



# OPEN

Compute Project

## Pivoting Blind Mate Coupling (PBMC) Specification

Revision 1.0

**Design Specification**

Effective April 15, 2026

Authors: Glenn Charest – Meta, John Fernandes - Meta, Nick Goenner – SafeWay,  
Andy Holst – Parker, Thomas DeVaux – CEJN, Robin Hansen - CEJN

## Version History

Date	Version #	Author	Description
04/15/26	1.0	G. Charest	Submitted for Publication

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Date: 04/15/26

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## **1.2. Acknowledgements**

The Contributors of this Specification would like to acknowledge the following companies for their feedback:

CEJN - Kenneth Kjellberg  
Meta - Agraj Sobti, Ellie Chen, Ben Kim  
Parker - Tim Marquis  
Cooler Master - Joseph Tseng

## **2. Compliance with OCP Tenets**

### **2.1 Openness**

This specification shares the key design interfaces and requirements to enable others outside of the group to use and adopt the valve designs for their application.

### **2.2 Efficiency**

The sharing of this specification will allow others to leverage the components and save development time.

### **2.3 Impact**

The sharing of this specification will allow others to leverage the components and save development time.

### **2.4 Scale**

The development of this specification with multiple suppliers that are interoperable enables the solution to be deployable at scale.

### **2.5 Sustainability**

This specification enables liquid cooling at scale and will help reduce power consumption.

## 3. Overview

### 3.1 Description

As the cooling needs grow with more powerful systems, there's a demand for a 1OU/1RU blind mate valve solution that offers higher flow and lower impedance. To achieve this at scale, PBMC was being developed as a multi-sourced and interoperable solution. The Pivoting Blind Mate Coupling (PBMC) is a self-contained blind mate valve solution designed to handle significant misalignment and variations in mate distance that are common in modular and rack-based systems. The design consists of a plug and socket valve and both feature an innovative approach for misalignment; the valve bodies pivot to accommodate misalignment. PBMC addresses common challenges related to hose selection (stiffness, materials) and hose routing for internal hose to IT gear to valve connections.

The specification will include the following collateral:

- Reference 3D design step files of the valves
- PBMC Test Fixture Guidelines & Procedures
- Test Order Example

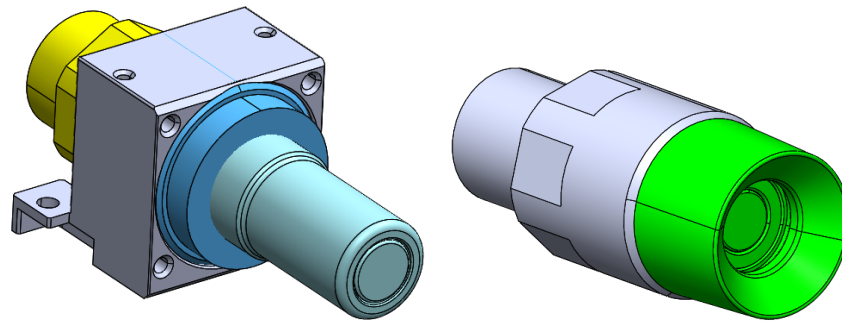
### 3.2 Rack Compatibility

The solution is not designed for a specific rack design. The PBMC design features large allowable misalignment and working range (mate distance) capabilities to enable use in rack level and modular solutions. The designer will need to validate that their design meets the requirements of PBMC.

## 4. Design Basics

The design consists of a blind mate plug and socket valve that each pivot about an internal vertex to adapt to radial and angular misalignment, see Figures 4.01 & 4.0.2 for details. The PBMC design includes the following:

- Both the plug and socket valves pivot to take up misalignment
- High flow and relatively low flow impedance
- The plug features several attachment options to attach the plug to the IT gear
- The plug valve pivoting mechanism is decoupled from fluid connections to enable the use of stiffer hoses and hose routing flexibility within the IT gear
- Plug valve design incorporates a swivel on the fluid connection to ease installation



Plug Valve

Socket Valve

Figure 4.0.1 PBMC Plug (left) and Socket (right)

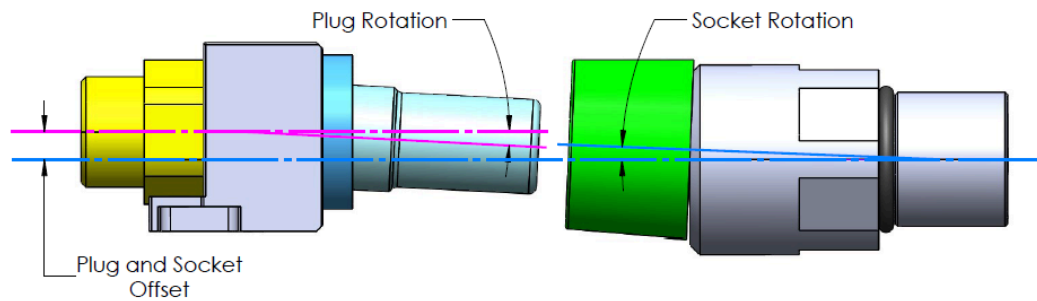


Figure 4.0.2 Plug and Socket Rotating to Accommodate Misalignment

### 4.1 Plug Valve Design

The plug valve assembly features (1) a fixed main body with interface features to attach and locate the valve to the chassis (2) a pivoting body that rotates about a centroid in the valve to adapt to misalignment and (3) a rear hose interface that rotates about its axis.

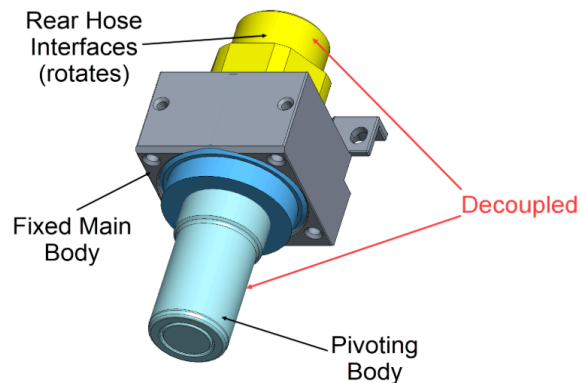


Figure 4.1.1 Plug Valve Components

The plug hose connection and the blind mate pivoting body are decoupled and separate components (see Figure 4.1.1). This design approach enables developers to have more hose selection and routing options as hose stiffness and routing do not affect valve movement on the connection side of the plug. For example, this decoupling enables a right angle connection directly after the plug (see Figure 4.1.2). Note the hose between the valve and the other end of the hose connection will need some flexibility to account for assembly tolerances and other effects.

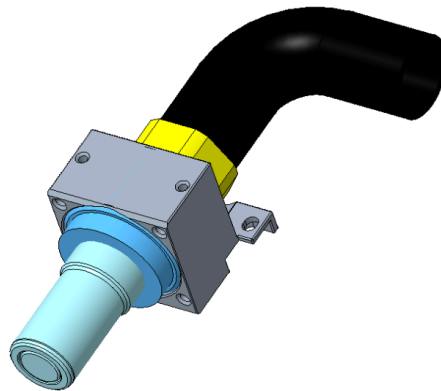


Figure 4.1.2 Plug with hose connected with close bend

The plug design also features a rear swiveling hose interface that rotates axially to allow the valve to rotate axially with respect to the hose allowing for rotation of the valve vs. the hose to ease the installation process. The swivel features a hex flat for use with an open face wrench to help with tightening the hose to the valve. This valve also has the potential to support other hose interface options.

