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ALPHA WHITE PAPER

CLOSED LOOP COOLING VALIDATION TESTING

R.A.S.E.R. H.D.

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Testing and Data

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R.A.S.E.R. HD Alpha Testing Validation

Background

Gkkworks has been contracted to act as third party agents in a validation study for a new product created for the Data Center by Elliptical Mobile Solutions (EMS).

Elliptical Mobile Solutions is a manufacture of Micro Modular Containers for the Data Center Industry. The company is located in Chandler, Arizona and has been in operation for the past six years. The company has developed a number of different patented Micro-Modular Data Centers. These solutions are part of a line of patented products that use a method for heat rejection called “Closed Loop Cooling”. These products can be configured with IT equipment and will handle loads from 6Kw to 40Kw redundant.

Over the next few months gkkworks will be providing data and feedback related to initial alpha testing using simulated server load and beta testing using actual server load. These results are formulated from testing criteria established by Gkkworks and executed as a third party tester for a new product developed by EMS called a R.A.S.E.R. HD.

The R.A.S.E.R. HD is a third product in a line of units created by EMS over the past few years. This unit uses closed loop heat rejection that close couples rejection of heat from the server source using a low flow, low power fan, coil, and exchanger developed and manufactured by a company called Schroff which is part of the Pentair Corporation.

The R.A.S.E.R. HD is built of the same components and materials that exist in Data Centers today. Considerations in the engineering of this product have taken into perspective the need to create a fault tolerant separation between the water rejection system and the electrical and IT loads, thus protecting the IT equipment from any failure in the heat exchanger.

The ability to make 100% utilization of the fans and coils associated with this product has produced a configuration that allows for direct closed coupled rejection of the heat produced from the CPU and other computer components in the most efficient manner available on the market today.

The unit has options for active fire detection/suppression as well as an electronic security system that is HIPPA/SOX compliant. It also has on board monitoring for all environmental elements associated with the operation of the unit. Shock and vibration isolation is inherent to the cabinet so fully populated IT loads can be shipped directly from supplier to Data Center. This provides a unique opportunity to configure data center solutions in a true Lean construct for allowing IT assets to move with a company in a non-capital intense environment.

Definition of Designed Components

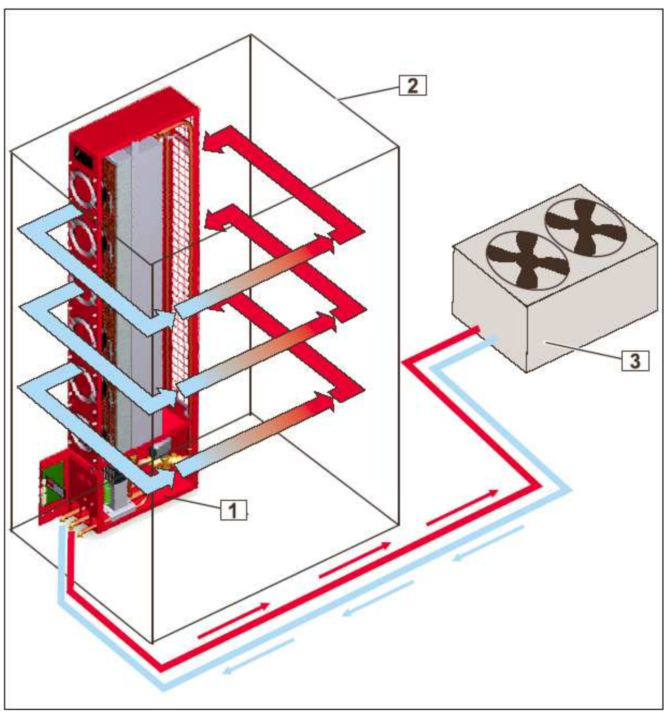
Closed-Loop Configuration:

Closed-loop cooling addresses the compute load independent of the room in which it's installed. The rack and heat exchanger work exclusively with one another, creating a microclimate within the enclosure. Those familiar with containment strategies can think of close-coupled, closed loop as containment fully evolved: both hot aisle and cold aisle in the same rack footprint using the same components you would use in a traditional Data Center environment but reconfiguring to maximize the rejection effort.

Close-Coupled Cooling Solution

The cooling system consists of an air and a water loop. The fans of the cooling unit (1) draw warm air from the rear section of the cabinet and into an air/water heat exchanger (2). The air is cooled and then blown into the front area of the cabinet.

