Systems

There are several ways to control snow-melting systems. They differ in their ability to detect when melting is required, as well as how they control the pavement temperature before, during and after melting operation. They also differ considerably in cost. The approach selected must be based on the expectation of the owner, the degree of unattended operation expected, the size of the area being melted and the class of system being designed.

Regardless of the control method used, some fundamental issues must be understood before a snowmelt system can be properly designed:

Antifreeze Issues

Some snow melting systems use a dedicated boiler as their heat source. The boiler and distribution piping is usually filled with an antifreeze solution (typically a 30 to 50% mixture of propylene glycol and water).

In other systems snow melting as one of several loads served by the same boiler(s). The boiler(s) and piping that's are not part of the snow melting system are filled with water. In this case, a heat exchanger must be installed to isolate the antifreeze solution in the snow melting distribution system from the remainder of the system. A stainless steel plate type heat exchanger is often used for such applications.

The freezing point of the mixture is a function of the % and type of glycol used. The following table helps select the correct mixture based on the outdoor temperature.

Glycol %	10%	20%	25%	30%	35%	40%	45%	50%	55%
Propylene	27°F	19°F	15°F	8°F	0°F	-3°F	-15°F	-28°F	-40°F
Ethylene	27°F	18°F	10°F	5°F	-2°F	-10°F	-20°F	-33°F	-50°F

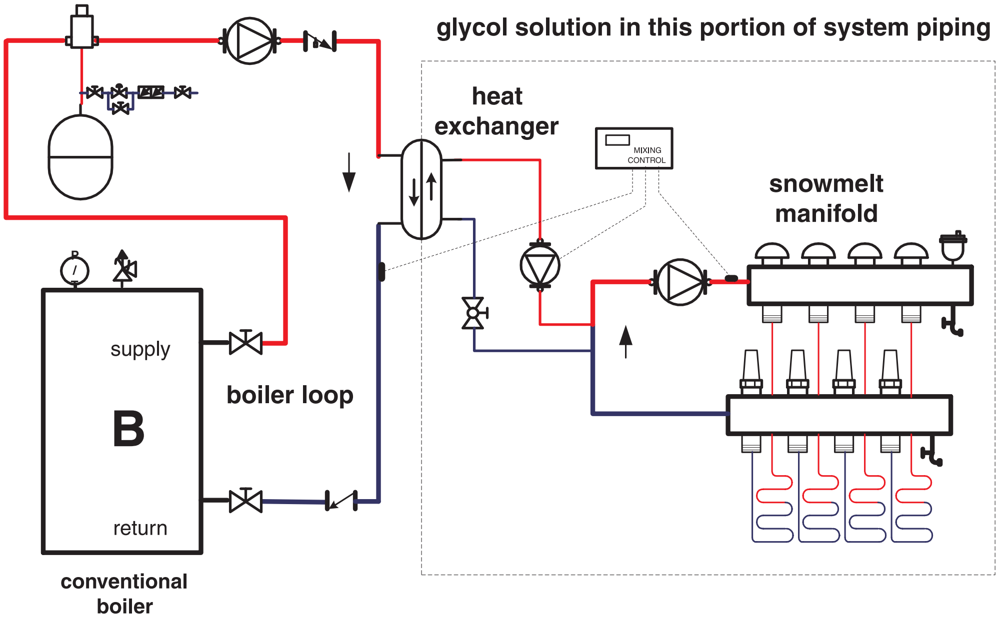
When the system starts with a cold boiler it may be possible for very cold antifreeze returning from the exterior circuits to flow through the heat exchanger before much heat is delivered from the boiler to the heat exchanger. This, combined with the fact that plate heat exchangers are very efficient and have little thermal mass, presents the possibility of freezing the water in the hot side of the exchanger before heat can be delivered from the boiler.

To avoid this possibility, use a temperature control to sense that hot water is flowing through the heat exchanger before allowing the circulator in the snow melting distribution system from operating. Some snow melting system controllers may have this capability built into them.

Boiler Issues

Section 3 described the necessity of maintaining the inlet temperature to a conventional boiler high enough to prevent sustained flue gas condensation. This is of utmost important when a conventional boiler is used as the heat source for a snow-melting system.

