Liebert®

IT White Paper

MANAGING EXTREME HEAT: COOLING STRATEGIES FOR HIGH-DENSITY SYSTEMS

EMERSON™
Network Power

SUMMARY

As computer manufacturers pack more and more processing power into smaller packages, the challenge of data center cooling becomes more complex – and more critical. New servers and communication switches generate as much as ten times the heat per square foot as systems manufactured just ten years ago.

As these new systems are installed alongside previous generation systems, they create hot zones within the data center that cannot be effectively managed using traditional approaches to cooling. New strategies and technologies must be implemented to provide the cooling high-density systems require for reliable operation.

The Liebert XD™ family represents a new class of cooling system designed specifically for high density systems. It combines innovative cooling technology with application flexibility to provide an efficient, cost-effective solution to the challenge of cooling extreme density systems.

High efficiencies are achieved by locating the cooling system close to the source of heat and by taking advantage of the heat-absorbing capabilities of a fluid as it changes state. This also eliminates the potential for liquid leakage as the coolant exists as a gas in the controlled environment. The ability to locate cooling close to racks also yields scalability. New cooling systems can be added incrementally as the need arises without consuming data center floor space or disrupting the flow of air beneath the floor.

To ensure adequate heat dissipation across the room, racks are being spaced further apart. This is reducing the number of racks that can be installed and driving up per-rack support costs. The Liebert XD brings rack support costs down by enabling the existing data center to support significantly more high-density racks than it could if it relied only on raised floor cooling. A typical 10,000 square foot facility can safely support only 50 racks with a heat load of 10kW each using raised floor cooling. When additional cooling capacity is added through the Liebert XD, the same facility is able to support 386 racks – almost eight times more than the traditional approach.

The Liebert XD allows existing data centers to address hot spots resulting from the installation of new high density systems and enables new data centers to create more scalable and more efficient cooling systems that combine traditional and extreme density cooling in a single solution.

Rack densities above 3-4kW are now becoming common. That appears to be the threshold at which current approaches to cooling reach their practical limits.

The Point of No Return

The history of the computer industry is the story of the quest to pack more processing power into a smaller footprint. One misconception that has resulted from this trend is the idea that power consumption and heat generation are shrinking along with equipment size. This is not the case.

Performance increases are being achieved by packing more transistors operating at higher speeds into processors and that is increasing transistor power consumption.

For example, Intel's next 64-bit processor is expected to consume somewhere between 140 and 180 Watts of power. Compare that with the Pentium 4, which consumes about 83 Watts at full power. Then consider that the Pentium 4 represented a 319 percent increase in power consumption over its predecessor, which had a maximum power consumption of 26 Watts.

These advances are, in turn, driving increases in power consumption by servers and switches. And remember that in electronics all power is transformed into heat – heat that must be removed from the data center.

Increases in computer system power consumption – and the resulting increases in heat generation – have been occurring for years and traditional approaches to data center cooling have consistently been able to scale to meet these increases. However, with their recent advances, computer system manufacturers have achieved densities that are testing the limits of traditional cooling systems.

Rack densities above 3-4kW are now becoming common. That appears to be the threshold at which current approaches to cooling reach their practical limits.

System manufacturers are expected to drive power densities even higher in the years ahead. The Uptime Institute, in its white paper, *Heat Density Trends in Data Processing Computer Systems and Telecommunications Equipment,* projects power densities continuing to rise throughout this decade (Figure 1) and states clearly where the biggest impact of this trend will be felt:

> While many existing technology spaces and data centers are likely to be able to provide sufficient electrical power, most will struggle or may not be able to provide sufficient air circulation and air cooling capacity if large numbers

