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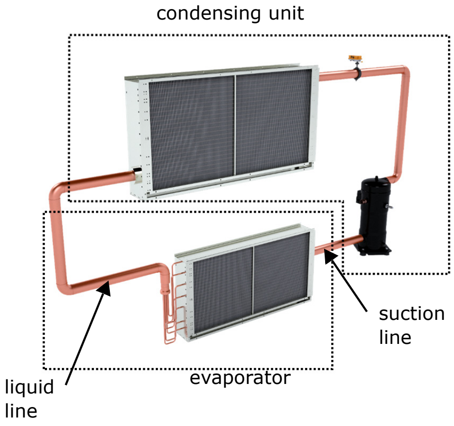
Engineers Newsletter

volume 48–4

Understanding the Selection of Direct Expansion (DX) Evaporator Coils



Introduction

In this *Engineers Newsletter*, we will examine the selection of Direct Expansion (DX) refrigerant-to-air evaporator coils, as applied with condensing units.

A condensing unit is part of an air conditioning system made up of compressor(s), and condenser(s). Condensing units may often include controls.

Matching evaporators to condensing units may sound complicated. However, in the hopes of demystifying the process, this newsletter will offer a simplistic approach to the selection process. After all, the requirements of the selection should be simple; meet the design specifications and create a reliable system. This means that the design requirements cannot be so restrictive as to inherently lead to systems that could be unreliable.

Guidelines

The selection of DX evaporator coils must be based on the compressor-bearing product requirements. Improper coil selection can cause the system to shut down due to a safety control, or worse, it can cause the compressor to fail. Therefore, the guidelines of the condensing unit manufacturer should always be followed in component selection.

For example, a two-circuit condensing unit should not use a single circuited evaporator coil—this would cause oil issues between the two compressor circuits.

The coil should be selected at a Saturated Suction Temperature (SST) that is applicable to the system in which it is applied.

- Constant Volume (CV): 43°F SST or higher,
- Variable Air Volume (VAV): 45°F SST or higher,
- Dedicated Outdoor Air Systems (DOAS): 48°F SST or higher.

These suction temperatures will allow for acceptable system modulation capability as indoor and outdoor conditions change. Lower design SST will limit minimum mixed air temperature, minimum airflow modulation, and/or the minimum outdoor ambient operating temperature.

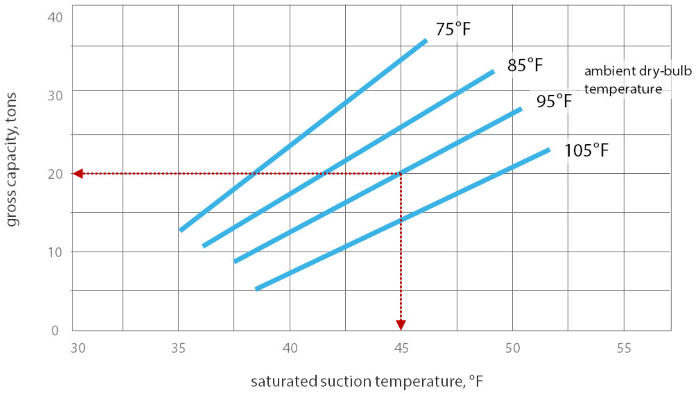
On the other hand, the operating SST of the coil should not be above that which is detrimental to the compressor. Generally, a compressor can operate through interim fluctuations of higher suctions, but higher suctions should not be part of the normal operating envelope. Only the manufacturer of the condensing unit can determine what this maximum limit is, and don't be surprised as it may vary from compressor to compressor. For now, an operating SST of <55°F should be considered safe for most scroll compressors, but once again, the condensing unit manufacturer should always be consulted for the correct maximum SST.

There is only ONE SST for a desired capacity and ambient temperature.