The system must use a control that measures the inlet temperature to the boiler and reduces the rate of heat transfer through the mixing device supplying to the snowmelt system, when necessary, to prevent sustained flue gas condensation. The mixing device



The entire system is filled with glycol solution

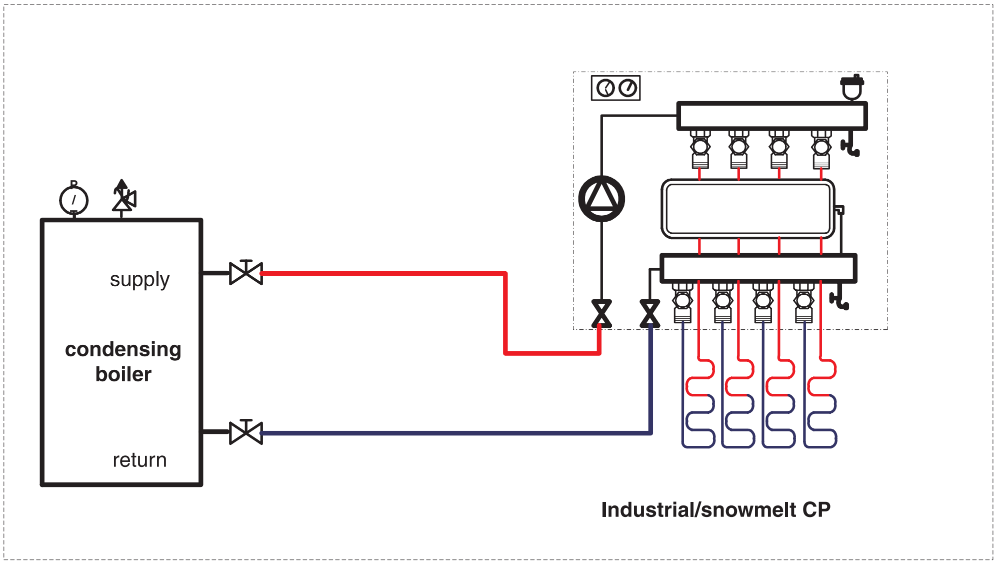


Figure 11-7

can be a 2-way, 3-way, or 4-way mixing valve or variable speed injection pump as discussed in section 3 and shown in figure 11-8.

Condensing boilers are well suited to the low operating temperatures of hydronic snow melting systems. In most cases there is no need to install a mixing device between a condensing boiler and the snow melt distribution system. If the condensing boiler is operated with the same antifreeze solution as the snow melt circuits, there is no need to install a heat exchanger. This minimizes the operating temperature of a condensing boiler and increases its efficiency.

Idling Pavement Surfaces

When the melting system starts from a cold temperature, it may take considerable time for the surface to reach melting temperature. To decrease this lag time, some snow melt controls can maintain the pavement at an “idling” temperature just above or below freezing.

If the pavement temperature is idled just above freezing, it will generally be free of frost and “black ice”, and be an important advantage in terms of safety. Idling the pavement just below freezing reduces standby heat loss, but still allows for rapid warm-up to melting temperature. Most controls let the installer adjust the pavement idling temperature.

Control systems with idling capability typically initiate the idling mode when the outside air temperature drops within a few degrees of freezing (35 to 40 degrees F.). Such air temperatures represent the possibility of frozen precipitation. Idling the system above these air temperatures is largely a waste of fuel.

To idle the pavement, the controller must sense pavement temperature. Typically, a small thermistor sensor is located within a “well” in the slab. This well is usually made of capped copper tubing that’s cast

