23 0501 – HVAC Design Criteria

1. Design Statement

    a. During the various design phases of this project, the architect/Engineer will develop options and schemes for selection of the appropriate HVAC system. This approach will enable the entire project team to partake in the decision-making process concerning the selection of the HVAC system and major equipment.

    b. The new HVAC system shall have the following characteristics:

        i. Energy Efficiency

        ii. Durability; ease of maintenance.

        iii. Reliability.

        iv. Redundancy (where required and cost effective, consult with HMS Project Manager).

        v. Future expansion (where required and cost effective, consult with HMS Project Manager)

        vi. Cost effectiveness.

    c. Design, layout and installation of equipment shall be in easily accessible locations, will provide for routine preventive maintenance, service and replacement.

    d. Equipment in mechanical spaces shall be designed to allow for proper access for routine preventive maintenance, service and replacement.

2. Design Phases: Each project shall be organized to follow a sequential design submission schedule that will include the following drawing sets. Design phases may be revised by HMS Project Manager dependent on scope and scale of the project.

    a. Review Owner Project Requirements with HMS Project Team.

    b. Conceptual narrative

    c. Schematic Design: Basis of design narrative, flow diagrams and major equipment layouts.

    d. Design development

    e. Construction documents

3. Energy

    a. The design team shall design all projects to meet the Harvard Sustainable Standards

    b. All projects should target a 15% improvement beyond current state energy standards (latest adopted ASHRAE 90.1 standard).

    c. Refer to Harvard Green Building Standards for additional requirements.

4. Codes, Standards and References

    a. The HVAC systems will be designed to comply with the latest volume or publication of following codes and standards:

        i. Massachusetts State Building & Mechanical Codes

        ii. City of Boston Article 37

        iii. Massachusetts Stretch Energy Code. Reference energy standard

        iv. American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE)

        v. United Stated Green Building Council (LEED)

        vi. International Energy Conservation Code (IECC)

        vii. Harvard Green Building Standards

        viii. National Fire Protection Association (NFPA)

            1. NFPA 70 National Electrical Code
            2. NFPA 72 National Fire Alarm Code
            3. NFPA 101 Life Safety Code

        ix. NFPA 110 Emergency and Standby Power Systems

        x. Underwriters Laboratories (UL)

        xi. Occupational Safety and Health Administration (OSHA)

        xii. Environmental Protection Agency (EPA)

        xiii. Massachusetts Department of Environmental Protection (DEP)

        xiv. American National Standards Institute (ANSI)

xv. American Society of Testing Materials (ASTM)

5. Outside Design Conditions:

    a. Summer: 95=3°F db/76°F wb for use in cooling coil selections)
    b. Winter: -10°F db (for use in heating coil selections)

6. Ventilation Criteria

    a. Laboratories

        i. One hundred percent of the air supplied to the Wet Laboratory areas will be exhausted. Supply air quantities will be based upon heat loads, minimum dilution/ventilation requirements and/or required make-up air for exhaust systems, whichever is greater.

        ii. High sensible heat load spaces (such as freezer farms, mas spec, and lab equipment corridors) shall be provided with minimum ventilation air and a separate sensible cooling unit. Sensible cooling units shall be fan coils and/or “chilled beam” induction units.

        iii. Wet Laboratories (with fume hoods) shall be served by pressure-independent variable air volume (VAV) ventilation air control systems with a minimum of six (6) air changes per hour (ACH) for dilution and/or removal of odors during occupied times. During unoccupied periods, the system shall have the capability to turn down to 2 ACH. Air volume control shall be through a venturi type air valve.

            1. Fume hoods shall be exhausted using a variable volume pressure-independent, fast acting, venturi type air valve for a minimum face velocity of 90 feet per minute (fpm). Lower face velocities require EH&S review prior to approval. Airflow control valves shall be designed for chemical resistance appropriate for the application.

        iv. Dry Laboratories (without fume hoods) shall be served by standard variable air volume (VAV) boxes or by venturi valves, pending review by the HMS project team. The duct mains serving dry lab spaces shall be sized such that the lab could be converted to a wet lab in the future.

        v. General Laboratory airflow rates will vary between 2 to 6 air changes per hour (ACH) or as required to meet the cooling loads and maintain space temperature and pressure setpoints while maintaining ASHRAE minimum ventilation requirements during occupied times.

        vi. Where cooling demand requires greater than 6 ACH chilled water fan coil units shall be used.

vii. Labs shall be sized with the capability for low turn down during unoccupied times. Space occupancy sensors shall dry contact outputs to the BAS for monitoring and automatic turndown of space VAV boxes where applicable.

viii. Air change per hour (ACH) requirements will be based on exhaust device requirements.

ix. All laboratory ventilation systems shall be designed with heat recovery system.

x. Laboratory ventilation system design should include considerations for redundancy.

b. Office, Classroom and other non-Lab spaces will be designed in accordance with the latest ASHRAE Standard for minimum ventilation air to occupied rooms.

c. Wherever possible, Office/classroom spaces suitable for air recirculation shall be served by separate air handling systems then lab spaces requiring 100% outside ventilation

d. Air distribution systems will be designed to afford flexibility for future redesign, primarily by providing accessibility to duct systems throughout facility and, where feasible, by applying a modular layout of air distribution devices and by providing symmetry and uniformity to the branch duct layout.

7. Interior Space Design Conditions shall be designed in accordance with ASHRAE Standard 55 and the following table:

Space Type	Minimum O.A. Ventilation Rate	Summer Design		Winter Design		Pressurization	Minimum Supply Air Filtration (ASHRAE 52)	Remarks
		Max. Temp. (F)	Max. Relative Humidity (%rh)	Min. Temp. (F)	Min. Relative Humidity (%rh)			
Public Spaces and Office Areas								
Common Areas	Note 1	75	50%	68	20%-30%	Note 4	90%	-
Lobby	Note 1	75	50%	68	20%-30%	Note 4	90%	-
Offices	Note 1	75	50%	68	20%-30%	Note 4	90%	-
Conference Rooms	Note 1	75	50%	68	20%-30%	Note 4	90%	Note 7
Class Rooms	Note 1	75	50%	68	20%-30%	Note 4	90%	Note 7
Auditorium	Note 1	75	50%	68	20%-30%	Note 4	90%	-
Laboratory Spaces								

Open Lab	100%	75	50%	68	20%-30%	(--)	90%	-
Enclosed Equipment Room	Note 1	75	50%	68	20%-30%	(--)	90%	-
Linear Equipment Corridor	Note 1	75	50%	68	20%-30%	(--)	90%	
Alcove (open)	100%	75	50%	68	20%-30%	(--)	90%	-
Tissue Culture	100%	75	50%	68	20%-30%	(+)	90%	Note 4
Procedure Room	100%	72	50%	68	20%-30%	(--)	90%	-
Vivarium/Animal Holding Room	100%	72	50%	68	30%-40%	(--)	90%	-
Glasswash	100%	78	60%	68	20%-30%	(---)	90%	-
Glasswash Equipment Space	100%	85	70%	68	20%-30%	(---)	90%	-
Environmental Room	Note 1 (If Req'd)	-	-	-	-	None	-	Note 2
Miscellaneous Spaces								
Mech. / Elec. Rooms	100%	95	None	68	None	None	30%	-
Tel/Data Rooms/BMS Control Room	-	75	50%	68	20%-30%	None	90%	Note 5
Elevator Machine Rooms	-	85	85%	60	No Control	None	30%	Note 5
General Storage	-	75	50%	68	20%-30%	None	90%	-
Hazardous Storage	100% Exhaust	75	50%	68	20%-30%	(-)	90%	-
Toilet / Locker Rooms	100% Exhaust	75	60%	68	20%-30%	(-)	90%	-
Loading Dock/Garage	100% Exhaust	85	70%	60	No Control	None	90%	Note 3
Copy Rooms	100% Exhaust	75	50%	68	20%-30%	(-)	90%	-
Housekeeping Closets	100% Exhaust	78	60%	68	20%-30%	(-)	90%	-
Server Room		75	50%	68	30%	(+)	90%	Note 5

Note 1: Minimum ventilation rate will be sized based on ASHRAE 62.1 Requirements. Each zone VAV system shall be capable of a reduced airflow setback mode initiated by the room occupancy sensor (provided by electrical division).
Note 2: Environmental room temperature control will be by Division 13.
Note 3: Enclosed loading dock receiving area will have CO monitoring and purge exhaust mode.

Note 4: Space pressurization will be positive relative to adjacent labs unless otherwise approved and coordinated with the Project Manager and tenants of the space. 150 cfm shall be the typical offset for a 36" wide door.

Note 5: Equipment cooling load served by dedicated chilled water or DX AC unit designed specifically for critical 24-7 cooling (similar to Liebert) (Chilled water coil preferred).

