SPECIAL SPECIFICATION

5740

JET FAN ASSEMBLIES

1. Description. This Item shall consist of furnishing, shop testing of pre-production model fan, installing and testing of tunnel jet fan assemblies complete with all required accessories, including motor units, sound attenuators, hangers, supports, and associated work as shown on the Contract Drawings, hereinafter specified or otherwise required for a complete and fully operable system.


   (1) References:

       Special Specification 5710 - Motor Control Centers

       Item 441 Steel Structures

       Special Specification 8332 - Programmable Logic Controllers (PLCs)

   (2) General:

       Power wiring for the jet fans will be provided in this contract under the applicable Electrical Section of the Specifications from the 480V Substation through the respective starter panel, to the disconnects near each fan through to the motor terminal box.

       Similarly monitoring wiring will be provided for the sensors located on the jet fan through to the monitoring and relay devices located in the starter panels.

       Control and monitoring wiring between the jet fan starter panels and the local PLC will also be provided under the applicable Electrical Section of this contract.

       In selecting equipment, provide interchangeability of parts.

   (3) Delivery, Storage and Handling

       (a) Product Delivery. Arrange for delivery of ventilation equipment components wrapped in opaque water-resistant covers and fastened to substantial pallet type shipping supports. Pack components with padding materials of sufficient quantity and thickness to prevent contact with each other or the shipping container, and to prevent damage to painted surfaces and other damage.

       (b) Storage: Store ventilation equipment components under cover in dry areas protected from the weather and all other hazards. Protect jet fans from vibrations to avoid the brinelling of the motor bearings.
If the fans are stored for extended periods; rotate impellers as required by the fan manufacturer, to circulate the bearing lubricants. When storing in environments with ambient temperatures at or below 55 degrees Fahrenheit, provide temporary power to the motor space heaters. Do not store jet fan assemblies with any component in contact with the ground.

(c) **Handling.** Handle ventilation equipment components to prevent damage to painted surfaces and to prevent other damage. Do not crowd or scrape components against one another or against abutting surfaces.

(d) **Protective Coverings.** Leave protective coverings in place in so far as practicable during installation and erection of components. After installation and erection of the components, provide new protective coverings to protect components during the performance of work by others in the tunnel structure. Leave protective coverings in place until directed to be removed by the Engineer.

(e) **Protective Coatings.** Provide on machined surfaces not requiring painting, including shaft ends, with a coating of suitable anti-corrosion compound.

(4) **Fans**

(a) **General Requirements**

In selecting jet fan assemblies, ensure that the exterior dimensions and the operating weight of the jet fan on supports do not exceed the maximum acceptable limit indicated on the Contract Drawings.

Furnish fans of the axial-flow type, direct-driven by internally mounted single speed motors for bidirectional operation, and with sound attenuators on each end. Permanently mark the forward direction of airflow in conspicuous location on the exterior of the fan housing.

Provide fans capable of being operated either locally from the motor starter panel or remotely from the local PLC or the operation control station. The operating procedures will require any number of fans to be operated either individually or simultaneously.

(b) **Operating Environment**

Normal Operation - Construct the entire fan-motor-sound attenuator assembly such that it has protection rating of IP 55. The fan shall be capable of withstanding water spray from tunnel washing vehicles, and suitable for the operating conditions that may be encountered in a vehicular tunnel. Make provisions for draining water that may enter the fan assembly during tunnel washing operations.

Emergency Operation - Construct the entire fan-motor-sound attenuator assembly including hangers, supports, monitoring sensors and cables etc., such that none of the components should suffer mechanical, electrical or structural failure when operating at full capacity with airflow through the fan at an ambient air temperature of at least 482 degrees Fahrenheit for a minimum period of one hour.
(c) **Performance Requirements**

The fan performance requirements are indicated in the Schedule on the Contract Drawing. The minimum thrust and exit jet velocity, in either direction of motor rotation, requirements indicated apply to fan operation with the standard air density of 0.075 pounds per cubic feet.

Select fan motor that is capable of starting and operating in ambient air temperature of minus 5 degrees Fahrenheit.

Furnish fans capable of satisfactorily withstanding the effect of all stresses and loads under starting, operating, and reversing conditions.

Provide fans capable of developing static thrust and exit jet velocity, in forward and reverse direction of motor rotation, not less than that indicated on in the Plans and with a brake horsepower less than the nameplate rating of the motor.

Provide fans capable of accelerating to full speed in 15 seconds or less.

Provide fans capable of reversing air flow in sixty seconds or less, from full speed forward to full speed reverse or vice versa with a maximum de-energized period of 30 seconds between reversals. The fan shall be capable of reversing airflow direction at least two times equally spaced during any one hour of continuous operation in the high temperature specified in Section 2.4.b.

The maximum acceptable sound power levels (in decibels dB re $10^{-12}$ watts) of jet fan assembly shall be such that with all fans operating, the jet fan noise within the tunnel shall not exceed 90 dBA at five feet above the roadway at any location within the tunnel.

Maximum vibration shall not exceed peak-to-peak amplitude of 1.6 mils for jet fans with nominal operating speed of 1800 revolutions per minute; and shall not exceed peak-to-peak amplitude of 0.8 mils for jet fans with nominal speed of 3600 revolutions per minute.

(d) **Fan Components and Materials**

Fabricate impeller hub and blades of aluminum-alloy casting (AISI 356 T6 aluminum alloy casting), or aluminum alloy forging (ASTM B247), ASTM A350 Grade LF6 forged steel, stainless steel (ASTM A588 / A588M Grade A), or other material suitable for the specified performance and environment.

Material for rotating components of the fan shall be selected so that no measured or calculated stress level exceeds 60 percent of the material’s yield strength at design temperature of 482 degrees Fahrenheit.

Fan blades in each rotor shall not vary in weight by more than two percent.

