Modify Section 23 70 00 as follows*:*

Delete current parts .01 Air-Handling Equipment (General) and .02 Central Station Air-Handling Units in their entirety (deletions are not specifically shown below), to be replaced with the new subsection 23 73 00 as described below.

Relocate the current part .03 Energy Recovery Units into a new subsection 23 72 00 Air to Air Energy Recovery Equipment per below (deletions are shown struck through and additions are double underlined).

Add new subsection/heading 23 73 00 Air Handling Units and add new parts .01, .02 and .03 with all new text after the new subsection 23 72 00 (additions are double underlined).

Include hyperlinks for subsection headings and embedded hyperlinks in body of text.

23 70 00 CENTRAL HVAC EQUIPMENT

23 72 00 AIR-TO-AIR ENERGY RECOVERY EQUIPMENT

.~~03~~ 01 ~~Energy Recovery Units~~General

A. Refer to 01 80 00 PERFORMANCE REQUIREMENTS. In general, apply energy recovery equipment in accordance with current edition of ASHRAE Standard 189.1 Standard for the Design of High-Performance Green Buildings: Energy Efficiency - Prescriptive Option. ~~Consider for areas with high exhaust rates and 100% outdoor air systems.~~

1. The Standard 189.1 supersedes the minimum requirements in International Energy Conservation Code/ASHRAE 90.1. It requires energy recovery equipment when the system's supply airflow rate exceeds the associated tabular values based on the climate zone and percentage of outdoor air at design conditions.
2. The energy recovery system effectiveness required by Standard 189.1 is also more stringent than the current minimum building code requirements.
3. Provisions shall be made to bypass or control the energy recovery system to permit air economizer operation as required elsewhere in the Standard 189.1.
4. Exceptions:
   - ~~A.~~a. Do not apply rotary energy recovery wheels to systems with risk of cross leakage from contaminated air streams such as

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chemical lab fume hood exhaust or animal facilities. Use equipment with no potential for cross leakage.

B. Submit cost analysis and control sequence for approval prior to submission of final review drawings.

C. In general, any factory-assembled air handling units with energy recovery equipment shall comply with requirements in **23 73 00 AIR-HANDLING UNITS.**

D. Additional Design Resources:
   1. ASHRAE Systems and Equipment Handbook (current edition); Air-to-Air Energy Recovery Equipment
   2. ASHRAE GreenGuide: The Design, Construction and Operation of Sustainable Buildings, current edition.
   3. National Institute of Building Sciences (NIBS) - Whole Building Design Guide; HVAC and Refrigerating Engineering; High-Performance HVAC

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23 73 00 AIR-HANDLING UNITS

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.01 General Owner Requirements and Design Intent

A. Professional shall design each application for optimal operating efficiency, reliability, and flexibility with the lowest life cycle cost.
   1. Evaluate and select basic fan configuration of each AHU system (whether relief damper, relief fan, or return fan) for best balance of energy optimization and reliable control function. Follow industry recommendations and review with OPP Engineering Services early in the design process. The following are general OPP application guidelines:
      a. Relief damper: These are the simplest and least expensive but can be used only for air distribution systems with few individual spaces and little or no return ductwork (negligible return external static pressure requirements – less than approximately 0.10"). Relief dampers (low-leakage type) shall be sized to limit pressure loss to 0.08-0.10"
      b. Relief Fan: Recommended for systems that require forced relief beyond that provided by separate general exhaust for proper outdoor air/economizer and space pressurization control and that have low return duct static pressure requirements – between approximately 0.10-0.30".
      c. Return fan: These configurations are the most expensive and most complicated to install, control and operate. Therefore they should only be used to meet high pressure return requirements – greater than approximately 0.3 inches of water (per ASHRAE HVAC Systems and Equipment Handbook, Chapter 2, Air Handling Unit Components).
   2. High Performance Energy Efficiency: Comply with requirements in ASHRAE Standard 189.1 for:

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a. Demand Controlled Ventilation
b. Economizers
c. Fan System Power Limitation
d. Part Load Capacity Controls
e. Energy Recovery

