Application Considerations

Table of Contents

Introduction

The VariTrane line of variable-air-volume (VAV) products has been an industry leader in performance and quality for many years. The VariTrane line includes single-duct VAV units, dual-duct VAV units, fan-powered VAV units (series, parallel, and low-height series and parallel), direct digital controls, pneumatic controls, analog-electronic controls, direct digital control retrofit kits and diffusers. This application section will focus on VAV units.

VAV Systems

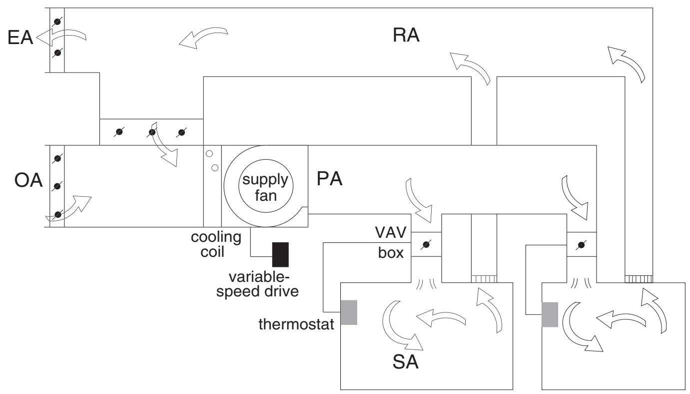
There are two primary types of VAV systems—single-duct and dual-duct.

Single-Duct Systems

Single-duct systems include one supply fan and a single supply duct, which is attached to each zone. The supply fan delivers cooled air to the VAV zones in variable volumes, depending upon the cooling requirements. The supply fan is usually designed to modulate airflow delivered to the VAV zones.

Many VAV zones require heating as well as cooling. The supply air-handling unit provides either no heat (cooling only), morning warm-up heat or occupied (changeover) heat. In addition, heat may be provided at any individual VAV zone (within the zone or within the VAV terminal) by reheating cool air provided by the central air handler.

Variable-Air-Volume (VAV) System



No Heat

Central Cooling Only—In some systems, the central air handler provides only cooling and ventilation during zone occupied periods. The supply air is maintained at a constant temperature and the supply airflow is modulated to match the VAV airflow rate with the zone cooling requirements.

Central Heat

Central Heat for Morning Warm-up—Many buildings cool down during the night. To be at a comfortable temperature in the morning when the building is again occupied, heat must be added to the spaces. Heat provided by the central air handler for morning warm-up is supplied at constant air volume to the zones, prior to the time of occupancy. During the morning warm-up period, the VAV terminal units must open to allow heated air to flow into the zones. In most instances very little additional heat is needed once the building is occupied.

Central Occupied Heating-Changeover—Some buildings use the same air handler to provide both occupied cooling and occupied heating. This is commonly referred to as a changeover system. The system changes between heating and cooling depending on the need of the zones on the system. In a changeover system, the operation of the VAV terminal units must also change over, opening to provide heat in the heating mode and opening to provide cooling in the cooling mode. Trane's main product in this type of application is called VariTrac™. VariTrane products can also be used in these systems. (These types of systems are beyond the scope of this manual and are discussed in detail in the VariTrac II Manual, VAV-PRC003-EN.)

Terminal Heat

Remote Heat—In some zones of a single-duct VAV system, perimeter heating equipment, remote from the terminal unit, is used to add heat to the zone when the cooling load is lower than the minimum cooling capacity of the VAV terminal unit. Heat is added directly to the zone while cool supply air continues to enter the zone at a minimum rate for zone ventilation.

Terminal Reheat—In some zones of a single-duct VAV system, a minimum flow of cool supply air is reheated at the terminal unit before entering the zone. Terminal reheat can be provided by electrical resistance heaters or by hot water coils.

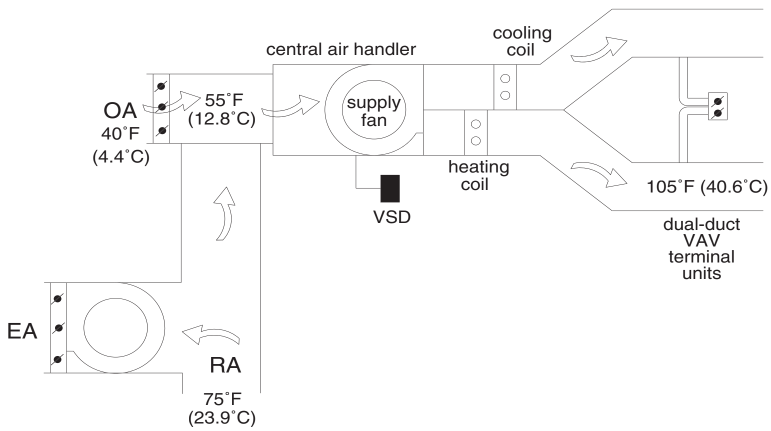
Parallel Fan-Powered Heat—In some zones of a single-duct VAV system, cool supply air at minimum flow is mixed with warm plenum air before entering the zone at a constant flow rate. A fan in the terminal unit, in parallel with the central fan, draws air from the plenum whenever the zone requires heat.

Series Fan-Powered Heat—In some zones of a single-duct VAV system, the airflow to the zone is held constant, during both heating and cooling, by a terminal unit fan that is in series with the central fan. The terminal unit fan runs continuously. When the zone requires heat, cool supply air at minimum flow is mixed with warm, return plenum air before entering the zone.

Dual-Duct Systems

Dual-duct systems have either one or two supply fans and two duct systems. One duct system carries heated air and the other duct system carries cooled air. Heated air and cooled air are modulated and/or mixed at each zone in the proper proportions to control zone temperature. Terminal reheat is not required in a dual-duct system.

Single-Fan, Dual-Duct VAV System



VariTrane VAV Terminal Units

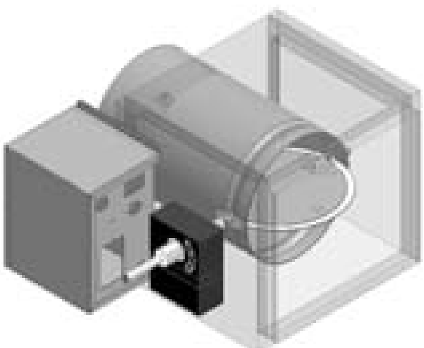
The function of the VariTrane terminal unit in a VAV control zone is to vary the volumetric airflow rate to the zone. VariTrane units are available with either microprocessor-based DDC controls or pneumatic or analog electronic controls. Factory-installed controls are available with all types of terminal units.

VariTrane VAV Terminal Unit Types

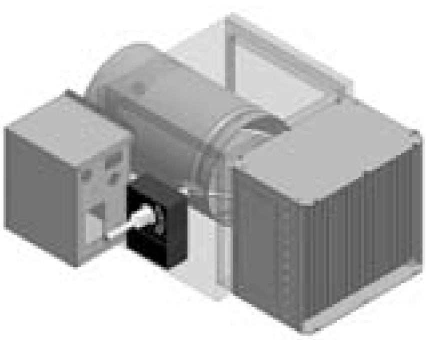
Single-Duct

Single-duct terminal units control the volumetric flow of supply air to the space to maintain the zone temperature at setpoint. These units are generally applied in cooling-only VAV zones that require no heat during occupied hours. If local zone heat is necessary it can be provided either remotely (for example, perimeter heat) or by terminal reheat (either electric or hot water coils).

Single-Duct Cooling Only Unit



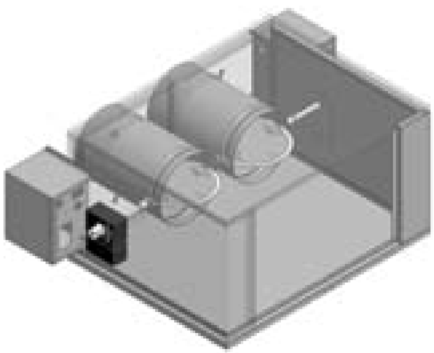
Single-Duct Unit with Hot Water Coil



Dual-Duct

Dual-duct terminal units are used in a special type of air distribution system where the main system has both warm air and cold air separately ducted to each terminal unit. The flow of both warm air and cool air is modulated, delivering air to the VAV zone at variable air volumes as well as variable temperatures. Since full capacity occupied heating is always available, control of additional local heat is not provided.

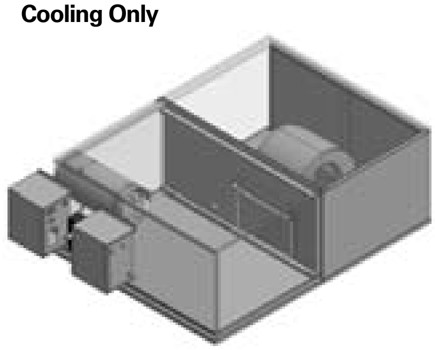
Dual-Duct Terminal Unit



Parallel Fan-Powered

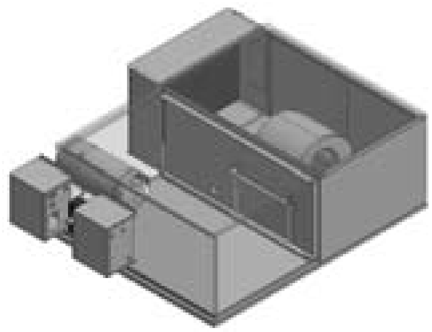
Parallel fan-powered units are commonly used in VAV zones which require some degree of heat during occupied hours—when the primary supply air is cool. The terminal unit fan is in parallel with the central unit fan; no primary air from the central fan passes through the terminal unit fan. The terminal unit fan draws air from the space return plenum.

Parallel Fan-Powered Unit Cooling Only

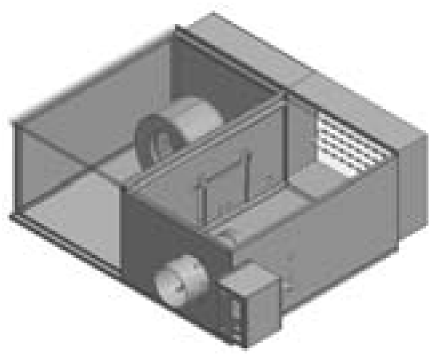


When no heat is needed, the local parallel fan is off and a backdraft damper on the fan's discharge is closed to prevent cool air entry into the return plenum. When cool airflow to the VAV zone is at a minimum and the zone temperature drops below setpoint, the local parallel fan is turned on and the backdraft damper opens. A constant volume of air is delivered to the zone because the fan delivers a constant volume of warm plenum air which is mixed with cool primary air at a minimum flow. Remote heat or terminal reheat can provide additional local heating.

