23 0501 – HVAC Design Criteria

1. Design Statement

    a. During the various design phases of this project, the Engineer will develop options and schemes for selection of the appropriate HVAC system. This approach will enable the entire Design Team (Owner, Architect and Engineer) 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. Flexibility for future changes.

        iii. Durability; ease of maintenance.

        iv. Reliability.

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

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

        vii. Cost effectiveness.

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

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 Manager.

    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 large projects to meet the Harvard Green Building Standards document. Smaller projects, while they may not pursue LEED certification, should also be designed to these HGBS standards.

    b. All projects should target a 20% 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.

        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: 91°F db/74°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 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, ceiling hung, 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 (ACPH) for dilution and/or removal of odors during occupied times. During unoccupied periods, the system shall have the capability to turn down to 2 ACPH (pending approval for EH&S authority). 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 HMS project manager. 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 6 to 12 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 8 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 (provided by electrical) shall dry contact outputs to the BAS for monitoring and automatic turndown of space VAV boxes where applicable.

viii. Air Quality Monitoring Systems, typically used to test the quality of air in a lab and automatically adjust the volume of air supplied to the lab, will not be acceptable.

ix. Air change per hour (ACPH) requirements will be based on exhaust device requirements and heat loads generated by equipment, people, lighting and solar heat gain.

b. Office, Classroom and other non-Lab spaces will be designed in accordance with the latest ASHRAE Standard 62.1 for minimum ventilation air to occupied rooms.

c. Wherever possible 100% exhausted lab spaces and Office/classroom spaces suitable for air recirculation shall be served by separate air handling systems.

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 control 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	Lighting Load	Equipment Load	Remarks
Public Spaces and Office Areas				
Common Areas / Lobbies	250 gsf/person	1-2 W/gsf	0-1 W/gsf	-
Lobby	250 gsf/person	1-2 W/gsf	0-1 W/gsf	-
Auditorium	25 gsf/person	1-2 W/gsf	1-2 W/gsf	-
Offices	100 gsf/person	1-2 W/gsf	1-2 W/gsf	-
Conference Rooms	25 gsf/person	1-2 W/gsf	2-4 W/gsf	-
Class Rooms	25 gsf/person	1-2 W/gsf	0-1 W/gsf	-
Laboratory Spaces				
Open Lab	100 gsf/person	1-2 W/gsf	7.5 W/gsf	-
Enclosed Equipment Room	100 gsf/person	1-2 W/gsf	10-20 W/gsf	-
Linear Equipment Corr	200 gsf/person	1-2 W/gsf	10-20 W/gsf	
Entry Alcove	100 gsf/person	1-2 W/gsf	5-10 W/gsf	-
Tissue Culture Alcove	100 gsf/person	1-2 W/gsf	5-10 W/gsf	-
Procedure Room	100 gsf/person	1-2 W/gsf	5-10 W/gsf	
Glasswash	200 gsf/person	1-2 W/gsf	Note 2	-

Glasswash Equipment Space	-	1-2 W/gsf	Note 2	-
Darkroom	100 gsf/person	1-2 W/gsf	2-6 W/gsf	-
Environmental Room	-	-	-	-
Vivarium Spaces				
Holding Rooms	100 gsf/person	1-2 W/gsf	Note 2	Note 4
Procedure Rooms	100 gsf/person	1-2 W/gsf	Note 2	Note 4
Testing Rooms	100 gsf/person	1-2 W/gsf	Note 2	Note 4
Miscellaneous Spaces				
Mech. / Elec. Rooms	-	-	-	Note 3
Tel/Data Rooms	-	1-2 W/gsf	Note 2	-
Elevator Machine Rooms	-	1-2 W/gsf	Note 2	-
General Storage	200 gsf/person	1-2 W/gsf	0-2 W/gsf	-
Hazardous Storage	200 gsf/person	1-2 W/gsf	0-2 W/gsf	-
Toilet / Locker Rooms	-	-	-	Note 4
Housekeeping Closets	-	-	-	Note 4
Loading Dock Receiving	-	-	-	Note 4
Server Room	200 gsf/Wgsft	1-2 W/gsf	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 ten (10) air changes per hour or as required for space cooling.

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 reduces via a pressure reducing station for medium pressure steam (MPS) and low pressure steam (LPS).

      i. MPS reduction shall be via a single stage, 125-50 psig, 1/3-2/3 pressure reducing station and will be distributed to process equipment such as cagewashers, autoclaves, glasswashers, clean steam generators and domestic hot water heaters.

      ii. Steam pressure reduction for LPS use will occur via a single stage 50-15 psig, 1/3-2/3 pressure reducing station and will be distributed to HVAC equipment such as hot water heat exchangers, AHU preheat coils and humidifiers.