Condensing Unit

At this point, it is important to discuss condensing unit performance curves (Figure 1). Typically, one can find this information in the condensing unit catalog or they can be requested from the manufacturer of the condensing unit. The condensing unit curves plot three variables; ambient temperature, SST, and capacity. Given any two, the third can be determined. Note that when the ambient temperature increases, the capacity decreases. Likewise, if the SST increases, the capacity increases. However, the most important takeaway from the curve data is that for a desired capacity and ambient temperature, there is only one SST that will meet the desired capacity. This is of utmost importance since this is the only SST at which the evaporator coil can be selected in order to obtain the desired capacity. As shown in Figure 1, if the desired capacity of the system is 20 tons and the ambient design is 95°F, then the SST of the condensing unit must be 45°F.

Figure 1. Typical condensing unit performance curve



Coil curves are fixed. A coil WILL operate on its coil curve if the air conditions remain constant as the SST changes. Like the condensing unit, they too are plotted as capacity versus SST.

Evaporator

Like the condensing unit, evaporator coils also have performance curves (Figure 2). The evaporator curves are plotted as capacity (tons) versus SST and are based on two fixed factors:

- Coil geometry (fins, rows, height, length, etc)
- Conditions of the air entering the coil (CFM, DBT, WBT)

Given the number of permutations of coil selections, coil manufacturers often provide software tools (like Trane® Select Assist™ or TOPSS™) to predict coil performance; or they may suggest a coil geometry which meets the desired conditions. In both cases, it is best to create or request a coil curve. The use and benefits of a coil curve and how to create one will be discussed later in this newsletter.

