Immersion Requirements Rev 2.0

First amended

Revision 2.10

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Revision History

Revision	Date	Comments
1.00	May 20, 2019	First publication
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In addition, the following contributors deserve recognition for their efforts to improve and complete the first amendment: Sandeep Ahuja (Intel), Jimil Shah, Arad Azizi and Joshua Close (Honeywell), Andrew Howard-Jones (Koura Global) Kevin Wirtz (Cargill), Amy Short (Lubrizol), Mustafa Kadhim (Iceotope) and all other members of the OCP Immersion-Requirements community.

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Changes or content proposals

Please suggest change proposals or content additions in the Immersion Requirements community calls. You can join the Immersion Requirements team by subscribing to the mailing list here:

https://ocp-all.groups.io/g/CE-Immersion-Requirements

All information about the OCP Immersion project, its workstreams, how to participate and meeting schedules can be found here:

https://www.opencompute.org/wiki/Cooling_Environments/Immersion

Table of Contents

Table of amendments

The following table outlines all major updates since the original release of the Immersion Requirements Rev2 document.

Paragraph/Context	**Req**	**Details**
4.1 Required liquid specifications	SR 4.1-1	• Dielectric strength: removed the ability to estimate 1mm value based on 2.5 mm measurement. • Flash point: Changed Flashpoint reference from "CoC" to "Cleveland Closed Cup", ASTM D 93 / ISO 2719. • Updated "Resistivity" to "Volume resistivity". • Require addition of unified specific temperatures for Specific heat, Thermal conductivity, Density, Kinematic viscosity, and vapor pressure. • Addition of footnote for calculation of dynamic viscosity. • Updated heat capacity format from # to #.### and added additional temperatures. • Addition of Boiling point (if below fire point). • Updated "Biodegradability" to format "Readily, Inherently or Persistent". • Addition of Latent heat of vaporization (2-phase only). • Addition of Surface tension (2-phase only). • Addition of Gas phase density (2-phase only).
4.2 Minimum dielectric requirements	SR 4.2-1	• Amended the Dielectric strength to represent kV/mm . • Changed Flashpoint reference from "CoC" to "Cleveland Closed Cup". • Auto ignition point increased from 250°C to 300°C as defined in IEC62368-1.
5.1 Minimum Management requirements	SR 5-1.1 OR 5-1.3	• Moved *"dielectric fluid volume/content/level detection"* and *"Dielectric fluid/water leak detection"* from optional High Safety requirements to minimum requirements.
6.2 Comparison metrics	SR 6.2 1	• Changed paragraph name from "Comparison metrics" to "Solution specification items". • Removed "Liquid Type" with "commodity/proprietary selection • Updated requirement from *"…shall be used for positioning any immersion solution."* to *"…shall be used for specification sheets of any immersion solution.".* • Changed Thermal Loss to air to # W. • Added a required procedure for Thermal Loss to air.
6.2 Thermal Loss to Environment	SR 6.2 3	• New requirement: The described test procedure shall be used for determining "Thermal Loss to Environment".

Paragraph/Context	Req	Details
6.3 Required available documentation	SR 6.3-2	• Addition of Biodegradability documentation. • Additional Specification Requirement for public availability of BIM files in accordance with the anticipated OCP Cooling Environments BIM specification for Advanced Cooling Facilities.
7.6 DCIM interfaces and Redfish definitions	N/A	Updated Redfish references

1. Introduction

This document is a requirements document and not a specification. This document defines common terminology, identifies immersion specific measures with parameters of importance, and contains requirements that future specifications and products need to adhere to. From this document, a checklist has been generated that any OCP specification and product needs to comply with. 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.

The requirements have been formulated in such a way that most known current technologies will be able to comply with this document, while at the same time allowing this "young" industry to keep coming up with innovative new ways of bringing efficiency and allowing access to all of these technologies into the data center space.

The information in this document should be considered a baseline. Updates to the content are foreseen and will be managed and evaluated by the OCP ACS Immersion project.

Related sources:

- Design guidelines for immersion optimized IT equipment
  https://www.opencompute.org/documents/design-guidelines-for-immersion-cooled-it-equipment-revision-1-01-pdf
- Open Cassette
  https://www.opencompute.org/documents/20200227-open-cassettes-specification-v1-0-pub-pdf
- Open Compute ACS Immersion Wiki page
  https://www.opencompute.org/wiki/Rack_%26_Power/Advanced_Cooling_Solutions_Immersion_Cooling

1.1 Requirements:

The requirements are defined throughout this document as follows:

SR 1.1-1 All Specification Requirements shall be met by the immersion 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 Immersion Community project leads.
2. The Project leads 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 leads at the latest 1 week before the scheduled community call.
    b. The presentation shall explain why and how the submitted solution qualifies against this Immersion Requirements document.
3. A 60-minute interactive review will be scheduled by a community committee:
    a. The committee is overseen by one of the immersion project leads.
    b. The committee will consist of the Immersion 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 Immersion Requirements.
4. The community committee is formed as follows:
    a. All authors of the Immersion Requirements document are invited to be panelists;
    b. One of the immersion 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.

2. Technology definitions

Direct Liquid cooling within the data center is the process where heat is extracted by a liquid in thermal conduction with heat producing components without a secondary fluid, air, being used as an intermediate thermal transport medium. Immersion cooling is when a liquid is in direct contact with the IT equipment components. Immersion cooling is not inclusive of systems when fluids are contained within a cold plate. This falls in the category of cold plate technology and more information about this technology can be found in the OCP Cold Plate Requirements document. There is a variety of liquid immersion technologies available to cool the IT equipment in the data center. The common denominator for each immersion system is that a dielectric liquid is in direct contact with the electronic components in need of cooling.

The dielectric liquid is thermally conductive and electrically insulating making it feasible to use in direct contact with electronic components. The dielectric liquid is used to capture and transport the heat to the data center facility heat rejection equipment. There is a range of heat rejection methods. They vary by facility and require interfaces to connect to the facility cooling system. The terminology defined by ASHRAE assists with determining the classification of liquid cooling infrastructure.

