

*Technical Note: Using EC Plug Fans to Improve Energy Efficiency of
Chilled Water Cooling Systems in Large Data Centers*

Introduction

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.

The data center cooling system is 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 approximately 38 percent of energy consumption.

Recently, Emerson Network Power has been studying the energy efficiency of different types of fan systems because the fans that pressurize the raised floor are a primary energy consumer. On chilled water cooling units, the fan comprises most of the energy usage. Using electrically commutated (EC) plug fans and variable frequency drive (VFD) are two effective methods for improving energy efficiency by controlling the fan speed. The energy efficiency gains come from decreasing the input power.

If cooling units are oversized, the fan speed can be reduced. The motor power varies with the cube of the motor speed.

$$\text{Motor kw2} = \text{Motor kw1} \times (\text{speed2}/\text{speed1})^3$$

For example, a 10 percent reduction in fan speed results in an energy savings of 27 percent. A 20 percent reduction in fan speed results in 49 percent energy savings. In order to prevent over-dehumidification, the water flow rate to the chilled water coil should also be reduced by the same percent as the fan speed.

Energy Efficiency of EC Plug Fans

Electrically commutated (EC) plug fans use a brushless EC motor in a backward curved motorized impeller (plug fan). An EC motor is actually a DC motor that can be connected to an AC supply line, due to a rectifier internal to the motor drive. Speed control is achieved by varying the control voltage from zero to 10 VDC.

Emerson Network Power wanted to compare the energy efficiency of centrifugal blower systems to EC fan systems. Rather than make the comparison based on estimations created using blower curves and static pressure calculations, three units were sent to independent testing lab Intertek for a “live” test. The first step was to determine the appropriate performance testing method.

Standards for Blower Performance Testing

It is imperative to use the same test method to make a fair comparison of the cooling capacity and energy use of various cooling systems. Results can vary widely because of the type of blower system, application of the blower system and test method used.

Motor kW can be measured in the lab, while the air volume is related to the total static pressure applied to the cooling system. Different test methods will result in different total static pressures and air volumes. The total static pressure is made up of several components, expressed as:

$$\text{Total Pressure} = \text{coil pressure drop} + \text{filter pressure drop} + \text{cabinet loss} + \text{system losses}$$

When designing systems, manufacturers commonly select fans based on pressure drop data derived from coil pressure curves and filter pressure drop curves, plotted on fan curves. However, internal system losses are difficult to calculate and may be underestimated. System losses are difficult to calculate and can vary widely depending on test method, fan location within the cabinet, proximity of the blowers to each other, and air outlet effects.

For example, a unit tested based on ASHRAE 127-2001 standard (which uses ASHRAE 37 straight ducts on individual blowers) compared to the new ASHRAE 127-2007 (a duct around the perimeter of the entire unit with measurement in the horizontal duct) will yield different results. At the same CFM and the same external static pressure, the difference in total static pressure is 28 percent higher for the ASHRAE 127-2007 duct (see figure 1) compared to the ASHRAE 127-2001 (ASHRAE 37) duct. The result is a 20.6 percent increase (for the 127-2007 method) in motor kW, due only to difference in measurement method.

Intertek used the ASHRAE 127-2007 method to compare the performance of the blower systems on the three units we submitted for testing because:

1. It is now the American standard for computer room air conditioning.
2. It allows centrifugal blowers to be compared to EC plug fans using the same test method.

