Rittal — **High Density Cooling**

Costs & Benefits Review Whitepaper

FRIEDHELM LOH GROUP

Introduction

In previous publications, Rittal Corporation has discussed the design and implementation requirements associated with deploying a high density cooling solution. Today, it can be said with a very high degree of certainty that the IT community is well aware of the critical issues of meeting the power and cooling requirements of the data center, and, in some cases, not having enough of one or the other, or even both. The discussions continue—from equipment vendors, to design engineers and consultants, facility personnel, various industry groups and even the government. All interested parties have their unique ideas and solutions, roadmaps and planning tools, and new products that will address these needs. In the middle are the end users, trying to make sense of it all, keeping up with the latest advances and information—making sure to get the most cost effective solution without penalizing performance.

As a global provider of modular enclosure and high density cooling solutions, Rittal Corporation chartered an international engineering firm to review and analyze performance of the Liquid Cooled Package (LCP) system versus traditional air cooled systems. For the comparison and analysis, a "typical" data center with a pressurized raised floor and hot aisle/cold aisle row orientation using CRAC units was considered. The same heat load was then "installed" in a data center using only LCP units. The resulting report, summarized in this paper, addressed the various cost and energy components of a typical data center and the potential savings to be realized.

Technology Review

Before looking at the results of the study, a brief review of current high density cooling systems is in order. Generally, there are three (3) main methods for high density cooling:

- Active Air systems using directed airflow and fans to circulate air through enclosures and exhaust the warm air to the room or ceiling spaces. These systems will still require CRAC or CRAH units in place.
- Fluid based systems using chilled water or refrigerant with a heat exchanger to transfer heat and remove it completely from the space through existing facility infrastructure. Depending on deployment, these systems may not require in-room air conditioning.
- Chip cooling solutions mounting heat exchangers directly to processors, removing the heat through a secondary transfer system.

Fluid based systems are available in two basic configurations:

- Closed Loop/Close Coupled with circulating air remaining inside the equipment enclosure and transferred to a heat removal medium.
- Open Loop/Close Coupled with heated air removed from the rear of equipment enclosures, passed over heat exchangers but returned to room spaces instead of directly to server air intakes. These systems are typically deployed as supplemental cooling systems, designed to reduce hot spots, placing cooling units closer to heat loads yet still working with installed CRAC systems.

Each system has specific benefits as well as some potential disadvantages. Any end user considering an installation should weigh the pros and cons of each system, considering such variables as existing infrastructure, available floor space, components to be installed, installation densities, and plans for future technology deployments. The key recommendation here is for an end user to insure all parties involved in the design and installation of a high-density system communicate with each other through all project phases. These should include design and engineering firms, IT personnel, facilities personnel, installation contractors and component vendors—with the stated goal to make sure there are no unpleasant surprises along the way.

Analysis and Discussion

A. Design Basis

In the analysis, a design basis for comparison was established. Initial costs for construction and equipment selection were concluded, a real estate comparison based on several market values and different cities was done, and finally, a total mechanical cooling system operating expense calculated on an average basis. Table 1 below shows the design parameters established for the comparison.

DESIGN COMPARISON

		SCHEME 1A	SCHEME 1B	SCHEME 2A	SCHEME 2B
		Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack
Data Center Power Load	Total Power (KW)	470		2,160	
Physical Data	Length (Ft)	46	36	125	70
	Width (Ft)	46	38	80	78
	Area (SqFt)	2,116	1,368	10,000	5,460
	Average Area Loading (W / SqFt)	222	344	216	396
Computer Density	Number of Racks	56	30	405	144
	Average Rack Loading (KW / Rack)	8.39	15.67	5.33	15.00
Computer Cooling Requirements	Equipment Capacity (KW)	118	15	118	15
	Minimum Cooling Unit (Qty)	3.97	31.33	18.25	144.00
	Total Required Cooling Unit (Qty)	4	32	19	144
	Redundancy	N+1	N+1	N+1	N+1
	Redundant Unit (Qty)	1	4	1	18
	Total Cooling Unit (Qty)	5	36	20	162

Table 1. Design comparison between the LCP and conventional cooling method

The total area of the data center for a given number of IT components is calculated based on an equal total of IT power consumption. Table 1 shows that LCP provides the benefits of a smaller footprint when compared to legacy cooled data centers. Data centers using LCP can achieve 35-45% savings in required real estate depending on the size, which translates to a higher heat flux (higher density) per rack and per square foot. Considering an N+1 system, the total numbers of CRAH units and LCP racks were calculated for both sizes of data centers as presented above.

B. Initial Costs

The principal costs associated with LCP as compared to a conventional raised floor cooling system are shown in Table 2 below.

