Hydronic System: For the purposes of this writing a *hydronic* system is defined as a non-potable water-based heat transfer system, excluding steam. It is acknowledged that steam is often included within the hydronic category. This section addresses closed loop hydronic systems, both heating and cooling, with an emphasis on hot water heating systems.

Compliance: Hydronic heating/cooling systems shall be in compliance with all applicable codes and standards including:

- *ASME B31.9 – Building Services Piping*
- *ASME B16* Standards for Pipe and Fittings as applicable.

Central Systems: Each building shall be served by a minimal number of central hydronic systems rather than numerous smaller systems.

Separate Systems: Two independent hot water heating systems shall be provided in each building. One shall serve reheat coils and other devices that must remain in service year-round. The other shall serve AHU preheat coils and perimeter heating units including finned tube, vestibule heaters, unit heaters and other devices potentially exposed to freezing conditions. Provision shall be made for disabling this system during warm weather conditions.

Each system shall incorporate a dedicated heat exchanger and duplex pumps along with other standard system components such as expansion tank, air/dirt separator and bypass filter. A dedicated controller along with dedicated static and differential pressure transmitters shall be provided for each system. The perimeter/preheat system shall be filled with inhibited ethylene glycol solution.

Glycol content shall be 30% by weight. The reheat system shall be filled with "inhibited" chemically treated water.

Advantages of separate building heating systems include:

1. Optimized temperature set-point for each system.
2. Increased opportunity for energy conservation strategies. For example, central air systems may be cycled off at night given that heating can be provided separately via the perimeter heating system.
3. Redundant heat sources to provide uninterrupted heat during system maintenance. One system can remain in service providing heat while the other is taken off line for maintenance or repair.
4. Redundant heat sources to prevent freezing during system failure. Upon failure of one system the other can provide reserve heat during cold weather conditions
5. Positive shut-off of perimeter/preheat system during building cooling mode operation. Prevents unwanted heat gain from hot piping, leaking control valves and any bypass flow.
6. Elimination of glycol solution from reheat system. Perimeter/preheat systems require glycol solution for freeze protection. Thus, combining systems results in reheat coils served by glycol solution. Separating systems allows reheat coils to be served by water only without glycol.
7. Reduced emergency power requirement for heating upon loss of electrical power. Central air systems can be turned off and perimeter heating system left in service to provide building heat. Central air systems incorporate larger fan motors in addition to pump motors while perimeter heating system requires electrical power for pumping only.

Reverse vs. Direct Return: A reverse return piping configuration is desirable but not required for hydronic systems that serve multiple terminal units. Direct return configuration is acceptable given that it is typically more cost effective and practical.

Oversize Piping: When direct return systems are used, risers, mains and main branches shall be "oversized" (i.e. generously sized) so as to reduce pressure differential and thus enhance balancing of the system while reducing pump head.

Constant vs. Variable Flow Systems: Subject to compliance hydronic heating/cooling systems shall be variable flow type and shall utilize two-way control valves exclusively at all central station and terminal units. Exception: Constant flow devices such as chillers, boilers and preheat coils shall be configured for localized constant flow as required. A discussion of preheat coils follows. Each pump motor in each variable flow system (regardless of size) shall be served by a variable frequency drive (VFD). A three-way control valve shall not be installed within a variable flow system, not even to prevent a potential no-flow condition or to maintain continual circulation throughout the entire system. Required minimum flow shall be maintained by providing a dedicated manual bypass valve as addressed below.

Balancing: Subject to compliance and as required, balancing of hydronic systems is to be provided.
Design considerations regarding balancing constant flow systems:

1. Manual calibrated balancing valves are to be provided as required to balance flow through each individual component as well as bypass flows. Balancing valves are also to be provided for balancing subsystems (e.g. sizable branch circuits) to the degree beneficial.
2. Total system proportional balancing is to be accomplished in accordance with applicable standards approved by the *University*.

