

SECTION 230800 – GENERAL MECHANICAL REQUIREMENTS

- 1.0 In addition to the requirements previously presented herein, each specification shall contain the following general information:
- A. General
 - 1. Incorporate, by reference, Division 1 into Divisions 21, 22, and 23.
 - 2. Define the contractors and sub-contractors covered by Divisions 21, 22 and 23 (i.e. HVAC, Plumbing and Drainage, Fire Protection, Insulation, Control, Testing, Balancing and Adjusting, etc.).
 - 3. Define any specific technical terms relating to the trades covered by the section.
 - B. Laws, Ordinances, Regulations and Requirements
 - 1. State that all workmanship must conform to all pertinent laws, ordinances and regulations of all bodies having jurisdiction.
 - 2. ASHRAE 90.1 Compliance: University of Pennsylvania buildings shall comply with the Commercial Energy Efficiency Requirements of ASHRAE Standard 90.1-2016. The ASHRAE 90.1-2016 compliance paths shall be followed instead of the International Energy Conservation Code (IECC) requirements as permitted by 2018 IECC Section 401.2 Application.
 - C. Commissioning, Factory Acceptance Testing and Field Testing
 - 1. Commissioning (when included in project)
 - a) The Project Specifications shall include a commissioning plan for mechanical systems developed by the Commissioning Agent (CA).
 - b) The CA shall develop the plan during the design phases of the Project. The CA shall establish the commissioning scope as well as establish roles and responsibilities during the Schematic and Design Development Phases of the Project. The commissioning plan shall be completed parallel to the construction documents and shall include the following:
 - 1) Definitions of the Commissioning Process.
 - 2) Requirements for Factory Acceptance Testing.
 - 3) Requirements for Installation Verification.
 - 4) Requirements to complete critical Punchlist Items.
 - 5) Requirements for Manufacturer Startup Services.
 - 6) Requirements for Operational Verification including Dynamic Testing.
 - 7) Submittal requirements for Operations and Maintenance Manuals and Warranties.
 - 8) Guidance for Operational Staff Training
 - 9) The Commissioning Plan shall define the following:
 - 10) Roles and responsibilities including participation by all Subcontractors.
 - 11) A list of systems (or portions thereof) to be commissioned.
 - 12) Sample Specific Installation Verification Checklists for each system.
 - 13) Sample Specific Operational Verification Checklists for each system that outline dynamic testing requirements that are critical to system operation.
 - 14) Sample System Acceptance Sheets that can be signed by all parties.

- 15) The Commissioning Specifications shall include the requirement for a Commissioning Manual to be maintained for each system consisting of the following:
 - 16) System design information.
 - 17) Completed Installation Confirmation Checklists.
 - 18) Start-up Procedures and Results.
 - 19) Test Reports (Factory and Field).
 - 20) Completed System Operational Checklist.
 - 21) Additional support documentation including:
 - a. Shop Drawings.
 - b. Operations and Maintenance Manuals.
 - c. Recommended Spare Parts List.
 - d. Training Documentation
 - e. Warranties.
 - 22) Completed System Acceptance Sheets.
 - 23) The Commissioning Manual shall be maintained in both electronic (.pdf format) and paper hard copy.
- c) On a project by project basis, define the requirements for Factory Acceptance Testing. In general, all custom equipment that is critical to the system operation shall be Factory Acceptance Tested. Items such as custom air handling units, major electrical transformers, electrical switchgear, standby/emergency generators, chillers, fume hoods, skid-mounted equipment (such as Purified Water Systems) shall be specified to be Factory Acceptance Tested. The Specification shall define performance parameters and associated course of action for performance below specified requirements.
2. Fume Hood Testing
- a) The fume hood specifications shall include fume hood factory and field testing requirements.
 - b) In general, the factory acceptance testing requirements shall include ANSI/ASHRAE 110 (latest version) testing for each type of fume hood that is utilized on the project. All fume hoods shall meet, at a minimum, the 4AM.05 standard.
 - c) The field fume hood testing requirements shall include a provision that all fume hoods installed be tested per the "as installed" component of the ANSI/ASHRAE 110 (latest version) standard including Local Visualization Challenge, Large-Volume Visualization Challenge, "As Installed" Tracer Gas Testing and Variable Air Volume (VAV) response test (if applicable). For laboratories with multiple fume hoods, a testing plan shall be developed that considers the room effects of the other exhaust devices in the space and multiple sash positions to demonstrate compliance with the standard. Supply and exhaust valves may need to be further adjusted, from the designed values, to accommodate for a specific fume hood manufactures requirement and specific design conditions/constraints. The values for airflows for fume hoods on the drawings are for reference only. Each lab and fume hood will most likely need specific adjusting to meet ASHRAE Standard 110 (latest version) and EHRS specific requirements. These adjustments must be closely coordinated with EHRS, fume hood manufacturer, air valve manufacture and balancer. All fume hoods, as a minimum, should meet the 4AI.10 Standard.
3. The University Office of Environmental Health and Radiation Safety (OEHRS) provides yearly certifications of each fume hood. Project specifications shall incorporate any

requirements of the department into the specifications. As described elsewhere, OEHRs shall be consulted during the design process.