Figure 2. Typical evaporator coil performance curve

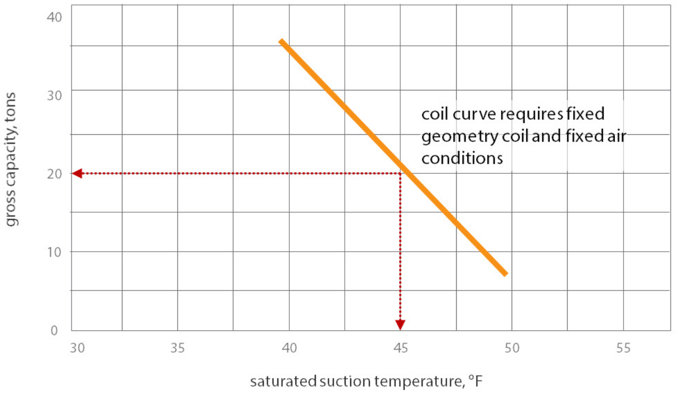


Figure 3. Cross plotting of an evaporator coil and condensing unit curves

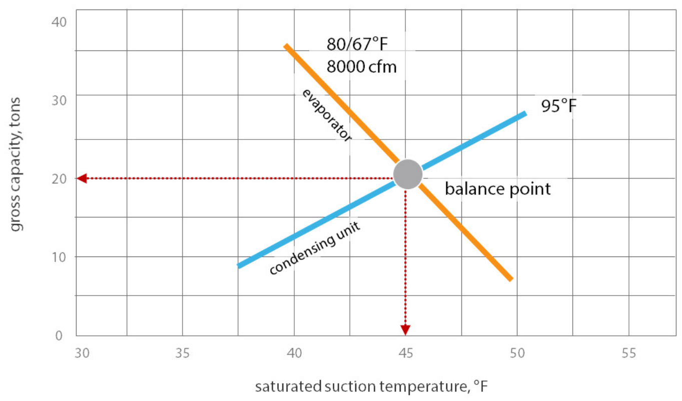


Figure 4. Suction line loss of 2°F SST

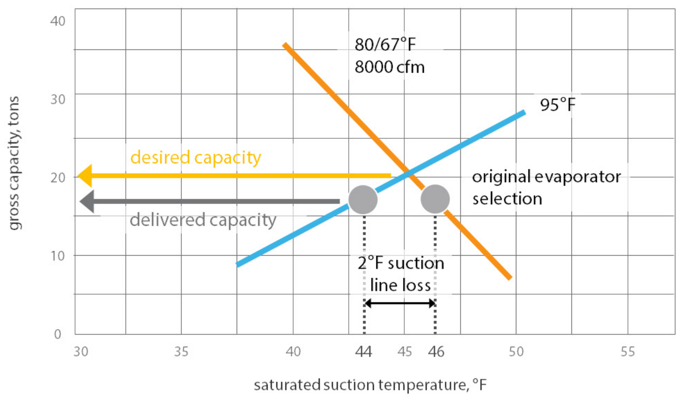
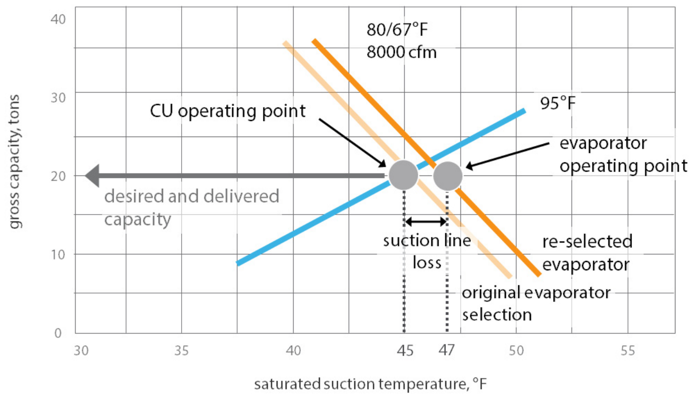


Figure 5. Evaporator and condensing unit operating points



Cross Plotting or Balance Point Performance

Cross plotting is simply superimposing a coil curve on a condensing unit curve. The purpose of cross plotting a system is to draw a visual representation and to understand how the system will operate and respond with changing conditions—which will be discussed later. The intersection of the evaporator and condensing unit curves is the balance point of the system. In Figure 3 the coil curve from Figure 2 is overlaid on the condensing unit curve from Figure 1. At 45°F SST, 95°F ambient, the system will deliver 20 tons of capacity.

But will it? This is the time to introduce a bit of complexity into the process of evaporator coil selection; specifically, the SST loss that occurs because of the pressure drop of the suction line. To cause the refrigerant vapor to flow from the evaporator to the condensing unit, there must be a lower pressure at the compressor than at the evaporator. This slight drop in pressure must be accounted for during evaporator selection in order to achieve the proper system performance. If this pressure difference is not accounted for while selecting an evaporator coil, the system will operate at lesser capacity than intended. In Figure 4, an unaccounted 2°F SST loss in the suction line shows roughly a two-ton loss in the delivered capacity.

Suction line loss MUST be taken into account in order to obtain true system performance.

Therefore, in order to deliver the desired capacity, the designer must select the evaporator at the same capacity as the condensing unit, but at a suction that is equal to the condensing unit suction plus the suction line loss. When the coil is re-selected at this higher SST that accounts for this suction line loss, and the new coil curve is cross plotted, it is shown that the evaporator operates 2°F SST higher than does the condensing unit SST and at the desired capacity (Figure 5). These are the operating points of the evaporator and condensing unit.

The evaporator MUST be selected at a SST higher than the condensing unit in order to make up for the suction line loss and to maintain the desired capacity. Historically, the HVAC industry has used a rule of thumb for suction line pressure loss of 2°F. However, it is advisable that the designer calculate a more accurate number for final design.

