Montpelier District Heating System

Montpelier, Vermont

STANDARDS AND GUIDELINES FOR DESIGNING HEATING SYSTEMS IN BUILDINGS CONNECTED TO A HOT WATER DISTRIBUTION SYSTEM

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CUSTOMER CONNECTION STANDARDS FOR DISTRICT HEATING

1. INTRODUCTION

The following basic design standards have been prepared for the Montpelier District Heating ("Utility Company") to assist district heating customers and installers in understanding the system connection, design parameters, and heating hot water service requirements.

This manual is designed to present technical information concerning the installation, operational reliability, and minimum standards governing system installations according to the Vermont Division of Fire Safety (VFBSC) 2012. This code references the International Building Code (2012) and all other codes referenced within.

Installations designed in accordance with these guidelines should operate satisfactorily with minimal maintenance operating costs. Operating and maintenance costs are reduced through the simplicity of circulating water systems with high efficiency pumps, and the use of control valves and/or variable speed pumps for accurate system control. The systems described may be modified if necessary to meet specific building needs, but it should be noted that more sophisticated systems generally have lower system reliability and higher maintenance costs.

The Utility Company's hot water is provided from the State heating plant located at 122 State Street in the winter months and from City Hall located at 39 Main Street in the Summer months. The Utility Company circulates the hot water through underground pipes to supply and return water from the customers. To service a building connection from the primary hot water network, pipes are sized for the building load and extended through the building foundation walls. The service connections for the supply and return water are terminated with shut off valves that are reserved exclusively for the Utility Company's servicing requirements.

For best efficiency, a hot water system needs the lowest feasible return water temperature from the district heating network. Under heating design day conditions, the Utility Company provides 220° F hot water at pressures up to 100 psig. Heat exchangers are required for all installations to exchange heat to the building while providing isolation from the distribution supply temperature and pressures.

2. PRIMARY HOT WATER SYSTEM DESIGN

2.1 System Temperature

The Utility Company supplies hot water to its distribution system at a temperature which is set according to the heating and non-heating months.

Table 2-1 Primary Hot Water Loop Temperatures

Temperatures	Heating Season Approximate Period (October 1 through April 30)	Non-Heating Season
Hot Water Supply	220° F	180° F
Hot Water Return	170° F	160° F

Based upon the table above, the highest District supply temperature is 220° F and the lowest is 180° F during the summer. The heat exchangers shall be selected so water provided to the building systems is at least 50° F lower in temperature than the primary supply water during the heating season. Otherwise, the building return temperature to the heat exchanger and consequently the district return hot water will be above 170° F, causing an increase in the required primary flow rate and a reduction in the capacity of the hot water distribution network which is designed for a 50° F temperature difference.

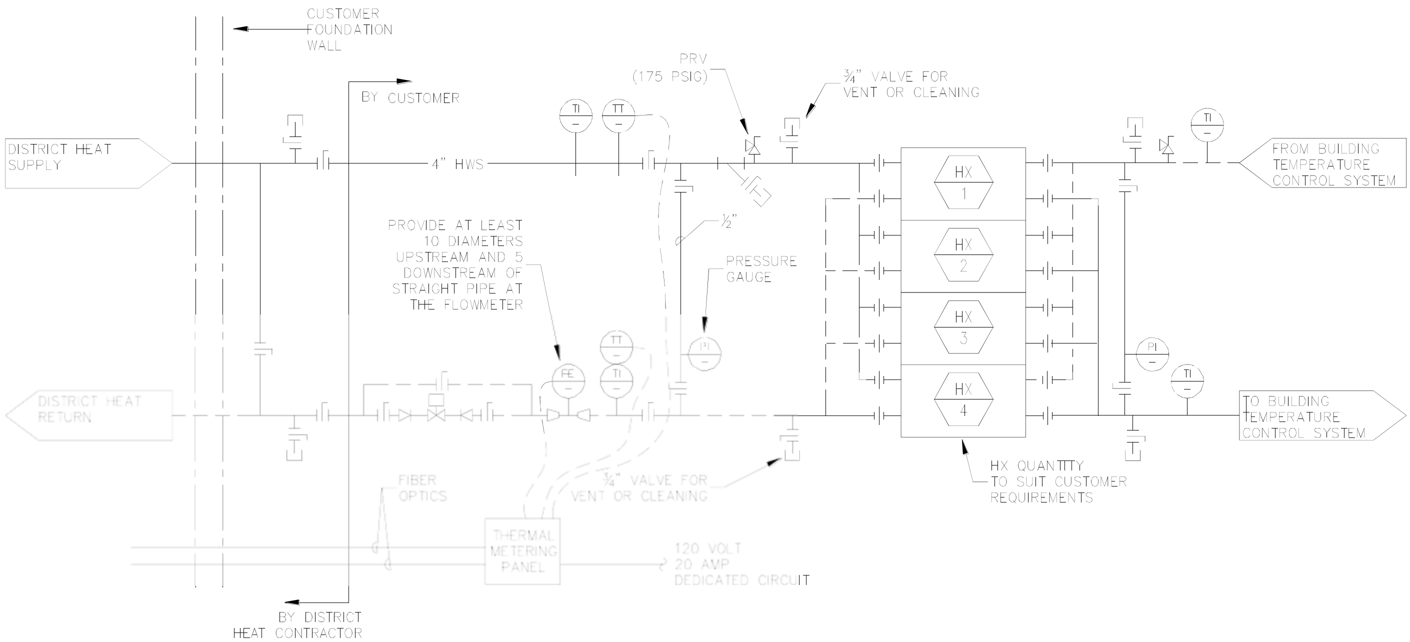
To ensure the system economics are met, minimum requirements were established for all customers. One of these requirements, written in the contract between the customer and the Utility Company, is that the temperature of the primary return water from the customer's building is maintained below 170° F. The most efficient use of low grade heat for a district heating system is obtained when low temperature water is returned from the customer to the plant after hot water is used for the customer's heating needs. Adherence to this standard benefits everyone because system efficiency is increased which lowers the customer's district heating costs.