4. Field Testing

- a) Define the Contractor's responsibility for execution, notification, documentation of results, and witnessing coordinated with the Project Construction Schedule Milestones.
- b) Define in detail, the tests required as part of the contract. Give specific details as to testing medium, duration, level, etc. Refer the Contractor to other specific test requirements in other Sections for systems such as Automatic Controls and Monitoring, Testing, Adjusting and Balancing, etc. Define in detail the manufacturer's services required for equipment and systems (e.g. start-up, testing, etc.).
- c) The following are the minimum field testing requirements for University Projects. The CA shall define additional tests as required in conjunction with University Representatives.
- d) Duct system leak testing (after branch connections are made to the main) to be witnessed by the University
- e) Hydronic system pressure testing to be witnessed by the University. Prior to testing all lines shall be cleaned and flushed to the satisfaction of the University.
- f) Point to point testing of automatic control systems as well as monitoring points to the Operations Control Center (OCC).

D. Instructing Owner's Personnel

1. Require the contractor(s) and manufacturer's agent(s) to fully instruct the representatives of the University in all details of operation of the equipment installed under his (their) contract(s). The lengths of the instruction periods specified shall be determined on a project by project basis with the University Representative.
2. Each contractor shall be directed to provide three (3) copies of printed Operation and Maintenance instructions in separate hardback, three-ring loose-leaf binders. The instructions shall be organized by specification section and contain final approved submittals (with performance data), dimensional data, detail operating and maintenance data including wiring and piping diagrams and related equipment data such as motor or variable speed drive information. Each section shall be labeled and include detailed parts list data and the name, address and phone number of the nearest supply source and all warranty information.
3. All O&M Manuals shall also be provided in electronic (.pdf) format.
4. To accommodate the University's Preventive Maintenance Program, the A/E shall require the Operations and Maintenance instructions to be submitted in a coordinated format with the University's Preventive Maintenance Program (AiM). Examples include equipment and equipment components cataloged by area and process served. The manual shall also include equipment manufacturer's Preventive maintenance procedures. The coordinated instruction manual shall be available at Operational Staff Training.
5. General catalog data for the Operations and Maintenance Manual is unacceptable. If manufacturer's specification sheets are generalized in any way, they shall be clearly marked to show exactly which item has been supplied, and the job designation for that item (e.g., PRV-1) will be noted on manufacturer's specification sheet which includes all details for this unit, including complete model no., serial no., and construction and performance data.
6. If there are differences between pieces of equipment, then include a specification sheet for each, properly marked.
7. Include control diagrams, (including Building Automation System Architecture diagram), sequence of operations, and service instructions (calibration, trouble shooting, etc.).

8. Provide one section for manufacturer's preventive maintenance procedures (recommended lubrication materials and procedures, frequency, etc.).
9. Include manufacturer's and Contractor's address and phone numbers with any other reference required to obtain warranty service.
10. Require specific warranty information for equipment (e.g. when warranty periods start, length of warranty, items covered, etc.). Typical warrantee periods are to be one (1) year after the University accepts the project. Consider options for longer warranties for specific equipment.

E. Mechanical-Electrical Coordination

1. Include an article which clearly defines the extent of responsibility between the mechanical, electrical and control contractors regarding equipment which involves the work of both trades.
2. Specific items to be addressed shall include, but in no case be limited to the furnishing and installation of:
 - a) Motors and starters.
 - b) Variable speed drives.
 - c) Power sources for control devices and panels.
 - d) Safety disconnect switches.
 - e) Control wiring.
 - f) Termination points of wiring for each contractor.
 - g) Terminal airflow and control boxes (mounting of box controls)
3. The specific contractor shall be directed to pertinent sections of the electrical and control specifications and Section 220500 of these standards which defines wiring standards, conduits, starter types, motor efficiencies, controllers and automatic control requirements. Require that these specifications apply to all mechanical equipment.
4. Require that coordinated drawings be submitted for approval during construction. Depending on the size of the project, electronic submissions shall be required for all coordinated drawings in a format compatible with the University system.
 - a) The specification shall include timing of the coordinated drawings generation, drawing scale, a defined process of generating the background drawings (sheetmetal drawings), subcontractor coordination sessions, a defined process of updating the drawings with all trades information, sign-off procedures and maintaining record copies.
 - b) The A/E shall review the coordinated drawings for equipment service access especially access to damper motors, actuators and switches.
5. Contractor/s shall prepare separate above ceiling punchlists for engineering systems before ceilings are installed. A/E shall then follow with their above ceiling punchlist.

