

SECTION 23 33 20

SOUND ATTENUATORS FOR TUNNEL VENTILATION

PART 1 GENERAL

1.01 SECTION INCLUDES

- A. The work of this Contract Specifications Section includes furnishing, installing, and testing of Sound Attenuators for Station and tunnel ventilation.

1.02 RELATED SECTIONS

- A. Section 23 31 14 – Ductwork for Tunnel Ventilation
- B. Section 23 34 14 – Fan Motor Units for Tunnel Ventilation

1.03 MEASUREMENT AND PAYMENT

- A. General: Separate measurement or payment will not be made for the work required under this Section. All costs in connection with the Work specified herein will be considered to be included or incidental to the Work of this Contract.

1.04 REFERENCES

- A. Where materials or equipment are required to conform to referenced industry standards, the current edition of the most recent revisions as of the date of Notice to Proceed shall apply.
- B. Contractor may propose for approval alternate standards to those listed herein, provided that the standards are submitted in the English language, with a point-by-point comparison between the specified and alternate standards included in the submittal. The requirements of proposed alternate standards shall be at least as stringent as the specified standards.
- C. Reference Standards:
 - 1. American Iron and Steel Institute (AISI):
 - a. Type 316, Stainless Steel
 - 2. Air Moving and Control Association (ANSI):
 - a. C1, General Requirements of a Quality Program
 - 3. American Society of Mechanical Engineers (ASME):
 - a. B18.21.1, Lock Washers.
 - 4. ASTM International (ASTM):
 - a. A 123, Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
 - b. A 193, Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service.

- c. A 194, Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service.
 - d. A 239, Locating the Thinnest Spot in Zinc (Galvanized) Coating on Iron or Steel Articles.
 - e. A 780, Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.
 - f. E 84, Surface Burning Characteristics of Building Materials.
 - g. E 477, Measuring Acoustical and Airflow Performance of Duct Liner Materials and Prefabricated Silencers.
5. American Welding Society (AWS):
- a. AWS B5.1, Specification for the Qualification of Welding Inspectors.
 - b. D1.1, Structural Welding Code - Steel.
 - c. D1.3, Structural Welding Code - Sheet Steel.
 - d. D19.0, Welding Zinc-Coated Steels.
 - e. QC1, Standard for AWS Certification of Welding Inspectors.
 - f. Round Industrial Duct Construction Standards.
6. Sheet Metal and Air Conditioning Contractor's National Association Inc. (SMACNA):
- a. Rectangular Industrial Duct Construction Standards, I-P Second Edition.
 - b. Duct Manual & Sheet Metal Construction for Ventilation & Air Conditioning Systems.
7. Steel Structures Painting Council (SSPC):
- a. PA-1, No. 1 Shop, Field and Maintenance Painting.
8. Underwriter's Laboratories, Inc. (UL):
- a. 181, Factory-Made Air Ducts and Air Connectors.

1.05 DEFINITIONS

- A. Attenuator splitter, or baffle, is defined as the part of the sound attenuator that contains acoustic media fill, perforated face sheets, nosing, and any required casing to support the media fill, face sheets and nosing.
- B. Attenuator outer casing is defined as a site or factory assembled sheet metal casing into which attenuator splitters are installed on site.
- C. Sound attenuating unit is defined as an attenuator outer casing and attenuator splitters assembled on site to form an overall sound attenuator of the dimensions (width/height/length) shown on the Contract Drawings.

- D. Attenuator/fan combined sound power level is defined as the maximum specified fan sound power level in decibels minus the specified attenuator insertion loss in decibels. See Contract Drawings for specified fan sound power level and insertion losses.
- E. Maximum face velocity is defined as the average cross-sectional velocity, perpendicular to the direction of flow, at flow rate (cubic feet per minute) through the sound-attenuating unit.
- F. Maximum static pressure loss is defined as the pressure loss across the sound attenuating unit at the maximum face velocity, based on aerodynamic performance tests in accordance with applicable ASTM, E 477 test codes.