2.2 System Pressure

The system will operate at a maximum pressure of 100 psig. All the Utility Company customers are required to connect to primary service valves with piping systems rated for 150 psig, and able to withstand 195 psig surge pressure to the heat exchanger.

3. SECONDARY SYSTEM DESIGN

Figure 3-1 Utility Company Typical Interface



The primary hot water distribution system exceeds the temperature and pressure limits of general space heating equipment. Isolation is accomplished through a heat exchanger to transfer the heat energy to the building, secondary loop.

The automatic control valve on the primary side modulates the flow through the heat exchanger in order to maintain a constant heat exchanger primary loop discharge temperature.

The building loop supply water temperature is controlled by increasing or decreasing the secondary water supply flow through the heat exchanger.

- On small installations, secondary flow through the heat exchanger may be controlled by a 3-way mixing valve.
- On larger installations, secondary flow through the heat exchanger may be controlled by variable speed hot water circulating pumps.

The secondary loop pump head pressure is calculated for pipes, equipment in the system, and motorized valves. The pressure difference varies depending on the valve positions in response to zone heat load. This change in system pressure can be managed to a single pressure set point by regulating the pump speed with a variable frequency drive which will save electrical energy by reducing the flow. The reduction in flow will also increase the temperature drop across the heat exchanger.

Energy can also be saved in buildings by lowering the supply water temperature during unoccupied hours at nights or on holidays. This process can be automatically controlled through the building automation system with programmed set points and schedules.

3.1 Secondary System Design – Space Heating

When designing new systems, the starting point for calculating water temperature should always be the return temperature on the secondary side, which should be kept as low as possible. This can be accomplished on most systems without increasing costs by proper selection of coils. A large temperature drop in the secondary system can allow for reductions in pipe sizes and installation costs.

Table 3-1 Common Design Temperatures for Heat Exchangers

	Primary Side		Secondary Side	
Type	Temp In Deg F	Temp Out Deg F	Temp In Deg F	Temp Out Deg F
Air Side[1]	220	170	140	180
Hot Water Radiation	220	170	160	180
Reheat	220	170	140	170
In-Floor Radiation	220	170	115	140
Domestic Hot Water[2]	180	160	95	130

[1] Typical of air handling coils, fan coils, unit ventilators, etc.

[2] Domestic hot water heating mixes city water in storage tank

Extending hot water service from the Utility Company's isolation valves inside the building is sole responsibility of the customer, with the exception that the Utility Company will provide sensors and metering equipment for monitoring energy usage. Primary water from district heating systems is never used directly in heating coils, radiators, etc. rather, the thermal energy is transferred through a heat exchanger before distribution within a building. Heat exchangers, control valves, pumps, and all other piping and related items are to be supplied and installed by the customer.

Only one common distribution system is generally required in a building, utilizing pumps to distribute water to all heat loads. Secondary systems can also be separated by pumps operating for different rooms, areas, or buildings, but connected to the same heat exchanger. Note: It is recommended that the system pump utilizes a variable frequency drive (VFD) and differential pressure sensor located at points across the furthest heat transfer equipment for proper control.

Generally, there is little advantage in separating ventilating and space heating loads into separate systems with separate heat exchangers. Multiple heat exchangers installed for redundancy and servicing purposes do ensure backup and ease of any future maintenance. A separate heat exchanger system may also be advantageous when supply water temperature requirements differ considerably. In such a case, the temperature of the combined return water from the ventilation system and the direct radiation system is low enough to satisfy the minimum requirements of the primary distribution network.