## 4.2 Socket Valve Design

The socket assembly features (1) a fixed main body with interface features to attach, seal, and locate the valve to the manifold (2) a pivoting body that rotates about a centroid in the valve to adapt to misalignment. The socket port interface is outlined in Section 4.3.2. The socket main body also includes a hex flat to allow for the use of an open box wrench to install the valves. Note special open face “crows foot” style wrench may be required when valves are mounted in close pitch, where the part needs to narrow to clear the valves when tightening.

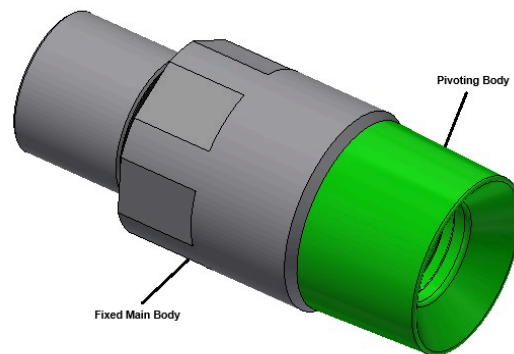


Figure 4.2.1.1 Socket Valve Components

## 4.3 Interfaces

### 4.3.1 Plug Valve Interfaces

#### 4.3.1.1 Fundamental Datums:

##### Datum A

Valve Main Body (Block) Face- This locates the valve to the chassis in the Y-direction. The valve features fasteners to tighten this face to the inside of the IT Gear Panel

##### Datum B

Valve Shoulder- This locates the valve to the chassis in the X- & Z-directions. The cylindrical feature is tightly controlled. To minimize assembly tolerances, tight fit hole design is recommended.

##### Datum C

Block Base- This surface is a secondary locator for the valve to the chassis in the Z-direction.

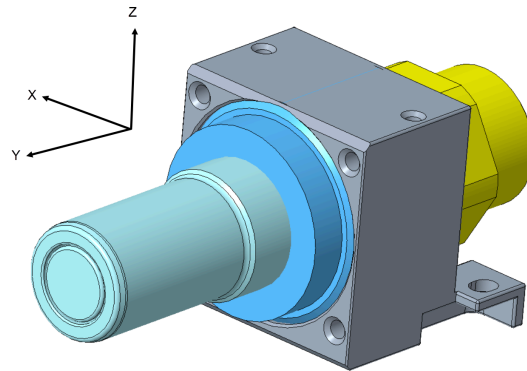


Figure 4.3.1.1.1 Plug Coordinate System

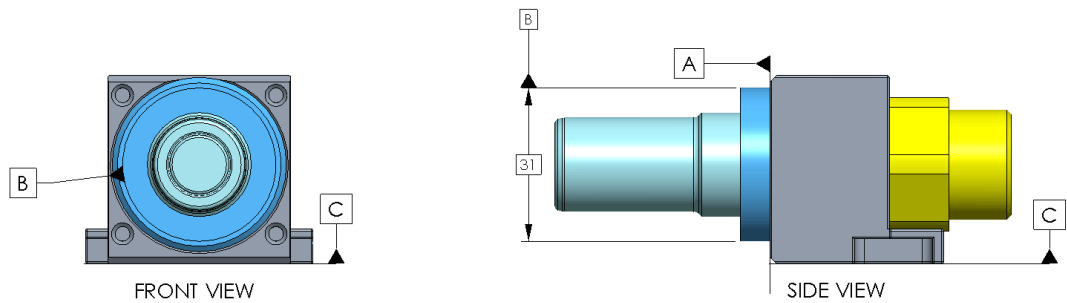


Figure 4.3.1.1.2 Plug Interfaces (Datums)

#### 4.3.1.2 Panel info

The maximum panel thickness for the plug valve (including any fasteners to attach the valve to the face) is shown in Figure 4.3.1.2.1 below. The panel hole size for the plug shoulder Datum B shall be as tight as possible, yet ensure clearance. The size and tolerance of the hole are not prescriptive as many manufacturing methods can affect the values. However, the designer shall account for the effect of the hole clearance and tolerances on their design tolerance analysis for the valves.

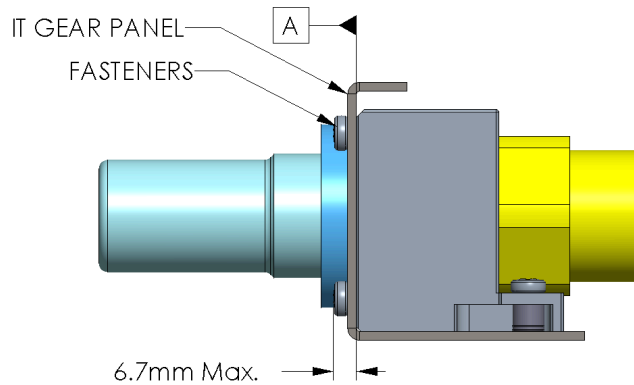


Figure 4.3.1.2.1 Plug Side View attached to a reference sheetmetal panel

#### 4.3.1.3 Plug Attachment Locations and Interfaces

The main body design includes several M3x0.5 threaded attachment options with varying thread depths as follows:

- Recommended: 4X threaded front face of the main body (the default fasteners used in fixture testing) recommended to be used
- Optional: 2X on the top of the main body
- Optional: 2X on the bottom of the main body
- Optional: 2X optional slotted clearance holes at the rear of the main body to support mounting the valve to a base sheet metal tray with a standoff; the main body features some clearance for sliding the valve into place during assembly

It is the designer's responsibility to determine the appropriate fastener lengths. Details on the screw interfaces are provided in Section 5.1.

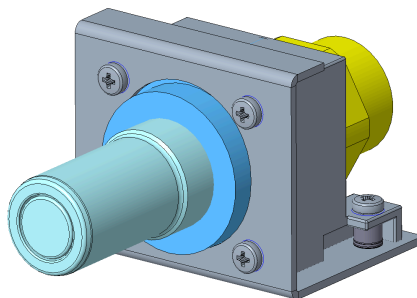


Fig. 4.3.1.3.1 Reference Example with bracket and fasteners on face and attached with standoffs on base

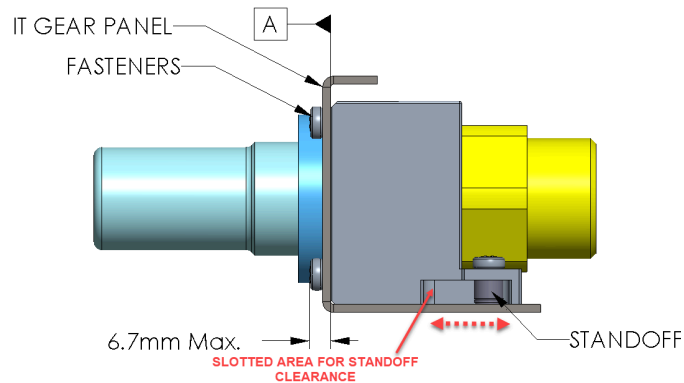


Fig. 4.3.1.3.2 Side View Showing Slot for Standoff Clearance

**Designer Reference Information:**

If the designer utilizes the top/bottom screws and/or attaches the valve to the base with standoffs, the designer will need to include the appropriate vertical hole to fastener clearances to account for valve and chassis tolerances to ensure the base will sit flush on the base of the chassis. This may include elongating the vertical locating panel hole for shoulder Datum B and/or elongating and/or increasing the diameter of the holes for the 4 face screws. The shoulder, Datum B, is one of the datums referenced for the misalignment capabilities, so it is recommended the locating hole for this be as tight as possible on the IT gear to minimize tolerance effects due to loose fit.

