TERMINAL UNIT ENGINEERING

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TERMINAL UNIT ENGINEERING

Engineering Terms & Definitions

CFM: Cubic feet per minute - a measurement of volumetric air flow rate.

ECM: Electrically commutated motor.

FPM: Feet per minute: A measure of air velocity.

L/s: Liters per second: A measure of volumetric air flow rate.

LwDIS: Discharge sound power level.

LwRAD: Radiated sound power level.

NC: Noise criterion represented by NC curves that were developed to represent lines of equal hearing perception in all bands and at varying sound levels. Most air terminal products are currently specified and reported as a single number NC rating.

Occupied Zone: The region normally occupied by people within a space, generally considered to be between the floor and 1.8 m (6 ft) above the floor and more than 1.0 m (3.3 ft) from outside walls/windows or fixed heating, ventilating or air conditioning equipment and 0.3 m (1 ft) from internal walls.

RC: Room Criteria represented by both a numerical value and a letter “Quality” rating. The number represents the spectrum’s speech interference level (SIL), and is obtained by taking the arithmetic average of the noise levels in the 500-, 1000- and 2000- Hz octave bands. The letter denotes the sound’s “quality” as it might subjectively be described by an observer.

RH: The amount of water vapor actually in the air divided by the amount of water vapor the air can hold. Relative humidity is expressed as a percentage and can be computed in a variety of ways. One way is to divide the actual vapor pressure by the saturation vapor pressure and then multiply by 100 to convert to a percent.

SCIM: Abbreviation for Standard Cubic Inches per Minute with Standard conditions are defined as 14.7 psia and 60°F.

Sound Power Level (Lw Or Pwl): The level, in dB as a ratio relative to some reference level, at which a source produces sound, usually given in octave bands. The equation is as follows:

$$Pwl = 10 \cdot \log10 \cdot (Wsource/Wref)$$

Wref is 10^{-12} Watts and Wsource is sound power in Watts.

Sound Pressure Level (lp or SPL): The level of sound energy, measured in dB, at a specific location. The frequency range of the measurement or calculation must be indicated along with the sound level in dB. The equation is as follows:

$$SPL = 10 \cdot \log10 \cdot (P^2/Pref^2)$$

Pref = $2 \cdot 10^{-5}$ Pa and P = sound pressure in Pa

“WG: Inches of water gage - measure of pressure

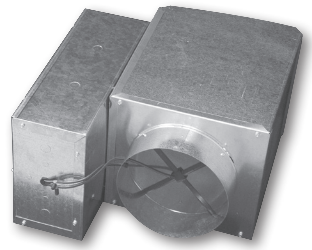
Terminal Unit Design Guidelines

TERMINAL UNIT DESIGN GUIDELINES

- Types of Air Terminals and Style of Space
- Design Guidelines
- Pressure Requirements
- Volume Control Requirements
- Sound Requirements and Specifying Sound Levels

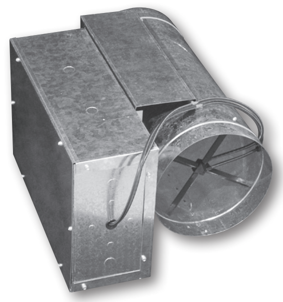
Types of Air Terminal Units & Style of Space

Air terminal units can be considered as a local air handling device for individual zones within a building. The air terminal unit manages supply air from a central air handling station by controlling the volume and temperature of the air supplied to a space via the air diffuser. All air terminal units consist of a supply inlet duct connection, discharge outlet duct connection, and at least one damper assembly, located in between for volume control of primary airflow. Air terminal units are often referred to as VAV (Variable Air Volume) units because the airflow to the space can be adjusted, based on varying loads in the space. Automatic controls are typically applied to air terminal units for the modulation of the primary air damper and optional reheat accessories, such as secondary fans, hot water coils, and electric heating coils.



LMHS

Single Duct Terminal Unit - The single duct terminal unit is the most commonly used terminal unit in the HVAC industry, primarily due to the cost and simplicity of installation and application. The single duct terminal unit is used primarily to modulate the amount of primary cooling air delivered to a specific zone or space. It consists of a rectangular sheet metal box, typically lined on the interior with insulation, with a round inlet and rectangular outlet. The inlet includes an airflow sensor that can be used to monitor the amount of air flowing through the unit, and a damper assembly that modulates the amount of air passing through the terminal unit and into the occupied space. Airflow capacities range from 40 - 7000 cfm, split among many different sizes and types. The applied volume controller and inlet duct conditions limit the flow range of each size. Typically, the airflow range for each size is between 500 fpm to 2500 fpm through the inlet of the terminal unit.

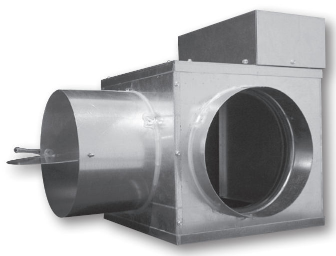


RVE

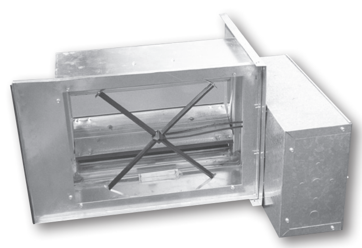
Single duct units are extremely popular for the control of space temperature in cooling only applications. However, hot water or electric reheat can be applied to the discharge of the unit if so desired. In many cases, a heating coil is provided to heat perimeter and interior zones. Single duct units applied to perimeter zones with high heat load requirements, typical of perimeter zones, are not the best choice economically. Perimeter zones often require high heat flow set points; therefore, heating increased amounts of cold primary air (at 55°F), which is not energy efficient. Also, single duct units with heat may be applied to interior zones to prevent sub-cooling, due to required high ventilation rates, which is becoming more common.

Krueger offers four different models of single duct units.

- **LMHS** - This is a round inlet for unit sizes 4 - 16, rectangular for sizes 20 and 22, and a rectangular discharge outlet shut-off VAV unit. It is available with both hot water and electric reheat coils, and is available in standard and attenuated versions. The attenuated version is longer, to provide some sound attenuation. When electric heat is ordered, the longer unit is always supplied.
- **RVE** - This is a round inlet/round outlet unit, originally designed to replace the dampers in mechanical constant volume regulated units. The RVE is now finding its way into other applications, including single diffuser zones, replacing low pressure high volume VVT-Type applications, laboratory applications, and return duct and supply return tracking applications. Reheat is not available with this design.
- **SVE** - This is a rectangular inlet/outlet, slip-in type retrofit unit. The SVE unit is designed to transform inefficient constant volume systems to present day variable volume systems with low installation costs.
- **KLB** - This is a bypass, single duct unit. It is not a true VAV device, as it is designed for constant volume supply air, low pressure input with air directed either to the zone or back to the air handler. Air is directed back to the air handler through the plenum or ducted directly. It almost always requires a balancing damper upstream for proper application and should not attempt to be controlled by pressure independent controllers.



KLB



SVE

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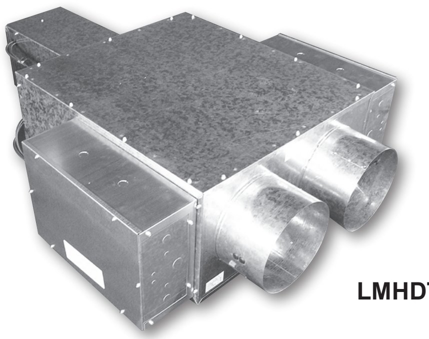
Terminal Unit Design Guidelines



LMHDT

Dual Duct Terminal Unit - Dual Duct terminal units are similar to single duct terminal units; however, the dual duct terminal includes two round inlets with dampers and a single rectangular outlet. Dual duct terminal units are for those applications in which the building employs two separate duct systems for heating and cooling, two separate air sources, or a dual duct type air handler that generates hot and cold air. Typically, local reheat at the dual duct terminal unit is not required. However, volume control arrangements for dual duct units tend to be more complex. Temperature mixing refers to the ability of a dual duct unit to accept two inlet airstreams of varying quantity and with temperature differences ranging up to 50°F. Dual duct units must be able to manage the discharge total air mass at uniform temperatures when mixing. Temperature mixing is rated in terms of the maximum variation across a plane downstream from the unit discharge, compared to the temperature differential of the two supply inlets. Temperature differences of 1°F to 2°F downstream, compared to a 20°F inlet difference, indicate good temperature mixing. Dual duct units are becoming popular for using the second duct to introduce metered amounts of outside air into the space. The outside air supply system can be tempered for supplemental heating or cooling, depending on space load requirements and/or regional climate conditions.

