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The DX Refrigerant Cooling Coil Conundrum

Q: What is the "best" kind of coil for DX/VAV system applications?

A: It depends.

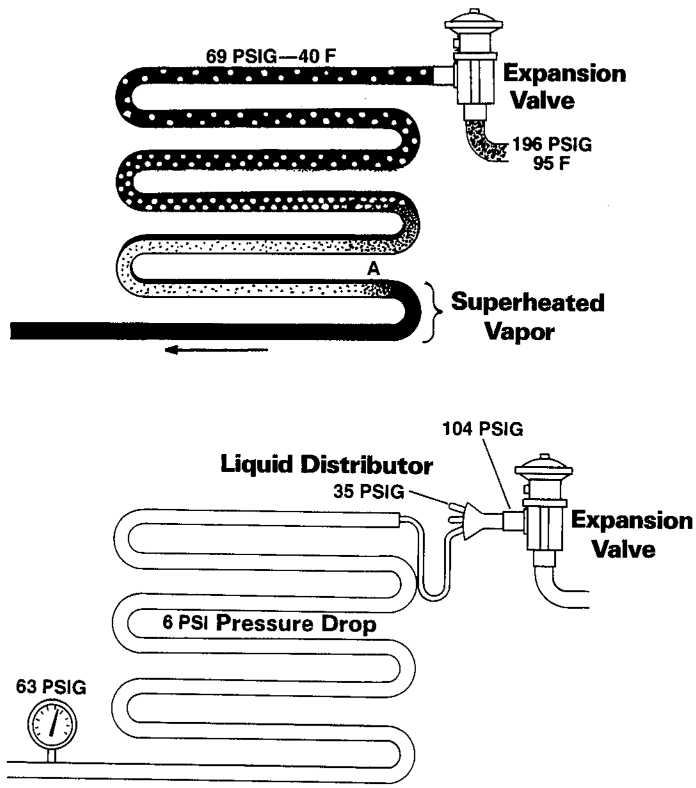

Figure 1: Refrigerant Cooling Coils

Review

Let's back up and revisit the basics of refrigerant coil construction. As seen in Figure 1, refrigerant cooling coils are arranged so that (subcooled) liquid refrigerant enters a thermal expansion valve and subsequently experiences a substantial drop in pressure. This causes some liquid to flash into gas in order to reach thermal equilibrium with the newly reduced pressure.

Thus, a mixture of mostly liquid and some gas enters the distributor. Here, additional pressure loss occurs. Refrigerant is then distributed to several coil tube paths. Conceptually, each path has the same pressure drop, thus equalizing the amount of refrigerant allocated to each tube path.

Conditioned air passed across the outside coil surface warms the tubes and causes liquid refrigerant to evaporate into a gas. After all the liquid has been evaporated, additional coil surface is devoted to superheating the gas beyond its saturation temperature. Superheating is necessary to assure completely dry gas entering the compressor suction. In order to accomplish superheating, several things must happen:

1
The coil must have sufficient surface to act as a superheater.

2
The thermal expansion valve must let only that amount of liquid into the coil that can be evaporated and superheated.

3
The airflow past the coil must be sufficiently warm to provide superheat.

4
The portion of the coil assigned to superheating should be in contact with the warmest conditioned air.

Clearly, these criteria present real challenges to equipment and system designers alike. It is particularly difficult to balance these criteria in VAV applications.