Fasten impeller to the motor shaft by means of positive locking devices which are fully effective for both directions of air flow, and for both starting and running, at all blade angle settings and for all conditions of operation specified.
Design and construct impeller to withstand stresses and loads created by over speed testing to 125 percent of the nominal operating speed.

Design and construct impeller and hub such that the pitch of blades can be manually adjustable without removing impeller. Provide the blades and hubs with index marks which show the design operating blade setting and a minimum of two increments of stagger angle larger and a minimum of two increments smaller than the design operating blade setting. Clearly indicate the maximum blade angle beyond which the motor will overload. Provide stops on the hub to prevent overload of the motor. As a substitute for index marks, each fan may have one metal template to facilitate accurate settings of the blade angle.

Fan housing, including motor mounts and motor supports, shall be fabricated of hot rolled steel. Housings for fans shall be not less than ¼ inch thick. Housings shall be formed to a true-round, concentric, cylindrical shape providing uniform clearance between the tips of the impeller blades and the fan housing. Welds located in air stream shall be ground smooth.

Provide adequate clearance between blade tips and the housing at all points to allow for expansion and contraction over a temperature range from minus 5°F to 482°F without developing interference. Contractor shall indicate on shop drawings the maximum and minimum clearances at the two extreme temperature conditions.

Flanged rings shall be continuously welded to the outer periphery at each end of the housings, or flanges may be rolled integrally or continuously welded to the outer periphery of the fan housing. Provide end flanges with the same thickness as the housing or thicker. Provide flanges of sufficient width having punched or drilled holes to allow sound attenuators to be rigidly bolted to the housing.

Design and construct motor mounts and motor supports to maintain the alignment of the fan motor unit in the specified mounting position. Provide motor mounts and motor supports in sufficient number and of the design to support the entire weight of the impeller and the motor and the loads developed by the fan operation.

Provide access doors of adequate size in the fan housing for access to blade locking devices, blade pitch angle, and field adjustment and vibration test instrumentation. Fabricate access doors of steel construction with AISI Type 316 stainless steel hardware and provide with not less than 1/8-inch thick silicone base gasket to ensure airtight construction. Select gasket material that is suitable for the operating conditions specified. Each access door location and sizes shall be determined by manufacturer and shall be shown on shop drawings.

Provide fan housing of sufficient length to totally enclose the fan impeller and motor within the housing.

Make the ends of the fan housing straight and smooth, suitable to receive sound attenuators at both ends. Connection between fan and sound attenuators shall facilitate assembly and disassembly of fan and sound attenuators in the field.
Provide lifting lugs of steel construction, welded on the exterior of fan housing and sound attenuators. Provide lifting lugs in sufficient number to facilitate future on-site installation and removal of the fan and sound attenuators.

Provide safety chains attached to the lifting lugs as shown on contract drawings.

(5) Motors

(a) General Requirements

Furnish motors for all jet fans supplied by a single manufacturer.

Provide motors that confirm to all applicable ANSI, IEEE, and NEMA (motor design “B”) or approved equivalent ISO standards IEC, designed for continuous operation for a minimum period of one hour in an ambient temperature of at least 482 degrees Fahrenheit.

Motors shall be equipped with a minimum of six resistance temperature detectors (RTD) in motor windings, two per phase and wired to a NEMA 4X terminal box mounted on the outside of the fan housing. RTDs shall have a nominal resistance of 100 ohms and be placed to most effectively determine maximum winding temperatures. Make the terminal box common for all monitoring devices specified under this Section. RTDs shall be compatible with the temperature monitor in the Motor Starter Panel. Thermistors may be used where it is impractical to place an RTD.

Provide motors of the totally enclosed, high efficiency, air-over; all cast iron or high-grade silicone steel frame, induction type. Wind motors for 460-volt, three-phase, 60-hertz alternating current. Wire motors for full voltage starting and reversing. Motors shall have a 1.15 service factor rating.

Provide motors capable of reversing in sixty seconds or less, from full speed forward to full speed reverse and vice versa with a de-energized period of thirty seconds maximum between reversals. The motor shall be capable of performing a minimum of two reversals equally spaced during a sixty-minute period with airflow over it at a temperature of 482 degrees Fahrenheit.

(b) Motor Performance Requirements

Provide motors capable of accelerating the fan impeller from stand still to the design rotational speed in not more than 15 seconds when connected to terminal voltage of 85 percent of the nominal supply voltage.

Provide motors capable of starting, reversing and operating continuously, under full load conditions, for a minimum period of one hour in ambient temperature of at least 482 degrees Fahrenheit.

The capability of performing a minimum three starts (one cold and two hot starts) during a sixty-minute period with 482 degrees Fahrenheit air flowing through the fan is required.
Select motors in accordance with NEMA Standards for the locked-rotor input (Kilovolt-amperes per horsepower) required meeting the indicated acceleration performance. Provide motors with a minimum of Class H insulation and rated for Class F temperature rise, when tested at the 1.15 service factor load.

Provide motors capable of operating continuously at rated torque at any terminal voltage between 85 percent and 110 percent of the nominal supply voltage.

c) Motor Components and Construction

Provide motor shaft of steel construction, designed to support and drive fan impeller under all specified operating conditions. Provide each motor with lifting lugs in sufficient numbers.

Equip motors with anti-condensation, 120 volts single-phase factory-installed resistance space heaters to prevent condensation of moisture in the motor windings. The heaters shall be energized whenever the motor is not in operation and shall be automatically de-energized whenever the motor is in operation. The heater shall be provided with leads terminated in the control wiring junction box on the exterior of the fan housing.