Inside the air/water heat exchanger the heat energy of the warm air is transferred to the medium of water. The air/water heat exchanger is connected to an external reciprocal chiller unit (depending on the water temperature being used and not supplied with the module) (3), where the water is cooled again.



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Close-Coupled Cooling Efficiencies

Modular and Scalable Infrastructure

Data center professionals must understand their current requirements for space, power, and cooling and predict how those needs will grow over time; otherwise, the data center can quickly become obsolete. A past approach addressed these concerns with excess-bigger spaces, more racks and air conditioners, and large chiller plants. This left ample headroom, it was thought, for redundancy and growth.

For today's data center, immersed in discussions of high density and even higher energy costs, this approach is problematic. As HP states in its Energy Efficient Datacenter paper, Building datacenters equipped with the maximum power and cooling capacity from day one is the wrong approach. Running the infrastructure at full capacity in anticipation of future compute loads only increases operating costs and greenhouse gas emissions, and lowers datacenter efficiency"

Close-coupled cooling embodies two of the industry's favorite buzzwords: modularity and scalability. Instead of building larger spaces and installing more air conditioners, professionals can "right-size" from the very beginning. Perhaps a 40kW installation, which is ordinarily spread over 5-7 racks, is now installed into 2 R.A.S.E.R. HD units redundant, perhaps a planned 5000 sq.ft. facility becomes a 2000 sq ft facility, with comfort HVAC systems to supplement for people comfort. Due to the modularity of these products, end users can add pieces in a "building-block" fashion, increasing capacity as business needs dictate. In fact this can be done at a much faster rate under a JIT delivery model in parallel with IT growth.

The close-coupled design offers consistency in cooling performance, independent of the raised floors, floor tiles, and fans associated with traditional cooling. These products scale to successfully support the full gamut of rack loads, from minimal to **high density**. A user with a closed-loop, close-coupled design knows that a predictable capacity is available as operations grow.

Fan Energy

In the traditional layout, fans must move the air from the perimeter of the room, under the raised floor, and through a perforated floor tile into the server intake. This process, of course, requires energy, which varies from facility to facility. Often impediments (large cable bundles, conduits) exist under the raised floor, which require additional fan energy to move the required volume of conditioned air.

A R.A.S.E.R. HD closed loop unit utilizes the fans included in the exchangers to move air across the server and draw heated air across the heat rejection coil. The fans are built from the same materials as server fans and configured vertically on the exchanger so that the air is uniformly drawn and circulated in the R.A.S.E.R. HD unit.

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Higher Chilled Water Temperatures

Chilled water supply temperatures typically range from 42 to 45 degrees F. The cold water is needed to produce cold air, which offsets the mixing that occurs on the data center floor. As cold inlet air and warm exhaust air interact, the resulting inlet temperature falls somewhere in the ASHRAE recommended range of 64.6-80 degrees F. Even new variations of this allow for inlet temperatures of 90-95 degrees F. However, in a traditional environment this makes for increased temperatures in the hot aisle.

As shown in this white paper the testing results of the R.A.S.E.R. HD accepted warmer inlet water temperatures. Due to the proximity of the heat transfer and the design of the cooling coil, a warmer water temperature can provide a desired server inlet temperature within current ASHRAE's guidelines.

This point is significant for three reasons:

- Chillers, depending on the source, are estimated to represent 33% to 40% of a facility's energy consumption, due in large part to the mechanical refrigeration process.
- A higher inlet water temperature maximizes the number of hours in which "free cooling" is possible through the use of water side economizers if the environment permits.
- Chiller efficiencies in kW/Ton increase at a higher supply water temperature

Testing Criteria / Results

Through an existing relationship with a local HVAC organization United Metal Products, Gkkworks was able to secure an adequate testing ground and access to an evaporative cooler that would allow for 60 to 65 degree water to be provided for the testing without a need for a chiller. In this testing it was determined that the need for traditional chiller systems was not necessary as the units in the system already have been proven to handle loads comparable to the exchangers at 45 degree water.

United Metal Products is a manufacturer of commercial HVAC equipment with a proven track record of excellence and a strong commitment to customer service. As the industry's leader in outside air energy recovery and evaporative cooling, United Metal Products specializes in developing innovative solutions while maintaining high standards of quality. This commitment to providing outstanding customer service along with the highest quality products has led to their equipment being installed on facilities throughout the world from Mexico to the Middle East and across the entire United States.