Krueger offers two models for the dual duct product line.

- **LMHD** - This consists of two, single duct units strapped together at the top and bottom. This provides an inexpensive alternative for handling dual ducted buildings; however, it provides no mixing at the terminal. This type of dual duct is not recommended for simultaneous heating/cooling delivery to the space or where a discharge flow measurement is required by the unit controls. The hot and cold airstreams are not forced to mix at the unit; therefore, stratification can occur when cold air is delivered to one branch and diffuser and warm air to the other. These units are fine for separate heating and cooling to satisfy room load conditions.
- **LMHDT** - This unit is longer to accommodate an internal mixing baffle, which ensures complete mixing of the hot/cold airstreams before the discharge of the unit and eliminates potential stratification problems. The average mixing ratio of 1:20 translates to 1°F of discharge temperature stratification per every 20°F differential between hot and cold primary airflow. The mixing chamber and increased length of this unit provides some acoustical advantages over the other model as well.

Fan Powered Terminal Unit - The fan powered terminal unit is used to recycle the heat load given off by machines, lighting, building systems and building occupants. The heat load migrates to the ceiling plenum and is induced (recycled) by the fan powered terminal unit and delivered into the space to lower operating costs for heating. These units are a logical solution for applications where there is a requirement for solving high variable space loads, high ventilation rates, and energy efficiency in recycling heat in a building.

Two types of fan powered terminal units exist - a constant volume (series flow) unit and variable volume (parallel flow) unit. Each unit is typically mounted in a ceiling plenum for induced plenum or return air, and both have similarities such as a variable volume damper, motorized fan with forward curved blades, electric or hot water heating options, and a variety of pneumatic, analog, and digital controls. An ECM (Electrically Commutated Motor) is available on all models of series and two models of parallel fan terminal units. The ECM motor can significantly reduce energy consumption and make balancing the unit easier. It is the following differences that allow for the flexibility in design options for the engineer.

Series Fan Terminal Units - Constant volume (series flow) fan powered terminal units provide a constant running fan throughout the occupied time period for the space. Space temperature is maintained by the modulation of the primary air damper to provide the proper blending of primary air with inversely proportionate amounts of induced plenum air. Under a call for cooling in the space, the primary damper provides an increased amount of cool primary air to the blower, resulting in less induced air from the plenum; therefore discharging cool air into the space. Under a call for heating, the primary damper throttles back the cool supply air to the blower, resulting in an increase of warmer induced air to the space. Note the large opening at the front of the unit next to the primary air inlet. This is the induced air inlet for the motor/blower to draw in warmer ceiling plenum air into the space. Constant ventilation requirements are maintained with the fan output remaining constant and the discharge air temperature varying in response to room load. The unit's fan has the option of being powered with two different motor types. The first option is a PSC motor with a SCR fan speed controller capable of reducing the fan output by as much as 55%. The second option is an energy efficient ECM motor with the ability to be turned down to 15% of the motor capacity. The ECM motor fan speed is controlled by either a manually adjusted VCU controller or a digitally controlled ACU controller that can communicate with a Building Automation System (BAS). With the fan continually running, the sound generated from the unit is also constant and less noticeable to the occupants than varying noise levels. However, it is important to pick the mounting location carefully since this terminal unit will operate at design flow at all times. It may be beneficial not to mount the series fan terminal unit directly over the occupied zone. At design flows, the overall sound may be greater (but constant) than a single duct or parallel fan powered terminal unit operating at the minimum airflow set point and the fan off. Typically, the series fan terminal unit is used for zones requiring a constant volume of air and constant noise levels. Common applications for variable discharge temperature from a

Terminal Unit Design Guidelines

unit with a constant volume fan and VAV primary include zones with high variable loads such as atriums, conference rooms, cafeterias, and lobbies. The direction of airflow paths are shown in the series fan unit diagram below. (See “Series Fan Terminal Unit” Diagram)

Krueger offers three types of constant volume (series flow), ceiling plenum mounted terminal units.

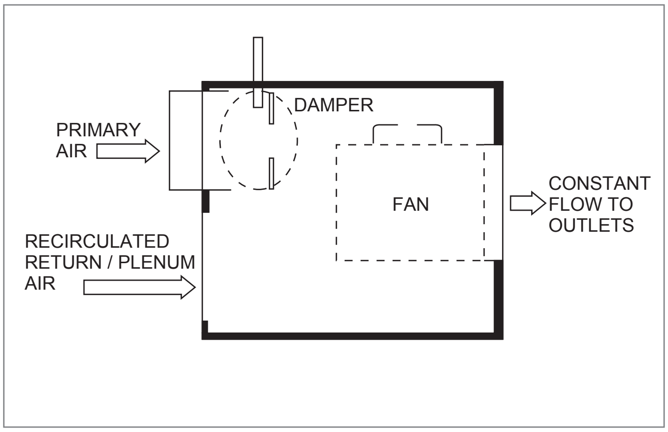
- **QFC** - This is Krueger’s standard series fan powered unit, which is available with either PSC or ECM motors, hot water or electric heat coils, and inlet sound attenuators.
- **KQFS** - This unit is a premium series fan terminal. Using a panel-post construction and integral attenuation, this unit offers improved sound deadening and has a broader range of options, including double wall construction and ECM motors.
- **KLPS** - This unit is available as a low profile series unit, where space height limitations require a low height unit. This unit is available with an optional ECM motor and hot water or electric heat coils.

Parallel Fan Terminal Units - Parallel, or intermittent fan powered, terminal units are equipped to provide pressure independent VAV primary damper control with a sequenced fan that is only energized during a requirement for heat. This terminal unit can operate essentially as a single duct VAV for cooling by modulating cold primary air in response to thermostat demand. The fan is located in parallel with the primary airflow, and does not impede the flow of cool air through the unit. Under a requirement for heat in the space, the primary damper should be at a user defined minimum flow and the terminal fan should be energized to introduce warmer ceiling plenum air to the space. The intermittent fan supplies warmer ceiling plenum air at volumes higher than typical minimum flows of single duct terminal units. This feature makes the parallel fan terminal an ideal selection for perimeter zone control. The cycling of the fan can become objectionable, so placement of the unit is more critical than for the series type. The fact that the motor does cycle allows the parallel fan unit to show power consumption savings over the series type. The diagram below shows the direction of airflow through a parallel unit. (See “Parallel Fan Terminal Unit Diagram) The standard unit fan is equipped with a SCR fan speed controller, capable of reducing fan output by as much as 50 to 55%.

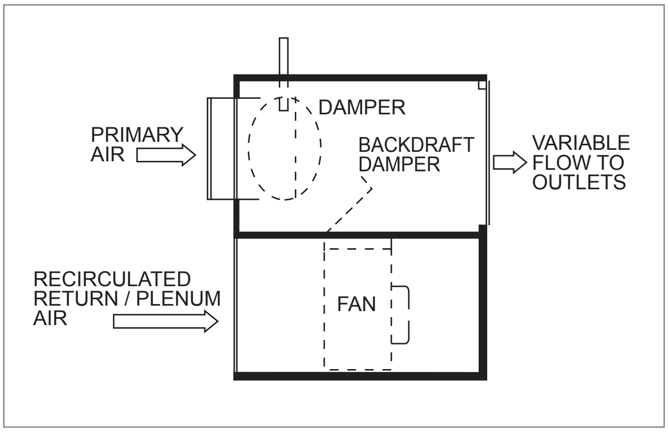
Krueger offers three types of variable volume (parallel flow) terminal units.

