Delete the following current section in its entirety (deletions are shown struck through).

23 34 00 HVAC FANS

~~**.01 Fans**~~

~~A. Fans, except power roof ventilators, shall be provided with lubricating type bearings with extended fittings as required.~~

~~B. All fans, including roof fans, shall be belt driven with solid sheaves. For speed adjustments, the Contractor shall provide required sheaves and pulleys to meet specified CFM. Band belts shall be used when multiple V-belts are required.~~

~~C. Fume hood exhaust fans shall have acid resistant coating, two (2) coats air dried "Heresite" or equal. Design static shall not be less than one (1) inch S.P. Spark resistant is required for explosive atmosphere. Where design conditions do not permit the use of coatings, discuss requirements with the University.~~

~~D. Fan schedule on drawing should be very complete, giving area served, fan location, method of control, performance characteristics. Controls must not be placed in public areas. If fans are interlocked, schedule shall indicate the unit the fan is interlocked with.~~

~~E. Fan ratings shall be AMCA certified.~~

~~F. All fans shall be statically and dynamically balanced and run tested at the factory.~~

~~G. 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.~~

Replace with following text.

23 34 00 HVAC FANS

.01 General Owner Requirements and Design Intent

A. Design for High Energy-Efficiency Performance: Professional shall design each fan application for optimal operating efficiency, and flexibility with the lowest life cycle cost.
    1. 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.

2. Air systems shall be designed to minimize pressure drops through each component, fitting, and the total system.
    a. Design ductwork to minimize 90 degree elbows and sharp transitions.
    b. Select all air distribution fittings and components that offer the lowest pressure drop.
    c. Wherever space allows, design larger duct sizes to reduce pressure drop and allow future flexibility if increased airflow is required.
    d. 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.
    e. 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.
        i. http://www.gorhamschaffler.com/system_effects.htm
        ii. http://www.amca.org/UserFiles/file/Mark%20paper.pdf
        iii. Rules of thumb - AMCA
            A. AMCA Publication 201 quantifies System Effect for a number of the more common causes, and offers recommendations for avoiding System Effect.
            B. On the fan's inlet side, AMCA Publication 201 recommends that elbows near the fan's inlet be located at least **three** duct diameters upstream of the fan, while acknowledging that elbows can cause System Effect when they are located up to five diameters upstream.
            C. On the fan's outlet side, AMCA Publication 201 introduces the term "Effective Duct Length."
            D. Effective Duct Length is 2.5 duct diameters when duct velocities are 2500 fpm or less, with one duct diameter added for each additional 1000 fpm. A centrifugal fan needs 100% of an Effective Duct Length on its outlet to avoid System Effect, while a vaneaxial fan needs 50% Effective Duct Length.
3. Design Professional shall carefully evaluate and properly select the most effective fan type and wheel to best suit the needs of the application with emphasis on stable and quiet operation and minimizing operating and life cycle cost, rather than minimizing size and first cost.
    a. 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.

b. Fan selections at the actual operating point(s) shall be within 10 points of the peak total efficiency.
c. In all cases, selections shall be made to avoid stall, surge and pulsating conditions throughout full range of operating range of fan system.
d. Select for quiet operation. The only valid basis for comparison are the actual sound power levels generated by the different types of fans when they are all producing the required volume airflow rate and total pressure. Sound power level data shall be obtained from the fan manufacturer for the specific fans being considered. Low outlet velocity does not necessarily ensure quiet operation, so selections made on this basis alone are not appropriate. Also, noise comparisons of different types of fans, or fans offered by different manufacturers, made on the basis of rotational or tip speed are not valid.

4. Part Load Capacity Controls shall be effectively applied to fullest extent practical for optimal energy efficiency over entire system operating range.
    a. Variable Frequency Drives for HVAC Motors: Designers shall use guide specification in 26 29 23 Variable-Frequency Motor Controllers. Guide specification shall be edited only as required to meet project specific requirements. Proposed modifications shall be reviewed with OPP Engineering Services.

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 fans for extremely critical applications (such as critical research laboratories and computer centers) and/or as otherwise defined specifically in the Owner's Project Requirements.
    3. For non-critical applications (such as general office spaces, general purpose classrooms, general commercial type spaces) full redundancy/complete standby is typically not required.
    4. Consider parallel fan configurations where effective and practical.
    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.

