TUNNEL JET FANS

1.0 GENERAL

1.1 SCOPE

This work shall consist of furnishing, installing and testing the tunnel jet fans including the motor units, sound attenuators, hangers, supports, fan starters, controls, conduit boxes, accessories, and associated work in conformance with to the requirements specified in these Special Provisions.

2.0 DEFINITIONS

The following definitions shall apply to this section:

A) Fan: the terms fan, jet fan, and fan assembly are synonymous and are deemed to mean a jet fan complete with sound attenuators, screens, deflectors, and directly-connected non-reversible motor.

B) Forward flow: airflow generated by the fan in the same direction as the normal traffic flow in the specific tube of the tunnel.

C) Pitch: the angle formed by the chord line of a fan blade root cross-section and a line parallel to the direction of rotation.

D) Manufacturer's Representative: a representative from the firm of the manufacturer for each and every category of equipment furnished under this special provision.

3.0 QUALIFICATIONS OF THE FAN MANUFACTURER

All jet fans provided under the Contract shall be the product of a single manufacturer whose name appears on the fan unit and theoretical fan performance curves submitted in accordance with this Specification. The manufacturer of the jet 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 road tunnel or rail transit application jet fans of size capacity and thrust equal or greater to that specified in the Technical Requirements Tunnel systems.

The fan manufacturer shall document at least ten years of continuous and current experience in the design, assembly , and testing of jet fans and experience in design and fabrication of jet fans capable of operating in 480 ^{o}F air stream for a minimum of one hour. 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 Specification have been satisfactorily used in road or rail transit tunnels for the last ten years. Include contact information for the case history fan owners. Provide all numerical data in USA units.

4.0 APPLICABLE PUBLICATIONS

The following codes, regulations, reference standards and specifications shall apply to the Work of this Section:

A) Anti-Friction Bearing Manufacturer's Association (AFBMA):

1) 99 Load Rating and Fatigue Life for Ball Bearings

2) 11 Load Rating and Fatigue Life for Roller Bearings

B) American Iron and Steel Institute (AISI):

1) 316 Stainless and Heat Resisting Steel.

C) Air Movement and Control Association, Inc. (AMCA):

1) 250 Methods of Testing Jet Fans for Rating

D) American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE):

1) 51 Laboratory Methods of Testing Fans for Rating

E) American Society for Testing and Materials (ASTM):

1) E84 Surface Burning Characteristics of Building Materials

2) A36 Specification for Carbon Structural Steel

F) American Welding Society (AWS):

1) D1.1 - Structural Welding Code, Steel

2) D1.3 - Structural Welding Code, Sheet Steel

3) D14.6 - Welding of Rotating elements of Equipment

G) G. Institute of Electrical and Electronic Engineers (IEEE):

1) 85 - Standard Test Procedure for Airborne Sound Measurements on Rotating Electric Machinery.

H) National Electrical Manufacturers Association (NEMA):

1) ICS - Industrial controls and Systems

2) ISI.1 - Enclosures for controls and systems

3) MG1 - Motors and Generators

4) MG1-12.43 -Temperature Rise for Medium Single phase and Polyphase Induction Motors

5) MG1-12.54- Efficiency

6) 4 Rain Tight Indoor/Outdoor

7) 4X Stainless Steel

I) Steel Structures Painting Council (SSPC):

1) SP-1 - Solvent Cleaning

2) 2. SP-2 - Hand Tool Cleaning

3) SP-3 - Power Tool Cleaning

4) SP-6 - Commercial Blast Cleaning

5) SP-10 - Near White Blast Cleaning

6) PA-1 - Shop, Field, and Maintenance and Painting

7) PA-2 - Method for Measurement of Dry Paint Thickness with Magnetic Gage

J) Underwriters Laboratories (UL)

1) UL 508 Industrial Control Equipment (ANSI)

2) 723 UL Standard for Safety Test for Surface Burning Characteristics of Building Materials

K) Institute of Electrical and Electronic Engineers (IEEE):

1) Standard Test Procedure for Polyphase Induction Motors and Generators

L) National Fire Protection Association (NFPA):

1) Standard Method of Test of Surface Burning Characteristics of Building Materials

M) International Standards Organization (ISO):

1) TC117.WG6 Methods of Testing the Performance of Jet Tunnel Fans

5.0 GENERAL REQUIREMENTS

The jet fan sizes and mounting arrangements shall be such that they do not encroach into the clearance envelope of the tunnel.

The Doyle Drive Contract No. 4 plans show the embedded struts in finish lining of the concrete ceilings to be used in supporting each jet fan in the Southbound Battery Tunnel.

The Developer 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, supervise the ventilation equipment installation and shall be present on site, when the work in connection with the ventilation equipment installation is proceeding, to verify that it is performed in accordance with the manufacturers written instructions.