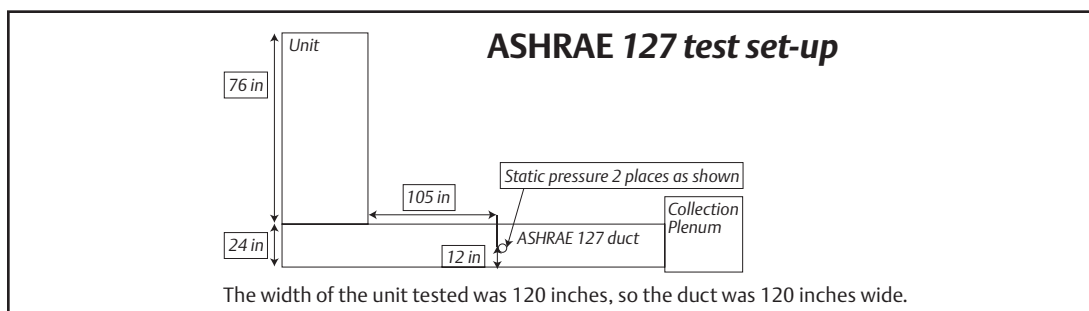


Figure 1. ASHRAE 127-2007 duct set-up for EC plug fan test.

The Initial Test

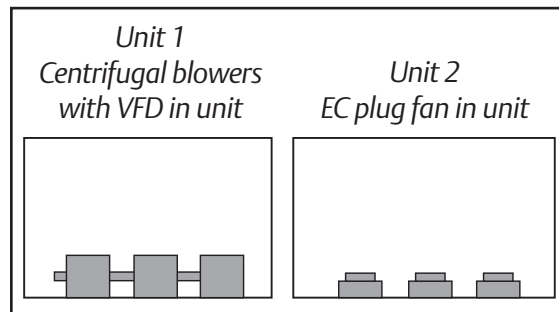
Two units were submitted to Intertek:

- Unit 1: Liebert Deluxe System/3 model FH600C equipped with a centrifugal blower and VFD
- Unit 2: Liebert Deluxe System/3 model FH600C with three(3) EC plug fans mounted inside the cabinet

The test point examined was 17,000 CFM at 0.3 inches external static pressure, at 100 percent speed. Figure 2 shows additional testing parameters and the results of the energy usage comparison.

Pushing EC Plug Fan Limits

Because of Emerson Network Power's commitment to engineering the most energy efficient products possible, the results of this test only made our product engineers more curious: How could EC plug fan technology be put to work to drive even greater energy efficiency in the Liebert Deluxe System/3?



After all, this system is designed for large data centers where addressing cooling system energy efficiency is particularly critical. The trend of consolidating multiple data centers into fewer, larger enterprises has definite economic advantages; however, concentrating a lot of heat-generating IT equipment into one room places extreme demands on the cooling system.

Our engineers set out to develop a better way for the EC plug fan to operate by reducing system losses associated with how air is directed through the cabinet. With the plug fan mounted inside the unit, the air is thrown horizontally in the cabinet and must be directed vertically through the cabinet openings. Additionally, the discharge of the air is positive pressure. This positive pressure has to be isolated from the rest of the cabinet, which is at a negative (suction) pressure. Isolating the two pressures can waste energy due to additional air-blocking that must be installed within the cabinet. Locating the fans under the floor allows for a continuous negative pressure in the cabinet, creating a suction that draws the air through. In theory, locating the fans under the floor provides a more direct path for the air to travel through the cabinet, so the fans operate more efficiently.

Energy Savings of Centrifugal Blowers vs. EC Plug Fan Mounted in the Unit

	Model FH600C, 72F/50% RH, 45EWT, 10 deg water TD, 0.3" External static pressure	Net Sensible Cooling Capacity (kBTUH)	Motor kW	EER (kBTUH/kW)	CFM	Savings from Base
100% speed	Centrifugal blowers w/VFD	284.0	11.0	25.8	17,000	-
	EC motorized impellar in unit	291.0	9.0	32.3	17,000	-18.2%

Figure 2. Using ASHRAE 127-2007, the tested EC plug fans mounted inside the precision air conditioning units drew 18.2 percent less power than the tested centrifugal fan due to the lower motor kW of the EC fans.

To see how this new configuration of the EC plug fan performed, a third configuration was tested:

- Unit 3: Liebert Deluxe System/3 model FH600C with an EC plug fan suspended from the bottom of the unit to simulate operating the fans within the raised floor.