Note 6: Space temperature setpoint and relative pressurization will be adjustable via the building automation system.

Note 7: Rooms with occupancy density greater than 25 people per 1000 square feet shall be provided with a CO2 sensor that will initiate a demand-controlled ventilation response by the associated VAV box or air valve.

8. Internal Load Design Criteria: The following are only estimates and, in all cases, the actual equipment and lighting cooling load should be calculated.

Space Type	People Load Note 1	Equipment Load	Remarks
Common Areas / Lobbies	250 gsf/person	0-1 W/gsf	-
Lobby	250 gsf/person	0-1 W/gsf	-
Auditorium	25 gsf/person	1-2 W/gsf	-
Offices	100 gsf/person	1-2 W/gsf	-
Conference Rooms	25 gsf/person	2-4 W/gsf	-
Class Rooms	25 gsf/person	0-1 W/gsf	-
Open Lab	100 gsf/person	7.5 W/gsf	-
Enclosed Equipment Room	100 gsf/person	10-20 W/gsf	-
Linear Equipment Corr	200 gsf/person	10-20 W/gsf	
Entry Alcove	100 gsf/person	5-10 W/gsf	-
Tissue Culture Alcove	100 gsf/person	5-10 W/gsf	-
Procedure Room	100 gsf/person	5-10 W/gsf	
Glasswash	200 gsf/person	Note 2	-
Glasswash Equipment Space	-	Note 2	-
Darkroom	100 gsf/person	2-6 W/gsf	-
Environmental Room	-	-	-
Holding Rooms	100 gsf/person	Note 2	Note 4
Procedure Rooms	100 gsf/person	Note 2	Note 4
Testing Rooms	100 gsf/person	Note 2	Note 4
Mech. / Elec. Rooms	-	-	Note 3

Tel/Data Rooms	-	Note 2	-
Elevator Machine Rooms	-	Note 2	-
General Storage	200 gsf/person	0-2 W/gsf	-
Hazardous Storage	200 gsf/person	0-2 W/gsf	-
Toilet / Locker Rooms	-	-	Note 4
Housekeeping Closets	-	-	Note 4
Loading Dock Receiving	-	-	Note 4
Server Room	200 gsf/Wgsft	Note 2	

Note 1: People loads will be based on actual count of people.

Note 2: Equipment loads will be based on actual equipment heat gains as published by manufacturer where available.

Note 3: Space loads based on estimated equipment heat gain.

Note 4: Exhaust and cooling requirements will dictate air flow quantity (minimal cooling load). Design shall be based on infrastructure sized for a minimum of six (6) air changes per hour

9. Heating Source – MATEP

   a. The majority of buildings on HMS campus are connected to the existing MATEP steam distribution system located at the basement level and through tunnels that connect each building. The initial distribution pressure shall be 125 psig, but shall be reduced via a pressure reducing station for medium pressure steam (MPS) and low-pressure steam (LPS).

      i. All steam condensate generated by the medium pressure steam system will be flashed, with flash steam recovered prior to returning to the condensate system.

      ii. Condensate will be collected in a central receiver and discharged back to the MATEP condensate return system, via a duplex condensate receiver/pump set. Condensate pumps sets will be required at other locations within the building for sterilizers, heat exchangers and steam line trapping condensate. Main pump set pressure shall be designed based on MATEP requirements.

      iii. The steam system shall include a flow metering station prior to PRV stations, Condensate flow meters are not required.

   b. Building heating hot water shall be generated in steam-to-hot water heat exchangers. Three (3) hot water loops will be installed with associated heat exchangers, pumps and flow/BTU meters, as follows:

      i. System No. 2: Building Reheat Water
      ii. System No. 3: Building Radiation Water
      iii. System No. 1: Animal Area Reheat Water (where applicable)

10. Heating and Cooling Energy Recovery (Required by Code)

a. Energy Recovery for air handling unit systems shall be designed in accordance with the latest adopted version of the state energy code (IECC,ASHRAE 90.1 and Energy Stretch Code).

b. Multiple options for energy recovery shall be evaluated for each project. The HMS project team must approve of the design team's proposal for energy recovery prior to construction documents phase.

c. Air handling systems with clean, non-hazardous exhaust airstreams shall utilize an enthalpy recovery wheel wherever possible.

d. Air handling systems with dirty or hazardous exhaust shall utilize standard glycol heat recovery coils within the exhaust air handing units and the supply air handling units to recover sensible heat before being exhausted to outdoors. The system fluid shall be 40% propylene glycol. During winter operation, the supply unit coil shall preheat the intake air. During summer operation, the supply coil is available to pre-cool the intake air.

    i. Heat pipes shall be an acceptable alternative to the glycol run-around loops for consideration in sensible only heat recovery applications.

11. Cooling Source – MATEP

    a. The majority of buildings on HMS campus are connected to the existing MATEP chilled water distribution system. (NRB and 641 Huntington Buildings have dedicated cooling plants).

    b. A chilled water flow meter will record the chilled water usage and report to the building automation system.

    c. A secondary chilled water pump and piping system will distribute chilled water to primary cooling equipment such as air handling units. The chilled water system will be designed with a minimum 15°F temperature difference between supply and return.

        i. Chilled water supply temperature = 45 degrees

    d. A deny valve piping arrangement will ensure the required building temperature difference of 15 degrees F is maintained.

    e. Chilled water pumps shall be variable flow/constant temperature difference to the building via a supply and return piping system. Pumps will be equipped with variable speed drives that will operate to maintain constant differential pressure across the system.

    f. Duplex Strainers shall be installed on all systems connected to the matep loop

12. Process Cooling

i. For Lab buildings that require a process cooling source, a separate process chilled water or condenser water loop shall be distributed throughout to serve environmental room condensers, process cooling loads, computer room type units, water cooled compressors, etc.

ii. Two (2) end suction pumps shall pump the water through a filter and a piping system shall distributed water to each floor via vertical risers.

1. If chilled water is to be used, it shall be via a plate and frame heat exchanger coupled with the MATEP cooling loop.

iii. If condenser water is to be used as a source for heat rejection of equipment, it shall be generated via a ducted closed-loop cooling tower. The condenser water supply temperature shall be 85 degrees maximum, or lower as outdoor conditions allow. The Warren Alpert Building and LHRRB building each have similar systems.

13. New Air Handling Units.

a. Units shall be custom fabricated by manufacturer experienced in providing full custom air handling units with 4" foam or fiberglass panels shall be provided for capacities greater than 5,000 cfm.

b. Floors shall be epoxy coated.

c. Smaller units shall be standard modular type units with 2" fiberglass wall construction unless otherwise determined by the HMS project manager and the design team.

d. Supply and exhaust AHUs shall be sized for 100% of the connected load, sum of the peaks.

e. Supply Units shall include the following components as standard:

i. Outside air and return air (where applicable) inlet Dampers and air flow stations,

ii. Return air type units shall have an air blender downstream of mixing section.

iii. Inlet sound attenuator,

iv. MERV 8 pre-filter bank and MERV 13 after filter banks (or per latest LEED Standards),

v. Energy Recovery Section (where cost effective and required by code),

vi. Steam or hot water Pre-heat coil (steam is preferred where available)

1. The First coil should have a Factory-Applied Corrosion-Resistant Coil Coating

    a. Electro Fin® E-Coat or equivalent that meets the specs below:
    ELECTROFIN® E-EOAT MEETS THESE TEST STANDARDS

    • ASTM B117 / DIN 53167 Salt Spray - 6,000+ hours

    • ASTM G85 Annex A3 SWAAT Modified Salt Spray - 2,500 hours

    • VA Master Construction Specification Division 23 for High Humidity Installations

    • CID AA-52474A (GSA)

vii. Chilled water coil

viii. Steam Humidifier,

ix. Supply fan array consisting of multiple plenum fans

x. Variable speed drive (or drives depending on number of fans and critical nature of the affected zones),

xi. Supply Airflow Station,

xii. Discharge sound attenuator.

xiii. Final HEPA Filters (only required for vivarium or other critical environments),

xiv. Discharge plenum and smoke/isolation dampers

xv. Additional filtration as required.

xvi. Pressure Independent Control Valves (PICV) at all large air handler coils

f. Access to all components requiring maintenance shall be accounted for in the layout of each unit.

g. Outside air Dampers shall be of aluminum or stainless-steel construction.