Welded components of jet fans shall conform to the following requirements:

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

B) Welders shall be qualified in accordance with the requirements of AWS D1.1, Section 5, "Qualification."

C) The welding process shall be the shielded metal arc, in accordance with AWS D1.1 and D14.6.

6.0 SUBMITTALS

Submit working drawings and the test procedures for the pre-production fans and components as a complete package.

Each working drawing and calculation sheet specified herein shall be signed by an Engineer who is registered as a Mechanical Engineer in the State of California.

6.1 PRODUCT DATA

The Developer shall submit manufacturer's catalog cuts and technical data of fans, motors, sound attenuators, supports, vibration isolators, flow switches, vibration and temperature sensors and hardware. In addition, brochures or other information describing the materials, construction methods and the general characteristics of the fans, motors and sound attenuators shall be submitted. Submit the name and address of subcontractors and suppliers.

6.2 WORKING DRAWINGS

Working drawings for the jet fan assembly shall include complete details, information, and drawings for the jet fans, jet fan housings, and supports and other appurtenances required for installation:

A) The dimensioned drawings of jet fans shall be submitted for approval showing sound attenuator assembly layout, supports, and other appurtenances required for installation. The working drawings shall show point loads at each support point including summary of dead loads, live loads, axial loads and thrust loads, and complete installation details. The dimensioned drawing shall include the location of the electrical boxes and the access panel on the outside of the fan.

B) The jet fan structural support design calculations shall be stamped and signed by an Engineer who is registered as a Civil Engineer in the State of California.

C) A general arrangement drawing, product data and test procedures shall be submitted for approval prior to conducting the pre-production unit tests.

6.3 TEST PROCEDURES AND REPORTS

A) Full details shall be submitted to the Department for approval of the scheduled tests and the expected duration of all test procedures. Samples of all test report forms, and full details of the methods, calculations and formula by which the raw test data is to be reduced, shall be submitted to the Department for approval prior to commencement of testing of the ventilation equipment to be furnished under this Contract.

B) The test report shall identify the name 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.

C) The test report shall include a list of attendees.

D) Certified test results for all fans, shall be submitted to the Department for approval within 30 days after the completion of each test. No equipment shall be released for shipment until certified test data is approved by the Department. 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.

E) Submit after completion of the performance test on each pre-production jet fan assembly all the performance test results required by these Special Provisions.

6.4 CERTIFICATES OF COMPLIANCE

The Developer shall provide certificates for the materials and components provided to show conformance with the standards specified in these Special Provisions.

6.5 OPERATION AND MAINTENANCE MANUALS

A) 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.

B) Include operating instructions, troubleshooting and fault isolation procedures, and equipment removal and replacement procedures and equipment disassembly and assembly procedures.

C) Include a preventive maintenance schedule and instructions detailing lubrication of moving parts and monitoring of vibration and temperature levels.

D) Include a list of tools and test equipment required to perform maintenance tasks and a list of recommended replacement components for one and five year's operation.

E) Include manufacturer's descriptive literature, catalog cuts, as-built drawings, fan and motor performance curves, and the name and contact details of subcontractors and suppliers.

F) Include operating and maintenance instructions for the installation or lifting device (fork lift truck) and cradle.

G) Furnish the final alarm and trip set points and time delays that need to be programmed into the motor manager, the vibration monitoring units and winding temperature monitors.

6.6 DELIVERY, STORAGE AND HANDLING

Ventilation equipment components shall be delivered wrapped in opaque water resistant covers and fastened to substantial pallet type shipping supports. Components shall be packed with padding materials of sufficient quantity and thickness to prevent damage to painted surfaces and to prevent other damage.

Ventilation equipment components shall be stored under cover in dry areas protected from the weather and other hazards.

Jet fans shall be protected from vibrations to avoid the brinelling of the motor bearings. If the fans are stored for more than a month, the impellers shall be rotated as required by the fan manufacturer, to circulate the bearing lubricants. Storage shall be in environments with ambient temperatures at or above 55°F if temporary power for the space heaters cannot be provided. Jet fan assemblies or components shall not be stored in contact with the ground.

The Developer shall schedule installation of jet fans with availability of permanent power to prevent condensation in the motors of the fans installed in place.

Ventilation equipment components shall be handled to prevent damage to painted surfaces and to prevent other damage. Damaged painted surfaces shall be repaired with filler compatible with the paint system specified in "Painting and Finishing" of these Special Provisions, and repainted with the three coat paint system specified herein.

Protective coverings shall be left in place during installation and erection of components. After installation temporary protective coverings shall be provided to protect against work by others in the tunnel structure.

A protective coating consisting of an anti-corrosion compound shall be provided on machined surfaces not requiring painting, including shaft ends.

