CHAPTER 4: BUILDING COOLING AND HEATING SYSTEMS

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4.1 INTRODUCTION

This chapter describes refrigeration and heating systems for building HVAC systems. Information given below should be used in conjunction with the VA Standard Details, Master Specifications, and associated documents, described in the TIL. See Chapter 1 for more information on the TIL.

(a) Refrigeration Systems

- Central chilled water plants
- Air-cooled chillers
- Chilled water system components
- Direct expansion (DX) systems

(b) Heating Systems

- Steam systems (excluding steam generation and outside distribution)
- Hydronic hot water systems
- Glycol systems
- Electrical heating systems
- Gas heating
- Miscellaneous systems

4.2 REFRIGERATION SYSTEMS

4.2.1 GENERAL

Selection of the refrigeration systems and equipment shall be based on applicability to the specific project and cost-effectiveness.

(a) Choice of Refrigerant: Evaluate and justify the choice of refrigerant for each project. The refrigerant shall be fully compatible with all local, state, and federal regulations. The refrigeration equipment selection shall be based on the new EPA-approved refrigerants such as HCFC 123, HFC 410a, and HFC 134a. The latest versions of ASHRAE Standards 15, Safety Code for Mechanical Refrigeration and ASHRAE Standard 34, Designation and Safety Classification of Refrigerants, shall be followed to ensure full compliance.

(b) Reciprocating Compressors: The use of reciprocating compressors is ***not*** permitted.

4.3 CENTRAL CHILLED WATER PLANTS

4.3.1 GENERAL

For new construction and major renovation projects, central chilled water plants shall comprise multiple (minimum two) water-cooled chillers, using centrifugal (open or hermetically sealed) or rotary-screw compressors or absorption machines.

4.3.2 SPECIAL REQUIREMENTS

4.3.2.1 Maximum Chiller Capacity

Capacity of a single chiller shall not exceed 1,250 tons of refrigeration when rated at ARI conditions. All chillers shall be the products of one manufacturer.

4.3.2.2 Standby Chiller Capacity

For new construction and major renovation projects, the central chilled water plant shall comprise N+1 chillers, where N = number of chillers in operation to meet the total cooling demand and 1 (one) is the installed standby chiller. Capacity of the standby chiller shall match the capacity of the largest installed chiller. Provide N+1 plant components.

- Chilled Water Pump
- Condenser Water Pump
- Cooling Tower
- Required Controls

Size chilled water and condenser water piping mains for total installed capacity.

4.3.2.3 Central Chilled Water Plant Sizing

Do not include cooling load requirements for special applications where mandated dedicated chillers are required.

Exception:

Surgical Suite – When selecting chillers, chilled water systems, and interfacing with the central, chilled-water plant, use the following criteria:

With Central Chilled Water Plant
Provide two banks of cooling coils arranged in series in the dedicated air-handling unit serving the surgical suite. Use chilled water from the central chilled water plant to perform the first stage of cooling with the water temperature at 44 F [7.0 C]. Use chilled water from the dedicated chiller serving the surgical suite to perform the second stage of cooling with a chilled water supply temperature at approximately 41 F [5 C].

With this arrangement, the dedicated surgical suite chiller size shall be reduced considerably and the central chilled water plant will not have to operate at 41 F [5 C]. Chilled water at a temperature of 41 F [5 C] is required to produce approximately 47 F [8.3 C] air leaving temperature, which is required to maintain inside design conditions of 62 F [16.7 C] and 60% relative humidity.

Without Central Chilled Water Plant
Where a central chilled water plant is not available, size the dedicated chiller to meet the following requirements:

- Total cooling demand of the surgical suite
- Inside design conditions with appropriate chilled water temperature and flow through a single bank of cooling coils

4.3.2.4 Minimum Performance Compliance, based on ASHRAE Standard 90.1 – 2007

Table 4-1: Water Chilling Packages – Minimum Efficiency
Water-Cooled, Electrically Operated
Based on FEMP Requirements

Equipment Type	Capacity	Minimum Efficiency Full Load (kW/ton)	Minimum Efficiency IPLV (kW/ton)	Test Procedure
Rotary Screw	150 - 299 Tons	.64	.49	ARI 550/590
	300 Tons and Larger	.64	.49	
Centrifugal	150 - 299 Tons	.59	.52	ARI 550/590
	300 - 2000 Tons	.56	.45	

Table 4-2: Water Chilling Packages – Minimum Efficiency
Air-Cooled, Electrically Operated
Based on FEMP Requirements

Equipment Type	Capacity	Minimum Efficiency Full Load (kW/ton)	Minimum Efficiency IPLV (kW/ton)	Test Procedure
Scroll	30 – 60 Tons	1.23	.86	ARI 550/590
Screw	70 – 200 Tons	1.23	.98	ARI 550/590

Table 4-3: Water Chilling Packages – Minimum Efficiency
Absorption Machines
Based on ASHRAE 90.1 - 2007 Requirements

Equipment	Capacity	Minimum Efficiency Full Load (COP)	Minimum Efficiency IPLV	Test Procedure
Single Effect	All Capacities	0.70	-----	ARI 560
Indirect-Fired Double Effect	All Capacities	1.00	1.05	
Direct-Fired Double Effect	All Capacities	1.00	1.00	

4.3.2.5 Use of Glycol – Chilled Water Systems

(a) Use of glycol is not permitted in chilled water systems, as it counteracts the mandated goal of increased energy conservation and results in higher maintenance. Specific reasons are:

- Reduced heat transfer efficiency of the chillers and cooling coils
- Increased pumping horsepower and energy consumption due to increased viscosity
- Increased recurring maintenance due to loss of glycol concentration over time
- Increased initial cost, due to requirements for glycol, pumping kit, and larger chilled water pumps

(b) To counteract the possibility of freezing, the A/E shall include project-specific measures in the design documents. A few suggestions are:

- Increase the thickness of the chilled water piping insulation by 1 inch [25.4 mm] over the recommended thickness for indoor applications.
- Select higher density (minimum 3.0 lb/ft^3 [48.055 kg/m^3]) for the pipe insulation.
- Provide thermostatically-actuated heat tracing by selecting a cable of appropriate density (Watts/Linear Foot). Connect heat-tracing circuit to emergency power.
- Provide a control sequence to start the pumps and keep chilled water in circulation below 32 F [0.0 C] ambient temperature.
- Provide a storage tank to store the exposed chilled water volume below pre-set chilled water temperature. Locate tank in covered and heated space.

4.3.3 COMPREHENSIVE CHILLED WATER SYSTEM STUDY

Provide a major study, in accordance with the guidelines given in Chapter 1, which evaluates and defines the lowest life-cycle cost performance. The study shall evaluate chillers, piping/pumping configuration, condenser water systems (cooling towers, pumps and piping), waterside economizers, and thermal energy storage.

4.3.3.1 Optimization – Chiller Performance

The chilled water supply and the chilled water temperature differential (between entering and leaving temperatures) shall be optimized during the system selection process. Past studies and recommendations have demonstrated that selecting a chilled water supply temperature lower than 44 F [6.7 C] and a chilled water temperature differential higher than 10 F [5.6 C] results in an energy-efficient and optimum design.

Chillers can be of uneven size if the design is deemed efficient to meet the part-load and winter cooling demand.

4.3.3.2 Chilled Water Pumping/Piping Configuration

A comprehensive study shall evaluate a cost-effective and appropriate piping and pumping system. Two systems are described here – Primary/Secondary System (PSS) and Variable Primary System (VPS). Chillers, cooling towers, and pumps shall be headered together to ensure total interoperability.

4.3.3.3 Primary-Secondary System (PSS)

(a) General: See Figure 4-1 for piping and pumping arrangement. Arrange piping and pumping in order to isolate a chiller and its associated auxiliary equipment (chilled water and condenser water pumps and cooling tower) while ensuring that the leaving chilled water temperature remains unchanged.

(b) Primary Loop: Design a constant-volume, primary loop with a dedicated pump for each chiller. Chilled water supply and return headers shall enable the use of any pump with any chiller. Include a two-way modulating control-valve and a flowmeter in each chiller circuit to isolate the idle chiller when not in operation and keep constant flow through each evaporator when one chiller or all chillers are in use.

(c) De-Coupler Piping: Provide hydronic separation (de-coupler piping) between the primary and secondary loops to separate the two circuits and enable the chilled water flow to change direction.

(d) Secondary Loop: system Provide secondary pumping loop with multiple pumps. Provide two-way modulating control valves in the secondary circuit for the cooling terminal devices. Provide a high-accuracy flowmeter in the secondary circuit. Secondary pumps shall be equipped with variable speed drives. The secondary system is a variable flow system.

(e) Control Strategy:

(1) The secondary chilled water pump speeds shall vary in response to part-load conditions by maintaining the set pressure differential in the secondary loop. Include a chilled water differential pressure assembly (DPA) in the secondary chilled water piping across the hydronically farthest loop. Multiple DPAs may be required to sample patently different loops. Using multiple differential assemblies, the drive shall move only if all devices are polled and their specific set-points are not compromised. Calibrate the actual set-point of the assembly in conjunction with the manual reading given by the TAB (Testing, Adjusting, and Balancing) contractor. Show exact location of the DPA on the floor plans and riser diagrams.

(2) Accomplish loading, unloading, and sequencing of chillers and associated auxiliaries in response to the prevailing load and accumulated run time. Include devices such as a chiller control panel, chilled water temperature sensors in the primary supply and return and the secondary supply and return and flowmeter to develop a control strategy.

(3) Integrate the function of microprocessor-based chiller controls with the chilled water control system. All microprocessor-based control points should be accessible from the remote building DDC control system.

(4) Include hardware and software in the control sequence to prevent reduction in the secondary flow below a pre-determined limit. Such situations would occur with:

- 100% outside air AHU
- AHUs equipped with economizer cycles

(5) Include bypass piping assembly near the DPA. The assembly shall comprise a two-way modulating valve and a pair of shutoff valves on either side of the bypass control valve. The bypass assembly should be sized to carry the minimum flow recommended by the pumps and/or variable speed drive manufacturers.

4.3.3.4 Variable Primary System (VPS)

(a) General: See Figure 4-2 for the piping and pumping arrangement. A VPS system is less expensive in first cost and energy efficiency compared to a “traditional” primary/secondary system. However, VPS is not suitable for all applications. While VA certainly encourages the use of VPS, inherent complexities of the system controls, start-up, and loading/unloading of the chillers must be resolved during the design development process. It is also important to ensure that minimum constant cooling load is always present for the VPS to be effective. The intent of either system is to maintain constant leaving chilled water temperature from full-load to part-load conditions.

(b) System Operation: In a VPS system, chilled water flow is allowed to vary throughout the loop, including in the evaporator tubes. Provide a common chilled water circulation/distribution loop to circulate water through the terminal cooling units and the chiller evaporators. Minimum flow through the system must not be allowed to drop below the manufacturer's recommended water velocity through the evaporator tubes. A bypass assembly, similar to the PSS system shall be included in the design as shown in the Figure 4-2.

(c) Control Strategy:

(1) Include a high-accuracy flowmeter to monitor chilled water flow in the system design. In place of a flowmeter, the pressure differential across the evaporator can be measured and converted to flow based on the specific manufacturer's published flow-pressure data. The pump speed shall decrease in response to part-load conditions, using the same concept used for the PSS systems. A differential pressure assembly (DPA) shall control the pump speed.