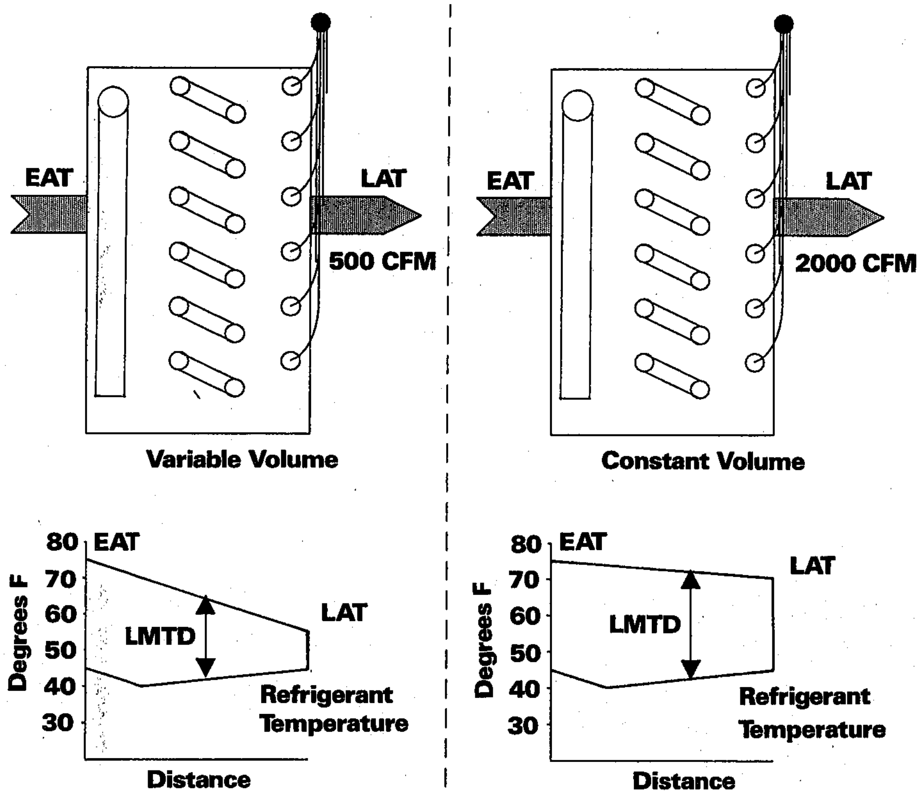

Figure 2: Part-Load (25%) Conditions

Why are VAV systems more temperamental when it comes to controlling superheat? Simply stated, VAV systems do not "load" the air side of the cooling coil in a constant way. As air flow changes, the ability of the passing air to transfer heat is significantly altered. Figure 2 compares the heat transfer characteristics of constant flow and variable flow processes.

While the surface area of both processes is (and remains) the same, the driving thermal force (log mean temperature difference) does not. It changes dramatically. In addition, VAV systems maintain a nearly constant supply air temperature. Air leaving the coil has very little ability to superheat refrigerant because of its low temperature. Special consideration must be given to coil construction in order to obtain adequate superheat.

On VAV systems, one of the most common symptoms of inadequate superheat is unexplained and repeated compressor failures. Often the cause can be traced to improperly applied or circuited expansion coils.

Coil Arrangements

Three basic arrangements are common:

1

Horizontal, or face split. Figure 3 shows this configuration. The coil bank consists of the equivalent two or more cooling coils. They are generally equal in size and capacity, and may be built in a common casing. Each section delivers the same leaving air conditions at design load. Individual sections may be connected to separate liquid line solenoid valves, or to completely separate compressors.

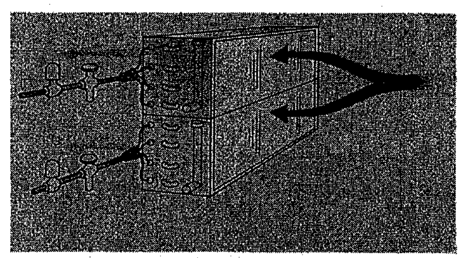

Figure 3: Horizontal Split

Part load conditions are accommodated by turning off individual sections as compressors are unloaded or cycled off. Clearly, air passing through an inactive section is unconditioned. It is mixed with air passing through active sections to arrive at the "average" leaving air condition. In order to maintain a constant supply air temperature, active sections must supply colder air than the average mixture temperature. Consequently, the refrigerant must be colder. Eventually, the coil temperature will need to be so cold that its surface may reach the point of frost accumulation.

With a constant air flow system, this is not a big problem because the average mixture temperature needs to rise at part load. Thus, the active sections of the coil do not need to produce such low temperature air. Coil frosting does not generally occur.

