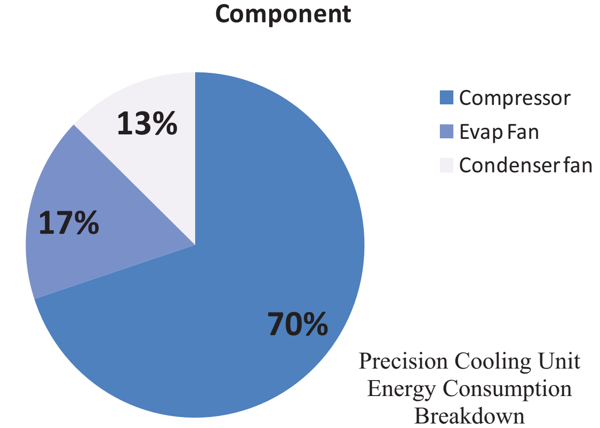
Tech Byte 26: Maximizing the Energy Conservation Benefit of Fan Speed Reduction in Precision Cooling Systems

Precision Cooling Systems Design For Maximum Operating Efficiency And Performance

A U.S. Environmental Protection Agency survey released in 2007 concluded that IT data centers consumed 61 billion kW of electricity at a total cost of $4.5 billion in 2006. As energy costs continue to rise, energy conservation has become a top-of-mind issue for data center management.



Precision Cooling Unit Energy Consumption Breakdown

Because of this, data center cooling systems are a primary target for energy efficiency improvements. An Emerson Network Power analysis of data center energy usage found that cooling systems - comprised of cooling and air movement equipment - can account for nearly 38 percent of energy consumption. Of this energy consumption, the bulk of the energy is consumed by the compressors - 70% of the total energy consumption. Second is the evaporator fan, which over the past couple of years has been receiving a high level of attention in an attempt to increase computer room cooling efficiency. Varying the speed on fans can have a significant effect in reducing energy consumption. As fan speed is reduced, the fan 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.

However, for precision cooling systems, we must consider the **complete system** efficiency performance when we integrate technology that impacts the way the system operates. This analysis is often lost in the variable fan speed discussion. In order to achieve the highest operational performance and maximize the operational energy efficiency, we must consider a couple key points: First, the precision cooling system's compressors are significantly larger consumers of energy and are often overlooked as a energy efficiency improvement opportunity. Second, cooling capacity modulation (variable capacity compressors) is a necessary ingredient to achieve significant ***system-level*** energy efficiency improvement because of how varying the fan speed can affect ***system-level performance*** without capacity modulation. This is the main focus of this technical paper.

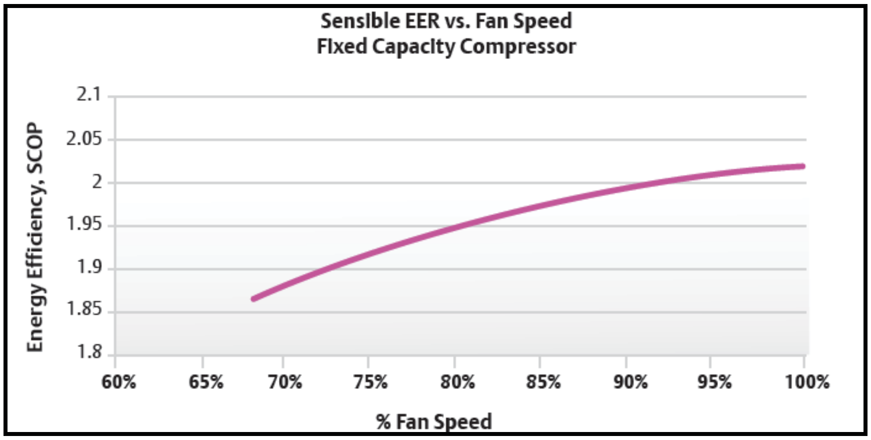


Figure 1: As fan speed is reduced on a fixed-capacity compressorized AC unit, energy efficiency decreases as well

Many components within the AC system must operate together to perform the ***precision*** cooling process, in order to meet the needs of a space with varying environmental needs. On the surface, it may seem logical to believe that increasing the efficiency of one of these individual components, such as reducing the evaporator fan speed, will save on system energy consumption. However, this is not necessarily the case. This tech byte demonstrates that overall ***system*** efficiency may ***not*** increase when fan speed is reduced on AC systems that do not have the ability to also modulate ***cooling capacity.*** For DX systems, that means to vary the capacity of the system compressors. In addition, the risk of coil freeze and wasteful re-humidification are increased.