(2) Control the sequencing of the connected load to avoid sudden variations and not compromise the system stability. Start-stop of all air-handling units shall be programmed and software controlled.

(3) Accomplish loading, unloading, and sequencing of chillers and associated auxiliaries in response to the prevailing load and accumulated run time. Include devices such as a chiller control panel, chilled water temperature sensors in the primary supply and return, and a flowmeter.

4.3.3.5 Single Chiller Systems, Constant Volume

See Figure 4-3 for the piping and pumping arrangement. For small chiller plants consisting of one chiller (and one standby chiller), provide a constant volume system with constant speed pumps and three-way valves at the air handling units.

4.3.3.6 Water Treatment (Chilled Water System)

(a) Chemical Shot Feeder: Provide a chemical shot feeder in bypass position to treat the closed-loop chilled water. Select the feeder size and chemicals based on the system volume and the water analysis, but not less than 3% of the chilled water flow rate.

(b) Water Filter: Provide a cartridge-type of filter in bypass position to remove solid suspended particles from the chilled water in circulation. Filter capacity shall be at least 3% of the chilled water flow rate. Include the bypass flow in the pump duty.

4.4 AIR-COOLED CHILLERS

4.4.1 GENERAL

The capacity of a single air-cooled chiller shall not exceed 250 tons.

4.4.2 CHILLER CONSTRUCTION

(a) Select chillers with rotary-screw or scroll compressors. Provide multiple compressors and independent refrigeration circuits.

(b) Select chillers with microprocessor-based controls that have the ability to interface with the building DDC system. All chiller points shall be viewable from the DDC system. Update specifications to ensure coordination between the chiller and controls requirements.

(c) For noise-sensitive locations, include the chiller manufacturer's standard acoustic options in the design. Ensure compliance with the physical security guidelines.

(d) For corrosive environments, include factory-applied anti-corrosion treatment for the condenser coil fins.

4.4.3 MINIMUM SYSTEM VOLUME

Each chilled water system must maintain minimum recommended water volume to avoid frequent cycling of the chiller and the resulting unstable operation. If the calculated water volume of the chilled water system as designed is less than the published recommendations of the chiller manufacturer (recommendations vary with manufacturers), an inline, pressurized, and insulated chilled water storage tank shall be included in the piping circuit to provide the required thermal inertia. Tank installation shall be complete with supports, isolating valves, drain connections, access to clean the tank, and inlet/outlet nozzles.

4.4.4 CONTROLS STRATEGY

(a) For a single chiller installation with chilled water pump horsepower 7.5 HP or less, provide a combination of three-way and two-way modulating chilled control valves to permit the pump to ride on its curve without dead-heading.

(b) Evaluate the use of VPS and include it in the design to meet the enhanced, energy conservation mandate.

(c) Accomplish loading and unloading of the chiller by maintaining the leaving water temperature through the microprocessor-based chiller capacity control.

4.5 CHILLED WATER SYSTEM COMPONENTS

4.5.1 PUMPS

4.5.1.1 General

Provide base-mounted, centrifugal (horizontal or vertical split-casing) or vertical turbine-type pumps for the chilled water and condenser water applications. For the condenser water system, available net positive suction head (NPSH) must exceed the required NPSH to avoid pump cavitation.

4.5.1.2 Selection Criteria

(a) Select pumps with an operating speed not in excess of 1,750 RPM, where feasible. A selection based on more than 1,750 RPM may be used if life-cycle cost-effective.

(b) Select pumps at or near the highest efficiency and to the left-hand side of the maximum efficiency point but not more than 5% from the maximum efficiency curve.

(c) Pump motors shall be non-overloading over the entire range of their operation and shall be compatible with variable speed drives, where used for such applications.

(d) In general, 5 HP and smaller pumps can be selected as inline pumps.

(e) For flow rates of 1,200 GPM [76 Liters/Second] and higher, make multiple pump selections, involving single suction or double suction pumps including horizontal split-case design. Optimum selection shall be based on efficiency, cost, and maintenance considerations.

(f) Selection of parallel pumps shall ensure that the pump curve is nearly flat to effectively operate in parallel configuration.

4.5.2 COOLING TOWERS

4.5.2.1 General

(a) Cooling towers shall be induced draft-type, gravity-flow, factory-fabricated, and factory-tested. Select the cooling towers that are certified by the applicable section of the CTI (Cooling Tower Institute), OSHA requirements for safety, and Physical Security Requirements. See Figure 4-4 for the piping and pumping arrangement.

(b) Corrosion resistance and noise levels shall be the prime selection criteria of the cooling towers, influencing the choice of design and materials. Depending upon the height restriction and available space, the cooling tower shall be single-cell or double-cell construction. See Chapter 2 for the noise and dispersion requirements.

4.5.2.2 Selection Options

Each cooling tower selection shall address and resolve such issues as:

- Cooling tower location
- Cross flow or counter flow towers
- Gear drive or belt-drive
- Concrete basin or steel basin
- Stainless steel basins are preferred, unless proven otherwise
- Tower accessories – fill, walking platform
- Stairs and ladder safety cage
- Tower loading and supporting structure
- Net positive suction head requirements
- Tower controls
- Basin heating

4.5.2.3 Additional Selection Criteria

(a) Provide a variable speed drive for the cooling tower fan motor. Keep the tower motor away from the water flow by a shaft extension.

(b) When the cooling tower is located on the roof, coordinate its operating weight with the structural discipline and design the supporting steel structure to support the tower on the roof. Design of the supporting steel shall permit elevating the cooling tower at least 4 Feet [1.2 Meters] (net) above the roof surface to facilitate access and re-roofing the surface underneath the cooling tower.

(c) During off-peak season, the control strategy shall allow the tower to lower the water temperature below the design, leaving water temperature and follow the ambient wet-bulb temperature.

(d) See Chapter 2 for acoustic treatment.

4.5.2.4 Water Treatment (Condenser Water System)

(a) General: Design a water treatment system for treating the cooling tower water based on the make-up water samples. Use non-toxic chemicals approved by local and EPA requirements. The water treatment shall operate automatically with the chemical feed and blow down systems.

(b) System Description: Provide a chemical feed pump for each chemical feed tank, specifically, tower scale and corrosion inhibitor, acid and biocide inhibitor. Each pumping system shall be equipped with a check valve, drain connections, and a safety relief arrangement. Monitor the pump status at the ECC. Provide a chemical feed controller, conductivity probe, and pH and oxidation reduction potential (ORP) systems.

(c) Watermeters: Provide a watermeter in the condenser water make-up line, and blow down line, capable of reading the actual instantaneous flow and totalized flow locally and at the ECC.

(d) Floor Space: Provide floor space marked reserved on the floor plans for the water treatment system to include an eye wash and emergency shower, and coordinate with plumbing to provide a washbasin. Provide a desk with storage cabinets to house the chemicals for the water treatment system.

(e) Solid Separator: Include a solid separator in the condenser water circuit to eliminate the suspended solid particles from the system.

4.6 DX SYSTEMS

4.6.1 GENERAL

Where chilled water is not available year around, non-patient spaces that require mechanical cooling can be treated using dedicated DX units, split-systems or complete factory-fabricated units.

Use of DX cooling systems is not permitted in patient wings, patient treatment and special procedures areas, or in high humidity locations.

4.6.2 SELECTION CRITERIA

Equipment selection shall comply with the minimum EER requirements outlined in ASHRAE Standard 90.1 – 2007.

4.6.3 EQUIPMENT LOCATION AND LAYOUT

(a) Location: Locations of the outdoor DX units shall be coordinated with the architectural discipline, Medical Center, and physical security requirements.

(b) Refrigerant Piping: Limit the lengths of the field-installed refrigerant piping and minimize bends and changes in elevations to avoid oil return problems and loss of efficiency. The refrigerant piping layout must meet prior approval of the equipment manufacturers.

(c) Multiple Compressors: Provide two compressors in parallel, where feasible, in place of a single compressor. With two compressors serving a single DX coil, design the coil circuiting to facilitate refrigerant flow through the entire coil even with one compressor in operation.

(d) System Controls:

- Provide local (non-DDC) thermostatic controls.
- Where the DX system is equipped with integral, local microprocessor-based controls, provide an interface with the ECC. If such an arrangement is not feasible, provide a DDC temperature sensor to sound a high and/or low limit alarm at the ECC.

4.7 HEATING SYSTEMS

4.7.1 STEAM HEATING SYSTEM

4.7.1.1 General

(a) High-pressure steam is generated at most VA facilities by a central boiler plant to serve a variety of applications, such as:

- Laundry service
- Sterilizers
- Kitchen equipment
- Building heating hot water
- Domestic hot water

(b) Obtain the actual steam generation pressure, as it varies with the facility. The average range is between 80 PSIG [552 KPA] and 125 PSIG [863 KPA].

4.7.1.2 Pressure Classification

For VA facilities, steam pressure is classified as shown below:

- Low-Pressure Steam (LPS) – 15 PSIG [103 KPA] and below
- Medium-Pressure Steam (MPS) – 16 PSIG [110 KPA] through 59 PSIG [407 KPA]
- High-Pressure Steam (HPS) – 60 PSIG [414 KPA] and above

4.7.1.3 Available Steam Pressure – High Pressure Steam (HPS)

(a) Obtain actual winter steam generation pressure from facility personnel for sizing the pressure-reducing valve (PRV) station.

(b) Calculate steam pressure loss between the boiler plant and the equipment room, where the PRV station will be installed. Restrict this pressure loss to 10 PSIG [6.9 KPA]. If required, modify the steam pipe sizing criteria, stipulated in Chapter 2, to contain the pressure loss to 10 PSIG [6.9 KPA].

4.7.1.4 Steam Pressure Requirements

Listed below are the suggested operating pressures:

Table 4-4: Suggested Steam Operating Pressures	
Equipment	**Operating Steam Pressure PSIG [KPA]**
Radiators	5.0 [34]
Convectors	5.0 [34]
Terminal Humidifiers; Duct Mounted	15.0 [105]
Heating Coils	30 [206]
Steam-to-Hot Water Converters	30 [206]
Unit Heaters	30 [206]
Domestic Water Heaters	30 [206]
AHU Mounted Steam Humidifiers	30 [206]
Sterilizers and Washers	Refer to Program Guide PG-18-6
Dietetic Equipment	Refer to Program Guide PG-18-6
Laundry Presses and Ironers	125 [860]

4.7.1.5 PRV Stations

(a) Provide dedicated PRV station(s) for each building and for each low-pressure steam setting.

(b) Do not provide two-stage PRV station to reduce high-pressure steam pressure.

(c) Provide two PRVs in parallel at the locations and applications where significant (> 2/3) variation in the steam demand is expected. Select two PRV valves of uneven sizes, the smaller valve of 1/3 and the larger valve of 2/3 capacities. Set the smaller valve at a higher exit pressure than the set exit pressure and the larger valve at a lower exit pressure than the set exit pressure so that the smaller valve shall open first, maintaining higher than the set-point pressure and delivering 1/3-steam flow rate. With the increase in load, the controlled pressure shall drop and the larger valve shall open, eventually admitting the remaining 2/3-steam flow rate. With the smaller valve already delivering 1/3 capacity, the total capacity shall be the full rated capacity.

(d) For sizing the steam PRV station, assume diversity for the process load by assuming 100% load of the largest equipment and 25% load of the remaining steam-consuming equipment from the same department.

