ACS Door Heat Exchanger Specification for Open Rack

<Revision X.Y>

Authors

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1. OVERVIEW

1.1 License

- May need to review/revise the below license term

1.2 Acknowledgements

The ACS Door Heat Exchanger specification for Open Rack was created under a collaboration from many OCP member companies facilitated by the ACS Door Heat Exchanger subgroup under the Rack and Power workgroup.

The ACS Door Heat Exchanger subgroup would like to acknowledge the following member companies for their contributions to the ACS Door Heat Exchanger specification for Open Rack:

- Name of company
- Name of company

1.3 Scope

This document defines the technical specifications and potential applications for a rack-mount door heat exchanger to be used with Open Rack. It is specifically scoped for a rear-side, rack mounted heat exchanger; however, physical dimensions of the heat exchanger should be compatible for both rear and front mounting. The performance of a heat exchanger can vary depending on its application, mounting mechanical system and fan location.

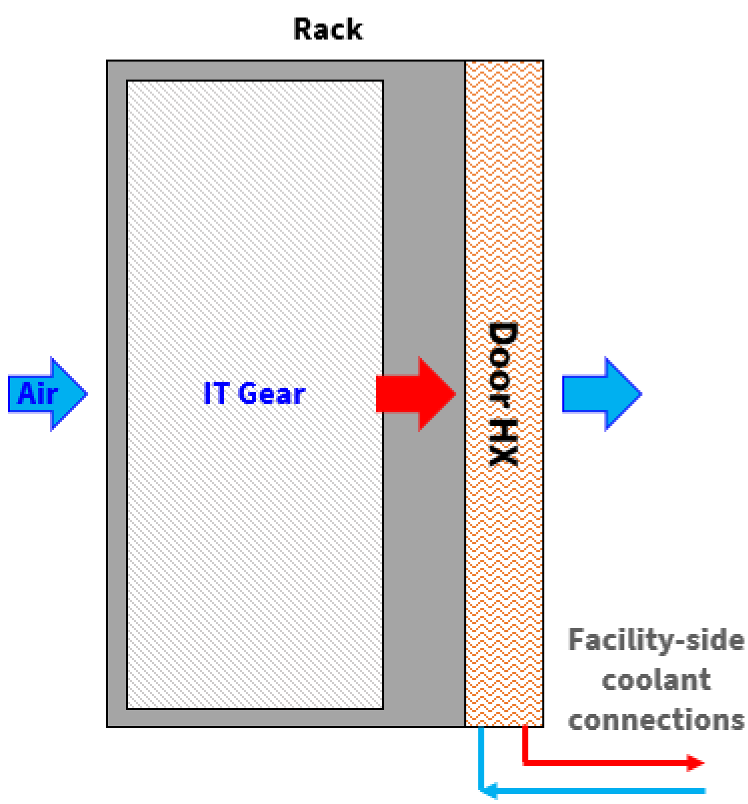


Figure 1: Simplified depiction of a traditional rear door heat exchanger

2. POTENTIAL APPLICATIONS

2.1 Traditional real door heat exchanger (air-to-liquid)

The most widespread application of a door heat exchanger is where the solution replaces the rear door of a rack and relies on the facility-provided coolant to make the rack thermally neutral to the room. Figure 1 provides a simplified representation of how a rack outfitted with a rear door heat exchanger functions. In general, IT hardware within the rack is air-cooled and the door heat exchanger uses facility coolant to absorb heat from exhaust air to return air to the facility at or near inlet air temperature to the rack. This rear door heat exchanger can either be a passive or active solution. The latter has fans integrated that help drive airflow to achieve the required amount of cooling and reduce back pressure on IT chassis fans. Depending on requirements, a passive solution may or may not have integrated sensors for monitoring.

