Dartmouth College

Building Low Temperature Hot Water Conversion Technical Guidelines

Prepared by Dartmouth College (DC)

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Acronyms

AHRI	Air-Conditioning, Heating & Refrigeration Institute
AHU	Air Handling Unit
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
BAS	Building Automation System
DC	Dartmouth College
DDC	Direct Digital Control
DES	District Energy System
DHS	District Heating Supply Temperature
DHR	District Heating Return Temperature
DPS	Distribution Piping System
ΔP	Differential Pressure
ΔT	Differential Temperature
EMS	Energy Management System
ETS	Energy Transfer Station
FO&M	Facilities Operations & Management
FVB	FVB Energy Inc.
HVAC	Heating, Ventilating and Air Conditioning
HW	Hot Water
HWS	Hot Water Supply Temperature
HWR	Hot Water Return Temperature
HX	Heat Exchanger
kW	Kilowatt
LMTD	Log Mean Temperature Difference
LTHW	Low Temperature Hot Water
MBH	Thousand BTUs per Hour
NDT	Non-Destructive Testing
NPT	National Pipe Thread Taper
OAT	Outside Air Temperature
OPDC	Office of Planning, Design & Construction
UPS	Uninterruptible Power Supply
VFD	Variable Frequency Drive

Lexicon

Primary Side	District Heating System Side
Secondary Side	Building Heating System Side

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1 Introduction

1.1 Background

Dartmouth's heating load is currently met predominantly through a co-generation plant that burns #6 fuel oil and a low pressure steam distribution system that pipes steam throughout the campus. In order to achieve Dartmouth's Green Energy Goals, Dartmouth will need to implement significant changes to its energy infrastructure. Accordingly, Dartmouth intends to implement a Campus Hot Water Conversion Project, with three major components:

1. Construct new low carbon thermal Generation Facilities to produce low temperature (Maximum 125 °F) hot water.
2. Construct a new campus low temperature hot water distribution system that will distribute hot water from the thermal Generation Facilities to the campus buildings.
3. Convert the Building Heating Systems as required to utilize low temperature hot water from the new campus low temperature hot water distribution system to meet facility heating requirements (primarily space heating and domestic hot water).

Existing buildings connected to the Dartmouth steam district heating piping network may need to be modified in order to ensure compatibility with the new LTHW DES. This will be established during the building conversion schematic design phase for these buildings.

Some of the building conversions may entail other upgrades, not related to district energy, such as, but not limited to: connection to district chilled water system, building envelope, electrical, controls, and heating, ventilation, and air conditioning (HVAC) upgrades.

1.2 Purpose

This document has been prepared to guide the design of the building conversions and to ensure compatibility with the planned LTHW DES.

This document is also intended to assist the designer with the design and selection of equipment for the building conversions.

2 District Energy System Overview

2.1 General

The LTHW buried pre-insulated distribution piping system (DPS) is currently in design. The DPS will be installed, in separate, concurrent projects to the building conversion work, taking place in the coming years on the DC campus. The DPS will be installed in different piping sections based on the steam system condition and other factors.

Buildings have been categorized into four (4) building groups; steam, hybrid (steam and hot water), hot water and buildings undergoing major renovations and/or efficiency upgrades, as summarized below:

Steam Buildings:
Steam buildings have been defined as buildings with all of the space heating being provided by steam terminal units. A steam building may also have a domestic hot water (DHW) heater which uses steam as the heating medium or uses steam for humidification or other process requirements.

Hybrid Buildings:
Hybrid buildings are defined as buildings with combined hydronic and steam systems. In many cases, hybrid buildings have hydronic terminal units throughout the building, with steam coils located in air handling units.

Hot Water Buildings:
Hot water buildings have been defined as buildings with fully hydronic heating systems. Despite having fully hydronic systems, these buildings may require modifications in order to ensure compatibility with the LTHW district heating system.

Major Renovation/Efficiency Upgrade Buildings:
Buildings undergoing major renovations include those with planned energy efficiency upgrades or other major renewal projects. Renovations and upgrades at these buildings may include envelope upgrades and/or major electrical and HVAC upgrades. All design and construction work will be completed concurrently to the building conversion work.

2.2 Dartmouth Design Guidelines

Refer to DC Design and Construction Guidelines for acceptable approved products/equipment (available at https://www.dartmouth.edu/~opdc/Standards/) in addition to this document. This building conversion technical guideline document shall be used in conjunction with the DC Design and Construction Guidelines.

2.3 Building Conversion District Energy Design Intent

A DES operates most efficiently when building hot water systems operate: (1) with a large building hot water supply and return differential temperature (ΔT) during peak and off-peak conditions; and (2) using low building hot water supply design temperatures which are reset based on outdoor air conditions in conjunction with building control valve polling.

Currently the LTHW DES is based on a district heating supply (DHS) temperature of 125°F at an OAT of 0°F, with an approximate average district heating return (DHR) temperature of 105°F. The LTHW DES DHS will linearly reset to 120°F at an OAT of 50°F.

3 Energy Transfer Stations

3.1 General

Energy Transfer Stations (ETS) transfer heat from a district heating source (steam or hot water) to hot water serving building systems. In some cases, one ETS can be established to serve multiple buildings.

3.2 Building ETS Overview

The Building ETS is mainly composed of:

- District heating supply and return piping.
- Heat exchangers (HX) to transfer heat from the DES to the building hydronic heating and DHW systems.
- Controls to regulate the flow required to meet the building heating demand and maintain the desired building supply temperature.
- Energy meters to monitor and measure the energy used by each building for billing and system optimization.
- Isolation valves on the primary and secondary sides of the HX to facilitate maintenance.

Consideration should be given to (shop) prefabricated ETS skids for ease of installation work on site. This is generally only practical for smaller installations, and only when space allows for prefabricated skids to be brought into the building. For larger installations, the ETS will be mostly site assembled.

Refer to Appendix C, Figure C1, for a typical hot water ETS flow schematic with an instantaneous type DHW system.

Flow through the primary district heating supply (DHS) side of the ETS is controlled to achieve the building's HWS temperature set point.

When steam/hybrid buildings are being converted to hot water-based buildings, consideration should be given to ensure that duplication of ETS design/construction work does not take place, e.g., ensure that for each building, if district hot water will be available for the building conversion construction schedule, that an interim steam to hot water ETS is not designed and that only a permanent LTHW hot water ETS is designed.

If DES LTHW is not available for the planned specific building conversion construction schedule, interim building steam to hot water ETSs will have to be utilized for that particular building or building group. The interim steam to hot water ETS shall be designed in a way that can be transitioned relatively seamlessly from a steam to building hot water ETS to a DES LTHW to building hot water ETS. Some demolition and modifications of piping/infrastructure may be required, however the ETS should be designed to accommodate this transition, to the future permanent LTHW ETS.

DC has completed a building steam to hot water conversion using a prefabricated steam-to-hot water ETS skid in Bartlett Hall. The prefabricated skid includes a plate and frame steam to hot water heat exchanger that can be modified (by adding plates) to operate with the future LTHW district energy system. There are numerous shell-and-tube steam-to-hot water ETS stations throughout the campus that will likely require full heat exchanger replacement for conversion to LTHW district energy. Each ETS station design, and whether or not it is prefabricated on a skid or site-built, should be evaluated on a case-by-case basis to determine the best approach that meets the project space constraints, construction timeline, and budget.

3.2.1 Redundancy

The building ETS will generally have two heat exchangers: one for space heating, and a second for DHW heating. This is in line with standard district energy industry best practices for LTHW systems in North America and Europe. There is a vast amount of experience regarding LTHW DES performance and reliability with this configuration. HXs are reliable (with no moving parts) therefore it is not (generally) necessary to have redundant HXs in an ETS. The single most critical item to protect on the ETS is the HX, which is done using fine mesh strainers at both the cold and hot side inlets. This, in combination with good water treatment, should ensure reliable operation. In the unlikely event of a failure, the HX can be repaired or replaced with minimum downtime. It is important to note that a leaking or fouled HX can often continue to supply heat (albeit at potential reduced capacity), and the repair/replacement can be scheduled for a convenient, low demand period. An ETS configured with redundant HXs is costlier and requires more mechanical room space. However, larger buildings or building groups may require two heat exchangers as dictated by HX capacity limitations. Furthermore, additional redundancy may be required for specific (critical) buildings/zones. Turn down and controllability of the selected heat exchangers should be reviewed for larger heat exchanger installations.

The following general redundancy strategy is recommended:

- Single heat exchanger (1@120%) for space/ventilation heating for capacities up to 8530 MBH.
- Two heat exchangers for space/ventilation heating (2@60% to 70%) for capacities over 8530 MBH.
- Single heat exchanger (1@100%) for DHW heating.

Emergency flanged/capped shall be planned on the supply and return hot water headers in each ETS. These connections would be used to temporarily connect heat exchangers in case ETS heat exchangers are not available (being cleaned or maintained). See Appendix C, fig. C.1 & C.3.

3.2.2 Strainers

A single strainer configuration will be designed for each individual heating ETS on the primary side. The strainers shall be y-pattern and line sized. All strainers protecting plate and frame HX shall incorporate a standard sized stainless-steel perforated basket with an additional 20 mesh liner at a minimum or as dictated by the HX manufacturer.

All control valves shall have strainers upstream.

3.2.3 Air/Dirt Separators

Air/Dirt Separators shall be installed on the building HWS side of the heat exchanger. Air/Dirt Separators shall be Spirovent or approved equivalent.

3.2.4 Pressure Relief Valves

Pressure relief valves will be installed to protect heat exchangers and equipment from over pressurization and shall be installed per relevant/governing code requirements and ASME standards. Set pressures to be determined during the building conversion design process based on the specific heating system under consideration. For glycol systems the pressure relief valve, discharge piping shall be piped into the glycol make-up system where feasible. Aluminum material shall not be used on glycol systems.

3.2.5 ETS Control System

All ETS control systems shall be designed using the existing Honeywell and Jonson Controls (JCI) control system in each respective building where possible. If there is not sufficient capacity on existing control systems, additional capacity shall be added to the control boards and/or new control panels installed as required. ETS field controllers shall be from Honeywell or JCI. Controllers by manufacturers other than Honeywell or JCI are not permitted. Prefabricated skids that are unable to incorporate Honeywell or JCI controllers at the factory shall be constructed with all skid control wiring terminating on a wire terminal strip for Honeywell or JCI field controller connection during building installation.

All existing Building Automation System (BAS) front-end graphics shall be updated to reflect the new ETS, including all control points and sequence of operation modifications. Communication protocol shall be open protocol (BACnet).

The ETS controller shall satisfy the building heating and demand for by modulating two-way pressure independent control valve(s) located on the primary side (supply or return depending on space constraints within the ETS under consideration) of the ETS to maintain a secondary side hot water supply setpoints for building heating and DHW. The secondary building hot water supply setpoint shall be reset according to an outdoor air temperature (OAT) reset schedule and building HW valve positions.

