

SECTION 23 73 23 - CUSTOM AIR HANDLING UNITS

PART I – GENERAL

[Note to PSC: This specification for Custom Air Handling Units applies to units with design airflow rate greater than 5,000 CFM. Units with design airflow less than or equal to 5,000 CFM will typically comply with requirements of specification Section 23 73 23 Modular Air Handling Units. However, in some cases it may be necessary to apply Custom Air Handling Unit specifications to smaller units to satisfy requirements not readily achievable with Modular Air Handling Units. Such requirements include:

- *Increased R value to satisfy more demanding interior and/or exterior ambient conditions*
- *Non-standard unit configurations*
- *Non-standard materials of construction or coatings*
- *Incorporation of custom heat recovery and/or auxiliary device requirements*

Owner is to be contacted to confirm AHU type for specific application.]

[Important Notes to PSC:

- *Of necessity these specifications include numerous options for inclusion or exclusion of specific features. Review carefully and edit text as appropriate for each item for each specific project.*
- *Included herein are numerous statements such as “if indicated” or “unless indicated otherwise” or “if scheduled” or “if specified” or similar. In each case edit text to clearly indicate project-specific requirements. Failure to do so has proven problematic.]*

1.1 SECTION INCLUDES

A. Custom Air Handling Units (AHU)

1. “Standard” Indoor Unit
2. Outdoor Unit
3. Aluminum Unit
4. Knock-Down Unit

[Note to PSC: Aluminum units have traditionally been specified and installed for purposes of decreasing weight of assembled unit and/or for durability on outdoor applications. However, in many cases there is no longer a significant upcharge for providing an aluminum unit in lieu of a standard unit. If so, AHUs are to be aluminum units. Reference section below entitled ALUMINUM UNIT. Confirm relative pricing of units for project and discuss unit type with F&S Engineering prior to final design.]

B. Dedicated Outdoor Air Units (DOAU)

[Note to PSC: DOAU is to be treated as project-specific AHU. Separate DOAU specifications have not been provided nor are they needed. Specifications provided herein apply equally to AHUs and DOAUs. As with AHUs, project specific requirements for DOAUs are to be incorporated into project documents.]

C. Energy Recovery Wheels

D. Plenums and Housings, including exhaust fan plenums

1.2 RELATED SECTIONS

Products provided under this section but specified under a separate section.

- A. 23 09 13 – Instrumentation and Control Devices for HVAC
- B. 23 09 13.43 - Control Dampers
- C. 23 09 23 – Building Automation Systems
- D. 23 34 00 – HVAC Fans
- E. 23 40 00 – HVAC Air Cleaning Devices

[Note to PSC: At the time of this writing, reference to Section 23 40 00 serves as a placeholder. Section has been temporality removed from Standards pending updating.]

- F. 23 82 16 – Air Coils
- G. 23 31 00 – HVAC Ducts
- H. 26 60 00 - Common Motor Requirements
- I. 26 29 23 - Variable Frequency Motor Controllers

1.3 REFERENCES

- A. AHRI Standard 430 – Performance Rating of Central Station Air-Handling Units
- B. AHRI Standard 1060 – Performance Rating of Air-to-Air Exchangers for Energy Recovery Ventilation Equipment
- C. AMCA Standard 311 – Certified Ratings Program – Product Rating Manual for Fan Sound Performance
- D. ASTM E90-09 – Standard for Measurement of Airborne Sound Transmission Loss
- E. ASHRAE Standard 62.1 – Standard for Indoor Ventilation for Indoor Air Quality
- F. ASHRAE Standard 84 – Method of Testing Air-to-Air Heat/Energy Exchangers
- G. ASHRAE Standard 90.1 – Energy Standard for Buildings
- H. ANSI/ASHRAE Standard 111 – Testing Adjusting and Balancing of HVAC Systems
- I. ASHRAE Standard 1350 – Mechanical Performance Rating of Central Air-handling Unit Casings
- J. SMACNA HVAC Air Duct Leakage Test Manual
- K. NADCA Standard ACR 2013 - Assessment, Cleaning and Restoration of HVAC Systems
- L. NFPA 255 - Standard Method of Test of Surface Burning Characteristics of Building Materials
- M. National Electric Code
- N. International Mechanical Code

1.4 QUALITY ASSURANCE

- A. Unit shall bear ETL label.
- B. Products and execution shall be in compliance with applicable codes and standards including those referenced above in paragraph entitled *REFERENCES*.
- C. Installation, start-up and operation shall be in compliance with Manufacturer's requirements, recommendations, and Installation Operation and Maintenance guides (IOM).

1.5 SUBMITTALS

- A. Dimensioned arrangement drawings of unit including plan, external elevations and internal sectional views and dimensions of overall unit, unit sections and significant components including:
1. Base frame and structural components
 2. Curb and/or structural support
 3. Platforms, ladders and railings
 4. Floor and drain pan(s)
 5. Drain trap configuration and dimensional requirements
 6. Wall, roof panels, including vestibule as applicable
 7. Weather-proof roofing for exterior units
 8. Architectural siding for exterior units as applicable
 9. Doors, access panels, other access points
 10. Structural supports for coils, fans and auxiliary devices
 11. Inlet / discharge openings for duct / plenum connection
 12. Fan(s)
 13. Vibration isolators
 14. Dampers, filters, coils, air blending devices
 15. Energy recovery wheel(s) as applicable
 16. Other heat recovery devices as applicable
 17. Humidifier, UV lighting, other auxiliary items as applicable
 18. Factory mounted VFD(s) as applicable
 19. Lights, switches
 20. Factory mounted piping, valves, wiring, junction boxes as applicable
 21. External piping and electrical connections
 22. Attenuating devices as applicable
- B. Large scale, detailed, cross sectional views including:
1. Wall and roof panel connections
 2. End corner connections
 3. Floor connections to support members, base frame and wall panels
 4. Drain pan connections to floor and frame
 5. Door, frame and wall interface
 6. Shipping split structural connections
 7. Shipping split floor connections
 8. Outdoor roof and architectural siding connections
- C. Thermal break heat transfer calculations at following points of connection. Provide interior and exterior surface temperatures:
1. Panel to panel connection
 2. Wall panel to roof panel connection
 3. Corner connection

4. Wall to floor to frame connection (most critical)
- D. Component materials including insulation, metal gauge/thickness, finishes, coatings
- E. Approximate shipping weight
- F. Multi-section / knockdown unit assembly details and instructions
- G. Installation instructions for fully assembled units
- H. Recommended / required clearances for operation and maintenance
- I. Field piping and electrical power/control wiring instructions and diagrams
- J. Damper size and performance data including air velocity and pressure drop
- K. Fan data including following:
 1. Fan type and class
 2. Wheel type, size
 3. Airflow (CFM), total static pressure (TSP), speed (RPM)
 4. Motor input frequency (Hz)
 5. Performance curves indicating specified operating point at design conditions
 - a. Individual fans
 - b. All fans in group operating as unit
 - c. Initial design operating conditions
 - d. Future design operating conditions, as applicable
- L. Fan motor data
 1. Type, rated BHP, RPM, electrical characteristics
- M. Coil data
 1. Coil type, configuration, number of rows
 2. System fluid (water, % glycol)
 3. Tube material, size (diam.), wall thickness
 4. Fin type, material, thickness, density (FPI)
 5. Coating data as applicable
 6. Header material, connection size
 7. Water flow rate, EWT, LWT, tube velocity, pressure drop
 8. Airflow rate, EAT, LAT, face velocity, pressure drop
 9. Certified thermal performance
- N. Filter data
 1. Type, size, efficiency, velocity, clean/dirty pressure drop
- O. Energy recovery wheel data
 1. Dimensioned drawings
 2. Structural component materials, finishes
 3. Media
 - a. Type, detailed description, manufacturing process
 - b. Number, dimensions of segments

- c. Airflow rates, face velocities, pressure drops, both sides of wheel
 - d. Purge angle, purge air flow rate
 - e. Entering and leaving air conditions, both sides
- 4. Motor, belt, gear drive data
- 5. VFD data
- 6. Media segment installation / replacement instructions
- P. Plate Heat Exchanger Data
 - 1. Dimensioned drawings
 - 2. Structural component materials, finishes
 - 3. Plate thickness, spacing
 - 4. Airflow rates, face velocities, pressure drops, both sides of exchanger
 - 5. Entering and leaving air conditions, both sides
- Q. Static pressure (SP) drops at operating conditions for each component (e.g. filters, coils, energy recovery devices). Pressure drop shall be provided for clean filters and separate pressure drop for loaded "dirty" filters
- R. Design external SP for system
- S. Unit sound power levels, (8) octave
 - 1. Discharge, inlet, radiated
- T. Catalog data, brochures and illustrations for unit including all auxiliary devices (e.g. energy recovery wheel, humidifier, UV lighting)
- U. Manufacturer's installation, operation and maintenance manuals for unit including all auxiliary devices
- V. Complete structural drawings
 - 1. Curbs, supports, platforms, ladders, railings
- W. Test Reports
 - 1. Certified factory test reports as applicable
 - a. Vibration
 - b. Air leakage
 - c. Deflection
 - d. Airflow
 - e. Sound
 - 2. Field test reports
 - a. Air Handling Unit as applicable
 - 1) Air leakage
 - 2) Deflection
 - 3) Vibration
 - b. Energy recovery wheel(s)
 - 1) Thermal performance: sensible, latent
 - 2) Pressure drop
 - 3) Purge angle setting

- 4) Cross contamination, as required for laboratory applications only
- c. Plate heat exchangers
 - 1) Thermal performance
 - 2) Pressure drop
- X. Signed and dated site visit logs
- Y. Startup report
- Z. Test and balance report
- AA. Signed and dated warranty documents
 - 1. Air handling unit
 - 2. Energy recovery wheel

1.6 DELIVERY, STORAGE, PROTECTION

- A. AHU and associated equipment shall be delivered to job site suitably packaged and protected for overland trucking using heavy-duty protective shrink-wrap plastic.
 - 1. All items shipped loose such as filters, steam humidifier assemblies, etc. shall be suitably secured in unit or on separate pallet similarly protected.
- B. Unit shall be stored in clean, dry environment protected from exposure to dust, debris and fluids.
 - 1. Temporary covers shall be maintained over openings in unit housing throughout storage and system installation to greatest degree possible.
- C. Construction Phase Operation
 - 1. AHU shall not be operated during construction phase of project unless specifically indicated otherwise in project documents.
 - 2. Unit shall not be operated in any manner that exposes it to inadequately filtered air flow. If unit is operated in dirty airflow conditions filters shall be changed frequently. Additional filtration shall be provided if practical.

1.7 EXTRA STOCK

- A. In addition to filters provided with AHU, spare set of filters shall be provided. Performance of both sets of filters shall be adequate to satisfy LEED preoccupancy purge requirements.
- B. For each belt driven fan, replacement set of matched belts shall be provided once proper belt length has been determined by TAB Contractor.

1.8 WARRANTY

- A. Air handling unit including energy recovery wheel and other auxiliary devices shall be warranted by AHU Manufacturer to be free from defects in material and workmanship and to perform as specified for period of one year from date of startup or 18 months from date of delivery whichever occurs first. Manufacturer shall repair or replace unit at no cost to Owner.
 - 1. Repaired unit shall be like new with no cutting, patching or notable modification as determined by PSC or Owner.
- B. Energy recovery wheel – Unconditional Ten Year Parts and Labor Warranty
 - 1. Energy recovery wheel assembly in entirety including motor, belt(s), gear drive and electrical components shall be warranted by heat recovery wheel Manufacturer to be free from defects in material and workmanship and to perform as specified for period of ten years from date of startup.

2. Further, for same time period, warranty shall cover cost of parts and labor to repair, replace and/or adjust any and all components as required for proper operation and full functionality.
3. Warranty shall include conformance to specified maximum allowable wheel deflection of 1/32" at design airflow and pressure differential conditions throughout full term of warranty. Reference section below entitled *ENERGY RECOVERY WHEELS*.
4. Warranty shall apply unconditionally to required repair, replacement or adjustments resulting from normal wear as well as manufacturing-related causes. Normal wear shall include but not be limited to replacement of motors, belts and drive components.
5. If necessary to accomplish above stated warranty, Manufacturer shall replace entire wheel at no cost to Owner.
6. Repaired or replaced unit shall be like new with no cutting, caulking, patching or notable modification as determined by PSC or Owner
7. This warranty shall take precedence over Manufacturer's published warranty.
8. Full satisfaction of this warranty as detailed above shall be at no cost to Owner.