- **Technology Cooling System (TCS)** is the cooling system/loop that reaches within the rack or tank to the IT equipment, which includes a Cooling Distribution Unit (CDU), a heat exchanger, or a condenser. The TCS liquid loop may use one of numerous components such as; dielectric fluids, heat exchangers, CDU's, condenser coils (for two-phase dielectric fluid systems) in combination with passive or forced (pumped) circulation methods, valves, interconnects, and control electronics. The CDU, heat exchanger, or condenser is used to transfer the heat between the TCS to the Facility Water System (FWS).
- **Facility Water System (FWS)** is the liquid facility cooling system and contains the heat rejection plant equipment (e.g., cooling towers, pumps, chiller units, dry coolers or district heating and/or cooling grids, etc.).
  Note: Within OCP, the facility water system is not limited to water-based liquids.

The main immersion technology differentiators between liquid technologies are based on single- or two-phase immersion in enclosed chassis or open bath. The main liquid groups used in immersion are synthetic hydrocarbons, esters (natural and synthetic) and fluorochemicals.

2.1 Single- and two-phase

Immersion cooling can be divided into single- and two-phase technologies.

- Single-phase immersion uses a circulation method for the dielectric liquid across the IT equipment and a heat exchanging approach. In the single-phase approach, the liquid is heated and cooled without changing phase, i.e., it stays as a liquid throughout the whole process. The circulation method of the liquid can be done through natural or forced convection.
- Two-phase immersion uses an evaporation process to cool the IT equipment and transfer the heat. The gas is cooled by a heat exchanging approach, which facilitates the phase change from gas to liquid, allowing a return flow into the larger liquid volume. In the two-phase approach, the liquid is heated and changes to gas. When the gas is cooled, it changes phase again to liquid. The movement of the liquid/gas is done through a natural buoyancy-driven flow.

2.2 Enclosed Chassis

Enclosed chassis would have its own dielectric fluid or means to maintain liquid level in each chassis if sharing common dielectric fluid within a vertical column. The enclosed chassis usually is configured for vertical stacking in a rack style configuration. These chassis may be referred to as sleds and are configured to be pulled out and inserted in horizontal plane for service of IT equipment. The fluid in such a chassis may be single-phase (liquid) or two-phase (liquid with some fraction of dielectric fluid as vapor produced in cycle of vaporization and condensation as means to transfer heat). The liquid gas interface (if present) may be with air, inert gas charge or vapor phase of dielectric fluid. The means of sealing chassis being adequate to keep dielectric mass loss to the surrounding environment at negligible levels.

2.3 Open Bath

Open bath systems are tanks which contain a larger body of dielectric liquid where IT equipment is immersed into the bath. In the common bath, multiple electronic solutions share the same liquid. The fluid in such open bath tanks may be single-phase (liquid) or two-phase (liquid with some fraction of dielectric fluid as vapor produced in cycle of vaporization and condensation as means to transfer heat). The liquid gas interface may be with air, inert gas charge or vapor phase of dielectric fluid. The means of sealing open bath tanks being adequate to keep dielectric mass loss to the surrounding environment at negligible levels.

Open bath systems are always opened from the top to service the IT equipment.

2.4 Hybrid

Immersion cooling solutions evolve rapidly and there are numerous solutions in the industry with unique and diverse approaches. These may not fit into the definitions above. However, when a mix between solution approaches is being used. They are hereafter classified as hybrid cooling solutions.

3. Quality and safety requirements

3.1 Certification markings

SR 3.1-1 Each immersion 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.

3.2 Safety requirements for any immersion technology

SR 3.2-1 Suppliers of dielectric fluids and immersion technology equipment shall supply written emergency procedures for each technology addressing remediation steps for uncontrolled release of dielectric fluids and mitigation and control of fire.

SR 3.2-2 Immersion systems shall be safe for use by normally skilled IT personnel in relation to normal server maintenance activities within the immersion system without any specific skill or training on the immersion technology. Instructional safeguards and/or interlocks that identify or prevent unsafe operations shall be assessed to determine adequacy for prevention of unsafe operations of untrained personnel.

SR 3.2-3 Horizontal busbars shall not be load-bearing and the solution shall contain features (i.e., guidance rails or slots) to force correct server placement in line with the Rack and Power Open Rack Specification and Open Rack Design Guide for IT Gear[1].

SR 3.2-4 Metal conductors of busbars shall be protected to prevent objects with a minimum conductive surface of 6 mm length (i.e., screws, tools and other debris) from creating an electrical short hazard to the busbars when dropped into the tank.

SR 3.2-5 Any electrical circuit must be fully certified in line with requirements which apply in the geographical region in which it is implemented.

SR 3.2-6 Any electrical assembly shall be accessible by qualified personnel and documented with full schematics.

SR 3.2-7 System installation shall contain an interface for electrical grounding that complies with all grounding requirements for region and type of installation.

SR 3.2-8 For grounding purposes, the electrostatic generation in dielectric fluids shall be considered and documented in such a way to assure adequate dissipation of static charge.

SR 3.2-9 Spill management measures shall be incorporated within the offer or furnished as factory accessory.

SR 3.2-10 Containment measures shall manage at least 100% of the volume of any single system without breach of containment, such means may include but not be limited to; leak trays, condensers, dual-hull, sealant material but also absorbent materials.

SR 3.2-11 Potential hazardous fumes shall be contained and/or ventilated outside the human workspace.

SR 3.2-12 There shall not be any dispersion of aerosol during normal operation or maintenance of the immersion solution.

[1] https://www.opencompute.org/wiki/Open_Rack/SpecsAndDesigns

3.3 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.

The following requirements shall apply to immersion technologies within data centers.

SR 3.3-1 A means to release pressure shall be present for any enclosed system (i.e., pressure vessel) and fully compliant with any relevant pressure vessel requirements such as CE PED (Pressure Equipment Directive), ASME, etc.

SR 3.3-2 Two-phase usage and other “volatile liquids” based implementations shall fully comply with local, national and international leakage levels allowed for the specific fluid into the atmosphere.

SR 3.3-3 When fluid temperatures increase vapor pressure to the point where evaporative losses may occur, losses shall be contained by combination of enclosure, condensation systems, proper pressure regulation, vapor recovery, and/or ventilation systems.