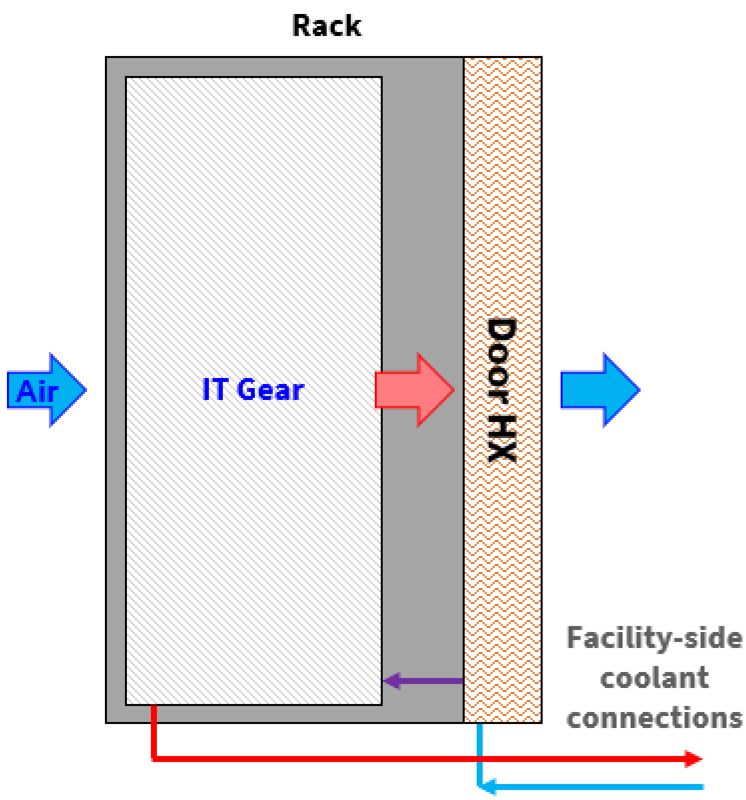


Figure 2: Simplified depiction of a rear door heat exchanger and facility coolant used to enable liquid cooling of IT gear

2.2 Liquid-cooled hybrid solution (air-to-liquid and liquid-to-liquid)

This solution is an extension of the traditional approach with the added feature of liquid-cooling IT hardware components in the rack. Availability of facility coolant at the rack is leveraged to liquid-cool high-power components in IT chassis. Rack-level liquid cooling infrastructure such as cold plates and manifolds are required. An in-rack CDU may also be employed for better control of coolant to the cold plates in each IT chassis. The rear door heat exchanger continues to serve a traditional function of capturing heat from exhaust air in order to return air to the room at or near the inlet air temperature to the rack. This approach may help enable higher IT component and rack powers. The rear door heat exchanger can be either a passive or active design.

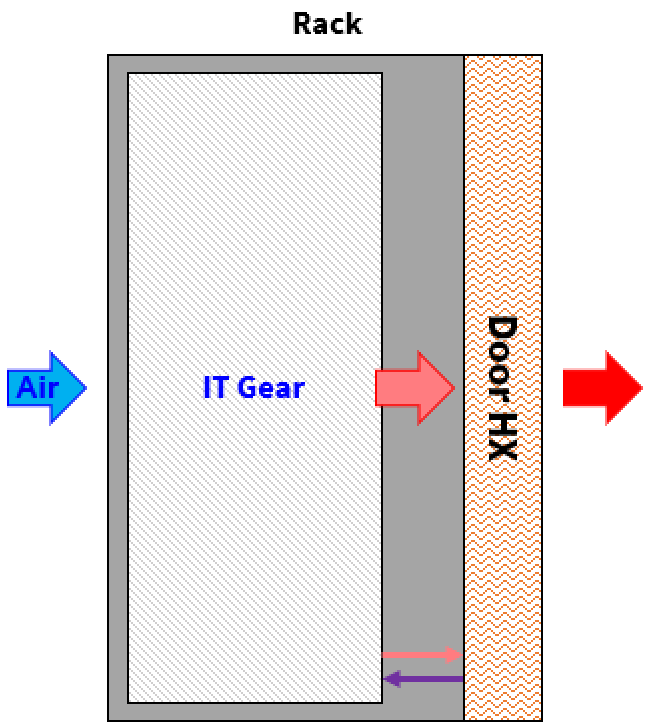


Figure 3: Simplified depiction of hybrid solution which use facility air to cool an internal coolant loop