1.9 MANUFACTURER SERVICES

A. AHU Manufacturer authorized service technician shall provide:

1. Periodic observation and oversight during field assembly/installation of AHU as required to ensure proper installation. Submission of written log of field visits and observations to PSC and Owner.
2. Daily supervision of field assembly of knock-down units to ensure proper installation. Submission of written log of daily activities to PSC and Owner.
3. Daily supervision of roof installation and architectural panel installation for outdoor units.
4. Preoperational inspection, oversight of startup and operator instruction including OIM. Submission of startup report and dated warranty document to Owner.
5. Oversight and witness of all field tests specified herein. Submission of test reports to PSC and Owner

B. Energy recovery wheel Manufacturer's authorized service technician shall provide:

1. Preoperational inspection, oversight of startup including optimal purge adjustment and operator instruction including OIM. Submission of startup report and dated warranty document to PSC and Owner.
2. Oversight and witness of field tests specified herein. Submission of test reports to PSC and Owner.
3. All services required to satisfy ten year unconditional warranty

1.10 APPROVED MANUFACTURERS

A. Air Handling Units

1. Buffalo Air Handling
2. Air Enterprises
3. TMI Climate Solutions
4. MAFNA Air Technologies
5. Ingenia
6. Governair
7. Huntair

8. Ventrol
 9. Temtrol
 10. Air Flow Equipment
- B. Energy Recovery Wheels
1. Thermotech
 2. Seibu Giken / SG America
 3. SEMCO

[Note to PSC: A key feature that separates tier one AHUs from tier two AHUs is method of thermal break. Tier one AHUs provide thermal break via use of rigid polymer thermal-break materials. Tier two AHUs typically provide thermal break (so called) via use of pliable gaskets.]

PART 2 – PRODUCTS

2.1 GENERAL REQUIREMENTS – INDOOR AIR HANDLING UNIT (STANDARD UNIT)

A. Basic Construction

1. AHU shall consist of sectionalized casing panels and flooring mounted upon a structural base. Unit shall incorporate fans, coils, filters, dampers and other components as indicated within project documents.
2. AHU, including structural base, flooring and casing panels, shall have adequate rigidity to satisfy specified deflection limits under all operating conditions.
3. Unit shall be completely water tight and shall be air tight within specified leakage test limits in all operating conditions.
4. All joints shall be sealed via inherent self-sealing design or with non-permeable gasket material. Caulk, butyl tape, mastic, etc. shall not be used as primary sealing method.
5. Unit shall have true thermal break construction with no metal-to-metal path for heat transfer.

B. Dimensions

1. Air handling unit selections indicated on project drawings are basis of design. Dimensions and other physical characteristics may slightly vary depending on manufacturer submitted. Such shall be fully coordinated with building/equipment room layout and available space.
2. Contractor and manufacturer shall verify that layout and dimensions of installed unit allow adequate clearances for equipment access, pull space, door swings, etc. Such shall include coordination with other equipment and systems including ductwork, piping, electrical, etc.

C. Thermal Performance

1. Exterior panels and floor of conditioned sections shall have minimum R value of 26 for 4" thick panels
2. Further, exterior surfaces and floor of conditioned sections shall not condense given following conditions:
 - a. Unit interior air conditions
 - 1) Lowest design operating temperature
 - 2) 52 degrees F maximum
 - b. Unit exterior ambient air conditions. Heat transfer and non-condensing requirements shall be satisfied at both operating conditions.
 - 1) 95 F DB/78 F WB

2) 80 F DB/78 F WB

[Note to PSC: These are conservative default numbers. Could consider less severe design conditions for well-conditioned space, e.g. 92F DB/76 WB. Less severe conditions such as these may allow use of more economical gasket type thermal break in lieu of specified polymer block type thermal break. Edit specification as appropriate.]

[Note to PSC: In determining project-specific equipment room conditions analyze space conditions surrounding unit. Adjust specification for dew point and dry bulb temperatures as appropriate. Consider heat and humidity within adjacent spaces relative to insulation, vapor barrier separation and internal heat sources. Coordinate with Architect to ensure proper design. Give consideration to providing environmental control within equipment room. Discuss with F&S Engineering.]

3. Interior panels and floor shall not frost given following conditions:

- a. Interior unit air conditions: 72 degrees F DB, 40% RH
- b. Exterior unit conditions: -10 degrees F

D. Deflection

1. Deflection of components including wall, floor and roof panels shall not exceed 1/240th of span under full operating conditions unless specified otherwise.

E. Configuration

1. AHU shall be configured as indicated within project documents. Unit shall be horizontal draw-through configuration as default. Alternate configuration may be presented to PSC for review and potential approval.

[Note to PSC: When achieving adequate mixing of airflow is of particular concern a blow-through configuration may be considered given that this configuration may be more effective in mixing air streams as they pass through the fan(s). In such case the supply plenum becomes a mixing box. The primary concern with blow-through configuration is that the supply airflow is near the saturation point, especially if there is any carry-over of mist or water droplets from the cooling coil. Thus, the supply plenum, final filters, if any, ductwork and downstream components may become wet and stay wet for extended periods of time.]

2. For applications with energy recovery wheel(s) exposed to contaminated exhaust air, AHU shall be configured such that supply air is maintained at positive pressure relative to exhaust air under all operating and failure conditions.
3. To greatest degree practical, air handling unit shall be configured to maximize height/width ratio for improved access (e.g. by providing vertically stacked fans rather than side by side).
4. Damper arrangements shall be provided as indicated on drawings including steam coil face and bypass dampers, cooling coil bypass dampers, energy recovery wheel bypass dampers, plate heat exchanger face and bypass dampers and air blender bypass dampers.

F. Additional Configuration Requirements

1. Mixed air units shall be configured to optimize mixing of return air and outdoor air over full range of velocities. *[Note to PSC: It is essential to "Do whatever it takes" to ensure good mixing of air streams without compromise. The University has found this to be, without question, the most important aspect of mixed air unit design.]*
2. To degree possible, outdoor air path shall be located above and centered upon return air path to minimize stratification. To degree possible, air streams shall enter mixing chamber from front, top or bottom rather than from either side. Coordination with Installing Contractor shall be provided. *[Note to PSC: To greatest degree possible coordinate ventilation system layout to conform to these recommendations.]*

3. Mixing chamber shall be of adequate length to ensure good mixing prior to filters. Dampers, including minimum OA damper shall be positioned and oriented to optimize mixing.
4. Air blending devices shall be provided to ensure thorough mixing of outdoor air and return air. *[Note to PSC: Show air blending devices and associated dampers on drawings.]*
5. 100% outdoor air units (located indoors or outdoors) shall be configured to minimize ingress of snow and associated snow loading of filters. OA Intake plenum section with drain shall be provided upstream of filter section to serve as stilling basin for rain and snow. OA plenum shall be 5 ft. minimum length in direction of airflow. This dimension shall not be reduced without approval of PSC and Owner. *[Note to PSC: In some cases 6 ft. or more may be required. Evaluate and edit accordingly. Ensure requirement is clearly reflected on drawings.]*
6. Outdoor air and mixing plenums shall be configured to yield constant air velocity across full face of filter bank such that maximum allowable airflow velocity is not exceeded at any point on downstream coil face.
7. AHU Manufacturer shall contact PSC prior to bid to review any configuration deemed vulnerable to inadequate mixing or snow ingress. Recommended design changes shall be provided by Manufacturer to PSC. *[Note to PSC: Be creative and aggressive in achieving a design that maximizes mixing and minimizes snow ingress. A cookie cutter approach may be inadequate and may result in operational problems later.]*

G. Access

1. Access section with man door shall be provided between all major component sections. Access door opening shall be nominal 24" wide x 60" high. Height may be reduced only to degree limited by AHU dimension. In no case shall space between coils be less than 24".
2. All interior components shall be fully accessible including rotating equipment (e.g. fans, energy recovery wheels) and auxiliary equipment (humidifiers, UV lights).
3. All internal components including fans, motors y recovery wheels shall be removable without significant unit disassembly.
4. Access doors and removable panels shall be provided as required to provide such access without impacting structural integrity of unit.
5. Access panels shall be provided on connection side of heat transfer coil sections to facilitate extraction of coils for repair or replacement. Access panels shall be provided on opposite end of coil to facilitate future repair of coil return bends. Individual panels shall be provided for each stacked coil section.
6. Platforms and ladders shall be provided within unit as required to provide

H. Hardware

1. All hardware, fasteners, gaskets required for field assembly shall be provided and clearly identified.
2. Fasteners and hardware shall be same material as connected components. Where connected components are dissimilar material, stainless steel hardware shall be used. Exception: Where aluminum components are attached to one another stainless steel hardware shall be used.

I. Coatings

1. All non-galvanized steel elements, welds and components shall be primed and painted.

J. Motor Removal Beam

1. Motor removal I-beam shall be provided to facilitate removal of motors 5 HP and larger. Structural steel frame shall be provided to support motor removal I-beam. *[Note to PSC: Discuss with Owner possible modification of this requirement if deemed appropriate for specific project.]*

K. Platforms

1. OSHA approved platforms, ladders and railings shall be provided as required for safe, convenient access to elevated sections as specified and shown on drawings. Platforms shall be adequate in strength and dimension to handle heaviest internal component at elevated level within AHU. *[Note to PSC: Small installations may not require such provision. If not, spec language shall be edited accordingly. If external structure is required, show on drawings. If design and construction of exterior platforms and ladders are extensive it may be appropriate to retain the services of a Structural Engineer and assign work to General Contractor. Such shall be reflected in drawings and specifications.]*

2.2 BASE

A. Base Frame Requirements

1. Base frame, cross members and structural reinforcement shall be welded construction using cold formed carbon steel standard shapes and sizes. Formed sheet metal structural components or bolted construction not acceptable.
2. Base frame shall be G90 galvanized with zinc coated welds or shall be finished with two part corrosion resistant epoxy coating or equivalent.
3. Base frame shall be 6" minimum height unless indicated otherwise in project documents.
4. Base frame deflection shall not exceed 1/300 given a maximum unsupported span of 8 ft.
5. Base frame shall have factory fabricated lifting lugs
6. As an alternate, base frame may be constructed of welded aluminum structural members. Strength and rigidity shall be equal to or greater than that of specified steel frame.

2.3 FLOOR

A. General

- 1 Floor shall be aluminum tread plate with non-slip diamond pattern, 0.125" minimum thickness (8 gauge).
- 2 Minimum floor design load shall be 150 lb./sq. ft.
- 3 Floor shall be completely insulated beneath with rigid two-part expanded urethane foam. Thickness of insulation shall be as required to satisfy specified thermal resistance and shall be 4" minimum thickness. Foam insulation may be injected or spray applied and shall completely fill all contours on underside of floor.
- 4 Sub-floor cover sheet shall be provided and shall completely encapsulate insulation. Sub-floor shall be G90 galvanized steel sheet, 20 gauge minimum.
- 5 Aluminum safety grating shall be provided over any air inlet or outlet opening in floor. Grating shall support service personnel while maintaining minimal impact on system air flow.

B. Thermal Break Requirement

1. Floor shall have 100% thermal break construction with no metal-to-metal path for heat transfer to adjacent or connected components (e.g. base frame, wall panel).
2. Thermal break shall incorporate rigid polymer thermal barrier at floor/frame/wall connections. Thermal break shall not rely upon gasket or other pliable material.

- a. Exceptions:
 - 1) Floors in sections of air handling unit conveying return, exhaust or relief air may utilize standard thermal break construction without rigid plastic thermal barrier.
 - 2) Vestibules and service corridors may utilize standard thermal break construction without rigid plastic thermal barrier.

C. Wet Sections

By definition, "wet sections" of AHU include all sections in primary air path (primary air tunnel) and other sections potentially exposed to moisture, condensation or frost. Wet sections also include sections where periodic washing of louvers, coils and energy recovery wheels is required. Wet sections include but are not limited to following:

1. Primary Air Path
 - a. Outdoor air intake plenum
 - b. OA / return air mixing plenum
 - c. Filter section
 - d. Heat recovery section
 - e. Heating coil section
 - f. Humidifier section
 - g. Cooling coil section
 - h. Fan section
 - i. Supply air plenum
 - j. Access section located after each wet section
2. Other Sections
 - a. Heat recovery coil section in exhaust air path
 - b. Total enthalpy wheel section in exhaust air path
 - c. Laboratory exhaust fan plenum
 - d. Access section for each "other section" identified herein

[Note to PSC: Clearly identify "wet sections" on drawings and indicate construction type required. Don't make the Manufacturer guess.]

