

A COMPREHENSIVE ANALYSIS OF SINGLE AND TWO-PHASE IMMERSION COOLING STRATEGIES FOR DATA CENTERS

Submitted in partial fulfillment of the requirements for the award of

**Bachelor of Engineering Degree in
Mechanical Engineering**

BY

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **SHAIK MOHAMMAD ZAHID(38150107)** and **I.B.V.V.L.S.BASANTH KUMAR (38150038)** who carried out the project entitled "**A COMPREHENSIVE ANALYSIS OF SINGLE AND TWO-PHASE IMMERSION COOLING STRATEGIES FOR DATA CENTERS**" under my/our supervision from November 2021 to March 2022

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DECLARATION

We, **SHAIK MOHAMMAD ZAHID (38150107)** and **I.B.V.V.L.S. BASANTH KUMAR (38150038)** hereby declare that the project report entitled “**A COMPREHENSIVE ANALYSIS OF SINGLE AND TWO-PHASE IMMERSION COOLING STRATEGIES FOR DATA CENTERS**”, done by us under the guidance of **Prof.Dr. J. JAYAPRAKASAR, M.E., Ph.D.** and **Dr. G. ARUNKUMAR, M.E., Ph.D.** at **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY, CHENNAI** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

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I am pleased to acknowledge my sincere thanks to Board of management of **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I convey my sincere thanks to **Dr. S. PRAKASH, M.E., Ph.D.**, Dean, School of Mechanical Engineering and **Dr. G. ARUNKUMAR, M.E., Ph.D.**, Head of the Department of Mechanical Engineering for providing me the necessary support and details at the right time during the progressive reviews.

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ABSTRACT

Servers that are completely submerged in electrically nonconductive oil have lately emerged as a possible method for reducing data centre cooling energy use. Because fluids have larger heat capacity than standard air coolers, liquid cooling provides several benefits over the latter technique generally. Oil cooling, although having a lesser heat capacity than water, offers benefits over other liquid cooling systems in that it does not need sophisticated infrastructure (piping, pumps, valves, etc.) inside each servers. Most data centre operators, however, are reluctant to use oil cooling in their mission-critical facilities due to a lack of publicly available data and verification of long-term dependability. Initial tests and data gathered on a single server submerged in oil suggest that it is feasible to utilise high temperature (45°C) low flow rate oil to cool a server, needing minimum cooling energy.

Is Liquid Cooling eventually here as the new disruptive cooling system? We don't know yet when such a disruption would happen, but it's a fact that the last three years have been full of news and announcement in the field. It's clear that it will be a race between different technologies. There are also several actors who can drive the adoption: chip manufacturers, server manufacturers, internet giants, major colicators. Understand the technologies is the first step before to look for adoption, development, investment. This application note wants to be a very basic document touching the principles of liquid cooling. Why it's so important and critical today, what are the current actual technologies, how liquid cooled rack can be integrated in chilled water-cooled facility. Each topic should, and it must, be investigated further.

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LIST OF ABBREVIATIONS

AI	-	Artificial Intelligence
CSP	-	Cloud Service Provider
DOL	-	Direct On Line
ESD	-	Electrostatic Discharge
GRC	-	Green Revolution Cooling
HPC	-	High-Performance Computing
ITE	-	Information Technology Equipment
PS1	-	Pump Suction

CHAPTER 1

INTRODUCTION

1.1 LIQUID COOLING

Liquid cooling is not a new cooling principle. It's been well known since the early steps of information technology. While pushing the limit of computational power, heat dissipation of CPUs requested to engineer some sort of liquid cooling system.

High performance computing, research laboratories, military and government agency have been the early adopters of this way to cool IT equipment. Thanks to Moore law's accuracy, periodically the liquid cooling has been declared on the brink of a cooling revolution.

A mainstream revolution outside University and Research laboratories that hasn't yet happened. Mainly because the combination of IT manufacturing technologies that allows to concentrate more power in same size (more cores for instance) and the modernization of air-cooling system.

Air cooling systems have been capable since today to cool the IT equipment arranged in hyperscale and retail DC, increasing the percentage of free – cooling, optimizing the efficiency, using renewable energy as main power supply.

But IT business is the fastest and it looks like this time CPU manufacturers are announcing the next generation of CPU almost impossible to cool using just air.

That's why in the last three years and in particular in the last year, it's clear an increased turmoil in the liquid cooling manufacturers pushing their different solutions and on the big IT players an increased interest in testing on a

real DC the new liquid cooled solutions. Liquid cooling of a computer is usually associated to gaming. Gamers are a community that requires higher performances from their own PC to run videogames hungry of CPU power GPU power.



Fig. 1.1: Liquid Cooled PC desktop

1.2 ORIGIN

However, despite the fact that liquid cooling in datacenters is by no means a new idea, the technology's applications are still somewhat confined to exascale and HPC.

According to Paul Finch, CEO and COO of Essex-based colocation provider Kao Data, fresh air conditioning is still the primary (and most frequent) method for controlling temperatures in data centres throughout the globe.

The company's mission is to become the UK's top supplier of datacenter capacity for the life science industry. It also claims to be the first wholesale colocation facility in the UK to employ indirect evaporative cooling without mechanical refrigeration, in which hot air created by the servers is discharged into the environment rather than outside air being pumped in to keep the equipment cool.

1.3 SPECIFIC STUDY

High-technology environments are those areas which contain expensive technological equipment and/or special processes. To operate correctly these machines need to be in a room with carefully controlled operative parameters which are not usually related to the comfort of people.

Data centre are built for High-technology environments like computer centers, process control centre, telephone exchanges, meteorological rooms, electronic component production areas, medical treatment areas which use powered electronic equipment, control rooms, and photographic laboratories

Temperature and humidity must be maintained 24 hours a day, seven days a week in most data centres.

Electronic equipment cooling is the only focus of precision systems. To keep electronics from overheating, they need to be cooled constantly using pure sensible heat.

It is possible for sensitive computer components to be damaged by electrostatic discharge (ESD) if the relative humidity is too low.

High humidity in a server or computer room may lead to the accumulation of moisture (air water content), which can lead to corrosion and equipment failure over time. There is a risk of short-circuits in the near term.

Precision Air Conditioning is required for Mission Critical Environments.

CHAPTER 2

LITERATURE SURVEY

CHENLONG WU(2019),Full-scale two stage fluid inundation cooling server farm framework in tropical climate. Two-stage fluid inundation server farm cooling framework: Experimental execution and thermo-financial examination.

XIANG YIN(2017),Experimental examination on the exhibition of a clever single-driving coordinated siphon and blower framework for electronic cooling.

KHOSROW EBRAHIMI, GERARD F. JONES, AMY S. FLEISCHER,A audit of server farm cooling innovation, working circumstances and the relating second rate squander heat recuperation potential open doors . The exhaustion of the world's restricted repositories of petroleum derivatives, the overall effect of a dangerous atmospheric deviation and the significant The high cost of energy is one of the primary factors fueling a renewed interest in the capture and reuse of waste energy in the United States. Because of the growing need for cloud-based network and execution, server farms are producing considerable amounts of waste energy. Current data shows that server farms use over 2% of the total electricity consumed in the US. Half of this electricity is used to cool the hardware, which generates an important amount of waste heat. Reusing and recycling this stream of waste heat is problematic since the heat has poor quality. Techniques and advancements that are most promising for the future are discussed in this study, recuperating server farm poor quality waste hotness in a viable and financially sensible manner are recognized and examined.

BRYONY WATSON, VINOD KUMAR VENKITESWARAN,Universal cooling of server farm.

ABDULMAJEED HAMAD ALMANEEA, Thermal investigation of fluid drenching hardware for server farm. Server farms have racks that incorporate servers which support computerized administrations. The developing interest on computerized administrations, for example, web based content, web administrations, broadcast communications, monetary and virtual entertainment has prompted a phenomenal development in server farms and in this manner their electrical power utilization. A huge piece of server farm energy is consumed by the cooling frameworks inside server farms. Energy utilization of server farms can be diminished by further developing their cooling frameworks. A few server farms are cooled via air it are cooled by fluid to cool while others. The fluid cooling approach has more noteworthy open doors for productive cooling, especially in high thickness server farms. The fluid cooling techniques can be named rack heat exchanger, in server and on chip heat exchangers and complete fluid submersion. The fluid drenched idea lowers the server in a dielectric fluid. This fluid is in direct contact with the entirety of the microelectronics and it has properties that cause no electrical release. The hotness from server parts, like the CPU, is moved through normal convection in the dielectric fluid to water channels, which transport the hotness.

YANNIS BLOSCH, Air cooling versus Fluid inundation cooling; can work on the energy and space effectiveness of server farm?. The interest for cloud administrations is rising consistently, blowing up the energy interest for server farms dramatically. The reason for this writing audit is to find the positive effect fluid inundation cooling can have on server farm effectiveness and thickness Utilizing a methodical writing survey, this paper outlines the exploration previously directed on drenching cooling. The determined outcomes, utilizing the accessible information, shows that by changing from air to fluid drenching cooling, about a portion of the energy utilized by a server farm and 66% of the space involved by a server farm can be liberated for extra equipment. This survey prevails with regards to showing the capacities of fluid submersion cooling in server farms. Further exploration can be directed on the genuine improvement when a server farm is switched over completely to drenching cooling.

RICCARDO LUCCHES, Cooling control systems in server farm for energy effectiveness in heat recuperation. Server farm are offices committed to the handling, stockpiling, and hand-off of a lot of advanced data. In general, It's a serious energy business, as shown by a high carbon footprint and a rapid but temporary growth rate.

A macro level, they must balance the supply and demand of computing, cooling and electrical power resources in order to operate effectively External variables such as the activity of end-users and the varying price of power have an impact on the computing burden and the total run-time expenses.