Parallel Fan-Powered Unit with Hot Water Coil



Parallel Fan-Powered Unit with Electric Coil



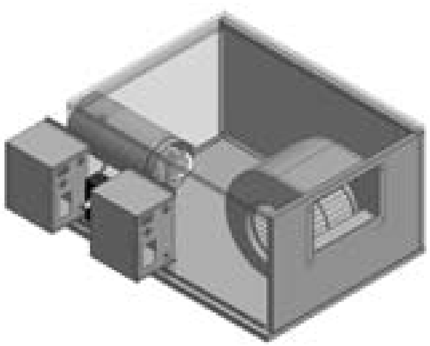
Series Fan-Powered

Series fan-powered terminal units are used commonly in VAV zones that not only require heat during occupied hours, but also desire constant air volume delivery. The terminal unit fan is in series with the central fan. Primary air from the central fan always passes through the terminal unit fan.

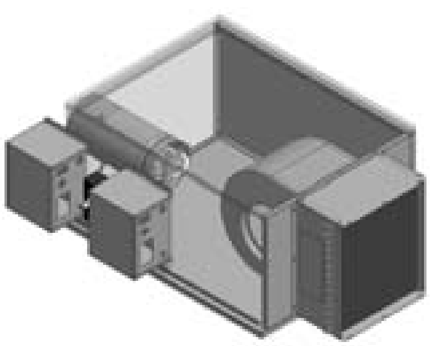
The local series fan within the terminal unit operates whenever the unit is in the occupied mode. The volume of air delivered to the VAV zone is constant, but the temperature of the delivered air varies. As the zone requires less cooling, the primary air damper closes. As the primary air damper closes, the air mixture supplied to the zone contains less cool air and more warm plenum air. Remote heat or terminal reheat can provide additional local heating.

Series fan-powered terminal units are also useful in low supply air temperature systems, since the terminal unit fan can be sized so that warm plenum air is always mixed with low temperature supply air. This raises the supply air temperature to an acceptable distribution level and reduces condensation potential.

Series Fan-Powered Unit Cooling Only



Series Fan-Powered Unit with Hot Water Coil



Low-Height Fan-Powered

Low-height fan-powered terminal units are a slightly modified version of a fan-powered terminal unit. As its name suggests, the low-height fan-powered unit has a shorter height dimension to accommodate applications where ceiling space is limited. To reduce the height, shorter terminal unit fans are integrated into the standard height series or parallel terminal unit. The result is a unit with a maximum height of 11.0"–11.5".

For low-height units with the smaller fan sizes (sizes 08SQ and 09SQ), a single low-profile fan is used. Low-height units with the largest fan size (size 10SQ) use two low-profile fans. Each fan operates off a separate motor. The fans still remain in series or parallel with the primary system central fan. Low acoustic levels are much more challenging in these low ceiling space applications, due to the reduced radiated ceiling pleunum effect.

The operation of the low-height terminal unit is exactly the same as that of a series or parallel terminal unit, as are the options for high-efficiency ECMs, insulation options, etc. As with the other fan-powered terminal units, additional local heating can be provided by remote heat or terminal reheat.

Fan-Powered versus Single-Duct VAV Terminal Units

In many climates, fan-powered systems are a lower operating cost alternative than single-duct systems. The energy inefficiencies inherent in reheating cold primary air can be eliminated with a key design characteristic of fan-powered terminal units, plenum air heating. Heating with warmer plenum air allows for recovery of heat from lighting and other heat sources in the building.

Comparison of Parallel and Series Models

Once it has been determined that a fan-powered system is to be specified, the designer must decide between parallel and series configurations. Each model carries its own characteristics of delivered airflow, energy consumption, and acoustics. For the end user, the designer might consider three goals: a comfortable and productive tenant environment, acceptable installed cost, and low operating costs.

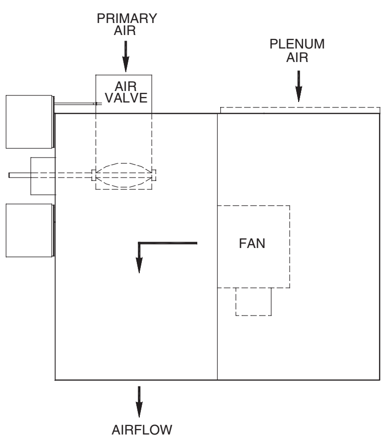
Parallel and series fan-powered terminal units offer specific advantages for particular applications. The following table compares the key similarities and differences between the models that the designer should consider in performing an engineering analysis.

Typical Application of Parallel Units:

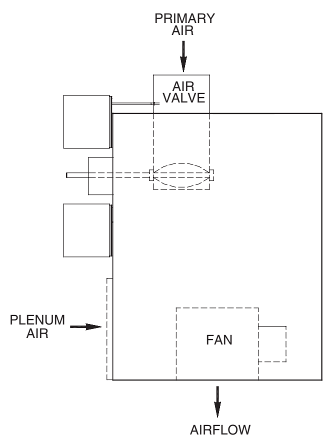
Parallel intermittent fan-powered terminal units are very common in perimeter zones or buildings where loads vary during occupied hours. Core zones, which maintain a more constant cooling requirement, are better suited for variable airflow (single-duct) units. Typical jobs combine parallel fan-powered units (exterior) and single-duct units (interior) to provide an efficient system with lowest first cost. Although the overall NC of parallel systems is lower than an equivalent series system, the intermittent fan is sometimes noticed when energized. To minimize the impact of this NC change, an ECM (Electrically Commutated Motor) can be used which has soft-start technology.

Typical Application of Series Units:

Applications requiring constant air movement or blending utilize series constant fan-powered terminal units. Conference rooms, laboratories, and lobbies are common applications. Because the series fan also adds to the system external static pressure, office buildings take advantage of this design feature and down size main air handling equipment. Finally, series terminals are used in low-temperature air systems to temper cold primary air with warm plenum air and deliver it to the zone.



PARALLEL FAN-POWERED TERMINAL



SERIES FAN-POWERED TERMINAL

	Parallel	Series
Fan Operation	Intermittent operation during occupied and unoccupied modes.	Continuous operation during the occupied modes. Intermittent operation during unoccupied mode.
Operating Sequence	Variable-volume, constant-temperature device during cooling. Constant-volume, variable-temperature during heating.	Constant-volume, variable-temperature device at all times. Delivers design airflow regardless of the load.
Fan Energization	Based on zone temperature deviation from setpoint. No interlock with central system fan required.	Interlocked with central system fan to deliver required air to the zone in both heating and cooling modes
Terminal Fan Operating and Size	Fan runs during heating load. Size for design heating load. Typically this is 40 to 60% of design primary cooling airflow.	Fan runs continually. Fan sizing should meet the greater of design cooling or heating airflow to the zone.
Air valve Sizing	Design cooling airflow.	Design cooling airflow.
Minimum Inlet Static Pressure Required for Central Fan Sizing	Sufficient to overcome unit, heating coil, downstream duct and diffuser pressure losses.	Sufficient to overcome air valve pressure loss only.
Acoustics	When operating under cooling loads the terminal fan does not run, offering superior acoustic performance similar to single-duct VAV. Under heating loads, the fan operates intermittently. Impact can be minimized by use of a ECM.	Produces slightly higher background sound pressure levels in the occupied space. This sound level remains constant and is less noticeable than intermittent fan operation with PSC motors.

Low-Temperature Air System

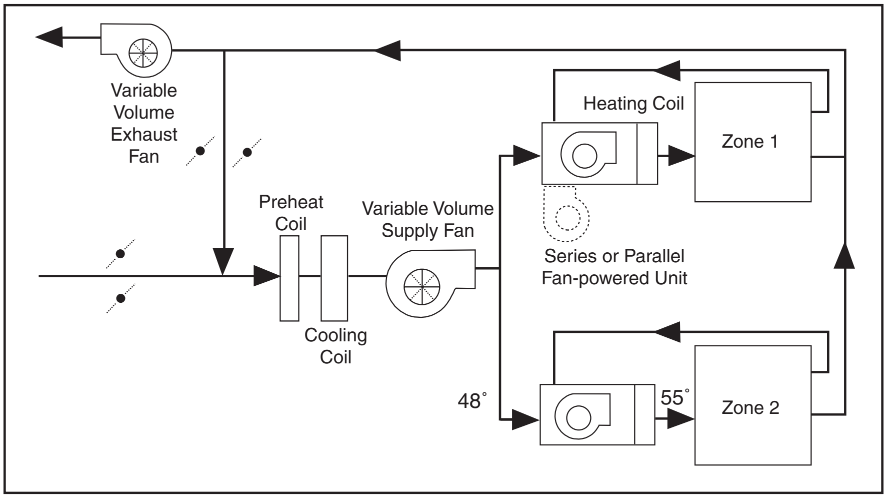
Benefits of Low-Temperature Air

The benefits of low-temperature air systems include reduced first cost, reduced operating cost and increased revenue potential. Since low-temperature air transports more energy per cubic foot, smaller fans and ducts can be used. An EarthWise™ system takes that a step farther and includes optimizing the waterside of the HVAC system as well with low flow rates through the chilled water and condenser loops.

Since low-temperature water can transport more thermal energy per gallon, smaller pumps, pipes, and valves can be used. Smaller HVAC equipment consumes less energy so both electrical demand and consumption are lowered, reducing operating costs. The amount of revenue generated by a commercial building is related to the amount and quality of rental floor space. The amount of rental floor space is increased in a low-temperature air system, since air handlers, riser ducts, and equipment rooms are smaller. Since smaller ducts reduce the required ceiling plenum, additional floors may be included without increasing building height.

The concept of the EarthWise system is to deliver superior comfort and be less expensive to install and operate. The method to do this involves both waterside optimization and airside optimization. The waterside is optimized using techniques of low water flow through the evaporator and condenser of the chiller as well as using chiller-tower optimization control strategies. For more information on the waterside of the EarthWise system, contact your local Trane representative or visit www.trane.com.

Low Temperature Air System Layout



Airside savings are obtained using a combination of lower air temperature and intelligent control strategies. The ability of the VAV unit to communicate information is vital to system coordination.

System Operation

A low-temperature air system could be done with chilled water or direct expansion equipment. A chilled water system includes a chiller plant, VAV air handlers, and series or parallel fan-powered VAV terminal units. The VAV air handlers use cold water, typically around 40°F (4.4°C), from the chiller plant, to cool the supply air to 45–50°F (7.2–10°C). The volume of supply air is determined by the airflow needs of the VAV terminal units. A direct-expansion system would include a VAV air handler or rooftop with series or parallel fan-powered VAV terminal units. The supply air would be cooled to 48–52°F (8.9–11.1°C).