D. Floor Requirements for "Wet Sections"

1. Floor shall have continuous seal-welded floor seams throughout.
2. Floor shall incorporate 2" upturned lip around perimeter of each shipping split to form water tight pan for each section. Lips may be continuous seal welded to floor in lieu of broken and upturned one-piece floor construction. Corners shall be seal-welded.
3. At shipping splits, upturned lips shall be butted section-to-section with "inside flange" configuration and retained with tight-fitting metal cap strip. Drilled or punched holes with fasteners not allowed. Potential trip hazard acknowledged and accepted.
4. If air inlet or outlet openings are provided in floor, welded construction with upturned lip configuration shall be maintained.
5. If pipe, conduit or similar penetrations are provided in floor, functionally similar configuration shall be maintained to prevent leaked fluid from passing to space below.
6. Aluminum tread plate floor in each AHU section shall be double or triple pitched toward drain outlet. Alternately, floor may be flat with 12"x 12" nominal welded box drain sump with corrosion resistant grating, conveniently located for wash down.

7. Pitched aluminum tread plate floor with drain as specified above shall be provided in outdoor air intake section(s). Alternately, stainless steel drain pan may be provided in lieu of pitched aluminum floor plate. Reference section below entitled *Drain Pans* for requirements.
8. Drain pipe shall be provided in each section. Drain pipe shall be 1.5" minimum schedule 40 galvanized steel, schedule 40 aluminum or schedule 10 stainless steel. Drain pipe shall be extended through unit wall or base and terminated with NPT cap.
9. Floors shall have no through-penetrations (e.g. threaded fasteners) including attachment points for internal equipment/devices (e.g. fan supports).
 - a. Alternate design that achieves intent of "no through-penetration" requirement may be submitted to PSC and Owner for review and potential approval. Equal consideration shall be given to all manufacturers.

[Note to PSC: Manufacturer feedback indicates that this requirement, although deemed important, may be difficult and costly to provide. Thus, such requirement remains open for review. Editing of specification may be required.]

B. Drain Pans

1. Pitched drainable stainless steel drain pans shall be provided in cooling coil, humidifier and heat recovery sections (located in outdoor air and exhaust air streams) in addition to other section(s) indicated on drawings. Drain pans shall be provided in these sections in lieu of aluminum plate with upturned lip construction. *[Note to PSC: Drain pans are required in heat recovery coil sections to facilitate regularly scheduled coil washing as well as possibility of collecting water from melting ice.]*
2. Drain pans shall be double wall construction and shall be completely insulated with rigid two-part expanded urethane foam, 4" minimum thickness. Foam insulation may be injected or spray applied. Drain pans shall be elevated as required to satisfy specified thermal resistance and/or minimum thickness requirements.
3. Drain pans shall have continuous welded seams. At no point shall fasteners penetrate pan(s).
4. Drain pans shall also incorporate seal welded upturned lips. "Inside flange" connections shall be maintained between floors and drain pans.
5. Drain pans shall be of sufficient depth and capacity to receive and drain by gravity "worst-case" water flow rate into pan.
6. Stainless steel structural channels shall be provided to support coils within drain pans.
7. Drain pans shall be double or triple sloped, pitched 1/4" per foot minimum toward outlet. Drain pans shall be IAQ compliant type and shall satisfy applicable requirements of *ASHRAE Standard 62.1*.
8. Drain pans shall be constructed of type 304 stainless steel sheet for standard applications, 16 gauge minimum. Drain pan supports shall be constructed of same material.
9. Drain pans shall extend full width and length of AHU section and shall be configured / positioned to capture all fluid / condensate. Cooling coil drain pans shall extend 24" minimum downstream of leaving coil face. *[Note to PSC: Drain pan extension may be reduced to 12" if required to shorten unit, but only if condensate generation rate and/or coil face velocity is low.]*
10. Drain pans shall incorporate one or more 1.5" NPT minimum pipe connection(s) of same material welded to lowest point. Connection shall be extended through unit frame to provide complete drainage.
11. Drain outlets shall be of adequate elevation for installation of drain trap of sufficient depth to ensure full drainage of pan during "worst- case" AHU operation.

12. Intermediate Drain Pans

- a. Intermediate drain pans shall be provided between coils when two or more cooling coils are stacked in assembly.
- b. Weight of upper coils shall be fully supported by intermediate drain pans and not by coils below.
- c. Intermediate drain pans shall satisfy all requirements of primary drain pan.
- d. Intermediate pans shall begin at leading face of coil and be of sufficient length extending downstream to prevent dripping or sheeting condensate from passing through air stream of coil below.
- e. Intermediate drain pans shall be independently supported as required to maintain rigidity.
- f. Intermediate pans shall include drain tube to direct condensate to primary drain pan. Drain tube shall be constructed of copper, aluminum or stainless steel.
- g. Intermediate pan outlets shall be located at lowest point of pan and shall be sufficient diameter to preclude drain pan overflow under any operating condition.
- h. Intermediate drain pans shall be insulated if required to prevent condensation on bottom surface of pan and resultant moisture carry over. Insulation shall be elastomeric foam type, 3/8" thick minimum, fully adhered to bottom of pan. *[Note to PSC: Some coils have a gap between the end of the fins and the casing which allows some bypass of unconditioned air. This contacts the bottom of the intermediate drain pan, condenses on the cold metal and causes moisture carry-over. The solution is to insulate the bottom of the pan.]*

C. Dry Sections

By definition, "dry sections" of AHU are sections not exposed to moisture, condensation or frost. Generally speaking, dry sections consist of return air, exhaust air and relief air paths within unit (exceptions identified above). Vestibules are typically dry sections.

D. Floor Requirements for Dry Sections

1. Floors shall have continuous seal-welded floor seams throughout.
2. Welded upturned lip construction not required.
3. "Inside flange" configuration at shipping splits not required.
4. Limited number of through-fasteners allowed at shipping splits and equipment connections.
5. Drain not required.

[Note to PSC: Identify any exceptions to wet and dry sections above for specific project and provide clarifications as appropriate. Identify any other section(s) for which upturned lip construction is required.]

2.4 CASING PANELS

A. Exterior Panels

1. Formed and reinforced casing panels shall be double wall, 4 inches minimum thickness.
2. Outer casing wall panels shall be G90 galvanized steel sheet, 18 gauge minimum.
3. Outer casing roof panels shall be G90 galvanized steel sheet, 16 gauge minimum.
4. Interior liners shall be G90 galvanized steel sheet for standard applications, 20 gauge minimum.
5. Inner liner shall be solid sheet. Perforated metal liner not allowed. Additional attenuation, if required, shall be provided via dedicated attenuator located within unit or

within duct. *[Note to PSC: A perforated liner cannot be used with foam injected panels.]*

6. Panels shall form water tight and airtight seal with adjacent panels. Fasteners shall not penetrate into air tunnel.
 7. Panels shall be completely insulated with rigid two-part expanded urethane foam. Foam insulation shall be injected into cavity between outer casing and inner liner. Cavity shall be completely filled with no voids. Rigid board, semi-rigid board or spray applied insulation not acceptable. *[Note to PSC: Ensure full compliance with this requirement. Provision of void-free injected foam insulation may be difficult for some manufacturers to provide.]*
 8. Openings in panels shall be framed with metal to ensure rigidity and encapsulation of insulation.
- B. Interior Panels (Partition Walls)
1. Formed and reinforced panels shall be double wall construction with thickness and insulation same as specified for exterior panel unless indicated otherwise in project documents. *[Note to PSC: Based upon air conditions on either side of the panel it may be acceptable to reduce the thickness of interior panels.]*
 2. Both sides of panel shall be constructed of 20 gauge minimum G90 galvanized solid steel sheet for standard applications. Perforated sheet is not acceptable unless otherwise indicated within project documents.
 3. Internal panels shall be completely sealed at connections to adjoining surfaces with non-permeable gaskets.
- C. Interior Blank-Offs and Safing
1. Interior partition or blank-off may be single wall under follow conditions:
 - a. No temperature differential exists across partition in any operating condition.
 - b. Low differential pressure exists in all operating conditions.
 - c. Requirements for structural integrity and allowable leakage can be fully satisfied.
 - d. Single wall construction is indicated on drawings.
 2. Blank-offs and safing shall be G90 galvanized steel sheet for standard applications, 16 gauge minimum.
 3. Panels shall be completely sealed at connections to adjoining surfaces with non-permeable gaskets.
- D. Wall Penetrations
1. Wall penetrations shall be kept to minimum and to greatest extent possible shall be located on same side of unit housing as doors.
 2. Pipe, tubing and electrical conduit shall be extended through wall of unit and properly terminated at unit exterior. Electric conduit and wiring shall be terminated in junction box or other approved enclosure mounted on unit exterior.
 3. Size and location of penetrations for conduit, conductors and enclosures for VFD driven motors shall be coordinated with Electrical Contractor. Electrical Contractor shall furnish and install conduit, conductors and enclosures.
 4. Wall penetrations shall be tightly sealed around components passing through wall.
 5. For mechanical piping, flexible rubber boots shall be provided to ensure tight seal around coil piping passing through panel opening.
 6. Wall penetrations for building automation field devices shall be provided by Temperature Control Contractor with approval of AHU manufacturer. Size, location,

manner of penetration and sealing shall be as approved by AHU manufacturer. Temperature Control Contractor shall furnish and install field devices.

E. Duct Connections

1. Flanged openings shall be provided for duct connections.
2. For supply plenums, duct openings shall be larger than duct size to facilitate installation of transition fitting at each duct connection. Size and location shall be coordinated with Contractor.
3. Bellmouth fittings shall be provided where space is inadequate to provide expanded area transition fittings.

[Note to PSC: Size AHU openings and duct size(s) to allow for fittings indicated above. Provide note and/or detail on plan drawings.]

2.5 DOORS

A. Access doors shall be provided as indicated in project documents including drawings and shall satisfy following requirements:

1. Doors shall be hinged double wall construction with four butt hinges each minimum. Hinges shall be adjustable in three planes.
2. Wall thickness, materials of construction and metal gauge shall be equal to that of corresponding wall panels, minimum.
3. Doors shall be insulated with same material as surrounding walls and shall comply with same thermal resistance performance requirements.
4. Door frames shall be extruded aluminum or stainless steel with thermal break construction.
5. Doors shall incorporate continuous non-permeable gasket.
6. Each door shall have minimum of two (2) high compression latches, operable from both sides. Doors on outdoor units shall have securable padlock hardware.
7. Each door shall include double pane tempered, reinforced or safety glass window.
8. Door dimensions shall be nominal 24" wide x 60" high minimum unless indicated otherwise on drawings. In no case shall door be less than 18" wide. Door(s) at fan section(s) shall be sufficiently sized to allow motor replacement. *[Note to PSC: Door width may be reduced to 18" only if absolutely required to shorten overall length of unit.]*
9. Each door servicing positive pressure section of AHU shall open inward. Each door servicing negative pressure section shall open outwards.
10. NOTE: Doors including gaskets shall allow no detectable air leakage at test pressure conditions.
11. Each door shall be provided with hold-open retainer.
12. Each door shall incorporate test hole with threaded cap for static pressure and air velocity measurement.

2.6 INTERNAL COMPONENTS

[Note to PSC: Edit for specific application.]

A. Air Blending Devices

1. Air blending / destratifying devices shall be provided for all mixed air applications to achieve thorough mixing of outdoor air and return air. Blending devices shall be provided as shown on drawings. *[Note to PSC: Blending devices are typically required for mixed air units and are to be provided by default. If blending devices are*

clearly not needed, delete requirement. This default requirement is relatively new to the University.]

- 2 Air blending devices shall be sized and positioned within AHU per air blending device manufacturer's recommendations. Manufacturer's recommended length of unobstructed air flow upstream and downstream of blending unit is typically marginal. Length shall be increased beyond these recommendations to degree practical, especially downstream of blending device.

[Note to PSC: As reflected in the text above, it is the experience of the University that manufacturer's recommended length of unobstructed area upstream and downstream of air blenders is marginal at best. Increased length of unobstructed area, especially downstream of the blender, is recommended.]

- 3 Air blending device shall be sized and located within unit to optimize mixing for winter economizer operation; i.e. blender shall be sized for minimum expected airflow. *[Note to PSC: Blenders become ineffective at low air velocities.]*
- 4 If winter airflow is less than maximum summer airflow, bypass damper shall be provided, located in parallel with blender to avoid excessive pressure drop and to facilitate air side economizer operation. Dampers shall be as shown on drawings.

[Note to PSC: If bypass dampers are clearly not needed delete requirement.]

