SECTION 23 3600 - HVAC TERMINAL UNITS

Revise this Section by deleting and inserting text to meet Project-specific requirements.

This Section uses the term "Engineer." Change this term to match that used to identify the design professional as defined in the General and Supplementary Conditions.

Verify that Section titles referenced in this Section are correct for this Project's Specifications; Section titles may have changed.

Delete hidden text after this Section has been edited for the Project.

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

B. The Contractor's attention is specifically directed, but not limited, to the following documents for additional requirements:

1. The current version of the *Uniform General Conditions for Construction Contracts*, State of Texas, available on the web site of the Texas Facilities Commission.
2. The University of Houston's *Supplemental General Conditions and Special Conditions for Construction.*

1.2 DESCRIPTION OF WORK

A. Work Included: HVAC terminal units shall include, but not be limited to:

1. Fan powered terminal units.
2. Single duct VAV air valve terminal units.
3. Double duct terminal units.

1.3 QUALITY ASSURANCE

A. Basis of Design: The following manufacturer models have been tested and found to comply with both the performance and design specifications that follow. These tests and inspections were performed to verify the availability of equipment that is in compliance with these Specifications when properly selected.

1. Titus **[TFS] [FLS] [TFS-F] [TQP] [FLP]** Series for fan powered terminal units.
2. Titus ESV Series for single duct terminal units.
3. Titus **[EDV] [EDC]** Series for dual duct terminal units.

B. Manufacturers: Terminal units from Nailor, Krueger, Enviro-Tec. Price, or Metalaire may be acceptable where documented independent test results and equipment submittals are reviewed by the Engineer to verify specification compliance.

C. Certification: Provide manufacturer's and independent test lab's certification of test results, signed by an authorized officer of the company.

D. Preparation: HVAC terminal units to be clean and free of all foreign matter prior to shipping. Units and associated equipment such as controls, shall be packaged in a manner to prevent dust and other foreign matter from entering the unit, controls, and similar items during shipment. All

external controls, operators, and sensors shall be covered by rigid metal shields during shipment and storage.

1.4 SUBMITTALS

A. Submittals shall include, but not be limited to, the following:

1. Cut sheets on each terminal unit, clearly marked to show sizes, configuration, construction, unique features, controls, clearances, accessories, performance data, sound data, operating sequence and other pertinent information.
2. Terminal unit **[and fan]** curves or charts which clearly show terminal unit **[and fan]** performance.
3. Performance characteristics for each terminal unit.
4. Wiring and control diagrams and air flow sensor calibration curves for each terminal unit type.
5. Copies of factory-certified sound, leakage and performance test results from actual tests of units of the same model and construction to those which will be provided for the project.
6. Written report of the test results including noise criteria (NC) in sound power as tested in **[an independent test lab]** reverberant room with terminal unit operating at the scheduled airflow. When reporting NC levels, no credits or reduction shall in any way be considered for room, plenum, ceiling, and similar item effects.
7. Certified dimensioned drawings showing the locations of all openings, support points, connections, sizes for same, overall dimensions of all boxes and any other pertinent information that may affect the installation of the boxes.
8. Submit the following certified performance data for each size and type of terminal unit to be used on the project:
    a. Maximum and minimum cfm ratings at 0.35 inches water-column discharge static pressure.
    b. Fan horsepower and cfm curves for each fan (fan powered terminal units only).
    c. Pressure drop through each primary air damper at 25%, 50% and 100% of design cfm.
    d. Pressure drop through terminal unit and heating coil at full plenum air mode for fan powered terminal units and full heating and full cooling modes as applicable for single and double duct terminal units.
    e. Radiated and discharge sound power data for each size terminal unit at 0.5", 1.0", and 1.5" primary duct static pressure, 0%, 25%, 50%, 75% and 100% primary cold air and design discharge cfm (constant fan powered terminal units only) and static pressure.
    f. Temperature mixing data for each size fan powered or dual duct terminal unit at maximum and minimum discharge cfm for the unit size with 25%, 50% and 75% primary air.
9. Product warranties and guarantees.
10. Additional information as required in Section 23 0100 “Mechanical General Provisions.”.

1.5 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Deliver HVAC terminal units in factory-fabricated water resistant packaging.

B. Handle HVAC terminal units carefully to avoid damage to components, enclosures, and finish.

C. Store HVAC terminal units in a clean, dry space and protect from weather.

PART 2 - PRODUCTS

2.1 MATERIALS

A. General: Provide HVAC terminal units of standard materials and components designed and constructed as recommended by the manufacturer and as required for a complete installation in compliance with these Specifications. Units with electrical equipment shall be constructed in accordance with NEMA and NEC and shall include disconnects or fused disconnects where specified required by the NEC.