More sustainable designs may be achieved via the use of control systems that optimise both mechanical and control elements, as well as co-design approaches. As energy efficiency improves, larger-scale installations in less desirable areas may be possible in the future. By-product heat recovery systems may help sustain other heat-intensive industries including district networks, wood drying, greenhouses, and food processing. The goal of this research is to find a way to match cooling resource supply to cooling demand without compromising compute performance. For current deployments, we provide top-down designs that take use of untapped control possibilities that have yet to be explored. To further simplify data centre optimum provisioning challenges, we take a bottomup viewpoint by modelling and analysing co-designed cooling arrangements. Among the central questions addressed by the study are: (i) what are the optimal flow provisioning policies at various levels of data centres? (ii) how can simple but effective control strategies be designed to address the complexity caused by large scales? (iii) what are the exhaust heat properties that can be expected in air-cooled and liquid-cooled data centre? Using a model-centric approach, we show the efficacy of customised control techniques in improving cooling efficiency while also improving the quality of heat harvest. Data centre control architectures may be simplified while maintaining or enhancing their performance, according to this thesis. In addition, it offers the groundwork for a comprehensive approach to the regulation of computing, cooling, and power distribution infrastructures. An essential development direction has been established, and the model-based research has confirmed current tendencies. Enabling intelligent data centre

management systems may not need more complicated tools; instead, a collaborative effort may result in control systems that are both simpler and more effective.

JOHN ROACH, To cool server farm servers Microsoft goes to bubbling liquids. "We are the primary cloud supplier that is running two-stage drenching cooling in a creation climate," said Husam Alissa, a main equipment engineer in Microsoft's group for server farm progressed advancement in Redmond, Washington.

CAROLINE DONNELLY, Data focus fluid cooling: what close to occur for it to become normal place in co-area? As interest for progressively thick racks and process weighty jobs increments inside server farms, could this prompt a discount move in inclination from air-to-fluid based cooling frameworks? Provided that this is true, at what cost to the climate?

STEPHEN LIANG, CTO VERTIV, How quick are we moving toward the tipping point for fluid cooled server farm ? The plan prerequisites of fluid prepared information centre. Overcoming hindrances to showcase acknowledgment. Energy proficiency and manageability measurements for fluid cooling options. How the financial aspects of drenching cooling are developing.

BILL KLEYMAN, Data focus advancement and the way to fluid cooling. Offices hoping to send very high-thickness racks and take for enormous scope Fluid cooling will be the only option for applications like artificial intelligence and machine learning in the future.

SHLOMO NOVOTNY, Vette Corporation's Vice President and Chief Technology Officer

Our economy is becoming more and more dependent on data. Green Field is a virtual machine server farm configuration water cooling for greatest effectiveness. The IT people group is encountering continually expanding requests in regions like Internet media and video, banking and money, exploration, and government, just to give some examples. Therefore, server farms keep on filling in

both size and numbers. What's more, the exhibition of IT servers keeps on adhering to Moore's regulation; this further develops the presentation per dollar spent on IT gear, yet additionally expands the hotness thickness inside the server farm hardware. Driven by these elements, the expense of running a server farm keeps on developing, even as the expense of the IT execution keeps on declining.

RUIYU SUN, YONGWEI LI, SHIFENG WNG, GUOFENG CHEN, QINGIMNG FU, An Advanced fluid cooling rack intended for server farm. As the arising plans of action and progressed client experience is driving a blast of information at the time of 5G, server farm has been advancing with progressively strong AI (Artificial Intelligence) figuring capacity for upgrading CSP (Cloud Service Provider) cloud administration by information investigation in information driven world. Elite execution registering, stockpiling and systems administration are fundamental to accomplish this. In the mean time, energy proficiency which is estimated with PUE is obligatory plan focus for present day server farm. Progressed warm arrangement is one of urgent advancements to ceaselessly address the interest of better execution figuring at lower PUE.

MADHU SUDHAN IYENGAR; MILNES DAVID, Server fluid cooling with chiller less server farm intended to empower critical energy reserve funds. Abstract: This paper sums up the idea plan and equipment fabricate endeavors as a feature of a US Department of Energy cost shared award, long term project (2010-2012) that was attempted to grow exceptionally energy productive, warm fluid cooled (2012) servers for use in chiller-less server farms.

LI LI, (Graduate Program in Electrical and Computer Engineering). Planning fluid and free air cooling with responsibility allotment for server farm power minimization. Server farms are looking for more effective cooling methods to diminish their working costs, since cooling can represent 30-40% of the power utilization of a server farm. As of late, fluid cooling has arisen as a promising option in contrast to conventional air cooling, since it can assist with wiping out undesired air distribution. Another arising innovation is free air cooling, which saves chiller power by using outside cool air for cooling. A few existing server farms have previously begun to embrace both fluid and free air cooling procedures

for fundamentally further developed cooling proficiency and more server farms are supposed to follow.

PETER JUDGE, Two stage fluid cooling has at long last shown up. Sellers are making carefully designed fluid cool servers. Data focus administrators have been keeping away from fluid cooling. Saving it as a likely choice for the future, however never a standard functional methodology.

GIULIOTRIMICERI, Cooling frameworks in server farms: condition of craftsmanship and arising innovations. An enormous amount of energy is being used as the quantity, size, complexity, and intricacy of server farms increase in response to an increase in demand for capacity, system management, and computation. A few measures to further develop energy proficiency are being contemplated, not exclusively to permit an acceptable industry development yet additionally to decrease functional expenses. Cooling energy utilization establishes a huge part of the absolute utilization of server farms, which can account up to 40% on account of wasteful cooling. In this paper a basic conversation on existing and arising innovations for server farm it was completed to cool frameworks. Crucial viewpoints concerning benefits and disadvantages of each inspected it were examined to cool framework. In addition a basic investigation on next future innovation answers for acquiring high energy effectiveness server farm is performed.

JONATHAN SHIEBER, Immersion cooling to balance server farms huge power requests acquires a major promoter in Microsoft. They're both dropping servers conveying touchy information into goop with an end goal to save the planet. Presently they're joined by one of the greatest tech organizations on the planet in their endeavors to further develop the energy effectiveness of server farms, on the grounds that Microsoft is getting into the fluid inundation cooling market.

ROBERT SHELDON, The mission to keep up with working temperatures for expanding registering densities has firms progressing from air cooling to fluid cooling. We survey both methods. Data focuses keep on pressing seriously

registering power into more modest spaces to combine jobs and oblige handling escalated applications, like AI and progressed examination.

FRED REBARBER, VERTIV, Six interesting points while bringing fluid cooling into your server farm. Server farm administrators have made various changes throughout the years to stay away from the need of bringing fluid cooling into their offices. Be that as it may, today they are out of choices.

CHAPTER 3

AIM AND SCOPE OF PRESENT INVESTIGATION

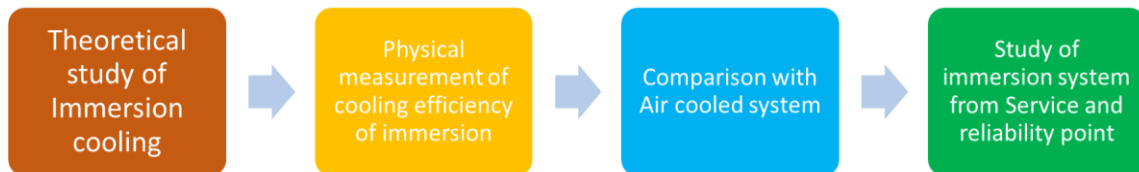
3.1 AIM

The goal of this study is to get a better knowledge of the submersion cooling of IT equipment idea (ITE).

The purpose of this study is to determine the cooling effectiveness of an ITE submerged in oil.

Efficiency (in terms of oil life cycle, component reliability and serviceability) of an oil-cooled data centre. Oil cooling efficiency.

3.2 SCOPE



Visit a immersion cooled liquid server site

Visit Air cooled architecture DC to measure the efficiency

Methodology of measuring operational efficiency

Studying the effects of liquid on servers reliability

How to handle serviceability of liquid cooled servers

CHAPTER 4

MATERIALS AND METHODS

4.1 PROCEDURE

4.1.1 *Types of Direct to Chip Liquid Cooling*

There are currently some established liquid cooling technologies on the market. They can be classified following different criteria. The first criteria is the segregation between the fluid and the electronic components (CPU, GPU, RAM). Using such criteria liquid cooling systems can be Immersive.

This family of liquid cooling technologies wet the electronic components. There is no separation between the fluid and the electronic components. For this reason, the fluid cannot be water but must be some other type of fluids. They're called engineered fluids and they have good dielectric property.

Direct – To – Chip (a.k.a. Cold Plate): This family of liquid cooling technologies uses specific heatsink (like the chip – to – air heatsink) in direct contact with the electronics. The cooling fluid flows inside the heatsink, separated by the electronics. Because of this separation between fluid and electronics, water can be considered as fluid. The second criteria is the pressure of the fluid.

Positive pressure: The fluid that cools the electronics inside the server has a hydraulic pressure greater than atmospheric pressure.

Negative pressure: The fluid that cools the electronics inside the server has a hydraulic pressure lower than atmospheric pressure.

The third criteria is the fluid phase.

Single phase: The fluid that cools the electronics inside the server stays liquid throughout the cooling cycle.

Two phases: The fluid that cools the electronics inside the server change phase (from liquid to gas and vice-versa) throughout the cooling cycle. The fourth criteria is the location of the servers.

Chassis: the server is enclosed in a box (chassis) together with the cooling fluid and additional hardware. The chassis ensure the electrical and network connections between the server and the outside.

Tub: The servers are vertically placed inside a tub, full of cooling fluid. There can be several combinations of above-mentioned types of liquid cooling. In the following and there are the current combinations available on the market.