2.3 Air-assisted solution (liquid-to-air)

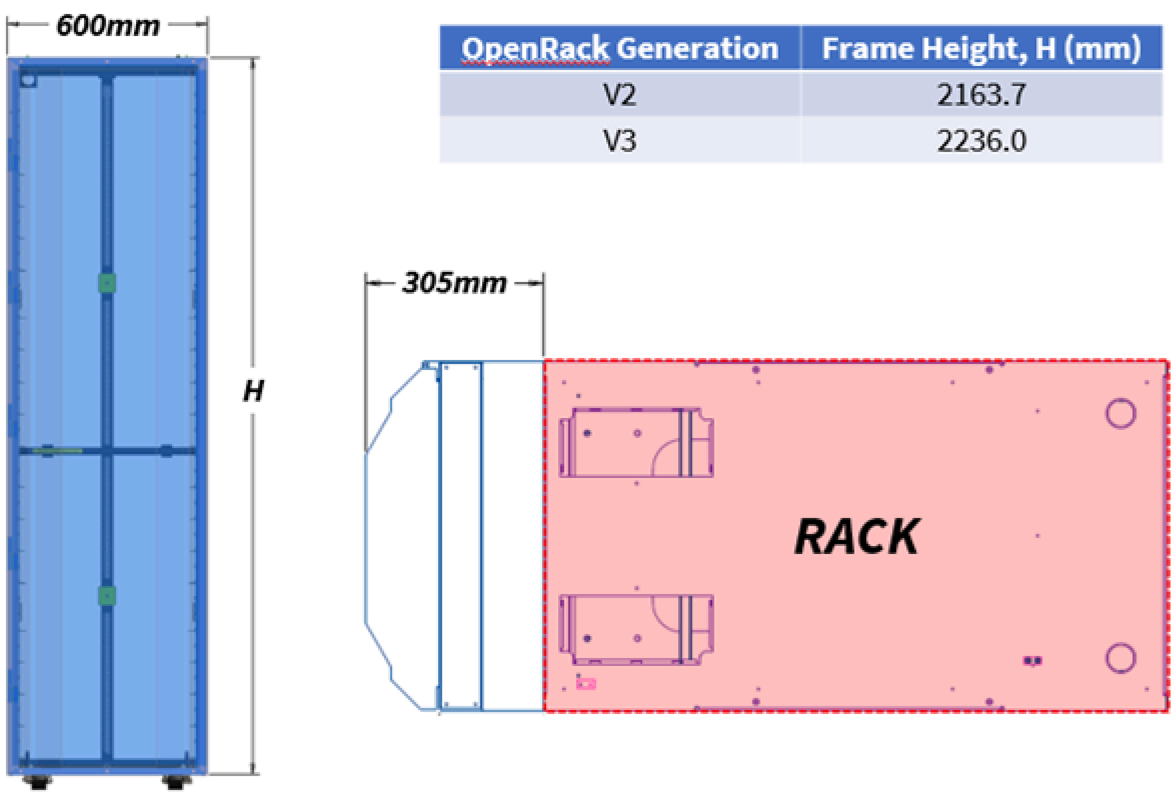
This solution can be envisioned as the opposite of the one described in section 2.2. Heat exchanged in an internal (closed) coolant loop is exhausted to facility air using a door heat exchanger. Figure 3 provides a simplified depiction of how this system functions. Rack-level liquid cooling infrastructure such as cold plates, manifolds and CDU (coolant distribution unit; term used in a general sense here) are used to cool high-power IT components such as CPUs, GPUs, etc. The CDU drives the internal fluid loop and the door heat exchanger exhausts heat by using exiting air from the IT gear. Therefore, such a rack is 100% air-cooled and cold plates installed on components will receive above-ambient temperature coolant for heat transfer. This solution can provide the benefits of liquid cooling in an air-cooled facility. The door heat exchanger can be either a passive or active type and is selected based on the capability of IT (server) fans and required cooling capacity (kW).

3. PHYSICAL SPECIFICATIONS

3.1 Physical dimension of Door Heat Exchanger (Door HX)

Face area dimensions of the Door HX should be compatible with Open Rack architectures. Installation of the door to a rack should not impact deployable rack-to-rack pitch or require the addition of auxiliary components. Guidance for Door HX designs, whether active or passive, are as follows:

- The overall width of Door HX should be within the Open Rack's primary structure/frame, including structural elements or the external frame housing the heat exchanger core and an adapter frame for mounting against the rack.
- The overall height of Door HX should be within Open Rack's primary structure/frame, not including components touching the facility floor such as castors and levelling feet. The only components permitted to extend beyond said definition are coolant connections and physical interfaces specific to active doors such as power delivery and communication. The adapter frame may have adjustable feet for height alignment and load bearing. In general, leveling feet (or features) should be compliant with rack-specific requirements.
- Maximum preferred depth is 1ft (305mm), including the adapter frame for mounting against the rack. The detail dimension of rack and depth of Door HX is shown in Fig. 4. This requirement may be violated as long as the aisle spacing and/or ability to open the door by at least 90° (as outlined in Fig. 5) are met. Note that this should be agreed upon between the end-user and solution provider.