3.2 Secondary System Design – Domestic Hot Water

Domestic hot water generation utilizes a double wall heat exchanger, as mandated by the plumbing code, to isolate district hot water service from potable supply. Domestic hot water generation is typically designed with a storage tank and circulation pump layout to provide a mixing chamber for city water and the hot water from the heat exchanger. See Figure 3-3 and 3-4 “Typical Domestic Hot Water Piping” and “Alternate Domestic Hot Water Piping”. This design eliminates the thermal shock of the cold water supply to the heat exchanger and reduces the temperature variance in the storage tank. The domestic hot water storage tank temperature needs to be set at a minimum of 120° F.

In remote and isolated areas of buildings, a hydronic sub circuit can be added to the secondary side of the building heat exchange for providing domestic hot water service. The exchanger must maintain the supply water temperature at least 20° F below the lowest summer water temperature in the secondary system.

Supply water temperature is maintained by utilizing an aquastat and/or setpoint controller for modulating the control valve or a packaged, self-operating control valve and temperature sensor. Sensor location is critical to ensure proper utilization of the system storage and prevent temperature fluctuations.

The domestic hot water heat exchanger should always be selected with a minimum fouling factor of 20%. This is essential when generating domestic hot water, because of the lime build-up on the heating elements of the heat exchanger. This condition becomes critical when the domestic water temperature is above 130° F. Clean in place ports are necessary for both sides of the heat exchanger. See also Section 7.3 “Preventive Maintenance: Heat Exchangers”.

Figure 3-2 Typical Domestic Hot Water Piping

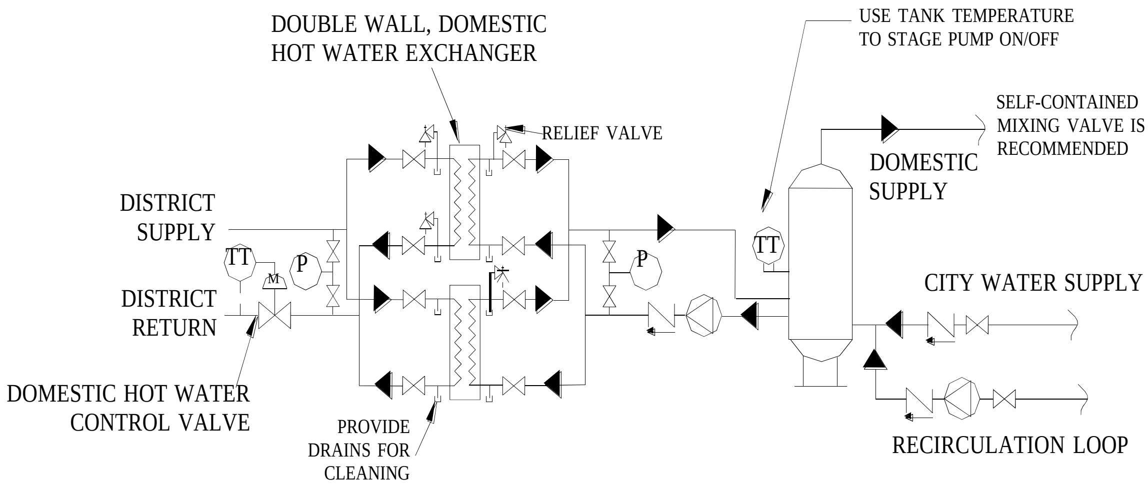
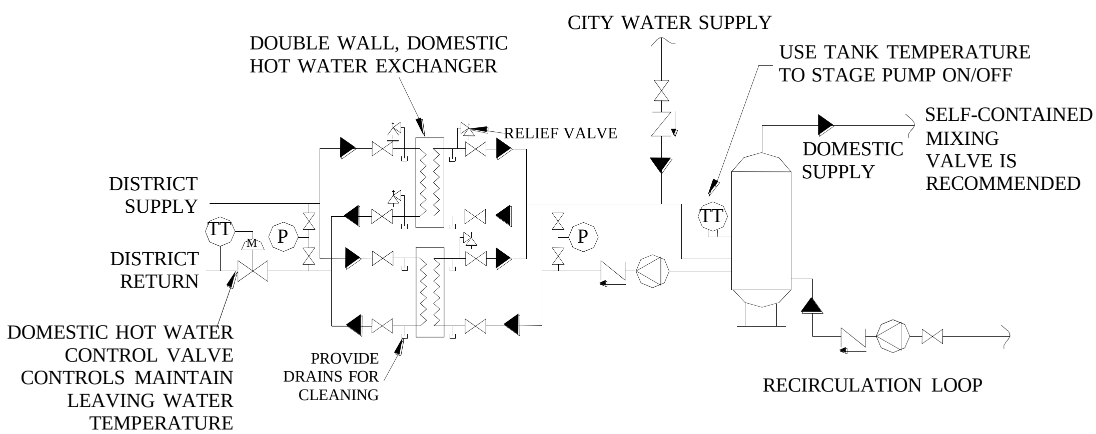


Figure 3-3 Alternate Domestic Hot Water Piping



Note 1: Relief valves must be installed on the both sides of the heat exchanger to protect against conditions that result in over pressurizing the heat exchanger.