With VAV systems, the situation is quite different. Since the leaving air temperature is held constant, active coil sections are required to produce significantly colder air at part load. Coil frosting, and all the problems that accompany it, can occur.

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2
Vertical, or row split. Figure 4 shows this arrangement. Although the coil is actually built on a single casing, it functions as if it were actually two coils placed in (air flow) series with each other. This configuration obviously solves the mixing problem previously described. But, two other difficulties evolve.

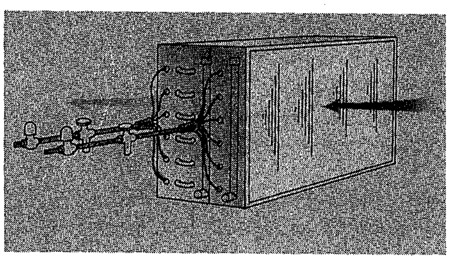

Figure 4: Row Split

The first appears as a capacity mismatch. Since the design load entering air conditions to each coil section are different from each other, it is nearly impossible to select a coil to provide exactly the same compressor load. If the sections were actually two different coils, this could be accomplished by using different fin series for each coil. Since they are not, the fin series must be the same for both sections.

The second problem concerns the performance of one coil section at part load conditions. Vertical splitting provides fewer rows in each section. Thus the active section, usually the downstream coil, may have difficulty providing adequate depth for complete dehumidification. Consequently, latent cooling performance suffers. In order to achieve the correct supply air temperature, refrigerant temperature must be lowered. Again, we find ourselves facing a potential coil frosting problem.

Additionally, the shallow coil has very little surface for superheating. This coil may be only one or two rows deep. It is not possible to circuit a coil so that part of a row generates superheat, while the other part is performing cooling through refrigerant evaporation. As a result, inadequate superheating surface causes the thermal expansion valve to become unstable, and compressors suffer.

3
Intertwined Circuits. Figure 5 shows a coil built with intertwined refrigerant circuits. The entire coil surface is active at all times. But at part load, one of the two refrigerant circuits is closed off by a liquid solenoid valve. The remaining active circuit keeps the entire fin surface cold, thus providing adequate coil depth for superheating and adequate surface area to compensate for the lower airside heat transfer rates.

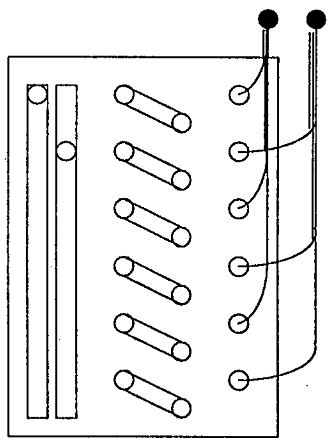

Figure 5: Intertwined Circuits

A Better Way
Intertwined coils have been used for some time on large unitary rooftop air conditioners made especially for VAV applications. A "split system" is nothing more than the same unit split in half, one half staying on the roof and the other half moved indoors into a central station air handler. There is good reason to design the "halves" in the same way they are designed in unitary equipment; i.e., with intertwined evaporator coils.

Intertwined coils meet each of the four essentials enumerated earlier:

1
Since the entire fin surface of the coil is always active, sufficient surface area is in contact with the passing conditioned air. No air bypasses the active coil surface.
2
Two separate and complete circuits are intertwined. Each circuit is equipped with a thermal expansion valve and refrigerant distributor. Consequently, capacity modulation of a single circuit easily accommodates low load conditions with full expansion valve stability.
3
The full coil surface is active and exposed to conditioned air. Thus, portions of the coil surface are exposed to warm air and can provide superheat.
4
The portion of the coil that encounters entering air is devoted to superheating refrigerant. Since there are several rows of tubes in each intertwined circuit, adequate superheating area can be assigned as a single entering air row of tubes.

Often, the "best" kind of coil for DX/VAV system applications turns out to be an intertwined circuit coil. Leaving air temperature control is better. Humidity control is better. The potential for coil frosting is dramatically reduced. Compressor integrity is enhanced. ●