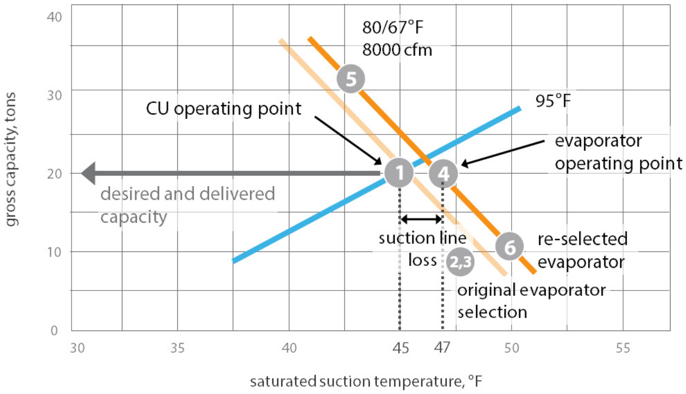
Evaporator coil SST= condensing unit SST + SST loss of suction line

Creating a Coil Curve

Now that we understand the benefit of coil curves, let's walk through the process of how to create them. A visual representation of each step can be seen in Figure 6.

1. Using the condensing unit curve, determine the required SST for the desired capacity at the design ambient temperature. This is the balance point. This will also be the final condensing unit operating point. Plot this point on the condensing unit curves.
2. Determine the SST loss of the suction line.
3. Add the SST loss of the suction line from Step 2 to the SST determined in Step 1.
4. Select a coil at the MBH from Step 1 and the SST from Step 3 using the required CFM, DBT, and WBT. Plot this point on the condensing unit curves.
5. Keeping the coil and air conditions fixed (meaning that the coil geometry and air conditions do not change from those selected in Step 4), re-run the coil performance at an arbitrary SST. Plot this new MBH and SST on the condensing unit curves.
6. Draw a straight line between and past the point plotted in Steps 5 and 4 which creates the coil curve.

Figure 6. Creating a coil curve

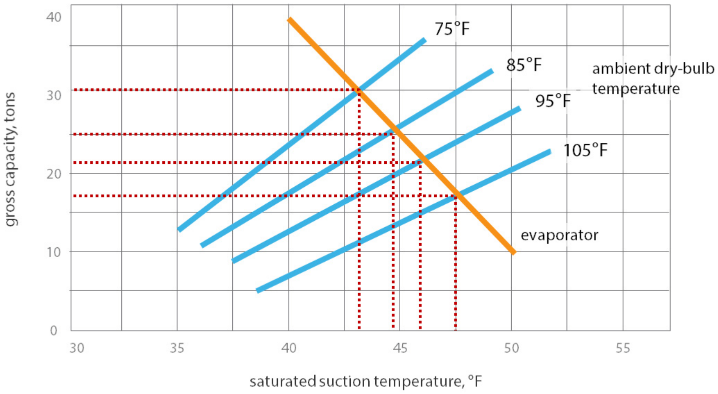


Visualizing how the Condensing Unit and Coil Operate

The next step after generating the coil curve and plotting it against a condensing unit curve(s) is to determine how to visualize the system response to changing situations.

Changes in Ambient Temperature. Figure 1 which shows the condensing unit capacity vs SST with respect to the ambient temperature has been reproduced in Figure 7. The coil curve previously shown in Figure 6 is plotted upon the condensing unit curves. The combination of these curves illustrate that if the airflow and entering-air conditions (DBT and WBT) remain the same, then as the ambient temperature drops the SST will also drop and the system capacity will increase.

Figure 7. System response due to changing conditions



The Effect of Coil Size on Operating Conditions. Rational thought would dictate that larger evaporator coils are able to produce more capacity; and indeed that is the case. Larger evaporator coils can handle more refrigerant than smaller coils, given the same airside conditions. Because of this, the larger coil will be able to produce a higher SST, and a higher condensing unit capacity. Figure 8 illustrates how the balance point of two differing coils changes from 45°F SST (point 1) to 42°F SST (point 2) as the size of the coil decreases from 21 ft^2 to 17 ft^2.

Effect of Airflow Changes. Virtually every system will experience changes in airflow if for no other reason than air-filter loading. These changes can be subtle, or dramatic as in a VAV (Variable Air Volume) system. With reduced airflow the system heat transfer also reduces resulting in a lower SST (Figure 9).

Effect of Changes in Mixed-Air Temperature. In a similar fashion and rational to cfm vs performance, if the mixed-air temperature entering the evaporator coil is reduced, the heat transfer will also be reduced, in turn, lowering the SST and the system capacity as shown in Figure 10.

