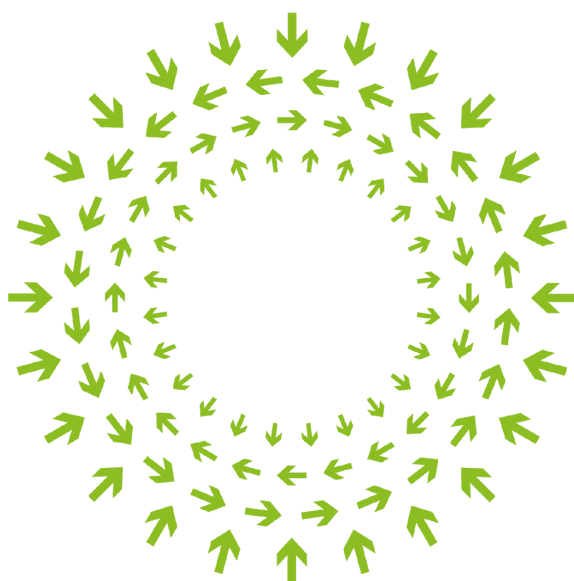




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Compute Project

Cold Plate Requirements

Revision {X.X}

Version {x.xx} March 7, 2022



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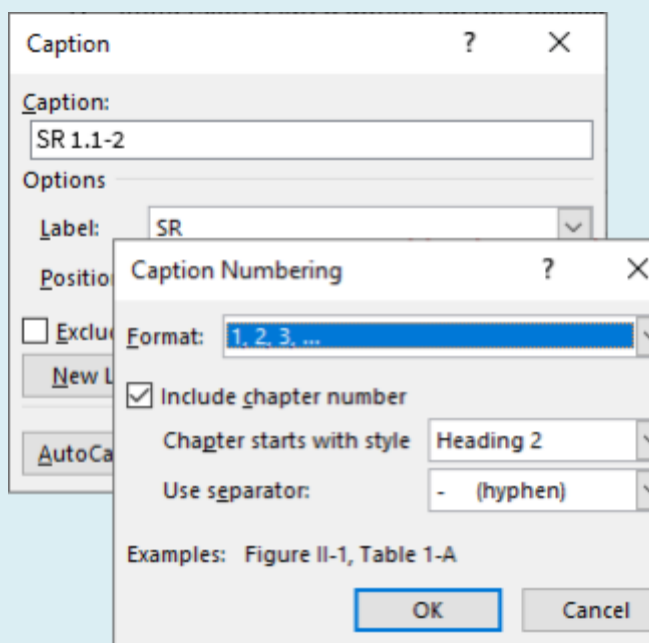
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Work package assignments (last updated May 19)

Introduction

- complete at end

Terminology

Ongoing

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Cooling Liquid selection

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Hardware Management

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Product Certifications

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Synchronization with ASHRAE

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1

Revision History

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1.00	{date}	First publication
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Introduction

This document outlines the requirements related to Liquid Cooling Cold Plate technology, which may be used in the Open Compute Project (OCP) environment. Liquid cooling technology is not a new technology, but until now most solutions have generally been proprietary. The OCP focuses on standardization and definition of critical interfaces, operational parameters, and environmental conditions that enable non-proprietary, multi-vendor supply chain of liquid cooled solutions.

This document is a requirement's document and not a specification. This document defines common terminology, identifies liquid cooling component selection with parameters of importance, and contains requirements that future liquid cooling design specifications need to adhere to. From this document, a checklist has been generated that any OCP liquid cooling specification must need to comply with (see the Cold Plate Qualification Requirement [1]). For contributions, this checklist needs to be filled out, and peer-reviewed by subject matter experts to ensure compliance with the requirements before the contribution is proposed for approval in the Incubation Committee meeting.

This requirement document is applicable to rack manifold distributed liquid cooling with a Technology Cooling System (TCS) fluid loop [2]. This is the fluid loop from the Coolant Distribution Unit (CDU) to the rack, through the manifold and the IT equipment, and then back through the manifold back to the CDU. The document assumes that the heat from the TCS cooling loop is transferred to the facility cooling loop, which is called the Facility Water System (FWS). FWS is not covered in this document. This requirement document does not apply to the IT equipment being cooled or fully air cooled specifications, but solely to the TCS cooling loop and its ingredients.

Background

More efficient cooling technologies are required as power and power density increase of the IT equipment to meet the continuous demand of increased compute performance.(refer OAM) Liquid cooling provides more efficient cooling compared to traditionally used air cooling. (evidence required)When to switch to liquid cooling depends primarily on the thermal requirements for the devices and augments many different parameters, such as targets of performance, power delivery, energy efficiency requirements, IT equipment density, compute density, cooling costs, future IT equipment needs, and strategy. All these parameters together with considerations of the potential need of retro-fitting the facility to pull in liquid to the racks/IT equipment or building a new facility to optimize the infrastructure feed into the total cost of ownership (TCO) model for the installation. From the TCO investigation, it can be determined when it is cost efficient to change to liquid cooling. Another reason for going to liquid cooling is that the IT equipment simply cannot be cooled to its temperature requirements any longer with air and therefore increased cooling is required. There is no general guideline on when or at what power levels liquid cooling will be required for the compute components, such as CPU and GPU. It should also be noted that in addition to the cost analysis, there are some new design considerations for liquid cooled solutions that need to be understood. The sub system design focus is derived from the requirements for each subsystem components and device of the ITE devices and their rack systems. This is essential for the success and operation of the liquid cooling solution. Another design consideration is to ensure that the cooling liquid used will never be mixed with any other cooling liquid, since the integrity of the cooling liquid is of utmost importance to ensure the longevity of the cooling liquid. In this requirements document, it is assumed that material compatibility between all cooling components and the cooling liquid has been determined, and it is therefore not repeated in all the different subsections. It is also assumed that no mixing of cooling liquids occurs.

Related sources:

1.1 Requirements:

The requirements are defined throughout this document as follows:

SR 1.1-1 All Specification Requirements shall be met by the solution vendor.

OR 1.1-1 Optional Requirements may be met to enable recognition of special functionality of features.

CR 1.1-1 Customer Requirements shall be met by owners, operators, or end users of the solution. Sufficient effort shall be made and demonstrated by the solution vendor to accommodate compliancy.

1.2 Qualification process

1. A qualification request with a filled-out checklist shall be sent to the community project lead(s).
2. The Project lead(s) will assess the submission and checklist and when accepted, schedule a 20-minute presentation for the submitter in the next available community call time slot.
 - a. The presentation shall be made available to the project lead(s) at the latest 1 week before the scheduled community call.
 - b. The presentation shall explain why and how the submitted solution qualifies against this Cold Plate Requirements document.
3. A 60-minute interactive review will be scheduled by a community committee:
 - a. The committee is overseen by one of the OCP project leads.
 - b. The committee will consist of the Requirements authors which are invited by the project leads.
 - c. All materials (checklist, community presentation, community questions and other collateral) are shared with the reviewers at least 1 week before the review meeting.
 - i. There will be 1 week to review materials, request additional feedback and ask follow-up questions after the review session;
 - ii. There will be 1 additional week to allow for all votes to be cast;
 - iii. The committee will approve, decline or provide feedback to resolve before approval, based on the Cold Plate Requirements.
4. The community committee is formed as follows:

- a. All authors of the Cold Plate Requirements document are invited to be panelists;
- b. One of the Cold Plate project leads oversees the qualification process and panel;
- c. Each company represented in the panel counts as 1 vote (excluding the qualifying company);
- d. A quorum is achieved with a minimum of 5 votes present in the panel.

