



OPEN

Compute Project

Cooling Environments: Coldplates

Single-Phase Direct-to-Chip Coldplate Base Specification

1.0.0

Base Specification

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1.2. Acknowledgements

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List all companies or individuals who may have assisted you with the specification by providing feedback and suggestions but did not provide any IP.

2. Compliance with OCP Tenets

This Base Specification defines a vendor-neutral, de-facto industry baseline for single-phase Direct-to-Chip (D2C) cold plates used in data center environments. It aligns with the Open Compute Project core tenets as follows.

2.1. Openness

This specification is openly published and vendor-neutral, enabling broad adoption and participation across the ecosystem. It avoids proprietary requirements and supports extensibility by defining baseline expectations without constraining implementation details, allowing future Design and Product Specifications to build upon it.

2.2. Efficiency

By enabling standardized single-phase D2C liquid cooling solutions, this specification supports improved thermal efficiency and reduced reliance on air cooling. Common baseline requirements and validation methods reduce duplicated effort and accelerate qualification and deployment.

2.3. Impact

This specification is intended to serve as a common industry reference for D2C cold plates, improving alignment between suppliers and operators. A shared baseline lowers adoption barriers, supports interoperable solutions, and accelerates ecosystem maturity for liquid cooling technologies.

2.4. Scale

The requirements are defined to support deployment across a wide range of system architectures and data center scales. The specification enables consistent procurement and qualification while allowing flexibility for suppliers to meet large-volume manufacturing and deployment needs.

2.5. Sustainability

Single-phase D2C liquid cooling enables reduced air cooling energy consumption and supports more efficient thermal management of high-density compute. Material compatibility and reliability considerations further promote longer component life and reduced environmental impact over time.

3. Overview

This document defines an OCP Base Specification that establishes a vendor-neutral, de-facto industry baseline for single-phase Direct-to-Chip (D2C) cold plates used in data center liquid cooling systems. It provides common terminology, baseline functional expectations, and recommended validation approaches to enable interoperability, consistent qualification, and simplified procurement.

Within the OCP modular specification framework, this specification defines the Base layer, intended to be reused and extended by future Design and Product specifications. It focuses on aligning the ecosystem on minimum expectations for cold plate functionality and integration without constraining implementation choices.

This Base Specification addresses common industry challenges, including inconsistent definitions, fragmented qualification practices, and non-comparable evaluation criteria across suppliers. Its utility within the Open Compute Project ecosystem is to provide a shared foundation that accelerates adoption of liquid cooling, supports multi-party collaboration, and enables scalable, interoperable solutions.

Unless explicitly stated otherwise, this Base Specification does not define or constrain specific dimensions, materials, manufacturing processes, connector types, or performance targets. Such details are intentionally deferred to future OCP Design Specifications, Product Specifications, or system-level requirements in order to preserve openness and enable innovation.

In scope: single-phase, direct-to-chip cold plates for data center server platforms.

Out of scope: two-phase cold plates, immersion cooling hardware, rack-level CDU/TCS assemblies, and system-level manifolds.

4. Base Specification

4.1. Description

A direct-to-chip cold plate is a liquid-cooled heat exchanger that interfaces to a heat-generating device through a TIM and transfers heat to a single-phase closed liquid loop.

4.2. Goals and Vision

The goal of this specification is to establish a de-facto industry baseline for single-phase D2C cold plates that supports interoperability, consistent qualification, and simplified procurement.

This Base Specification is intended to reduce ecosystem fragmentation while providing a foundation for future OCP Design and Product Specifications that address specific platforms or applications.

4.3. User Requirements/User Stories

- Integrators, ODMs and OEMs need a common baseline to evaluate and procure cold plates from multiple suppliers using consistent criteria.
- Suppliers need an open, vendor-neutral reference that defines minimum expectations without limiting innovation.
- OCP contributors need a Base Specification that can be extended by downstream specifications.

4.4. Solution Architecture

Within the OCP modular specification framework, this document defines the Base Specification layer for single-phase D2C cold plates. It describes what is required at a high level while intentionally deferring design, implementation, and optimization details to future Design and Product Specifications.

The cold plate is treated as a component that interfaces mechanically, thermally, and hydraulically with a heat-generating device and a single-phase liquid cooling loop.

4.5. Functional Requirements

The cold plate shall function as a reliable, single-phase heat transfer component that removes heat directly from a heat-generating device and transfers it to a liquid cooling loop under normal data center operating conditions.