Effect of Unloading a Compressor Circuit. Many systems include circuits designed to unload system capacity to match the changing load. This reduction in capacity is achieved by sequentially turning off compressors in a manifold set, by unloading an unloading compressor, or by reducing the compressor rpm. Use of these unloading methods increases the SST of the system while reducing capacity. Figure 11 shows this effect from 100 percent capacity at design conditions (point 1) to 25 percent capacity (point 4).

Figure 8. Coil size effect on operating conditions

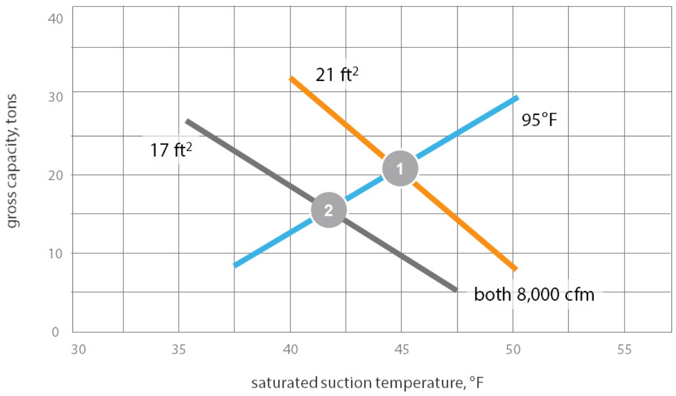


Figure 9. Effect of reduced airflow on the system

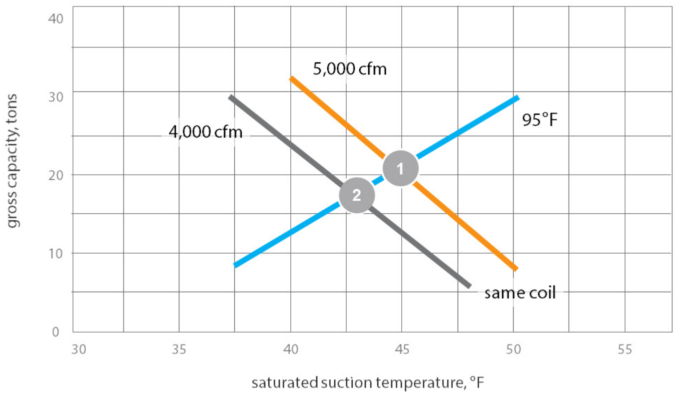


Figure 10. Effect of change in mixed-air temperature

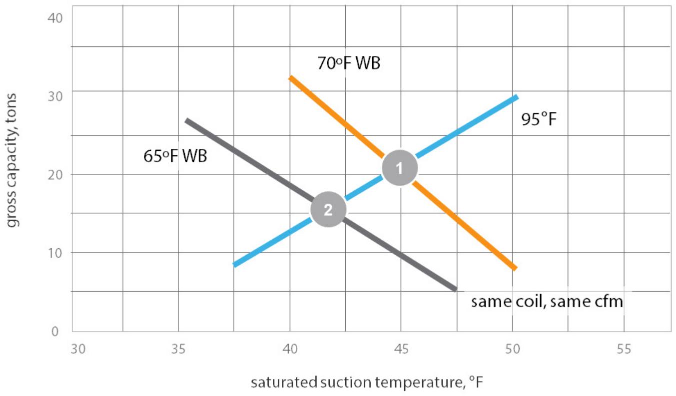
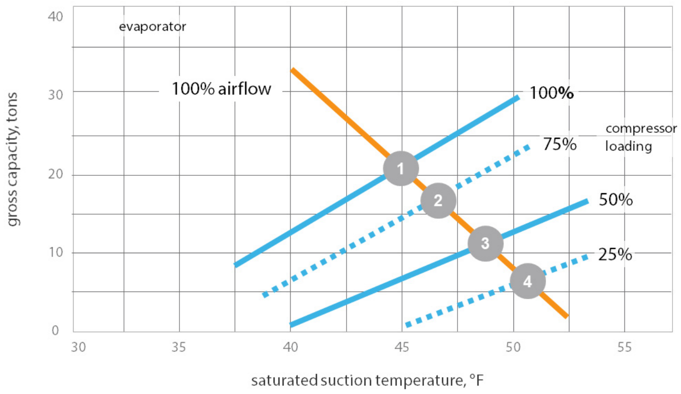