Technology definitions

The terminology used in the Data Center is the same as used by ASHRAE [Ref] when discussing cooling solutions. The terminologies are:

- TCS, Technology Cooling System, is the cooling system from the Coolant Distribution Unit (CDU) to the rack, through the manifold and IT equipment, and back to the manifold and to the CDU.
- FWS, Facilities Water System, is the facility cooling system. The definition of FWS is extended in this document to also include other cooling liquids in addition to water.

1.3 Liquid Cooling Cold Plates

Liquid cooling cold plates refers to the technology of closed loop liquid cooling, where liquid or liquid/gas phase change is used as the heat transfer medium. Conduction of the heat occurs through cold plates, which are attached to the electronics power components in need of cooling. This is also sometimes called direct liquid cooling, since the cooling liquid is delivered directly to the components via a cold plate, thereby directly transferring the heat to the liquid. This should not be confused with indirect liquid cooling and immersion. Indirect liquid cooling is when air is the heat transfer medium to the liquid (f.ex. door heat exchanger). Immersion cooling is when the electronic components are in direct contact with a dielectric cooling liquid.

1.4 Cold Plates

The liquid cooling system design is multiple subsystems comprising heat capture devices (cold plate and cold plate array Connections to cold plates (joints, couplings and hoses/pipes), manifold , working fluids (coolant/refrigerant), Row based distribution and Coolant distribution. Cold plates are heat exchangers or heat sinks with internal tubing or channels to allow cooling liquid to flow through. Cold plates are placed on the electronic components in need of cooling and provide a conductive heat transfer path to the cooling liquid. There is a layer of thermal interface material (TIM) applied between the component and the cold plate. This is outside the scope of this document, but should be examined by the customer as it affects thermal performance, serviceability and reliability. There are different types of cold plates, where the design can be optimized to enhance heat removal from the electronic components. A simple example of a cold plate is a metal block with integrated fluid piping, while a more complex and commonly used cold plate design applies micro-channels to enhance the thermal performance in single-phase applications. The cold plates are often called evaporators in two-phase applications, where nucleation sites are introduced into the evaporator design to enhance the thermal performance. The enhanced cold plate/evaporator designs are often used for high power and high power density components.

1.5 Hybrid Cooling

Hybrid cooled solutions referenced in this document refers to cooling using both air cooling and direct liquid cooling. A common hybrid installation is to use direct liquid cooling for high power and high power density components, while air is used to transfer heat from the low power components. An example of hybrid cooled IT equipment is servers with cold plates attached to the microprocessors, while fans are used to cool all other components. Hybrid solutions still require room air-conditioning.

1.6 Full Liquid Cooling

Full liquid cooling refers to cooling solutions where all heat is rejected to liquid. For the IT equipment, such as a server solution using full liquid cooling, a heat transfer path is required to the cooling liquid through cold plates for all components. An example of full liquid cooled server installation is to use micro-channel cold plates for the high power components, while plates with internal piping are used to cool all other low power components. A common example of a full liquid cooled rack is a hybrid IT equipment solution with a door heat exchanger that captures all the heat from the air and transfers it to the cooling liquid. Full liquid cooling requires minimal room air-conditioning to remove heat transferred to the air only through unintentional thermal losses.

1.7 Single- and Two-Phase Cooling Liquids

The heat can be transferred to cooling liquids that either operate in single-phase or two-phase. For single-phase liquids, the liquid stays in liquid phase during the whole operation, while being circulated and removing heat from the hot components. The cooling liquid is cooled in a heat exchanger approach. Examples of single-phase liquids used are water with additives, glycol based liquids, and dielectric liquids with high boiling temperatures.

Two-phase liquids have a low boiling temperature and remove heat predominantly through a process of heat of vaporization and condensation via a heat exchanger. Either dielectric or refrigerant liquids can be used as the two-phase liquids, and many liquids are available with different saturation/boiling temperatures. The cold plates using two-phase technology are sometimes called evaporators. In this document, cold plate applies to both single- and two-phase cold plates, and cooling liquid refers to the coolant in both single-phase and two-phase implementations.

It is essential that there is material compatibility between the cooling liquid and all the materials exposed to the cooling liquid, which are referred to as wetted materials, to minimize

any long term risks of corrosion. Even when ensuring material compatibility between cooling liquid and all wetted materials, it is still important to regularly check the quality of the cooling liquid to ensure that there are no changes to chemistry over time.

This document only covers single phase cooling solutions.

1.8 Coolant Distribution Unit

The purpose of the Coolant Distribution Unit, CDU, is to provide an isolated cooling loop to the IT equipment. Heat transfer occurs inside the CDU, via a heat exchanger, between the heated liquid from the IT equipment loop (TCS) and the facility liquid (FWS) on the facility side. The CDU options are in-rack, row level, or facility level. One or several in-rack CDUs can be present in a rack to cool the IT equipment. The row level CDU often provides cooling to one or several racks full of IT equipment. A facility level CDU is a distribution solution with facility level pumps and heat exchangers that service the combined heat load of all the liquid cooled racks with TCS quality cooling liquid. It is common that filters are incorporated in the CDUs, while the filter size requirements are specified by the components in the cooling loop that are the most sensitive to particles, such as quick disconnects and/or micro-channel cold plate geometry. The filters ensure that potential particles in the cooling fluid do not get stuck in the fluid loop and block the flow of the cooling liquid. This should be evaluated on a per system basis.

1.9 Rack Manifold

The rack manifold distributes cooling liquid inside the rack from the CDU to the IT equipment and back again. The manifold must be able to deliver the flow rate required to cool the IT equipment, at targeted pressure drop, and provide a uniform flow distribution within the rack. This requires careful design considerations.

1.10 TCS Pipeworks

<Manifold and piping between CDU and Rack Manifold>

1.11 Quick Disconnect Couplings

Quick disconnect (QD) couplings are used to quickly disconnect the IT equipment or its components from the liquid cooling loop for serviceability. A liquid cooled installation should use drip-less couplings, where liquid flow is shut off at both ends when being disconnected. This limits the potential issue of unwanted liquid inside or outside the IT equipment.

There are two options of QDs between the rack manifold and the IT equipment, either hand mate or blind mate connectors. Hand mate couplings are manually connected, while blind mate connects through a sliding or snapping action.

1.12 Certification Markings

Each liquid cooled technology needs to comply with all relevant regulations, standards, and certifications, which are valid for the geographic location where the liquid cooled system is used. Different regions have different requirements.