At a minimum, a cold plate conforming to this Base Specification shall:

- Provide effective thermal coupling between the heat-generating device and the cooling fluid
- Operate with single-phase liquid coolant in a closed-loop system
- Maintain fluid containment without leakage under specified operating and transient conditions
- Support predictable hydraulic behavior suitable for integration into rack-level liquid cooling systems
- Maintain mechanical integrity and thermal performance throughout its intended operational life

The cold plate shall be compatible with common data center operating environments and shall tolerate expected variations in flow rate, pressure, and fluid temperature without loss of function.

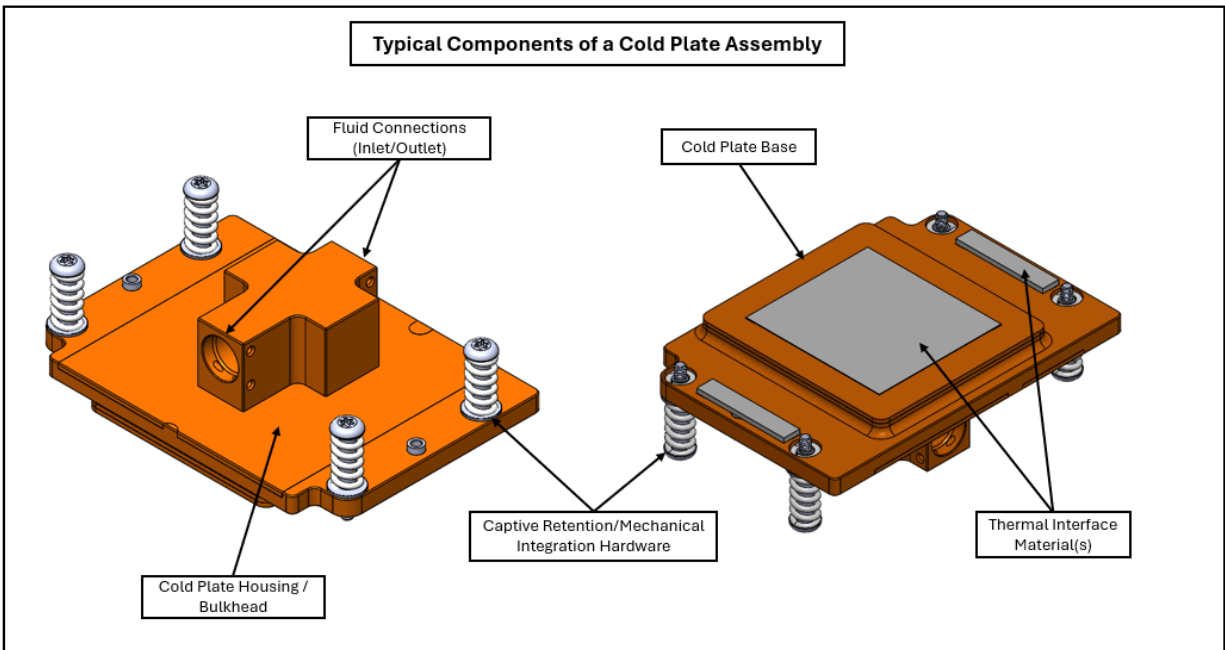
4.6. Non-Functional Requirements

Cold plates shall be reliable, durable, serviceable, and interoperable for data center deployment and multi-supplier qualification.

4.7. Features

Cold plates conforming to this Base Specification include the following baseline features:

- **Cold plate base:**
A flat or controlled-flatness surface intended for application of a thermal interface material (TIM) and direct contact with the component being cooled.
- **Captive Retention/Mechanical Integration Hardware:**
Mechanical mounting points (e.g., threaded holes or through-holes) designed to accept fasteners that apply a controlled clamping force between the cold plate and the motherboard, server tray, or retention structure.
- **Fluid Connections (Inlet/Outlet):**
Defined fluid connection points that enable integration into a single-phase, closed-loop liquid cooling system.
- **Cold plate Housing/Bulkhead:**
A structural enclosure that supports internal fluid containment, interfaces with fluid inlet and outlet points, and provides mechanical integrity for integration into the host platform.



5. Requirements

Cold plates conforming to this Base Specification shall be designed to fit within the available mechanical envelope provided by the target server, motherboard, or server tray.