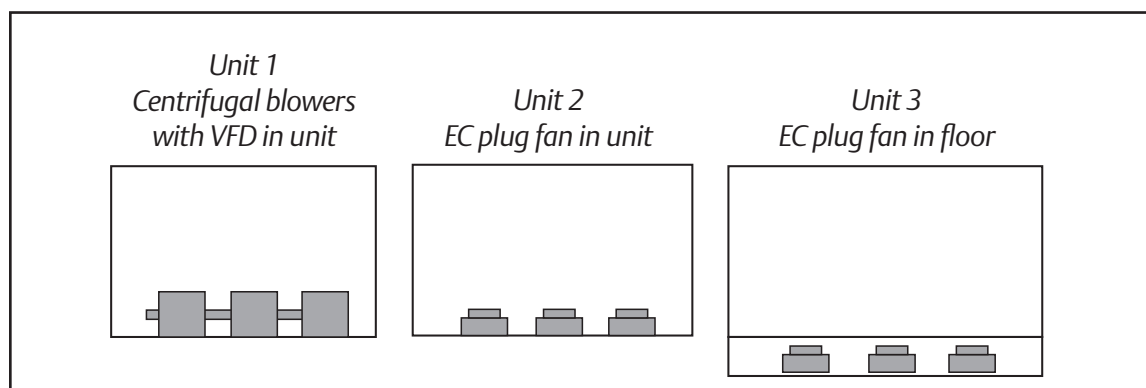
Intertek again used ASHRAE 127-2007, which provides an equivalent method for comparing the performance of an EC plug fan in the unit to one mounted under the unit. The test point examined was 17,000 CFM at 0.3 inches external static pressure, at 100 percent speed.

Most significantly, this new test documented that installing the EC plug fan in the raised floor under the unit reduces energy consumption another 12 percent on top of the 18 percent savings gained by installing the plug fan inside the unit. Complete specifications and results are shown in Figure 3.

Comparing EC Plug Fans to Centrifugal Fans with Variable Frequency Drives

EC plug fans are inherently more efficient than centrifugal fans with variable frequency drives (VFDs) due to the difference in wheel design, and because direct drive systems eliminate belt losses, which account for losses of approximately five percent. Nonetheless, VFDs are a good option for improving energy efficiency in data centers when the site specifications do not warrant using EC plug fans. The EC plug fan mounted on the bottom of the Liebert Deluxe System/3 requires a minimum 24-inch raised floor. Centrifugal fans generally have a wider range of air volume and can provide more static pressure. EC plug fans may not be suitable for ducted upflow cooling units, where higher static pressures may be required.

For our final tests, the Liebert Deluxe System/3 model FH600C was again used



Energy Savings of Centrifugal Blowers vs. EC Plug Fan Mounted in the Unit vs. EC Plug Fan Mounted Under the Unit

	Model FH600C, 72F/50% RH, 45EWT, 10 deg water TD 0.3" External static pressure	Net Sensible Cooling Capacity (kBTUH)	Motor kW	EER (kBTUH/kW)	CFM	Savings from Base
100% Speed	Centrifugal blowers w/VFD	284.0	11.0	25.8	17,000	---
	EC plug fan in unit	291.0	9.0	32.3	17,000	-18.2%
	EC plug fan under floor	296.0	7.6	38.9	17,000	-30.9%

Figure 3. Mounting EC plug fans in the raised floor under the Liebert Deluxe System/3 is approximately 12 percent more energy efficient than mounting the EC plug fan inside.

to compare energy efficiency of centrifugal fans to EC plug fans mounted in the base of the unit to EC plug fans mounted under the unit in the raised floor, at varying motor speeds. The centrifugal fan at 100 percent speed served as the base case.