Design considerations regarding balancing variable flow systems:

1. The use of calibrated balancing valves in variable flow systems is generally discouraged at terminal and unitary devices such as reheat coils, finned tube elements and fan coils. Installation of balancing valves in series with control valves reduces valve authority and thus hinders optimal control of the heat exchange device.
2. However, it is acknowledge that provision of balancing valves at such devices may be useful for diagnostic purposes. Although rarely used for troubleshooting at the University, manual balancing valves may be included in hydronic system design if deemed essential by the designer.
3. Balancing valves are to be provided as required for balancing relative flow through multiple parallel devices served by a single control valve assembly such as stack coils within an AHU or multiple heat exchangers.
4. Balancing valves are not to be provided in conjunction with pressure independent control valves that incorporate flow measurement capability.
5. Reducing the number of balancing valves within a hydronic system reduces material cost and may reduce the scope of balancing contractor services.
6. The value of overall proportional balance of a variable flow system is limited given that system flows are dynamic. The operational system is essentially self-balancing as control valves determine required flow rate through each device.

Flow Limiting Valves: Design considerations regarding application of pressure independent automatic flow control (flow limiting) valves:

1. Flow limiting valves may be most useful at providing constant flow through devices with two position open/closed control valves, particularly within systems that have fluctuation pressures (e.g. variable flow systems). Examples of fixed flow devices that benefit from application of flow limiting valves include bypass filters, process equipment and unit heaters.
2. In some cases providing an adjustable flow limiting valve may prove beneficial.
3. Flow limiting valves are not to be installed in series with a two-way modulating control valves. When installed in series, the two valves work at counter purposes. The function of the modulating control valve is to vary flow rate, whereas the function of the flow liming valve is to maintain constant flow rate.

Pressure Independence:
It is acknowledged that pressure independence within variable flow hydronic systems has certain advantages over a strictly pressure dependent system design. Advantages include enhanced controllability and reduced valve “hunting”.
Design considerations for pressure independent systems.

1. In general, chilled water coils served by the campus central chilled water system shall be fitted with pressure independent control valves. Exception: Small chilled water control valves such as those serving fan coil units should typically be

pressure dependent type. It has been the experience of the University that adequate control can be maintained without use of PI valves for these applications.

2. Large heating coils may also be appropriate applications for pressure independent control valves.
3. At the time of this writing it is the University's position that high quality pressure dependent control valves are to be provided at terminal and unitary devices within variable flow hydronic heating systems. Such devices include reheat coils and finned tube elements. When a measure of pressure independence is deemed particularly beneficial PI regulating devices may be provided within mains and main branches within the piping system. An example of a main branch would be the piping system dedicated to an individual floor within a building. This results in reduced pressure fluctuations near the primary pump(s) in addition to a measure of pressure independence throughout the entire system.

Note: Refer to HVAC instrumentation and controls sections within these *Facilities Standards* for specific applications and additional requirements.

Continuous Circulation and Minimum Flow: Continuous circulation and minimum flow are to be maintained in variable flow hydronic systems. No-flow conditions are to be avoided. Required circulation is to be maintained by providing a calibrated balancing valve in bypass configuration between the supply and return piping at a location near (but not too near) the system differential pressure transmitter. A modulating control valve is to be provided in series with the balance valve such that bypass flow may be enabled or disabled via the Building Automation System (BAS). The control and balance valves are to be sized for the required minimum flow rate.

Appropriate minimum flow rate is to be maintained for the following reasons:

1. To protect boilers, chillers, process equipment, etc. from damaging effects of an inadequate flow condition.
2. To protect the system pump, particularly it's seals, from damage due to inadequate flow.
3. To protect the VFD controlled pump motor from overheating at low motor speed conditions.
4. To enhance system response time. Maintaining circulation can enable equipment to start and increase output more quickly. It can provide HW to terminal heat exchange devices (e.g. reheat coils and finned tube elements) more quickly. However this is of limited importance in such systems given that loads typically change slowly.