Note 2: Domestic water systems that have end use devices with quick-closing valves such as dishwashers and multiple washing machines must have adequate shock arrest type devices installed to ensure normal heat exchanger life expectancy.

4.0 DISTRICT HEATING INTERFACE - PRIMARY SYSTEM DESIGN

4.1 District Piping and Insulation

All piping shall be standard weight, carbon steel pipe, schedule 40, unless otherwise noted. Fittings must be of the same material, finish, and strength as its associated piping. All piping on the primary side is recommended to be welded, however threaded piping with 250 psi rated fittings is acceptable. As accepted per ASME codes, copper Type “L” piping with brazed connections are also allowed on service applications under one inch.

The piping, valve body, etc., on the primary side shall have insulation based on the peak media temperature for the thickness specified in the Vermont Commercial Building Energy Standards.

4.2 Isolation/Shut-off Valves

Valves on the primary district hot water supply and return piping shall be provided by the customer. Isolation valves can be of ball (preferred) or butterfly type, but must be designed for not less than 150 psig working pressure and ensure a positive close off.

4.3 Pressure and Temperature Gauges

Pressure gauges and thermometers shall be installed where indicated in the typical piping diagram on the primary side and across the heat exchanger on the secondary side as shown. The thermometers shall be installed into wells for ease of replacement. The unit should be an industrial glass thermometer or comparable model with a scale graduation of 30° F to 300° F and must be accessible and easy to read. Round-face bimetallic, adjustable angle thermometers are also recommended

Pressure gauges should have 4-1/2" diameter dials with white backgrounds and sharp graduations or digital readouts. Gauges should be graduated in pounds per square inch (psi), have a range of one and one-half times the operating range of the system, and have ASME Grade A accuracy. Locating a single, common gauge with connected piping and proper isolation valves allows for accurate readings by negating any gauge offset.

4.4 Metering Equipment (Thermal Meter/Flow Meter/Temperature Sensors)

The energy meter is typically installed adjacent to the heat exchanger installation. The meter collects supply and return temperature and flow information to record and transmit the building energy usage back to the Utility Company. The temperature sensors – known as resistance temperature detectors (RTDs), and related thermo wells are provided by the Utility Company. The flow meter is installed in the district heating return pipe. See Figure 3-1 in Section 3. Meters will be sized by the Utility Company in accordance with information supplied by the mechanical engineer for the system load. To ensure uniform flow and accurate flow measurements, there shall be a length of straight pipe <u>ten times (10X) the pipe diameter of the flow meter at the inlet of the flow tube</u>, and a length of straight pipe <u>five times (5X) the pipe diameter at the outlet of the flow tube</u>. Shorter lengths are allowable, with permission from the Utility Company.

Temperature sensors (transmitters) for the meter are required to be installed with the tip of the probe in approximately the center of the pipe and positioned into the flow. An optional location for the RTDs is in a pipe ‘tee’, such that the sensor is placed into the flow as the flow is diverted into the branch of the tee. A strainer with a mesh perforation of 3/64 to 1/16 inch is required to protect the heat exchangers. As depicted in Figure 4-1 the strainer requires upstream and downstream pressure taps for strainer service inspection as well as the ability to read supply and return pressure through use of one pressure gauge.

The installer is required to run the Utility Company’s fiber optic communication cable from the service entrance to the metering equipment.

The Utility Company will furnish and provide final wiring and termination of the thermal meter in each building. The Utility Company will furnish customer with flow meter to be installed by the building contractor and the temperature wells for the RTDs to be installed by the building contractor.

4.5 Temperature Controls

The primary district water temperature is reset according to the heating season. The heat exchanger is intended to operate at a constant primary loop return temperature. Primary hot water flow through the heat exchanger is controlled by a modulating control valve, which is controlled by the primary hot water return temperature sensor.

- When the building is not calling for heat, the primary loop control valve may be fully closed.
- When the building again calls for heat, the controller shall command the primary loop control valve open in order to initiate flow and begin to provide heat. Once flow has been established, the primary control valve can return to being controlled by the primary loop return temperature.
- It is recommended customer control systems include some method of periodically opening the valve during heating periods when the district heat control valve is closed, to ensure the controls are adequately sensing the return water temperature.