F. Piping and Equipment Identification

1. All piping and duct systems shall be required to be labeled to comply with OSHA and ANSI A13.1 (latest edition) standards for the identification of systems, operating pressure and flow.

G. Piping Identification

1. Aboveground Piping

- a) After all other specified work is performed on piping systems, all exposed and concealed piping shall be identified by means of self-adhering markers.
- b) Pipe markers shall be applied in the following locations.
 - 1) At changes in direction.
 - 2) At each valve.
 - 3) At each tee.
 - 4) At each point of exit and entry where pipe passes through walls, floors, partitions or ceilings.
 - 5) Every 50 ft. on straight runs of pipe.
- c) Provide an arrow marker adjacent to each pipe marker with the arrow showing direction of flow and pointing away from pipe marker. Use double-headed arrows or an arrow on either side of pipe marker if flow can be in both directions. Indicate characteristics of fluids moving through the pipes (type fluid/gas, temperature, pressure). This is particularly important at the influent and effluent points of service changing the conditions of the fluid, at pumps, heat exchangers, compressors, PRV etc.
- d) Marker and legend colors shall comply with ANSI and OSHA Standards.
- e) Apply markers where view is unobstructed and legend can be easily read. Apply markers in strict accordance with manufacturer's instructions. Band the ends of all markers with banding tape of same color as marker.
- f) Pipe marker legends and background colors shall be coordinated with Owner's existing standards and approved by Owner's Representative.
- g) Exterior piping identification shall be similar.

H. Valve Identification

- 1. Valves that isolate equipment, control valves and accessories do not require identification where such valves are located immediately adjacent thereto. Otherwise, identify all valves and control valves installed.
- 2. Charts of tagged valves shall be provided as follows
 - a) Prepare charts and insert each chart into a separate aluminum frame with plastic window. Locate and install where directed by Owner's Representative.
 - b) Prepare a duplicate set of charts and insert each chart into a separate plastic protective envelope consisting of two (2) sheets of clear vinyl plastic laminated around all edges with a vinyl frame and having grommets on edges. Include a length of nickel plated chain for each chart assembly. Give charts to Owner.
 - c) Charts of tagged valves shall be provided. Each chart shall include the following:
 - 1) Identification number (coordinated with University's Preventive Maintenance Program).
 - 2) Abbreviated service identification from Key to Symbols on the Drawings.
 - 3) Location (floor, column number, etc.)
 - 4) Type of valve.
 - 5) Specific purpose for the valve and area of service.
 - d) Provide electronic copy (Excel) to University of valve charts with building location map indicating area served.
 - e) Tags shall be coordinated with University's existing tag system and shall be approved by Owner.

- f) Tag type shall be phenolic or brass.
- g) Stream traps shall be identified in the same manner as valves above.
- h) Require markers on ceiling T-bars to indicate location of devices above. Marker to include device, valve or steam trap number.

I. Mechanical Equipment Identification

- 1. All mechanical equipment shall be identified by the name and identification shown on the Schedules on the Drawings.
- 2. Require that nameplates be coordinated with University's existing nameplate system, and shall be approved by Owner's Representative.
- 3. Require hazards such as low ductwork, low horizontal piping, etc., to be identified according to OSHA standards.
- 4. Require equipment nameplates to be also provided by manufacturer for major equipment. Nameplate to list Manufacturer, Address, Model No., Serial No., Code Stamps, Size, Capacity, Performance Data, etc.). Performance data shall replicate drawing schedules.
- 5. Require that all equipment be identified using phenolic nameplates and labeled in accordance with the nomenclature used on the drawings and the Universities Preventive Maintenance Program.