OpenRack Generation	Frame Height, H (mm)
V2	2163.7
V3	2236.0

Figure 4: Rear and top view of Open Rack showing maximum dimensions of mounted Door HX assembly

3.2 Layout Impact to Data Center

The Door HX shall be removable and mounted to Open Rack with a hinged solution for quick access to the rear side of the rack for easy servicing and maintenance, such as fans, power-bus bar, manifolds, etc. The operation of the Door HX should not impact any pre-existing data center layout or design aspects. This includes:

- When mounted to a rack and primed with coolant, the combined weight should be ≤1400kg (3086lbs) for Open Rack v2 and ≤1600kg (3520lbs) for Open Rack v3. Correspondingly, dry weight of the Door HX assembly and fluid volume should be provided for engineers to determine if this could meet data center floor loading limitations based on coolant employed. The maximum weight of Door HX with fluid volume shall be less than 150kg. The preferred weight of Door HX with fluid volume should be ≤ 100kg.
- Depending on layout and design of the data center, width of the aisle between rack faces can vary. The door heat exchanger defined here will require a minimum 3.94ft (1200mm) spacing in the aisle to permit opening of the hinged door heat exchanger at least 90° without interfering with adjacent racks as well as those across the aisle. The diagram describing this detail is in Fig. 5.

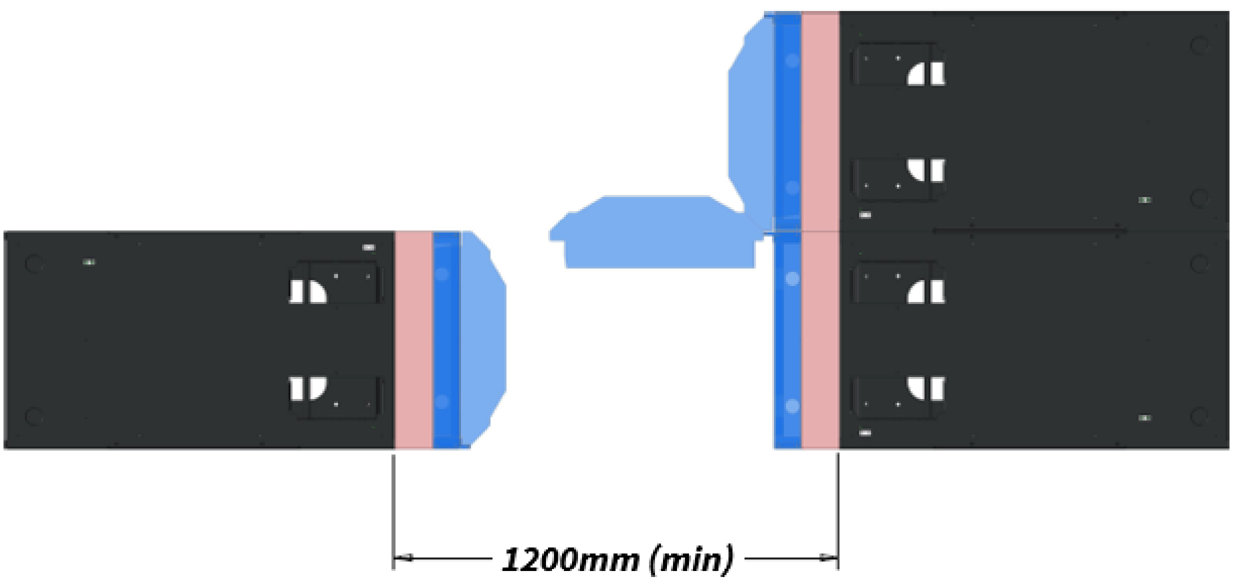


Figure 5: Required minimum aisle width to accommodate opening of Door HX by 90°

3.3 Physical Interfaces connections

As previously outlined, a Door HX may be either a passive or active variant. Depending on the type, following connections might be required

- *Connections to facility coolant*: Connections should be permitted from both top and/or bottom sides and should accommodate different interface types for flexibility on-site. Rigid pipe terminations at the door heat exchanger assembly are recommended to be 1" ID BSP type, with potential to accommodate/grow up to 1.5" ID. There should not be more than two connections to facility coolant; one connection for cold-coolant supply and another for hot-coolant return.

- *Electrical connections*: The active Door HX should include active fans mounted on the accessible side of heat exchanger assembly. To provide power to the assembly, 110 or 230VAC (50/60Hz) supply options via standard C14 or C20 plug-in connector are recommended. Additional recommendations include door heat exchanger assembly being powered by the IT rack it is mounted against as well as support for A/B power supply redundancy (AC only). DC power may be supplied directly from the Open Rack busbar to the Door HX solution. In this case, it's important to ensure that PSU and BBU shelves, and bus-bar design account for additional load.
- *Communication*: RS485 or RJ45 (Ethernet) ports should be supported along with the following protocols - Modbus RTU/IP, SNMP v2/3 or HTTP (webserver). Similar to electrical connections, from a communication standpoint, it is recommended the Door HX assembly be a part of the rack it supports.