It is recommended that the temperature on the secondary side be reset from the outdoor/indoor temperature controller. The secondary side temperature must be kept as low as possible to keep the coil flow close to design figures and to optimize the operation conditions for the control valves. A stand alone or a network controller can monitor outdoor temperature and reset the building loop temperature. This technique will reduce energy costs while maintaining comfortable interior temperatures.

The controller for the control valve shall have an interface that is easy read and to set, so the set points that can be easily checked by the building engineer or customer. The importance of freeze-up protection cannot be overstressed because local winters can produce strong winds with severe cold conditions. Even if a large amount of recirculated air is returned to and air handling system, coil freezing may still occur without proper monitoring and freeze protection logic.

4.6 Control Valves

Depending on the heat load design, normally, one motorized control valve is installed for smaller installations with service lines under three inch. For three inch and larger service it is advisable to use two valves operating in a one-third and two-thirds sequence for the total capacity. In some cases - when safety requirements are high or equal loads are desired for all exchangers - it may be advantageous to install one set of control equipment for each heat exchanger. All curves must be set equal in these cases, but a temperature variation of a few degrees is acceptable as long as the average temperature is correct. It is very important that temperature sensors be located by the exchangers being controlled rather than in the common pipe. Improperly located sensors will cause one control valve to open and others to close, resulting in unequal loads in the exchangers. Care should be taken to size control valves correctly; oversized valves will shorten valve service life and cause hunting in the secondary system.

Hot Water District Heating System pressure varies depending on the location of the customer's building. The Utility Company has the information on the minimum and maximum pressure anticipated. This information will be essential in the proper selection of control valves for heat exchangers. The correct size of valve should be designed for each system for proper building system control and to minimize the noise, cavitation, and general wear on valves.

The motorized control valve shall be designed for a maximum pressure of 150 psig and a maximum temperature of 220° F. Materials shall consist of a cast iron, bronze, or steel with screwed or flanged connections. The valve shall be equal percentage type with a spring-loaded Teflon V-ring. Motorized control valve for heat exchangers shall have a minimum rangeability of 30:1.

Control equipment should be electronic. Electric control valve actuator shall maintain in their set position during power interruptions. The actuator shall be equipped with a manual override in the event of a loss of control signal. The operation mode should be proportional-integrating (PI), i.e., dictated by temperature accuracy and response time. Close temperature control is desirable for low energy consumption.

The valve shall be designed with a minimum of 50% of the pressure drop of differential pressure allowed by the Utility Company at the customer’s site at full flow and capable of withstanding a maximum pressure drop of 110 psi without cavitation and excessive noise generation. Design pressure losses for the control valves can be determined by subtracting pressure losses through the heat exchanger, energy meter, strainer, and pipes from the value of the minimum pressure difference between the supply and return lines at the design outdoor temperature 20° F. Control valves are installed in the return line for two primary reasons: return water has a lower temperature, which increases the life of the valve seals and actuators and improved control by reduced valve cycling.