2.2 FAN POWERED TERMINAL UNITS

A. General: Provide **[constant] [variable]** volume, pressure independent **[constant] [intermittent]** fan-powered terminal units consisting of a sheet metal housing with a control damper, damper operator, fan assembly, heating coil (where scheduled), and flow controls. Fan powered terminal units shall be compatible with the temperature controls as specified under Division 25. Terminal unit capacities and sizes shall be as scheduled and shown on the Drawings.

B. Housing: Shall be constructed of 20 gauge minimum galvanized sheet metal with a rigid frame with mechanical seals and gaskets to minimize housing leakage. Housing shall be lined with one inch, dual density fiberglass. Insulation shall meet the requirements of NFPA 90A and UL 181 **[and be protected with a perforated steel inner liner]. [Housing shall be designed such that both cold air and plenum air are equally split between both sides of the double inlet unit fan.]** Gasketed access doors **[with a maximum of four speed latches]** shall be provided on the bottom of each unit. Housing shall be provided with a round or oval inlet for use with flexible duct (1800 fpm maximum velocity) and a rectangular outlet for slip and drive connection to sheet metal ductwork (1600 fpm maximum velocity).

C. Control Damper: Shall be of a low leakage, **[sliding plate "zebra" design with stainless steel plates and] [opposed blade or] [single blade design with]** self-lubricated bearings. Dampers shall be suitable for use with **[pneumatic] [electric]** operators. Damper leakage shall not exceed the following airflows at 4 inches water column:

1. 4 inches inlet duct diameter: 6 cubic feet per minute.
2. 5 inches inlet duct diameter: 6 cubic feet per minute.
3. 6 inches inlet duct diameter: 6 cubic feet per minute.
4. 7 inches inlet duct diameter: 6 cubic feet per minute.
5. 8 inches inlet duct diameter: 6 cubic feet per minute.
6. 9 inches inlet duct diameter: 6 cubic feet per minute.
7. 10 inches inlet duct diameter: 6 cubic feet per minute.
8. 12 inches inlet duct diameter: 6 cubic feet per minute.
9. 14 inches inlet duct diameter: 7 cubic feet per minute.
10. 16 inches inlet duct diameter: 7 cubic feet per minute.

D. Damper Operators: Shall be a **[pneumatic] [electric]** type normally closed damper operator rigidly attached to the terminal unit and connected to the damper with an adjustable linkage. Operators shall be sized to properly operate the unit dampers. Dampers shall be factory-mounted and **[piped] [wired]** including all controls required for operation, except **[main air and thermostat] [control wiring]** connections. Operator**[s] [springs]** shall be selected to coordinate with the control

sequence shown on the Drawings and specified. All exposed operator/linkage components shall be protected with removable metal covers.

Consider allowing EC motors for fan powered terminal units.

E. Fans: Provide fans balanced statically and dynamically, of the indicated capacity, designed and assembled to be easily removed for servicing. **[Fans shall move design airflow at all times of box operation.]** Fans shall be of metal construction. Provide centrifugal fan wheels designed for discharge static pressures indicated on the Drawings. System shall be non-overload. Provide vibration isolation as required.

Retain one of the following two paragraphs.

F. [Motors: Provide motors of the indicated or required capacity, installed for easy removal, with automatic reset thermal overload protection of the permanent split-capacitor type suitable for use with a fan speed controller. Provide sleeve type motor bearings, graphite bronze or equivalent. Motor voltage shall be as scheduled on the Drawings. Fan-motor combination shall be a manufactured product with sufficient actual installed experience to verify a minimum of a 15 year average service life. Average service life shall be certified by an authorized officer of the company. Motors shall be of a type suitable for use in the specified terminal unit. Motor shall turn fan in the proper rotation, irrespective of condition at fan start up. Provide full range speed controls for final balancing. Speed controls shall have minimum voltage stops factory-set to protect motors from low speed burnout.]

G. [Motors: Fan motors shall be suitable for operation with the field power source provided and the ambient temperature encountered. In situations where the motor is downstream of the heating source, the motor shall be capable of continuous operation in the leaving air temperature of the coil. Motor shall be electronically commutated motor (ECM), variable speed, direct current brushless motor specifically designed for use with single phase, 60 hertz. Power efficiency rating of motor shall be at least 70 percent maintained throughout entire operating range. Provide motor with a controller/inverter that provides pulse width modulated signal to motor. Controller shall control motor speed through either manual adjustment at the unit or remote adjustment. Terminal unit manufacturer shall provide Division 25 BMS provider with control algorithm to allow fan airflow adjustment through the BMS.]