4. OPERATING (DC ENVIRONMENTAL) CONDITIONS

This section outlines supply conditions and operational targets of cooling resources provided by the facility for both IT gear within the rack as well as the Door HX. The final thermal solution of the system should be optimized and energy-efficient under both data center environmental and server operational conditions with the lowest capital and operating costs.

4.1 Air-side conditions

OCP Ready guidelines stipulate that compliant gear should meet Class A1 allowable environmental specifications as outlined in the fourth edition of Thermal Guidelines for Data Processing Environments (ASHRAE, 2015).

4.2 Water-side conditions

Following details outline the data center water-side supply or operating conditions.

- Coolant supply (inlet) temperature is a function of the data center or facility's capability. As general guidance, it's recommended to not drop below 16°C to avoid excessive condensation in the door heat exchanger solution. This is within range of W1 class by ASHRAE's definition. Note, this does not stipulate that coolant temperature be maintained between 16~17°C, but rather defines a minimum requirement.
- Coolant-side temperature difference across Door HX: This value should be maximized to boost efficiency of facility-level cooling infrastructure, unless explicitly specified/defined by the data center (for example, ≥ 8°C). In practice, this parameter would depend on desired air-side performance and cooling capacity, it is usually specified by the customer, and involves a tradeoff between Door HX and chiller performance.
- Supported coolant types: May include water, glycol/water mixture and dielectric (highlighted for reference only), and is usually specified by the customer.
- Operating pressure is a function of the data center or facility's capability. As general guidance, a floor-level coolant distribution unit may have a range of 140 – 450kPa. Direct use of facility water may expose the equipment to higher operating pressures, especially

in multi-story facilities. The door heat exchanger assembly must be designed to operate under said conditions.

- If water is used as the coolant for the door heat exchanger assembly, it is recommended to follow ASHRAE's guidelines for water quality in the second edition of Liquid Cooling Guidelines for Datacom Equipment Centers (ASHRAE, 2014). Note there are specific recommendations based on whether the door heat exchanger assembly is connected to the FWS (Facilities Water System) or TCS (Technology Cooling System) loops.
    - Facility level coolant: Chapter 5, Table 5.3 Water Quality Specifications for Facility Water System (FWS) Loop
    - Equipment-level coolant: Chapter 6, Table 6.2 Water Quality Specifications - TCS Cooling Loop

  In addition, the following guidance may also be leveraged - VDI 2035 Part 2, Table 1
- Filtration requirements depend on the type of implementation. In the traditional application of a Door HX, IT gear in the rack is air-cooled, and filtration at the facility-level should be adequate. For a hybrid solution, coolant is used by Door HX and IT gear (cold plates, manifolds and in-rack CDU). Due to smaller flow dimensions in this case, specific filtration requirements may need to be addressed, as outlined in the white paper on Water-Cooled Servers - Common Designs, Components and Processes (ASHRAE, 2019).

5. PERFORMANCE / METROLOGY

Before performance and operational requirements can be highlighted, parameters of importance should be defined (as outlined in the following table). These apply to both active and passive types of the Door HX.

Table 1 – Parameters of importance and associated units

Parameter	**Units**
Rated cooling capacity	kW
Power consumption (at rated capacity)	W
Coolant inlet temperature	°C
Coolant outlet temperature	°C
Coolant flow rate	m^3/h or l/min
Coolant system pressure difference	kPa; curve based on flow rate should be provided
Air inlet temperature (approaching door)	°C

Air outlet temperature (leaving door)	°C
Air flow rate (through door; at 0Pa pressure difference between rack interior and room ambient)	m^3/h or ft^3/min
Air-side pressure drop across door assembly (for passive type)	Pa; curve based on flow rate should be provided

Requirements are highlighted as follows:

- For the active variant, N+1 rotor/fan redundancy is a must. In the event of a failure, increasing speed of functioning fans is permitted. To prevent recirculation or leakage through a failed unit, fans may be equipped with baffles (or equivalent component).
- Face area of the heat exchanger within the supporting frame should be maximized for performance and minimal backpressure. Finned footprint of Door HX core should be outlined for simulation/analysis.
- Curves (or table) of cooling capacity based on given coolant and air flow rates, inlet temperatures to the door, coolant of choice and operation at sea-level. Curves (or tables) corresponding to fan failure operation should also be included; specifically, impact to airflow requirements to achieve the rated cooling capacity.
    - Test conditions should be based on IEC 62610-4 for verification and reporting of performance parameters such as cooling capacity, etc.
    - For the purpose of defining a rated cooling capacity, the following boundary conditions may be assumed