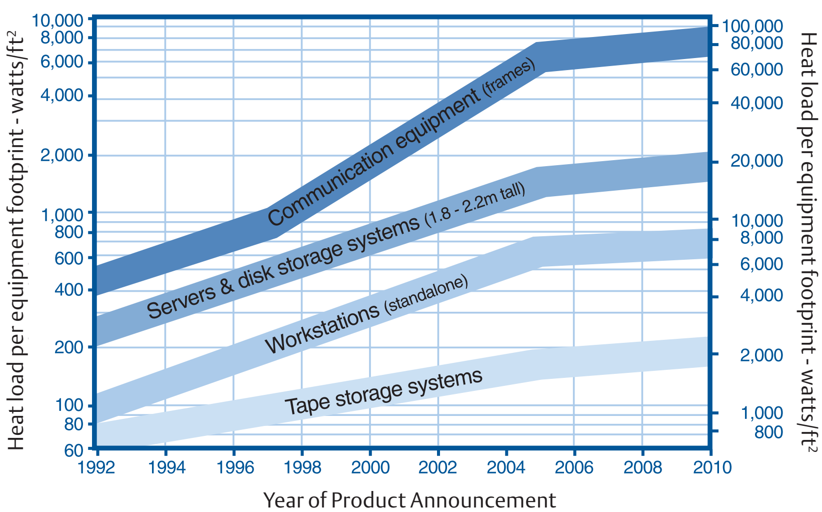

Figure 1. Heat densities of data center equipment are projected to continue to rise throughout this decade. (Chart reprinted with permission of The Uptime Institute from a White Paper titled *Heat Density Trends in Data Processing Computer Systems and Telecommunications Equipment, Version 1.0.)*

of future high-performance IT products are installed. As the projected trends occur over the next three to six years, air from under the floor by itself will not be sufficient to remove the heat being generated.

Data Center Cooling

Raised floor cooling systems are typically designed to handle densities up to 100 Watts per square foot. These systems provide room-level cooling by distributing air from floor-mounted precision air conditioning systems under a raised floor and up through perforated floor tiles.

Dense loads of electronic equipment, such as those found in most data centers, generate a drier heat than general purpose environments that are humidified by people and increased exposure to outside air. Consequently, precision air conditioners are deigned to deliver a higher sensible heat ratio than comfort cooling systems. That means they spend less energy removing moisture from the air and more energy removing heat. In fact, these systems are typically equipped with a humidification device that allows them to add moisture to keep the environment at the 45-50 percent relative humidity range that is optimum for electronics.

As equipment densities increase, precision air systems can continue to meet the humidity control and air filtration requirements of the room, which change little based on equipment density. But they are not able to meet the increased demand for sensible cooling that is being created by high-density equipment. As a result, hot spots are being created that can not be easily reached by raised floor systems (Figure 2).

Arranging equipment racks to support alternating hot and cold aisles can increase the efficiency of raised floor cooling and should be adopted as a first step in addressing heat density issues. In this approach, equipment racks are placed face-to-face so the cooling air being pushed into the cold aisle is drawn into the face of each rack and exhausted out the back onto the adjacent hot aisle. This raises the temperature of the air being drawn into the precision air conditioners, enabling them to operate closer to their capacity. Blanking panels can be used to fill open spaces in racks to keep hot air from being drawn back through the rack.

Other approaches to dealing with high-density systems that have been tried include increasing equipment spacing, adding more precision air conditioning units, and attempting to increase airflow through perforated floor tiles. Each of these approaches may provide some improve-

"As the projected trends occur over the next three to six years, air from under the floor by itself will not be sufficient to remove the heat being generated."

The Uptime Institute

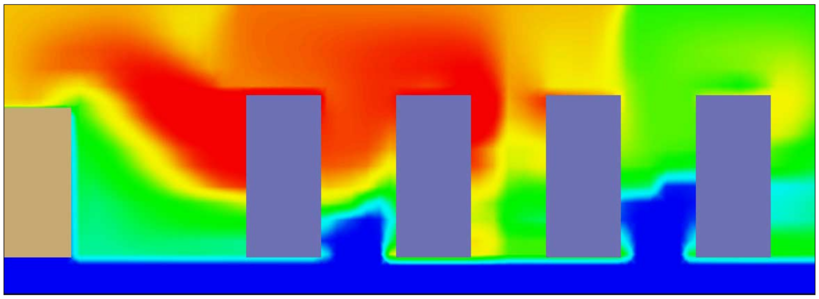

Figure 2. A computational fluid dynamic model (side view) showing air temperatures for high-density racks cooled by traditional underfloor cooling in the Liebert XD test lab. Red in the image indicates areas where air is above 93° F.

ment but none represent a true solution to the problem and several actually increase data center operating costs.

