Appendix I
Variable-speed Injection Mixing

This appendix outlines the use of variable-speed injection mixing to precisely transfer heat from the high-temperature boiler (primary) loop to the lower-temperature radiant (secondary) loop in hydronic heating systems.

Various devices and plumbing arrangements can be used to accomplish this transfer. In the past, it was common to use a mixing valve in order to temper the water between the primary and secondary loops in a system. In some instances, the heat source (condensing or electric boiler, geothermal heat pump, etc.) can be operated at lower temperatures and dedicated solely to operating a low-temperature radiant heating system. In the vast majority of systems, mixing is required because of one or more of the following:

- A boiler minimum operating temperature is required.
- High temperature water is required for other system needs.
- Water temperatures vary over a wide range (e.g. solar heat sources, waste heat utilization, wood fired boilers, etc.).

When the available heat source produces higher water temperatures than is required by the radiant heating system, a tempering device is required. To achieve the lower water temperature required for the radiant system, the high-temperature boiler water must be blended or injected into the return side of the radiant system to a level that meets the required supply water temperature for the radiant side. Technologies have evolved to the point of using small wet-rotor pumps to accurately adjust the secondary radiant supply water temperature regardless of the flow activities on either primary or secondary loops (see **Figure I-1**).

The speed of the injection pump is automatically adjusted to deliver the desired volume of hot boiler water to the lower-temperature radiant loop. The injection pump speed is constantly adjusted as the radiant heating system demand and the supply water temperature change. If the boiler return temperature becomes too cold, the injection pump can be slowed down to reduce the heat injection rate, resulting in an increased boiler return temperature.

Uponor offers a variety of controls that use variable-speed injection pump output. This output modulates the power supply to the circulator to vary its rotational speed. For residential and many commercial systems, the controls have a 120VAC 50/60Hz output to directly power small circulators.

A permanent-capacitor, impedance-protected motor (no start switch) on the circulator is required. The maximum allowable amperage for this output is 2.2 amps, which limits the allowable circulator size to ⅙ hp.

This type of system can use a small circulator to inject a high BTU/h input into a relatively large system flow. Typically, the injection pump only needs to deliver ⅙ to ¼ of the system flow for low-temperature radiant panels if high-temperature water is available for injection. In small hydronic systems, the smallest available circulator for variable-speed injection may be too large. It is important to properly size the injection pump and use a globe valve on the return injection leg.

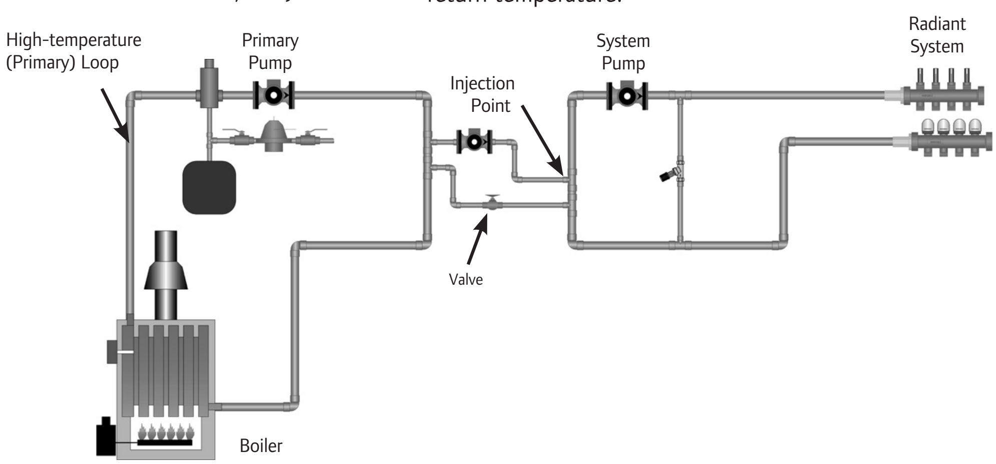

Figure I-1: Mixing with Variable-speed Pump

For proper injection pump sizing, the designer must know the following information (see **Figure I-2**).

F_V = Flow rate (injection loop) in gpm

F_1 = Radiant (secondary loop) flow rate in gpm

T_1 = Boiler (primary loop) supply temperature

T_2 = Radiant (secondary loop) supply temperature

T_R = Radiant (secondary loop) return temperature

T_D = Radiant (secondary loop) temperature differential (T_2 - T_R)

Note: All values are to be given at design conditions.
The formula used for sizing the injection pump is shown below.

$F_V = (F_1 \times T_D) / (T_1 - T_R)$

Example:
If values at design conditions are:

F_1 = Radiant (secondary) flow = 30 gpm

T_1 = Boiler (primary) supply = 180°F

T_2 = Radiant (secondary) supply = 140°F

T_R = Radiant (secondary) return = 120°F

T_D = Radiant (secondary) differential = 20°F

To find the injection pump flow rate:

$F_V = (30 \times 20) / (180 - 120)$

$F_V = (600) / (60)$

F_V = 10 gpm

In order to provide the proper amount and temperature of supply water on the radiant heating loop, the variable-speed injection pump needs only to inject 10 gpm at design conditions.

