White Paper: Guidelines to Rack Manifold Requirements and Qualification

Authors:

Berhanu Wondimu, Edward Kung & David Zhou (Intel Corporation)

Contributors:

Jimmy Chuang, Jordan Johnson & Jessica Gullbrand (Intel Corporation), Cam Turner, Jerry Kao & Sebastian Varela (CoolIT), Rock Cheng & Ray Liu (Ingrasys/Foxconn), Sean Tung (Inventec), Liren Wang, Kun Huang & Edward MC Wu (Wistron), Sam Lin & Nick Tan (Delta), Tony Huang (Chia Cherne), Brad Huang (Jabil), Sway Wang (CEJN), CW Chen (Supermicro), Clyde Chu (Meta Green Cooling), Joe Peng (SouthCo)

Contents

Introduction 4

1 Nomenclature 4

2 Key Performance Indicators 5

3 Form/Fit/Function..5

3.1 Features and Dimensions..6

3.2 Terminations 7

3.3 Functional Requirements..8

4 Performance Requirements...9

4.1 Operating Condition Requirements 9

4.2 Testing Requirements 10

4.3 Durability Requirements 11

4.4 Shelf and Service Life Requirements 12

5 Manufacturing Requirements...12

6 Surface Treatment 14

7 Quality Control 14

8 Assembly Requirements 15

9 Wetted Materials 16

10 Conclusion...18

11 References 19

12 License...19

13 About Open Compute Foundation 19

14 Appendix...19

14.1 Southco Floating Mechanism using UQDB04...20

14.1.1 Functional and Performance Requirements 20

14.1.2 Test Requirements 21

14.2 Ingrasys Mechanism for ORV3........22

14.2.1 Functional and Performance Requirements........22

14.2.2 Test Requirements........23

Introduction

The scope of this whitepaper is to provide recommendations on manifold design, manufacturing and testing for standard 19” rack and ORV3 rack with a goal to have a common product as a stock item for liquid cooling integration. The objective is to help development of a modular type of manifold which can be used interchangeably on a similar size rack/cabinet configuration regardless of product brand or origin. This rack manifold requirement and qualification guideline specifies some of critical features and dimensions for interchangeability and defines performance expectations for rack level information technology equipment (ITE) cooling application. The scope extends from concept to productization, and manifold suppliers and liquid cooling solution providers contributed in this effort to enable the liquid cooling ecosystem for OEM/ODM. This whitepaper recommends critical interfaces and provides an example of manifold design to allow multiple vendors to design qualified manifolds that meet customer requirements.

1 Nomenclature

The following are definition of terms used in this document:

ORV3 – Open Rack Version 3

VRM – Vertical Rack Manifold

ITE – Information Technology Equipment

QD – Quick Disconnect

UQD – Universal Quick Disconnect

UQDB – Universal Quick Disconnect (Blind Mate)

CDU – Coolant Distribution Unit

KPI – Key Performance Indicator

MAWP – Maximum Allowable Working Pressure

NPT – National Pipe Thread

SAE – Society of Automobile Engineers

ISO – International Standards Organization

BSPP – British Standard Pipe Parallel

QRE – Quality and Reliability Engineering

EOL – End of Life

FOD – Foreign Object Debris

FAI – First Article Inspection

PDU – Power Distribution Unit

HMI – Human Machine Interface

OEM – Original Equipment Manufacturer

ODM – Original Design Manufacturer

2 Key Performance Indicators

Key Performance Indicators (KPI's) are measured parameters that are crucial in defining the product performance and help on product selection.

- Temperature
- Pressure (MAWP and burst pressure)
- Pressure drop
- Fluid loss (leakage)
- Flow rate
- Mechanical resistance (shock/vibe)
- Material compatibility
- Certification (ISO, CE, RoHS, UL, etc.)

3 Form/Fit/Function

Manifold shape and size may vary depending on rack size and application. Therefore, manifold selection is determined by performance parameters and installation requirements. This document is particularly focused on standard 19" rack manifold and ORV3 rack mount manifold.

3.1 Features and Dimensions

Table below shows a minimum list of recommended physical parameters of rack manifold to drive normalization and adaptation in liquid cooling systems.