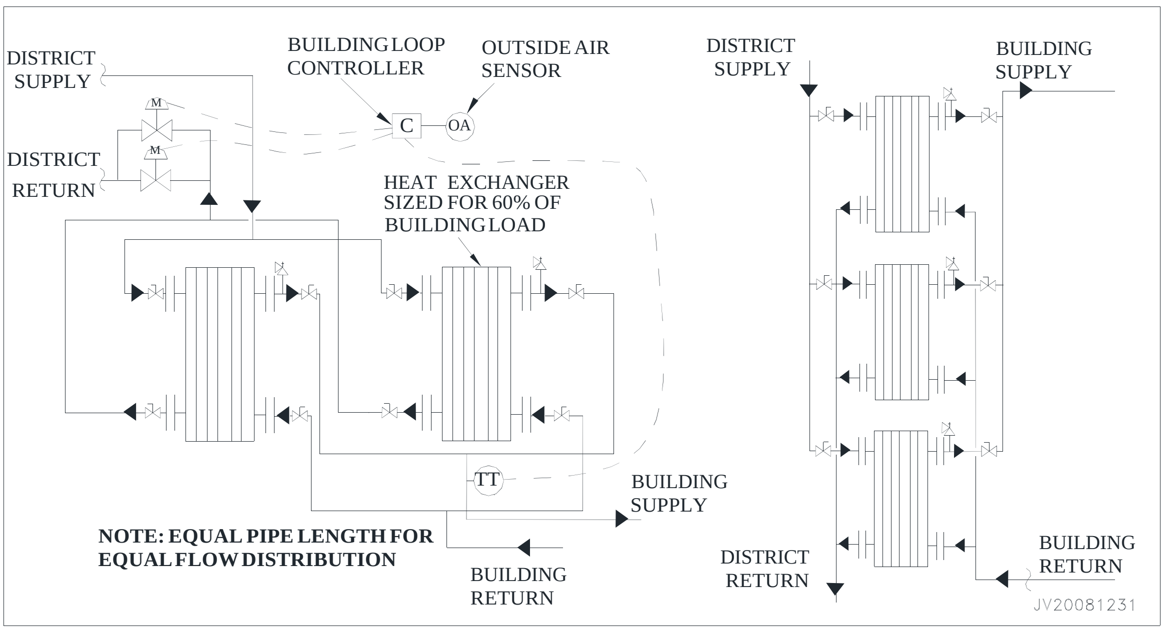
4.7 Heat Exchangers

Although heat exchangers are very reliable, at least two units (each designed for approximately 60% load capacity) are recommended for space heating. One heat exchanger can carry the full load for 80-85% of the heating season, but if both exchangers are operating continually, the return temperature can be lowered. Heat exchangers should be connected in parallel for uniform load (see Figure 4-2 below).

Heat exchangers are selected based on system design with operating temperatures based on Table 3-1. Based on the size of the building load, the Utility Company can assist with a recommendation for the heat exchanger. The Utility Company has selected a heat exchanger as the standard and obtained completive pricing on common sizes.

The engineer must choose a heat exchanger based on system design load and guidelines. Heat exchanger designs must be brazed plate exchangers and compatible with the requirements of the district heating system and the needs of the building. Plate heat exchangers usually utilize 316 stainless steel. The maximum primary side design pressure shall be 150 psig with a test pressure of 195 psig. The maximum secondary side design pressure shall be 150 psig with a test pressure of 195 psig. Fouling allowance should always be included. The fouling allowance will depend on the mineral content in the water.

Figure 4-1 Principal Connection Methods for Uniform Flow



4.8 Safety Valves

Safety relief valves shall be designed according to ASME codes. Each valve should be piped on the secondary side with proper floor drain routing installed. Safety valves shall be sized to relieve 100% of the heating capacity. Pressure and temperature safety relief valves are required for all heat exchangers (primary and secondary sides), and pressure vessels including domestic hot water heat exchangers and to be located on the building supply side.

5.0 CUSTOMER INTERFACE – SECONDARY SYSTEM DESIGN RECOMMENDATIONS

5.1 Distribution Pumps

Two distribution pumps are normally installed for back-up and to operate in a lead/lag fashion. The pumps are usually shut down during the summer when no heating is required, but some small loads may still require heat (e.g., reheat, small domestic water heaters). A small pump can be installed to serve these units rather than using the larger pumps. Smaller pumps might also be advantageous in buildings where large loads are shut down on nights and weekends.

Pump heads must be calculated carefully, as oversized pumps have a negative influence on the controllability of the motorized valves. Operating conditions for the motorized valves become unsatisfactory at pump heads exceeding 15 to 22 psid. Flat pump curves should be chosen to prevent the system pressure from rising during low use conditions. Pressure increases between the calculated working point and the zero flow point should not exceed 3 psi.

If a steep pump curve cannot be avoided, a differential pressure sensor must be installed with a variable frequency drive (VFD) to modulate the pump output. Refer to the typical large and small building diagrams. The pressure sensor should be located across the heating coil at the farthest location of the system to provide feedback to the VFD for maintaining system pressure. A strainer shall be installed in the return pipe to protect the heat exchanger, pump, and control valves from debris damage.

5.2 Expansion Tanks and Air Removal

A water expansion system should be installed for every closed loop system. Any standard device such as a diaphragm tank should be sized for the proper volume expansion calculated for the system.

Air control should also be considered when converting an existing steam system to hot water heating. Entrapped air may result in pump cavitation, inefficient water circulation, and a potential lack of heat transfer resulting from suspended air pockets.

5.3 Control Valves – Building Heating Equipment

Secondary heating systems operate with a variable flow rate and a variable pressure difference between the supply and return pipes. It is very important that the control valves be sized correctly to maintain the correct temperature and to minimize energy use. Safety factors should not be included in the valve calculations. Motorized valves shall be sized according to the specific flow and pressure drop of the coil When the most remote valve has been sized, the pressure drop is obtained by adding the drop through the pipes, bends, valves, heat exchangers, and served equipment (such as air handlers or radiators), if the latter do not have circulating pumps of their own.

The pressure drop for valves serving air heaters and water heaters is usually assumed to be equal to the pressure drop through the heating elements. When a circulating pump is installed for the air handler, pressure drop over the air handler is handled by the pump. The pressure drop through the control valve must be considered in the pump head calculations. When sizing the motorized valves, the main pump head must be considered, and valves located closer to the pump must be sized for considerably higher pressure drops.