INITIAL COST ANALYSIS

Criteria		SCHEME 1A	SCHEME 1B	SCHEME 2A	SCHEME 2B
		Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack
Construction Cost	Construction	$317,400.00	$205,200.00	$1,500,000.00	$819,000.00
	Raised Floor Construction	$31,740.00	$16,416.00	$150,000.00	$65,520.00
	Drop ceiling cost (plenum)	$11,638.00	-	$55,000.00	-
	Drop ceiling return grills	$250.00	-	$1,250.00	-
	Perforated tile cost	$3,200.00	-	$12,000.00	-
	Mechanical Construction	$98,091.00	$173,632.00	$310,000.00	$610,585.00
	Electrical wiring	7,100	19,900	18,500	84,000
	Total Construction Cost	469,419	415,148	2,046,750	1,579,105
Cooling Equipment cost	CRAH	100,000	-	400,000	-
	CRAH Installation	50,000	-	200,000	-
	LCP Cabinet cost	-	360,000	-	1,728,000
	LCP cabinet installation	-	15,000	-	72,000
	CDU	-	not required		not required
	CDU installation	-	not required	-	not required
	cabinet/rack cost	61,600	-	445,500	-
	cabinet/rack installation	28,000	-	202,500	-
	Total Cooling Equipment Cost	239,600.00	375,000.00	1,248,000.00	1,800,000.00
Total Initial Cost		709,019.00	790,148.00	3,294,750.00	3,379,105.00

Table 2. Initial cost analysis

In developing Table 2 below, several assumptions were made:

- The construction cost is based on $150/ft^{2.}$
- Legacy data center raised floor height is based on 36" while that of the LCP is based on 12". Raised floor is based on 6000 lbs concentrated load and zero seismic design criteria. A raised floor may not be necessary for data centers with LCP.
- The legacy data center is assumed to have a drop ceiling and return air grills installed, although many are operating with out this and rely on the fact that rising warm air will find its way back to the CRAH return plenums. In this calculation, a separate return duct was not accounted for assuming that the space above the drop ceiling can be used as a return plenum
- The costs include chilled water and condensate drain pipes and fittings, pipe insulation, high performance butterfly valves, system fill, flush, and equipment start up for N+1 system
- Electrical construction costs are based on engineering estimates associated with required wiring from the distribution panels to the CRAH's and LCP's. It includes feedboxes, circuit breakers, panels, and labor.
- Perforated tile cost was captured in the conventional data center cooling methodology

C. Real Estate Analysis

REAL ESTATE ANALYSIS

	Averaged Office Lease Rate		SCHEME 1A	SCHEME 1B
	US $ / sqft / Year		Hot/Cold Aisle	Rittal LCP Rack
Physical Data	Length (Ft)		46	36
	Width (Ft)		46	38
	Area (Sqft)		2,116	1,368
Annual Real Estate Cost	Chicago, US (Note 1)	$28.6	$60,412	$39,056
	Boston, US (Note 1)	$43.2	$91,327	$59,043
	Frankford, Gemany (Note 2)	$50.5	$106,767	$69,025
	Hong Kong, China (Note 1)	$55.2	$116,712	$75,455
Annual Real Estate Saving	Chicago, US		$21,355	
	Boston, US		$32,284	
	Frankford, Gemany		$37,742	
	Hong Kong, China		$41,257	

	Averaged Industrial Park / Warehouse Lease Rate		SCHEME 1A	SCHEME 1B
	US $ / sqft / Year		Hot/Cold Aisle	Rittal LCP Rack
Physical Data	Length (Ft)		125	70
	Width (Ft)		80	78
	Area (Sqft)		10,000	5,460
Annual Real Estate Cost	Chicago, US (Note 1)	$4.4	$285,500	$155,883
	Boston, US (Note 1)	$6.9	$431,600	$235,654
	Frankfort, Gemany (Note 2)	$9.3	$504,571	$275,496
	Hong Kong, China (Note 1)	$13.7	$551,568	$301,156
Annual Real Estate Saving	Chicago, US		$129,617	
	Boston, US		$195,946	
	Frankfort, Gemany		$229,075	
	Hong Kong, China		$250,412	

1. Averaged lease rate is based on CB Richard Ellis, Market View, First Quarter 2007.
2. Averaged lease rate is based on CB Richard Ellis, Market View, Third Quarter 2006.