1.06 COORDINATION

- A. The sound attenuator manufacturer shall coordinate with the tunnel ventilation fan-motor unit manufacturer to confirm that combined fan/attenuator sound (fan sound power level in decibels minus attenuator dynamic insertion loss in decibels) does not exceed the location and sound level in the Contract Drawings. The sound attenuator manufacturer and the fan-motor unit manufacturer shall jointly provide written certification that the fan-motor units and attenuators have been coordinated to accomplish this.

1.07 SUBMITTALS

- A. Provide submittals in accordance with Contract Specifications Section 01 33 00, Submittal Procedures, Contract Specifications Section 01 33 23, Shop Drawings, Product Data, and Samples, Contract Specifications Section 01 42 19, Reference Standards, and the requirements herein. In case of conflict, the more stringent requirement shall take precedence.
- B. Within 90 Days after Notice to Proceed, Contractor shall submit names and qualifications of manufacturers of sound attenuators. Such qualification statements shall include, but need not be limited to the following data:
 - 1. Certified performance data of equipment proposed to be furnished under this Contract.
 - 2. Manufacturer's quality assurance programs in accordance with ANSI C1.
 - 3. Complete list of projects on which similar equipment for rail projects or other industrial applications with high temperature requirements in the United States have been installed or furnished. List shall include:
 - a. Name of authority or user (Include installations of the Owner, if any).
 - b. Contract number(s).
 - c. Original installation date(s).
 - d. Current condition of equipment.
 - e. A list of all known failures including apparent cause(s), corrective work affected, and description of equipment service and operating conditions.

4. List of components to be purchased from other manufacturers. Give name of manufacturer, type and characteristic of each item, and include for each the data requested herein above.
- C. The Contractor shall submit the following:
1. Certified Shop Drawings, including Bill of Materials, for sound attenuators; installation drawings, installation instructions; dimensioned drawings for installation of structural steel members (columns, mullions, lintels, and other structural support members) to be furnished by manufacturer; weight of components and additional components and additional data required for proper installation.
 2. Certificate of Compliance signifying that equipment to be furnished under this Contract meets the requirements specified herein.
 3. List of technical support items specified and list of additional support items required.
 4. Attenuator product data, including construction sizes, pressure drop, and acoustical performance data for specified sound attenuators.
 5. Attenuator manufacturer's assembly-type Shop Drawings indicating dimensions, weight loadings, required clearances, and methods of assembly of components.
- D. Within 14 Days after successful completion of all factory tests specified herein and of any additional tests conducted at Contractor's option, Contractor shall submit the following:
1. Certified results for all tests conducted. All data shall be bound in one report. The test report shall be indexed and cross-referenced in an easily understood manner.
 2. All records and results of non-destructive examinations made at completion of each examination.
 3. Field sound test procedures.

1.08 QUALITY CONTROL

- A. Welding: All Components in this Contract requiring welding shall be welded as follows:
1. Code Requirement: Welding shall conform to the requirements of AWS D1.1 and AWS D1.3.
 2. Welder Qualification: Welders welding on the work of this Contract shall be qualified in accordance with the requirements of AWS D1.1.
 3. Welding Inspections:
 - a. Visual Inspection: All welds shall be visually examined in accordance with AWS D1.1, Sections 6 and 7.8, as applicable. Quality of welds and standards of acceptance shall be in accordance with AWS D1.1, Sections 8.15.1, 9.25.1, and 10.17.1, as applicable.