- Nationally Recognized Test Laboratory (NRTL, e.g. UL) and FCC markings in the US
- CE Mark and Declaration of Conformity certification in Europe. Depending on the cooling technology and size of system, a type of certificate from Notified Body may also be applicable (e.g. EU Pressure Equipment Directive, category II or higher)
- Countries might have their own additional requirements that need to be adhered to

Examples of certification marks for different regions can be found here: https://en.wikipedia.org/wiki/Certification_mark.

1.13 Pressure Safety Requirements

The liquid cooled installation and its parts need to comply with local codes. Some of the standards to be aware of are the safety standards from the International Electrotechnical Commission (IEC) for IT equipment is IEC 62368-1 [Ref] and for Electrical Appliances with Refrigeration is IEC 60335-2-40 [Ref].

- The IEC 62368-1 “Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements” 3rd edition (2018) is the new safety standard.
- The IEC 60335-2-40 "The Household and similar electrical appliances – Safety –Part 2-40: Particular requirements for electrical heat pumps, air-conditioners and dehumidifiers" 6th Edition (2018) includes requirements for A2L refrigerants.

It should be noted that different standards (e.g. facility vs. equipment) may have different design and test pressure requirements which must be taken into consideration when selecting components and system ingredients. Typical operating pressure for the TCS loop is usually in the range of 140 - 450 kPa (i.e. 20 – 65 psi) when using in-rack and row level CDUs, while the facility CDU might provide a higher operating pressure. The ASME B31.n series contains requirements for interconnecting piping used in buildings and facilities, where B31.3 “Process Piping” (2018) [12] requires a leak test at the 1.5x design pressure. While the IEC 62368-1 standard contains requirements for IT equipment in-rack and servers which requires leak tests at 3x under normal operating pressure and 2x under abnormal and single fault conditions. The liquid cooling loop and its ingredients must be tested to the highest pressure of the applicable safety standards.

1.14 Risk Management

It is required to follow local regulations and to have a detailed risk assessment and processes in place before installing liquid cooling in Data Centers. It is recommended for the risk assessment to include a leakage mitigation plan, including designs for reduced leakage risk, leakage detection, leakage intervention, spill/leak management and containment strategy, and strategy for pump failures. A few examples of this are:

- Determine service and maintenance requirements of the cooling liquid and hardware before deployment of liquid cooled racks
- Use of overpressure relief valves and containment vessel for overflow
- Coolant decomposition risk (e.g. due to excessive heat) and mitigation strategy
- Coolant/Refrigerant flammability risk (e.g. determination of explosive atmosphere/hazardous location)
- Decommissioning at end of Life assessment (e.g. determination of decontamination process)
- Determine redundancy requirements of cooling solution
- Cooling fluid material safety data sheet (MSDS) and Technical Data Sheet (TDS) availability for anyone working in the data center
- Sufficient spill management and absorption materials must be present to manage a catastrophic spill
- Appropriate disposal procedures in place for spill/leak management and/or replacement of cooling liquid
- Liquid containment strategy, which complies with local regulations
- Two-phase and other highly evaporative liquid implementations should prevent any gas leakage into the atmosphere
- Full health and safety documentation must be present
- Full action plan for liquid cooling loop and IT equipment if leakage detected
- Comparison Metrics

The following classifications and metrics can be used to compare different liquid cooling installations with each other.

Table 12, Comparison Metrics.

Classification	Metrics
IT equipment width	19" or 21"
Rack width	# inches or mm (24"/600 mm) or custom
Rack height	# U
Rack depth	# m (1.1 and 1.2 m) or custom
Rack service area - Back	# m x # m

Rack service area - Front	# m x # m
Wall Power/rack	# kW/rack
IT equipment chassis height (i.e. server, blade)	U (1U, 2U, any U, custom)
Fully loaded rack weight (i.e. rack with IT equipment and cooling liquid)	# kg
Manifold location	Front, Back
Manifold connector type	Manual connect, Blind mate
Cooling liquid	Water with additives, Glycol based, Dielectric, Refrigerants
Rack cooling classification	With or without door heat exchanger
IT equipment cooling classification	Basic hybrid, intermediate hybrid, advanced hybrid, full liquid
Cooling type	Single-phase, Two-phase
Maximum TCS cooling liquid supply temperature to racks	#°C Can be based on the facility cooling liquid max temperature according to ASHRAE's definitions (W1: 17 °C, W2: 27 °C, W3: 32 °C, W4: 45 °C, W5 > 45 °C) + temperature rise over the CDU
Maximum TCS cooling liquid return temperature from racks	#°C
Coolant Distribution Unit (CDU)	In-rack, Row, Facility (and dimensions of the CDU)
Number of Racks/CDUs	#
Maximum CDU approach temperature	#°C Definition as used in ASHRAE (TCS supply temp – facility liquid supply temp)
CDU Power	# W

Total cooling subsystem (fan/pump) power/rack	# W
Total power subsystem losses/rack	# W
Total power into the compute components*	# W (including CPUs, GPUs, Memory, Storage, Networking)
Maximum allowable pressure on TCS side	# Pa
Maximum allowable pressure on facility side	# Pa
Maximum pressure drop on TCS side	# Pa
Maximum pressure drop on facility cooling liquid side	# Pa
Maximum CDU TCS flow rate	# l/s
Maximum CDU facility cooling liquid flow rate	# l/s
Maximum operating temperature on FWS side	# °C
Leak Detection	Indirect/Direct
Leak Mitigation	Manual/Automatic

*<https://docs.google.com/viewer?a=v&pid=sites&srcid=bGJsLmdvdnxiZWWhwY3dnfGd4OjM4ZmNhZjk4YjNIZjUwYTk>

Appendix: References

[1] www.coolitsystems.com “Technology” CoolIT Systems <http://www.coolitsystems.com> (accessed July 7, 2022).

END OF DOCUMENT

Quality and safety requirements

1.15 Certification markings

SR 3.1-1 Each technology shall comply with all certification regulations which are compulsory to the geographic location where it is implemented.

SR 3.1-2 Any such equipment shall be listed and or marked in accordance with such compulsory regulations.

These requirements may be different for each territory. E.g.:

- United States UL or other NRTL and FCC markings (depending on the systems used);
- European Union requires CE certification;
- Local countries will require additional certifications and/or requirements which must be complied with.

For an overview of certification marks for any region, please refer to https://en.wikipedia.org/wiki/Certification_mark.

1.16 Safety requirements for any technology

1.17 Liquid management

Based on the liquid type, a full risk assessment shall be in place before implementation within a data center environment.

Liquid containment measures shall be implemented to meet industry standards. This involves leak prevention, leak containment and spill management measures, materials and procedures.

TCS Fluids

Feature classifications

1.18 Minimum management requirements

SR 5.1-1 Each immersion system shall have at least the minimum prescribed management features.

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-
-

Where subsystems are present in the overall system then provision for the monitoring of each shall be provided accordingly.