Note that fixturing for all durability and flow testing only uses the four M3 screws securing the panel to face Datum A with additional registration from the shoulder Datum B. Alternative mounting features are provided for design flexibility. If use of these optional features is desired, the designer will need to account for any additional tolerances and test to validate their design.

**4.3.1.4 Plug Fastener Tightening Torque:**

The maximum fastener tightening torque for the M3X0.5 threaded holes on the main body is 0.68 N-m (6.0 in-lb).

**4.3.1.4 Plug Hose Interface**

The plug hose interface is outlined below. The swivel could be designed to support other hose interfaces like a hose barb or internal threaded interface. The alternate interfaces are not part of the specification at this time.

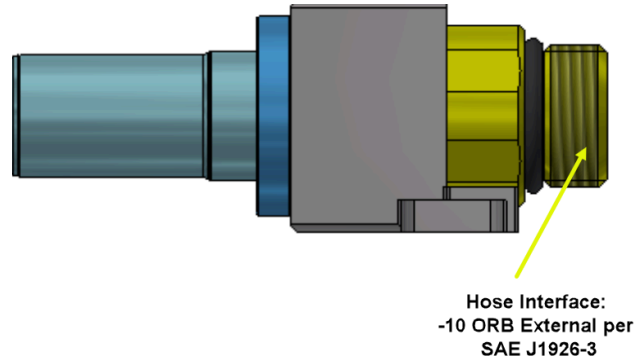


Figure 4.3.1.4 Plug Hose Interface

## 4.3.2 Socket Valve Interfaces

### 4.3.2.1 Fundamental Socket Datums

#### Datum A

Valve Seating Plane- This is the surface of the socket valve that sits flush with the manifold spot face when fully tightened to the manifold and constrains the valve in the Y-direction.

#### Datum B

Valve Shoulder- This is the center axis of the threaded section of the valve that threads into the manifold threaded port and constrains the valve in the X- and Z-directions.

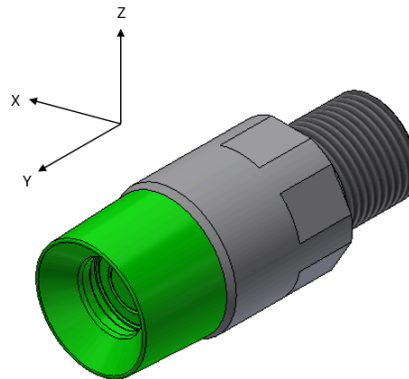


Figure 4.3.2.1.1 Socket Coordinate System

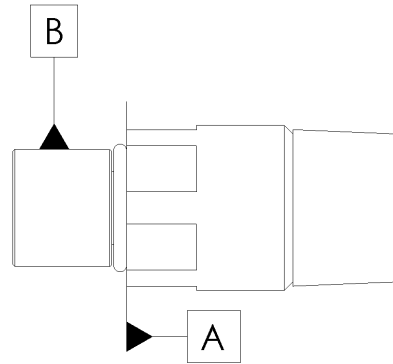


Figure 4.3.2.1.2 Socket Side View with Datums Annotated

#### 4.3.2.2 Socket Interfaces

The socket valve threads into a port with an ISO threaded interface. Details on this Interface information are provided in the table and image below.

**Table 4.3.2.2 Socket Interfaces**

Parameter	Value
Socket Valve threaded Interface	-12 ORB per ISO 11926-3 Exception: the stud length is longer than the standard (see below)
Socket Valve threaded stud length	MAX 26mm
Manifold Port Interface Standard	1 1/16-12 UN PER ISO 11926-1
Manifold Length spot face to end of port threads	MIN 14mm

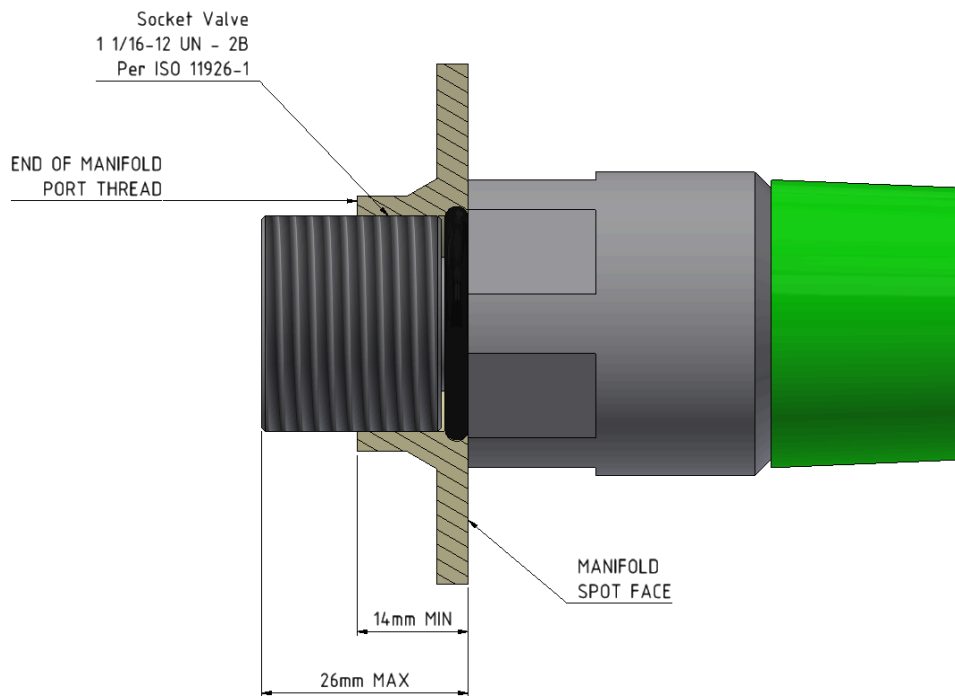


Figure 4.3.2.2 Socket Interface Info

#### 4.3.2.2 Socket Tightening Torque

The recommended maximum tightening torque for the socket is 60 N-m.

## 4.4 Mate Distance

### 4.4.1 Mate Distance Diagram

Below is a diagram outlining the interfaces and references used in defining the mate distance of a mated valve pair.

