

WHITE PAPER:
AN ADVANCED LIQUID COOLING RACK DESIGN FOR DATA CENTER

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Executive Summary

Scope:
This document outlines an advanced liquid cooling rack system architecture and design for JD.COM data center and details key learnings from JD.COM liquid cooling solution engineering practice.

Overview:
As the emerging business models and advanced customer experience is driving an explosion of data at the era of 5G, data center has been evolving with increasingly powerful AI (Artificial Intelligence) computing capability for enhancing CSP (Cloud Service Provider) cloud service by data analytics in data centric world. High-performance computing, storage and networking are essential to achieve this. Meanwhile, energy efficiency which is measured with PUE is mandatory design target for modern data center. Advanced thermal solution is one of crucial technologies to continually address the demand of higher performance computing at lower PUE.

D2C (Direct to Chip) liquid cooling, as a typical advanced thermal solution, has been accepted by the industry as an effective cooling solution for high density datacenters. JD.COM has years of liquid cooling engineering design experience from rack level to data center level. This document introduces liquid cooling rack architecture for JD.COM data center as well as the key learnings from JD.com engineering practice and validation data. The other focuses are system level liquid cooling design related ingredients' design and selection, such as CPU cold plates, memory cold plates, leakage detection, and quick disconnects, etc. Moreover, JD.com's advanced methodology for optimized CPU cold plate design is presented, which comes from engineering practice data analytics. At last, this white-paper discusses the implementation of whole-loop leakage detection in a JD datacenter, as whole-loop leakage detection has been considered as one of the pain points in the industry.

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Introduction

This document describes an advanced liquid cooling rack system design for JD.COM data center as well as related key learnings of cold plate based liquid cooling engineering practice. This paper provides system architecture reference for the audiences who have less data center liquid cooling design experience, and also can be ecosystem sharing and reference.

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2. Revision History

Revision	Date	Comments
0.5	*Jan 04, 2020*	*Initial Release for Internal Review*
0.6	*Jan 16,2020*	*2nd review in OCP Intel Task Force*
0.7	*Feb.24*	*Updated per 2nd review comment*
0.8	*Feb.28*	*V0.8 Release*
0.9	*Apr. 26*	*Clean All Review Feedback and Convert to V1.0 for OCP Release*
1.0	*June. 4*	*V1.0 Release*

3. Document Organization

The remaining content of this document is organized as following: Section 4 introduces JD liquid cooling system architecture and design for entry level readers who expect to learn a real liquid cooling rack system architecture for data center. Coolant Distribution Unit (CDU) with pump, filtering, heat exchanger, and pressure stabilization system is explained in detail, also pipework leakage detection, pipeline design, manufacturing and setup, as well as manifold and server node design for liquid cooling rack server are introduced. Typical Environmental Requirements for Data Center Liquid Cooling System are summarized at last. Section 5 details key learnings from JD.COM liquid cooling design engineering practice and pilot, including cold plate, pipeline, fasten and quick connection, mini manifold, server node leakage detection and coolant requirement.

4. Liquid Cooling Rack System Architecture and Design for JD.COM Data Center

With the increasing system power density as well as more strict government regulations on power saving, traditional air-cooling solution has become the bottleneck in datacenters due to insufficient cooling capability, high PUE and low space utilization. Because of higher cooling capacity advantage, liquid cooling is becoming popular for high power density servers increasingly and trending to be a major cooling technology in the emerging datacenters.

4.1. Liquid Cooling System Architecture

Design with redundancy is one of reliable engineering practices of data center infrastructure for cloud service uptime competitiveness. The liquid cooling system is designed with two CDUs to meet redundancy requirements. Each CDU can meet maximum system cooling requirement, but each will be run at 50% load during the normal operating condition. The CDU and rack design with outlet on the top and drainage at the bottom. Leakage detection system is implemented at the bottom of the trough.

In order to minimize pressure drop inside the loop and achieve tier 3 level of maintenance, ring-shape pipework is designed for secondary side loop from CDU to racks. Maintenance level is recommended by Uptime Institute in order to categorize the reliability of data centers which consists of four levels, tier 1 is categorized of meeting basic requirements, tier 2 is categorized of meeting redundancy requirements, tier 3 for meeting online maintenance requirements and tier 4 for meeting fault tolerance requirements.

The connection for the water supply to racks uses hand mate ball valve and male quick connector, while in-rack manifold is used with quick disconnect.

CDU provides an isolated cooling loop to the IT equipment. The coolant is driven by CDU through filter and secondary loop to IT equipment and rout back to the CDU. The heat from IT equipment will be eventually transferred to external environment. As shown in Figure 1, the heat from IT equipment will be transferred to the coolant in secondary loop, and then through heat exchanger to the coolant at primary side, and eventually be transferred to external environment.

The active heat exchange capacity depends on external ambient temperature and IT workload. The PLC controller will precisely adjust the water supply temperature based on a series of sensor readings.