(e) Size the PRV bypass valve and the safety valve according to National Board Inspection Code of the National Board of Boiler and Pressure Vessel Inspectors (Columbus, Ohio). Size the safety valve to handle the maximum flow of the largest PRV or the bypass. Verify that the bypass valve capacity does not exceed the capacity of the safety valve.

4.7.1.6 Miscellaneous Design Requirements

(a) **Shutoff Valve – HPS:** Include a shutoff valve and a pressure gage, 4.5 inch [114.3 mm], for each incoming HPS service in the mechanical equipment room. For a shutoff valve, larger than 4 inch [100 mm] size, include a factory-installed, integral warm-up valve of .75 inch [20 mm] or 1 inch [25 mm] size in bypass position.

(b) **Steam Flowmeter:** For each steam PRV station, include a steam-flow measuring meter with interface to the EEC. Provide capability to read instantaneous and total steam flow.

(c) **Stress Analysis:** Perform a computerized stress analysis on the actual steam piping layout and show anchors, guides, and expansion loops to avoid pipe deflection and contain expansion. All devices shall be shown in the floor plans at approximately the same location where they are intended. Submit calculations for review and approval.

(d) **Flash Tank:** The piping design shall not permit any direct connections between the high-pressure gravity return and medium-pressure gravity return to the low-pressure gravity return lines to avoid flashing. Provide a flash tank, where all gravity returns shall reduce pressure and temperature. From the flash tank, low-pressure gravity return shall flow into the condensate receiver of the condensate return pump. Adjust the elevation of the flash tank outlet to ensure gravity flow into the condensate receiver. Gravity return must ***not*** be lifted. The flash tank shall be shown at all applicable locations in drawings and specifications.

(e) **Steam Reheat Coils:** Do not locate steam reheat coils above suspended ceilings of the occupied areas. Problems due to trap noise, condensate return requiring pitch, trap maintenance, and ceiling height restriction are viable reasons for avoiding steam traps. Trap installation requires at least 12 inch [300 mm] for static lift and 6 inch [150 mm] for the dirt leg.

(f) Vent Line(s): Provide an atmospheric vent line to extend above the building roof. Vent lines from the condensate tank and flash tank can be combined into a single line. The vent line from the safety valve at the PRV station shall extend above the roof, to a height of 6 Feet [1.8 Meters], independent of the other vent line.

To avoid long safety valve discharge piping, safety valves may be located close to the terminal point, provided no shut-off valve is installed between the PRV and the safety valve.

(g) Condensate Return Pump: Provide a duplex condensate pump, complete with a receiver, to return the liquid condensate up to boiler plant. Provide emergency power for the pumps. If the duplex condensate pump is installed in a pumppit, the starter, disconnect switch, and alternator must be located outside the pump pit. Provide an alternator to facilitate switching the pump operation.

(h) Steam Traps – Selection Criteria and Limitations:

(1) Provide float and thermostatic (F&T) traps for all modulating loads such as heat exchangers, domestic hot water heaters, and modulating control valves (where used) for the preheat coils and the equipment with modulating load.

(2) Provide minimum 12 inch [300 mm] static lift for the trap operation. Space permitting, provide 18 inch [450 mm] lift. Static lift should not only be shown in the steam trap installation detail but the floor plans must emphasize the need to provide maximum available static lift. Non-compliance with this requirement has been a cause of operational problems in many installations.

(3) Size all F&T traps at ¼ PSIG [1.7 KPA] pressure drop.

(4) Size traps for heat exchangers and AHU preheat coils at 250% of the design load to meet the start-up needs. No single trap shall sized for more than 5,000 Pounds [2,358 KG] per hour.

(5) Steam traps on the steam line drip points shall be inverted bucket type, with bi-metallic thermal element for air removal. Select the working pressure range suitable for the maximum line pressure.

(6) For steam lines in continuous operation with infrequent shut downs, drip traps shall be sized for the line radiation loss, in Pounds [KG] per hour, multiplied by three. The trap pressure differential shall be about 80% of the line operating pressure.

(7) Each coil shall be individually trapped.

(8) Provide a steam trap schedule by assigning a unique trap number and location. Indicate the type, capacity, and the pressure differential at which the trap is selected. The trap schedule shall be shown on the drawings.

4.7.1.7 Steam Gun Sets

Provide a steam gun set, comprising of steam, water, and detergent, at the following places. See VA Standard Detail for more information.

- Trash or trash compaction rooms
- Dietetics – manual cart wash
- Supply, Processing, and Distribution (SPD) – manual cart wash

4.7.2 HYDRONIC HOT WATER SYSTEMS

Note: Requirements for chilled water and condenser water pumps apply to hot water pumps.

4.7.2.1 Introduction

Hot water heating systems are commonly used due to ease of transportation of the heating medium, flexibility of piping layout, and versatility of the controls. For terminal heating devices not in direct contact with freezing ambient air, use a hot water heating system. See Chapter 3 for information on AHU-mounted heating coils, VAV/CV air terminal units, and radiant ceiling panels.

4.7.2.2 System Description

(a) For most VA facilities, either steam is available from the central boiler plant or the existing steam distribution loop is used to generate hydronic hot water.

(b) Each hot water generating system shall comprise two steam-to-hot water heat exchangers, circulating pumps, and associated system auxiliaries. One heat exchanger and circulating pump shall act as 100% standby. See Figure 4-5 for the piping and pumping arrangement.

(c) Maximum limiting parameters of the hydronic hot water are:

- Supply Water Temperature – 180 F [82.2 C]
- Temperature Differential (Supply – Return) – 20 F [11.1 C]
- In general, maintaining lower supply water temperature with the control valve manufacturer's recommended water flows has ensured stable system operation

(d) The following is a list of the terminal units using hydronic hot water:

- Hot water coils (VAV/CV) terminal units
- Unit heaters
- Cabinet unit heaters
- Radiant ceiling panels
- Duct-mounted reheat coils
- AHU-mounted preheat and reheat coils
- Fan coil units
- Convectors
- Base-board heaters
- Finned tube radiation
- Heating hot water curtains

(e) For large installations such as new and/or replacement hospitals or clinical additions, evaluate the feasibility of providing multiple heating systems to minimize the piping runs and ensure flexibility. Provide variable-speed drives for 10 horsepower and larger pumps.

(f) For hydronic preheat coils that come in contact with ambient or mixed air below freezing temperatures, provide freeze protection by mixing propylene glycol in the heating hot water. Provide a dedicated glycol-hot water heating system with a heat exchanger, circulating pumps, and interconnecting piping. The heating system shall be similar to the conventional hot water heating system serving the building reheat coils and other terminal heating units.

(1) Select the smallest possible concentration of the glycol to produce the desired antifreeze properties. Include an inhibitor in the glycol solution to prevent corrosion.

(2) Selection of the affected equipment shall take into account the loss of efficiency, impact on the pressure drops, and pump BHP.

(3) Additional information is available in the Appendix 4-A Propylene Glycol and the latest edition of the 2007 ASHRAE Handbook of Systems and Equipment (Chapter: Hydronic Heating and Cooling System Design).

(4) Water used in conjunction with the glycol shall be low in chloride and sulfate ions.

4.7.2.3 Water Treatment (Hot Water)

(a) **Chemical Shot Feeder:** Provide a chemical shot feeder in bypass position to treat the closed-loop hot water system. Select the feeder size and chemicals based on the system volume and the water analysis, but not less than 3% of the hot water flow rate.

(b) **Water Filter:** Provide a cartridge-type filter in bypass position to remove solid suspended particles from the hot water in circulation. Filter capacity shall be at least 3% of the hot water flow rate. Include the bypass flow in the pump duty.

4.7.2.4 Controls Strategy

(a) Provide two-way modulating control valves for all terminal units. Use three-way valves at the end of each run only if the circulating hot water pump is scheduled to ride on its own curve. Prevent dead-heading of the pump by ensuring that at least 20% flow remains constant.

(b) For non-critical applications such as unit heaters installed in attic spaces, control valves need not be provided. Water can “run wild” with the space temperature controlled by cycling the heater fan.

(c) Provide a hot water reset control to inversely vary the supply water temperature with the ambient temperature. Reset shall be adjustable and limited. For many applications and situations, reheat load is approximately constant. Selection of the lowest water temperature, selected nominal water flow, and the terminal units shall be such that the required heating output is not compromised.

4.7.3 ELECTRICAL HEATING SYSTEMS

4.7.3.1 General

Use electrical heat only when heat generated by fossil fuel is not cost-effective.

4.7.3.2 Compliance

U.L. Rating

4.7.4 GAS HEATING SYSTEMS

4.7.4.1 General

Use gas heating where natural gas is readily available at the site. Alternately, Liquid Propane Gas (LPG) can also be used.

4.7.4.2 Applications

Gas-fired equipment is generally used for miscellaneous heating and applications. These applications are:

- Mechanical rooms
- Warehouses
- Large storage spaces
- Laundries
- Vehicle maintenance facilities
- Gymnasiums

4.7.4.3 Heating Equipment

- Unit heaters
- Roof-top HVAC units
- Heating and ventilation units

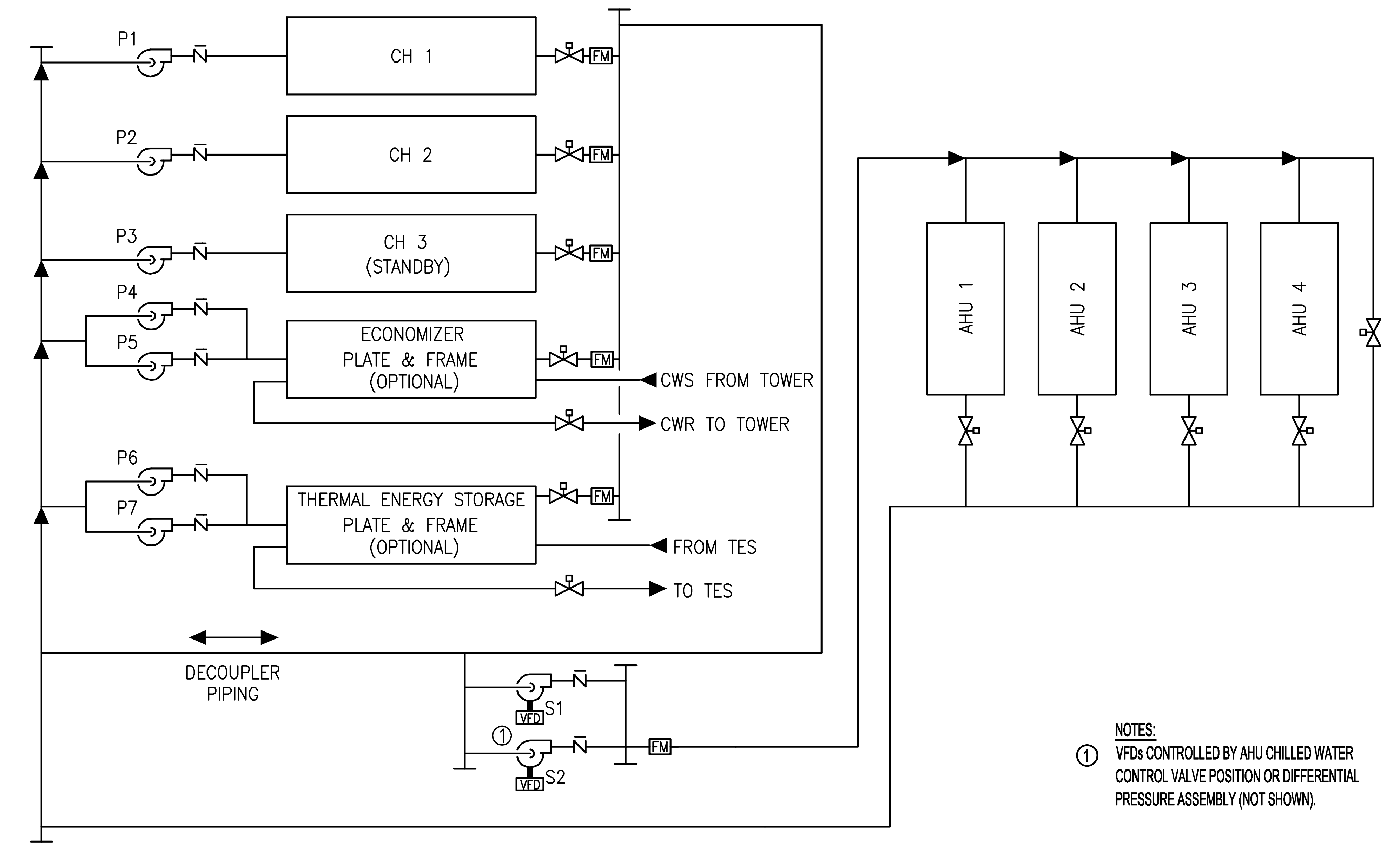
All devices shall be thermostatically-controlled.