B. Fans and Motors

1. Fans shall fully comply with requirements of *Section 23 34 00 – HVAC Fans*. Referenced section presents more complete and detailed specifications for fans. As such, it shall be incorporated in its entirety into this document, *Section 23 73 23 – Custom Air Handling Units* by means of this reference.
2. Reference *Section 26 29 23 - Variable Frequency Motor Controllers for VFD* requirements
3. Reference *Section 26 60 00 – Common Motor Requirements* for motor requirements.
 - a. TEAO motors also approved for direct drive fan arrays
4. Fans shall be housed centrifugal or plenum type, factory mounted complete with motor and drive.
5. Number of fans shall be as indicated in drawings or schedule.
6. Plenum fans may be configured in "fan array" unless indicated otherwise in drawings or schedule.
7. AHUs with multiple plenum fans shall have motors and associated variable frequency drives (VFDs) configured in accordance with project drawings and applicable specifications. *[Note to PSC: Provide clear direction regarding fan/VFD configuration. Discuss design with Owner prior to document preparation. Ensure VFDs comply with UIUC Standards.]*
8. For motors 10 HP and smaller, number of fans served by single VFD shall not exceed six. For motor sizes larger than 10 HP maximum number of fans served by single VFD shall be reduced. *[Note to PSC: Discuss with Owner prior to completion of design.]*
9. Fans shall be selected for optimal efficiency at design operating point.
10. Fan/motor combination shall be capable of providing design performance (100% CFM at design operating conditions) **without exceeding 90% nameplate amperage**.

Note to Contractor and Manufacturer: Do not overlook 90% nameplate amp limit. It will be factory and/or field tested per specifications.

[Note to PSC: Motor HP listed in schedule must incorporate this requirement. Thus, scheduled HP will likely be larger than HP provided by Fan Manufacturer data for specific application.]

11. VFD size/selection shall be based upon 100% of increased motor HP and associated 100% nameplate amperage. Contractor shall confirm with Fan Manufacturer that scheduled HP satisfies this requirement.
12. Traditional non-overloading selection not required when fan is served by variable speed drive. VFD shall be configured and adjusted to prevent overloading.
13. VFD size/selection shall be based upon 100% of increased motor HP required to satisfy requirement above.
14. Fans shall be direct drive unless indicated otherwise on drawings or schedule. *[Note to PSC: Given the substantial inefficiency and maintenance requirements of belt-driven systems the University has standardized on direct drive fans for all but a few exceptions. Reference Section 23 34 00 – HVAC Fans for exceptions. Standards do not currently identify an across-the-board maximum size for direct drive fans. Apparent and/or recommended exceptions are to be discussed with Owner.]*
 - b. Exceptions - Following AHU fans shall be belt driven:
 - 1) DWDI (double width double inlet) fans
 - 2) SWSI fans only if available fan selections require operation outside approved motor frequency range. This is rare and shall be demonstrable. *[Note to PSC: Fewer fan selections are available for housed fans than for plenum fans. Thus a suitable selection for a direct drive SWSI fan may not be available for a given performance requirement. In such case, a belt driven fan shall be provided.]*
15. Direct drive fans shall be selected such that at design conditions motor frequency shall be within 60-80Hz range if possible. In no case shall motor frequency under any condition exceed 90 Hz. *[Note to PSC: Given limited number of fan size options for a given application selection is to be based upon optimal performance within allowable speed range (motor frequency range). Without belts and adjustable sheaves it is unlikely that optimal fan selection will be at nominal synchronous speed of motor (frequency = 60 Hz.)*
16. Fan motors shall be 1,800 RPM synchronous speed unless indicated otherwise in schedule.
17. Motors for belt driven applications shall be provided with heavy duty slide bases.
18. Each fan shall be provided with individual isolation damper to prevent reverse flow.
 - a. Damper shall be constructed of aluminum and shall be specifically designed and configured to yield negligible impact on fan performance.
19. Base support frame shall be provided for each fan.
20. For fan arrays, pre-engineered structural frame shall be provided such that fans are supported independently of each other. Fans and motors shall be removable independently without affecting other fans and motors.
21. Fans shall be positioned relative to cooling coil (or other major component) to provide equal distribution of airflow across full face of coil or component. One fan diameter minimum shall be provided between fan and cooling coil (or other major component). Note: Factors may require substantially more than one fan diameter downstream clearance, especially for smaller fans configured in array.
22. Fasteners for mounting fan(s) in “wet sections” of AHU shall not penetrate floor. Reference section entitled “Wet Sections”. *[Note to PSC: Reference note in referenced section addressing floor penetrations.]*
23. Flexible duct connector shall be provided between discharge of each housed centrifugal fan and associated duct opening in AHU cabinet such that flexible duct connection is not required at unit exterior.

[Note to PSC: When selecting number and size of fans the following factors shall be considered:

Efficiency: Selection point yielding most efficient fan performance will typically be achieved when all fans are energized, operating in parallel. Efficiency over full range of operation is to be evaluated when making fan selections. Selection based upon atypical operating conditions to maintain full redundancy often results in selection of less efficient fans. This can be addressed by providing a “spare fan” (aka N+1) selected for design operating conditions but that remains inactive during normal operation. However, this is typically unnecessary and may have negative impact on airflow distribution depending upon number, size and configuration of fans.

Redundancy: Fan redundancy requirements can typically be satisfied by simply providing two or more fans operating in parallel. Reduced airflow due to failure of one fan is typically acceptable and often goes unnoticed while repairs are being made. Provision for redundancy is to be limited to degree truly required for application. Redundancy requirements shall be evaluated and identified for each project. For truly critical applications N+1 fans with dedicated VFD per fan may be required. An option for providing a limited measure of redundancy is provision of an “oversized” motor for each fan, allowing increase in speed via VFD if needed to increase performance. However, fan speed should not exceed 80 Hz as stated previously within these Standards.

Number of VFDs: Multiple fans may be served by single VFD up to maximum six fans per VFD. In such cases, a failed fan can be temporarily disconnected from VFD and remainder of fans placed back in service. Reduced number of fans per VFD may be required to satisfy increased redundancy requirements. When multiple fans are served by a single VFD overload protection is to be provide for each fan as required by per NEC. Overload protection devices shall be located within VFD enclosure. Coordination with Electrical Designer and Electrical Contractor shall be provided.

Fan Arrays: Fan array configuration must not be applied as a “cookie cutter” design as has become common practice. In addition to efficiency and redundancy considerations other factors shall be considered such as dimensional limitations of AHU, complexity of mechanical systems, maintenance requirements, noise generation/attenuation, scope of electric power circuits/devices, fan and housing performance reducing effects, and complexity of control systems.]

24. Vibration Isolators

- a. Fan vibration isolators shall be provided and installed by AHU manufacturer. Reference *Section 23 34 00 - HVAC Fans* regarding fan vibration isolation.
 - b. Spring type vibration isolators with seismic restraints shall be provided per fan manufacturer’s recommendation. Spring type isolators shall deflect 1-2” minimum based upon fan size. Isolators shall be selected for isolation efficiency of 95% minimum. For small fans rubber isolators are allowable as recommended by fan manufacturer.
 - c. As required, structural inertia bases shall be provided with 2” spring isolators, concrete factory poured. *[Note to PSC: If spring-supported inertial base is required show on drawings.]*
 - d. Thrust restraints shall be provided as required to limit horizontal movement of fan to ¼”.
 - e. Fan(s) shall be sufficiently isolated such that isolation of AHU assembly is not required.
25. Each fan shall be statically and dynamically balanced within assembled unit as required to bring vibration levels within limits specified in *Section 23 34 00 – HVAC FANS*.
- a. Referenced section indicates maximum allowable fan vibration level as follows:

- 1) Belt-driven fans: 0.15 in/sec peak velocity, filter in
- 2) Direct drive fans: 0.10 in/sec peak velocity, filter in.

D. Coils

1. Coils shall fully comply with requirements of Section 23 82 16 – Air Coils. Referenced section presents more complete and detailed specifications for coils. As such, it shall be incorporated in its entirety into this document, Section 23 73 23 – Custom Air Handling Units by means of this reference.
2. Provision shall be made for coils of adequate size to satisfy specified face velocity and pressure drop limitations. Specified face velocity limitations shall not be exceeded.
3. Individual coil sections (i.e. sections with continuous plate fins) shall not exceed 48” in height.
4. Length of coil sections shall not exceed limitations of available coil pull space provided adjacent to unit.
5. Pre-engineered structural frame shall be provided such that coil sections are supported independently of each other. Coil sections shall be removable independently without affecting other coil sections above, below or on either side. Such may require installation of horizontally staggered coil sections.
6. Unit shall be configured such that all coils are removable by sliding out through side of unit. Structural frame shall be configured to facilitate such removal. Individual access panels shall be provided as required. Piping and other exterior system components shall be configured to facilitate such removal. Access panels shall be provided on opposite end of coil to facilitate future repair of return bends. *[Note to PSC: “Slide out” configuration can substantially facilitate coil removal and replacement. It is not an uncommon requirement for University campuses. If this configuration is deemed inappropriate or unnecessary a standard “through-the-door” design may be pursued. Owner approval is required prior to proceeding with any design other than slide-out.]*
7. Structural channels shall be provided to support cooling coils within drain pans.
8. Coil supports and blank-offs shall be of same material as coil casing.
9. Coils shall be completely enclosed within unit casing including all return bends and headers.
10. Fasteners and hardware shall be same material as connected components. Where connected components are dissimilar material, stainless steel fasteners shall be used.
11. Coil piping, drain and vent connections shall be extended full size to unit exterior, same side as access doors unless otherwise indicated on drawings. Coil piping shall extend 4-6” beyond unit exterior.
12. Alternatively, vents and drains, complete with valves, may be configured to discharge into respective drain pans inside unit. In such case, valves shall be readily accessible to maintenance staff. Reference related specifications for valve requirements.
13. Pipe connections within unit shall be welded or brazed. Grooved fittings or press fittings not allowed.
14. Coil headers and piping within unit shall insulated by Installing Contractor as required to prevent undesirable heat transfer or condensation. Reference *Section 23 07 19 – HVAC Piping Insulation* for insulation requirements. Protective lagging shall be provided by unit manufacturer on all insulated piping within housing. Insulation and lagging shall be applied after unit and piping system has been installed and tested.
15. Coils shall be installed dead-level in unit to ensure complete drainage by gravity.
16. Moisture eliminators, if scheduled or shown on drawings shall be chevron type.

E. Filters

Filters shall fully comply with requirements of Section 23 40 00 – HVAC Air Cleaning Devices. [Note to PSC: At the time of this writing, reference to Section 23 40 00 serves as a place-holder. Section has been temporality removed from Standards pending updating

1. Filters shall be front loading unless indicated otherwise on drawings.
 2. To greatest extent possible filters shall be 24" x 24" nominal size. Otherwise filters shall be 24" x 12".
 3. Prefilters shall be 4" pleated type, MERV 8. Final filters shall be 22" bag type, MERV 11 for standard applications and MERV 14 for laboratory applications. Additionally filtration shall satisfy applicable LEED requirements. *[Note to PSC: Edit as appropriate for project and ensure coordination with drawings.]*
 4. Prefilters and final filters shall be positioned within AHU to provide filtering of all air passing through coils, fans and auxiliary devices.
 5. If airflow entering heat recovery wheels, plate heat exchangers or coils is otherwise unfiltered, filter shall be provided upstream of such devices. Filters shall be 4" pleated type, MERV 8.
 6. Filter frames shall be designed to hold specified prefilters and final filters in single frame. Filter frame assemblies shall be provided by Manufacturer and shall be factory installed.
 7. Filter frames shall be assembled into racks. Structural supports shall be provided as required for rigidity.
 8. Filter frames shall be standard universal clip type constructed of 16 gauge galvanized steel for standard applications.
 9. Filter frame assemblies larger than two 24"x24" panels high by three 24"x24" panels wide shall utilize UIUC filter retention system per *Drawing 23 41 00-1*. System utilizes EMT conduit for filter retention as opposed to standard clips.
 10. Filter frames shall incorporate sealing flange with replaceable gasket.
 11. Filters used during pre-occupancy building purge shall satisfy LEED requirements.
 12. Final filters located within AHU downstream of all other internal components shall be provided only as required for special application.
- D. Control Dampers
1. Control dampers shall be provided as shown on drawings and as specified.
 2. Control dampers shall include:
 - a. Steam coil face and bypass dampers
 - b. Cooling coil bypass dampers
 - c. Energy recovery wheel bypass dampers
 - d. Heat pipe face and bypass dampers
 - e. Plate heat exchanger face and bypass dampers
 - f. Air blender bypass dampers
 3. Control dampers shall fully comply with requirements of *Section 23 09 13.43 - Control Dampers*. Special consideration shall be given to following:
 - a. Damper placement/configuration for optimized airflow mixing
 - b. Damper type (opposed vs. parallel blade) for optimized control.
 - c. Adequate pressure rating for AHU test pressure
 - d. Proper sizing for adequate damper authority

- e. Ease of damper removal/replacement
- f. Access to damper linkage
- g. Provision for proper actuator mounting

[Note to PSC: Ensure that these items are adequately addressed within project design documents including drawings.]