- b. All shop and field welding for Station ventilation fan system ductwork shall be visually inspected and approved by an independent inspection or testing laboratory, or technical consultant. The inspector shall be an independent Certified Welding Inspector (CWI) who has met the qualification and program requirements of the American Welding Society (AWS) to certify welding inspectors, as specified in QC1 and the requirements of 5.2, 6.1, and 6.2 of AWS B5.1.
- c. The CWI shall submit an inspection results report for approval.
- d. The welding shall be subject to inspection and tests in the shop and in the field. Inspections shall be made prior to galvanizing, painting, or otherwise finishing of the welded materials. Inspection in the shop will not relieve the Contractor of the responsibility to furnish welds of satisfactory quality.
- e. When inspection indicates defects in the weld joints, the welds shall be repaired using a qualified welder or welding operator as applicable. Corrections shall be made in accordance with the requirements of AWS D1.1/D1.1M. Corrections and repairs shall be made at no additional cost to the District.
- f. All welds are subject to inspections and tests and will be selected at random by the District Representative.

1.09 STORAGE AND PROTECTION

- A. Storage: Store all materials and equipment in dry, ventilated, weather tight enclosures.
- B. Protecting Machined Surfaces: Apply a rust preventive on machined surfaces such as flanges and shafts. Use material of a type that is easily removable with solvent during equipment installation.
- C. Protecting Openings: Close pipe connections, ends, and other openings with easily removable plugs, stoppers, or flange covers.

PART 2 PRODUCTS

2.01 GENERAL

- A. Each sound attenuating unit shall be formed from an attenuator outer casing with attenuator splitters
- B. Attenuator splitters for use in attenuator outer casings shall be of uniform length. Attenuator splitters total length shall be equal to the overall length of the sound attenuator unit. Divide the length of the attenuator splitters as necessary to provide ease of assembly, installation, support, disassembly, and maintenance. Each length of the divided splitters shall extend over the span of a minimum of two floor supports, and the splitters shall be of sufficiently rigid construction to transfer the weight of the splitters to the floor supports without transferring any of their weight the attenuator outer casings.
- C. The pressure loss through each sound attenuator under specified airflow conditions shall not exceed the maximum acceptable values shown in the sound attenuator schedule.

- D. Sound attenuators shall provide full octave band dynamic insertion loss (DIL) not less than the values specified in the attenuator performance schedule. The DIL in the 1/3-octave bands containing the fan blade pass frequency and its first harmonic (two times blade pass frequency) shall not be less than the indicated full octave band values. The selection of sound attenuators shall be coordinated with the associated fan design specified in Contract Specifications Section 23 34 14, Fan-Motor Units for Tunnel Ventilation.

2.02 MATERIALS

- A. The materials and methods used to fabricate the sound attenuating units shall be selected and designed to permit operation as provided in Article 2.03 Design Temperature Conditions, herein.
- B. Attenuator outer casings shall be designed and fabricated in accordance with the requirements of Contract Specifications Section 23 31 14, Ductwork for Tunnel Ventilation.
- C. Attenuator splitters shall be formed of not less than No. 18 U.S.S gauge galvanized steel sheet perforated to provide the required acoustic transparency. Perforated face sheets shall be mounted within galvanized steel frames of not less than 16 U.S.S gauge. Face sheets shall be spot welded at not more than 3 inches on center. Interior partitions shall be located not more than 2 inches from edge of the attenuator outer casing.
- D. Channel spacers built into ductwork outer casings to separate attenuator splitters shall be constructed of not less than No. 16 U.S.S. Gauge galvanized steel in accordance with SMACNA Duct Manual and Sheet Metal Construction for Ventilation and Air Conditioning Systems. Retaining angles used to support attenuator splitters shall be constructed to withstand the weight of the attenuator module without buckling or deflection.
- E. Outer casings shall be sufficiently modularized to allow for ease of disassembly, installation, and re-assembly. Outer casings shall be sufficiently braced with reinforcing angles to limit panel vibrations to not more than 50 percent of panel metal thickness during operation.
- F. All longitudinal seams (connecting the side panels or sheets to each other) shall be of the continuous welded type only. Longitudinal seams shall be one of the following types: SMACNA Standard Figure 11-1, types A, B, C, D, E, and F, and Figure 11-2, type G, H, and I, and including the welded seam that is labeled type J, with the exception that a continuous weld shall be used in every location in the SMACNA figures that indicates use of a stitch weld.
- G. Non-welded longitudinal seams of any type shall not be permitted. SMACNA standard Figure 11-2, type K, L, and the grooved seam pipe lock also tagged as type J shall be specifically excluded from use on this Contract.
- H. Covering or obscuring of welded ductwork seams with any miscellaneous materials which are not part of the ductwork construction, as indicated in the SMACNA standards shall not be permitted. Any such materials that are installed shall be removed and the ductwork surfaces repaired.
- I. Contractor shall comply with the requirements of AWS D19.0 calling for welds to be made on surfaces free of lead and zinc, and shall coordinate with the hot-dip galvanizing vendor to mask those portions of the duct and casing panels that shall be subjected to further welding