6.0 PROCEDURE FOR CONNECTING HOT WATER SERVICE

6.1 Engineering Standards and Regulations

Engineering standards for the safety of unfired pressure vessels shall follow the current edition and current published revisions and interpretations of the construction codes of the American Society of Mechanical Engineers (ASME). Heat exchangers are pressure vessels that must conform in every detail to the boiler pressure vessel requirements of the State of Vermont and the rules and regulations adopted by the Vermont Fire and Building Safety Code (VFBSC). Each heat exchanger is required to be stamped with the ASME code symbol.

Any pressure piping to the heat exchanger or pressure vessel appurtenances - such as valves, meters, and gauges - shall be hydrostatically tested to ensure that it can withstand the peak temperature and pressure of the district heating distribution system. This Standard serves as a guideline but cannot define a successful heating system for every instance.

6.2 Drawings and Specifications Requirement

Customers are not required to provide drawings of their heating systems to the Utility Company for review, but can request a review if they choose. The owner/installer is responsible for the design, functionality and operability of their heating systems.

6.3 Mechanical Room

It is essential that engineers and contractors coordinate their design work with the Utility Company for design and installation parameters and building's service entrance. The location of the mechanical room will determine how the district heating piping will be supplied to the building and serviced. The room shall be sized in accordance with the State Building Code, and it shall be accessible for inspection and maintenance. The mechanical room space must be sufficient to allow for easy serviceability for routine maintenance and future heat exchanger removal. The room shall be locked to keep out unauthorized people. Personnel from the Utility Company must be able to enter the room unassisted.

6.4 Construction Process

Examination of the plans and specifications by the Utility Company and approval of the drawings for installation does not relieve the owner/installer of this responsibility. The owner/installer must arrange access for observation of the installation by the Utility Company on both the primary and the secondary sides. If, in the opinion of the observer, there is an improper installation or installed materials do not meet the minimum standards, remedial action must be taken to satisfy the minimum requirements presented in this section.

6.5 Service Start Up

Before the heat exchangers are put into operation the building piping must be cleaned and flushed prior to pressure testing.

A. System Cleaning/Flushing Primary Service Pipe:

- For primary system side cleaning the Contractor will connect the primary supply and return piping for the Utility Company system into a loop. Next, with the contractor's pump, a solution of a pipe cleaning compound (non-phosphate TSP substitutes are commonly used for this purpose) shall be circulated through the piping for 24 hours (or less if it is a small amount of piping). Contractor to use the product manufacturer's recommend solution rate, typically about ¼ cup of non-TSP for every 2 gallons of water.
- Following the cleaning, drain the entire system, refill and flush the piping with city water for sufficient period of time to remove all cleaner, weld slag, oils, bacteria, etc.
- When sufficient flushing has been performed (as much as 24 hours of clear city water flush), fill with city water and contact the Utility Company. The Utility Company representative will perform a visual check of the water clarity, no visual discoloration or particulates shall be present in order for the system to be accepted. This ensures that the excess cleaner and other contaminates are sufficiently removed from the water. If necessary, additional flushing may be required until an acceptable clarity is achieved.

B. Pressure Testing (Hydrotest) for Primary Service Pipe:

- Hydrotest the primary piping system with the heat exchangers isolated to 150 psig for a minimum of 15 minutes, or as needed for a representative from the Utility Company to perform a visual inspection of each joint. To protect the heat exchanger, the building side piping shall be filled and isolated to provide counteracting pressure within the exchanger. A Utility Company representative must be present to observe this test. Only the Utility Company representatives are permitted to operate mainline service valves for start-up operation.
- Building side pressure testing should be limited to the architects/engineer's specifications for the project. This testing work is provided under the direction of the building owner/installer.

6.6 As Built Drawings

Upon completion of the conversion work, a set of mechanical as built drawings are requested to be sent to the Utility Company to be kept on file. The drawings may be hardcopy however electronic PDF versions are preferred.

7.0 PREVENTIVE MAINTENANCE

7.1 Water Treatment

The Utility Company maintains the water quality in the primary system.

In a closed water loop system (on the secondary side of the heat exchanger) where make-up water requirements are low, the chemical water treatment is limited to the removal of corrosive properties and control of scaling in the heat exchangers. The chemical treatment must be non-toxic and non-damaging to the heat exchanger or other components. Water treatment testing should be conducted routinely and monitored for changes.

