ROOFTOP UNITS

Energence®/Landmark®/Strategos®/T-Class™

MSAV® (Multi-Stage Air Volume) Supply Fan Option Applications

APPLICATION AND DESIGN GUIDELINES

Form No. 485112
March 2012

MSAV supply air blower option is available on Energence® 3 to 30 ton models, Landmark 7.5 tons to 25 tons rooftop units, Strategos® 10 to 24 tons rooftop units, and T-Class™ 7.5 tons to 20 tons split systems

TABLE OF CONTENTS

Theory

Application

Background

There are several methods of obtaining variable airflow from a rooftop unit. The most common methods are Constant Air Volume (CAV) units with bypass dampers, units with a multi-speed motor, and units with supply blower motors coupled with Variable Frequency Drives (VFDs):

- In a bypass damper system, a damper in the supply duct modulates the airflow to send enough air to meet the requirements of the space redirecting the rest of the supply air back to the return, bypassing the space. The damper modulates based on the static pressure of the duct. With this method of modulating airflow, regardless of the position of the damper, the blower will continue to operate at full speed resulting in unnecessary energy usage from the blower.

  CAV units with bypass dampers are typically used in multi-zone Variable Air Volume (VAV) applications where a single RTU supplies airflow to multiple zones with *varying cooling loads and multiple temperature sensors (See Figure 2)*.

- Lennox multi-speed motors can use either a belt or a direct drive. Lennox's multi-speed belt-drive motors use different pole windings to stage the blower. Lennox's direct drive motors utilize an Electronic Commutated Motor (ECM) motor. An ECM motor is an ultra high efficient motor that utilizes a permanent magnet rotor with a built in inverter. Lennox utilizes multi-speed motors in Energence RTUs 5 tons and smaller.
- A Variable Frequency Drive (VFD) is an electrical device that varies the frequency and voltage of the power supplied to the blower motor to control airflow (see Figure 1). With a VFD, the blower is able to operate at multiple speeds to provide the required airflow, helping the rooftop unit control energy usage while meeting comfort requirements and lower operating costs.

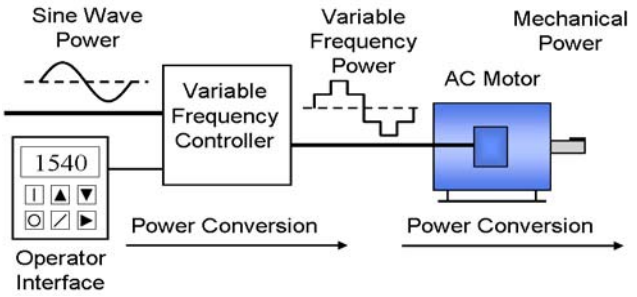


Figure 1- VFD varies the frequency and voltage supplied to the blower motor controlling energy consumption

VFDs can be used in multi-zone or single-zone VAV applications.

In multi-zone VAV applications, a VFD typically modulates blower speed to maintain the duct static pressure setpoint. As zone dampers open, static pressure in the duct decreases and the VFD increases the blower speed to maintain the static pressure setpoint. As zone dampers close, static pressure in the ducts increase, and the VFD reduces blower speed to maintain the static pressure setpoint. In addition, a discharge air temperature sensor is required to stage the compressors based on zone cooling demands. Most VAV systems try to maintain a 55°F discharge air temperature.

Multi-zone VAV applications involve more than just a VFD, these systems incorporate controls, equipment and systems integration. See Figure 2 below.

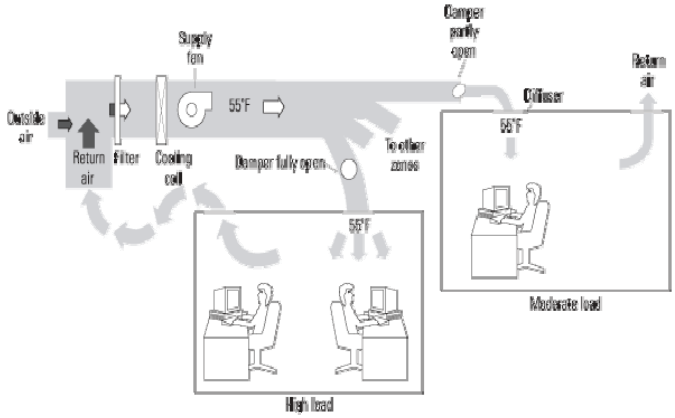


Figure 2. Multi-zone VAV schematic. Multi-zone VAV systems require more than just a VFD, they require zone dampers, pressure transducers, and more.