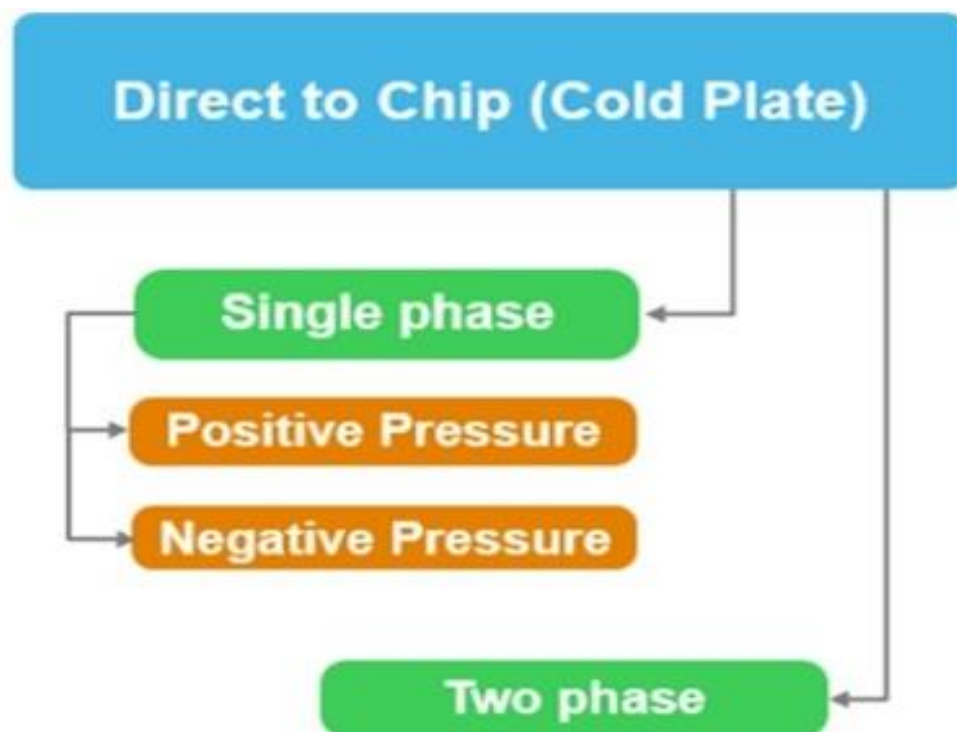


Fig.4.1: Types of direct to chip liquid cooling

4.1.2 *Types of Immersive Liquid Cooling*

Currently negative pressure system is available only in single phase direct to chip liquid cooling. While for both two phase and single phase there is the positive pressure option.

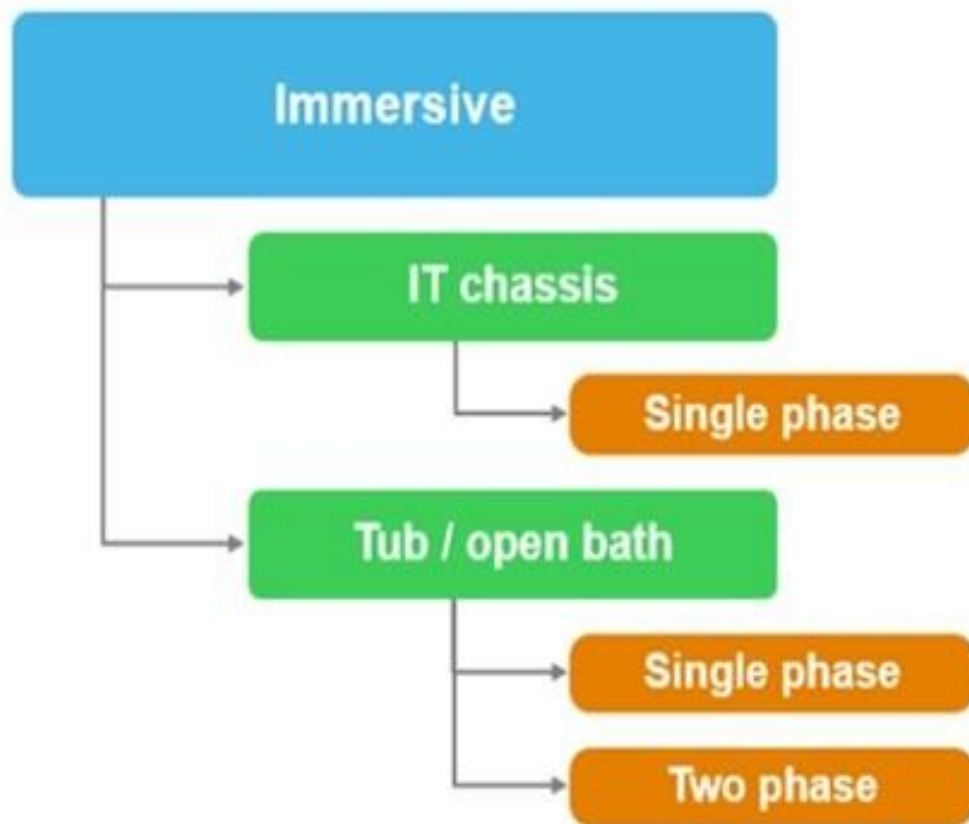


Fig.4.2: Types of Immersive Liquid Cooling

Immersive cooling includes single phase fluid in combination with the chassis type, while the tub/open bath version has both single phase and two-phase fluid.

4.1.3 IT Chassis

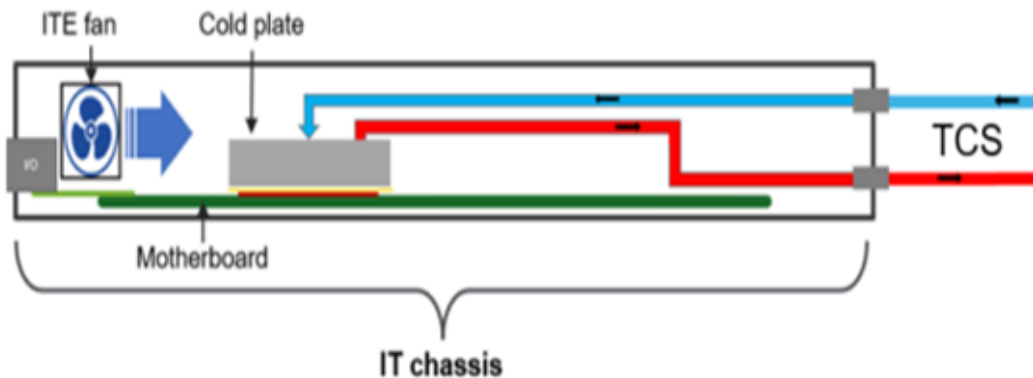


Fig.4.3: IT Chassis

In the direct to chip one phase liquid cooling system, each server needs specific heatsink to be mounted in the electronic components that have to be liquid cooled. It's the so-called "cold plate". Fans typically present in air cooled server are still required because there is some heat to be rejected. For instance, RAM modules are not always liquid cooled, as well as other secondary CPU and power equipment. Typically, the liquid cooled heatsink is mounted on the most dissipating component such as CPUs and GPUs. Fluid is water (from TCS loop) and there is a piping system inside the server IT chassis to supply cold water and return water. Supply and return pipes are then moved outside the IT chassis to be connected to a manifold on the back of the rack cabinet. On the back of the rack cabinet there are dripless disconnectors. Direct to chip technique is flexible in terms of cooling also the hottest chips. Designing the proper heatsink liquid cooled and providing the optimal water flow at proper temperature, is possible to achieve highest level of heat rejection. Water can reach up to 50°C in the TCS loop. The amount of heat liquid – cooled can be in the range of 65% to 90%, depending on the number of IT components liquid cooled and the remaining heat to be air cooled. When this type of liquid cooling system is adopted, there are also standard air-cooling equipment in the room.

4.2 FOR THE REJECTION OF THE HOT AIR

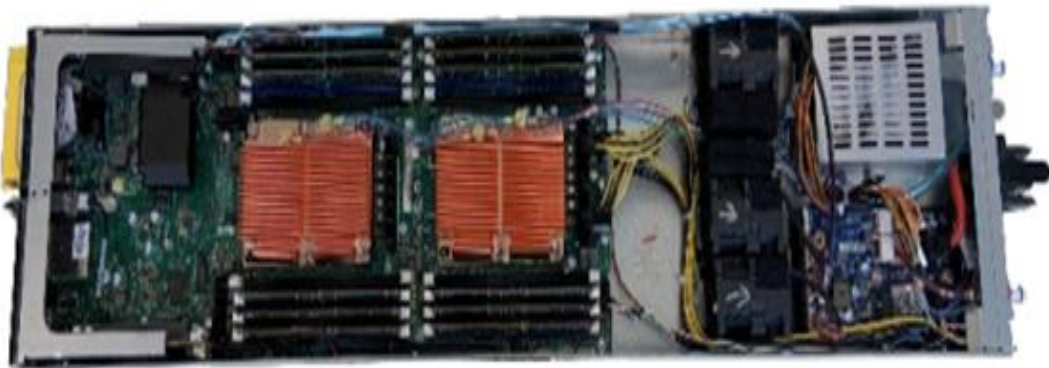


Fig.4.4:Direct - to - Chip heatsink on server

4.3 CDU WIRING

The direct – to – chip single phase requires a component to manage the distribution and the control of the TCS chilled water loop. This hardware is called CDU. In figure there is a view of a typical CDU. While in figure there is the one wire diagram (simplified).

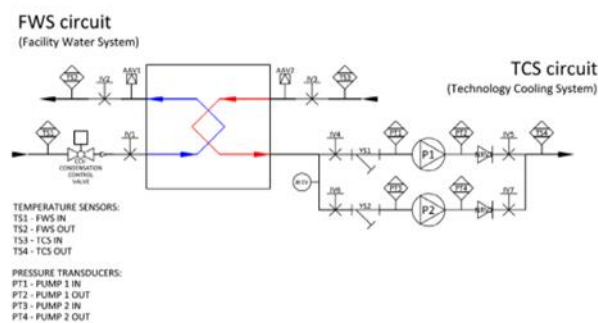


Fig.4.5: Simplified one wire diagram of the CDU

The CDU provides heat exchange between FWS chilled water loop and TCS, separates the water circuits and control the parameters of TCS: waterflow, pressure, temperature, water quality. Pressure is on the range of 2 bar on TCS and the piping and connectors must be highly reliable, especially close to servers. Any water leakage inside the servers or in the manifold in the rack cabinet is dangerous for the servers. For this reason, piping and fittings are quite expensive to minimize leakage risk. Other points of attention in this type of liquid cooling system is properly venting the TCS and guarantee compatibility between water in the TCS and material in the liquid cooling system.

4.4 NEGATIVE PRESSURE APPROACH

To reduce to zero the leakage risk, a negative pressure approach can be the solution. The technology is used in other critical application: the cooling of highly flammable fluids. The key element on this approach is the CDU that provides and keep the vacuum inside the TCS loop and in the heatsink and piping inside the rack.



