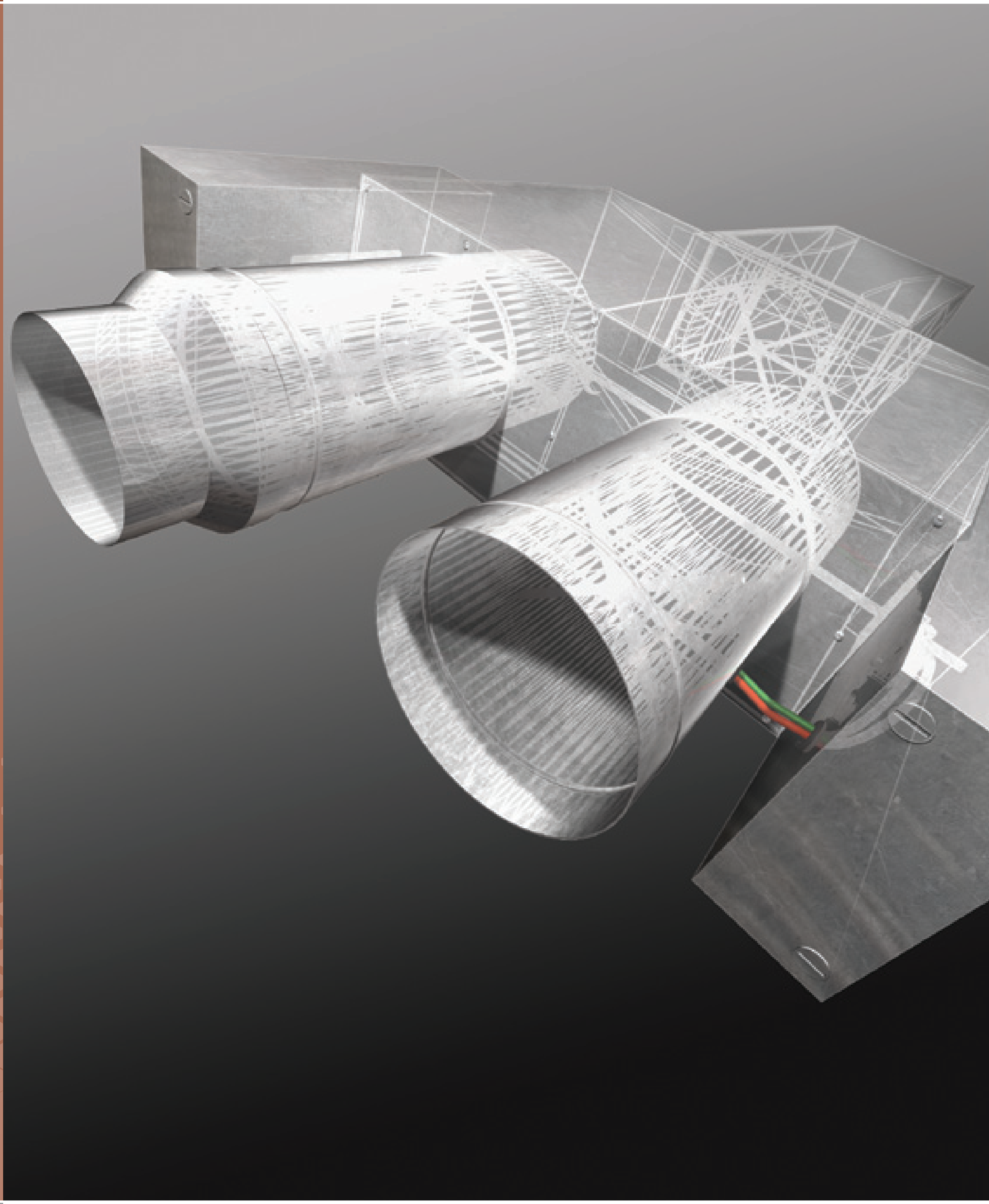
SECTION **F**



Engineering Guide
Terminal Units

Terminal Unit Types

Single Duct Terminal

A single duct terminal consists of an air inlet assembly, housing with an insulation liner and a discharge outlet. Typical accessories for this unit include a variety of liners, discharge attenuators, access doors and multiple outlets plenums. Low profile configurations can be used to suit applications where plenum space is restricted. A low profile configuration is defined as a terminal unit whose overall height does not exceed 12 ½ in. A round inlet and round discharge is also available. The round outlet unit is often used for retrofit applications or laboratory applications. The single duct terminal is also available in a low temperature construction. Low temperature construction is recommended when low temperature air distribution is used and in areas with a condensation risk.

Constant Volume Single Duct

A single duct terminal with constant volume operation may or may not have an actuator, flow sensor and controls. If the unit does not have an actuator it is typically supplied with a manually locking quadrant allowing the damper blade to be locked into a single position.

Variable Volume Single Duct

A variable volume single duct will have a flow sensor, an actuator and some type of controls. Depending on the control scheme selected, the VAV single duct will typically either provide a constant air volume or constant discharge pressure control.

VAV terminal units are controlled with automatic controls that operate as either pressure-dependent or as pressure-independent. Pressure-dependent control is where the terminal unit damper is modulated in response to zone temperature. Pressure-dependent controlled terminal units may experience air volume flow that increases or decreases as the static pressure in the main duct varies.

Pressure-independent control is where the air volume is measured and controlled by modulating the terminal unit damper in response to both zone temperature and air volume.

An example of a common system-level control sequence is shown in **Figure 3** This sequence (cooling only) controls the zone temperature by varying the volume of cooling air to the zone based on thermostat demand. The dead band shown is typically ± 2 °F. In the example shown, there is a minimum airflow that can either be a predetermined volume (based on occupancy or other concern) or can act as a shut off valve by closing completely.

Figure 1: Single Duct Terminal

Figure 2: Single Duct Terminal Air Path

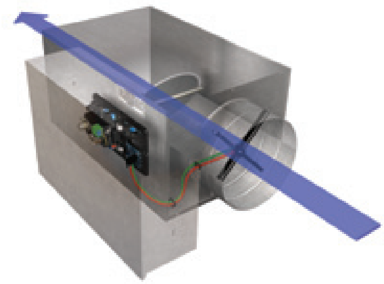
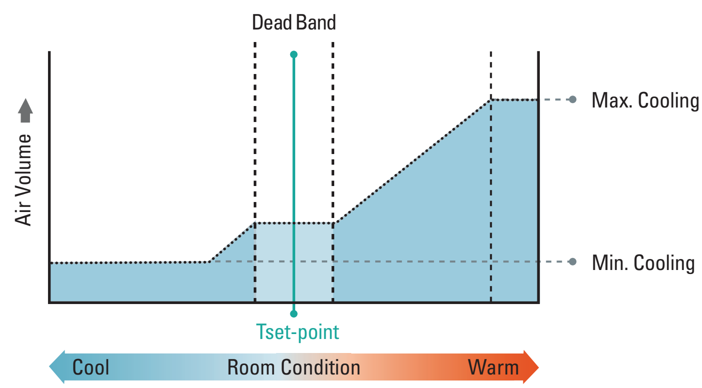


Figure 3: Typical single duct VAV control sequence with max and min airflows



CONTROL TIP

It is important to properly size the inlet valve to obtain the proper level of control at the desired minimum airflow rate.

All Metric dimensions ( ) are soft conversion.
Imperial dimensions are converted to metric and rounded to the nearest millimetre.

Terminal Unit Types

Single Duct Terminal with Reheat

The basic single duct terminal unit with reheat is similar to the single duct, but has a reheat option built into the unit. The reheat option is either a water coil, or an electric heater. Accessories for the single duct with a water coil include access doors in the coil section upstream and downstream of the water coil.

Single duct with reheat is often used for zones which require a source of supplemental heat. Usually, the single duct with reheat operates at some minimum airflow rate to minimize the amount of heat required to offset the conditioned air being supplied to the zone.

Common Applications Include:

Exterior zones (adjacent to outside walls or the upper floor in the case of multiple story buildings) where heat losses through the exterior walls create a needed for heating.

Interior and exterior zones where the minimum volume of ventilation air exceeds the volume of conditioned air required to satisfy the cooling load which leads to an overcooling of the zone. Reheat is often used when this condition occurs.

There are two different commonly used ways to provide supplemental heat to the zone, hot water and electric heat. An example of a system-level control sequence is shown in **Figure 6**. This is the use of hot water as a source of the supplemental heat. In this sequence, there is a minimum cooling air volume, maximum cooling volume and a reheat air volume. During cooling mode the temperature in the zone is moderated by modulating the damper position, increasing or decreasing the volume of cool air to the zone. In heating mode, when the zone temperature drops below the lower dead band limit, the controller increases the supply air volume to the reheat volume. At the same time, the hot water valve is opened. As the zone calls for additional heat, the hot water valve will continue to open until at some point the valve is fully open. Other common control schemes for hot water reheat include on/off valve control and mixing valve (3 way valve) control.

Electric reheat is shown in **Figure 7** and has the same control cycle as the hot water reheat sequence shown in **Figure 6**. In heating mode, when the zone temperature drops below the lower dead band limit, the controller increases the supply air to the reheat air volume. As the same time, the first stage of electric heat is activated. As the zone temperature continues to drop, the additional stages of electric heat are activated (if present).

Figure 4: Single Duct Terminal with water reheat coil

Figure 5: Single Duct Terminal with water reheat Air Pathway

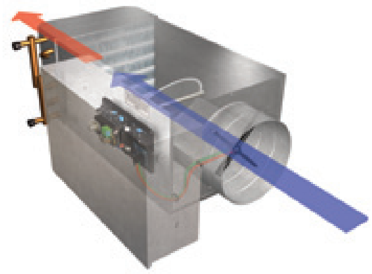


Figure 6: Single duct with reheat (hot water coil), typical VAV control sequence

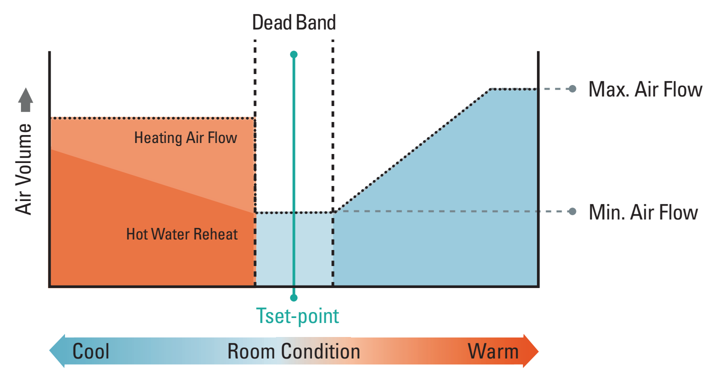
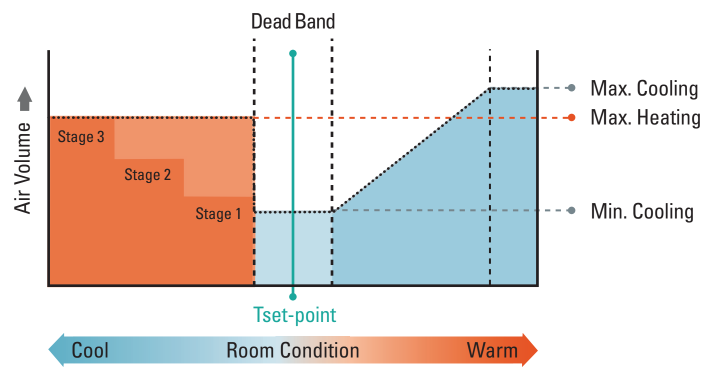


Figure 7: Single duct with reheat (3 stage electric), typical VAV control sequence



ENGINEERING GUIDE - TERMINAL UNITS

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Terminal Unit Types

Exhaust Single Duct Terminal

A single duct terminal that is configured to control exhaust air has the same basic components as a standard single duct terminal. However, the airflow direction is reversed and typically there is an inlet attenuator section. The inlet attenuator is used to help lower the sound generation by the valve when it is operating in a less than full open position.