7.0 PRODUCTS

Fans shall be of the axial-flow type, direct-driven by internally mounted single speed motors which are capable of delivering air in the forward direction. The forward direction of airflow shall be permanently marked in a conspicuous location on the exterior of the fan housing. In selecting equipment, interchangeability of parts shall be provided.

Fans shall be operated manually or automatically, locally from the motor control centers in the substation control room or remotely from the operation and maintenance control center. The operating procedures will require any number of fans to be operated either individually or simultaneously.

8.0 OPERATING ENVIRONMENT

8.1 NORMAL OPERATION

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

8.2 EMERGENCY OPERATION

Construct the entire fan-motor-sound attenuator assembly including hangers, supports, and cables etc., such that any of the components does not suffer mechanical, electrical or structural failure when operating at full capacity with air flowing through the fan at an ambient air temperature of at least 480ºF for a minimum period of one hour.

9.0 PERFORMANCE REQUIREMENTS

The fan performance requirements for Southbound Battery Tunnel are specified in the Technical Requirements – Tunnel Systems. The static thrust and maximum exit jet velocity requirements shown shall apply to fan operation with the standard air density of .075 lbs/cu ft and the fan fully dressed with sound attenuators, safety screens and deflectors.

Fans shall be capable of developing static thrust and exit jet velocity not less than that required and with a brake power, at maximum air density conditions, less than the nameplate rating of the motor at the selected design point and blade angle.

The fan performance requirements are go/no go values. No allowances or tolerances shall be applied to shop test data for measurement error. If the recorded shop test results are less than the performance requirements the fan has failed the test. Performance data shall be corrected for air density.

Fan motors shall be capable of starting and operating in an ambient air temperature of 32 ºF to 104 ºF and operating satisfactorily for not less than one hour in 480ºF ambient air.

Fans shall be capable of withstanding the effect of all stresses and loads under starting, and operating conditions.

Motor horsepower selection shall also be such that, when operating at maximum air density conditions and a blade angle 2 degrees above the selected design point, the service factor of the motor shall not be exceeded.

Fans shall be shop performance tested with the safety screens and deflectors in place. No reduction in thrust below that shown in the schedule shall be deemed acceptable.

Fan motor units shall have an efficiency of not less than 65 percent when operating in either direction of airflow at the specified nominal static thrust and exit jet velocity.

The maximum vibration amplitude of the jet fan assembly shall not exceed the peak-to-peak amplitude of 1.6 mils at the nominal operating speed of 1750 rpm.

9.1 FAN COMPONENTS AND MATERIALS

Impeller hub and blades shall be cast aluminum-alloy. The impeller shall be fastened to the motor shaft by means of positive locking device. The impeller shall be designed and constructed to withstand stresses and loads created by over speed testing to 125 percent of the nominal operating speed.

The impeller and hub shall be designed and constructed such that the pitch of blades can be manually adjusted without removing the impeller. The blades and hubs shall have index marks that show the design operating blade setting and a minimum of three increments of stagger angle larger and three increments smaller than the design operating blade setting, and shall clearly indicate the maximum blade angle beyond which the motor will overload. Provide stops on the hub to prevent overload of the motor. In addition to index marks, each fan shall have one metal template to facilitate accurate settings of the blade angle.

Fan blades shall not vary in weight by more than 2 percent on each fan rotor. Each blade shall be stamped with its accurate weight in Kg to within two decimal places.

Structural Steel: Structural steel shapes and plate shall be ASTM A 276, Type 316L stainless steel.

The fan housing, motor mounts and supports, mounting brackets, and housing supports shall be fabricated of AISI Type 316L stainless steel, hot or cold rolled steel sheet conforming to the requirements of ASTM A 240. The fan housing shall be continuously welded construction and of thickness not less than 3/16”. Welds located in air stream shall be ground smooth.

Form the fan housing to a true-round, concentric, cylindrical shape providing uniform clearance between the tips of the impeller blades and the housing. Adequate clearance shall be provided between blade tips and the housing at all points to allow for expansion and contraction over a temperature range from 32ºF to 480ºF without developing interference. Indicate on shop drawings the maximum and minimum clearances at the two extreme temperature conditions.

End flanges for the housing shall be the same thickness as the housing or thicker. Flanges may be rolled integrally or continuously welded to the outer periphery of the fan housing. Flanges shall have sufficient width and punched or drilled holes to allow sound attenuators to be rigidly bolted to the housing.

Nosepiece coverplates fabricated from a single piece of sheet steel, where provided shall be secured by means of positive fastening devices which are fully effective for both directions of impeller rotation, for all blade settings, and for all conditions of operations specified herein.

Each fan shall be furnished with bushings located in the fan housing at the annulus for calibration of the fan. Fans shall be delivered with the bushings closed with a plug. Fan manufacturer may propose other means to measure jet flow.