Fig.4.6: Piping inside the rack



Fig.4.7: Plastic piping in negative pressure liquid

The negative pressure CDU has internal arrangement that provides the vacuum (approx. 0,5 bar). The system is slightly more complex than a positive

pressure CDU. There are some advantages in using a negative pressure system. During start-up of the system venting of the TCS loop is internally done by the vacuum system. At any time if air would enter in the system it will be soon captured and extracted by the vacuum system. In case of leakage, water cannot exit from the TCS loop because the vacuum keeps it sealed inside the piping while air starts to enter from the leaking point. Depending on the implementation, but even dramatic leakage (complete cut of a pipe inside the server) doesn't allow any water on the motherboard. The system, if well designed, can measure and estimate the amount of air extracted from the TCS and it can raise alarm if a leakage is detected. Thanks to this principle, very cheap and easy-touse piping and fitting can be used for hydraulic connections.

The vacuum system allows to automatically dry the internal part of the cooling system in the server in case of disconnection of the server for maintenance, without interrupting the rest of the cabinet operations. Thanks to the automatic venting, a rapid and effective filling happens when the server is connected again to the TCS. Any direct to chip liquid cooling system using chilled has to manage the condensation risk. The surface of the cold plate cannot be at or lower temperature than the dew point in the white space. Any condensation happening on the cold plate or on the chilled water piping inside the server can damage the server.

4.5 ASHRAE CLASSIFICATION OF LIQUID COOLING SYSTEM

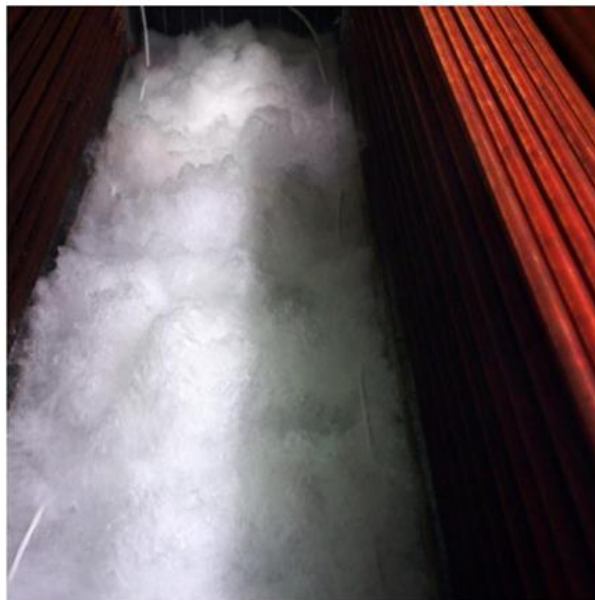


Fig.4.8: Two phases tub liquid cooling bubbling

Liquid Cooling Class	Typical Infrastructure Design		Facility Water Supply Temperature
	Primary Facilities Cooling Equipment	Secondary/Supplemental Cooling Equipment	
W1	Chiller / Cooling Tower	Water Side Economizer (with Dry Cooler or Cooling Tower)	2°C – 17°C
W2			2°C – 27°C
W3	Cooling Tower	Chiller	2°C – 32°C
W4	Water Side Economizer (with Dry Cooler or Cooling Tower)	N/A	2°C – 45°C
W5	Building Heating System	Cooling Tower or Dry Cooler	> 45°C

Fig.4.9: ASHRAE classification of liquid cooling system

Hybrid systems is the key, where “liquid cooled islands” stay side by side to air cooled rack cabinets. The chilled water system then can have different design. It depends mainly on how much of the total load is liquid cooled and how much is still air – cooled. There are some guidelines on how is possible to design the chilled water system.

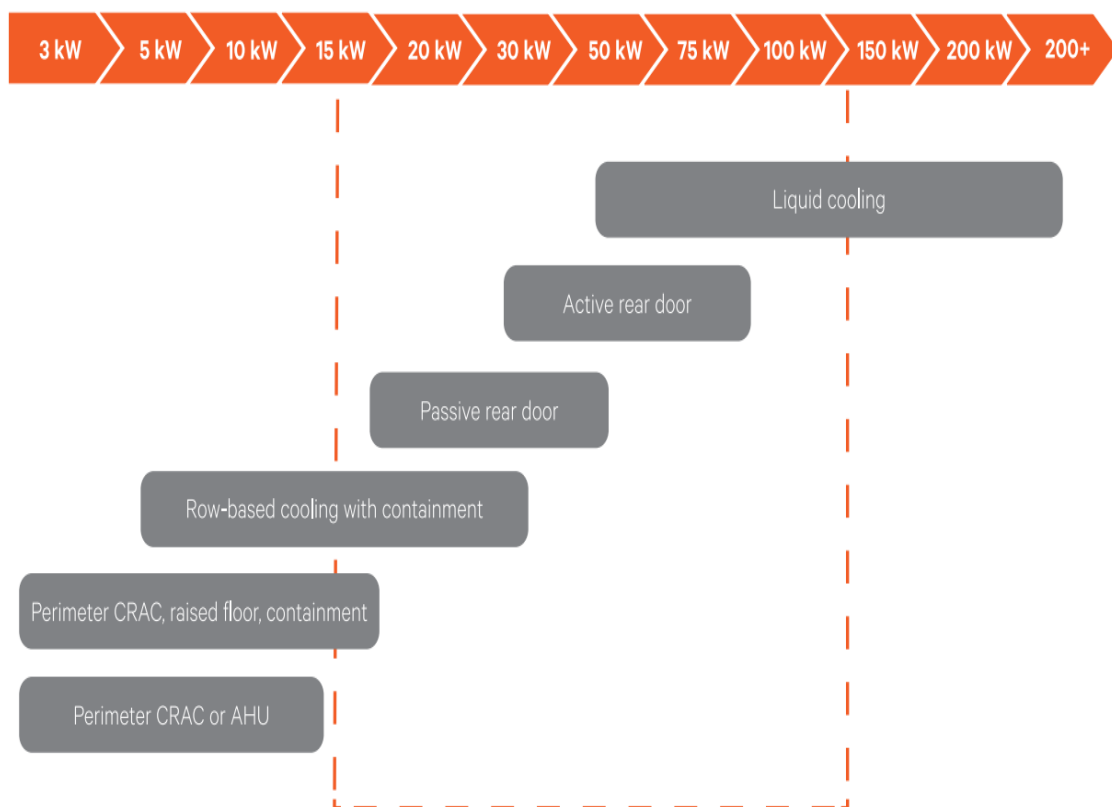


Fig.4.10:Effectiveness Reduction

Air-based cooling systems lose their effectiveness when rack densities exceed 20 kW, at which point liquid cooling becomes the viable approach.

4.6 OPERATION

An Overview of the Controller. Unattended IT settings may use the CDU controller to regulate the flow of cooling water to up to six RDHx computers. At a predetermined temperature and flow rate, cooling water is provided to maintain the desired temperature. After turning on the power, the main red 'Power On' bulb will be illuminated, the inverter drive will start up, and the controller's graphic display area will be illuminated as well. To begin with, the controller's display will show a logo of its maker as it goes through an initiation cycle. During this period, the control valves may open and shut. This is normal.

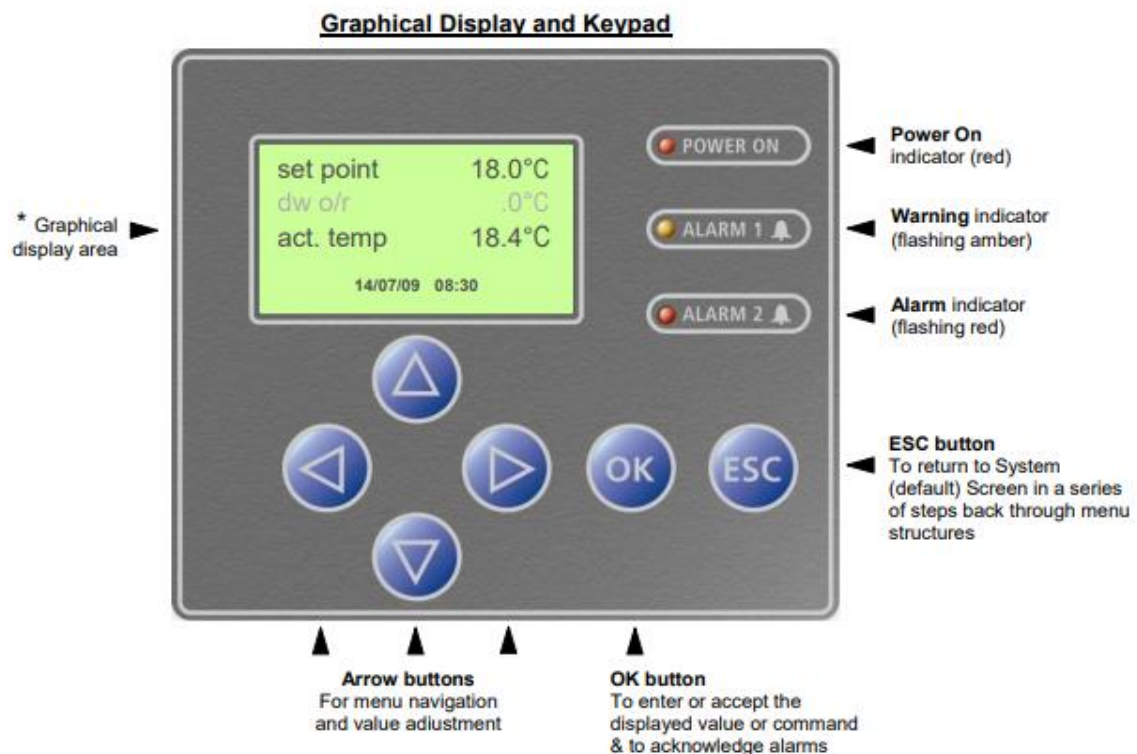
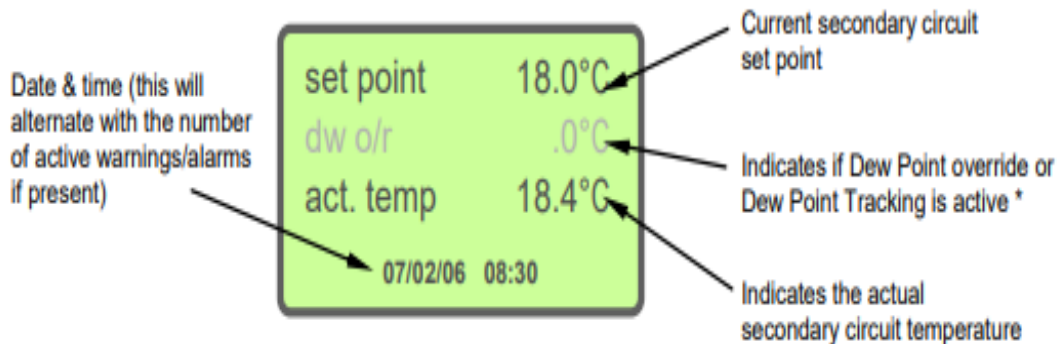


Fig.4.11: Graphical display and keyboard

Warning = non-urgent warning alarm (investigate on routine inspection/maintenance) Alarm = urgent alarm (requiring immediate attention).