Table 1: Features of Rack Manifold

Feature	Description
Orientation	Vertical
Configuration	Single or Double
Server loop spacing	Based on rack units "RU" size (44.45mm / 1.75") for EIA-310-D rack and "OpenU" (48.0mm / 1.89") for ORV3 rack [1]
Geometry	Square or circular cross section
CDU connection size	Hose ID, ¾", 1", 1.25", etc. based on rack flow requirement
Server loop connection size	Hose ID, ¼", 3/8", ½", etc. based on system flow requirement
Safety features	Pressure relief valve (PRV) (or auto air vents) & drain valve (optional if there is low point drain in the loop)
Control features	Shutoff or bypass valve & flow control valves

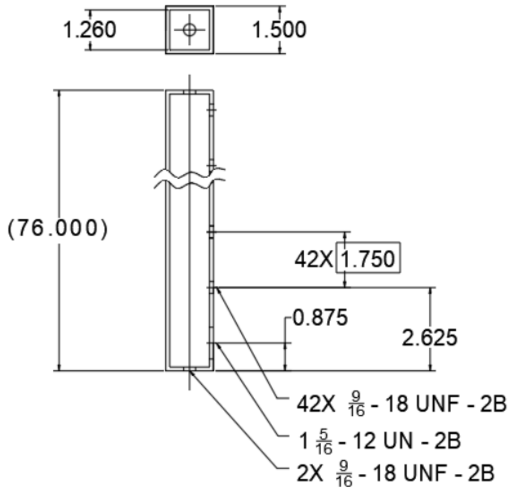
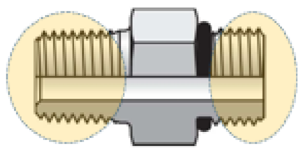
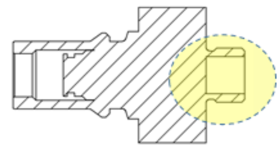


Figure 1: Example of 19" EIA-310-D Rack Manifold Drawing

3.2 Terminations

Rack manifold termination selection depends on several factors, such as measurement standard used (metric/SI, Imperial, etc.), type and size of adapter fittings, manufacturing method, etc. Therefore, termination options are left to discretion of the manufacturer. At a minimum a straight SAE thread with O-ring boss (ORB) termination (per ISO 11926-1) is recommended to connect hose/pipe adapters to the CDU and servers [2], [3]. This will help to normalize quick disconnect (QD) interface and reduce assembly complications due to manufacturing and operator error. NPT (National Pipe Thread) connection can be used for thick walled (machined) manifold, but not recommended due to sealing challenges on tapered thread. For thin walled (extruded tube or formed pipe) manifold, a straight thread with O-ring boss (SAE/BSPP) connection is ideal since there may not be enough room to fit tapered thread fitting. Special fixtures have been developed for blind mate quick disconnect (UQDB) installation onto the manifold. These designs have a floating mechanism to align and engage the UQDB connectors during server installation into the rack (see some examples in Appendix 14 for details).

Table 2: Recommended Termination Options

		
Termination	**Adapter Fitting**	**UQD / UQDB**
CDU	Straight (SAE/BSPP) or Tapered (NPT)	Straight, O-Ring Boss, Stud End – PER ISO 11926-3 to mate with port per ISO 11926-1
Server	Straight (SAE/BSPP) or Tapered (NPT)	Straight, O-Ring Boss, Stud End – PER ISO 11926-3 to mate with port per ISO 11926-1

3.3 Functional Requirements

The manifold geometry and connections must be designed to support full rack level cooling load and provide uniform flow distribution to each server loop from the CDU. Below are some of design considerations to improve manifold performance:

- Material selection of the manifold and components used in liquid cooling system depend on coolant fluid and must be within approved wetted materials list (WML) to meet application requirements.
- CDU and server connection should be optimized to reduce pressure drop and provide uniform flow to each server loop.
- Manifold ports must accommodate UQD/UQDB terminations to ease assembly and servicing. As a minimum requirement, the manifold terminations must meet thread type and size specifications given in Section 3.2.
- High point bleed/vent valves are required on top of the manifold to remove trapped air.
- Low point drain valve is required at the bottom of manifold to remove sediments from the loop and drain the system during a system flush or servicing. In some applications the lowest QD port on the manifold is used as a drain during maintenance.