4.7.4.4 Miscellaneous Items

(a) Ensure that make-up air and exhaust needs are addressed and included in the design per the manufacturer's recommendations and NFPA 54, National Fuel Gas Code.

(b) Care shall be taken to avoid any possibility of the exhaust vent short-circuiting into any intake or the operable windows of the occupied spaces. Follow the recommendations of the dispersion analysis.

(c) Wherever available and feasible, use modulating or two-step burners to provide energy-efficient and smooth temperature control.

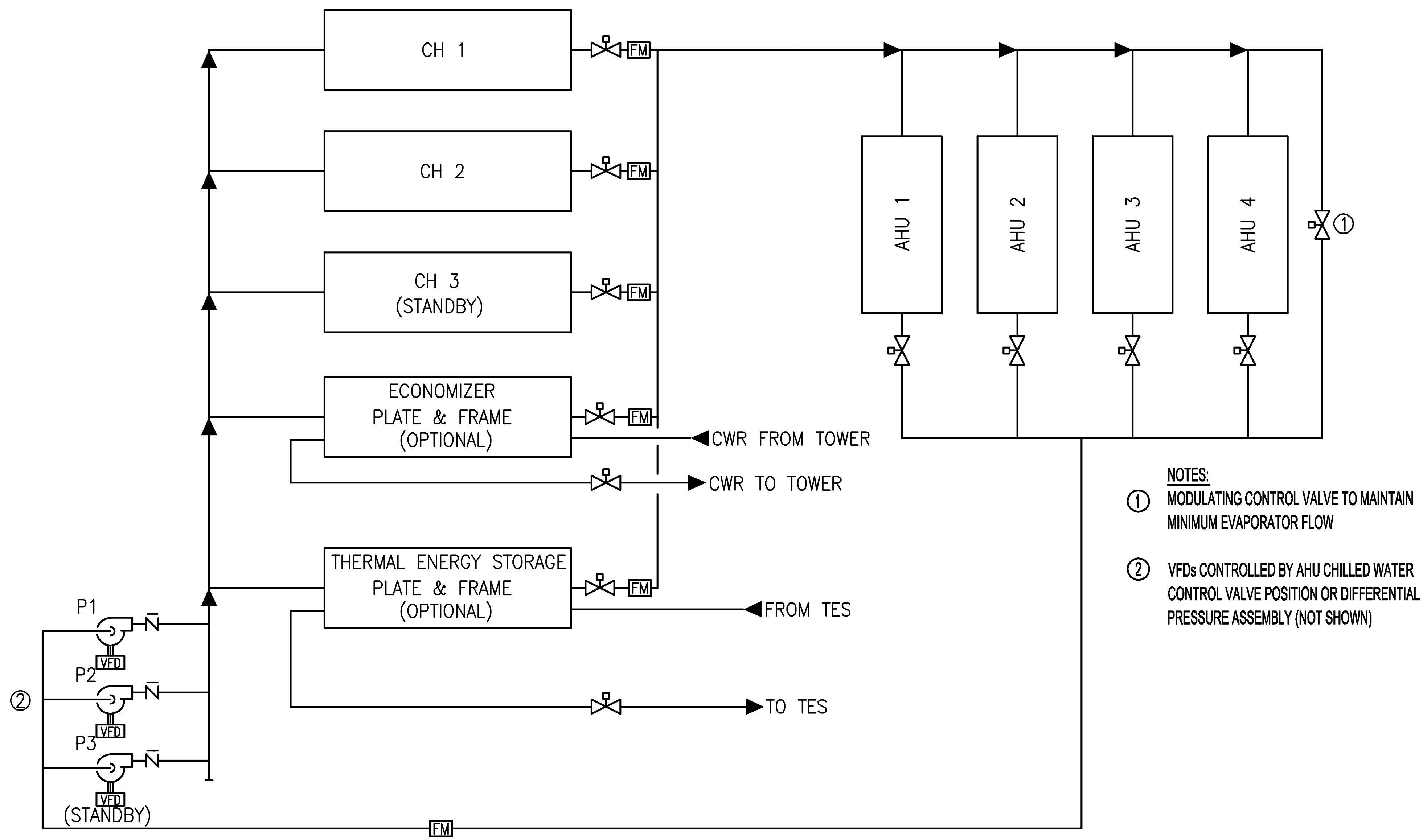


NOTES:

① VFDs CONTROLLED BY AHU CHILLED WATER CONTROL VALVE POSITION OR DIFFERENTIAL PRESSURE ASSEMBLY (NOT SHOWN).

CHILLED WATER PRODUCTION AND DISTRIBUTION - PRIMARY- SECONDARY SYSTEM (PSS)

Not to Scale



NOTES:

① MODULATING CONTROL VALVE TO MAINTAIN MINIMUM EVAPORATOR FLOW

② VFDs CONTROLLED BY AHU CHILLED WATER CONTROL VALVE POSITION OR DIFFERENTIAL PRESSURE ASSEMBLY (NOT SHOWN)

CHILLED WATER PRODUCTION AND DISTRIBUTION - VARIABLE PRIMARY SYSTEM (VPS)

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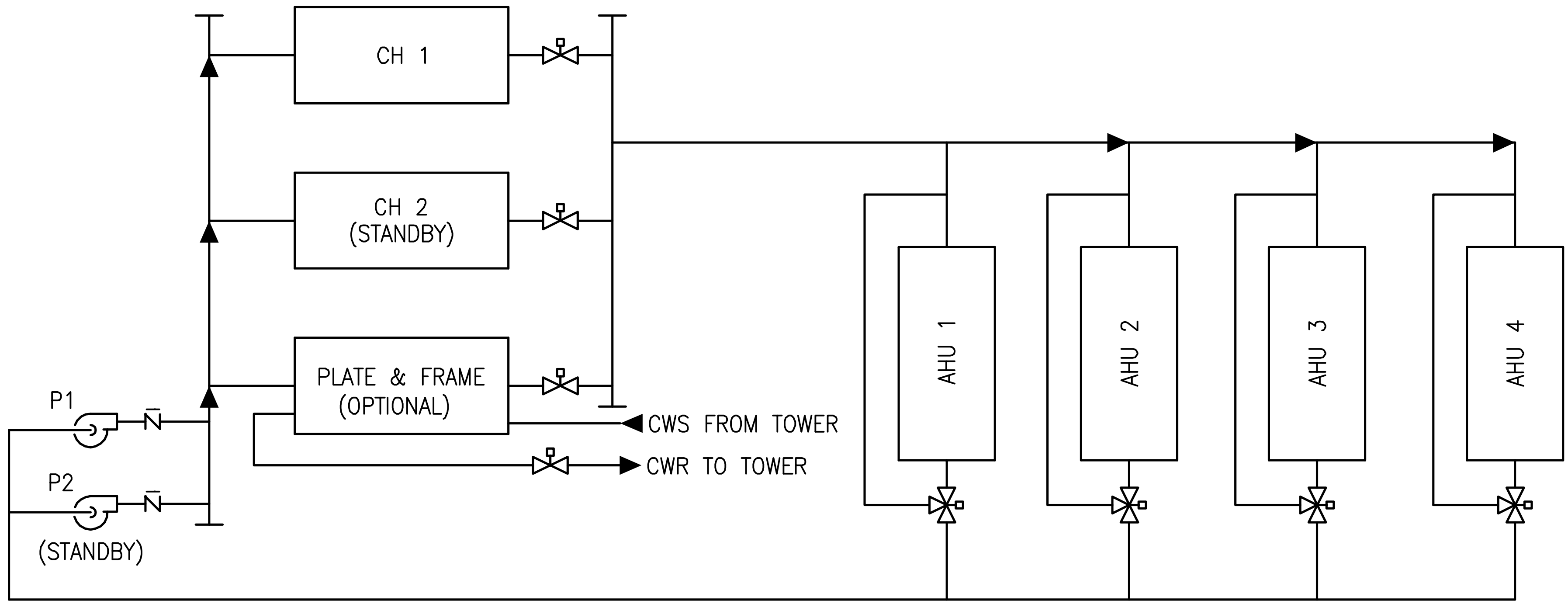

CHILLED WATER PRODUCTION AND DISTRIBUTION - SINGLE CHILLER SYSTEMS, CONSTANT VOLUME

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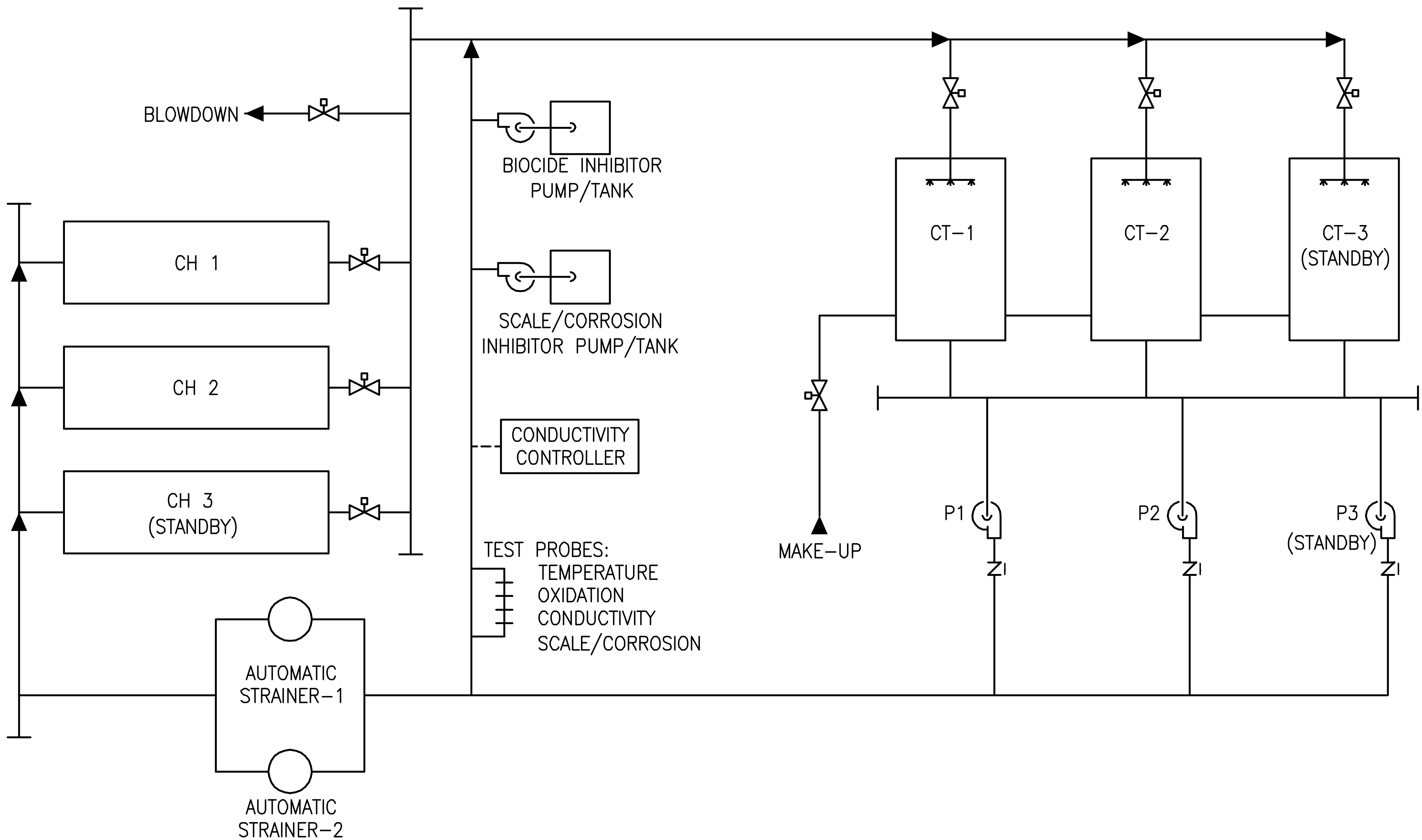