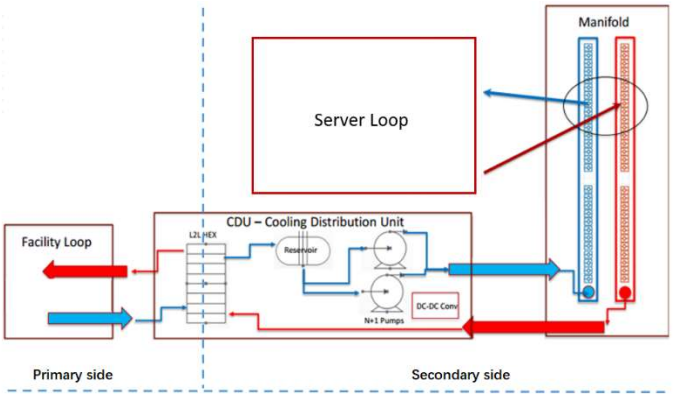


Figure 1, Liquid Cooling System Topology

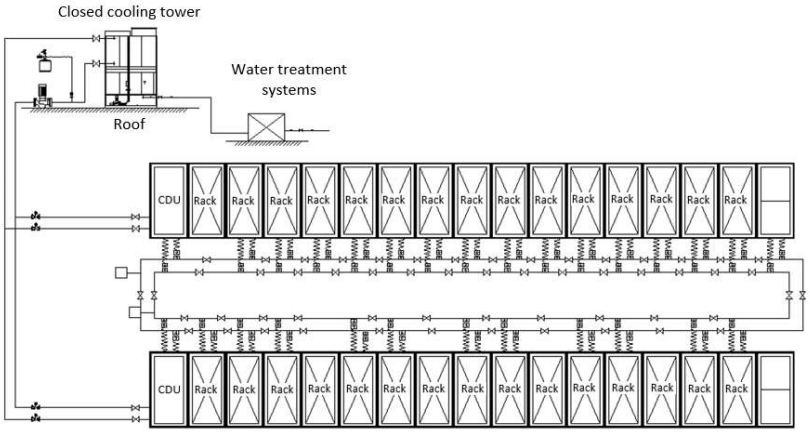


Figure 2, Liquid Cooling Loop Overview

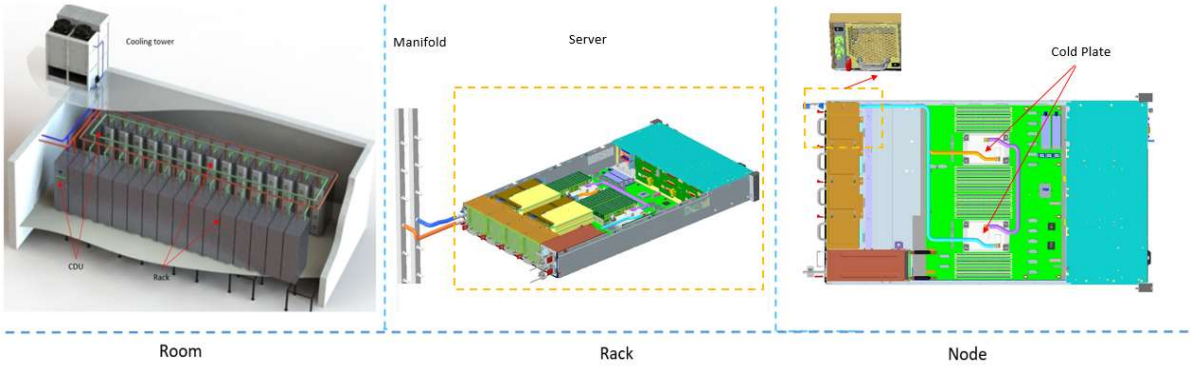
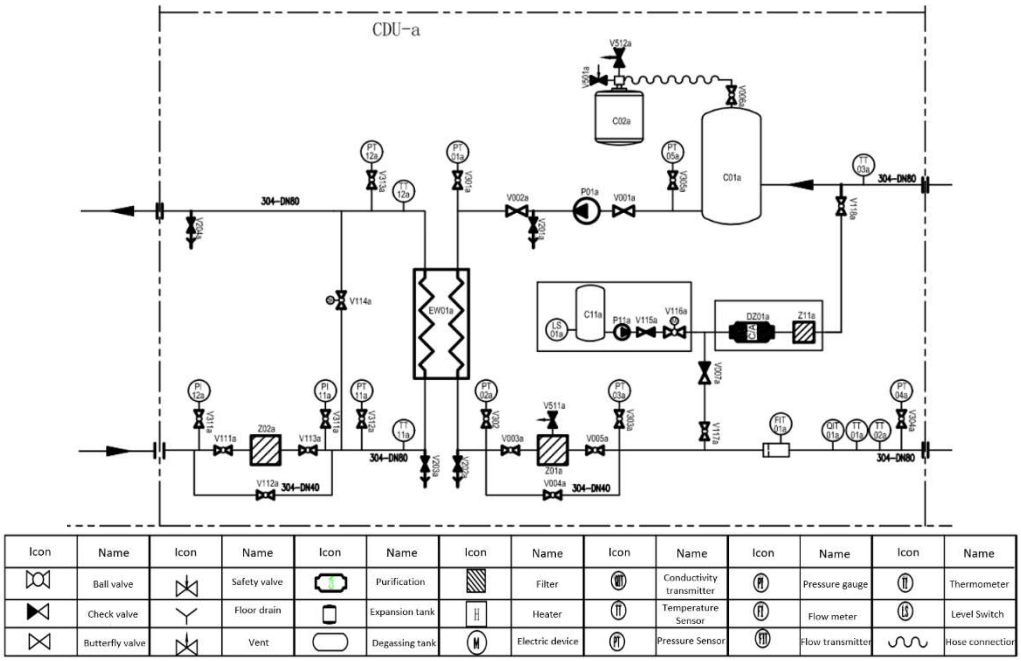


Figure 3, Liquid Cooling System from Room to Server Node

4.1.1. Coolant Distribution Unit

The coolant distribution unit (CDU) is a dedicated equipment that facilities heat transfer and removal between dedicated liquid loops. The CDU is constituted of sets of interfaces, pumps, liquid-to-liquid heat exchangers,

reservoir tanks, valves, controllers, power/flow/temperature monitor and sensors. CDU controls water supply temperature based on the external ambient temperature and IT workload.
Usually the CDU has a buffering system to maintain stable operating pressure within the loop to prevent external air and contamination as well as the cavitation of the pump.
Each CDU has an independent control system which monitors all ingredients and sensors inside the CDU and primary/secondary loop and provides real-time communication though the friendly Human-Machine Interaction. The operating parameters, the status of the main equipment and any alarm signal can be transmitted to the host computer. Once there is any signal alarm, CDU sends "Request to stop CDU" warning message and the operator needs to shut down the CDU manually with admin privilege passcode.
Figure 4 illustrates diagram of a typical CDU with size of 600mm (W)x1200mm(L)x2300mm(H), which is located at the inside of rack.



Icon	Name	Icon	Name	Icon	Name	Icon	Name	Icon	Name	Icon	Name	Icon	Name
	Ball valve		Safety valve		Purification		Filter		Conductivity transmitter		Pressure gauge		Thermometer
	Check valve		Floor drain		Expansion tank		Heater		Temperature Sensor		Flow meter		Level Switch
	Butterfly valve		Vent		Degassing tank		Electric device		Pressure Sensor		Flow transmitter		Hose connection

Figure 4, A Typical In-Rack CDU Diagram

4.1.1.1. Main Pump

Pumps are the heart of the system providing liquid flow to vital components. Non-redundant high-speed centrifugal pump with mechanical seal and stainless steel 304 or above wetted material is widely used today. It is controlled by a frequency converter and can runs at variable frequencies. When the main pump fails or cannot provides the rated pressure drop, an alarm signal will be triggered immediately.
The pump used in JD liquid cooling rack design is Grundfos model CRN64-2-2 which is made of 304 stainless steel. Operating point Q = 57m3 / h, H = 33.4m, rated power 7.5kW. Figure 5 shows the key parameters of the main pump.

