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## PART 1 - INTRODUCTION

1.1 This section applies to fans for Building Systems.


## PART 2 - GENERAL DESIGN REQUIREMENTS

- 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.
- B. Air systems shall be designed to minimize pressure drops through each component, fitting, and the total system.
  - 1. Design ductwork to minimize 90 degree elbows and sharp transitions.
  - 2. Select all air distribution fittings and components that offer the lowest pressure drop.
  - 3. Wherever space allows, design larger duct sizes to reduce pressure drop and allow future flexibility if increased airflow is required.
  - 4. Minimize fan System Effects: Avoid poor fan inlet and outlet conditions that reduce fan performance and increase energy waste. Always consult manufacturer's installation requirements and AMCA publication 201.
- C. 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.
  - 1. 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.
  - 2. In all cases, selections shall be made to avoid stall, surge and pulsating conditions throughout full range of operating range of fan system.
  - 3. 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

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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.

- D. Part Load Capacity Controls shall be effectively applied to fullest extent practical for optimal energy efficiency over entire system operating range.
- E. 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).
- F. Flexibility: Consider potential future expansion. Extent of expansion will be determined on a case-by-case basis. Consult with the University Project Stakeholders and Facility Engineering.
- G. Maintenance and Space Planning:
  - 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, or comply with manufacturer minimum requirements. The greater of the two criteria shall apply.
  - 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.
- H. 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 applicable design guide, best practices, manufacture requirements, AMCA

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guidelines, and ASHRAE publication “A Practical Guide to Noise and Vibration Control for HVAC Systems”.


- c. Minimize objectionable fan noise from intake or exhaust points to nearby buildings or sensitive neighboring areas.
- d. Determine and specify appropriate allowable vibration limits for each application of fan, motor and base combination according to level of criticality.
- e. Comply with local ordinances for maximum permissible sound levels to neighboring property, for both daytime and nighttime requirements.
- f. Fan systems shall undergo baseline vibration testing prior to turn-over to facility operations. Baseline vibration shall be conducted by a third party, and the report shall be turned over to Yale. Any deficiencies identified in the report shall be corrected by the installing contractor.

I. 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 governing 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.

J. Quality Assurance and Uniformity:


- 1. Equipment manufacturer shall be ISO-9001 certified
- 2. 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.

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- 3. UL Listed and Compliance: Provide fan which have been listed and labeled by UL.
- K. Adequate space and access shall be provided for all fan locations for maintenance and operations.
- L. Maximum brake horsepower at design speed shall, under no condition, exceed the nominal motor horsepower. Each fan motor shall be factory mounted. Motors shall be premium efficiency type. Select appropriate motor enclosure for the intended service.
- M. Fans and shafts shall be statically and dynamically balanced at the factory and so certified and be designed for continuous operation at the maximum rated fan speed and motor horsepower.
- N. Provide bearings with service life in excess of 200,000 hours at maximum cataloged fan operating conditions.
- O. Select fans exposed to corrosive atmospheres constructed of corrosion-resistant materials suitable for intended use, and factory finished with epoxy or other approved corrosion-resistant coatings.
- P. Select fans exposed to elevated temperatures constructed of components rated for high temperature service. Do not use belt drive assemblies exposed to the airstream. Use direct drive motors certified for high temperature service.
- Q. Select fans used to convey flammable vapors constructed of non-sparking (non-ferrous) materials, and use explosion-proof motors.
- R. Select fans used to exhaust grease-laden vapors with motor drive and bearings completely external of air stream.
- S. 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 applicable standards.