H. Electrical Connections: Provide fan powered terminal units designed for a single electrical power feed and complying with all applicable NEC and UL requirements and all other applicable Codes and Standards. For terminal units without electric heating coils, provide unit-mounted fused disconnect switches with factory wiring from the load side of the disconnect switch to the fan motor. The only field wiring shall be to the line side of the disconnect switch. For terminal units with electric heating coils, provide individual unit-mounted fused disconnect switches, one for the fan motor and one for the heating coil. Disconnect switches shall be factory-wired on the load side to the load served and shall be tapped together on the load side such that only a single incoming electrical feeder connection is required. Refer to Division 26 for fuse and disconnect switch specifications. Fuses shall be sized for a nominal 125% of full load amperes of the load served.

[INCLUDE FOR INTERMITTANT FAN UNITS ONLY]

I. [Backdraft Damper: Fan backdraft damper shall be a low noise, low leakage type with aluminum blades and blade seals.]

[SELECT ONE OF THE FOLLOWING]

J. [Electric Heating Coils: Electric heating coils shall be provided on fan powered terminal units where scheduled or shown on the Drawings. 480 volt heaters shall be delta wired. Units with heaters shall be UL-listed for zero clearance, shall bear the UL-listing mark and label and shall meet all National Electrical Code (NEC) requirements. Heater frames, enclosures, and terminal boxes shall be constructed of galvanized steel. Heating elements shall be Type A 80-20 nickel/ chromium wire and shall not glow when operating per design. Heaters shall be provided with factory-installed and wired branch circuit fusing as required by the NEC and UL. Each heater shall be complete with silent magnetic contactors for each stage, a primary thermal cutoff to de-energize the heater in case of overheating, a differential air pressure switch and [a pneumatic heater control switch (PE switch)] [electronic controls] for each heater contactor.]

[**OR**]

K. [Hot Water Heating Coils: Hot water heating coils shall be provided on fan powered terminal units, where scheduled or shown on the Drawings. Hot water heating coils shall be constructed with 0.010 inch aluminum plate fin with collars drawn, belled and firmly bonded to ½ inch diameter [0.020 inch] [0.035 inch] wall copper tubes. Coil headers shall be brass or bronze. No soldering or tinning shall be used in the bonding process. Coils shall have galvanized steel casing and [manual] [automatic] air vents. Coil header and U-bends shall be insulated and shall not be exposed. Coils shall be provided with automatic air vents and drain valves. Factory test coils with 300 psig air pressure under water. Coil face velocity shall not exceed 700 fpm. Coils shall have a maximum of 12 fins per inch. Coil air and water pressure drops shall not exceed scheduled maximums.]

[INCLUDE FOR HOT WATER COILS ONLY]

L. [Hot Water Coil Valves: Valves shall be electrically-operated and shall be furnished under [Division 25,] [shall be electrically-operated and shall be furnished, and wired with the terminal unit.]

[VERIFY PROJECT REQUIREMENTS]

M. Casing Leakage: Overall terminal unit casing leakage for pressurized portions of the housing shall be less than the following airflows at 4.0 inches water column interior casing pressure, as rated by ARI 880 (latest Edition):

1. 4 inches inlet duct diameter: 6 cubic feet per minute.
2. 5 inches inlet duct diameter: 6 cubic feet per minute.
3. 6 inches inlet duct diameter: 6 cubic feet per minute.
4. 7 inches inlet duct diameter: 11 cubic feet per minute.
5. 8 inches inlet duct diameter: 11 cubic feet per minute.
6. 9 inches inlet duct diameter: 12 cubic feet per minute.
7. 10 inches inlet duct diameter: 12 cubic feet per minute.
8. 12 inches inlet duct diameter: 14 cubic feet per minute.
9. 14 inches inlet duct diameter: 19 cubic feet per minute.
10. 16 inches inlet duct diameter: 20 cubic feet per minute.

N. Controls: Fans, pressure independent volume controls and heater controls shall be factory-installed, including a multipoint air flow sensor for inlet air volume measurement, **[a Titus II Flow Logic Analyzer or equal, an adjustable fan control PE Switch [, adjustable heater stage PE**

switches]] [a DDC terminal unit controller, fan contactor [, heater stage contactors]] and related accessories and components. Controls shall provide adjustable minimum and maximum cfm limits, adjustable throttling range and a constant throttling range option. Adjustments for control settings and gauge tees for flow measurement and balancing shall be easily accessible. **[DDC controllers and damper operators shall be furnished by the [Temperature Control] [Division 25] Contractor for factory installation, wiring and testing by the terminal unit manufacturer.]** Fan **[and heater]** contactors **[and PE switches]** shall be provided by the terminal unit manufacturer. Coordinate control voltages with the **[Temperature Control] [Division 25]**. Controllers operators and contactors shall be located for easy access from the ceiling below the unit. Temperature control functions and sequences shall be as specified in **[Division 25]** and as shown on the Drawings. **[The terminal unit manufacturer shall provide an appropriately sized [120] [277] volt control power transformer to serve the terminal unit controller.]** An airflow sensor calibration curve label shall be attached to each terminal unit in a location visible from the unit controller.