Located in the heart of one of the harshest climatic regions of the world, where temperatures can exceed 120℉, United Metal Products is uniquely experience d in dealing with the toughest of cooling issues. The base of their operations is in a 96,000 square foot facility in Tempe, Arizona, where they manufacture energy saving cooling and heating air handling equipment for facilities around the world.

This initial testing was to show the robust nature of the unit in its ability to handle varying loads and efficiencies at higher water temperatures. As shown in the data, these units can handle better than traditional loads at 42U than a conventional data center design and that the R.A.S.E.R. HD unit can provide solutions for eliminating chiller systems altogether while maintaining very low PUEs.

A part of product and testing the following criteria was established for the alpha testing. As this is a new product EMS was looking to establish the following data.

1. Ease of transport and installation to an evaporative cooler system
2. Ability to run the unit under load at 65 degree water
3. Ability to simulate in rush of a full load and capture time to recover operating temperature (chip instant on)
4. Ability to run the unit under load to determine unit capacity at higher water temperature, up to 85 degrees.

All of the testing was completed in an outdoor environment on a clear day in Phoenix, Arizona. The temperature outside, taken prior to each test, is denoted with the results.

The R.A.S.E.R. HD unit configuration during testing was that the exchangers are installed in separate compartments from the IT load. Air is circulated in a closed loop vortex through the servers; water is isolated from the main electrical distribution. The unit itself is welded to rails that keep the unit off the floor by six inches. This also allowed for ease of transportation as the unit was delivered with a pallet jack off of a truck.

The exchangers are equipped with an array of power, temperature sensors, and an auto shut off valve. In the event of power loss the valve will remain open. This serves as a well-engineered solution between water and electrical in the data center.

The R.A.S.E.R. HD unit is constructed of a steel frame in a frame configuration with vibration isolation mounted via welded connections. This type of configuration allows for an ability to stack 42U IT hardware solutions off site, burn them in with software applications, and deliver them to a Data Center fully configured and ready to plug into electrical, mechanical, and network splines. Using secure cyber lock keying that comes with these units would keep them from being accessed while in transit. Additionally uni-body construction of these units will withstand a 3000lbs impact. This type of solid construction allows for the units to reside in less hardy brick and mortar facilities. A consideration would be to mount them to the floor in a compliant earthquake or tornado proof installation.

Another observation in the testing was that the units are NEMA 4 constructed water tight weather heads are used to allow cable penetration to the units which allows for mitigation of water infiltration from the outside. All of the connections to the exchangers are configured in the same fashion that is seen in CRAH units as well as in Data Center Mechanical rooms. While quick connects could be used, it is felt that threaded connections are more durable and wear longer.

One last observation related to accessibility of these units and protection of client asset. The access to the mechanical components is through separate doors than the IT equipment. With the separation of access using keys the concurrent maintenance of these units can take place by technicians without access allowed to the IT space.

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Testing Criteria / Results

Product Configuration

R.A.S.E.R. HD
23Kw of Load Bank

Exchangers located in separated chambers right and left of the load banks

R.A.S.E.R. HD Unit operated with doors closed; leaves not required for outdoor testing.

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Testing Criteria / Results

General Note Humidification

During all of the following tests the humidity dew point level in the unit never changed. There was a constant dew point well within the ASHRAE range. It is noted that under normal conditions the unit is sealed from the outside environment. Therefore humidification will maintain a constant in the R.A.S.E.R. HD without much variation. The opening of doors on a live environment could produce some condensation on the coil of the exchanger but operating at higher water temperatures this would be minimal or nonexistent.