Motor mounts and motor supports shall be designed and constructed to make the motor axis and fan-housing axis concentric. Motor mounts and motor supports shall be in sufficient number and shall be designed to support the entire weight of the impeller and the motor and the loads developed by the fan operation.

Access doors shall be of adequate size in the fan housing for inspection of blade locking devices to facilitate blade angle adjustment and for access to vibration and test instrumentation. Access doors shall be steel construction with AISI Type 316 stainless steel hardware and minimum 1/8-inch thick silicone base gasket to make an air-tight construction. The silicone gasket material shall be designed for use in 32ºF to 480ºF ambient air temperature.

The fan housing shall be of sufficient length to totally enclose the fan impeller and motor within the housing. The ends of the fan housing shall be straight and smooth to receive sound attenuators at both ends. The connection between fan and sound attenuators shall facilitate assembly and disassembly of jet fan and sound attenuators in the field.

Fan mounting brackets shall provide longitudinal and transverse rigidity. Mounting brackets shall be designed to allow proper functioning without warping when exposed to the specified operating temperatures. The fan mounting bracket shall interface with the fan supports. The Developer shall be responsible for the interface requirements of attaching the fan to structural steel embedments in the tunnel ceiling.

The hanger system design shall focus on reducing the time required for installation and the standard features of the manufacturer's jet fans.

Stainless steel screen shall be provided at each discharge end of sound attenuator.

Provide lifting lugs of AISI Type 316 stainless steel construction. The lifting lugs shall be welded on the exterior of the fan housing and sound attenuator to facilitate lifting and transport of the fan as a single assembly.

9.2 MONITORING SYSTEMS

Monitoring devices describe elsewhere within this Specification include:

A) Each fan motor bearing shall be furnished with a vibration monitoring system;

B) Each fan motor shall be furnished with two RTD’s in the stator winding of each phase.

All monitoring devices (motor winding RTD’s and vibration monitors) shall have their leads terminated in a common junction box, separate from power or motor heater wiring, mounted on the fan. This junction box shall be a NEMA-4X junction box with threaded hubs for conduits.

9.3 MOTOR GENERAL REQUIREMENTS

Motors for all jet fans shall be supplied by a single manufacturer. Motors shall conform to the requirements in all applicable ANSI, IEEE, and NEMA or approved equivalent ISO standards and shall be NEMA Design B, designed for continuous operation for a minimum period of one hour in an ambient temperature of at least 480ºF.

Motors shall be totally enclosed, premium efficiency, air-over, all cast iron or high grade silicone steel frame, induction type. Motors shall be wound for 460 V, three-phase, 60 Hz alternating current. Motors shall be wired for full voltage starting.

Each fan motor shall be furnished with two 100 ohm, 3-wire, platinum RTD's in the stator winding of each phase. One RTD in the winding of each phase shall be connected to an RTD input module in a distributed I/O cabinet (DIC). The second RTD in the winding of each phase shall be terminated in the monitoring junction box at the jet fan. The PLC shall be programmed to monitor over-temperature levels as determined by the motor manufacturer.

Motors shall have a 1.15 service factor rating.

9.4 MOTOR PERFORMANCE REQUIREMENTS

Motors shall be capable of accelerating the fan impeller from standstill to the design rotational speed in not more than 15 seconds when connected to terminal voltage of 85 percent of the nominal supply voltage.

Motors shall be capable of operating continuously at rated torque at any terminal voltage between 85 percent and 110 percent of the nominal supply voltage.

Motors shall be capable of starting, and operating continuously, under full load conditions, for a minimum period of one hour in ambient temperature of at least 480ºF. Motors shall be capable of a minimum of three starts during a sixty minute period with 480ºF air flowing through the fan.

Motors shall conform to the requirements in NEMA standards for the locked-rotor input (Kilovolt-amperes per kW) required to meet the indicated acceleration performance.

Motors shall have a minimum of Class H insulation and rated for Class F temperature rise, when tested at the 1.15 service factor load.

9.5 MOTOR COMPONENTS AND CONSTRUCTION

Motor shafts shall be steel construction, designed to support and drive fan impeller under all specified operating conditions. Each motor shall have lifting lugs in sufficient numbers.

To prevent condensation during the off cycle, the motor windings shall be heated by 460 V, single phase power supplied to heaters in the motors to prevent condensation during the off cycle. The heaters shall be pre-wired in rigid steel conduit to an auxiliary NEMA 4X conduit box on the outside of the fan housing.

Motor leads shall be insulated copper, wired to an oversized weatherproof NEMA 4X conduit box mounted on the exterior of the fan housing. The conduit box shall have screw-type or bolt down pressure terminals and exterior mounting lugs. Lead wires shall be protected from the air stream by enclosing them in an airtight, high tensile strength, seamless metal rigid conduit.