CR 3.3-1 Open bath liquid system shall be placed in a well-ventilated room, as specified in relation to MSDS documentation provided by the dielectric liquid provider.

CR 3.3-2 Dielectric liquid shall be prevented from entering any sewage system.

CR 3.3-3 Disposal of dielectric liquid shall be organized though appropriate disposal procedures.

CR 3.3-4 Immersion implementation shall follow a containment strategy which complies with local regulations for the dielectric liquid type. I.e., dual-hull or leak trays with the capacity of at least 100% of the largest container (include volume of interconnected containers).

CR 3.3-5 Sufficient spill management and absorption materials shall be present to manage a catastrophic spill from the full contents of the largest tank which is present on-site.

CR 3.3-6 Full liquid documentation shall be present within the room where the systems are installed (MSDS & TDS).

CR 3.3-7 Full health and safety documentation shall be present and available for access for all personnel that may come into contact with fluids.

CR 3.3-8 During service and maintenance there shall be a minimum of one person present with training related to spill management (which could be the service operator).

CR 3.3-9 Each operator shall be trained on the properties of each dielectric liquid in use within the facility.

4. Immersion Fluids

4.1 Required liquid specifications

SR 4.1-1 In addition to full MSDS and TDS documentation, the following summarized specifications shall be made available for anyone who needs to evaluate health and safety protocols, fire safety or electronics compatibility and any recipient (users or customers) or operators. For 2-phase fluids, any high-temperature testing shall exclude temperatures near or above the fluid's boiling point.

Specification	**Test method(s)**	**Format**
Dielectric strength, measured at 1 mm	ASTM D 1816	kV/mm
Dielectric Constant (Relative permittivity) *Measured at:* • *5 VAC* • *20 GHz and 40 GHz* • *20°C and 70°C*	*There is no prescribed method at this point. IEC 60247 may or may not provide a basis for this testing procedure.* *NB: The high temperature 70°C test can be lowered in line with evaporation temperatures of 2-phase fluids*	#.## @# GHz and #°C
Loss tangent	*Data must be associated with tests conducted for Dielectric Constant with the referenced properties*	#.#### @# GHz and #°C
Volume resistivity	ASTM D1169	#.## GΩm
Volumetric expansion	ASTM D 1903	#.####/°K
Maximum moisture content for dielectric breakdown *(100% Water saturation point)* at 20°C, 30°C, 40°C, 50°C, 60°C, 70°C	ASTM D1533-20	# ppm @#°C
Density at 20°C, 30°C, 40°C, 50°C, 60°C, 70°C	ISO 12185	#.## kg/m3 @#°C
Specific heat at 20°C, 30°C, 40°C, 50°C, 60°C, 70°C	ASTM E 1269	# J/kg*K @#°C
Thermal conductivity at 20°C, 30°C, 40°C, 50°C, 60°C, 70°C	ASTM D 7896	#.### W/m*K @#°C
Kinematic viscosity[2] at 20°C, 30°C, 40°C, 50°C, 60°C, 70°C	ASTM D7042	#.# mm^2/s (cSt) @#°C

[2] The industry standard reference for Kinematic viscosity is in centiStokes, which is not an SI unit. Dynamic viscosity (cP) information can be calculated based on Kinematic viscosity and density measured at the same temperature. *Dynamic viscosity (cP)= Kinematic viscosity (mm^2/s) x Density (kg/m^3)*

Specification	Test method(s)	Format
Vapor Pressure at 20°C, 30°C, 40°C, 50°C, 60°C, 70°C	ASTM D2879 (non-volatile fluids) ASTM D6378 (boiling point <85°C)	# mbar @#°C
Pour point	ASTM D 97 / ISO 3016	# °C
Boiling point temperature at which 10% of mass has boiled (if below fire point OR decomposition point)	ASTM D2887	#.# °C
Flash point (Cleveland Closed Cup)	ASTM D 93 / ISO 2719	# °C
Fire point	ASTM D 92 / 2592	# °C
Auto ignition point	DIN 51794/ ASTM E659	# °C
Sulphur content	ISO 14596	#,# ppm
Acidity	IEC 62021-2 / IEC 62021-1	#.## mg KOH/g
NSF Nonfood Compounds certification	NSF certificate	Yes/No
Odor	n/a	{TDS spec}
Color	ASTM D 156 / ISO 2211	SDS{MSDS spec}
Hazard statements	GHS Classification[3]	SDS{MSDS spec}
STOT - single exposure	Safety Data Sheet	SDS{MSDS spec}
STOT - repeated exposure	Safety Data Sheet	SDS{MSDS spec}
Biodegradability[4]	OECD 301	Readily, Inherently or Persistent
Oxidation Stability	IEC 61125	Values per method
Global warming potential (GWP)	IPCC 2007	#.#
Ozone Depletion Potential	PNNL-16813[5]	Yes/No
Latent heat of vaporization (2-phase only)	ASTM E2071	# J/kg

[3] If any hydrocarbon has a kinematic viscosity <=20.5mm2/s at 40°C, it should be classified as Category 1 of Aspiration hazards.
[4] Multiple test definitions exist (A-F) which depends on the specific fluid. The appropriate test method for the type of fluid shall be used.
[5] https://www.pnnl.gov/main/publications/external/technical_reports/pnnl-16813.pdf

Specification	Test method(s)	Format
Surface tension (2-phase only)	ASTM D1331	#.## N/m
Vapor density (2-phase only)	N/A[6]	#.### kg/m^3

4.2 Minimum dielectric fluid requirements

SR 4.2-1 The following table presents the minimum requirements which shall be met for any dielectric liquid to facilitate the safe operation of electronics. The specifications and requirements may be different for varying applications and technological solutions.