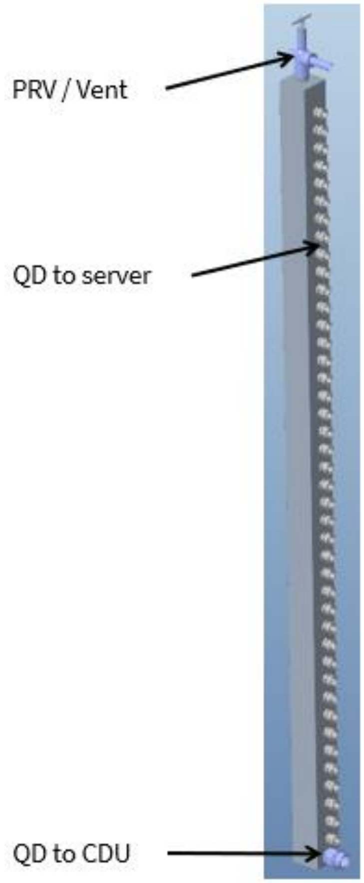


Figure 2: An Example of Manifold Assembly

4 Performance Requirements

To comply with liquid cooling application requirements, the product must meet or exceed performance expectations of customer applications. The manifold must be validated through testing to qualify for use in liquid cooling rack.

4.1 Operating Condition Requirements

The following are minimum operating condition requirements derived from secondary flow network ingredients like adapter fittings, tubing, QD, etc. [3]:

Table 3: Operating Condition Requirements

Parameter	Description	Priority
Maximum operating pressure	MAWP	Required
Minimum burst pressure	3x MAWP	Required
Flow distribution	Capable of delivering uniform flow to each server loop per cooling demand	Required, (velocity < 1.5m/s per ASHRAE guideline [4])
Geometry	Cross section (circular/square) x Height	Shape & size left to discretion of the manufacturer
Operating temperature range*	17°C - 65°C	Required, (per ASHRAE W45, 2°C approach in CDU & ~13°C ΔT [4])
Shipping temperature range	-40°C – 75°C	Required
Certification	RoHS, CE	Required
Surface treatment	Passivation / pickling / electropolishing / Platting / coating etc.	Required (option left to discretion of the manufacturer)

* Support for higher temperature range is desirable as an option as there are known solutions that may operate in the range 17°C - 75°C. It is expected that product rating would be published by supplier.

4.2 Testing Requirements

Supplier is responsible to validate the product per performance requirements outlined by the customers and recommendations presented in this document. Table 4 below shows minimum list of tests recommended to validate the product. These test requirements are derived from UQD specification document published on OCP, which is related secondary loop ingredient used on the rack manifold as well as manufacturing floor testing processes and quality inspection as well as design points to ensure a factor of safety drives much of the following requirements [3].

Table 4: Testing Requirements

Parameter	Description	Priority
Pressure test (ASME B31.3)	100 psig 300 psig	Required
Temperature test (ASME E1003 or ASME E499 or EN1719)	High temp / high pressure Low temp at pressure (storage)	Required
Flow resistance test	Flow resistance / pressure drop	Required
Fluid leakage test (ASME E1003 or ASME E499 or EN1719)	Leakage at terminations & seals	Required
Corrosion test (ASME B117) (ASTM B368-1997)	Salt spray or other accelerated testing	Required
Mechanical load test (ISTA 3-E when mounted to a packaged and loaded rack) (NEBS GR 63 cord SPEC)	Shock / vibe (fully assembled system)	Required

4.3 Durability Requirements

Manifold assembly must withstand accelerated testing cycle, (e.g., a minimum of 5000 flow/pressure upset condition or water hammer tests) to qualify for durability. Typical example of cyclic test is done for pressure, which involves pressurizing the manifold with coolant fluid from 0 psig to 150 psig and hold for 3 seconds. Then repeat the cycle until it reaches the 5000th cycle. All performance requirements listed in Table 4 must be met or exceeded when the manifold assembly is tested at first (time 0), and 5000th cycles.