1.19 Thermal optimized systems

Some technologies apply control features for integration with data center facilities. For immersion fluids the control scheme is typically based on setpoints for flow rates, temperatures and pressures, with tolerances and control parameters (e.g., Proportional /Integral /Differential) according to the dynamics of the system. These systems may be classified as Thermal Optimized Systems. Examples of this are to set and maintain temperature ‘delta’ to form thermal cascades of systems to enable heat reuse or minimize flowrate according to heat load to improve cooling efficiency and alternatively set pressure ‘delta’ to balance the flow across a network of systems.

OR 5.2-1 Technologies which are advertised as “Thermal optimized”, shall contain at least the prescribed integrated features and capabilities.

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1.20 High Safety requirements

Some technologies include a high level of safety for the electronics, facility, or end user. These systems may be classified as High Safety Systems. The safety mechanisms include multiple failure detections and automatic safety mechanisms to protect the safety and integrity of the electronics inside, as well as the facility and operator from any likely failure scenario.

OR 5.3-1 Technologies which are advertised as “High Safety”, shall contain at least the prescribed integrated features and capabilities.

-
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1.21 High Availability requirements

Some technologies have addressed any single point of failure in the solution. These systems may be classified as High Availability Systems. The availability features include full 2N power and cooling to ensure the highest availability.

OR 5.4-1 Technologies which are advertised as “High Availability”, shall contain at least the prescribed integrated features and capabilities.

-
-
-

High Availability systems must have explicit provision for redundancy for power and heat removal to be classified as such.

General standards

To allow comparison between different technologies, several metrics and classifications are defined, which can be adopted by each technology.

None of the comparison standards are meant to apply quality, maturity or suitability figures. They are merely given as tools to allow proper evaluation by end-users and buyers.

1.22 Measurement units

Due to varying shapes, sizes and fundamental different properties regarding surface area and special planning, immersion systems cannot be compared to traditional racks. From a technology point of view, a single tank can be considered a rack, but with a non-comparable footprint. To make the technologies comparable, all used metrics are based on the International System of Units (SI). Wherever required or commonly accepted, a metric prefix shall be applied to ensure workable number formats. (i.e., kg, kN, mm, GJ, etc.)

SR 6.1-1 The listed SI units shall be used for all technology definitions.

- Distance: meters (m)
- Surface area: square meters (m²)
- Volume: Cubic meters (m³) or liters (l)
- Power: Watt (W)
- Temperatures: Degrees Celsius (°C)
- Temperature Delta: Degrees Celsius or Kelvin (°C or K)
- Pressure: Pascal (P)
- Pressure drop: Kilopascal (kPa)
- Flow Rate: Volume indication per time index (hour, minute or second) m³/h, l/min, l/s
- Weight: Grams (g or kg)
- Static load (construction): Newtons per square meter (kN/m²)
- Thermal energy: Joules (J)

1.23 Comparison metrics

SR 6.2-1 The metrics listed in the comparison metrics table shall be used for positioning any immersion solution.

SR 6.2-2 Any metric which is marked with * shall be included in public technical data sheets.

Specification	Format

1.24 Required available documentation

SR 6.3-1 For any immersion technology, the listed documentation shall be available for data center facilities, end users and operators.

- Certification compliance documentation;
- Liquid (spill) management procedures (may be part of MSDS);
- Fire management documentation (may be part of MSDS);
- User manual;
- Service manual, incl. electrical schematics (if any).

Datacenter interface requirements

Interfaces can be defined for both electrical power and water services. This document focuses on the water services internal to the rack for the liquid loop. Alternative fluid services are currently out of scope, such as refrigerants and dielectric liquid.

Each technology may be required to interface with a common Facility Water System (FWS). This interface needs to conform to OCP standards. The following specifications for FWS are implemented and required for each applied technology.

1.25 Input/output differentiation

Connectors shall be mechanically secure and have secure fastening with adequate thread engagement (6 minimum, ACS ref for connector locking). Quick Disconnects are not recommended for FWS systems, due to the high operating force associated with the high operating pressure.

SR 7.1-1 Each immersion system's FWS interface shall have clearly marked flow direction using color, with blue as inlet and red as outlet, to prevent inadvertent crossing of the flow direction.

1.26 FWS compatibility

CR 7.2-1 The materials compatibility of components in the FWS, including any connectors in contact with either the fluids or conduits, shall be compliant to the industry standards¹.

SR 7.2-1 All solutions shall be able to deal with FWS with partial vacuums down to 50 kPa (absolute) and pressures up-to 1000 kPa (gauge).

SR 7.2-2 Both plain water and glycol mixtures up-to 50% shall be supported.

For fluid compatibility purposes, examples of component materials in both primary & secondary circuits are listed in the following paragraphs. The intention is to minimize the number of different materials within the wetted materials circuit. The use of regular testing of the liquid within the FWS and secondary circuit will ensure any changes in chemical composition are detected early for corrective action to be taken.

¹ Liquid Cooling Guidelines for Datacom Equipment Centers, Second Edition (ASHRAE 2014)
TC9.9 Water-Cooled Servers Common Designs, Components, and Processes (ASHRAE 2019)

Couplings are identified as critical to prevent leaks. The critical features that impact fluid compatibility in couplings are the seals, or O-rings. Seals are typically a configurable feature within couplings to allow the correct seal for the correct fluid. Many suppliers will have charts available for chemical compatibility. These charts are derived from the polymer providers for chemical compatibility so for general material options, the charts should be consistent among suppliers. However, for specific material compounds, this is more likely to vary based on supplier due to sourcing the same compound from multiple sources. One supplier may have worked with a polymer supplier to provide a specific compound for an application, whereas another supplier would not have been involved to incorporate that compound in their portfolio. See the following paragraphs for a typical compatibility chart. However, please consult the appropriate chart from suppliers for precise recommendations.

The OCP Hose Manual Couplings – Best Practices² and Leak Detection and Intervention³ whitepapers by the ACS Cold Plate community are recommended materials for further reading.

The FWS circuit for cooling IT equipment typically uses a mixture of propylene glycol and deionized water. Other coolant mixtures are also possible and can be chosen to maximize heat transfer over a specified temperature range or protect against phase change (freezing and evaporating). Additionally, biocides and corrosion inhibitors can be added to the coolant. It is recommended to review the fluid compatibility of all the elements of a fluid mixture with the hose and pipework manufacturer to be sure the inner liner of the hose is compatible with the fluid. In many cases, the coolant mixture will contain proprietary additives for which compatibility may be difficult to predict. The best way to verify compatibility is to conduct a physical test of the tube material with the specific coolant mixture chosen by the facility.

² <https://www.opencompute.org/documents/ocp-manual-couplings-at-hoses-pdf>

³ <https://www.opencompute.org/documents/acs-cold-plate-leak-detection-and-intervention-white-paper-pdf-1>

1.27 Wetted material for primary water and secondary with propylene Glycol

This following table is assembled from multiple sources including ASHRAE and interviews with engineers from manufacturers and consulting engineers focusing on liquid cooling infrastructure for the data center.