operations during assembly of the ductwork and attenuator casings. This includes, but is not limited to, the locations of the intermediate stiffeners, hanger frames, and the edges of the panels to be welded to form the longitudinal seams. Contractor shall restore the protective coating of all system components when welding and assembly are completed, in compliance with the requirements of ASTM A 780 to build a zinc-rich film to the thickness required by the standard.

- J. Sound attenuating units shall be furnished with flanges at both ends, to permit the units to be rigidly bolted to adjacent components. Flanges shall be fabricated of galvanized steel structural channels in conformance with ASTM A123 and shall be bolted to the outer periphery of the casings unless otherwise indicated. Angles shall be protected by an additional coating of zinc-rich paint after installation. Gaskets or sealant, if required, shall be capable of withstanding Design Temperature Conditions Article 2.03A herein without degradation of sealing ability. Flanges shall be sized in accordance with the requirements of SMACNA Rectangular Industrial Duct Construction Standards Section 6.7 Auxiliary Tables 6 B2 through 6-B20, but no less than the minimum flange height specified in Table 6-G1.
- K. Filler material shall be inorganic mineral or glass fiber of a density sufficient to obtain the required acoustic performance, and shall be packed under not less than 5 percent compression, to eliminate voids due to vibration and settling. The material shall be inert, vermin-proof, and resistant to high humidity conditions. The combustion rating of the filler material, when tested in accordance with ASTM E 84 shall be not greater than the following:
 - 1. Flame Spread Classification: 15
 - 2. Smoke-Developed Rating: 0
- L. The acoustical fill shall comply with UL 181 for impact and erosion characteristics.

2.03 PERFORMANCE

- 1. Design Temperature Conditions: Sound attenuating units shall be selected and designed to permit operation for not less than 1 hour in an ambient temperature of not less than 482 degrees Fahrenheit and not less than 2 hours in an ambient temperature of not less than 392 degrees Fahrenheit.
- 2. Design Pressure Conditions: Sound attenuators shall be capable of withstanding the stresses caused by transient pressures from train piston action, and by reversal of airflow. The differential pressure from train piston action cycles between plus and minus 14 inches water gauge. Sound attenuators shall be capable of withstanding the stresses caused by fan shut-off pressure (resulting from possible operation of the ventilation fan against a closed damper. Coordinate with fan vendor to establish maximum fan shut-off pressure.
- 3. Critical Load Conditions: The design of attenuator exterior casings shall account for the largest total load that the exterior casings will be subjected to under the various operating conditions described in Contract Specifications Section 23 31 14, Ductwork For Tunnel Ventilation Article 2.02.