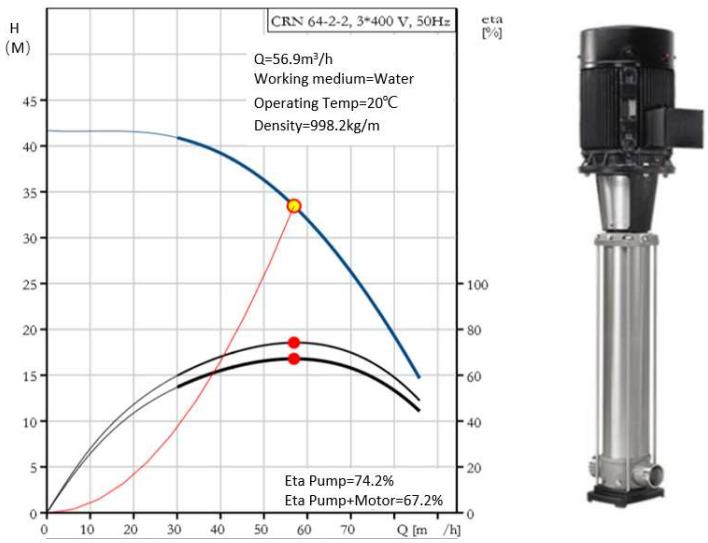


Figure 5, The Parameters of Main Pump

4.1.1.2. Filtering

Filters are used to maintain quality and prevent operational issues arising from the contamination of particulates, debris, and bacteria. Particulates are basically microscopic, measured in micrometer (μm), and filters size is required to fit to trap particulates, so that it can prevent them from circulating within the liquid loop. Typically, 200 μm is the typical filtering precision nowadays and has been used in JD data centers. Moreover, the filter is equipped with a pressure gauge or pressure transmitter to monitor the operating pressure drop and remind the operator to clean on time.

The effective wet material for filter is stainless steel 304 or above. As illustrated in Figure 6, the filter is designed with stop valves at the front and back and bypass valves, which allows the filter to be replaced and cleaned online. During online replacement and cleaning, the bypass valves should be opened first, then the front and rear valves should be closed. The bottom of the filter cavity is designed with a vent cleaning valve. When the filter has minor fouling, open the vent cleaning valve directly to restore the filtering capability. Attention to avoid any residual coolant dripping into the CDU during removal of the filter.

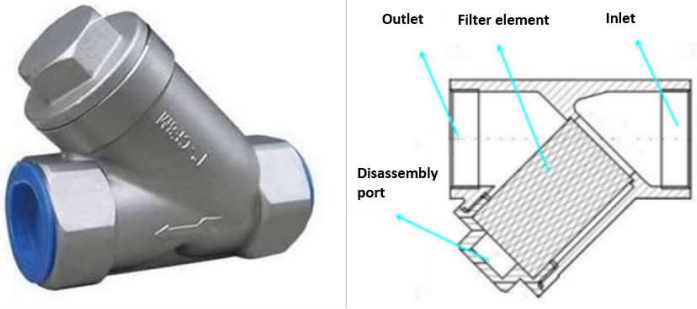


Figure 6, A Glance of Filter

4.1.1.3. Pressure Stabilization System

A liquid cooling system is mainly designed with a pressure stabilization system to avoid the pressure fluctuation or even pipe damage due to thermal expansion and contraction of the coolant, also to avoid negative pressure at the inlet due to pressure drop through the pipeline.

A buffer tank is typically used as one key pressure stabilization device. As shown in Figure 7, the tank is pre-charged with a certain amount of compressed gas to provide a suitable static pressure to prevent negative pressure at the pump inlet. When the coolant expands, the buffer tank can absorb the expansion volume of the coolant to ensure that the operating pressure of the pipework remains balanced. When the coolant contracts, the coolant in the tank can be released into the pipework to ensure that the coolant is enough, as well as the operating pressure is balanced.
The buffer tank is designed with a pre-charged pressure of 0.5 to 0.75 bar, and the rated static pressure can be reset according to the actual operating conditions of the system.



Figure 7, Buffer Tank

4.1.1.4. Heat Exchanger

Plate heat exchanger is the core heat exchange equipment, shown in Figure 8. The heat exchanger in JD data centers is brazed design with cooling capacity is 100% of the total heat dissipation. It's made of stainless steel 304 or above and designed for high heat exchange capacity and efficiency. Key parameters are shown in Table 1.

Table 1, Heat Exchanger Design Parameters

Item	Parameter
Inner Loop Liquid	Pure water
Inner Loop Flow Rate	57m^3/h
Inner Loop Inlet Temperature	≤45℃
Inner Loop Temperature Difference	6-7℃
Outer Loop Liquid	Pure water + 40% EG
Outer Loop Flow Rate	65m^3/h
Outer Loop Inlet	≤35℃
Outer Loop Temperature Difference	6-7℃
Rate Cooling Capacity	400KW
Design Margin	5~20%
Design Pressure	1.0 MPa
Test Pressure	1.2 MPa

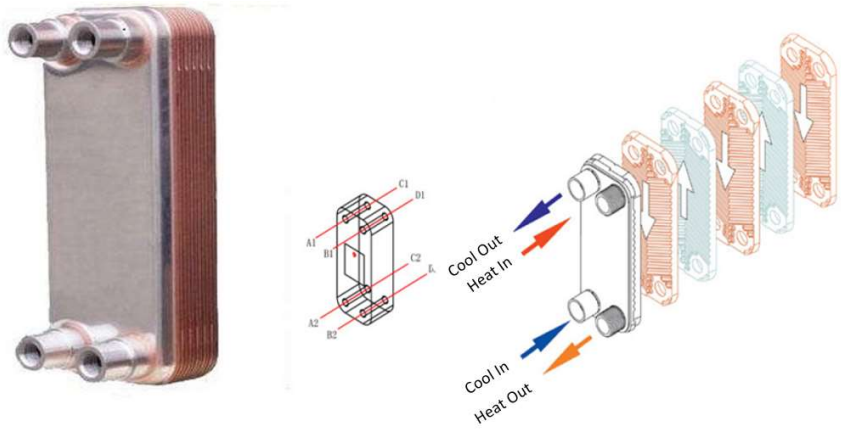


Figure 8, Plate Heat Exchanger

4.1.2. Pipework Leakage Detection

To further ensure the reliability, the liquid cooling system is implemented with leakage detection mechanism. Drainage trough is implemented under the pipework to collect any accidental leakage and drained through the drainage channel. A dedicated leakage detection system was implemented at the bottom of the drainage trough. Once there is any leakage detected, the system will send alarm signal to maintenance personnel. JD.COM has used leakage detection rope solution as shown in Figure 9.