The conduit box shall be the next larger size than the NEMA standard size for the number of wires shown on the plans. The conduit box shall be oriented to receive feeder conduit from the direction it is routed.

The motor bearings shall be designed and constructed for the maximum radial and thrust loads anticipated during starting, and operating conditions. Bearings shall have a minimum L-10 life rating equal to 40,000 hours as defined by the Anti-Friction Bearing Manufacturers Association (AFBMA), which is an average bearing life of approximately 200,000 hours.

Each fan/motor bearing shall be furnished with a vibration monitoring system designed and installed for integration with the PLC remote I/O network through the distributed I/O cabinets

(DICs). The vibration monitoring system shall be a two-wire, current-loop powered system operating on 24 volt, 4-20 mA base. The velocity sensor shall use solid-state, epoxy encapsulated circuitry with a piezoelectric crystal and output current proportional to velocity. The system shall have a frequency response range from 10 Hz to 10,000 Hz. The vibration monitoring components shall be designed, constructed, and capable of full operation from -20°F to +160°F, 100 percent humidity, and blowing rain. Encasements and enclosures shall be NEMA 4X stainless steel. The 4-20 mA signal shall be connected to an analog input module in a DIC for processing at the PLC. The PLC shall be programmed to “alert” and “alarm” vibration levels as determined by the fan/bearing manufacturer. The alert level shall relate to general wear and/or minor defects indicating that maintenance is required. The alarm level shall relate to dangerous vibration caused by damage and/or sudden out-of-balance conditions.

Lubrication lines shall be brought from motor bearings to the exterior of the fan housing and terminated in straight lubrication fittings. Grease relief lines, if used, shall be terminated in spring loaded relief fittings. Grease fittings shall have covers to exclude water and dust. Bearing lubricant shall be 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 480ºF.

Lubrication lines for motor bearings shall be high strength, seamless stainless steel tubing without kinks or sharp bends. Lubrication lines shall be secured to the housing to prevent vibration of the lines and the leakage.

9.6 SOUND ATTENUATOR GENERAL REQUIREMENTS

Sound attenuators for jet fans shall be selected by the fan manufacturer to meet all the operating conditions specified.

Cylindrical (tubular) sound attenuators shall be provided, one mounted directly on each end of the fan housing. The inside diameter of the sound attenuator shall match the inside diameter of the fan. An inner nose piece if required shall be of aerodynamic design. The exterior diameter of the nose piece shall match the diameter of motor and hub.

Sound attenuators shall be the minimum length required, but not less than two fan diameter length each side.

Sound attenuators shall be provided with safety screens bolted to the bellmouth ends. Screens shall be fabricated of minimum 1/8 inch stainless steel wire. The net free area of the inlet screen shall not be less than 75 percent of the gross area.

9.7 SOUND ATTENUATOR PERFORMANCE REQUIREMENTS

Sound attenuators shall be provided so that jet fan assemblies do not exceed the acceptable maximum sound power or sound pressure levels.

9.8 SOUND ATTENUATOR CONSTRUCTION

The materials and methods used to fabricate sound attenuators shall be such that they will be operational for minimum period of one hour in ambient air temperature 480°F, without any mechanical or a structural failure.

The exterior casing shall be not less than 1/16 inch thick of AISI Type 316L stainless steel, hot or cold rolled steel sheet conforming to the requirements of ASTM A 240. The sound attenuator shall be internally lined with inorganic mineral wool or glass fiber acoustic in fill covered with not less than 1/32 inch thick, AISI Type 316 thick stainless steel perforated sheets.

A drain hole of 1/2 inch minimum diameter shall be provided in the exterior casing of each sound attenuator, to drain water that may enter into fan assembly during tunnel washing operations.

The acoustic in-fill material shall be vermin free and moisture resistant. The facing on the in-fill shall prevent erosion of the fibrous particles by the air stream under all conditions of operation specified. The acoustic fill material shall have a combustion rating not more than the following when tested in accordance with ASTM Designation: E 84, NFPA 255, or UL 723:

A) Flame spread classification: 25

B) Smoke developed rating: 5

C) Fuel contribution rating: 20

9.9 FAN SUPPORTS

Fan mounting brackets supports and the suspension system shall be designed and constructed to provide adequate support as required against the fluctuating loads imposed by fan operations and moving traffic, and designed per the Specification for Structural Steel Buildings, Allowable Stress Design Method, June 1, 1989 by the American Institute of Steel Construction.

The support system shall facilitate easy dismantling and reinstallation of fan assembly for maintenance.

Provide AISI Type 316L for sheet and plate and ASTM A276 Type 316L for angles and flats. Supports shall be bolted to the fan housing and cross braced to provide rigidity and to absorb all axial loads. Supports shall be designed for attachment to the tunnel structure and shall conform to the space constraints as shown on the plans. Calculations for the supporting structures shall be provided in conformance with the requirements specified herein.