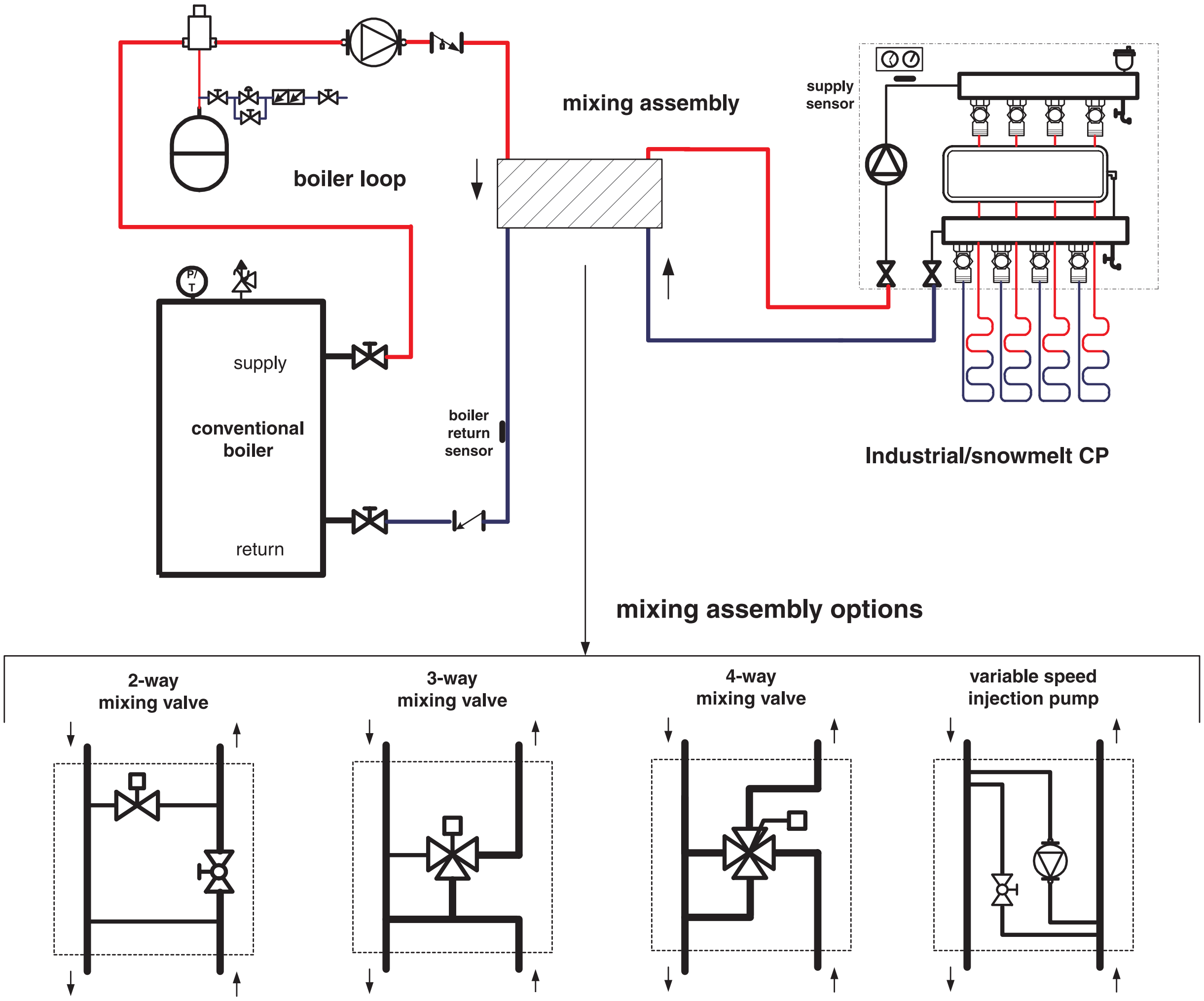


Figure 11-8

into the pavement. The position of the slab temperature sensor is crucial to the proper performance of the control system. The slab sensor is typically located 1" below the top of the pavement, and halfway between adjacent tube circuits. The open end of the well should lead to an accessible location so the sensor can be replaced if it ever fails. Be sure to follow the control manufacturers' recommendations regarding installation of the pavement temperature sensor.

Manual Melting Control

Systems can be designed with manually operated start and stop controls. Typically the system begins supplying heat to cold pavement when a switch is moved to the "on" position. Heat flows to the pavement as long as the switch remains on.

This approach is fine, provided someone pays close attention to the status of the snow on the pavement, and turns the system off as soon as melting is completed. If the attending person forgets the system is operating, it could run indefinitely (or until it runs out of fuel). The cost of unnecessary operation can be high, especially on larger systems. This possibility is the single biggest argument against a manual start / manual stop control system.