ETS control systems shall trigger an alarm on the BAS if the suction pressure of the building space heating pumps falls below a certain set point. This alarm would alert the operator to potential leaks within the system.

3.2.6 Uninterruptible Power Supply

An uninterruptible power supply (UPS) is required to the control and metering panel (including all loads sub-fed from this panel) in the ETS. The BAS shall be on standby power where possible w/ UPS to prevent tripping during the ten second generator start delay.

The system will consist of a battery charger, static rectifier/inverter, a storage battery, static bypass switch and all required accessories. The UPS System will be rated for 120-volt, AC, single phase. Unit is to be sized to carry the load of the metering and control panel for a period of twenty minutes. ETS control panels shall be powered by the building emergency stand-by system if available.

The UPS panel can be a stand-alone panel or be included within the ETS control panel based on individual ETS system design.

3.2.7 Sequence of Operation Controller Programming

The completed open protocol (BACnet) based control and metering system shall be programmed to allow operation of the system as described below. The system should integrate into the new or existing BAS, with similar remote operation functionality. See Appendix B for sample points list.

Heating Supply:
During normal operation, the secondary supply temperature setpoint shall be reset based on OAT and building valve positions.

- The building base supply temperature setpoint varies according to an outside air reset schedule.
- A slow PI loop modulates a temperature readjustment setpoint from -5°F (adj.) to +5°F (adj.) in response to valve position.
  - If any valve >95% open (adj) for 5 min (adj), the temperature setpoint modulates toward the maximum readjustment setpoint.
  - If all valves <90% (adj), the temperature setpoint modulates toward the minimum readjustment setpoint.
- The final heating network supply temperature set point is equal to the base temperature setpoint plus the calculated temperature readjustment.

The base OAT reset schedules, when used, are to be system specific, but should, as a minimum, have set points at OAT of -20°F, 0°F, and 60°F. All set points shall be adjustable.

Operator's Terminal:
The operator’s terminal shall be programmed to permit the operator the ability to override automatic heating/cooling/DHW temperature setpoints and permit limited adjustment of those same temperature setpoints.

Alarms:

The Direct Digital Control System (DDC) system shall monitor hot water supply and return temperatures. If temperatures exceed high or low limits, an alarm shall be recorded at the operator's workstation/controls front end system.

3.3 Primary District Heating Guidelines

3.3.1 District Heating Design Temperatures

The annual ambient dry bulb temperature distribution is illustrated in Figure 3-1 below. Dartmouth College Design & Construction Guidelines require that heating equipment be designed for an extreme outside air temperature (OAT) of -17.1°F. The ASHRAE 99.6% and 99.0% design temperatures are -9.1°F and -2.7°F, respectively.

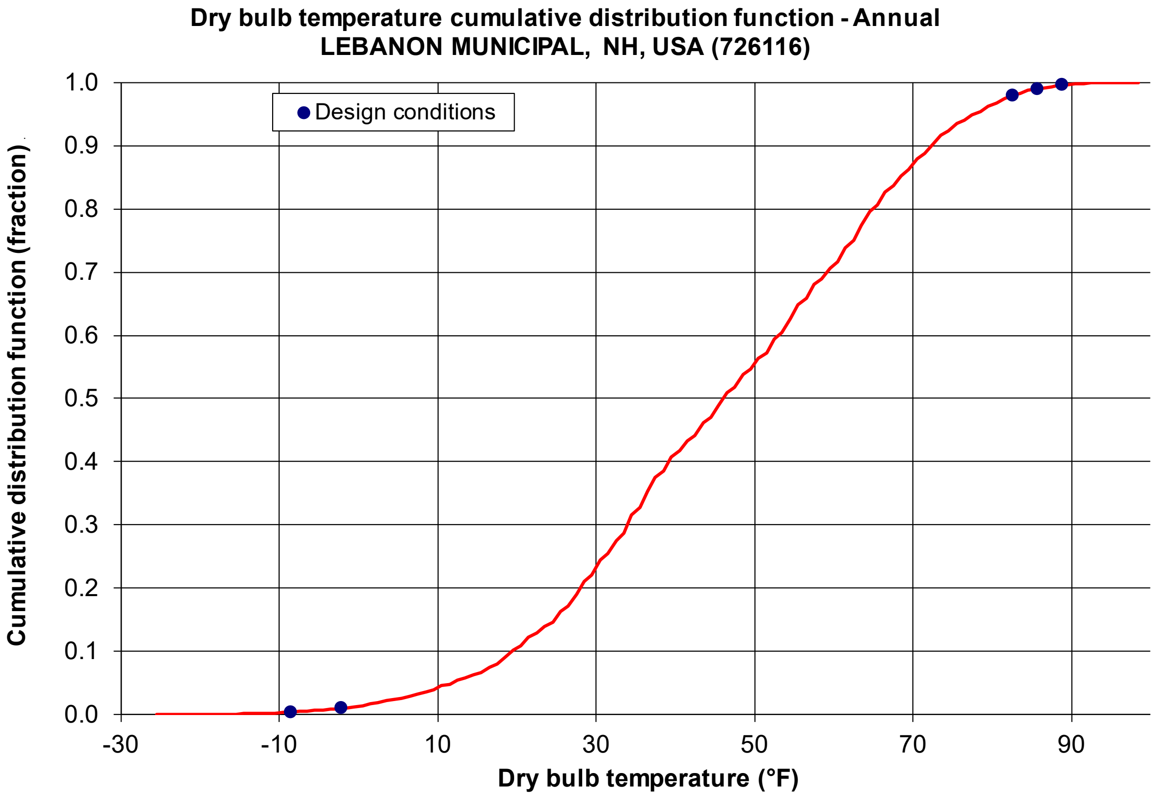


Figure 3-1: Dry Bulb Temperature Distribution per ASHRAE

At the design condition, the district hot water supply temperature will be 125°F. The district hot water supply temperature will be reset downward based on OAT, reaching a low supply temperature of 120°F at an OAT of 50°F (adjustable).

Table 3-1 summarizes the LTHW primary design conditions upon which ETS design should be based.

Table 3-1: District Heating Design Parameters

Description	Unit	District / Primary Heating
Design Parameters Provided By	-	KFI Engineers
Design Maximum Operating Pressure	psi	150 psig
Operating Pressure	psi	60 psig
District Heating Piping Max. Design Supply Temp.	°F	125°F
District Heating Supply Temp. at ≤ 0°F OAT	°F	125°F
District Heating Supply Temp. at ≥ 50°F OAT	°F	120°F
District Heating Building Return Temp. at ≤ 0°F OAT	°F	100°F
District Heating Average Return Temp. at ≤ 0°F OAT	°F	105°F
Max. Pressure Drop Through Heat Exchanger (District Side)	psi	8.5 psig
Max. Pressure Drop Through Heat Exchanger (Building Side)	psi	4.4 psig

**Where existing pumps in hot water or hybrid buildings are not being changed, the maximum secondary side pressure drop through the new LTHW or interim steam to hot water ETS will be dictated by the existing available differential pressure. This element shall be confirmed during the building conversion design stage.*

All LTHW DHW DES HXs shall be selected using the DES DHS reset design temperature of 120°F.

In the buildings with DHW or process DHW, where the DHWS temperature set point is above that of the LTHW DES DHS temperature, supplemental localized electric should be investigated.

In the scenario where DES LTHW is not available at the time of conversion, the ETS must be designed to operate with steam as the primary side heating source. Sizing of the HX in this case should be based on available campus steam at approximately 18-20 psig saturated steam, depending on the existing steam pressure availability in that building.

3.3.2 Design Pressure

The DC LTHW DPS is currently being designed by KFI and has a design maximum operating pressure of 150 psig and an operating pressure of 60 psig as indicated in Table 3-1 above.

The differential pressure (ΔP) at each ETS will vary depending on its location in the distribution system. A minimum of approximately 22 psi should be allocated for the critical primary ETS on the LTHW DES, which includes the ETS equipment and interconnecting piping. Buildings closer to the thermal energy plants may experience higher pressures. All ETS equipment must be selected to handle the higher-pressure conditions. The final locations of the new thermal energy plants are currently being reviewed.

3.4 Heat Exchangers

Heat exchangers (HX) are critical components of an ETS in terms of performance and reliability. Factors which must be analyzed for optimal selection of each HX include:

- Sizing each unit's capacity to match the load and turn-down capabilities
- Critical nature of the load/operation
- Ability/Need to expand capacity
- Need for fluid isolation (e.g., double wall HX for potable water application)
- Temperature and pressure conditions
- Available space in mechanical room
- Allowable differential pressure on both sides of HX
- Reliability and track record

Plate type HXs are recommended for HW to HW applications. Table 3-2 outlines HX selections depending on the availability of LTHW when the ETS under consideration goes into service.

Table 3-2: ETS Heat Exchanger Selections

Primary Service	Secondary Service	Heat Exchanger Types
Steam	DHW	Shell and Tube & Double Wall Plate & Frame
Steam	Hot Water / Glycol	Shell and Tube & Plate & Frame
LTHW	DHW	Double Wall Plate & Frame
LTHW	Hot Water / Glycol	Plate & Frame

3.4.1 Interim Heating Strategy

An interim heating strategy is required such that the buildings may be converted to hot water in advance of the new LTHW DES being available. The scheduling for availability of LTHW DES is currently being finalized by DC.

Special consideration is required here as the building secondary systems may be converted in advance of the availability of the new LTHW DES. Thus, these buildings would have to be heated by the existing steam district system on an interim basis. This will require the installation of new steam-to-hot water converters and associated infrastructure to be used until the new LTHW system is operational.

The new LTHW ETS can be configured in parallel with the interim steam ETS if required based on the building under consideration. This shall be decided on a case by case basis.

If there is an existing steam to DHW ETS, the system should be reviewed to determine is it more beneficial from both a cost and a constructability standpoint to leave the steam DHW ETS in place until the final ETS can be installed.

3.4.2 Heat Exchangers - Interim Heating Strategy

While considerations could be made to install dual purpose heat exchangers for the interim steam solution, there are several factors that must be addressed.

Heat exchangers selected for LTHW – district hot water require significant additional heat exchanger surfaces as compared with (5 to 18 psig) steam.

The same concerns with significant oversizing (up to 4 times) also applies to shell & tube heat exchangers. Thus, the "dual" purpose scenario is not recommended for shell & tube heat exchangers either.

Shell and tube heat exchangers are generally costlier than plate & frame heat exchangers, and due to size limitations, additional units (in parallel) would be required compared to the plate option. Thus, for the interim ETS, they are not deemed a cost-effective solution.

Gasketed plate heat exchangers operating with steam at less than 280°F (34.8 psig) have a service life of approximately 10 years, which satisfies the requirements of the building steam to LTHW conversion timeline.

Based on the above discussions, the interim heat exchangers[1] and the future LTHW heat exchangers shall be sized based on respective duty and configured as separate systems.