**PART 3 - MINIMUM PRODUCT CRITERIA**

**3.1 FAN SELECTION AND BALANCING**

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- A. Fan ratings shall be AMCA certified.
- B. Fans shall be statically and dynamically balanced and run tested at the factory.
- C. 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. Fan housings shall have continuously welded seams. Spot welded, or riveted construction is not acceptable.
- D. Fan wheels shall be continuously welded, extruded, or die cast. Stamped, spot welded, and or riveted fan wheels are not acceptable.
- E. 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.
- F. Fans shall be explosion proof and or spark resistant where required.
- G. Static Pressure Variations: Provide fans capable of accommodating static pressure variations of +10%.
- H. Fan Motor Brake Horsepower: Shall include air performance drive losses, inlet vane losses and all other losses of related manufacturer furnished components as applicable.
- I. Direct drive motors are preferred where applicable.
- J. Sheaves: Provide balanced variable sheaves where applicable for motors 15 HP and under, and fixed sheaves for 20 HP and over..
- K. Balancing: Statically and dynamically balance fans to eliminate vibration or noise transmission to occupied areas of the building.
- L. Belt and Shaft Guards: Galvanized steel sides and expanded metal face with opening for tachometer for belts and sheaves, galvanized steel for exposed drive shafts.
- M. Safety Screen: Provide where inlet or outlet is exposed.
- N. Weather Hood: Provide for fan motors and drives exposed to the weather.

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- O. Equivalent fan selections shall not increase motor horsepower, increase noise level, increase tip speed by more than 10%, or increase inlet air velocity by more than 10%, from that scheduled.
- P. Base fan performance on altitude rating conditions for 200' above sea level.
- Q.

### 3.2 Fan Painting

- A. Factory Prime Coat: Required on all surfaces of ferrous fan housings and wheels. Painting outside is not required on aluminum fans.
- B. Ferrous Fans Exposed to Weather: Prime coat and finish with corrosion resistant epoxy paint.
- C. Ferrous Fans (Not Stainless Steel) Exposed to Solvent or Toxic Exhaust: Prime coat and finish all ferrous surfaces with epoxy phenolic coating system, Plasite 7122 or approved equal.

### 3.3 Bearings:

- A. Fans, except power roof ventilators, shall be provided with lubricating type bearings with extended fittings as required. Extend grease fittings to safe, accessible locations.
- B. 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 L10) of 200,000 hours.


### 3.4 Shafts:

- A. Designed for continuous operation at maximum-rated fan speed and motor horsepower, and with field-adjustable alignment. Shafts shall be solid material, hollow shafts are not acceptable.

### 3.5 Motors:

- A. Refer to Motors Standard.


### 3.6 Belt Drives:

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- A. Drive assemblies: Factory mounted, with adjustable alignment and belt tensioning with 1.5 service factor based on rated nameplate HP of motor.
- B. For speed adjustments, the Contractor shall provide required sheaves and pulleys to meet specified CFM.
- C. Belts: Oil-resistant, heat-resistant, non-sparking, and anti-static cogged v-belts; in matched sets for multiple-belt drives.
- D. Where option is available, provide synchronous belts for VFD systems.
- E. Where option is available, shall have a minimum of 2 belts, each rated to carry full load..
- F. 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.
- G. Drives for belted motors shall be flame retardant and by Allis-Chalmers, Browning or Woods V-belt drives shall be specified with an adjustable motor sheave.
- H. Sheaves shall be balanced statically and dynamically.
- I. Fume hood exhaust drives shall be 2 groove (2 belt) minimum.
- J. Belts shall be type AX or BX.
- K. All belt driven equipment shall include properly selected adjustable sheaves and matched V belts, all rated for 150% of motor horsepower. Removable and vented metal guards shall be provided for safety protection and to allow for proper ventilation and cool operation of belts. Solid sheaves and band belts shall be used to minimize vibration in multiple V-belt driven equipment.
- L. Motor grease fittings shall be extended so belt guards do not need to be removed.
- M. All adjustable sheaves shall be replaced with suitable fixed sheaves following final air-balancing. Sheave information shall be then turned over to Yale Facility personnel.

3.7 Accessories:


- A. Belt guards: Where required, guards shall be fabricated to comply with OSHA and

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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.