O. Unit Performance: The following performance tests shall be performed by an independent testing lab to verify compliance prior to equipment submittal. Acceptability of the testing facilities shall be subject to review by the Engineer. Cold air shall be supplied at 55°F and bypass air at 75°F. Test results and criteria which shall be considered acceptable are as follows:

1. Radiated sound power levels shall not exceed **[NC 35] [NC 40]** at unit with maximum unit discharge cfm, 1.0 inch inlet static pressure and 0.35 inch outlet static pressure with any percentage of primary air.

[USE NC 35 CRITERIA FOR PARALLEL FAN POWERED TERMINAL UNITS AND NC 40 CRITERIA FOR SERIES FAN POWERED TERMINAL UNITS]

Band	Hertz	NC **[35] [40]** Criteria
1	63	**[60] [64]** dB
2	125	**[53] [57]** dB
3	250	**[46] [51]** dB
4	500	**[40] [45]** dB
5	1000	**[36] [41]** dB
6	2000	**[34] [39]** dB
7	4000	**[33] [38]** dB
8	8000	**[32] [37]** dB

Test to be conducted in a mock-up condition approved by the Engineer.

2. Discharge noise level in sound pressure measured 5 feet from the terminal unit in a duct with ½ inch acoustical lining shall be a maximum of NC 30. The 5 foot duct shall include one elbow with turning vanes.
3. Temperature variation at the fan discharge (with fan operating) shall not vary more than 3°F across the opening with 50% cold air at 55°F and 50% at 75°F.
4. Cold deck cfm fluctuation at any given flow setting over static pressure range shall be a maximum of +10%.
5. Dampers shall and unit casing shall perform as specified with regards to leakage.
6. Maximum fan motor horsepower shall be as indicated on the Drawings and at no time shall power draw exceed motor rating. Fans shall be balanced or arranged to prevent motor overload.

7. Provide written report to Engineer and Owner of results of the independent testing. Independent testing shall be compared to the specified limits. The unit shall be considered to have failed the test if any decibels are higher than the specified levels for a given frequency or if the leakage is greater than 10% from specified levels.

P. [Samples: A sample production run unit of each type [and size] of terminal unit specified on the project shall be submitted for examination and approval by the Engineer, Owner and Testing and Balancing (TAB) [Contractor]. If approved, the unit shall remain at the job site for comparison with units as shipped to project. The unit may be installed in the project at an accessible, marked location. The unit manufacturer shall test and certify that each terminal unit provided for the project has been constructed and tested as specified and are the same as the sample units.] [Where only one unit of each type is required for testing, the submitted unit shall be the largest size unit of that type scheduled for the project.]

Q. [Shipment Testing: A random sampling of the terminal unit supplied for the project and selected by the Engineer or Owner will be tested for conformance to this specification. The contractor shall allow sufficient time during construction and space for the TAB [Contractor] to perform all testing as may be required. Testing shall include airflow, pressure drop, coil performance, fan performance (where applicable), general conformance to the Drawings, Specifications and acoustics.]

1. **[If the results of the Shipment Testing show that any of the units do not perform as specified, then additional units shall be tested. If this testing in the Engineer's opinion shows that 10% or more of the units tested do not perform as specified, then 100% of all sizes of the units shall be tested for conformance with these specifications. The results of that testing shall be reviewed carefully between the Contractor, manufacturer, Owner, and the Engineer. A method of repair or replacing the units shall be negotiated. The Owner, however, shall maintain the right of final approval of any proposed solution. All testing shall be at no additional expense to the Owner.]**

R. [Should for any reason the testing described above under "Sample" and "Shipment Testing" prove that any of the units do not perform as specified, the unit manufacturer shall be responsible for all subsequent labor, travel, travel expenses, and incidental expenses, penalties, or other costs required to prove that the units perform as specified. This shall include, but not be limited to, the labor, travel and incidental expenses of Engineer[,] [and] Owner [and TAB Consultant].]

2.3 SINGLE DUCT VAV AIR VALVE TERMINAL UNITS

A. General: Provide pressure independent single duct VAV air valve terminal units consisting of a sheet metal housing with a control damper, damper operator, **[heating coil]** and flow controls. Single duct VAV air valve/terminal units shall be compatible with the temperature controls as specified under Division 25. Terminal unit capacities and sizes shall be as scheduled and shown on the Drawings.