Preheat Coil: The localized hydronic piping at each preheat coil within a variable flow system shall be configured to provide constant flow through the coil. This requires the addition of a dedicated circulation pump and recirculation bypass line for each coil (*See Drawings 23 21 00-02 and 23 20 00-3.)* Constant hot water flow through preheat coils yields more consistent leaving air temperature across the full face of the coil. This results in a reduction of nuisance freeze-stat trips. Providing a "pumped coil" in this manner is not accomplished to provide freeze protection for the coil. Coil freezing is of no concern given that the system is filled with glycol solution.

Differential Pressure Control: For variable flow closed loop hydronic systems, pump speed shall be governed by differential pressure feedback. The associated DP transmitter shall be located near the most hydraulically remote point in the system and connected to the building EMS. Occasionally it may be necessary to provide multiple DP transmitters for large and/or complex building systems where it is difficult to identify the most hydraulically remote point in the system. DP sensors shall be connected to "mains" in the building system rather than smaller branch lines. They shall not be located on the "coil side" of any coil isolation valve. The goal here is to minimize the impact that a single coil or grouping of coils has on the measured DP of the larger building system. Toward this end, consideration shall be given to converting a branch into a main (in effect) by increasing its size. See paragraph entitled *Pressure Differential / Fill Pressure Control* within the *Energy Management, Building Automation Systems* section within these *Facilities Standards.*

Static Pressure Monitoring: As applicable, static pressure feedback at the building level shall typically be accomplished by connecting a pressure transmitter to a return main at or near the highest point in the building system and incorporating it into the building EMS. Where suitable the SP transmitter shall be connected to the system at the same location as the DP transmitter. As with the DP transmitter the SP transmitter shall be connected to a "main" rather than a branch.

Terminal Zoning: As reflected in the paragraph entitled *Terminal Zoning* within the *HVAC Systems* section within these *General Guidelines,* heating systems shall be configured such that each occupied space shall be controlled as a separate temperature zone.
Heated vestibules and similar applications shall also be configured and controlled as a standalone zone with fan operation and temperature controlled via BAS rather than unit mounted controls.

Backup Equipment: A 100% backup or duplex unit shall be provided for each truly critical piece of hydronic heating or cooling equipment that is vulnerable to failure (e.g. chillers, boilers, heat exchangers, pumps, etc.). When a hot water heat exchanger serves only one of two heating systems (i.e. a perimeter/preheat system or a reheat system) it may be viewed as a non-critical unit requiring no backup. If it serves a single combined perimeter/preheat/reheat system it shall be viewed as critical, requiring backup.

Pumps: Centrifugal pumps that incorporate motors 2 HP or less may be of the close-coupled in-line type. The goal of limiting the size of in-line pumps to 2 HP is facilitation of removal and replacement by service personnel working off of a ladder. Accessibility of in-line pumps shall be such that the rotating assembly can be removed from the pump without removing the pump casing from the piping. Otherwise, coordination of multiple trades would be required. Pumps that incorporate motors 3 HP or larger shall be of the base mounted type. Pumps with inlet connection size through 6" shall be end-suction type. Double-suction horizontal split case pumps shall be used for applications with inlet connection size larger than 6". Double suction vertical split case pumps are not allowed (e.g. B&G VSC, VSCS).

Pump Support: In-line pumps shall be supported by connected piping with no flexible connections provided. Pipe supports shall be provided near the pump on either side. When located on the lowest floor of a building, base-mounted pumps shall typically be "hard-mounted" and "hard-piped" without spring supports and without flexible pipe connectors. Pumps located on upper floors may have inertia bases, spring supports and flexible connectors to the degree required to reduce transmission of noise and vibration. Exception: Pumps on lowest floor may be spring supported with flex connectors if required to limit transmission of vibration to adjacent spaces with ultra-sensitive laboratory devices such as electron microscopes. Regardless of location, all spring-supported pumps shall incorporate inertia bases.

Impact of Bypass Flow: The overall system shall incorporate bypass flow at two locations: 1) at the remote bypass valve addressed above and 2) at the bypass bag filter addressed below. Total bypass flow will impact the system operating point. This shall be accounted for in pump selection. Total bypass flow is typically on the order of 10%. Design documents shall incorporate bypass flow.