9.10 FASTENERS

Bolts shall be not less than 1/2-inch in diameter unless otherwise indicated.

All bolts and tap bolts shall be stainless steel and shall conform to the requirements of ASTM A 193, Grade B8M or B8MA, equivalent to AISI Type 316, with suitable lock washers.

All Nuts shall be alloy steel and shall conform to the requirements of ASTM A 194, Grade 2H, equivalent to AISI Type 316. Nuts for low torque sealing application between fan splits and at connecting flanges shall be stainless steel ASTM A 194, Grade 8M, AISI Type 316.

9.11 NAMEPLATES

Nameplate shall be furnished for each fan assembly. Each nameplate shall show the name and address of the fan manufacturer, 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. An additional nameplate shall be furnished for each fan which shows, in characters 3 inches high, the number of the fan as shown on the plans or as directed by the Department. Nameplates shall be riveted or screwed to the fan housings.

Two identical nameplates shall be furnished for each motor. Each nameplate shall show the name and address of the motor manufacturer, the motor model number and serial number, motor speed in revolutions per minute, nominal power in kW, voltage, phase, frequency, no-load, full-load, and locked-rotor currents, NEMA code-letter designation, NEMA frame size, service factor, and the terminal connection chart for the motor. One of the two nameplates shall be securely fastened to the motor housing; the other shall be riveted or screwed to the fan

housing adjacent to the fan nameplates. Nameplates shall be stainless steel. The specified data shall be permanently marked on the nameplates.

10.0 PAINTING AND FINISHING

All surfaces of fan housings, sound attenuators, supports, cradles and exterior surfaces of motors, except the items that are fabricated of either aluminum or stainless steel, shall be factory painted to the appropriate finish in accordance with these Special Provisions. Primer and paint materials shall have a design life of minimum 10 years in the environmental conditions normally encountered in a vehicular tunnel. The color of the finish coat shall be black.

A) All paint material shall be provided from one source and shall be volatile organic content (VOC) compliant in accordance with California state regulations, and shall conform to the following requirements:

1) Primer paint material for bare carbon or alloy steel materials shall be a solvent based, high solids, inorganic zinc rich primer, and shall meet requirements for ASTM Designation: A 490, Class B slip co-efficient and creep test,

2) ASTM Designation: B 117 salt spray test, ASTM Designation: D 3363 film hardness by pencil test, and AASHTO standard M300. Solids content shall be 89 percent minimum, by weight. The zinc content shall be 82 percent minimum, by weight, in dry film. Primer paint material for galvanized surfaces shall be a tie bond epoxy penetrating sealer.

3) Intermediate paint material shall be a high solids, high build, cycloaliphatic amine epoxy. The solids content shall be 73 percent minimum, by volume.

4) Topcoat paint material shall be a high gloss, high solids aliphatic acrylic polyurethane, and shall meet SSPC Paint 36 for a level 3 urethane. Solids content shall be 68 percent minimum, by volume.

B) Surface preparation shall be as follows:

1) Bare carbon steel surfaces, except surfaces of motors, to receive 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 0.04 mm.

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

C) Surfaces specified to receive paint shall receive one coat of primer paint material, one coat of intermediate paint material and one coat of topcoat paint material. The dry film thicknesses shall be as follows:

1) The dry film thickness of the primer coat shall be 0.05 mm to 0.075 mm.

2) The dry film thickness of the intermediate coat shall be 0.10 mm to 0.15 mm.

3) The dry film thickness of the topcoat shall be 0.05 mm to 0.075 mm.

Primer, intermediate 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.

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 are found to be deficient shall be re-cleaned, re-primed and re-painted until the specified coating requirements have been met.

11.0 CRADLE

The jet fan manufacturer shall design and furnish a cradle fabricated from carbon steel. The cradle shall be used by the fan manufacturer to install the fan using a forklift truck or other suitable lifting device. The forklift truck or other device shall have a minimum lift capability of 20 feet from the roadway surface excluding the height of the fan cradle. The cradle shall be designed for a static load of 115 percent of the weight of the jet fan assembly. The cradle shall be designed to allow removal and replacement of jet fans in the future without interference with or damage to the adjacent tunnel light fixtures.

12.0 SPARE PARTS

Manufacturer shall provide a recommendation for required spare parts. As a minimum, provide the following:

A) One fully assembled jet fan identical to those provided under this Contract, ready for immediate installation and operation; and

B) One motor for jet fan identical to those provided under this Contract.

Provide one set of all special maintenance tools and templates required for installation and maintenance. Manufacturer shall identify requirement for special tools.