Figure 11. System as the compressor unloads



Selecting a replacement coil or condensing unit only

In some cases, it may occur that only the DX evaporator coil or condensing unit will need replacement. If this is the case, it may be acceptable to change like-for-like if there are no reliability or comfort issues present. However, problems may arise if product descriptions are incorrect or incomplete. This is where the importance of a cross plot comes into play. In retrofit situations, the author recommends that a cross plot is developed to demonstrate the operational parameters as accurately as possible.

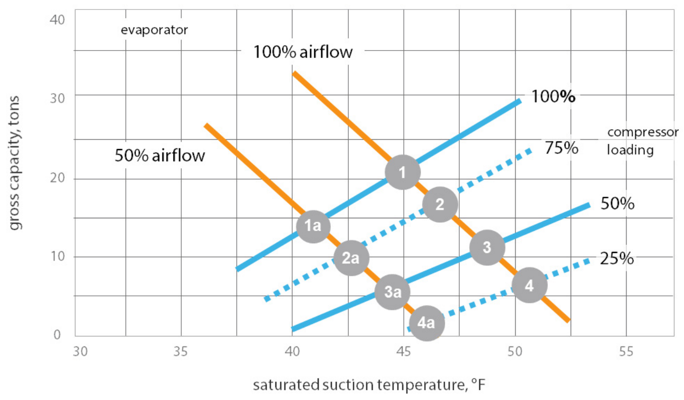
1. Start by requesting the original submittal and condensing unit catalog
2. Plot the coil performance on the condensing unit curve. This may require using a coil performance program to obtain the two points required to plot the curve.

If the submittal does not exist, a coil curve will need to be created through input of the coil geometry, cfm, and mixed air conditions into a coil performance program. The old condensing unit catalog should be attainable through the condensing unit manufacturer. A search of old balance reports and service records may provide information on cfm and mixed air conditions.

Questions to consider...

- Have there been reliability or comfort problems?
- Can I obtain the original coil submittal sheet?
- Does a load analysis exist?
- Does a system log exist through a service company?

Figure 12. System operation as both the load changes and the compressor unloads



Combining Condensing Unit and DX Evaporator Operation. The changing parameters discussed throughout this EN will most likely occur simultaneously and their dynamic effects on the DX system are cumulative. It is virtually impossible to pinpoint the exact operating conditions they will lead to; however, it is essential to attempt to understand what plausible operating conditions may occur. Figure 12 shows the simultaneous results of both lowering the airflow and unloading the compressor. Note that as the compressor unloads, the SST rises and capacity reduces, and as the CFM reduces, both SST and capacity reduce. One can make an engineering prediction of a plausible operating point.

Conclusion

Proper selection of DX evaporator coils is critical in order to avoid system shutdown or compressor failure. It is important to understand the interaction between the condensing unit and evaporator and to understand how slight design changes can affect the operation of the system. Cross plotting is the vital tool that HVAC designers should consider utilizing in order to create a visual representation of the operation of the system as temperature or airflow change on the evaporator coil, or compressor loading or ambient changes on the condensing unit.

By Paul Solberg, Trane. To subscribe or view previous issues of the *Engineers Newsletter* visit trane.com/EN. Send comments to ENL@trane.com.