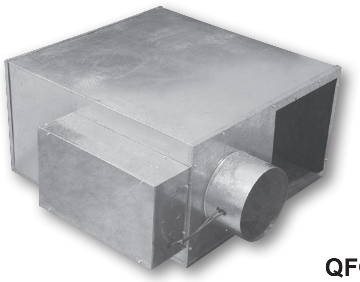
- **QFV** - This standard parallel fan powered unit is available with optional hot water or electric heat coils and an optional inlet attenuator.
- **KQFP** - This unit is a premium parallel fan terminal. Using a panel-post construction and integral attenuation, this unit offers improved sound deadening and a broader range of options, including double wall construction and ECM motors.
- **KLPP** - This low profile parallel unit is commonly used where there are space height limitations which require a low height unit. It is available with an optional ECM motor, hot water or electric heat coils.

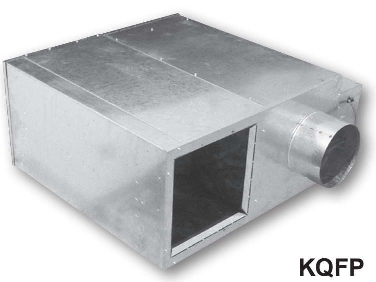
SERIES FAN TERMINAL UNIT

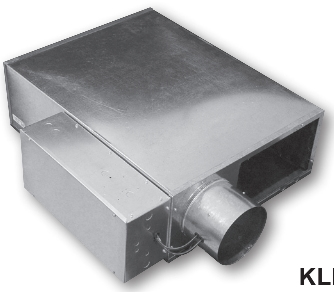


PARALLEL FAN TERMINAL UNIT




QFC


KQFP


KLPP

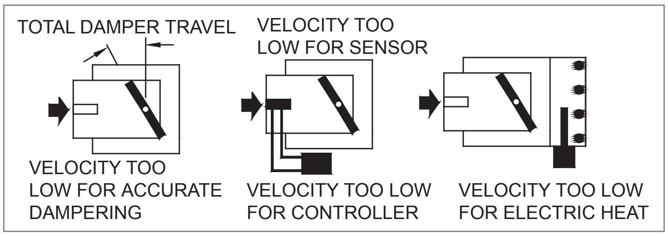
Terminal Unit Design Guidelines

Design Guidelines

"Total Environmental Quality" (TEQ) must be considered for commercial buildings. The fan powered terminal unit has an important role in the TEQ equation with its link to temperature control, ventilation effectiveness, and noise level control. Building design considerations are very important in optimizing terminal unit discharge air temperature, flow rate, energy efficiency and occupant comfort levels. The goal of the designer is to expose occupants of a building to acceptable TEQ levels. The following is a list of some design criteria that should not be overlooked.

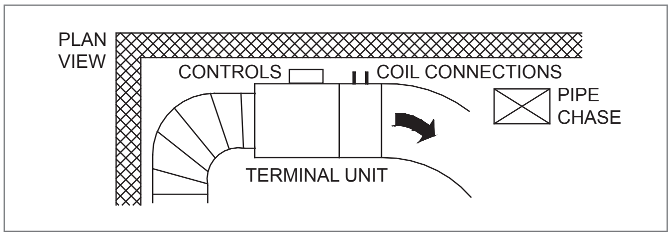
- Specify one terminal unit per zone to ensure individual comfort levels are maintained. An office with four walls is a zone; two offices with one terminal and thermostat can cause occupant discomfort.
- A clean installation environment means provisions for enough space around the terminal unit to ensure straight runs of inlet duct and discharge duct work (3 diameters preferred) and ample room for future service of the unit. Proper inlet conditions provide accurate airflow measurement for increased energy savings and occupant comfort.
- Proper unit size selection equates to accurate airflow measurement, energy savings and occupant comfort. Oversizing terminal units provides little to no acoustical performance advantage.
- Proper unit reheat selection equates to improved warm air distribution in the space and less room temperature cycling around set point. Selection of hot water coils and electric heat capacities should be based upon a leaving air temperature of less than 90°F (per the ASHRAE Fundamentals Handbook) for reasonable air distribution in the space to avoid stratification and ventilation short-circuiting and to meet ASHRAE Standard 62.1, 2004.

OVERSIZING TERMINAL UNITS



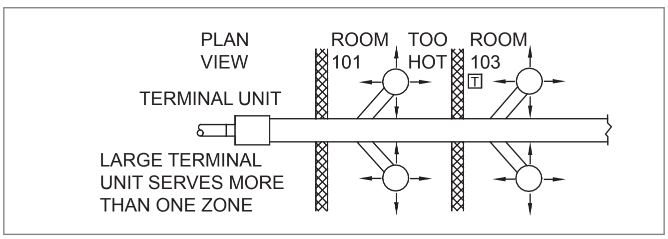
NOTES: The direct result of oversizing is low air velocity. With the velocity too low, the damper must operate in a pinched-down condition most of the time, making control difficult. The inlet velocity can also be too low for effective operation of the sensor and controller. Too low a velocity through an electric heater will cause the safety airflow switch to shut down the heater.

INSUFFICIENT SPACE



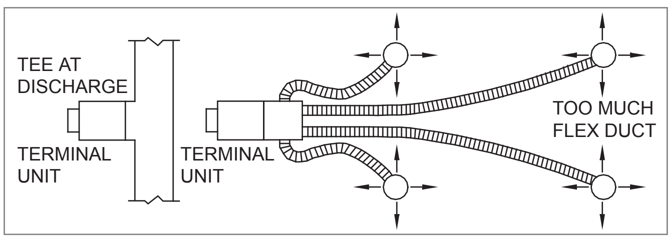
NOTES: Carefully planning the locations of the terminals avoids problems with installation, performance, and maintenance. The control side of the terminal is against the wall, making connections difficult and service impossible. The cramped location also creates the need for close-coupled duct elbows, which reduce performance.

CAPACITY CONCENTRATED IN TOO FEW TERMINALS



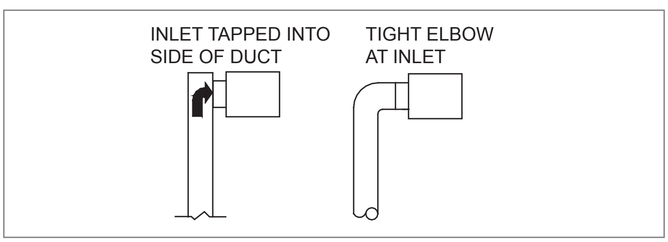
NOTES: When one large terminal unit serves a space that should be served by two or more smaller unit, comfort problems can result. There may be noticeable temperature differences between rooms, since the thermostat is located in just one room. Also, for a given air velocity, the larger the fan powered terminal, the more power it generates.

IMPROPER DISCHARGE CONDITIONS



NOTES: The duct connections at the discharge end of the terminal have a major affect on pressure drop. A tee close to the discharge should be avoided, along with transition pieces and elbows. Another common error is running too much flex duct. It would have been better to continue the rectangular duct to the last diffuser, then install short flex branches.

IMPROPER INLET CONDITIONING



NOTES: The arrangement of duct at the terminal inlet affects both pressure drop and control accuracy. The conditions shown (left) will create turbulence at the inlet. This makes it difficult for the sensor to measure airflow. Although Krueger velocity sensors correct for a considerable amount of turbulence, the best practice is to use straight duct at the inlet.

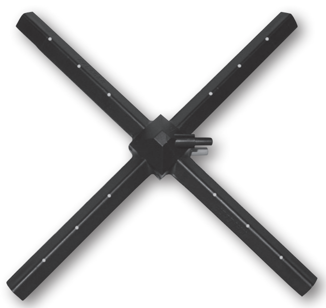
Terminal Unit Design Guidelines

Pressure Requirements
Control of duct pressures is the most effective means of ensuring low sound levels, accurate flow control, and minimum energy use. For each terminal unit, there is a minimum static pressure difference required to assure delivery of the design airflow rate. The pressure difference is measured across the terminal, inlet to discharge and is reported in inches of water ("WG). The inlet pressure required by any given unit is the rated static pressure plus the pressure requirements of the discharge ducts and outlets. Inlet static pressure is also a determining characteristic for the sound level that can be anticipated downstream from the terminal unit. The minimum inlet static pressure shown in the terminal unit performance tables is the pressure required by a given size terminal unit to push a specified amount of airflow through the unit with the damper wide open. The pressure was measured by tests conducted in accordance with AHRI Standard 880.