3. Design for minimizing fan energy.
   a. The total allowable fan power limitation for each system shall be 10% less than the limits set by ASHRAE 90.1 or the current International Energy Conservation Code (whichever is more stringent), or as otherwise modified by most current edition of ASHRAE Standard 189.1.
   b. Minimize fan System Effects: Avoid poor fan inlet and outlet conditions that reduce fan performance and increase energy waste. Always consult manufacturer's installation guidelines.
   c. Select any associated coils and filters with low air pressure drops. Limit face velocity as follows:
      i. VAV systems: **400 (recommended) to 450 (max)** feet per minute (fpm)
      ii. Constant air volume systems: **300 (recommended) to 350 (max)** fpm.
   d. Carefully evaluate and properly select the most effective fan type and wheel to best suit the needs of the application with emphasis on minimizing operating and life cycle cost, rather than minimizing size and first cost.
      i. Typically the backward oriented wheel designs (airfoil, backward curved, and backward inclined) offer greater peak efficiency, greater strength and non-overloading power characteristics and should be used whenever available as an option in lieu of forward curved wheels for central fans and air handling equipment.
      ii. Fan selections at the actual operating point(s) shall be within 10 points of the peak total efficiency.
      iii. Plenum fans not recommended for high static (>6") applications.
      iv. Plenum fans might not comply with ARI 430. Verify.
      v. Direct drive fans: May be considered but they need to be carefully selected to match motor rpm closely to max fan rpm.

4. In cooling applications where there can be a net gain in energy performance, consider blow-through supply fan arrangement. Primary potential energy benefit is to reduce latent subcooling required to account for fan heat. Sensible heat of fan is added prior to coil and takes less energy to remove than to subcool air a few degrees below design supply air temperature (at saturated conditions) in typical draw-through

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arrangement. However, care must be taken to achieve evenly distributed air across coils in blow-through arrangement with the least pressure drop penalty or reduction in fan efficiency. Caution: Evaluate leaving air conditions and do not apply on systems in which discharge air conditions can cycle and cause condensation on components and casing downstream of cooling coil due to air being at or very near saturation.

5. Air Mixing/Blender Section: Recirculation systems intended with mixing of air streams shall have a mixing section with necessary components specifically engineered to achieve evenly and thoroughly mixed conditions prior to entering heating or cooling coils. This is critical in cold climates to avoid stratification and nuisance freezestat tripping. Complete mixing is also important to achieve optimal coil performance, controllability and energy efficiency. Professional shall include in the engineered design the application of air blenders, directional deflectors/baffles designed to force air streams into each other to mix, and/or blow-through supply fan arrangements in which air is mixed in fan section prior to coils. Manufacturers "standard" mixing damper sections have repeatedly performed inadequately and are not acceptable.
    a. Actual performance shall be field verified as part of Functional Performance Testing.
    b. Design for adequate mixing between leaving face and bypass preheat coils and entering cooling coils.
    c. Complete mixing external to AHU is another alternative.
    d. Other resources for further reference: Functional Testing Guide, Air Blenders and Baffle Plates
    e. Make sure blenders are designed for adequate mixing at lowest anticipated airflow. Lower face velocities can affect blender performance.

6. Coil Selection Criteria:
    a. Coils shall be "right-sized" for the application. Carefully evaluate operational full and part load profile and system turndown requirements. Do not substantially oversize and then rely on controls to effectively control at low load conditions.
    b. Design for low flow, high temperature differences, low water side pressure drop, and variable flow distribution systems to minimize pump energy.
    c. For buildings connected to campus utilities, coordinate requirements with 33 62 00 CAMPUS CHILLED WATER DISTRIBUTION and 33 63 00 STEAM ENERGY DISTRIBUTION as applicable.
    d. Selection of cooling coils in typical HVAC applications is recommended with a 14-16°F rise at peak conditions.
    e. For applications requiring cooling/dehumidification of high latent loads and reheat within the air handling unit such as Dedicated Outdoor Air Systems or high occupant assembly spaces, use

technologies to avoid or minimize use of mechanical cooling and simultaneous addition of heating and cooling energy. Options include:

i. Wrap-around dehumidification heat pipe cooling coil assemblies. http://heatpipe.com/abouthpt/heatpipes.htm
ii. Cross flow heat exchangers.
iii. Energy Wheels.

f. Freeze Protection: Reliable and effective means of freeze protection shall be provided on all applications in which coils are subject to freezing.