- B. Equip fans with lifting lugs.
- C. Access for Inspection, Cleaning, and Maintenance: Comply with requirements in ASHRAE 62.1.
- D. Scroll Drain Connection: NPS 1 steel pipe coupling welded to low point of fan scroll.
- E. Inlet Screens: Provide where required to adequately protect maintenance staff. Grid screen of same material as housing.
- F. Roof Exhaust fans:
  - 1. 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.
- G. 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.
- H. Shaft Seals: Airtight seals installed around shaft on drive side of single-width fans.
- I. Weather Cover: For exterior applications, provide removable protective cover with ventilation slots over motor and drive assembly.
- J. 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, and bypass of air stream.
- K. 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



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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.

### 3.8 Baseline Vibration Analysis:


- A. Critical fans, and or systems identified during the design phase shall be subject to baseline vibration analysis. Testing shall be completed by a third party vendor. A report must be submitted by the third party vendor for documentation of the initial conditions of the newly installed equipment. Facility Operations will also perform a full analysis to verify the third party vendor's measurements and to ensure proper baseline vibration measurements and conditions. The maximum allowable fan vibration shall be 0.15 in/sec peak velocity.

### 3.9 Belted Utility Vent Sets For Laboratory Exhaust

- A. Fume hood exhaust fans shall be belted vent sets. Substitutes will not be accepted. Fans shall be of the centrifugal type with non-overloading, backward-inclined blades. They shall have self-aligning ball bearings with serviceable grease boxes. Fans and motors shall be provided with variable pitch, V-belt pulleys, V-belts, motor angle iron base rails, vibration isolators and welded sheet steel protective hood over the belt and motor assembly. Motor to be explosion-proof, bearing (L50) life of 200,000 hours.
- B. Minimum ¾" shaft.
- C. The fan scroll housing and fan wheel shall be coated with a corrosion inhibitor similar to a Heresite V504 coating of not less than 5 mils, achieved in a two-coat application.
- D. Each fan shall have an electric motor with fan and motor mounted on common base; V-belt drive shall be capable of handling 150% of motor rating, and shall have provision for belt-tension adjustment and shall have at least two V-belts. Sheaves shall be cast iron variable pitch type permitting 10% increase and 10% decrease in design RPM as desired. V-belt drive and pulleys shall have a sheet metal belt guard with 1½ inch diameter holes opposite each motor and fan wheel axle for insertion of a tachometer.
- E. Provide scroll access doors, belted shaft guards, spark-resistant construction (AMCA Type C) and aluminum and neoprene shaft seal.

### 3.10 Axial Fans

- A. Airfoil Impeller Blades: Adjustable die cast aluminum alloy or welded steel die formed


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blades with belt drive. The number of blades shall suit the operation required to prevent fan stalling at low flow.

- B. Hub: Die cast aluminum alloy or cast iron hub or with belt drive of spun, welded steel, bored and keyed to shaft; to facilitate indexing of blade angle with manual adjustment stops.
- C. Continuously welded casing, with inlet and outlet flange connections, and motor or shaft supports. Incorporate flow straightening guide vanes for fans specified for static pressures greater than 1.5 inch wg (375 Pa).
- D. Finish with one coat enamel applied to interior and exterior.
- E. Bearings: Pillow block type, self-aligning, grease-lubricated roller bearings.
- F. Shafts: Hot rolled steel, ground and polished, with keyway, protectively coated with lubricating oil.
- G. V-Belt Drive: Cast iron or steel sheaves, dynamically balanced, keyed.
- H. Belt Guard: Fabricate to SMACNA Standards; 0.106 inch (2.6 mm) thick, 3/4 inch (19 mm) diamond mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation, with provision for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
- I. Lubrication: Extend lubrication fittings to outside of casing.
- J. Inlet Bell: Bell mouth inlet fabricated of steel with flange.
- K. Outlet Cones: Fabricated of steel with flanges, outlet area/inlet area ratio of 1.5, with center pod as recommended by manufacturer.
- L. Inlet Screens: Galvanized steel welded grid to fit inlet bell.