K4 "LineaCross" Airflow Sensor: The K4 'LineaCross' airflow sensor is provided as a standard on all Krueger VAV terminal units. This sensor has a 12-point total pressure, center averaging flow cross-type design. Using an equal area layout, the sensor complies with ASHRAE's recommended measurement points for accurate determination of duct air velocity. The K4 'LineaCross' is accurate to 5% of the maximum flow set in the controller of the unit. By providing the equal area layout, in combination with the high magnification, the Krueger "LineaCross" airflow sensor offers the most accurate and consistent flow sensing available.

Flow Constants: The controls on most new projects are Direct Digital Controls (DDC), which require that flow parameters be loaded during start-up to translate the sensed pressure into a measured flow rate. There are several conventions (and no universally accepted method) in use for representing this flow factor:

K4 LINEACROSS



- **Magnification Factor**: The magnification factor may be expressed as the ratio of either velocity or pressure, of the output of the sensor to that of a pitot tube. For example, a velocity magnification may be used. All Krueger sensors develop an average signal of 1" WG @2625 fpm. This gives a velocity magnification of 4005/2625, or 1.52. Alternatively, it may be a pressure magnification factor. In this case, the ratio of pressures at a given air velocity is presented. For a velocity constant of 2625, at 1000 fpm, this is 0.1451/0.0623 = 2.33.

- **K-Factor**: The 'K-Factor' may be represented in two ways. First, it may be a velocity K-Factor, which is simply the velocity factor, (which for all Krueger sensors, both Linear and the "K4 LineaCross", is 2625 fpm/"WG). Alternatively, it may be the airflow K-Factor, which is the velocity factor times the inlet area. For an 8" Krueger unit, this would be 2625x0.349 = 916. A separate factor is required for each size. Below is a K-Factor table for all Krueger VAV terminal inlets. (Dual Duct discharge factors are different.)

As there is no standard method of description for this factor, care has to be taken when providing data to the controls person setting up a DDC VAV unit to ensure that both parties are using common terminology.

By designing the Krueger sensors so that all models and sizes use a common velocity K-Factor, regardless of flow sensor type, both the design engineer and the controls contractor have a consistent reference for selection and installation of the units.

Minimum Flow: The minimum flow shown in the table below and graph "Inlet Flow Sensor, CFM vs. Signal" (page a2-15), is based on a flow signal of 0.03" WG. Flows below this value cannot be assured to be able to be controlled by all available DDC controls. When attempting to control below these levels, erratic performance may result, and objectionable sounds may be produced. Additionally, electric heat is not permitted to be set below these values as the flow safety switches will probably not energize, and discharge temperatures will probably be too high, and the diffusers are likely to be ineffective. See the section on Heating Coil Selection on page a2-13 for recommendations for overhead heating with VAV terminal units.

Balancing: Often, the air balancer will measure the flows through the supply diffusers, and establish an "effective flow constant" for the unit in that application. While ideally the flow measurement should agree closely with the calculated flow, using the inlet sensor K-Factor, this may not be the case when non-ideal inlet conditions are present. This difference is also possibly due to discharge duct leakage. The use of equal-area total pressure sensing with the Krueger "K4 LineaCross" flow sensor will result in the most accurate initial balance possible.

INLET PROBE AREA & K-FACTOR

LMHS	04	05	06	07	08	09	10	12	14	16	20	22
Inlet Diameter	4"	5"	6"	7"	8"	9"	10"	12"	14"	16"	13.5"x8"	24"x16"
Velocity Magnification	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52
Velocity Constant	2625	2625	2625	2625	2625	2625	2625	2625	2625	2625	2625	2625
CFM @ 1"WG	229	358	515	702	916	1160	1432	2062	2806	3665	2100	7000
Inlet Area, ft^2	0.087	0.136	0.196	0.267	0.349	0.442	0.545	0.785	1.069	1.396	.738	2.667
Recommended Min CFM	40	62	89	122	159	201	248	357	486	635	420	1212

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With the Krueger inlet sensors, whatever balancing constant is loaded into the controller at maximum flow is usually a very close approximation to the effective constant at minimum flow, regardless of the system conditions, down to the minimum recommended 0.03” WG sensed pressure limit. What this means is that the established flow data will likely result in satisfactory performance over the range of expected flows.

Volume Control Requirements
There are a variety of control methods available for sequencing Krueger terminal units. While control types and sequences vary, all share the basic fundamentals for controlling temperature in a space.

Room control begins with sensing space temperature, usually with a thermostat containing a temperature sensing element and a means of changing the set point. The thermostat can be pneumatic or electronic, both of which measure the difference between actual space temperature and the user defined temperature set point. The difference is translated into a pneumatic or electronic signal by the thermostat and is output to a controller mounted on the terminal unit.

The terminal unit contains an amplifying air velocity sensor located at the inlet of the primary air damper. The Krueger linear averaging sensor or K4 LineaCross center averaging sensor sends the velocity pressure (Vp) signal to the terminal mounted controller. (See “Inlet Flow Sensor: CFM vs. Signal” Graph, page a2-15.)

Terminal unit controllers consist of three basic varieties: pneumatic, analog, and digital. All types analyze the signals from the inlet airflow sensor and space temperature sensor to determine the amount of airflow and/or reheat required to bring the space temperature equal to the space temperature set point. The controller outputs a pneumatic or electronic signal to a factory mounted primary damper actuator to regulate the amount of primary air delivered to the space.

Pneumatic terminal unit control systems operate on compressed air from a central source at approximately 15 to 25 psi (main pressure).

The pneumatic thermostat also operates on main pressure. There are two basic types of pneumatic thermostats: direct acting and reverse acting. A direct acting thermostat increases its pressure output in response to an increase in room temperature, relative to set point. A reverse acting thermostat decreases its pressure output in response to an increase in room temperature, relative to set point. The thermostat output is piped to the terminal unit mounted controller, fan, and optional hot water reheat valve or electric reheat. Control sequences for each unit are available on the Krueger website (www.krueger-hvac.com).

Analog terminal control systems operate on a 24 VAC power source. A factory supplied (mounted and wired) transformer steps down electric power resident in typical commercial buildings to 24 VAC. Analog controls are an excellent low cost, non-communicating alternative to the pneumatic control offering. Air balancing of terminal units with analog controls is easier than pneumatics, in that min/max airflow and temperature set points are adjusted at the thermostat. The integral controller/actuator is pre-wired to the optional control transformer and/or optional fan relay (fan terminal unit) and mounted inside a factory supplied steel control enclosure. Field wiring includes building power to the transformer and wiring between the room thermostat and terminal controller. See the “Inlet Flow Sensor: CFM vs. Signal” graph (page a2-15) for flow sensor voltage values.

Digital control systems (DDC) for terminal units are available from a wide variety of control manufacturers. Again, electric power resident in typical commercial buildings is stepped down to 24 VAC by a factory, mounted and wired transformer with power (VA) sized appropriately. Krueger will factory mount and wire a variety of control sequences and control brand names. For a complete listing, contact your local representative or visit us on our website at (www.krueger-hvac.com).

Series Fan Terminal Unit Pneumatic Control Sequence 1300: User defined primary airflow set points are maintained, regardless of central system pressure, while the terminal unit fan runs continuously. (See “Series Fan Terminal Unit Pneumatic Control Sequence 1300: Direct Acting” Chart on next page.)

Under a load for cooling, primary airflow is at maximum when the thermostat (DA - Direct Acting) is at or above 13 psig. Primary airflow should not exceed the fan airflow set point. When the thermostat branch pressure decreases, the primary airflow reduces to the user defined minimum airflow set point at 8 psig. As primary airflow is reduced, the constant volume terminal fan unit proportionally induces ceiling plenum return air or ducted return air to maintain a constant volume of air to the occupied space.

Under a load for heating, the thermostat branch pressure will continue to decrease. Optional, proportional hot water heat (3-8 psig) or sequenced ON/OFF staged electric heat (up to 3-stages) will be initiated in response to the thermostat signal.

Pneumatic air consumption of the single function controller is 14.4 scim at 20 psig (.236 l/m @ 138 kPa). Upon a loss of pneumatic air, the terminal unit damper fails “Open” (NO - Normally Open).