B. Housing: Shall be constructed of 22 gauge minimum galvanized sheet metal with mechanical seals and gaskets to minimize housing leakage. Housing shall be insulated with one inch, dual density coated fiberglass insulation meeting the requirements of NFPA 90A and UL 181 **[and protected with perforated steel liner].** Housing shall be provided with a round or oval inlet for use with flexible duct (1800 fpm maximum velocity) and a rectangular outlet for slip and drive connection to sheet metal ductwork (1600 fpm maximum velocity).

C. Control Dampers: Shall be of a low leakage, opposed blade or single blade design with galvanized steel blades and self-lubricating bearings. Dampers shall be selected to limit pressure drop to 0.010 inches wc pressure loss when operating at a velocity of 2000 fpm. Damper leakage shall not exceed the following airflows at 4 inches water column:

1. 4 inches inlet duct diameter: 6 cubic feet per minute.
2. 5 inches inlet duct diameter: 6 cubic feet per minute.
3. 6 inches inlet duct diameter: 6 cubic feet per minute.
4. 7 inches inlet duct diameter: 6 cubic feet per minute.
5. 8 inches inlet duct diameter: 6 cubic feet per minute.
6. 9 inches inlet duct diameter: 6 cubic feet per minute.
7. 10 inches inlet duct diameter: 6 cubic feet per minute.
8. 12 inches inlet duct diameter: 6 cubic feet per minute.
9. 14 inches inlet duct diameter: 7 cubic feet per minute.
10. 16 inches inlet duct diameter: 7 cubic feet per minute.

D. Damper Operator: Shall be a **[pneumatic] [electric]** type normally closed damper operator rigidly mounted to the terminal unit and connected to the damper with an adjustable linkage. Operators shall be sized to properly operate the unit dampers. Damper shall be factory-mounted and **[piped] [wired]** including all controls required for operation, except **[main air and thermostat] [control wiring]** connections. Operator**[s] [springs]** shall be selected to coordinate with the control sequence shown on the Drawings and specified. All exposed operational/linkage components shall be protected with removable metal covers.

E. [Electric Heating Coils: Electric heating coils shall be provided on single duct VAV terminal units where scheduled or shown on the Drawings. 480 volt heaters shall be delta wired. Units with heaters shall be UL-listed for zero clearance, shall bear the UL-listing mark and label and shall meet all National Electrical Code (NEC) requirements. Heater frames, enclosures, and terminal boxes shall be constructed of galvanized steel. Heating elements shall be Type A 80-20 nickel/ chromium wire and shall not glow when operating per design. Heaters shall be provided with factory-installed and wired branch circuit fusing as required by the NEC and UL. Each heater shall be complete with silent magnetic contactors for each stage, a primary thermal cutoff to de-energize the heater in case of overheating, a differential air pressure switch and [a pneumatic heater control switch (PE switch)] [electronic controls] for each heater contactor.]

[**OR**]

F. [Hot Water Heating Coils: Hot water heating coils shall be provided on single duct VAV terminal units, where scheduled or shown on the Drawings. Hot water heating coils shall be constructed with 0.010 inch aluminum plate fin with collars drawn, belled and firmly bonded to ½ inch diameter [0.020 inch] [0.035 inch] wall copper tubes. Coil headers shall be brass or bronze. No soldering or tinning shall be used in the bonding process. Coils shall have galvanized steel casing and [manual] [automatic] air vents. Coil header and U-bends shall be insulated and shall not be exposed. Coils shall be provided with automatic air vents and drain valves. Factory test coils with 300 psig air pressure under water. Coil face velocity shall not exceed 700 fpm. Coils shall have a maximum of 12 fins per inch. Coil air and water pressure drops shall not exceed scheduled maximums.]

[INCLUDE FOR HOT WATER COILS ONLY]

G. [Hot Water Coil Valves: Valves shall be pneumatically-operated and shall be furnished and installed under Division 25.] [shall be electrically-operated and shall be furnished, piped, and wired with the terminal unit.]

[VERIFY PROJECT REQUIREMENTS]

H. Casing Leakage: Overall terminal unit casing leakage for pressurized portions of the housing shall be less than the following airflows at 4.0 inches water column interior casing pressure, as rated by ARI 880 (latest Edition):

1. 4 inches inlet duct diameter: 6 cubic feet per minute.
2. 5 inches inlet duct diameter: 6 cubic feet per minute.
3. 6 inches inlet duct diameter: 6 cubic feet per minute.
4. 7 inches inlet duct diameter: 11 cubic feet per minute.
5. 8 inches inlet duct diameter: 11 cubic feet per minute.
6. 9 inches inlet duct diameter: 12 cubic feet per minute.
7. 10 inches inlet duct diameter: 12 cubic feet per minute.
8. 12 inches inlet duct diameter: 14 cubic feet per minute.
9. 14 inches inlet duct diameter: 19 cubic feet per minute.
10. 16 inches inlet duct diameter: 20 cubic feet per minute.