4. Control dampers internal to unit shall be furnished and installed by AHU manufacturer. Damper actuation/automation shall be provided by Temperature Control Contractor.
5. Mixing dampers shall be configured to maximize mixing of outdoor air and return air. To degree possible, outdoor air path shall be located above and centered upon return air path to minimize stratification.
6. “Minimum outdoor air dampers” shall be provided to ensure provision of and optimized control of ventilation and makeup air during periods of reduced total outdoor airflow.
7. When face-and-bypass dampers are provided with standard (non-IFB) steam preheat coil(s), bypass damper shall be “external” type. Bypass airflow shall be introduced back into air stream downstream of cooling coil. Configuration shall prevent “wiping” of downstream face of cooling coil with cold air. Face-and-bypass dampers with “internal” bypass around heating coil only not allowed.
8. In cooling mode, external bypass damper shall allow no air leakage resulting in bypass of unconditioned warm/humid around cooling coil.
9. Automated bypass damper shall be provided at air blending device to increase velocity when mixing of airstreams is required (closed position) and to decrease pressure drop when mixing is not required (open position). *[Note to PSC: Show damper on drawings. Damper is to be sized and placed to optimize both functions. If damper not required for proper air blender operation delete this paragraph. Damper typically required. Reference section above entitled Air Blending Devices.]*
10. Without exception, automated dampers shall be provided in both air streams at each energy recovery wheel (i.e. outdoor/supply, return/exhaust) to enable bypass of air when wheel is not active to reduce air pressure drop, facilitate economizer operation and provide frost control.
11. Automated face and bypass dampers shall be provided at plate heat exchangers to enable bypass of air when heat exchanger is not active to reduce air pressure drop, facilitate economizer operation and provide frost control.

[Note to PSC: Fan isolation dampers or removable inlet blank-offs are to be provided for multiple parallel fans to prevent reverse flow through an idle fan. Reference paragraph above entitled Fans and Motors]

12. Damper design and installation shall be coordinated with Temperature Control Contractor.

F. Electrical

1. Electrical components and installation thereof shall comply with National Electric Code (NEC).
2. Electrical components and assemblies shall comply with NEMA standards.
3. Electrical components and assemblies shall comply with all requirements of UIUC *Facilities Standards – Division 26 – Electrical*

[Note to PSC: Review applicable UIUC Standards and ensure that all requirements are incorporated into project documents.]

4. Conduit and Conductors

- a. Electrical conduit and conductors for power, lighting, and other devices shall be provided by AHU manufacturer, factory and/or field installed. Field installation of conduit and conductors at shipping splits shall be provided by Installing Contractor.
 - 1) Exception: Conduit, conductors and enclosures shall not be provided for motors served by VFDs. In such cases conduit, conductors and enclosures shall be furnished and field installed by Electrical Contractor.
 - 2) Location and size of associated wall openings shall be coordinated with Electrical Contractor.
 - b. Separate circuits shall be provided for electrical power, lighting and controls/instrumentation.
 - c. All conductors shall be enclosed within electrical conduit.
 - d. Conduit and conductors shall be terminated at one or more junction boxes or approved enclosures on unit exterior.
 - e. Size and location of conduits and electrical enclosures shall be coordinated with Electrical Contractor. Excess length of conductors shall be provided at each enclosure, coiled and tie wrapped.
 - f. Conduit shall be EMT, 3/4" minimum. Non-metallic conduit not allowed.
 - g. Use of flexible conduit shall be limited to that required by NEC. Flexible conduit shall not exceed 3' in length and shall be as short as possible at AHU shipping splits.
 - h. Use of flexible conduit in lieu of EMT not allowed.
 - i. Exposed conduit shall be securely clamped and supported with metallic pipe supporting devices rigidly fastened to structure.
 - j. Conduit shall be supported not more than 12" from points of connection to boxes and fittings. Conduit bends shall be supported not more than 12" from each change in direction.
 - k. All wall penetrations shall be sleeved and sealed as specified in *General Requirements* above to prevent air leakage and migration of moisture into insulated wall cavity.
 - l. Conduit shall be sealed in accordance with *NEC* to prevent moisture migration resulting in condensation within electrical components.
5. Electrical Receptacle
- a. 20 Amp duplex electrical receptacle shall be provided, mounted on unit exterior.
6. Lighting
- a. Dedicated electric lighting shall be provided within each section of AHU. Lighting shall be factory mounted replaceable LED lamps within moisture tight corrosion resistant fixtures.
7. Dedicated switch shall be provided on unit exterior for each unit section. Switch shall be spring return timer type.
8. Auxiliary Equipment
- a. Factory installed conduit and wiring shall be provided for auxiliary equipment and shall be terminated in junction box or approved enclosure on AHU exterior. Conduit and conductors shall be provided for factory mounted controller as applicable. Exception: Conductors shall not be provided for VFD driven motors.
9. Electrical Receptacle
- a. 20 Amp 120 VAC duplex receptacle shall be provided in appropriate enclosure on unit exterior.

F. Controls

[Note to PSC: Owner is to be contacted to confirm control requirements for specific project. Sections below are to be edited as appropriate.]

1. Control dampers and actuators shall be furnished and factory installed by AHU manufacturer in compliance with referenced specifications.
2. Filter differential pressure gauge(s) shall be furnished and installed by AHU manufacturer in compliance with specification provided herein.
3. Ultraviolet light controls shall be provided by AHU manufacturer.
4. With exception of items listed above, controllers and associated devices for monitoring and control including sensors, tubing, conduit, conductors and enclosures shall be furnished and field installed by others. Programming shall be provided by others.

G. Hydronic Piping and Valves

1. Hydronic piping and valves exterior to AHU shall be provided by AHU manufacturer only if specifically indicated within project documents. Reference related specifications for piping and valve requirements as applicable.

H. Humidifiers

1. Humidifier shall be provided if indicated within project documents. Humidifier shall be steam-to-steam reboiler type consisting of steam generation unit, steam dispersion manifold and associated components.
2. Entire humidifier assembly including steam generation unit, dispersion manifold, associated components and controls shall be furnished by Heating Contractor unless indicated otherwise within project documents. Heating Contractor shall furnish dispersion manifold, mounting brackets and hardware to AHU manufacturer for factory installation within AHU.
3. Humidifier manifold shall be securely positioned within dedicated AHU section located between heating coil and following downstream component (typically cooling coil) unless indicated otherwise on drawings. *[Note to PSC: Humidifier manifold may be provided in heating coil section in lieu of dedicated humidifier section only if required to shorten unit. Stainless steel drain pan must still be provided in appropriate section(s) to capture water droplets.]*
4. Steam piping and manifold shall be insulated to provide burn protecting and minimize heat transfer to airstream. Insulation shall be provided by Installing Contractor.
5. Access section with man door shall be provided on both sides (upstream and downstream) of humidifier manifold unless indicated otherwise on drawings. In no case shall manifold be positioned less than 6" from upstream component or 18" from downstream component.
6. Steam shall be fully dispersed no less than 12" upstream of following component (typically cooling coil) under any operating condition. Undispersed water shall not impinge or condense upon said component.
7. Steam supply and condensate drain piping shall be extended through AHU housing and terminated outside unit.
8. Approved Manufacturers
 - a. Dri-Steem
 - b. Armstrong

I. Ultraviolet (UV-C) Lights

1. UV-C lighting system shall be provided if indicated within project documents. UV-C fixtures and lamps shall be provided by AHU manufacturer, factory installed.

2. Performance
 - a. Design of UV-C light array shall assure that UV-C energy striking intended coil and drain pan surfaces shall not be less than 200 microwatts / sq. centimeter and provide not less than 99 percent surface disinfection efficiency. Minimum intensity at any point on surface plane of coil must exceed 50 microwatts / sq. centimeter. Energy consumption at design intensity shall not exceed 13 watts / sq. ft. of treated, cross sectional plane.
3. Lamps and Fixtures
 - a. UV-C lamps and fixtures shall be positioned to provide equal distribution of UV-C energy and minimize shadowed areas.
 - b. Fixtures and lamps shall be configured for ease of lamp replacement. Lamps shall be field replaceable stock items.
 - c. Fixtures and racks shall be stainless steel construction.
 - d. Fixtures shall meet UL drip-proof design criteria.
4. Controls
 - a. UV-C system shall incorporate power source and controls.
5. Polymeric Materials
 - a. All polymeric materials shall be fully shaded from direct or indirect exposure to UV-C light.
6. Safety
 - a. Access doors that yield potential exposure of personnel to UV-C light shall be equipped with interlock switches to disable lights when opened.
 - b. In addition to mechanical interlock switch, each AHU shall be equipped with externally mounted switch that disconnects power to UV-C lights.
 - c. AHU shall have OSHA compliant safety warning label(s) applied to exterior of section that contains UV-C lights.
 - 1) Units with interlocking doors shall be marked with the words "WARNING UV LIGHT SOURCE"
 - 2) Units without interlocking doors shall have the same wording plus "DISCONNECT POWER BEFORE SERVICING".
7. Basis of design: Steril-Air
8. Other approved manufacturers
 - a. Evergreen
 - b. Lumalier
 - c. UV Resources
- I. Instrumentation
 1. Differential pressure gauge
 - a. Differential pressure gauge shall be provided at each filter bank, viewable on exterior of unit.
 - 1) Die cast aluminum case and bezel with acrylic cover
 - 2) 4" diameter face
 - 3) $\pm 2\%$ full scale accuracy
 - 4) 0-2.0" w.c. range

- 5) Adjustable set point indicator
 - 6) Static pressure probes
 - 7) Mounting bracket
 - 8) Basis of design: Dwyer Magnehelic Series 2000
- b. Gauge shall be exterior bracket mounted for ease of removal and access to tubing connections.
 - c. Separate differential pressure transmitter shall be provided by Temperature Control Contractor for remote monitoring.
2. Flow Sensors
- a. If indicated within project documents (including referenced fan specifications), piezometric ring sensor shall be provided at fan inlet cone, optimally positioned. Sensing ring shall be furnished and factory-mounted by fan manufacturer. *[Note to PSC: If flow ring is required delete "If indicated..." Piezometric ring sensors are to be used only for constant flow or limited turn-down applications given that they typically have poor turn-down performance. Accuracy shall be evaluated at lowest airflow rate anticipated.]*

2.7 ENERGY RECOVERY WHEEL(S)

A. Performance

- 1. Manufacturer shall provide certified performance data in accordance with ASHRAE Standard 84 and AHRI 1060. Independent performance test results shall be used to rate product in accordance with AHRI Air-to-Air Energy Recovery Ventilation Equipment Program.