14. Chillers:

a. Existing buildings may continue to be served by the campus/MATEP chilled water loop. The HMS Energy & Utilities Manager shall review all new service concepts for conformity with supply contract obligations.

b. New buildings shall include a connection to the MATEP system, but shall also be provided with a local chilled water plant.

c. At a minimum all equipment must exceed code required efficiencies. A life cycle cost analysis of all options must be performed and reviewed with HMS Energy & Utilities Manger to guide decisions.

d. New Chiller plants shall have the ability to back feed the campus chilled water distribution system.

e. Steam driven chillers are not permitted

f. Acceptable chiller manufacturers subject to compliance with the specification:

i. Trane
ii. York
iii. Carrier
iv. Multistack

15. Environmental Rooms
    a. New or renovated cold/warm rooms should have the following
        i. Supply air from conditioned space/ductwork
        ii. Dehumidification
        iii. Temp/humidity sensors tied into campus monitoring system or BACnet compatible controllers where we can access data to transfer to HMS monitoring system at https://trenddata.hms.harvard.edu/hms
        iv. Energy Conservation measures
            1. Example: ECM motors on the evaporator fans.
        v. LED lights
        vi. No wood- products
    b. Warm/cold rooms in specialty research areas should have cooling coils designed for the environment
        i. Example –coils in fly rooms dipped in anti-corrosion material
    c. Walk in freezers shall be equipped with a Panic button

23 0510 – HVAC Commissioning

1. HVAC Commissioning

    a. The Project Team shall provide fully integrated design documents to ensure all required Contractors are fully responsible for supporting the 3rd Party Commissioning activities. All required labor hours and materials shall be included for, at a minimum but not limited to, meetings, supporting documentation, field testing activities, ancillary testing equipment, off-season testing, data storage, support for 1 year warranty verification (if required), etc.

b. The Project Team shall work with the project Commissioning Agent to incorporate all of their testing requirements into the contract specifications.

23 0514 – Variable Frequency Drives

1. Provide a complete variable frequency drive (VFD) in a single enclosure for each fans and each pump 2 hp or greater serving variable loads.
    a. ECM motors will be acceptable for motors less than 2 HP.
    b. Integral pump / VFD will be acceptable for motors less than 2 HP (similar to Grundfos Magna3).
    c. Greater than 2 HP, needs HMS approval
2. VFD's associated with an air handling unit fan array shall be arranged in one of two options depending on unit capacity, total peak HP, and any required redundancy based on the critical level of the building.
    a. At the least, two VFDs for each fan array shall be provided for redundancy.
    b. One VFD per fan may be required for certain applications (such as Fan wall technology)
    c. For smaller motor sizes, ECM motors may be an alternative.
3. Acceptable manufacturers contingent on compliance with specifications are:
    a. 30 HP and Larger (18-Pulse or Greater Units Only)
        i. Yasakawa – Preferred Vendor. Matrix preferred model
        ii. Square D
        iii. ABB
        iv. Cutler Hammer
        v. Emerson
        vi. Danfoss
    b. 25 HP and Less (**6 Pulse or Greater)**
        i. Yasakawa – Preferred Vendor – Matrix preferred model
        ii. Square D
        iii. ABB
        iv. Cutler Hammer
        v. Emerson
        vi. Danfoss

c. The VFD manufacturer shall include with submittal information, harmonic calculations made in accordance with IEEE 519-1992 Standards showing the specified THVD, line notching and the specified THCD limits are met. Calculations shall assume worst case system conditions. System 1-line, 480V transformer data, standby generator data, and primary fault current data are required to make these calculations and shall be provided in the system short circuit study.

   i. Total harmonic voltage distortion must be less than 3%

   ii. Total harmonic current distortion must be less than 5% and harmonic table requirements ISC / IL <20

   iii. A detailed description of the tests, procedures and supporting calculations required to substantiate the installed systems compliance with the specified THD limits.

d. Where 18 pulse drives will not fit in the available space or must be installed outdoors, an alternative to provide 6-pulse drives with a harmonic filter (similar to Matrix MTE) may be acceptable pending review by HMS project team. A complete harmonic analysis will be required per item c above.

e. Each drive shall be mounted with its accessories in a single cabinet.

f. Installation and start-up services for the equipment shall be covered by this specification.

   i. A direct BAS connection for relay of data via BACNET IP or Siemens FLN protocol is required for all VFDs. Analog signals are not acceptable.

g. Input control signal to all VFDs shall be compatible with the automatic controls and/or building automation control system in the building.

4. All Drives

   a. VFDs located indoors shall be housed in a signal NEMA 1 metal enclosure (including 18-pulse transformer, filters, line reactor, and other required accessories.

   b. Drives located outside shall be provided with a single NEMA 3R enclosure and an independent heating and cooling system to maintain manufacturer's ambient operating conditions.

5. For VFDs greater than 50 HP, the Contractor shall provide independent harmonic testing by an independent testing company. Provide readings with printouts of the harmonic current at each harmonic as well as the total voltage distortion. The following readings shall be provided:

   a. At each point of common coupling:

i. With all drives running with load
ii. With all drives off

b. At the power connection to each drive:

i. With the drive running loaded
ii. With drive off

23 0516 – Pipe Expansion

1. Furnish and install all necessary offsets, joints, expansion loops, compensators, anchors and guides so that no stress is placed on the piping systems or equipment due to thermal expansion.

2. Make proper provision for expansion and contraction in all parts of piping systems wherever possible by means of pipe bends, pipe offsets, swing connections or changes in direction of piping. Where piping network cannot be employed to absorb expansion and contraction in the piping systems, provide expansion joint compensators.

3. Expansion compensator elements shall be selected by the engineer and/or manufacturer to withstand system pressure and temperature conditions and to absorb thermal expansion of the piping. Use of expansion compensators in non-accessible locations shall not be permitted.

4. The Engineers specifications shall require that the Contractor retain a registered Professional Engineer licensed to practice in the project state to review all loads imposed on the building structure and piping system to assure that no points are overstressed.

5. The maximum allowable stress shall be 15,000 psi for cold water, hot water, condensate, and steam and the maximum allowable stress shall be 2500 psi for generator exhaust piping if pipe material is low carbon steel A53 B or A106 B (Marks' Standard Handbook for Mechanical Engineers, Tenth Edition).

6. The Contractor shall submit shop drawings with calculations (with P.E. stamp) detailing the proposed piping support locations for review.

7. All anchor details and forces shall be submitted to the project structural engineer for review prior to any installation.

8. Make proper provision for expansion and contraction in all parts of piping systems:

a. Steam and condensate (all pressures including vents)
b. Hot water
c. All underground piping
d. Emergency Generator exhaust.
e. Relief vents

9. Wherever possible, provide expansion and contraction by means of pipe bends, pipe offsets, swing connections or changes in direction of piping.

10. Where piping network cannot be employed to absorb expansion and contraction in the piping systems, provide expansion joint compensators. Securely anchor all piping utilizing expansion loops and joints to the building structure with steel angles, properly braced and welded to the pipe.

11.

12.

23 0519.10 – Meters

These specifications are located in the HMS Facilities "Metering Standard".

23 0523 – HVAC Valves and Strainers

1. Provide isolation valves at all drains, piping mains and branches at all piping systems, equipment, risers and before and after all control valves.

2. Automatic Valve actuators shall be Belimo as standard (no plastic internal parts) for locations with limited or restricted access. Alternate manufacturers will be acceptable for other areas provided their warrantee includes a standard 5 year warranty.

3. Strainers on main building level water systems shall include a duplex basket strainer for redundancy and ease of service.

4. Pressure Independent Control Valves for coils should be considered when they can be installed across an entire building or floor

5. Valve Chart

Service	Minimum Class and Material			Joints	
	2" and Less	**2½" to 12"**	**14" & Up**	**2" and Less**	**2½" & Up**
Chilled water supply and return	MSS Class 150 Bronze	MSS Class 150 Ductile iron or steel	ANSI Class 150 Cast Steel	Threaded	Flanged or Grooved*
Secondary chilled water system	MSS Class 150 Bronze	MSS Class 150 Ductile iron or steel	ANSI Class 150 Cast Steel	Threaded	Flanged or Grooved*