I. Controls: Pressure independent volume controls shall be factory-installed, including a multipoint air flow sensor for inlet volume measurement, **[a Titus II Flow Logic Analyzer or equal], [a DDC terminal unit controller]** and related accessories and components. Controls shall provide adjustable minimum and maximum cfm limits, adjustable throttling range and a constant throttling range option. Adjustments for control settings and gauge tees for flow measurement and balancing shall be easily accessible. [DDC controllers and damper operators shall be furnished by **the [Temperature Control] [Division 25]** Contractor for factory-installation, wiring and testing by the terminal unit manufacturer. Controllers shall be located for easy access] from the ceiling below the unit. Temperature control functions and sequences shall be as specified in Division 25 and as shown on the Drawings. **[The terminal unit manufacturer shall provide an appropriately sized [120] [277] volt control power transformer to serve the terminal unit controller.]** An air flow sensor calibration curve label shall be attached to each terminal unit in a location visible from the unit controller.

J. Unit Performance: The following performance tests shall be performed by an independent testing lab to verify compliance prior to equipment submittal. Acceptability of the testing facilities shall be subject to review by the Engineer. Test results and criteria which shall be considered acceptable are as follows:

[VERIFY REQUIREMENTS]

1. Radiated sound power levels shall not exceed **[NC 30] [NC 35]** for any value unit discharge cfm, **[one inch] [_____inch]** inlet static pressure and 0.35 inch outlet static pressure with any percentage of primary air.

Band	Hertz	NC **[30] [35]** Criteria
1	63	**[57] [60]** dB

2	125	**[48] [53]** dB
3	250	**[41] [46]** dB
4	500	**[35] [40]** dB
5	1000	**[31] [36]** dB
6	2000	**[29] [34]** dB
7	4000	**[28] [33]** dB
8	8000	**[27] [32]** dB

Test to be conducted in a mock-up condition approved by the Engineer.

2. Discharge noise level in sound pressure measured 5 feet from the terminal unit in a duct with ½ inch acoustical lining shall be a maximum of NC **[25] [30]**. The 5 foot duct shall include one elbow with turning vanes.
3. CFM fluctuation at any given flow setting over static pressure range shall be a maximum of +10%.
4. Dampers and unit casing shall perform as specified with regards to leakage.
5. Provide written report to Engineer and Owner of results of the independent testing. Independent testing shall be compared to the specified limits. The unit shall be considered to have failed the test if any decibels are higher than the specified levels for a given frequency or if the leakage is greater than 10% from specified levels.

K. **[Samples: A sample production run unit of each type [and size] of terminal unit specified on the project shall be submitted for examination and approval by the Engineer, Owner and Testing and Balancing (TAB) [Contractor]. If approved, the unit shall remain at the job site for comparison with units as shipped to project. The unit may be installed in the project at an accessible, marked location. The unit manufacturer shall test and certify that each terminal unit provided for the project has been constructed and tested as specified and are the same as the sample units.] [Where only one unit of each type is required for testing, the submitted unit shall be the largest size unit of that type scheduled for the project.]**

L. **[Shipment Testing: A random sampling of the terminal unit supplied for the project and selected by the Engineer or Owner's Representative will be tested for conformance to this specification. The contractor shall allow sufficient time during construction and space for the TAB [Contractor] to perform all testing as may be required. Testing shall include airflow, pressure drop, coil performance, fan performance (where applicable), general conformance to the Drawings, Specifications and acoustics.]]**

1. **[If the results of the Shipment Testing show that any of the units do not perform as specified, then additional units shall be tested. If this testing in the Engineer's opinion shows that 10% or more of the units tested do not perform as specified, then 100% of all sizes of the units shall be tested for conformance with these specifications. The results of that testing shall be reviewed carefully between the Contractor, manufacturer, Owner, and the Engineer. A method of repair or replacing the units shall be negotiated. The Owner, however, shall maintain the right of final approval of any proposed solution. All testing shall be at no additional expense to the Owner or Engineer.]**

M. **[Should for any reason the testing described above under "Sample" and "Shipment Testing" prove that any of the units do not perform as specified, the unit manufacturer shall be responsible for all subsequent labor, travel, travel expenses, and incidental expenses, penalties, or other costs required to prove that the units perform as specified. This shall include, but not**

be limited to, the labor, travel and incidental expenses of Engineer[,] [and] Owner [and TAB Consultant].]