Noise Attenuation

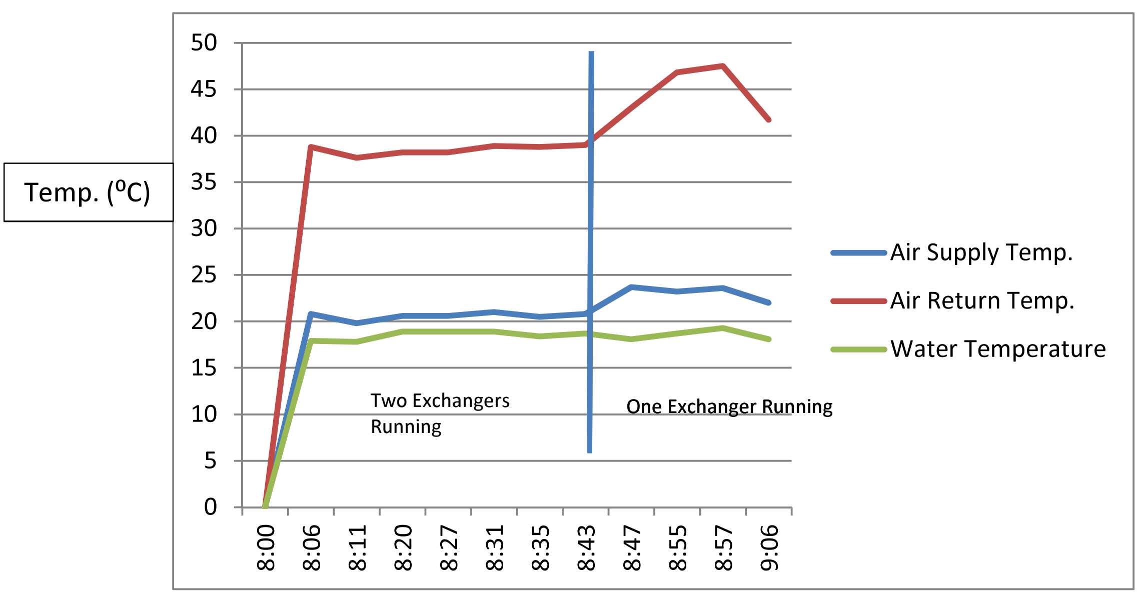
While there were no DB readings taken during the testing it is interesting to note that the fans on the evaporator units and the water pump adjacent to this unit gave off more noise than the load banks at full operation inside the unit with the door closed.

Test One (Outside air temperature 85º F (29.4ºC))

R.A.S.E.R .HD unit was installed with 23Kw of load banks operating at 230V single phase protected with two 50 amp breakers. Fans are powered with 230v 15 amp breakers total and power to the fans is provided through an onboard rectifier that steps power to the fans from AC to DC. Four water hoses were installed to the distribution lines in the units that provided supply and return to two exchangers in the R.A.S.E.R. HD.

The first test performed was to run the load banks at full load with water flowing through both exchangers at 12 gpm ea. and fans running at 80%. The units vary their independent fans between 80% and 100% depending on air return temperature. The water temperature was set at 64.5F (18.1^{o}C).

The following chart shows the temperature exchange in the R.A.S.E.R. HD during the test.



Test One Cont.

As seen in the chart a supply air temperature was maintained close to the water temperature (within a few degrees). Heat rise occurs due to one of the units being varied off line to see the effect of temperature rise in water and air distribution. It is interesting to note that these temperatures from the hot side of the load bank to the coils are showing a direct and immediate exchange of heat to the water source with no bleed through to the front of the load bank or intake server area. In most traditional designs the need to force air out of the server cabinet leaves racks with hotter temperatures at the top of the rack. It was found in the R.A.S.E.R. HD that the temperatures all remained constant.

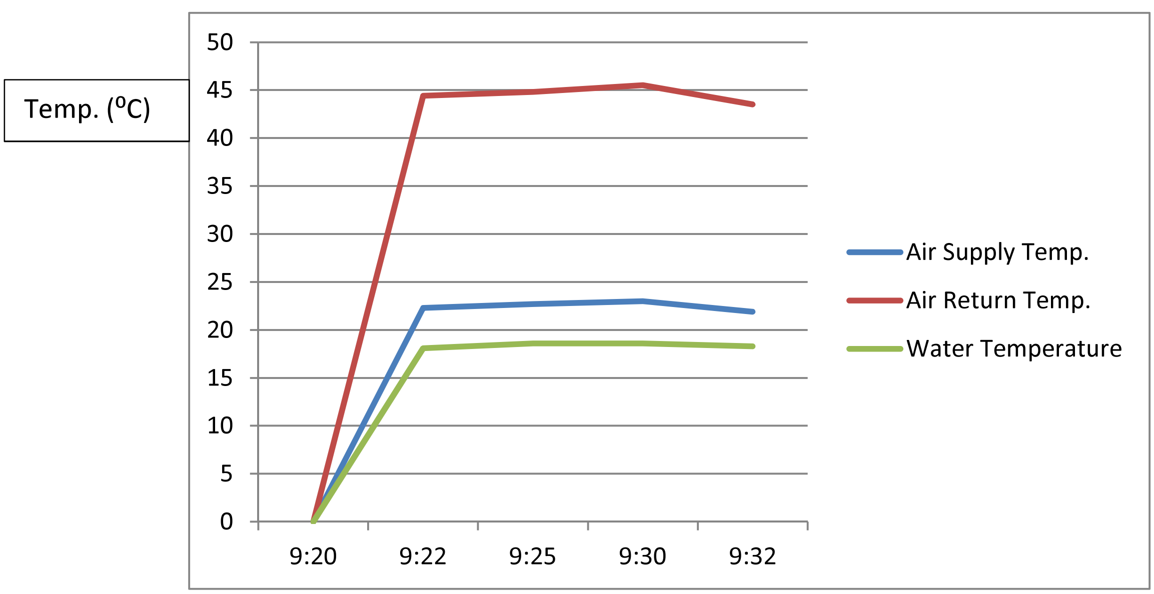
Temperature sensors are located at the top middle and bottom on the supply and return side of the exchangers. Additional sensors were added directly behind the load banks top and bottom to capture the temperatures directly after the load banks