The exhaust single duct terminal is commonly used in spaces that require either exhaust air volume control, or space pressurization control. They may also be found in applications that use a supply-exhaust tracking control scheme. The supply-exhaust tracking control scheme requires both a supply and an exhaust single duct terminal where the supply will be controlled by the thermostat demand and the exhaust by either a percentage of supply air volume or direct pressurization control of the occupied space.

Single Duct Terminal with Integral Silencer

A sound sensitive space often requires more attenuation in the air duct system to prevent too much discharge noise from making it into the occupied space. Spaces such as conference rooms, private offices, music studios, concert halls, classrooms, etc. often benefit from using a single duct terminal with an integral silencer.

The difference between a standard single duct attenuator and a silencer is significant when it comes to sound attenuation. A silencer that is just attached to a single duct may not provide the same amount of sound attenuation, as does the integrated unit that is manufactured and certified as an assembly. A common issue in taking two different components such as a single duct terminal and a silencer and simply fastening them together is called system effect. System effect is the additional pressure drop and sound generation due to duct elements that are placed too close together with less than ideal inlet conditions. Additional information on the system effect is located in Chapter 8—Introduction to Duct Design of the Price Engineer's HVAC Handbook. The integrated single duct with silencer is designed to minimize the system effect and maximize the sound control characteristics of the silencer.

For more on how a silencer operates and sound attenuation characteristics, see the Silencer section of Chapter 10—Introduction to Noise Control in the Price Engineer's HVAC Handbook. For a discussion on the impact of system effect on ductwork pressure drop, see the System Effect section of Chapter 10—Introduction to Noise Control of the Price Engineer's HVAC Handbook.

Figure 8: Exhaust Single Duct Terminal Unit

Figure 9: Exhaust Single Duct Terminal Air Pathway

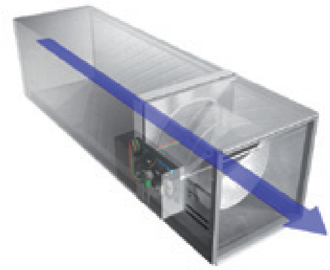


Figure 10: Single duct exhaust terminal, pressure differential control sequence

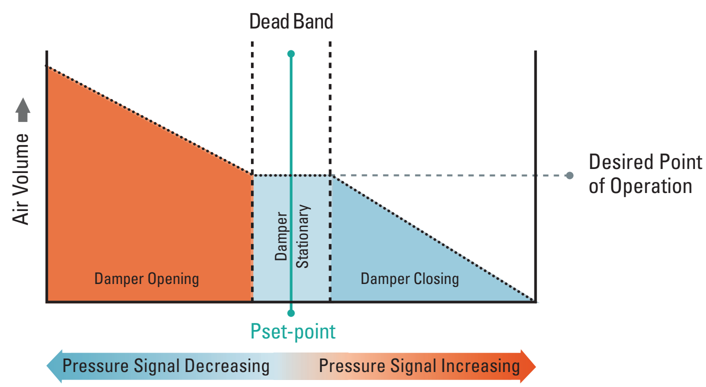


Figure 11: Single Duct Terminal with Integral silencer

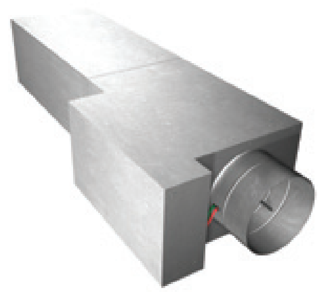
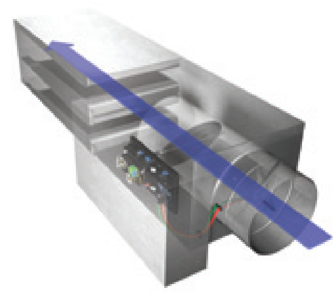


Figure 12: Single Duct Terminal with Integral silencer Air Pathway



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Imperial dimensions are converted to metric and rounded to the nearest millimetre.

Terminal Unit Types

Bypass Terminals

A Bypass terminal unit is designed to maintain a constant volume of supply air, while varying the amount of supply air to the control zone in response to a control signal, such as a thermostat. Bypass terminals are often used with air handling equipment such as packaged rooftop equipment (RTU) that have a direct expansion coil to minimize the risk of coil freeze-up at partial airflow rates. This system design approach typically has a low first cost, but does not provide the energy saving advantages of a true VAV system. The bypassed air is either dumped into the return air plenum or ducted back to the RTU.

The most common sequence of operation for a bypass terminal is to provide a constant airflow through a rooftop unit while maintaining the proper flow or static pressure to the zone ductwork (see **Figure 15**). As the zone calls for less air, the bypass damper passes more air from the rooftop unit to the return which maintains the total flow rate through the rooftop unit. It is common to need a constant airflow across a DX coil that is being used for latent heat removal / humidity control. Should the airflow drop, there is a distinct chance that the DX coil may freeze and this will potentially lead to higher than desirable humidity levels in the zone.

Another common sequence for a bypass terminal is shown in **Figure 16**. This sequence adds supplemental heat to the zone, perhaps baseboard heat or an optional downstream heater.

Figure 13: Bypass Terminal Unit

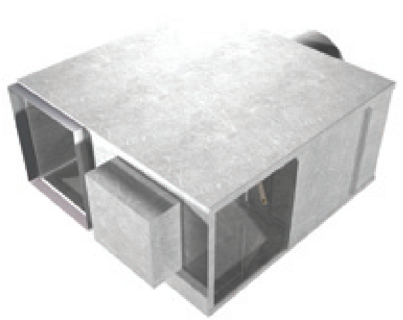


Figure 14: Bypass Terminal Air Pathway

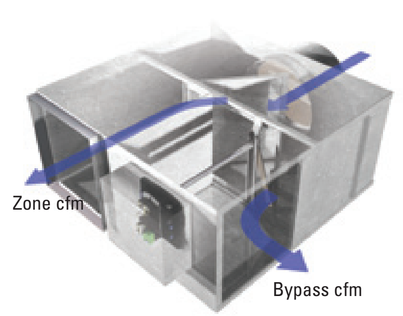


Figure 15: Total airflow through rooftop equipment and to zone through bypass terminal

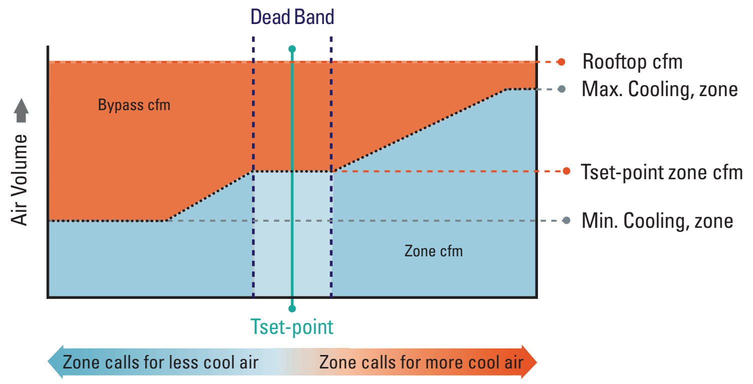
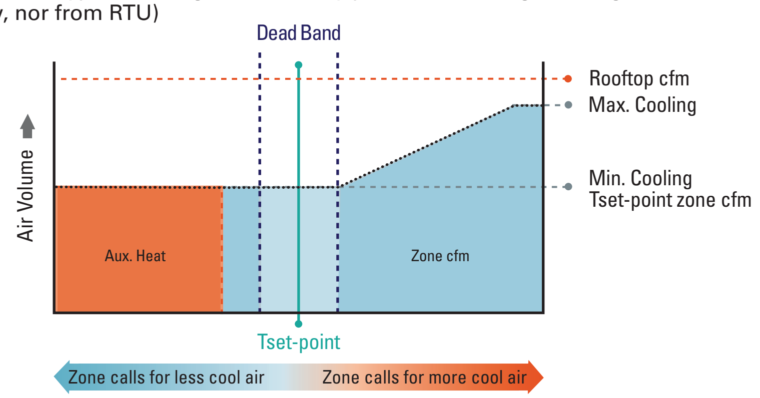


Figure 16: Bypass cooling with auxiliary perimeter heating (Heating is not in the airflow, nor from RTU)



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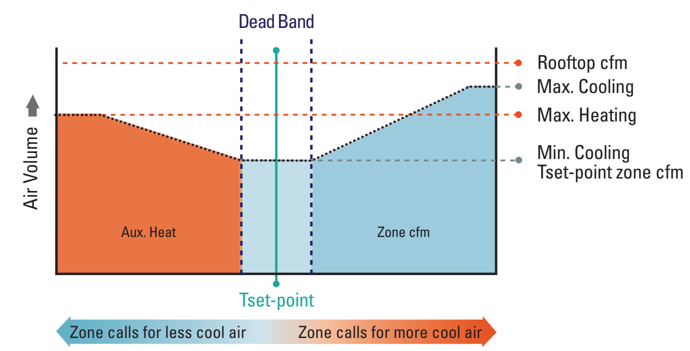
Terminal Unit Types

The changeover temperature is the point where the heat gain to the space is balanced by the volume of conditioned air to the space. Below this point, cooling is not required and if the zone temperature drops, the unit will change to heating mode. This sequence is shown in **Figure 17.**

Figure 17: Bypass cooling with auxiliary duct heating (Heat / Cool changeover)



Dual Duct Terminals (Non-Mixing)

A non-mixing dual duct terminal is essentially two single ducts fastened together with one common discharge opening. The inlets are connected to two of the following types of air supply: cold air supply; warm air supply; or fresh air supply. The non-mixing type of dual duct terminal has the potential to have thermally stratified discharge air and should have a minimum of three to five equivalent diameters of discharge duct to allow the different temperature air to mix.

Non-Mixing Dual ducts are commonly used for exterior zones in buildings where the use of auxiliary reheat (such as water coils) is not desired and where a zero minimum flow is acceptable during changeover from heating to cooling (see **Figure 18** for a typical non-mixing dual duct terminal)

Figure 18: Dual Duct Terminal Unit (non-mixing)

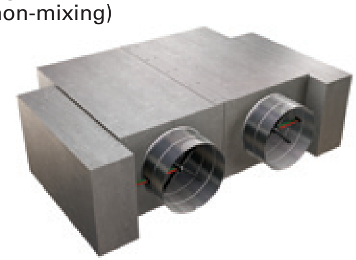


Figure 19: Dual Duct Terminal Unit (non-mixing) Air Pathway

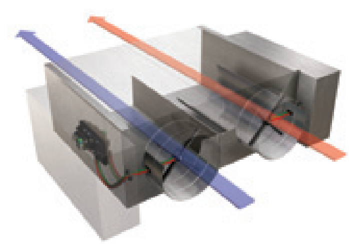


Figure 20: Non-Mixing Dual Duct - Cooling Mode

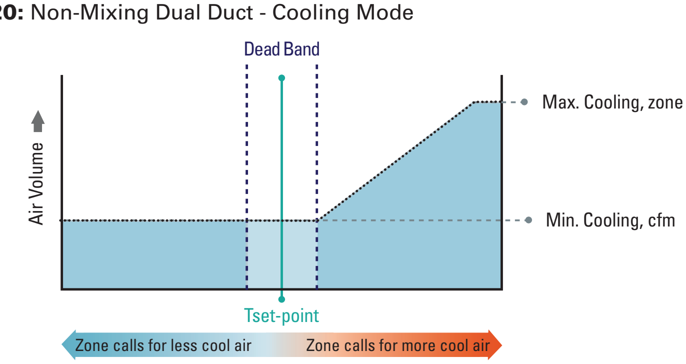
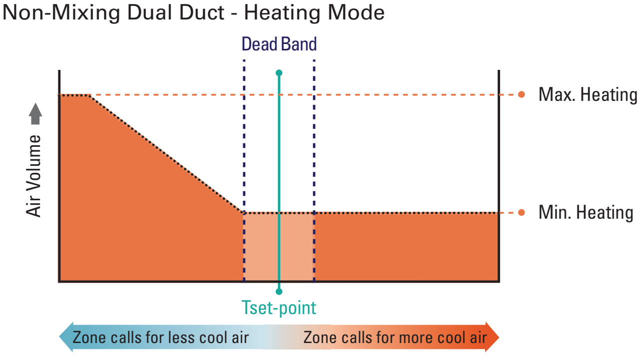


Figure 21: Non-Mixing Dual Duct - Heating Mode



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Terminal Unit Types

Dual Duct Terminals (Mixing)

A dual duct with integral mixing is similar to the non-mixing type, but has an integral mixing section between the two supply valves and the discharge duct connection (see **Figures 22 and 23**). Different levels of mixing performance are available. The standard mixing dual duct should provide, at a downstream distance of three equivalent diameters from the dual duct, a uniform discharge air temperature profile (±1 °F). A high mixing performance dual duct should provide, at a discharge of six in., a uniform discharge air temperature profile (±1 °F).