The VAV terminal units include a parallel or series fan with the central air handler or rooftop fan. The terminal unit fan operates continuously, mixing 45-50°F (7.2–10°C) supply air with warm plenum air, to provide 50–55°F (10–12.8°C) cooling air to the occupied space at design conditions. As the cooling load in the space decreases, the VAV terminal air valve closes to reduce the flow of cold supply air and increase the flow of warm plenum air in the case of series terminal units. The temperature of air supplied to the space rises, but the volume flow rate to the space is constant for the series unit.

Considerations for VAV products

To achieve the maximum benefit from the low-temperature air system, several VAV considerations must be addressed.

Insulation

The units must be insulated to ensure that no condensation occurs on the units. How much insulation is needed? Trane has tested its insulation with the goal of developing a thermal resistance ratio for each type of insulation. The thermal resistance (TR) ratio is discussed on page AC 16. The TR ratio can be used, along with the properties of the insulation and the system operating conditions to determine the necessary insulation thickness required.

In the low-temperature air system with fan-powered units, the ducts and diffusers downstream from the terminal unit handle air that is 55°F (12.8°C) or warmer. Therefore, condensation considerations are no different from conventional systems. Linear slot diffusers are recommended to take advantage of the Coanda effect described in the Diffusers section later in the catalog.

Terminal unit surfaces that are traditionally not insulated—electric and hot water reheat coils and the primary air inlet for example—should be thoroughly field-insulated.

Leakage
When the terminal unit fan is off, the air valve will close, and not leak. Ducts upstream of the terminal unit must also be thoroughly insulated and constructed for very low leakage.

Duct and terminal unit insulation can be internal or external. Keep in mind that internal insulation has hidden thermal leaks at joints and seams. These areas must be located and insulated externally to avoid condensation. External Insulation, on the other hand, allows a complete, uniform thermal seal.

Minimum settings and IAQ
Indoor air quality is usually best when a specific quantity of outside ventilation air reaches each building occupant. Maintaining a minimum ventilation rate is a challenge in any VAV system because the amount of supply air that reaches a particular space decreases as the cooling load decreases. To insure that a minimum amount of supply air reaches the space at all times, a minimum flow setting on the terminal unit is used. In low-temperature air systems, when the space needs heating, this minimum flow setting results in increased heating load. Therefore, it is important to include the additional load imposed by the cold supply air when calculating heating loads. Reheat may be required since the ventilation values are absolute requirements and not percentage of total airflow requirements.

EarthWise or Low-Temperature Air Distribution Design Considerations with Parallel Fan-powered Terminal Units
The parallel fan-powered unit needs to be set up to run continuously rather than intermittently. Since it is in parallel, the airflow required by the fan is less than a comparable series unit. This results in energy savings. Running the parallel fan continuously will take some minor control changes. It will, however, create a better acoustical installation.

The parallel fan should be large enough to temper the design cooling airflow at 45–50°F to 50–55°F (7.2–10°C to 10–12.8°C). For instance, if the design cooling airflow is 1000 cfm at 55°F (472 L/s at 12.8°C), you will need 781 cfm of 48°F (368 L/s of 8.9°C) supply air and 219 cfm of 80°F (103 L/s of 26.7°C) plenum air. The parallel fan can be sized for the 219 cfm (103 L/s) rather than the total room airflow.

The fan airflow plus the minimum primary airflow must be checked with the minimum airflow of the diffusers to insure that dumping doesn't occur. If that is a concern, the minimum could be adjusted up or the fan airflow could be adjusted up.

As the valve closes, the downstream static pressure will decrease because the pressure is related to the airflow. The fan will supply more air at the valve minimum condition than at design due to the decreased static pressure. This should be a consideration when calculating how much airflow would occur at the minimum valve plus fan airflow condition. The new fan airflow would be found by looking at a fan curve at the new SP point. The new SP can be calculated:

$$\left(\frac{\text{Fan Airflow} + \text{Valve Minimum}}{\text{Fan Airflow} + \text{Valve Design}}\right) \times SP_1 = SP_2$$

The following table can be used to determine what percentage of the total airflow should come from the fan to temper the supply air, assuming 80°F (26.7°C) plenum air.

Percentage of Airflow from Fan

Supply Air Temp. (deg. F (C)	Primary Air Temperature (deg. F (C))					
	45 (7.2)	46 (7.8)	47 (8.3)	48 (8.8)	49 (9.4)	50 (10)
50 (0)	14%	12%	9%	6%	3%	0%
51 (10.6)	17%	15%	12%	9%	6%	3%
52 (11.1)	20%	18%	15%	13%	10%	7%
53 (11.7)	23%	21%	18%	16%	13%	10%
54 (12.2)	26%	24%	21%	19%	16%	13%
55 (12.8)	29%	26%	24%	22%	19%	17%

If anything other than 80°F (26.7°C), the following equation can be used to calculate the percentage:

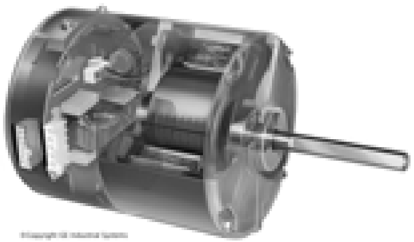
SupplyTemperature = (%*primarytemperature) + (1-%)*plenumtemperature

Low-Temperature Air Distribution Design Considerations with Series Fan-powered Terminal Units
The VAV terminal unit includes a fan that operates continuously. The series fan should be large enough to insure that the mixture of cold supply air and warm plenum air is 50–55°F (10–12.8°C) at design cooling flow conditions. In these types of systems, it is a good design practice to develop the system based upon 55°F (12.8°C) air being provided to the space from the fan-powered terminal unit. If a lower temperature air is used downstream of the VAV terminal unit, the system designer will have some concerns related to condensation on diffusers and other low-pressure ductwork accessories. For instance, if the occupied space must receive 1000 cfm of 55°F (472 L/s at 12.8°C) air to satisfy to design cooling load, 715 cfm must be 45°F (337 L/s must be at 7.2°C) supply air and 285 cfm must be 80°F (135 L/s must be 26.7°C) plenum air. Therefore, the series fan-powered terminal must be sized to have the air valve deliver 715 cfm (337 L/s) of supply air at design conditions, but the fan must be sized to deliver 1000 cfm (472 L/s).

Airside System Factors
A couple of system related factors should be noted as they apply to condensation. The first is the advantage the colder primary air has from a humidity standpoint. As noted in the description above, the low-temperature system operates at space relative humidity of 30–45% while a standard system operates at space relative humidity of 50–60%. The drier zone air means that the plenum air returning to the series terminal unit will also be drier and, therefore, less of a problem with condensation.

The second condensation factor to note is related to systems that shut down in the evening. Many people believe that immediately sending low-temperature primary air to these boxes that have been off for some time will cause a shock to the system and may cause condensation problems at startup. The solution to this has been the advent of gradual pull-down or "soft start" systems. In this type of system, the primary air temperature is higher on initial startup (typically 55°F(12.8°C)) and then gradually reduced to the normal operating point over the next 30 to 60 minutes.

Electrically Commutated Motor (ECM)

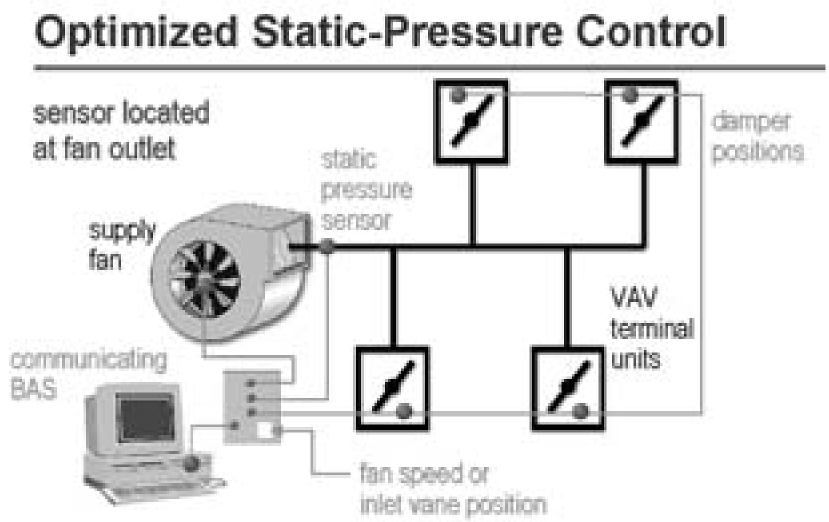


The ECM provides an additional energy-saving option to the system designer. Some of the advantages of the motor include high efficiency, quiet operation, short payback, and easy installation. There are several considerations that need to be addressed when deciding whether to use these motors or not. The primary benefit may be seen as increased efficiency.

Operating Hours—The added cost of an ECM can be offset more quickly in applications which require a relatively high number of hours of operation. However, if a space does not require extensive running time for the unit fan, then it may not be a good candidate for this type of motor based solely on payback. Therefore, the decision about using the ECM may be based on other benefits, depending on the needs of the customer.

Airflow Flexibility—The ECM allows a greater airflow range per fan size. If a space is going to change uses and load components frequently, the ability to change supply airflow with the ECM without changing units will be a benefit.

Airflow Balancing—The ability of the ECM motor to self-balance to an airflow regardless of pressure can be an asset when trying to air balance a job. This will help eliminate additional dampers or changes to downstream ductwork to ensure proper airflow. For more information, please contact your local Trane sales engineer.



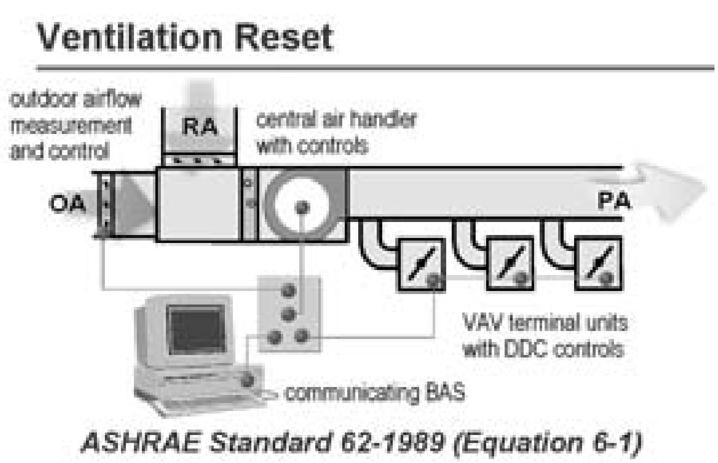
Fan-Pressure Optimization
With Trane's Integrated Comfort System, the information from VAV terminal units can be used for other energy-saving strategies. Fan-pressure optimization is the concept of reducing the supply fan energy usage based on the position of the terminal unit dampers.

The control system allows this scenario. The system polls the VAV units for the damper position on each unit. The supply fan is modulated until the most wide-open damper is between 85% and 95% open. The correct airflow is still being sent to the zones since the controls of the VAV units are pressure-independent, and the fan modulates to an optimal speed and duct static pressure which results in fan energy savings.