Series Fan Terminal Unit Pneumatic Control Sequence 1303: User defined primary airflow set points are maintained regardless of central system pressure, while terminal fan runs continuously. (See “Series Fan Terminal Unit Pneumatic Control Sequence 1303: Reverse Acting” Chart on next page.)

Under a load for cooling, the primary airflow is at maximum when the thermostat (RA - Reverse Acting) is at or below 3 psig. Primary airflow should not exceed the fan airflow set point. When the thermostat branch pressure increases, the primary airflow reduces to the user defined minimum airflow set point at 8 psig. As primary airflow is reduced, the constant volume terminal unit fan proportionally induces ceiling plenum return air or ducted return air to maintain a constant volume of air to the occupied space.

Terminal Unit Design Guidelines

Under a load for heating, the thermostat branch pressure will continue to increase. Optional, proportional hot water heat (8-13 psig) or sequenced ON/OFF staged electric heat (up to 3-stages) will be initiated in response to the thermostat signal.

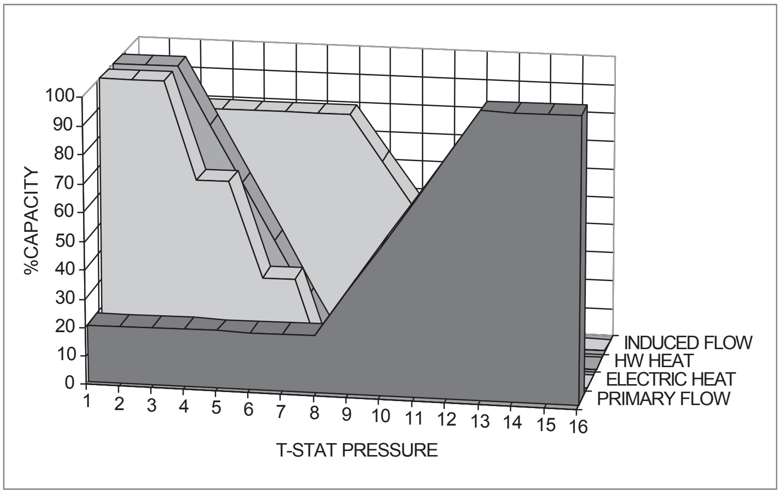
Pneumatic air consumption of the single function controller is 14.4 scim at 20 psig (.236 l/m @ 138 kPa). Upon a loss of pneumatic air, the terminal damper fails “Closed” (NC - Normally Closed).

Sound Requirements
Two types of sound transmission are traceable to air terminal units. “Radiated Sound” escapes through the casing walls and induced air ports of fan powered units, entering a room randomly. “Discharge Sound” travels through the duct work and enters a room via the outlet. The most common method for analyzing these sound levels is by the use of Noise Criteria (NC) curves. The curves cover a range of decibel (dB re 10^{-12} Watts) levels, per octave band, that are most recognizable to the human ear. These bands are designated 2 through 7. (See “Sound Power (Lp) vs. Center Frequency” Graph, bottom right.)

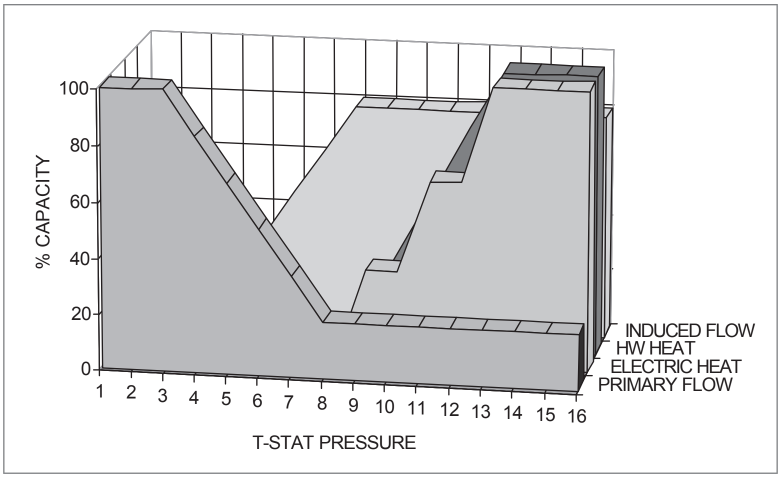
Equipment performance for VAV terminals is usually rated in terms of sound power levels (Lw). Sound pressure is measured in a special acoustical chamber, then printed in sound tables in the form of sound power. Each terminal unit size, various static pressure levels, and flow capacities in both radiated (LwRAD) and discharge (LwDIS) are recorded. By taking these ratings and subtracting various attenuation factors, (see acoustical notes under specific product sections of this catalog) a sound pressure level (Lp) is arrived, which can be compared against the recommended NC values, as shown. (See “Recommended Indoor Design Goals” on page a2-11.)

For radiated sound power levels (LwRAD), the readings from the acoustical chamber are measured and various adjustments are then subtracted. NC is determined from Octave Band Sound Power data with allowances for an environmental factor and a combined ceiling/space factor for a typical mineral tile ceiling. The reductions are calculated in accordance with AHRI 885-08 Appendix E, a procedure for estimating occupied space sound levels in the application of air terminals and air outlets. (See reduction tables on next page.) Reductions used to determine Discharge NC levels are different than that of Radiated NC levels. AHRI 885 was modified in 1998 to reflect data obtained in ASHRAE sponsored research.

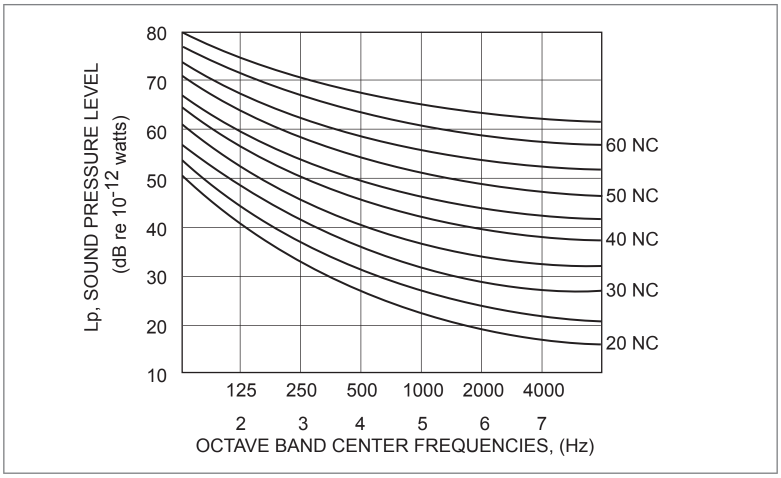
SERIES FAN TERMINAL UNIT
PNEUMATIC CONTROL SEQUENCE 1300: DIRECT ACTING



SERIES FAN TERMINAL UNIT
CONTROL SEQUENCE 1303: REVERSE ACTING



SOUND POWER (Lp) VS. CENTER FREQUENCY



Terminal Unit Design Guidelines

Krueger presents application data which incorporates the latest and most accurate application assumptions. This NC is 3-5 NC louder than NC calculated by the older (AHRI 885-90) method. If one stands under an installed unit with a sound power meter, the data in the NC column is probably what will be recorded. See the white paper on acoustics on the Krueger website located at www.krueger-hvac.com.

For discharge sound power levels (LwDIS), NC was determined from octave band sound power data with allowances for environmental factor, 5 ft. of 1” lined duct matching the discharge dimension of the terminal, branch division, end reflection assuming 5 ft of 8” diameter flexible duct and room absorption based on a 2,500 ft^3 room with an observer 5 ft from the sound source. Again, these reductions are calculated in accordance with AHRI 885-08, Appendix E. The table used for determining NC levels per unit size is shown below. (See “AHRI 885-08 Discharge Reductions” Table, Left)

AHRI 885-08, Appendix E lists standard deductions for discharge sound based on airflow. Shown is a table for less than 300 cfm, one for 300-700 cfm, and another for units with more than 700 cfm. We have calculated discharge NC levels, based on reported airflow, as required by the 885-08, Appendix E standard.

End reflection loss accounts for low frequency sound reflecting from a room through a diffuser. The attenuation of frequencies through various sizes, shapes, and lengths of duct is known as duct insertion and is a significant reduction. Branching represents a reduction in sound as the air is divided into separate airstreams.