i. Recirculating units shall have air blenders to ensure thorough mixing as described above.
ii. Steam coils shall be steam-distributing type for even temperature distribution across entire coil with modulating control.
iii. Multiple Staged Coils: When high temperature rises are required (with high percentages of outside air and/or above typical preheat conditions of approximately 55°F), two or more single row staged steam heating coil assemblies, arranged in series in the airstream, controlled with individual control valves per stage provides some redundancy, protection against freezing, and better turndown control operation. Review project specific application with AHU manufacturer and Engineering Services.
iv. Face and Bypass: Some sources recommend that when entering air is near or below 32°F, the steam supply to the coil should not be modulated, but controlled to a reset minimum open or full open position to ensure continuous flow, which is less likely to freeze. Temperature control is then achieved via face and bypass damper assembly.
    a) However, face and bypass sections inherently cause large leaving temperature variations and require extra considerations for adequate means of remixing to prevent nuisance freezestat trips if cooling coil is located downstream.
    b) Integral face and bypass coils are an option but still require sufficient distance downstream and/or mixing baffle option.
    c) Alternately an external face and bypass assembly can be used to bypass unheated air around the heating coil and the cooling coil to the discharge or fan section to be remixed there without risk to cooling coil or freezestat trips.
    d) Internal face and bypass sections have tended to be the most problematic for temperature stratification and

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therefore shall be avoided if cooling coil is downstream.

v. Designers and installers must give particular care in the selection and installation of piping, controls, and insulation necessary to protect the coil from freeze-up caused by incomplete condensate drainage.
    a) Components shall include a vacuum breaker, thermostatic air vent, and a minimum 14" fill leg to trap inlet.
    b) Steam coil condensate drains shall be double trapped in parallel with fully redundant assemblies. On coils subject to freezing conditions, provide a Thermoton liquid expansion steam trap (Spirax/Sarco Type C Thermoton or similar) and isolation valve at lowest point to drain coil if condensate fails to drain through primary trap assembly. Trap shall be set to open and release subcooled condensate at 75°F. Trap outlet shall be rotated down for full drainage.

vi. Review other heating mediums with University when steam is not available.

vii. Hot water coils with glycol antifreeze circulating system fluid are another alternative.

viii. In general, coil freeze protection pump arrangements are strongly discouraged. Pumps themselves are prone to failure and would be required to be on emergency standby electrical power. Any exceptions for extreme cases must be reviewed with Engineering Services.

ix. Consider application of freeze burst protection via removable pressure relief caps on all return bends and applicable headers and tube ends as required. Similar to “Sentry-Guard” by USA Coil and Air.

7. Additional Design Resources:
    a. ASHRAE Systems and Equipment Handbook (current edition).

B. Reliability and Redundancy: Professional shall determine the consequences of system failure and provide for adequate system redundancy for each application.
    1. Confirm Owner requirements for redundancy are defined and met.
    2. Install fully redundant (N+1) stand-by units for extremely critical applications (such as critical research laboratories and computer centers) and/or as otherwise defined specifically in the Owner's Project Requirements.

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3. For non-critical applications (such as general office spaces, general purpose classrooms, general commercial type spaces) full redundancy/complete standby is not required.
4. Consider parallel fan configurations where effective and practical for running a single fan at part load and for partial redundancy.
5. Determine and specify applicable emergency power requirements. (research, lab fume hood, process or other specific critical application).

C. Flexibility: Consider potential future expansion. Extent of expansion will be determined on a case-by-case basis. Consult with the University Project Leader and Engineering Services.
   1. Casings for heat and vent applications shall have space for installation of future cooling coil and associated access for inspection and cleaning.
   2. Consider potential for and make provisions for future heat recovery components whenever appropriate.

D. Equipment Location, Layout and Design Team Coordination:
   1. Comply with all Space Planning Requirements indicated in Section 01 05 05.01 Planning for Engineered Building Systems.
      a. To the greatest extent possible, mechanical equipment shall be located indoors to maximize useful service life and for safety and ease of maintenance staff, particularly during adverse weather conditions.
   2. Maintain recommended minimum service clearances. Units shall be installed to allow removal of all coils, filters, and fan shaft. Provide full finned width of coil on one side of each coil section to facilitate removal.
   3. Units shall include a structural base rail and placed on a concrete housekeeping pad with sufficient combined height for adequate condensate drain trapping and steam fill leg and trap assembly.
   4. Provide at least 24" of access space upstream and between each coil with doors to facilitate installation of sensors and for inspection and cleaning.