4.4 Shelf and Service Life Requirements

Manifold performance requirements must be met or exceeded when tested after the service life cycle and at end of life (EOL). Shelf life and service life requirements are shown in Table 5 and Table 6 respectively. Total life span could include shelf life plus service life.

Table 5: Shelf Life Requirements

Parameter	Requirement	Test Method	Note
Shelf Life	5 years	Real-time aging / accelerated aging	Required

Table 6: Service Life Requirements

Parameter	Requirement	Test Method	Note
Service Life	10 years	Real-time aging / accelerated aging	Required

5 Manufacturing Requirements

Manufacturing method can vary from vendor to vendor based on material type and available resource to make the parts. Below are some of common manufacturing processes used to make rack manifold:

- **Manifold from billet** – costly manufacturing process, requires special tooling and setup. The advantage of this manufacturing process is purity of material which is good for compatibility (no need of welding/brazing, etc.).
- **Manifold from standard size pipe** – easy and cost-effective manufacturing method. Square/circular cross section pipes are available in standard sizes. Vendor can select a pipe with the right size and material to make the manifold.
  - **Pierce extrusion drilling and tapping** technique can be used to make a manifold from thin-walled pipe, which provides enough depth for tapping thread.
- **Welding** – must be done by experienced welder. Special attention needed on filler material selection and welding process. Vendors should develop their own “Welding Procedure Specification” (WPS) to achieve quality production welds that meet all relevant code requirements. The recommendation is to

use compatible materials for the coolant fluid. E.g., Tungsten inert gas (TIG) welding in inert gas (e.g., argon) medium using similar filler material to the base metal.

- CAUTION: Welding must be followed by descaling and pickling/passivation to protect the surface from corrosion.

- **Finishing** – Manifold surface and ports must be deburred and finished to high standards for safe handling and installation. O-ring seats on the manifold are weakest points for potential fluid leakage. Therefore, the sealing areas must be machined/polished to a surface finish value, Ra ≤ 63 µin (1.6µ) depending on seal type and size.

6 Surface Treatment

Surface treatment is crucial to protect the manifold from corrosion and damage from handling. There are different surface treatment options used by vendors. Table 7 below shows some of common surface treatment options used for stainless steel.

Table 7: Surface Treatment Process for Stainless Steel

Surface Treatment Options	Description	Priority
Pickling	Chemical process (uses HNO3 + HF mix), often combined with descaling for welded parts	Recommended (if chemicals are allowed by regulatory)
Passivation	Chemical process (uses HNO3 + water, per ASTM A380/A967)	Required
Electropolishing	Electrochemical process (uses H2SO4 + H3PO4 per ASTM B912)	Recommended (for better quality)
Protective coating	Surface coatings, especially used during shipment	Recommended

7 Quality Control

Manufacturing process alignment is key to make quality products in high volume production environment. This will reduce scrap rate and improve productivity and quality. Post-production cleaning is another important process to minimize FOD (Foreign Object Debris) contaminants from the part. Table 8 shows some of post-production cleaning operations used by vendors. Inspection is last line of defense in controlling product quality. All finished products must pass through FAI (First Article Inspection) and other check points outlined by QRE (Quality and Reliability Engineer) before shipping out to customers.

Table 8: Post-production Cleaning Process

Cleaning Process	Description	Priority
Air drying	Cleaning process using compressed air – commonly used in shops but not adequate to remove FOD from parts	Recommended after washing process
Washing*	Washing with soap and water to remove machining fluids and debris	Required
Steam pressure washing*	Washing with pressurized hot water and soap – this provides better quality as compared to washing/drying	Highly recommended for better quality
Ultrasonic steam bath cleaning*	Washing in ultrasonic steam bath – process used by jewelries for ultimate quality	Recommended (but expensive process)

* All washing processes must be followed by air drying to remove moisture marks from the product. CAUTION: compressed air system used for drying process must have a proper filter setup to provide clean air.