In two-phase Immersion Cooling (2PIC), the below materials compatibility corresponds only with components exterior of the 2PIC tank. Internal components should adhere to the specific two-phase fluid manufacturer⁴.

Primary Circuit Materials	Secondary Circuit Materials
316 Stainless Steel, EPDM seals	316 Stainless steel, EPDM seals
304 Stainless Steel	304 Stainless steel
	Polyoxymethylene (body & valve)
Brass DZR (body), Stainless steel (Inserts for wetted component), PTFE seats & EPDM (O-ring seals)	Ethylene propylene diene monomer rubber (EPDM) (O-ring seals), Stainless steel (e.g., springs)
Nickel plated brass, EPDM (O-ring seal)	Ethylene propylene diene monomer rubber (EPDM) (diaphragm), polyamide body
Polycaprolactam	304 Stainless steel, copper brazed
EPDM (O-ring seal)	Brass (body), Stainless Steel (valve insert)
	Copper
	Fluorinated ethylene polypropylene (FEP)
	Acrylonitrile butadiene rubber (NBR)
	Fluoroelastomer (FKM)
	Polytetrafluoroethylene (PTFE)
	Teflon (PTFE) based thread sealant

1.28 FWS Water quality

The ASHRAE guidelines define requirements for FWS water quality, reproduced in the table below.

Parameter	Unit	Value
-----------	------	-------

⁴ https://www.3mcanada.ca/3M/en_CA/p/c/advanced-materials/b/novec/

pH	-	7-9
Corrosion inhibitors	-	required
Biocide	-	optional
Sulfide	ppm	<10
Sulfate	ppm	<100
Chloride	ppm	<50
Bacteria	CFUs/mL	<1000
Total hardness (as CaCO ₃)	ppm	<200
Residue after evaporation	ppm	<500
Turbidity	NTU (nephelometric)	<20

In addition, it is recommended that a side stream water filter (strainer) be applied to remove particles above 500 microns and use the loop to dose additives, monitor and maintain quality. Any exception may cause damage, degrade performance or reduce stability

All solutions must be able to deal with any FWS with partial vacuums and pressures up to in multiples of atmospheres, where limits are to be set so that boiling and rupture are prevented. Pipe diameters are to be sized according to flow speed restriction in order to reduce risk of water hammer (also see ASHRAE guidelines⁵).

Filtration and water quality guidelines are referenced to the ASHRAE guidelines for facilities and not required as part of the immersion solution. Any higher filtration requirements should be integrated in the solution or addressed with a closed secondary circuit system.

1.29 Galvanic interface properties

If a solution contains a metal interface which connects to another metal interface at the FWS, the solution interface should be specified with an electrochemical potential difference of no more than 0.15V as compared to the FWS interface. If this difference is higher, a strategy towards preventing galvanic corrosion must be applied. If multiple metallic materials are applied in direct contact with a metallic coolant circuit and one or more materials are outside the galvanic compatibility bandwidth then sacrificial anodes are recommended.⁶

1.30 DCIM interfaces and Redfish definitions

Redfish is a standard designed to deliver simple and secure management for converged, hybrid IT and the Software Defined Data Center (SDDC). An open industry standard specification and schema, Redfish specifies a RESTful interface and utilizes defined JSON payloads - usable by existing client applications and browser-based GUI.

⁵<https://www.ashrae.org/technical-resources/bookstore/datacom-series>

⁶http://www.atlassteels.com.au/documents/TN7-Galvanic_Corrosion_rev_Aug_2010.pdf

The information in this chapter represents a snapshot of work in progress within the DMTF. This information is subject to change without notice. The standard specifications remain the normative reference for all information.⁷

SR 7.6-1 Immersion systems shall include a Redfish compliant management system which can be used to monitor the performance and/or condition of the technology.

SR 7.6-2 For legacy purposes, the controller shall output data via Modbus, SNMP or BACNet.

SR 7.6-3 The physical layer for the management interface shall be ethernet (802.3) with the transport layer being TCP/IP or UDP.

Vendors will need to consider potential regional regulations for IoT devices with respect to their certification compliance as described in SR 3.1-1. (I.e., “California SB-327 Information privacy: connected devices”⁸)

SR 7.6-4 The system shall comply with Redfish Schema for reporting and data collection.

Optionally linked ICT related equipment may be placed in their respective domains and linked via the link fields.

SR 7.6-5 Immersion units shall be placed in the Redfish Cooling domain as that is the highest correlation for these devices.

SR 7.6-6 Each immersion system shall include at least the minimum data items.

The following is an overview of the required minimum management features:

- Thermal monitoring and reporting of dielectric liquid at least at 2 locations:
 - Input (or bottom of open bath)
 - Output (or top of open bath).
- Warning system in case of overheating with at least 2 warning levels (warning, critical);
- TCS pump operational status (if any).