E. Related Standards Sections
   1. 23 00 01 Owner General Requirements and Design Intent
   2. 23 00 10 Systems Selection and Application
   3. 23 01 00 OPERATION AND MAINTENANCE OF HVAC SYSTEMS
   4. 23 05 01 Mechanical General Requirements
   5. 23 05 93 Testing, Adjusting, and Balancing for HVAC
   6. 23 21 00 HYDRONIC PIPING AND PUMPS
   7. 23 30 00 HVAC AIR DISTRIBUTION
   8. 23 40 00 HVAC AIR CLEANING DEVICES
   9. 25 00 00 INTEGRATED AUTOMATION
   10. 25 90 00 GUIDE SEQUENCES OF OPERATION
   11. 26 29 23 Variable-Frequency Motor Controllers

F. Documentation:

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1. Schedules shall be complete with area served, location, total air quantity, outside air (min/max), external and internal static pressures, all coil selection parameters and performance characteristics, filter characteristics, fan rpm, minimum fan efficiency (or maximum brake horsepower), motor hp, voltage, (including starter/speed drive type), and whether on normal/emergency standby power (where applicable), allowable dimensions and weights, octave band sound level performance.
2. Provide mechanical identification per University Standards, 23 05 01.05 Mechanical Identification.

G. Quality Assurance and Uniformity:
1. Equipment manufacturer shall be ISO-9001 certified.
2. Equipment shall be of U.S. manufacturer.
3. Provide equipment of same type by same manufacturer.
4. Fan ratings shall be AMCA certified.
5. ARI Certification:
    a. Air-handling units and their components shall be factory tested according to ARI 430, "Central-Station Air-Handling Units," and shall be listed and labeled by ARI.
    b. Coils shall be ARI 410 certified.
    c. Sound data shall be ARI 260.
6. ASHRAE Compliance: Applicable requirements in ASHRAE 62.1, Section 5 - "Systems and Equipment" and Section 7 - "Construction and Startup.". Surfaces in contact with the airstream shall comply with requirements in ASHRAE 62.1.
7. ASHRAE/IESNA 90.1 Compliance: Applicable requirements in ASHRAE/IESNA 90.1, Section 6 - "Heating, Ventilating, and Air-Conditioning."
8. NFPA 70 Compliance: Electrical Components, Devices, and Accessories shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
9. NFPA 90A Compliance: Comply with NFPA 90A for design, fabrication, and installation of air-handling units and components.
10. Air Leakage Testing: Specify requirement for independent pressure test of unit isolated from system to determine total air leakage of cabinet for units 10,000 cfm and greater.

.02 Product Requirements

A. General: Provide factory-fabricated and factory-tested air handling units as described herein.
1. Unit layout and configuration of all components, including required dimensions for all internal access sections and external access clearances and shall be clearly defined in project plans and schedules.

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2. Unit shall be constructed of a complete structural frame with removable panels. The removal of side panels shall not affect the structural integrity of the unit.
3. Unit manufacturer shall construct and ship separate segments as required so unit can be broken down for ease of installation in tight spaces.
4. Units shall be mounted on vibration isolators, unless fan and drive assemblies are internally isolated by the manufacturer.

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B. Unit Casings:

1. General: All unit casings shall be double wall, corrosion-resistant, sheet metal panel construction with thermal breaks at connections, including those serving heating and ventilation only applications. Exposed insulation is not acceptable.
2. Thermal Performance:
    a. Panel insulation shall provide a minimum thermal resistance (R) value of 12 ft²•h•ºF/Btu throughout the entire unit. Insulation shall completely fill the panel cavities in all directions so that no voids exist and settling of insulation is prevented. Panel insulation shall comply with NFPA 90A.
    b. Cabinet shall have additional insulation and vapor seals if required to prevent condensation on the interior and exterior of the cabinet.
    c. Portions of cabinet located downstream from the cooling coil shall have a thermal break at each thermal bridge between the exterior and interior casing to prevent condensation from occurring on the interior and exterior surfaces. The thermal break shall not compromise the structural integrity of the cabinet.
3. Leakage Performance: All casings shall be constructed to minimize leakage and shall be in accordance with duct and plenum leakage class required by Energy Conservation Code or better.
    a. The casing air leakage shall not exceed duct leakage class 6 (CL = 6) per ASHRAE 111 at specified casing static pressure (P in inches w.g.), where maximum casing leakage (cfm/100 ft^2 of casing surface area) = $CL \times P^{0.65}$.
    b. Air leakage shall be determined at 1.25 times maximum casing static pressure up to +/-8 inches w.g. Specified air leakage shall be accomplished without the use of caulk. Total estimated air leakage shall be reported for each unit in CFM, as a percentage of supply air, and as an ASHRAE 111 Leakage Class.
4. Use bellmouth transition fittings at discharge connections to reduce pressure losses.
5. All components shall be accessible via access doors and removable panels.
    a. Formed and reinforced, single- or double-wall and insulated panels of same materials and thicknesses as casing.
    b. Hinges: A minimum of two ball-bearing hinges or stainless-steel piano hinge and two wedge-lever-type latches, operable from inside

and outside. Arrange doors to be opened against air-pressure differential.

c. Gasket: Neoprene, applied around entire perimeters of panel frames.

d. Include a viewing window in access section doors requiring inspection/troubleshooting of operation of components while unit is running (such as downstream of cooling coil to detect moisture carryover or humidifier section to check visual plume distance). Fabricate of double-glazed, wire-reinforced safety glass with an air space between panes and sealed with interior and exterior rubber seals.

e. Size: At least 18 inches wide by full height of unit casing up to a maximum height of 72 inches.

6. Sound Attenuation: Provide fan or intake/discharge plenum sections with perforated liner and sound absorbing material to provide acoustical attenuation as required for each application.

    a. The liner shall be fabricated from stainless steel perforated material to prevent corrosion and designed to completely encapsulate acoustic insulation. The perforation spacing and hole size shall be such as to prevent insulation breakaway, flake off, or delamination when tested at 9000 fpm, in accordance with UL 181 or ASTM C1071.

    b. Insulation material must be resistant to fungi in accordance with ASTM C1338.

7. Safety guards: Provide as required for safe and convenient service access inside unit: at open bottom connections, large plenum fan inlets and discharges.

C. Fan and Drive Assemblies:

1. Fans and motors on 5 tons and larger shall be on a common isolation base or rail unless internally isolated by the equipment manufacturer.

2. Provide thrust restraints between AHU casing and fan housings on horizontal discharge fans >3" total s.p.

3. Shall be statically and dynamically balanced and designed for continuous operation at maximum-rated fan speed and motor horsepower.

4. Fan wheels shall be optimally designed and selected with sufficient strength and minimum inertia for the application.

    a. Evaluate 9 vs. 12 blades on airfoil fans.

    b. Consider aluminum vs. steel wheel construction for weight reduction to reduce inertia and bearing stresses, particularly on direct drive applications.

5. Bearings: Shall be grease-lubricated, self-aligning type, minimum L10 life of 200,000 hours (preferred, but no less than L10 life of 100,000 hours - Note: L50 life of 200,000 hours is NOT acceptable.) Provide extended grease lines to safe and readily accessible location with 1/8" steel tubing and flush plugs with relief set at 5 psig.

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6. Shafts: Designed for continuous operation at maximum-rated fan speed and motor horsepower, and with field-adjustable alignment.
    a. Turned, ground, and polished hot-rolled solid steel with keyway. Ship with a protective coating of lubricating oil.
    b. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.
    c. Adequate fan shaft pull space must be provided.
7. Belt Drives, Refer to 23 05 01 - Motors and Drives:
    a. Drive assemblies: Factory mounted, with adjustable alignment and belt tensioning with 1.5 service factor based on rated nameplate HP of motor.
    b. Belts: Oil-resistant, heat-resistant, non-sparking, and anti-static **cogged** v-belts; in matched sets for multiple-belt drives. Shall have a minimum of 2 belts, each rated to carry full load in case one breaks. *[Designer Note: Cogged belts have slots that run perpendicular to the belt's length. The slots reduce the bending resistance of the belt. Cogged belts can be used with the same pulleys as equivalently rated V-belts. They run cooler, last longer, and have an efficiency that is about 2% higher than that of standard V-belts.]*
    c. Belt guards: Where required, guards shall be constructed of expanded metal mesh to allow for quick visual inspection of belts and pulleys without removal. Guards shall be attached to equipment with hinges and/or quick release fasteners that can be turned without tools to allow for ease of maintenance.
    d. Consider synchronous belt drive assemblies on large units where they can be applied cost effectively to eliminate slip losses.
        i. Typically not available on standard units. Custom only. Can be noisy.
        ii. http://www1.eere.energy.gov/industry/bestpractices/pdfs/39157.pdf
        iii. *http://www1.eere.energy.gov/industry/bestpractices/pdfs/replace_vbelts_motor_systemts5.pdf*