Ventilation Reset
The Ventilation Reset control strategy enables a building ventilation system to bring in an appropriate amount of outdoor air per **ASHRAE Standard 62.1**. The basis for the strategy is measuring airflow at each zone, calculating current system ventilation efficiency using the multiple-zone system equations of the standard, and communicating a new outdoor airflow setpoint to the air handler.

This strategy continually monitors the zone ventilation needs and system outdoor air intake flow, minimizing the amount of ventilation air and increasing the energy efficiency of the system. This insures that the right amount of air is brought in at all times and that proper ventilation can be documented. Trane has integrated this control ability into the VAV controls, air-handler controls, and building controls.

For more detailed information on these energy-saving strategies, please refer to the "Additional References" section on page AC 23 of the catalog for appropriate material.



Agency Certifications

There are numerous regulations and standards in the industry that determine the construction and performance parameters for VAV terminal units. Some of the more important of those standards and regulations are listed below, along with a brief description of what each one addresses.

American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) - 41.1

ASHRAE - 41.2

ASHRAE - 41.3

These standards specify methods for temperature measurement (41.1), laboratory airflow measurement (41.2), and pressure measurement (41.3). While none of these standards specifically discusses VAV air terminals, they discuss topics that are aspects of terminal box systems. Therefore, some engineers will include these standards in their specifications as a primer on accepted measurement techniques.

ASHRAE - 62

This standard specifies the minimum ventilation rates and indoor air quality that are acceptable for occupied spaces.

ASHRAE - 111

This standard calls out procedures to be followed for testing and balancing HVAC systems. It includes descriptions of the equipment used, procedures followed, and field changes that must be made when a system is balanced.

Air Conditioning and Refrigeration Institute (ARI)

ARI 880 - 1998

This standard sets forth classifications, performance testing requirements, and test results reporting requirements for air terminal units. The standard contains very detailed procedures that are to be followed for the testing and certification program associated with this standard. This is one of the most commonly referenced standards in the VAV terminal unit industry. The ARI-880 certification program is designed to police the accuracy of documented performance for terminal units. The certification program requires a sampling of at least four units be tested annually. The tested units are chosen at random by ARI and sent to an independent laboratory for the testing. The performance is tested at one specific operating condition. The operating characteristics tested include discharge and radiated sound power (for the damper and, in the case of fan-powered boxes, the fan), wide-open damper pressure drop, and fan motor amp draw. ***VariTrane terminal units are certified according to ARI-880.***

ARI 885-98-02

This document provides a procedure to estimate sound pressure levels in an occupied space. The standard accounts for the amount of sound pressure in the space due to the VAV air terminal, diffusers and their connecting low pressure ductwork. While sound generated from the central system fan and ductwork may be a significant factor in determining the sound pressure level in the room, this standard does not address those factors. It focuses solely on the VAV terminal and items downstream of it. This standard is related to ARI-880 by using sound power determined using ARI-880 methodology as a starting point for the ARI-885 procedure.

Underwriter's Laboratory (UL) 1995

Underwriter's Laboratory is an independent testing agency that examines products and determines if those products meet safety requirements. Equipment manufacturers strive to meet UL guidelines and obtain listing and classifications for their products because customers recognize UL approval as a measure of a safely designed product. ***VariTrane VAV air terminals are listed per UL-1995, Heating and Cooling Equipment.*** The terminals are listed as an entire assembly.

National Fire Protection Association (NFPA) 70

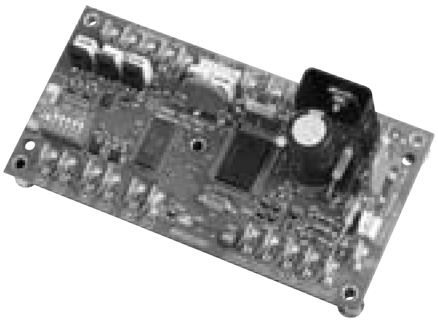
This standard is also known as the National Electrical Code (NEC). The Code gives standards for installation of wiring and electrical equipment for most types of commercial and residential buildings. It is often referred to in VAV air terminal specifications when fan-powered boxes, electric heat or electric controls are included.

NFPA 90A

This standard does not speak directly to VAV air terminals but does discuss central system considerations pertaining to a fire and/or smoke condition. The standard discusses safety requirements in design and construction that should be followed to keep the air-handling system from spreading a fire or smoke. The standard specifies practices that are intended to stop fire and smoke from spreading through a duct system, keep the fire-resistive properties of certain building structures (fire walls, etc.) intact, and minimize fire ignition sources and combustible materials.

Control Types

VAV terminal units are available with many different options. These options fall into three main categories of controls: direct digital (DDC), pneumatic, and analog electronic. All of these control types can be used to perform the same basic unit control functions, yet differences exist in accuracy of performance, versatility, installed cost, operating cost, and maintenance cost.



Direct digital control (DDC) systems became available as advances in computer technology made small microprocessors available and affordable. Much of the hardware in DDC systems is similar to analog electronic systems. The primary difference is that DDC controllers allow system integration, remote monitoring, and adjustment. The microprocessor is programmed using software that gives the controller a higher level of capability than either the pneumatic or analog electronic options.

Benefits:

Performance—DDC controls offer PI control capability. A PI control scheme is the most accurate and repeatable control scheme available in the VAV terminal unit industry.

Versatility—DDC controls accepts software commands to determine how its outputs will be controlled. When a control sequence must be modified, making changes to the software instructions is easier and quicker than changing hardware.

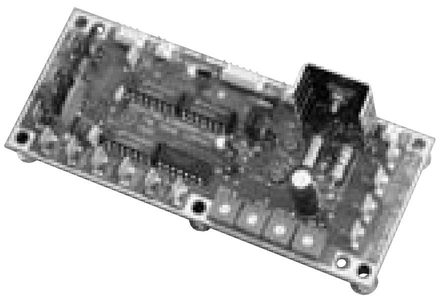
Operating and Maintenance Costs—DDC controls can be networked together to provide system-control strategies for energy savings. Multiple controllers can be easily monitored and adjusted from a remote location. DDC controls also have system and individual diagnostic capability.

Disadvantages:

Versatility—The communications protocol between controllers will be different from one controller manufacturer to another.

Installed Cost—DDC controls are the most expensive of the three control types.

Operating and Maintenance Costs—Building personnel must be trained to operate and maintain the system.



Analog electronic control systems began to be used in the 1970s and 1980s. Cost effective and reliable transistors, resistors, relays, and triacs (electronic relays) allowed analog electronics to become a substitute for pneumatic controls. Analog electronic controls use varying voltage signals to change an output in response to a monitored variable.

Benefits:

Performance—Analog electronic controls are a basic technology that has good repeatability.

Operating and Maintenance Costs—Analog electronics have minimal drift and therefore require much less recalibration than pneumatics.

Ease of Use—Analog electronic controls can be modified using tools as basic as a screwdriver and a voltmeter. Knowledge and availability of a personal computer is not required.

Disadvantages:

Performance—Analog electronics provide proportional-only control for VAV terminal unit systems. This control scheme is less accurate than the more advanced control schemes.

Installed Cost—Analog electronics have a higher installed cost than pneumatic controls for systems with basic functions.

Operating and Maintenance Costs—Diagnostic capability for analog electronics is not available.

Pneumatic control systems use compressed air through simple mechanical control devices, such as diaphragms, springs, and levers to change an output in response to a change in a monitored variable. With VAV terminal units, the output is typically a primary airflow and the monitored variable is zone temperature.

Benefits:

Performance—Pneumatic controls are a proven technology that is effective and has a long life cycle.

Installed Cost—When a source of compressed air exists at the facility, pneumatics generally have a lower installed cost than other types of controls when only a basic functionality is required.

Operating and Maintenance Costs—Pneumatics are still the most familiar control technology to many building designers and maintenance people.

Large Installed Base—Pneumatic systems are very common in existing buildings. This eliminates the need to purchase the most expensive piece of equipment in a pneumatic control system—the control air compressor. Extensions to existing pneumatic systems are generally very simple and extremely cost-effective.

Disadvantages:

Performance—Pneumatic controls provide proportional-only control for VAV terminal unit systems. This control scheme is less accurate than the more advanced control schemes. Improper calibration of pneumatic controls leads to poor energy utilization.

Versatility—A central pneumatic control system, where each of the control zones can be monitored and adjusted from a remote location, is extremely costly to configure and to modify.

Operating and Maintenance Costs—Pneumatics easily drift and require constant upkeep and scheduled maintenance. Diagnostic capability for pneumatics is not available. A main compressor which is not maintained and becomes contaminated with oil or water can pump those contaminants into the compressed-air-distribution system. This may require costly cleaning of the system and a possible replacement of system components.

DDC Controls Basic Information
DDC controls have become the industry standard for VAV terminal unit control systems. DDC systems use electronic field devices such as a flow transducer, a primary air modulating damper, and an electronic thermostat. These field devices report software instructions of how the outputs are positioned in relation to the inputs to a controller. The VariTrane system uses a primary air valve and flow transducer for both DDC systems and analog electronic systems. However, the DDC zone sensor is different from the analog electronic thermostat.

DDC controls provide much flexibility and considerable diagnostic capability. DDC controllers can be connected together to form a network of controllers. Once the controllers are networked, they can be monitored for proper operation from a remote location. Commands and overrides can be sent for groups of controllers at one time to make system-wide changes. Commands and overrides can be sent to individual units to allow problem diagnosis, temporary shutdown, startup schedules or other specialized changes. When integrated into a building management system, the operation of the VAV terminal unit system can be modified to do such things, as coincide with occupancy schedules and reduce energy charges.

DDC control of VAV terminal units is a key element in providing intelligent and responsive building management. Precision control, flexible comfort, and after hours access are all available with the VariTrane DDC control system for VAV terminal units.

Key features of the system include:

- An advanced unit controller
- Flexible system design
- User-friendly interaction

Analog Electronic Controls Basic Information
Analog electronic controls continue to be useful in specific applications. The users of analog electronic controls can benefit from the analog electronic product without the necessary air compressor capacity for pneumatic applications or computer-literate personnel for DDC applications. However, as more and more people become computer literate, DDC controls have become the standard for non-pneumatic VAV terminal unit controls. The analog electronic control system will control room temperature by modulating the position of the electronic air valve in response to zone temperature changes. VariTrane analog electronic controls are only available in pressure-independent operation. Therefore, the flow is proportional to the deviation from the zone setpoint. The primary airflow through the air valve is monitored by means of an electronic pressure transducer connected to the standard VariTrane flow ring. The thermostat used with the VariTrane electronic control system is a thermistor which completes a voltage divider circuit when wired back to the analog control board. The thermostat is designed to operate specifically with VariTrane analog electronic controls and is not interchangeable with the VariTrane DDC zone sensor.