The ratio of branch flow to total flow can be charted for specific levels of attenuation per octave band as shown. (See “Ratio of Branch Flow to Total Flow” Table, Left)

NOTE: When comparing NC sound performance from different manufacturers, be sure that sound reductions are identical or understand the differences in the application reductions relative to sound power octave band.

An acoustical requirement of 35 dBA for classrooms has been proposed under the American Disabilities Act (ADA), resulting in an NC 26 in most cases. In order to meet this stringent requirement, diffuser and air terminal unit sound must be accurately accounted for; NC values are probably not sufficient. For this reason, Krueger is providing octave band data for most ceiling diffusers. Using a spreadsheet provided on the Krueger website, one can combine air terminal and diffuser sound to accurately predict occupant perceived sound levels. With the use of Krueger’s product selection program for air terminal units, grilles, registers, and diffusers, sound power can be produced at any flow rate for many devices. When sound power levels are not known, octave band sound can be estimated from NC for most grilles and diffusers (but not linear diffusers, which have an “uncharacteristic” sound spectra). For most diffusers, the 5th octave band (1000 Hz) sound power is NC plus 10 dB. The 4th band (500 Hz) is NC plus 13, and the 6th band (2000 Hz) is NC minus 5. This will give a close approximation in most cases.

Historically, most sound levels are both specified and reported as either dBA or NC. A dBA value is the average of all sound frequencies weighted against a standard curve, and is, as a result, essentially useless as a sound descriptor or diagnostic. NC (Noise criteria) is a better descriptor, but has some shortcomings, especially as a predictor of speech privacy. The use of RC (room criteria) has been proposed as a better descriptor, and has been substituted for NC in recent ASHRAE handbooks.

Speech privacy is a condition where an occupant sitting at his or her desk and can hear adjacent conversations, but does not understand enough of them to be distracted by them. Surveys of occupants have shown that preferred background sound

AHRI 885-08 DISCHARGE REDUCTIONS

AHRI 885-08 Discharge / < 300 CFM	Octave Bands					
	2	3	4	5	6	7
Environmental Effect	2	1	0	0	0	0
Duct Lining, 5', 8"x8"x1"	2	6	12	25	29	18
End Reflection	9	5	2	0	0	0
Power Division (0 outlets)	0	0	0	0	0	0
5', 8" Flex Duct	6	10	18	20	21	12
Space Effect	5	6	7	8	9	10
Total Attenuation	**24**	**28**	**39**	**53**	**59**	**40**

AHRI 885-08 Discharge 300-700 CFM	Octave Bands					
	2	3	4	5	6	7
Environmental Effect	2	1	0	0	0	0
Duct Lining, 5', 12"x12"x1"	2	4	10	20	20	14
10" End Reflection	9	5	2	0	0	0
Power Division (2 outlets)	3	3	3	3	3	3
5', 8" Flex Duct	6	10	18	20	21	12
Space Effect	5	6	7	8	9	10
Total Attenuation	**27**	**29**	**40**	**51**	**53**	**39**

AHRI 885-08 Discharge >700 CFM	Octave Bands					
	2	3	4	5	6	7
Environmental Effect	2	1	0	0	0	0
Duct Lining, 5', 15"x15"x1"	2	3	9	18	17	12
End Reflection	9	5	2	0	0	0
Power Division (3 outlets)	5	5	5	5	5	5
5', 8" Flex Duct	6	10	18	20	21	12
Space Effect	5	6	7	8	9	10
Total Attenuation	**29**	**30**	**41**	**51**	**52**	**39**

AHRI 885-08 RADIATED REDUCTIONS

NC Radiated (dB re 10^{-12} Watts)	Octave Bands					
	2	3	4	5	6	7
Environmental Adjustment Factor	2	1	0	0	0	0
Plenum/Room Effect	16	18	20	26	31	36
Total dB Reduction	18	19	20	26	31	36

RATIO OF BRANCH FLOW TO TOTAL FLOW

% of Total Air Flow	5	10	15	20	30	40	50	60
Attenuation (dB re 10^{-12} Watts)	13	10	8	7	5	4	3	1

Terminal Unit Design Guidelines

levels that achieve speech privacy do not correspond well with NC curves, which is the basis of the change to RC ratings. Lack of acoustical privacy and distraction due to poor acoustics are one of the highest complaints from building occupants today.

The table below, “Room Sound Spectra”, shows five different room sound spectra. The high and low speech privacy spectra reflect survey data taken during the development of open office acoustical criteria. An RC = 40(N) is the mean RC level meeting this criteria. Also listed are NC 35 and 40 spectra.

Specifying Sound Levels

Often, specifications list a maximum space NC value as a design criterion. The supplier of a VAV terminal unit; however, cannot guarantee sound levels without knowing a number of acoustical parameters, including inlet static pressure, length of lining, ceiling type and plenum depth, etc. Also, the equipment supplier cannot control installation details. What is really required is the opposite, a not-to-exceed sound power specification value. This can be accomplished by starting with a desired room sound pressure level, and then adding the expected acoustical deductions to that value, creating a maximum allowable sound power requirement.

ROOM SOUND SPECTRA

	Octave Band, dB					
	2	3	4	5	6	7
Suggested Room Sound Pressures	**125**	**250**	**500**	**1000**	**2000**	**4000**
High Speech Privacy	57	53	48	43	37	31
Low Speech Privacy	52	49	44	37	32	20
RC=40N	60	55	45	40	35	33
NC=40	55	50	44	41	39	39
NC=35	52	45	40	36	34	32

RECOMMENDED INDOOR DESIGN GOALS

Indoor Space		NC*
Private Residences		25 - 35
Apartments		25 - 35
Hotels/Motels	Individual Rooms/Suites	25 - 35
	Meeting/Banquet Rooms	25 - 35
	Halls, Corridors, Lobbies	35 - 45
	Service/Support Areas	35 - 45
Offices	Executive	25 - 35
	Conference Rooms	25 - 35
	Private	25 - 35
	Open-plan Areas	30 - 40
	Teleconference Rooms	25 (max)
	Public Circulation	40 - 45
Hospitals & Clinics	Private Rooms	25 - 35
	Wards	30 - 40
	Operating Rooms	25 - 35
	Corridors	30 - 40
	Public Areas	30 - 40
Churches		25 - 35
Schools	Classrooms up to 750 ft^2	26 (max) *
	Classrooms over 750 ft^2	28 (max) *
	Lecture Rooms	26 (max) *
Libraries		30 - 40
Courtrooms	Unamplified Speech	25 - 35
	Amplified Speech	30 - 40

* *LEED 2012 recommends using AHRI 885 to predict HVAC sound levels.*

MAXIMUM RADIATED & DISCHARGE SOUND POWER WITH 5 ft. DUCT LINING

	Maximum Radiated Sound Power							Maximum Discharge Sound Power						
	Octave Band Sound Power, dB						AHRI 885-08, Appendix E	Octave Band Sound Power, dB						AHRI 885-08, Appendix E
	2	3	4	5	6	7		2	3	4	5	6	7	
Fan Plus 100% Primary	**125**	**250**	**500**	**1000**	**2000**	**4000**		**125**	**250**	**500**	**1000**	**2000**	**4000**	
Minimum	70	64	60	62	65	68	**NC=35**	80	75	80	87	85	70	**NC=35**
Maximum Speech Privacy	75	72	68	69	68	67	**RC=42N**	85	83	88	94	88	69	**RC=42N**
Maximum	78	74	65	66	66	69	**RC=40N**	88	85	85	91	86	71	**RC=40N**

MAXIMUM RADIATED & DISCHARGE SOUND POWER WITH NO DUCT LINING

	Maximum Radiated Sound Power							Maximum Discharge Sound Power						
	Octave Band Sound Power, dB						AHRI 885-08, Appendix E	Octave Band Sound Power, dB						AHRI 885-08, Appendix E
	2	3	4	5	6	7		2	3	4	5	6	7	
Fan Plus 100% Primary	125	250	500	1000	2000	4000		125	250	500	1000	2000	4000	
Minimum	70	64	60	62	65	68	**NC=35**	78	71	71	69	68	58	**NC=35**
Maximum Speech Privacy	75	72	68	69	68	67	**RC=42N**	83	79	79	76	71	57	**RC=42N**
Maximum	78	74	65	66	66	69	**RC=40N**	86	81	76	73	69	59	**RC=40N**

Terminal Unit Selection Guidelines

Starting with one of the room sound pressure curves from the table on the previous page, and applying the AHRI 885, Appendix E “standard” assumptions, this develops a “standard” acoustical specification with a high expectation of the space actually meeting the required sound levels. If there is no duct lining allowed, as which often happens in health care and other applications, the 885 tables must be modified slightly. Shown are suggested specifications for both lined and unlined duct applications. (See “Maximum Radiated Sound Power with 5 ft. Duct Lining” and “Maximum Discharge Sound Power with No Duct Lining” on previous page.)