Table 3. Real estate analysis

Table 3 compares real estate costs associated with leasing a space in office or industrial park areas in four different cities based on the required footprint as depicted in Table 1. For a small data center that could be housed in an office space, savings on the order of 30% should be expected. For a larger data center, where industrial park locations could be considered, an expected savings around 40% can be achieved in the same city. (Note: Data referenced based on CBRE market review (2006, 2007)

D. Energy Analysis

ENERGY ANALYSIS - UNIT, ENVELOPE & LIGHTS

		SCHEME 1A	SCHEME 1B	SCHEME 2A	SCHEME 2B
		Hot/cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack
Unit Fan Power Consumption	Unit Fan Power Consumption (KW)	11	1.2	11	1.2
	Total Cooling Unit (Qty)	5	36	20	162
	Total Fan Power consumption (KW)	56	43	224	194
Fan Energy Use	Per year (KWHr/Year)	489,924.90	378,432.00	1,959,699.60	1,702,944.00
Fan Energy Cost	Per year ($/Year)	$48,992.49	$37,843.20	$195,969.96	$170,294.40
Fan Energy Saving	Per year ($/Year)	**$11,149.29**		**$25,675.56**	
Lighting Power Consumption	1.8 KW/sqft (KW)	3830.0	2476.1	18100.0	9882.6
Lighting Energy Use	Per year (KWHr/Year)	33550.4	21690.5	158556.0	86571.6
Lighting Energy Cost	Per year ($/Year)	$3,355.04	$2,169.05	$15,855.60	$8,657.16
Lighting Energy Saving	Per year ($/Year)	**$1,186.00**		**$7,198.44**	

ENERGY ANALYSIS - CENTRAL PLANT

		SCHEME 1A	SCHEME 1B	SCHEME 2A	SCHEME 2B
		Hot/Cold Aisle	Rittal LCP Rack	Hot/Cold Aisle	Rittal LCP Rack
Data Center Power Load	Tower Power (KW)	470		2,160	
Unit Flow Rate	Flow Rate (GPM)	79.0	11.0	79.0	9.8
	Total Cooling Unit (Qty)	5	36	20	162
	Total Chilled Water Plant Flow Rate (GPM)	395.0	395.0	1,580.0	1,580.0
Chilled Water	Entering Chilled Water Temperature (Deg F)	48.0	56.3	48.0	55.4
	Entering Chilled Water Temperature (Deg K)	282.0	286.7	282.0	286.1
	Differential Chilled Water Temperature (Deg K)	4.6		4.1	
Center Plant Power	Excellent (KW)	141.0	121.3	648.0	568.3
	Average (KW)	258.5	222.4	1,188.0	1,041.9
	Poor (KW)	611.0	525.8	2,808.0	2,462.6
Center Plant Energy Use	Excellent (KWHr/Year)	1,235,160.0	1,062,855.2	5,676,480.0	4,978,273.0
	Average (KWHr/Year)	2,264,460.0	1,948,567.8	10,406,880.0	9,126,833.8
	Poor (KWHr/Year)	5,352,360.0	4,605,705.8	24,598,080.0	21,572,516.2
Center Plant Energy Cost	Excellent ($/Year)	$123,516.00	$106,285.52	$567,648.00	$497,827.30
	Average ($/Year)	$226,446.00	$194,856.78	$1,040,688.00	$912,683.38
	Poor ($/Year)	$535,236.00	$460,570.58	$2,459,808.00	$2,157,251.62
Center Plant Energy Saving	Excellent ($/Year)	**$17,230.48**		**$69,820.70**	
	Average ($/Year)	**$31,589.22**		**$128,004.62**	
	Poor ($/Year)	**$74,665.42**		**$302,556.38**	

Table 4. Energy Analysis

The first portion of Table 4 shows the total fan power consumption associated with the conventionally CRAH cooled data centers compared to total fan power used in LCP cooled data centers. Fans are assumed at full load and at rated power consumption for both systems. There is also an associated savings in envelope and light load, leading to a total annual cost reduction of about 30-45% in related cost. In this calculation, it was assumed that lights are not activated by a motion sensor. In all energy calculations, $0.10/kWh was assumed as the cost from the utility company.

In determining the impact on the central chilled water plant, Figure 1 shows that the temperature of the chilled water supply needed to meet the cooling load of 15Kw. The supply of chilled water temperature for the LCP data center was compared to that of the conventional data center for both sizes.

In calculating central plant power consumption, which includes all the components in the mechanical cooling system, the analysis considered an ecosystem approach looking at the overall power consumption of a given data center. This approach is termed a burden factor or power usage factor (PUE) and resultant global warming impact. Briefly, PUE is a metric that categorizes data centers based on total IT power consumption, mechanical power consumption, electrical power support from utility mains down to the PDUs, RPPs, and also other power consuming systems such as fire/smoke protection system, BMS, and EPMS.