Provide motor leads of insulated copper, wired to an oversized weatherproof conduit box mounted on the exterior of the fan housing. Provide conduit box with screw-type or bolt down pressure terminals and exterior mounting lugs. Protect lead wires from air stream by enclosing them in an airtight, high tensile strength, seamless metal rigid conduit. Provide the conduit box of at least the next size larger than the NEMA standard size for motor frame. Orient the conduit box to allow receiving feeder conduit.

Design and construct motor bearings for maximum radial and thrust loads anticipated during starting, reversing and operating conditions. Furnish bearings having a minimum L-10 life rating equal to 40,000 hours as defined by the Anti-Friction Bearing Manufacturers’ Associations (AFBMA), which is an average bearing life of approximately 200,000 hours.

Bring lubrication lines from motor bearings to the exterior of the fan housing and terminate in straight lubrication fittings. Terminate grease relief lines, if used, in spring loaded relief fittings. Provide grease fittings with covers to exclude water and dust. Select bearing lubricant, which is capable of providing the lubrication properties specified by the bearing manufacturer under conditions of operation for one hour in ambient air at a temperature of 482 degrees Fahrenheit.

Fabricate lubrication lines for motor bearings of high strength, seamless stainless steel tubing without kinks or sharp bends. Secure lubrication lines rigidly to the housing to prevent vibration of the lines and the leakage of air.

Furnish motor bearing with a vibration monitoring system, complete with velocity pick-up transducer, for each motor bearing. Furnish the monitoring system that is to trigger remote alarms for two levels of vibrations: “Alert” and “Alarm.”
The alert level is to trigger an alarm when general wears and minor defects have increased motor vibration to a level where maintenance is needed. The alarm level is to safeguard the motor against dangerous vibration caused by damage of sudden out of balance. Provide measuring range that includes 0.1 to 1.0 inches per second RMS for alert and 0.1 to 2.5 inches per second RMS for alarm. Wire the transducer to the common control terminal box mounted on the exterior of the fan housing.

(6) **Sound Attenuators**

(a) **General Requirements**

Furnish sound attenuators for jet fans selected by the fan manufacturer to meet all operating conditions specified.

Provide cylindrical (tubular) sound attenuators, one mounted directly on each end of the fan housing. Match the inside diameter of sound attenuator to the inside diameter of fan. Provide inner bullet, if required, of aerodynamic design. Match the exterior diameter of the bullet to the diameter of motor and hub. Sound attenuator length shall be minimum two times the fan diameter. Sound attenuator ratings shall be in accordance with ASTM E477.

Attach deflecting vanes to sound attenuators as shown on Contract Drawings.

(b) **Performance Requirements**

Furnish sound attenuators of such design that jet fan assemblies do not exceed the acceptable maximum sound power levels indicated in Section 2.4.c.

(c) **Sound Attenuator Construction**

Select the materials and methods used to fabricate sound attenuators such that they are operational for minimum period of one hour in ambient air temperature specified in the Emergency Operation conditions specified in Section 2.4, without any mechanical or a structural failure.

Fabricate the exterior casing of not less than No. 18 United States Standard Gage (USSG), hot dipped galvanized steel, internally lined with inorganic mineral wool or glass fiber acoustic in-fill covered with not less than No. 22 USSG stainless steel perforated sheets.

Provide drain hole of 0.5 inch (12 mm) diameter minimum in the exterior casing of each sound attenuator, to drain water that may enter into fan assembly during tunnel washing operations.

Select the acoustic filler material, which shall be mineral, glass fiber of a density sufficient to obtain the required acoustic performance. Filler material shall be inert, vermin-proof, and resistance to high humidity conditions. Select the facing on the in fill of the type that prevents erosion of the fibrous particles by the air stream under all conditions of operation specified. The filler material shall not ignite, degrade, nor support combustion in thermal environment of 482 degrees Fahrenheit.
Select the acoustic filler material, which has the combustion rating not more than the following when tested in accordance with ASTM E 84, NFPA 255, or UL 723.

Flame spread classification - 20
Smoke Developed Rating - 20
Fuel Contribution - 15

(7) Miscellaneous Appurtenances

(a) Fan Supports

Design and construct fan support and suspension system to provide support as required against the fluctuating loads imposed by fan operations and moving traffic. Design per the Specification for Structural Steel Buildings, Allowable Stress Design Method, June 1, 1989 by the American Institute of Steel Construction. Use AISI Type 316 stainless steel bolts and hot dip galvanized or stainless steel support members, with rubber isolating material separating the support steel from the fan’s steel attachment locations. Design support system to facilitate easy dismantling and reinstallation of fan or sound attenuators as required for maintenance.

Design the hanger system to suspend the fan from embedded steel in the tunnel roof. The hangers shall be furnished by the Contractor and customized to field conditions. The fan support, the vibration isolators and the hardware shall be supplied by the fan manufacturer. Shop drawings shall show sufficient detail to fabricate the hanger system and shall be signed and sealed by a registered structural engineer in the state of Texas.

Fabricate fan supports using hot dip galvanized or stainless steel. Bolt supports to the fan housing and cross brace to provide rigidity.

Design supports shall be suitable for the existing provisions in the field for attachment and shall meet the space constraint as shown on the Contract Drawings.

Furnish all bolts, nuts, washers, and lock washers of AISI Type 316 stainless steel. Furnish bolts that are consistent with the existing tunnel embedded inserts, where applicable.

Provide lifting lugs or eyes in sufficient numbers as specified in Section 2.4.d.

(b) Nameplates

Nameplates shall be attached to respective component in a location conspicuous after installation.

Furnish nameplates for each fan assembly. On each nameplate, show the name and address of the fan manufacturer, the Contractor’s name and address, serial number of the fan, the maximum safe rotational speed of the fan in revolutions per minute and the design operating conditions of the fan.
Furnish an additional nameplate for each fan, which shall bear, in numerals not less than 3 inches high, the Engineer’s fan designation number. Rivet or screw nameplates to the fan housings in conspicuous location.