D. Motors: Refer to other requirements in .01 Motors and Drives
1. Shall be **NEMA Premium** efficiency.
2. Motors on variable speed drives shall be inverter duty, with factory installed motor shaft grounding.
3. Do not select motor within the service factor range.

E. Dampers: High-performance, low resistance, airfoil type.
1. Shall have edge seals, low leakage (2%) type.
2. Provide separate min OA damper, economizer damper (when present), return damper with separate actuators for each.

3. On economizer applications, apply dual OA dampers for better control and airflow measurement accuracy; (1) for minimum OA and (1) for economizer.
4. Minimum Outdoor, Economizer, Return, and Relief damper types and sizes shall be selected per ASHRAE Guideline 16.
    a. OA and Relief air dampers shall be opposed blade.
    b. Return damper shall be parallel blade.
    c. Minimum OA damper must be sized for a minimum of 200 fpm at absolute minimum OA flow rate for proper control.
5. Comply with airflow measuring device manufacturer's recommendations and instructions regarding airflow measuring devices to avoid inaccuracies such as turbulence created by adjacent crossflows of return air streams.

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F. Coil Sections:
1. All coils shall be completely cleaned prior to installation into the air handling unit. Complete fin bundle in direction of airflow shall be degreased and steam cleaned to remove any lubricants used in the manufacturing of the fins, or dirt that may have accumulated, in order to minimize the chance for water carryover.
2. Provide at least 24" of access space upstream and between each coil with doors to facilitate installation of sensors and for inspection and cleaning.
3. All coils shall be air vented and arranged for proper drainage.
4. Fabricate coil section to allow removal and replacement of each coil segment and to allow in-place access for service and maintenance of coil(s). For units with banks of multiple coil segments, provide independent supports of coils to allow slide out removal and replacement of each coil segment. Coils shall not act as structural component of unit or support other coils.

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Designer Note: Independent coil supports for multiple stacked coils are typically only available on semi-custom or custom grade units, not standard units. Verify.

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5. Primary Drain Pans: All cooling coil sections and heat recovery coils subject to condensing conditions shall be provided with an insulated, double-wall, **stainless steel** drain pan.
    a. The drain pan shall be designed in accordance with ASHRAE 62.1 being of sufficient size to collect all condensation produced from the coil and sloped in two planes, pitched toward drain connections, promoting positive drainage to eliminate stagnant water conditions when unit is installed level and trapped per manufacturer's requirements. See below for specifications on intermediate drain pans between cooling coils.
    b. The outlet shall be located at the lowest point of the pan and shall be sufficient diameter to preclude drain pan overflow under any normally expected operating condition.

c. All drain pan threaded connections shall be visible external to the unit. Threaded connections under the unit floor shall not be accepted.
d. Drain connections shall be of the same material as the primary drain pan and shall extend beyond the base to ensure adequate room for field piping of condensate traps.

6. Intermediate Drain Pans: Units with stacked coils shall have an intermediate drains pan to collect condensate from each row of coils.
   a. The intermediate drain pan shall be designed being of sufficient size to collect all condensation produced from the coil and sloped to promote positive drainage to eliminate stagnant water conditions.
   b. The intermediate drain pan shall be constructed of the same material as the primary drain pan.
   c. The intermediate drain pan shall begin at the leading face of the water-producing device and be of sufficient length extending downstream to prevent condensate from passing through the air stream of the lower coil.
   d. Intermediate drain pans shall have drop tubes to guide condensate to the main drain pan, thus preventing flooding of lower coils that would result in moisture carryover.