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Figure 1 on the previous page shows that energy efficiency (SCOP - coefficient of performance) goes down as the air volume is reduced for AC units without compressor capacity modulation capability. The 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.

> ***"...the reduction in fan power is more than offset by the increase in compressor energy...This reduced air volume case actually results in a 1% increase in energy consumption—in effect a tie..."***

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, increasing compressor on-time.

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 need. For example, Figure 2 shows the impact on energy consumption resulting from a 30 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 requirement: 70.1 percent operation for full air volume versus 86.3 percent operation for 70 percent air volume, as shown in Figure 2. 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. 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.

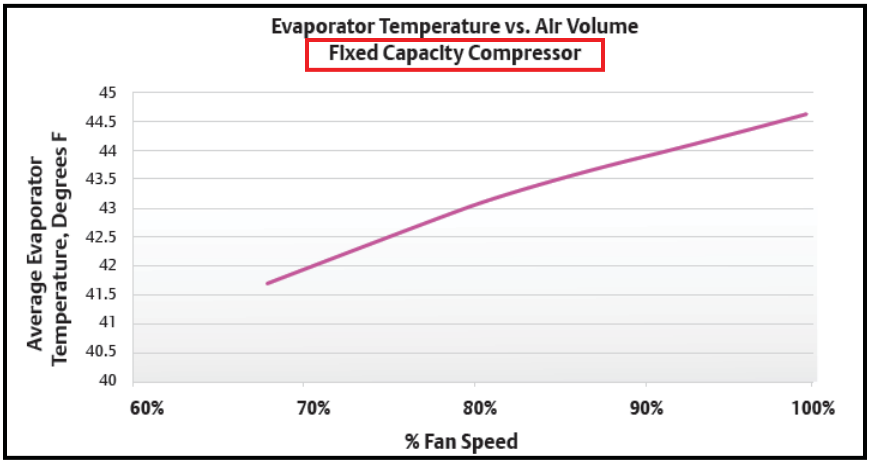

Figure 3: Lower air volume and decreased evaporator temperature result in increased coil freezing potential in fixed compressor systems.

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How to Maximize Energy Efficiency in Precision Cooling Systems

Lastly, another concern in this case is coil freezing. 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. See figure 3.

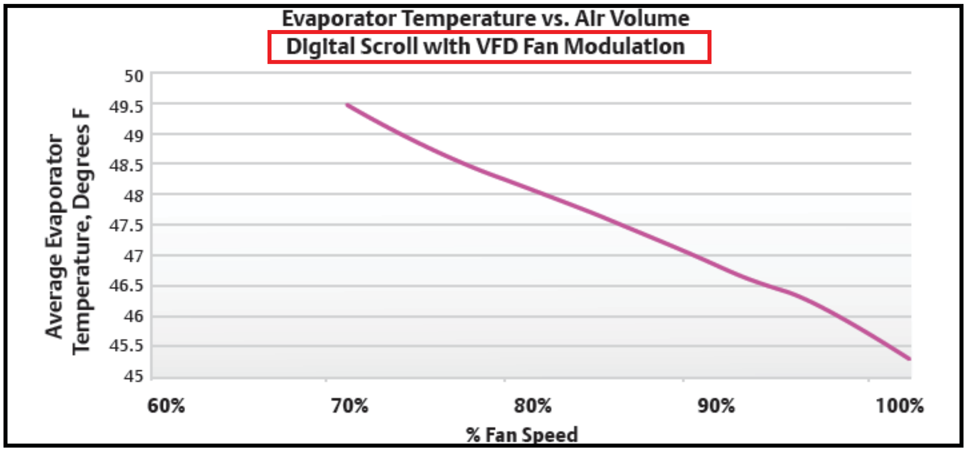

Figure 4: A Digital Scroll compressor's modulation lowers refrigerant flow rate, producing a higher evaporator temperature.