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

iv. 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 pumpset pressure shall be designed based on MATEP requirements.

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

vi. Each building shall have a conductivity meter or monitoring building condensate that is pumped back to the central plan t.

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 and ASHRAE 90.1).

b. Multiple options for energy recovery shall be evaluated for each large scale project. The HMS project manager must approve of the design teams 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, Warren Alpert and 641 Huntington Buildings have dedicated cooling plants).

b. The cooling medium for this project shall be provided by new chilled water mains from the Longwood Medical Area central plant (AES).

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

d. 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.

   i. Chilled water supply temperature = 42 degrees

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

f. 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.

g. New buildings on campus shall receive a plate and frame heat exchanger installed in a manner that will decouple the building from the campus/MATEP loop. Heat exchanger will be located in the basement with an automated control valve arrangement that shall allow for cooling to be supplied either to the building from campus, or from the building to campus should the building have its own chilled water source.

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 the 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.

         a. Note that the process chilled water temperature could be set low enough to support the use of chilled beams throughout the building (approx. 58 degrees F).

b. Alternatively, and only if the building has a local closed loop chilled water supply, blending of chilled water return with the supply could be used to serve a medium temperature chilled water loop to support chilled beams.

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)

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.

h. Refer to section 237323 of these Standards for further requirements and acceptable manufacturers.

14. Chillers:

a. Existing buildings shall continue to be served by the campus/MATEP chilled water loop.

b. New buildings shall include a connection to the MATEP system, but shall also be provided with a local chilled water plant. The type and quantity of chillers will depend on capacity and the need for redundancy.

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

d. New Chiller plants shall have the ability to backfeed the campus water distribution system.

e. 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. Dehumidification
ii. 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
iii. Energy Conservation measures
    1. Example: NMR Cooltrol system for door heater controls, ECM motors on the evaporator fans.
iv. LED lights
v. No wood shelving

b. Warm/cold rooms in specialty research areas should have cooling coils designed for the environment
    i. Example –coils in fly rooms dipped in anto corrosion material

23 0510 – HVAC Commissioning

1. HVAC Commissioning

    a. The Design Team shall provide fully integrated design documents to ensure all required Contractors are fully responsible for supporting the 3rd Party Commissioning activities for the proposed systems to be commissioned. 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 10 month warranty verification (if required), etc.

    b. The Design 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 all fans and pumps 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 Grundfoss Magna3).

2. VFD’s associated with 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 Fanwall 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. General Electric
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. General Electric
iv. Cutler Hammer
v. Emerson
vi. Danfoss

c. The VFD manufacturer shall supply 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 manager and facilities department. 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 anchor 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.

23 0519.10 – Meters

1. Acceptable manufacturers subject to compliance with the specifications.

    a. GE (preferred vendor)
    b. Controlotron
    c. Onicon Preso
    d. Barco
    e. Foxboro
    f. Veris

2. Sensing system components

    a. Provide self-averaging annular sensor flow metering stations

i. At each pump
ii. At each central utility service entrance (MATEP Connections)
iii. Where shown on drawings

b. Flow metering systems shall include annular sensors with self-averaging interpolating tube design at each flow station and a portable meter set supplied by one manufacturer.

c. Each annular measuring station shall be complete with safety shutoff valves, quick coupling connections, and a tag showing designed flow rates, meter readings for designed flow rates, metered fluid, line size and tag, and station or location number.

d. Annular measuring sensor shall be made of 304 stainless steel.

e. Stations shall be either nipple suction or weld insert type, rated to 300 psi at 400°F. Annular measuring stations shall be rotatable sensing elements so that all pressure sensing ports can be pointed downstream when station is not in use.

f. Permanent pressure loss to the system shall not exceed 5" of water column (0.42 foot) of head on sizes over 1 1/2". Accuracy of the flow measuring elements shall be ±2.3%, as verified by independent laboratory reports.

g. All annular averaging flow elements shall have isolation or wet tap feature, 3 or 5 way manifold, and an indicating flow transmitter.

3. All Meters shall be integrated to the BAS either by BACNET IP, Modbus TCP, or direct BAS connection.

4. In-line type meters shall be used where the manufacturers required upstream and downstream piping distance for insertion meters cannot be met. In-line meters shall be installed with a bypass for servicing.