J. Submittals

- 1. Each submittal shall be identified by the following
 - a) Project Name
 - b) Specification Section
 - c) Drawing Numbers
 - d) Product data submittals shall include but not be limited to:
 - 1) Manufacturer and Model Number.
 - 2) Complete electrical data and wiring diagrams.
 - 3) Dimensions, capacities, ratings, materials, finishes, special features and storage conditions.
 - 4) Recommended installation procedures, performance, and conditions of performance, testing, and calibration certifications.
 - e) Each submittal shall be required to bear the review stamp of each contractor associated with the processing of the document. The processing of shop drawings shall follow contractual relationships between the Prime Contractor and all Sub-contractors.
 - f) Submittals which require coordination of two or more trades shall be required to bear the stamp of the coordinating trades.
 - g) Require for equipment submitted that is not a basis of design, the contractor is to ensure the ability to fit in the original space allotted, the ability to be routed into the building and all required access is maintained, and indicate such on the submittal.
 - h) Each submittal shall clearly identify which product and components are being furnished and eliminate reference to units, components and features not being furnished.
 - i) All submittals shall be in electronic (.pdf) format.

K. Site Conditions

1. All renovation and expansion projects shall require the Design Professional(s) and by specification the contractor(s) to visit the site and inspect all existing conditions. Any discrepancies noted between the contract documents and existing conditions shall be brought to the A/E's attention prior to the issue of the Contract Documents by the Contractor. Change order requests shall not be considered for any additional work relating to the connection of new work to existing systems, relocation of existing systems, or adaptability of new systems to existing structures after site inspection(s) has (have) occurred.
2. For renovation projects, consider removing all the ceiling tiles to allow for a more complete survey during the walkthrough.
3. Specific consideration during site visits shall be given to extension of new required services to existing renovated areas. Areas out of the project scope may require disturbance to bring the required services to the renovated spaces. With the issue of the Contract Documents, fully define each condition for Contractor bid and University scheduling purposes.

L. Installation of Equipment

1. Each contractor shall be responsible for all necessary rigging required for the completion of work under his contract.
2. The A/E shall be responsible for ensuring space constraints to ensure equipment is able to clearly fit in space allotted and that clear passage through new or existing building openings is available before confining walls, ceilings and other construction or equipment is installed. The A/E shall also be responsible for defining equipment removal paths from the building after construction is complete. Existing building constraints shall be part of the analysis and modifications identified on the Contract Drawings.
3. The A/E and by specification each Contractor shall be responsible for ensuring space is available for equipment replacement and service meeting minimum manufacturer's recommendations. Contractor shall review service space and equipment removal paths during Operational Staff Training. Any item not having proper service clearance shall require sign-off by the University.

M. Servicing of Equipment and Systems

1. Upon Certification of Substantial Completion of the project by the Owner, the warranty period of all equipment and materials will be initiated. During this period, the contractor shall make a minimum of two (2) visits to the site (six (6) months after acceptance and immediately prior to the end of the warranty period). During each visit, the contractor shall thoroughly check all equipment for proper operation. Reports shall be generated, signed-off and forwarded to the Facilities Operations describing the systems inspected, date of inspection and status of equipment. All deficiencies and adjustments shall be corrected during warranty period.

2.0 Drawings

- A. The following applies to the preparation of Contract Drawings:
- B. All Division 21, 22, and 23 drawings shall be labeled as follows:
 1. Heating, Ventilating and Air Conditioning: H-1, H-2, etc.
 2. Plumbing and Drainage: P-1, P-2, etc.
 3. Fire Protection: FP-1, FP-2, etc.

- C. Separate sheets shall be used for small scale plans, large scale plans, details, schedules, sections, piping and airflow diagrams, and small scale plans, larger scale plans, automatic control diagrams.
- D. Standard University details shall be used where applicable.
- E. All equipment rooms or major equipment installations on the roof shall be drawn at scale not less than 1/4" = 1'-0" and shall show accessibility for maintenance and equipment removal.
- F. All drawing sections shall be coordinated sections for all trades to demonstrate overall coordination at each typical construction condition as well as congested areas. Zones for fire protection services as well as electrical distribution shall be indicated in the sections.

3.0 Additional Design Considerations

- A. All equipment installed on the campus shall be globally controlled and monitored from the centrally located Operations Control Center (OCC). The Automatic Control and Monitoring Systems Section 230900 in this standard describes the specific minimum requirements associated with the central control and monitoring system.
- B. Exterior HVAC equipment installations and intake and exhaust locations shall consider the aesthetics of the building, noise pollution, exhaust air re-entrainment (wind wake), accessibility, maintainability, security, safety regulations and health effects. Suggested design professionals for wind-wake analysis are:
 - 1. Ali Malkawi, Associate Professor Head, Building Simulation Group
Department of Architecture University of Pennsylvania
Meyerson Hall G-17
Philadelphia, PA 19104-6311
Phone: 215-573-8718 Fax: 215-573-2192
Email: malkawi@design.upenn.edu
 - 2. Bill Smeaton
Principal/Senior Project Manager
Rowan Williams Davies & Irwin Inc. (RWDI) Consulting Engineers
650 Woodlawn Road West
Guelph, Ontario, Canada N1K 1B8
Tel: 519.823.1311 x 2318
Fax: 519.823.1316 bill.smeaton@rwdi.com
- C. The A/E shall obtain University approval during the design process for exterior mounted equipment, roof screens and access around equipment.
- D. Coordination of the design for the location of all floor and wall openings, lintels, equipment pads, etc. is the responsibility of the A/E to design the system which penetrates the floor, wall or roof and provide details on the Contract Drawings. Coordinate with required fire and smoke ratings of new or existing construction.
- E. The following is a list of prohibited installations
 - 1. Internally lined duct systems (small sections of return ductwork are allowed only in critically sensitive acoustic spaces and with approval of the University Engineering Department).