7. On applications that will condense moisture, such as typical air conditioning cooling/dehumidification and exhaust air heat recovery provide coil casings of minimum 0.0625" thick **stainless steel** channel frames.
8. Water Coils:
   a. Factory tested to 300 psig according to ARI 410 and ASHRAE 33.
   b. Supply and return header connections shall be clearly labeled on outside of units such that direction of coil water-flow is counter to direction of unit air-flow.
9. Refrigerant Coils: Factory tested to 450 psig according to ARI 410 and ASHRAE 33.
10. Steam coils:
   a. Coils shall be "non-freeze", steam-distributing type specifically designed to evenly distribute steam along the entire coil.
   a. Tubes shall consist of nominal 1" O.D. outer tubes with 5/8" inner tubes. Inner tubes shall have orifices that ensure even steam distribution throughout the length of the outer tube. Orifices shall direct steam toward return connections to ensure steam condensate is properly drained from coils to prevent flashing of condensate.
   b. Coils shall be pitched in units for proper drainage of steam condensate from coils.
   c. Coils shall be proof tested to 300 psig and leak tested to 200 psig air pressure under water.

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d. Steam supply, condensate return, and vacuum breaker connections shall be clearly labeled on unit exterior.

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A. Air Mixing/Blender Section: Air mixers (blenders) shall be provided and located as indicated on the schedule and drawings to enhance the mixing of outside air with return air to a required mixing effectiveness to eliminate freeze stat trips, minimize sensor error and enhance outdoor air distribution. The air mixing device shall provide even airflow and temperature across filters, coils and control sensors to ensure accuracy of averaged temperature readings.

Designer Note: Manufacturer's standard "mixing damper" sections have repeatedly performed inadequately and are not acceptable.

1. Mixers shall incorporate fixed blades, with no moving parts.
2. Mixer panels shall be sized and installed in the unit with adequate distances upstream and downstream, based on the manufacturer's cataloged performance, to ensure a minimum mixing effectiveness.
3. The performance requirements for each system should be as listed in the schedule of equipment shown on the plans. The required mixing effectiveness shall be stated in terms of % range mixing effectiveness at the appropriate outside air percentage at one mixer diameter downstream of the mixer. Range mixing effectiveness is defined as follows: (Emixer= 1-(Range/(Tra-Toa))) Where: Tra= Return air temperature, Toa=Outside air temperature, Range=Tmax-Tmin at one mixer diameter downstream.
4. Static air mixers shall be geometrically scaled to ensure consistent performance across full range of applications. Mixers that are not geometrically scaled are not acceptable.
5. The mixing device shall maintain mixing performance across the anticipated airflow range of each application.
6. Pressure Drop: The pressure drop rating for static air mixers shall include the pressure loss due to the mixer design and the mixer-to-plenum area ratio.
7. Installation shall be in accordance with the manufacturer's written installation instructions and SMACNA plenum construction guidelines. If necessary, provide reinforcement in plenum where the mixing device is installed to eliminate excess vibration or deflection of blank off plenum.
8. Actual performance shall be field verified as part of Functional Performance Testing.

B. Controls:
1. General: Coordinate and comply with Division 25 00 00 INTEGRATED AUTOMATION
2. Sequences: Refer to 25 90 00 GUIDE SEQUENCES OF OPERATION
3. Air Flow Measuring Stations: Refer to specific requirements in BAS Guidespec for "COMBINATION AIR FLOW /TEMPERATURE MEASUREMENT STATION (AFMS)". Coordinate locations and proper

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mounting details with manufacturer of air flow measuring stations for accurate sensing and control.