Leakage Detection Rope Leakage Detector

Figure 9 Leakage Detection Solution Used in JD.COM Data Centers

4.1.3. Pipeline Design, Manufacturing and Setup

All stainless steel equipment and pipelines are made by argon arc welding, and with acid cleaning, degreasing, cleaning, rinsing and other procedures. Pipelines are prefabricated to ensure quality, safety and quick installation. In order to maintain the high purity of the coolant, all pipelines are made of stainless steel 304 or above. All wet material is not prone to corrosion and designed for at least 6-year of normal operation. JD.COM has adopted 304 stainless steel in design, which is the proved solution in the industry.

4.2. Liquid Cooling Rack Server

4.2.1. Manifold in Rack

The manifold is a key component to distribute cooling liquid within the rack to and from the IT equipment. As shown in Figure 10, quick disconnect is implemented on the top side of manifold to facilitate the rack deployment and the manual drain outlet is designed at the bottom to facilitate system drainage maintenance. Manifold in JD data centers is customized according to the actual rack dimension.

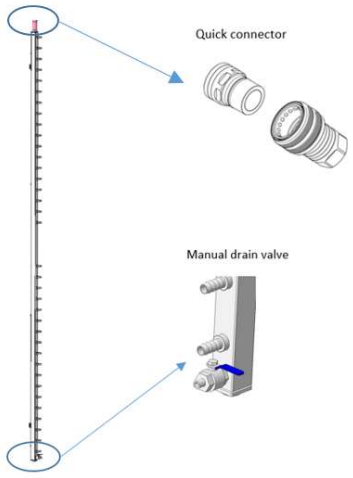


Figure 10, Manifold

4.2.2. IT Equipment

Server node is the IT equipment that is deployed in data center racks. It can be different form factors, 1U/2U/3U/4U and above. As shown in Figure 11, Liquid cooling server node mainly consists of mainboard, fans, power supply, CPU cold plate, pipes and connection. Basically, each server node is designed with one fluid inlet and outlet for coolant.

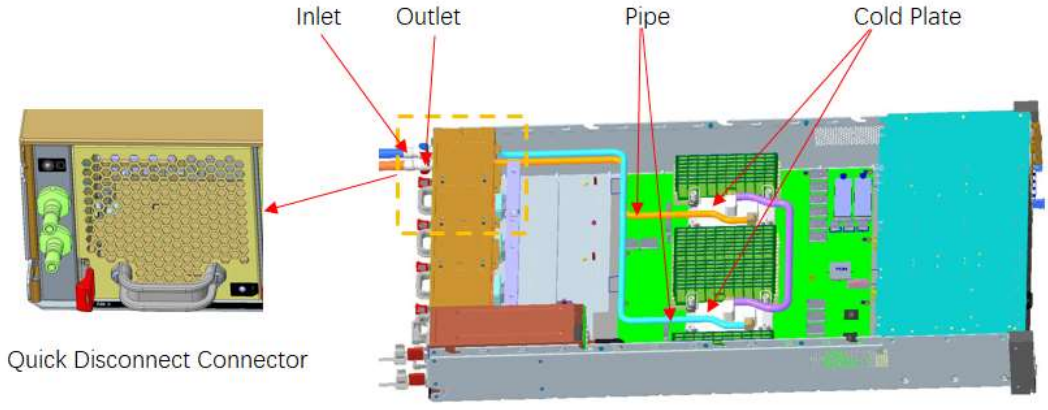


Figure 11, Liquid Cooling Server Node

4.3. Industrial Recommended Environmental Requirements

Liquid cooling system in JD data centers follows below Industrial Recommended environmental requirements.

4.3.1 Temperature

- Water supply temperature: 20~45℃;
- No system failure or warning when water supply temperature is below 45℃. Recommended air temperature range: 18~27C, the accuracy of temperature monitoring is ±1℃.
- Storage and shipping: -20~70C;
- Temperature change rate: <=20C/h

4.3.2 Humidity

- Operating: 10% RH-90% RH
- Storage and shipping: 5% RH-95% RH

4.3.3 Pressure

- 0.6 bar < node inlet < 3 bar

4.3.4 Altitude

- Operating: <=2000m, no impact when inlet temperature is 5~45C

5. JD Engineering Practice and Key Learnings

5.1. CPU Cold Plate

As one of the key components in open loop liquid cooling system, cold plate transfers the heat from CPU to the pipeline, the optimization of the cold plate design is the key to the whole cooling system. Figure 12 shows major types of cold plate design.

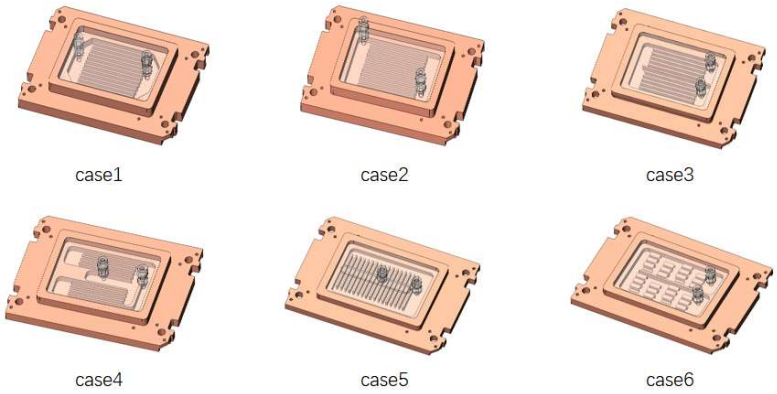
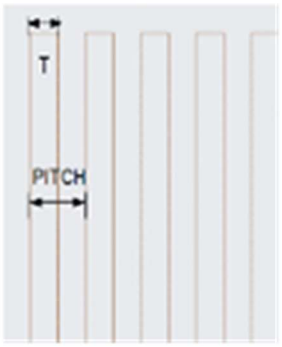


Figure 12, Major Types of Cold Plate Design



Figrue 13 Case 1~5 Fin Design

Figure 13 shows the uniform internal fin structure for case 1 to case 5. Skived fins with 1mm thickness, 3mm fin pitch and 3mm fin height are designed for these cold plates.

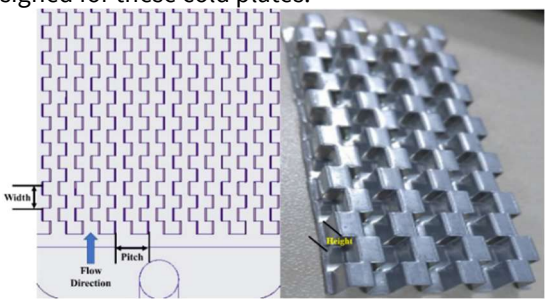


Figure 14 Case 6 Fin Design

For case 6, a special fin structure is designed to improve the liquid flow disturbance in the micro channels as shown in Figure 14. The detailed parameters are 0.3mm fin thickness, 7mm pitch, 2.8mm fin height and 5.4mm width.