Single-zone VAV RTUs vary the airflow to a single zone. For example, a movie theater in which one RTU supplies different air flows to the theater depending on load demands.

What is MSAV®

MSAV (Multi-Stage Air Volume)

MSAV is a Lennox single zone VAV System.

For Energence RTUs 3 to 5 tons, multi-speed motors are used to accomplish various airflows. On Energence RTUs, Strategos RTUs, Landmark RTUs and T-Class split systems 7.5 tons and above, VFDs are used to vary supply airflow. Landmark RTUs and T-Class Splits stage the VFD based on cooling stages while Energence RTUs and Strategos RTUs stage the blower according to compressor stages, heating demand, ventilation demand, or a smoke alarm. Table 1 summarizes the differences between MSAV single-zone systems and multi-zone/VAV systems.

Overview

MSAV option is only for single zone, non 100% outside air applications and, depending on the control mode of the rooftop unit and the rooftop selected, MSAV can provide up to seven blower speed settings:

- 4 cooling speeds
- 1 heating speed
- 1 ventilation or free cooling speed
- 1 smoke speed

As the unit switches between different stages of cooling, the supply fan will either slow down or speed up to match the cooling demand.

Table 1- MSAV VS. Multi-zone/VAV Systems

Method		VFD	Control	Benefits	Drawback	Available on
Bypass Damper - Multizone		No	Static pressure transducer modulates damper in supply duct bypassing air to the return duct	Lowest upfront cost	When occupied, supply fan runs at 100% constant speed which results in highest energy consumption	All RTUs
VAV – Multizone (Variable Air Volume)		Yes	Static pressure transducer modulates VFD; compressor circuits staged based on discharge air	Modulate supply fan saving energy	Most expensive upfront cost. Requires controls and systems integration	Energence RTUs 20 tons and above
MSAV - Single-zone (Multi-speed Motor)	Belt-Drive Motors	No	Supply fan stages either low or high speed. First stage cooling is low speed, second stage cooling is high speed. Heating is high speed only.	Multi-speed motors can handle significantly higher external static than PSC motors	Multi-speed belt-drive motors have only 2 available speeds: 6 poles low speed and 4 poles high speed option.	Energence RTUs 3,4,5 tons
	ECM Motors			ECM motors are more efficient than belt drive motors; Blower setpoints can easily be adjusted in field via Prodigy Unit Controller	ECM motors have a higher upfront cost than belt-drive motors	Energence RTUs 3,4,5 tons
MSAV – Single-zone(Multi-Stage Air Volume)	Landmark and T-Class Units	Yes	Supply fan stages up and down based on cooling circuits in use, heating, or ventilation	For Landmark and T-Class Splits, up to 2 fan speeds	Field installed option only for T- Class splits; No heating speeds, and no free cooling speeds.	Landmark RTUs and T-Class splits 7.5 tons and above
	Energence and Strategos RTUs			For Energence and Strategos RTUs, up to 7 fan speeds for different modes of operation and energy savings.	Increased first cost	Energence RTUs 7.5 tons and above Strategos RTUs 10 tons and above

For example, when there is a low demand for cooling and the unit is operating in low stage cooling, the blower will reduce airflow to the low speed setting, saving energy. As the cooling demand increases and additional cooling stages turn on, the unit will increase airflow.

The blower can also run at a different speed during ventilation mode to minimize energy usage. If the unit is equipped with an economizer and outside air is suitable, the blower will run at its ventilation setting to meet space demands with the least possible amount of energy. To meet fresh air requirements the outside air damper has up to 3 minimum positions to provide the right amount of outside air at various speeds, and avoid conditioning more outside air than is necessary. Please refer to Damper Setup on page 8 for more information.

On select models, the electronic VFD bypass option may help avoid the need for an emergency service call in case there is a problem with the VFD. In case of a VFD malfunction, the Prodigy® Unit Controller can be set up to automatically bypass the VFD to operate the blower as a CAV unit. This helps maintain unit operation and keeps the space conditioned while eliminating the need to immediately service the unit. Please refer to Bypass Control Section on page 7 for more information.