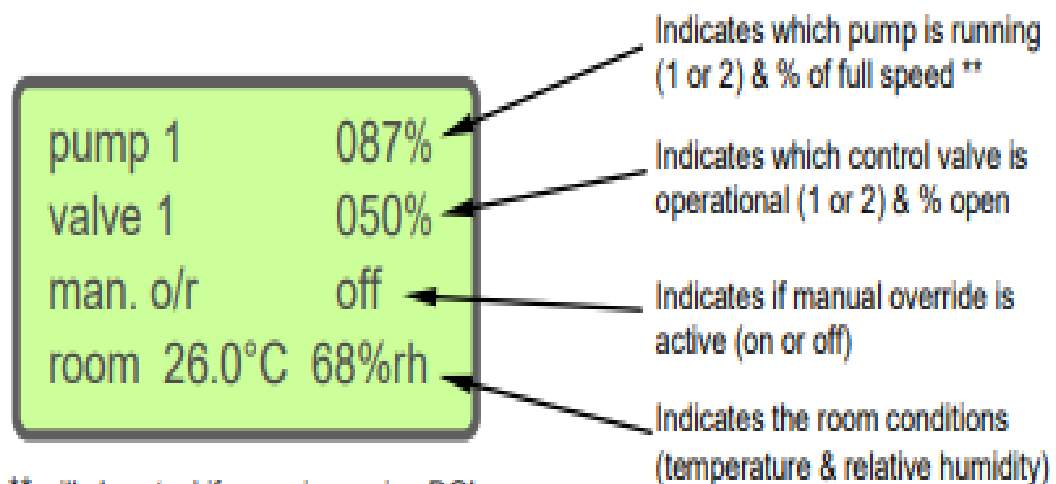
SI units are used in all of the screenshots in this tutorial.

The welcome screen will appear on the display panel after activation.



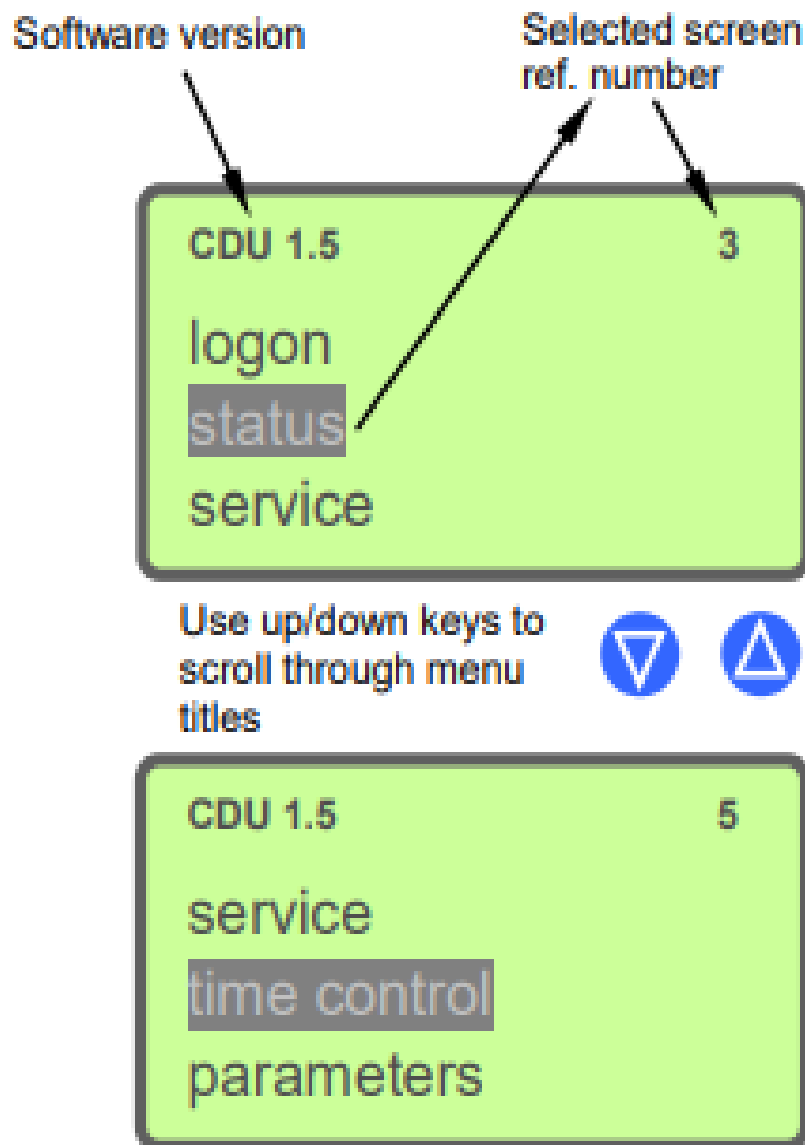
* This line will not normally show unless Dew Point Override or Dew Point Tracking are active. Text will blink slowly when operational – see Section 6.3

Pressing the down arrow key on the keyboard will bring up a second information panel, as seen below.



** will show 'on' if pump is running DOL

The or button may be pressed for 1 to 2 seconds to change the display from SI to imperial units (when the default is SI) (when default is imperial). the screen's units are set to their default state after you flee



The following additional "status" functions of the device may be observed: To go to the next screen, press both & keys simultaneously for 1 to 2 seconds. When you get to the 'Status' title (on screen 3), just use the arrow key to enter. It's not necessary to provide a login password to access any of the data under the 'Status' menu section. You may examine a list of the available functions on the 'Status' panel by consulting the table.

4.6.1 Automatic Operation

Start/Stop button on control panel is all that is needed to start unit in automated mode after commissioning.

4.6.1.1 *Primary circuit operation*

- The principal water temperature is measured at the CDU cabinet's input. Using a water temperature of between 41°F and 50°C, the CDU cabinet's cooling capacity was estimated. - This warning is issued when the main temperature climbs to 11°C (52°F). Until the temperature drops below the preset hysteresis threshold of 1°C (2°F), this warning will stay active. - A 'Primary Water Temp Low' alert will be sent if the primary temperature drops to 4°C (40°F). This warning will continue to appear until the temperature climbs over the default hysteresis threshold of 1°C (2°F). - As a default, the high and low temperature alerts are ignored for 20 minutes after system startup in order to prevent unnecessary alarms from occurring. In order to use the temperature PI control loop, push the Start/Stop button and wait for the pump to reach full speed before pressing the button again. Increased primary cooling water flow via the heat exchanger is initiated if the secondary circuit temperature rises over a certain threshold.
- The control valve modulates from 0% (closed) to 100% (totally open) - the valve position may be viewed on the second welcome screen or the Status screen 3-2. By default, every 15 minutes, demand signals are checked with valve position feedback signals to ensure smooth operation. For example, when the feedback signal is more than 10% different than the demand signal, the "Valve 1 Fault" warning will be sent and Valve 1 will be forced closed and the demand signal passed to the second valve. - It's the same with Valve 2: if the feedback signal is more than 10% different from demand (taking into account the driving time of the actuator to react to load changes), then a "Valve 2 Fault" notice will be created, and the demand signal will be sent to Valve 1. - As soon as both valves 1 and 2 are found to be malfunctioning, the warning level for each valve is raised to alarm status (operation will revert back to the default valve and will stay on that valve until fault is rectified). This means that the control valves will work in a similar manner as the pumps, with one operating valve ramping down to

closed and the other responding to the demand signal to continue operating for another 7 days, as is the case in regular healthy running.

- The default time for changeover is 3:00 a.m. In the case of a power outage, both control valves include a 'spring return' mechanism that ensures the valves shut. Plate heat exchanger water intake has a primary water filter of 300 (50mesh) installed. PS3 and PS4 sensors (see controller Status screen ref. 3-5) monitor the differential pressure to determine when the filter should be cleaned or flushed. - A 'Primary Filter Dirty' signal is sent if the difference pressure reaches 0.6Bar (9PSI). Section 7 explains how to cleanse the filter while it is still working. 5. The rate of water flow is monitored by a flow metre in the principal water return line. The controller Status screen ref. 3-8 shows the flow. It is important to note that the flow metre is in series with the flow control valves and only registers a flow when either valve is fully open or partly open. - Primary Low Flow is only sent if the Secondary High Temperature Warning is active, there is no Primary High Temperature Warning present, and the operational control valve's demand is 100%. When the following circumstances are satisfied, a 'Primary No Flow' warning may be issued.
- In addition to the Secondary High Temperature warning and Primary High Temperature alarm, the operational control valve is being used at full power. - Flows below 20 litres per minute (5 gallons per minute) may not appear at all.

4.6.1.2 *Secondary circuit operation*

- When the green Start/Stop push button is illuminated and the reservoir level switch is made, Pump 1 begins to rise in speed - the pump speed as a percentage of maximum may be read from the second welcome screen (see Section 6.1). You may also see in real time what frequency is being sent to the pump motor on the inverter's display. - Only one main pump will be permitted to operate at a time if the level switch is not made, which indicates that there is not enough water. - The green 'Fill Pump Enable' bulb

will light up in this situation, and the fill pumps will begin to fill the system. The fill pumps will stop if the level switch does not make after three minutes, and a 'Insufficient Water Level' alert will be produced. Until the alarm has been manually deactivated, the device cannot be started up once more.