The following heat exchangers are recommended for the interim heating application:

- Gasketed plate & frame heat exchangers for space/ventilation heating (2@60%) for capacities up to 10,200 MBH.
- Shell & tube or shell & plate heat exchangers for capacities > 10,200 MBH..

A temporary shell and tube HX for a temporary interim steam ETS may be used, with the intent to replace the shell and tube HX with a plate and frame HX for LTHW in the future. Cost benefit analysis should be completed in determining which interim steam to hot water solution should be utilized on a case by case basis.

In some buildings, the existing steam convertors are in a congested mechanical room, where space is limited for the parallel installation of the ETS. In these situations, it may be necessary to conduct a staged decommissioning of the steam-to-hot water converters in coordination with the new LTHW ETS.

3.4.3 Permanent ETS

The permanent heating ETS and DHW ETS should be considered when an interim steam to hot water ETS is required. Designers to design the interim ETS in a way that can facilitate the replacement and/or modification to complete final ETS installation when LTHW DES is available in that building location.

3.4.4 Plate and Frame Heat Exchangers

Heat exchanger must meet AHRI 400 specifications. Plates shall be Type 316 stainless steel. The space between portholes not feeding channels, and channels shall be vented to atmosphere. Metal to metal contact shall exist between adjacent plates. The plates should have no supporting strips and should be pressed in one step. The part of the plate in contact with the carrying and guide bars shall be reinforced to prevent bending and twisting during the handling of the plates. The plates shall be fully supported and fully steered by the carrying bar and guide bar to prevent misalignment in both vertical and horizontal directions. Plate design shall permit the removal of any plate without the removal of all other plates. Plate thickness shall be a minimum of 0.020”.

The frame shall have sufficient build-out capacity for 20% additional plates. The frame shall be carbon steel with baked epoxy enamel paint. The frame shall be designed without additional welds and reinforcements. The carrying and guide bars shall be bolted to the frame, not welded. The carrying and

[1] The interim heat exchangers could potentially be salvaged for reuse in other suitable buildings or projects on the DC campus.

guide bar surface in contact with the plates and roller shall be clad with a corrosion resistant material such as stainless steel. The bolts shall be greased with molybdenum grease and protected with plastic sleeves. For heat exchangers with 4-inch diameter connections and larger, a minimum of four bearing boxes shall be used on the tightening bolts.

Gaskets shall be EPDM based on system design temperatures and pressures. The gaskets shall be in one piece, as well as one piece molded, in a groove around the heat transfer area and around the portholes of the plates. The gasket groove shall allow for thermal expansion of the gaskets. The gaskets shall have a continuous support along both their inner and outer edges to prevent over-compression of the gaskets.

The heat exchangers shall be insulated with removal insulation blankets or clamp-on insulation kits (preferred).

The heat exchangers shall be designed for the following continuous operating pressures and temperatures: 140°F and 150 psi and to operate and satisfy load requirements with primary side heating mediums of steam (~18-20 psig steam available) or LTHW from DES.

Acceptable manufacturers: Alfa Laval, AIC, APV or approved equivalent.

3.4.5 Double Wall Plate and Frame Heat Exchangers

The frame shall be carbon steel with baked epoxy enamel paint. The frame shall be designed without additional welds and reinforcements. The carrying and guide bars shall be bolted to the frame, not welded. The carrying and guide bar surface contact with the plates and roller shall be made of, or cladded with, a corrosion resistant material such as stainless steel. The bolts shall be greased with molybdenum grease and protected with plastic sleeves.

Connections shall be NPT, male threads or flanged. Flanged connections shall conform to ANSI/ASME standards.

The double wall plates shall be composed of two plates pressed together simultaneously and laser welded at the port. Failure of one plate or weld shall result in external detection without inter-leakage. The plates shall be corrugated Type 316 stainless steel. Metal to metal contact shall exist between adjacent plates. The plates should have no supporting strips and should be pressed in one step. The part of the plate in contact with the carrying and guide bars shall be fully supported and fully steered by the carrying bar and guided by the guide bar to prevent misalignment in both vertical and horizontal directions. Plate design shall permit the removal of any plate in the pack without the need to remove all of the other plates ahead of it. Plate thickness shall be a minimum of 0.015”.

Gaskets shall be EPDM based on system design temperatures and pressures. The gaskets shall be in one piece, as well as one piece molded, in a groove around the heat transfer area and around the portholes of the plates. The gasket groove shall allow for thermal expansion of the gaskets. The gaskets shall have a continuous support along both their inner and outer edges to prevent over-compression of the gaskets.

The heat exchangers shall be insulated with a removal insulation blankets or clamp-on insulation kits (preferred).

The heat exchangers shall be designed for the following continuous operating pressures and temperatures: 210°F (99°C) and 150psi and to operate and satisfy load requirements with primary side heating mediums of steam (~18-20psig steam) or LTHW from DES.

Standard of acceptance: Alfa Laval, AIC, APV or approved equivalent.

3.5 Controls and Metering

Optimization of the hydronic heating system Delta T (ΔT) is critical to the successful operation of a LTHW system. The ETS controls the supply water temperature to the secondary hot water system based on an outdoor air temperature reset schedule and a building control valve monitoring system (see Section 3.2.5). The temperature reset schedule dictates the maximum temperature available to the building hydronic systems.

The ETS controls and metering equipment would generally be connected to the DC EMS with remote connection to the BAS front-end system. Controls hardware should be of high-grade commercial standard with electric actuated control valves.

It is crucial that high-quality integrated energy meters are used to achieve optimum metering accuracy and performance. Energy (BTU) meters generally include in-line magnetic or clamp-on ultrasonic flow meters furnished with a matched pair of platinum temperature sensors and a dual-channel factory sealed pre-programmed integrator (i.e., calculator). In cases where a single ETS serves multiple buildings, service to each building should be separately metered as required by DC.

Refer to DC Design Guidelines “230520 – Thermal Utility Meters” for specific campus metering requirements.

3.5.1 LTHW ETS Primary Control Valves

Primary LTHW ETS control valves shall be sized on the basis of ~50% of available ΔP or ~ maximum 11 psi pressure drop. Lower pressure drops may be used based on specific location of ETS or available system ΔP.

Valves shall be pressure independent, equal percentage type, two way, single-seated and equipped with characteristic type throttling plug, #316, stainless steel stem and seat. Provide control valves with necessary features to operate in sequence with other valves and adjustable throttling range as required by the sequence of operations.

Control valves shall be able to handle a minimum of 50 psi differential pressures for modulating service with rangeability greater than 100:1. Actuator selection shall be for close-off pressures greater than 100 psi. Arranged to fail safe as called for, tight closing and quiet operating. Leakage shall be less than 0.1% of C_V.

Parallel control valves should be installed when primary district heating design flow rates exceed 80 gpm or if specific redundancy is required for the particular ETS under consideration. Dual primary control valves can be installed sized based on a 1/3 and 2/3 design flow capacity. The 1/3 control valve will open first until the heating load cannot be satisfied, then the 2/3 control valve will open while closing the 1/3 control valve. If the heating load cannot be satisfied the 1/3 control valve will open, as well as the 2/3 control valve. Two primary control valves sized at 50% can also be considered depending on the ETS and heat system requirements.

3.5.2 Pressure Independent Control Valves

Pressure independent control (PIC) valves shall be utilized on all primary system and secondary system control valves. Refer to Appendix C, Figure C.1.

3.5.3 ETS LTHW Control Valve Electric Actuators

Provide 24 VAC control valve actuators which are 2-10 VDC input proportional with spring return as needed by control sequence and designed for water service valve bodies. Operator shall be synchronous motor driven with minimum 168.6 pounds of thrust and force sensor safe.

Control stroke time shall be less than 30 seconds. The actuator shall include a manual clutch that enables manual positioning of valves during power failures and servicing. Upon restoration of power, the actuator will automatically reposition itself without intervention. The actuator shall have self-lubricating bearings to minimize maintenance requirements. Indication of position shall be visible at all times.

3.5.4 Energy Metering Components

Refer to DC Design Guidelines "230520 – Thermal Utility Meters" for specific campus metering requirements.

The energy meter is made up of a flow meter, two temperature sensors, an energy calculator, and plug-in modules. A read-out unit makes it possible for the operator to observe the operating parameters. The energy meter shall be furnished with an open protocol output (e.g., BACnet) for integration with a control panel with remote communication capability.

The energy calculator shall comply with OIML R75 and EN1434, with accuracy: +/- (0.15+2/Δt) %, water temperature range 33.8°F – 320 F°), and 30 second flow calculation intervals. The meter shall have a permanent memory (EEPROM). The meter display shall show the following:

- Accumulated thermal energy: Btu or kBtu
- Accumulated water flow: gallons
- Actual thermal power: Btu/hr or MBH
- Actual water flow: gpm
- Supply temperature: °F
- Return temperature: °F
- Temperature differential: °F
- Peak thermal power: Btu/hr or MBH
- Peak water flow: gpm or gph
- Hour Counter: HRS

The meter shall be factory calibrated and supplied with a verification certificate.

The flow meter shall be magnetic or ultrasonic in compliance with OIML R75 and EN1434, with accuracy +/- 0.5% of reading within flow range of -40 to +40 ft/s and minimum rangeability 300:1. Fluid temperature range shall be -4°F to 248°F and fluid pressure range full vacuum to 232 psi. Meter to be factory calibrated.

Energy meters to be furnished with precision matched, platinum, 3-wire Resistance Temperature Detectors (RTDs) furnished with thermowells, junction head and heat transfer paste. System differential temperature accuracy: +/- 0.3°F ΔT or better. Energy meters shall be provided with BACnet/IP communications protocol communicating over an RJ45 ethernet cable to a campus data port (data port furnished by DC).

For some buildings on campus DC may choose to provide energy metering on the secondary side heating zones. This shall be confirmed by DC during the preliminary design stages.

3.6 General Layout and Footprint

Some of the buildings that will be connected to the LTHW DES have peak heating loads smaller than 1000 MBH. In cases where multiple small buildings are located in close proximity, the use of a centralized ETS should be considered. In general, the standard footprint of the heating ETS varies with the configuration and capacity, ranging from 20 ft^2 for a small (~1,000 MBH), single heat exchanger to 110 ft^2 for a large load (~8,000 MBH) with three heat exchangers (heating and DHW). Since the majority of the ETS for this project will be building retrofits, the configuration and space allocations may not conform to the standard footprint allocation due to space constraints. Refer to Appendix C Figure C2 for a typical hot water DES ETS configuration and standard footprint allocation.

4 Building Secondary System Conversion

The primary goals of the building conversion process are as follows:

1. Convert all buildings to hydronic heating systems.
2. Improve occupant comfort and system control.
3. Enable a streamlined changeover from steam to LTHW if an interim steam to hot water ETS is required.
4. Minimize building hot water return temperatures and maximize building hot water ΔT.
5. Utilize lower temperature building hot water supply design temperatures.
6. Implement variable flow hot water systems with large building hot water supply reset schedule.