Additional observation of the exchangers while the R.A.S.E.R. HD doors were open showed that with the power off on the load banks there was enough CFM flow to drive the fans on the load banks. Since there was a variable drive on the load banks the fans were set to minimum. At no time during any of the testing did the Load Banks experience any kind of fault or alarm.

Test Two (Outside air Temperature 90^{o}F)

In this test the Load Banks were set to 17Kw. The R.A.S.E.R. HD was run with one exchanger off line and one exchanger running. The water temperature was set to 64.9º (F) 18.3º(C). The fans on the unit ran at 80% for the entire time of testing. As a reminder all of testing in this report was done outside with no cover. As the sun moved over the course of the day the R.A.S.E.R. HD was exposed to direct sun with outside temperatures noted in each test.

United Metal Products maintained water temperatures for their evaporative unit over the course of the day. This unit ran with no compressor system, only coil and cascading outside water media system.
The following chart notes the results of temperature readings taken during this test.



At 65º F 18.4ºC water and one exchanger running the R.A.S.E.R. HD maintained a constant 17Kw of heat rejection.

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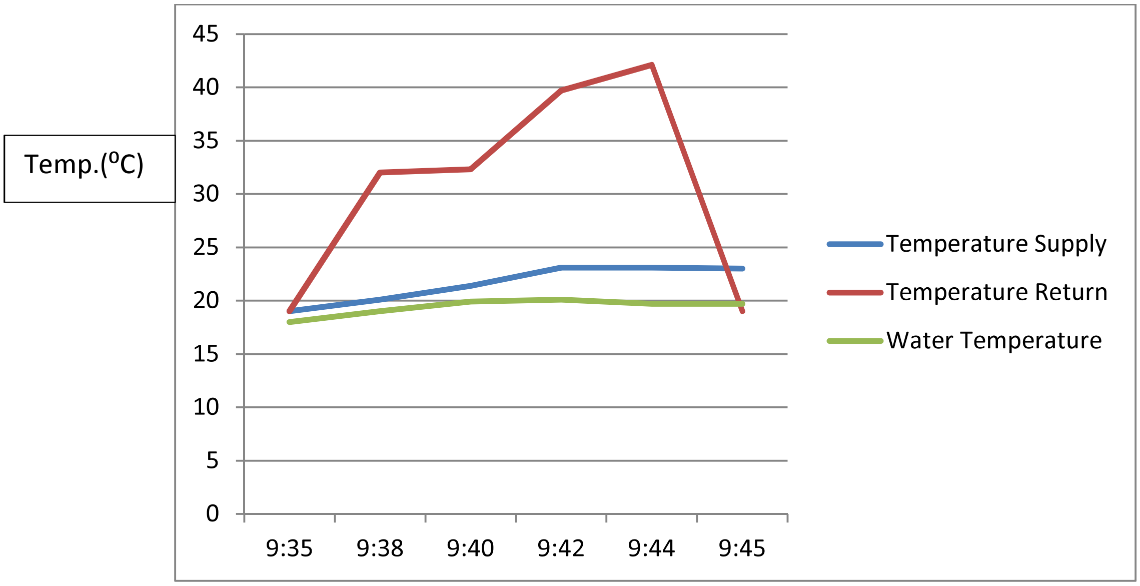
Test Three (Outside air Temperature 90ºF)

For test three load banks were left at 17Kw. The system was shut down with the exception of one exchanger. The unit was left idle to simulate a no load status in the R.A.S.E.R. HD. Using the feed breakers for the load banks the 17Kw of load was initiated instantaneously. This was to simulate as close as possible an instant on of a CPU load in a typical compute cycle were no process was running. As seen in the chart the readings showed an instantaneous absorption of heat by the exchanger to the water sub straight.