Service	Minimum Class and Material			Joints	
	2" and Less	2½" to 12"	14" & Up	2" and Less	2½" & Up
Condenser water supply and return	MSS Class 150 Bronze	MSS Class 150 Ductile iron or steel	ANSI Class 150 Cast Steel	Threaded	Flanged or Grooved*
Boiler blowdown and blowoff	ANSI Class 300 Cast Steel	ANSI Class 300 Cast Steel	ANSI Class 300 Cast Steel	Threaded	Flanged
Hot water supply and return	MSS Class 150 Bronze	MSS Class 150 Ductile iron or steel	ANSI Class 150 Cast Steel	Threaded	Flanged or Grooved
Secondary hot water system	MSS Class 150 Bronze	MSS Class 150 Ductile iron or steel	ANSI Class 150 Cast Steel	Threaded	Flanged or Grooved
Low pressure steam (0 to 15 psig)	MSS Class 150 Bronze	MSS Class 150 Ductile iron or steel	ANSI Class 150 Cast Steel	Threaded	Flanged
Medium pressure steam (16 psig to 99 psig)	MSS Class 150 Bronze	MSS Class 150 Ductile iron or steel	ANSI Class 150 Cast Steel	Threaded	Flanged
High pressure steam (225 psi max.) (100 psig to 225 psig)	ANSI Class 300 Cast Steel	ANSI Class 300 Cast Steel	ANSI Class 300 Cast Steel	Threaded	Flanged
High pressure condensate return	MSS Class 250 Cast Iron	ANSI Class 300 Cast Steel	ANSI Class 300 Cast Steel	Threaded	Flanged
Low pressure condensate return	MSS Class 150 314 Stainless Steel	MSS Class 150 314 Stainless Steel	ANSI Class 150 Cast Steel	Threaded	Flanged
Medium pressure condensate return	MSS Class 150 314 Stainless Steel	MSS Class 150 314 Stainless Steel	ANSI Class 150 Cast Steel	Threaded	Flanged
Pumped condensate	MSS Class 150 314 Stainless Steel	MSS Class 150 314 Stainless Steel	ANSI Class 150 Cast Steel	Threaded	Flanged
Makeup and fill	MSS Class 150 Bronze	MSS Class 150 Ductile iron or steel	ANSI Class 150 Cast Steel	Threaded	Flanged or Grooved*
Miscellaneous drains 2½" and up		Match system			Flanged or Grooved*

Service	Minimum Class and Material			Joints	
	2" and Less	2½" to 12"	14" & Up	2" and Less	2½" & Up
Miscellaneous drains to 2"	Match system			Threaded	
Refrigerant system	MSS Class 150 Bronze	MSS Class 150 Steel	N/A	Silver Brazed	Flanged
Fuel oil	MSS Class 300 Bronze UL Listed	ANSI Class 150 Cast Steel UL Listed	ANSI Class 150 Cast Steel UL Listed	Threaded	Butt Weld
Fuel oil supply and return (boiler room)	ANSI Class 150 Cast Steel UL Listed	ANSI Class 150 Cast Steel UL Listed	ANSI Class 150 Cast Steel UL Listed	Socket Weld	Butt Weld
Fuel oil supply and return below grade	ANSI Class 150 Cast Steel UL Listed	ANSI Class 150 Cast Steel UL Listed	ANSI Class 150 Cast Steel UL Listed	Socket Weld	Butt Weld
Other piping	MSS Class 150 Bronze	MSS Class 150 Ductile iron or steel	ANSI Class 150 Cast Steel	Threaded	Flanged or Grooved*

* Grooved piping systems of standard wall shall be roll grooved or cut grooved according to Victaulic groove specification standards. On piping heavier than standard wall, cut grooving required per Victaulic cut groove specification standards. All grooved valves shall be a minimum class of 300.

23 0529 – Hangers and Supports

1. All system components shall be installed in accordance with local codes including seismic isolation as required.

2. All piping shall be hung to true alignment, using appropriate and substantial hanger arrangements. Wire and strap hangers will not be permitted. Hangers shall be located so that piping and hangers will be clear of other piping, hangers, conduits, lighting and other obstructions.

3. All pipes shall be hung free of dependence on pipe sleeves for support.

4. Install flexible connectors on the equipment side of the shutoff valves, horizontal and parallel to equipment shafts whenever possible.

5. Furnish and install all necessary vibration isolation materials to eliminate excessive noise and vibration from all building mechanical systems

6. Provide concrete inertia base at all floor mounted pump sets.

7. Curb mounted rooftop equipment shall be mounted on structural spring isolation curbs that bear directly on the roof support structure, and are flashed and waterproofed into the roof's membrane waterproofing system.

8. Rooftop fans, condensing units, air handlers, etc. shall be mounted on continuous support piers that combines equipment support and isolation into (1) assembly. Support Rails shall incorporate spring or neoprene isolators which are adjustable, removable and interchangeable after equipment has been installed. Wooden sleepers that are not permanently affixed to the roof will not be accepted as they do not meet code.

9. Isolation systems must be installed in strict accordance with the manufacturer's written instructions and submittal data. Vibration isolators shall not cause any change of position of equipment resulting in stress on equipment connections

10. Avoid contact between dissimilar metals.

11. Provide double nuts on all threaded hangers.

12. The utilization oif piping snubbers is permitted

13. There shall be no load imposed on equipment nozzles from connected piping

14. All piping stanchions shall be steel shimmed and grouted

23 0593 – Testing, Adjusting and Balancing

1. Furnish and install all hangers, supports and assemblies for all parts of the mechanical systems. This shall include all piping, ducts and equipment specified in this Division and as shown on the drawings

2. All completed piping shall be pressure tested unless open to the atmosphere.

3. Renovation projects will require a pre-construction verification balancing report to identify any preexisting deficiencies of existing systems being utilized, the drawings and specifications shall clearly indicate this requirement. Report shall include local hood readings, traverse of local and floor main ducts as required, and pertinent fan system data.

4. Design cannot be considered complete without approved final balance report.

5. System balancing shall include:

a. Air System Balance
b. Hydronic System Balance
c. Control Systems Verification
d. Duct leakage testing
e. System Performance Verification
f. Opposite Season Test
g. Pre-Construction Verification survey report (for renovation projects)

23 0713 – Duct Insulation

1. Duct insulation thicknesses shall meet Code required thicknesses and R-Values.

2. Ductwork located in mechanical rooms or where exposed to view shall be rigid board.

3. Duct service type and flow direction shall be labeled every 15 feet at a minimum.

4. Where connecting to existing ducts, replace an additional 5 ft of insulation on either side of connection.

5. Where ductwork passes thru exterior building walls, the exterior portion shall use double the thicknesses scheduled up to 24 inches beyond the point where ducts (supply and return) enter the building.

6. Furnish and install all duct insulation, vapor barriers, jackets, finishes, adhesives, cements and accessories to make a complete and insulated system of all ductwork, fittings, joints, offsets and accessories.

7. All insulation system materials shall conform to the maximum flame spread/smoke developed ratings specified herein.

8. All kitchen hood exhaust ductwork and accessories shall be insulated with a rated fireproof insulation system with zero clearance allowed. The system shall extend continuously from the hood connections to the fan intake connection.

9. Duct insulation exposed to weather: Cover all ducts exposed to weather with insulation in accordance with the insulation specification and Table 4.1 below but in no case shall this be less than 3” thick fiber glass rigid board insulation with vapor barrier for ductwork. When insulation application is completed, the entire installation shall be covered with EPDM roofing material or 3M Venture Clad Model 1579GCW-WH. All joints shall overlap a minimum of 6 inches.

10. Insulation for the various duct systems and associated equipment shall be composed of materials which are non-combustible and/or provide a fire resistive system of insulation which complies with the applicable Code having jurisdiction. Generally, it is required that fire hazard ratings shall not exceed the following, except as noted:

a. Flame Spread Rating: 25 (No Exceptions)
b. Smoke Developed Rating: 50

11. All fire hazard ratings shall be as determined by NFPA 255 "Method of Test of Surface Burning Characteristics of Building Materials", ASTM E84 or UL 723.

23 0719 – HVAC Piping Insulation

1. Pipe insulation thicknesses shall meet Code required thicknesses and R-Values.

2. Pipes 2-1/2” or greater located in mechanical rooms and high traffic areas shall include an additional PVC service jacket in accordance with HMS color code standard. Pipes 2” or less can be painted.

3. Pipe service type and flow direction shall be labeled every 15 feet at a minimum and at each side of wall penetrations. Insulation shall be continuous thru wall.,

4. Where connecting to existing ducts or piping, replace an additional 5 ft of insulation on either side of connection.

5. Provide removable blankets for hot service valves 2 1/2” or greater. Blankets shall not be sewn together, provide Velcro, strings or other system that can be refastened.

6. Equipment drains and floor drains from cooling coils as well as drinking fountain waste shall be insulated 6 feet downstream from connection point

7. Underground (direct buried piping):

    a. The underground piping system for steam, condensate, chilled water, fuel oil and all components shall be of the prefabricated and pre-engineered types specifically designed for direct buried application. Piping shall be installed in strict accordance with the manufacturer’s recommendations.

    b. The use of coat & wrap or cathodic protection systems is required for all steel piping.

    c. Acceptable manufacturers shall include Perma Pipe and Thermacore Process Inc.

    d. Provide stress calculations and forces at all anchors, guides and supports based on actual installed locations.

    e. All underground prefabricated piping shall be conforming to ANSI 31.1 requirements

    f. Steam and condensate service: Provide a product similar to Perma Pipe Multi Therm 500.

g. Chilled Water Service piping installed underground: Provide a product similar to PPR-CT plastic piping.