Table 2 – Reference conditions for verification of cooling capacity

Parameter	**Value**
Coolant inlet temperature	16°C
Air inlet temperature (approaching door)	45°C
Air outlet temperature (leaving door)	30°C
Altitude	0ft (sea-level)
Coolant type	Water (purified)

- For the passive type, low air-side pressure drop is highly recommended to minimize or eliminate the need for server fans to operate at higher speeds, thereby increasing cooling power. Impedance curve (pressure drop versus volumetric flow rate) based on sea-level operation should be provided.
    - For the passive type, it's recommended to maintain a pressure drop ≤ 15Pa at rated airflow
    - For the active variant, total power consumption should be ≤ 2% of rated cooling capacity (not including operation under fan failure)

- Low coolant-side pressure drop is highly recommended for efficient operation of the facility. Impedance curves for different coolant operations should be provided.
    - Pressure drop across the entire door heat exchanger assembly (including piping, valves, sensorics, etc.) should be ≤ 100kPa at rated coolant flow rate
    - Nominal operating coolant pressure should be ≤ 600kPa. This value is adequate to cover a row-level CDU (coolant distribution unit); however, a facility-level CDU might provide a higher pressure. In such cases, the vendor and end-user should work together to address this.
    - Maximum allowable coolant pressure should be ≤ 1000kPa (short-term operation; safety measure may be triggered beyond this value).

6. MONITORING & CONTROL

To ensure effective and efficient operation of the door heat exchanger, sensors and control represent valuable implementations or additions to the solution. Clear definition of sensor parameters (such as thresholds and alarms) enable the operator to ensure the device continues to function as intended in the long-term. Since passive and active variants function and may be operated differently, definitions/requirements are listed separately.

Table 3 – Sensors, controls and alarms for a passive Door HX

SENSORS – REQUIRED	
Type	**Detail/Comment**
Air temperature, In	More than one sensor preferred
Air temperature, Out	More than one sensor preferred
SENSORS - OPTIONAL	
Type	**Detail/Comment**
Air differential pressure	
Water temperature, In	
Water temperature, Out	
Water flow rate	
Water pressure	
Air humidity	

CONTROLS – OPTIONAL LOOP TYPE	
Parameter	**Detail/Comment**
Air temperature, Out	
Air temperature, Differential	
Water temperature, Out	
Water temperature, Differential	
CONTROLS – MANUAL	
Parameter	**Detail/Comment**
Water valve position	Manually adjusted at deployment; Pressure Independent balancing and Control Valves (PICV) are recommended, especially for multi-door installations.
ALARMS	
Name/Type	**Detail/Comment**
General	A single, binary definition that indicates there is an alarm condition
Power status	Binary (ON/OFF)
Air temperature, In	
Air temperature, Out	
Door open	Optional
Leak detection	Optional
Air differential pressure	Optional
Water temperature, In	Optional
Water temperature, Out	Optional
Water flow rate	Optional

Water pressure	Optional
Water valve position	Optional
Smoke	Optional

As an active rear door heat exchanger has more components and functionality compared to its passive counterpart, the following definitions/requirements apply in addition to those defined for the passive solution.

Table 4 – Additional sensors, controls and alarms for an active Door HX

SENSORS – REQUIRED	
Type	**Detail/Comment**
Fan speed	
Number of fans installed	To check deployed configuration
Input power	AC or DC input power
CONTROLS – OPTIONAL LOOP TYPE	
Parameter	**Detail/Comment**
Air temperature, In	
Air differential pressure	
CONTROLS – MANUAL	
Parameter	**Detail/Comment**
Fan speed	Manually adjusted at deployment or in-operation
ALARMS	
Name/Type	**Detail/Comment**
Fan speed	

Monitoring and reporting should employ the REDFISH standard (Redfish Scalable Platforms Management API). For more information, refer to: https://www.opencompute.org/wiki/Hardware_Management/SpecsAndDesigns

The table below outlines parameters that may be defined in the header section of the REDFISH Door HX JSON file.

Table 5 – Parameters in header section of JSON file

Parameter	**Detail/Comment**
Name	
Manufacturer	Static
Model number	Static
Serial number	Static
Manufacture date	Static
Door HX type	Static; active or passive
Hardware revision	
Firmware revision	
Physical location	Optional
Asset tag	Optional

REDFISH schema and reference documentation are currently TBD.