The next logical refinement would be a control system with manual start and automatic shut off. The system is shut off after a set time has elapsed. The time is selected by the person turning on the system based on the amount of snow and previous experience with the system. Overriding conditions such as very cold air temperatures, or sustained air temperatures above freezing, may also be used to terminate operation. The goal is to turn the system off as soon as melting is complete and the pavement is in the process of drying. The latter is important to prevent the formation of dangerous "black ice." Some manual start/automatic off snowmelt controllers also allow the pavement to be maintained at a set idling temperature.

Automatic Melting Control

More sophisticated snow melting controls are available that automatically detect frozen precipitation on the slab surface and initiate melting operation. They also terminate heat input when melting is complete. Most can also be configured to idle the pavement at a specific temperature when desired.

Fully automatic snow melting controls require a snow detection sensor. Some sensors are mounted directly into the top surface of the pavement and can detect when frozen precipitation is present, as well as measure pavement temperature. Other types of sensors are mounted above the pavement. They provide an electrical contact closure whenever precipitation is occurring AND the outside air temperature is below a given temperature.

Both types of sensors have a small heated cell at the top of their housing. Precipitation is detected by the electrical conductivity of the water on this cell. This, in combination with an air temperature just above freezing, provides the start-up criteria for the system.

Control systems that monitor pavement temperature tend to reduce fuel usage by allowing the system to maintain the pavement surface just a few degrees above freezing. The cooler the pavement surface, the lower the heat losses.

Many snow melting controls can also prevent or terminate melting if the outside air temperature rises above a preset value. In non-critical applications (class 1 systems), melting can also be prevented or terminated during very cold weather when heat loss would be excessive.

11-6 Circuit Design Information

Selecting the proper tube size, spacing and flow rate is an important part of system design. The section gives technical guidelines and formulas that can be used to evaluate the trade-offs and help optimize the system.

Flow requirements

The flow rate required for a snow melting circuit to deliver a given amount of heat to the pavement can be determined using formula 11-1.

Formula 11-1

$$f = \frac{q}{k \times \Delta T}$$

where:

f = required flow rate (gpm)

ΔT = temperature drop on the loop(degF)

q = rate of heat output required (Btu/hr)

k = a constant based on the concentration of antifreeze used (see chart below)

100% water	30% Propylene glycol	40% Propylene glycol	50% Propylene glycol
k=500	K=477	K=465	K=449

For example: the flow rate required to deliver 22,000 Btu/hr using a 40% solution of propylene glycol in a circuit operating with a 20 degree F. temperature drop is:

$$f = \frac{22000}{465 \times 20} = 2.36 \text{ gpm}$$

The rate of heat delivery required for many snow melting applications is considerably higher than that required for a typical floor heating system. To deliver more heat without excessive temperature drop, the flow rate in the embedded circuits must be increased. The use of glycol-based antifreeze solution (instead of 100% water) reduces the heat carrying ability of the heat transfer fluid, and further increases the flow requirement.

For example: the flow rate in a 250 foot long floor heating circuit, with tubing spaced 12" apart, delivering 25 Btu/hr/sqft with a 20 degree F. drop in water temperature is:

$$f = \frac{q}{500 \times \Delta T} = \frac{250 \times 25}{500 \times 20} = 0.63 \text{ gpm}$$

This flow is easily handled by a 3/8" or 1/2" tube.

However, the required flow rate in a 250 foot long circuit using tubing spaced 12" apart, delivering 150 Btu/hr/sqft with a temperature drop of 20 degrees F., and using a 50% solution of propylene glycol is:

$$f = \frac{q}{450 \times \Delta T} = \frac{250 \times 150}{449 \times 20} = 4.2 \text{ gpm}$$

This flow rate is well beyond proper range of application for a 1/2" tube.

The common solution to the high flow requirement of snow melting systems is to use larger diameter tubing. 5/8" Kitec pipe is commonly used in snow melting applications, while 3/4" diameter Kitec pipe is sometimes used in larger systems.

In some locations, such as steps, the bending limitations of 5/8" and 3/4" Kitec pipe does not allow it to be used. In these situations, use multiple shorter circuits of 1/2" pipe.