Mixing dual ducts are used in both interior and exterior zones in buildings such as hospitals, or buildings where the use of auxiliary reheat such as hot water or electric reheat is not desirable.

A typical VAV sequence of operation is shown in **Figure 24**. In this control scheme, the zone air volume is allowed to vary based on thermostat demand while maintaining a minimum airflow to the zone. For this sequence, it is common to measure the cold air and hot air volumes.

A constant volume sequence of operation is shown in **Figure 25**. In this control scheme, the total volume of air is maintained by varying the percentages of cold and hot air. For this sequence, it is common to measure the volume of the cold air and the volume of the discharge air.

CONTROL TIP

Dual duct systems have the potential to maintain high levels of occupant comfort, but may not be as energy efficient as other design approaches. The inefficiency in design is due to the continuous mixing of warm and cool air during all seasons of the year. To improve the efficiency, the system design should minimize the call for mixing of the warm and cool air.

Figure 22: Dual Duct (mixing)

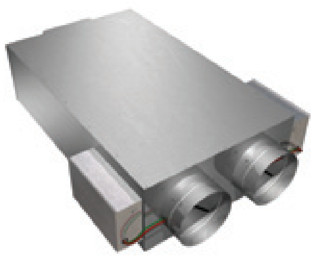


Figure 23: Dual Duct Mixing Air Pathway

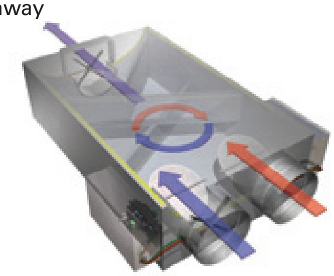


Figure 24: Dual duct terminal with different maximum heating and cooling airflows and zero minimum airflows, but with a minimum zone airflow requirement.

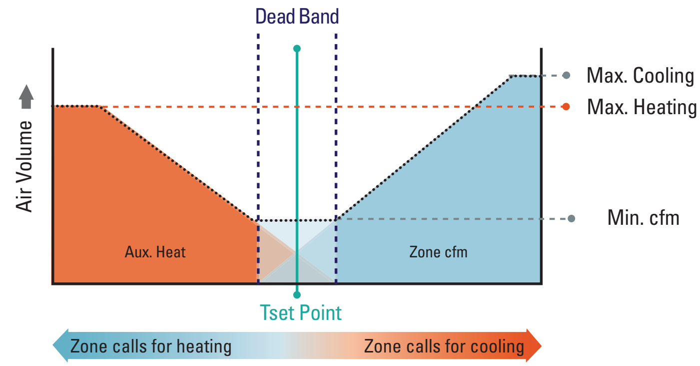
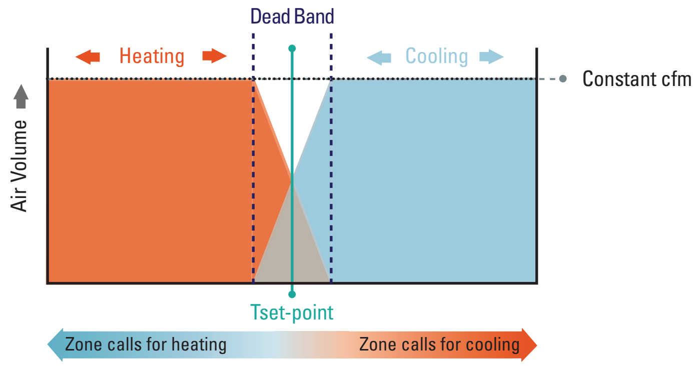


Figure 25: Dual duct terminal with a constant zone supply air volume and zero minimum cooling and heating airflows



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Terminal Unit Types

Fan Powered - Series (Overhead Applications)

The basic series fan powered terminal (sometimes referred to as constant volume or constant fan) consists of an air inlet assembly similar to a single duct, a housing, a blower/motor assembly, a return air opening/plenum opening and a high voltage connection (**Figures 26 and 27**). All discharge air from the series fan powered terminal goes through the blower/motor assembly. Discharge air from the blower/motor assembly is a mixture of supply air from the air inlet assembly and the return air opening. The percentage of supply air and percentage of return/plenum air will vary based on the regulation of the supply air inlet valve due to room cooling calls by the thermostat. The fan volume for a series fan powered terminal is sized to handle the cooling load in the zone.

Standard accessories for a series fan powered terminal include: inlet and discharge attenuators, discharge silencer, different liners, low temperature construction, electric reheat, hot water reheat, return air filter, ECM, and PSC motor.

Due to access requirements for high voltage electrical enclosures, it is recommended that the designer consider using a door interlock switch. Most local codes require a main disconnect and the integral interlock switch is an economical choice. Also, most local codes require a minimum of 3 ft clearance in front of a high voltage enclosure. As a result, care should be taken when selecting an installation location for the terminal unit.

A standard height series fan powered terminal has the blower/motor assembly installed with the blower inlets and the motor oriented in the horizontal position. The standard height series fan powered terminal is typically no taller than 20 in.

A low profile construction style is available with a typical height no taller than 12.5 in. Due to the height restrictions, the typical low profile series fan powered terminal will have the blower motor installed such that the motor and blower intake opening are oriented to the bottom of the terminal housing.

The overhead series fan powered terminal unit typically has bottom access panels to allow maintenance. There are some models that have a combination of side, top and bottom access openings.

Figure 26: Series Fan Powered Terminal Unit (Overhead Applications)

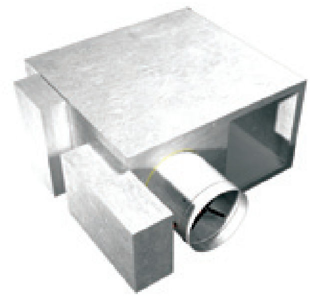


Figure 27: Series Fan powered terminal unit (Overhead Applications) Air Pathway

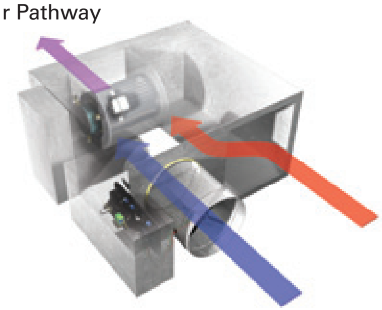
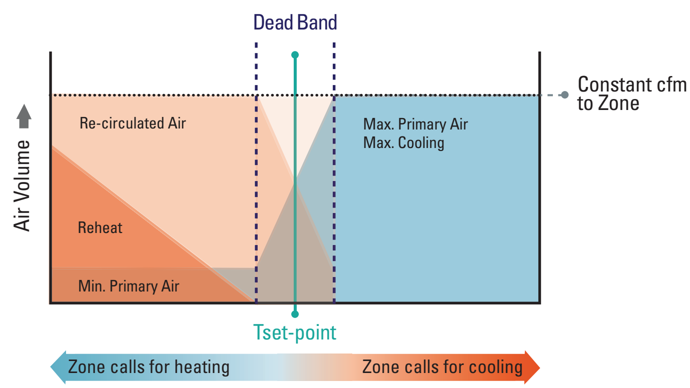


Figure 28: Constant or series FPU with minimum primary air and proportional hot water reheat



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Terminal Unit Types

Series fan powered terminals are commonly used in exterior zones where the heating and cooling loads vary. They are also used in buildings to provide heat during periods of non-occupancy where it is desirable to leave the central air handling system off.

For most typical sequences, the fan in a series FPU will operate at the maximum cooling air volume. Alternative sequences that allow the fan volume to vary based on zone thermostat call for cooling or heating are sometimes used in an attempt to minimize the potential for over-supplying air to the occupied zone.

One of the main benefits of the series fan powered terminal is the consistent delivery of the same air volume to the occupied zone. Many occupants prefer the consistent air movement and consistent ambient sound levels.

One weakness in a series fan powered terminal is that they can generate significant levels of sound power, in particular radiated sound. Care should be taken to not select too large of a fan capacity and to locate the unit over an unoccupied space in the building such as a closet or hallway. To minimize potential noise complaints most designers prefer to limit the overall airflow capacity of the series fan powered terminal to no more than 3000 cfm, with many preferring no greater than 2500 cfm depending upon the type of occupancy and building construction.

There are two common types of electric motors used in fan powered terminals: the permanent split capacitor (PSC) and the electrically commutated motor (ECM). For a complete description of these two motor types, please see the section on motors later in this chapter.

A common sequence of operation is shown in **Figures 28 and 29**. In these control sequences, the primary air valve is varied from minimum airflow volume which is typically determined by the minimum zone fresh air volumes required for the zone occupancy type. The maximum cooling airflow rate is typically determined by the maximum anticipated cooling load for that zone. As the demand for cooling varies, the percentage of return air vs. primary air will vary while the total volume of air to the zone is held constant. As in other reheat sequences, the hot water coil or electric reheat coil will be activated when the zone temperature falls below the lower dead band limit.

Figure 29: Constant or series FPU with minimum primary air and 3 stage electric reheat

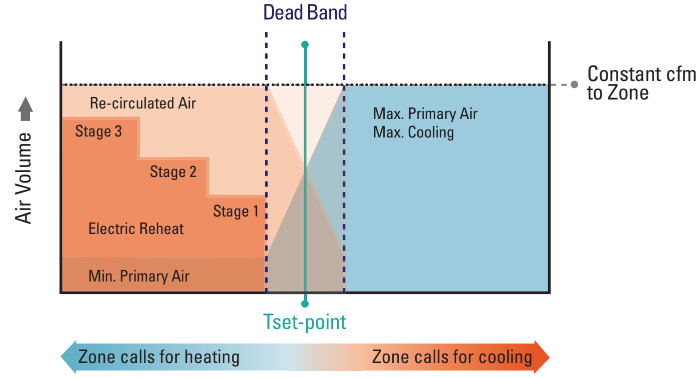


Figure 30: Constant or series FPU with ECM motor and variable fan volume, minimum primary air, and 3 stage electric reheat

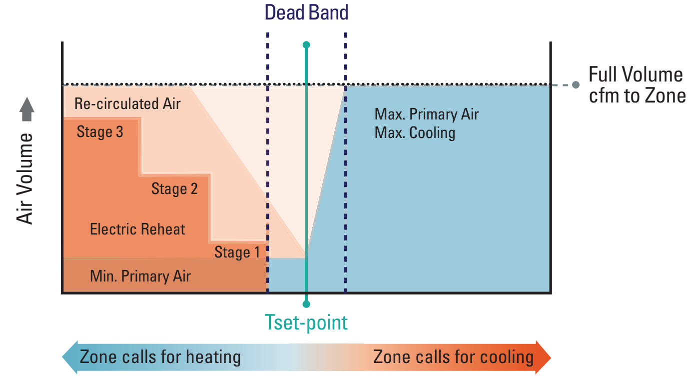
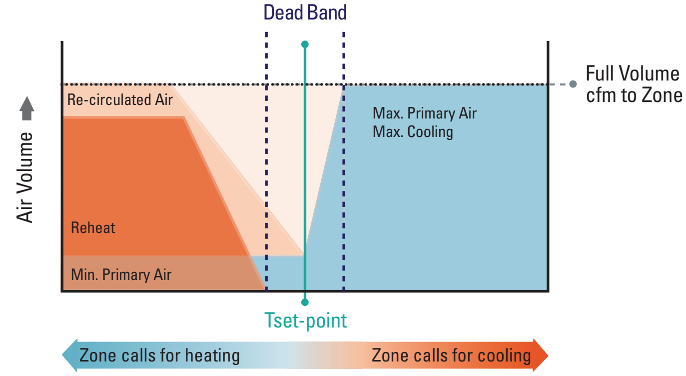


Figure 31: Constant or series FPU with ECM motor and variable fan volume, minimum primary air, and hot water reheat



Terminal Unit Types

Some designers prefer to use the series fan powered unit (FPU) for reheat during periods of unoccupancy and will shut down the central fan during these periods. See **Figures 30 to 34** for common control sequences. At the start of occupied mode it is important to start the series FPU before the central fan to prevent dumping of primary air into the return plenum. It is also important to do this because there is a slight potential for the blower to spin backward due to the flow of primary air through the blower when the motor is not in operation. It is possible that if the blower is spinning backward, when power is applied to the motor, the blower will continue to operate with the reversed rotation. This reverse operation will result in lower air volumes, potential noise issues and motor overheating.