### 3.11 Centrifugal Fans


- A. Airfoil Wheel: Steel construction with smooth curved inlet flange, back plate die formed hollow airfoil shaped blades continuously welded at tip flange, and back plate; cast steel hub riveted to back plate and keyed to shaft with set screws.

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- B. Wheels shall be continuously welded construction.
- C. Steel continuously welded, braced and designed to minimize turbulence with spun inlet bell and shaped cut-off.
- D. Bolted construction with horizontal flanged split housing, where indicated.
- E. Bearings: Pillow block type, self-aligning, grease-lubricated roller bearings.
- F. Shafts: Hot rolled steel, ground and polished, with key way, protectively coated with lubricating oil, and shaft guard.
- G. V-Belt Drive: Cast iron or steel sheaves, dynamically balanced, keyed.
- H. Belt Guard: Fabricate to SMACNA Standard; 0.106 inch (2.6 mm) thick, 3/4 inch (20 mm) diamond mesh wire screen welded to steel angle frame or equivalent, prime coated. Secure to fan or fan supports without short circuiting vibration isolation, with provision for adjustment of belt tension, lubrication, and use of tachometer with guard in place.
- I. Scroll Drain: 1/2 inch (13 mm) steel pipe coupling welded to low point of fan scroll.

3.12 ROOFTOP CURB OR PLATFORM MOUNTED EXHAUST FANS – STROBIC TYPE

- A. General: Provide industrial quality, corrosion resistant direct drive upblast fans with integral base and inlet air plenum designed for maintaining a minimum discharge velocity of 4000 fpm. Where required, provide internal spray system for fans scheduled for acid exhaust.
- B. Wheel: The impeller shall be a radial mixed flow configuration manufactured of welded steel (no riveted wheels will be accepted). It shall be part backward curve centrifugal to avoid axial stall characteristics and part axial to minimize mass and provide straight through flow. The wheel shall be capable of handling system effects without stall. Balance shall not exceed 0.5 mil, peak-to-peak at the building structure. This shall be done with the use of Rubber-in-shear isolation.
- C. Inlet Air Plenum: Provide all 316 stainless steel construction with packless acoustical baffles and minimum 3 air inlets as follows. The main exhaust air inlet shall be in the bottom, 36" x 36" duct (or suitable dimension), and shall include a slide gate damper for fan isolation from duct.

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- D. The outside air inlets shall be in opposite sides of plenum and shall include Ruskin stainless OBD's and control dampers (or equal) with short inlet ducts for balancing total exhaust air through fan.
- E. Discharge Stack: The nozzles shall be manufactured of chemical resistant fiberglass resins (or equal) to reduce roof line mass and prevent caustic erosion. The twin nozzles shall be suitable for minimum outlet velocities 4,000 to 7,000 fpm without vibration and shall be engineered to provide a passive third central stack over the motor and entrainment capabilities. Lower velocities are permitted, if suitable for application, consultant shall confirm lowest permissible velocity for each specific application. Provide manual or automated velocity control device, verify with Yale Facility Engineering.
- F. An entrainment wind band, shall be located at the discharge to prevent cross flow contamination and to improve overall entrained performance by volume to 270% of design flow.
- G. Coating: Provide baked-on phenolic (not air dried) epoxy resin coating on all carbon steel or aluminum fan wheels, housing, etc., which comes into contact with the airstream. All exposed hardware shall be Monel or Yale approved equivalent.
- H. Isolation: Provide Mason (or equal) 5/16" thick "Super W" neoprene pads with brackets for mounting fan and pads to building structure or roof curb. Provide sheet metal straps (minimum 2 per side) with hardware to "hold down" fan to platform grating during high winds.
- I. Note: Design fan, plenum, and supports to place fan center of gravity as low as possible compared to support points.
- J.
- K. Motor: Provide TEFC, Chem-Duty motor suitable for outdoor use. Bearings shall be permanently lubricated, 200,000 hour L-50 rated.
- L. Disassembly: Fan shall be capable of being disassembled into sections so that it can be moved into place between roof ductwork without the use of large cranes or helicopters. No section may weigh in excess of 625 pounds.