ACHIEVING ENERGY-EFFICIENT DATA CENTER COOLING: DOES REDUCING FAN SPEED ALWAYS RESULT IN ENERGY SAVINGS?

Introduction

Energy efficiency is a top criterion when selecting a data center precision cooling system, but determining the actual energy efficiency of cooling units is not a simple matter. On the surface, it may seem logical to believe that reducing the fan speed on a direct expansion (DX) precision cooling unit will save energy. Indeed, as fan speed is reduced, the motor power reduces by a cube relationship. For example, a 20 percent reduction in air volume results in an approximate 50 percent power reduction of the fan motor.

But that is only part of the story. This technical note demonstrates that overall efficiency suffers when fan speed is reduced on fixed scroll cooling systems. In addition, the risk of coil freeze and wasteful rehumidification are increased.

Energy Efficiency is Reduced At Lower Air Volumes

Figure 1 shows that energy efficiency (coefficient of performance) goes down as the air volume is reduced. Coefficient of performance is the cooling capacity per energy input (expressed as Watts of sensible cooling per Watts of electrical power input). The reason for this is that the cooling capacity diminishes at a faster rate than the reduction in energy.

Compressor On-time Increases at Lower Air Volumes, Increasing Energy Consumption

Because reducing the air volume reduces the cooling capacity, for a given cooling load the compressors must stay on longer in order to meet the load. For example, Figure 2 shows the impact on energy consumption resulting from a 70 percent reduction in fan speed. Note that the full-load (100 percent fan speed) sensible capacity is 199.8 kBTUH, while the sensible capacity at 70 percent fan speed is 162.2 kBTUH. In both cases the compressor power is about the same, 20.4 kW versus 20.1 kW.

However, as a result of reducing the cooling capacity, for the same cooling load (140 kW for this example), the compressor stays on longer to meet the load: 70.1 percent operation for full air volume versus 86.3 percent operation for 70 percent air volume, as shown in Figure 2.

Reducing air volume on a fixed capacity compressor increases latent cooling capacity and increases the risk of coil freeze. Digital scroll compressors do not carry that risk.