In this simulation it was surmised that with further testing in the beta stage confirmation would be provided that closed loop configuration could act as a direct rejection for the CPU the same as if it were attached to a water heat sink. Additionally, due to the efficient rejection of heat from the system there is potential opportunity to eliminate server fans altogether.

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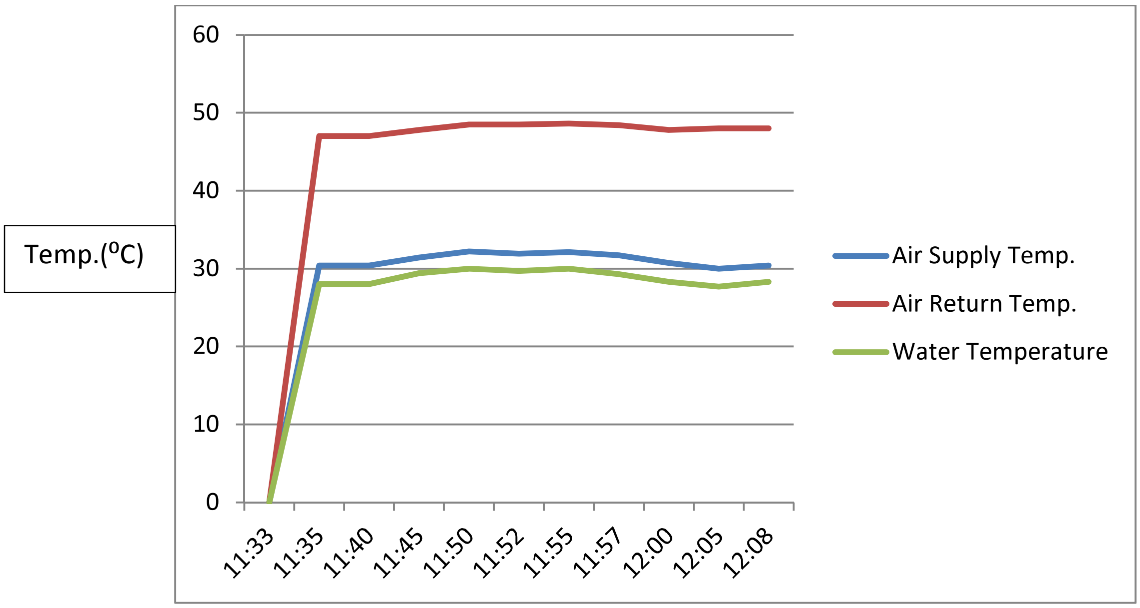
Test Four (Outside Temperature 100ºF)

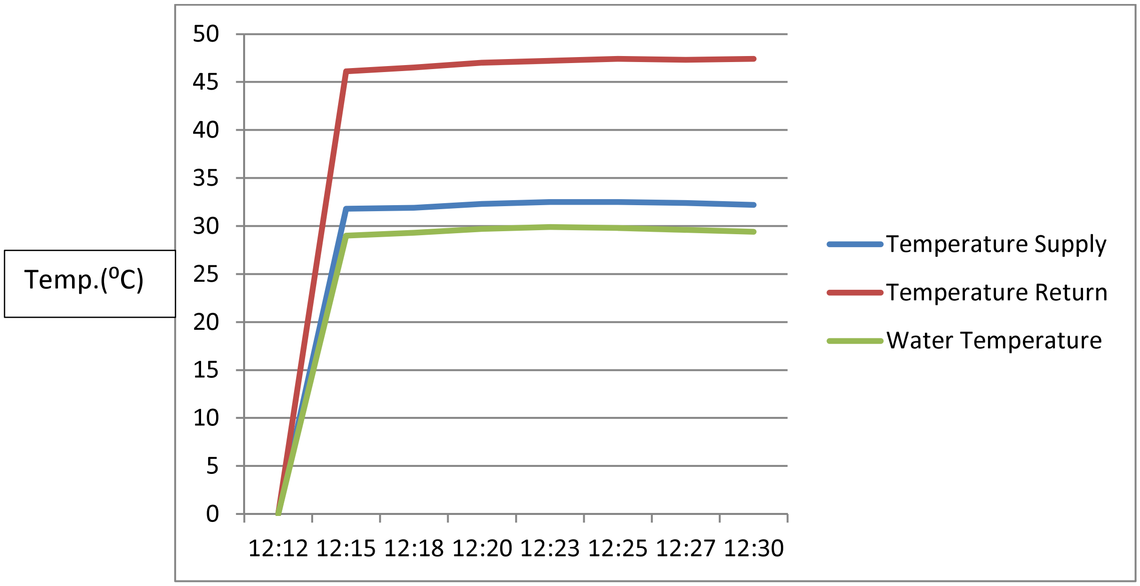
During this next test the load banks are set to full load (23Kw) and water temperature is increased to 85.1º (F) 29.5º(C). Both exchangers are powered on in the R.A.S.E.R .HD. The following chart represents the readings taken during this testing. We were able to maintain a simulated server inlet temperature of 86.3º(F) 30.2º(C) with 85.1º (F) 29.5C water temperature.