At 100 percent motor speed, the 15hp motor draws 11 kW. At the identical CFM, the EC plug fan installed in the base of the unit draws 9 kW. By locating the EC plug fan under the unit in the raised floor, the resistance against the blower is reduced, so the motor can work less to reduce the same amount of CFM. This reduction results in only 7.6 kW of power consumed. The same holds true at slower speeds, with additional reduction in motor kW as you slow down the motor RPM. (Note that the chilled water valve is throttled back proportionally as the fan speed is lowered).

As previously shown, at similar speeds an EC plug fan draws approximately 18 percent less power than a centrifugal blower, and placing the fan in the floor saves an additional 12 percent. But by reducing the motor RPMs using VFD, even the centrifugal blower can achieve substantial energy savings—65.5 percent energy savings at 70 percent speed. These results are shown in Figure 4.

EC Plug Fans: Worth the Investment?

Answering this question requires determining how reduction in motor kW translates into payback. A payback analysis was conducted using Liebert Deluxe System/3 model FH600C (10 units) at 284 MBH sensible cooling per unit (N+2 redundant) in three configurations based on previous testing. The results of the payback analysis are shown page 6.

Energy Savings of EC Plug Fans vs. VFD

	Model FH600C, 72F/50% RH, 45EWT, 10 deg water TD 0.3" External static pressure	Net Sensible Cooling Capacity (kBTUH)	Motor kW	EER (kBTUH/ kW)	CFM	Savings from Base
100% Speed	Centrifugal blowers w/VFD	284.0	11.0	25.8	17,000	---
	EC motorized impellar in unit	291.0	9.0	32.3	17,000	-18.2%
	EC motorized impellar under floor	296.0	7.6	38.9	17,000	-30.9%
90% Speed	Centrifugal blowers w/VFD	260.0	8.0	32.4	15,300	-27.1%
	EC motorized impellar in unit	265.0	6.6	40.4	15,300	-40.4%
	EC motorized impellar under floor	268.0	5.5	48.4	15,300	-49.6%
80% Speed	Centrifugal blowers w/VFD	233.0	5.6	41.4	13,600	-48.8%
	EC motorized impellar in unit	237.0	4.6	51.4	13,600	-58.1%
	EC motorized impellar under floor	239.0	3.9	61.4	13,600	-64.6%
70% Speed	Centrifugal blowers w/VFD	192.0	3.8	50.5	10,710	-65.5%
	EC motorized impellar in unit	193.0	3.1	62.3	10,710	-71.8%
	EC motorized impellar under floor	194.0	2.6	74.6	10,710	-76.4%

Figure 4. Energy analysis of fan system options based on Intertek testing labs' comparison using ASHRAE 127-2007.

The annual energy costs and ROI are shown below.

Fan Option	Cost for 10 Units	Annual Energy Cost*	ROI
Centrifugal blower with no VFD (11 kW)	Base price	\$96,360	---
Centrifugal blower with VFD (5.6 kW)	Base price + \$36,000	\$49,056	9 months
EC plug fan under the floor (3.9 kW)	Base price + \$50,000	\$34,194	9.7 months

* Assumes \$0.10 per kWh and operation at 80 percent fan speed.

Conclusion

Based on the performance tests discussed in this application note, it is clear that operating the fan motor at lower speeds using EC plug fans or VFD provides substantial energy savings in the large data centers with chilled water cooling systems. It is easy to upgrade an installed Liebert Deluxe System/3 to VFD for the energy savings that solution offers. With new installations, the VFD offers lower capital costs compared to the EC plug fan, so it is a good option when budget constraints rule out installation of EC plug fans. In raised floor data centers in which it can be used to best advantage, however, the EC plug fan offers the lowest annual operating cost and is the best solution for the life of the product.

For a comprehensive look at how businesses can save energy in the data center, see the white paper *Energy Logic: Reducing Data Center Energy Consumption by Creating Savings that Cascade Across Systems* at www.liebert.com.

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