Furnish two identical nameplates for each motor. On each nameplate, show the name and address of the motor manufacturer, the motor model number and serial number, motor speed in revolutions per minute, nominal horsepower, electrical characteristics (voltage, phase, frequency); no-load, full-load, and locked-rotor currents, NEMA code-letter designation, NEMA frame size, service factor, rating of space heater and the terminal connection chart for the motor. Securely fasten one of the two nameplates to the motor housing; rivet or screw the other to the fan housing adjacent to the fan nameplates.

Each sound attenuator shall be provided with a stainless steel nameplate permanently stamped with the name and address of the manufacturer, Contractor’s name and address, model type and serial number. The nameplate shall be securely attached to the exterior of the attenuator unit in a conspicuous location.

Fabricate all nameplates of stainless steel. Permanently mark the specified data on the nameplates.

(c) Jet Fan Deflector Vanes

The purpose of the deflector vanes is to direct the discharge airflow of the jet fans into the tunnel and to reduce the wall impact on airflow.

Deflector vanes shall be manufactured from stainless steel or hot dip galvanized steel. Deflector vanes shall be installed as shown in the Contract Drawings.

The deflector vanes installation shall not cause a decrease in jet fan thrust of more than 7 percent in the forward or reverse direction nor increase sound levels by 2 dBA at 33 feet from the fan in the forward or reverse direction of operation.

(d) Safety Chains

The purpose of safety chains is to prevent jet fan from falling onto the road. Safety chains shall be manufactured from stainless steel or hot dip galvanized steel, and shall be arranged on the tunnel ceiling independent of the jet fan support as shown in the Contract Drawings.

Under normal operating conditions, the safety chains do not bear any load.

(8) Local Instrument Panel (LIP)

Fan manufacturer shall furnish a local instrument panel (LIP) to house remote electronics for motor winding resistance temperature detectors (RTD), fan bearing vibration monitor, air flow switches and and flow indicators. Local instrument panel shall be furnished for each fan.

Local instrument panel shall be furnished with a cabinet and hardware for mounting.
Cabinet components shall be as required for a complete instrument installation. Cabinet shall be factory finished with baked enamel paint. Cabinet construction shall conform to UL 50 and be formed of No. 14 gauge steel sheet. Provide openings for wire and pipe into cabinet. Cabinet shall be factory assembled and finished with baked enamel paint. Pressure gauge and operating (manual) switches relative to control cabinet shall be installed through door facing outside. Permanent identification tags shall be firmly attached to door under each item.

Control and instruments used for the operation of specified fans shall be tested and certified in accordance with NEMA ICS 2.

Operating and maintenance instructions for local instrument panel shall be included in the Operation and Maintenance Manual.

(9) **Airflow Indicating Devices**

(a) **General**

An airflow indicator device shall be provided for local and remote indications of fan operation and forward and reverse air flow.

Use one airflow indicator for forward air flow and another airflow indicator for reverse air flow.

(b) **Pressure Switch.** Furnish each fan assembly with a differential pressure switch, capable of detecting a difference in air pressure to provide positive indication of airflow generated by the fan.

Differential pressure switches shall be diaphragm operated to actuate a single pole double throw snap action switch.

Motion of the diaphragm shall be restrained by a calibrated spring that can be adjusted to set the exact pressure differential at which the electrical switch will be actuated.

Motion of the diaphragm shall be transmitted to the switch button by means of a direct mechanical linkage.

Set point adjustment shall be screw type with set point indicated on a visual scale.

Housing shall be weatherproof, 16 gauge steel zinc plated with gasket cover.

Electrical rating shall be 15 amps, 120 volts, 60 Hertz.

Switches shall be suitable for operating in temperature range of minus 5ºF to 120ºF. Operating range shall be 0.2 in wg to 1.0 in wg.

(c) **Speed Pickup.** As an alternate to the Airflow Indicating Device the Contractor may provide a speed pickup to indicate operation of the fan.
Furnish a proximity transducer and probe with electronics enclosed in a NEMA 4 enclosure and compatible with the speed monitor located in the Motor Starter Panel. The monitor shall receive the speed signal from the proximity probe and close a relay contact at or near the design operating speed of the jet fan motor.

The Contractor shall determine the exact location and position required for the proximity probe and the notch on other pulse device on the motor shaft. Contractor shall develop details and show on shop drawings the support, probe length, mounting thread and stand off adapter options to suite the mounting scheme.

(10) Painting and Finishing

(a) General

Surfaces on fan housings, supports, exterior surfaces of sound attenuators, motors, and any other miscellaneous metal except galvanized and stainless steel components, nameplates, and machined surfaces to receive appurtenances, shall be painted in accordance with the requirements specified herein.

Finishes shall be factory-applied and shall be certified by the manufacturers of the finishing materials to be capable of withstanding exposure to an ambient temperature of 482 degrees Fahrenheit for a minimum of one hour without producing smoke or toxic fumes.

Applied and cured paint shall be tested to ensure that the specified dry film thickness is achieved. The dry film thickness shall be measured in place with a calibrated magnetic film-thickness gauge. Only the primer coat and the primer combined with topcoat will be measured.

Machined surface not requiring painting shall be provided with a coating of suitable anti-corrosion compound before leaving the place of manufacture.

Contractor shall supply necessary paint to repair any damage to the ventilation equipment during installation.

(b) Paint Material

Paint material provided shall be from one source.

Primer Paint Material: Primer paint material shall be Carboline, Carbo Zinc 11 HS, a high solids inorganic zinc rich primer, or approved equal.

Topcoat Paint Material: Topcoat paint material shall be Carboline, Carbothane D134 HS, high gloss, high solids urethane, or approved equal.