7. SERVICEABILITY

In general, the Door HX solution should be designed with ease of maintenance or serviceability in-mind. This includes (but may not be limited to) the following:

- Ease of replacing Door HX - draining, un-mounting, installation and priming/charging
- Ease of access to physical interfaces (coolant connections, power supply and communication cables)
- Collection of expelled coolant (in case of leaks) and condensation in a drip tray with a feature to enable draining in-operation (or intermediate/external collection in facilities that do not have a raised floor or run-off area)
    - As a general guidance, coolant supply to the door heat exchanger may be raised to ≥ 16°C to avoid excessive condensation in the door heat exchanger (or specific value depending on the air-side operating conditions of the facility)
- Ease of replacing fan modules

- Ease of replacing sensors or other accessible parts

8. RELIABILITY & QUALITY

This section will focus on aspects such as pressure or leak testing, sealing of airflow within the rack and other areas that can influence operational quality of a Door HX solution.

8.1 **Pressure/leak testing**

Ensuring the door heat exchanger solution has undergone adequate checks to prevent leaks in-operation is critical to deploying with confidence. Checks at both manufacturer and end-user locations are generally recommended. However, it's up to both parties to agree upon a course of action. Following sections outline recommended procedures for pressure testing and leak prevention.

- *Checks at manufacturer (required)*

  A common leak detection test is the pressure decay method. The complete door heat exchanger assembly should be pressurized with gas to a factor times the maximum allowable pressure (defined as ≤ 1000kPa in the section on Performance & Metrology). In general, the factor required for pressure testing is based on which standard is employed. IEC 62638-1 stipulates setting twice (2) the abnormal or single-fault condition and ASME B31.n series, specifically B31.3 for process piping, states setting 1.5x design pressure (both can be based on maximum allowable pressure as outlined earlier in this section). As to which standard should be followed, that's a decision to be made between manufacturer and end-user.

  The leak value can be calculated as follows: $Q = (P_1 - P_2)V/t$

  Where,

  Q is the leak rate in mbar.l/s

  P_1 is pressure at the start of the test in mbar

  P_2 is pressure at the end of the test in mbar

  V is internal volume of the test sample in l (liters)

  t is duration of the test in s (seconds)

  Since both P_1, V and are known, test duration (t) is the variable that is adjusted to achieve a desired leak rate (Q) and depends on the sensitivity of the test equipment (primarily, the pressure transducer). Industry standards define 'water tight' as a leak rate of 10^{-2} mbar.l/s when helium is employed as the test medium.

Table 6 – Helium leak rate for different seal qualities [reference]

Leak definition (seal quality)	Helium leak rate (mbar.l/s)

Water-tight	10^{-2}
Vapor-tight	10^{-3}
Bacterial-tight	10^{-4}
Fuel-tight	10^{-5}
Virus-tight	10^{-6}
Gas-tight	10^{-7}
Insulator seal-tight	10^{-10}

Gases other Helium may be employed for testing, such as air or Nitrogen. However, the leak rate definitions in Table 1 should be adjusted using multiplication factors based on whether the leak rate qualifies as either laminar viscous or molecular flow.

Table 7 – Converting leakage rate of helium to other gases

Medium to convert to	Multiply factor (multiply helium leakage rate by)	
	Laminar flow	Molecular flow
Argon	0.88	0.316
Air	1.08	0.374
Nitrogen	1.12	0.374
Water vapor	2.09	0.469
Hydrogen	2.23	1.410

Prior to shipment, the product should be charged with Nitrogen at the nominal operating pressure limit. At the integrator or end-user's site, if pressure is deemed present at-release (auditory signal), the product could be considered to have passed transportation.

- *Checks at integrator or end-user (recommended)*

Prior to deployment, the product (post-integration) should undergo a final pressure check (like the criteria in Table 7, but with compressed air) prior to charging. To accommodate this, the Door HX assembly may be outfitted with a separate valve.

- *Leak detection in operation (recommended)*
  - Regular inspection of the system to check for droplets/leaks
  - Optional electronic leak detection at cabinet or floor level

1. **Sealing of in-rack airflow**

Sealing on the adapter frame and/or Door HX should be adequate to minimize leakage of server exhaust or entrainment of facility air. It's important to note that sealing within the rack is equally critical and should be considered as well.