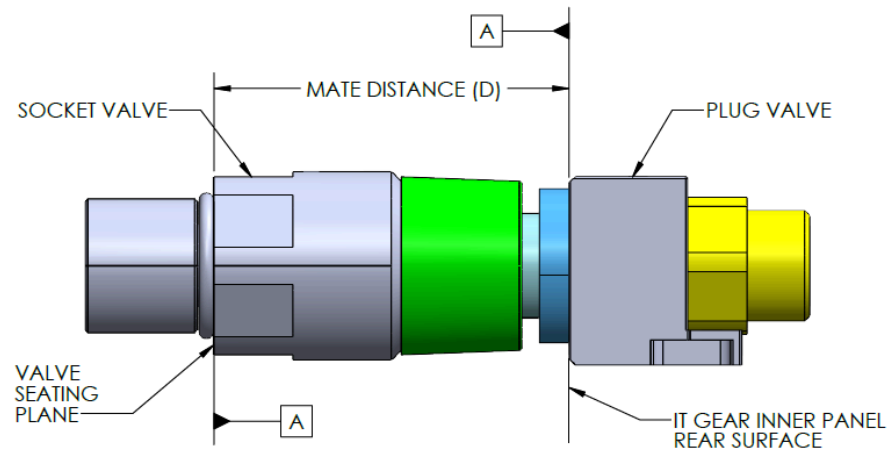


Figure 4.4.1 Mate Distance References for a Mated PBMC Plug & Socket

## 5.0 Mechanical Design Specifications

This section outlines the detailed design specifications for the PBMC valves and dust caps. Note that the drawings only define the critical interfaces and features, internal features for movement, general functionality, and self-centering are left to the supplier to define. The notes in Figure 5.0 below apply to all engineering drawings in this section.

1. INTERPRET DIMENSIONS AND TOLERANCES PER ASMY14.5-M 2009.
2. ALL DIMENSIONS ARE IN MM. 3D CAD FILE ALSO PROVIDED FOR REFERENCE.
3. DEFINED DIMENSIONS AND TOLERANCES, INCLUDING GD&T CONTROLS, TO MEET  $C_{pK} \geq 1.33$ .
4. ALL COMPONENTS SHALL BE ROHS AND UL COMPLIANT. ALL SEALS TO BE  $< 0.4g$  (EACH SEAL).
5. ALL PARTS AND COMPONENTS TO BE FREE OF BURRS AND SHARP EDGES.
6. ALL EDGES OR INTERFACES SURFACES TO BE RADIUSSED TO REMOVE BURRS AND SHARP EDGES TO PREVENT SCORING AND DAMAGE TO SEALS WHEN MATING. SIZE RADII PER SUPPLIER PREFERENCE.
7. SURFACE FINISH CALLOUTS SHALL BE INTERPRETED PER ASME Y14.36M AND ASME B46.1 STANDARDS. THE SPECIFIED REQUIREMENT REPRESENTS THE MAXIMUM ROUGHNESS AVERAGE ( $R_a$ ) ANYWHERE ALONG THE INDICATED SURFACE.
8. STUD & O-RING DIMENSIONS SHOWN FOR REFERENCE, SEE SPECIFIC SPECIFICATION FOR DETAILS.
9. MODELED 3D GEOMETRY FEATURES INSIDE SOCKET & PLUG THAT ARE NOT SPECIFIED WITH DIMENSIONS ARE MODELED FOR REFERENCE AND ARE TO BE DESIGNED TO SUPPLIER'S PREFERENCE
10. ANY FEATURES ON THE SOCKET PIVOTING BODY TO HAVE CHAMFERS OR RADII ON ANY FEATURES THAT ARE PROUD OF THE MAIN BODY.
11. VALVES TO BE SUPPLIED WITH DUST CAPS AS OUTLINED IN THE SPECIFICATION.
12. DEFINED ASSEMBLY DIMENSIONS DO NOT REQUIRE MEASUREMENT AFTER ASSEMBLY BUT COMPONENT FEATURES THAT AFFECT THIS DIMENSION SHALL BE CONSIDERED KEY CHARACTERISTICS PER NOTE 3 TO ENSURE ASSEMBLY LEVEL TOLERANCES ARE MET.
13. MARK PARTS IN AREAS SHOWN. MARK PART WITH:  
(1) SUPPLIER NAME, (2) PARTNO, & (3) BUILD DATE. SUPPLIER NAME CAN BE ABBREVIATED TO TWO LETTERS THAT INCLUDE THE FIRST AND LAST LETTER. FORMAT: SUPPLIERNAME-PARTNO-DATECODE
14. FIRST ARTICLE INSPECTION REPORT TO BE PERFORMED ON ALL DIMENSIONS CALLED OUT IN THE SPECIFICATION FOR THE VALVE COMPONENTS AND ASSEMBLIES. ON A MINIMUM OF 3 SAMPLES. REPORT TO INCLUDE FOR EACH DIMENSION:
  - A. DESCRIPTION OF THE DIMENSION
  - B. NOMINAL, MINIMUM, MAXIMUM VALUES PER THE SPECIFICATION
  - C. MEASURED VALUE
  - D. UPPER/LOWER DEVIATION (%)
  - E. MEASUREMENT DEVICE
  - F. SAMPLE SIZE OR MEASUREMENT FREQUENCY (AS APPLICABLE)
  - G. MEETS SPECIFICATION VALUE - YES/NO
15. FOR PROCESS CAPABILITY STUDY, MEASURE MINIMUM 32 SAMPLES FOR ALL DIMENSIONS DESIGNATED PER NOTE 3. INCLUDE THE SAME DETAILS AS NOTE 14 & ALSO INCLUDE FOR EACH DIMENSION:
  - H. CALCULATED  $C_{pK}$
  - I. MEETS  $C_{pK} 1.33$  - YES/NO

Figure 5.0 Drawing Notes

## 5.1 Plug Valve Design

### 5.1.1 Detailed Plug Valve Design

The detailed plug design drawings are provided below:

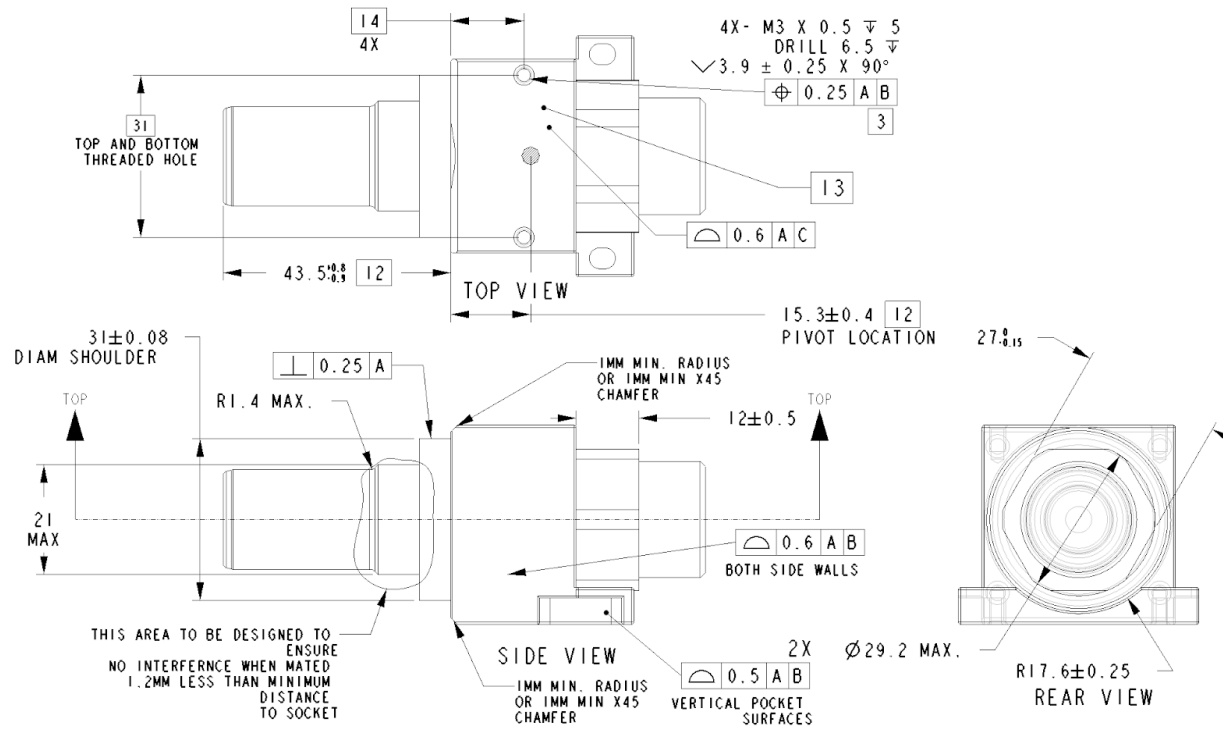


Figure 5.1.1.1 Various Views of Plug Valve

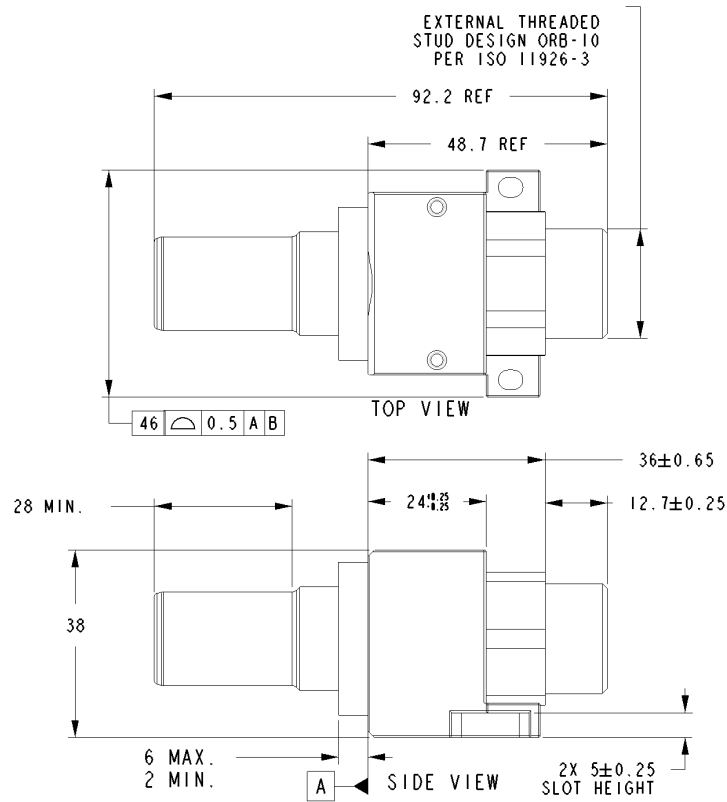


Figure 5.1.1.2 Various Views of Plug Valve

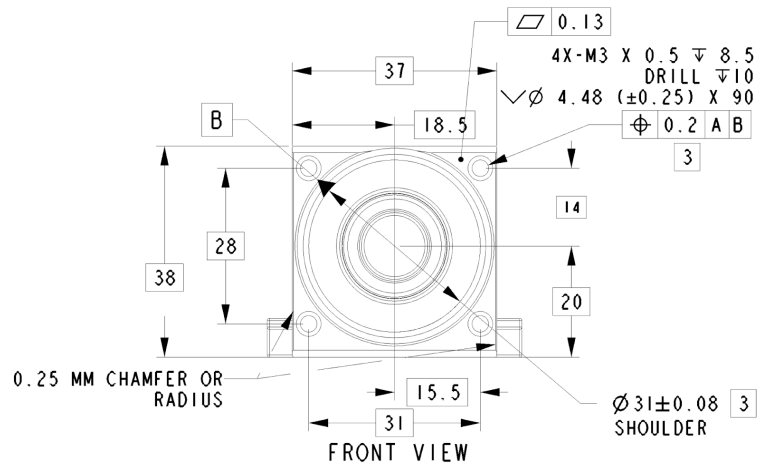


Figure 5.1.1.3 Front View of Plug Valve

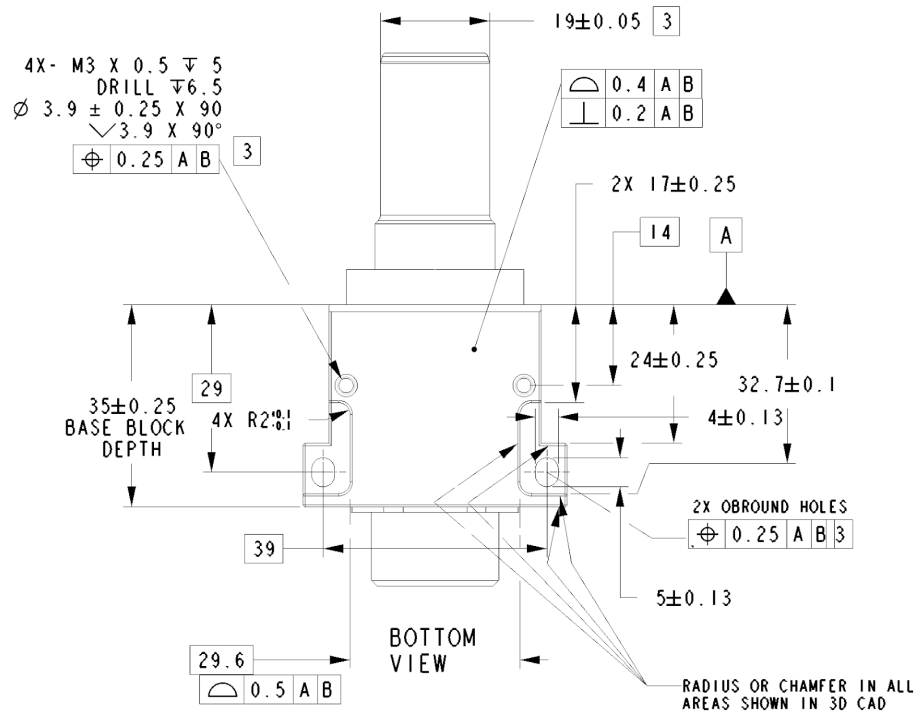


Figure 5.1.1.4 Bottom View of Plug Valve

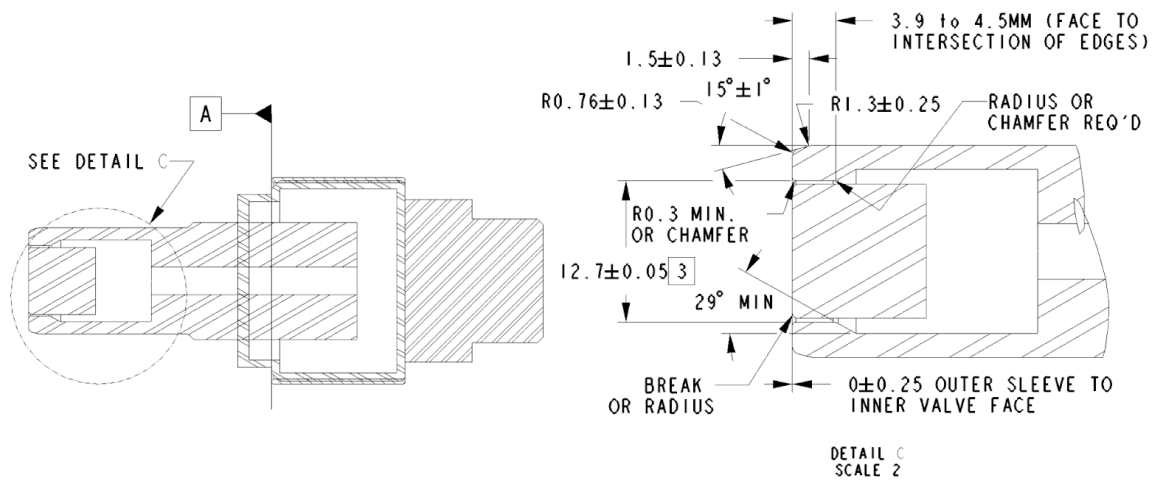


Figure 5.1.1.5 X-Section Side & Detailed View of Plug Valve

### 5.1.2 Plug Valve Weight

The plug valve shall have a weight not to exceed 330g.