The following table gives suggested maximum circuit lengths for various sizes of Kitec pipe used in snow melting applications. These lengths assume a 50% propylene glycol solution is carried by the tubing, and that the allowable head loss is equivalent to that of a 300 foot long circuit of 1/2" Kitec pipe used in a typical floor heating application.

maximum	1/2" Kitec	5/8" Kitec	3/4" Kitec	1" Kitec
circuit length	180 ft.	250 ft.	400 ft.	560 ft.

Note the allowable length of 1/2" tubing circuit is approximately 50% that of 3/4" tubing. Likewise, the allowable length of a 5/8" Kitec tubing circuit is approximately 65% that of 3/4" tubing.

Circuit Head Loss

The head loss of the snow melting circuits along with the system flow requirements will determine the size of the system's circulator(s). It's important to select tube sizes and limit circuit lengths to prevent excessive head loss in snow melting circuits.

Formula 11-2 can be used to estimate the head loss and resulting pressure drop in Kitec tubing carrying a 50% solution of propylene glycol and water at a mean temperature of 100 degrees F. This temperature was selected as representative of average conditions is a class 1 (residential) system. The head loss is about 12% higher than predicted by the formula when the mean fluid is at 80 degrees F., and about 15% lower when the fluid temperature is 140 degrees F.

Formula 11-2

$$H_{loss} = c \times L \times f^{1.75}$$

where:

H_{loss} = head loss (feet of head)

c = a constant based on tube size (see table below)

L = circuit length (feet)

f = flow rate (US gpm)

1.75 = an exponent of the flow rate

c value	1/2" Kitec	5/8" Kitec	3/4" Kitec	1" Kitec
	0.062	0.0154	0.00526	0.00189

Circuit Temperature Drop

Most snow melting systems are designed with circuit temperature drops of 20 to 30 degrees F. under steady state operation. However, during start-up of a cold pavement, the temperature drop can easily be 3 to 5 times greater than this. This is why it's so important to protect a conventional boiler as discussed in the previous section. As the slab gradually warms up, the temperature drop decreases towards its nominal design value.

Temperature drops in excess of 30 degrees F. can result in uneven melting patterns on pavement surfaces. One novel approach to correcting this situation is to periodically reverse the flow through the tubing circuits. A motorized 4-way mixing valve that cycles from one end of its travel range to another based on signals from a time delay relay is one way to do this. This concept allows more even heat distribution to the pavement, and arguably could allow the system to use higher steady state temperature drops. The larger temperature drops would reduce flow rates and required pumping power. The concept is shown in figure 11-9.

Estimating Heat Output

The exact heat output of a heated exterior pavement depends on many simultaneous conditions such as air temperature, wind speed, relative humidity, snow coverage, rate of snow fall, pavement drainage characteristic, tube diameter, tube spacing, R-value of underside insulation, soil temperature and thermal properties of the paving. Many of these conditions change from one melting cycle to the next. Some of these parameters may not be known or readily obtainable by the designer. Thus, it is very difficult to develop a highly precise engineering model of a given