Even at this temperature we were able to see that the exchangers could provide an efficient heat rejection with a high delta T. It is surmised that with such a closed close coupling to the exchanger and the tightness in separation between the hot and cooler side of the coil the rejection is very efficient.

Test Five (Outside temperature 103ºF)

In our last test we wanted to see how much KW we could get from one exchanger in a closed loop configuration delivering 85.1º (F) 29.5⁰(C) water. The load banks were set to 10.5 Kw and the single exchanger was running for the duration of the test.



The R.A.S.E.R. HD unit was able to maintain a supply air temperature of 89.6º (F) 32º(C) for the duration of the test while the water temperature was maintained at 85.1º(F) 29.5ºC. As additional testing is preformed it is surmised that in an interior controlled environment these temperature variations will remain consistent and will even improve. At this point of the testing we are confident that given a server load to test we could see PUE's of 1.03 and better.

Data Center Abstract

While energy efficiency has been the 'hottest' challenge in data center developments in the past years, a new challenge has already caught up: "extreme" flexibility.

With IT developments moving ever faster and the advent of cloud computing and resilience of software changing the data center, everything is changing. However, few, if any at all, know how this will eventually transform the data center landscape.

Most uncertainties are related to:

- White space: from containers, to DC power supply, water-on-the-chip-cooling or non UPS power supply;
- Power densities: ranging from a conservative average of 10 kVA per rack to hotspots of 80 kVA per rack (and rising);
- Room conditions: ranging from standard ASHRAE conditions, to desert conditions;
- Changes or elimination of TIER levels.

Given the very short market forecast or IT horizon common to the data center market, these uncertainties result in a demand to be able to 'change on the spot'. In meeting the demand Gkkworks has spent many of its own professional hours working on analyzing these future extremes and has developed a number of metrics and designs that are going to occur over the next hardware refreshes for the Data Center Industry.

This paper is being presented to provide some insight to these challenges and offer real cost controlled solutions that will enable business to adapt on the move without having to reinvent the wheel.

As an industry the organizations that have supported the data center industry from an infrastructure stand point have really not done a lot in terms of innovation over the years to support real stack, IT architectural growth and flexibility in the data center. We have been so tasked with keeping up with the demand through every hardware refresh there hasn't been a lot of time to innovate. The infrastructure industry for data centers has been and continues to be reactionary to IT growth demands. We continue to see growing loads in the IT cabinet, not from a power stand point but from one of heat rejection. We continue to purport that the solution to this heat issue is to spread out the load, because all we can do is handle a finite amount of heat rejection due to the size of the cooling systems and associated coils in various CRAC, CRAH, and Evaporative or Abiotic HVAC systems that have been created to handle these heat loads.

A common fear that has been instilled in the end user community within the data center industry is: "Do not put water in your data center." Why increase the density of the load at the rack level and put water there when you can spend more capital on real estate and support equipment while keeping the water at the edge of your data center? Or better yet, create a separation of more real estate and equipment and create a hallway in which to put the equipment? These fears are based on fallacies. Research, including that conducted in our study, proves that water and IT equipment can not only operate in the same environment but can function with greater efficiency than the traditional approaches.