13.0 JET FAN SHOP TEST

13.1 GENERAL

Provide test facility at the fan manufacturer’s facility or at a testing laboratory, which is suitable for all tests, specified. The motor manufacturer may perform the motor test at the manufacturer’s facility. Submit all testing standards and procedures for approval by the Department prior to proceeding with any of the tests. Notify the Department in writing, of all shop test dates not less than 14 days prior to all tests so that the Department may witness the tests.

Test procedures and reports shall conform to the following:

The narrative test reports for all pre-production unit tests shall include the raw data as recorded during each test.

13.2 MOTOR TESTS

Arrange for factory testing of each fan motor. Tests shall be witnessed (pre-production motors) and unwitnessed (production motors).

13.2.1 Tests for Pre-production Motors (Witnessed)

The motor to be used in the fan performance test, also known as the pre-production unit, shall be independently tested in the presence of the Department. One motor of each nameplate horsepower rating and service factor shall be tested. The Department will designate motors for testing.

Test each pre-production motor in accordance with the procedures specified in ANSI/IEEE Publication 112.

Tests shall be as follows:

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

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

1) Full load current in amperes;

2) No load current in amperes;

3) Full load input in kilowatts;

4) No load input in kilowatts;

5) Locked rotor current in amperes;

6) Locked rotor input in kilovolt amperes;

7) Locked rotor torque in pound feet;

8) Rotational moment of inertia of rotor in pounds feet squared (as determined by calculation);

9) Displacement power factor in percent at full load amperes;

10) Winding resistances;

11) Losses, no load and full load; and

12) Vibration.

13.2.2 Tests for Production Motors (Unwitnessed)

Each of the remaining production motors shall be tested at its rated synchronous speed unwitnessed. Tests shall be as follows:

A) Winding resistances;

B) No load current in amperes;

C) Dielectric tests;

D) No load speed;

E) Single or three phase locked rotor current in amperes (at full or reduced voltage);

F) Bearing installation and greasing verification;

G) Cold resistance measurement;

H) Insulation resistance and winding temperature at time taking insulation resistance; and

l) Vibration check.

Only those motors for which the Department has approved test reports and performance curves may be assembled into fan-motor units.

Rerating and renameplating of motors after testing will not be accepted under any circumstances.

13.2.3 Pre-Production Fan Tests (Witnessed)

The pre-production tests verify that the design of each unique fan type to be supplied will meet the requirements. Prior to commencing the manufacture of the production jet fans to be supplied, testing as specified in the following paragraphs, on each preproduction model fan-motor-sound attenuator-safety screen-deflector assembly unit must be successfully completed and the test results approved by the Department.

Prior to assembly in the pre-production jet fan assembly, the impeller shall have been overspeed tested and balanced to conform the requirements of these Special Provisions. Testing of pre-production jet fan assembly shall conform to the following requirements:

13.2.4 Overspeed Test

Balance each impeller statically and dynamically at the rated operating speed prior to conducting the overspeed testing. Overspeed test each impeller at 125% of design rotational speed for a period of not less than three minutes. Examine impellers for loose blades and other damages. Replace defective parts and repeat the overspeed test prior to conducting any further tests.

13.2.5 Vibration Test

Check each fan for obviously rough operation. Replace defective bearings and recheck fan operation. Test each fan for vibration, measured in two radial planes 90 degrees apart (front and rear), and in the axial direction. 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.

13.2.6 Run-in Test

Operate the jet fan assembly continuously for 24 hours with the predetermined blade angle and monitor the date, time, power (kW) to the fan, and motor frame and bearing temperatures, and vibration levels. Record above parameters every 30 minutes for the duration of the run-in test.

13.2.7 Performance Test

Test the pre-production jet fan assembly for performance in accordance with the requirement of AMCA 250/ASHRA 51. For measurement of thrust developed, test jet assembly in accordance with the requirements of ISO/TC 117 WG6. Test the jet fan assembly in forward direction of air flow to determine the thrust developed, air flow, exit jet velocity and motor brake power (or input power). Record all electrical information during each test such as volts, amps and power factor. Change the angle of fan blades and repeat test as required until the specified requirements are satisfied. If the maximum power listed on the schedule is exceeded when delivering the specified thrust, the jet fan shall be redesigned to meet the maximum power (HP) requirements.

Fan performance testing shall be conducted outdoors only when the average ambient wind speed in any direction is 3-miles per hour or less over the duration of testing. Developer shall identify in the test procedure how the ambient wind condition will be monitored and recorded

during testing for approval. If the Department witnessing the test deems this requirement is not being satisfied, the test, in its entirety, shall be repeated at no additional cost to the Owner.

The submitted test results shall include a tabulation showing the static thrust, exit jet velocity, power input and sound power level of the jet fan assembly at the design point blade angle setting and at two additional settings, one at a blade angle 2 degrees above the design point and the other at a blade angle 2 degrees below the design point. 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.