5.1. Mechanical

The cold plate shall support secure attachment to the host platform and maintain mechanical integrity under expected installation, operational, and service loads.

5.2. Rack Compatibility

The cold plate shall be compatible with server platforms intended for installation in OCP-approved or industry-standard data center racks.

5.3. General Requirements

The cold plate shall integrate with the host platform without adversely impacting adjacent components, system assembly, or serviceability.

5.4. Thermal Design Requirements

The cold plate shall enable effective heat transfer from the cooled component to a single-phase liquid cooling loop under normal operating conditions.

5.5. Performance Requirements

The cold plate shall deliver predictable thermal and hydraulic behavior suitable for qualification, comparison, and procurement across suppliers.

5.6. Constraints

The cold plate design shall conform to platform-defined mechanical, thermal, and system-level constraints without requiring modification to the host server architecture.

6. Test and Validation Requirements

This section covers all of the validation tests required for a coldplate. This section does not cover typical production testing.

6.1. Leakage & Pressure

Leak Detection

Test Description	Detects micro-leaks in cold plate assemblies using pressurized hydrogen or helium gas. The cold plate is sealed and pressurized, then leak detection is performed via vacuum chamber, sniffer probe, or immersion bubble testing. Leak rate criteria are referenced to INFICON industry standards.
Test Setup	Fully assembled cold plate, including all connectors and seals, pressurized and sealed.
Test Fluid	Hydrogen (typically as forming gas: 5% H ₂ , 95% N ₂) or helium gas.
Test Temperatures	Ambient laboratory temperature unless otherwise specified by the customer.
Timing/Transition Rate	Hold at test pressure for the specified dwell time (typically 5–10 minutes).
Acceptance Criteria	No leaks detected by sniffer probe. Leak rate criteria should align with INFICON industry standards (e.g., < 0.6 SCCM for water-tight).

Gas Pressure Decay / Dwell

Test Description	The cold plate is pressurized with a specified gas (air, nitrogen, hydrogen, or helium) and monitored for pressure decay over a defined dwell period. Differential pressure measurement may be used for increased sensitivity. Leak rate criteria are referenced to INFICON industry standards.
Test Setup	Assembled cold plate, pressurized and isolated from external influences.
Test Fluid	Air, nitrogen.
Test Temperatures	Ambient laboratory temperature unless otherwise specified.
Timing/Transition Rate	Dwell period as specified by internal specification (typically 5–30 minutes).

Acceptance Criteria	Pressure decay within allowable limits (e.g., less than 0.5% loss over dwell period); no leaks detected.
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Hydrostatic Pressure / Dwell

Test Description	The cold plate is filled with liquid and hydrostatically pressurized to its maximum rated operating pressure for 5 minutes, then to three times the maximum operating pressure for 2 minutes. Checks for leaks, deformation, and structural integrity. Dimensions measured before and after to ensure no permanent deformation. Test pressure may reference IEC 62368-1 or UL requirements.
Test Setup	Fully assembled cold plate, including connectors and seals, filled and pressurized.
Test Fluid	Water or specified cooling fluid (e.g., water/glycol mixture). It is preferable to use a fluid that has color and/or is observable with UV light.
Test Temperatures	Typically performed at room temperature (20–25°C) unless otherwise specified.
Timing/Transition Rate	5 minutes at maximum operating pressure; 2 minutes at 3× maximum operating pressure.
Acceptance Criteria	Using a UV light for inspection, no detectable leaks or deformation are present during or after the test; dimensions statistically equivalent before and after the test. Test pressure may reference IEC 62368-1 or UL requirements.

Burst Pressure

Test Description	This is a destructive test to determine the maximum pressure the cold plate assembly can withstand before failure. The cold plate is pressurized (using water or specified fluid) until rupture or until reaching three times the minimum proof pressure, whichever is lower. The test is performed on both fully assembled and disconnected components to verify the robustness of all interfaces. The pressure rise rate should be controlled as per ISO 18869. The acceptance criterion is that the burst pressure exceeds the minimum requirement, with no rupture or leaks below that threshold.
Test Setup	Fully assembled cold plate, including connectors and seals; also tested in disconnected state if specified.
Test Fluid	Water or specified test fluid.

Test Temperatures	Ambient laboratory temperature (unless otherwise specified).
Timing/Transition Rate	Pressure rise rate per ISO 18869 (e.g., gradual increase to failure, typically 1–5 bar/min).
Acceptance Criteria	Burst pressure is above the minimum required (e.g., >20 bar); no rupture or leaks below specified threshold.