The Contractor may propose to use other paint systems by other manufacturers, provided that the Contractor submit the other manufacturer's paint systems, including surface preparation and dry film thickness, for acceptance by the Engineer.
(c) Finishes

Surfaces Except Surfaces of Motors: primer paint material shall be prepared in accordance with the requirements of SSPC SP-6. The minimum height of profile after completion of blast cleaning shall be 1.5 mils.

Surfaces of Motors: Surfaces of motors to receive primer paint material shall be prepared in accordance with the requirements of SSPC SP-3.

Surfaces specified to receive paint shall receive one coat of primer paint material and three coats of top coat paint material. Successive topcoats shall be tinted to differentiate between coats.

The minimum dry film thickness of the primer coat shall be three mils.

The dry film thickness of each topcoat shall be two to three mils.

Primer and topcoat paint materials shall be applied in accordance with the requirements of the paint material manufacturer's printed paint application instructions and in accordance with the applicable non-conflicting requirements of SSPC PA-1.

As specified herein, the applied and cured paint film shall be tested to determine the dry film thickness. Measurement of dry film thickness shall be in accordance with the requirements of SSPC PA-2.

Surfaces which after painting and after installation of components are not as specified shall be re-cleaned, re-primed and re-painted as may be required until the specified coating requirements have been obtained.

3. Construction.

(1) Clearance Limitations. The traffic clearance envelope and niches where applicable, in the respective tunnel is clearly shown at each jet fan location. The jet fan sizes and mounting arrangements shall be such that they do not encroach into the envelope. Contractor to verify the clearance is met.

(2) Temporary and Permanent Supports. All lifting of jet fans into place shall be provided with Contractor supplied equipment located on the tunnel roadway or walkway surface. Contract Drawings show the embedded steel in the tunnel roof, for use by this contractor in supporting each jet fan. Provide temporary supports and bracing as required during handling and erection.

(3) Installation

(a) The Contractor shall provide the services of a qualified erection superintendent who is competent and experienced with the work involved in the installation of ventilation equipment of this type.
The erection superintendent shall, at the site, supervise the ventilation equipment installation and shall be available when any of the work in connection with the ventilation equipment installation is proceeding, to verify that the Work is properly performed.

(b) Install jet fan assemblies in the space provided in such a manner as to be readily serviceable. Verify existing inserts or existing structural steel as applicable and other installation provisions prior to fabrication of hangers and supports.

(c) Adjust supports for fans, and for sound attenuators if provided, such that they align accurately on the same horizontal plane. The Contractor may, at his option, attach sound attenuators and deflecting vanes to each end of the fan housing prior to lifting the jet fan assembly to the tunnel roof for installation.

(d) Install jet fan assemblies as recommended by the fan manufacturer, using vibration isolators of adequate strength and deflection to minimize transmission of high frequency vibration to the structure.

(e) The requirements for installation of conduit disconnect switches; wiring, etc. are specified in the related Electrical Sections.

(f) After installation and before the start of testing, the equipment shall be checked for clearances and proper alignment. Manufacturer representative shall be present and approve start-up in writing prior to energizing the fan.

(g) After installation and before the start of testing, the ventilation equipment shall be lubricated. Lubricants of the correct type and grade shall be provided where required.

(h) Conform to the applicable requirements in the Electrical Sections, the permanent anti-condensation motor space heaters for the ventilation fans shall be energized with temporary power before and after installation until permanent power is available.

(i) Airflow Indicating Devices

Install differential pressure switches and relays in local instrument cabinet for each fan assembly.

Provide 3/8 inch copper tube for total and static pressure probes. Insert tubes through sound attenuators and extend into air stream approximately 8 inches.

Terminate total pressures probe facing inlet side of fan assembly.

(4) **Welding.** All components in this Contract requiring welding shall be welded as follows:

Welding shall conform to the requirements of AWS D1.1 and AWS D1.3, and AWS D14.6 as applicable.

Welders welding on the work of this project shall be qualified in accordance with the requirements of AWS D1.1, Section 5, qualification.
The welding process employed on the Work of this project shall be the shielded metal arc process, in accordance with AWS D1.1 and D14.6 as applicable.

4. Factory Tests and Inspections

(1) General

Provide test facility at the fan manufacturer’s place or at a testing laboratory, which is suitable for all tests specified. The motor manufacturer may perform the motor test at the place of the manufacture.

Submit full details of all test procedures, including samples of test report form and details of test methods and data acquisition for approval by the Engineer. Subsequent to approval, notify the Engineer in writing, of all shop test dates not less than 14 days prior to the test so that the Engineer may witness the test.

The Engineer may, at his option, witness any or all tests. Observations made during the tests and all test results shall be recorded in a document form, certified by the Contractor and submitted to the Engineer for approval.

Any fan type or size or any component thereof, which fails to satisfactorily perform any test as specified shall be considered unacceptable. Failing parts shall be replaced and the entire component shall be retested as specified herein.

(2) Motor Test: Motors shall be tested in accordance with the procedures specified in IEEE 112 and NEMA MG-1. Factory test each pre-production jet fan motor. The test will be witnessed and unwitnessed.

(a) Witnessed Tests: One motor of each nameplate horsepower rating and service factor shall be tested at its rated speed for forward and reverse mode of rotation. The Engineer will designate motors for testing.

Tests shall be as follows:

Tests to obtain actual fan motor performance curves verifying the theoretical fan motor performance curves and other data submitted as specified herein.

Tests to obtain values for the following electrical and mechanical characteristics with rated voltage and frequency applied to motor terminals:

- Full load current in amperes.
- No load current in amperes.
- Full load input in kilowatts.
- No load input in kilowatts.
- Locked rotor current in amperes.
- Locked rotor input in kilovolt amperes.
- Locked rotor torque in pound-feet.
Rotational moment of inertia of rotor in pounds-feet squared.
Displacement power factor in percent at full load amperes and locked rotor amperes.