4.1 New Secondary Hot Water Design Parameters

4.1.1 Design Temperatures

Table 4-1 below summarizes district supply and return water temperatures and building secondary system supply and return temperatures. Building hot water design ΔT can be larger than noted in Table 4-1.

4.1.2 Design Pressure

The building hot water system design pressure(s) will be based on a number of factors, such as existing conditions, static height of system and size of system. The specific design pressure for each system will be determined by the building HW conversion designer.

Maximum pressure drops through the ETS heat exchanger (building side) should be 4.4 psi. Where existing pumps in hot water or hybrid buildings are not being changed, the maximum secondary side pressure drop through the new LTHW or interim steam to hot water ETS will be dictated by the existing available differential pressure. This element shall be confirmed during the building conversion design phase.

4.2 Building Hot Water Trending Data

For existing buildings with hot water systems, it is important to establish existing hot water system ΔT, and hot water supply and return temperatures to establish how the buildings are performing, during peak and off-peak periods.

Designers working in existing buildings that have significant existing hot water infrastructure shall work with Dartmouth to agree on hot water systems approach. BAS trending data should be reviewed to assist with analyzing existing hot water supply and return conditions.

4.3 Reset Schedules

The ETS controls the supply water temperature to the secondary system based on an outside air temperature reset schedule and building valve positions. This is the maximum temperature available to the building secondary hydronic systems. Adjustments based on building valve positions would be supplemental.

All building types, renovated or new construction, will continuously optimize their hot water operating temperatures in addition to using valve polling in addition to OAT reset schedule. See section 3.2.7 Sequence of Operation Controller Programming.

The general control strategy to be implemented for the new ETS shall be secondary supply reset based on the OAT in conjunction with maximum control valve position. Some zones may operate with a lower design hot water supply temperature based on oversized terminal units. **Generally, this can only be established by testing during various external air design conditions during normal building operations.**

4.4 Constant to Variable Flow Conversion

For existing hot water buildings, depending on the existing specific hot water system design, converting the system from a constant flow, variable temperature system to a variable flow, variable temperature system should be investigated during the building conversion design process. Variable flow secondary hot water systems generally perform with better ΔT during off peak conditions when compared to a constant flow hot water system. Variable speed pumps will operate more efficiently than constant speed pumps and consume less energy. Conversion to a variable flow system requires the removal of three-way diverting valves and bypasses and replacing these with two-way valves. A differential pressure control valve can be used to maintain minimum flow in the event all building valves close.

This modification also requires the use of variable speed pumping and may require existing pumps to be retrofitted with VFDs (if possible) or replaced.

<u>Variable Flow Secondary Heating Systems:</u>

All new hot water heating systems should be designed as variable flow systems with hot water supply temperature reset based on OAT in conjunction with maximum control valve position. All hot water pumps should be VFD type pumps.

A differential pressure sensor located in the piping distribution system shall be used to modulate pump speed.

Designers must verify that existing hydronic terminal equipment is compatible with a variable flow system.

Refer to Appendix C, Figure C3 for an example of a building secondary system. The design shown utilizes 3-way mixing valves and 2-way valves to regulate the flow at the terminal unit. No 3-way diverting valves or bypasses are shown in Figure C3.

The primary DHW district heating control valve modulates to maintain the DHW set point. Refer to Appendix C, Figure C.1.

4.5 Controls

In order to obtain the lowest possible return temperature from the building terminal end devices (such as heating coils, re-heat coils, unit heaters, convectors etc.), the system should be designed for variable flow with a hot water temperature reset based on the outside air temperature and building valve positions. End devices should be controlled by either a two-way modulating or three-way mixing valve (pumped configuration). Both of these methods, with correctly sized control valves, should prevent laminar flow conditions and thereby maintain a high heat transfer coefficient through the end device, and consequently produce a high differential temperature across the unit.

4.6 Energy Valves

New hot water coils in AHUs with connection to outside air intakes will have freeze protection pumps for protection and or have 40% glycol in the system. Large (+10,000 CFM) AHU's coils shall be fitted with Belimo energy control valves. Smaller AHU's (<10,000 CFM) coils will be fitted with PICCV control valves.

4.7 Repurposing vs. Replacement

Designers shall consider the age/condition of existing steam equipment during the conversion process and if it is reusable.

Designers should make DC aware of any mechanical equipment associated with the building conversion that is nearing or beyond its useful service life. Replacement of systems that are near the end of their useful life should be accounted for in a lifecycle cost comparison.

Designers should not provide like-for-like replacements of equipment without first analyzing capacity and appropriateness of equipment type. Load calculations must be performed by the design engineer for all replacement equipment.

Review of BAS trending is also recommended. The DC Energy Management system (EMS) may have trend data available that could provide insight for how a particular piece of equipment has operated historically.

Refer to Appendix A for guidelines relating to repurposing of steam equipment for a hot water application.

4.8 Humidification

Humidification will no longer be provided by the campus steam system with the adoption of a LTHW DES. All plant steam humidifiers will need to be replaced with electric or adiabatic type humidification systems. Designers should also review the need/requirement for existing humidification systems.

High-pressure Reverse osmosis (RO) humidification systems should also be investigated for the specific application.

4.9 Domestic Hot Water

The designer shall review options for generation of Domestic Hot Water and shall coordinate the system to be included in the design with DC. Options to be considered include the following:

- Instantaneous double-wall plate HX connected to the DES
- Water source heat pump with storage tank(s)
- Air source heat pump with storage tank(s)
- Electric domestic water heater
- Point of Use electric domestic water heaters
- Solar thermal domestic hot water system

Instantaneous domestic hot water systems with no storage volume have a shorter stagnation time in the building, thus reducing the chance of bacteria growth such as Legionella and allowing for reduced DHW supply temperatures.

In some DHW systems where there is a large coincidental demand, such as residence halls, the use of storage or buffer tanks should be evaluated on a case by case basis. Strategies to maintain 140°F water in the storage tanks should be reviewed with DC. Stainless steel type DHW tanks should also be reviewed.

4.10 Back-up Power

Back-up power will be required to sustain all critical hot water equipment. In the case of steam buildings, it is possible that the existing back-up power system may not have adequate capacity to support the added hot water equipment. Distribution pumps, control valves and ETS metering equipment must be connected to backup power at all times in the event of a power outages to ensure critical heating systems are sustained during prolonged power outages. Designers shall provide the standby electrical load summary for each building to FOM-Engineering at early stage of design. FOM-Engineering will provide information to the designer on whether sufficient standby capacity is available to meet these loads and where it will come from. The design will provide a panelboard for the standby loads dedicated to the hot water system loads. If no standby system exists, this panelboard shall be connected to a normal power source. In cases where the standby system has capacity, this panelboard will be connected to existing standby and the design may offer other recommendations for alternate equipment connections to the existing standby system depending on existing system configuration.

4.11 Water Quality

Dartmouth currently plans on circulating deionized (DI) water through the primary district heating loop. As such, it is critical that ETS components that come into contact with primary water are safe for use with DI water.

During the cleaning and flushing stages of the hot water systems, it is important to achieve velocities of a minimum of 5ft /s (1.5 m/s). Under no circumstances shall flushing take place through heat exchangers or energy meters on the primary or secondary side.

Building side heating loops shall include a side water treatment loop. Water shall be drawn off of the bottom of an air/dirt separator and pumped through a filter feeder and coupon rack, returning to the building hot water supply line. A site glass makes balancing the loop to a desired flow possible using an isolation valve.

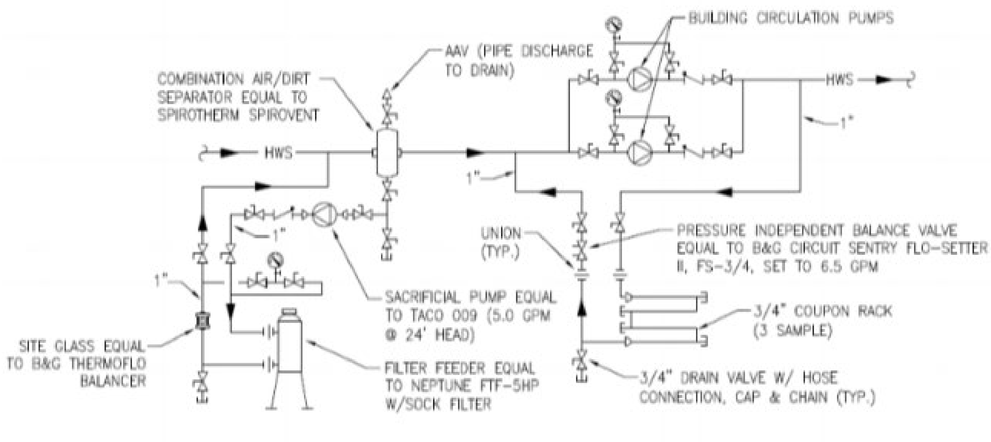


Figure 4-1: Secondary Water Treatment Loop

In some cases, the new building low temperature hot water piping distribution system will be connected to the existing building hot water distribution piping system. When this occurs, the existing building hot water system should be tested prior to connection to the new building low temperature hot water system. If the testing indicates that the water quality of the existing hot water system is poor, the existing hot water system should be chemically treated and flushed as required to meet DC water quality standards.

Refer to DC's water treatment and water quality specifications for the design standards for all secondary heating hot water systems.

Cleaning-In-Place (CIP) is recommended to regularly clean fouling. CIP as part of a routine maintenance procedure prolongs the time between opening a plate heat exchanger for manual cleaning. In order to facilitate CIP, service tappings should be added on inlet and outlet heat exchanger piping branches. Refer to Appendix C.

4.12 Freeze Protection

On air handling unit (AHU) fresh air systems, there is inherent risk of freezing coils during cold periods. AHU coil freeze protection pumps can be utilized on a bypass line, with a check valve, across the supply and return lines at the hot water coil to prevent freezing of coils. Additional fresh air damper and fan shut-off interlocks should also be implemented to prevent freezing of coils. Depending on the air or hydronic system under consideration, glycol systems can also be considered if it is deemed that hot water freeze protection alone will not suffice based on the system configuration/design conditions.

4.13 Steam Coils and Face and Bypass Dampers

On AHUs with steam coils and face and bypass dampers, the air side bypass control sequence of operation should be updated, and the air side bypass modified to reflect the design of the new hot water/glycol coil. Designers to observe if additional energy savings can be realized by utilizing the bypass to reduce air pressure drop. For example, in summer conditions. Designers should be mindful of Delta T.

Generally, the entire air flow should pass through the new hot water coil when in heating mode.

It is common for steam coils and face and bypass dampers to be installed as preheat coils. These steam coils, when replaced with hot water coils could have a high susceptibility to freeze up, therefore freeze protection is extremely important for these coils.