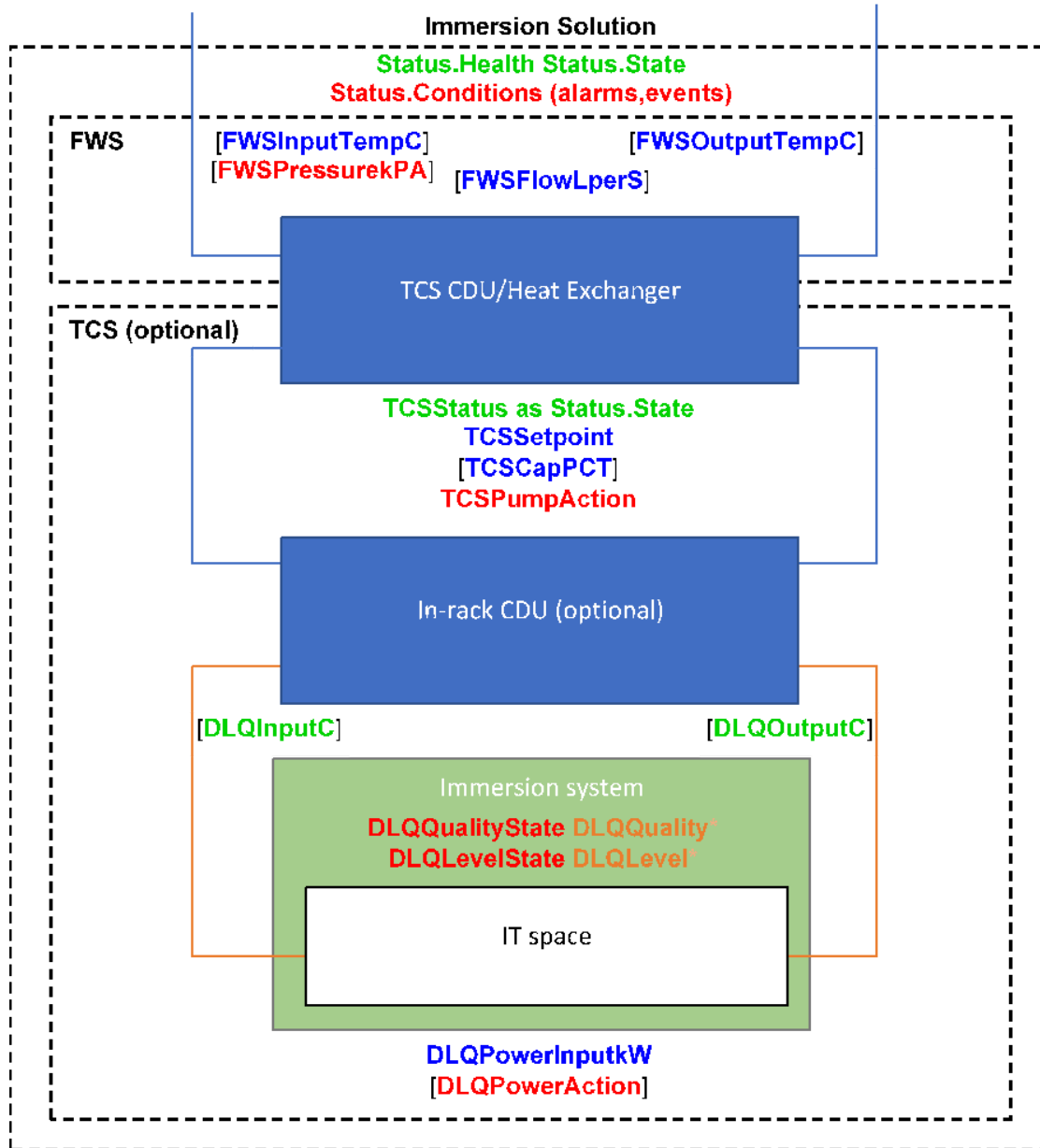
⁷ www.dmtf.org

⁸ https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB327

Below is a schematic of the immersion solution with the FWS and TCS domains marked, and the data variables named.

Legend:

- **Green:** Minimum requirement
- **Blue:** Thermal Optimized requirement
- **Red:** High Safety requirement
- **Orange:** suggested but not (yet) required items



The data variable names start with the domain and end with the units for the data variable as follows:

- C for degrees Centigrade;
- LperS is liters per second;
- kPa is absolute pressure in kilo pascals;
- kW for kilowatt etc.;

- Status is enumeration; Enabled, Disabled, etc. from Redfish Resource Health.state.;
- Overall health is enumeration; Critical, Warning or OK;
- Cap is capacity, 0-100%.

Sensor, status, link, actions and other items are setup the same as the default redfish implementation.

- OUTPUTS -- pressure, temp, flow, power;
- STATUS -- state, conditions and overall health (Critical, Warning, OK);
- ALARMS -- visual (light with 'flash/color change') leak, out-of-spec, on the chassis or tanks;
- CONFIGURATION/CONTROLS -- safety settings, escalations, control criteria: return temp, flow, delta-T.

SR 7.6-7 The alarms shall be based on a configurable escalation scale.

The escalation scales should allow operatives sufficient notification time to respond in good time to remedy field issues, without compromising safety.

SR 7.6-8 No single factor (sensor) shall be used to activate a shutdown to prevent false negative scenarios impacting production uptime.

Control criteria should be based on providing stable operating conditions to provide a high level of system integrity and reliability. This may be selected according to end-user needs, and would for example include setpoints for:

- Flowrate;
- Return temperature;
- temperature change (outlet to inlet on water);
- Local ambient (dielectric).

The control system parameters (e.g., tolerance and PID) are defined in the firmware of the local hardware (e.g. PLC controller).

Below is an annotated example for an immersion system which is defined at CDU or integrated tank level. Shown items are the generalized items which each immersion technology should follow. Additional sensors can be added as the arrays shown below allow.

Legend:

- ¹ **Green**: Minimum requirement
- ² **Blue**: Thermal Optimized requirement
- ³ **Red**: High Safety requirement
- ⁴ **Orange**: suggested but not yet required items (optional)

Redfish Version: 2021 Release 4

Linked From: *CoolingUnitCollection*

Schema Name: CoolingUnit (sub-typed as EquipmentType = 'ImmersionUnit')

Schema Id: <http://redfish.dmtf.org/schemas/v1/CoolingUnit.json>

Mockup Name: public-immersion-cooling or wipcdcu

Immersion Solution Sample Data

```

"Name"           : "ABC123",
"Manufacturer"   : "ABC123",
"Model"          : "ABC123",
"SerialNumber"   : "1234567",
"FirmwareVersion": "3.4.5",
"Version"        : "1.5",
"ProductionDate" : "03012019",
"Location"       : {<...>}, --Descriptor of physical location of the Immersion Unit
"Links"          : {<...>}, -- Links to other items within the Redfish Network

```

"Status":

"Conditions" : [

An Array of all alarm statuses of the Immersion Unit as well as any other adverse conditions

"Condition" : The specific condition (alarm) with Message, MessageId and Severity.

]

"Health" : "Warning",

-- Thermal system status, shows total thermal status of the ImmersionUnit.

-- Must include options: "OK", "Warning" and "Critical".

"State" : "Enabled" -- the overall operating state/mode of the unit.

"Controls" : ["<temp sensor w SetPoint URI">" OR "Control URI"],

-- Array of controls including power actions, setpoints, etc

--Array of setpoints for the ImmersionUnit, can be setpoints for entire unit

--FWS, TCS or Dielectric liquid (as control excerpts). See below.

"Sensors" : "<sensors collection URI>",

Comprises a collection of sensors represented on the immersion unit as directly attached or abstracted (relative to system operation, but not necessarily physically attached to immersion unit). Any below references to "<Sensor URI>" can be included here as a sensor.

Facility Water System

Linked from: *PrimaryLoopConnections* collection or *SecondaryLoopConnections* on *CoolingUnit*.

Maybe direct from Immersion Cooling unit instance or indirect CDU or other intermediary.

Schema Name: *LoopConnection* (sub-typed as LoopConnectionType = 'Primary' || 'Secondary' || 'Closed')

Schema Id: <http://redfish.dmtf.org/schemas/v1/LoopConnection.json>

Topology: Either a) Linked from a full model LoopConnection instance OR as a sensor in the CoolingUnit.Sensors collection or CoolingUnit.ThermalMetrics singleton.

- ² **"FWSInputTempC"** : ["<sensor URI>"],
 - Array of temperature sensors for the FWS coolant loop(s).
 - Required at all inputs for Thermal Optimized systems
 - Source = LoopConnection.SupplyTemperatureCelsius
- ² **"FWSOutputTempC"** : ["<sensor URI>"],
 - Array of temperature sensors for the FWS coolant loop(s).
 - Required at all outputs for Thermal Optimized systems
 - Source = LoopConnection.ReturnTemperatureCelsuis
- ² **"FWSFlowLperS"** : ["<sensor URI>"],
 - Array of flow sensors in the FWS coolant loop(s) in litres per second.
 - Required at all interfaces for Thermal Optimized systems
 - Source = LoopConnection.FlowLSeconds
- ³ **"FWSPressurekPA"** : ["<sensor URI>"],
 - Array of pressure sensors in kilopascals.
 - Required at all FWS interfaces for High Safety systems
 - Source = LoopConnection.ReturnPressurePA or LoopConnection.SupplyPressurePA

Technology Coolant System (Optional)

Linked from: PrimaryLoopConnections collection or SecondaryLoopConnections on CoolingUnit. Maybe direct from Immersion Cooling unit instance or indirect CDU or other intermediary.