For an IT rack employing a Door HX, the quality of airflow sealing at both sub-rack (or chassis) and cabinet (or rack) levels can be determined in accordance with IEC 62610-6. This standard helps define metrics for airflow recirculation and bypass, as well as measurement methods and should serve as guidance for rack integrators. In general, both recirculation and bypass ratios should be kept to a minimum to ensure cooling efficiency. Following are a few points to take note of:

- Installation of a rear-mounted door heat exchanger should not impact sub-rack or chassis inlet temperatures. When employing a passive door heat exchanger, added impedance should be understood to not severely impact recirculation. This could be addressed with adequate in-rack sealing.
- A rear-mounted door heat exchanger solution should interface with adequate sealing to the rack frame to avoid unnecessary, rack-level airflow bypass. When employing an active door heat exchanger, fan control logic should be appropriately tuned to ensure airflow is efficiently used or prioritized through the IT chassis. Once again, adequate in-rack sealing is critical here.

9. ENVIRONMENTAL & REGULATIONS

9.1 Storage, Transportation & Contamination

The following environmental tests are recommended for execution per MIL-STD-810G, IEC 60068-2. The systems pre- and post-test should be verified for any functional impact.

Table 8 – Non-operational environmental conditions

Parameters	**System**
Gaseous Contamination	Severity Level G1 per ANSI/ISA 71.04-1985
Storage Relative Humidity	10% – 90%
Storage Temperature (Long Term)	-40°C – +70°C
Transportation Temperature (Short Term)	-55°C – +85°C

System should meet the following set of tests as applicable to reliability, and compliance needs

- Hydrostatic Pressure Test
  - Normal, Abnormal operation, and Creep resistance based hydrostatic pressure tests per IEC/UL62638-1 are to be executed.
  - The system is expected to meet the criteria of being able to sustain three times, and two times the maximum working pressure per design specifications while testing for normal, abnormal operational conditions respectively.
  - Creep resistance tests involve pre-conditioning of the units followed by hydrostatic pressure tests as listed above with the general requirement of no visible signs of rupture, cracking, embrittlement, and loose parts, or assemblies.
- Tensile Strength Test
  - Tensile strength of the system is recommended to be tested per ISO 527, IEC/UL62638-1. Tensile strength of the pre-conditioned unit should not be < 60% of tensile strength before the test.
  - System should not see any visible signs of cracks, rupture, as well as functional impact.
- Mechanical Strength Test
  - Force test on critical assemblies, part of the system is recommended to be executed per IEC/UL62638-1.
  - System should not see any visible signs of cracks, rupture, as well as functional impact.

9.2 Vibration & Shock

Table 9 - Vibration and shock requirements

		Non-Operational
Rack	**Product Sine Sweep**	0.25G, 1-200-1 Hz, 1 Octave/min, 1 Cycle
Product Vibration Test	**Mechanical Handling-I**	1. Rotational Flat Edge Drop 2. Rotational Corner Drop 3. Side/inclined Impact 4. 22 deg Tilt 5. Flat/Vertical Drop 6. ASTM D880-92, D6179-07 Level-II
	Truck Transportation Test	ASTM D4169-16, D4728-17 (1-200 Hz, 180 min)
	Mechanical Handling-II	1. Rotational Flat Edge Drop 2. Rotational Corner Drop

		3. Side/inclined Impact 4. ASTM D880-92, D6179-07 Level-II

9.3 Regulations / Compliance

- Comply with IEC/UL 60950-1, 62638-1 3rd edition
- General safety construction requirements
  - All products shall not contain any hazardous, flammable, or toxic substances classified by law or local regulation, and MSDS (Material Safety Data Sheet) must be provided. No liquid spillage is allowed during normal and abnormal operating conditions.
  - Galvanic corrosion should be mitigated, and essential coating/protection requirements should be enforced so as to curtain high temperature, relative humidity conditions.
- Plastic parts flammability
  - Plastic parts shall be made of min. V-1 material.
  - Tubing can be made of min. HB75 class material if the thickness of the material is < 3 mm, or min. HB40 class material if the thickness of the material is ≥ 3 mm.
- Leakage fail safe
  - The system shall provide safeguards (such as a barrier or drip pan or supplementary containment vessel) against any spillage of internal liquid to effectively limit the spread of the spillage.
  - The leak from tubing connectors and similar joints in the liquid system shall not bridge an insulation in the final end product.
  - If the liquid is corrosive, the leak shall not touch any connection of a protective ground conductor.

9.4 Labels and Markings

Labels and marking indicating the compliance of the system and/or sub-assemblies should be affixed for clear visibility.