Tech Byte 24: Capacity Modulation For Energy Efficient Computer Room Cooling

Proven Technologies for Achieving Energy Conservation in Precision Cooling Systems

There are four significant factors critical to determining the actual efficiency of Computer Room Air Conditioning (CRAC) units in the computer room space. These factors are:

- ***How efficiently do the units operate at partial load?***
- ***How efficient are the units at removing sensible heat as compared to latent heat?***
- ***Are the units equipped with economizing capability and how many hours of free cooling are available?***
- ***How well do multiple units work together as a team in a common space?***

In this paper, we will focus on technologies that provide a means to positively address the first two factors above; improving energy efficiency at partial load conditions, and maintaining a high sensible cooling ratio. The technologies discussed here allow for effective cooling capacity modulation in CRAC units. To understand the need for capacity modulation, consider the practice of how computer room cooling systems are specified. Load calculations for cooling systems are most often based on both the design ambient temperatures and the nameplate equipment load in the computer room. In addition, the vast majority of computer rooms are designed with some level of cooling system redundancy.

To add to this, the actual capacity of a direct expansion or air-cooled CRAC unit ***increases*** as the outdoor ambient temperature decreases below the peak design condition (typically 95° F). According to the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE), weather conditions below the peak design condition occur ***more than 95% of the time each year***.

So when you consider all of these factors, and the fact that protected equipment rarely, if ever, operates close its nameplate maximum heat rejection value, it becomes clear that precision cooling systems will necessarily run at a fraction of their full load design capacity. This creates the opportunity to design systems to operate more efficiently during these typical, part-load conditions. Because operating conditions aren't stable, this requires some method of varying capacity based on operating conditions.

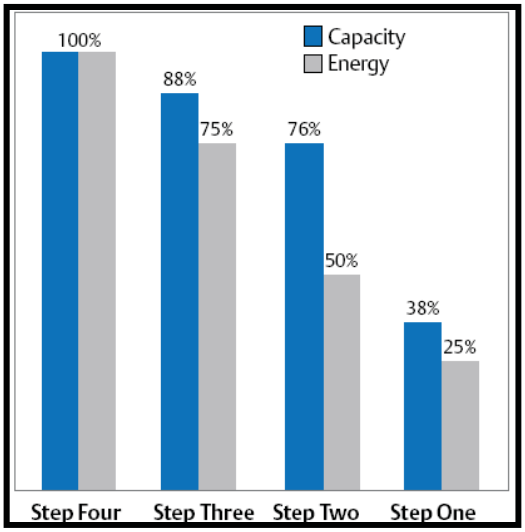

Figure 1: Efficiency Improvements Thru 4-Step Compressor Unloading

Compressor unloading has proven to be an effective approach to capacity modulation and ensuring efficiency at reduced capacities. There are several approaches to providing capacity modulation in a direct expansion CRAC unit. The two most common are four-step compressor unloading, and Digital Scroll™ compressor technology.

The concept of four-step compressor unloading works by shutting off the flow of refrigerant to some of the cylinders within the system; thereby, minimizing the need to cycle compressors on and off to control capacity. Because unloading essentially changes the compressor operating point, it enables the cooling system to operate more efficiently at lower capacities. For example, a system operating with two compressors "unloaded" will consume approximately 50 percent of the energy of a fully loaded system but will deliver 76 percent capacity because the condenser and evaporator are sized for full load. Figure 1 above shows the efficiency improvements that can be achieved through compressor unloading.

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Digital Scroll™ compressor technology offers a newer way to precisely match capacity and power consumption to the desired load and can deliver significantly lower energy consumption compared to standard "fixed-capacity" compressors. Traditional modulation technologies (cycling units on and off to match load conditions) often consumes close to full-load energy regardless of the required capacity. In a system designed for high reliability, the compressors do not just turn on and off. There is a turn-on delay period and a turn-off pump-down period where the compressor is actually running, ensuring proper oil lubricant to the compressor bearings, before power is removed. Digital Scroll™ technology allows the compressor to never be cycled off. It reduces power consumption linearly as it modulates capacity, resulting in optimum system performance and control.