A complete test of each motor shall include the following:
Performance speed-current and speed-torque tests.
Temperature test, full load.
Insulation resistance-temperature test shall be taken following heat run, readings being taken in degrees Celsius at one-hour intervals for a period of four hours. Temperature shall be determined by the resistance method.
Cold and hot resistance measurement.
Dielectric Test: (Voltage to be applied shall be based on the voltage rating of insulation plus 1000.)
Visual bearing inspection.
Noise test in accordance with IEEE 85 with results expressed in decibels of sound pressure and power on the A scale.
Tests to determine:
Winding resistances.
Losses, no load and full load.
Temperature rise.

(b) Unwitnessed Tests: Each of the remaining motors shall be tested at its rated synchronous speed Unwitnessed. Reversible motors shall be tested in one direction.

Tests shall be as follows:
Winding resistances.
No load current in amperes.
Dielectric tests.
No load speed.
Locked rotor current in amperes.
Bearing inspection.
Running-no load current.
Cold resistance measurement.
Insulation resistance and winding temperature at time taking insulation resistance.
Vibration check.
Only those motors for which test The Engineer has approved reports and performance curves may be assembled into fan-motor units.

(3) Fan Tests

(a) Radiographic inspection: Provide a certification in accordance with ASTM E115 that, for all fan hubs and blades, x-rays have been taken, with notation of the x-ray numbers, and also that zyglo testing has been performed. Certification of visual acceptability, the x-ray procedure, the x-ray films, and proof of traceability of conformance with alloy specifications of the metal used to cast the hub and blades shall be submitted to The Engineer for approval.

(b) Over-speed Test: All fan rotor assemblies shall be subjected to an over-speed test prior to assembly of the complete fan motor units. After radiographic inspection and after static and dynamic balancing, each completely assembled fan impeller shall be spin tested in both directions. Spin tests each impeller at 125 percent of design rotational speed for a period of not less than three minutes in each direction. Examine impellers for loose blades and other damages. Replace defective parts and repeat the spin test before further testing.

(c) Vibration test: Each fan motor unit shall be checked in each speed for bearing operation in both directions of rotation. Defective bearings shall be replaced and the fan shall be rechecked before further testing. Test each fan for vibration, measured in two radial planes 90 degrees apart, in the axial direction at the front and rear of the fan. Compare the measured vibration levels with the acceptable vibration limits specified. If the measured vibration exceeds the specified limits, determine the cause(s), correct it and then retest the fan.

(d) Run-in Test: Each fan shall be operated continuously for 24 hours, 12 hours in each direction of rotation. During reversal, fan shall be allowed to coast for a minimum period of five minutes before being restarted in the reverse direction.

(4) Pre-Production Model Fan Tests: Prior to commencement for manufacture of jet fans to be procured under this Contract, test as specified in the following paragraphs each pre-production model fan-motor-sound attenuator assembly unit which has successfully completed the preceding tests.

Pre-Production Model defines a unique fan of which there may be one or more identical copies. The tests described in subparagraphs 2 and 3 apply to all jet fans; The following tests described in subparagraphs 4.a, 4.b and 4.c apply to the pre-production model of each identical set. The test described in subparagraph 4.c is required for one pre-production model jet fan.

(a) Performance Test: Test the pre-production jet fan assembly for thrust and performance in accordance with the requirement of AMCA 250. Test the jet fan assembly in both directions of airflow to determine the thrust developed, airflow, exit jet velocity and motor brake horsepower (or input power).
The jet fan assembly shall be tested with and without the deflector vanes. Change the angle of fan blades and repeat test as required until the specified requirements are satisfied. If the maximum H.P. listed on the schedule is exceeded when delivering the specified thrust, the jet fan shall be redesigned to meet the maximum H.P. requirements.

(b) **Noise Test:** Test the pre-production jet fan assembly in accordance with the requirements of AMCA 250 and ISO 13350 and other applicable international standards, with and without the deflector vanes. Test to obtain sound pressure data at eight-octave midband frequencies from 63 Hertz to 8000 Hertz. Present measured data for each octave band and in the A-weighting (DBA).

(c) **High Temperature Test:** Test one pre-production fan motor unit (without sound attenuators) to demonstrate that it is capable of operating for a minimum period of one hour when the airflow passing through the fan is at a temperature of 482 degrees Fahrenheit or higher.

5. **Acceptance**

(a) Any pre-production fan motor unit used to satisfy the high temperature requirements shall be considered sacrificial unit and will not be accepted for procurement under this Contract.

(b) The pre-production jet fan assembly which has satisfactorily passed all specified tests, except any used for the high temperature test, may be accepted as production unit, if all parts and components are in like new and operating condition, by the Engineer under this Contract.

5. **Submittals**

1. **Shop and Working Drawings:** Shop drawings, working drawings, catalogs, catalog cuts, samples, etc. shall be submitted in accordance with the requirements Item 5. Submit dimensioned drawings of tunnel jet fans showing sound attenuator assembly layout, supports, and other appurtenances required for installation. Show on shop drawings, point loads at each support point including summary of dead loads, live loads, axial loads, thrust loads, clearance between jet fan and structure and roadway, and complete installation details. Design the fan supports in accordance with the design criteria on the Contract Drawings.

Submit structural support design calculations, certified by a professional engineer registered in the State of Texas.

Submit a tabulation showing the static thrust, exit jet velocity, horsepower input and sounds power level of the jet fan assembly at the design point blade angle setting and at three additional settings, in 2 degree increments, above and below the design point. Derive the data from the actual fan assembly performance tests. The fan manufacturer shall identify the possibility of fan stalling if it exists within the fan performance region covered by 10 percent above and below the design thrust as specified. Separate data shall be furnished for both directions of airflow.
Submit motor performance curves, which are either derived from actual performance tests or from analytical data.