## 5.2 Socket Design

### 5.2.1 Detailed Socket Valve Design

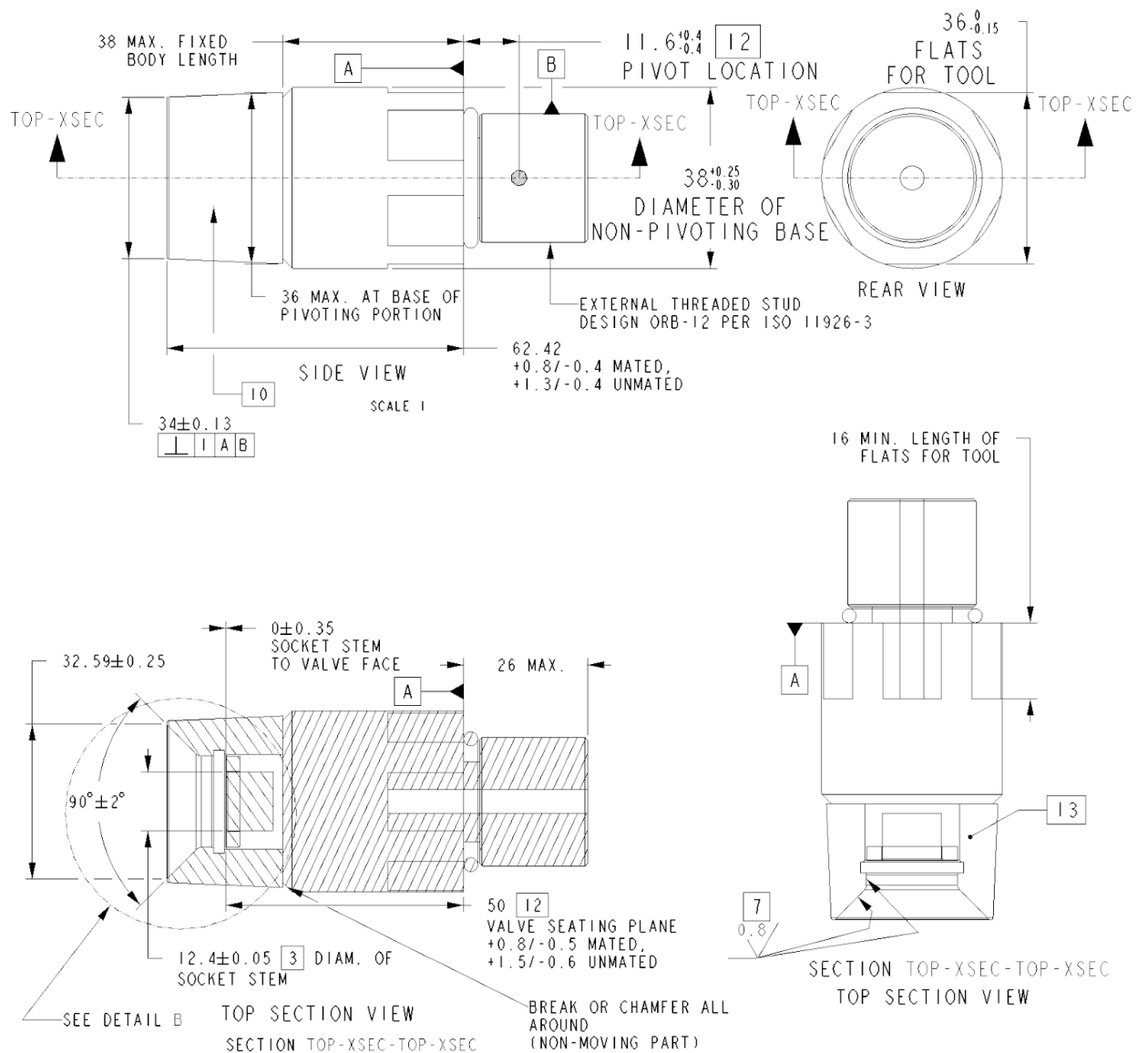


Figure 5.2.1.1 Various Views of Socket Valve

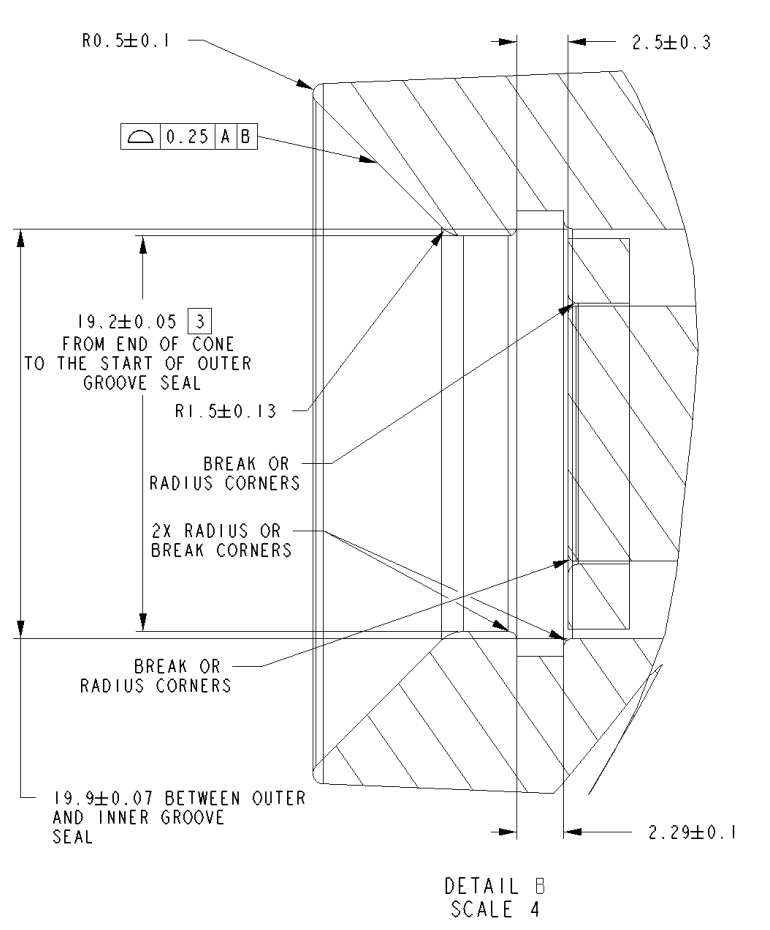


Figure 5.2.1.2 Detail B View Of Socket

The socket design pivots to adjust for misalignment. Below, is the nominal radial keepout zone that reflects how the socket moves to avoid interference. The designer should ensure that the system does not encroach upon the keepout zone below.