For example, when airflow in raised floor sites is measured, it typically averages 250 cubic feet per minute or less through each perforated floor tile. Spacing the equipment to allow existing airflow to dissipate a 16kW rack would require aisle widths of more than 16 feet – hardly a practical solution considering the cost of data center space.

New approaches to cooling must result in an increase in overall cooling efficiency.

Adding more room-level precision air conditioners may not prove to be practical or effective either. Space in the controlled environment is often scarce and expensive. In addition, room-level precision air conditioners may not provide cooling where it is most needed – around new high density systems. Optimizing the placement of room-level air conditioners to handle the hot spots results in all other equipment being cooled less efficiently, increasing costs.

The amount of air that can be pushed through a raised floor is also a limiting factor. It may not be possible to push enough air through the floor tiles to handle increasing cooling requirements, regardless of how many precision air conditioners are installed. Doubling the floor height has been shown to increase capacity by as much as 50 percent; however, this is a very disruptive solution that requires the removal of all existing equipment while the new floor is installed.

Keys to Improving Data Center Cooling

Raised floor cooling by itself will simply not have the capacity to meet the cooling requirements of high-density systems. New approaches to cooling must be considered. These new approaches must have the following characteristics:

- *Focused cooling:* The ability to address specific zones within the data center, providing targeted cooling for high density systems as the combination of new and old systems increase heat diversity across the room.
- *Scalability:* The ability to scale significantly as heat densities continue to increase and more high-density systems are installed.
- *Flexibility:* The flexibility to adapt to existing physical conditions within the data center.
- *Minimal footprint:* Significant increases in cooling cannot be achieved at the expense of large pieces of data center real estate.
- *Energy Efficiency* : New approaches to cooling must result in an increase in overall cooling efficiency.
- *Low Risk:* New technologies must not increase the perceived risk to data center equipment. Specifically, water-free approaches to cooling eliminate the risk associated with leaks in the data center.

The Liebert XD™ Family

Liebert has responded to the challenge of cooling high density systems with the Liebert XD, a new family of cooling systems that provide a flexible, scalable and water-less solution to supplemental cooling. Liebert XD systems can deliver sensible cooling of heat densities of over 500 Watts per square foot without consuming any data center floor space.

The Liebert XD family includes both an air flow enhancer and true complementary cooling systems.

The Liebert XDA is a lightweight, rear-mounted flow enhancer installed on the rack. These specially designed fans can move up to 2,000 cubic feet per minute of air, increasing air flow through densely populated enclosures. The Liebert XDA represents a simple, easy-to-install solution that does not consume any rack space. However, it is designed to enhance air flow, not provide additional cooling capacity.

The Liebert XDV and XDO systems do provide additional cooling capacity. The Liebert XDV is mounted to the top of the rack and provides sensible cooling of over 500 Watts per square foot. The Liebert XDO system is mounted to the ceiling above the rack.

Both the Liebert XDV and XDO systems take advantage of the "hot aisle/cold aisle" rack arrangement, drawing hot air directly out of the rack or from the hot aisle and exhausting cold air into the cold aisle where equipment air intakes are located (Figure 4).

They also both utilize an electrically non-conductive coolant that operates at low pressure and becomes a gas at room temperatures, making it ideal for use around electronic equipment. This allows these systems to provide high efficiency sensible cooling without introducing any liquid into the controlled space.