Submit shop drawings and the test procedures for the pre-production units as a package.

Submit narrative test reports for all factory and field tests. Include the raw data as recorded during each test.

(2) Test Procedures and Reports

Full details shall be submitted of the scheduled tests and the expected duration of all test procedures. Samples of all test report forms, and full details of the methods by which the raw test data is to be reduced, shall be acceptable to the Engineer before testing is begun on ventilation equipment to be furnished under this Contract.

The test report shall identify the name of manufacturer, model numbers, serial numbers, and the last date of calibration of test instrumentation. Documentation shall be furnished to verify that these instruments have been calibrated not more than nine months prior to the tests.

The test report shall include a list of attendees.

Certified test results for all fans, shall be submitted within 30 days after the completion of each test. No equipment shall be released for shipment until the Engineer accepts certified test data. Copies of accepted test procedures, raw data measured results, calculations and all data derived from tests shall be included as part of report. All test data for each size of jet fan shall be bound in one report. The test report shall be indexed and cross-referenced in an easily understood manner.

Submit after completion of the performance test on each pre-production jet fan assembly, with a unique combination of size, RPM, thrust and horsepower, all the performance test results require by these special Provisions.

(3) Certificates of Compliance

Submit certificate of compliance that the design and fabrication of various components of the tunnel ventilation system meet the requirement of the Contract.

Submit certificate of compliance that the jet fan assemblies meet the requirement of operation at the elevated temperature specified in the Emergency Operation conditions in Section 2.4.

Provide data substantiating that materials comply with the requirements of the various standards as specified.

Submit catalog cuts of fans, motors, sound attenuators, supports, vibration isolators, and hardware. Submit brochures or other information describing the materials, construction method and the general characteristics of the fans, motors and sound attenuators.
(4) **Operation and Maintenance Manuals**

Furnish manuals that provide a clear explanation of operation and maintenance of the jet fan assemblies accompanied by photographs, schematics, wiring and assembly diagrams as required. Furnish manuals that are printed and loose leaf bound.

Provide operating instructions, troubleshooting and fault isolation procedures, and equipment removal and replacement procedures.

Provide a preventive maintenance schedule and instructions detailing lubrication of moving parts and monitoring of vibration levels.

Provide a list of tools and test equipment required to perform all maintenance tasks and a list of recommended replacement components for one year’s operation.

Provide manufacturer’s descriptive literature, catalog cuts, as-built drawings, fan and motor performance curves, and the name and address of subcontractors and suppliers.

6. **Qualifications of the Fan Manufacturer:** The manufacturer of the ventilation fans to be provided under this Contract shall be a manufacturer who for at least ten years has been regularly engaged in the production of axial flow ventilation fans of size capacity and thrust comparable to that specified herein. The fan manufacturer shall submit documents to show continuous and current experience in the design, assembly and testing of axial flow tunnel ventilation fans and experience in design, fabrication and testing of tunnel ventilation fan assemblies capable of operating in an environment as specified in Section 2.4.b.

7. **Quality Control**

   (1) **Source of Quality Control:** jet fan assembly shall be the product of a single manufacturer whose name shall appear on the theoretical fan-motor unit performance curves and all other data submitted.

   (2) **Documentation:** Submit documentation by the manufacturer that jet fans, of the capacity (thrust and exit jet velocity) not less than that to be furnished under this Section, have been satisfactorily used in above named applications for at least five years.

   (3) **Service Support:** The Contractor shall make available the services of the manufacturer’s service representative for a period of two eight hour days to instruct the authority’s personnel on the proper operation, repair, and maintenance of the system.

   (4) **Warranty:** The Contractor shall furnish one year of Warranty service on the jet fan assembly that shall commence from the Authority’s acceptance of the tunnel ventilation system and shall continue up to and including the first anniversary of the Authority’s acceptance. Warranty service shall include labor and materials to replace any parts or controls that might fail in service as the result of a defect in materials, installation or manufacture.
8. Equipment Start-Up and Field Tests

The testing and start-up of the tunnel ventilation equipment complete with all required accessories, including jet fans, fan motors, motor control centers, programmable logic controllers and workstations, interconnecting power and control wiring and conduits as shown on the Plans, hereinafter specified or otherwise required for a complete and fully operable system.

(1) General Requirement

(a) Field Test Data: The following shall be submitted:

Full details of the scheduled field testing, proposed testing procedure, test report forms, test instrumentation and staffing shall be submitted in writing for acceptance before testing.

At completion of field-testing, six copies of test records shall be submitted for acceptance.

(b) Supervision of Start-Up and Testing:

The Contractor shall provide a qualified individual(s) competent and experienced in the testing and start-up of the ventilation equipment specified herein. This individual(s) shall supervise, at the site, all start-up and test activities associated with the ventilation equipment to verify that the start-up and testing is properly performed and in accordance with these specifications.

(c) Certificate of Compliance: A certificate of compliance that all components furnished meet the requirements specified herein shall be submitted by Contractor after completion of all field tests and after the final inspections.

(2) Tests and Inspections

Upon completion and certification of the installation of the ventilation equipment in the tunnel and the installation and verification of the permanent power and local control wiring, startup testing of the fans and their auxiliaries shall commence. Following the manufacturer’s recommendations contained in the Operations and Maintenance Manual, all equipment operation shall be verified individually prior to initial operation of the entire unit. The technical representative(s) shall direct all startup activities and provide advice and guidance as appropriate.

The following specifies the testing requirements for tunnel ventilation equipment to be procured under this Contract. All tests described herein shall not preclude any additional standard test normally performed for similar equipment.

The Contractor shall notify the Engineer in writing of all test dates not less than 14 Days prior to tests including the expected duration and sequence of testing. The Engineer representative may witness any or all tests unless waived by the Engineer.
(3) Field Tests

(a) Start-up Testing

This section describes the requirements for field testing which includes the start-up of the jet fans installed in the tunnels, as specified herein.