While these solutions have all provided a false sense of comfort to the industry, they have not been able to address the bigger problems that are being created by building out facilities in this manner. That is the issue around the tremendous amount of increased power utilization, duration and compensation of power because of the size of these facilities. Copper feeders are upsized to run longer distances so we can get full utilization of transformers, breakers, and panel space. At this rate we will be building facilities that will require substations for distribution just inside the data center. And by the way these types of facilities exist now.

As IT hardware is innovating through equipment and software, the systems and infrastructure to support it have not, for the most part, been able to keep up. There has not yet been a marketing scheme or design, to date, that has been able to totally encompass a full solution at the rack level. The IT equipment manufacturers do not focus on what your heat load is and infrastructure to support the IT load cannot be consumed in small increments. Whether you have 1Kw or 40Kw, these enclosures can support your needs and create reliable and available systems that will enable your company to grow your IT needs at your business pace.

Gkkworks has conducted extensive studies and finds that the majority of Data Centers today are building on design concepts developed in the 1990's and that only a handful of useful facilities have been developed to mitigate increased heat load. These newer facilities have been designed around free cooling and dependency on geographic and hydro availability for power. While these facilities have been created to take advantage of these technologies they have created a huge encumbrance on local ecology by having to destroy acres of natural lands to make room for this expanse. Additionally, there has been little done in the true development of benefits achieved around energy efficiency. Since the utility systems that provide energy to Data Centers are provided at such a cheap cost and locating facilities to areas that support this low cost, there is little concern over efficiency when it comes to operating these facilities. However as these facilities grow and the encumbrance of power is seen at the utility level by the providers there will most certainly be a re-evaluation.

Initial Installation Observations

The R.A.S.E.R. HD product will require a water system; supply and return lines will install in a configuration concurrent with container installations (Spline). Due to the Micro Modular aspect of the R.A.S.E.R. HD the current findings dictate, that these systems could be coupled to existing traditional building systems. The units, if configured correctly with IT equipment, could provide a new twist to data centers that maintain archaic "data center in a closet" designs. The densities also could be configured in such a manner that close coupling of the IT server, the storage as well as the network solution in a standalone data center, could provide the same compute capacity as five conventional IT racks with petabytes of storage and larger network capable systems than in a traditional data center.

With the fact that these units come equipped with on board fire suppression and detection as well as security capabilities, these units could be set standalone lights out in whole and monitored from remote location. There would be no need to risk concerns around loosing several lines of asset in a string of these units due to the fact that the IT asset is all individually contained in a 42U configuration.

With a refreshed visit on the part of IT hardware manufacturers, constructs of new configurations could be assembled that would allow for operation at slightly higher densities. This would permit coupled configurations to optimize software, storage, and networking solutions, dramatically changing the need for the traditional environments in which they reside today.

This coupled with the ability to dramatically change the operating parameters of these configurations utilizing better designed water systems, pure fault tolerant solutions can be configured to allow any component on the system to passively fail without effecting the IT equipment.

Conclusion

The considerations for close-coupled designs are many. Product selection depends largely on the individual installation and requires input from a number of groups, from IT and facilities staff, consulting engineers, and vendor representatives. Yet, the end result of this concerted effort can be considerable. Consider the following examples:

- An HP Mission Critical Facilities presentation compares conventional cooling architecture with 45 degree chilled water vs. a close-loop, close-coupled cooling strategy with 55 degree chilled water. The presentation projects annual energy savings of over $1 million with the closed-coupled design.
- For facilities where it's impractical to raise the chilled water temperature, a manufacturer study with a 45 degree chilled water supply using an In-Row product reports a $60,000 annual energy savings over perimeter CRAH technology (Bean & Dunlap, 2008).
- The oft-cited EPA's Report to Congress christens close-coupled liquid cooling as a "State of the Art" technology-a key element in curbing cooling plant energy consumption.
- Close-coupled cooling can accommodate a "Zone" approach to data center expansion, addressing the higher performance loads. The approach allows for, according to Gartner, "adequate power distribution and cooling…without having to create a power envelope for the entire data center that supports high density". This zone approach reduces first-costs and continuing electricity costs.

The final point is key. The benefits of energy efficiency are not exclusive to the environment. The R.A.S.E.R. HD, along with other best practices, offers significant financial benefit. From lowered real estate and construction costs, lower monthly utility costs, potential utility rebates to operating bills, the business case is there. The ecological results are simply an added bonus.