Understanding The Benefits Of Four-Step Capacity Modulation Technology

Compressor unloading removes the load from a cylinder, or group of cylinders, to adjust capacity without turning off the cylinders. When integrated with the proper controls, unloading becomes the basis for a cooling system that combines flexibility, efficiency and scalability.

Liebert has utilized this technology, in conjunction with sophisticated microprocessor controls, to create a "Four-Step" precision cooling system that provides efficient operation at a wide range of operating conditions. This system achieves four steps of capacity control using compressor unloading. Because unloading essentially changes the compressor operating point, it enables the cooling system to operate more efficiently at lower capacities. This approach to capacity control significantly reduces energy costs at lower capacities and reduces stress on internal components, while providing the required capacity for extreme conditions or computer room growth.

Liebert DS System Compressor Section: Dual Semi-Hermetic Compressors With Unloaders Option

How does the four-step system achieve these higher efficiencies as shown in Figure 1 on the previous page? The key is the compressor operating point, which changes with unloading. When the compressor is unloaded, its mass flow rate is cut by half. This means the evaporator and condenser in a given circuit are now oversized compared to the unloaded compressor. An oversized evaporator results in a higher suction temperature, while an oversized condenser results in a lower condensing temperature.

	SUCTION TEMP		
SCT	45	50	55
90	21.2	23.5	26.0
100	17.7	19.5	21.5
110	14.8	16.3	17.9
120	12.4	13.6	15.0
130	10.4	11.5	12.6

Figure 2: Energy Efficiency Ratio (EER) Improvement in Response to Operating Point Change

When we are able to modulate the compressor in response to a partial load condition, it results in an increase in EER (Energy Efficiency Ratio). Figure 2 above illustrates this for a given load condition. When the suction temperature is low (45F) and the condensing temperature is high (which represents a system without modulation operating at part load) you can see the EER is much lower at 10.4 than it would be at the same load condition if the compressor were unloaded. The EER rockets up to 26.0 in the unloaded compressor condition. The system compressor is simply able to operate more efficiently when it can modulate its capacity according to load demand.

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Also of consideration is how capacity modulation promotes consistent, high-sensible cooling performance, as computer room environments are nearly 100% sensible. A four-step approach to compressor unloading offers advantages when humidifying at part load. As each compressor unloads, the latent capacity is reduced, increasing the net humidification capacity. The evaporator coils in the unloaded compressor dry up, so moisture is not being removed when it doesn't need to be. For example, the system is most likely to operate with both compressors unloaded during the winter months. This is also the time when humidification is most needed. When both compressors are unloaded the system is providing only sensible cooling, eliminating the need for re-humidification.

Liebert DS systems are supplied with two (2) compressorized cooling circuits. Each compressor circuit is rated for half of the unit's total cooling capacity. In their 4-step systems, Liebert utilizes two (2) semi-hermetic type compressors, each supplied with an electrically controlled suction cut-off cylinder unloader valve. The electrical solenoid valve is used to unload or reduce the cooling capacity of the compressor. The compressors will operate in an on/off - loaded/unloaded configuration method to cool the space, as shown in Figure 3 to the right.

STAGE	COMPRESSORS - UNLOADER STATE
1	Compressor 1 On - Unloader On (Energized) Compressor 2 Off - Unloader Off (De-Energized)
2	Compressor 1 On - Unloader On (Energized) Compressor 2 On - Unloader On (Energized)
3	Compressor 1 On - Unloader Off (De-Energized) Compressor 2 On - Unloader On (Energized)
4	Compressor 1 On - Unloader Off (De-Energized) Compressor 2 On - Unloader Off (De-Energized)

Figure 3: Liebert DS 4-Step System: Stages of Cooling

Understanding The Benefits Of Digital Scroll Capacity Modulation Technology

The Digital Scroll™ is the next generation of variable capacity compressor technology. Not only does the Digital Scroll™ offer the same set of benefits introduced by the 4-step design described previously, it improves on matching capacity to load demand from 10% of rated capacity up to 100% of rated capacity seamlessly. The beauty of this technology is its inherent simplicity. The standard Copeland Scroll has a unique feature called axial compliance. This allows the fixed scroll to move in the axial direction, by very small amounts, to ensure that the fixed and orbiting scrolls are always loaded together with the optimal force.