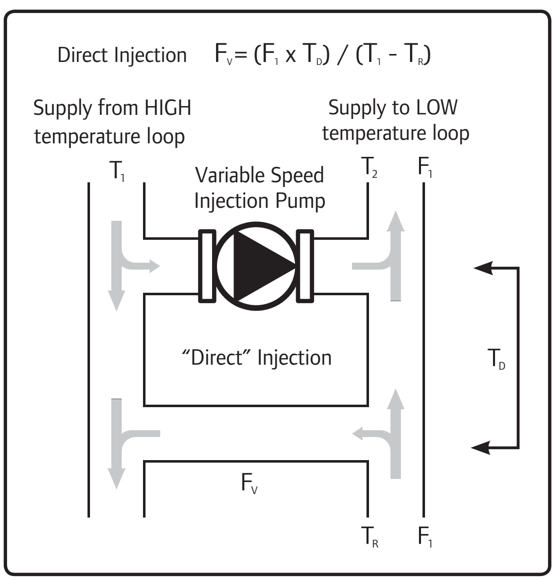

Figure I-2: Direct Injection Mixing (F_V Formula)

Figures I-3 and I-4 show the two most common piping layouts for variable-speed injection mixing. Pay particular attention to the drop lines (or thermal traps) shown in the injection legs. These are particularly important to prevent "thermal siphoning" from the primary loop into the secondary loop. Consult the pump manufacturers' chart (below) to assist in the selection of the proper injection pump for the project.

In the piping arrangement shown, the variable-speed injection pumps are plumbed this way to limit head pressure in the injection legs to only a few feet at most. Use standard pressure drop calculations and equivalent length of feet charts for exact calculations, if required.

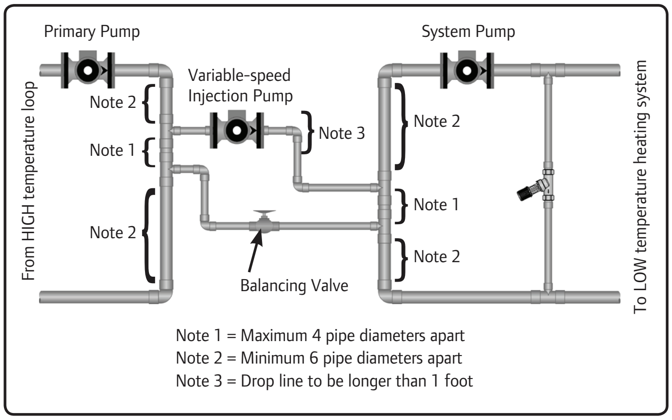

Figure I-3: Injection into a Horizontal Loop

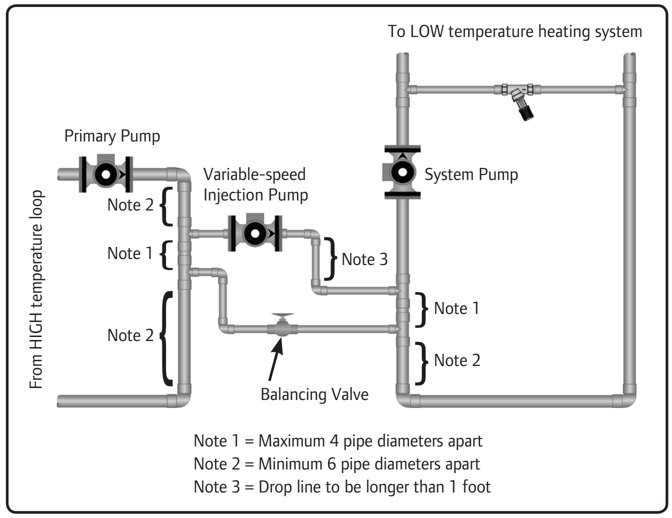

Figure I-4: Injection into a Vertical Loop

Variable-speed Injection Design Flow Rates

Design Injection without Globe Valve	Flow Rate (gpm) with Globe Valve	Turns Open of the Globe Valve (%)	Nominal Pipe Diameter (inches)	Manufactured Approved Pump Models												
				Grunfos (F)				Taco				B&G			Armstrong	
				15-42		26-64	43-75	003	007	0010	0012	NRF 9	NRF 22	NRF 33	Astro	
				2*	3**										30	50
-	1.5	20	0.5	X	X				X				X		X	
2.5	2	100	0.5					X								
4-5.5	3.0-4.5	100	0.5	X	X				X			X	X		X	
4.5-6.5	4-5.5	100	0.75					X				X				
9-10.5	7.5-8.5	100	0.75		X				X				X		X	
9	8	100	1									X				
14-15	12-13	100	1		X				X				X			
19	17	100	1.25													X
22-24	19-21	100	1.25			X				X				X		
26-28	-	100	1.5			X				X				X		
35-37	31-32	100	1.5				X				X					
33	30	100	2											X		
41-45	39-42	100	2				X				X					

*Speed 2, **Speed 3 (Brute)
Table courtesy of Tekmar®. This table assumes 5 feet of pipe, four elbows and branch trees of the listed diameter. These circulators have been tested and approved by the manufacturers for use with the Uponor controls.