Benefits of using MSAV Technology

1. Energy Savings

According to the Department of Energy (DOE) 40-60% of all electricity used in US industry today is consumed by Heating, Ventilation and Air Conditioning (HVAC) systems making them the prime targets for energy-efficient initiatives. MSAV units not only save energy by staging compressors based on cooling demands but also offer the option of utilizing reduced fan speeds in multiple modes of operation. The MSAV option controls blower speed based on cooling, heating (select models only), and ventilation demands (select models only).

Significant energy savings can be achieved by utilizing MSAV because, as the Fan Laws state:

- Airflow (CFM) is ***directly proportional*** to the blower speed of the fan (RPM)

$$CFM = RPM$$

- Static pressure (SP) is proportional to airflow ***squared***

$$S.P. = CFM^2$$

- Power (HP) is proportional to airflow cubed

$$HP = CFM^3$$

According to these laws, at full speed the blower operates at full power. The same fan running at 50% speed consumes only 12.5% of the rated horse power. Therefore, by reducing airflow by half, the horse power consumption is reduced 87.5% resulting in significant energy savings (see Figure 3).

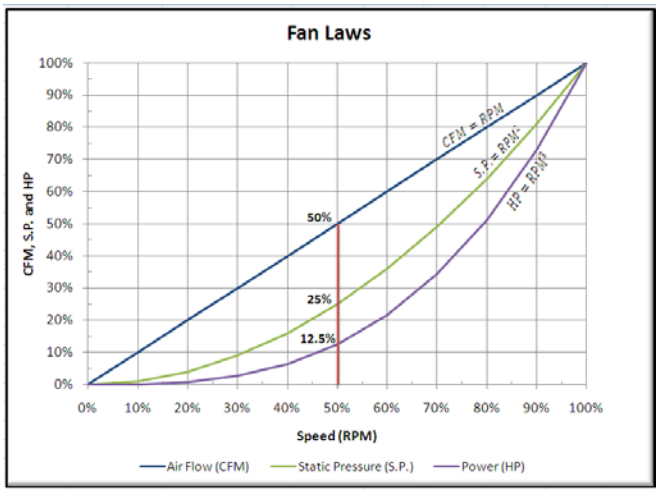


Figure 3- Reducing airflow reduces power consumption exponentially, not linearly.

In addition, HVAC systems are typically sized for peak load conditions at full capacity, which only occurs 1-5% of the annual operating hours. This means that while cooling, blower motors run at full speed unnecessarily 95-99% of the time. Utilizing the MSAV technology, staging of the blower motor according to capacity helps the rooftop unit lower operational energy consumption year round. As shown in Figure 4, Energence units equipped with MSAV blower option are capable of achieving up to 27% higher part-load ratings.

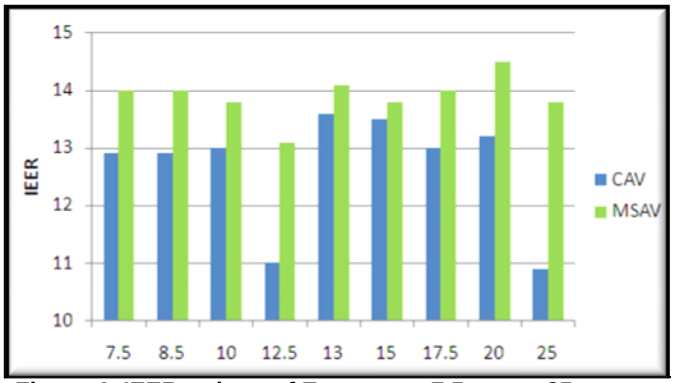


Figure 4- IEER ratings of Energence 7.5-ton to 25-ton CAV and MSAV units.

2. Temperature and Humidity Control

By staging the blower according to compressor stages and cooling demand, units with MSAV are capable of removing more moisture than CAV equivalent units.

3. Noise Reduction

One of the main sources of sound in HVAC units is supply fan operation. The faster the fan rotates the more sound the system produces. Since a unit with MSAV varies the fan speed as needed by space conditions, the fan will run at lower speeds most of the time producing on average less noise.

4. Load Shedding (Strategos and Energence Only)

MSAV technology provides the ability to run units in part-load when load shedding is required. Since MSAV units stage their blowers in part-load operation, MSAV RTUs will have a lower energy demand than the equivalent CAV RTUs.