Property	Unused fluid minimum requirements	Lifetime fluid minimum requirements
Dielectric strength, measured at 1 mm	-	≥6 kV/mm
Volume resistivity	≥2.00 GΩm	≥0.20 GΩm
Flash point (Cleveland Closed Cup)	≥150 °C	≥150 °C
Auto ignition point	≥300 °C	≥300 °C
Sulphur content	<10 ppm	-
Acidity: hydrocarbons natural esters synthetic esters fluorocarbons	 ≤0.01 mg KOH/g ≤0.06 mg KOH/g ≤0.03 mg KOH/g ≤0.001 mg KOH/g	-
Odor (unsealed solutions only)	≤Slight	≤Slight

[6] Vapor density does not have an industry standard reference, but can be derived via the “Peng-Robinson Cubic Equation of State” in proximity to the normal boiling point, based on lab measurements of vapor pressure and the critical point. https://pubs.acs.org/doi/10.1021/i160057a011

4.3 Dielectric fluid quality management guidelines

For the consistent performance and reliable operation of data centers, the fluid supplier and/or solution provider shall deliver the fluid hygiene/maintenance best practices. The guideline shall include sources of contaminants and their mitigation strategies or fluid quality management system. Contaminants may be accidental or anticipated and their sources may be external or self-generated by the fluid itself. The following tables provide the list of contaminants, their sources and mitigation strategies for single-phase and two-phase hydrocarbon fluids/oils and fluorochemical fluids respectively.

Single-Phase fluids

Mineral oils should be avoided. Only synthetic oils, synthetic esters or processed natural esters should be used.

SR 4.3-1 Hydrocarbon fluids and Esters shall follow the requirements as described in the Hydrocarbon and Esters Quality Management table.

SR 4.3-2 Fluorochemical fluids shall follow the requirements as described in the Fluorochemical Quality Management table.

Hydrocarbon and Esters Quality Management Table

Contaminants	**Sources/Cause**	**Prevention/Remediation/Detection**
Particles or fiber	Manufacturing residue, poor system hygiene or possible wear of moving components.	Mechanical circulation systems include continuous filtration. Increases in particles may be detected by reduction in dielectric strength.
Moisture	Atmosphere/manufacturing process	Any open bath solution should contain a lid to limit ventilation of the air to liquid interface.
Sludge	Oxidation in oil	Oxidation could be detected by acidity and color appearance monitoring. It could be mitigated by moisture level, overheating and contamination control.
Corrosive Sulfur	Introduced by IT materials	Monitor for Sulfur contents on a regular basis
Degradable products and soluble polar contaminants	Incompatibility	Check change in interfacial tension or dielectric dissipation factor
Generation of low molecular hydrocarbons and oxidation at high temperatures	Produced by overheating or electrical discharge/cause lowering in flash point of fluid.	Avoid significant (localized) overheating. In case of overheating, analyze the fluid for flashpoint and resistivity.
Contamination by plasticizers, grease, adhesive, ink, elastomers, rubber, solder flux, coatings, etc.	Server components	Check material compatibility. Refer to the OCP whitepaper “Design Guidelines for immersion optimize IT equipment” for more details.

SR 4.3-3 The suppliers shall indicate the tests and intervals to monitor fluid quality ensuring consistent performance over time.

The tests may include oxidation stability, interfacial tenson, particle count, dielectric strength (break down voltage), dielectric dissipation factor, flash point, viscosity, density, corrosive sulfur, or other indicative tests.

Fluorochemical and 2-phase Quality Management Table

Contaminants	**Sources/Cause**	**Prevention/Remediation**
“Inert” hydrocarbon such as DOP, PDMS, etc.	Wire insulation, silicone rubber, solder flux, etc.	Activated Carbon
Chemically “active” hydrocarbon such as solder flux	Printed Circuit Boards	Activated Carbon
Water	Condensation. Heat Exchanger Leak	Silica Gel or Metal Sulfate
Particulate	Manufacturing Residue	Mechanical Filtration to <1 µm
Decomposition Products: COF2, Unsaturated, HF, etc.	Electrical Failure resulting in Arc or Red-hot burn	Activated Alumina or Base Wash
Loss of gasses to environment	Seal failure or improper maintenance procedures	Check system integrity and follow maintenance guidelines

SR 4.3-4 A 2-phase fluid conditioning system shall be available and capable of removing water, oils, acids and thermal decomposition products from Fluorochemical fluids.

5. Feature classifications

Any immersion environment requires at least a basic management system which is used to monitor the performance and/or condition of the technology. In addition to the minimum requirements, there are optional feature classifications which may be added to a technology datasheet to indicate specific value properties.

5.1 Minimum management requirements

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

- Dielectric liquid temperature at 2 locations accurately (within +/- 1.0°C) indicating:
    - Input or lowest temperature (i.e., bottom of open bath);
    - output or highest temperature (i.e., top of open bath).
- Safety system in case of overheating, based on at least two measurement locations, with at least 2 warning levels (warning, critical);
- A pressure and vacuum sensor to indicate pressure of the gas phase in 2-phase systems;
- A means to release out of bounds working pressure or vacuum in 2-phase systems;
- Dielectric fluid volume/content/level detection;
- Dielectric fluid and water leak detection;
- Pump operational status;
- This system shall comply with Redfish reporting and data collection.

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

5.2 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.

- IT-Independent power monitoring for all electrical input to the dielectric liquid;
- Thermal monitoring of the FWS at each input and output interface;
- Flow rate monitoring and control of each FWS input/output combination;
- Controlled TCS variable speed dielectric pump (if any).

5.3 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.

- Full reporting and logging of all sensory information;
- Pressure sensing, reporting and logging of each FWS input/output combination;
- Safety shut off features on each FWS input/output combination;
- Admin pump control (if any);
- IT independent administrative power control of all electrical input into the dielectric liquid;
- Full fault reporting and alerting to DCIM based on Redfish;
- Sensor quality reporting;
- High resiliency safety protocol implementation with false alarm prevention;
- Automated safety responses of the immersion system to protect immersed electronics and facility with either of the following controls:
    - Power-off;
    - FWS shut-off;
    - Pump shut-off (if any).

5.4 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.

- The system critical components are concurrently maintainable without immersed IT equipment downtime;
- Compliance with all "Thermal Optimized" and "High Safety" requirements;
- Dual power and selectivity:
  - Certified selectivity reported by independent 3rd party of all critical powered systems (A and B feed);
  - Redundant distribution of power to all electronics.
- N+1 or 2N cooling capability (N+1 or 2N availability);
  - Dual heat exchangers or CDUs;
- N+1 availability may be addressed or supplemented with ride through capabilities to provide at least 30 minutes of operation without cooling. (Ride Through availability)

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

6. 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.