8. Furnish and install all piping insulation, vapor barriers, jackets, finishes, adhesives, cements and accessories to make a complete insulated system for all piping, valves, fittings, joints, offsets and flanges specified herein.

9. All insulation system materials shall conform to the maximum flame spread/smoke developed ratings specified herein.

10. Hard insulation material or insulation shields shall be provided at all hangers.

11. Insulate the following:

    a. All scheduled piping, all valves, fittings, elbows, flanges and accessories.

    b. All piping exposed to weather including provision of additional weatherproof jacket.

    c. All cold-water make-up piping and valves. All drain and overflow piping receiving cold water. Piping to/from expansion/compression tanks.

    d. All vents and blow-offs in mechanical rooms and elsewhere within reach of personnel.

    e. Piping jacket covers.

    f. All heat traced piping.

12. Piping insulation for the various piping systems and associated equipment shall be composed of materials which are non-combustible and/or provide a fire resistive system of insulation which complies with the applicable Code having jurisdiction. Generally, it is required that fire hazard ratings shall not exceed the following, except as noted:

    a. Flame Spread Rating 25 (No Exceptions)
    b. Smoke Developed Rating: 50

13. The finished installation shall present a neat and workmanlike appearance with all jackets smooth, with all vapor barriers sealed and intact.

14. All chilled water system piping, components and accessories are to be insulated in a manner so as to provide a complete, uninterrupted vapor barrier. This includes sealing ends of at all butt joints of insulation segments.

15. Ensure insulation is continuous through interior walls. Pack around pipes with fire proof self-supporting insulation material, fully sealed. Insulation on all cold surfaces where vapor barrier jackets are specified must be applied with a continuous, unbroken vapor seal. Hangers, supports, anchors, and other heat conductive parts that are secured directly to cold surfaces must be adequately insulated and vapor sealed to prevent condensation

16. All pipe elbows shall be insulated with short radial and mitered pieces of board or block insulation or removable pre-molded pieces of pipe insulation. Each piece shall be butted tightly against the adjoining piece and all joints, seams, voids and irregular surfaces shall be filled with insulating cement finished to a smooth, hard and uniform contour. Coat with MAS-1 mastic and reinforce with ADJ-2 additional jacket. In addition, place a fitted PVC cover (ADJ-4) over insulated elbow.

17. Additional Insulation Jacket

    a. ADJ-1: Approximately 6 ounce per square yard glass cloth jacket with thread count of 5 strands per square inch.

    b. ADJ-2: Approximately 2 ounce per square yard glass cloth jacket with a thread count of 10 strands by 10 strands per square inch. Jacket shall be used for covering pipe and pipe fittings.

    c. ADJ-3a: 0.016 inch thick aluminum jacket conforming to ASTM B-209 with a 1 mil factory applied polykraft moisture barrier. Longitudinal joints shall be placed at the side of the pipe facing downward at either the 4 o'clock or 8 o'clock position so as to shed water. Aluminum fitting covers, two-piece elbows, tees, valve and flange covers, etc., with a 1 mil polykraft or acrylic vapor barrier.

    d. ADJ-4: 20 mil PVC jacket suitable for all types of paint. Similar to Manville Zeston 25/50.

    e. ADJ-6 A finish jacket of an Asbestos-free and woven as high temperature, heat-resistant fabric. Lagging Cloth having a treated weight of 24 oz./sq.yd. Material shall be suitable for a sustained operation at 1100°F. Calcium silicate piping for generator exhaust piping shall also be jacketed with corrugated aluminum.

23 2000 – HVAC Piping and Joints

1. Piping:

    a. (Basis of Design) Heat Fused Piping: Contractor option to provide polypropylene (PPR-CT) piping for chilled water, process water, and Heating hot water service. Acceptable manufacturers include: Aquatherm.

        i. Piping to be installed by certified installer and per manufacturer recommendations.

        ii. PPR Connections shall heat fused.

            1. Socket fusion preferred for sizes ½” to 4”

            2. Butt Weld 6” – 24”

            3. Electrofusion (EF) by exception only. Must be approved

iii. Refer to language from plumbing spec.

b. Alternate: Victaulic: Contractor's option to provide mechanical couplings and fittings in lieu of welded fittings and joints for water service not exceeding F in exposed areas and mechanical rooms or runs above ceiling tile or drop ceiling that provide access.

c. Alternate: Pro-Press: Contractor's option to provide Pro-Press fittings for chilled water, cold condenser water and hot water piping (service up to 200 degrees) fittings in accessible locations (not in shafts) for copper piping sized 2-1/2" and below as noted in pipe schedule.

i. The Apollo Factory has recommended that their Pro-Press ball valves not be used on the Cambridge campus. Longwood Campus is following this directive

ii. Note that this only applies to valves that use Pro-press type connections; threaded and solder connections are not affected. While these four types have been specifically identified, others might be affected also: Apollo Series 77V, 77VLF, 77W, and 77WLF

2. Provide all piping, fittings, flanges, couplings, unions, bolting, gaskets, welding, threading and soldering for main piping network, branches and connections to equipment as shown on the drawings and as required to provide complete systems. All piping, fittings and accessories shall conform to the appropriate Service Pipe Schedule as specified herein after.

3. Elbows shall be long radius ANSI B16.9 unless otherwise specified

a. Provide drains at low points and vents at high points of all piping systems and between pumps and check valves.

b. Steam pipes shall be provided with drip legs and traps at all low points and as otherwise specified.

4. Steam service as specified herein shall include steam trap piping to and including shut-off valve on trap discharge and relief valve discharge

5. Service Pipe Schedule

Service	Type	Grade	Wall		Joints (Minimum Sch. Shall match Wall)		Test Pressure
			to 10"	12" & Up	2" and Less	2½" & Up	PSIG
Chilled water supply and return (New Work)	PPR-CT	-	Sch.40	Standard 0.375"	Heat Fused	Butt Welded Note 3&5	225
Chilled water supply and return	A106 or A53 Seamless or ERW	A or B	Sch.40	Standard 0.375"	Threaded Note 3	Butt Welded Note 3 & 5	225

(**Renovation work less than 10 feet to existing pipe mains**)							
Hot water supply and return	A106 or A53 Seamless or ERW	A or B	Sch.40	Standard 0.375"	Threaded Note 3	Butt Welded Note 3	225
Pumped condensate	A106 or A53 Seamless	A or B	Sch.80	Extra Strong 0.5"	Threaded	Butt Welded	225
Low pressure steam (0 to 15 psig)	A106 or A53 Seamless or ERW	A or B	Sch.40	Standard 0.375"	Threaded Malleable	Butt Welded	225
Medium pressure steam, supply, & RPV Safety relief vents thru roof (16 psig to 99 psig)	A106 or A53 Seamless or ERW	A or B	Sch.40	Standard 0.375" Note 4	Socked Welded	Butt Welded	225
High pressure steam (100 psig to 225 psig)	A106 or A53 Seamless	A or B	Sch.80	Extra Strong 0.5"	Socket Welded	Butt Welded	325
High pressure condensate return	A106 or A53 Seamless or ERW	A or B	Sch.80	Extra Strong 0.5"	Socket Welded	Butt Welded	225
Hot well steam condensate and pump discharge to 2½" & up	A106 or A53 Seamless or ERW	B	Sch.80	Extra Strong 0.5		Butt Welded	325
Hot well steam condensate and pump discharge to 2"	A106 or A53 Seamless or ERW	B	Sch.80	Extra Strong 0.5"	Threaded Malleable		325
Low pressure condensate return	A106 or A53 Seamless or ERW	A or B	Sch.80	Extra Strong 0.5"	Threaded Note 1	Butt Welded	225
Medium pressure condensate return	A106 or A53 Seamless or ERW	A or B	Sch.80	Extra Strong 0.5"	Threaded Note 1	Butt Welded	225
Make-up and fill (up to 150F on grooved)	Hard Drawn Copper	ASTM B88	Type L		95-5 Solder Note 3	Silver Brazed Note 3	225
Miscellaneous atmospheric vents (up to 150F on grooved)	A53	A or B	Sch.40	Standard 0.375"	Threaded Note 3	Butt Welded Note 3	225 (with air)
Miscellaneous drains 2½" & up (up to 150F on grooved)	A53	A or B	Sch.40	Standard 0.375"		Butt Welded or Grooved	225