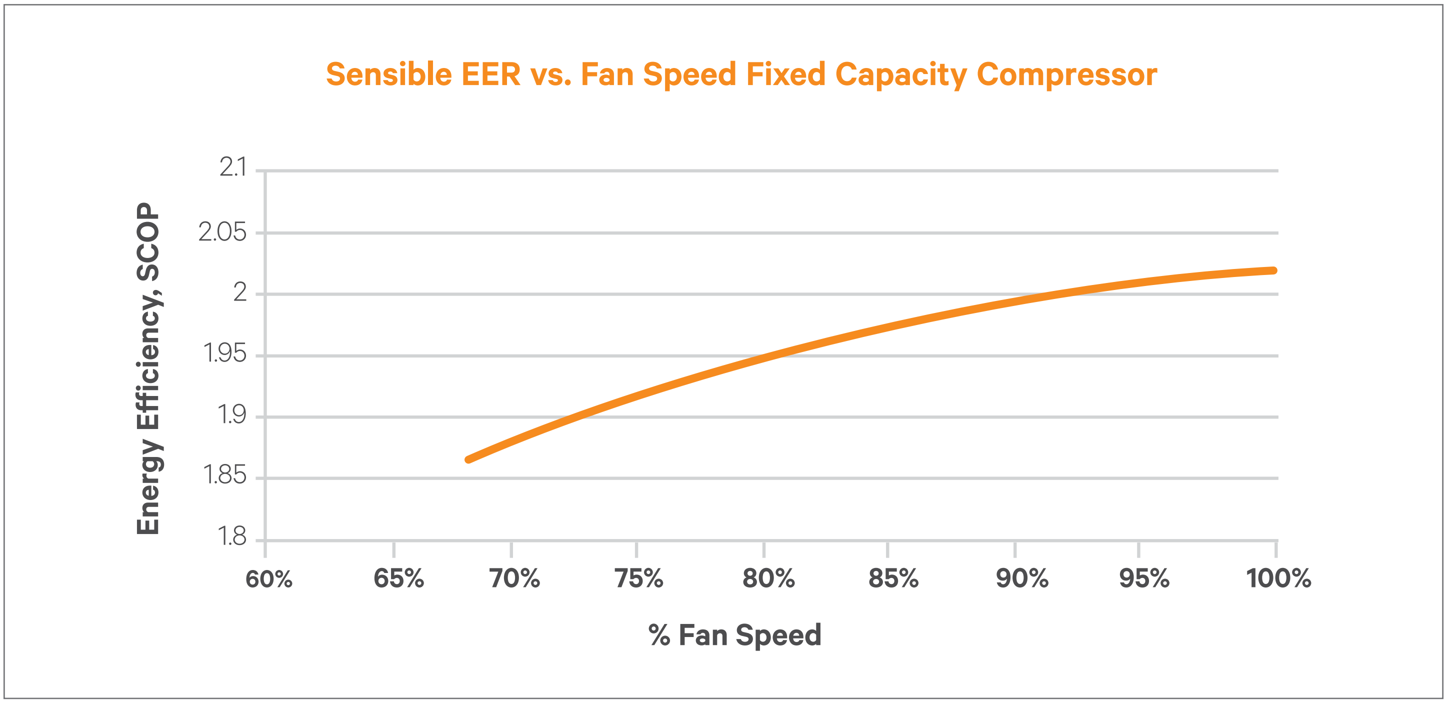

Figure 1: *As fan speed is reduced on a fixed capacity compressor, so is energy efficiency.*

The result is that over a period of one year, the compressor operation increases from 125,271 kWh to 151,954 kWh, a 21 percent increase in compressor energy consumption.

As predicted, the fan energy was lowered from 4.1 kW to 1.5 kW – a 63 percent reduction in energy consumption.

Reducing Fan Speed Alone Does Not Reduce Energy Consumption

	100% FAN SPEED	70% FAN SPEED
Sensible Load, kBTUH	140.0	140.0
Sensible Capacity	199.8	162.2
Compressor kW	20.4	20.1
% Compressor Operation	70.1	86.3
Compressor kWh	125,271	151,954
Fan kW	4.4	1.5
Fan kWh	38,544	13,140
Sum kWh	163,815	165,094

Figure 2: *Reducing fan speed results in lower sensible capacity, causing longer compressor on-time, here representing a 21% increase in compressor energy consumption over one year.*

However, since the compressor energy makes up most of the energy consumption, the reduction in fan power is more than offset by the increase in compressor energy. The reduced air volume case actually results in a 1 percent increase in system energy consumption – in effect a tie.

Another challenge to efficiency resulting from reducing air volume on a fixed capacity compressor is that the latent cooling capacity increases. Latent cooling capacity is the amount of moisture removed from the air. In this case, a 20 percent reduction in air volume causes the latent cooling capacity to double from 20 kBTUH to 40 kBTUH.

Over- dehumidification results in even more energy consumption by rehumidifying. Conversely, using Digital Scroll compressors mitigates this problem. Digital scroll compressors modulate as the air volume is decreased. Because the average refrig-erant flow is reduced, the evaporator coil runs warmer, reducing the latent capacity. (See figure 3.)