TERMINAL UNIT SELECTION GUIDELINES

- Selection Guidelines
- Fan Requirements
- Acoustics
- Heating Coil Selection

Selection Guidelines

Krueger offers many different types of VAV terminal units, as described earlier. Once a specific type has been chosen, the selection of the proper size is based on a number of factors. Selecting a unit as small as possible will reduce first costs and allow the lowest possible minimum airflow, but will typically be a little louder than a larger unit.

For example, if a Krueger Model QFC is selected for a project, the table below shows the flow ranges available:

NOTES: QFC maximum primary airflow (CFM) cannot be greater than the maximum induced airflow (fan airflow). A properly balanced QFC unit will be set with the primary CFM equal to or less than the induced CFM.

QFC maximum primary airflow (CFM) is based on 1.00” WG velocity pressure signal (Vp) per inlet size, using either the Krueger linear averaging or K4 LineaCross 12 point center averaging sensor.

Minimum recommended airflow (CFM) is based on 0.03” WG differential pressure of the inlet flow probe or 0 airflow. 0.03” WG is typically equal to 15% - 20% of the nominal flow rating of the terminal unit. Less than 15% - 20% may result in greater than +/-5% variation in control of the unit flow. Attempting to control a VAV unit between the recommended minimum and 0 can result in erratic performance and noticeably changing sound levels.

Maximum Fan (induced) airflow (CFM) is based on 0.1” WG external (downstream) static pressure (the minimum recommended).

Minimum Fan (induced) airflow (CFM) is based on 0.6” WG external (downstream) static pressure.

Motor amps are the maximum rated power consumption as a function of supply voltage.

Fan Requirements

Proper selection of the size of the fan (unit size) affects sound levels, motor life, and airflow. Selection of the fan airflow rate is accomplished through the use of the fan performance curves. The fan airflow requirement should be selected based on the load requirements of the space and then the effect of downstream static pressure relative to fan output (See Fan Performance Curves, Per Product). Fan curves are shown for airflow (CFM or L/s) as a function of downstream pressure. Additional downstream static pressure drop must be accounted for when applying a hot water coil to the fan terminal unit. Krueger’s Terminal Unit selection program will calculate the pressure drop.

Selections near the top of a fan curve should be avoided when possible. If there is slightly more pressure than predicted, the unit may not be able to meet space loads. Additionally, the higher the fan RPM (i.e. the closer to the max flow rate), the more sound the fan produces. At the same time, selecting at too low a flow will cause the motor to run slightly hotter. The published minimum fan curve is based on a combination of the lowest setting on the supplied SCR fan speed controller and a lower limit of 600 RPM, whichever is greater. Operating below 600 RPM, with a sleeve bearing motor, increases the possibility of poor bearing lubrication, and shortened motor life. However, ECM motors have ball bearings and can operate at lower RPM.

Series and parallel fan selections have different selection criteria as well.

- Insufficient Series unit airflow may result in insufficient cooling to the space. Excess Series fan unit airflow will likely be louder than predicted, but has little thermal consequences. Either condition has little consequence when heating.
- Parallel units, on the other hand, where cooling is independent of the fan rate, should have as much fan airflow as possible when heating to avoid stratification and to maintain adequate diffuser induction. Too little fan airflow will likely result in temperature and ventilation stratification.

QFC AIRFLOW DATA

		QFC with PSC Motor								QFC with Attenuator			
Unit Size	Inlet Size	Primary Airflow		Fan Airflow		Motor HP	Motor Amps			Primary Airflow		Fan Airflow	
		Max.	Min.	Max.	Min.		120V	208/240V	277V	Max.	Min.	Max.	Min.
2	6	515	90 or 0	560	100	1/10	1.8	1	0.7	480	90 or 0	480	100
3	6	515	90 or 0	990	300	1/4	3.6	2	1.5	515	90 or 0	890	300
	8	920	160 or 0							890	160		
4	8	920	160 or 0	1440	550	1/4	5	2.8	2.1	920	160	1400	580
	10	1430	250 or 0							1400	250		
	12	1440	360 or 0							1400	360		
5	10	1430	250 or 0	2140	1100	1/2	8.3	4.6	3.5	1430	250	2050	1100
	12	2060	360 or 0							2050	360		
6	12	2060	360 or 0	2530	1200	3/4	9.5	5.8	4.4	2060	360	2500	1200
	14	2530	480 or 0							2500	480		
7	16	3660	630 or 0	3900	2100	(2) 3/4	N/A	13.2	9.9	3660	630	3900	2100

Terminal Unit Selection Guidelines

Acoustics

From the project specifications, determine what radiated and discharge sound power levels and/or sound pressure levels are required. Ideally, a specification should be based on the acoustical requirements in a space, whether in NC, RC, or a sound spectrum, much like a load calculation. This requirement should then be compared with acoustical absorption characteristics in the design, and a maximum sound power specification developed. A computer program (Soundspec. exe) and a spreadsheet (885-spec.xls) are available on the Krueger website (www.krueger-hvac.com) to assist in generating a sound power specification based on the AHRI 885-08 acoustical prediction methodology.

The sound power levels (Lw) of a terminal unit are measured in an acoustical reverberant room with measurements in decibels in octave bands 2 - 7. Sound pressure levels (Lp) can be measured by sound pressure meters in any room. A terminal unit's sound pressure performance is obtained by subtracting various attenuation path elements from the unit's sound power levels, which are presented as a function of airflow rate and inlet or discharge pressure. These room sound pressure levels are typically presented as a single number Noise Criteria or NC, and are displayed as a curve on a NC chart inclusive of bands 2 - 7 (See Acoustical Data, per product).

The latest AHRI 885-08 standard includes Appendix E with recommended attenuation factors to be used when publishing NC (or RC) values with AHRI certified sound power data. These factors are based on a typical space, including flexible duct at the diffusers and lined duct after the unit. If neither of these are present, custom attenuation factors should be used to determine the overall allowed sound power.

Once the sound power requirements, or the acoustical attenuation factors, are known, these values can be used to select a unit that will comply with the requirement. There is also a spreadsheet available that can assist in calculating the sound pressure levels produced by products with known sound power data and stated attenuation components for both air terminal units and diffusers (885-calc.xls). Krueger's selection software program, will allow for any desired set of attenuation effects to be applied, analyzed, and saved for use on other projects.

Heating Coil Selection

Determine the terminal unit heating requirements to supplement the induced plenum air and whether it will be electric or hot water heat. Determine the heating demand for the zone, typically measured in BTUH or MBH (thousands of BTUs). The heating load requirements for the zone can be used to determine any of the unknown variables as expressed below:

BTUH (ZONE) = 1.085 x (SATZ - SPTZ) x Q

Where:

SATZ = Supply Air Temperature Entering the Zone
SPTZ = Set Point Temperature of the Zone
Q = Airflow (CFM) Entering the Zone

It is recommended that supply air temperatures entering the zone should not exceed 85°F - 90°F, in order to avoid potential temperature stratification in the zone. The BTUH requirements of the heating coil can be determined by the leaving air temperature of the terminal unit, LAT. The SATZ plus any duct heat losses should equal the LAT of the terminal unit.

NOTES: The ASHRAE Handbook of Fundamentals states that discharge temperatures in excess of 90°F are likely to result in objectionable air temperature stratification in the space. Also, there is a likelihood of ventilation short circuiting. ASHRAE Standard 62 now limits discharge temperatures to 90°F or increasing the ventilation rate when heating from the ceiling.