"Over-Speed": Pump selection shall be based upon 60 Hz motor frequency at design operating point. However, if desired, capacity can be increased in the future by "over-speeding" the motor via VFD. Electric motor operation above 60 Hz. has become accepted practice. However, pump speed can only be increased within the limits of FLA. Thus, a motor may need to be "oversized" initially to provide an amperage buffer for future. Initial pump selection shall not be based upon frequency less than 60 Hz. in anticipation of future speed increase. This approach limits available motor HP. Pump motors shall never be operated in excess of 80 Hz.

Pipe, Valves, Fittings: Pipe, valves and fittings in hydronic heating/cooling systems

shall be metallic and shall be joined by means of soldering, threading or welding. Unions and flanges shall be used in conjunction with such systems. Grooved or press-fit systems are not allowed. See *Section 23 21 13 – Hydronic* Piping for other disallowed products.
Exceptions:

- With specific approval of Owner, grooved and/or press-fit components may be used in locations where hot-work is problematic. This exception typically applies to portions of systems rather than entire systems. Conditions that disallow hot work are rare.
- Nonmetallic pipe and fittings may be used within limitations presented in following paragraph entitled *Nonmetallic Piping.*

Nonmetallic Piping: Non-metallic piping design considerations:

1. General: Non-metallic (polymeric) hydronic piping systems present certain advantages over traditional metallic systems. The foremost of which are elimination of corrosion within the system and elimination of leaks resulting from poor installation of metallic systems. Both issues have been ongoing problems here at the University in recent years. Leaking solder joints have proven to be a troublesome problem with newly installed systems. Thus, PP-R and PP-RCT pipe and fittings may be used on a case by case basis within rated pressure/temperature limitations. Use of PP-RT (e.g. Aquatherm) shall be limited to lower temperature applications. PP-RCT may be used for elevated temperature applications. See *Section 23 21 13 – Hydronic Piping. D*efault wall thickness for lower temperature application shall be SDR 11. Default wall thickness for elevated temperature application shall be SDR 7.4.
2. Worst Case Analysis: For each elevated temperature application a “worst-case” analysis shall be performed. A typical worst-case scenario for a HW heating system would be as follows: pumps off, steam valve open (or leaking), elevated system pressure. In such case the water temperature could reach the steam saturation temperature and the pressure could reach the relief valve set-point. A judgement shall be made regarding how long such failure mode could realistically persist. The manufacturer shall be engaged to determine the impact of such event on the life of the PP-RCT system as well as any impact on the product warranty. A summary of this evaluation shall be presented to F&S for approval.
3. Fail Safe: If a PP-RCT system is installed for an elevated temperature application several feet of metallic pipe shall be provided at each connection to heat producing equipment to facilitate heat dissipation. Relief valve set-point shall be as low as practical. Fail-safe controls with hard-wired safeties shall be provided.
4. Valves: Standard metallic valves and specialties with NPT or flanged connections shall be utilized as specified within project documents. Use of non-metallic valves and components are not approved at the time of this writing but will continue to be evaluated for potential use in the future. Installation of any nonmetallic pipe, fitting or component within a hydronic system is contingent upon approval of *F&S Engineering*.

Valves: For the most part gate and globe valves shall no longer be installed in campus buildings. With few exceptions valves shall be quarter turn ball or butterfly type. Quarter turn and rotary valves now dominate campus building steam and hydronic systems. Exception: Globe valves may be used for manual throttling service.

Isolation: At a minimum, valves shall be provided to enable isolation of each individual piece of equipment in a hydronic system. In addition to other isolation valve requirements valves shall be provided in major branch lines at connections to mains. Specific requirements for main risers: Isolation valves shall be provided in branch lines serving each floor. Dedicated vents and drains shall be provided at these isolation valves.