Liebert XD systems are intended to complement, not replace, traditional cooling systems. Floor mounted precision cooling systems will continue to play a vital role in balancing the air flow across the room and controlling humidity and air quality.

Liebert XD systems can deliver sensible cooling of heat densities of over 500 Watts per square foot without consuming data center floor space.

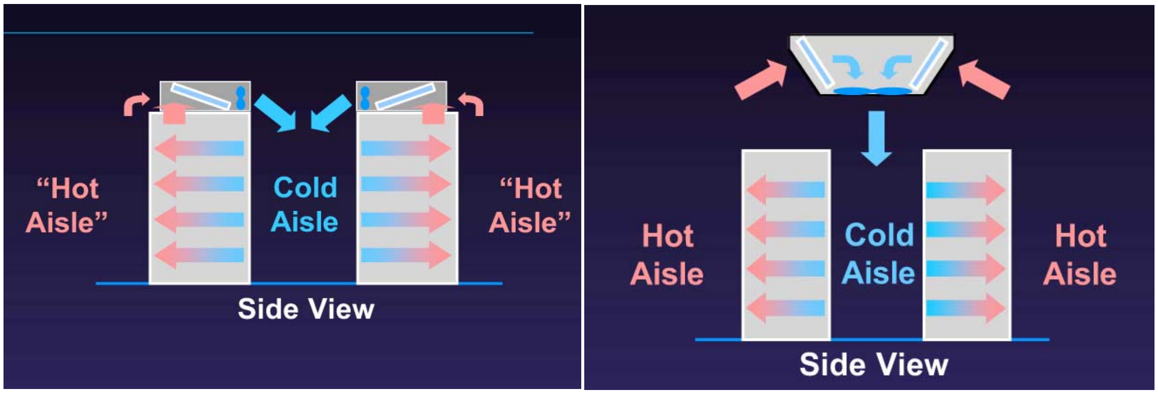

Figure 4. The Liebert XDV (left) and XDO (right) systems take advantage of the hot aisle/cold aisle rack arrangement to provide focused, high efficiency cooling.

Placing the cooling near the heat source shortens the distance which air must be moved ...This reduces the energy required for air movement by more than 70 percent.

Achieving High Efficiency

The high efficiency of the Liebert XD family is achieved through the following combination of factors:

- The Liebert XD system takes advantage of the energy absorption capacity of a fluid as it changes state. This reduces the pumping power by 85 percent compared to a water-based system.
- Placing the cooling near the heat source shortens the distance which air must be moved (only 3 feet on a Liebert XDV). This reduces the energy required for air movement by more than 70 percent.
- The Liebert XD chiller has an optional fluid economizer that allows for energy savings of over 25 percent in climates such as Washington DC. Colder climates will realize greater savings.

The Economics of Complementary Cooling

By delivering a compact, high-efficiency cooling solution, the Liebert XD family reduces data center space costs and operating costs.

Space costs are reduced because the number of racks that can be supported within a particular space is increased, reducing the cost per rack of the data center infrastructure.

For example, at 1kW per rack, a 10,000 square foot data center using raised floor cooling can accommodate about 500 racks. Assuming a facility “shell” cost of $175 per square foot and a cooling cost of $928 per kW, the combined facility infrastructure and cooling cost is $4,428 per rack.

However, if per rack power increases to 10kW, this same infrastructure can now support only about 50 racks because of heat density issues. The cost to support each rack climbs to $44,280 – a tenfold increase.

With the installation of Liebert XD cooling units, the number of 10 kW racks the facility is able to support increases to 386, almost eight times as many as can be supported without XD cooling.

The infrastructure and cooling cost per rack drops from $44,280 to $11,644 – including the cost of the Liebert system – without compromising rack performance. This creates a substantial annual costs savings compared with the installation of additional room-level air conditioning units – if floor space or tile flow restrictions even permit more room air conditioners.

Rack Density	No. of Racks Supported		Cost per Rack	
	Raised floor only	Raised floor with XD	Raised floor only	Raised floor with XD
1kW	500	-	$4,428	-
10kW	50	386	$44,280	$11.644

Figure 5. Complementary cooling can reduce the cost of supporting high density racks.