4.14 Heating/Cooling Change-Over System

There are some instances in buildings where simultaneous heating and cooling is not required. In these buildings there may be an opportunity of exploring a heating and cooling change-over system. The option of using existing cooling pumps or installing new pumps should be investigated. In addition to this, use of existing cooling piping main risers and existing chilled water coils for heating is a possibility that should be considered. The existing piping, coils, pumps, valves would have to be reviewed to confirm suitability for a hot water system. Specific controls sequence of operation would have to be completed for a summer and winter change over scenario. The changeover could be automated by the BAS, using electrically motorized 3-way diverting valves, or a single 6-way valve. Expansion provisions and stress in piping and equipment would have to be investigated based on the change in design temperature and operating temperatures of the heating hot water system. Existing valves and controls would have to be reviewed for suitability of the proposed heating/cooling changeover system.

When intending to use cooling coils and/or cooling distribution piping for a hot water application, specific consideration to be given to the following:

- Sufficient pipe expansion and piping stress from temperature change,
- Heat output requirements,
- Water flow from heating circuits,
- Water velocity required for proper heat transfer,
- Adequate temperature control valve, including quality of valves,
- Potential problems with the heating cooling change over, and
- Existing control valves.

4.15 Hot Water Distribution

Generally, hot water systems fall into one of the following 'closed type' systems:

- Direct return -- a circulation system routing water back to the primary heat source (heat exchanger) via the shortest path from each terminal unit. *Direct return is generally the most common system used for hot water systems connecting to DES.*
- Reverse return -- a circulation system using a return piping path from each terminal unit such that all circuits are of equal pipe length, which provides a self-balancing system.
- Series loop -- a one-pipe system where all heated water flows through each consecutive heating element and then directly back to the heat source. Series loop is not as common as direct return and reverse return systems.

Conventional forced hot water systems can generally be adapted to use district heating with few changes. The major considerations which should be evaluated are suitable design temperatures and temperature drop. Some hot water systems may have been designed for constant flow, with constant temperature or temperature reset from an outdoor air controller. Constant flow systems commonly have 3-way diverting valves so that the hot water will bypass into the return when the thermostat is satisfied. To meet the return temperature requirements in a DES, this bypass should be removed, and the heating system converted to a variable flow system.

In large buildings, not all control valves will close at the same time to generate a dead head scenario in the hot water heating pump. By eliminating the bypass on 3-way diverting valves (replacing with 2-way valves) a constant speed pump can ride its own pump curve. The required approach however is to replace or retrofit the existing constant speed pump with a variable frequency drive (VFD) pump and control the pump speed by differential pressure via a differential pressure sensor(s) located at the system index node(s). See Section 4.4 Constant to Variable Flow Conversion.

Plugging or modifying 3-way diverting valves can be investigated, however installation of properly sized 2-way control or on-off electrically actuated valves is normally the best approach.

4.16 Hot Water Radiation

Generally, existing hot water radiation of any type is compatible with LTHW DES. However, temperature requirements and sizing must be checked for suitability with LTHW DES. The capacity of existing heating terminals utilizing the maximum LTHW entering design temperature should be evaluated during the design process, at design OAT conditions.

Panel radiators like Runtal perform much better with low flows and high ΔT than conventional fintube radiation.

4.17 Building Secondary Cascading

Some types of hot water systems, such as radiant floor systems, can operate at lower entering water temperatures. These systems can offer an opportunity to heat with return water from other terminal units or zones, thereby assisting with reducing the LTHW DES return water temperature. If required, an injection loop can be installed on the higher temperature system to boost the temperature in the event the building return water does not achieve the required low temperature set point. Additional pumps may be required for these secondary cascaded systems.

The applicability of cascading is to be reviewed by the Designer, based on cost versus overall system benefit.

4.18 Electrical Resistance Heating

Electric resistance heating should be identified and evaluated for conversion to hot water based on the availability and suitability for the installation of a comparable hot water heat emitter. The following major items should be considered:

- Annual energy consumption, installation and operational cost of equipment, including payback,
- Benefits of installing hydronic heat emitters,
- Benefits to DES and energy efficiency benefits.

4.19 Air Handling Systems

Existing hydronic hot water coils in AHUs may be suitable for conversion provided that they provide adequate capacity at the LTHW design entering water temperature. Temperatures must be checked along with control and control valve configuration. If it is determined that the existing AHU coil(s) do not provide adequate heating capacity, new heating AHU heating coils shall be provided.

4.20 Rooftop Units

Packaged AHUs are used to heat make-up air in buildings and can be gas or oil fired, and may have electric, steam or hydronic based heating coils. These units can be retrofitted with hot water or glycol hot water coils. Special consideration should be given to air pressure drop, age of equipment, condition of equipment, location of equipment to hot water source, energy consumption of equipment, cost to convert vs operational and energy efficiency benefits of gas, electricity, and DES.

4.21 Pneumatic Controls

DC intends on replacing pneumatic controls in buildings with electrically actuated valves during the building conversion process. If pneumatic controls are present in the building or heating zone under consideration, these controls should be replaced with DDC controls.

4.22 Strainers

A single strainer configuration will be designed for each individual heating ETS on the secondary side. The strainers shall be y-pattern and line sized. All strainers protecting plate and frame HX shall incorporate a standard sized stainless-steel perforated basket with an additional 20 mesh liner at a minimum or as dictated by the HX vendor.

All control valves shall have a strainer upstream.

4.23 Snow Melt Systems

Existing snow melt systems that operate at a hot water supply temperature greater than 120°F should be reviewed and options for a new or supplemental heating source (electric boiler, electric booster, etc.) to provide hot water at the required snow melt system temperature should be analyzed and coordinated with DC.

New snow melt systems should be designed for a hot water supply temperature of 120°F. The designer should confirm with DC if the snow melt system is to be connected to the LTHW system or if an alternative heating source (electric boiler, etc.) shall be utilized.

5 Steam Building Secondary System Conversion Strategy

5.1 Equipment

5.1.1 Radiation

It is recommended that existing steam radiators and associated steam and condensate piping be replaced by new hot water-based infrastructure. Steam radiators are most commonly used in older buildings where the existing infrastructure has passed its useful service life. Additionally, reusing existing radiators often requires higher water temperatures than would be available from the LTHW system.

In some instances, based on oversizing of steam emitters the terminal units can work with hot water. It is recommended for Designers to review trending data of the control valves during peak conditions to evaluate the capacity of the existing steam emitters.

If absolutely necessary, steam radiators may be converted to hot water if they have sections connected at the top and bottom, can withstand the required static pressure and have adequate heating capacity with low temperature hot water. A steam radiator or convector radiates less heat when used with hot water due to the lower media temperature. Convector heating elements composed of copper tubing with aluminum fins may also be converted to hot water. Refer to Appendix A for guidelines relating to repurposing of steam equipment for a hot water application.

Existing steam control valves should be replaced with hot water valves. Existing thermostatic radiator valves can be reused depending on age and condition of equipment.

Steam traps connected to two-pipe steam systems can be removed. The existing air vents should be removed, and a new manual air vent designed for hot water should be installed at the high point of the radiator.

In two-pipe systems, the existing condensate lines may be reused with hot water if they are large enough, are in good condition and meet the design requirements of the new building hot water system. Non-destructive testing (NDT), or destructive testing, if appropriate, should be used to determine the condition of existing piping.

5.1.2 Coils

Steam coils located in AHUs or fan coil units must be replaced with new hot water (or glycol) coils. Steam coils are generally designed for a high pressure and low temperature drop, which is not ideal for a hot water system. Depending on the age of the equipment the coils or the entire AHU may require replacement.

If only steam coils are being replaced, they should be selected for a low hot water supply temperature with a large ΔT where possible (i.e. 120/90°F) water/glycol temperature.

BAS trending data should be reviewed to assist with proper sizing of HW coils based on actual operations of the air system under consideration.

Careful consideration should be given to existing AHU available fan static pressure when selecting lower temperature coils as the surface area required may be greater than the original steam coil.

5.1.3 Unit Heaters, Force Flow and Cabinet Unit Heaters

Unit heaters configured with universal single-row coils may be converted from steam to hot water, if the units have sufficient capacity based on the hot water conversion. The existing coil should be modified to operate with hot water and its capacity should be assessed based on the hot water supply temperatures.

Unit heaters with steam only coils shall be replaced with new units selected for 120/100°F water temperatures.

In both cases, the reduction in capacity may require the addition of additional unit heaters to satisfy the required load.

5.1.4 Process Steam

In buildings where campus steam is used as process steam (dishwashers, cage washers, cooking specialty equipment, etc.), the process steam requirements must be assessed to determine if using hot water is a viable alternative. If not, a steam boiler sized for the process steam load may be considered and shall be electrically or propane fired. If viable, the feedwater for the steam system can be pre-heated from the LTWH DES through a plate and frame HX. The primary heating loop water shall not be used for make-up water for steam production.

Consideration should be given to replacing the specialty steam equipment with other equipment that does not require steam, for example electric kettles in lieu of steam to steam units.

5.1.5 Distribution Pumping

Hot water distribution pumps with VFDs will need to be added to the buildings to provide variable flow conditions for the heating loops being converted. Designers must carefully size the pumps and be sure to account for additional piping losses as a result of sections of steam and condensate piping being reused and account for the pressure drops through interim steam to hot water ETS and future LTHW DES ETS.

5.1.6 Abandoned Steam Equipment

Steam equipment being abandoned should be removed during the building conversion.

5.1.7 Heating Mechanical Rooms

Mechanical rooms converted to hot water may require supplemental heat and should be reviewed during the building conversion process.

6 Hybrid Building Secondary System Conversion Strategy

6.1 General

The hydronic portion of hybrid buildings shall be converted to a variable flow system as described in Section 4.4. In most cases, hydronic systems have been designed for a 20°F ΔT and 180/160°F supply and return temperature. Replacement of coils and terminal units may be required to provide the required heating capacity utilizing LTHW.

Refer to Section 5 above for information relative to steam conversion strategies.

6.2 Equipment

6.2.1 Hydronic Terminal Units

Outdated hydronic terminal equipment should be replaced with modern alternatives designed to operate with low temperature hot water. For example, fin tube radiators at end of life may be replaced with European style panel radiators. Runtal or approved equivalent.

6.2.2 Distribution Pumping

Designers shall determine whether the existing distribution pumps can be reused. The pumps may be reused if adequately sized and are either currently controlled by VFDs or can be retrofitted with VFDs. If the pumps are not adequately sized, new pumps with VFDs shall be specified. Pumps which are not of adequate size but are in good condition may be reused in other buildings if possible.

Designers must consider all building modifications which may increase or reduce the required pump head or capacity, especially if steam equipment or piping is being retrofitted or reused.