Thermal resistance and pressure drop are the two key parameters of cold plate. In order to evaluate performance of cold plate accurately, JD.COM innovatively defines below equation to calculate cold plate performance. This equation is based on fan power efficiency and proved to be very useful in selection of cold plate designs.

$$S = \frac{100}{k_1 * Q + k_2 \Delta P + k_3 R}$$

S – Performance Index, bigger value means better performance
100 – Amplifier
Q – Flow rate (L/min)
ΔP – Pressure drop (Bar)
R – Thermal resistance (°C/W)
$K_1/K_2/K_3$ – Weight coefficient for Q, ΔP and R respectively (0~1)
With the test data on case 1 to 6, the performance of each cold plate can be calculated from equation (1) with the assumption of $k_1=k_2=k_3=1$.

Table 2, Performance of Each Cold Plate

		S				
	Q（L/min）	0.5	0.7	1	1.2	1.5
Case	1	169.43	126.35	91.04	76.71	61.60
	2	164.86	124.60	89.50	75.48	60.43
	3	166.44	125.44	90.97	75.63	60.48
	4	166.44	125.44	90.88	76.38	60.27
	5	168.38	127.54	92.19	77.51	61.14
	6	170.71	128.14	92.34	77.43	61.01

As shown in Table 2, case 6 is optimal with 0.5~1L/min flow rate, case 5 is optimal with 1.2L/min and case 1 is optimal with 1.5L/min. The common flow rate used in JD.COM data centers is 1L/min.

5.2. Memory Cold Plate

Memory cooling is another key design in liquid cooling system. JD.COM has implemented three different solutions for memory cold plate: liquid loop, heatpipe loop and fin type.

- Liquid loop: Flattened liquid pipe is implemented on the cold plate as Figure 15 shows. This type of solution needs DIMM pitch >0.35” (0.37” as best case). TIM material is implemented between the cold plate and memory case with compressed size of 0.03”.

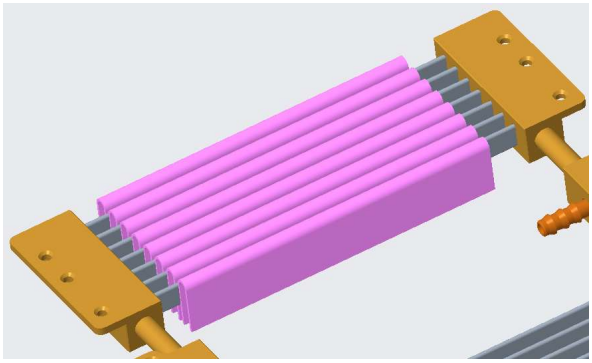


Figure 15, Liquid Loop Memory Cold Plate

- Heatpipe Loop: Flattened heat pipe is attached to memory case with TIM in the middle as Figure 16 shows. Heat pipes are connected to water loops to take away the heat. This solution works for the finer DIMM pitch design. 0.3” thickness of flattened heat pipe and 0.03” thickness of compressed TIM.

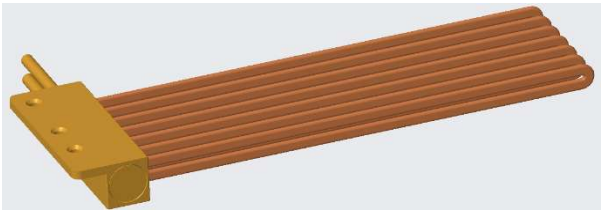


Figure 16, Heatpipe Loop Memory Cold Plate

- Fin-type: the cold plate is implemented on the top of memory section and fin pitch is precisely designed to contact with memory case as figure 17. This solution is dedicated for extreme fine DIMM pitch scenario.

To ensure the effective contact with memory surface, this solution requires vertical force onto the memory which might impact the memory reliability which needs special attention. The fin thickness is 0.2” and compressed TIM is 0.03” which is the same as above 2 solutions.

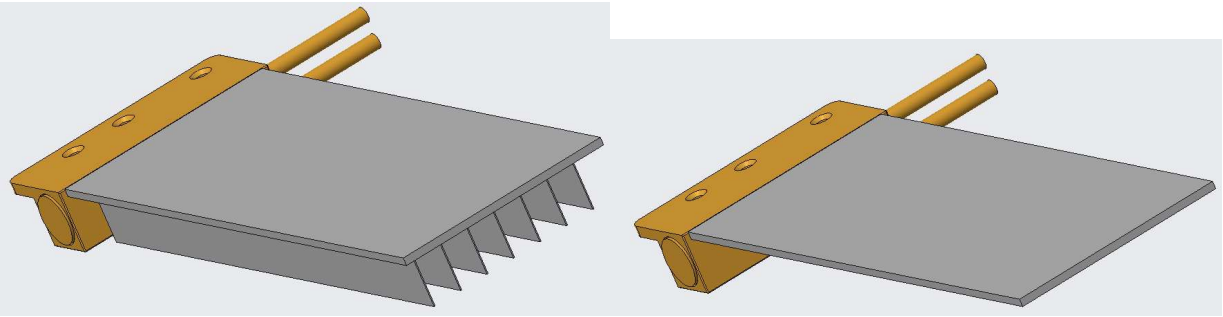


Figure 17, Fin-type Memory Cold Plate

5.3. Pipeline

The pipeline within IT equipment is designed as transportation of the coolant. Generally, it can be divided into two categories which are rigid tubes and hoses.
The rigid pipe has smaller bending radius and evapotranspiration rate and requires higher processing accuracy. Due to very poor commonality among different types, the rigid pipe requires overall assembly and disassembly. There are two types of hoses: plastic and rubber hoses. Following “JD test specification for Liquid Cooling Hoses”, JD team has done comparison tests among 5 typical pipes: BIIR, EPDM with reinforcement, EPDM without reinforcement, PTFE, and FEP as Table 3 shows. Each type of pipe is tested with sample size 15 samples, 3 times per sample. The pipe cracked or damaged in any time during test will be judged as fail. Currently, JD.COM continues to collect test data with more samples.

Table 3, Different Pipe for Comparison

Sample Group#	01	02	03	04	05
Type	BIIR（with rein-forcement）	EPDM（with rein-forcement）	EPDM（no reinforce-ment）	PTFE	FEP

5.3.1 Test Details and Conclusions

Total 9 items of test have been performed for 5 different types of pipe samples. Test items of 1 to 7 are for material reliability and test items of 8 & 9 are functional reliability. All the tests are conducted in sequence with the same sample. Table 4 summarizes test items, procedure, criteria and the results.