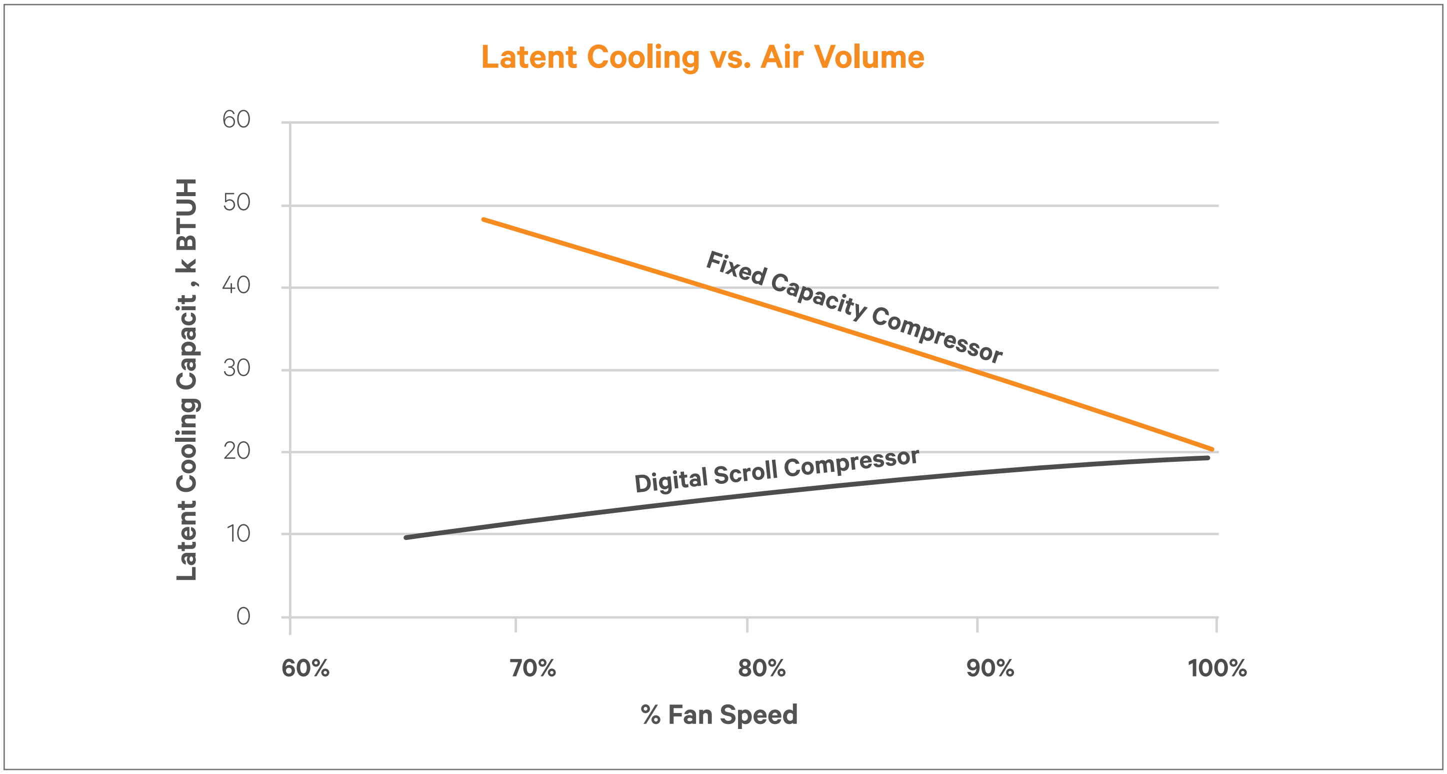

Figure 3: *Digital scroll compressors reduce the need for rehumidification when the fan operates at lower speeds.*

When air volume is decreased, the cooling coil temperature also decreases, causing a risk of coil freeze, as Figure 4 illustrates. The risk of coil freezing is higher if certain conditions occur simultaneously: low air volume, high wetbulb temperature and low condensing temperature.

By contrast, when a digital scroll compressor is used and modulates as air volume decreases, the evaporator temperature actually increases compared to a fixed scroll compressor. When the digital scroll modulates to reduce cooling capacity, the refrigerant flow rate is reduced, resulting in a higher evaporator temperature than when at full flow.