B. General Requirements

- 1. Casing
 - a. Rotor casing shall be provided with structural framework to rigidly support rotor.
 - b. Casing sheet metal shall be reinforced as required to provide solid mounting surface for peripheral and radial seals.
- 2. Rotor
 - a. Rotor frame shall be hub, spoke and rim system constructed of extruded aluminum.
 - b. Rotor shall not deflect in excess of 1/32" from no-flow condition to full design airflow condition. Deflection shall be measured at rim of wheel where exposed to greatest force of airflow. Deflection shall be measured relative to wheel support frame.
 - c. Rotor design shall allow replacement of media segments in field conditions without removal of rotor.
 - d. Anti-rotation feature shall be provided to prevent reverse rotation.
 - e. Energy recovery wheels that require field assembly shall be assembled by service personnel in direct employ of Manufacturer, no exceptions.
- 3. Rotor Bearings
 - a. Rotor shall be supported by two pillow block bearings that can be maintained and replaced without disassembly of rotor.
 - b. Bearings shall provide L10 life of 1,000,000 hours operation.
- 4. Rotor Seals

- a. Face seal and perimeter seal shall be provided to prevent cross leakage between two air streams.
5. Seals shall be field adjustable non-contact labyrinth type.
- a. Factory fabricated field adjustable purge unit shall be provided.
 - b. Purge shall be designed to limit cross contamination to less than 0.5% of exhaust stream concentration at any operating condition for standard applications. Cross contamination shall be limited to 0.04% for laboratory fume hood applications or other systems conveying toxic or noxious vapors.
6. Drive
- a. For units with design airflow 10,000 CFM and less, rotor shall be driven by belt system and electric motor. For units with design airflow greater than 10,000 CFM rotor shall have direct gear drive.
 - b. Variable speed control of wheel for capacity and frost control shall be accomplished via use of VFD. VFD shall comply with *Section 26 29 23 - Variable Frequency Motor Controllers* for VFD requirements.
 - c. Motor shall comply with *Section 26 29 00 - Common Motor Requirements*.
7. Coating
- a. For non-laboratory applications, all metal surfaces shall be provided with corrosion resistant coating.
 - b. For laboratory applications, all metal surfaces exposed to airflow shall receive acid resistant epoxy or phenolic coating. *[Note to PSC: If different material or coating is more appropriate for specific application such is to be identified and inserted into specification in lieu of specified coating.]*
8. Filters
- a. Filtration shall be provided upstream of energy recovery wheel in each air path. As indicated within filter specification above, filters shall be front loading 4" pleated type, MERV 8.
 - b. Filter assembly shall comply with requirements presented above in paragraph entitled *Filters*.
9. Bypass Dampers
- [Note to PSC: Bypass dampers are to be shown on project drawings. Dampers may not be deleted from design without the written approval of owner.]*
- a. Without exception, automated dampers shall be provided in both air streams at each energy recovery wheel (i.e. outdoor/supply, return/exhaust) to enable bypass of air when wheel is not active to reduce air pressure drop, facilitate economizer operation and provide frost control. Dampers shall be sized such that combined airflow through damper and wheel is sufficient for 100% outdoor air economizer.
 - b. For laboratory fume hood or other corrosive vapor applications, dampers shall be constructed of type 304 or type 316 stainless steel and/or or coated with appropriate phenolic material (e.g. Heresite) *[Note to PSC: If different material or coating is more appropriate for specific application, such is to be identified and inserted into specification in lieu of specified coating (e.g. some applications may require type 316 stainless steel in lieu of type 304).]*
 - c. Bypass dampers shall comply with requirements presented above in paragraph entitled *Control Dampers and Actuators*.
10. Controls
- [Note to PSC: Owner is to be contacted to confirm control requirements for specific project. Sections below shall be edited as appropriate.]*

- a. All controllers, associated control devices and programming shall be provided by Temperature Control Contractor in accordance with requirements of *Section 23 09 23 – Building Automation System (BAS) for HVAC* and *Section 23 09 13 – Instrumentation and Control Devices for HVAC*.
- b. Manufacturer / Installing Contractor shall coordinate installation of controls and startup of AHU with Temperature Control Contractor.

C. Media

1. Total Enthalpy Wheel

- a. Wheel shall provide both sensible and latent heat recovery. Sensible and latent heat transfer effectiveness shall meet or exceed scheduled values.
- b. Energy recovery effectiveness values shall be tested in accordance with ASHRAE 84 and shall be certified in accordance with AHRI Standard 1060.
- c. Media shall consist of corrugated aluminum foil substrate coated with molecular sieve desiccant or ion exchange resin configured into honeycomb structure. Edges shall have anti-corrosion coating.
- d. Corrugations shall have high surface area per volume to ensure no fouling occurs on internal heat transfer surface. Dry particles up to minimum of 800 shall freely pass through media.
- e. Molecular sieve and ion exchange resin coating shall be designed to selectively transfer water vapor while allowing other gaseous chemicals to pass.
 - 1) For laboratory applications (corrosive, toxic or noxious vapors):
 - (a) Molecular sieve desiccant internal pore diameter shall limit absorption to materials having 3 angstrom kinetic diameter or less.
 - (b) Ion exchange resin shall provide same or better performance in all regards.
 - 2) For standard applications, including laboratory general exhaust:
 - (a) Molecular sieve desiccant internal pore diameter shall limit absorption to materials having 4 angstrom kinetic diameter or less.
 - (b) Ion resin shall provide same or better performance in all regards.
- f. Media shall be cleanable with low temperature steam, hot water or light detergent solution without degrading latent recovery.
- g. Media shall have flame spread of less than 25 and a smoke developed of less than 50 when rated in accordance with ASTM E-87.

2. Sensible-Only Wheel

- a. Wheel shall provide sensible heat recovery. Sensible heat transfer effectiveness shall meet or exceed scheduled values.
- b. Heat recovery effectiveness values shall be tested in accordance with ASHRAE 84 and shall be certified in accordance with AHRI Standard 1060.
- c. Media shall consist of corrugated aluminum foil substrate with corrosion resistant coating configured into honeycomb structure.
- d. Corrugations shall have high surface area per volume to assure no fouling occurs on internal heat transfer surface. Dry particles up to 800 microns shall freely pass through media.
- e. Media shall be cleanable with low temperature steam, hot water or light detergent solution without degrading latent recovery.

- f. Media shall have flame spread of less than 25 and smoke developed of less than 50 when rated in accordance with ASTM E-87.

D. Sizing

- 1. Heat wheel shall be sized to yield average face velocity not to exceed 800 FPM.

2.8 PLATE HEAT EXCHANGER

[Note to PSC: Potential difficulty of cleaning plate heat exchangers is a significant concern when considering their use. The goal is that plate heat exchangers be designed and selected such that they are no more difficult to clean than an eight row air coil, 12 fins/inch. Cleaning method typically utilizes power washing.]

A. Description

- 1. Plate heat exchanger shall be stand-alone assembly of parallel heat transfer plates affixed within rigid supporting framework configured for installation within air handling unit.

L. Performance

- 1. Plate type air-to-air heat exchanger shall be AHRI Certified to *Standard 1060 – Performance Rating of Air-to-Air Exchangers for Energy Recovery Ventilation Equipment* and shall bear the AHRI Certified Product Seal.

C. Materials of Construction

- 1. Clean air applications, including laboratory general exhaust:
 - a. Aluminum
- 2. Laboratory fume hood exhaust; other systems conveying corrosive vapors:
 - a. Type 304 stainless steel or phenolic coated

D. Condensate Management

- 1. Heat exchanger shall be designed and oriented to facilitate condensate drainage to drain pan below without restricting airflow.
- 2. Heat exchanger shall be sized/selected to achieve design performance without condensate carryover into air stream. Face velocity shall typically not exceed that of associated cooling coil within AHU.

E. Leakage

- 1. Clean air applications including laboratory general exhaust
 - a. 1% airflow at 1.5" w.c. differential pressure
- 2. Laboratory fume hood applications
 - a. 0.1% airflow at 1.5" w.c. differential pressure

E. Dampers

[Note to PSC: Face and bypass dampers are to be shown on project drawings. Dampers may not be deleted from design without written approval of Owner.]

- 1. Automated face and bypass dampers shall be provided to enable bypass of air when heat exchanger is not active to reduce air pressure drop, facilitate economizer operation and provide frost control.
- 2. Dampers shall be sized such that combined airflow through bypass damper and heat exchanger is sufficient to provide 100% outdoor air economizer.
- 3. For laboratory fume hood or other corrosive vapor applications, dampers shall be constructed of type 304 or type 316 stainless steel and/or or coated with appropriate phenolic material (e.g. Heresite) *[Note to PSC: If different material or coating is more appropriate for specific application, such is to be identified and inserted into*

specification in lieu of specified coating (e.g. some applications may require type 316 stainless steel in lieu of type 304).]

4. Dampers shall comply with requirements presented above in paragraph entitled *Control Dampers and Actuators*.
5. Dampers shall conform to requirements of *Section 23 09 23 – Control Dampers*.

2.9 KNOCK-DOWN UNITS

- A. Knock-down construction for field assembly of AHU shall be provided if transfer constraints prevent suitable installation of factory assembled unit and shall satisfy following requirements:
 1. AHU components and pre-assembled sections shall be provided in sizes that can be readily transported to installed location based upon design documents and/or facility drawings.
 2. AHU shall be designed and constructed such that no field modification (e.g. re-drilling of holes) is required.
 3. Non-permeable gaskets shall be provided at all connections. Holes in gaskets shall be pre-punched. Use of caulk, butyl tape, mastic or similar material as primary sealing method not allowed.
 4. Each piece or assembly of pieces shall be clearly marked and referenced to a clear assembly drawing.

2.10 ALUMINUM AIR HANDLING UNITS

“Aluminum Unit” shall be provided in lieu of standard air handling unit specified herein if indicated within project documents. *[Note to PSC: As stated above, aluminum units have traditionally been specified and installed for purposes of decreasing weight of assembled unit and/or for durability on outdoor applications. However, in many cases there is no longer a significant upcharge for providing an aluminum unit in lieu of a standard unit. If so, AHUs are to be aluminum units. Reference section below entitled ALUMINUM UNIT. Confirm relative pricing of units for project and discuss unit type with F&S Engineering prior to final design.]*

- A. Aluminum unit shall satisfy all requirements specified herein for standard unit with following exception: Galvanized and/or coated carbon steel components shall be replaced with comparable aluminum or aluminum alloy components including but not limited to casing panels, doors and structural base.
- B. Each component of aluminum unit shall possess, at a minimum, equal structural strength and rigidity as same component in standard unit. Gauge, weight and dimension of each aluminum component shall be adequate to satisfy such requirement.
- C. Specified deflection limits for standard units apply to aluminum units.
- D. Specific requirements:
 1. Minimum Sheet Thickness
 - a. Outer casing: 0.063” minimum (14 gauge)
 - b. Outer roof casing: 0.08” minimum (12 gauge)
 - c. Interior liner: 0.063” minimum (14 gauge)
 - d. Walk-on floor: 0.125” minimum (8 gauge)
 - e. Subfloor liner: 0.063” minimum (14 gauge)
 2. Exterior aluminum sheet surfaces shall be stucco embossed.

2.11 OUTDOOR AIR HANDLING UNITS

- A. Design of outdoor air handling unit shall be based upon “standard unit” or “aluminum unit” as indicated within project documents and as specified above. *[Note to PSC: Installation of aluminum outdoor air handling unit in lieu of standard outdoor unit is encouraged. Discuss with F&S Engineering prior to final design.]*
- B. Outdoor air handling unit shall satisfy all specified requirements for indoor air handling unit plus additional requirements as identified below. Indoor air handling unit shall not be installed outdoors.
- C. Outdoor unit shall incorporate walk-in vestibule or reach-in enclosure as specified below.
- D. Outdoor AHU shall be specifically designed for exposure to harsh weather conditions, including high wind, heavy snow loading, torrential rain and UV exposure. At minimum, requirements shall comply with all applicable design and construction standards for geographic location.
- E. Exterior surfaces:
1. All exposed steel surfaces shall receive electrostatically applied powder coat or baked enamel coating. Any scratches or defects in coating shall be touched up after installation per manufactures recommendations. Any coating substitution shall be approved by PSC prior to unit construction. *[Note to PSC: Confirm with Manufacturers that specified coating is available and economically viable. Better to specify required coating prior to bid than to approve substitution after bid.]*
 2. Coating not required for aluminum or stainless steel surfaces unless required by Architect and indicated within project documents. Aluminum sheet surfaces shall be stucco embossed.

[Note to PSC: If appearance of exterior unit is a consideration, consider requiring embossed aluminum panel surfaces given that imperfections, warping, and oxidation are substantially more visible than coated metal surfaces. Edit spec language accordingly.]
 3. Color of visible exterior surfaces shall be selected by Architect. Color sample shall be submitted for approval.
- F. To greatest degree practical, air handling unit shall be configured to provide adequate height for walk-in vestibule (e.g. by providing vertically stacked fans rather than side by side).
- G. Vestibule, Walk-in
1. Minimum of one full-length, full height service vestibule with interior walkway shall be provided for each outdoor air handling unit greater than or equal to 60” interior clear height.
 2. Vestibule shall be integral to unit. Multiple vestibules shall be provided as required to provide specified access to all sections of AHU including supply and return/exhaust air paths.
 3. Vestibule structure, panels, floors, doors and components shall be of same material and construction as balance of AHU. Vestibule shall satisfy specified requirements for base AHU. Exception: Standard floor design without upturned lips may be used in vestibule in lieu of welded floor design. Otherwise, requirements for materials and insulation remain as specified.
 4. Vestibule shall be adequately sized and configured to satisfy all accessibility requirements specified for standard indoor unit.
 5. Additionally, vestibule shall be 54” wide minimum interior clear dimension between interior wall of vestibule and wall of AHU.
 6. Additionally, vestibule shall be of adequate dimensions to house pumps, piping, valves, controls, VFDs, panels and other components in manner that provides adequate access for operation, maintenance and replacement.