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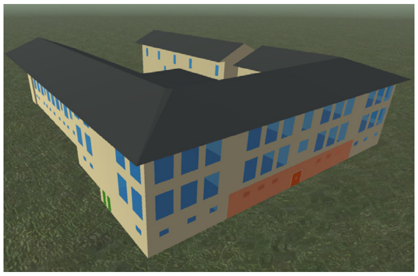

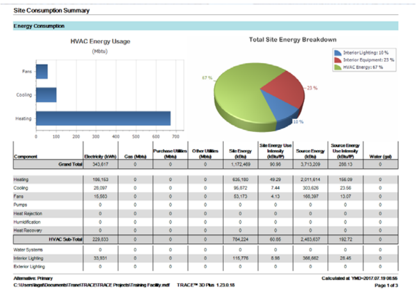
Site Consumption Summary

Energy Consumption

Component	Electricity (kWh)	Gas (Mbtu)	Purchase Utilities (Mbtu)	Other Utilities (Mbtu)	Site Energy (kBtu)	Site Energy Use Intensity (kBtu/ft²)	Source Energy (kBtu)	Source Energy Use Intensity (kBtu/ft²)	Water (gal)
Grand Total	343,617	0	0	0	1,172,469	90.98	3,713,209	288.13	0
Heating	186,153	0	0	0	635,180	49.29	2,011,614	156.09	0
Cooling	28,097	0	0	0	95,872	7.44	303,626	23.56	0
Fans	15,583	0	0	0	53,173	4.13	168,397	13.07	0
Pumps	0	0	0	0	0	0	0	0	0
Heat Rejection	0	0	0	0	0	0	0	0	0
Humidification	0	0	0	0	0	0	0	0	0
Heat Recovery	0	0	0	0	0	0	0	0	0
HVAC Sub-Total	229,833	0	0	0	784,224	60.85	2,483,637	192.72	0
Water Systems	0	0	0	0	0	0	0	0	0
Interior Lighting	33,931	0	0	0	115,776	8.98	366,662	28.45	0
Exterior Lighting	0	0	0	0	0	0	0	0	0

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Page 1 of 3

TRACE 3D Plus has been completely redesigned with updated building drawing tools and capabilities, while significantly improving the performance/scaling of the application. This update will allow you to create robust real-world building models much faster and with fewer errors or hassles than previous versions.

Some other features you will find in the update include:

- Ability to model rooms that span multiple floors
- Ability to model CoolSense systems
- Ability to model complex roofing systems
- New snapping tools to make it easier to identify what you are snapping to
- New window array
- and skylight capabilities
- Ability to import gbXML ("How to and Limitations" document will be included)
- New data visualization variables and features
- Ability to simulate models in the cloud

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Mark your calendar!

Impact of DOAS Dew Point on Space Humidity (March) Dedicated outdoor-air systems (DOAS) are used in a variety of building types to provide ventilation; and when the outdoor air is dehumidified, a DOAS can help prevent high space humidity levels. But many of the systems designed and installed today are not dehumidifying adequately. This ENL will demonstrate how space humidity levels are affected by the DOAS discharge-air conditions, at both full load and part load.

Indoor Agriculture: HVAC System Design Considerations (May). Growing plants indoors is growing in popularity, but conditioning spaces for plants instead of humans introduces new challenges. This ENL will discuss plants, the dehumidification challenges they pose, and how precision cooling for indoor agriculture differs compared to comfort cooling.

Electrification (October). Many municipalities throughout the United States are taking action to reduce their carbon emissions. One of the tactics they are using that effects the HVAC industry is the reduction, or removal, of natural gas for heating. This ENL will cover the motivation to electrify, areas currently effected by this trend, and potential systems to meet electrification needs.

Demystifying VRF Systems (November). This program, builds upon the 2014 broadcast "Applying Variable Refrigerant Flow" with detailed discussions around several considerations. Topics will include: when to use heat recovery instead of heat pump configurations, how to apply VRF with traditional ducted systems, system and sizing considerations for both hot and cold climates, ventilation delivery, and more.

Contact your local Trane office for dates and details.

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