2. Fiberglass duct systems (room transfers are the exception).
 3. Bullhead piping connections.
 4. Dual temperature hydronic systems. (Two-pipe fan coil unit systems).
 5. Medium and High static pressure HVAC systems. For operational cost considerations, it is desired to maintain HVAC systems at as low of an operating pressure as possible (the minimum total pressure required for air terminal box operations).
 6. Two-pipe fan coil unit systems.
 7. Induction units.
 8. Multi-zone units.
 9. Packaged rooftop mounted units (exception: retail and residential applications).
 10. Vertical pumps.
 11. Integral mechanical fluid temperature controls (Danfoss valves).
 12. Heat pumps (exception: Retail and Residential applications).
 13. Internally-lined air terminal boxes which do not use an internal metal or mylar liner.
 14. Single wall air handling units.
 15. City water source electrical humidifiers.
 16. Steam preheats on 100% O/A - AHUs.
 17. Hot & Cold deck systems.
 18. Victaulic piping systems. (Exception: sprinkler systems)
- F. All equipment must be installed on raised concrete pads. Pads shall be a minimum of 4" high and be reinforced with steel.
- G. Pipe and duct spaces shall be designed to adequately house the intended quantity of materials and to allow for a minimum future expansion of 25%. The Design Professional shall size the shaft and locate future expansion space so it is accessible to install parallel piping and ductwork in the future with minimal system disturbance or affect to current program space. The shaft space shall have minimum interior dimensions of 2'-0" square. Hinged and locked access doors shall be installed and provide access to the shaft on alternate levels. Access doors shall be minimum nominal 24 inches by 48 inches.
- H. No rotating or other equipment should be designed for above ceiling installation. All equipment (air terminal boxes, fan coils for specific purposes, reheat coils, and duct humidifiers being exceptions) must be designed for equipment room installation and be serviceable from the floor level. When devices that are exempt are located above ceilings, they will be confined as much as possible to corridors and be kept out of critical spaces. For areas where access to the space is a hazard to employees (Vivarium) it is required that all terminal devices be located outside of the program space and a dedicated mechanical corridor be considered to maintain separate access for program functions and maintenance functions.
- I. All valves, balancing dampers, and miscellaneous materials located above inaccessible ceilings must be made accessible by installing access doors of appropriate size. (Access doors shall generally be a minimum of 24"x24".)
- J. Consideration must be given to the proximity of outdoor air intakes to relief outlets, exhaust outlets, streets, and loading docks. Outdoor air intakes located below grade should be avoided.
- K. The project shall give consideration to utilizing Computational Fluid Dynamic (CFD) analysis for vivarium holding rooms and laboratories with multiple fume hoods to optimize room airflow.
- L. For renovation projects, where cooling and heating loads increase for the renovated

space of (more than 25 tons or 500 lbs./hr.), the A/E shall provide a Utility Capacity Study and indicate where increased service sizes are required and where they will be connected. For new building projects, a similar study shall be performed in conjunction with the University Engineering Department.

- M. Floor drains shall be provided by pumps, process equipment, AHU coils, water treatment stations, etc. to allow drainage of equipment without installing low horizontal piping that would be a tripping hazard.
- N. Energy recovery systems shall be provided in accordance with the requirements of Section 6.5.6 of ASHRAE 90.1-2016.
- O. For all 100 percent outdoor air applications the A/E shall perform a heat recovery study to determine the payback from recovering heat in the exhaust air stream to preheat and/or precool outdoor air. Different methods of energy recovery shall be investigated.
- P. Where office space is segregated from laboratory or vivarium spaces, separate recirculating systems or returning the office air to the 100 percent outdoor air laboratory or vivarium system shall be considered.
- Q. Efficiencies affecting energy usage of equipment shall be clearly specified and scheduled on drawings. Equipment shall be selected to meet or exceed the minimum requirements in accordance with Table 6.8.1 of ASHRAE 90.1-2016.