						Note 2, 3	
Miscellaneous drains to 2"	Hard Drawn Copper	ASTM B88	Type L		DWV 95-5 Solder Note 3		225
Emergency generator exhaust	A106 or A53 Seamless or ERW	B	Sch.40	Standard 0.375" Note 4	Butt Welded	Butt Welded	225 (with air)
Fuel oil supply and return	See Fuel System Specification Section						See Spec
Fuel oil supply and return below grade	See Fuel System Specification Section						See Spec
Contractor option Chilled water 2" or Less	A106 or A53 Seamless or ERW	A or B	Sch. 40	Standard 0.375"	Threaded Note 3	Butt Welded Note 3	225
Contractor option Chilled or Hot water 2" or Less	Hard Drawn Copper	ASTM B280	Type L	None	Silver Brazed Note 3		225
Other piping (up to 150F on grooved)	A106 or A53 Seamless or ERW	A or B	Sch.80	Extra Strong 0.5"	Threaded Malleable Note 3	Butt Welded Note 3	325

Note 1: In concealed inaccessible location provide socket welded.
Note 2: Outdoor portion of piping shall be painted with a high temperature rust inhibiting primer and two coats of high temperature enamel paint (color shall be black unless otherwise selected by the architect).
Note 3: Pro-Press: fittings will be acceptable as a contractor joint option for chilled water, cold condenser water and hot water pipe fittings in accessible locations (not in shafts) for copper piping sized 2" and below as noted in pipe schedule.
Victaulic: Contractor's option to provide mechanical couplings and fittings in lieu of welded fittings and joints for water service not exceeding 150°F in exposed areas and mechanical rooms or runs above ceiling tile or drop ceiling that provide access.
Note 4: Where piping extends above roof and is exposed to weather, it shall have an additional 20-gauge polished stainless steel external protective cladding.
Note 5: Polypropylene (PPR-CT) piping: Contractor option to provide polypropylene (PPR-CT) piping for chilled water and cold-water service. Where PPR piping is installed outdoors, UV protection shall be provided. Connections to be Heat fused, socket weld preferred for sizes ½" – 4".

6. All equipment and piping installed shall be tested and found tight. Insulated or otherwise concealed piping shall be tested before being closed in. All leaking joints shall be corrected, retested and found tight.

7. All piping systems shall be subjected to a hydrostatic test at the scheduled test pressure for a period of (4) hours without drop in pressure.

8. All oil piping shall be subject to a test with oil at 225 PSIG for a period of (4) hours without drop in pressure.

9. Tests of piping systems shall be conducted before connections to equipment are made and before piping is covered, buried or otherwise concealed.

10. Welded joints shall be subjected to a hammer test while under pressure.

11. Piping Identification and Valve Tags

    a. Please refer to HMS Plumbing Standard 22 0553 – Plumbing Identification

23 2123 – HVAC Hydronic Pumps and Accessories

1. Furnish and install all pumps and accessories for all systems which are part of the building HVAC systems. This shall include all accessories specified in this Division and as shown on the drawings.

2. Provide base mounted, horizontal axial split-case, or vertical mounted split-case, double-suction, single-stage centrifugal pumps, or base mounted, single-stage end suction radial pumps, as shown on the drawings. Capacity, RPM, head and electrical motor characteristics shall be as scheduled on the drawings.

3. Pumps General:

    a. Pumps up to 2 HP shall include an integral VFD and controller with outputs for BAS monitoring.

        i. Pump sized 3” and larger shall include monitoring of flow, inlet and outlet temperature, pressure and power thru the VFD and on-board controller.

            1. Meter accuracy shall be within 1% or as defined in the VFD specification section 230514.

            2. These meters are in addition to standard flow meters mounted to pipes.

        ii. Input control signal shall be compatible with automatic controls and/or building automation control system.

        iii. Provide a direct BAS connection for relay of pump/VFD data via BACnet IP or Siemens FLN protocol is required for all VFDs. Analog signals are not acceptable.

iv. The pump mounted dP sensor shall not replace the system sensor. A dP sensor shall still be required at the furthest hydraulic point in the system for monitoring and speed control.

b. Pumps greater than 2.5 Hp require external VFD including Current transducer to verify pump status.

c. Construction shall permit complete servicing without breaking pipe or motor connections.

d. Pumps to operate at 1750 rpm unless scheduled or specified otherwise.

e. Provide guards around shafts and couplings in accordance with OSHA and ANSI recommendations.

f. All parts shall be suitable for variable frequency drives; including but not limited to motor, pump, all pump components, coupling, and base.

g. Pumps shall be installed so as to ensure easy accessibility for service or removal and replacement of all components such as, but not limited to, impellers, motors, drive couplings, bearings, strainers, other pump appurtenances and isolators.

h. Set pump on concrete base, anchor, level and grout according to manufacturer's instructions. Provide vibration isolators under pump base.

i. Provide line sized shutoff valve and strainer on suction and line sized silent check valve and flow control balancing valve on discharge.

4. Decrease from line size, with long radius reducing elbows or reducers. Support piping adjacent to pump such that no weight is carried on pump casings. Provide supports under elbows on pump suction and discharge line sizes 4 inches and over Expansion Tanks

a. Provide expansion and compression tanks, air separator and other pump hydronic accessories for each closed loop water circulation system.

i. Ensure that tanks have capability/Fitting for testing and re-pressurization.

ii. Tanks should include Bladder Integrity Monitor

b. Tanks shall be the pressurized captive air bladder type.

c. Provide replaceable elastomeric bladder suitable for a maximum operating temperature of 240 deg F

d. Provide integral steel base ring for vertical mounting.

e. Tanks shall be constructed and certified to ASME Section VIII

i. Pressure rating 150 psig
ii. Temperature of 240□F

f. Provided with charging valve enclosure, remote air connector coupling, system connection and lifting rings.

g. Tanks shall be provided with factory applied rustproof coat of paint to the exterior of tanks.

5. Air Separators:

a. Provide air/dirt separator with flanged inlet and outlet connections for each closed loop pumping system.

i. Provided with drain connection with valve.
ii. Shall be tangential type with bottom blow down.
iii. Full size removable strainer.
iv. Pressure drop shall be 1 foot of water and maximum velocity shall be 4 fps.
v. Provide temporary bypass around all air/dirt separators.
vi. Acceptable Manufacturers: Spirotherm or B&G.

23 2223 – Steam and Condensate Specialties

1. Furnish and install all steam and condensate specialties and equipment to make complete and operations systems.

2. All systems shall be installed in accordance with local code including vent piping and relief discharge termination points.

3. Pressure Reducing Valves

a. Acceptable manufactures subject to compliance with the specifications:

i. Spence

b. Furnish and install, as shown and scheduled on the drawings, steam pressure reducing valves of the self-operated, external pilot type, single seated, normally closed, metal diaphragm actuated, similar to Spence Type ED.

c. Valves shall regulate an accurate delivery pressure within ±1 lb. throughout the range of pressure and flow conditions scheduled, regardless of deviation of the inlet steam pressure. Valves shall function quietly and shut tight on deadend shutoff. Regulators shall respond quickly and accurately without pressure deviation when installed on a 2-stage reduction.

d. A 1/3 – 2/3 dual valve arrangement shall be used for each reducing stage sized for greater than 1000 pounds per hour, or when significant turndown or widely fluctuating loads are anticipated.

e. Bodies 2" and under shall have screwed ends, cast iron body, 250 lb. working pressure construction, size 2 1/2" and up shall have flanged ends. Seats and discs shall be guaranteed by the manufacturer against the wire drawing action of steam. Stems shall be stainless steel.

f. The pressure pilot shall be separate from the main valve and connected to it by unions. A strainer screen shall be built into the pilot inlet. Pilot shall be interchangeable with all sizes of main valves and connected to the main valve by unions. Bleed ports and other orifice fittings shall be externally connected to facilitate troubleshooting and cleaning. Internal bleed ports will not be permitted.

g. The maximum or end point capacity of the regulator shall not pass more than 20% in excess of the required capacity. (Safety valve to be sized to pass 100% of the maximum or end point capacity.)

h. Valves shall be sized so that the valve body inlet velocity does not exceed 8000 fpm and the valve body outlet velocity does not exceed 20,000 fpm or the combined inlet and outlet velocity does not exceed 28,000 fpm.

i. Provide inlet gate valve, steam strainer, outlet gate valve, bypass and safety.

j. Provide noise suppressors and muffling orifice plates downstream of each PRV valve as required to meet job conditions. Suppressors similar to Spence Model "B".

4. Safety Valves

a. Acceptable manufactures subject to compliance with the specifications:

i. Kunkle
ii. Spence
iii. Dresser Inc.

b. Safety valves shall be of size and setpoint as required by PRV manufacturer.

c. Valves shall be cast iron body, lead seal, asbestos free packing and gasket and brass shaft. All internal parts made of cold rolled steel shall be cadmium plated. Provide drain pipe and valve to nearest floor drain and flexible connectors at pipe discharge as shown on the drawings.

d. Poppet valves are not acceptable.