Operating costs will also be lower. A system that provides cooling at the source of the heat will consume less energy over its life than a system that has to drive down temperatures across the room.

Adaptability and Scalability

Liebert XD systems can deliver substantial amounts of sensible cooling capacity to an exact location in a data center with virtually no changes to the facility's infrastructure. Maintenance is minimal, and additional units can be added easily as the data center expands or as its configuration changes.

The Liebert XDV provides additional sensible cooling capacity in 8kW increments, requires no floor space, plugs directly into the computer rack's power strip, is immediately integrated into the protected power network, and requires only 1 amp of power per module at 208 volts.

Individual ceiling-mounted Liebert XDO units require no floor space and can be added as needed to an existing loop as the data center expands.

The Liebert XDV pumping unit requires only 7.7 sq. ft. of space and can be located wherever a chilled water loop is available, either inside or outside the data center.

Both the Liebert XDV and Liebert XDO have the flexibility to adapt to existing physical constraints within the data center. A Liebert representative can tailor the Liebert XD system to the specific requirements of the application.

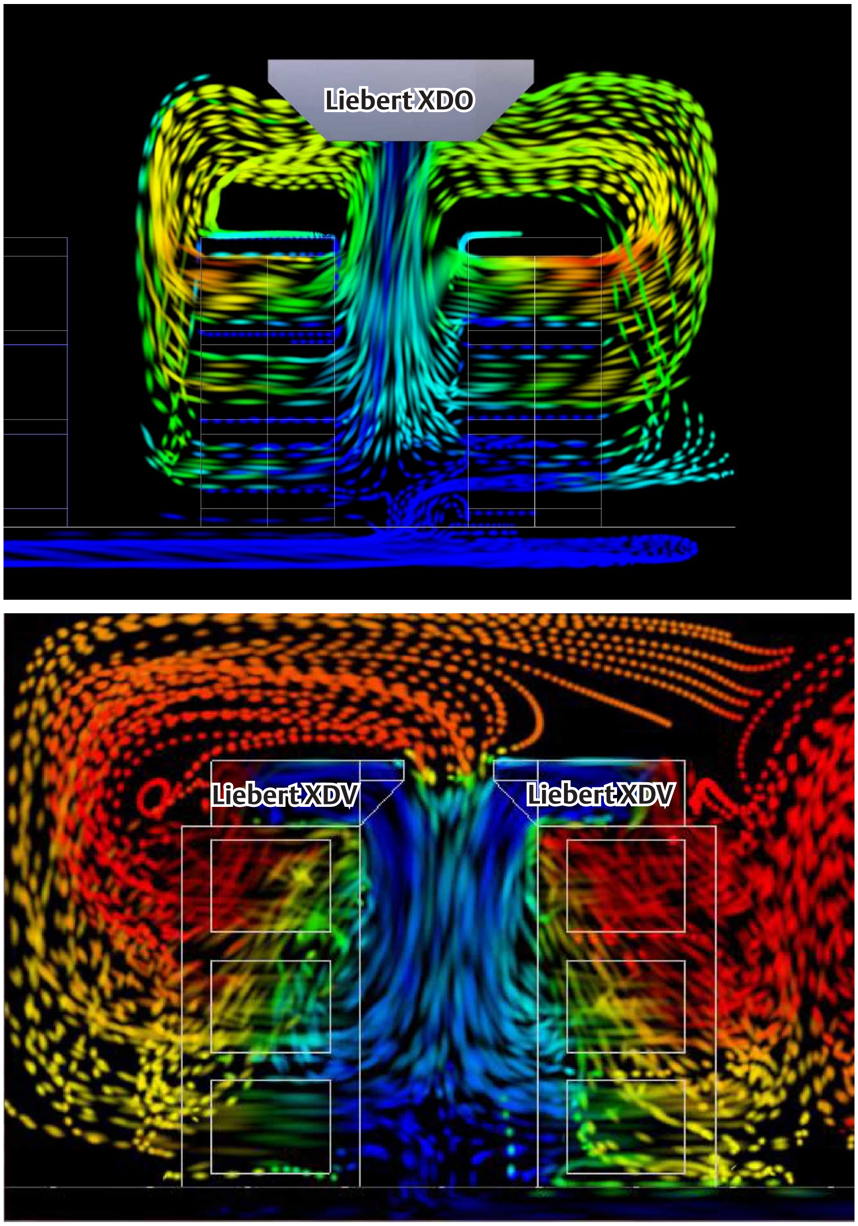

Figure 6. Computational fluid dynamic models (side view) show how the Liebert XDO (above) and Liebert XDV (below) cooling systems complement raised floor cooling systems, providing focused cooling in areas that cannot be effectively reached by the conditioned air coming up from the floor. The blue represents cool air.

Case Study
Cooling the World's Third Fastest Supercomputer

When Virginia Tech University developed plans to create a supercomputer by clustering 1,100 dual-processor, 64-bit Power Mac G5 desktop computers, the challenge of heat removal had to be addressed.

Virginia Tech University. Inset: Liebert XDV units installed on the racks of the Virginia Tech supercomputer.

Cooling specialists, used projected heat loads for the project to model air flow for two different cooling configurations: one that relied exclusively on traditional precision air conditioning units and a hybrid solution that combined traditional cooling with complementary cooling provided by rack-mounted Liebert XDV systems.

They determined that nine 30-ton precision air conditioners – seven primary units and two backups – would be required to provide the necessary cooling capacity. When the projected air flow from this configuration was analyzed, it was shown to be extremely uneven – varying from -70 CFM to +1520 CFM through the perforated floor tiles, depending upon location.