COOLING TOWER SYSTEM

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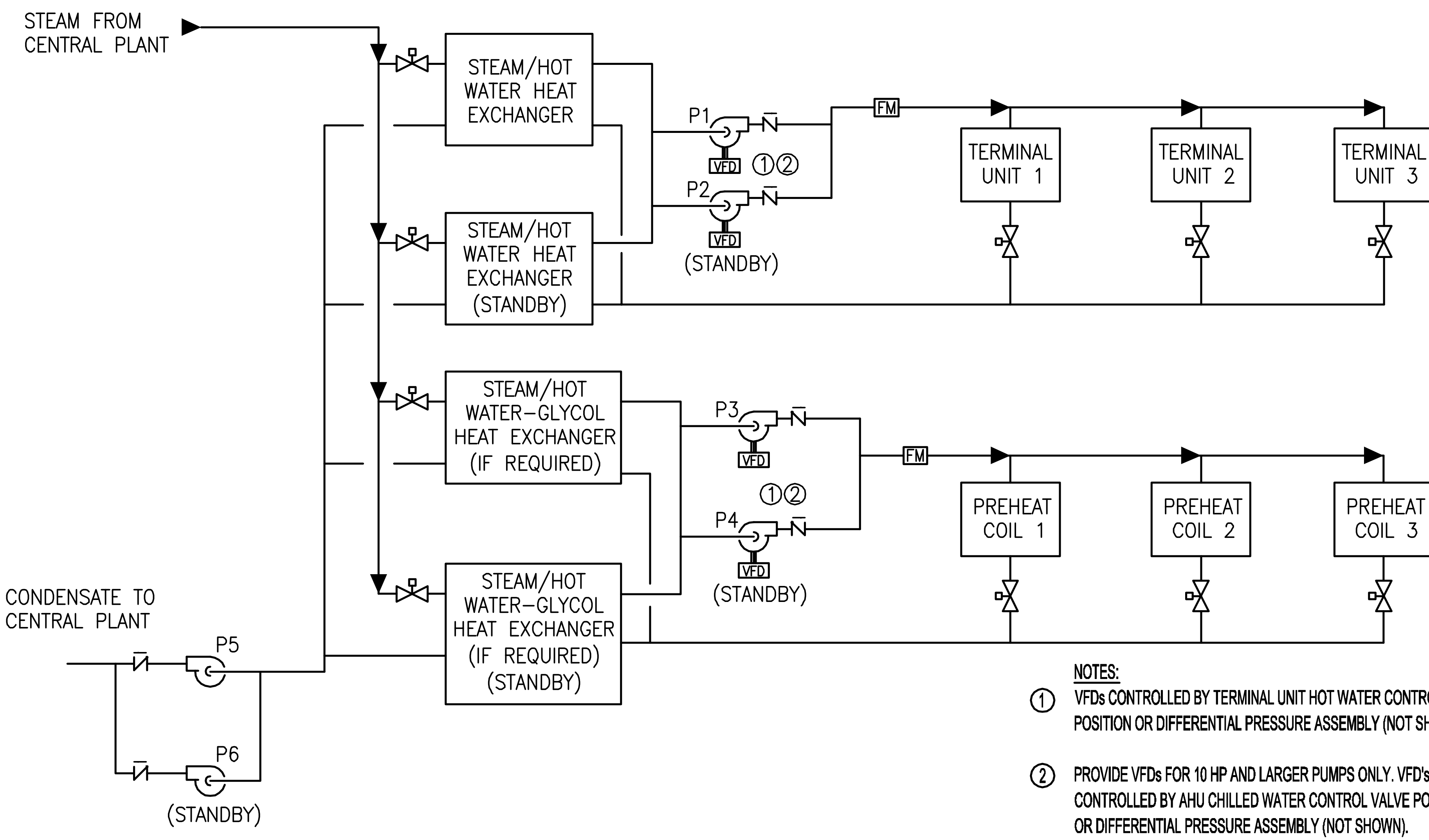


NOTES:

1. VFDs CONTROLLED BY TERMINAL UNIT HOT WATER CONTROL VALVE POSITION OR DIFFERENTIAL PRESSURE ASSEMBLY (NOT SHOWN).
2. PROVIDE VFDs FOR 10 HP AND LARGER PUMPS ONLY. VFD's CONTROLLED BY AHU CHILLED WATER CONTROL VALVE POSITIONER OR DIFFERENTIAL PRESSURE ASSEMBLY (NOT SHOWN).

HYDRONIC HOT WATER DISTRIBUTION

Not to Scale

APPENDIX 4-A: PROPYLENE GLYCOL

4-A.1 PROPYLENE GLYCOL – WATER SYSTEMS

4-A.1.1 INTRODUCTION

For freeze protection of the hot water preheat coils and heat recovery coils (used in runaround systems), use propylene glycol solution with hot water.

4-A.1.2 GLYCOL CONCENTRATION

Concentration of glycol shall be determined using the following criteria.

(a) Propylene glycol freezes and forms slush at 30% concentration by volume. Viscosity of the glycol solution rises dramatically as the fluid temperature drops.

Glycol Temperature	Viscosity, Centipoises
68 F [20.0 C]	60.5
32 F [0.0 C]	243

To address this phenomenon, the A/E shall avoid situations where freeze protection is required to prevent damage to the equipment during idle periods in winter season. It is important to ensure that while designing the glycol system, the flow rate and glycol concentration are optimized to control the adverse effect of higher viscosity.

(b) For applications that require the fluid to remain a liquid, select a concentration with a freezing point 5 degrees F [2.8 C] below the expected operating temperature of the equipment/piping system.

(c) Excessive concentrations of glycol shall be avoided.

(d) Refer to the ASHRAE Fundamentals Handbook for physical properties of propylene glycol solutions.

4-A.1.3 CORRECTION FACTORS

4-A.1.3.1 Flow Correction Calculation

Use the correction factors shown in Table 4-A1 to determine the flow rate due to glycol concentration. The glycol concentration corrected flow value shall be used in the equipment schedules.

Table 4-A1: Propylene Glycol Solution Flow Correction Factors – Increased Viscosity

Solution by Volume (Percent)→	20	30	40	50
30 - 40 F [1.1 - 4.4 C]	1.04	1.06	1.10	1.15
180 - 190 F [82.8 – 87.8 C]	1.03	1.05	1.07	1.11

Example:
200 GPM water at 40 foot head and a 30% solution by volume at 30 F using a pump with 69% efficiency.

$$FlowRate = 200 \times 1.06 = 212 GPM$$

4-A.1.3.2 Pressure Drop Correction Calculation

Use the correction factors shown in Table 4-A2 and Table 4-A3 to determine the pump head due to glycol concentration. The glycol concentration corrected pump head value shall be used in the equipment schedules. Note that two correction factors must be applied, one due to increased flow and one due to increased viscosity.

(a) The following correction factors applied to the head calculated for the water flow will give the increased head due to the increase in solution flow.

Table 4-A2: Propylene Glycol Solution Pump Head Correction Factors – Increased Flow				
Solution by Volume (Percent)→	20	30	40	50
30 - 40 F [1.1 – 4.4 C]	1.08	1.12	1.21	1.32
180-190 F [82.2 – 87.8 C]	1.06	1.10	1.14	1.23

Example:

Using the above example, the calculated pressure drop due to increased flow is:

$$\Pr essureDrop = 40 \times 1.12 = 45\,Feet$$

(b) The following correction factors applied to the head calculated for the increased flow will give the total head for the solution.

Table 4-A3: Propylene Glycol Solution Pump Head Correction Factors – Increased Viscosity				
Solution by Volume (Percent)→	20	30	40	50
30 F [1.1 C]	1.14	1.34	**	**
40 F [4.4 C]	1.12	1.28	1.4	1.6
180 F [82.2 C]	No correction is needed for solutions above 160 F [71.1 C]			
190 degrees F [87.8 C]				

**The viscosity of this mixture/temperature combination is too great and pumping will not occur.

Example:

Using the above example, the calculated pressure drop from increased viscosity is:

$$Total\ \Pr essureDrop = 45 \times 1.34 = 60\,Feet$$

4-A.1.3.3 Power Correction Calculation

Propylene glycol solutions affect pump performance. A power correction factor is required due to the higher specific gravity of the propylene glycol mixture. Use the following formula to determine the pump horsepower required due to glycol concentration. The specific gravity of the solution mixture shall be used in the equation. The glycol concentration corrected horsepower value shall be used in the equipment schedules.

$$BHP = GPM \times Head \times SpGravity \Big/ 3960 \times PumpEfficiency$$

Example:
Using the above example, the calculated horsepower from increased flow and head is:

$$BHP = 212 \times 60 \times 1.04 \Big/ 3960 \times .69 = 4.84 Hp$$

CHAPTER 5: AUTOMATIC TEMPERATURE CONTROLS

Table of Contents

5.1 GENERAL

(a) Provide a Direct Digital Control (DDC) system for new and replacement hospitals and major renovations of existing facilities. The DDC system will monitor and control the HVAC/ Plumbing and other systems. See specifications, VA Standard Detail, and Chapter 6 (Applications) for additional information.

(b) The A/E shall determine the cost-effectiveness of the following options:

- Integrate the new DDC system into the existing system (use the same manufacturer).
- Integrate all existing and new DDC points and functions into one new system. The control system shall be open protocol.
- Provide a standalone system for all new DDC points and functions if approved by the VA Authorities. The control system shall be open protocol.

(c) The interface with the existing ECC shall be seamless. The system shall include PC (personal computer), laptop computers, color printer, distributed DDC controllers, panels, sensors, switches, alarms, flowmeters, relays, control valves and dampers, wiring, system graphics, control sequences, and accessories to make a complete and workable system.