Figure 32: Constant or Series FPU, Min. Primary Air, Water Reheat, Night Set Back/ Unoccupied Mode/Operation

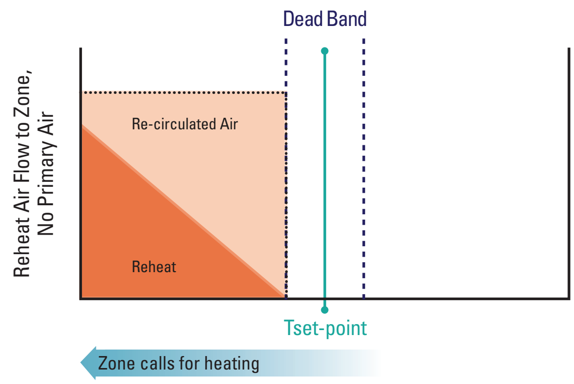


Figure 33: Constant or Series FPU, Min. Primary Air, Electric Reheat, Night Set Back/Unoccupied Mode/Operation

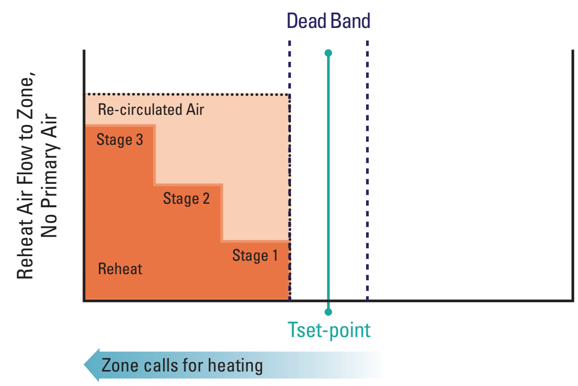
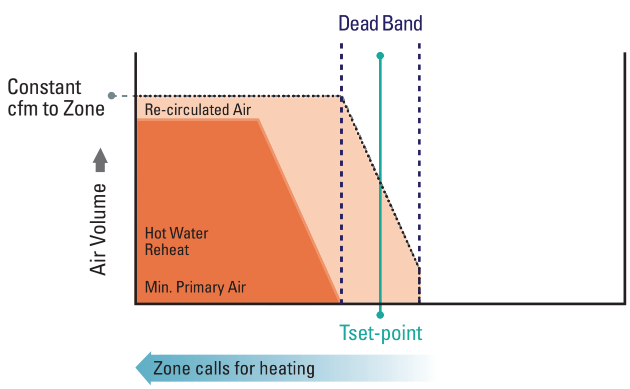


Figure 34: Constant or series FPU with ECM motor and variable fan volume, minimum primary air, and hot water reheat



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Terminal Unit Types

Fan Powered- Parallel

The basic parallel fan powered terminal (sometimes referred to as Intermittent) consists of an air inlet assembly similar to a single duct, a housing, a blower/motor assembly with back draft damper, a mixing chamber, a return air opening/plenum opening and a high voltage connection (see **Figures 35 and 36**). The discharge air from the parallel fan powered terminal is a combination of primary air and fan air volume. During cooling operation, the fan is not in operation and only the primary air is discharged. During heating operation, the fan is energized which pumps plenum air into the mixing plenum where it is mixed with the primary air and then discharged from the terminal unit. The fan in a parallel fan terminal is sized for the heating airflow required for the zone.

Standard accessories for a parallel fan powered terminal include: inlet and discharge attenuators, different liners, low temperature, electric reheat, hot water reheat, return air filter, ECM motor, PSC motor.

Due to access requirements for high voltage electrical enclosures where the connections for the terminal controls and motor are contained as well as fused (if present), it is recommended that the designer consider using a door interlock switch. Most local codes require a main disconnect and the integral interlock switch is an economical choice. Also, most local codes require a minimum of 3 ft clearance in front of a high voltage enclosure. Care should be taken when selecting an installation location for the terminal unit.

A standard height parallel fan powered terminal has the blower/motor assembly installed with the blower inlets and the motor oriented in the horizontal position. The standard height parallel fan powered terminal is typically no taller than 20 in.

A low profile construction style is available with a typical height no taller than 12.5 in. Due to the height restrictions, the typical low profile parallel fan powered terminal will have the blower motor installed such that the motor and blower intake opening are oriented to the bottom of the terminal housing.

The overhead parallel fan powered terminal unit typically has bottom access panels to allow maintenance.

One weakness in a parallel fan powered terminal is that when the fan is in operation, they can generate significant levels of sound power, in particular radiated sound. Also, when the fan cycles on and off, there is a change in the ambient background noise that occupants can become aware of and in some cases, may lead to complaints about noise. Care should be taken to not select too large of a capacity and to locate the unit over an unoccupied space in the building such as a closet, or hallway. Most designers prefer to limit the overall airflow capacity of the parallel fan powered terminal to no more than 3,000 cfm, with many preferring no greater than 2,500 cfm depending upon the type of occupancy and building construction.

Another weakness in parallel FPUs is the leakage of primary air through the back draft damper on the fan and the mixing chamber housing. Recent research by ASHRAE and Texas A and M University (Furr, 2007) have demonstrated that many of the energy savings due to the intermittent fan cycling are offset and in fact may be significantly less than the energy loss associated with the conditioned primary air leaking into the return plenum space through the back draft damper and the mixing chamber housing. It is recommended that if leakage through the back draft damper is of concern that the designer either use a different terminal type, or require that the leakage from the terminal housing as an assembly be limited and certified to some specified amount.

Figure 35: Parallel or Intermittent Fan Powered Terminal

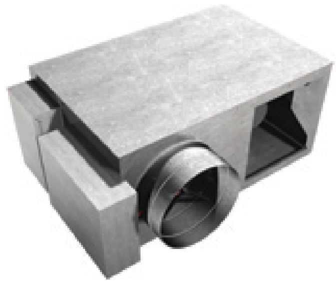


Figure 36: Parallel or Intermittent Fan Powered Terminal Air Pathway

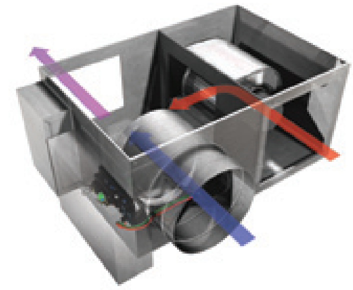
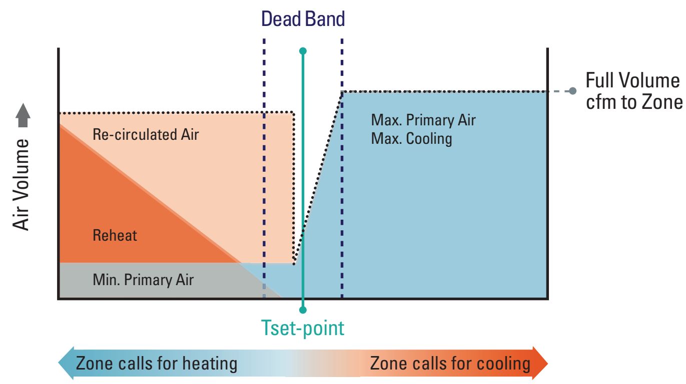


Figure 37: Variable or Parallel FPU with Minimum Primary Air and Water reheat



CONTROL TIP

When using a parallel FPU for reheat when the central air handler is not in operation, it is advised to ensure that the control sequence closes the primary valve prior to turning on the fan, particularly when using electric reheat. The issue is that the fan discharge air will take the path of least resistance and if the primary air valve is open, without the air handler in operation, there is a chance that some of the fan discharge air will not go through the electric reheat coils and then to the zone, but instead will discharge through the primary air valve. If there is not sufficient airflow across the electric reheat coils, nuisance tripping of the electric reheat thermal limits is a distinct possibility.

All Metric dimensions ( ) are soft conversion.
Imperial dimensions are converted to metric and rounded to the nearest millimetre.

Terminal Unit Types

A commonly specified leakage rate for certification is 2% of nominal primary airflow. The ability to certify the leakage of a parallel terminal back draft damper and mixing chamber housing is not common in all manufacturers of these devices.

Parallel fan powered terminals are commonly used in exterior zones where the heating and cooling loads vary. They are also used in buildings to provide heat during periods of un-occupancy where it is desirable to leave the central air handling system off.

The fan is usually sized for the heating air volume and not operated during cooling mode. Energy consumption due to air leakage through the backdraft damper should be evaluated when determining which type of FPU terminal to select.

There are two common types of electric motors used in fan powered terminals, the permanent split capacitor (PSC) and the electrically commutated motor (ECM). For a complete description of these two motor types, please see the section on motors later in this chapter.

A common sequence of operation is shown in **Figures 37 and 38**. In these control sequence, the primary air valve is varied from minimum airflow volume which is typically determined by the minimum zone fresh air volumes required for the zone occupancy type. The maximum cooling airflow rate is typically determined by the maximum anticipated cooling load for that zone. As the demand for cooling varies, the volume of primary air will vary. When reheat is activated, the fan will energize and, the hot water coil or electric reheat coil will be activated when the zone temperature falls below the lower dead band limit.

It is possible to operate the parallel FPU with a variable fan volume during reheat as is shown in **Figure 39**. This is not a common sequence, but there has been some interest in this as a way of saving fan energy.

Figure 38: Variable or Parallel FPU with Minimum Primary Air and 3 Stage Electric Reheat

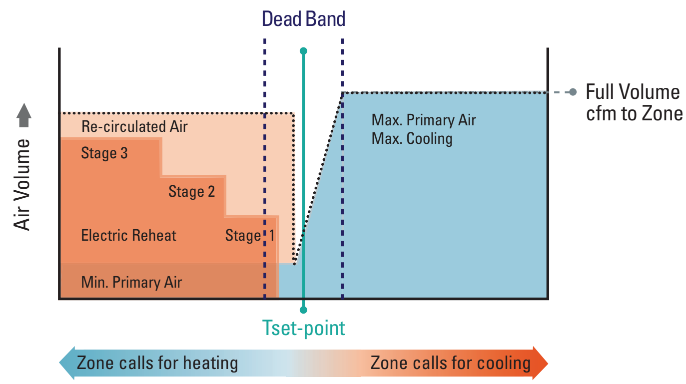
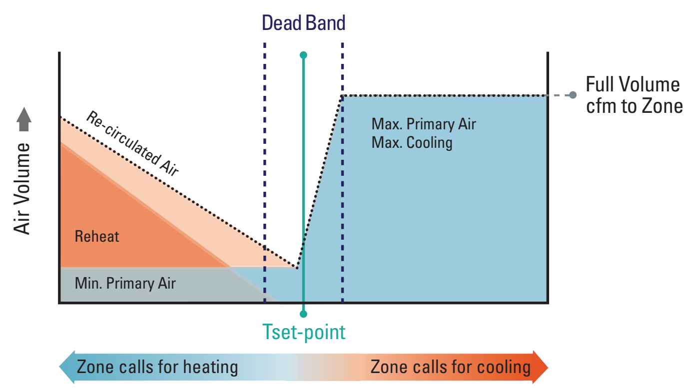


Figure 39: Variable or Parallel FPU with ECM, Variable Fan Volume, Minimum Primary Air, and Water Reheat



PRODUCT TIP

Certified leakage in parallel FPUs is not standard construction and would require special manufacturing. This is not a standard unit offered by any manufacturer.