6.2. Thermal & Flow

Thermal Resistance

Test Description	The cold plate is mounted with the recommended TIM2 material onto a thermally functional processor stack or TTV. The cold plate heat exchanger is connected to a cooling loop. After ensuring no bubbles in the test loop, the fluid flow rate is stabilized and power is applied to the processor. Once the sink temperature (base of the coldplate) and incoming fluid temperature stabilize, the measured pressure drop, case temperature, fluid inlet temperature, applied power, and flow rate are recorded. Thermal resistance is calculated as $R=(T_s-T_i)/P$. The test is repeated at multiple flow rates to generate a performance curve. <i>section 9.1.2 of the UQD Spec.</i>
Test Setup	Assembled cold plate on processor, in cooling loop.
Test Fluid	Water or specified cooling fluid (e.g., water/glycol mixture).
Test Temperatures	Fluid temperature typically $45^{\circ}\text{C} \pm 2^{\circ}\text{C}$.
Timing/Transition Rate	Stabilize temperatures before measurement; test at multiple flow rates.
Acceptance Criteria	Thermal resistance meets product requirements at all tested flow rates; performance curve is within specified limits.

Pressure Drop

Test Description	The cold plate is installed in a laboratory bench-scale cooling system loop with the cold plate, tubing and quick disconnects. Pressure is measured at the inlet and outlet at constant flow rates. The pressure drop is calculated as the difference between the pressure recorded in the test setup and the tare setup (loop without cold plate). The test is performed at multiple flow rates (typically 25% to 150% of rated flow), if the cold plate is designed for flow in both directions, it should be tested under both scenarios. Results are reported as a curve fit equation for pressure drop vs. flow rate, as described in section 9.1.4 of the UQD Spec.
Test Setup	Assembled cold plate in test loop.
Test Fluid	Water or specified cooling fluid.
Test Temperatures	Fluid temperature typically $45^{\circ}\text{C} \pm 2^{\circ}\text{C}$.
Timing/Transition Rate	Select at least six flow rates from 25% to 150% of rated flow, including 100% of rated flow.
Acceptance Criteria	Pressure drop below maximum allowed by cooling system; curve fit coefficients (A, B) meet specification; minimum Cv at rated flow is achieved.

Flow Rate

Test Description	The cold plate is tested to verify minimum and maximum flow rates. Flow rate curves are generated by measuring flow at increasing rates up to $<1.5 \text{ m/s}$ to ensure no erosion or leaks. The test is performed in the directions prescribed and at multiple flow rates. <i>section 9.1.4 and Table 7 of the UQD Spec.</i>
Test Setup	Assembled cold plate in test loop.
Test Fluid	Water or specified cooling fluid.
Test Temperatures	Fluid temperature typically $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$.
Timing/Transition Rate	Test at multiple flow rates up to maximum recommended velocity.
Acceptance Criteria	Flow rate meets product requirements; no erosion or leaks at maximum flow.

6.3. Mechanical & Structural

Retention Force

Test Description	The retention force test measures the force required to retain the cold plate or connector in place. A pulling force (typically 30N $\pm$ 10%) is applied for 5 seconds in any direction on the tubing or connector using a calibrated pull gauge. The test is performed on both mated and unmated assemblies to verify the robustness of the retention mechanism. The test ensures that the cold plate remains securely attached during installation, operation, and servicing, as described in section 9.4 and Table 67 of the Blind Mate Spec.
Test Setup	Assembled cold plate with tubing attached.
Test Temperatures	Ambient laboratory temperature unless otherwise specified.
Timing/Transition Rate	Apply force for 5 seconds in each direction.
Acceptance Criteria	No rupture or leakage during or after test; retention force meets or exceeds product specification.

Flatness

Test Description	The flatness of the cold plate base is measured using ISO 12781-2:2011 methodology. Precision metrology equipment (surface plate, dial indicator, or CMM) is used to ensure the bottom surface is within specified tolerances. The test is performed prior to assembly and is critical for ensuring proper thermal contact and mechanical fit. Any distortion or deformation may impact performance.
Test Setup	Cold plate base, prior to assembly.
Test Temperatures	Ambient laboratory temperature unless otherwise specified.
Acceptance Criteria	Flatness within product specification; no visible distortion or deformation.