(d) Use of DDC controls shall result in energy-efficient operation and help achieve the mandated goal of energy conservation. See Chapter 1 for details.

5.2 SYSTEM REQUIREMENTS

Include, at a minimum, the following features in the DDC system.

5.2.1 CONTROL ACTUATORS

Automatic control valves and dampers shall have electric control actuators.

5.2.2 CONTROL VALVES

Select control valves with equal percentage, or linear flow characteristics. Provide bubble tight shutoff against 1.5 times design pressure. Select control values at 3 PSIG [20.7 KPascal] maximum pressure drop at design flow rate.

5.2.3 CONTROL DAMPERS

Select airfoil type control dampers with blade and edge seals to minimize air leakage while in the shutoff position. Show all damper sizes on the Mechanical Equipment Room (MER) plan and section drawings. End-switches are also required for 100% outside air units to ensure that the outside air damper is fully open before the supply air fan is energized.

5.2.4 FIRE AND SMOKE DAMPERS

See Chapter 2 for requirements. End-switches are also required for 100% outside air units to ensure that the outside air damper is fully open before the supply air fan is energized.

5.2.5 SAFETIES

Indicate hard-wired connections for all safety alarms, including freeze stats, smoke detectors, smoke dampers, refrigerant leak detection, and any other critical alarms. Include this information in the controls schematic diagram and written sequence of operation.

5.2.6 STATUS MONITORING

Provide current transducers (analog) for monitoring the status and energy of all fan (including cooling towers) and pump motors. Do not use DP (differential pressure) switches for status monitoring.

5.2.7 WIRING

Specify all UL listed components and wiring installation in accordance with National Electric Code. All control wiring shall be installed in EMT (electric metallic tubing) or conduits, unless otherwise approved by VA Authorities.

5.2.8 ROOM TEMPERATURE SENSORS

Use commercial grade room temperature sensors with limited temperature adjustment and night setback push button override capabilities.

5.2.9 PERSONAL COMPUTER (PC)

Provide a PC with sufficient memory, hard-drive capacity, and processing speed, and at least a 21 inch [533.4 mm] color monitor. Provide expanded keyboard, CD drive, and a mouse. Ensure coordination with the specifications to include up-to-date PC features. Provide two printers: one for status and one for reports. Report printer shall be color ink jet type.

5.2.10 LAPTOP COMPUTER

Provide a laptop computer with up-to-date features and a 19 inch [425 mm] color monitor.

5.2.11 SOFTWARE

Indicate an operator programmable system, based on project-specific applications. All controllers shall be connected through a dedicated communication network to share common data and reports with the work station. Provide download and upload capabilities between the PC and the local controllers.

5.2.12 COLOR GRAPHICS

Provide a complete dynamic color graphics package on PC and laptop computers. Provide a schematic diagram for each control system and sub-system with the design set-points and actual conditions. Indicate the mode of operation and alarm status.

5.2.13 SPREADSHEETS

Provide Excel-type spreadsheet tables for each item of equipment to trend and log the data with set-points, actual sensor readings, and status.

5.2.14 SECURITY

Provide three levels of password protection to restrict altering the device set-points.

5.2.15 REMOTE METERING REQUIREMENT

(a) Use the ECC system to track and optimize the performance of the metering system. Metering is required for each building for the following utilities and applications:

- Steam
- Chilled Water
- Hot Water
- Gas
- Cooling Tower Make-Up Water and Blowdown
- Total Building Domestic Water
- Building and Sub-System KW and KWH

(b) Coordinate the final metering system with ongoing VA metering project.

5.3 SYSTEM APPLICATIONS

5.3.1 GENERAL

(a) Listed below are generic control sequences for various HVAC systems. The list does not cover all sequences and sub-sequences. Similarly, all sequences are ***not*** applicable to all situations, as their inclusion or deletion would depend upon the project-specific requirements.

(b) Using the information given below, and other available resources, the A/E shall develop a detailed sequence of control and operations, in which all modes of the system are described.

5.3.2 AIRSIDE CONTROLS

Airside controls include operation of the air-handling units, exhaust systems, room level controls, and other miscellaneous controls. See Chapter 6 for specific applications and details of sequences.

5.3.2.1 Air-Handling Units

- System Start-Up
- Morning Warm-Up
- Morning Cool-Down
- Supply Air Temperature Control (include all applicable modes):
  - Heating
  - Mechanical Cooling
  - Economizer
  - Mechanical Cooling with Economizer Cycle Mode
- Freeze Protection (Pre-Heat Coil)
- Fan Speed Control (Supply Air Fan)
- Fan Speed Control (Return/Relief Air Fan)
- Fan Tracking (Supply and Return Air Fans)
- Minimum Ventilation (Outside Air) Control
- Freeze Stat Operation
- Smoke Detector/Smoke Damper Operation
- Filter Maintenance Alarm
  - Pre Filters
  - After Filters
  - HEPA Filters
- Volumetric Data
  - Supply – CFM

  - Return – CFM
  - Minimum Ventilation Air – CFM
- Heat Recovery System Operation
- **Supply Air Temperature Reset Control:** Use of this subroutine is viable during heating mode only. Care must be taken to ensure that the de-humidification is not compromised while attempting the supply air temperature reset.
- **Operating Static Pressure Reset Control:** See ASHRAE Standard 90.1 – 2007 for the mandated subroutine.
- Interlocked Exhaust Fan(s) Operation
- Winter Humidification Mode
- Demand Ventilation Control
- Summer High-Humidity Override Control
- Unoccupied Mode

5.3.2.2 Room Controls

- **Room Air Terminal Unit Control:** Minimum supply air volume setting for the VAV air terminal unit shall be based on the following considerations:
  - Direct exhaust requirement from the space
  - Make-up air for the communicating exhaust system
  - Limiting supply air temperature in heating mode to 95 F [35.0 C]
  - Minimum air for positive space pressurization, where applicable
- Dead-Band Control
- Sequential Heating Mode

See Figure 5-1 for control sequence for constant volume terminal reheat with perimeter heating and dead-band.

See Figure 5-2 for the control sequence for variable air volume terminal reheat with perimeter heating and dead-band.

See Figure 5-3 for the control sequence for year around variable air volume terminal reheat with perimeter heating and 0° dead-band.

See Figure 5-4 for the control sequence for year around constant volume terminal reheat with perimeter heating and 0° dead-band.

5.3.2.3 Exhaust Systems (Laboratories):

See Chapter 3 and Chapter 6 for further details regarding:

- Laboratory part-load volumetric ontrols
- With or without hoods
- Perchloric acid wash-down control
- Laboratory fume hood sash control
- Laboratory HEPA filter control

5.3.2.4 Isolation Rooms Exhaust:

See Chapter 6.

5.3.3 HEATING SYSTEMS

- System Start-Up
- Leaving (from converter) Hot Water Temperature Control
- Hot Water Temperature Reset Control
- Pump Speed Control (where applicable)
- Minimum Pump Speed Control
- Pump Start-Stop and Sequencing Control – Based on Equal Runtime

5.3.4 CHILLED WATER PLANT CONTROLS

- System Start-Up (cold start procedure)
- Leaving (from chiller) Chilled Water Temperature Set Point Control
- Chilled Water Temperature Reset Control (generally used with constant volume system)
- Chiller Start-Stop and Sequencing Control
- Variable Speed Drive Control – Primary only or Primary-Secondary Chilled Water Pump
- Cooling Tower Temperature Control
- Cooling Tower Fan Speed Control
- Cooling Tower Vibration Isolation Control
- Cooling Tower Make-Up Water Control
- Cooling Tower Basin Temperature Control
- Plate Heat Exchanger Control – Economizer Mode Operation
- Chilled Water Pump – Minimum Speed Control
- Secondary Loop – Variable Set Point Control/ Pressure Differential Assembly Control
- Thermal Energy Storage (water or ice) Control

5.3.5 NON-DDC CONTROLS

For standalone applications, DDC controls and connection to the central ECC system can be eliminated if it is determined that remote monitoring, alarm, and start-up are not necessary. Such applications are generally non-critical. Examples of such controls are:

- Light Switch Operated Toilet Exhaust (Remote Location)
- Vestibule Heater
- Exterior Stairs Heater
- Attic Heating and Exhaust
- Mechanical Room – Heating/Ventilation Control

See the Room Data Sheets for room alarm parameters.

5.4 DOCUMENTATION REQUIREMENTS

5.4.1 SCHEMATIC DIAGRAM AND CONTROL SEQUENCE

Provide a control diagram showing all controlled devices with unique designation numbers such as valves V-1 and V-2, dampers D-3 and D-4, etc. Describe the role of each controlled device in the sequence of operation and control. Describe the sequence of operation in all modes, generally as outlined above. Control schematic diagram and the sequence of operation must be included on the drawings. Do ***not*** include the sequence of operation in the specifications.

5.4.2 POINT LIST

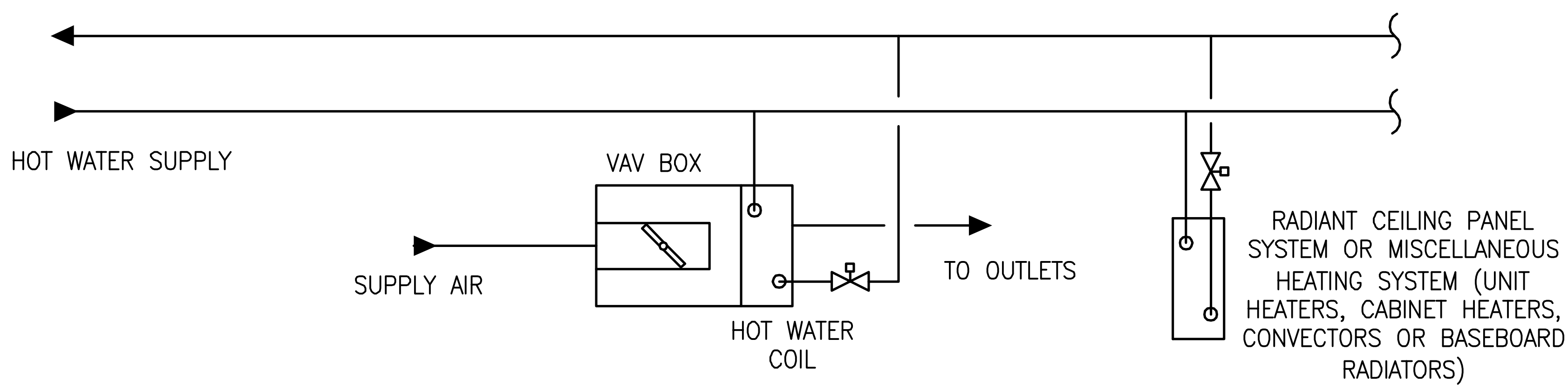
Provide a comprehensive point schedule for each system listing all analog and binary points, alarm requirements, and measurement needs.