- System pressure (PS1) at the pump suction (PS1) is constantly monitored (see controller screen 3-4) to ensure that the system is constantly pressured. - Because of this, the main pumps will continue to function until a low system pressure of 0.3Bar (5PSI) or less is detected at PS1, at which time the fill pumps will be turned off. When this happens, you'll also get a notice to 'Check Water Make-up Level' A 'Water Make-up Empty' alert is produced if the fill pumps have been running for more than three minutes and the PS1 pressure is still less than 0.5Bar (8 PSI). If you don't manually clear this latching warning, the device should continue to work as usual.
- PS1 & PS2 sensors are used to monitor the operational pump's difference in pressure, and the speed of the pump is increased in stages via a control loop until the differential pressure matches a predefined setting in the software, based on how many RDHx's were installed during the commissioning stage. Ten seconds are set as the scan time default in order to prevent oscillation in the pump pressure regulation loop. A pump flow failure is assumed if Pump 1 fails to achieve within 0.5Bar (8PSI) of this differential pressure in a defined time period (default 80 seconds). Pump 1 will ramp down to a halt, and Pump 2 will be initialised after a 5 second pause. A 'Pump 1 Inverter Low Flow' alert will also be triggered. Assuming Pump 2 does not meet the differential pressure in time, this pump will shut down and Pump 1 will be started directly on line if Pump 2 does not meet the differential pressure (DOL). A 'Pump 2 Inverter Low Flow' warning will also be triggered at this time. It will also shut down and Pump 2 will initiate DOL if Pump 1 DOL fails to meet an alternate differential pressure established for DOL operation (by default, a 2Bar (30PSI) differential pressure). At the same time, a 'Pump 1 DOL Low Flow' alert will sound. Pump 2 DOL Low Flow warning will be sounded if Pump 2 fails to attain pressure. As long as there are no alerts or problems, Pump 2 DOL will keep the machine running.

- It is expected that the pumps will function on a duty-sharing cycle, with the operative pump ramping down to a halt every 7 days (the default) and the standby pump starting after a 5 second delay to continue working for the following 7 days. The default time for changeover is 3:00 a.m.
- At the reservoir exit, secondary water temperature is measured. Component redundancy is ensured by the placement of two temperature sensors. The controller will use the average of the two values as its input. A 'Secondary Temp Diff Error' warning will sound if the difference between the two sensors is more than 1.0°C (2°F) (after a 2 minute delay).
- A 'Sec Temp Out of Range' warning will sound if either sensor fails, and the controller will solely monitor the remaining functional sensor. In order for the primary water control valve to retain the required set point temperature, the secondary temperature must match the desired set point temperature. The default fixed set point is 18°C (65°F), which is shown on the welcome screen. Screen 3-2, under the Status heading, displays information about the current position of the control valve. When either 'Fixed SP' or 'Fixed SP + Dew Point override' control is chosen from screen 6-3-3, warnings are set at a default value of 2°C (4°F) each side of set point (floating with set point) with a default hysteresis of 1°C (2°F). 'Secondary Water Temp High' notice will be sent if the secondary temperature deviates by more than 2°C (4°F) over fixed point for more than 2 minutes.
- For as long as the temperature is over a certain threshold, this alert will sound. - A 'Secondary Water Temp Low' alert will be sent if the secondary temperature drops by more than 2°C (4°F) for more than 2 minutes. Until the temperature reaches the threshold, this alert will continue to sound. - For the first 20 minutes of operation, the warnings for high and low temperatures are disregarded so that the system may settle down without creating unnecessary alerts. This control mode allows for a Dew Point override, which means that the set point may be overruled in the event of condensation at the RDHxs. "dw o/r --.-°C (°F)" is flashing on the welcome screen when Dew Point Override is engaged. – The controller uses a remote sensor to monitor the room's temperature and relative humidity, which is then utilised to predict the dew point. The controller will override

the set point to a default setting of 2°C (4°F) above dew point if there is a possibility of condensation inside the RDHx.

On the second line of the welcome screen, the Dew Point override will display the new set point value as a flashing message (& also on the Status screen 3-2, which will alternate between fixed set point & override set point). It is also possible to set the supply temperature to a default of 2°C (4°F) above the current dew point, provided that is what is selected as a control mode. In order to monitor the dew point, the display will flash "Dw Tracking" – Using a remote sensor, the controller calculates the dew point in the room based on ambient temperature and relative humidity. Afterwards, the controller will determine a set point to keep the water temperature at a default setting of 2 degrees Celsius (4 degrees Fahrenheit). On the second line of the welcome screen, DW Tracking will appear as a pulsating light (new set point also visible on the Status screen 3-2). This may not always be possible due to the unit's limited cooling capacity. For example, if the dew point was 7°C (44°F), the controller would adjust the set point to 9°C (48°F). However, the plate heat exchanger is designed for an 8°C (14.5°F) minimum temperature differential between the primary water inlet and secondary outlet temperatures, even though the controller will display the new Dew Point Tracking setting.

This means that the actual temperature shown will almost certainly be higher than 18 degrees Celsius (64.5 degrees Fahrenheit) even if the main water temperature is set at 10 degrees Celsius (50 degrees Fahrenheit). With these fixed SP or fixed SP + Dew Point override control modes the device might be continuously in warning status, hence it is not viable to operate the Secondary High/Low temperature warnings that float with the set point. There is no Secondary Water Temp Low alert set by default; it is only activated if the temperature falls to or below the dew point for a period of three minutes or longer.

4.7 MAINTENANCE

4.7.1 *Preventative Maintenance*

- The CDU has to be cleaned and examined for leaks and malfunctions on a regular basis.

- The unit must be electrically isolated/disconnected before beginning any repair work within the cabinet.
- At 3 Months (or less)
- Remove the strainer from the cooling water intake and clean or replace it. Take a look at the pump and listen for any strange sounds (s) Water make-up may be topped up with deionized water treated with inhibitor/biocide if required. Inspect for leaks.
- Six months after birth: (or less)
- On top of it, there are three monthly payments: Make sure the hoses are in good working order. Make sure all hose connections are secure.
- Additional to the three and six-monthly checks: • After 12 months (or less)
- Make sure that all of the bolts and seals are in good working order.

4.7.2 Filter Flushing

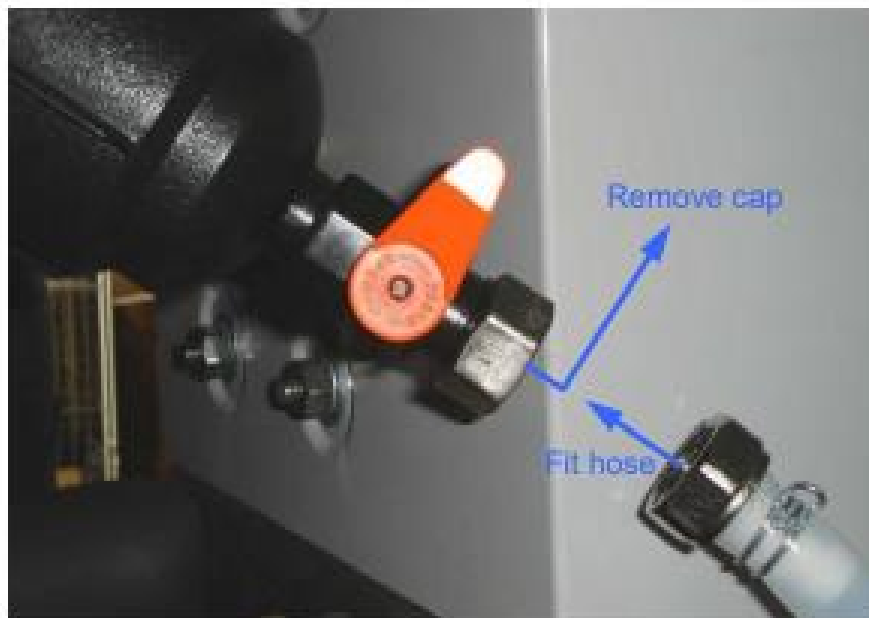


Fig. 4.12: Filter Flushing

You may flush the main filter while the system is running if the bottom valve is closed (handle at 90 degrees to valve body) and the cap on the end of the valve is removed. Using a sealing washer, fasten the drainage hose to a bucket or other container and secure the free end of the hose with the washer. A bucket with a

hose and a filter bowl valve must be opened to enable water to pass over and remove dirt and other particles from within the filter bowl. No more than 5 litres (1.3 gallons) of fluid should be used to flush out the filter screen. For the main circuit, the water loss is rapidly restored by the chiller make-up system, thus this is a straightforward process. Secondary filter drain line is coiled and cable-tied to the pipework nearby.

The filter screen should be changed if flushing the filter does not improve conditions. Closing 11/2" ball valves at back of cabinet and emptying filter with drain hose as used for flushing operation will isolate main circuit from chilled water supply. The filter screen may be removed and changed once the water has been drained and the filter bowl has been unscrewed. Close the filter drain valve and open the chilled water ball valves again after re-fitting the filter bowl.