5. Increased Reliability- Smooth Speed Transitions

When a motor is started, it draws much higher current than during normal operation. This inrush current can be three to ten times the full-load operating current for the motor, generating both heat and stress in the motor's components, belts, bearings, and pulleys. This high inrush causes unnecessary wear and tear, possibly leading to a shortened motor, belt, bearings, and pulley life span.

However when using a unit with VFD, the VFD controls the inrush ampacity to the motor, gradually ramping up until the unit runs at normal operating conditions. As a result of reducing the inrush current, the blower motor, pulleys, bearings, and belts should have an extended life span and increased reliability.

6. Compliance with Regulations California's Title 24 & ASHRAE 90.1-2010

As of January 1st 2012, prescriptive compliance requires air conditioning equipment 110,000 Btu/hr (9.2 tons) or larger serving a single zone to be designed to modulate supply airflow down to a minimum of 2/3 of the full fan speed at low cooling demand.

MSAV Limitations

In the HVAC industry, there are three main evaporator coil arrangements: face-split, row-split and intertwined. At full load, all coil configurations have the same performance, however, at part-load, performance and airflow allowances differ. Depending on the coil type, airflow ranges for MSAV will have different limitations. Below are guidelines, advantages and disadvantages of each of the different coils. For a summary of Lennox RTU coil configurations, see Table 2.

1. Face-Split

Figure 5 shows the horizontal or face-split configuration. In this arrangement, each coil has an independent circuit on the top and the bottom. Each circuit is equal in size and capacity.

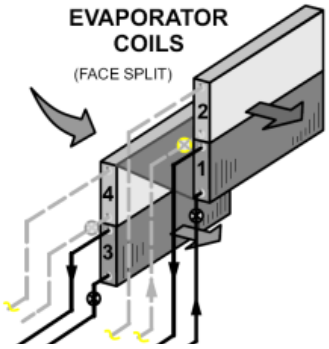


Figure 5- Face-Split evaporator coil configuration

During stage 1, compressor 1 energizes and drives refrigerant through coil 1; for stage 2, compressor 2 energizes coil 2… etc. Refrigerant circuits are energized and de-energized as the corresponding compressors are cycled on and off. In this configuration part-load conditions are achieved by turning off individual sections. Therefore, air passing through an inactive section is unconditioned and mixed with conditioned air to arrive at the supply air temperature and humidity set point. One of the advantages of this arrangement is that, at part-load, air travels through multiple coil rows providing extra moisture removal. At part-load face-split coils provide the greatest energy efficiency, however, as air velocity through the coil decreases, the risk of freezing the coil

increases. Therefore, for MSAV units, **airflow should never fall below 220 cfm/ton to prevent the evaporator coil from freezing.**

2. Row-Split

Figure 6 is an example of a 4 stage, 2 coil row-split design. In a row-split design, the circuits are placed in series with each other. In this configuration part-load conditions are achieved by turning on and off individual circuits as compressors are cycled on and off. Since air passes across the entire face of the coil with no stratification, row-split coils provide more uniform cool air distribution than the face-split configuration. Therefore, row-split coils are ideal for low airflows at part-load, On the other hand, at part-load, air passes over fewer rows of coil reducing the coil's ability to dehumidify. **There are no minimum airflow requirements on MSAV units with a row-split coil configuration.**

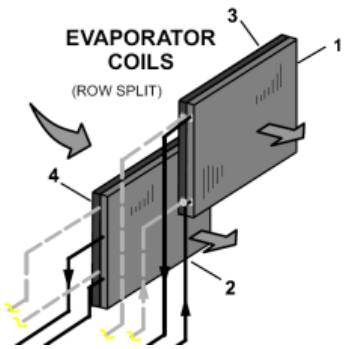


Figure 6- Row-Split evaporator coil configuration

3. Intertwined Coil

Figure 7 is a two stage, intertwined coil example. In this arrangement, the refrigerant circuits alternate rows of the coil, making the entire coil surface active at all times. At part-load, as refrigerant circuits de-energize, the remaining active circuits keep the entire surface cold providing uniform temperature control. Intertwined coils provide better stratification than face-split coils but are not as efficient at moisture removal. And likewise, intertwined coils are marginally better at moisture removal than row-split coils but don't provide even cooling at part-load. Intertwined coils are not currently used on Lennox units.