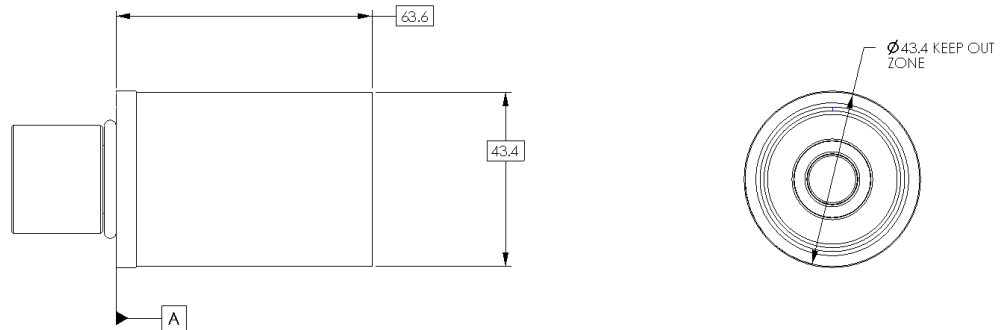


Figure 5.2.1.3 Socket Nominal Keepout Zone

### 5.2.2 Plug Valve Weight

The plug valve shall have a weight not to exceed 320g.

### 5.3 Dust Caps

Below are the dimensional and material requirements for the plug and socket valve dust caps. No dust cap is required for the threaded hose-interface end on the plug valve or the threaded port interface on the socket valve. However, care should be taken to protect threads or sealing surfaces on hose barbs during transit. The shipping packaging should be designed in a way that prevents dust/debris ingress to the valves during transit.

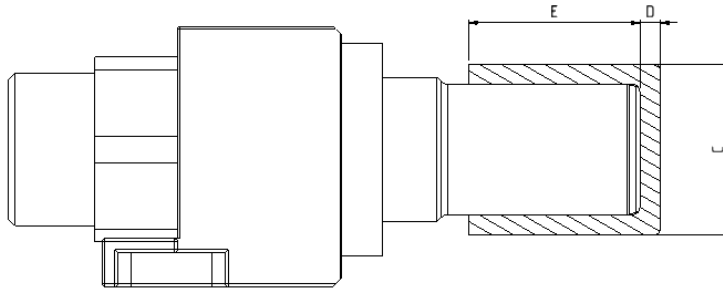


Figure 5.3.1 Plug Valve with Dust Cap

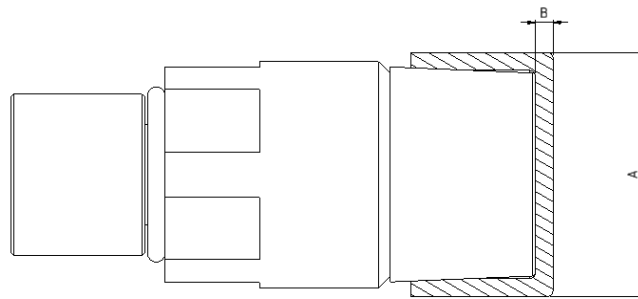


Figure 5.3.2 Socket Valve with Dust Cap

**Table 5.3 Dust Cap Dimensions**

Item	Valve	Requirement
A	Socket	MAX Ø41mm
B	Socket	MAX 4 mm

C	Plug	MAX Ø27 mm
D	Plug	MAX 4 mm
E	Plug	MIN 25 mm
Color Requirement	All	Pantone 2028C, or similar
Material Requirements	All	-RoHS (Restriction of Hazardous Substances) is a mandatory requirement. - Recommended: UL94V0 flammability requirement

## 6. Performance Requirements

**Table 6.0 Various Requirements**

Parameter	Specification
Pressure Drop	See Figure 6.9
Maximum Working Pressure	5.17 bar (75 PSIG)
Maximum Flow Rate	36 LPM
Maximum Fluid Temperature	60°C
Spillage	0 PSIG: ≤0.06cm <sup>3</sup> 75 PSIG: ≤0.12cm <sup>3</sup>
Hydrostatic Pressure Coupled	300 PSIG
Hydrostatic Pressure Un-Coupled	300 PSIG
Air Inclusion	0.6 ml/mate cycle
Maximum Mate/De-Mate Speed	310 mm/s

Any references to mate distance in the requirements below are based on the mate distance between Datum A on the socket and Datum A on the plug as shown in Figure 6.1.

### 6.1 Working Range (Allowable Mate Distances)

#### Mate Distance Considerations

Table 6.1 provides the allowable mate distance ranges within which the valves will support full flow with minimal variation in pressure loss. The designer should ensure that the system does not violate the minimum mate distance as this could result in binding

and/or irreparable damage to the valves. The valves are not designed to be a stop for IT gear. Hard stop features for the removable IT gear within the system are required to prevent violating this distance and potential valve damage. The designer should ensure that the system does not exceed the maximum mate distance as flow performance beyond this distance is not guaranteed.

Factors that can affect the working range and performance include, but are not limited to, tolerances of the various subcomponents & interfaces (rack, manifolds, chassis, IT gear support brackets, etc.), manufacturing tolerances, gaps, skew between components due to gaps, deflections due to loads from the valves and coolant pressure (deflections at the rack, manifolds, and module/chassis), chassis loading & friction, shipping and handling (shock and vibration considerations), and CTE (coefficient of thermal expansion) effects as the ambient and/or fluid temperatures change. Appropriate structural analysis, tolerance analysis, and testing by the developer are required to validate their design. Designers should design their nominal mate distance in their system to account for the items mentioned above.

**Table 6.1 Valve Working Range**

Parameter	Mate Distance D (mm)	Valve Seating Plane to Rear Hose Interface - E (mm) (Ref.)
Maximum Mate Distance	78.5	114.5
Minimum Mate Distance	72.0	108.0

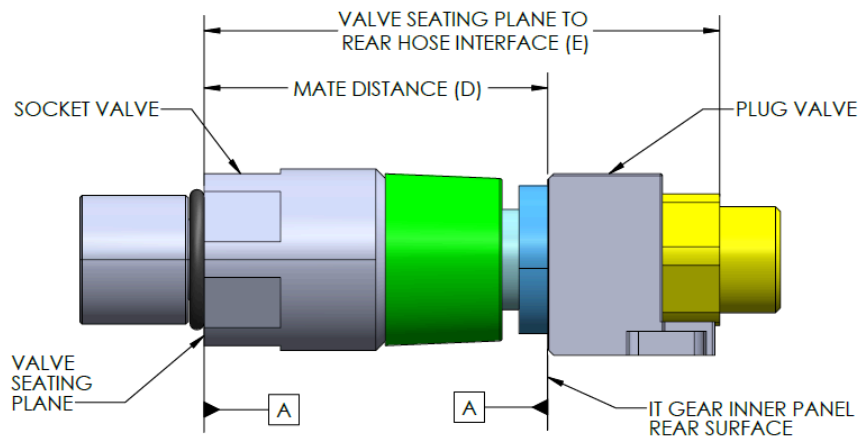


Figure 6.1 Side View of Valve Pair Mated and Mate Distance “D” is Identified

Hypothetical example of mate distance analysis for a system design with PBMC (*note: the designer shall determine their own nominal mate distance and perform their own analysis of their actual design; this is for demonstration purposes only*):