8 Assembly Requirements

Manifold assembly depends on rack size and components (tubing, UQD, adapter fittings, etc.) used for integration. For liquid cooling application, a deep rack design (e.g., 1200 mm) is recommended to provide enough room at the back side for plumbing without interfering with electrical/network cables & PDU (Power Distribution Unit). Some of manifold assembly considerations are:

- Manifold assembly can be done in single or double arrangement depending on server design and cooling load requirement of the rack.
    - Single manifold setup is used for single loop per “RU” size (44.45mm / 1.75 inch spacing) or “OpenU” size (48.00mm / 1.89 inch spacing) rack installations (with low cooling loads). Vendors are recommended to provide rack mounting kit (e.g., plates, screws, etc.) for manifold installation.

  - Double manifold setup is used for multi-node server systems (with high cooling loads). In this setup, two manifolds are paired to provide supply and return flow to support the required cooling demand. Manifold vendors are recommended to provide rack mounting plate and bracket for installation.

- Flow rate control system
  - For In-rack CDU system, the CDU in situ provides flow control to the servers based on cooling demand – this can be automated or monitored through HMI (Human Machine Interface).
  - For end-of-row CDU systems, local flow control devices (e.g., check valve, solenoid control valve, etc.) are recommended to control the flow and ease servicing without interfering with the rest of systems assembled in the same flow network.
- Pressure drop can be reduced by using good plumbing technique and the right parts for the application.
- Manifold plumbing must consider ease of installation and serviceability. Cluttered plumbing will make assembly and maintenance problematic.
- Use of UQD / UQDB is recommended for easy assembly and rack servicing. Consider using calibrated torque gauge for assembling BSPP thread adapter (per ISO8434-6).

9 Wetted Materials

All components used on the manifold assembly must be made from materials compatible with the coolant fluid used in secondary flow network. The supplier is responsible for validating material compatibility and meet performance expectations of the customer. Table 9 shows example of wetted materials list for components used with DOW Chemical, DOWFROST LC 25/55 and Huntsman Chemical, JEFFCOOL ISF-25/55 propylene glycol coolant fluids. On the other hand, Recochem OAT PG 25 coolant fluid is compatible with brass EN 12165 CW617N (CuZn40Pb2) nickel plated brass, NBR (Nitrile Butadiene Rubber) and silicone (polymerized siloxane) in addition to all materials listed in table 9.

Table 9: Wetted Materials Requirements

Material	Types
Copper	CDA110, UNS C11000, minimum 99.95% Cu + 0.002% Ag CDA1020, minimum 99.95% Cu + 0.002% Ag CDA1220, 99.9% Cu + 0.02% P CDA1100, 99.9% Cu + 0.04% O
Stainless Steel	SS302, UNS S30203 SS304, UNS S30403 SS316, UNS S31603 SS321, UNS S32103 SS410, UNS S41000
Brazing Filler	B-Ni-6, 88.9% Ni + 11% P BCuP-2, 93% Cu + 7% P BCuP-3, Cu 89%, Ag 5%, P 6%, others 0.15% BCuP-4, Cu 87%, Ag 6%, P 7% BCuP-5, Cu 80%, Ag 15%, P 5% TF-H600F, Cu 74.9%, Sn 15.6%, P 5.3%, Ni 4.2%
Titanium	Grade 2, UNS R50400
FEP	Fluorinated Ethylene Propylene
PTFE	Polytetrafluoroethylene
PP	Polypropylene
PEEK	Polyether Ether Ketone
HDPE	High Density Polyethylene
EPDM	Ethylene propylene diene monome
Viton A	Vinlylidiene fluoride hexaflouropropylene
Viton GF	Vinlylidiene fluoride hexaflouropropylene tetrafluoroethlyene

Viton ETP	Ethylene, tetrafluoroethlene, perfluoromethylvinylether
CR	Polychloroprene (Neoprene)

10 Conclusion

This white paper provides detailed guideline and recommendation on manifold requirements (design, performance, operation condition, testing, durability, shelf life, service life, manufacturing, etc.). Manifold manufacturers and integrators can use this document as a reference to build their product and contribute towards liquid cooling ecosystem enabling. As extension of this effort, blind mate QD installation mechanisms are included in Appendix 14, where two floating mechanism examples are provided for use with standard 19” rack or ORV3 manifold.

11 References

1.) Glenn Charest, Steve Mills, Loren Vorreiter, “Open Rack V3 Base Specification”, Rev. 1.0, Open Compute Project, Aug. 24, 2022.