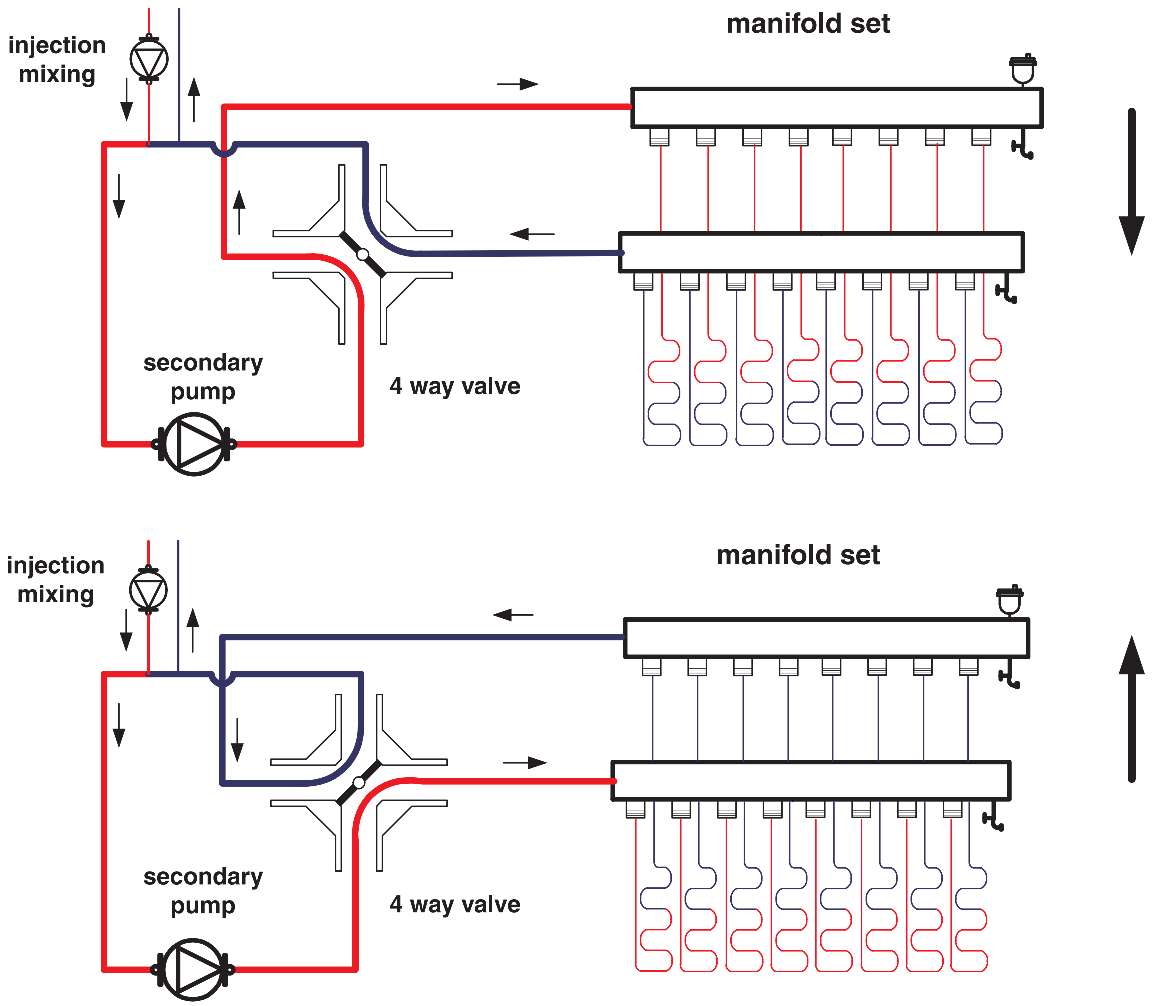


Figure 11-9

snow melting installation.

Formula 11-3 is an empirically derived relationship that can be used to approximate the heat output of a snowmelt slab using tubing spaced 12 inches apart, and covered with snow in the process of melting.

$$Q = 2 \times (MFT - 33)$$

where:

Q = heat output (Btu/hr/sq. ft.)

MFT = mean fluid temperature in the circuit (degree F.)

For example: assume a tube circuit installed at 12 inch spacing is supplied with 120 degree F. fluid and operates with a 20 degree F. temperature drop. The mean fluid temperature in the circuit is 110 degrees F. When the slab is covered with a film of water (from the melting snow), its rate of heat output is approximately:

Formula 11-3

$$Q = 2 \times (110 - 33) = 154 \text{ Btu/hr/sq.ft.}$$

Tube Spacing Factors

Figure 11-10 can be used to estimate the relative gain in heat output when tubes are spaced closer than 12 inches apart. Simply multiply the slab's heat output assuming 12 inch tube spacing by the multiplier to estimate its heat output, using the same mean fluid temperature, at closer tube spacing.

For example: if the pavement's heat output using tubing spaced 12 inches apart averages 154 Btu/hr/sq. ft., its estimated average heat output using 6 inch tube spacing, and the same mean fluid temperature is 154 x 1.34 = 206 Btu/hr/sq. ft.

The following tube spacings are suggested as a general guideline based on the system's class. Obviously closer tube spacing allow higher rates of heat delivery, albeit at a higher cost. Tube spaced more than 12" apart can lead to excessively uneven melting patterns, and is not recommended.