4.7.3 Unit Draining

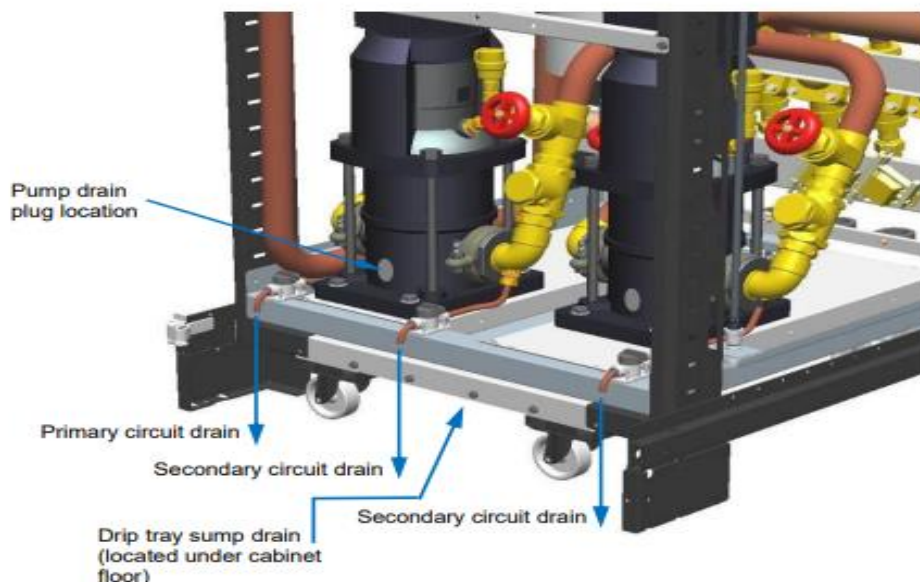


Fig. 4.13: Unit Draining

Figure 4.13 shows that the front of the device has three drain points. In order to shut off the main circuit, close the isolation ball valves on both inlet and exit at the cabinet's back. Drain the pipe and open the drain valve into an appropriate collecting vessel. The manual air bleed valve positioned on top of the

pipe at the main input to the plate heat exchanger is here to help in draining. Open this vent by unscrewing the brass cover and pressing the spindle that is clearly visible. Draining the main filter is also necessary for flushing.

Using the other two drain valves and allowing air to enter the system via the automated air vents will empty the secondary circuit. It is recommended that the input and return manifolds and RDHx hoses be disconnected first, and then the fast release couplings should be emptied manually by depressing the self sealing valves. If just a pump replacement necessitates adequate drainage, isolate the malfunctioning pump using the red-handled valves and then open the drain valve connected with that pump alone. In order to remove the pump without spilling any water, make sure to remove the drainage plug at its base (seen in the picture below).

4.8 SAFETY INSTRUCTIONS

4.8.1 General

Equipment that regulates temperature is susceptible to mechanical, electrical, noise, and vibration dangers, among others. All safety, installation, operating, and maintenance instructions should be followed. Installation, maintenance, and operation of the equipment may only be performed by those who have received the appropriate training and possess the necessary technical expertise. The Cooling Distribution Unit is intended to prevent mechanical and electrical dangers by completely blocking access via unit casings, doors, and covers while the equipment is in operation. Additional safeguards may be required in certain setups to avoid unintentional contact with components. To ensure the CDU is properly protected, the CDU manufacturer may provide guidance and suggestions. Work must be done in accordance with the instructions for safety, installation, operation, and maintenance before the device may be used in any way. Equipment must be turned OFF before any maintenance work may begin. Controls and equipment are no longer powered by the electrical source. There are no more moving components left. The CDU manufacturer, their agent, or their designated distributor must be approached for guidance and clarification if there is

any uncertainty as to the right interpretation of the instructions for safe use, installation, operation, and maintenance.

4.8.2 *Installation / Handling*

According to local legislation and established practises, the installation and operation should be carried out. To guarantee the safety of everyone involved, care must be used while moving or lifting the unit. Lifting equipment must only be used if it has been authorised by the manufacturer.

4.8.3 *Application*

The device should only be used for the purpose for which it was intended. In order to be utilised in a hazardous environment, the device must be specifically built and authorised for that purpose.

4.8.4 *Warranty*

The warranty may be voided if the equipment is not installed in accordance with the instructions provided by the manufacturer. This guide's warranty section (Section 11) and the sales contract both specify that warranty coverage is contingent on the installation of a service agreement.

4.8.5 *Electrical Connection*

A separate external isolator/disconnect must be used if the unit does not have one already. Installation of electrical wiring must adhere strictly to national and regional standards. When making unit circuit connections, ensure the power supply is disconnected at the disconnect (isolator).

4.8.6 *Service Parts*

Only the original equipment manufacturer (OEM) can provide compatible replacement components for CDUs. If you use the wrong components to fix your appliance, you risk voiding your warranty.

4.8.7 Codes of Practice

Good engineering practise and rigorous adherence to: i. IEEE Standards ii. Codes of good engineering practise are required for every work. iii. Municipalities iv. Requirements imposed by legislation insistence on following all warnings and directions provided by the manufacturer Additional rules and laws are included in this section as well.

4.8.8 Waste Disposal

When it comes time to get rid of trash, it's important to do it correctly and in accordance with all applicable environmental laws. Local environmental organisations can provide further information.

4.9 REFERENCES

1. One year after developing its closed water cooling circuits, Asetek secured an OEM order from HP in 2007. As a brand-new technology at the time, HP was the first to include this into their gaming and commercialworkstations.
2. The air/water heat exchanger in the bayed enclosure system VX25 was worked on by Rittal and his colleagues. VX25 enclosures that are 600 or 800 mm deep and 2,000 mm high may be accommodated. There is an air outlet that is either 5 kW on each side or 10 kW on one side alone Top or bottom water connections may be made with ease.
3. Many firms are aiming to implement racks with power needs of 50 kW or more because of the increasing amount of processing power being packed into servers supporting artificial intelligence and other processor-intensive applications, and Vertiv has experimented with this as well.
4. GREEN REVOLUTION COOLING: That is the cold, hard truth. No other firm has the history, worldwide reach, or skill in liquid immersion cooling that we have. A decade ago, GRC pushed the boundaries of data centre cooling

efficiency and performance, introducing patented technology that increased performance, improved sustainability and optimised total cost of ownership.

5. The Chillydyne Cool-Flo® Technology provides coolant under negative pressure and is a direct-to-chip liquid cooling system. Technology developed by Chillydyne is aimed at eliminating liquid cooling's related dangers while also keeping deployment and operation costs low.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 IMMERSION COOLED SYSTEM ARCHITECTURE – SINGLE PHASE

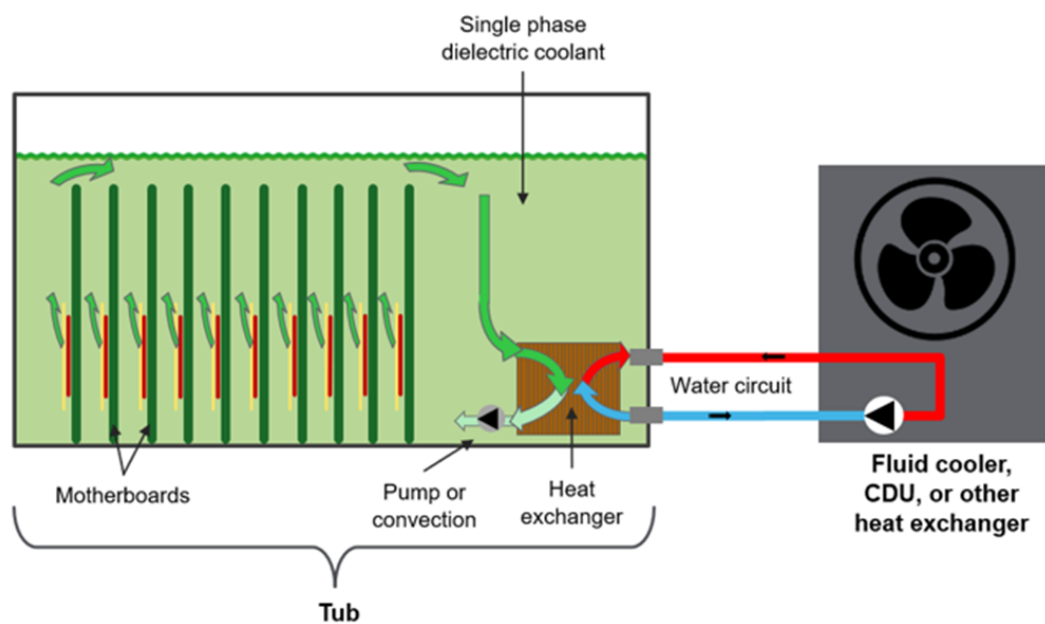


Fig.5.1: Immersion cooled system architecture – Single Phase

- Special tub design, not rack based Servers are stripped of chassis and hung brackets.
- Less scalable – grow in larger chunks
- Removes > 95% of IT heat
- Requires more fluid than chassis based – cost effective oil based dielectric is typical
- No fans. Can use pumps or convection to move dielectric fluid

5.2 IMMERSION COOLED SYSTEM ARCHITECTURE – DUAL PHASE

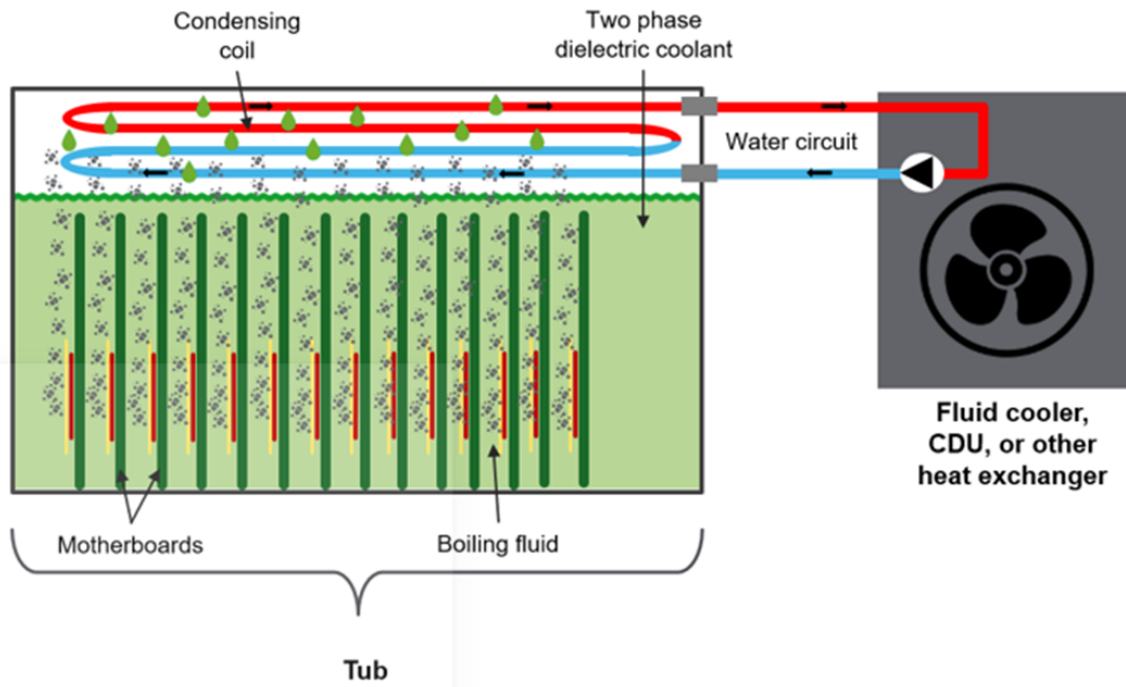


Fig.5.2: Immersion cooled system architecture – Dual Phase

- Special tub design, not rack based Servers are stripped of chassis and hung on
- Brackets.
- Less scalable – grow in larger chunks.
- Removes > 95% of IT heat.
- Requires more fluid than chassis based.
- No fans and typically no pumps. Boiling phase change moves the fluid.