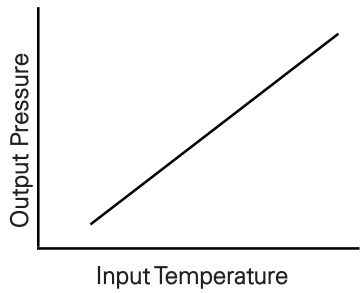
Pneumatic Controls Basic Information
Pneumatic controls modulate air pressure of a controller to maintain setpoint. For VAV systems, there are two primary types of pneumatic controllers—the room thermostat and the pneumatic volume regulator (PVR).

Room Thermostats
The most visible controller to the customer is the room thermostat. Pneumatic room thermostats can be classified by two characteristics: the tubing connection(s) to the thermostat and the action of the thermostat output in response to a change in the input.

Room thermostats are available in models that require a one-pipe or a two-pipe configuration. The name is derived from the number of tubes that must run to the thermostat location. The difference is really in the construction of the thermostats. The two-pipe thermostats have a constant pressure supply connected via an air tube to the thermostat supply air port. The supply air travels through the thermostat's relays, levers, diaphragm, and bleed port to produce an output. The output line is connected to the output port of the thermostat and extends to the controlled device. The one-pipe thermostat has, as its name suggests, only one air line connection. The thermostat works by opening and closing an air bleed valve. This will either decrease or increase the pressure on the controlled device, which is connected to the same line that runs to the thermostat.

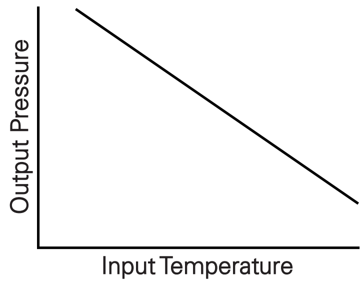
Room thermostats also can be classified by their reaction to a change in temperature. Room thermostats classified this way are denoted as either direct-acting or reverse-acting. Direct-acting thermostats will increase their output pressure as the temperature the thermostat measures increases.

Direct-Acting Thermostat Response



On the contrary, reverse-acting thermostats will decrease their output pressure as the temperature the thermostat measures increases.

Reverse-Acting Thermostat Response



Pneumatic Volume Regulators
These controllers accept the room thermostat signal and modulate the VAV terminal unit primary air damper. The primary air damper is controlled for an airflow setpoint that is determined by the room thermostat. The thermostat increases the PVR's airflow setting when the temperature in the space is warm. On the other hand, the thermostat decreases the PVR's airflow setting when the temperature in the space is cold.

Currently, VariTrane offers two models of pneumatic volume regulators in its controls offering—the 3011 regulator (used in most applications) and the 3501 model (used in dual-duct constant- volume applications). The primary difference is the 3501 PVR's ability to change the velocity pressure linearly with a change in thermostat pressure, which results in improved stability at low flows. In contrast, the 3011 PVR resets the velocity pressure with a change in thermostat pressure.

Reset Control of Minimum and Maximum Flow—The 3011 PVR and 3501 use fixed reset control of minimum and maximum flow settings. The primary benefit of fixed reset in a pneumatic volume regulator is stable flow control without excessive damper movement.

Fixed Reset—A fixed reset controller operates over a thermostat signal change of 5 psi between minimum and maximum flow, regardless of the differential pressure flow sensor signal. The thermostat is usually set for a gain of 2.5; i.e. it produces a 2.5 psi output change per degree of space temperature change. This control strategy provides stable flow control with the primary air valve throttling between minimum and maximum flow over a 2°F space temperature change.

Example 1: Air valve with a 6" inlet, Pneumatic thermostat gain = 2.5 psi/degree:

Minimum Flow = 0 cfm, 0.0 in. wg flow signal
Maximum Flow = 680 cfm, 2.0 in. wg flow signal
2.0 in. wg signal range

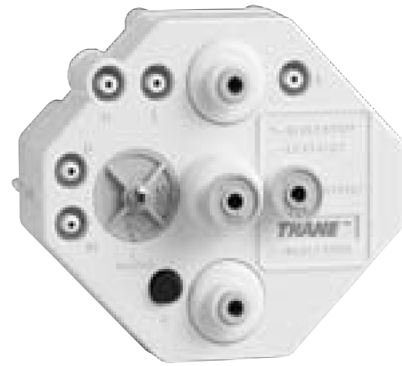
The damper will modulate from zero to maximum position over a 2°F temperature change.

Bleed Port to Atmosphere—Bleeding air to the atmosphere is a normal operation for a volume regulator. The 3011 volume regulator addresses this function with a dedicated bleed port. When air is bled through the flow sensor, the differential pressure signal from the sensor is affected. As a result, the flow sensor signal can be radically altered if the volume regulator is bleeding air, and may cause excessive damper movement.

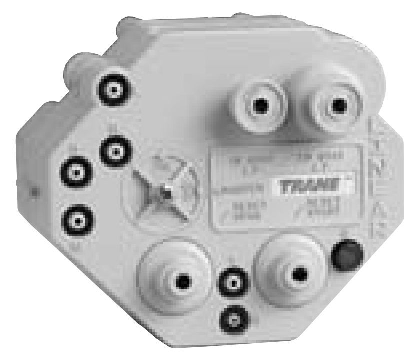
Calibration—The minimum and maximum settings are independent of each other and need to be set only once during calibration.

Signal Configuration Flexibility—Both can be configured to work with both normally-open and normally-closed pneumatic air valves, and both direct-acting and reverse-acting thermostats.

Pneumatic Volume Regulators



PVR 3011

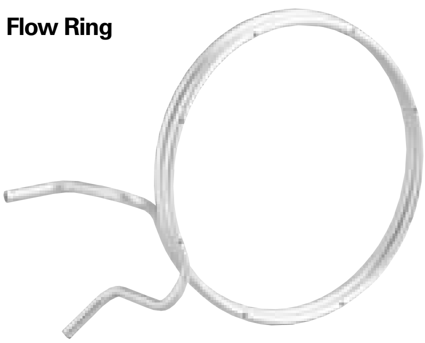


PVR 3501

Flow Measurement and Control

One of the most important characteristics of a VAV terminal unit is its ability to accurately sense and control airflow. The VariTrane terminal unit was developed with exactly that goal in mind. The patented, multiple-point, averaging flow ring measures the velocity of the air at the unit primary air inlet. The differential pressure signal output of the flow ring provides the terminal unit controller a measurement of the primary airflow through the inlet. The terminal unit controller then opens or closes the inlet damper to maintain the controller airflow setpoint

Flow Ring



Flow Measurement

Most VAV terminal units contain a differential pressure airflow measurement device, mounted at the primary air inlet, to provide a signal to the terminal unit controller. Numerous names exist for the differential pressure measurement device—flow sensor, flow bar, flow ring. The differential pressure measured at the inlet varies according to the volumetric flow rate of primary air entering the inlet.

The total pressure and the static pressure are measurable quantities. The flow measurement device in a VAV terminal unit is designed to measure velocity pressure. Most flow sensors consist of a hollow piece of tubing with orifices in it. The VariTrane air valve contains a flow ring as its flow measuring device. The flow ring is two round coils of tubing. Evenly spaced orifices in the upstream coil are the high-pressure taps that average the total pressure of air flowing through the air valve. The orifices in the downstream ring are low-pressure taps that average the air pressure in the wake of flow around the tube. By definition, the measurement of static pressure is to occur at a point perpendicular to the airflow. The low-pressure taps on the VariTrane flow ring measure a pressure that is parallel to the direction of flow but in the opposite direction of the flow. This "wake pressure" that the downstream ring measures is lower than the actual duct static pressure. The difference between the "wake pressure" and the static pressure can be accounted for so that the above relationship between flow and differential pressure remain valid. The difference also helps create a larger pressure differential than the velocity pressure. Since the pressures being measured in VAV terminal box applications are small, this larger differential allows transducers and controllers to measure and control at lower flow settings than would otherwise be possible.

The average velocity of air traveling through the inlet is expressed in the equation:

$$FPM = 1096.5\sqrt{\frac{VP}{DENS}}$$

Where:

FPM = Velocity of air in feet per minute

1096.5 = A constant

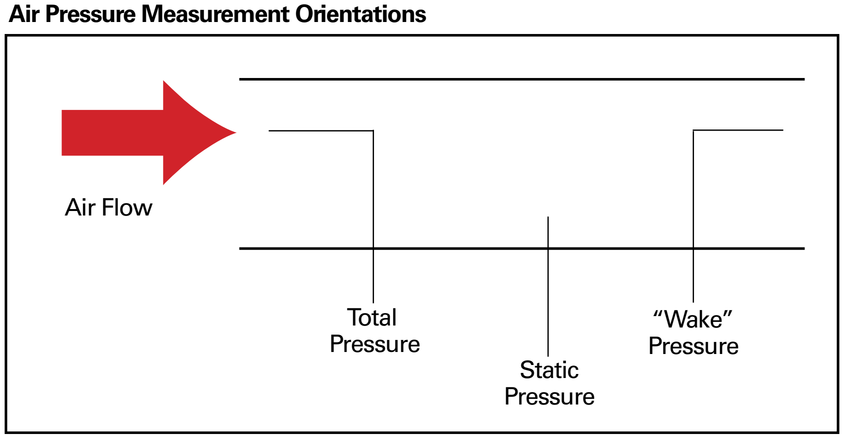
VP = The velocity pressure of the air expressed in inches of water

DENS = The density of the air expressed in pounds per cubic foot

Often, the density is assumed to be a constant for dry air at standard conditions (68°F (20°C)) and sea level pressure of 14.7 psi (101.4 kPa)). These conditions yield the following commonly used equation:

$$FPM = 4005\sqrt{VP}$$

Air Pressure Measurement Orientations



The velocity pressure is defined as the difference between the total pressure in the duct and the static pressure in the duct:

VP = TP - SP (All units are expressed in inches of water)

The amount of air traveling through the inlet is related to the area of the inlet and the velocity of the air:

AIRFLOW = AREA (square feet) x AVERAGE VELOCITY (feet per minute)

Accuracy

The multiple, evenly spaced orifices in the flow ring of the VariTrane terminal unit provide quality measurement accuracy even if ductwork turns or variations are present before the unit inlet. For the most accurate readings, a minimum of 1½ diameters, and preferably 3 diameters, of straight-run ductwork is recommended prior to the inlet connection. The straight-run ductwork should be of the same diameter as the air valve inlet connection. If these recommendations are followed, and the air density effects mentioned below are addressed, the flow ring will measure primary airflow within ±5% of unit nominal airflow.