This optimal force, which holds the two Scrolls together at all operating conditions, ensures high efficiency of Copeland Scrolls. The Digital Scroll operation builds on this principle. The Digital Scroll operates in two stages - the "loaded state", when the solenoid valve is normally closed and "unloaded state", when the solenoid valve is open. When the solenoid valve is open, the two scrolls separate from each other, so compression of gas is not taking place. During the loaded state, the compressor operates like a standard scroll and delivers full capacity and mass flow. However, during the unloaded state, there is no capacity and no mass flow through the compressor.

At this stage, let us introduce the concept of a cycle time. A cycle time consists of a "Loaded State" time, and "Unloaded State" time. The duration of these 2-time segments determine the capacity modulation of the compressor. Example: In a 20-second cycle time, if the loaded state time is 10 seconds and the unloaded state time is 10 seconds, the compressor modulation is (10 seconds x 100% + 10 seconds x 0%)/ 20 = 50%. If for the same cycle time, the loaded state time is 15 seconds and the unloaded state time is 5 seconds, the compressor modulation is 75%. See Figure 4 on the following page.

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The capacity is a time averaged summation of the loaded state and unloaded state. By varying the loaded state time and unloaded state time, any capacity (10%-100%) can be delivered by the compressor.

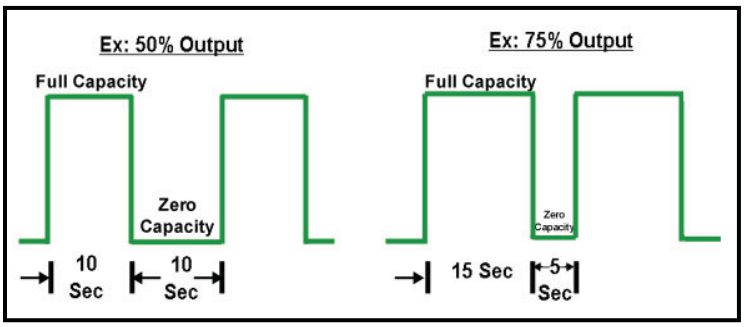

Figure 4: Liebert DS Digital Scroll: Duty Cycle

The advantages of the Digital Scroll™ begin with the wide capacity range, suited for environments with unpredictable heat load and heat load variation, typical of computer rooms. Capacity from 10%-100% results in an unmatched output from the Digital Scroll™. This wide capacity output is continuous and seamless and is an improvement over the inverter technology, where capacity outputs can only be achieved in steps. The seamless delivery of capacity also ensures that there is a very tight control on room air temperature.

The Digital Scroll™ also demonstrates a high seasonal energy efficiency. Frequent start-stops of the compressor consume more energy, and the wider capacity output of the Digital Scroll reduces these start-stops. The Digital Scroll™ performance has been evaluated as per JIS & ARI standard and showed excellent SEER. Figure 5 below illustrates the operational savings available by utilizing the Digital Scroll compressor in lieu of a non-capacity modulating design.