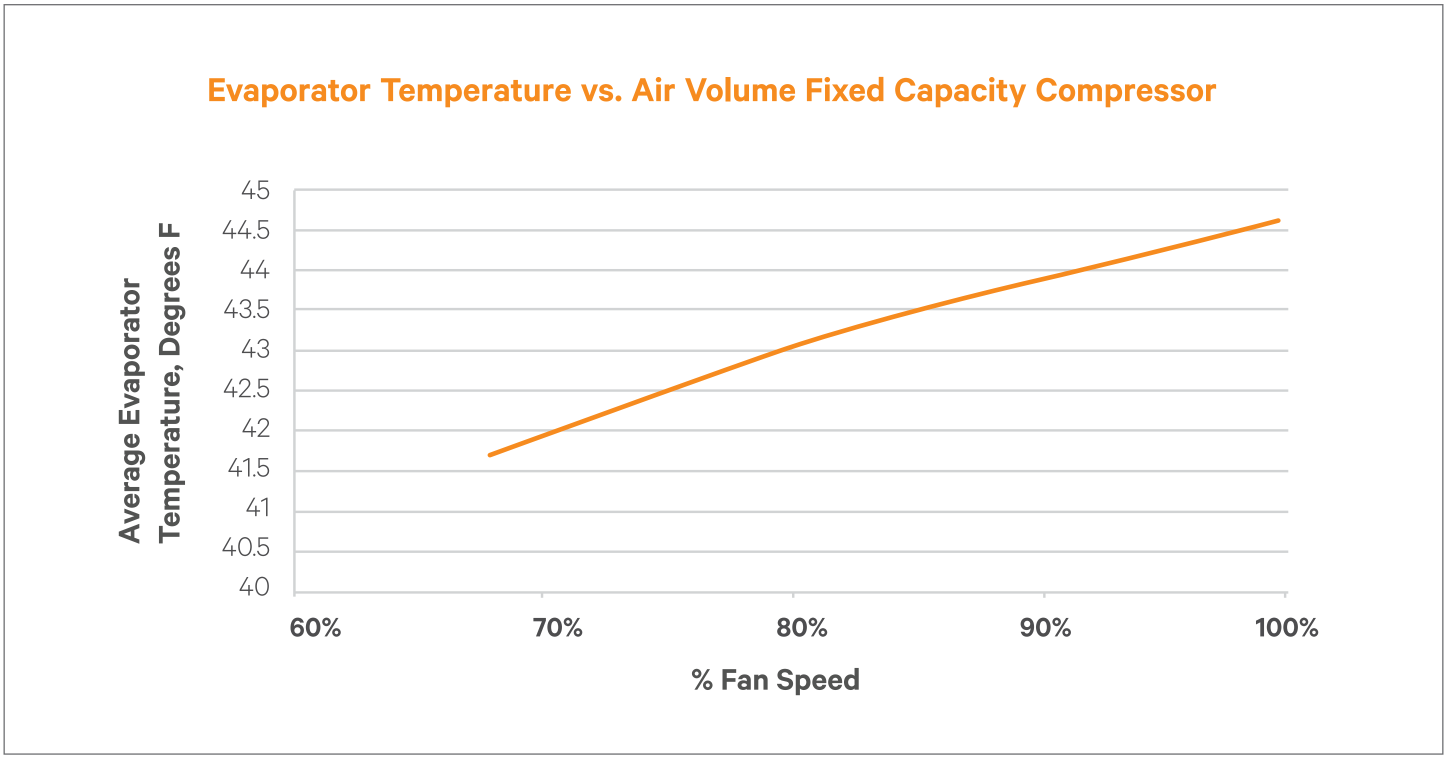

Figure 4: *Lower air volume and lower evaporator temperature increase the risk of coil freeze in fixed compressor systems.*