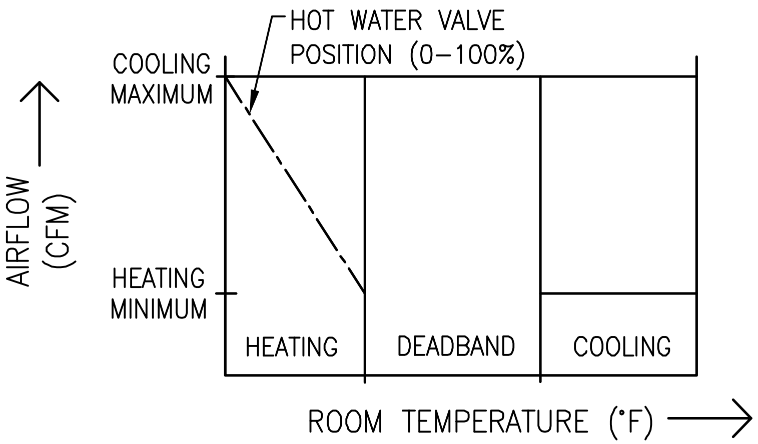
Examples:

- CFM
- GPM
- Static Pressure
- Pressure Differential

5.4.2.1 Sample List of Points

Sample lists of points for air handling units, chilled water and condenser water systems, heating and boiler systems, and miscellaneous systems are shown in Figures 5-5 through 5-8. The point lists are not all inclusive and do not include items such as software features describing the programming needs and capabilities. This list is meant to show the general format. The A/E shall include all features and project specific details, as required. All items shown in the point lists may not be applicable to each situation.





VAV BOX CONTROL SEQUENCE

CONTROL SEQUENCES

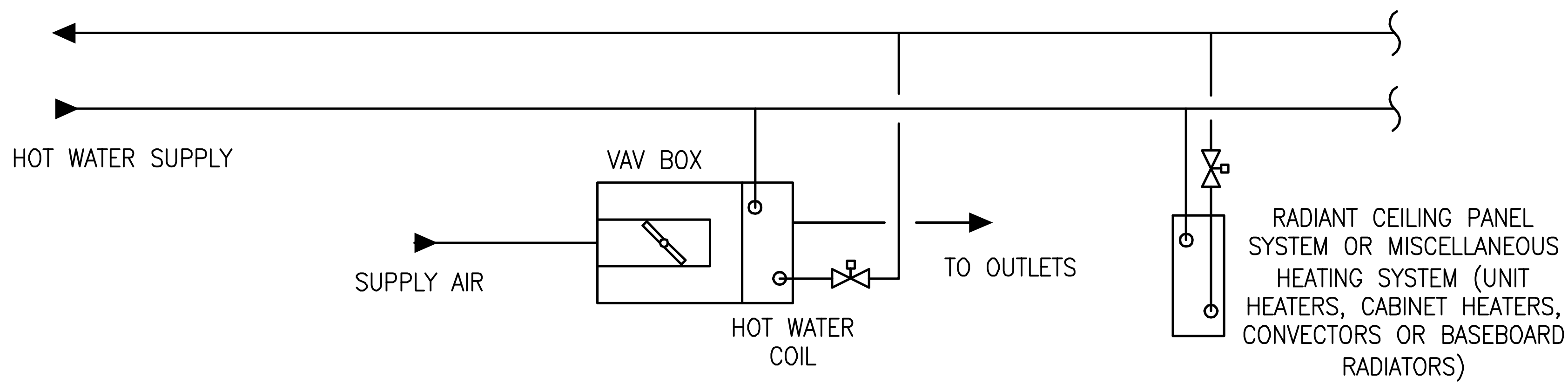
CASE 1: NO PERIMETER HEATING
A. HOT WATER VALVE ENABLED AT ALL TIMES.
B. HOT WATER VALVE OPENS IF ROOM TEMPERATURE IS LESS THAN SET POINT.

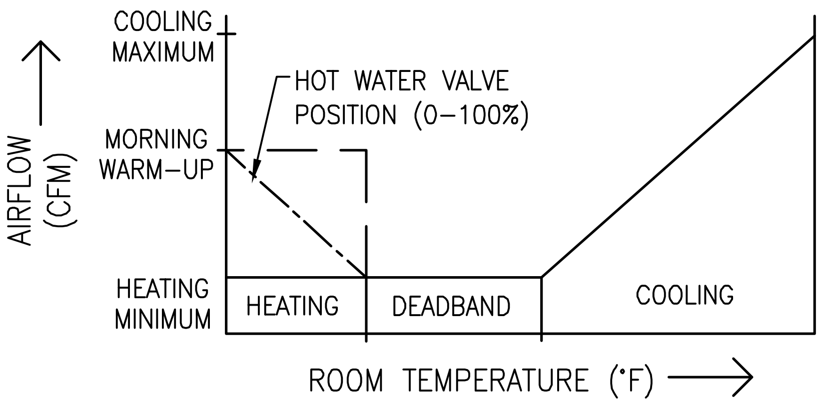
CASE 2: WITH RADIANT CEILING PANEL SYSTEM
A. RADIANT PANEL CONTROL VALVE ENABLED BELOW A SPECIFIED OUTSIDE AIR TEMPERATURE.
B. IF CV BOX HOT WATER VALVE IS 100% OPEN AND ROOM TEMPERATURE IS LESS THAN SETPOINT, RADIANT CEILING PANEL HOT WATER VALVE MODULATES OPEN TO MAINTAIN ROOM TEMPERATURE SET POINT.

CASE 3: WITH MISCELLANEOUS HEATING
A. CONTROL VALVE FOR MISCELLANEOUS HEATING SYSTEM ENABLED BELOW A SPECIFIED OUTSIDE AIR TEMPERATURE.
B. IF CV BOX HOT WATER VALVE IS 100% OPEN (AND RADIANT CEILING PANEL SYSTEM VALVE, IF INSTALLED) AND ROOM TEMPERATURE IS LESS THAN SETPOINT, MISCELLANEOUS HEATING HOT WATER VALVE MODULATES TO MAINTAIN ROOM TEMPERATURE.

CV TERMINAL UNIT WITH REHEAT AND PERIMETER HEATING, WITH 5° DEADBAND

Not to Scale





VAV BOX CONTROL SEQUENCE

CONTROL SEQUENCES

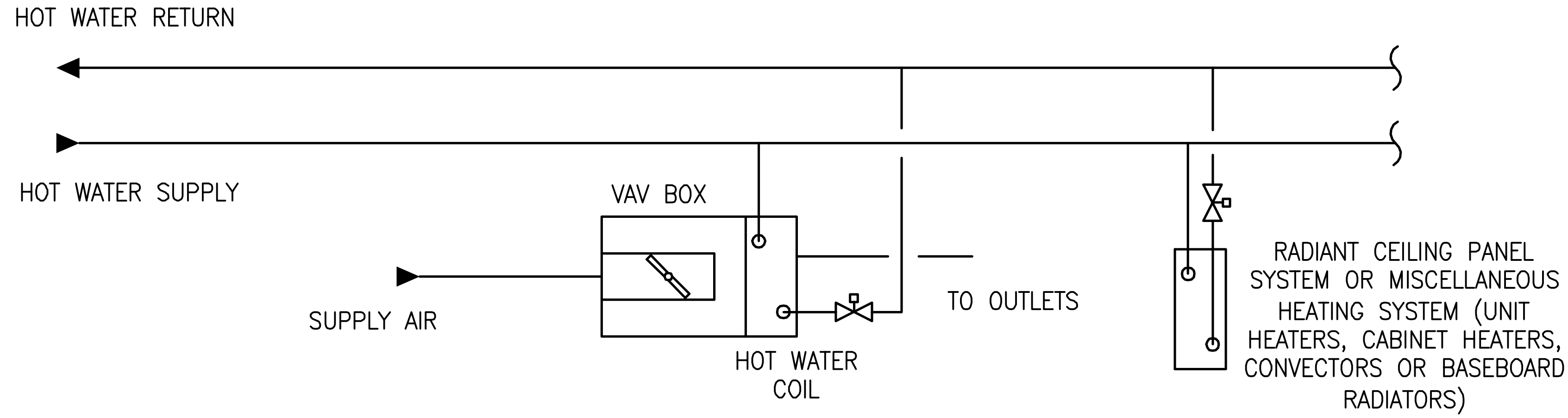
CASE 1: NO PERIMETER HEATING
  A. HOT WATER VALVE ENABLED AT ALL TIMES.
  B. HOT WATER VALVE OPENS IF ROOM TEMPERATURE IS LESS THAN LOWER DEADBAND LIMIT.

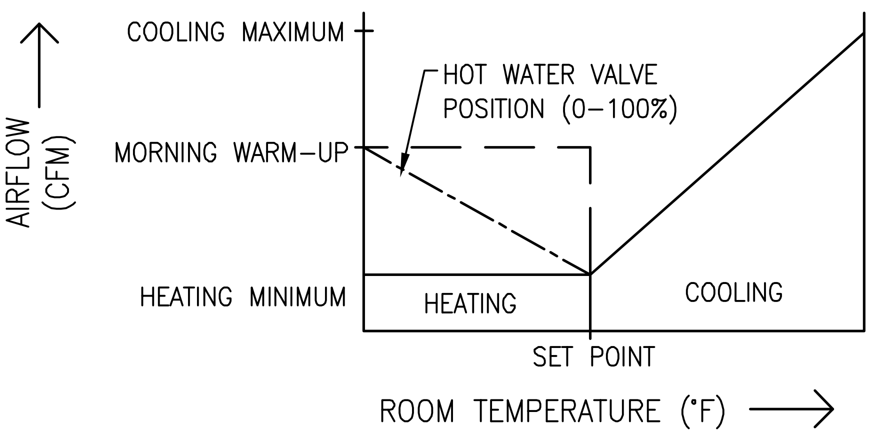
CASE 2: WITH RADIANT CEILING PANEL SYSTEM
  A. RADIANT PANEL CONTROL VALVE ENABLED BELOW A SPECIFIED OUTSIDE AIR TEMPERATURE.
  B. IF VAV BOX HOT WATER VALVE IS 100% OPEN AND ROOM TEMPERATURE IS LESS THAN SETPOINT, RADIANT CEILING PANEL HOT WATER VALVE MODULATES OPEN TO MAINTAIN ROOM TEMPERATURE SET POINT.

CASE 3: WITH MISCELLANEOUS HEATING
  A. CONTROL VALVE FOR MISCELLANEOUS HEATING SYSTEM ENABLED BELOW A SPECIFIED OUTSIDE AIR TEMPERATURE.
  B. IF VAV BOX HOT WATER VALVE IS 100% OPEN (AND RADIANT CEILING PANEL SYSTEM VALVE, IF INSTALLED) AND ROOM TEMPERATURE IS LESS THAN SETPOINT, MISCELLANEOUS HEATING HOT WATER VALVE MODULATES TO MAINTAIN ROOM TEMPERATURE.