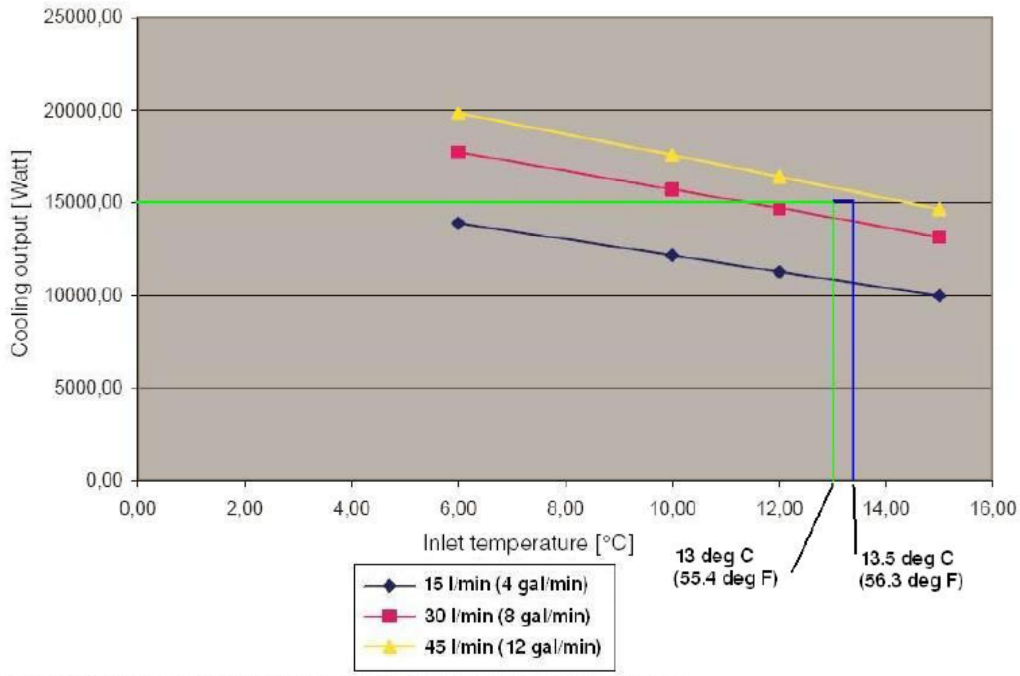

Figure 1: Cooling output of the LCP equipped with three cooling modules

When considering the overall savings for a given data center size, the chilled water savings, fan power savings, as well as envelope and lighting savings need to be added. For an average efficiency data center, one would quickly calculate an annual savings of $45,000 and $160,000 for the small and large data centers considered in this study, respectively.

It should be pointed out that increased chilled water temperature has a positive impact on the water side economizer if the central chilled water plant is equipped with such technology. For a traditional water side economizer system, the number of economizer hours depends on the number of hours that the outside wet bulb temperature is less than the chilled water set point. The exact impact depends on the climatic zone of the city of interest. With such systems in place, the energy savings mentioned above can be enhanced even further.

One additional point to consider regarding energy savings and the cost benefits; by deploying energy efficient systems that demonstrate measureable savings, end users may be eligible for rebates from their electrical supplier. Many utilties have formal programs in place to measure energy savings from a variety of components installed in the data center and supporting facility. The greater the savings, the greater the potential rebates. Rittal encourages end users to contact their local utility to determine what programs are available, what products or technologies qualify for possible rebates, and how to apply for these progams.

Conclusion

Deploying a high density cooling solution should be considered if:

A. There is a space limitation at a site that would limit the quantity of enclosures that could be deployed to support existing and planned hardware installations.
B. Existing facilities cannot add more in-room cooling capacity, but do have sufficient chiller plant capacity to support additional hardware.
C. There is, or will be, an installation of high performance computing products—either blade server systems or high-density rack mount products.
D. A review of the factors described above show the potential savings to be realized from a high density cooling installation.

Deployment of a high-density cooling system can have a significant impact on an end user's ability to grow and meet greater demands for IT applications. These impacts may not only be limited to the actual data center, but could have broader effects on an overall site including chiller plants, power distribution, construction costs, etc. An additional benefit may be realized through improved hardware performance, reduced MTBF and shortened MTTR of IT components. "Green" considerations can also be affected, again leading to costs savings and rebates, as well as compliance with current and proposed energy usage guidelines.

Rittal Corporation recognizes that not every site and every end user will need or benefit from deploying an LCP system. Additionally, the results published here are of a general nature, and individual results and performance parameters must be evaluated and may vary. However, for current, and more importantly, future installations and deployments of next generation technologies, an LCP system will offer a viable solution to meet the ever-increasing cooling demands of the IT world.

The focus must shift from "How?" to "Why?" The end user community should no longer consider whether these systems are feasible or practical, but what benefits can be gained? As more systems are brought on-line, Rittal and other vendors will gain even more practical experience and data on costs savings. The goal is to identify the "Sweet Spot"—the point where, looking at all the variables, it makes sense to install an LCP-based high density cooling system.

For further information, please contact Rittal Corporation at 937.399.0500 or visit our websites at www.rittal-corp.com, www.rimatrix5.com or www.rittal.com.

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