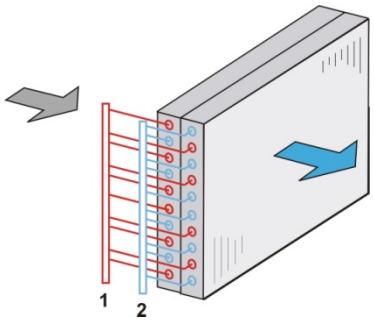


Figure 7- Intertwined evaporator coil configuration

Table 2- Evaporator coil design based on product line and tonnage

Product Line	Tons	Evaporator Coil
Energence	3-5 Tons	Single Coil
Energence	7.5-12.5 Tons	Face-Split
Energence	13-25 Tons	Face-Split
Energence	20-30 Tons	Face or Row-Split
Energence	35-50 Tons	Face or Row-Split
Landmark	3-7.5 Tons	Single Coil
Landmark	7.5-25 Tons	Face-Split
Strategos	3,5 Tons	Face-Split
Strategos	10-24 Tons	Face or Row-Split
T-Class	7.5-20 Tons	Face-Split

Note: Part-load airflow for a face-split coil in cooling mode should not be set below 220 CFM/ton to reduce the risk of evaporator coil freeze-up.

How MSAV technology works?

Blower Speed Control

The number of fan stages available with MSAV units differs depending on the controller used and the number of cooling stages available, as shown on Table 3. For example, an Energence 20 ton rooftop unit with a standard 2 stage cooling thermostat can run 5 supply fan speeds: 2 speeds for cooling, 1 for heating, 1 for ventilation, and an extra speed for the smoke alarm option. When a zone sensor or discharge air control mode is used, the 20-ton MSAV unit can take advantage of up to 7 available supply fan speeds (4 cooling, 1 heating, 1 ventilation, and 1 smoke alarm).

Table 3- Energence 20 Ton MSAV Control Example

Max # of Blower Stages	Controller	Supply Air Blower Speed
5	2 Stage Thermostat	➢ 2 Cooling ➢ 1 Heating ➢ 1 Ventilation ➢ 1 Smoke
6	3 Stage Thermostat	➢ 3 Cooling ➢ 1 Heating ➢ 1 Ventilation ➢ 1 Smoke
7	Zone Sensor Discharge Air Building Automation System	➢ 4 Cooling ➢ 1 Heating ➢ 1 Ventilation ➢ 1 Smoke

Please refer to the Installation Instructions and Prodigy Unit Controller Application and Design Guideline for more information.

VFD Bypass Option
MSAV/VAV units equipped with a VFD have the option to be ordered with a VFD Bypass. In case the VFD on the unit fails, a bypass enables the unit the ability to continue operation as a constant air volume unit.
Lennox offers two different bypasses, an automatic bypass and a manual bypass.

Electronic Bypass Option
Energence and Strategos MSAV RTUs have the option to be equipped with an electronic bypass. In case of a VFD malfunction, the electronic bypass can be configured to switch the unit over to CAV automatically or manually. If a VFD malfunctions, an alarm will be generated by the Prodigy Controller. The Prodigy Controller will try 4 times to get the VFD back online, however if the VFD is unsuccessful and an electronic bypass is installed, the Prodigy Controller will either shut down the unit to prevent further damage (if the bypass is not set to automatically switch over) or switch the unit over to CAV (if the bypass is set to automatically switch over).

Manual Bypass Option
On Landmark and T-Class units, a manual bypass option will be available as a field installed kit. A technician will be able to manually switch over the unit from MSAV to CAV until either the VFD can be repaired or until a replacement VFD can be installed.

Phase and Voltage Protection
Phase detection (standard on all MSAV units) monitors power supply to assure phase is correct at unit start-up. This prevents phasing issues such as backwards running compressors. If the phase is incorrect or missing, an alarm code is generated and the unit will not start-up.
Voltage detection (standard only on Energence and Strategos MSAV RTUs) monitors power supply voltage to assure proper voltage to the unit. If the voltage conditions are not correct (over/under voltage conditions) the unit will not start and an alarm code will be generated.