Stiffness

Test Description	The stiffness of the cold plate assembly is measured by applying specified loads and measuring deflection using calibrated force application and displacement measurement. The test ensures the cold plate maintains integrity under operational loads and does not deform excessively, which could compromise thermal or mechanical performance. The test is performed in accordance with product technical specifications.
Test Setup	Assembled cold plate.
Test Temperatures	Ambient laboratory temperature unless otherwise specified.
Acceptance Criteria	Stiffness meets or exceeds product specification; deflection is within allowable limits.

6.4. Reliability & Environmental

Operational Temperature Cycling

Test Description	The cold plate is exposed to repeated temperature extremes to simulate operational conditions. The plate is cycled between low and high temperatures (e.g., 10°C for 72h, then 65°C for 72h, then back to room temp). After cycling, a hydrostatic pressure test is performed to check for leaks or performance degradation. This test is performed with the cold plate connected to the cooling loop and under pressure. <i>section 9.2.2 of the UQD Spec.</i>
Test Setup	Assembled cold plate in cooling loop, pressurized.
Test Fluid	Water or specified cooling fluid.
Test Temperatures	Cycle between 10°C and 65°C, dwell 72h at each temperature.
Timing/Transition Rate	5–10°C/min transition rate; dwell times as specified.
Acceptance Criteria	No visible leakage; passes hydrostatic pressure test after cycling; no performance degradation.

Non-Operational Temperature Cycling (Shipping)

Test Description	Simulates shipping environmental exposures. The cold plate is cycled between -40°C for 72h and +70°C for 72h, then back to room temp. Helium leak tests are performed prior to and after cycling. The test is performed with the cold plate capped and pressurized. <i>section 9.2.1 of the UQD Spec.</i>
Test Setup	Assembled cold plate, capped and pressurized.
Test Fluid	Air at specified pressure.
Test Temperatures	Cycle between -40°C and +70°C, dwell 72h at each temperature.
Timing/Transition Rate	5–10°C/min transition rate; dwell times as specified.
Acceptance Criteria	No visible leakage; helium leak rate $\leq 1 \times 10^{-5}$ mbar-L/s after test.

Shock

Test Description	Applies mechanical shock to the cold plate assembly per product qualification standards. After shock, inspect for cosmetic damage and perform hydrostatic pressure test to check for leaks or damage. The test is performed with the cold plate mounted on a representative product board with representative retention HW mechanical boundary conditions. <i>Section 9.2.3 of the UQD Spec.</i>
Test Setup	Assembled cold plate on processor stack.
Test Fluid	Water or specified cooling fluid (if under pressure during test).
Test Temperatures	Ambient laboratory temperature unless otherwise specified.
Timing/Transition Rate	Shock pulse duration and magnitude per product specification.
Acceptance Criteria	No leaks, no cosmetic damage, thermal performance statistically equivalent after test.

Vibration

Test Description	Applies vibration to the cold plate assembly per product qualification standards. After vibration, inspect for cosmetic damage and perform hydrostatic pressure test to check for leaks or damage. The test is performed with the cold plate mounted on a representative product board with representative retention HW mechanical boundary conditions. <i>section 9.2.3 of the UQD Spec.</i>
Test Setup	Assembled cold plate on processor stack.
Test Fluid	Water or specified cooling fluid (if under pressure during test).
Test Temperatures	Ambient laboratory temperature unless otherwise specified.
Timing/Transition Rate	Vibration frequency, amplitude, and duration per product specification.
Acceptance Criteria	No leaks, no cosmetic damage, thermal performance statistically equivalent after test.

Salt Spray (Corrosion)

Test Description	Assesses corrosion resistance of exterior surfaces. The cold plate is exposed to salt spray per ASTM B117 (5% NaCl solution, 35°C, 8h). After exposure, inspect for corrosion, pitting, or leaks. Hydrostatic pressure test is recommended post-exposure. The test is performed with the cold plate sealed and placed in the chamber. <i>section 9.2.4 of the UQD Spec.</i>
Test Setup	Assembled cold plate.
Test Fluid	5% NaCl solution (for salt spray chamber).
Test Temperatures	35°C chamber temperature.
Timing/Transition Rate	8 hours exposure at 35°C.
Acceptance Criteria	No corrosion, pitting, or discoloration; passes hydrostatic pressure test after exposure.