5. Pilot Valves

a. slope

6. Steam Traps

a. Acceptable manufactures subject to compliance with the specifications:

i. Armstrong (preferred)
ii. Sarco
iii. Velan
iv. Strong

b. Provide drip trap assemblies as follows:

i. Steam piping

1. Maximum of 75 feet intervals.
2. At rising points in piping
3. At the bottom of all vertical pipes.

c. At all steam entrance points at building wall

d. Provide temp sensors on discharge side for 2” and larger traps with BAS connection for alarm.

e. Provide steam traps at all low points of the low pressure, medium pressure and high-pressure steam systems, at equipment and as shown on the drawings and required by job conditions. Steam traps used for equipment using low pressure steam (LPS) shall be the closed float and thermostatic type.

f. Traps used for medium (MPS) or high-pressure steam (HPS) shall be Class 300 inverted bucket type for modulating loads. Inverted Buckets shall be utilized for steam line trapping and other constant loads. Main line warm up shall be timed so that traps may clear the condensate from the main without flooding or producing objectionable water heaters.

i. Disk type traps are not acceptable since central / MATEP steam may be dirty.

g. Add clarification for each type of steam service.

h. General Trap Requirements:

i. Provide dirt pockets at all traps (min 12”)

ii. Provide union on both sides.

iii. Provide inlet with strainer

iv. Provide discharge check valve.

v. Provide discharge shut off valve.

vi. Locate traps.

1. So, all traps can be accessed for replacement and maintenance.

2. At steam equipment.

3. Locate so as not to be subject to freezing.

7. Condensate Pump Sets (Electric)

a. Acceptable manufactures subject to compliance with the specifications:

i. Shipco
ii. Skidmore
iii. Domestic
iv. Webb (stainless steel)

b. Unit shall consist of a cast iron receiver, inlet strainer, (2) pumps (maximum 2'-0" NPSH each), float switches, electrical controls and accessories, as follows:

i. Receiver shall be manufactured of stainless steel when available at the designed capacity. The receiver shall be equipped with externally adjustable 2-pole float switch, water level gauge and eye bolts. Pressure gauges shall be provided in the field by the Contractor.

ii. A cast iron inlet strainer with vertical self-cleaning bronze screen and large dirt pocket and (1) dial thermometer with well shall be mounted on the receiver. The screen shall be easily removable for cleaning, requiring no additional floor space for servicing.

8. Flash Tanks

a. Acceptable manufactures subject to compliance with the specifications:

i. Modern welding.
ii. Armstrong
iii. Wessel

b. Provide flash tanks as indicated on the drawings. Each tank shall be ASME rated. All seams shall be continuously welded.

c. The minimum ASME rating shall be 125 PSIG unless scheduled greater.

d. Provide trap arrangement, relief valve and vent (pipe to atmosphere) and connections to low pressure steam, as shown on the drawings.

23 2500 – Chemical Water Treatment

1. Furnish and install all equipment, controls, chemicals, labor and accessories to make a complete system for chemically treating the HVAC hydronic systems specified herein.

2. All chemicals shall be environmentally safe and compatible.

3. Furnish a complete water treatment system, designed to minimize corrosion and scale formation in all water systems. This system shall include providing the equipment, controls, chemical feed pumps, shot feeders, all chemicals and consulting analysis service for the initial start-up of each system.

4. Service Period: Provide chemicals and service program for a period of one (1) year from start-up of a new system

    a. Chemical treatment representative shall visit the site once every month during the guarantee period. The representative shall check and adjust water treatment system operation during each visit, check efficiency of chemicals and chemical applications, and instruct and advise operating personnel.

    b. The Project team shall closely coordinate with the water treatment company to ensure that each piping system is properly cleaned prior to placing in use and that no system is filled with water without proper water treatment chemicals being added.

5. Systems

    a. Glycol Systems - Provide complete initial fill of 30% propylene glycol/70% water for all glycol systems. Propylene glycol solution shall be similar to Dowfrost as manufactured by Dow Chemical Co. or Union Carbide UCAR-17. Top off, test and adjust system solution after all piping systems have been tested and received. System shall include chemical injection pump and automatic glycol fill system.

23 3100 – Sheet Metal Work and Accessories

1. to be installed under this Contract, shall conform to the drawings, specifications, Standards, details and recommendations of the latest edition of SMACNA "HVAC Duct Construction Standards - Metal and Flexible"; and "Round and Industrial Duct Construction Standards" (hereinafter referred to as Duct Manual).

2. The Project team shall install all duct mounted smoke detectors and provide proper cross trade layout coordination to allow for appropriate service/access requirements.

3. The Project team shall furnish and install all plenums with automatic or manual dampers attached to louvers.

4. In addition to sheet metal ductwork provided under this Contract furnish and/or install accessories and devices furnished by others, including but not limited to smoke detectors. Provide and install miscellaneous sheet metal work including safing, mixing baffles, and blank off panels at unused louver areas.

5. Coils and valves shall not be located above large microscopes, mass specs and other critical lab equipment.

23 3363 – Air Flow Measuring Stations

1. Space pressure monitors

2. Airflow/Temperature Measurement Devices

3. Manufacturers
    a. Setra
    b. Ebtron
    c. Or provide by fan manufacturer: Plenum fan pitot tube integral airflow stations are also acceptable in AHU's.

23 3390 – Fans and Accessories

1. Centrifugal

2. Mixed flow is preferred.

3. Plenum

4. Inline

5. Roof lab exhaust fans
    a. Add signage to each new exhaust fan as to which area it serves (in labelling standard?)
    b. Shall have cogged vx style fan belts

6. AHUs – plenum fan array

7. Provide VFD's on all fans over 2.5hp

8. Fans less than 2.5HP shall be ECM type motor.

9. Consider fan capacity redundancy where possible:
    a. Labs – 50%
    b. Vivarium – N+1 (100%)
10. Acceptable Manufactures contingent on compliance with the specification.

TBD 23 3600 – Air Terminal Boxes

1. Controls provider shall provide box mfg with control panels for factory installation when possible.
2. VAV boxes shall be provided with discharge air temperature sensor.
3. VAV boxes shall be lined with minimum of 1” thick thermal and acoustic insulation meeting "Hospital Grade". Closed cell foam may be used to meet this requirement.
4. Access doors shall be securely attached to the box upstream and downstream of the integral hot water heating coil.
5. Identify each terminal unit with clearly marked with: Box Identification number matching the drawings, Air flow, Maximum factory-set air flow, Minimum factory-set air flow, Coil type, and Direction of air flow.
6. The damper actuator shall be mounted on the exterior of the terminal for ease of service.
7. VAV boxes shall include sound attenuating section.
8. Refer also to BAS specifications and standards for control system requirements.

23 3620 – Laboratory Pressurization Control System

1. The airflow control device shall be a venturi type valve with electric actuation. The airflow control device shall be pressure independent over its specified differential static pressure operating range.
    a. Manufacturer - Accu-spec, Antec, Siemens, Pheonix
2. For lab renovation projects where existing Phoenix control systems are in operation, consult HMS Project Team to advise if the existing system should be reused or replaced. Factors such as system age, conditions, controls system compatibility, maintenance and cost of replacement shall all be considered.

3. A laboratory airflow control system shall be furnished and installed to control the airflow into and out of laboratory rooms. The exhaust volume of a laboratory fume hood shall be precisely controlled by an Adaptive Face Velocity controller to maintain a constant average face velocity into the fume hood at either a standard/in-use or standby level based on actual hood usage. The laboratory control unit shall vary the amount of air into the room to maintain temperature control, minimum ventilation, airflow balance, and laboratory pressurization in relation to adjacent spaces (positive or negative). All laboratory airflow control systems devices shall be by a single manufacturer and integrated to the building/campus BAS.

4. The laboratory airflow control system shall use volumetric offset control to maintain room pressurization and auxiliary fume hood make-up air tracking. The system shall respond and maintain room pressurization (negative or positive) within one second of a change in room/system conditions.

5. The laboratory airflow control system shall maintain specific airflow (±5% of signal) with a minimum 15 to 1 turndown to ensure accurate pressurization at low airflow and guarantee the maximum system diversity and energy efficiency.

6. Fume hood monitor shall include a numerical velocity display to indicate a relative measure of hood face velocity, visual indication for normal operation, visual and audible alarm for an unsafe alert and visual and audible alarm to indicate emergency exhaust operation.

7. Class A-The airflow control device for non-corrosive airstreams such as room/lab supply and general exhaust shall be constructed of 16-gauge aluminum. The device's shaft and shaft support brackets shall be made of 316 stainless steel. The pivot arm and internal mounting link shall be made of aluminum. The pressure independent springs shall be spring-grade stainless steel. All shaft bearing surfaces shall be made of a Teflon, or polyester, or PPS (polyphenylene sulfide) composite.