2.4 DOUBLE DUCT TERMINAL UNITS

A. General: Provide **[variable] [constant]** volume, pressure independent double duct terminal units consisting of a sheet metal housing with control dampers, damper operators, mixer-attenuator and flow controls. Double duct terminal units shall be compatible with the temperature controls as specified in Division 25. Terminal unit capacities and sizes shall be as scheduled and shown on the Drawings.

B. Housing: Shall be constructed of 22 gauge minimum galvanized sheet metal with mechanical seals and gaskets to minimize housing leakage. Housing shall be insulated with one inch, dual density coated fiberglass insulation meeting the requirements of NFPA 90A and UL 181 **[and protected with perforated steel liner]**. Housing shall be provided with a round or oval inlet for use with flexible duct (1800 fpm maximum velocity) and a rectangular outlet for slip and drive connection to sheet metal ductwork (1600 fpm maximum velocity).

C. Mixer-attenuator: Each unit shall include a mixer-attenuator section as an integral part of the unit to minimize downstream stratification. The mixer shall provide less than 1°F downstream variation with 10°F difference between the two inlets. Certified independent test lab data shall be submitted for approval subject to witness testing by the Engineer or Owner's Representative.

D. Control Dampers: Shall be of a low leakage, opposed blade or single blade design with galvanized steel blades and self-lubricating bearings. Dampers shall be selected to limit pressure drop to 0.25 inches wc pressure loss when operating at a velocity of 2000 fpm. Dampers shall be arranged to allow units to operate at constant or variable volume air flow.

E. Damper Operators: Shall be **[pneumatic] [electric]** type normally open damper operators rigidly mounted to the terminal unit and connected to the dampers with an adjustable linkage. Operators shall be sized to properly operate the unit dampers. Damper shall be factory-mounted and **[piped] [wired]** including all controls required for operation, except **[main air and thermostat] [control wiring]** connections. Operator**[s] [springs]** shall be selected to coordinate with the control sequence shown on the Drawings and specified. All exposed operational/linkage components shall be protected with removable metal covers.

[VERIFY PROJECT REQUIREMENTS]

F. Leakage: Overall leakage for the control damper and pressurized portions of the housing shall be less than 3% of nominal cfm at **[3 inches] [6 inches]** SP, as rated by ARI 880 (latest Edition).

G. Controls: Pressure independent volume controls shall be factory-installed, including multipoint air flow sensors for cold deck inlet volume measurement and mixer-attenuator discharge flow measurement, **[a pneumatic volume controller] [a DDC terminal unit controller]** and related accessories and components required to operate the unit as a dual duct **[variable] [constant]** volume unit. Controls shall provide adjustable minimum and maximum cfm limits, adjustable throttling range and a constant throttling range option. Adjustments for control settings and gauge tees for flow measurement and balancing shall be easily accessible. **[DDC controllers and damper operators shall be furnished by the [Temperature Control] [Division 25] Contractor for factory-installation, wiring and testing by the terminal unit manufacturer. Controllers shall be located for easy access]** from the ceiling below the unit. Temperature control functions and sequences shall be as specified in Division 25 and as shown on the Drawings. **[The terminal unit manufacturer shall provide an appropriately sized [120] [277] volt control power transformer to**

serve the terminal unit controller.] An air flow sensor calibration curve label shall be attached to each terminal unit in a location visible from the unit controller.

H. Unit Performance: The following performance tests shall be performed by an independent testing lab to verify compliance prior to equipment submittal. Acceptability of the testing facilities shall be subject to review by the Engineer. Cold air shall be supplied at 55°F and warm air shall be supplied at **[80°F] [_____°F]**. Test results and criteria which shall be considered acceptable are as follows:

[VERIFY REQUIREMENTS]

1. Radiated sound power levels shall not exceed **[NC 30] [NC 35]** for any value unit discharge cfm, **[2.0 inch] [_____inch]** inlet static pressure and 0.35 inch outlet static pressure with any percentage of cold air.

Band	Hertz	NC **[30] [35]** Criteria
1	63	**[57] [60]** dB
2	125	**[48] [53]** dB
3	250	**[41] [46]** dB
4	500	**[35] [40]** dB
5	1000	**[31] [36]** dB
6	2000	**[29] [34]** dB
7	4000	**[28] [33]** dB
8	8000	**[27] [32]** dB

Test to be conducted in a mock-up condition approved by the Engineer.