Table 4, Test Procedure for Hose

#	Test Item	Test Procedure	Criteria	Results
1	Low-Temperature	The sample needs to be kept at -20±2℃（-4±3.6℉）for 12 hours，then wrapped around a shaft with a diameter of 10 times of pipe diameter.	No crack or damage	All pass
2	Accelerating Test	The sample needs to be kept in a sink filled with coolant at 100±2℃（212±3.6℉）for 75 hours and cooled down to room temperature.	No crack or damage	All pass
3	Salt Spray	Salt spray.	No crack or damage	All pass
4	Deformation Test	The sample needs to be is repeatedly compressed with steel plates at a speed of 12.7 mm/min from 0 deformation to full compressed for 50 cycles.	No visual damage	01~03 pass, 04~05 fail
5	Twisting	The sample needs to be fixed on the rotating device and twisted for 100 times. For each cycle, the hose should be twisted by 180 ° in one direction along the core (the natural curvature of the hose) and then twisted in the opposite direction. Each cycle should be done in 8 to 12 seconds.	No damage	01~03 pass, 04~05 N/A
6	Bending	The hose should be able to withstand 100 repeated bending cycles	No damage	All pass
7	Pulling	The hose needs to be pulled with certain force and hold for 5mins with appropriate test fixture.	No damage	All pass
8	Static Pressure	The hose should be able to withstand a hydrostatic test of 1 MPa (145 psi) and hold for 1 minute.	No damage	03 fail, others pass
9	Infiltration	The sample is filled with coolant and then placed in a 38 ± 2 ° C (100 ± 3.6 ° F) incubator. The weight of each sample needs to be daily measured with accuracy of ± 0.01g.	Lower infiltration is better	See Table 5

Test item 9 was conducted for 14 days and the detailed results is shown in table 5.

Table 5, Test 9 Detail Results

Sample #	01	02	03	04	05
Daily Infiltration (%)	0.223	0.247	0.174	0.106	0.020

Overall test data shows liquid cooling loop higher than 0.45MPa need to adopt plastic pipe or rubber pipe with reinforcement layer. Plastic pipe also performs better from infiltration perspective.

5.4. Connection

The connection method between pipes as well as pipes to cold plates is also very important in liquid cooling system design. Usually fastening connection is used between pipes and cold plates, and quick disconnect is used between server nodes and rack. JD.com has adopted fastening connection.

5.4.1 Fasten Connection

There are several connection methods for small diameter pipelines, such as pagoda openings, clamps, and buckles as Figure 18 shows, all of which have been used for long time. The pressure is much higher than the operating pressure of the liquid cooling system (0.2MPa).
JD.com has used barbed connection in current design while keeping open for other types according to different scenarios.



Figure 18, Different Types of Fasten Connection

5.4.2 Quick Disconnect

Quick disconnect (QD) couplings are used to quickly connect/disconnect the server node from liquid cooling loop. There are usually two options of QDs between the rack manifold and IT equipment, hand mate and blind mate connectors as Figure 19 shows.

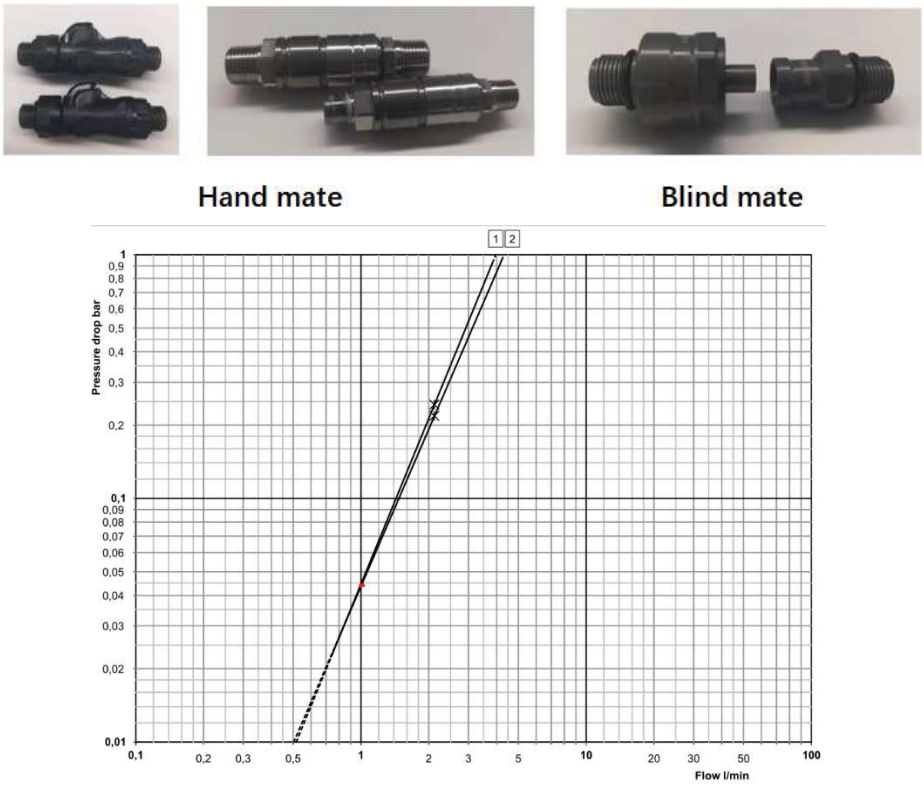


Figure 19, Hand Mate and Blind Mate Quick Disconnect

To achieve easier maintenance and better interchangeability, thread connection is used at both ends of the quick connector in JD.com's design.
The quick connector is used with an adapter, one end of the adapter is connected to the quick connector, and the other end is connected to the rubber pipe, which is shown in Figure 20.