8. Class B-The airflow control device for corrosive airstreams such as fume hoods and biosafety cabinets shall have baked-on corrosion resistant phenolic coating. The device's shaft shall be made of 316 stainless steel with a Teflon coating. The shaft support brackets shall be made of 316 stainless steel. The pivot arm and internal mounting link shall be made of 316 or 303 stainless steel. The pressure independent springs shall be a spring grade stainless steel. The internal nuts, bolts and rivets shall be stainless steel. All shaft bearing surfaces shall be made of Teflon or PPS (polyphenylene sulfide) composite.

9. A night energy waste alert circuit employing a light level sensor shall be included in the monitor to sense the combination of a darkened laboratory room and a fume hood that has its sash left up.

10. The laboratory control system shall have the ability to change the minimum ventilation and/or temperature control set points, based on the occupied state, in order to reduce energy consumption when the space is not occupied. The occupancy state may be set by either the BMS, as a scheduled event, or through the use of a local occupancy sensor or switch.

11. Consider local heat generated by equipment, airflow design consideration in specific spaces to remove heat from equipment.

23 4100 – Air Filters

1. MERV 8 prefilters and MERV 13 final filters (or as required by current codes) cartridge filters shall be standard at AHUs or per latest version of LEED. (Harvard green building services)
2. Carbon filters are required wherever standing vehicle exhaust is possible at building air intakes.
3. Vivarium and clean room spaces require final HEPA filters.
4. Temporary filters for new construction

23 5700 – Heat Exchangers

1. Shell and tube type Acceptable Manufactures contingent on compliance with the specification
2. Shell and tube Heat exchangers shall be constructed with cast iron heads, steel shell baffles, and steel or cast-iron removable tube sheets for heating hot water, copper tie rods, and steel nuts and bolts.
3. Plate and Frame type Acceptable manufacturers subject to compliance with the specifications:
4. Heat exchanger construction shall consist of an epoxy coated steel frame with steel plate carriers, steel compression bolts, gaskets, Type AISI 304 stainless steel replaceable plates.
5. A minimum of 25% capacity shall be included in the frame length to allow for future expansion.
6. Flow meters required on all hot water distribution systems.
7. Provide Inlet and outlet temperature sensors.
8. ASME U certification is required for all vessels.
9. Sufficient space must be allocated for tube bundle replacement

23 7323 – Factory Built-Up Air Handling Units

1. Supply air to Laboratory spaces shall be via 100% outside air systems without recirculation.
2. Supply air to Office, Classroom and other non-Lab spaces shall be via recirculating air handling units.

3. General Unit Requirements:

    a. Recommended manufacturers subject to compliance with the specification:

        i. Air Enterprises
        ii. Buffalo Air Handling
        iii. Environmental Air Systems (EAS)
        iv. Haakon
        v. Ventrol
        vi. Trane Custom
        vii. Hunt Air

4. A multiple fan array shall be provided at all laboratory air handling units greater than 5,000 cfm. Fan quantity shall be optimized based on performance and serviceability.

    a. Each fan assembly shall be supplied with a complete flow measuring system, which indicates airflow in Cubic Feet per Minute.
    b. A surface mounted airflow indicator, located on the unit exterior, shall provide a digital analog CFM readout, and/or a (4-20 ma) (0-10 volt) output control signal for use in the BAS as specified elsewhere.)

5. The unit housing shall meet latest energy code

6. Exterior of casing shall be Painted galvanized steel (indoor and outdoor units), painted aluminum (outdoor units only), or unpainted stainless steel (unless noted hereinafter to also be painted).
7. Interior of unit casing shall be solid painted galvanized steel Solid Aluminum, or Solid Stainless Steel, dependent on the application.

8. Lab Exhaust AHUs shall have all aluminum or stainless-steel interior construction.

9. The floor of each unit section shall be diamond safety plate. Floor shall be continuously welded to form a guaranteed waterproof surface. The entire floor system shall hold 2” of water throughout the unit footprint.

    - Provide Epoxy floors on all new and retrofit AHUs similar to Aquis Solutions.

10. Coil support framing and drain pans shall be stainless steel. Filter frames shall be stainless steel.

11. Provide access doors of the same construction and thickness as the unit casing for all unit sections containing equipment requiring service.

23 8235 – Terminal Heat Transfer Units

1. Unit Heaters

a. All type heaters, as applicable, shall be hung with vibration spring isolators as hereinbefore specified.

b. The Contractor shall provide control valves and unit or remote mounted thermostats and wire to fan, to cycle fan “on/off.”

c. The Contractor shall make provisions to "open/close" the steam or water control valves when heaters are "on/off", as indicated hereinafter.

d. Unit manufacturer shall provide starters and disconnect switches.

e. Thermostats used with all type heaters shall be coordinated with the unit manufacturer for compatibility with equipment.

f. Recommended manufacturers subject to compliance with the specifications shall be as follows.

i. Sterling
ii. Trane
iii. Modine
iv. Vulcan
v. Airtherm
vi. Sigma

2. Cabinet Unit Heaters

a. Hot water

i. Recommended manufacturers subject to compliance with the specifications shall be as follows.

1. Sterling
2. Trane
3. Modine
4. Vulcan
5. Airtherm

3. Fan Coil Units

a. Provide horizontal or vertical fan coil units where shown and indicated on the drawings. Unit capacities shall be certified in compliance with Air Conditioning and Refrigeration Institute Standard 440-81. Units shall be UL listed under the Re-Examination Service.

b. Entering water temps (Hot/Chilled water)

- Hot water 140 Degrees

- Chilled water 45 degrees

c. Recommended manufacturers subject to compliance with the specifications shall be as follows:

i. Airtherm
ii. Trane
iii. Carrier
iv. York
v. International Fan Coil
vi. Williams

d. All new FCUs shall be provided with ECM motors and the appropriate Siemens controller.

e. All ECM motors need to accept a 0-10 speed input signal.

f. Filter and motor access shall be coordinated during design phase.

g. Reference BAS standard for water bugs (overflow sensors) in drain pans.

i. Ceiling hung fan coil units require a liquid high-level sensor in the drain pan per the Mechanical code. The sensor shall be provided by the fan coil unit manufacturer which will be tied to the BAS for alarm.

ii. Condensate drains shall be piped into a drain header of adequate capacity to address the entire population of interconnected drains.

iii. All units shall be located sufficiently away from exterior doors to avoid winter freeze by doors inadvertently left ajar or not closing completely.

4. The basic unit shall be fabricated of 18 gauge galvanized steel. Provision for hanging the unit shall be provided by slots in the top wrap of the basic housing. The standard arrangement shall be furnished with a 1 inch discharge duct collar with extended collars furnished where shown with ductwork.

5. Coil dipping in animal holding/Fly rooms

6. Finned Tube Radiation

a. Recommended manufacturers subject to compliance with the specifications shall be as follows:

i. Vulcan
ii. Sterling

b. Radiation shall have net I=B=R approved ratings in accordance with the Hydronics Institute "Testing and Rating Standard for Finned Tube Radiation".

c. Heating Elements (Typical All Radiation Types)

i. Heating elements shall be steel or copper/aluminum supported at 4'-0" intervals with a wall mounted slide-cradle type hanger. Provide additional horizontal pipe hangers as required.

7. Radiant Heating Panels

a. Provide a radiant heating panel system as indicated on the drawings and connect to hot water piping.

b. Recommended manufacturers subject to compliance with the specifications shall be as follows:

i. Price
ii. Sun-El
iii. Sterling
iv. Airtex
v. Airtite

c. Performance data and dimensional specifications shall be available from the manufacturer for all products. Performance and capacity data shall be based on testing performed by the manufacturer or confirmed by a testing laboratory recognized in the Industry.

8. Chilled beams

a. Chilled beams shall be considered as a design option for cooling of laboratories, common areas, offices and other suitable spaces.

23 General installation requirements for sealing penetrations of HVAC and related equipment

Penetrations: Whether pre-existing or created for new mechanical, electrical, plumbing or ventilation purposes, each penetration – **whether or not required by code** - should be sealed by an appropriate method that not only preserves the fire / smoke rating of the penetrated structure but also sustainably prevents the entry and passage of insect and rodent pests. Escutcheon plates are acceptable only if the penetration behind is first sealed. Weep holes in the building's exterior façade shall be protected by an insect- and rodent-resistant device or product that will permit flow of air and water. To exclude rodent and insect pests, penetrations in masonry may be packed with cement or grout. If firestopping compounds are used in masonry, wall board or other partitions, the openings might first be tightly packed, as practical, with non-oxidizing metal meshes such as stainless steel mesh pads (e.g. 'Xcluder' brand blocks or fabric) or copper mesh (e.g. 'Stuf-Fit' brand). Guidance on such product application is available from

the Harvard University EH&S Senior Environmental Public Health Officer and from the pest control vendor.