7 Hot Water Building Secondary System Conversion Strategy

7.1 General

Despite having fully hydronic systems, these buildings may require some modification in order to ensure compatibility with the DES. Specifically, many existing hot water systems have been designed for 180°F supply and 160°F return temperatures. The building LTHW supply maximum design temperature is 120°F.

Existing hydronic buildings will need to be converted to a variable flow system, as described in Section 4.4. The main components of converting a building to a variable flow system are the implementation of variable flow distribution pumping, removal of three-way diverting valves and bypasses, and confirmation that the existing terminals are compatible with variable flow.

If the removal of three-way diverting valves is not feasible, the valve may be reduced to two-way operation by closing the balancing valve of the equipment bypass line.

7.2 Equipment

7.2.1 Terminal Units

Outdated hydronic terminal equipment should be replaced with modern alternatives designed to operate with low temperature hot water. For example, fin tube radiators at end of life may be replaced with Runtal steel panel radiators or approved equivalent.

7.2.2 Distribution Pumping

Existing distribution pumps for hot water buildings should be adequately sized for the building loads. If not already equipped, VFDs should be installed. If pumps are not compatible with the addition of VFDs, new pumps with VFDs shall be installed.

8 Major Renovation Building Secondary System Conversion Strategy

8.1 General

Major renovation projects will involve more comprehensive redesign of building systems. Major renovations may include replacement of terminal equipment, distribution piping, valves, and other components. They may also include the addition of new equipment for heat recovery or other means of increasing building efficiency. The scope of major renovation projects should be coordinated closely with DC Facilities and Operations Management (FO&M) and DC Project Management (PM) Services.

9 Schematic Design

9.1 Basis of Design

The basis of design (BOD) document for each building or building group shall include:

- Design indoor and outdoor temperatures
- Calculated ventilation for all applicable spaces
- Block and zone (space) design heat loss calculations
- Hot water design supply and return temperatures
- Energy analysis and annual hot water building ΔT analysis, including building hot water return temperatures
- Domestic Hot Water design loads and design strategy
- Relevant codes and standards
- Proposed scope of work definition/approach
- Proposed system descriptions/options, as applicable
- Major new equipment identification, as applicable
- Equipment and energy upgrade life cycle cost comparisons
- Identification of, and proposed solutions for, any issues to address constructability issues, code compliance, hazardous materials etc.

9.2 Drawings

The schematic design drawings shall include:

- Demolition drawings
- Riser diagrams with sizes for main distribution piping and ductwork
- Equipment layouts showing major equipment such as heat exchangers, pumps, heating coils in AHU's, terminal units (show one or two final heat emitters that would be a typical layout for the building, such as fan coil or radiator), humidification units, process steam, etc.
- Pipe routing and sizing of main lines; show one or two terminal branches as typical for the building under consideration, for example final piping serving a heat emitter as typical for the building
- Demolition P&ID drawings and layout demolition drawings showing demolition of steam equipment, steam piping, steam coils etc. For terminal units such as steam radiators where multiple terminal units exist, show location and demolition of all final heat emitters
- New Work P&ID drawings and piping diagrams
- Major equipment selections
- Controls system description
- ETS locations coordinated with campus HW distribution system schematic design

9.3 Thermal Load Analysis

Designers shall design hydronic systems to maximize energy efficiency, and should be sized correctly based on the coincidental building peak heating load. Load calculations shall be completed for individual zones and the building as a 'block'. Opportunities to increase building energy efficiency should be identified and evaluated by the designer during the building conversion design process.

Designers will have access to Dartmouth College Energy Management System data which provides historical energy usage data at various time intervals.

Thermal modeling shall be completed as required for building/heating zones as necessary by the Designer.

Designers shall evaluate the impact of their proposed design, along with any energy efficiency improvements (including building envelope improvements), on the building's energy usage.

9.4 Building Operations Feedback

In assisting with building conversion designs, feedback from operations relating to mechanical equipment and 'problematic building zones' such as areas where heat complaints are common should be assessed by the designer and included in the conversion to address the problematic area related to the hot water system under consideration. Problems for the specific area could relate to plugged heat emitters, controls issues or leaky building fabric such as windows/doors.

9.5 Hazardous Materials

DC will provide available documentation of the presence of hazardous materials in each building. DC will provide additional testing and surveys as needed and will be responsible for any hazardous material mitigation needed for project implementation. Designers should identify design strategies which will minimize hazardous material abatement where feasible.

9.6 Capital Cost Estimates

DC requires a level of detail in the schematic design such that capital cost estimates with +/- 20% cost accuracy can be provided by an independent estimator.

10 Appendix A – Repurposing Existing Steam Equipment

For some buildings being converted from steam to hot water, there may be an opportunity to convert existing steam emitters and/or steam infrastructure for a hot water application. This could serve as an interim solution, until a scheduled major renovation or demolition for that particular building occurs in the near future, or as a more permanent solution. This will be dependent on a number of factors such as, but not limited to: the condition of the steam equipment being reused, the heating system/zone under consideration, the space which is being served from the reused equipment, and future planned renovation projects.

There are no universal rules when it comes to repurposing existing steam emitters and/or steam infrastructure for a hot water application. Each respective building group and associated heating system should be analyzed on a case-by-case basis. The following are recommendations for assessing reuse of existing steam equipment and addressing associated challenges and risks.

1. The condition and age of the existing steam system / steam infrastructure should be assessed before opting to repurpose the equipment for a hot water application.

2. Non-Destructive Testing (NDT) such as ultrasonic and radiography testing can be used to determine the condition of existing piping in relation to corrosion, pitting, general condition and wall thickness of existing piping, compared to original pipe specifications. Radiography testing presents challenges relating to the required evacuation of the area surrounding the test location, which in turn could pose challenges for the building. The results of NDT testing could be used as a measure to decide whether to proceed with additional testing methods.

3. After confirming the decision to re-use the steam piping, the piping should be pressure tested with water to (minimum) HW pump deadhead pressure.

4. The design of the specific steam equipment should be investigated to confirm if repurposing for a hot water application is feasible. To convert steam radiators for example, the radiators need to be a two-pipe type design not a pipe-in-pipe design. Generally, there is a top connection for the steam pipe and a bottom connection for the condensate return. Data sheets for each piece of steam equipment under consideration for reuse should be reviewed in detail during the building conversion design stage.

5. Additional consideration should be given to the location of the steam equipment and/or infrastructure being considered for reuse. The building contents should be considered in buildings such as museums containing important documents or critical building spaces. Assessment of the ramifications of potential leaks within the specific space as a direct result of repurposing existing steam equipment should be considered.

6. Consideration should be given to the location of the steam equipment which is concealed or behind areas containing hazardous materials. If leaks were to occur behind these areas a plan should be in place to rectify the issues where hazardous materials are present.

7. Reduction in output of reused steam equipment can be estimated based on the change in log mean temperature difference (LMTD) calculation. Significant reduction in capacity is anticipated due to the LTHW design temperatures. The addition of hydronic heat emitters could be investigated to compensate for the reduced capacity. Consideration should also be given to any building envelope upgrades which may reduce the required heating load within the building/space under consideration.

8. The impact of the hot water Delta T needs to be considered when repurposing for a hot water application. Reuse will partially depend on the system performance criteria of the hot water system design. Reuse alone may not work for a low temperature hot water system.

9. Modifications to steam piping such as removing and capping steam traps may have to be completed before the system is able to operate with hot water. Areas where steam piping is concealed can make it challenging to determine exact locations of steam equipment which would require modifications to be compatible with hot water. Steam piping and components shall be completely removed if fully accessible. If the steam piping and components are not accessible, these items will be removed as part of a future major renovation project.

10. Reusing condensate piping presents challenges based on the condensate pipe typically being a smaller diameter than the steam supply pipe – this can present flow and pressure drop issues. In addition to this, condensate piping can corrode at a faster rate than the steam piping based on the steam system operations.

11. Review of existing pipe hangers and equipment support must be completed to determine if the existing support system can support the additional load associated with a hot water system. Additional structural consideration should be given when additional load from hot water is being proposed.

12. Stress and hydraulic analysis of the steam piping being repurposed should be investigated during the design stages of the building conversion. A review of existing steam equipment, such as but not limited to anchors and expansion components, may be required.

13. In critical building areas where steam piping is being repurposed, breaking up the piping into small test sections could be beneficial to identify leaks. An interim pneumatic pressure test could be completed on the test rig before water is introduced. This could assist with reducing some risk associated with pressure testing. Locating leaks with pneumatically tested systems generally requires exposed joints/piping sections and a soapy water test at every joint to reveal leaks via air bubbles.

14. For each respective steam piping and steam infrastructure system being reused for a hot water application, a site/system specific testing procedure should be completed to assist with mitigating risks.

15. The system pressure test procedure should include items such as, but not limited to, test pressure, pressure test fluid, pressure test time and the pressure test section. In addition to this, potential risks should be identified, and a plan should be in place to address the potential issues such as system leaks.

16. Generally, existing steam air handling unit (AHU) heating coils are not convertible to hot water. Installing new hydronic heating coils will enable heating coils to be designed considering the lower heating supply temperatures and larger delta Ts associated with the hot water system.

17. New hot water coils in AHUs with connection to outside air intakes will have freeze pump for protection and or have 40% glycol in the system. Large (+10,000 CFM) AHU's coils shall be fitted with Belimo energy control valves. Smaller AHU's (<10,000 CFM) coils will be fitted with PICCV control valves.