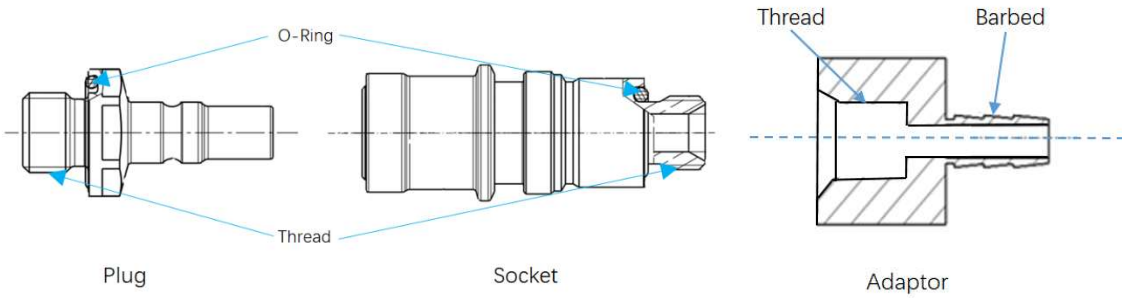


Figure 20, Quick Disconnect

Aluminum alloy, copper and stainless steel are the main material used for quick disconnect, and some manufacturers are trying to use plastic in quick connector design recently. The material selection is case by case to ensure chemical compatibility to avoid pitting issue.
The plastic quick disconnect in the design has been verified and proved to meet the requirements of no dripping during disconnection and connection under 0.8MPa pressure, which is shown in Figure 21.

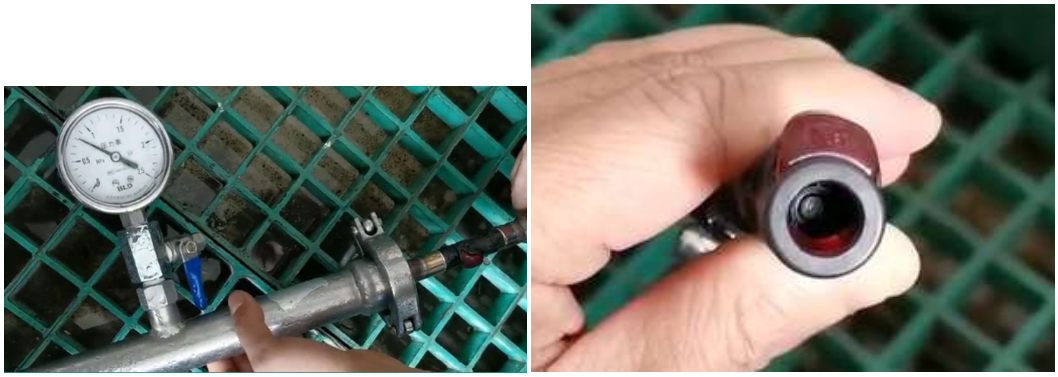
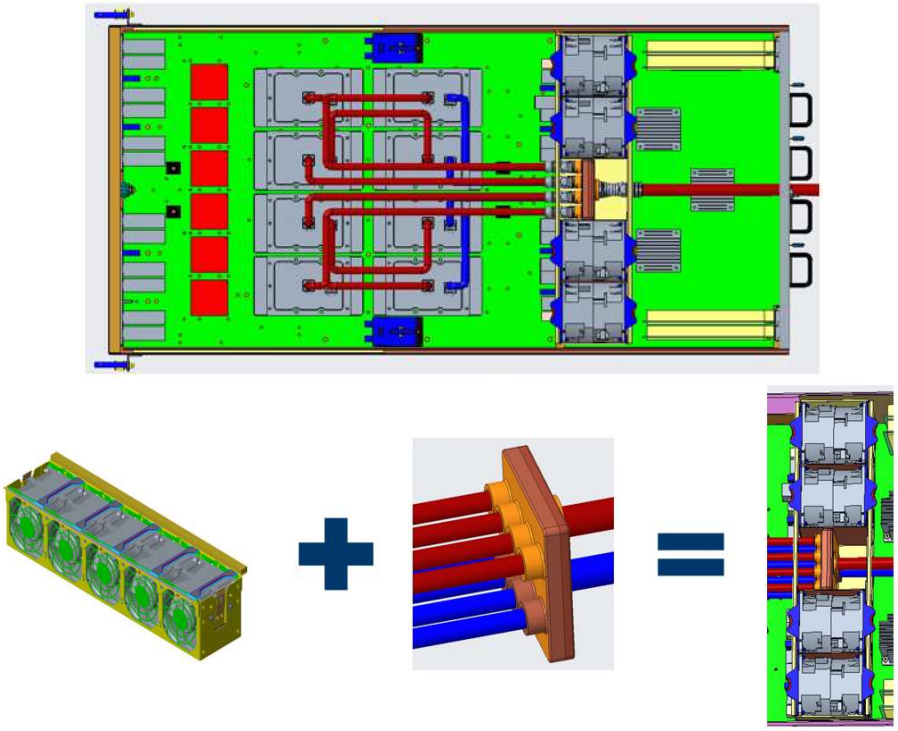


Figure 21, Quick Disconnect Test

5.5. Mini-manifold

The dimension of manifold is same as fan cage in server nodes. When liquid cooling solution is implemented, the manifold is designed to replace the middle fan in the fan cage in order to prevent any air flow recirculation as shown in Figure 22.



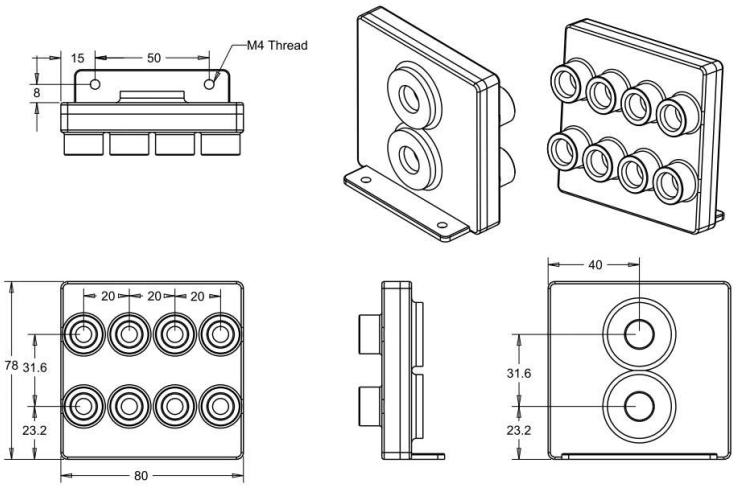


Figure 22, Mini-Manifold

5.6. Liquid Leakage Detection for Server Node

The leakage detection features are also implemented at server node level. The leakage detection sensor cable is routed around the liquid cooling loop, with electrical signal connected with motherboard BMC controller via I2C protocol shown as shown in Figure 23.