D. Space Planning: Refer to 01 05 05 Space Planning, .02 Planning for Engineered Building Systems

    1. Make sure that minimum clearances are maintained, as required by manufacturer.
    2. Allow at least three feet between all service sides of fans, and other large equipment and obstructions.
    3. Mechanical room locations and placement must take into account how fans and replacement parts can be moved into and out of the building during installation and future major repair/replacement.
    4. Plan for and clearly label any future equipment space needs on drawings.
    5. Controls must not be placed in public areas.

E. Sound and Vibration Control:
    1. Determine sound attenuation requirements.
        a. Properly locate and specify to meet project needs.
        b. Comply with requirements for **vibration isolation** devices specified in Division 23 Section 23 05 01 Mechanical General Requirements, .04 Sound and Vibration Control
    2. Minimize objectionable fan noise from intake or exhaust points to nearby buildings or sensitive neighboring areas.
    3. Determine and specify appropriate allowable vibration limits for each application of fan, motor and base combination according to level of criticality.

F. Specialized exhaust systems - (Clothes Dryer, Kitchen Grease/Heat, Hazardous, Research Lab Fume Hood, Smoke Control, etc.):

    1. General:
        a. Apply variable air volume control wherever practical for optimal energy conservation – beyond code minimum prescriptive requirements.
        b. Comply with Chapter 5 Exhaust Systems of International Mechanical Code for special requirements.
        c. Select fan materials and construction most suited for the application. Considerations in selecting materials include resistance to chemical attack and corrosion, reaction to condensation, flame and smoke ratings, ease of installation, ease of repair or replacement, and maintenance costs. Appropriate materials shall be selected from standard references and by consulting with manufacturers.
    2. Lab Fume Hood systems:
        a. Comply with ANSI/AIHA Z9.5-(current) Laboratory Ventilation
        b. Refer to the U.S. EPA and DOE sponsored Labs for the 21st Century (Labs21) Tool Kit, including the Best Practices Guides, and best-fit apply them to each specific project scope.

G. Documentation:
    1. Schedules: Shall be complete with area served, location, total air quantity, static pressures, operating temperatures minimum fan efficiency (or maximum brake horsepower), motor hp, voltage, (including starter/speed drive type), and whether on normal/emergency standby power (where applicable), any maximum dimensions and weights, sound power level data, method of control, and if fans are interlocked, indicate the unit(s) the fan is interlocked with.
    2. For lab fume hood high plume exhaust fan systems, Engineer must provide all pertinent selection criteria including: minimum plume heights; laboratory fume exhaust air and total flow design rates; quantity, size and location of bypass dampers; special corrosion-resistant materials and finishes; spark-resistance class, and any other application-specific options and accessories on equipment schedules.
    3. Provide mechanical identification per University Standards, 23 05 01.05 Mechanical Identification.
    4. The configuration of all components of fans, including fan/motor arrangement, rotation, and required dimensions for all internal access sections and external

access clearances, shall be clearly defined in sufficient detail in plan and elevation views on the design documents.

H. 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. AMCA Compliance:
      a. Airflow Performance Ratings: Fans shall conform to AMCA 210 and bear the AMCA Certified Ratings Seal.
      b. Sound ratings: Fans shall be sound rated in accordance with AMCA 301 and AMCA 300 "Test Code for Sound Rating Air Moving Devices" and bear the AMCA Certified sound ratings seal.
   5. UL Compliance: Provide centrifugal fan electrical components which have been listed and labeled by UL.

I. Submittals: Documents shall require the following:
   1. Product Data: Submit manufacturer's technical product data for fans, including:
      a. Selection characteristics and rated capacities.
      b. Fan performance curves with system operating conditions indicated.
      c. Sound power ratings, with an 8 octave band analysis for large, central system fans.
      d. General specifications: Fan type description, material of construction, thicknesses and finishes,
      e. Motor type, ratings and electrical characteristics
      f. Accessories furnished
      g. Product data on special coatings and construction where applicable.
      h. For laboratory fume hood exhaust fan systems, provide nozzle velocity of exhaust fan, total exhaust flow, and results of the effective discharge plume height based on the specified wind velocity of **[15 mph – Design Professional shall confirm and edit for project specific requirements].**
   2. Shop Drawings: Include the following:
      a. Plans, elevations, sections, and attachment details.
      b. Details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
      c. Vibration Isolation Base Details: Detail fabrication, including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.
   3. Wiring Diagrams: Submit manufacturer's electrical requirements for power supply wiring to fan units. Submit manufacturer's ladder-type wiring diagrams for interlock and control wiring. Clearly differentiate between portions of wiring that are factory-installed and portions to be field-installed.
   4. Coordination Drawings: As required to meet project complexity, show fan room layout and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate and certify field measurements.
   5. Maintenance Data: Submit operation and maintenance instructions, including lubrication instructions, motor and drive replacement, and spare parts lists.