6.1 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 6.1-1The listed units shall be used for all immersion 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)

6.2 Solution specification items

SR 6.2-1 The items listed in the specifications table shall be used for specification sheets of any immersion solution.

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

Specification	Format
***Rack type**	Rack/Tank
***Solution type**	Single phase/Two phase
Liquid category	Hydrocarbon(synthetic or natural)/Fluorinated/Ester (synthetic or natural) fluids
Compliancy (combinations may apply)	Thermal optimized, High safety, High availability
"--" Density (highest possible IT load with defined temperature facility coolant, in relation to the surface area)	# kW/m2, #°C "--" density
Compute Density kW per single rack/tank floorspace	(Bare rack kW)/(Rack surface), #°C *Rack/Tank capacity only, at specified temperature for unique solution
Solution Density kW per full solution floorspace	(#Full rack kW)/(#Rack+1CDU surface), #°C *Must include required spacing for infrastructure on and between Racks/Tanks/CDU's *May use optimal rack/CDU count and spacing
Solution footprint Whitespace area reserved for solution	(#Rack kW)/(#Rack+CDU+service area surface), #°C *Must include required spacing or access area per rack (I.e., servicing, airflow, traffic etc. front & back) *May account for shared service area with large deployments.
ASHRAE density (add W1-5) W(##) Compute density W(##) Solution density W(##) Solution footprint ***W32 solution footprint required**	Density figures as above with fixed cooling temperatures, equal to the maximum ASHRAE definitions for each class. W17: 17°C W27: 27°C W32: 32°C W45: 45°C W55: 55°C
Power per volume of liquid	# kW/liter
Bare solution static load	# kN/m2, Solution without liquid (as delivered), without packaging
***Full solution static load**	# kN/m2, Bare solution filled with liquid, incl. liquid interfaces
IT solution static load	# kN/m2, Full solution including (estimated) IT weight to 100% load
***Height clearance**	# m (to ceiling) *Incl. clearance for lid, servicing mechanisms etc.
***Non-IT power/kW**	# W/kW(IT), Power consumption per kW IT (I.e., pump, CDU)

Specification	Format
***Non-IT power overhead/m2**	# W/m2
***Thermal loss to environment (details below)**	# W
***Pressure drop - ASHRAE W32**	# kPa (Max load at 32°C, preferred dT)
***Maximum pressure rating**	# kPa
***Maximum flow rating**	# L/s
***Temperature delta rating (min-max)**	#-# °C or °K
Highest temperature tolerance	# °C or °K
***Required air changes per hour**	# ACH
IT chassis type	Enclosed/Immersion-optimized/Air
Max IT chassis form factor	15/19/21/custom", 1U/2U/any/custom
Rack capacity	#U or #OU
IT brand compatibility	Proprietary (own), Agnostic, {brand name}

Thermal Loss to Environment in Immersion Cooling Systems

Thermal loss to environment is a measure of how much heat an immersion cooling system releases into the surrounding air. This is critical for facilities to consider for effective cooling strategies and managing environmental impacts. Before outlining the test procedure, it is essential to understand the scientific principles behind it and what the test aims to achieve.

Scientific Principles and Relevance

Immersion cooling systems are designed to keep electronic components at optimal temperatures using a dielectric fluid. As the system operates, it generates heat. This heat is primarily transferred to the fluid and then needs to be rejected to prevent the system from overheating.

The amount of heat that escapes into the environment is mainly governed by the temperature difference between the fluid inside the system and the ambient air outside. This is because heat naturally flows from a hotter area to a cooler one. The greater this temperature difference, the more heat will flow out.

In operational scenarios, the temperature of the fluid will vary based on several factors, including the computational load. However, the thermal loss to the environment is not directly dependent on the computational load but rather on the absolute temperature of the fluid.

Heat loss to the environment occurs via convective and radiative transfer. Convective transfer involves heat being carried by air, while radiative transfer relates to heat emitted as infrared radiation. While understanding these mechanisms is useful in certain detailed analyses or cooling system optimizations, for this test's purpose, which is to assess thermal impact on a facility's environmental cooling system, the total heat loss is paramount. The facility's cooling needs to counter both convective and radiative heat loss. Thus, this test aims to quantify the total thermal loss to the environment as a single value, which efficiently enables facilities to gauge and manage the influence of immersion cooling systems on their air-cooling infrastructure.

SR 6.2-3 The described test procedure shall be used for determining "Thermal Loss to Environment".

Test Procedure

The following test simulates an operational immersion environment by maintaining a specific temperature difference between the fluid and ambient air, which would be representative of a real-world operational scenario. By doing this, it becomes possible to assess how much heat would be lost to the environment under those specific conditions.

Note: For testing with 2-phase systems, a single-phase fluid with similar characteristics shall be used as proxy to prevent pressure build-up in a tank while simulating critical temperature levels.

Note: Care should be taken to prevent inadvertent human contact with surfaces above 48°C during the test to prevent risk of burn.

- **Prepare the system:** Turn off the cooling supply so the system does not reject heat to its liquid cooling circuit. Close the lid or any openings to mimic how the system would usually operate.
- **Set the room conditions:** Make sure the room temperature matches the expected environmental conditions for the deployment. The system should be placed in an adequately sized room to provide stable temperatures with (relatively) still air. If this is not possible, the system may be shielded from direct airflow with temporary walls or canvas.
- **Heat the fluid:** Gradually heat the fluid inside the system using electrical heating elements or an alternative controllable electric heating method, until it reaches a desired steady-state temperature, resembling the average expected and intended operational temperature. The steady state means the fluid's temperature stays consistent over time.

- **Maintain the temperature:** Keep the fluid at this steady temperature for at least 8 hours. This requires adding electrical heat as needed to account for the heat that's lost to the environment.
- **Measure the electrical input:** Record how much electrical energy is needed to maintain the temperature for those 8 hours. Measurements should be taken using a power meter that is calibrated by a certified lab in accordance with ISO/IEC 17025 or an equivalent national standard. The measurement should be in kilowatt-hours (kWh) or watt-hours (Wh) for consistency.
- **Calculate the average:** Divide the total electrical input by the duration of the test in hours. This value represents the Thermal Loss to the environment in Watts.