Expansion Tank: A replaceable bladder type expansion tank shall be provided for each closed loop hydronic system. See *Drawing 23 21 00-1, Flow Diagram – Hot Water Heating System.*

Air/Dirt Separator: An in-line coalescing air/dirt separator (not to be confused with a traditional centrifugal type separator, e.g. B&G Rolairtrol) shall be provided in each closed loop hydronic system.
The University has embraced this as a standard requirement given that poor water quality has become an ongoing problem in hot water heating systems. In addition to removing particulate, these devices have proven to be quite effective at removing entrained air. See *Drawing 23 21 00-1, Flow Diagram – Hot Water Heating System*. Please note: The referenced flow diagram has been updated. It presents a new piping configuration that allows blow-down of the air/dirt separator through the bypass bag filter. Thus the air/dirt separator can be blown down without removal of fluid from the system.

Air Vents: An air vent shall be provided at each system high point. Each vent shall consist of a manual valve with provision for connection of flexible hose. Automatic air vents are generally disallowed given that they are prone to "spitting" and leaking. This can result in substantial removal of fluid from the system over time. Automatic air vents also allow air to be draw into the system when localized system pressure drops below atmospheric. If it is determined that an automatic vent must be permanently installed, copper tubing shall be extended from the vent outlet to a suitable drain. Each automatic air vent shall be fitted with an isolation valve between itself and the piping system.

Bypass Filter: Each closed loop hydronic system shall incorporate a bypass bag filter in conjunction with the air/dirt separator to further improve particulate removal. After initial system cleaning, bypass flow through a clean filter shall be adjusted to 5-10% of system design flow rate. See *Drawing 23 21 00-1, Flow Diagram – Hot Water Heating System.* The balancing device shall be an adjustable pressure independent flow limiting valve.

Fill Unit: A permanent fill unit shall not be provided. Such units increase risk of inadvertent glycol dilution resulting in freeze failure of system components. A portable fill unit shall be provided for each hydronic system to reduce such risk. See *Section 23 21 13* for specification.

Cleaning, Chemical Treatment: Hydronic systems shall be chemically cleaned, flushed and charged with ethylene glycol and/or other water treatment chemicals prior to placement into service. Achieving an adequately cleaned and properly treated hydronic system is among the greatest challenges faced when installing or modifying such systems. Permanently mounted building pumps may be used for recirculation of cleaning solution to achieve specified system cleaning within closed loop systems. For hydronic systems that do not incorporate building pumps, such as those served by the central chilled water system, portable pumps shall be provided to achieve required recirculation. The building system shall be isolated from the central system during cleaning and flushing operations. Once cleaning and flushing is complete the building system may be opened up to the larger central system. Chemical treatment of the central chilled water is not required at the building level. It will be accomplished remotely at the central chilled water plant(s).

Freeze Protection: Hydronic piping systems that contain no antifreeze solution (and never will) shall not be installed in locations that present vulnerability to freezing conditions (e.g. outdoors without sufficient earth cover, within unheated spaces, within building exterior walls or wall cavities, within exposed overhangs, within exposed exterior walkways, etc.) Hydronic systems that incorporate components that are likely to be exposed to freezing conditions (e.g. preheat coils, perimeter finned tube elements, vestibule heating units, outdoor chillers, etc.) shall be filled with ethylene glycol solution. Glycol content shall be 30% by volume. Antifreeze solution shall never be used in any chilled water system that is served by the campus central chilled water system. The system fluid in each hydronic heating or cooling system, whether water or antifreeze solution, shall contain corrosion inhibitors appropriate for

protecting components within that specific system.
Note: Although the University has standardized on ethylene glycol for hydronic heating/cooling systems propylene glycol may be required in some cases such as fluid systems associated with food grade products.

Elastomers: Devices that incorporate elastomers that are vulnerable to hardening, cracking and leaking with age shall not be installed in hydronic systems. This includes dielectric fittings, bolt-on saddle tap type pipe connectors and rubber gaskets ("red rubber gaskets").
Many leaks have developed within hydronic systems across campus over the years as elastomers within these devices hardened and cracked with age.
Dielectric Fittings: Dielectric materials are to be provided between dissimilar metals in hydronic systems. However, separation of copper and ferrous piping shall not be accomplished using standard dielectric fittings. If it is deemed essential to provide a dielectric fitting a "Clearfow" fitting is to be used. Such fittings incorporate a thermoplastic liner that yields no contact between system fluid and metal components.