Fluid Compatibility/Corrosion

Test Description	Verifies chemical compatibility and corrosion resistance of wetted surfaces. The test is performed with all wetted materials in the cooling loop. The metal compatibility is tested with specified cooling fluid per modified ASTM D8040 (glassware corrosion test) followed by fluid analysis D6130 (ICP trace elements), D1287 (pH), D1121 (reserve alkalinity), & D5827 (IC anions). Ion concentration, pH, and reserve alkalinity are measured. The test is performed with all wetted materials in the cooling loop. Compatibility of elastomers with the cooling fluid is tested per ASTM D471, and changes in volume, hardness (Shore A) and tensile properties are evaluated per D412 and D2240. The compatibility of plastics in the cooling loop is tested per ASTM D543, followed by D638 (tensile properties), D2240 (Shore D hardness) and volume measurements to evaluate the changes in properties. For brazing materials, the ASTM D7933 test method is used, followed by analysis of trace impurities in the cooling fluid with ICP (D6130). The exposure temperature can be adjusted according to the operating conditions. <i>section 9.2.4 of the UQD Spec.</i>
Test Setup	As specified in ASTM standards and referenced OCP documents.
Test Fluid	Specified cooling fluid (water/glycol mix, etc.).
Test Temperatures	As specified in ASTM standards and referenced OCP documents.
Timing/Transition Rate	As specified in ASTM standards and referenced OCP documents.
Acceptance Criteria	No significant corrosion, leaching, or degradation; meets product requirements for cooling fluid and all tested materials.. A detailed list of acceptable limits can be found in the referenced OCP documents.
Document references	• Base Specification for Single-Phase Propylene Glycol-Based Fluids (PG 25) • Guideline for Using Water-Based Heat Transfer Fluid in single-phase cold plate-based liquid-cooled racks

Humidity

Test Description	Exposes product to high/low humidity conditions to assess resistance to condensation and corrosion. The cold plate is exposed to 40°C @ 93% RH for 16h and 40°C @ 10% RH for 16h. After exposure, inspect for leaks, rust, or oxidation. Hydrostatic pressure test is performed post-exposure. <i>section 9.2.5 of Blind Mate Spec.</i>
Test Setup	Assembled cold plate.
Test Fluid	Water/glycol mix or specified cooling fluid.
Test Temperatures	40°C chamber temperature.
Timing/Transition Rate	Dwell times as specified; ramp rates as specified.
Acceptance Criteria	No leaks, rust, or oxidation; passes hydrostatic pressure test after exposure.

6.5. Cleanliness

Flush/Cleanliness

Test Description	The cold plate heat exchanger is flushed with clear fluid while immersed in an ultrasonic bath. The discharged fluid is inspected for discoloration and particulate content. Must meet ASTM/ISO cleanliness standards (particulate <50µm). The test ensures that the cold plate is free of manufacturing debris and suitable for installation in a liquid cooling system. <i>section 1.3.1.4 of Cold Plate Dev.</i>
Test Setup	Assembled cold plate.
Test Fluid	Clear flushing fluid (e.g., deionized water).

Test Temperatures	Ambient laboratory temperature unless otherwise specified.
Timing/Transition Rate	Flush duration and ultrasonic bath time per internal specification.
Acceptance Criteria	Discharged fluid is clear; particulate <50µm; meets cleanliness requirements for installation.

7. Compliance

Conformance requires completion and reporting of all tests listed below using the methods in Section 6 or technically equivalent methods.

ITEM	REQUIREMENT	REFERENCE	MANDATORY
1	Helium Leak Detection		Y
2	Gas Pressure Decay / Dwell		Y
3	Hydrostatic Pressure / Dwell		Y
4	Burst Pressure		Y
5	Thermal Resistance		Y
6	Pressure Drop		Y
7	Flow Rate		Y
8	Retention Force		Y
9	Flatness		Y
10	Stiffness		Y
11	Operational Temperature Cycling		Y
12	Non-Operational Temperature Cycling (Shipping)		Y
13	Shock		Y
14	Vibration		Y
15	Salt Spray (Corrosion)		Y
16	Fluid Compatibility / Corrosion		Y
17	Humidity		Y

18	Flush / Cleanliness		Y
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7.1. References (recommended)

[1] "Title", publication year, OCP specification, version, link to publication if available.

[2] "Title", publication year, publication journal/conference/standard, volume, pages, link to publication if available.