In order to achieve the higher energy efficiency performance out of precision cooling systems, it is necessary to ensure that all internal components work efficiently together. To obtain the efficiency gains of varying the evaporator fan speed, we likewise must provide the system the ability to vary the evaporator coil temperature. This is accomplished by utilizing capacity modulating compressors in DX systems. Liebert systems incorporate the Digital Scroll compressor in order to achieve capacity modulation.

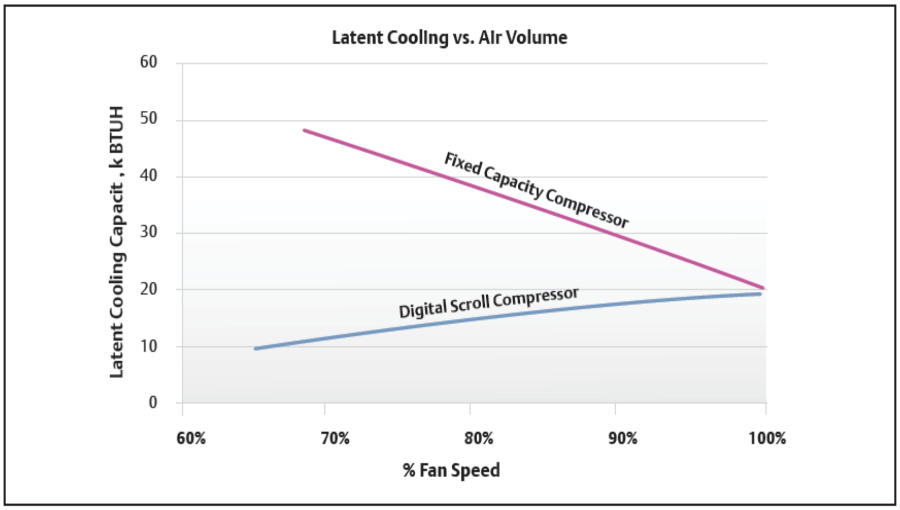

Figure 5: Digital Scroll compressors reduce the need for rehumidification when the fan operates at a lower speed.

When variable speed fan technology is utilized in conjunction with the Digital Scroll, the Digital Scroll can "unload" as the air volume is decreased in response to room conditions. Because the average refrigerant flow is then reduced, the evaporator coil runs warmer, reducing the latent capacity. This maintains a high sensible cooling ratio, limits excessive re-humidification need, and prevents coil freeze potential. See figures 4 and 5..

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.

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The "Smart" Solution

The Liebert approach to achieving performance and efficiency focused datacenter cooling is called SmartAisle control. This strategy includes a combination of high performance component technologies optimized with multi-location environment sensing for system level controlling. This allows for maximizing energy efficiency potential, and also ensuring the highest level of cooling performance.

For cooling capacity control, Liebert utilizes Digital Scroll Compressors. The Digital Scroll allows for closely matching colling unit capacity with part load conditions in the space. Supply sensors under the raise floor communicate to the system controller, which in turn sets a duty cycle for the Digital Scroll compressor. It then ramps up or down accordingly, maintaining an appropriate evaporator temperature to optimize sensible cooling capacity.

For precise humidity control, the Liebert system maintains a humidity sensor in the return path of air flow. This gives the unit an accurate humidity reading of the space being controlled, so that the unit can accurately supplement with its on-board humidifier, or else engage dehumidification. See figure 6.