All Metric dimensions ( ) are soft conversion.
Imperial dimensions are converted to metric and rounded to the nearest millimetre.

Terminal Unit Types

Induction Terminals

The induction terminal is designed to induce warm air from the ceiling plenum without a fan/blower by utilizing a variable aperture 'flow nozzle' (see **Figure 41**). When conditioned air is not required, warm air from the ceiling plenum is introduced, thereby increasing comfort by maintaining airflow in the room.

This unit can be used instead of fan powered terminal units. The traditional induction terminal is a high inlet pressure supply device. Modern induction terminals can operate properly as long as the inlet static pressure is greater than 0.5 in. w.g.

An induction terminal uses the larger and more energy efficient central fan to provide pressurized supply air to induce the room air rather than the lower efficiency motor/ blower in a FPU.

The basic unit consists of a conditioned supply air inlet, with combination damper/ jet flow nozzle, actuator, velocity sensor and related controls, a return air damper and related controls.

Optional accessories include water reheat and electric reheat and various liner types.

The sequence of operation is shown in **Figure 42**. The primary air volume is regulated by closing or opening the primary induction aperture, with the volume of primary air based on the zone cooling requirements. The supply air to the zone is a mixture of the primary air and the induced return air. The amount of induced return air is regulated by the return air damper and will vary between full open at the set-point to full close at the peak cooling call. Optional reheat will activate when the zone temperature drops below the set-point.

Figure 40: Induction Terminal Unit

Figure 41: Induction Terminal Air Pathway

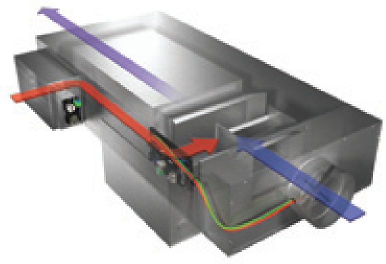
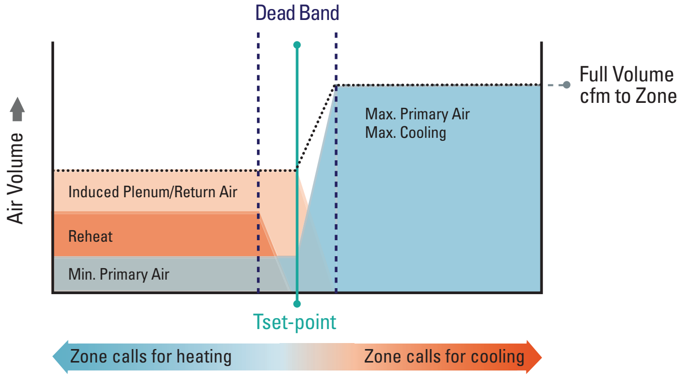


Figure 42: Induction Terminal with Minimum Primary Air and Water Reheat



Acoustical Selection Procedure

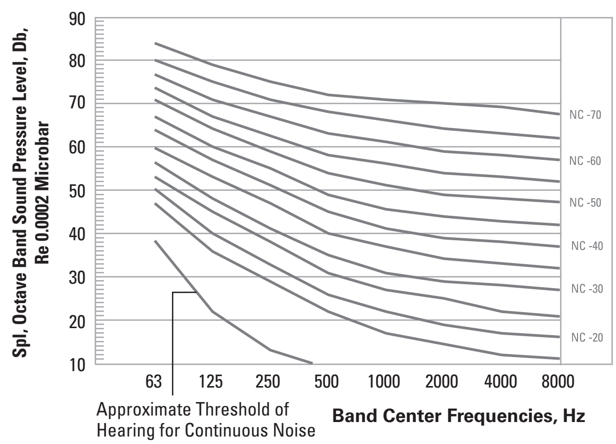
Estimating Sound Levels:
Noise Criteria – NC

Noise Criteria or NC level values have become widely accepted as a measure of room noise levels and as a rating scale for equipment that is expected to stay within those levels.

When deriving NC levels for terminal units, the sound pressure level of octave bands two through seven (125 to 4000 Hz) should be considered. These pressure levels are plotted on a standard NC curve form (**Figure 43**). The highest pressure level when measured against the NC curves, regardless of frequency, determines the NC of the unit.

Table 1 illustrates the ASHRAE recommended space NC values for many commercial air conditioning applications (ASHRAE, 2007). Terminal units should be selected so that the tabulated NC levels are within these design goals. Most manufacturers' catalog data for terminal units lists the sound power levels at various operating conditions. To determine the actual sound pressure level in the space, we must evaluate which attenuation factors are present in the system and subtract these values from the manufacturers' sound power levels. The Air-Conditioning, Heating and Refrigeration Institute (AHRI) has published "A Procedure for Estimating Occupied Space Sound Levels in the Application of Air Terminals and Air Outlets," known as AHRI Standard 885-2008. This standard forms the basis for the sound estimation guidelines presented on the following pages. These guidelines are offered for typical conditions. For a more detailed analysis, refer to AHRI Standard 885-2008 and the ASHRAE HVAC Applications Handbook (ASHRAE, 2007)

Figure 43: Noise Criteria Curves



All Metric dimensions ( ) are soft conversion.
Imperial dimensions are converted to metric and rounded to the nearest millimetre.

Acoustical Selection Procedure

Table 1: Design Guidelines for HVAC System Noise in Unoccupied Spaces

Room Types	RC(N) (QAI[5 dB[a,b])
Private residences	25-35
Hotels/Motels	
Individual rooms or suites	25-35
Meeting/banquet rooms	25-35
Corridors, lobbies	35-45
Service/support areas	35-45
Office Buildings	
Executive and private offices	25-35
Conference rooms	25-35
Tele-conference rooms	< 25
Open-plan offices	< 40
- With sound masking	< 35
Corridors and lobbies	40-45
Hospitals and clinics	
Private rooms	25-35
Wards	30-40
Operating rooms	25-35
Corridors and public areas	30-45
Performing Arts Spaces	
Drama theatres	25
Music teaching studios	25
Music practice rooms	30-35
Schools	d
Classrooms	25-30
Large lecture rooms	25-30
Large lecture rooms, without speech amplification	25
Laboratories (with Fume Hoods)	
Testing/research, minimal speech communication	45-55
Research, extensive telephone use, speech communication	40-50
Group teaching	35-45
Church, Mosque, Synagogue	
General assembly	25-35
With critical music programs	c
Libraries	30-40
Courtrooms	
Un-amplified speech	25-35
Amplified speech	30-40
Indoor Stadiums, Gymnasiums	
Gymnasiums and natatoriums[e]	40-50
Large seating-capacity spaces with speech amplification[e]	45-55

[a] The values and ranges are based on judgment and experience, not quantitative evaluations of human reactions. They represent general limits of acceptability for typical building occupancies. Higher or lower values may be appropriate and should be based on a careful analysis of economics, space use and user needs.

[b] When quality of sound in the space is important, specify criteria in terms of RC(N). If the quality of the sound in the space is of secondary concern, the criteria may be specified in terms of NC or NCB levels of similar magnitude.

[c] An experienced acoustical consultant should be retained for guidance on acoustically critical spaces (below RC 30) and for all performing arts spaces.

[d] Some educators and others believe that HVAC-related sound criteria for schools, as listed in previous editions of this table, are too high and impede learning for affected groups of all ages. See ANSI Standard S12.60-2002 for classroom acoustics and a justification for lower sound criteria in schools. The HVAC component of total noise meets the background noise requirement of that standard if HVAC-related background sound is [RC 25(N).

[e] RC or NC criteria for these spaces need only be selected for the desired speech.

Reference
- 2007 ASHRAE Applications Handbook, Table 42, page 47.34
- AHRI Standard 885-2008, Table 15, page 31

Acoustical Selection Procedure

Environmental Adjustment Factors

According to AHRI Standard 885-2008, an environmental adjustment factor must be applied to manufacturers' data if the sound power data has been obtained in accordance with AHRI Standard 880-2008. Sound power levels obtained in accordance with Standard 880 are based on a free field calibration of the reference sound source. According to AHRI, real rooms at low frequencies behave acoustically more like reverberant rooms than open spaces (free field). Because of this, it is necessary to adjust power levels obtained in accordance with AHRI Standard 880-2008 by the Environmental Adjustment Factor listed in **Table 2**.

Sound Paths

In order to estimate the sound level in the occupied space, one must first identify the sound source and determine by which paths the sound enters the occupied space. **Figure 44** illustrates a fan powered terminal as an example of a sound source and identifies five sound paths. These sound paths are as follows.

- Upstream Duct Breakout Radiated - This is the noise generated by the terminal that is transmitted through the upstream ductwork.
- Inlet and Casing Radiated - This is the noise generated by the terminal that is transmitted through the terminal casing or which escapes out the return air opening.
- Discharge Duct Breakout Radiated - This is the noise generated by the terminal unit which is transmitted through the downstream ductwork.
- Outlet Discharge - This is the noise generated by the terminal that travels down the duct and escapes at the air outlet.
- Outlet Generated - This is the noise generated by the air outlet. Since the discharge and upstream duct breakout noise paths are functions of the quality of the ductwork construction and installation rather than the terminal unit performance, they are not dealt with in the following estimating procedure. Generally, if care is taken in the design and installation of the ductwork, breakout noise will not be a contributing factor to the occupied level. However, for a detailed analysis of duct breakout noise, please refer to AHRI Standard 885-2008.

Now that we have identified the relevant sound paths, we can evaluate the attenuation factors for each.

Radiated Sound

Figure 45 illustrates the sound path for inlet and casing radiated sound. The attenuation factors that apply to this sound path are Ceiling / Space Effect and Environmental Adjustment Factor. The Environmental Adjustment Factor was presented earlier in the Engineering Guide.

Table 2: Environmental Adjustment Factor

Octave Band Mid Frequency, Hz	2	3	4	5	6	7
Environmental Adjustment Factor, dB	2	1	0	0	0	0

Reference: AHRI Standard 885-2008, Appendix C, Table C1, page 385.

Figure 44: Fan Powered Terminal or Induction Terminal Acoustical Model.

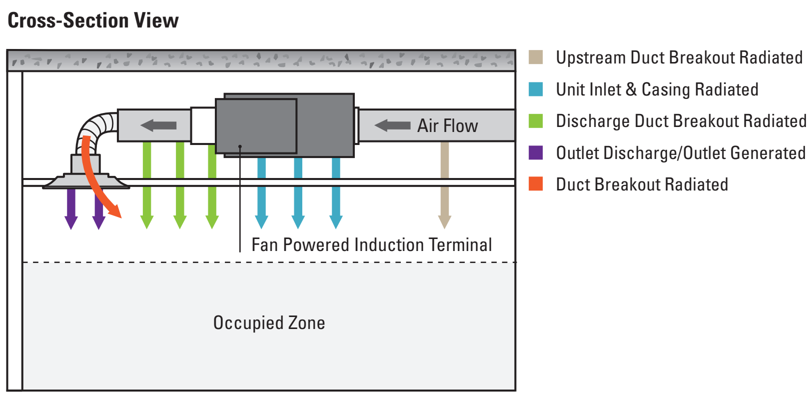


Figure 45: Fan Powered / Induction Terminal Acoustical Model - Radiated Sound Path

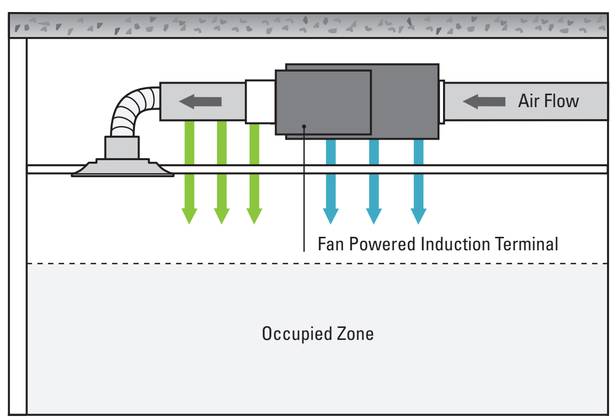


Table 3: Ceiling/Space Effect, dB

Octave Band Mid Frequency, Hz	2	3	4	5	6	7
Type 1: Mineral Tile 5/8 in. – 20#/ft^3	18	19	20	26	31	36
Type 4: Glass Fiber 5/8 in. – 4 #/ft^3	19	19	21	25	29	35
Type 7: Solid Gypsum Board 5/8 in. – 43 #/ft^3	23	26	25	27	27	28

Reference • AHRI Standard 885-2008, Appendix D, Table D15, page 54

All Metric dimensions ( ) are soft conversion.
Imperial dimensions are converted to metric and rounded to the nearest millimetre.