Air Density Effects

Changes in air density due to the conditions listed below sometimes create situations where the standard flow sensing calibration parameters must be modified. These factors must be accounted for to achieve accuracy with the flow sensing ring. Designers, installers, and air balancers should be aware of these factors and know of the necessary adjustments to correct for them.

Elevation—At high elevations the air is less dense. Therefore, when measuring the same differential pressure at elevation versus sea level the actual flow will be greater at elevation than it would be at sea level. To calculate the density at an elevation other than standard conditions (most manufacturers choose sea level as the point for their standard conditions), you must set up a ratio between the density and differential pressure at standard conditions and the density and differential pressure at the new elevation.

$$\frac{\Delta P \text{ Standard Conditions}}{\text{DENS Standard Conditions}} = \frac{\Delta P \text{ New Conditions}}{\text{DENS New Conditions}}$$

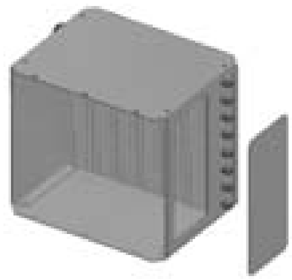
Since the data from the manufacturer is published at standard conditions, this equation should be solved for the differential pressure at standard conditions and the other quantities substituted to determine the ratio for the differential pressure measured at the new conditions.

Duct Pressure and Air Temperature Variations—While changes in these factors certainly affect the density of air, most operating parameters which VAV systems need keep these effects very small. The impact on accuracy due to these changes is less than one half of one percent except in very extreme conditions (extreme conditions are defined as those systems with static pressures greater than 5 in. wg (1245 Pa) and primary air temperatures greater than 100°F (37.8°C)). Since those types of systems occur so infrequently, we assume the effects of duct pressure and air temperature variations to be negligible.

Linearity —With the increase in DDC controls over pneumatic controls, the issue of linearity is not as great as it once was. The important aspect of flow measurement versus valve position is the accuracy of the controller in determining and controlling the flow. Our units are tested for linearity and that position versus airflow curve is downloaded and commissioned in the factory to insure proper control of the unit.

Hot Water Reheat

Hot Water Coil



Hot water heating coils are generally applied on VAV terminal units as reheat devices. When applying these coils it is important to make sure that they are operating in the proper air flow and water flow range. Either a two-way or a three-way valve controls the coils.

Hot Water Valves

The most important factor when sizing valves is the coefficient of velocity or C_V. The C_V is defined as the flow rate, in gallons of 60°F (15.56°C) water, that will pass through the valve in one minute with a one pound pressure drop. The coefficient of velocity, which is commonly called the flow coefficient, is an industry standard rating. Valves having the same flow coefficient rating, regardless of manufacturer, will have the same waterside performance characteristics.

The equation that governs valve sizing is:

$$C_v = \frac{GPM}{\sqrt{\Delta P}}$$

Where:

C_V = Flow coefficient

GPM = The maximum water flow rate through the valve in gallons per minute

ΔP = The maximum allowable differential pressure across the valve in psi

The flow and differential pressure are generally the known quantities. The equation is solved for the flow coefficient. The flow coefficient is then compared to the published C_V values for the control valves that are available. The control valve with the C_V that is the closest, but greater than, the calculated flow coefficient is the correct choice for the control valve. This choice will keep the valve pressure drop below the maximum allowable valve pressure drop. The valve pressure drop should then be checked against the coil pressure drop. If the coil pressure drop is appreciably larger than the valve pressure drop, a valve with a smaller C_V should be selected to produce a larger control valve pressure drop. If this new valve has a pressure drop that is much larger than the maximum allowable pressure drop for valves, the system designer should be consulted to make sure that the system hot water pumps can deliver the water at the new conditions.

Electric Reheat

Electric heating coils are applied on VAV terminal units as terminal reheat devices. Electric heat coil capacity is rated in kilowatts (kW). Coils are available with the total capacity divided into one, two, or three stages.

Electric heat coils are available in single-phase or three-phase models. This refers to the type of power source connected to the coil. Single-phase models have resistance elements internally connected in parallel. Three-phase models have resistance elements internally connected in a delta or a wye configuration.

The current draw for the electric coil will depend upon whether it is a single-phase coil or a three-phase coil. The current draw is necessary for determining what size wire should be used to power the electric coils and how big the primary power fusing should be.

The equations for current draw for these coils are:

$$1\,\phi \text{ amps} = \frac{\text{kW x 1000}}{\text{Primary Voltage}}$$

$$3\,\phi \text{ amps} = \frac{\text{kW x 1000}}{\text{Primary Voltage x} \sqrt{3}}$$

VariTrane three-phase electric heat is available in balanced configurations. For example, a 9 kW three-phase coil, each stage would carry 1/3 or 3 kW of the load.

It is important to note that these coils have certain minimum airflow rates for each amount of kW heat the coil can supply to operate safely. These airflow values are based upon a maximum rise across the electric heat coil of 50°F (28°C).

The equation that relates the airflow across an electric coil to the temperature rise and the coil change in temperature is:

$$CFM = \frac{\text{kW x 3145}}{\Delta T}$$

Where:

CFM = Minimum airflow rate across the coil

kW = The heating capacity of the electric coil

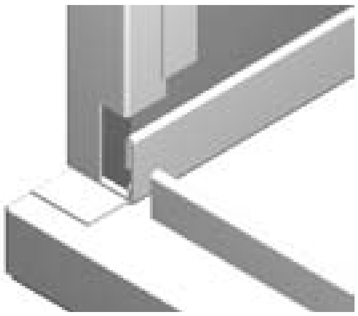
3145 = A constant

ΔT = The maximum rise in air temperature across the coil (usually 50°F (28°C))

Electric heat coils are available with magnetic or mercury contactors. Magnetic contactors are less expensive than mercury contactors. However, mercury contactors can be cycled at a more rapid rate without failing. Mercury contactors are rated for heavier duty use and should be used in as many applications as possible. For pneumatic applications the electric coils are available with factory-installed pressure-electric switches.

Insulation

Insulation in a VAV terminal unit is used to avoid condensation on the outside of the unit, to reduce the heat transfer from the cold primary air entering the unit, and to reduce the unit noise. The VariTrane line offers four types of unit insulation. The type of facing classifies the types of insulation. To enhance IAQ effectiveness, edges of **all insulation types have metal encapsulated edges**.



Encapsulated Edges

Matte-Faced
This type of insulation is used for typical applications. It consists of a fiberglass core covered by a high-density skin. The dual-density construction provides good sound attenuation and thermal performance.

Foil-Faced
This type of insulation is used in applications where there is some concern regarding airborne contaminants entering the space, or dirt being trapped in the fibers of the insulation. The insulation is composed of a fiberglass core laminated to a foil sheet. Foil-faced insulation will provide the same sound attenuation performance as matte-faced insulation.

Double-Wall
This type of insulation is used in applications where there is extreme concern regarding airborne contaminants entering the space or dirt being trapped in the fibers of the insulation. The insulation is the same as the matte-faced insulation. However, after the insulation is installed, a second solid wall of 26-gage steel covers the insulation. All wire penetrations of this insulation are covered by a grommet. This type of insulation will result in higher discharge and radiated sound power.

Closed-Cell
This type of insulation is used in applications where IAQ and fibers are of primary concern. The acoustics of the closed-cell insulation are similar to double-wall insulation. The thermal properties are similar to fiberglass insulation. This insulation contains no fiberglass.

Acoustical best practices:

Acoustics with terminal units is sometimes more confusing than it needs to be. As we know, lower velocities within a unit leads to improved acoustical performance. Additionally, if the VAV terminal unit has a fan, a lower RPM provides better Acoustics performance. It is as simple as that—there are some catches, however.

We know that lower velocities and lower RPMs in VAV terminal units result in improved acoustical performance. Additional considerations will be discussed in more detail throughout this portion of Application Considerations that pertain to unit size and type, appurtenance affects (due to insulation, attenuation, etc.) certification, and computer modeling. Let's take a look at the first consideration, sizing of units.

Sizing of units

Before blindly increasing the size of units, we must first understand what is setting the acoustics within the space. In general, over 95% of acoustics in VAV terminal units, which set the sound pressure levels and ultimately the NC within the space, is from radiated sound. This is readily known for fan-powered units, but less commonly known for single- and dual-duct units. Radiated sound emanates from the unit and enters the occupied space via means other than through the supply ductwork. The most typical path is through the plenum space, then through the ceiling, then into the occupied space. While discharge sound should never be ignored, radiated sound is the most dominant and usually the most critical sound source.

When increasing **air valve** sizes, BE CAREFUL. Oversizing an air valve can adversely impact the ability to modulate and properly control temperature in the space. In extremely oversized situations, the air valve will operate like a two-position controlled device, with air either being "on," or "off," and not really much in between. The best way to avoid this is to understand that the minimum for most air valves is 300 FPM. This is a function of the flow sensing device (see wake pressures pp. AC 13) and the ability of the pressure transducer and controller to properly read and report flow. This is not manufacturer specific, as physics applies to all. Therefore, when sizing air valves, regardless of the max cooling velocity the minimum velocity for proper pressure independent flow is 300 FPM.

Modulation capability and range is vital for proper operation of VAV systems. With grossly oversized units, the unit will act as a constant volume system eliminating the energy saving and individual zone control advantages of VAV systems. A good rule of thumb is to size cooling airflow for around 2000 FPM. VAV systems only operate at full flow when there is a maximum call for cooling in the zone. The greatest portion of the time, an air valve will be operating at partial flows.

When sizing fan-powered units, the fan airflow range can be determined by looking at the fan-curve. Because parallel and series fan-powered units operate at a constant fan flow, selections can be made all the way to the lowest flow ranges of the fan curve. A good balance of performance and cost is to select fans at 70-80% of maximum fan flow.

Series vs. Parallel Fan-Powered Units

Acoustical considerations affect whether a series or parallel fan-powered terminal unit is selected. Both units have their advantages.

The parallel unit has the advantage of the fan being on and contributing to the sound levels only when heating is needed. The fans are usually smaller because they are sized for 30–60% of total unit flow. This creates a unit which is quieter than series units. The disadvantage of the parallel unit is that the sound is intermittent. This impact can be minimized by using an ECM, which has slow fan ramp-up speed.

The primary acoustic benefit to the series fan-powered unit is that the fan runs continuously. Sometimes the unit can be selected at slightly higher sound levels due to the constant nature of the sound.

The primary acoustic disadvantage the series unit has compared to the parallel unit is the need to size the unit fan for the total room airflow. Series units require a larger, louder fan than parallel configurations.

Note: Operating parallel units with a continuously operating fan may be considered for some applications. This provides the quietest overall fan-powered system with the benefit of continuous fan operation.