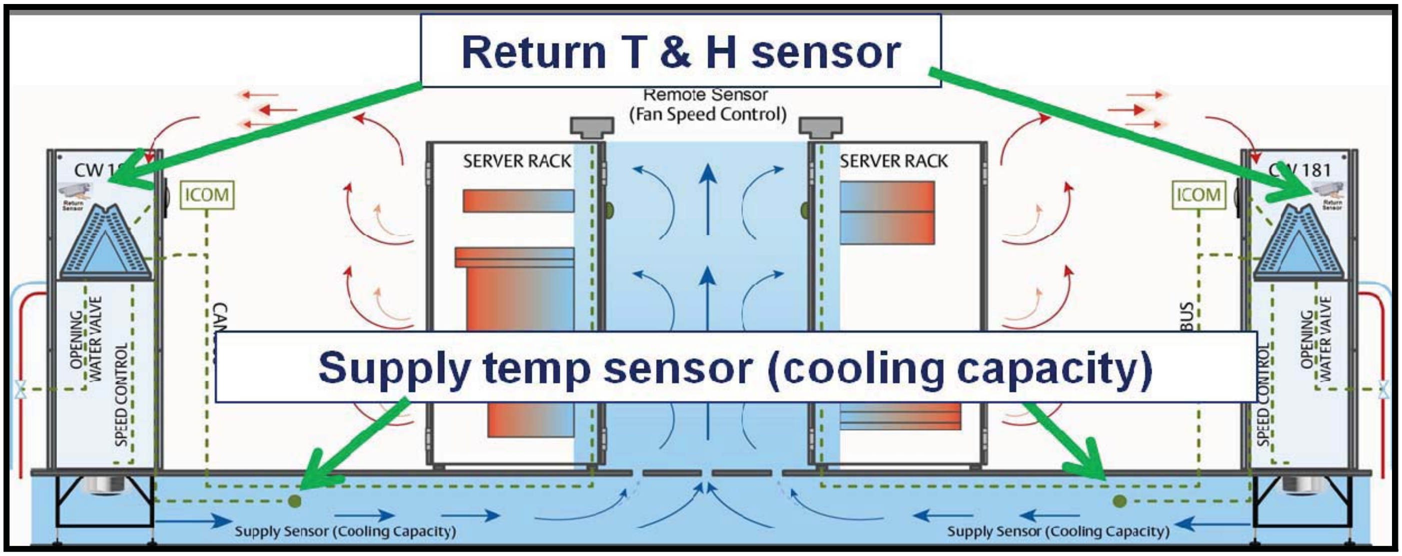

Figure 6: Diagram of the Liebert SmartAisle system. This diagram shows sensor locations for supply air control (which controls cooling capacity) and return air control (which controls humidity).

Lastly, and most importantly, we need to ensure that the computing equipment is receiving the proper airflow at the right conditions. So one last set of sensors is placed on the air intake side of the IT equipment racks. Each of these rack level sensors report back to the Liebert unit(s), where it can be assessed with other sensor data to determine the necessary fan speed in order to create the desired rack inlet air conditions. The Liebert unit will then utilize its variable speed device on its centrifugal fan, or its EC fan, to provide the proper fan speed to satisfy the rack air needs. See green lines on figure 7 below.