Class 1 systems: 9-12 inches

Class 2 systems: 6-9 inches

Class 3 systems: 6 inches

IPEX Radiant™ design software can be used for further studying the performance trade-offs of various tube spacing and fluid supply temperatures.

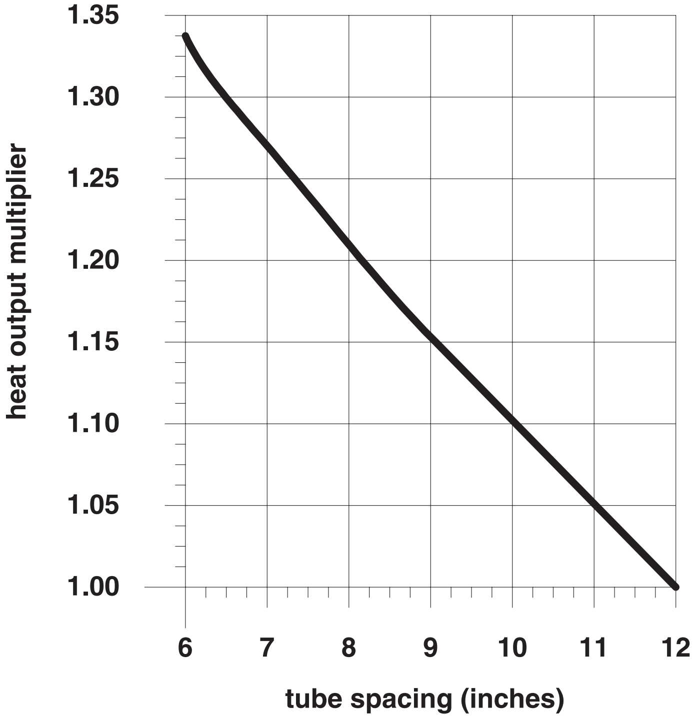


Figure 11-10

SECTION

12

IPEX RADIANT™ DESIGN SOFTWARE

The heating system is an integral part of building design and requires a specific and detailed design process. Heating engineers must analyze building location, function, occupancy and control requirements in order to select and design the proper system and specify the appropriate components.

IPEX offers the state-of-the-art IPEX Radiant™ Design software program to assist designers in calculating a number of the key design features of hydronic radiant heating systems.

IPEX Radiant™ greatly assists designers by performing the following tasks:

- Building heat loss calculations
- Floor output sizing to compensate for heat loss
- Floor piping details and specifications
- Control Panel and Manifold Selection
- Supply and Return Piping Design
- Temperature Control Selection Suited to the Project
- Project Material List and Report Generation

Project calculations are summarized in reports of varying details depending on your needs. Summary reports provide overall project design information while detailed reports present every aspect of your calculations.

IPEX Radiant comes complete with a WarmRite Floor component data base and prices. It lets you add non IPEX components to your own data base of heating items regularly specified and it creates customer and project data bases to assist in managing on-going designs and for future follow-up.

All of these features are compiled inside an interactive, user friendly software that gives designers the flexibility to create and specify the best possible hydronic radiant heating system.

IPEX Radiant™ Design Software System Requirements

The program is offered on CD-ROM and must be loaded onto the hard drive of your computer. Minimum operating system requirements are as follows:

Processor	Pentium 133 or greater
Hard Disk Space	50 MB
RAM	32 MB minimum; 64 MB or greater recommended
Video Adapter	VGA
Operating System	Windows 95, Windows 98, Window NT4 (SP5) or Windows 2000

Insert the disk and loading starts automatically. If the Auto Run does not start choose Start / Run, type D:SETUP then choose OK. The setup wizard will install the software onto your hard drive. Follow the screen prompts during this process.

When the installation is finished an icon will appear on your desktop, giving you access to IPEX Radiant at the click of your mouse.

The IPEX Radiant™ Design Software is supported with a Help Wizard and full program tutorial.

To obtain your personal copy of the IPEX Radiant™ Design Software, please copy, complete and fax through the required form on the following page.

REQUEST FORM
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Fax this completed form to 905-403-1124 to request your copy of the IPEX Radiant™ Design Software and/or IPEX Manual of Modern Hydronics.

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