.03 Execution

A. INSTALLATION

1. General: Install air handling units where indicated, in accordance with equipment manufacturer's published installation instructions and with recognized industry practices, to ensure that units comply with requirements and serve intended purposes.
2. Coordination: Coordinate with other work, including ductwork, roof decking and piping, as necessary to interface installation of air handling units with other work.
3. Access: Provide access space around air handling units for service as indicated, but in no case less than that recommended by manufacturer.
4. Support:
   a. Install indoor air handling units on a minimum 4" high concrete housekeeping pad. Coordinate installation with General Contractor for final size of pad.
   b. For rooftop applications in which the unit is to be supported on a raised structural platform, refer to 07 70 00 ROOF AND WALL SPECIALTIES AND ACCESSORIES for minimum height requirements of legs to allow for future roofing replacement.
5. Electrical Wiring: Install electrical devices furnished by manufacturer but not specified to be factory-mounted. Furnish copy of manufacturer's wiring diagram submittal to Electrical Installer.
   a. Verify that electrical wiring installation is in accordance with manufacturer's submittal and installation requirements of Division-16 sections.
   b. Grounding: Provide positive equipment ground for air handling unit components.
   c. Do not proceed with equipment start-up until wiring installation is acceptable to equipment installer.
6. Piping Connections: Refer to related Division-23 HVAC sections. Provide piping, valves, accessories, gauges, supports and flexible connectors as indicated.
   a. Steam coils:
      i. Shall be piped to ensure condensate can fully drain by gravity to trap or vented condensate receiver pump assembly to prevent freeze-ups. This shall include a vacuum breaker, thermostatic air vent, and a minimum 14" fill leg to trap inlet, which may dictate that units be mounted on extended rail or frame above housekeeping pad.
      ii. Shall be double trapped in parallel with fully redundant assemblies.

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iii. On coils subject to freezing conditions, provide a Thermoton liquid expansion steam trap (Spirax/Sarco Type C Thermoton or similar) and isolation valve at lowest point to drain coil if condensate fails to drain through primary trap assembly. Trap shall be set to open and release subcooled condensate at 75°F. Trap outlet shall be rotated down for full drainage.

iv. Since they can become blocked and obstruct condensate, strainers in front of the traps in freeze prone applications shall require regularly scheduled screen removal and cleaning along with steam trap service. Coordinate locations of these steam trap and strainer assemblies with Owner's Preventative Maintenance Manager at time of project turnover.

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7. Duct Connections: Refer to related Division-23 HVAC sections. Provide ductwork, accessories and flexible connections as indicated.

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B. FIELD QUALITY CONTROL

1. Upon completion of installation of units, and after motor has been energized with normal power source, perform the following tests and inspections with the assistance of a factory-authorized service representative to demonstrate compliance with requirements:
   a. Verify that shipping, blocking, and bracing are removed.
   b. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.
   c. Verify that cleaning and adjusting are complete.
   d. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, make final alignments of pulleys and belt tension, and install belt guards.
   e. For vibration testing requirements, refer to Section 23 05 01 .05 Sound and Vibration Control.

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      i. **IMPORTANT: Incorrect alignment and belt tension causes energy losses and premature equipment failure. This work must be completed to the satisfaction of the University as part of the criteria determining Substantial Completion.**
      ii. The Contractor shall coordinate and contract the services of the University's HVAC Vibration Analyst (At University Park, arranged through the Supervisor of Refrigeration and Mechanical Services) whenever available. Otherwise (and at Commonwealth Campus locations) the Contractor shall

hire an independent, third party Vibration Analyst meeting the approval of the University.

iii. Measured results of vibration testing and final alignment and tensioning shall be recorded and coordinated to be entered into University's Preventative Maintenance Software at time of start-up AND included in final report to be submitted as part of TAB/O&M submittals.

f. Adjust damper linkages for proper damper operation.
g. Verify lubrication for bearings and other moving parts.
h. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.
i. See Division 23 Section "Testing, Adjusting, and Balancing For HVAC" for testing, adjusting, and balancing procedures.
j. Air Leakage Test: Pressurize casing to positive and negative ratings and measure leakage. If leakage exceeds specified performance, seal leakage points with a permanent solution. Repeat test. If the AHU still does not pass, contact the manufacturer to seal unit. Submit a field test report with testing data recorded. Include description of any corrective actions taken.
k. Test and adjust controls and safeties. Controls and equipment will be considered defective if they do not pass tests and inspections.
l. Prepare test and inspection reports.

2. Remove and replace malfunctioning units that cannot be satisfactorily corrected and retest as specified above.

END of revision

Update Commentary:

Section was updated primarily for the following reasons:

1) *Multiple and extensive additions, revisions and overall reorganization into General design intent and selection criteria, Product specifications, and Execution parts.*
2) *To create new and separate subsections for Energy Recovery Equipment and Air Handling Units.*