2.) ISO 11926-1 & 11926-3: 1995 – Connections for General Use and Fluid Power

3.) Mark Sprenger, “Universal Quick Disconnect (UQD) Specification” Rev. 1.0, Open Compute Project, Sep. 4, 2020.

4.) ASHRAE TC 9.9 Reference Card, “2021 Equipment Thermal Guidelines for Data Processing Environments”, 5^{th} edition, 2021

5.) J. Gullbrand, et al, Journal of Electronic Packaging, “Liquid cooling of compute system”, by ASME, Vol. 141, 2019.

12 License

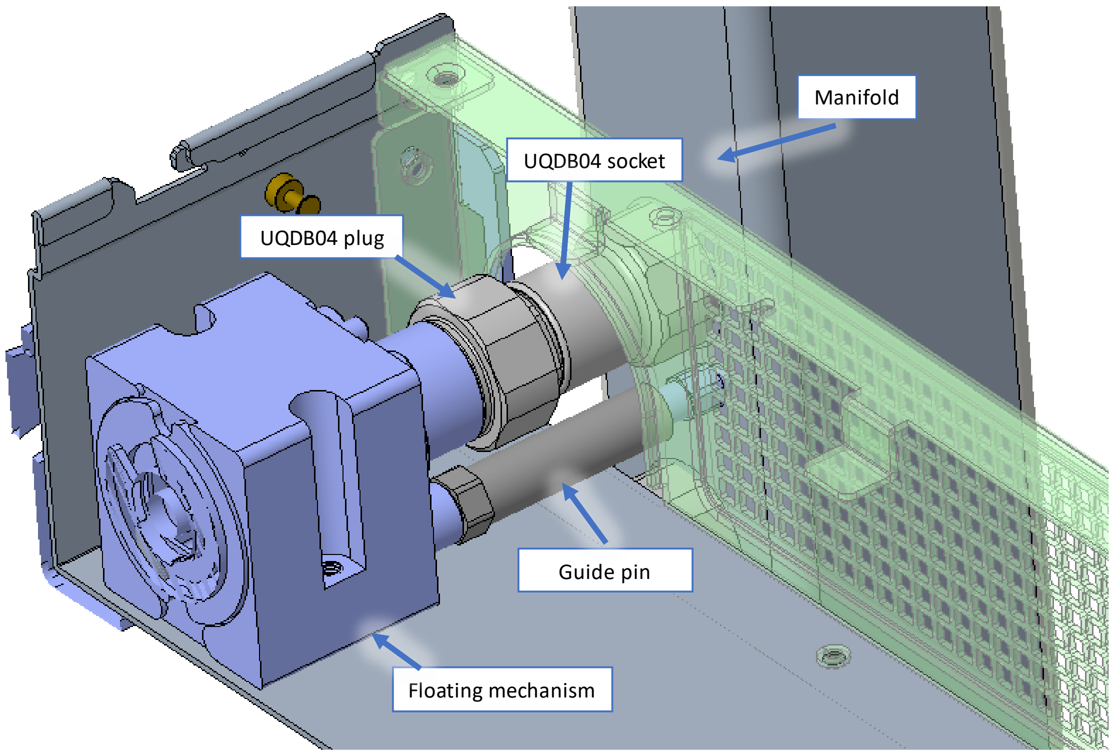
13 About Open Compute Foundation

At the core of the Open Compute Project (OCP) is its community of hyperscale data center operators, joined by telecom and colocation providers and enterprise IT users, working with vendors to develop open innovations that, when embedded in product are deployed from the cloud to the edge. The OCP Foundation PAGE 22is responsible for fostering and serving the OCP Community to meet the market and shape the future, taking hyperscale led innovations to everyone. Meeting the market is accomplished through open designs and best practices, and with data center facility and IT equipment embedding OCP Community-developed innovations for efficiency, at-scale operations and sustainability. Shaping the future includes investing in strategic initiatives that prepare the IT ecosystem for major changes, such as AI & ML, optics, advanced cooling techniques, and composable silicon. Learn more at www.opencompute.org