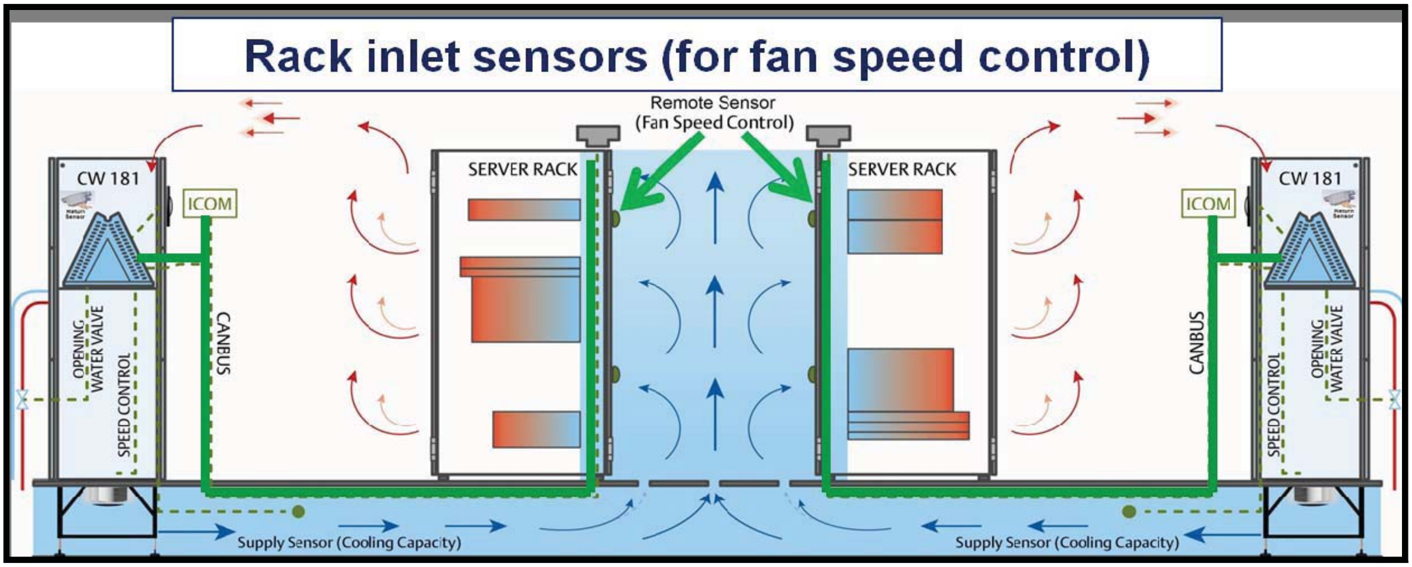

Figure 7: Diagram of the Liebert SmartAisle system. This diagram shows sensor locations for fan speed control (which controls fan speed and airflow).

The SmartAisle system is the most comprehensive solution for achieving high level precision cooling performance, while ensuring high operational energy efficiency across a wide range of potential load levels. A variety of energy saving components are available for Liebert systems and can be integrated together for optimal performance, including:

- **VFD Driven Centrifugal Fans** for varying fan speed when possible
- **EC Plug Fans** for varying fan speed when possible
- **Digital Scroll Compressors** for modulating cooling capacity based on varying load levels
- **Semi-Hermetic Compressors** for modulating cooling capacity based on varying load levels
- **VFD Driven Fan Speed Condensers** for maximizing heat rejection energy efficiency
- **Micro-Channel Coil Condensers** for further maximizing heat rejection energy efficiency
- **Fluid and Air Economizers** for taking advantage of free-cooling opportunities
- **Pumped Refrigerant CRAC Unit Economizers**, the latest technology offering unmatched cooling efficiency during free cooling hours.
- **Pumped-Refrigerant, Point of Use Supplemental Cooling** for addressing higher cooling loads and providing energy efficient sensible cooling at the point of use.
- **Unit-to-Unit Networking** for ensuring that multiple units do not operate in opposing modes. This prohibits one unit from reheating while another unit is cooling, or keeps one unit from humidifying while another is dehumidifying.

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Liebert is the industry leader in the Precision Cooling industry. They offer a full range of Precision Cooling product and service solutions to address any customer need.

Liebert Challenger
Upflow or Downflow Systems

- 3 and 5 Ton Design Points
- Digital Scroll Compressor
- Variable Speed Fan Option
- Unit-to-Unit Network Ready
- Micro-Channel Condenser Option
- Economizer Options

Liebert CRV
In-Row Cooling System

- 6 and 10 Ton Design Points
- Digital Scroll Compressor
- EC Fans
- Unit-to-Unit Network Ready
- Micro-Channel Condenser Option

Liebert DS
Upflow or Downflow Systems

- 8 to 30 Ton Design Points
- Dual Digital Scroll Compressors
- Dual Semi-Hermetic Compressors
- Variable Speed Centrifugal Fans
- EC Fans
- Economizer Options
- Pumped Refrigerant Economizer Option
- Unit-to-Unit Network Ready