11 APPENDIX B – Sample Control Points List

HOT WATER SYSTEM	HARDWARE POINTS				SOFTWARE POINTS						SHOW ON GRAPHIC	NOTES
									ALARM			
	DI	DO	AI	AO	DV	AV	SCH	TREND	BMS	DESCRIPTION		
OUTSIDE AIR TEMPERATURE			X					X			X	One common sensor per building
OUTSIDE AIR DEWPOINT			X					X			X	One common sensor per building
BUILDING HWST STATUS			X					X			X	
BUILDING HWST SETPOINT COMMAND						X		X			X	Reset per OAT
BUILDING HWRT STATUS BEFORE HP/CH			X					X	X	+/- 2 degF from CHWRT setpoint for more than 10 minutes with pump running	X	
BUILDING HWRT STATUS AFTER HP/CH			X					X			X	
CAMPUS HWST STATUS			X					X			X	
CAMPUS HWRT STATUS			X					X			X	
EACH CAMPUS HW CONTROL VALVE COMMAND				X				X			X	
EACH CAMPUS HW CONTROL VALVE POSITION STATUS			X					X			X	From actuator position
EACH HW PUMP ENABLE/DISABLE COMMAND		X						X			X	
EACH HW PUMP STATUS			X						X	Commanded ON but not confirmed	X	Via current sensor
EACH HW PUMP SPEED COMMAND				X				X			X	
EACH HW PUMP SPEED (RPM) STATUS						X		X	X	Differ more than 10% from command	X	BACnet MSTP point from VFD
EACH HW PUMP POWER (KW) STATUS						X		X			X	BACnet MSTP point from VFD
PUMPS LEAD/LAG/STANDBY COMMAND							X					
HP/CH BYPASS CONTROL VALVE COMMAND		X										
HP/CH BYPASS CONTROL VALVE POSITION STATUS	X							X			X	From actuator position
HXs LEAD/LAG COMMAND							X					
EACH HW HX ISOLATION VALVE COMMAND		X					X				X	
EACH HW HX ISOLATION VALVE STATUS	X						X				X	From actuator position
SYSTEM STATIC PRESSURE COMMAND						X		X			X	
SYSTEM STATIC PRESSURE STATUS			X					X	X	High/Low limit	X	Min 2 sensors
CAMPUS INSTANTENEOUS ENERGY USE [BTUH]						X		X			X	From E&U energy meter
CAMPUS CUMULATIVE ENERGY USE [BTUH]						X		X			X	Calculated Hourly, Daily, Weekly, Monthly, Annually.
BUILDING HW TOTAL FLOW			X					X			X	Building flow meter.
BUILDING INSTANTENEOUS ENERGY USE [BTUH]			X					X			X	From building energy meter
BUILDING CUMULATIVE ENERGY USE [BTUH]						X		X			X	Calculated Hourly, Daily, Weekly, Monthly, Annually.
SYSTEM TOTAL POWER						X		X			X	Cumulative of all operating pumps

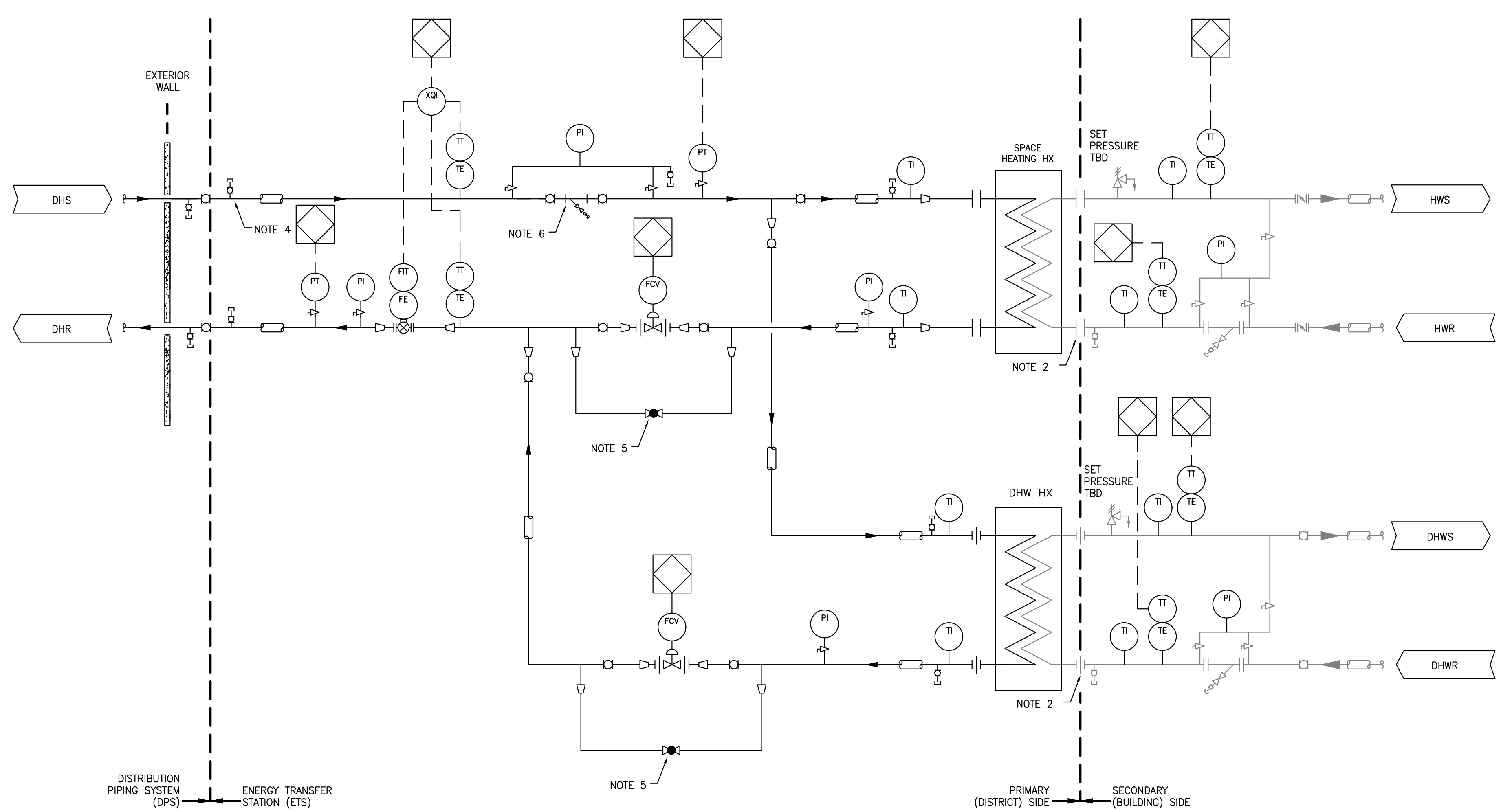
12 APPENDIX C – Sample Drawings

Figure C1: Typical Hot Water Flow Schematic

Figure C2: Typical Hot Water ETS Layout

Figure C3: Building Secondary System Example

FIGURE C1: TYPICAL HOT WATER ETS FLOW SCHEMATIC



LEGEND

BV	BALANCING VALVE
DPT	DIFFERENTIAL PRESSURE SENSOR/TRANSMITTER
DPS	DIFFERENTIAL PRESSURE SWITCH
FSL	FLOW SWITCH; L=LOW, H=HIGH
FE	FLOW METER
FIT	FLOW METER INDICATOR & TRANSMITTER
FCV	FLOW CONTROL VALVE
PI	PRESSURE INDICATOR
PT	PRESSURE TRANSMITTER
TE	TEMPERATURE ELEMENT
TI	TEMPERATURE INDICATOR
TS	TEMPERATURE SWITCH
TT	TEMPERATURE TRANSMITTER
PSV	PRESSURE SAFETY/RELIEF VALVE
PRV	PRESSURE REGULATING VALVE
XQI	ENERGY METER
VFD	VARIABLE FREQUENCY DRIVE
	PLANT CONTROLLER
	EQUIPMENT CONTROLLER
DHS	DISTRICT HEATING SUPPLY
DHR	DISTRICT HEATING RETURN
HWS	BUILDING HOT WATER SUPPLY
HWR	BUILDING HOT WATER RETURN
DHWS	DOMESTIC HOT WATER SUPPLY
DHWR	DOMESTIC HOT WATER RETURN

SYMBOLS

	SOLENOID VALVE
	CONTROL VALVE
	GLOBE VALVE
	BALL VALVE
	BUTTERFLY VALVE
	GATE VALVE
	CHECK VALVE
	THREE WAY VALVE
	NEEDLE VALVE
	CAP
	REDUCER
	ECCENTRIC REDUCER
	FLEX CONNECTION
	COUPLING
	STRAINER
	TRAP
	CATHODIC ISOLATION FLANGES
	FLANGE
	UNION
	INSULATION
	FLOW METER
	PUMP
	FLOW ARROW
	TIE–IN POINT
	PIPE BREAK
	DRAIN
	PRESSURE RELIEF/SAFETY VALVE
AAV	AUTO AIR VENT
	VACUUM BREAKER
AV	MANUAL AIR VENT

NOTES:

1. REFER TO BUILDING CONVERSION GUIDELINES FOR STRAINER SCREEN AND MESH SIZES.

2. PROVIDE DIELECTRIC COUPLING/UNION BETWEEN DISSIMILAR METALS. (i.e. BETWEEN STAINLESS STEEL AND COPPER)

3. PRESSURE RELIEF VALVES SHALL BE PIPED TO FLOOR DRAINS OR GLYCOL FILL TANKS AS APPLICABLE. SECURE RELIEF DISCHARGE PIPING TO STRUCTURE.

4. PROVIDE 1" BYPASS BETWEEN PRIMARY SUPPLY AND RETURN AT BUILDING ENTRANCE IN BUILDINGS THAT WILL SHUT ETS DOWN DURING SUMMER DUE TO NO HEATING OR DHW REQUIREMENTS. BYPASS SHALL INCLUDE ISOLATION VALVES, 2–POSITION CONTROL VALVE (ONLY OPEN WHEN ETS SHUT DOWN OCCURS), AND AUTOMATIC BALANCE VALVE (SET TO 5 GPM). BYPASS TO BE CONFIRMED WITH DC ON A CASE–BY–CASE BASIS.

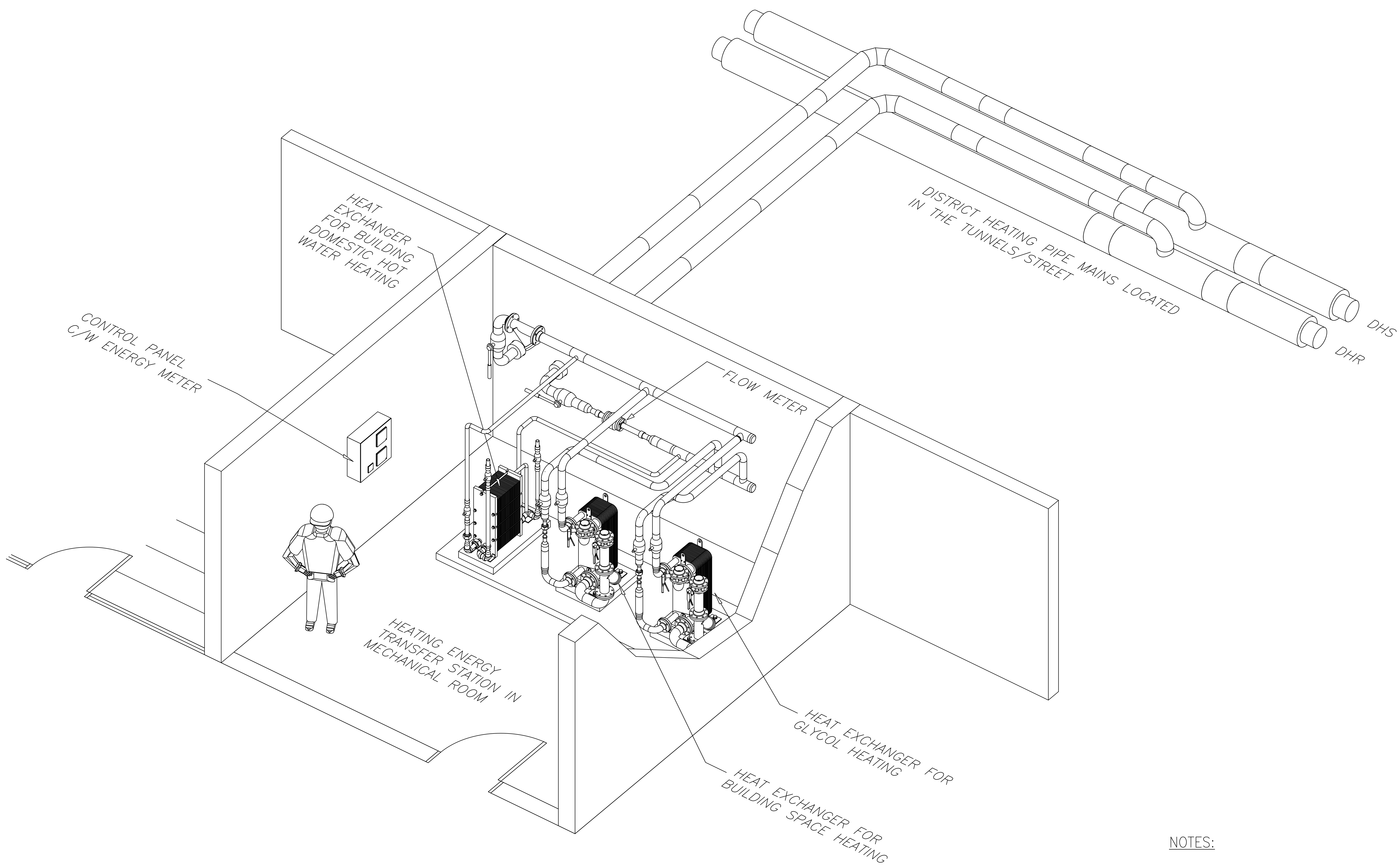
5. PROVIDE PRIMARY CONTROL VALVE BYPASS ACROSS SINGLE AND DUAL CONTROL VALVES. DUAL CONTROL VALVES ARE REQUIRED FOR FLOW RATES GREATER THAN ~80 GPM.