Freeze Protection
To protect the evaporator coils in low airflow operation, models are equipped with low temperature switches (freezestats) located on the return bend of each evaporator coil circuit to protect them from ice build-up due to low/no airflow, or low refrigerant charge.

Each freezestat is a single pole, single throw, normally closed, auto−reset switch which opens at 29°F ± 3°F on a temperature drop and closes at 58°F ± 4°F on a temperature rise. To prevent coil icing, freezestats open during compressor operation to temporarily disable the respective compressor until the coil warms sufficiently to melt any accumulated frost.

If the freezestats trips frequently due to coil icing, the unit's charge, airflow, and filters need to be checked to prevent any damage to the system. **For MSAV applications, part-load airflow in cooling mode should never be set below 220 CFM per ton to reduce the risk of the evaporator coil freezing.**

MSAV Application

Duct Design
There are some duct design criteria that should be followed at all times when designing the air distribution for MSAV applications. First, the duct system design must be capable of delivering adequate airflow to sustain proper heating and cooling. MSAV and constant air volume (CAV) need to be able to provide sufficient airflow at full load, however, MSAV duct design differs from CAV in that a MSAV duct system needs also to be able to provide sufficient air stratification at partial load and reduced fan speed. Second, the duct system must provide minimum resistance to air flow by reducing the static pressure that is created. Round ducts instead of square ducts are particularly good for MSAV units since round ductwork minimizes the amount of static pressure created. Lastly, registers and diffusers must be selected properly so that they provide adequate air distribution to the space at low and high speeds. If the return is placed too close to the supply, at low airflow, air will bypass the space and go directly back to the return. Engineers should also be very cautious in designs using concentric diffusers with MSAV

applications. As long as these factors are considered when designing the distribution system, MSAV units can run effectively and efficiently.

Damper Setup

Lennox RTUs with MSAV capability and motorized outside air dampers or economizers have multiple damper positions available to minimize over ventilating. See Table 4 for a summary of RTU outside air damper position availability.

Table 4- OA Damper Position Availability

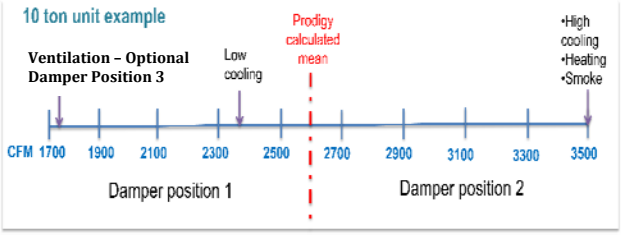
RTU Class	Outside Air Damper Positions Available
Energence	3
Landmark	2*
T-Class	2*
Strategos	3

**Motorized air dampers for Landmark and T-Class units have 1 damper position*

For Energence, Landmark, and T-Class Units, the outside air damper minimum positions #1 and #2 are adjusted during setup to provide minimum fresh air requirements at the indicated supply fan speeds per ASHRAE standard 62.1.

For Energence RTUs, the Prodigy Unit Controller will automatically calculate the mean CFM based on the unit set-up. Damper position 1 will automatically be used for airflow below the mean value and Damper Position 2 will automatically be used for airflow above the mean value. Position 3 is an optional damper position that can be used for ventilation. For an example, see Figure 8.

Figure 8- 10 ton RTU Damper Position Example



Applications

➢*Good Applications*

MSAV units are ideal for any location that requires full load for only a small percentage of the operating hours. Ideal applications include but are not limited to restaurant dining rooms where make up air is less than 40% of the minimum airflow requirements, warehouses, retail spaces, super markets, museums, movie theaters and schools.

➢ *Applications to Approach with Caution*

There are some applications that are a better fit for Energence MSAV units than others. Retrofit jobs with a concentric duct system that replace a constant volume unit with Energence MSAV unit should be handled cautiously. Some concentric diffusers do not throw air well no matter what type of system is used and at low air velocity, the air can bypass cooling the space and go directly back to the return.

Applications to pay special attention to are building prototypes where the shelving or other barriers can restrict proper airflow. Retrofit applications with high static duct configurations and older style concentric duct diffusers should also be cautiously approached due to potential distribution and noise problems.

MSAV is not for 100% Outdoor Air Applications. Outside air units are used to bring in a set amount of outside air into the space, and by varying the blower speed, the outside air into the space is also varied. **For more information, please refer to Lennox Product Specifications bulletins.**