7. Additionally, vestibule shall be of adequate dimension to provide 36" minimum clearance between vestibule wall and nearest component as listed above.
[Note to PSC: Design and coordinate installation of all components and appurtenances listed above to ensure specified clearances are achieved. AHU manufacture cannot ensure such clearances are maintained.]
8. One or more exterior doors shall be provided as required for convenient access and entry. Door(s) shall be sized and configured as required to satisfy specified access requirements. One or more oversized or double-doors typically required.
9. Vestibule shall incorporate OSHA compliant elevated interior walkway(s), ladder(s) and railings as required to provide safe and convenient access to elevated sections within AHU.
10. Lighting shall be provided as specified for unit interior. Multiple fixtures shall be provided as needed for adequate lighting. Switch shall be provided at each door.
11. Source of heating shall be provided to maintain comfort conditions within vestibule during winter weather conditions. Active or passive vestibule heating shall be provided as indicated within project documents. Coordination with other Contractors shall be provided.

[Note to PSC: Specification for heat source shall be provided. Active heat source may be hot water unit heater, electric unit heater or other heating device. Passive heat source may be dampered opening in AHU supply plenum or open grating in vestibule floor to allow transfer of tempered air from plenum below. Discussion with Owner is to occur prior to final design.]

12. Source of cooling shall be provided to maintain comfort conditions within vestibule during summer weather conditions. Active or passive vestibule cooling shall be provided as indicated within project documents. Coordination with other Contractors shall be provided.

[Note to PSC: Provide specification for cooling source. Active cooling source may be chilled water fan coil or similar unit. Passive cooling source may be dampered opening in AHU supply plenum or open grating in vestibule floor to allow transfer of tempered air from plenum below. Discussion with Owner is to occur prior to final design.]

F. Enclosure, Reach-in

1. In lieu of walk-in vestibule, exterior reach-in enclosure(s) shall be provided for each outdoor air handling unit less than 60" interior clear height (i.e. too short for internal vestibule). Enclosure(s) shall be integral to unit. Multiple enclosures shall be provided as required to provide weather protection for all pumps, piping, valves, controls, electrical, VFDs, and other components as required and/or as indicated on drawings.
2. Enclosures shall be sized and configured in manner that provides adequate access for operation, maintenance and replacement of all housed components.
3. Enclosure structure, panels, doors and components shall be of same material and construction as balance of AHU. Enclosure shall satisfy specified requirements for base AHU. Exceptions: Panels may be 2" double wall construction with R-12 minimum insulation value. Panelized floor design may be used in lieu of specified welded floor design. Otherwise, requirements for materials and insulation remain as specified.
4. One or more exterior doors with hinges and latches shall be provided as required for convenient access to all components. Door(s) shall be sized and configured as required to satisfy specified access requirements.
5. Provision shall be made for heating and cooling/ventilating vestibule(s) as required to maintain temperature within allowable limits.

[Note to PSC: Method of active or passive heating/cooling requirements is to be identified and clarified in project documents. Reference related notes above regarding heating/cooling of walk-in vestibules.]

G. Component Location

1. AHU manufacturer shall determine location of field installed AHU components (e.g. VFD(s), electrical panels/devices, control panel(s)/devices, mechanical piping/devices) and shall coordinate with Installing Contractors as applicable.
2. Clear dimensions at electrical panels shall comply with requirements of NEC.
3. Provision shall be made to access drain piping and trap(s) for cooling coil condensate and other fluids as applicable. Piping and trap(s) shall be removable for cleaning and replacement of same.

H. Component Access

1. Outdoor AHU shall be configured to facilitate removal of coils and other internal components including fans, motors, energy recovery wheels, etc. without significant unit disassembly. Components shall be removable through walk-in vestibule if applicable. If not possible as determined by PSC or Owner, components may be removed through opposite side of unit by means of removable panel(s) designed for such purpose.

I. Platforms

1. OSHA approved platforms, ladders and railings shall be provided as required for safe, convenient access to vestibule and entire reach-in enclosure as specified and shown on drawings.
2. Platforms shall be integral to unit or field erected as shown on drawings. If field erected, platform shall be provided by Installing Contractor.
3. Platforms shall be constructed of aluminum, stainless steel or epoxy coated steel.
4. Platforms shall be configured to facilitate maintenance and replacement of internal components and shall be adequate in strength and dimension to handle heaviest component.

[Note to PSC: Delete this section if platforms are not required. If external structure is required, show on drawings. If structure is substantial it may be appropriate to retain services of Structural Engineer and assign work to General Contractor. In such case, structural requirement may be removed from AHU spec.]

J. Roof

1. Roof shall cover entire unit including vestibule(s).
2. Roof shall be sloped 1/2"/ft., minimum. Roof shall be double sloped with center ridge if unit greater than 20 ft. overall width. *[Note to PSC: Width is to be edited as appropriate for project.]*
3. Roof deflection shall not exceed 1/240th of span with applicable snow and wind loading.
4. Minimum design snow load shall be 25 lbs./sq. ft.
5. Minimum design wind speed shall be 90 MPH.
6. Roof shall be standing seam type with 1 1/2" minimum rib height.
7. Roof shall be separate from AHU casing and shall be installed over casing with air gap between to guarantee no water penetration.
8. Construction shall use special brackets to hold outer roof to AHU casing in manner that eliminates any possibility of water leakage.
9. Roof panels shall be continuous with no end laps.

10. Roof shall extend beyond walls of unit to prevent sheeting of water. Flashing shall be provided at roof edge.
 11. Roof shall be factory installed. At shipping splits, adjacent roof sections shall be properly connected in field.
- K. Architectural Siding
1. Architectural siding shall be provided over unit exterior as indicated within project documents to satisfy aesthetic requirements and/or to provide additional weather protection.
 2. Architectural siding shall not be integral to unit construction. Siding shall be field applied over exterior of completed unit. Siding attachment channels shall be factory installed for field attachment of panels.
 3. Fasteners shall engage channels without penetrating exterior of AHU. Integrity of unit exterior shall not be compromised in any manner.
 4. Material type, thickness, construction details and flashing details shall comply with project drawings and specifications. Shop drawings indicating such shall be submitted to PSC for approval prior to manufacturing. *[Note to PSC: Provide design of siding and roofing system. Include in project drawings and specifications.]*
- L. Intake plenum
1. Intake air plenum section shall be provided upstream of filter section to serve as stilling basin for rain and snow.
 2. Outdoor air plenum shall be configured to yield constant air velocity across full face of filter bank such that maximum allowable airflow velocity is not exceeded at any point on downstream coil face.
 3. Plenum shall be 5 ft. minimum length in direction of airflow. This dimension shall not be reduced without approval of PSC and Owner. *[Note to PSC: Increased length may be required for specific project.]*
- M. Hoods and Louvers
1. Intake air hoods and louvers shall be provided to prevent ingress of rain and light powdery snow. Combination of hood and louver shall be provided at each intake opening. *[Note to PSC: The University has repeatedly experienced problems with filters becoming clogged with snow as a result of inadequate outdoor air intake design.]*
 2. Airflow velocity across net free area of each hood opening shall not exceed 400 FPM. Velocity across net free area of louvers shall not exceed 500 FPM.
 3. Intake hood shall be same material, thickness and coating as unit exterior.
 4. ½" bird screen shall be provided over exterior face of each louver.
 5. Air intake hoods and/or louvers shall be provided in end, side(s) and or top of plenum as required to satisfy airflow velocity limits. Top intake shall incorporate louvered penthouse (dog house) or hood as required. Free area velocity limits apply.
- N. Gutters
1. Gutters/channels shall be provided to shed water away from doors and other exterior components requiring such protection.
 2. 1" gutters shall be provided around perimeter of hoods and louvers to convey water away from air path.
- O. Doors
1. Doors shall be as specified for indoor AHU.
- P. Electrical

1. Electrical and control devices shall be located within walk in vestibule or reach in enclosure unless NEC dictates otherwise.
2. Exterior electrical enclosures shall be NEMA 3R.
3. Duplex outlet shall be GFI protected.
4. Exterior lighting and associated switching shall be provided as indicated on drawings. Coordination with Electrical Contractor shall be provided.
5. Interior lighting shall be provided as specified for indoor unit. Multiple fixtures shall be provided as needed for adequate lighting.

2.12 PLENUMS AND HOUSINGS

- A. Specifications provided herein shall be applied to following items as indicated within project documents to degree applicable
1. Plenums, including exhaust air fan plenums
 2. Housings
 3. Casings

[Note to PSC: It may be appropriate to decrease wall thickness requirement from 4" to 3" for specific applications.]

2.13 SPECIAL APPLICATIONS

[Note to PSC: Clearly identify project-specific application. Identify air contaminant type as applicable.]

- A. Laboratory fume hood exhaust and other systems conveying corrosive vapors:
1. All components, hardware and fasteners exposed to corrosive vapors shall be constructed of type 304 stainless steel or coated with appropriate phenolic material (e.g. Heresite). *[Note to PSC: If application warrants, replace type 304 stainless steel with type 316.]*
 2. Corrosion resistant components shall include but not be limited to sheet metal liners, floors, partitions, safing, filter frames, fans, dampers, heat transfer coils, structural members, electrical, lighting and all hardware and fasteners.
 3. Metal thickness and gauge shall be same as that specified for standard applications.
 4. Coated heat transfer coils shall provide scheduled performance after coating has been applied.
 5. Systems with ignitable concentrations of flammable gases:
 6. Fan, motor, electrical and other components shall comply with UL explosion standards.

[Note to PSC: Delete paragraph 2.12 above or provide project specific requirements.]

2.14 FACTORY PREASSEMBLY

- A. All units specified herein, excluding knock-down units, shall be fully factory assembled prior to shipment. *[Note to PSC: This requirement may be deleted if deemed appropriate. For example, if factory air leakage test is not required then it may not be essential to require factory preassembly.]*

2.15 FACTORY TESTING

[Note to PSC: Factory testing requirements are to be determined on a case by case basis and are to be discussed with Owner prior to finalizing design. Specifications for factory testing have been provided below. Each test may be incorporated into project specifications or deleted as deemed appropriate. Factory air leakage testing and associated cabinet deflection testing is most appropriate for fully assembled units that require no disassembly or reassembly. Field assembled units must be field leak tested after assembly is complete. Thus, in such

case, factory leakage testing may be of limited value. Sound testing and airflow testing may be deemed optional. These can only be performed in the factory.]

A. Prior Notification

1. Unit manufacturer shall notify Owner no less than 14 calendar days prior to factory testing to accommodate witnessing.

B. Testing Requirements

1. Unit manufacturer shall notify Owner no less than 14 calendar days prior to factory testing to accommodate witnessing. Complete factory testing shall be performed on all units as specified below unless indicated otherwise within project documents. Testing shall be in compliance with all applicable standards.
2. Exception: Factory testing not required for field assembled knock-down units. Testing as specified herein shall be performed on site.

[Note to PSC: Be mindful that testing includes up to four components, i.e. leakage, deflection, airflow and sound. It should be made clear that "factory testing" may apply to any or all of these.]

C. Air Leakage Test

1. AHU housing shall be assembled and factory pressure tested prior to shipment.
2. Testing shall be in compliance with ANSI/ASHRAE Standard 111.
3. Test pressure shall be 12" SP for positively pressurized unit sections and -12" SP for negatively pressurized unit sections unless indicated otherwise within project documents. Additionally, test pressure shall not be less than 1.25 x fan shut-off SP.
 - a. Exception: For units with design airflow 10,000 CFM or less test pressure shall be 10" SP in lieu of 12" SP.
4. Cabinet air leakage shall not exceed 1% of design airflow rate at test pressure unless indicated otherwise within project documents.

D. Deflection Test (Required)

1. Under air leakage test conditions assembled unit shall be factory tested for deflection prior to shipment.
2. Deflection of wall and top panels shall not exceed 1/240th of span.

E. Airflow Performance Test

1. Airflow testing shall be conducted for each fan or group of fans (e.g. fan array) by measuring discharge airflow while operating fan(s) at design total static pressure. Inlets and/or outlets shall be throttled as required to simulate field installed external static pressure.
2. Test requirements shall be satisfied without operation of "N+1" redundant fan if applicable.
3. Exception: Factor or field airflow performance test not required for knock-down units.

F. Sound Performance Test (Optional)

1. Air-born sound transmission measurement shall be taken at each AHU air inlet opening and each discharge opening with unit operating at design conditions. Radiated sound level measurement shall also be taken at design operating conditions. Test method shall be in compliance with applicable industry standard procedure. Sound power levels shall be identified for eight octave bands.
 - a. Sound power levels shall not exceed following:

Note to PSC: Complete table below as appropriate for project.