2.04 CONSTRUCTION

- A. Sound attenuating units shall be designed and structurally reinforced in accordance with SMACNA Rectangular Industrial Duct Construction Standards and shall be capable of withstanding the critical load for each emergency ventilation system. The critical load shall be the largest total load that the ductwork will be subjected to under the various operating conditions described in Contract Specifications Section 23 31 14, Ductwork For Tunnel Ventilation, Article 2.02B, under the design pressure conditions described in Article 2.03B herein, air leakage from or into the sound attenuator shall not exceed 10 cubic feet minute per square foot of face area.
- B. Sound attenuating units shall be furnished complete with full width structural floor support elements required for installation. Floor support spacing shall be as noted on the Contract Drawings. Structural support elements shall be designed to be bolted to the outer casing of sound-attenuating units, except where noted in the Contract Drawings. All parts of the structural bracing and support elements shall have either a hot-dipped or an electro-deposited zinc coating.
- C. Sound attenuating units shall be designed to be readily disassembled and re-assembled in the field, in the event that such disassembly/re-assembly is necessitated by the physical constraints of the installation. Sound-attenuating units shall be designed to be capable of all operating and performance requirements specified herein, when the elements are disassembled and reassembled in accordance with the explicit, written instruction of the manufacturer of the elements.
- D. Continuous metallic nosing fabricated of not less than No. 16 U.S.S. gauge galvanized steel shall be provided to prevent air and sound leakage through the abutting surfaces when the sections are installed in the field to make up one complete sound attenuating unit.
- E. Nameplates: Each sound attenuator unit shall be provided with a nameplate fabricated of Type 316 stainless steel not less than No. 10 U.S.S.-gauge thick, permanently stamped with the name and address of the manufacturer, Contractor's identification number, model type, shop order number and serial number and the Owner designated attenuator number. The nameplate shall be securely attached to the exterior of the attenuator unit in a conspicuous location.

2.05 FACTORY TESTING

- A. The District Representative may, at his option, witness any or all of the tests specified herein. Contractor shall notify the District Representative, in writing, not less than 3 weeks in advance as to the location and dates of all factory tests.
- B. Before fabrication of sound attenuators to be furnished under this Contract, one sound attenuating duct unit of each type consisting of at least four splitters and a temporary ductwork outer casing, or a test unit having minimum cross-sectional area of 24 inches by 24 inches, shall be factory-tested. The test unit shall represent the full aerodynamic and acoustical design features of the assembled sound attenuator unit. The tests shall be conducted at the operating pressure specified and certified test reports of performance shall be furnished to the Engineer for approval. Factory testing of sound attenuators shall be in accordance with the requirements of ASTM E 477. Test procedures shall be submitted to the District Representative for approval before the factory tests. Test procedure submittal shall

also include a dimensional drawing of the attenuator test unit, sample test forms and pass/fail criteria for the test.

- C. The required acoustic performance ratings are indicated in the Sound Attenuator Equipment Schedule. The acoustic performance of the test module shall equal or exceed the indicated ratings.
- D. The acoustic performance of the test unit shall be determined using a duct-to-reverberant-room test facility that provides for airflow in both directions through the module during the rating procedure. The test facility and rating procedure shall be such, to the satisfaction of the District Representative, that all effects due to end reflection, directivity, flanking transmission, standing waves, and test-chamber sound absorption are eliminated. Acoustic performance ratings shall include in decibels for both forward flow through the test unit (airflow and sound transmission traveling in the same direction), and for reverse flow through the test unit (airflow and sound transmission traveling in opposite directions). The ratings shall be determined with air flowing uniformly over the entering face of the test unit at 2,000 fpm. Acoustic performance data shall be presented in tabular form showing decibels at 8-octave-band center frequencies from 63 Hertz to 8,000 Hertz, and at the 1/3-octave band center frequencies containing the fan blade pass frequency and first harmonic.
- E. Acoustical-performance of sound attenuating duct elements shall be determined in an acoustical laboratory that is accredited by the National Voluntary Laboratory Accreditation Program (NVLAP) for ASTM E 477 testing. Before proceeding with the performance certification testing, Contractor shall submit for the District Representative approval schematic drawings of the test facility, identifying all test instruments, and test procedures. A copy of the NVLAP accreditation certificate for the test facility shall be included.
- F. Aerodynamic performance data shall be determined for the identical test units for which acoustic performance is specified, and under the same conditions of airflow. Airflow measurements shall be made in accordance with the applicable portions of ASTM Standard E 477. Static pressure loss through the test unit at the indicated airflow rate shall not exceed the values indicated in the Sound Attenuator equipment schedule.