5. Pumps that are provided with integral VFD shall also include on-board metering.

6. Hydronic Flow Meter

a. Ultrasonic flow meters are preferred. Meters on MATEP water shall have no direct contact with the water.

b. Turbine meters (insertion or inline) may be used on process water closed loops that are local to the building.

7. Hydronic BTU Meter

a. Provide a BTU measurement system on all building chilled water, hot water and process water systems similar to Onicon System-10 BTU Meter.

b. The BTU meter electronics shall be housed in a steel 8"x10"x4" NEMA-13 enclosure and shall include a front panel mounted two-line LCD display for indication of BTU total, BTU rate, flow rate, and supply / return temperatures.

c. An internal 120 VAC or 24 VAC power supply shall be included to provide power to the BTU meter electronics and the turbine flow meter.

d. The BTU meter shall be compatible with building and campus communication networks and shall provide the following information via the main control bus:

   i. Total thermal energy transfer
   ii. Thermal energy rate
   iii. Supply temperature
   iv. Return temperature
   v. Liquid flow rate
   vi. Liquid flow total.

e. Temperature sensors shall be PT100 RDT type located in wells with 4-20 ma transmitters.

8. Steam Flow Meters – Ultrasonic preferred

   a. The flow meter shall be sized by the manufacturer for each specific application and installed according to manufacturer’s recommendations. Measurement shall be within 2% accuracy or better across the full range of flow.

   b. Install meter in accordance with manufacturer’s recommended straight pipe run requirements (including a flow straightener, if required) to ensure the accuracy of 2%. Provide lateral and horizontal supports as required to minimize vibration at the meter location.

   c. For saturated steam applications, the flow meter shall calculate mass flow corrected for density with real time calculations based on temperature measured by an integral 1000 ohm platinum RTD (similar to Onicon model F-4600 or 4200).

   d. Temperature sensors shall be PT100 RDT type located in wells with 4-20 ma transmitters.

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*
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

Service	Minimum Class and Material			Joints	
	2" and Less	2½" to 12"	14" & Up	2" and Less	2½" & Up
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*
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. All auxiliary steel required for pipe, duct and equipment supports shall be furnished and installed by the Mechanical Contractor

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

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

8. 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.

9. 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.

10. 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

11. Avoid contact between dissimilar metals.

12. Provide double nuts on all threaded hangers.

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. 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.

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

4. 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 or exceed Code required thicknesses and R-Values.

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

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: Insulation Contractor shall 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 VentureClad 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.

12. Installation of all insulation work shall be executed by a qualified Insulation Contractor who is thoroughly experienced in this particular type of work at Harvard Medical School and who has adequate facilities and equipment for installation of all insulation work herein specified and who is familiar with the requirements of the Code enforcing Authorities as to fire hazard rating.

13. Ductwork Insulation Schedule

23 0719 – HVAC Piping Insulation

1. Pipe insulation thicknesses shall meet or exceed 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 wired together, provide Velcro, strings or other system that can be refastened.

6. Provide vapor barrier on all cold water and rainwater piping.

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

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

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

    d. All underground prefabricated piping shall be accountable to ANSI 31.1 requirements

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

    f. Chilled Water Service piping installed underground: Provide a product similar to PPR-CT plastic piping. No insulation or thrust blocks are required.

9. 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.

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

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

12. 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. Emergency generator piping and entire exhaust systems.

f. Piping jacket covers.

g. All heat traced piping.

13. 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

14. Installation of all insulation work shall be executed by a qualified Insulation Contractor who is thoroughly experienced in this particular type of work at Harvard Medical School and who has adequate facilities and equipment for installation of all insulation work herein specified and who is familiar with the requirements of the Code enforcing Authorities as to fire hazard rating.

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

16. 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.

17. 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

18. 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.

19. 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-5: shall be a Cell-Co plastic jacket with the following color coded pattern:

i.	Steam (HP/LP):	White
ii.	Condensate (Pump/Gravity):	White
iii.	Hot Water:	Orange
iv.	Chilled Water:	Blue
v.	Condenser Water:	Green
vi.	Vent:	Black
vii.	City Water:	Gray
viii.	Fuel Oil:	Yellow
ix.	Boiler Services:	White
x.	Engine Exhaust & Breeching:	Brown
xi.	Glycol Heat Recovery Water:	Orange
xii.	Process Cooling Water:	Green
xiii.	Other	Yellow-green

f. 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. 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 hereinafter.

