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 AHU preheat coils and perimeter heating units including finned tube, vestibule heaters, unit heaters and other devices potentially exposed to freezing conditions. These units can all be disabled during warm weather conditions. The other hot water heating system shall serve reheat coils and other devices that must remain in service year-round.

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. Redundant heat sources to provide heat during system maintenance
2. Redundant heat sources to prevent freezing during system failure
3. Optimized temperature set-point for each system
4. Positive shut-off of perimeter/preheat system during building cooling mode operation
5. Reduced emergency power requirement for pumping upon loss of electrical power.

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. When direct return systems are used, it is preferred that risers, mains and main branches be “oversized” (i.e. generously sized) so as to yield a somewhat self-balancing system.

Constant vs. Variable Flow Systems: All 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 Valves: The use of balancing valves in variable flow hydronic systems is generally discouraged, especially at terminal and unitary units such as reheat coils, finned tube elements and fan coil units. Manual balancing valves can actually do more harm than good. There are multiple valid reasons supporting this position. These include:

1. The installation of balancing valves in series with control valves reduces control valve authority and thus hinders optimal control of the heat exchange device.
2. The installation of balancing valves results in increased project cost. Deletion of balancing valves not only eliminates the installed cost of the

valves themselves but also eliminates the need for a balancing contractor to adjust them.

3. Typically, the reference point for proportional balancing is not fixed as loads vary from design conditions. Thus, relative flow rates through devices are not consistently proportional. Balancing fluid flow throughout a variable flow hydronic system is like balancing airflow throughout a medium pressure VAV duct system. For optimal control, flow rate adjustment should be accomplished with a dynamic control device (control valve or VAV box) rather than a static balancing device (balancing valve or balancing damper).

Exception: Balancing valves are more appropriately applied for balancing flow through multiple parallel devices served by a single control valve assembly such as stacked coils within an AHU.

Flow Limiting Valves: Although common practice, a pressure independent flow limiting valve shall not be installed in series with a two-way control valve. When installed in series, the two valves work at counter purposes. The function of the control valve is to vary flow rate, the function of the PI flow control valve is to maintain constant flow rate.

Continuous Circulation: A measure of continuous circulation shall be maintained in variable flow hydronic heating systems.
A no-flow condition shall be avoided. Traditionally it has been deemed necessary to maintain <u>substantial</u> continuous flow for at least three reasons: 1) to protect system pump(s) from operation below recommended minimum flow rate, 2) to protect pump motor(s) from overheating at low speed and 3) to support a perceived requirement for instantaneous heating at all locations within the system. With regard to motor overheating: Today's VFDs and motors generate very little heat at reduced speed allowing them to operate at very low speed/frequency. VFDs are typically programmed at 15 Hz minimum. In order to maintain DP system set-point the pump will rarely operate below 25% speed. With regard to on-demand hot water: In HVAC heating systems, loads typically change slowly and thus quick response is not required. So why is continuous circulation needed? It is needed to ensure adequate flow/velocity of hot water past the temperature sensor(s) located downstream of heat exchanger(s) in order to ensure proper sensing of supply HW temperature. The required circulation shall be maintained by providing a manual balance valve in bypass configuration between hot water supply and return piping at a location near the system differential pressure transmitter. The valve shall be adjusted to provide adequate flow across the temperature sensor not to exceed 5% of the total system design flow rate. An automated valve shall not be used given vulnerability to operational failure.

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.

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. See paragraph entitled *Pressure Differential / Fill Pressure Control* within the *Energy Management, Building Automation Systems* section within these *General Guidelines.*

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 (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.

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.

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. 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.*

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 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. The blancing valve shall be a pressure independent flow limiting devide. See *Drawing 23 21 00-1, Flow Diagram – Hot Water Heating System.*

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.

Elastomers: Devices that incorporate elastomers that are vulnerable to hardening, cracking and leaking with age shall not be installed in hydronic systems. This includes certain dielectric fittings, bolt-on saddle tap type pipe connectors and specific rubber gaskets (e.g. “red rubber gaskets”).
Many leaks have developed within hydronic systems across campus over the years as elastomers within these devices harden and crack with age.

Dielectric Fittings: Separation of copper and ferrous piping within a hydronic heating /cooling system shall not be accomplished by installing standard dielectric fittings. However, “Clearfow” dielectric fittings may be used. Such fittings incorporate a thermoplastic liner that yields no contact between system fluid and metal components. Brass fittings, bronze fittings and bronze body valves may also be used to separate copper and steel piping.