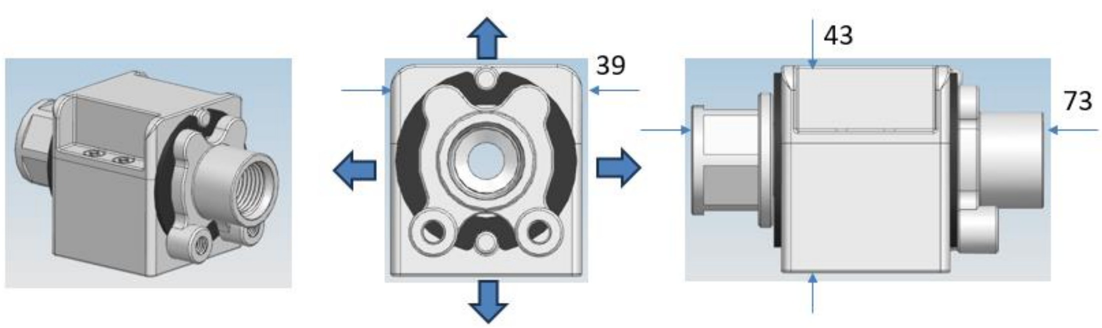
14 Appendix

This Appendix states the deployment of ORV3 manifold using UQDB or other blind mate termination design. The purpose of a blind mate manifold here is to enable the attachment and detachment of liquid cooling IT equipment without the need for tools or manual alignment. To facilitate a smooth and secure connection between the liquid cooling IT equipment and the manifold, self-aligning features should be incorporated on either side of the interface. These features could be achieved by designing a generous float or guiding mechanism, which eliminates the possibility of an unsecured connection between the male coupler on the IT equipment and the female coupler on the manifold.

14.1 Southco Floating Mechanism using UQDB04



14.1.1 Functional and Performance Requirements



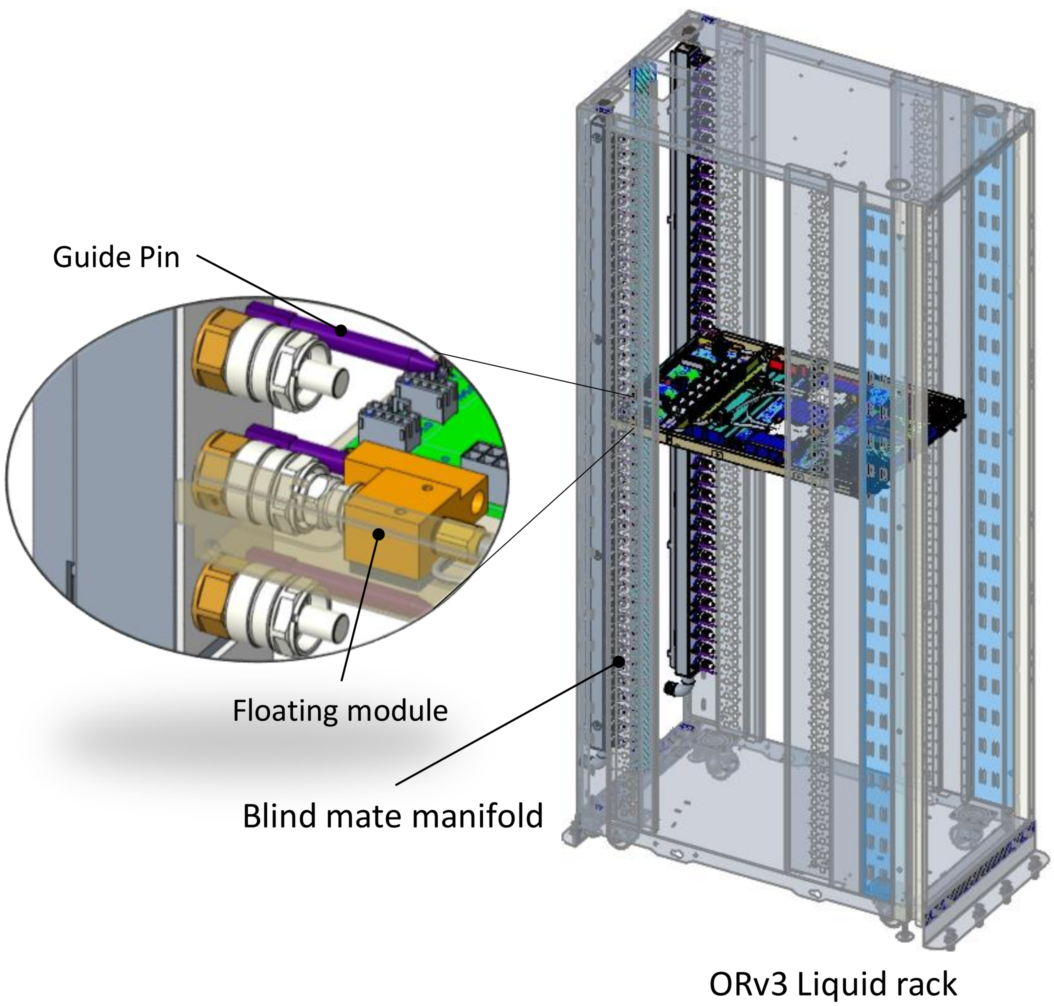
The Floating Connector is designed to provide a sealed connection between two plugs with 4mm radial floating in any direction. Below are design considerations to achieve the required function and performance:

- The floating mechanism is mainly composed of a housing and connector, with overall 39mm width, 43mm height and 73mm length.
- The connector shall provide female threads on the two ends for sealed connection with the specific plugs.
- Material selection of the assembly must comply with the approved wetted material list (WML) provided in this document. Housing material is stainless steel or specific engineering plastic and connector material is stainless steel.
- Two end washers with high strength engineering plastic are there to provide smooth radial floating.
- Two mounting holes with M4x0.7 threads on the connector will be provided to mount proper guiding pins for blind mating operation.
- Proper guiding feature and mounting screws will be provided on the bottom of the housing for proper mounting on server chassis.
- Two guiding features design to allow customer to place junction block on either the left or right side of sever using the same item.

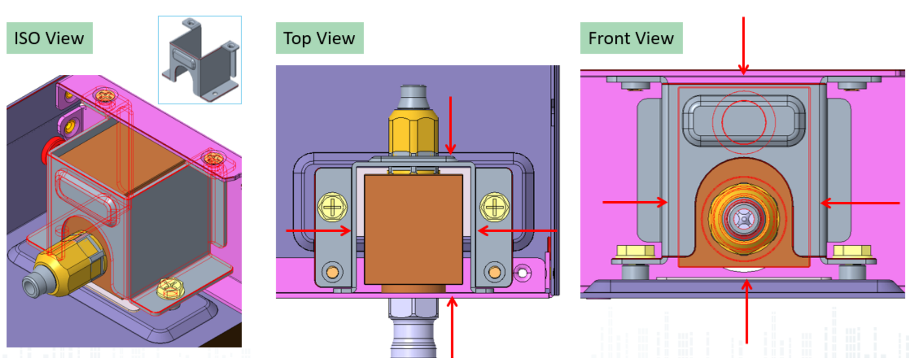
14.1.2 Test Requirements

To comply with manifold operating condition, the floating mechanism must meet or exceed performance requirements given in this document. The unit must be inspected and validated through testing together with the whole system to qualify for use in liquid cooling applications.

14.2 Ingrasys Mechanism for ORV3



14.2.1 Functional and Performance Requirements



- The floating module is designed to be a connection between manifold and cold plate loop. Its floating function is 2mm at four directions to meet the manifold tolerance.

- The Floating module is limited by an adapter holder which is fixed on the rear wall and bottom chassis of server.
- Guide pin is designed on the blind mate manifold and it can be either way on the upper or side of manifold. The guide socket is on the server chassis for the alignment match.
- The floating module dimension is 46.4mm width, 48mm length, and 22mm height for left guide pin type; 30.6mm width, 32mm length, and 38mm height for top guide pin type.
- Multi-connection interface of liquid cooling rack provides challenges on standardization with different suppliers. Integration with server cold plate loop, floating module, blind mate manifold, and ORv3 rack frame for whole system validation are important.

14.2.2 Test Requirements

To comply with manifold application condition, the floating mechanism must meet or exceed performance requirements given in this document. The unit must be inspected and validated through testing as a component as well as a whole system to qualify for use in liquid cooling.