6. DUAL STRAINERS IN PARALLEL TO BE INSTALLED ON A CASE–BY–CASE BASIS, AS CONFIRMED WITH DC.

7. A DIFFERENTIAL PRESSURE TRANSMITTER SHALL BE INSTALLED ON THE PRIMARY SIDE OF HEATING ETS FOR USE AT CENTRAL PLANT TO CONTROL PUMP SPEED.

8. SCHEMATIC DRAWING IS FOR INDICATIVE PURPOSES ONLY AND DOES NOT CONSTITUE ALL MECHANICAL AND ELECTRICAL EQUIPMENT REQUIRED.

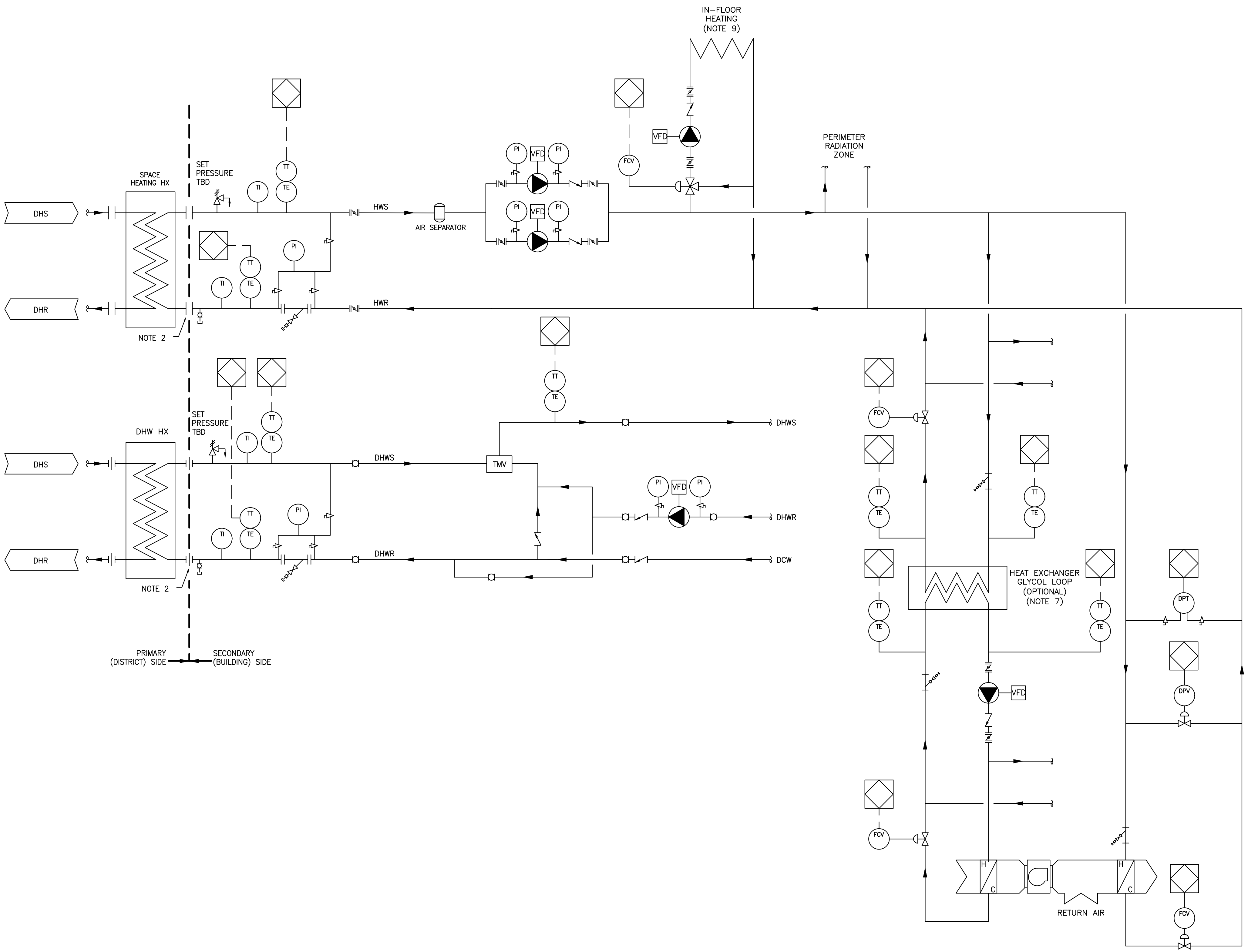
FIGURE C2: TYPICAL HOT WATER ETS LAYOUT



NOTES:

1. DRAWING IS FOR INDICATIVE PURPOSES ONLY AND DOES NOT CONSTITUTE ALL MECHANICAL AND ELECTRICAL EQUIPMENT REQUIRED.

FIGURE C3: EXAMPLE BUILDING SECONDARY SYSTEM



LEGEND

BV	BALANCING VALVE
DPT	DIFFERENTIAL PRESSURE SENSOR/TRANSMITTER
DPS	DIFFERENTIAL PRESSURE SWITCH
FSL	FLOW SWITCH; L=LOW, H=HIGH
FE	FLOW METER
FIT	FLOW METER INDICATOR & TRANSMITTER
FCV	FLOW CONTROL VALVE
PI	PRESSURE INDICATOR
PT	PRESSURE TRANSMITTER
TE	TEMPERATURE ELEMENT
TI	TEMPERATURE INDICATOR
TS	TEMPERATURE SWITCH
TT	TEMPERATURE TRANSMITTER
PSV	PRESSURE SAFETY/RELIEF VALVE
PRV	PRESSURE REGULATING VALVE
XQI	ENERGY METER
VFD	VARIABLE FREQUENCY DRIVE
	PLANT CONTROLLER
	EQUIPMENT CONTROLLER
DHS	DISTRICT HEATING SUPPLY
DHR	DISTRICT HEATING RETURN
HWS	BUILDINGHOT WATER SUPPLY
HWR	BUILDING HOT WATER RETURN
DHWS	DOMESTIC HOT WATER SUPPLY
DHWR	DOMESTIC HOT WATER RETURN
DPV	DIFFERENTIAL PRESSURE VALVE

SYMBOLS

	SOLENOID VALVE
	CONTROL VALVE
	GLOBE VALVE
	BALL VALVE
	BUTTERFLY VALVE
	GATE VALVE
	CHECK VALVE
	THREE WAY VALVE
	NEEDLE VALVE
	CAP
	REDUCER
	ECCENTRIC REDUCER
	FLEX CONNECTION
	COUPLING
	STRAINER
	TRAP
	CATHODIC ISOLATION FLANGES
	FLANGE
	UNION
	INSULATION
	FLOW METER
	PUMP
	FLOW ARROW
	TIE-IN POINT
	PIPE BREAK
	DRAIN
	PRESSURE RELIEF/SAFETY VALVE
AAV	AUTO AIR VENT
	VACUUM BREAKER
AV	MANUAL AIR VENT

NOTES:

1. REFER TO BUILDING CONVERSION GUIDELINES FOR STRAINER SCREEN AND MESH SIZES.

2. PROVIDE DIELECTRIC COUPLING/UNION BETWEEN DISSIMILAR METALS. (i.e. BETWEEN STAINLESS STEEL AND COPPER)

3. DIFFERENTIAL PRESSURE VALVE TO BE LOCATED ON INDEX LOOP TO PROVIDE MINIMUM PUMP FLOW.

4. PROVIDE AIR SEPARATOR ON SECONDARY SUPPLY PIPING BETWEEN DISTRICT ENERGY HEAT EXCHANGER AND PUMPS.

5. SECONDARY DISTRIBUTION PUMPS TO BE CONTROLLED BY DIFFERENTIAL PRESSURE SENSORS.

6. BUILDING SECONDARY FILL AND EXPANSION COMPONENTS NOT SHOWN FOR CLARITY PURPOSES ONLY.

7. GLYCOL HEATING HEAT EXCHANGERS CAN BE SERVED FROM THE DISTRICT HOT WATER SYSTEM.

8. SCHEMATIC IS INDICATVE AND DOES NOT CONSTITUTE ALL MECHANICAL AND ELECTRICAL EQUIPMENT REQUIRED, NOR THE ONLY SECONDARY SYSTEM CONFIGURATION.

9. SECONDARY HOT WTAER SYSTEMS CAN BE CASCADED FROM THE BUILDING HOT WATER RETURN IF HIGHER DELTA T CAN BE REALIZED. INJECTION LOOPS WITH A CONTROL VALVE MAY BE REQUIRED TO BOOST SUPPLY TEMPERATURES ON THE SECONDARY CASCADED SYSTEM.

10. PROVIDE THERMOSTATIC MIXING VALVE(S) AS REQUIRED BY GOVERNING CODES ON DHW SYSTEM AND SPECIFIC SYSTEM REQUIREMENTS.

11. PROVIDE NECESSARY 3-WAY VALVES ON TERMINAL UNIT(S) AT END OF LOOP TO MAINTAIN MINIMUM REQUIRED GPM FOR HEAT EXCHANGER AS REQUIRED.