2. Discharge noise level in sound pressure measured 5 feet from the terminal unit in a duct with ½ inch acoustical lining shall be a maximum of NC **[25] [30]**. The 5 foot duct shall include one elbow with turning vanes.
3. Temperature variation at the mixer-attenuator discharge shall not vary more than 3°F across the opening with 50% cold air at 55°F and 50% warm air at **[80°F] [_____°F]**.
4. CFM fluctuation at any given flow setting over static pressure range shall be a maximum of +10%.
5. Dampers and unit casing shall prevent leakage in excess of 3% of maximum rated terminal unit capacity when operating against **[3 inches] [6 inches]** of static pressure (SP).

I. [Samples: A sample production run unit of each type [and size] of terminal unit specified on the project shall be submitted for examination and approval by the Engineer, Owner and Testing and Balancing (TAB) [Consultant] [Contractor]. If approved, the unit shall remain at the job site for comparison with units as shipped to project. The unit may be installed in the project at an accessible, marked location. The unit manufacturer shall test and certify that each terminal unit provided for the project has been constructed and tested as specified and are the same as the sample units.] [Where only one unit of each type is required for testing, the submitted unit shall be the largest size unit of that type scheduled for the project.]

J. [Shipment Testing: A random sampling of the terminal unit supplied for the project and selected by the Engineer or Owner's Representative will be tested for conformance to this specification. The contractor shall allow sufficient time during construction and space for the TAB [Consultant] [Contractor] to perform all testing as may be required.]

1. **[If the results of the Shipment Testing show that any of the units do not perform as specified, then additional units shall be tested. If this testing in the Engineer's opinion shows that 10%**

or more of the units tested do not perform as specified, then 100% of all sizes of the units shall be tested for conformance with these specifications. The results of that testing shall be reviewed carefully between the Contractor, manufacturer, Owner, and the Engineer. A method of repair or replacing the units shall be negotiated. The Owner, however, shall maintain the right of final approval of any proposed solution. All testing shall be at no additional cost to the Owner or Engineer.]

K. [Should for any reason the testing described above under "Sample" and "Shipment Testing" prove that any of the units do not perform as specified, the unit manufacturer shall be responsible for all subsequent labor, travel, travel expenses, and incidental expenses, penalties, or other costs required to prove that the units perform as specified. This shall include, but not be limited to, the labor, travel and incidental expenses of Engineer[,] [and] Owner [and TAB Consultant].]

PART 3 - EXECUTION

3.1 INSTALLATION

A. General: Except as otherwise indicated, install HVAC terminal units including components and controls required for operation, in accordance with manufacturer's instructions.

B. Location: Locate each unit accurately in the position indicated in relation to other work. Position unit with sufficient clearance for normal service and maintenance, including clearance for cabinet removal.

C. Supports: Minimum support requirements for terminal units shall be as follows. Terminal units weighing less than 150 pounds shall be supported by four (4) 16 gauge, one inch wide sheet metal straps with ends turned under bottom of unit at corners and secured by two maximum ¾ inch long by ¼ inch diameter sheet metal screw per strap. The other strap end shall be attached to the structure by ¼ inch diameter threaded bolt into the concrete insert or into drilled-hole threaded concrete expansion anchor. Boxes over 150 pounds in weight shall be supported the same as described above except ¼ inch diameter sheet metal screws shall be located with one screw on the side of the unit and one screw on the bottom of the unit. Seal all screw penetrations into the terminal unit air stream. **[Refer to Section 23 0548 "Vibration Isolation" for terminal unit vibration isolation requirements. Spring isolated terminal units shall be supported using channel and threaded rod.]**

D. Leveling: Level terminal units to the tolerances recommended by the manufacturer.

E. Flow Graphs: Graphs shall be provided to coordinate pressure at flow measuring taps with unit primary cfm.

F. Unit Connections: Duct connections shall be the more stringent of the connections detailed on the Drawings and the terminal unit manufacturers recommendations.

G. Access Doors and Panels: Provide access doors or panels as required to provide full terminal unit access.

1. Label access doors to identify what is accessible behind door. Labels shall be metal or plastic and shall be mechanical fastened to the access door. Letter size shall be ¼ inch minimum.

3.2 TESTING

A. General: Installed terminal units shall be leakage tested with the connected ductwork.

B. [Sample Testing: Sample terminal units shall be leakage tested by the project Testing and Balancing [Contractor] in the presence of the Engineer and Owner.]

C. [Shipment Testing: Leakage testing of randomly selected terminal units shall be performed by the project Testing and Balancing [Contractor] on site, prior to installation. Units to be tested shall be selected on site by the Engineer or Owner.]

3.3 IDENTIFICATION

A. Refer to Section 23 0300 “Basic Materials and Methods” for applicable painting, nameplates and labeling requirements.

END OF SECTION 23 3600