13.2.8 Noise Test

Test the jet fan assembly with and without deflection vanes, in accordance with the requirements of AMCA 250 to obtain sound pressure data at eight-octave band center frequencies from 63 hertz to 8000 hertz. Record the measured data for each octave band and in the A-weighting (dBA).

14.0 ACCEPTANCE

The pre-production jet fan assembly which has satisfactorily passed all specified tests, except for the high temperature test, shall be accepted by the Department as part of the Procurement under this Contract.

14.1 PRODUCTION FANS TEST (UN-WITNESSED)

Production fans are the remaining impellers and assembled fans that shall be tested in the shop using the procedures defined in the pre-production fan test, as follows:

A) Overspeed Test;

B) Vibration Test; and

C) Run-in Test.

Record and submit test results for all fans.

15.0 INSTALLATION

The jet fan shall be mounted without encroaching in to the clearance envelope of the tunnels.

The Developer shall coordinate with the finish lining work in the placement of the embedded struts, and shall provide temporary supports and bracing as required during handling and erection.

The fan manufacturer shall provide the services of a qualified field representative who is experienced with the work involved in the installation of ventilation equipment of this type. The fan manufacturer’s representative shall be present on site during the installation of the fans and shall also direct the activities specified in "Field Quality Control" of these Special Provisions.

The jet fan assemblies shall be installed in the space provided with access panel and junction boxes oriented in such manner as to allow the fan motor and blades to be serviceable. The Developer shall verify and coordinate location and type of inserts in the finish concrete and required bracing of the fan to the concrete and other installation provisions prior to fabrication of hangers and other structural steel supports.

Supports for fans and sound attenuators shall be adjusted such that they align accurately on the same horizontal plane.

16.0 FIELD QUALITY CONTROL

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

16.1 GENERAL REQUIREMENTS

16.1.1 Field Test Data

The following shall be submitted for approval:

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.

When field-testing is completed, six copies of test records shall be submitted for approval.

16.1.2 Supervision of Start-Up and Testing:

The Developer 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 Special Provisions.

Certificate of Compliance: A certificate of compliance that all components furnished meet the requirements specified herein shall be submitted for approval.

16.1.3 Tests and Inspections

Upon completion and certification of the installation, startup 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 Developer shall notify the Department in writing of all test dates not less than 14 Days prior to tests including the expected duration and sequence of testing. The Department may witness any or all tests unless waived by the Department.

17.0 START-UP TESTING

17.1 DESCRIPTION

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 Owner's operations personnel.

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

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

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 as often as required until satisfactory performance is demonstrated.

The Developer shall provide the accepted field test instrumentation. After field-testing is completed and accepted by the Department, the field test instrumentation shall remain the property of the Developer.

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

18.0 TESTING REQUIREMENTS FOR THE JET FANS

18.1 VIBRATION TESTS

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 Department.

18.2 RUN-IN TESTS

Demonstrate that fans are operational in the forward direction. Operate each fan continuously for one hour. Measure and record for each fan 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 running in the forward direction.

18.3 STARTING TEST

Each fan shall be operated with three starts within one hour. The starts 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.

18.4 PERFORMANCE TEST

Test each jet fan 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. Based on the measured value of velocity and volume, calculate the thrust developed by the fan.

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.

18.5 TUNNEL AIR DISPLACEMENT MEASUREMENT

Conduct the air displacement measurement for the tunnel to determine the actual air displacement in the tunnel. Immediately before and after each measurement, measure and record the natural airflow and its direction through the tunnel. Operate fans as determined by the Department in one direction and let the air flow through the tunnel stabilized for 15 minutes. Measure the airflow rate at a minimum of 2 locations with traverses and repeat for the reverse airflow direction. Repeat the above test with each fan in the tunnel.

18.6 NOISE MEASUREMENT

Measure and record sound pressure levels of each fan set operating. Measure sound pressure levels 5 feet above the roadway surface and at15 feet and 30 feet from the both ends of the fan. Measure ambient sound level before fan is started and after fan is turned off. With all fans in the tunnel operating simultaneously, measure sound level at locations determined by the Department.

18.7 AIR VELOCITY MEASUREMENT

Measure and record tunnel air velocity measurements at locations approximately two hundred feet inside of the tunnel entrance and exit portals. The air velocity measurement locations shall be selected such that the effects from any adjacent ventilation fans are minimized. The ventilation system operating mode shall represent the mode of operation for fire conditions in the tunnel. The velocity measurements shall be recorded and the average velocity shall be calculated for each location. The wet and dry bulb temperatures shall also be recorded at each location. Immediately before and after each measurement, measure and record the natural airflow and its direction through the tunnel. Operate fans as determined by the Department in one direction and let the air flow through the tunnel stabilized for 10 minutes. Measure the airflow rate at a minimum of 2 locations with traverses.