Include this data, product data, shop drawings, and wiring diagrams in maintenance manuals; in accordance with requirements of Section 23 01 00 OPERATION AND MAINTENANCE OF HVAC SYSTEMS.

6. Field quality-control reports.

.02 Product Requirements

A. General:
   1. Fan ratings shall be AMCA certified.
   2. All fans shall be statically and dynamically balanced and run tested at the factory.
   3. Fan housings shall be aerodynamically designed and engineered to reduce incoming air turbulence and provide maximum efficiency. Housing shall be suitably braced to prevent vibration or pulsation.
   4. All fan and system components shall be corrosion resistant. Materials and finishes shall be selected appropriately for each application. Considerations in selecting materials include resistance to chemical attack and corrosion and protection from reaction to condensation where it can occur.

B. Bearings: Fans, except power roof ventilators, shall be provided with lubricating type bearings with extended fittings as required.
   1. Bearings: on primary/central fan applications, provide heavy-duty, grease-lubricated, precision anti-friction, self-aligning, ball or roller or tapered double spherical roller, pillow block type bearings, **selected for minimum life (AFBMA L_{10}) of 200,000 hours**.

      Designer Note: Refer to Understanding Bearings for the Fan Industry (FA/103-00) http://www.greenheck.com/library/articles/6

   2. Extend grease fittings to safe, accessible locations.

C. Shafts: Designed for continuous operation at maximum-rated fan speed and motor horsepower, and with field-adjustable alignment.

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** technology. Designer Note: Indicate CLEARLY on contract documents, preferably noted on equipment schedules, so they are less likely to be missed by equipment vendors. The objective is to most pro-actively and cost-effectively protect the motors to avoid expensive and disruptive corrective field installed work, which otherwise becomes necessary after unprotected motors have started failing prematurely.
   3. Do not select motor within the service factor range.

E. Belt Drives, Refer to 23 05 01 - Motors and Drives:
   1. Drive assemblies: Factory mounted, with adjustable alignment and belt tensioning with 1.5 service factor based on rated nameplate HP of motor.
   2. For speed adjustments, the Contractor shall provide required sheaves and pulleys to meet specified CFM.

3. Belts: Oil-resistant, heat-resistant, non-sparking, and anti-static **cogged** v-belts; in matched sets for multiple-belt drives.
    a. Where option is available, shall have a minimum of 2 belts, each rated to carry full load in case one breaks.

Designer Notes:

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.

Consider synchronous belt drive assemblies with soft start capabilities, where they can be applied appropriately and effectively to eliminate slip losses for best efficiency. However, cogged belts may be a better choice when vibration damping is needed or shock loads cause abrupt torque changes that could shear a synchronous belt's teeth. Synchronous belts also make a whirring noise that might be objectionable in typical HVAC applications where fan/drive noise could be transmitted to noise-sensitive occupied areas.

For more information, refer to US Department of Energy, Energy Efficiency and Renewable Energy (EERE), Motor Systems Tip Sheet #5, "Replace V-Belts with Cogged or Synchronous Belt Drives":
http://www1.eere.energy.gov/industry/bestpractices/pdfs/replace_vbelts_motor_systemts5.pdf

As an alternative to belt drives, on variable flow systems, consider application of direct drive fans with variable speed driven motors via VFDs or ECM motor-controllers.