The alternate cooling configuration consisted of two 20-ton room air conditioners complemented by 48, 8kW Liebert XDV modules – one for every other rack. This configuration delivered the required cooling capacity and created a much more uniform air flow and was the configuration chosen for the Virginia Tech supercomputer.

It is now providing ample cooling capacity to meet the requirements of the supercomputer, which became just the third system ever to exceed 10 Tflops/s (10.28), placing it third in the annual ranking of the world's fastest computers.

At Virginia Tech, the use of complementary cooling was able to eliminate the need for seven floor mounted air conditioners while providing more uniform cooling across the room, enhancing energy efficiency and optimizing data center floorspace.

The use of complementary cooling was able to eliminate the need for seven floor-mounted air conditioners while providing more uniform cooling across the room, enhancing energy efficiency and optimizing data center floorspace.

Conclusions

Power densities have exceeded the capacities of traditional approaches to cooling and are going even higher. Over the next five years, data centers installing new systems will be faced with two challenges:

- Managing hot spots within the data center caused by new systems that have much higher densities than the systems around them.
- Managing increasing overall temperatures as high-density systems displace older systems, creating higher heat across the room.

Forcing increased cooling through the raised floor is simply not a practical solution to this problem due to the limited capacity of floor tiles, physical space limitations within the data center for additional computer room air conditioners and the inefficiency of this approach.

The Liebert XD family is the first complete solution to extreme density cooling, providing a scalable, flexible solution that can be optimized for new and existing data centers. The Liebert XD family supplements the existing cooling system with 100 percent sensible cooling designed specifically to meet the needs of high-density systems. The Liebert XD family's range of solutions enables data center managers to address specific hot spots within the data center and increase cooling capacity as new systems are installed.

Liebert®

LIEBERT CORPORATION
1050 DEARBORN DRIVE
P.O. BOX 29186
COLUMBUS, OHIO 43229
800.877.9222 (U.S. & CANADA ONLY)
614.888.0246 (OUTSIDE U.S.)
FAX: 614.841.6022
www.liebert.com

Printed in U.S.A. 0204

EMERSON™
Network Power