Octave Band	1	2	3	4	5	6	7	8
Frequency Hz								
Discharge dB								
Inlet dB								
Radiated dB								

- b. Modifications shall be made as required to satisfy specified maximum sound level in all octave bands. All modifications shall be approved by PSC.

I. FACTORY PREP

1. Unit shall be provided with factory blank-off panels at inlet openings, discharge openings, fan inlets and other locations required for field testing. Dampers or inlet screens located in these areas shall ship loose in unit for installation by Contractor after testing is complete.
2. Other provisions shall be made to prepare unit for field testing as identified in section below entitled *FIELD TESTING*.

2.16 ALTERNATE DESIGN

- A. Alternate design and/or construction method accomplishing intent of specifications may be submitted to PSC and Owner for review and potential approval. *[Note to PSC: Substantive alternate designs are to be discussed with Owner prior to approval.]*

PART 3 – EXECUTION

3.1 EQUIPMENT LOCATION

- A. Indoor unit shall be located to allow full access to all components.
- B. Indoor and outdoor unit shall be located no less than 24” to nearest wall or obstruction. *[Note to PSC: This allows room for personnel to access the back side of the unit to inspect and facilitate various repairs including repair of coil return bends.]*
- C. Outdoor unit shall be located no less than 48” from edge of roof.

3.2 EQUIPMENT SUPPORT

A. Indoor Unit

1. AHU shall be placed upon and firmly anchored to steel reinforced concrete pad provided by Installing Contractor.
 - a. Pad shall be anchored into concrete floor.
 - b. Pad shall be 6” minimum thickness.
 - c. Curb shall extend 6” beyond fan support frame on all sides, minimum.
 - d. Pad elevation shall be adequate to accommodate installation of cooling coil condensate drain trap and/or steam condensate drip trap at adequate elevation above floor to ensure full drainage during “worst- case” unit operation.
 - e. *[Note to PSC: AHUs are often installed with insufficient vertical height to accommodate required trap depth. This happens all-to-frequently and is not easily remedied. Design must incorporate generous AHU condensate outlet elevation relative to adjacent floor to ensure full drainage in worst case operating condition. Drawings are required to clearly indicate this requirement.]*

B. Outdoor Unit

1. AHU support system shall be provided by Installing Contractor as specified and shown on drawings.

[Note to PSC: Show field fabricated structure on drawings. If structure is substantial it may be appropriate to retain services of Structural Engineer and assign work to General Contractor. In such case, structural requirement may be removed from AHU spec.]

2. AHU shall be firmly mounted upon enclosed and insulated roof curb or open structural support system of adequate strength and rigidity to support full operating weight of unit.

- a. Curb and/or support system shall include support of full perimeter of unit including vestibule(s).

3. Roof Curb Requirements

- a. Roof curb shall place AHU at 12" minimum height above roof surface.

- b. Roof curb shall provide uninterrupted enclosure around entire perimeter of unit.

- c. Roof membrane termination and two piece counterflashing shall be provided as specified and detailed elsewhere within project documents and in compliance with published *UIUC Facilities Standards*. *[Note to PSC: Review applicable UIUC Standards and ensure that requirements have been incorporated into project documents.]*

- d. Curb shall incorporate continuous welded stainless steel cap, 16 gauge minimum. Horizontal surface of cap shall not be penetrated in any manner. Penetrations may be made through vertical portions of cap only. Attachment of structural members or hardware to horizontal surface of cap shall be made by means of welding only. All welded attachments shall be stainless steel.

- e. Curb design shall be provided as specified and detailed elsewhere within project documents and in compliance with published *UIUC Facilities Standards*. *[Note to PSC: Review applicable UIUC Standards and ensure that requirements have been incorporated into project documents.]*

4. Open Support Structure Requirements

- a. Open support structure and associated access platform shall provide 36" minimum clearance between bottom of structure and roof surface to facilitate roof maintenance and future replacement of roof membrane.

- b. Attachment of roof membrane to vertical supports shall be provided as specified and detailed elsewhere within project documents and in compliance with published *UIUC Facilities Standards*.

[Note to PSC: Review applicable UIUC Standards and ensure that requirements have been incorporated into project documents.]

3.3 INSTALLATION

- A. During site handling including crane transport, each factory assembled segment of air handling unit shall be structurally supported to prevent undue stress on unit components resulting in weakening or permanent deformation.

- B. AHU shall be assembled per Manufacturer's instructions and shall satisfy following requirements:

1. AHU shall be leveled to ensure full drainage of coils by gravity and proper operation of rotating equipment. Support structure/pad shall be rigid and level prior to installation.

2. Unit shall be firmly anchored to structural support in compliance with applicable code requirements.

3. For AHUs supported upon concrete curb, base frame shall be grouted after leveling and anchoring.

4. Shipping restraints shall be removed (e.g. spring isolators, coil headers).
5. Ductwork connections shall be made as indicated on drawings.
 - a. Ductwork connections to AHU plenums shall utilize expanded area transition fittings.
6. Filter media shall be installed.
7. Drain pans shall be piped individually to unobscured floor drain.
 - a. Existing drain shall be relocated as required.
8. Clearances
 - a. Adequate clearance shall be provided for full functionality of access doors and removal/replacement of major components including coils and fans.
 - b. Adequate clearance shall be provided for installed piping.
 - c. Adequate coil pull area shall be provided.
 - d. Piping and other exterior system components shall be configured for disassembly without substantial modification to facilitate coil slide out. Coordination with other Contractors shall be provided.
9. Touch-up
 - a. After installation is complete exterior coating, if provided, shall be touched up per Manufacturer's recommendations.

3.4 PLATFORMS, FIELD FABRICATED

1. OSHA approved platforms, ladders and railings shall be provided as specified and shown on drawings. Such shall provide safe, convenient access to plenum and exhaust fan assembly. Reference section above entitled *Platforms*.
2. Field erected platforms shall be structurally supported as specified for air handling units. Reference section above entitled *EQUIPMENT SUPPORT*.

[Note to PSC: As with outdoor AHUs, show field fabricated structure on drawings. If structure is substantial it may be appropriate to retain services of Structural Engineer and assign work to General Contractor. In such case, structural requirement may be removed from AHU spec.]

3.5 CLEANING

- A. When installation is complete, final cleaning of AHU shall be provided. AHU shall be cleaned to satisfaction of PSC and Owner. Cleaning requirement shall include coils and energy recovery wheel(s).
 1. *NADCA Standard ACR 2013 Assessment, Cleaning and Restoration of HVAC Systems* shall be utilized by PSC as basis for determining need for cleaning, extent and methodology to be employed.
 2. Only non-hazardous non-toxic cleaning agents and materials shall be used. MSDS cut sheets shall be provided upon request.

3.6 STARTUP

- A. Prior to start-up Installing Contractor and Manufacturer's service technician(s) shall verify following items have been completed:
 1. Unit is clean to satisfaction of PSC and Owner.
 2. Spring isolator shipping restraints removed and components leveled.
 3. All interconnections completed (i.e. electrical and control wiring, piping, casing joints, bolting, welding, etc.). Power wiring including motor starters and disconnects serving unit completed.
 4. IFB steam coil lower header restraints removed.

5. All water and steam piping connections completed, hydrostatically tested and all water flow rates set in accordance with capacities scheduled.
6. All ductwork connections completed and all ductwork pressure tested.
7. All temperature control and safety systems completed and functional.
8. All dampers fully operational.
9. All filter media installed and clean.
10. All bearings properly lubricated.
11. Belts properly aligned and tensioned.
12. Fan(s), energy recovery wheel(s) turn freely.
13. Energy recovery wheel purge(s) and seals properly adjusted and secured.
14. Condensate drain trap and piping properly installed.

B. Labeling

1. After ventilating system balancing has been completed by Balancing Contractor embossed label shall be permanently applied to front cover of VFD indicating airflow rate (CFM) and associated VFD output frequency (Hertz) as indicated within balance report.

Note to Contractor: This has not been a common practice but shall be performed before final approval.

3.7 FIELD TESTING

A. Air Leakage Test

1. Field assembled air handling units shall be tested for air leakage after assembly and prior to operation.
2. Testing shall be in compliance with ANSI/ASHRAE Standard 111.
3. Test pressure shall be 12" SP for positively pressurized unit sections and -12" SP for negatively pressurized unit sections unless indicated otherwise within project documents. Additionally, test pressure shall not be less than 1.25 x fan shut-off SP.
 - a. Exception: For units with design airflow 10,000 CFM or less test pressure shall be 10" SP in lieu of 12" SP.
4. Cabinet air leakage shall not exceed 1% of design airflow rate at test pressure unless indicated otherwise within project documents.

[Note to PSC: Test pressure and allowable leakage rate may be adjusted as appropriate for specific project.]

5. Modifications shall be made as required to pass test. Modifications shall be approved by PSC and Owner and shall be at Contractor's expense. Use of caulk and other sealants shall be minimized. Responsibility for providing corrective modifications falls jointly upon Ventilating Contractor and AHU Manufacturer.
6. Positive pressure test may be substituted for negative test only with approval of PSC and Owner. *[Note to PSC: Delete if desired. Evaluate difficulty of requiring separate test for positive and negative AHU sections.]*

B. Deflection Test

1. In conjunction with air leakage testing, assembled unit shall be tested for deflection under leak testing conditions.
2. Under air leakage test conditions deflection of wall and top casing panels shall not exceed 1/240th of span.

C. Airflow Performance Test

1. Airflow performance testing shall be conducted at factory only. *[Note to PSC: This is somewhat difficult to test on-site as compared to factory testing.]*

D. Sound Testing

1. AHU sound testing shall be performed at factory only. *[Note to PSC: This is not impossible to test on-site but can be quite difficult.]*

E. Field Balance

1. Field balance of fan/motor assembly not required unless, in judgment of PSC or Owner, vibration level is deemed questionable or unacceptable. In such case, vibration analysis and balancing shall be performed by qualified technician as specified above in section entitled *Factory Run Test / Balance*.
 - a. Referenced section indicates maximum allowable fan vibration level as follows:
 - 1) Belt-driven fans: 0.15 in/sec peak velocity, filter in
 - 2) Direct drive fans: 0.10 in/sec peak velocity, filter in

F. Energy Recovery Wheel

1. All applications
 - a. Thermal performance testing shall be conducted for total enthalpy and sensible heat wheels.
 - b. Testing shall be conducted by wheel manufacturer's authorized service technician. Testing shall be witnessed by PSC and Owner.
 - c. If purge setting is changed at any point throughout testing, tests shall be repeated at new setting.
 - d. Modifications shall be made as required to pass test as required per specification above. Modifications shall be approved by PSC and Owner and shall be performed by Manufacturer at no cost to Owner. If suitable modifications cannot be achieved, wheel shall be replaced at no cost to Owner.
2. Fume hood applications
 - a. Cross-contamination testing shall be conducted for wheels in laboratory fume hood applications where potential exists for contamination of supply air from contaminated exhaust airstream.
 - b. Test shall be conducted using SF-6 tracer gas testing procedure similar to that outlined by *ASHRAE Standard 84*.
 - c. Testing shall be accomplished by Owner approved independent test agency at expense of Manufacturer. Testing shall be witnessed by manufacturer's authorized technician, PSC and Owner.

[Note to PSC: Performance requirements are to be provided in project documents.]

[Notes to PSC: If testing is not deemed necessary, requirement for such may be deleted.]

*Given the high cost of cross contamination testing (e.g. \$20,000); such will be required only when concentration of known chemical(s) present at energy wheel exceeds threshold limit value (TLV) of chemical(s) present. **Subject to compliance with requirements, certain applications are not allowed to utilize cross-contaminating type energy recovery devices such as energy wheels.***

Owner will identify chemical(s) and concentration of each relative to TLV.

Concentration are to be based upon operation of system at design conditions and steady state operation of fume hoods. Adequate consideration shall be given to dilution rate within manifolded systems.

Concentration is to be based upon appropriate time average rather than instantaneous state.

Concentration is not to be based upon worst-case scenario. Attempts to identify "worst-case scenario" consistently lead to conclusions that are subjective and unrealistic. Consideration is to be given to significance of cross-contamination exposure relative to other potential sources of exposure.]

[Note to PSC: Based upon outcome of Owner evaluation, project specific documents are to clearly indicate test requirements for each system and quantitative performance requirements.]

[Note to PSC: Due to exorbitant cost of testing, previous requirement for one-year or five-year post startup testing has been deleted from specifications.]

END OF SECTION 23 73 23

This section of the *U of I Facilities Standards* establishes minimum requirements only.
It should not be used as a complete specification.