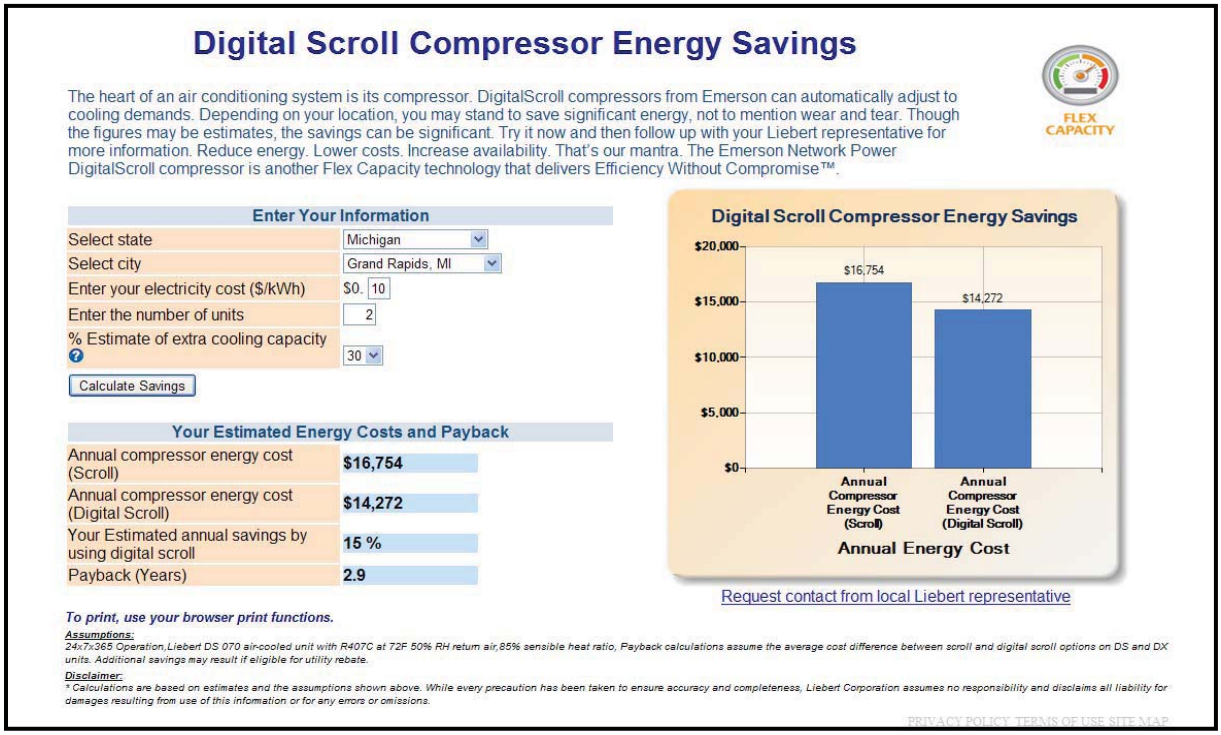

Figure 5: Liebert Digital Scroll ROI calculator. Based on 20-Ton Liebert DS systems operating at typical datacenter design setpoints. One unit with standard scroll compressors and one unit with Digital Scrolls.

Copeland Digital Scroll Compressor

Link to Energy Savings Estimating Tool: **http://applications2.liebert.com/market_apps/WebPages/EnergyTools/DSCTool.aspx**

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Conclusion

Computer room cooling systems must operate efficiently at a wide range of operating conditions to accommodate variations in ambient temperature, changes in the load, and growth within the space. Compressor unloading provides a practical, economically attractive approach to increasing cooling system efficiency at partial loads. Depending on product type, Liebert offers one or two options for compressor unloading in their floor standing precision cooling systems. The 4-step system or the Digital Scroll™ system. Because unloading changes the operating point of the compressor, the Liebert systems actually achieve higher efficiencies at partial loads, while also enhancing system reliability by minimizing compressor starting and stopping. In a time when excessive energy usage is being highly scrutinized, and in an environment with varying, sometimes unpredictable cooling demand, capacity modulation technology is a must have for all computer room cooling systems.

Liebert CRV
In-Row Precision Cooling System
6 Ton and 10 Ton Models
Standard with Single Digital Scroll™

Liebert DS
Large System Precision Cooling
Upflow or Downflow
8 - 30 Tons
Standard with Dual 4-Step Semi-Hermetic
With Optional
Dual Digital Scroll™ Compressors

Liebert Challenger
Small System Precision Cooling
Upflow or Downflow
3 Ton and 5 Ton Models
Optional Single Digital Scroll™

Liebert Precision Cooling Products:
http://www.emersonnetworkpower.com/en-US/Products/PrecisionCooling/Pages/default.aspx