Unified Testing parameters for data sheet disclosures

To have a common reference point, this test must be performed with the following parameters:

- The room temperature shall be between 17°C and 28°C.
- The fluid temperature shall be 20°C higher (+/- 2°C) than the room temperature (ambient + 20°C).
- For 2-phase systems, the fluid temperature shall be the critical fluid temperature, resembling the used or marketed fluid specification for the solution and the different dT from the solution to the environment shall be disclosed.

Note: While the explicit ambient temperature can have minor effects on the properties of air and materials, which in turn could influence heat transfer, within the practical range of 17°C to 28°C, these effects are generally negligible. Therefore, maintaining a consistent delta temperature (dT) between the fluid and the ambient air is the primary focus for this test.

Note: The given parameters are relevant for the solution specification, it may be recommended to consider this test with varying temperatures to enhance the performance for field deployments and communication to customers.

6.3 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.

- System and/or critical component certification compliance documentation;
- Liquid storage, handling and spill management procedures (may be part of SDS);
- Fire management documentation (may be part of SDS);

- Biodegradability documentation[7] according to OECD 301 guidelines or other industry recognized guidelines;
- User/Operators manual;
- Service manual, incl. electrical schematics (if any).

SR 6.3-2 For any solution, BIM files shall be made publicly available in accordance with any OCP Cooling Environments BIM specifications for Advanced Cooling Facilities.

[7] Ready biodegradability serves as an indication of the proper treatment and handling of spills and disposal. This information should be used in conjunction with the product SDS.

7. 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 immersion 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.

7.1 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.

7.2 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 standards[8].

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.

[8] 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 Practices[9] and Leak Detection and Intervention[10] 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.

[9] https://www.opencompute.org/documents/ocp-manual-couplings-at-hoses-pdf
[10] https://www.opencompute.org/documents/acs-cold-plate-leak-detection-and-intervention-white-paper-pdf-1

7.3 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 manufacturer[11].

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)
	Fluor elastomer (FKM)
	Polytetrafluoroethylene (PTFE)
	Teflon (PTFE) based thread sealant

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

7.4 FWS Water quality

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

Parameter	Unit	Value
pH	-	7-9
Corrosion inhibitors	-	required
Biocide	-	optional
Sulfide	ppm	<10
Sulfate	ppm	<100
Chloride	ppm	<50
Bacteria	CFUs/mL	<1000
Total hardness (as CaCO3)	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 guidelines[12]).

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.

7.5 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.[13]

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[12] https://www.ashrae.org/technical-resources/bookstore/datacom-series
[13] http://www.atlassteels.com.au/documents/TN7-Galvanic_Corrosion_rev_Aug_2010.pdf

7.6 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.

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.[14]

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"[15])

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:

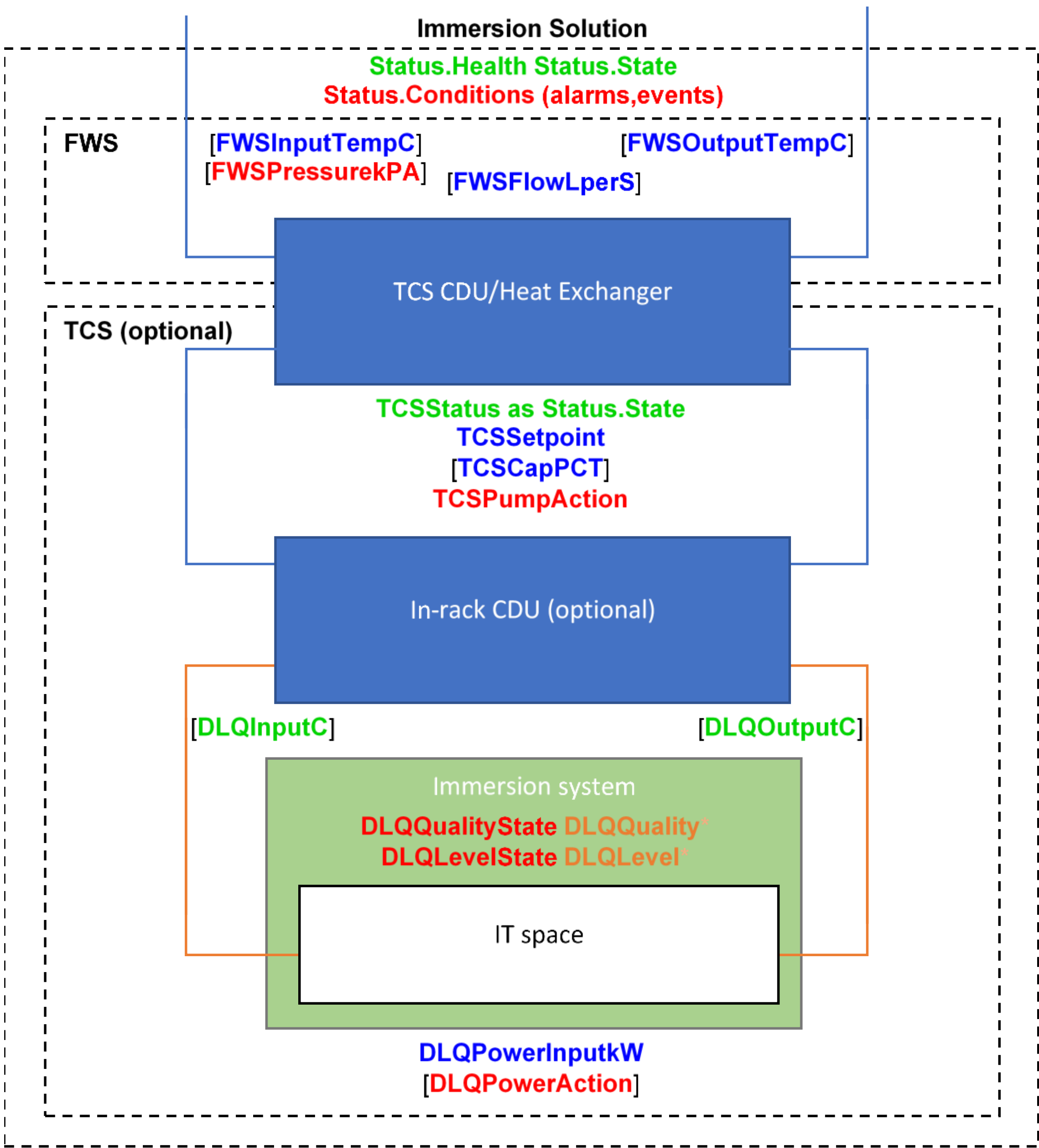
- Thermal monitoring and reporting of dielectric liquid at least at 2 locations:
    - Input (or bottom of open bath)
    - Output (or top of open bath).
- Warning system in case of overheating with at least 2 warning levels (warning, critical);
- TCS pump operational status (if any).