2.06 INSTALLATION HARDWARE

- A. Fasteners:
 - 1. In accessible areas, fasteners shall be hexagonal head bolts with hexagonal head nuts, washers and heavy-duty lock washers.
 - 2. In inaccessible areas, fasteners shall be hexagonal head tap bolts with suitable flat washers and heavy-duty lock washers.
 - 3. Bolts shall not be less than ½ inch in diameter unless otherwise indicated.
 - 4. Hardware shall be stainless steel bolts, nuts, and flat washers. Bolts and tap bolts shall conform to the requirements of ASTM A 193, Grade B8M or B8MA, equivalent to AISI Type 316, with suitable lock washers in accordance with ANSI B18.21.1. Nuts shall be stainless steel and shall conform to the requirements of ASTM A 194, Grade 2H, equivalent to AISI Type 316.

5. Expansion Bolts:

- a. Expansion bolts for bolting sound attenuating units to concrete floor shall be Type 316 stainless steel double element type of not less than 3/4 inch in diameter, with suitable Type 316 stainless steel flat and heavy-duty lock washers.
 - b. Expansion bolts shall be submitted for approval.
- B. Apply coat of dielectric separator, Themec 10-99 or equal, to galvanized steel surfaces in contact with stainless steel hardware and expansion bolts, or use plastic insulators with shoulders to prevent direct contact of stainless steel hardware and expansion bolts with galvanized surfaces.

2.07 SHOP FINISHES

- A. All galvanized parts shall have either a hot-dipped or an electro-deposited zinc coating. The weight of the coating shall not be less than 2.5 ounces per square foot of surface. The zinc coating shall be applied after the material is fabricated. Galvanized steel angles used for companion flanges, structural support elements, or legs for ductwork and attenuators shall be protected by an additional coating of zinc-rich paint after installation. The galvanizing shall conform to ASTM A 123; and withstand an eight-dip Preece Test in accordance with ASTM A 239.
- B. All steel components provided with a hot-dip galvanized coating shall be sufficiently braced during the galvanizing process to prevent buckling or warping of surfaces.
- C. Zinc-rich topcoat paint material shall be applied to galvanized structural steel ductwork and sound attenuator angles in accordance with the paint manufacturer's printed paint application instructions and in accordance with the applicable non-conflicting requirements of SSPC PA-1.

PART 3 EXECUTION**3.01 EXAMINATION**

- A. Surfaces and structures to which the products will be affixed, placed, and installed shall be inspected by Contractor in the presence of the equipment manufacturer and the District Representative before the work begins. Surfaces that will be concealed by products shall be finished before products are installed.

3.02 INSTALLATION

- A. Products shall be installed, aligned, connected, and tested in accordance with approved Shop Drawings, and in accordance with the respective equipment manufacturer's printed installation instructions and under supervision of equipment manufacturer's field service engineer.
- B. Apply anti-seizing compound to the threads of stainless steel bolts and studs.
- C. Use torque wrenches to obtain required bolt tension without applying excessive torque.

- D. Galvanized surfaces damaged during shipment, welding or installation and any areas of steel surfaces remaining uncoated after hot-dip galvanizing shall be repaired in accordance with the requirements of ASTM A 780-01 to build a zinc-rich film to the thickness required by the standard.

3.03 FIELD TESTING

- A. The Contractor shall test the noise level after installation in the actual field configuration with the actual fans, dampers and ductwork. The Contractor shall provide certified documentation detailing the actual noise levels and how the levels compare to the Contract requirements.

END OF SECTION 23 33 20