F. Accessories: Select most appropriately for each application and clearly indicate on contract documents.
    1. Belt guards: Where required, guards shall be fabricated to comply with OSHA and SMACNA requirements, 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. Secure to fan or fan supports without short circuiting vibration isolation.
    2. Equip fans with lifting lugs.
    3. Access for Inspection, Cleaning, and Maintenance: Comply with requirements in ASHRAE 62.1.
    4. Scroll Drain Connection: NPS 1 steel pipe coupling welded to low point of fan scroll.
    5. Inlet Screens: Provide where required to adequately protect maintenance staff. Grid screen of same material as housing.
    6. Roof Exhaust fans: Roof Curbs: Provide manufacturers roof curb with outer finish to match fan. Provide hinging kit to allow easy access to damper. Curb shall be insulated with 2" thick sound and thermal insulation. Exception: Fans

used for grease or dishwasher exhaust application shall not have exposed acoustic insulation. Provide vented curb extension and grease trap and drain for grease duct application.

7. Shaft Cooler: Metal disk between bearings and fan wheel, designed to dissipate heat from shaft on fans with operating temperatures higher than 250 degrees F.
8. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.
9. Weather Cover: For exterior applications, provide removable protective cover with ventilation slots over motor and drive assembly.
10. Isolation Damper: For multiple fans on a common header, equip each fan with isolation damper on inlet or outlet (depending on application and arrangement) to prevent it from turning in reverse rotation when the fan is off.
11. Vibration Cut-out Switch: In applications subject to damage to equipment or facility or unacceptable effect on vibration-sensitive research equipment due to outside of normal operating tolerance levels of vibration, each fan shall be provided with vibration cut-out switch. The switch shall incorporate a manual reset button and SPDT contacts encased in a NEMA type enclosure suitable for the application. The switch shall be mounted on the motor support plate and also be accessible for manual adjustment and reset by the Owner. A 2-conductor cable and cable clamps are to be supplied with each switch.

.03 Execution

A. INSPECTION

1. Examine areas and conditions under which fans are to be installed. Do not proceed with work until unsatisfactory conditions have been corrected in manner acceptable to Installer.

B. INSTALLATION

1. General: Install fans where indicated, in accordance with manufacturer's installation instructions, and with recognized industry practices, to ensure that fans comply with requirements and serve intended purposes.
    a. Install fans level and plumb.
    b. Protect belts, sheaves, bearings, motors and other fan parts during installation.
    c. Protect units with protective covers during balance of construction.
2. Access: Provide adequate access and service clearance space around and over fans as indicated, but in no case less than that recommended by manufacturer. Allow adequate and safe pathway for components and unit replacement.
3. Isolation: Comply with requirements for vibration isolation devices specified in Division 23 Section 23 05 01 Mechanical General Requirements, .04 Sound and Vibration Control
4. Duct Connections:
    a. **Minimize fan System Effects: Avoid poor fan inlet and outlet conditions**. Comply with manufacturer’s installation guidelines.
    b. Make final duct connections with flexible connectors.
    c. Install ducts adjacent to fans to allow service and maintenance.

d. Provide access door in duct below power roof ventilators to service damper.

5. Piping Connections: Install piping from scroll drain connection, with trap with seal equal to 1.5 times specified static pressure, to nearest floor drain with pipe sizes matching the drain connection.
6. Secure roof-mounted fans to roof curbs with cadmium-plated hardware.
7. Electrical Connections:
   a. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."
   b. Connect control wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."
8. Identification: Label fans according to requirements specified in "Mechanical Identification".

C. CLEANING AND TOUCH-UP

1. After construction and painting is completed, clean exposed surfaces of units.

2. Touch up marred or scratched factory-finished surfaces, using finish materials furnished by manufacturer.

D. FIELD QUALITY CONTROL

1. Upon completion of installation of fans, 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 .04 Sound and Vibration Control.
      1) **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.**
      2) 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.
      3) 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. Test and adjust controls and safeties. Controls and equipment will be considered defective if they do not pass tests and inspections.
k. 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) To develop and document General Owner Requirements in order to define basic design intent and selection criteria.
    a. Goal – to provide guidelines to promote and achieve Efficiency and Reliability throughout entire operating range
    b. To add requirements for limiting allowable fan power which include minimizing system air pressure drops and optimizing selection of efficient fans.
2) To update the Equipment Requirements for fans, motor and drive components, and accessories to achieve better and more serviceable fan systems.
3) To develop and document the Execution (Installation, Operation and Start-up/Commissioning) requirements.
    a. Goal – to achieve better installations, better operating efficiency and longer life from fan systems.
    b. Note the following special points:
        i. Minimize fan System Effects: Avoid poor fan inlet and outlet conditions. Comply with manufacturer’s installation guidelines.