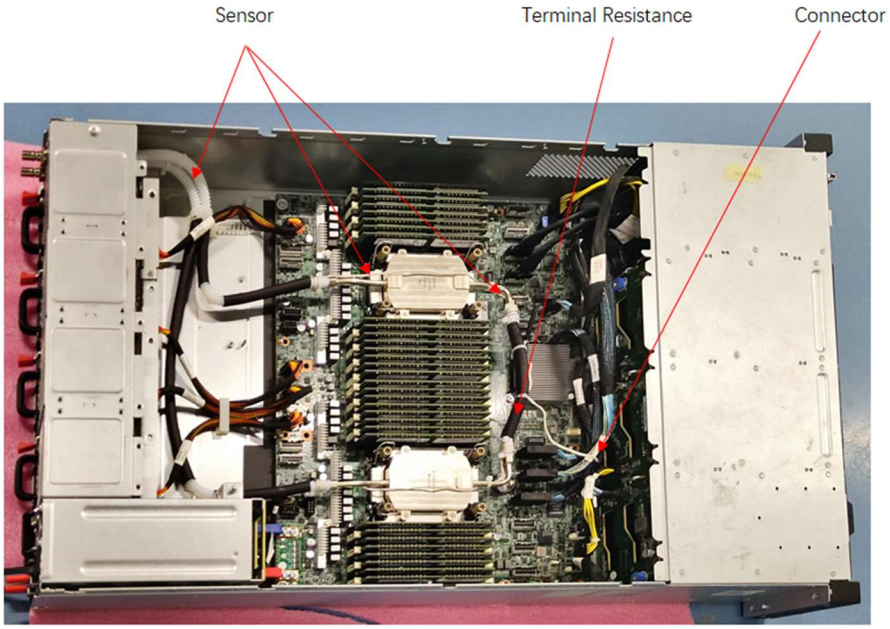
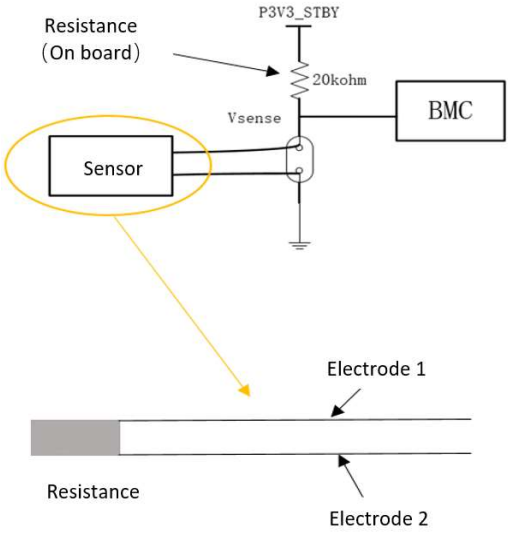


Figure 23, Leakage Detection Design in Server Node

The liquid detection sensor contains two electrodes, a resistor connected to the end and wires with a water-absorbing material as outer skin. During normal operation, there is a micro-level current between the electrodes. When liquid drips to any position on the sensor loop, water will invade through the outer skin, and the two electrodes will be turned on, and the whole loop resistance will drop sharply. When the sensor loop is disconnected at any position, the whole loop resistance will approach infinity. BMC will detect the change of the loop voltage in real time. The corresponding alarm event is logged. Detailed detection procedure is listed as

shows in Figure 24 below with an engineering example of 3.3V motherboard, 20kOhm resistance for both sensor and on-board resistance.
When the system operates at normal condition, the regular voltage is around 1.65V. Considering the variation of the voltage, the voltage thresholds are set from 1.4V to 2.0V as normal condition.
When there is any leakage happens in the system, the liquid will shorten the electrodes between electronde#1 and electronde#2, and the resistance between the two electrodes will drop sharply. At this time, the voltage monitored by the BMC will also decrease accordingly. If the lower voltage threshold is reached, a liquid leakage status will be logged and reported.
On the other hand, when there is failure in leakage detection sensor, the circuit between electronde#1 and electronde#2 will be broken which results in large resistance. In this case, the voltage will increase, and the upper voltage threshold will be exceeded. The sensor failure status will be logged and reported.



Vsense	Spec
≤1.4V	Leakage
1.4~2V	Normal
≥2V	Sensor failure

Figure 24, Node Level Leakage Detection Diagram

5.7. Coolant Requirement

The deionized water is the major part of the coolant with other composite requirements. Considering some IP protection in current phase, report of water quality is to be joint published with JD.COM, Intel, and other third-party suppliers separately later.

6. ACKNOWLEDGEMENTS

The authors would like to thank Intel Jessica Gullbrand for valuable advice on OCP white paper development and submission guideline, as well as paper content polish. Also, thanks for Intel Kang Li, Xiaofang Zhou, Zhongru Song, Jessica Liu, Yuehong Fan, Hang Cheng, Xingping Ruan, and Ken Zhang for the great support on JD.COM and Intel Joint Innovation Lab Project.

7. References

- “Water-Cooled Servers - Common Designs, Components, and Processes”, ASHRAE White paper by Technical Committee 9.9, 2019,
- Liquid Cooling Design Guide rev1.1, Intel, 2019
- “OCP ACS Liquid Cooling Cold Plate Requirements”, OCP
- GB/T 10125/ISO 9227: 2006 Corrosion tests in artificial atmospheres-Salt spray tests
- UL Standard for Safety for Hose and Hose Assemblies for Dispensing Flammable Liquids, UL 330 Seventh Edition, Dated December 16, 2009
- GB/T 29044-2012 Water quality for heating and air conditioning systems
- “JD.COM Liquid Cooling Pipe Test Standard Pipeline”, JD.com
- “JD Smart Cloud Data Center Design Specification”, JD.com
- Data Center Site Infrastructure Tier Standard: Topology
- Data Center Site Infrastructure Tier Standard: Operational Sustainability
- A Method for Calculating Aerodynamic Performances of Engine Cooling Fans 10.3969/j.issn.1000-3703.2009.12.003
- BLOCH G., GOGINENI S., ESTEVADEORDAL J. ,et al. Flow field in a low-speed axial fan: a DPIV investigation[J]. 2000,23(1).
- “Numerical Simulation of Water-cooled Radiator of Power Electronic Equipment”, North China Electric Power University, 2006
- “Heat sinks for power semiconductor devices. Part 2: Test methods for thermal resistance and flow resistance”, Xi'an Power Electronics Technology Institute, 2004
- Numerical predictions of fluid flow and heat transfer in corrugated channels using time dependent and time-independent flow models [J]. Journal of Enhanced Heat Transfer， 2004，11（4）：347-357. Xu W， Min J C.
- “A Novel Concept Methodology of In-direct Cold Plate Liquid Cooling Design for Data Center in CPU Socket Area”, 2020 19th IEEE Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems (ITherm)
- Two and Three–dimensional numerical models of flow and heat transfer over louvered fin arrays in compact heat exchangers，Int J Heat MassTransfer 1998，41：4063-4080. Atkinson K N，Drakulic R，Heikal MR.