Insulation types

Insulation is a factor to consider when dealing with the acoustics of terminal units. Most insulation types will provide similar acoustical results, but there are exceptions. Double-wall and closed-cell foam insulation will generally increase your sound levels because of the increased reflective surface area that the solid inner-wall and closed-cell construction provides. This increase in sound will have to be balanced with the IAQ and cleanability considerations of the dual-wall and closed-cell construction.

Placement of units

Unit placement in a building can have a significant impact on the acceptable sound levels. Locating units above non-critical spaces (hallways, closets, and storerooms) will help to contain radiated sound from entering the critical occupied zones.

Unit Attenuation

Terminal unit-installed attenuators are an option available to provide path sound attenuation. Manufacturer-provided attenuators on the discharge of a terminal unit are targeted at reducing discharge path noise and are typically a simple lined piece of ductwork. It would often be easier and less expensive to design the downstream ductwork to be slightly longer and require the installing contractor to include lining in it. Attenuators on the plenum inlet of fan-powered terminals are targeted at reducing radiated path noise since the plenum opening on a fan-powered terminal unit is typically the critical path sound source. Significant reduction in radiated path noise can result from a well-designed inlet attenuator. The attenuation from these attenuators is due to simple absorption from the attenuator lining and occupant line of sight sound path obstruction. Therefore, longer attenuators and attenuators that require the sound to turn multiple corners before reaching the occupied space provide superior results, particularly in the lower frequency bands.

Octave Band Frequencies

Octave Band	Center Frequency	Band Edge Frequencies
1	63	44.6–88.5
2	125	88.5–177
3	250	177–354
4	500	354–707
5	1000	707–1414
6	2000	1414–2830
7	4000	2830–5650
8	8000	5650–11300

Attenuators that are simple "cups" at the plenum inlet(s) have been shown in Trane's acoustical mock-up to provide no measurable reduction in sound pressure in the critical octave bands which set the occupied space noise criteria.

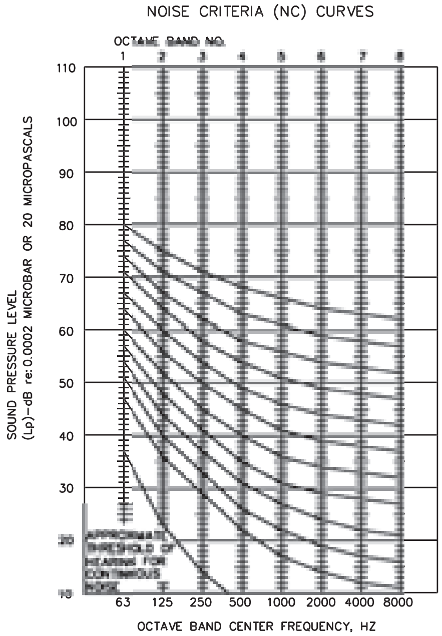
Certification and Testing

Terminal units should be submitted based on the same criteria. There are several ways to ensure this by certification and testing.

Raw unit sound data can be good measurement criteria for evaluation. In using this as a basis for comparison, the designer needs to make sure that the information is based on the ARI Standard 880 that gives the procedure for testing.

Specifying NC or RC sound levels is a possible comparison, but the designer needs to be sure the comparison is fair. Two options are to specify the attenuation effect on which you would like the units to be evaluated or to specify that ARI Standard 885-98 transfer functions be used. The importance of ARI Standard 885-98 is that it is the first ARI Standard that specifies exact transfer functions to be used for evaluation. Previous versions of the standard gave guidelines, but the manufacturers could choose their own set of factors.

NOISE CRITERIA (NC) CURVES



By using NC sound levels, it is possible to express acceptable sound levels for various types of buildings or environments. A few examples are:

Concert Hall	NC-22
Hospital Room	NC-30
School Room	NC-35
General Office	NC-40
Cafeteria	NC-45
Factory	NC-65

Path Attenuation

Sound is generated by a terminal unit can reach the occupied space along several paths. The terminal unit generated sound will lose energy—i.e., the energy is absorbed by path obstacles—as it travels to the occupied space. This acoustical energy dissipation as it travels to the occupied space is called path attenuation. The amount of energy lost along a particular path can be quantified and predicted using the procedure outlined in ARI-885. Each path must be considered when determining acceptable sound power generated by a terminal unit.

The term "transfer function" is often used to describe the entire path attenuation value for each octave band (i.e., the sum of all components of a particular path).

Examples of path attenuation include locating the terminal unit away from the occupied space, increasing the STC (sound transmission classification) of the ceiling tile used, internally lining ductwork, drywall lagging the ceiling tiles or enclosing the terminal unit in drywall. All of these choices have costs associated with them that must be weighed against the benefits. Some of these alternatives can be acoustically evaluated from application data provided in ARI-885. Others may require professional analysis from an acoustical consultant.

Computer Modeling

Computer modeling of acoustical paths is available to help estimate sound levels and determine problem sources. The software used by Trane for computer modeling is called Trane Acoustics Program (TAP™).

TAP can analyze different room configurations and materials to quickly determine the estimated total sound levels (radiated and discharged) in a space.

The Trane Official Product Selection System (TOPSS™) can also be used to determine sound levels of terminal units. You can base selections on a maximum sound level and enter your own attenuation factors (defaults based on ARI-885 are also available).

Other Resources

Please refer to "Additional References" (page 29) of the Applications section to see a list of publications to help with the basics of acoustical theory and modeling. You can also contact your local Trane salesperson to discuss the issue.

Duct Design

Designing cost-effective VAV duct systems is challenging. Some duct design methods result in better pressure balance than others do. Duct shape and duct material can influence duct system design and cost. In addition, duct layout is properly designed for optimal duct installation and operation.

Design Methods

The two most widely used supply duct design methods—equal friction and static regain—are discussed below.

Equal Friction – Using this method, ducts are sized at design flow to have roughly the same static pressure drop for every 100 feet of duct. Static pressures throughout the duct system can be balanced at design flow using balancing dampers, but are no longer balanced at part load flows. For this reason, equal friction duct designs are better suited for constant volume systems than for VAV systems. If the equal friction method is used for the VAV supply duct design, the terminal units usually require pressure-independent (PI) control capability to avoid excessive flow rates when duct pressures are high.

In VAV systems, the ducts located downstream of the terminal unit are usually sized for equal friction. The advantage of this design method is its simplicity. Often, calculations can be made using simple tables and duct calculators. Drawbacks include increased higher total pressure drops and higher operating costs.

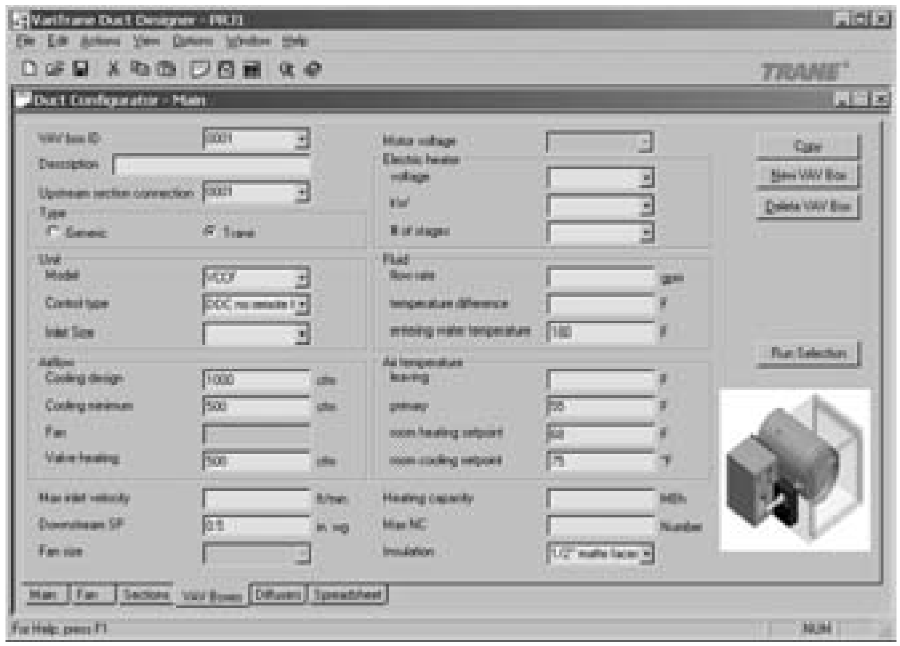
Static Regain – In the static regain method, ducts are sized to maintain constant static pressure in each section, which is achieved by balancing the total and velocity pressure drops of each section. In other words, static pressure is "regained" by the loss of velocity pressure. Since the static pressures throughout the duct system are roughly balanced at design and part load flow, static regain duct designs can be used successfully for either constant volume or VAV systems. When the static regain method is used for VAV systems, the system is roughly pressure balanced at design.

Advantages of the static regain method include reduced total pressure drops, lower operating costs, and balanced pressures over a wide range of flows. The drawback of this design is the time-consuming, iterative calculation procedure and for large systems, it is essential to have a duct design computer program.

Duct Design Program

Trane has developed a computer program, VariTrane™ Duct Designer, to aid in the duct design process. This program is used to calculate duct sizes, fitting sizes, terminal unit sizes, and pressure drops according to the equal friction or static regain method.

The duct design program can be easily incorporated into the selection of VAV terminal units. The inputs and outputs for the program enable VariTrane units to be selected based on the conditions you require. This makes selecting and scheduling units much easier. Contact the local sales office or the Trane C.D.S.™ department for more details on this program.



Selection Program

The advent of personal computers has served to automate many processes that were previously repetitive and time-consuming. One of those tasks is the proper scheduling, sizing, and selection of VAV terminal units. Trane has developed a computer program to perform these tasks. The software is called the Trane Official Product Selection System (TOPSS™).

The TOPSS program will take the input specifications and output the properly sized VariTrane VAV terminal unit along with the specific performance for that size unit.

With TOPSS, the user can integrate selections of single-duct, dual-duct, and fan-powered VAV boxes with other Trane products allowing you to select all your Trane equipment with one software program.

The program has several required fields, denoted by red shading in the TOPSS screen, and many other optional fields to meet the given criteria. Required values for selections include the maximum and minimum airflows, the control type, and unit model. When selecting models with reheat, information regarding the heating coil is needed for selection. In addition, the user is given the option to look at all the information for one selection on one screen or as a schedule with the other VAV units on the job.