Acoustical Selection Procedure

Ceiling / Space Effect

To calculate the sound level in a space resulting from a sound source located in the ceiling cavity, a transfer function is provided which is used to calculate the sound pressure in the space. This transfer function includes the combined effect of the absorption of the ceiling tile, plenum absorption and room absorption.
The procedure assumes the following conditions:

a. The plenum is at least 3 ft [0.9 m] deep.
b. The plenum space is either wide (over 30 ft [9 m]) or lined with insulation.
c. The ceiling has no significant penetrations directly under the unit.

Table 3 provides typical values for ceiling space effect of several ceiling types from manufacturers' sound power level data. Price tests all terminal units in accordance with AHRI Standard 880-2008, therefore these corrections should be applied when estimating the sound power in occupied spaces.

Discharge Sound

Figure 46 illustrates the sound path for outlet discharge sound. The attenuation factors which apply to this sound path are:

- Branch Power Division
- Duct Insertion Loss
- Lined Flexible Duct Insertion Loss
- Elbow and Tee Loss
- End Reflection Factor
- Space Effect

Branch Power Division

At branch take-offs, acoustic energy is distributed between the branches and/or the main duct in accordance with the ratio of the branch cross-sectional area to the total cross-sectional area of all ducts leaving the take-off. In other words, the acoustic energy is divided in proportion to the flow division of the take-off. **Table 4** lists the attenuation of various percentages of total flow carried by the branch ductwork.

Duct Insertion Loss

Acoustically lined ductwork is effective in absorbing sound as it travels down the duct. **Table 5** lists the attenuation in dB/linear ft for various duct sizes coinciding with the outlet size of commonly used Price terminals. Data is based on discharge duct that is the same size as the unit outlet, lined with 1 in.,1.5 lb/ft^3 insulation. A more complete list of duct sizes and the method of calculating custom sizes is outlined in the AHRI 885-2008 Standard, Appendix D.

Figure 46: Discharge Sound

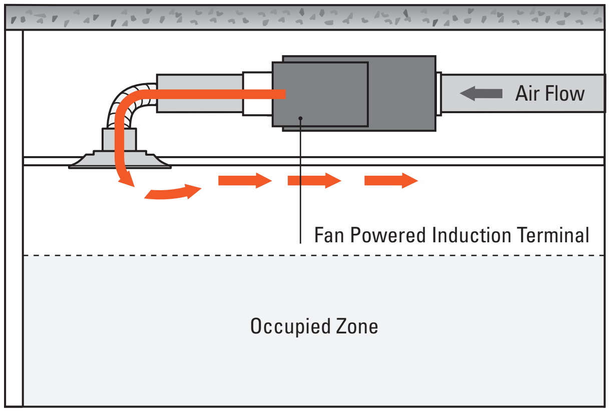


Table 4: Flow Division

% Total Flow	5	10	15	20	30	40	50	60
dB Attenuation	13	10	8	7	5	4	3	2

Reference • AHRI Standard 885-2008, Appendix D, Table D2, page 40

Table 5: Sound Insertion Loss / Attenuation in Straight Lined Metal Ducts

Model Type	Discharge Duct (in.) [mm]	Octave Band 2	3	4	5	6	7
Fan Powered Single Duct	12 x 8 [305 x 203]	0.4	1.0	2.1	4.5	4.9	3.2
	12 x 10 [305 x 254]	0.4	0.9	2.0	4.2	4.4	2.9
	14 x 12 ½ [356 x 318]	0.3	0.8	1.8	3.9	3.7	2.6
	16 x 15 [406 x 381]	0.3	0.7	1.7	3.5	3.3	2.4
	20 x 17 ½ [508 x 445]	0.3	0.6	1.5	3.2	2.8	2.1
	24 x 18 [610 x 457]	0.3	0.5	1.5	3.1	2.5	2.0
	28 x 17 ½ [711 x 445]	0.2	0.5	1.4	3.0	2.4	1.9
	34 x 17 ½ [864 x 445]	0.2	0.5	1.4	2.9	2.3	1.8

Reference • AHRI Standard 885-2008, Appendix D, Table D8, page 47
• 2007 ASHRAE Handbook, HVAC Applications, Chapter 4, Table 12

All Metric dimensions ( ) are soft conversion.
Imperial dimensions are converted to metric and rounded to the nearest millimetre.

Acoustical Selection Procedure

Lined Flexible Duct Insertion Loss

Nonmetallic insulated flexible ducts can significantly reduce airborne noise. Insertion loss values for specified duct diameters and lengths are given in **Table 6.** Recommended duct lengths are normally from 3 to 5 ft Care should be taken to keep flexible ducts straight; bends should have as long a radius as possible. While an abrupt bend may provide some additional insertion loss, the airflow generated noise associated with the airflow in the bend may be unacceptably high.

Because of potentially high duct breakout sound levels associated with flexible ducts, care should be exercised when using flexible ducts above sound sensitive spaces. The data in **Table 6** is based on solid core flexible duct (non-perforated or woven] with a 1 in. [25 mm] thick insulation and plastic jacket.

Elbow and T Loss

Lined and unlined rectangular elbows provide attenuation as per **Tables 7** and **8**. **Tables 7** and **8** apply only where the duct is lined before and after the elbow. Attenuation of a tee fitting can be estimated by considering the tee as two elbows placed side by side as is illustrated in **Figure 47**.

End Reflection Factor

When low frequency plane sound waves pass from a small space such as a duct into a large space the size of a room, a certain amount of sound is reflected back into the duct, significantly reducing low frequency sound. **Table 9** lists the attenuation values for end reflection. The values of **Table 9** apply to straight runs of duct entering a room therefore caution should be exercised when a condition differs drastically from the test conditions used to derive the table.

Table 6: Lined Flexible Duct Insertion Loss, dB

Duct Diameter (in.] [mm]	Duct Length (in.] [mm]	Octave Band Mid Frequency					
		2	3	4	5	6	7
6 [150]	3 [0.9]	5	6	13	17	19	11
6 [150]	5 [1.5]	6	9	18	22	24	15
8 [200]	3 [0.9]	4	7	14	15	16	8
8 [200]	5 [1.5]	6	10	18	20	21	12
10 [250]	3 [0.9]	4	7	14	12	13	6
10 [250]	5 [1.5]	5	11	18	18	18	9
12 [300]	3 [0.9]	3	6	12	10	11	4
12 [300]	5 [1.5]	4	9	16	16	15	7
14 [350]	3 [0.9]	2	4	10	9	9	4
14 [350]	5 [1.5]	3	7	14	14	13	6
16 [400]	3 [0.9]	1	0	8	8	8	4
16 [400]	5 [1.5]	2	2	11	12	11	5
Reference • AHRI Standard 885-2008, Appendix D, Table D9, page 48							

Table 7: Insertion Loss of Unlined and Lined Elbows without Turning Vanes, dB

Model Type	Duct Diameter	Octave Band Mid Frequency					
		2	3	4	5	6	7
Unlined Duct	5-10 [100-125]	0	0	1	5	8	4
	11-20 [260-700]	1	5	5	8	4	3
	21-40 [710-1000]	5	5	8	4	3	3
	41-80 [1010-2000]	5	8	4	3	3	3
Lined Duct	5-10 [100-125]	0	0	1	6	11	10
	11-20 [260-700]	1	6	6	11	10	10
	21-40 [710-1000]	6	6	11	10	10	10
	41-80 [1010-2000]	6	11	10	10	10	10
Reference • AHRI Standard 885-2008, Appendix D, Table D12, page 51 • 2007 ASHRAE Handbook, HVAC Applications, Chapter 47, Table 17							

Table 8: Insertion Loss of Unlined and Lined Elbows with Turning Vanes, dB

Model Type	Duct Diameter	Octave Band Mid Frequency					
		2	3	4	5	6	7
Unlined Duct	5-10 [100-125]	0	0	1	4	6	4
	11-20 [260-700]	1	4	6	4	4	3
	21-40 [710-1000]	4	4	6	4	4	3
	41-80 [1010-2000]	4	6	6	4	4	3
Lined Duct	5-10 [100-125]	0	0	1	4	7	7
	11-20 [260-700]	1	4	7	7	7	7
	21-40 [710-1000]	4	7	7	7	7	7
	41-80 [1010-2000]	4	7	7	7	7	7
Reference • AHRI Standard 885-2008, Appendix D, Table D12, page 51 • 2007 ASHRAE Handbook, HVAC Applications, Chapter 47, Table 19							

All Metric dimensions ( ) are soft conversion.
Imperial dimensions are converted to metric and rounded to the nearest millimetre.

Acoustical Selection Procedure

Space Effect

A sound source terminating in the occupied space is assumed to be a point source. The calculation of the sound pressure level Lp in rooms for the entering sound power level Lw can be accomplished using the Schultz equation:

$$Lp = Lw - 10 \times \log(r) - 5 \times \log(V) - 3 \times \log(f) + 25$$

where:

r = the shortest distance in ft [m] from noise source to the receiver.
V = the room volume in ft^3 [m^3]
f = the octave band mid frequency of interest, in Hz

The Schultz equation is to be used for a single sound source in the room. This includes a diffuser, and is also valid for computing the sound traveling from an air terminal through the supply ductwork and entering the room through the diffuser. The sound generated by the diffuser and the air terminal sound transmitted through the diffuser should be logarithmically added per the following equation.

$$Lp = 10 \log (10^{Lp_1/10} + 10^{Lp_2/10} + \ldots 10^{Lp_n/10})$$

where:

n = the number of sound sources being added logarithmically.
Lp = the sound pressure level.

In order to compare the noise levels of different systems at the design stage where exact room dimensions are not known, the following default room values are suggested.

1. Small room, single outlet, 1500 ft^3 [42 m^3]
2. Large rooms, four outlets or more, 8000 ft^3 [220 m^3]

It is also recommended that noise level predictions be made at heights 5 ft [1.5 m] above the floor when no specific height is specified.

Outlet Generated Sound

This is the sound generated by the air outlet itself. In many cases, for outlets, manufacturers publish only a single NC diffuser rating. In this case, a conservative estimate of outlet generated sound power levels can be obtained by assuming the individual octave band sound pressure levels associated with the published NC rating and then adding to these values 10 dB for the manufacturer's assumed room attenuation to each value.

To arrive at the final sound power level you will need to add the 10 dB room absorption to the value of the sound pressure found in **Table 10**. **Table 10** provides a comparison of NC versus sound pressure.

Figure 47: Tee Fitting Loss

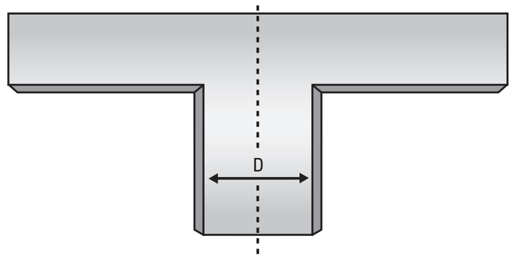


Table 9: End reflection, dB

Duct Diameter (in.) [mm]	Octave Band Mid Frequency 2	3	4	5	6	7
6 [150]	12	6	3	1	0	0
8 [200]	9	5	2	0	0	0
10 [250]	8	3	1	0	0	0
12 [300]	6	3	1	0	0	0
16 [400]	5	2	0	0	0	0

Reference • AHRI Standard 885-2008, Appendix D, Table D13, page 47. ISO Standard 5135

Table 10: NC versus Sound Pressure Level (dB]

NC	Octave Band Mid Frequency 2	3	4	5	6	7
15	36	29	22	17	14	12
20	40	33	26	22	19	17
25	44	37	31	27	24	22
30	48	41	35	31	29	28
35	52	45	40	36	34	33
40	56	50	45	41	39	38
45	60	54	49	46	44	43
50	64	58	54	51	49	48
55	67	62	58	56	54	53
60	71	67	63	61	59	58
65	75	71	88	66	64	63

Reference • AHRI Standard 885-2008, Table 13, page 27

Example 1 - Estimating Sound Power of Outlets
An SCD 12 x 12 square cone diffuser with a neck size of 6 in. at 176 cfm provides a NC level of 20. The individual octave band power levels can be estimated by adding 10 dB room absorption to the values found in **Table 10**.