Heating airflows are dependent on the type of unit. With fan units, the heating airflow is set either by the fan airflow with series units, or the fan plus minimum primary air with parallel units. Single duct units may have a different heating airflow than when cooling, depending on the type of controls installed. The electric heat elements require a minimum flow to prevent coil damage. The table (below) shows max/min flow ranges and minimum electric heat with single duct units. (The max and min data is applicable for fan terminals as well, as a function of inlet size.)

LMHS UNITS

Inlet Size	Maximum Airflow, CFM	Minimum Airflow*		Minimum Ps.
		Standard	Electric Heat	
4”	230	40 or 0	55	0.03
5”	360	62 or 0	85	0.08
6”	515	89 or 0	110	0.17
7”	700	121 or 0	140	0.16
8”	920	159 or 0	190	0.17
9”	1160	201 or 0	240	0.30
10”	1430	248 or 0	300	0.17
12”	2060	357 or 0	425	0.17
14”	2800	486 or 0	580	0.18
16”	3660	634 or 0	750	0.17
16”x24”	7000	1212 or 0	1800	0.17

**Some DDC controls supplied by others may have differing limitations. This value is based on a signal of 0.03” WG differential pressure of the inlet flow probe.*

Note that if airflows are set to the electric heating minimum, and cooling airflows are selected near the top end of the range for that size, effective room heating, ventilation mixing, and occupant comfort all are likely to be compromised. Diffusers are typically selected on the basis of full cooling loads, of which at high turndown ratios, low discharge velocities will be realized. In these cases, poor temperature mixing, stratification, and ventilation short-circuiting is likely.

The heating coil can be sized per the following expression:

BTUH (COIL) = 1.085 x (LAT - EATC) x Q

Where:

LAT = Leaving Air Temperature of the Coil
EATC = Entering Air Temperature Before the Coil
Q = Airflow (CFM) Through the Coil

Terminal Unit Selection Guidelines

Hot water requirements can be compared to the published Krueger hot water coil performance data. Electric heat requirements can be compared to the kW offering per unit size as shown in the “Electric Heat Capacities” section of this catalog.

BTUH is converted to kW by the following expression:
kW = (btu x .293) / 1000

LineaHeat™
In many cases, staged electric heat cannot provide the necessary flexibility to meet the latest comfort, energy and ventilation requirements. With improved perimeter glass and insulation, the heating demands are often low, and energy codes are many times proscriptive in terms of reheat flow rates.

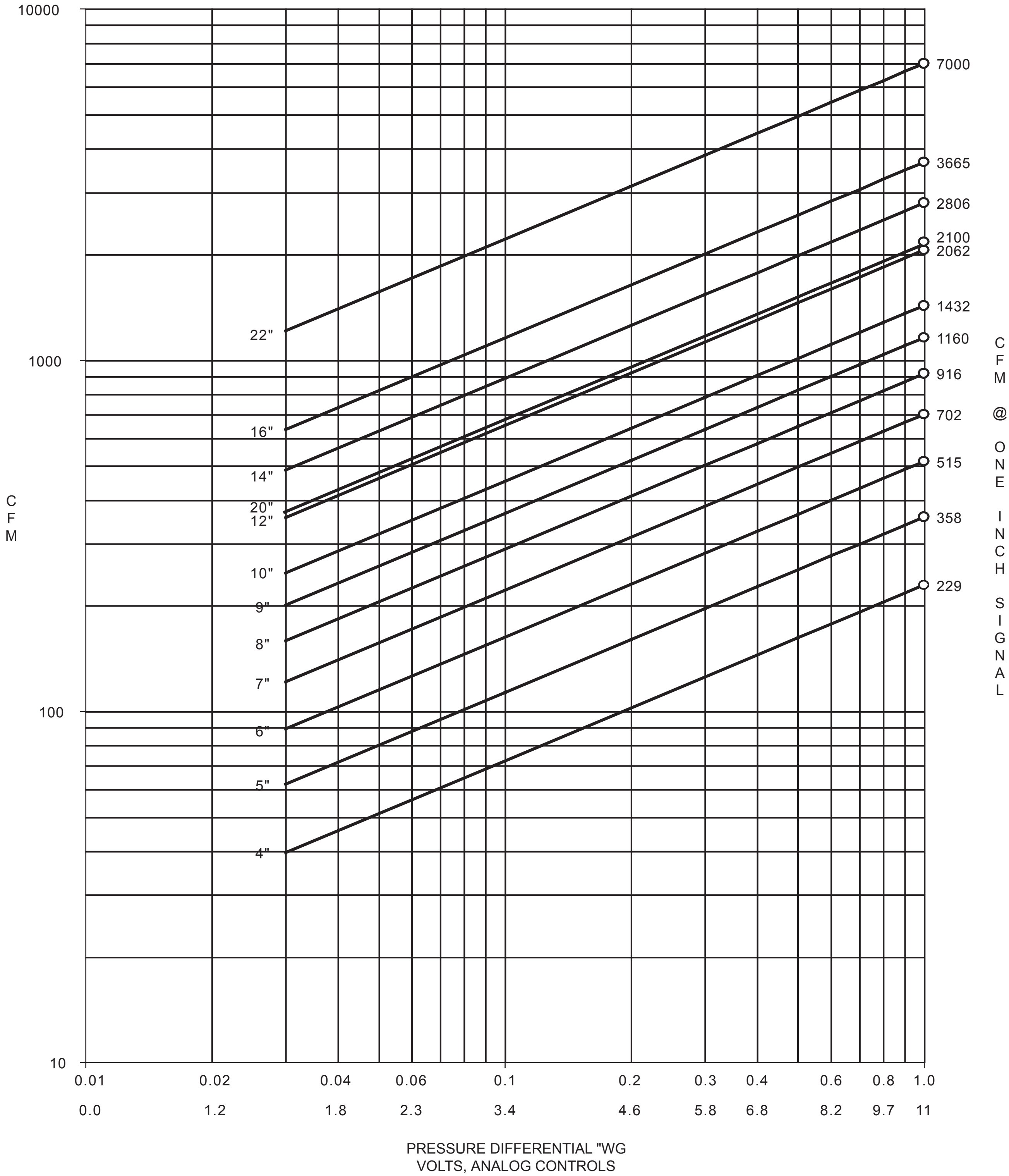
The Krueger LineaHeat™ controller solves all these needs. It optimizes the combination of flow and reheat, allows for the maintenance of velocity and temperature control, and most importantly, can be used with all DDC controllers currently offered on the market today.

The LineaHeat™ product employs a non-communicating digital electric heat controller to send a pulse modulated output either to the solid state relay in a provided electric heating circuit or to a properly configured proportional hot water valve. The LineaHeat™ module is an easily configured circuit board that can be factory set and field modified to accept inputs of 0-10 VDC, 0-20 mA, or 24 VAC from the DDC controller. Other applications include direct pulsing and intermittent staging from the DDC controller. The three-point floating application is unique and allows low cost controllers to proportionately modulate heat with two, 24 VAC outputs. An optional discharge temperature sensor causes the LineaHeat™ controller to maintain a desired discharge temperature based on the input signal, as a percentage of the board set maximum duct air temperature.

With changes in standards, the need for better control of overhead heat is imperative. Krueger’s LineaHeat™ option provides cost effective temperature control that allows designers to meet new ventilation requirements, while assuring low first cost, providing silent operation, minimizing energy use and maximizing occupant comfort.

Terminal Unit Selection Guidelines

INLET FLOW SENSOR, CFM VS. SIGNAL



$CFM = K \sqrt{\Delta P}$
CFM = ft^3/minute
ΔP = Pressure Differential (“WG)
K = Sensor Constant

KRUEGER
Excellence in Air Distribution

References

A-10: NC Chart. 2001 ASHRAE Fundamentals Handbook; Chapter 7, Figure 6.

A-11: NC Radiated Reductions. Data in Accordance with AHRI Standard 885-08.

A-11: NC Discharge Reductions. Data in Accordance with AHRI Standard 885-08, Appendix E.

A-11: Ratio of Branch Flow to Total Flow. Data in Accordance with AHRI Standard 885-08.

A-12: Recommended Indoor Design Goals (NC Ranges). 2001 ASHRAE Fundamentals Handbook; Chapter 7, Table II.