[14] https://www.dmtf.org/
[15] 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 wipcdu

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 intermediatory.

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 intermediatory.
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] " TSCSetpoint" : ["<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] "**TCSPumpAction**" : ["<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 "wipcdu"

8. Immersion related uptime factors

8.1 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 refers to the buffer capabilities of the dielectric liquid. A full cooling failure will result in overheating, but this overheating may be delayed by the way in which the solution is thermally designed. The internal dielectric buffer may be capable of delaying overheating for seconds or days, depending on the technology, cooling parameters before failure, the IT specification and the IT utilization.

Quantification of ride through effects are to be defined and may become specifications for this document.

Partial dielectric ride through refers to the capability of a solution which is normally connected to two separate water circuits, to operate on only a single circuit.

This capability may allow full 2n capabilities if this is designed for continuous operation during a full cooling circuit failure. Adjusted FWS flow rates and the ability to deal with higher temperature deltas may be taken into account.

The "partial dielectric ride through" may also be specified for extended operation after a single cooling loop has failed. In this case, the secondary loop only extends the "dielectric ride through" without supporting continuous operation. It effectively "buys" more time to facilitate the repair of a failed circuit.

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.

8.2 Thermal design

Immersion provides high stability in thermal conditions in which an IT system operates. The level to which this thermal stability is predictable, controlled or maintained may vary for each immersion technology. High thermal stability may prevent mechanical impact on microelectronics due to thermal stress. Low component-level temperature fluctuations (throttling) may have a longer lifetime than high, or varying fluctuations.

The following measures may have a positive impact on thermal stability:

- A technology may have a particularly high dampening effect on FWS fluctuations (natural circulation);
- A predictable or controlled dielectric flow to each individual IT system may also affect the thermal stability of IT equipment.

8.3 Cooling infrastructure

Immersion systems can typically tolerate higher fluid temperatures compared to air. This results in reduced complexity of cooling infrastructure, which reduces the failure potential of an overall liquid infrastructure. The higher the thermal tolerance of a solution, the higher the resiliency of the full solution.

For 2n or n+1 installations, immersion may allow for new ways of implementing resilience. Technology may be capable of operating with alternate cooling supplies like lake water, tap water or even chlorinated water (swimming pools) for backup purposes.

If systems are designed for energy reuse, the re-user becomes part of the cooling strategy, eliminating part of the cooling requirements within the facility, again eliminating potentials for failure.

8.4 Oxidation and moisture

Depending on the immersion technology, dielectric liquids contain no oxygen and moisture may be separated naturally (natural circulation) or by water separators (mechanical circulation) which prevents any type of oxidation. This results in an increased lifespan of IT equipment.

In 2-phase applications, oxidation is a consideration and appropriate coating methods, or material selection is required.

8.5 IT compatibility

All mentioned uptime advantages are fully dependent on the compatibility and/or optimization of IT equipment in immersion. The following OCP papers describe important aspects for IT equipment design, test and evaluation for immersion cooling. If these documents are followed, the maximum uptime benefits may be expected.

- Design Guidelines for Immersion Cooled IT Equipment[16], published December 2020
- Material Compatibility in Immersion Cooling[17], published November 2022
- OCP Base Specification for Immersion Fluids[18], published December 2022

[16] https://www.opencompute.org/documents/design-guidelines-for-immersion-cooled-it-equipment-revision-1-01-pdf

[17] https://www.opencompute.org/documents/material-compatibility-in-immersion-cooling-document-version-1-0-nov-28-2022-1-pdf

[18] https://www.opencompute.org/documents/ocp-base-specification-for-immersion-fluids-20221201-pdf

9. Requirements catalogue

9.1 Specification Requirements

SR 1.1-1 *All Specification Requirements shall be met by the immersion solution vendor.*
SR 3.1-1 Each immersion 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 3.2-1 Suppliers of dielectric fluids and immersion technology equipment shall supply written emergency procedures for each technology addressing remediation steps for uncontrolled release of dielectric fluids and mitigation and control of fire.
SR 3.2-2 Immersion systems shall be safe for use by normally skilled IT personnel in relation to normal server maintenance activities within the immersion system without any specific skill or training on the immersion technology. Instructional safeguards and/or interlocks that identify or prevent unsafe operations shall be assessed to determine adequacy for prevention of unsafe operations of untrained personnel.
SR 3.2-3 Horizontal busbars shall not be load-bearing and the solution shall contain features (i.e., guidance rails or slots) to force correct server placement in line with the Rack and Power Open Rack Specification and Open Rack Design Guide for IT Gear.
SR 3.2-4 Metal conductors of busbars shall be protected to prevent objects with a minimum conductive surface of 6 mm length (i.e., screws, tools and other debris) from creating an electrical short hazard to the busbars when dropped into the tank.
SR 3.2-5 Any electrical circuit must be fully certified in line with requirements which apply in the geographical region in which it is implemented.
SR 3.2-6 Any electrical assembly shall be accessible by qualified personnel and documented with full schematics.
SR 3.2-7 System installation shall contain an interface for electrical grounding that complies with all grounding requirements for region and type of installation.
SR 3.2-8 For grounding purposes, the electrostatic generation in dielectric fluids shall be considered and documented in such a way to assure adequate dissipation of static charge.
SR 3.2-9 Spill management measures shall be incorporated within the offer or furnished as factory accessory.
SR 3.2-10 Containment measures shall manage at least 100% of the volume of any single system without breach of containment, such means may include but not be limited to; leak trays, condensers, dual-hull, sealant material but also absorbent materials.
SR 3.2-11 Potential hazardous fumes shall be contained and/or ventilated outside the human workspace.
SR 3.2-12 There shall not be any dispersion of aerosol during normal operation or maintenance of the immersion solution.
SR 3.3-1 A means to release pressure shall be present for any enclosed system (i.e., pressure vessel) and fully compliant with any relevant pressure vessel requirements such as CE PED (Pressure Equipment Directive), ASME, etc.
SR 3.3-2 Two-phase usage and other "volatile liquids" based implementations shall fully comply with local, national and international leakage levels allowed for the specific fluid into the atmosphere.
SR 3.3-3 When fluid temperatures increase vapor pressure to the point where evaporative losses may occur, losses shall be contained by combination of enclosure, condensation systems, proper pressure regulation, vapor recovery, and/or ventilation systems.
SR 4.1-1 In addition to full MSDS and TDS documentation, the following summarized specifications shall be made available for anyone who needs to evaluate health and safety protocols, fire safety or electronics compatibility and any recipient (users or customers) or operators. For 2-phase fluids, any high-temperature testing shall exclude temperatures near or above the fluid's boiling point.