Octave Band Mid Frequency	2	3	4	5	6	7
Octave Band Lp for NC = 20 (see Table 10)	40	33	26	22	19	17
+10 dB Typical Room Attenuation Assumption	10	10	10	10	10	10
Estimated Outlet Generated Lw	50	43	36	22	29	27

All Metric dimensions ( ) are soft conversion.
Imperial dimensions are converted to metric and rounded to the nearest millimetre.

Acoustical Selection Procedure

Multiple Sound Sources

All outlet sound data is for a single source. Allowances must be made for multiple outlets when this occurs in a space since the overall noise level may be the resultant of more than one outlet or sound source. One way to calculate the sound pressure level in a room associated with multiple sound sources is to first use the Schultz equation to calculate the sound pressure levels associated with each individual air outlet at specified locations in the room. Then logarithmically add the sound pressure levels associated with each diffuser at each observation point.

This calculation procedure can be very tedious and time consuming for a large number of air outlets. For the special case of a distributed ceiling array of air outlets where all of the sources have the same Lw, the calculation can be greatly simplified by using the following equation for space effect.

$$Sa = Lw - Lp = 5\log(x) + 28\log(h) - 1.13\log(N) + 3\log(f) - 31 \text{ dB}$$

where:

- Sa = Distributed Ceiling Array Space Effect
- x = Ratio of floor area served by each outlet to the square of the ceiling height, ft [m]
- h = ceiling height in ft [m]
- N = number of evenly spaced outlets in the room, minimum four
- f = octave band center frequency in Hz

Data based on the above calculation method is presented for an array of four outlets for four different room heights, three different outlet areas in **Table 12**. The table assumes an array of four diffusers.

Note: this table does not apply for a row of linear diffusers.

Table 12: Room Sound Attenuation For an Outlet Array, 4 Outlets

Ceiling Height	Ceiling Height	Octave Band Mid Frequency					
		2	3	4	5	6	7
200 ft^2 [20 m^2]	8 ft [2.4 m]	2	3	4	5	6	7
300 ft^2 [30 m^2]		3	4	5	6	7	8
400 ft^2 [40 m^2]		4	5	6	7	7	8
200 ft^2 [20 m^2]	9 ft [2.7 m]	3	4	5	6	7	8
300 ft^2 [30 m^2]		4	5	6	7	8	9
400 ft^2 [40 m^2]		5	6	7	8	8	9
200 ft^2 [20 m^2]	10 ft [3.0 m]	4	5	6	7	8	9
300 ft^2 [30 m^2]		5	6	7	8	9	10
400 ft^2 [40 m^2]		6	7	7	8	9	10
200 ft^2 [20 m^2]	12 ft [3.6m]	6	6	7	8	9	10
300 ft^2 [30 m^2]		6	7	8	9	10	11
400 ft^2 [40 m^2]		7	8	9	10	11	12

Reference • AHRI Standard 885-2008, Appendix D, Table D17, Page 55

All Metric dimensions ( ) are soft conversion.
Imperial dimensions are converted to metric and rounded to the nearest millimetre.

Acoustical Selection Procedure

Typical Sound Attenuation Values

NC levels presented in the Typical Selection Guide are based on typical attenuation values as outlined in AHRI Standard 885-2008, Appendix E. AHRI Standard 885-2008, Appendix E provides typical sound attenuation values for air terminal discharge and radiated sound. The typical attenuation values are intended for use by manufacturers to estimate application sound levels. In the product catalog, end use environments are not known and the factors presented in AHRI Standard 885-2008 are provided as typical attenuation values. Use of these values will allow better comparison between manufacturers and provide the end user a value that will be expected to be applicable for many types of spaces. The typical attenuation values in Appendix E are required for use by manufacturers to estimate NC values printed in catalogs. If a terminal has a liner or construction style that differs from the standard construction style, the manufacturer should provide NC values that have been estimated with the appropriate attenuation factors taken from AHRI Standard 885-2008.

NC vs. Sound Power Levels – Compare Them Carefully

Sound performance data for terminal units is provided in two manners:

- Sound Power
- NC

The laboratory attained discharge and radiated sound power levels for each unit at various flows and inlet static pressures is presented as acoustical data tables. This data is derived in accordance with AHRI Standard 880-2008 and shows the "raw" sound power levels of the terminal in the second through seventh octave bands with NO attenuation allowances.

The attenuation allowances listed are based on values provided in AHRI Standard 885-2008, Appendix E. The attenuation allowances are intended to be representative of typical jobsite construction. If your conditions differ significantly from these it is recommended you utilize the sound power level data and the procedures outline in AHRI Standard 885-2008.

If the NC levels listed in the Price catalog or performance sheets are being compared to other manufacturers' cataloged NC information, a careful review of the other manufactures' attenuation allowances must be made. If allowances other than AHRI Standard 885-2008, Appendix E are used, a fair comparison of NC levels cannot be performed.

Radiated Sound

Table E1 of Appendix E AHRI Standard 885-2008 provides typical radiated sound attenuation values. The following table provides total deduction values for several different types of Mineral Fiber ceilings:

The ceiling/space effect assumes the following conditions:

1. $^5/_8$ in. tile, 20 lb/ft^3 density
2. The plenum is at least 3 ft [0.9 m] deep
3. The plenum space is either wide (over 30 ft [9 m]) or lined with insulation
4. The ceiling has no significant penetration directly under the unit

Table 13: Ceiling/space effect, dB (AHRI Standard 885-2008, Appendix E, Table E1)

NC	Octave Band Mid Frequency					
	2	3	4	5	6	7
Type 1, Mineral Fiber Tile	16	18	20	26	31	36

Discharge Sound

Table E1 of Appendix E provides typical discharge sound attenuation values. The following table provides the total deduction values for several sizes of terminal boxes. For standard construction style, the manufacturer should provide NC values that have been estimated with the appropriate attenuation factors taken from AHRI Standard 885-2008.

Table 14: Terminal sound power, dB (AHRI Standard 885-2008, Appendix E, Table E1)

	Octave Band Mid Frequency					
	2	3	4	5	6	7
Small Box	24	28	39	53	59	40
Medium Box	27	29	40	51	53	39
Large Box	29	30	41	51	52	39

1. Small Box (8 in. x 8 in. [0.2 m x 0.2 m]) <300 cfm [0.14 m3/s]
2. Medium Box (12 in. x 12 in. [0.3 m x 0.3 m]) 300 to 700 cfm [0.14 to 0.33 m3/s]
3. Large Box (15 in. x 15 in. [0.4 m x 0.4 m]) > 700 cfm [0.33 m3/s]

Diffuser Sound

Table E1 of Appendix E of AHRI Standard 885-2008 provides typical discharge sound room attenuation values. The deduction of 10 dB is taken in all bands before computing diffuser NC.

Table 15: Attenuation factors for dual density fiberglass

Large box, >700 cfm [330 L/s]						
Octave Band Mid Freq, Hz	2	3	4	5	6	7
	125	250	500	1000	2000	4000
Lining Reduction (1 in. fiberglass, 15 x 15 in. duct)	2	3	9	18	17	12
Power Splits (3 diffusers)	5	5	5	5	5	5
End Reflection (8 in. duct)	9	5	2	0	0	0
Flex Duct Reduction (8 in. duct)	6	10	18	20	21	12
Environmental Adj. Factor	2	1	0	0	0	0
Room Attenuation 2400 ft^3	5	6	7	8	9	10
Total Attenuation	29	30	41	51	52	39
Reference • AHRI Standard 885-2008, Appendix E, Discharge Sound Attenuation Factors						

Acoustical Selection Procedure

If a liner other than 1 in. fiberglass is selected, the designer is urged to consider the impact that this will make on the estimated sound values in the space. It is suggested that for liner types other than 1 in. dual density fiberglass (which is the 'standard construction'), attenuation factors should be adjusted to reflect this change. For instance, if the design intent is a terminal unit with solid metal liner (no exposed insulating material) then the standard AHRI Standard 885-2008, appendix E attenuation factors for lined ductwork downstream of the terminal unit should not be used. If the attenuation factors are not adjusted by removing the estimated absorption of the fiberglass liner, the actual sound values in the occupied space will vary significantly from the estimate provided by the Appendix E attenuation factors and may lead to an overestimate of how much sound power will be absorbed by the ductwork. This can lead to loud spaces.

Discharge Sound Attenuation Factors For Alternative Liners

For liner types such as foil faced fiberglass liner, fiber free liner, or solid metal liner on single duct, the attenuation factors used for estimating the sound values in the space are modified by using the attenuation factors shown in tables 16 and 17. The attenuation factors values for the fiber free foam are not generally available and are shown for illustration purposes only as they are from only one brand/type of foam insulation. Due to different materials used in the manufacturing of the foam insulation liner, it is recommended that the designer use the attenuation factors for solid metal for all liner types other than 1 in. fiberglass.

As an example, three different liner types are explored for a large terminal unit. The discharge sound attenuation factors are shown by type of factor. In tables 15, 16 and 17, it is easy to see that the solid metal liner has the lowest attenuation of discharge sound, and that the fiber free foam falls between the standard fiberglass liner and the solid metal in discharge sound attenuation. This difference in attenuation is magnified when the terminal unit is operating with pressure drops over 1 in. w.c. (see **Table 18**).

PRODUCT TIP

The attenuation for fiber free foam liners is based on the data from one manufacturer of this product type, and may not be available from all vendors. To be safe, it is suggested that the designer use the attenuation factors for solid metal liners.

Table 16: Adjusted attenuation factors for solid metal liner

Large box, >700 cfm [330 L/s]						
Octave Band Mid Freq, Hz	**2** **125**	**3** **250**	**4** **500**	**5** **1000**	**6** **2000**	**7** **4000**
Lining Reduction (solid metal liner, 15 x 15 in. duct)	0	0	0	0	0	0
Power Splits (3 diffusers)	5	5	5	5	5	5
End Reflection (8 in. duct)	9	5	2	0	0	0
Flex Duct Reduction (8 in. duct)	6	10	18	20	21	12
Environmental Adj. Factor	2	1	0	0	0	0
Room Attenuation 2400 ft^3	5	6	7	8	9	10
Total Attenuation	27	27	32	33	35	27

Table 17: Adjusted attenuation factors for fiber free foam liner

Large box, >700 cfm [330 L/s]						
Octave Band Mid Freq, Hz	**2** **125**	**3** **250**	**4** **500**	**5** **1000**	**6** **2000**	**7** **4000**
Lining Reduction (fiber free foam liner, 15x15 in. duct)	0	1	0	2	3	2
Power Splits (3 diffusers)	5	5	5	5	5	5
End Reflection (8 in.duct)	9	5	2	0	0	0
Flex Duct Reduction (8 in. duct)	6	10	18	20	21	12
Environmental Adj. Factor	2	1	0	0	0	0
Room Attenuation 2400 ft^3	5	6	7	8	9	10
Total Attenuation	27	28	32	35	38	29

Table 18: Price SDV, 12 in. single duct with 2000 cfm air volume

Discharge NC Values	**Pressure drop across terminal unit, in. w.c.**				
	0.5	**1.0**	**1.5**	**2.0**	**3.0**
Using AHRI 885-2008, Appendix E, 1 in. fiberglass 15 x 15 in. duct	<20	23	27	31	35
Using adjusted factors for solid metal	30	36	40	43	46
Using adjusted factors for fiber free foam	20	28	32	35	40

All Metric dimensions ( ) are soft conversion.
Imperial dimensions are converted to metric and rounded to the nearest millimetre.