VAV TERMINAL UNIT WITH REHEAT AND PERIMETER HEATING, WITH 5° DEADBAND

Not to Scale





VAV BOX CONTROL SEQUENCE

CONTROL SEQUENCES

CASE 1: NO PERIMETER HEATING

A. HOT WATER VALVE ENABLED AT ALL TIMES.
B. HOT WATER VALVE OPENS IF ROOM TEMPERATURE IS LESS THAN LOWER DEADBAND LIMIT.

CASE 2: WITH RADIANT CEILING PANEL SYSTEM

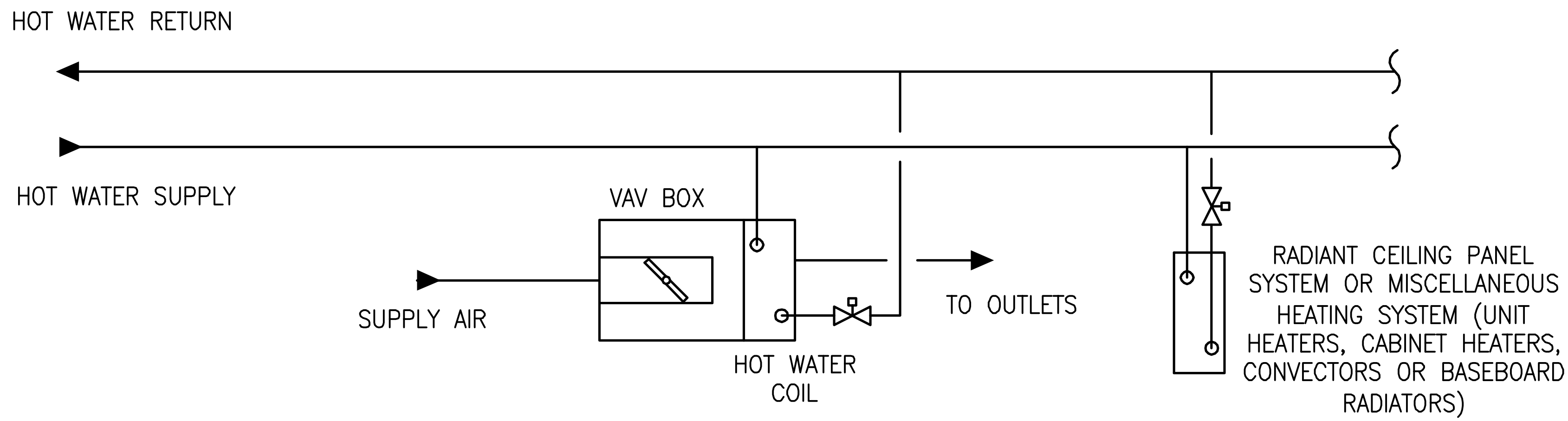
A. RADIANT PANEL CONTROL VALVE ENABLED BELOW A SPECIFIED OUTSIDE AIR TEMPERATURE.
B. IF VAV BOX HOT WATER VALVE IS 100% OPEN AND ROOM TEMPERATURE IS LESS THAN SETPOINT, RADIANT CEILING PANEL HOT WATER VALVE MODULATES OPEN TO MAINTAIN ROOM TEMPERATURE SET POINT.

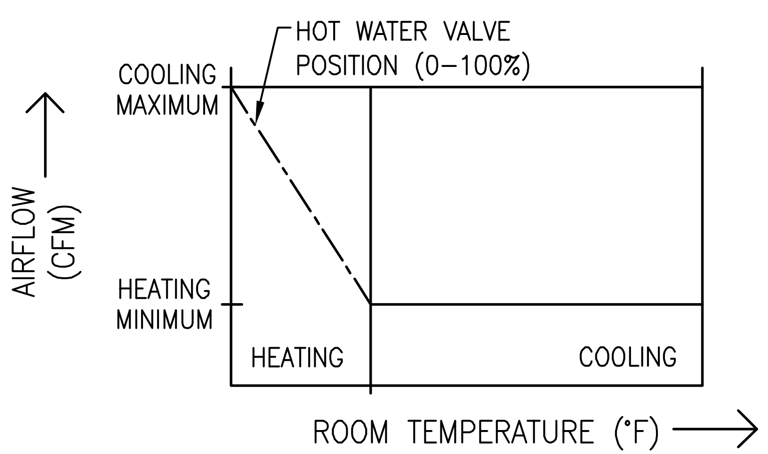
CASE 3: WITH MISCELLANEOUS HEATING

A. CONTROL VALVE FOR MISCELLANEOUS HEATING SYSTEM ENABLED BELOW A SPECIFIED OUTSIDE AIR TEMPERATURE.
B. IF VAV BOX HOT WATER VALVE IS 100% OPEN (AND RADIANT CEILING PANEL SYSTEM VALVE, IF INSTALLED) AND ROOM TEMPERATURE IS LESS THAN SETPOINT, MISCELLANEOUS HEATING HOT WATER VALVE MODULATES TO MAINTAIN ROOM TEMPERATURE.

VAV TERMINAL UNIT WITH REHEAT AND PERIMETER HEATING - 0° DEADBAND

Not to Scale





VAV BOX CONTROL SEQUENCE

CONTROL SEQUENCES

CASE 1: NO PERIMETER HEATING
- A. HOT WATER VALVE ENABLED AT ALL TIMES.
- B. HOT WATER VALVE OPENS IF ROOM TEMPERATURE IS LESS THAN SET POINT.

CASE 2: WITH RADIANT CEILING PANEL SYSTEM
- A. RADIANT PANEL CONTROL VALVE ENABLED BELOW A SPECIFIED OUTSIDE AIR TEMPERATURE.
- B. IF CV BOX HOT WATER VALVE IS 100% OPEN AND ROOM TEMPERATURE IS LESS THAN SETPOINT, RADIANT CEILING PANEL HOT WATER VALVE MODULATES OPEN TO MAINTAIN ROOM TEMPERATURE SET POINT.

CASE 3: WITH MISCELLANEOUS HEATING
- A. CONTROL VALVE FOR MISCELLANEOUS HEATING SYSTEM ENABLED BELOW A SPECIFIED OUTSIDE AIR TEMPERATURE.
- B. IF CV BOX HOT WATER VALVE IS 100% OPEN (AND RADIANT CEILING PANEL SYSTEM VALVE, IF INSTALLED) AND ROOM TEMPERATURE IS LESS THAN SETPOINT, MISCELLANEOUS HEATING HOT WATER VALVE MODULATES TO MAINTAIN ROOM TEMPERATURE.

CV TERMINAL UNIT WITH REHEAT AND PERIMETER HEATING, WITH 0° DEADBAND

Not to Scale

		System Outputs				System Inputs									System Software/Control					
		Binary		Analog		Binary		Analog							Alarm Processing			Application/Function		
System Component	Point ID	Electric	Pneumatic	Electric	Pneumatic	Status		Temperature	Pressure	Humidity	Flow	Current	Percent	Data	Equipment Status	Low Limit	High Limit	Lead/Lag	Start/Stop	
Supply Fan																				
On/Off												X			X					
Start/Stop		X																	X	
Status Auto						X														
Status Hand						X														
VFD Control Panel														X						
Return Fan																				
On/Off												X			X					
Start/Stop		X																	X	
Status Auto						X														
Status Hand						X														
VFD Control Panel														X						
Relief Fan																				
On/Off												X			X					
Start/Stop		X																	X	
Status Auto						X														
Status Hand						X														
VFD Control Panel														X						
Exhaust Fan																				
On/Off												X			X					
Start/Stop		X																	X	
Status Auto						X														
Status Hand						X														
VFD Control Panel														X						
Glycol Energy Recovery Pump																				
On/Off												X			X					
Start/Stop		X																	X	
Status Auto						X														
Status Hand						X														
Outside Air Temperature								X												
Outside Air Humidity										X										
Mixed Air Temperature								X								X	X			
Heat Recovery Coil Temperature								X								X	X			
Preheat Coil Temperature								X								X	X			
Chilled Water Coil Temperature								X								X	X			
Supply Air Temperature								X								X	X			
Supply Air Temperature Humidity										X						X	X			
Space Temperature								X								X	X			
Space Humidity										X						X	X			
Pre-Filter Status						X									X					
After-Filter Status						X									X					
Freezestat Status						X									X					
Duct Mounted Smoke Detector Status						X									X					
Static Pressure Sensor									X							X	X			
Return Air Damper Position													X							
Outside Air Damper Position													X							
Mixed Air Damper Position													X							
VAV Box Flow											X									
VAV Box Supply Air Temperature								X								X	X			

AIR HANDLING SYSTEM OVERVIEW

		System Outputs				System Inputs									System Software/Control				
		Binary		Analog		Binary		Analog							Alarm Processing			Function	
System Component	Point ID	Electric	Pneumatic	Electric	Pneumatic	Status		Temperature	Pressure	Level	Flow	Current	pH	Data	Equipment Status	Low Limit	High Limit	Lead/Lag	Start/Stop
Chilled Water Pump																			
On/Off												X			X				
Start/Stop		X																X	X
Status Auto						X													
Status Hand						X													
VFD Control Panel Data														X					
Chilled Water Supply Temperature								X								X	X		
Chilled Water Return Temperature								X								X	X		
Chilled Water Supply Flow											X								
Chiller Control Panel																			
Safeties/Failures						X										X	X		
On/Off												X			X				
Start/Stop		X																X	X
Data														X					
Chilled Water Pump																			
On/Off												X			X				
Start/Stop		X																X	X
Status Auto						X													
Status Hand						X													
VFD Control Panel Data														X					
Cooling Tower Make Up Flow											X								
Cooling Tower Blow Down Flow											X								
Cooling Tower Fan																			
On/Off												X			X				
Start/Stop		X																X	X
Status Auto						X													
Status Hand						X													
VFD Control Panel Data														X					
Condenser Water Supply Temperature								X								X	X		
Condenser Water Return Temperature								X								X	X		
Cooling Tower Fan Vibration					X														
Condenser Water pH					X														
P&F Economizer																			
Chilled Water Supply Temperature								X								X	X		
Chilled Water Return Temperature								X								X	X		
Chiller kW												X							
Cooling Tower Fan kW												X							
Chilled Water Pump kW												X							
Condenser Water Pump kW												X							

CHILLED WATER SYSTEM OVERVIEW

		System Outputs				System Inputs									System Software/Control				
		Binary		Analog		Binary		Analog							Alarm Processing			Application/Function	
System Component	Point ID	Electric	Pneumatic	Electric	Pneumatic	Status		Temperature	Pressure	Differential Pressure	Level	Flow	Current	Data	Equipment Status	Low Limit	High Limit	Lead/Lag	Start/Stop
Hot Water Pump																			
On/Off													X		X		X		
Start/Stop		X																X	X
Status Auto						X													
Status Hand						X													
VFD Control Panel Data														X					
Hot Water Supply Temperature								X								X	X		
Hot Water Return Temperature								X								X	X		
Hot Water Flow												X							
Boiler Control Panel																			
Safeties/Failures						X									X				
On/Off															X				
Start/Stop		X																X	X
Data														X					

HEATING SYSTEM OVERVIEW

		System Outputs				System Inputs									System Software/Control				
		Binary		Analog		Binary		Analog							Alarm Processing			Function	
System Component	Point ID	Electric	Pneumatic	Electric	Pneumatic	Status		Temperature	Pressure	Differential Pressure	Level	Flow	Current	Data	Equipment Status	Low Limit	High Limit	Lead/Lag	Start/Stop
Freezers and Refrigerators																			
Dietetics								X								X	X		
Laboratories								X								X	X		
Blood Bank								X								X	X		
Mortuary								X								X	X		
Compressed Air																			
On/Off						X													
Safeties/Failures						X									X				
Pressure						X										X			
Medical Gas																			
On/Off						X													
Safeties/Failures						X									X				
Pressure						X										X			
Vacuum System																			
On/Off						X													
Safeties/Failures						X									X				
Pressure						X											X		
Emergency Generators																			
Control Panel Data														X					
On/Off													X		X				
Domestic Hot Water Supply Temperature								X								X	X		
Domestic Hot Water Return Temperature								X								X	X		
Domestic Hot Water Pump																			
On/Off													X		X				
Start Stop		X																X	X
Status Auto						X													
Status Hand						X													
Sewage Pumps																			
Elevator Machine Room Temperature								X									X		
Electrical Room Temperature								X									X		

MISCELLANEOUS SYSTEM OVERVIEW