2. 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.

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

4. Piping alternates:

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

        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

        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 ProPress 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.

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 Note 2, 3	225
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: ProPress: 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 repressurization.

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 rating150 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. Bleedports and other orifice fittings shall be externally connected to facilitate troubleshooting and cleaning. Internal bleedports 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. 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 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.

6. 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 capcity. 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.

7. 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. The Mechanical Contractor shall engage the services of a nationally recognized water treatment manufacturer with local representative of such manufacturer to provide a complete water treatment service, designed to minimize corrosion and scale formation in all water systems. This service 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 date of condensing equipment.

    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 HVAC Contractor shall closely coordinate with the water treatment company to insure 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. Hot water and chilled water - Provide a 5 gallon capacity, bypass feeder with the wide mouth opening and quick disconnect cap for each hot water and chilled water system

    b. Condenser water - Provide an automatic prefabricated analyzing control and chemical feed system consisting of continuous monitoring of system.

        i. The Contractor shall provide ASTM corrosion coupon test racks in accordance with the chemical treatment service organization requirements

    c. 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. Furnish and install a complete system of air distribution, including accessories, to all areas indicated on the contract documents. Provide all ductwork, fittings and accessories to make a complete and operational system in all respects.

2. All ducts and fittings shall be manufactured by a sheet metal fabrication company whose primary business experience is the manufacture of commercial and industrial quality ducts and fittings. Sheet Metal Contractor shall have adequate experience of building ductwork of the types required for this project as well as successful experience with projects of similar scope. Bids from sheet metal shops which do not meet the specified requirements shall not be acceptable.

3. All duct systems specified 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).

4. The Sheet Metal Contractor shall install all duct mounted smoke detectors and provide proper cross trade layout coordination to allow for appropriate service/access requirements.

5. The Sheet Metal Contractor shall furnish and install all plenums with automatic or manual dampers attached to louvers.

6. 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.

7. Control panel location shall be outside of rooms requiring critical level access (Vivarium, DNA Suite, Tissue Culture or as required by HMS).

8. 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 (preferred mfg),
   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 exh fans
    a. Add signage to each new exhaust fan as to which area it serves
    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. Provide fan capacity redundancy where possible:

    a. Labs – 50%

    b. Vivarium – N+1 (100%)

10. Acceptable Manufactures contingent on compliance with the specification.
    a. 1
    b. 1

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. Siemens shall be the basis of design for all new laboratory controls systems 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.

2. For lab renovation projects where existing Phoenix control systems are in operation, consult HMS Project Manager 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 insure 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.

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.

2. Carbon filters are required wherever vehicle exhaust is possible at building air intakes.

3. Vivarium spaces require final HEPA filters.

23 5700 – Heat Exchangers

1. Shell and tube type Acceptable Manufactures contingent on compliance with the specification

   a. Bell & Gossett
   b. Armstrong
   c. Amtrol
   d. Patterson-Kelly

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:

   a. Alfa-Laval
   b. Bell & Gossett
   c. Mueller

d. Patterson-Kelly.

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, and an aluminum or galvanized steel protective plate pack shroud.

5. A minimum of 25% capacity shall be included in the frame length to allow for future expansion.

6. Heat exchanger shall be UL certified

7. Flow meters required on all hot water distribution systems.

8. Provide Inlet and outlet temperature sensors.

9. ASME U certification is required for all vessels.

23 7323 – Factory Built-Up Air Handling Units

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

2. Supply air to Laboratory spaces shall be via 100% outside air systems without recirculation.

3. Supply air to Office, Classroom and other Non-Lab spaces shall be via recirculating air handling units.

4. General Unit Requirements:

   a. Acceptable 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

5. 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.)

6. The unit housing shall have a minimum U value 0.062.

7. 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).
8. Interior of unit casing shall be solid painted galvanized steel Solid Aluminum, or Solid Stainless Steel, dependent on the application.

9. Lab Exhaust AHU's shall have all aluminum or stainless steel interior construction.

10. 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.

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

12. 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. Acceptable 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. Steam or Hot water

        i. Acceptable 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. Acceptable 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

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

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

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

    f. 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.

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. Finned Tube Radiation

    a. Acceptable 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.

6. Radiant Heating Panels

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

    b. Acceptable 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.

7. Chilled beams

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

    b. Chilled beams will not be acceptable in labs where the required fume hood makeup air is enough to satisfy the peak cooling load.