Acoustical Selection Procedure

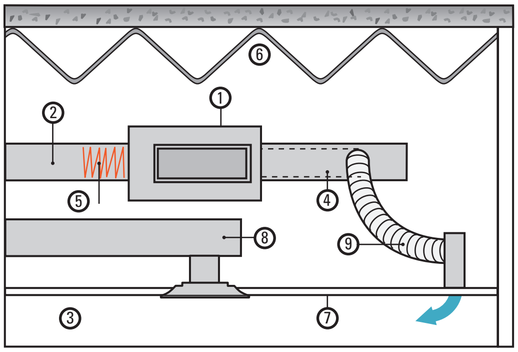
Radiated Sound For Alternative Liners

For liner types such as foil faced fiberglass liner, fiber free liner or solid metal liner on terminals, the attenuation factors used for estimating the sound values in the space are the same for standard fiberglass. The only absorbing factors in the sound path from the terminal unit to the receiver (space occupant) are distance and ceiling type. The designer is cautioned that the radiated sound power levels from the terminal unit will not be the same as for standard fiberglass liner. That means that when a terminal unit is selected with a liner other than fiberglass, the radiated sound power levels will always be different than that for the standard fiberglass liner. The designer is urged to consider the accuracy of the supplied data from a vendor when the radiated sound power levels for an alternative liner (as outlined on the submittal) are the same as the sound power levels for the standard fiberglass liner (as printed in the vendor literature). This is a common complaint item from design engineers. Price tests all of our terminal units with fiber free, foil faced, metal lined (solid and perforated) and provides the adjusted radiated sound power levels when using our terminal selection program. See **Table 19** for a comparison between radiated sound power levels for a typical single duct terminal using different liner types and different pressure drops across the terminal unit.

Table 19: Price SDV, 12 in. single duct with 2000 cfm air volume

Radiated NC Values	Pressure drop across terminal unit, in. w.c.				
	0.5	1.0	1.5	2.0	3.0
Using AHRI Standard 885-2008, Appendix E 1 in. fiberglass 15 x 15 in. duct	<20	24	28	31	33
Using Solid Metal liner	<20	<20	20	23	27
Using Aluminum Foil Faced Insulation	20	26	29	31	35
Using Fiber Free Foam Insulation	22	29	33	35	39

Figure 49: Acoustical design considerations



Acoustic Design Considerations

1. Selection
2. Inlet Static Pressure
3. Location
4. Discharge Ductwork
5. Duct Breakout Noise
6. Ceiling Plenum
7. Ceiling Construction
8. Return Air Opening
9. Acoustic Flex

Terminal Unit Acoustical Design Considerations

To ensure an acceptable NC level in the occupied space, several design considerations should be taken into account.

1. Select a terminal which will operate in the mid to low area of its operating range. Lower fan speeds produce lower sound levels.
2. Design duct systems to provide adequate but not excessive static pressure at the primary air inlet. Excess static pressure generates noise.
3. Locate terminals above non-critical areas like corridors, closets or file areas. This will isolate critical areas from potential sources of radiated noise.
4. Locate terminal to allow maximum length of lined discharge duct work. Consider a larger number of smaller diffusers to minimize discharge sound.
5. Flex duct and fiberglass duct board allow significantly greater breakout noise than metal duct and should be avoided. Flex duct can also generate sound if bending, folding or sagging take place.
6. Locate terminal units in the largest plenum volume available for increased reduction of radiated noise.
7. A ceiling with high transmission loss will help reduce radiated sound.
8. Avoid locating terminals near return air openings. This allows a direct path for radiated noise to enter the space.
9. The use of acoustically lined flex duct on the diffuser will reduce discharge sound.

All Metric dimensions ( ) are soft conversion.
Imperial dimensions are converted to metric and rounded to the nearest millimetre.

ENGINEERING GUIDE - TERMINAL UNITS

Price Catalog Data Updated According to New ANSI/AHRI Standard 880 - 2011

New AHRI regulations require manufacturers to catalog discharge sound power levels with duct end reflection corrections by January 1, 2013. This will result in published discharge sound power levels appearing higher than before, and possibly higher than other manufacturers who have not yet updated their data. In addition certified ratings must now be imbedded with application rating tables.

Catalog Highlight 1 – Updated Discharge Sound with Duct End Reflection Corrections

Discharge sound power levels for all Price terminals have been updated to include duct end reflection corrections to comply with the 2011 version of ANSI/AHRI Standard 880 – Performance Rating of Air Terminals.

How Does This Affect Data?

Discharge Sound Power Levels

Duct end reflection is a calculated value that is dependent on octave band center frequency and equivalent discharge duct diameter. The correction is highest at low frequencies and small discharge duct sizes. **As a result, the new published discharge sound power levels will be higher than previous levels, particularly for small terminals in the low octave bands.** For an example, see the following table of duct end reflection corrections for Price single duct terminal model SDV. The updated catalog sound power levels will be higher than previous by the decibel amount tabulated below.

Unit Size	Octave Band Center Frequency					
	125	250	500	1000	2000	4000
4	8	3	1	0	0	0
5	8	3	1	0	0	0
6	8	3	1	0	0	0
7	7	3	1	0	0	0
8	7	3	1	0	0	0
9	6	2	1	0	0	0
10	6	2	1	0	0	0
12	5	2	0	0	0	0
14	4	1	0	0	0	0
16	3	1	0	0	0	0
24x16	2	1	0	0	0	0

Discharge NC Levels

Note that the resultant catalog discharge noise criteria (NC) levels will also increase in most cases. This does not mean that actual room noise levels will be affected since the actual terminal sound output has not changed. Field measurements are not affected by this new calculation procedure; however, HVAC designers may find that a certain terminal model size at a certain flow rate may no longer meet their room NC specification based on the new catalog values. **Remember that the terminal is not actually any louder than before and the same noise level will be heard or measured in the field.** Relaxing the room NC specification may be the best option. Otherwise a quieter terminal will need to be selected which usually carries a cost premium. The table below illustrates how the updated Price single duct terminal (SDV) NC values compare with previous cataloged values. Note that the small size units increase the most.

Noise Criteria (NC) Table			
Size	cfm	Old NC	New NC
4	225	27	34
6	400	23	30
8	700	24	30
10	1100	24	26
12	1800	27	31
14	2500	29	31
16	3500	30	33
24x16	6000	39	41

Comparing Data

According to the deadline imposed by AHRI, manufacturers have until January 1, 2013 to catalog discharge sound power levels with duct end reflection corrections. Until that time it will be important to understand if cataloged discharge performance data includes duct end reflection corrections or not. **Discharge sound power level or NC level comparisons cannot be made between manufacturers unless both are based on the same calculation procedure.**

New Price AIO Catalog Data Adheres to New ANSI/AHRI Standard 880-2011

As stated on the previous page, the new AIO catalog provides discharge sound data with duct end reflection corrections applied for all Price terminals. This fact is clearly stated in the performance notes on each page of the performance data, and can be seen in the example below.

Performance Notes:

1. Test data obtained in accordance with AHRI Standard 880-2011 and ASHRAE Standard 130-2008.
2. Sound power levels include duct end corrections per AHRI Standard 880-2011.
3. Airflow giving in Pa and in. w.g.
4. AHRI certified data is highlighted in blue. All other data are application ratings.
5. Application ratings are outside the scope of the ARI 880 Certification Program.

Catalog Highlight 2 – Application Data with Embedded Certified Ratings

To comply with AHRI Standard 880-2011, manufacturers must rate their equipment at ‘standard rating conditions’ as specified by AHRI. Data based on these conditions are defined as Standard Ratings. The Standard Ratings for Price certified products are listed with the performance data tables for each certified product and are identified with the AHRI seal. In addition to Standard Ratings, Price as well as most manufacturers also publishes application ratings. These application ratings are based on tests performed at conditions other than the Standard Rating conditions and are not certified. All tests are, however, performed in accordance with AHRI Standard 880-2011. These application ratings give the design engineer a wider range of data from which to make a selection. The new AHRI Standard 880-2011requires that certified standard ratings are imbedded with application rating tables and that they be clearly designated as such. To comply with this requirement, Price has updated application rating tables to include the certified ratings which are consistently highlighted in blue, as seen in the example below.

Discharge Sound Power Levels, Basic Assembly

Sound Power Levels Lw dB re 10^{-12} Watts

Unit Size	Airflow L/s	Airflow cfm	0.5 in. w.g. [125 Pa] Octave Band 2	3	4	5	6	7	1.0 in. w.g. [250 Pa] Octave Band 2	3	4	5	6	7	1.5 in. w.g. [375 Pa] Octave Band 2	3	4	5	6	7	3.0 in. w.g. [750 Pa] Octave Band 2	3	4	5	6	7
4	35	75	56	49	41	37	36	29	58	52	46	41	42	36	59	53	48	44	46	40	60	55	53	49	52	48
	59	125	64	57	47	43	40	32	65	59	52	47	46	40	66	61	54	50	50	44	68	63	59	55	56	52
	71	150	67	60	49	45	42	34	68	62	54	49	48	41	69	63	56	52	51	46	70	66	61	57	57	53
	106	225	73	66	54	49	45	37	74	68	58	54	51	44	75	70	61	57	55	49	76	72	65	61	61	56
5	59	125	57	46	43	38	36	32	60	50	48	43	42	39	62	53	51	46	46	43	64	57	56	51	52	51
	94	200	64	53	48	43	39	35	66	57	53	48	46	42	68	59	56	51	49	47	70	63	61	56	55	54
	118	250	66	56	50	45	41	37	69	60	55	50	47	44	71	62	58	53	51	48	73	66	63	58	57	55
	165	350	71	60	54	49	43	39	74	64	59	54	49	46	75	66	62	57	53	50	78	70	66	61	59	58
6	71	150	58	49	38	36	34	28	62	54	43	41	41	36	65	57	47	44	44	41	68	62	52	50	51	48
	106	225	63	54	43	40	37	31	66	59	49	45	44	39	69	62	52	49	47	43	73	67	58	54	54	51
	142	300	66	58	47	43	39	33	69	63	53	48	46	41	72	66	56	52	49	45	76	71	62	57	56	53
	189	400	68	62	51	46	41	35	72	67	57	51	48	42	75	70	60	55	51	47	79	75	66	60	58	55
	212	450	70	63	53	47	42	36	74	68	58	53	49	43	76	71	62	56	52	48	80	77	67	61	59	55
7	118	250	60	54	42	40	38	34	64	60	49	46	44	41	66	63	53	49	48	45	70	68	60	55	55	52
	165	350	63	58	46	43	40	36	67	63	53	48	46	43	69	67	57	52	50	47	73	72	64	58	57	54
	212	450	66	60	49	45	41	37	69	66	56	50	48	45	72	69	60	54	51	49	75	75	66	60	58	56
	260	550	68	63	51	46	42	39	71	68	58	52	49	46	73	71	62	56	53	50	77	77	69	61	59	57
	307	650	69	64	53	48	43	40	73	70	60	54	50	47	75	73	64	57	54	51	79	79	70	63	60	58
8	189	400	62	56	44	42	39	34	66	62	51	48	45	41	69	65	55	51	49	45	73	71	62	57	56	53
	236	500	64	58	46	44	40	35	68	64	53	50	47	42	71	67	57	53	50	47	75	73	64	59	57	54
	283	600	66	59	48	46	41	36	70	66	55	51	47	43	72	69	59	55	51	48	76	75	66	61	58	55
	330	700	67	61	50	47	42	37	71	67	57	53	48	44	74	71	61	56	52	49	78	77	68	62	59	56
	378	800	69	62	51	48	42	38	73	68	58	54	49	45	75	72	63	57	53	49	79	78	70	63	59	57

Performance Notes:

1. Test data obtained in accordance with AHRI Standard 880-2011 and ASHRAE Standard 130-2008.
2. Sound power levels include duct end corrections per AHRI Standard 880-2011. Please refer to page F25 for more details.
3. Airflow given in L/s and cfm.
4. Pressure is given in Pa and in.w.g.
5. AHRI certified data is highlighted in blue. All other data are application ratings.
6. Application ratings are outside the scope of the AHRI 880 Certification Program.
7. Asterisks (*) indicate minimum static pressure of the unit exceeds the minimum operating pressure across the unit.

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