5.3 WORK DONE

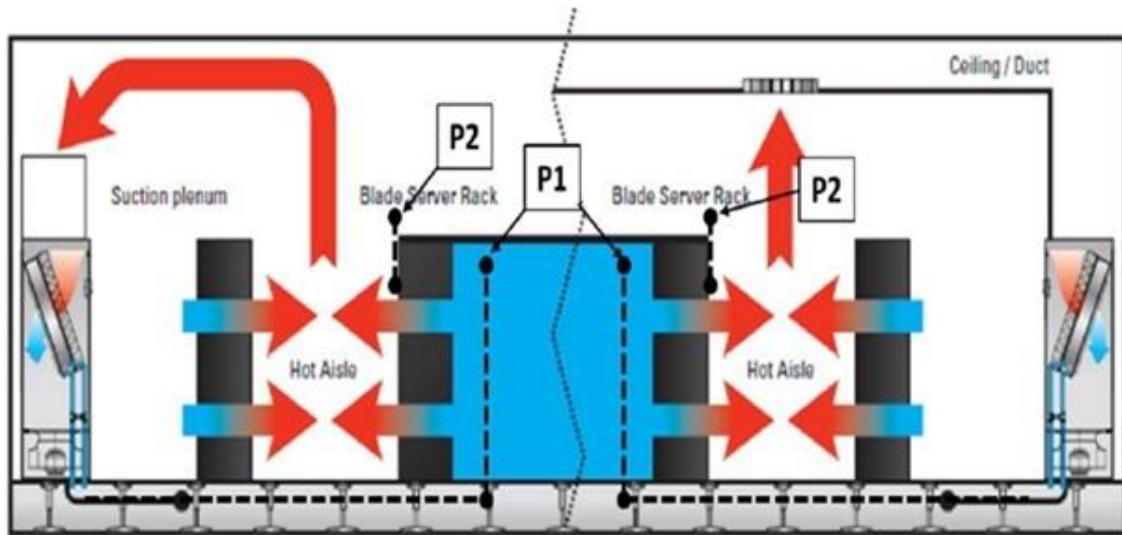


Fig.5.3: Illustration of pressure sensor locations

5.4 OUTCOME

Outcome of the project would be related to our findings and would be published in technical journals.

	Air cooled packaged chiller	Chassis-based immersive liquid cooled
Core & Shell cost	\$90/sq ft (\$969/sq m)	
Power redundancy	2N power dist / 2N UPS / N+1 Generator	
IT equipment cost	Server cost not included	
Cooling redundancy	N+1 chiller, CRAH, & pumps	N+1 (DX CRAC / dry cooler / pumps)
IT design capacity (kW)	2,000	1,880
Non-cooling server capacity (kW)	1,820	1,820
IT equipment fan savings	N/A	9% *
Micro-pump penalty	N/A	3%
Rack heat loss to air	N/A	5.5%
Adiabatic cooling	Yes	No
Floor type	Hard floor	Hard floor
Containment	HACS	None
Chilled / Condenser water setpoint	20/30°C (68/86°F)	40/47.75°C (104/117.95°F)
Glycol %	25%	25%
IT room supply air setpoint	24°C (75.2°F)	23.8°C (74.84°F)
IT room supply air delta T	14°C (25.2°F)	9.8°C (17.64°F)
Electrical room supply air setpoint	24.6°C (76.28°F)	24.6°C (76.28°F)
Electrical room supply air delta T	8.4°C (15.12°F)	8.4°C (15.12°F)
Rack density (kW/rack)	10	9.4
Rack U height	42	42
Quantity of racks	200	200
Racks per pod	40	40

Fig.5.4: Outcome representation

5.5 REAL IMAGES OF LIQUID COOLING SYSTEM









5.6 REFERENCES

1. Submer : Another name for this technique is submersible liquid refrigeration. Thermally, but not electrically, conductive liquid (dielectric coolant) is used to submerge computer components (or whole servers), allowing for better heat transfer performance than air and a host of other advantages.
2. Iceotope : Liquid cooling is a many-headed Hydra. At the simplest level, well-deployed, you're going to save a lot of space, you're going to save a lot of energy, and you're going to save a lot of water. But most infrastructure, in the technology of the data center, just introduces a constraint to be managed.
3. Fujitsu : When developing and manufacturing our cooling solutions, we go to extremes. Our thinnest products are only 0.8 mm thick. Nevertheless, the wafer-thin cooling elements offer high cooling

capacities of up to 1,000 watt per square meter. This is possible because we build them up in several layers, mostly using the high thermal conductivity of copper. We often combine this material with stainless steel components. Our cooling components are made entirely of metal. They are characterised by a high degree of flatness and, depending on requirements, are vacuum-tight up to the UHV range. By material joining through vacuum brazing, we are able to manufacture even complex structures very precisely and in a corrosion-resistant manner. Water, liquid nitrogen or even helium can be used as a cooling medium.

4. Aspen System : For liquid cooling, it's come a long way. With today's liquid cooling technology, there are more alternatives than ever before. Data centres all across the world are under pressure to become more energy efficient, streamline operations, and cut costs all at the same time. Data centres account for around 2% of worldwide electricity usage each year. When it comes to the Green Computing revolution, liquid cooling systems are a critical component.

5. Ebulient : Ebulient, located in Madison, Wisconsin, has created a two-phase direct-to-chip cooling system that overcomes the dangers and needs of single-phase liquid cooling. To ensure the safety of important server components, two-phase DirectJet precision cooling systems use sealed cooling modules.

6. Aquila : When I started a firm with other colleagues to make high-performance telecoms switches, it was a few years ago. We hired a CFO after the second round of investment. In spite of his lack of expertise in IT, he was trusted to oversee our small but crucial IT team because of his reputation as a trustworthy leader. In his haste, he relied too much on reports and advisors to run the organisation. Disaster occurred after a few weeks. Just before a major technical milestone, our development environment fell out for two days. The network seems to have been re-

configured by an inexperienced consultant. After that, the IT department was handed back over to the engineering team.

7. EXAScalar :High-efficiency submersion liquid cooling machines and related systems are developed, produced, and sold by EXAScalar. Original design submersion liquid cooling technology was used for the development, manufacture, and sale of the super computer system Original submersion liquid cooling technology was used for the development, manufacturing, and sale of the computer system A submersion-specific system board, an accelerator board, and related items are developed, manufactured, and sold. HPC systems and cooling systems for data centres that were handed to a third party.

CHAPTER 6

SUMMARY AND CONCLUSION

So we are here to conclude that before pandemic datacentre industry use to follow air cooling methodology for server temperature control for the thermal management of the servers. After pandemic there is huge demand in the server loads like suppose if it was 20KW/rack before pandemic now it is moving towards 100KW/rack to 300KW/rack.

To remove that much huge amount of heat air cooling technology will not support, the only way to move forward is liquid cooling at the server level. This technology is not a new one it is old one only but where, as in lot of gaming stations where we have high processing servers or may be in rockets, NASA space centre this technology may use.

Now, data centre industries also evolving this methodology, But there is a lot of confusion between data centre builders, operators and users, infrastructure companies. But they are looking for which technology is good which is more efficient, which is more reliable, which is more easy to adopt. This is not a kind of research paper but a kind of application analysis paper to understand and help the user community with the help of international bodies like ASHRAE, GREEN GRID, ISOTOPE, etc. So all are doing lot of research to find out which technology is good.

And we have done the similar work to help the user community to understand about this technology and also to understand different technologies in the market and how to adopt them.

The main one is the effort servers' manufacturers are putting in developing "liquid cooling ready" version of their widely adopted DC servers. The process would take one to two years, but it's already started. Each manufacturer is looking for the broadest applicable liquid cooling system. It's not yet clear which

one will be the most adopted, but it will be very likely in the list described above. On the long run chip manufacturers will set the pace with their high TDP new generation CPU and GPUs (allegedly over 1kW each). From a cooling system perspective, the opportunity can be seizing if a broad set of chilled water solutions would be liquid – cooling ready. But what does “liquid cooling ready” mean? On hardware it means to have CDU suitable for the range of application required (sizes, performances, control logic), while on existing unit like chillers, crac, fan wall, it means to have them ready for even higher temperature (high condensing temperature chiller for liquid cooling – only), and control system smart enough to optimize an hybrid chilled water system. The race has begun.

6.1 REFERENCES

1. Asperitas: We provide plug and play immersion cooling solutions for datacentres. Trusted by cloud service providers, enterprise IT, emerging tech developers, telecom providers and HPC users.
2. Liquid Stacks: For each IT rack, LiquidStack's technology provides at least 21 times more heat rejection than air cooling, with no water used for outdoor heat rejection. Energy consumption is reduced by 41 percent and whitespace needed for computing infrastructure by up to 60 percent using this cooling technology.
3. DCX The Liquid Group: New-Generation DLC System offers considerable savings in data centre cooling infrastructure and maintenance by being the first open direct-to-chip liquid cooling technology. When we say "open solution," we imply that we don't use proprietary, server-specific solutions. Liquid cooling has never before been so easy for customers to use in their servers and racks because of DCX modules. Finally, DCX Next Gen DLC's modular design allows for future expansion, and it's just as simple to buy and install modules as installing an extra PCI card on a new server. All of this delivers the finest return on investment from any DLC system on the market at this time. To achieve low data centre running expenses, one may easily include liquid cooling technology into their data centre, decreasing infrastructure CAPEX and power usage.