Schema Name: LoopConnection (sub-typed as LoopConnectionType = 'Primary' || 'Secondary' || 'Closed')

Schema Id: <http://redfish.dmtf.org/schemas/v1/LoopConnection.json>

- ¹ **"TCSStatus"** : ["<sensor URI>"],
 - Status of TCS, must show running status between Disabled and Enabled. Excerpt of "Resource/Status/Status" for the Loop connection or Cooling Unit (TCS) or un-tethered.
- ² **"TCSSetpoint"** : ["<Control URI>"],
 - Setpoint of the TCS
- ⁴ **"TCSSupplyTempC"** : ["<sensor URI>"],
 - TCS input temperature sensors
 - Source = LoopConnection.SupplyTemperatureCelsius
- ⁴ **"TCSReturnTempC"** : ["<sensor URI>"],
 - TCS output temperature sensors
 - Source = LoopConnection.ReturnTemperatureCelsuis
- ² **"TCSCapPCT"** : ["<sensor URI>"],
 - TCS load (i.e. pump capacity) in percentage
 - Sensor uses the "Percent" unit to represent pump load.
- ³ **"TCS PumpAction"** : ["<Control URI>"],
 - Actions to change TCS pump mode (auto, run, manual etc.)
 - Only reachable under high security level
 - Represented as a Control object and maybe referenced in main unit Controls collection.

Dielectric Liquid

```

1 "DLQInputC" : ["<sensor URI>"],
    -- Temperature of the immersion liquid at the output (top) location in the dielectric liquid,
    -- array for all sensors
    -- Presented in the ThermalMetrics object of the Immersion cooling unit
1 "DLQOutputC" : ["<sensor URI>"],
    -- Temperature of the immersion liquid at input (bottom) location in the dielectric liquid
    -- array for all sensors
    -- Presented in the ThermalMetrics object of the Immersion cooling unit
3 "DLQQualityState" : CoolingLoop.FluidQualityState,
    -- Shows quality of dielectric liquid, E.g Normal or Abnormal.
3 "DLQQuality" : ["<sensor URI>"],
    -- Shows quality of dielectric liquid as a percent. Optionally represents as a scale 0-100
    regardless of physical sensor implementation.
3 "DLQLevelState" : CoolingLoop.FluidLevel,
    -- Shows level of DLQ, options: "Low – Critical", "Low - Warning", "Low", "Normal", "High", "High
    - Warning", "High – Critical
3 "DLQLevel" : ["<sensor URI>"],
    -- Shows level of DLQ as a value from a fluid level sensor in percentage.
    -- Optional sensor that expresses fluid level state as a percentage regardless of physical
    sensor implementation.
2 "DLQPowerInput" : ["<sensor URI>"],
    -- Total electrical input into the dielectric liquid in Watts. Aka the input power to the equipment
    contained in the liquid. E.g. PDUs or power distribution shelves, etc.
3 "DLQPowerAction" : ["<Control URI>"],
    -- Actions to change power delivery to dielectric liquid equipment.
    --Only reachable under high security level
    Cuts all power to equipment in the dielectric fluid

```

Sensor, status, link, actions and other items are setup the same as the default redfish implementation.

Further redfish references:

Redfish Minimum Version: 2022 Release 1

Linked From: *CoolingUnitCollection*

Schema Name: CoolingUnit (sub-typed as EquipmentType = 'ImmersionUnit')

Schema Id: <http://redfish.dmtf.org/schemas/v1/CoolingUnit.json>

Mockup Name: public-immersion-cooling or "wipcdcu"

Immersion related uptime factors

1.31 Ride through

A large contributor to the overall resiliency of an immersion strategy in a facility is driven by the “ride through” capabilities. “Ride through” describes the effect in which cooling is not applied, but the thermal energy is buffered in available liquids.

The advantages of a ride through design directly relate to the resiliency measures which need to be implemented in line with common facility standards related to availability. An n+x or 2n strategy can be facilitated with a ride through design instead of physical equipment. If MTTR data is known, ride through can be designed such that MTTR windows can be facilitated by specific immersion solutions. Instead of racing to switch off IT equipment, a window can be created to repair a failed circuit or to bypass part of the circuit.

Dielectric ride through {deleted for CP template}

Partial dielectric ride through {deleted for CP template}

FWS ride through refers to the buffer capabilities of the Facility Water System or FWS. A cooling failure which does not affect circulation pumps, may still provide sufficient cooling capabilities to the system, thus significantly extending the dielectric ride through. The ride through is determined by the water volume which is present in the water circuit. Additional features like mixing and buffer tanks increase the ride through effect. The effectiveness of facility water ride through is dependent on the entire facility and other consumers of this ride through.

The FWS ride through is not part of the Immersion requirements document.

1.32

1.33 Cooling infrastructure

1.34 Oxidation and moisture

1.35 IT compatibility

Requirements catalogue

1.36 Specification Requirements

SR 1.1-1 All Specification Requirements shall be met by the solution vendor.

SR 3.1-1 Each technology shall comply with all certification regulations which are compulsory to the geographic location where it is implemented.

SR 3.1-2 Any such equipment shall be listed and or marked in accordance with such compulsory regulations.

SR 5.1-1 Each immersion system shall have at least the minimum prescribed management features.

SR 6.1-1 The listed SI units shall be used for all technology definitions.

SR 6.2-1 The metrics listed in the comparison metrics table shall be used for positioning any immersion solution.

*SR 6.2-2 Any metric which is marked with * shall be included in public technical data sheets.*

SR 6.3-1 For any immersion technology, the listed documentation shall be available for data center facilities, end users and operators.

SR 7.1-1 Each immersion system's FWS interface shall have clearly marked flow direction using color, with blue as inlet and red as outlet, to prevent inadvertent crossing of the flow direction.

SR 7.2-1 All solutions shall be able to deal with FWS with partial vacuums down to 50 kPa (absolute) and pressures up-to 1000 kPa (gauge).

SR 7.2-2 Both plain water and glycol mixtures up-to 50% shall be supported.

SR 7.6-1 Immersion systems shall include a Redfish compliant management system which can be used to monitor the performance and/or condition of the technology.

SR 7.6-2 For legacy purposes, the controller shall output data via Modbus, SNMP or BACNet.

SR 7.6-3 The physical layer for the management interface shall be ethernet (802.3) with the transport layer being TCP/IP or UDP.

SR 7.6-4 The system shall comply with Redfish Schema for reporting and data collection.