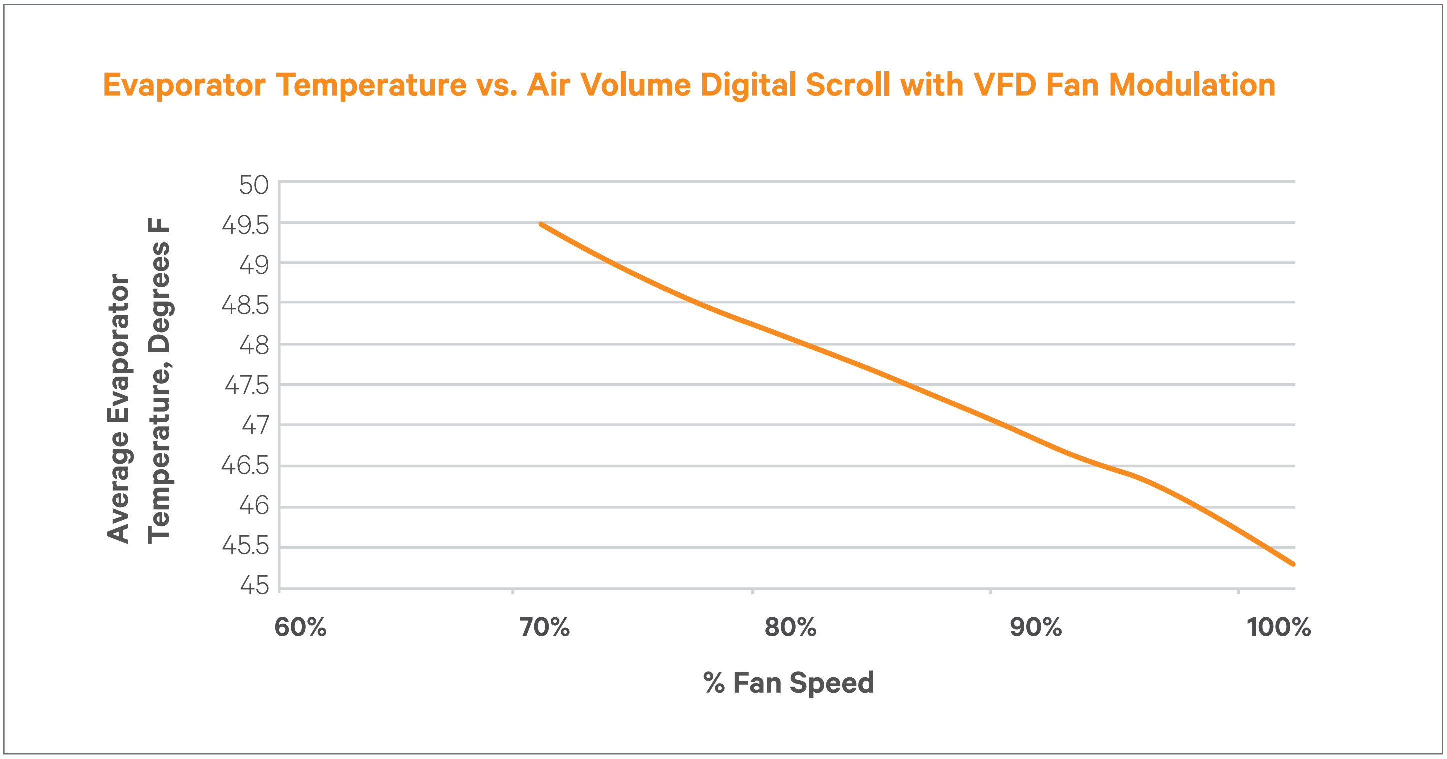

Figure 5: *A digital scroll compressor's modulation lowers refrigerant flow rate, producing a higher evaporator temperature.*

Conclusion

Lowering fan speed does not necessarily improve the energy efficiency of a DX cooling system. In fact, overall efficiency suffers when fan speed is reduced on fixed scroll cooling systems, and the risk of coil freeze and wasteful rehumidification are increased. Choosing a cooling system that utilizes digital scroll compressors that finely modulate fan speed and temperature depending on room conditions overcomes the inefficiencies and risks of fixed capacity compressor operation.

To see how much energy you can save by using digital scroll compressors, available only on Liebert® cooling systems from Vertiv™, visit **Liebert.com** and click Efficiency Without Compromise.

VERTIV™

TN-00012 (R05/11)