The Work includes continuous run tests, and providing field instruction on operation of the ventilation equipment for the Operation’s personnel.

Field-testing shall be performed when the Engineer has determined that interfacing work is sufficiently complete to allow for valid results.

Field-testing shall not be performed without the presence of the Engineer.

Jet fans and all associated motor controllers, and monitoring and control equipment shall be tested as specified herein.

Tests, which fail, shall be repeated upon corrections of any deficiencies until satisfactory performance is demonstrated, at no increase in Contract Price or Contract Time.

Any defect that develops with the installation work during the field tests shall be corrected by Contractor at no increase in Contract Price or Contract Time.

The Contractor shall provide instrumentation to meet the field test requirements specified herein. After completion of field-tests and upon acceptance of test results by the Engineer, the field test instrumentation shall remain the property of the Contractor.

Testing, checkout and start-up of the PLC and workstation equipment shall be performed under the technical direction of the manufacturer's service engineer. The Contractor in conjunction with the PLC manufacturer shall provide at no additional cost, a start-up service package for all PLC and workstations provided.

A copy of all tests and checks performed in the field, complete with meter readings and recordings, where applicable, shall be submitted to the Engineer for its record.

(b) Tests Requirements for Jet Fans

(1). Vibration Test: Check fans for obviously rough operation. Replace defective bearings and recheck fan operation. Measure amplitude and frequency of radial and axial vibration levels, and check for conformity to the specified acceptable vibration levels. For a jet fan assembly whose vibration level exceeds the specified limit, balance impeller as required and re-measure vibration level until the specified requirement is met. Record and submit the measurements to the Engineer.
(2). **Run-in Test**: Demonstrate that fans are operational in each direction. Operate each fan continuously for one hour in each direction. Measure and record for each motor individually, the motor starting current, running current, starting voltage, full load voltage and power factor. Measure and record running current and full load voltage with all the fans in operation in the same tunnel.

(3). **Starting Test**: Each fan shall be operated with two starts and two reversals within one hour. The starts and reversals shall be equally spaced within the hour and shall occur immediately following a stop and coast down. The motors shall not overheat nor shall the fans experience excessive vibration during this test.

(4). **Performance Test**: Test each jet fan in forward and reverse airflow for the actual “in-tunnel” performance. Measure and record the direction and magnitude of the natural wind velocity in the tunnel just prior to starting each jet fan for this test. Measure the exit jet velocity and air volume generated by the jet fan assembly in each direction of airflow. Based on the measured value of velocity and volume, calculate the thrust developed by the fan in each direction.

If the calculated thrust is at least 90% of, or more than, the specified value, no further testing is required. If the calculated thrust is less than 90% of the specified value, adjust the fan blade angle to increase the airflow. Re-measure the exit jet velocity and air volume until the calculated thrust is at least 90% of the specified value. Record the new running current and power input to the jet fan.

(5). **Noise Measurement**: Measure and record sound pressure levels in 8 octave midbands of each fan operating alone. Measure sound pressure levels 5 feet (1.5 meters) above the roadway surface under the fan and at 15 feet and 30 feet (4.5 and 9 meters) from the both ends of the fan. Record ambient sound level before fan is started and after fan is turned off. With all fans operating simultaneously in the tunnel, measure sound level at locations determined by the Engineer.

(c) **Service Operation Test** (Applies to all Ventilation Equipment):

A 90 Day service operation test of the ventilation equipment will be made by the Engineer when all components of each of the ventilation systems are installed and tested as herein before described.

During the test, the Engineer will be allowed free access to the equipment installed by the Contractor, but the Contractor will not be permitted to control or interfere with the making or conducting of any test by the Engineer.

The Contractor shall correct any defect that develops during the test at no increase in Contract Price or Contract Time.
(d) **Training:** Provide a three eight-hours Day Training for the Operating Agency’s personnel. Training shall be divided as follows:

- One (1) eight hour day of instruction for operators
- One (1) eight hour day of instruction for PLC maintenance training
- One (1) eight hour day of instruction for fan and fan monitoring instrumentation maintenance training

Each training class shall consist of up to fifteen (15) individuals.

Training shall be held on dates and at a location designated by the Engineer. Provide an agenda defining the training objectives and containing a detailed outline identifying the content of each training session.

The Training period shall describe the operation and maintenance of the equipment and systems provided and the instruction period shall be conducted by qualified competent instructor(s) certified by the equipment and system manufacturers as qualified to conduct the training.

Training shall be based on the O & M manuals. Design the training curriculum to enable the Operating Agency to develop a self-sufficient operations and maintenance team for all equipment provided.

Training shall be comprehensive and thoroughly cover all topics including:

- Overview
- Equipment Operation
- Theory of operation
- Manual operation from PLC workstations
- Sequence of Operations of the fans in PLC Control
- Alarms
- Troubleshooting procedures including the proper use and purpose of PLC diagnostics.
- Removal and Replacement of field replacement units
- Equipment interfaces including communication software between PLC’s and any field equipment.
- Preventative and Corrective maintenance procedure
- Use of all Contractor supplied tools and special test equipment
- PLC programming and troubleshooting including training on the PLC ladder logic Diagrams
Troubleshooting techniques at interfaces between hard/software systems

Training participants shall operate actual equipment, run all applicable diagnostic software and repair simulated failures.


Tunnel ventilation jet fans and all associated equipment shall be measured on a lump sum basis, complete-in-place, connected, energized, tested and made fully operational.

10. Payment. Tunnel ventilation jet fans and all associated equipment will be paid under “Measurement” will be paid for at the unit price bid for “Jet Fan Assemblies,” at the lump sum price and shall include the cost of all related work specified in this Section.