SR 7.6-5 Immersion units shall be placed in the Redfish Cooling domain as that is the highest correlation for these devices.

SR 7.6-6 Each immersion system shall include at least the minimum data items.

SR 7.6-7 The alarms shall be based on a configurable escalation scale.

SR 7.6-8 No single factor (sensor) shall be used to activate a shutdown to prevent false negative scenarios impacting production uptime.

1.37 Optional Requirements

OR 1.1-1 Optional Requirements may be met to enable recognition of special functionality of features.

OR 5.2-1 Technologies which are advertised as "Thermal optimized", shall contain at least the prescribed integrated features and capabilities.

OR 5.3-1 Technologies which are advertised as "High Safety", shall contain at least the prescribed integrated features and capabilities.

OR 5.4-1 Technologies which are advertised as "High Availability", shall contain at least the prescribed integrated features and capabilities.

1.38 Customer Requirements

CR 1.1-1 *Customer Requirements shall be met by owners, operators, or end users of the solution. Sufficient effort shall be made and demonstrated by the solution vendor to accommodate compliancy.*

CR 7.2-1 *The materials compatibility of components in the FWS, including any connectors in contact with either the fluids or conduits, shall be compliant to the industry standards.*

Appendix: Glossary

This glossary provides definitions within the context of immersion technology within data centers.

Aerosol	A suspension of fine solid particles or liquid droplets in air or another gas.
ACPH (or ACH)	Air changes per hour, or air change rate is a measure of the air volume added to or removed from a space divided by the volume of the space.
Auto ignition point	The lowest temperature at which a substance spontaneously ignites in normal atmosphere without an external source of ignition. Also referred to as autoignition temperature or kindling point.
Containment strategy	A set of measures to prevent any spillage of liquid into the (work) environment.
CR	Customer Requirement, the requirement which a customer or end user of the technology needs to comply with. Sufficient materials shall be included by the vendor to point out any Customer Requirement.
Dielectric constant	Also called the relative permittivity indicates how easily a material can become polarized by imposition of an electric field on an insulator. Relative permittivity is the ratio of "the permittivity of a substance to the permittivity of space or vacuum".
Dielectric liquid	A liquid which functions as an insulating substance to allow the immersion of electronics with the purpose of heat transfer.
Dielectric strength	The maximum electric field that the material can withstand under ideal conditions without breaking down.
Dripless connectors	A type of pluggable liquid connector which eliminates drips and is able to withstand long term use.
Dynamic viscosity	The ease in which a substance flows in Pascal-second (Pa.s). It is also referred to as poise or centipoise (cP).
Electrochemical potential	A thermodynamic measure of chemical potential that does not omit the energy contribution of electrostatics.
Enclosed chassis	Solution type with which dielectric liquid is circulated through a sealed server chassis.
Esters	Organic compounds containing carbon, hydrogen, and oxygen that are extracted and purified from plant oil seeds (natural) or synthesized from a hydroxyl compound and one or more carboxylic acids (synthetic).
Evaporation temperatures	Temperature at which vaporization occurs on the surface of a liquid as it changes into gas.

Fire point	The lowest temperature at which the vapor of that fuel will continue to burn for at least 5 seconds after ignition by an open flame.
Flash point	The lowest temperature at which vapors of the material will ignite, when given an ignition source.
Fluorochemicals	Class of dielectric fluids characterized by the predominance of Fluorine in their molecular structure.
FWS	Facility Water System, a liquid circuit which allows the transport of heat throughout a facility.
Galvanic corrosion	An electrochemical process in which one metal corrodes preferentially when it is in electrical contact with another, in the presence of an electrolyte.
GWP	Global Warming Potential, a measure of how much heat a greenhouse gas traps in the atmosphere up to a specific time horizon, relative to carbon dioxide.
Hydrocarbons	Organic compounds consisting of predominantly hydrogen and carbon. These can also be described as polymers, oils or organic compounds.
(M)SDS	Material Safety Data Sheet is a document that lists information relating to occupational safety and health for the use of chemicals.
Open bath	Solution type with which dielectric liquid is shared across multiple electronic systems in a horizontal bath style container and an open liquid-air interface.
OR	Optional Requirement, requirements which are not required for qualification, but allow qualification for optional classifications and which can be used for product positioning.
Partial vacuums	A FWS which runs below environment pressure (partial vacuum) to prevent water leaking outward when a leak occurs.
Pour point	The temperature below which the liquid loses its flow characteristics.
Redfish	Data center Infrastructure Management (DCIM) application which is used within OCP environments.
Single-phase	Liquid application in which the state of matter is not intended to change.
Specific heat	The amount of thermal energy (Joules) which is required to be added to 1 kg of a substance to achieve a 1°K temperature increase.
SR	Specification Requirement, requirements which must be met to qualify for Open Compute product listing.
STOT	Specific Target Organ Toxicity, indicates which bodily organs are most likely to be affected by exposure to a substance.
TCS	Technology Cooling System, a closed liquid circuit which allows the transfer of heat from an immersion system to the FWS.

TDS	Technical Data Sheet is a document that lists all required technical information for chemicals.
Thermal conductivity	A measure of the ability of a substance to conduct heat.
Thermal loss	Amount of energy which is not contained by a cooling solution.
Two-phase	Liquid application in which the state of matter is designed to change from liquid to gas and back.
Vapor	A substance in the gas phase at a temperature lower than its critical temperature, which means that the vapor can be easily condensed to a liquid by increasing pressure on it or by reducing the temperature.
Volumetric expansion	A coefficient of thermal expansion. The rate of expansion of a material with a 1°K temperature increase.

Appendix: References

- OCP Immersion Workgroup: on-going projects information (see wiki for details)
https://www.opencompute.org/wiki/Rack_%26_Power/Advanced_Cooling_Solutions_Immersion_Cooling
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<https://www.opencompute.org/documents/design-guidelines-for-immersion-cooled-it-equipment-revision-1-01-pdf>
- OCP ACS-Immersion, Asperitas Open Cassette
<https://www.opencompute.org/documents/20200227-open-cassettes-specification-v1-0-pub-pdf>
- OCP ACS-Cold Plate, Cold Plate Requirements. 2019. Rev 1.0.
<https://www.opencompute.org/documents/ocp-acs-liquid-cooling-cold-plate-requirements-pdf>
- OCP ACS-Cold Plate, Hose and Manual Couplings – Best Practices
<https://www.opencompute.org/documents/ocp-manual-couplings-at-hoses-pdf>
- OCP ACS-Cold Plate, Leak Detection and Intervention
<https://www.opencompute.org/documents/acs-cold-plate-leak-detection-and-intervention-white-paper-pdf-1>
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http://www.atlassteels.com.au/documents/TN7-Galvanic_Corrosion_rev_Aug_2010.pdf
- Example of certification guidelines compliance
<https://www.cemarkingassociation.co.uk/technical-documentation/>
- Example of spill management documentation:
<https://smah.uow.edu.au/content/groups/public/@web/@ohs/documents/doc/uow136688.pdf>
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