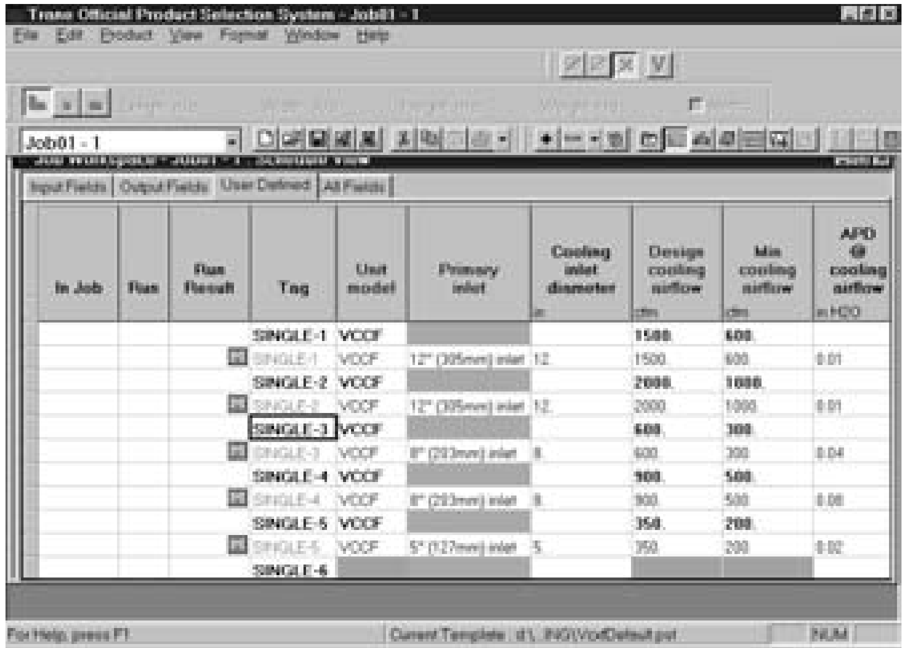
Also, TOPSS will calculate sound-power data for a selected terminal unit. The user can enter a maximum individual sound level for each octave band or a maximum NC value. The program will calculate acoustical data subject to default or user supplied sound attenuation data.

The program has many time-saving features such as:

- Copy/Paste from spreadsheets like Microsoft® Excel
- Easily arranged fields to match your schedule
- Time-saving templates to store default settings
- Several output report options including schedules

The user can also export the Schedule View to Excel to modify and put into a CAD drawing as a schedule.

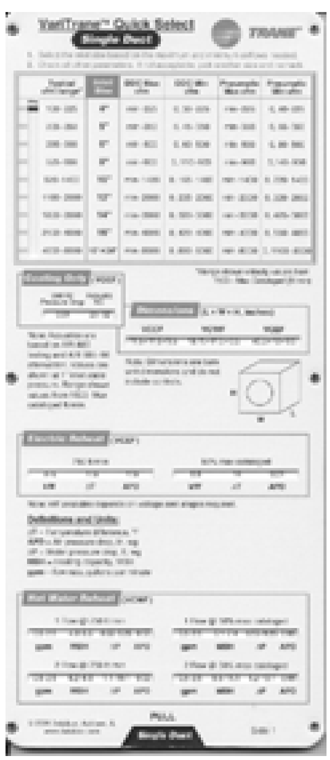
Specific details regarding the program, its operation, and how to obtain a copy of it are available from your local Trane sales office.

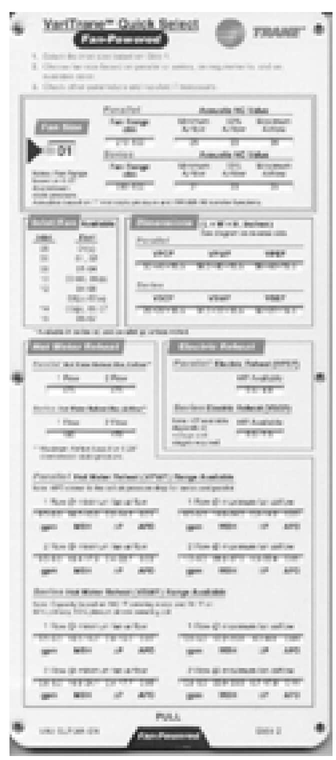


Sample screen image from TOPSS Selection Program

VariTrane Quick Select

The VariTrane Quick Select is a tool used by consulting and contracting firms for specifying and choosing VariTrane VAV terminal units. The tool has basic information regarding dimensions, pressure drops, acoustics, electric and hot water reheat, and fan data. For more information, please contact your local Trane sales office.





Common Mistakes

Some of the most common system or installation errors are discussed below.

Reducers at Unit Inlet

This problem is a very common issue that is seen in applications of VariTrane products. It is often mistaken by those in the field as an unacceptably large static pressure drop through the unit. It is also sometimes mistaken as a malfunctioning flow ring, pressure transducer (if DDC or analog electronic controls are present) or PVR (if pneumatic controls are present).

This problem is sometimes unknowingly encountered because of the capability of the VariTrane unit to allow greater airflow for a specific size duct than other terminal units. For example, a project engineer specifies an 8" (203 mm) round take off from the main duct trunk to the VAV terminal unit. The person supplying the VAV terminal unit checks the required airflow and finds that a VariTrane unit with a 6" (152 mm) inlet will provide the specified terminal unit performance. The terminal unit supplier submits, receives approval, and orders the 6" (152 mm) inlet unit. While this is happening, the installing contractor has run the connecting duct from the main trunk to the terminal unit in the specified 8" (152 mm) round. The unit arrives at the job site, and the installer notices that the 8" (203 mm) duct and the 6" (152 mm) terminal unit inlet do not match. To get the unit installed, an 8- to 6-inch reducer is placed at the inlet to the terminal unit air valve.

The reducer will cause a phenomenon called flow separation at the unit inlet. Fluid dynamics analysis can present a detailed technical explanation of flow separation, but the characteristics important to this discussion are the production of pressure loss and turbulence. The reducer will have a significant static pressure drop associated with it since the air velocity is increased (i.e., static pressure is given up for increased velocity pressure). The pressure loss is sometimes mistaken as a loss due to the function of the terminal unit. The turbulence is at its greatest just downstream of the reducer. Unfortunately, this is the location of the flow ring at the air-valve inlet. The reducer will cause the flow ring to give an inaccurate and inconsistent reading because of the turbulent air.

The solutions to this situation are:

- Locate the reducer upstream of the terminal unit at least three duct diameters to eliminate flow separation and turbulence at the unit inlet and to improve the airflow measurement accuracy.
- Consider proper sizing of the terminal unit in the duct design and account for the pressure loss of the reducer in the central fan selection if a reducer is required. Be cautious of "oversizing" a VAV terminal. It is good practice to make sure that the inlet duct velocity at the minimum airflow setting is no lower than 500 feet per minute.

Improper Use of Flexible Ductwork

While flexible ductwork has many benefits, improper use can cause numerous problems in a VAV system. Flexible ductwork causes turbulent airflow and relatively large static pressure drops. Flexible ductwork at a primary damper inlet (i.e., the flow sensor location) may cause flow accuracy and repeatability problems due to turbulence. The use of flexible ductwork should be primarily limited to the downstream side of the terminal units in a VAV system. Use of flexible ductwork upstream of terminal units should be kept to an absolute minimum. All runs of flexible ductwork should be kept as short as possible. While most know these guidelines, the ease of installation which flexible ductwork provides is always an enticement to push the limits of what are acceptable practices.

Static Pressure Measurement Errors

Improper measurement techniques for static pressure can lead many to mistakenly believe that the terminal unit is causing a large pressure drop in the system. The chief error made here is taking a static pressure measurement in turbulent locations such as flexible ductwork or near transitions. This produces invalid static pressure readings. Another error commonly made is trying to read the static pressure at the same point as the flow sensing device. The inlets to VAV terminal units produce turbulence and will give poor readings. Flow sensors with their multiple-point averaging capability are best equipped to deal with this type of flow, while a single-point static probe is not. Another common error is the incorrect orientation of the static pressure probe. The static pressure is correctly measured when the probe is oriented perpendicular to the direction of airflow. The probe, or a part of it, should never be facing the direction of airflow, because the total pressure will influence the reading of the probe.

Conversions of Length and Area

To convert	From	To	Multiply by
Length	In.	m	0.0254
Length	Ft	m	0.3048
Length	m	In.	39.3701
Length	m	Ft	3.28084
Area	$In.^2$	m^2	0.00064516
Area	Ft^2	m^2	0.092903
Area	m^2	$In.^2$	1550
Area	m^2	Ft^2	10.7639

Conversions of Velocity, Pressure, and Flow Rate

To convert	From	To	Multiply by
Velocity	Ft/min	M/s	0.00508
Velocity	M/s	Ft/min	196.850
Pressure	Psi	Pa	6894.76
Pressure	Ft of water	Pa	2988.98
Pressure	In. of water	Pa	249.082
Pressure	Pa	Psi	0.000145038
Pressure	Pa	Ft of water	0.000334562
Pressure	Pa	In. of water	0.00401474
Flow Rate	Cfm	L/s	0.4719
Flow Rate	Cfm	m^3/s	0.000471947
Flow Rate	Gpm	L/s	0.0630902
Flow Rate	m^3/s	Cfm	2118.88
Flow Rate	L/s	Cfm	2.1191
Flow Rate	L/s	Gpm	15.8503

VAV System and Product References

VAV Systems Air Conditioning Clinic—
This clinic is designed to explain the system components, the system configurations, many of the VAV system options and applications. A great resource for VAV system understanding.

Literature # TRG-TRC014-EN

Indoor Air Quality – A guide to understanding ASHRAE Standard 62-2001—
The guide helps to explain the ASHRAE Standard as well as the fundamentals of good indoor air quality. A great resource for understanding the standard and ways of designing VAV systems around that standard.

Literature # ISS-APG001-EN

Managing Outdoor Air – Traq™ Comfort Systems—
This brochure is a good, quick reference of the issues of managing outdoor air for a VAV system.

Literature # CLCH-S-26

Ventilation and Fan Pressure Optimization for VAV Systems—
An engineering bulletin designed to how a Trane Integrate Comfort™ system can effectively control building ventilation and supply fan pressure for increased comfort and IAQ while keeping energy costs to the lowest possible.

Literature # SYS-EB-2

Trane DDC/VAV Systems Applications Engineering Manual—
This manual gives detailed descriptions of the Trane DDC/VAV system. Topics include system components, how the system interacts and specific inputs and outputs of the system.

Literature # ICS-AM-6

Acoustics in Air Conditioning Applications Engineering Manual—
This manual describes the basic fundamentals, behavior, measurement, and control of sound, all directed at the design of quiet systems.

Literature # FND-AM-5

VariTrac® Catalog—
The catalog will help explain features and benefits of VariTrac, how the VariTrac product works, applications for the product, and selection procedures.

Literature # VAV-PRC003-EN

ASHRAE Handbook of Fundamentals

ASHRAE Handbook of HVAC Systems and Equipment

ASHRAE Handbook of HVAC Applications

ASHRAE Handbook of Refrigeration

Web sites:

www.ashrae.org

www.ari.org

www.trane.com