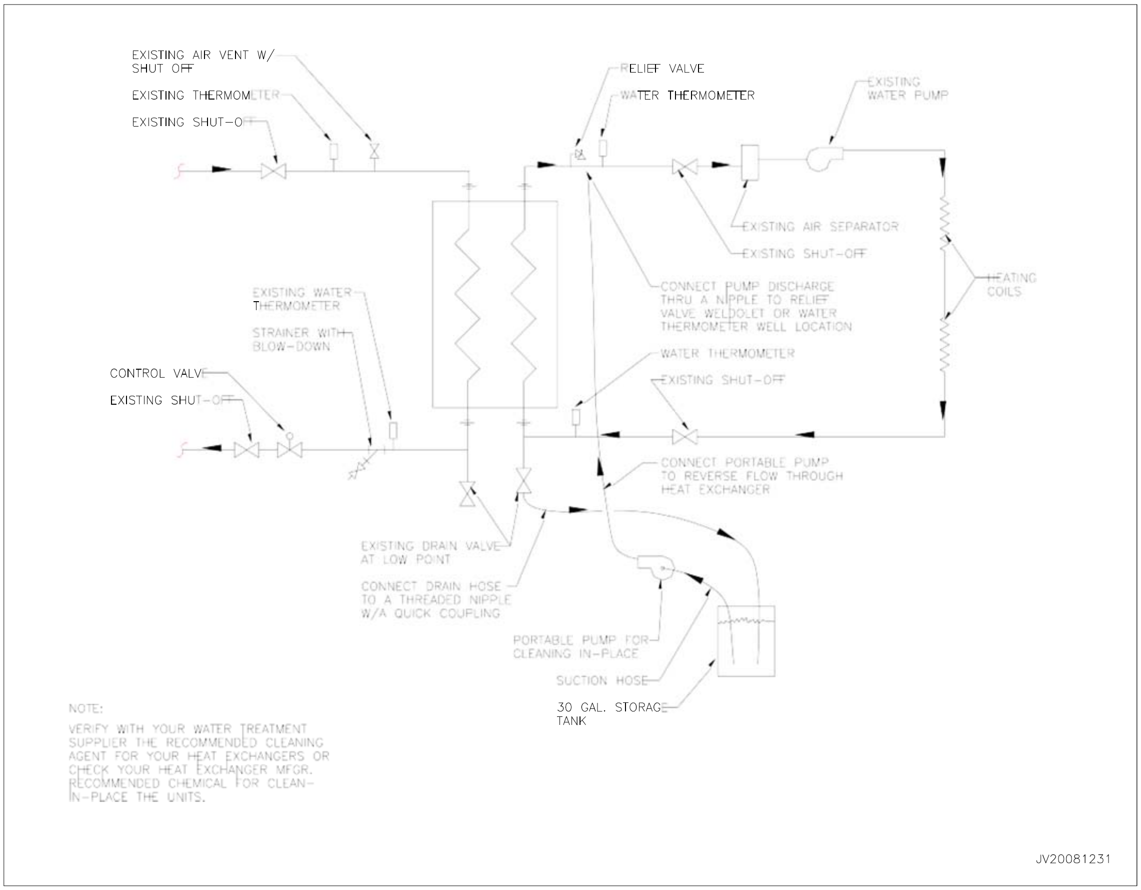
7.2 Strainers

Strainers typically should be operated at less than a 2 psid pressure drop. Strainers located on both the primary service and the secondary building side should be inspected and maintained annually.

7.3 Heat Exchangers

Heat exchangers are a critical component of the district heating system. Scale and deposits will over time reduce the efficiency and the water flow through the heat exchanger. Periodic flushing is possible for both sides of the heating exchanger through the use of installed service ports. See Figure 7-1 below. Pressure gauges on either side of the heat exchanger will also indicate if deposits are forming and pressure differential increases above 5 psid or the design pressure drop.

<u>Figure 7-1</u> Heat Exchanger Cleaning Procedure



7.4 Control Valves

Control valves must have leak free stems and be able to provide full range of operation. Operation must ensure of full close off. Control valve operation is a key component in controlling heat exchanger transfer rate and corresponding district return water temperature.

GLOSSARY

Main Heat Exchangers .... Devices designed to transfer heat between two physically separated fluids. In district heating systems, heat exchangers transfer heat from the primary hot water supply to water on the secondary side.

Plate Heat Exchanger............... Heat exchangers with fixed plates to separate the fluids on the primary and secondary sides, typically a brazed design.

Primary Hot Water Return........ The District system side return water from the building heat exchanger.

Primary Hot Water Supply .... The District system side supply water to the building heat exchanger.

Secondary Side .... The building side of a typical heat exchanger connected to the district heating system.

BTUH Meter .... Thermal meter that measures building thermal energy consumption and demand.

ABBREVIATIONS

PSID, psid	Pounds per Square Inch, Differential
PSIG, psig	Pounds per Square Inch, Gage
TT	Temperature Transmitter
TI	Temperature Indicator (thermometer)
PI	Pressure Indicator (pressure gage)
PT	Pressure Transmitter
FE	Flow Element (flowmeter)
µS/cm	Micro Siemens per centimeter
° F	Degrees Fahrenheit
BTUH	British Thermal Units per Hour, measure of thermal demand