SR 4.2-1 The following table presents the minimum requirements which shall be met for any dielectric liquid to facilitate the safe operation of electronics. The specifications and requirements may be different for varying applications and technological solutions.
SR 4.3-1 Hydrocarbon fluids and Esters shall follow the requirements as described in the Hydrocarbon and Esters Quality Management table.
SR 4.3-2 Fluorochemical fluids shall follow the requirements as described in the Fluorochemical Quality Management table.
SR 4.3-3 The suppliers shall indicate the tests and intervals to monitor fluid quality ensuring consistent performance over time.
SR 4.3-4 A 2-phase fluid conditioning system shall be available and capable of removing water, oils, acids and thermal decomposition products from Fluorochemical fluids.
SR 5.1-1 Each immersion system shall have at least the minimum prescribed management features.
SR 6.1-1The listed units shall be used for all immersion technology definitions.
SR 6.2-1 The items listed in the specifications table shall be used for specification sheets of any immersion solution.
*SR 6.2-2 Any metric which is marked with * shall be included in public technical data sheets.*
SR 6.2-3 The described test procedure shall be used for determining "Thermal Loss to Environment".
SR 6.3-1 For any immersion technology, the listed documentation shall be available for data center facilities, end users and operators.
SR 6.3-2 For any solution, BIM files shall be made publicly available in accordance with any OCP Cooling Environments BIM specifications for Advanced Cooling Facilities.
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.

9.2 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.

9.3 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 3.3-1 Open bath liquid system shall be placed in a well-ventilated room, as specified in relation to MSDS documentation provided by the dielectric liquid provider.

CR 3.3-2 Dielectric liquid shall be prevented from entering any sewage system.

CR 3.3-3 Disposal of dielectric liquid shall be organized though appropriate disposal procedures.

CR 3.3-4 Immersion implementation shall follow a containment strategy which complies with local regulations for the dielectric liquid type. I.e., dual-hull or leak trays with the capacity of at least 100% of the largest container (include volume of interconnected containers).

CR 3.3-5 Sufficient spill management and absorption materials shall be present to manage a catastrophic spill from the full contents of the largest tank which is present on-site.

CR 3.3-6 Full liquid documentation shall be present within the room where the systems are installed (MSDS & TDS).

CR 3.3-7 Full health and safety documentation shall be present and available for access for all personnel that may come into contact with fluids.

CR 3.3-8 During service and maintenance there shall be a minimum of one person present with training related to spill management (which could be the service operator).

CR 3.3-9 Each operator shall be trained on the properties of each dielectric liquid in use within the facility.

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

Please refer to the OCP Cooling Environments Harmonized Glossary

https://docs.google.com/spreadsheets/d/1jk0-xSvULP8gyxGE9eCVuDAdRji4R_R3YUmtxkVxx3w

Appendix: References

- OCP CE Harmonized Glossary
  https://docs.google.com/spreadsheets/d/1jk0-xSvULP8gyxGE9eCVuDAdRji4R_R3YUmtxkVxx3w
- OCP Immersion Project: on-going projects information (see wiki for details)
  https://www.opencompute.org/wiki/Cooling_Environments/Immersion
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- ASHRAE. 2014. Liquid cooling guidelines for datacom equipment centers, second edition:
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- ASHRAE.2019. Water-Cooled servers common designs, components, and processes: http://tc0909.ashraetcs.org/documents/ASHRAE_TC0909_Water_Cooled_Servers_11_April_2019.pdf
- OECD Guidelines for the Testing of Chemicals, Section 3, Test No. 301: Ready Biodegradability https://www.oecd-ilibrary.org/environment/test-no-301-ready-biodegradability_9789264070349-en
- Analytical Method for the Detection of Ozone Depleting Chemicals (ODC) in Commercial Products Using a Gas Chromatograph with an Electron Capture Detector (GC-ECD) https://www.pnnl.gov/main/publications/external/technical_reports/pnnl-16813.pdf
- Analysis of Dielectric Properties Comparison Between Mineral Oil and Synthetic Ester Oil http://resolver.tudelft.nl/uuid:868501da-8cae-473c-9753-b2f72de56eff
- Shah, J., Eiland, R., Siddharth, A., and Agonafer, D., 2016, "Effects of Mineral Oil Immersion Cooling on IT Equipment Reliability and Reliability Enhancements to Data Center Operations", 15th IEEE Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems (ITherm), Las Vegas, NV, May 31–June 3, pp. 316–325.
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About Open Compute Project

The Open Compute Project Foundation is a 501(c)(6) organization which was founded in 2011 by Facebook, Intel, and Rackspace. Our mission is to apply the benefits of open source to hardware and rapidly increase the pace of innovation in, near and around the data center and beyond. The Open Compute Project (OCP) is a collaborative community focused on redesigning hardware technology to efficiently support the growing demands on compute infrastructure. For more information about OCP, please visit us at http://www.opencompute.org