- If the nominal mate distance in the system is designed to 74.75mm
- The system design has a hypothetical +/-1.25mm tolerance on valve mate distance
- The gap from nominal mate distance to the removable tray with PBMC installed hard stop (to prevent the system from violating the PBMC valve minimum mate distance) = 0.5mm (closer to manifold). The tolerance when the removable module is at the hard stop = +/- 0.75mm
- The hypothetical system design deflection budget from various loads (connectors, valves, fluid pressure acting on valves, & CTE affects manifolds/chassis) = +/-1.0mm

Tolerance Analysis based on above assumptions:

Overdrive margin = 74.75 (nominal mate distance) - .5 (gap to stop) - 0.75 (hardstop tolerance) = 73.25 (1.25mm margin vs. allowable minimum mate distance of 72mm\*)

Maximum Mate Distance Margin = 74.75 (nominal mate distance) + 1.0 (deflection) + 1.25 (mate tolerance) = 77mm (1.5mm margin vs. 78.5mm\* maximum mate distance).

\* Per Table 6.1

## 6.2 Misalignment

Misalignment Considerations:

In the sections below, the allowable misalignment maximums are provided for both radial only and combined radial and angular offset. It is important that the system design ensures that valve misalignment does not exceed the requirements to ensure proper function and avoid damaging the valves. Potential contributors to misalignment include, but are not limited to, tolerances of the various subcomponents & interfaces (rack, manifolds, chassis, IT gear support brackets, etc.), manufacturing tolerances, gaps, skew between components due to gaps, deflections due to loads from the valves and coolant pressure (deflections at the rack, manifolds, and module/chassis), chassis loading & friction, shipping and handling (shock and vibration considerations), and CTE (coefficient of thermal expansion) effects as the ambient and/or fluid temperatures change. Appropriate structural analysis, tolerance analysis, and testing by the developer are required to validate their design.

The offsets are based on the following Datums for the valves:

- Plug Valve (see Section 4.3.1.1):
  - Datum A: The face of the block feature that contacts the inside of the IT gear panel
  - Datum B: The shoulder protruding from Datum A
- Socket Valve: (see Section 4.3.2.1):

- Datum A: The seating face of the valve to the manifold
- Datum B: The center of the threaded stud that threads into the manifold

### 6.2.1 Radial Offset

The design supports 5mm of pure radial offset. The offset is measured between the 'B' datum axes of both the plug and socket. The 72.0mm mate distance is provided for reference and is not critical in determining the allowable radial offset.

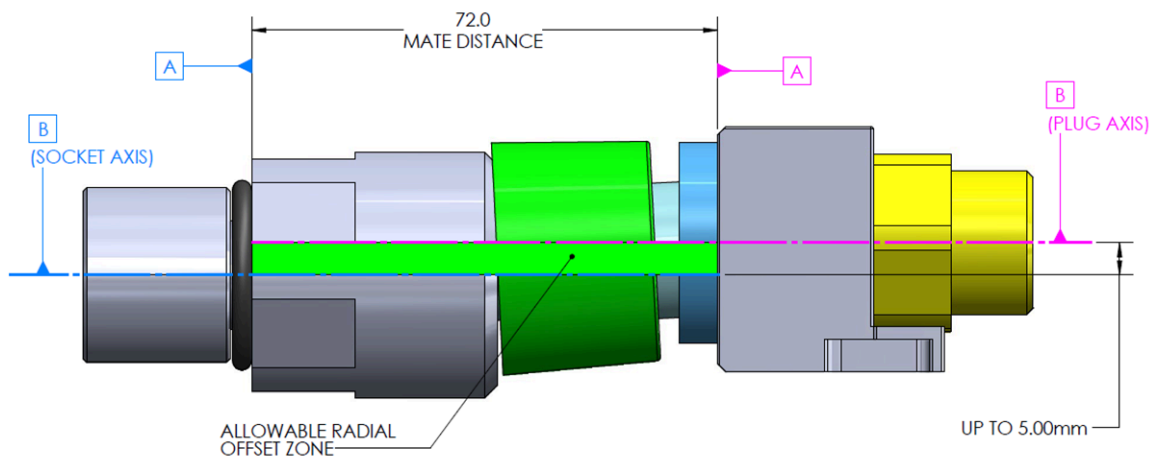


Figure 6.2.1 Image Showing Valves at Maximum Radial only Offset Condition

### 6.2.2 Combined

The design supports 5mm & 2.5 degrees combined offset within the 5mm radial zone. In this configuration, radial offset is measured normal from the base Datum 'B' axis to the intersection of the 'A' and 'B' datums on the mating half. Angular offset is measured between the plug and socket 'B' datum axes. In Fig 6.2.2, the plug is depicted in its offset and rotated state relative to the socket axis, but the case where the socket is offset and rotated relative to the plug axis is also allowed. Both conditions are included in the test matrix and are referenced in Table 7. Refer to the Fixture & Test Guidelines in the collateral for additional context.

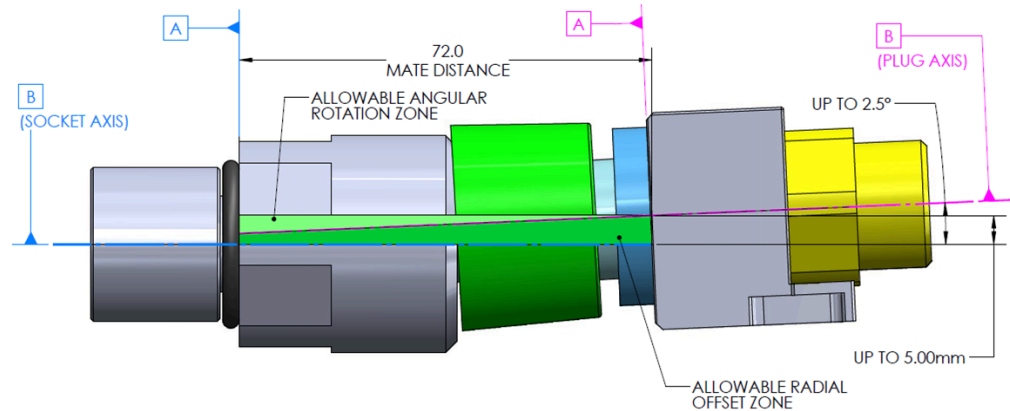


Figure 6.2.2 Valves at Combined Max. Radial and Angular Offset Condition

### 6.3 Self-Centering

The requirements for the plug and socket floating body skew in a free state is shown in Figure 6.3.1 and Figure 6.3.2 below. The pivoting body of the plug and socket shall stay within the zone when:

- (1) in normal state when unmated
- (2) after mating and un-mating (pivoting body must lie within the zones afterwards)
- (3) dry and with fluid
- (4) 0 to 75 PSI fluid pressure

The valves are designed to allow for the misalignment outlined in Section 6.2. To ensure proper function, it is critical that the final solution ensures the pivoting body of the plug and pivoting body of the socket are within the diametrical zones outlined. Failure to meet this requirement may result in increased mate forces, failure to align and mate, binding, and irreparable damage to the valves.

#### 6.3.1 Plug Self-Centering

A jig design that references the Datum B shoulder on the plug to verify centering during testing is recommended. See below for the requirement.

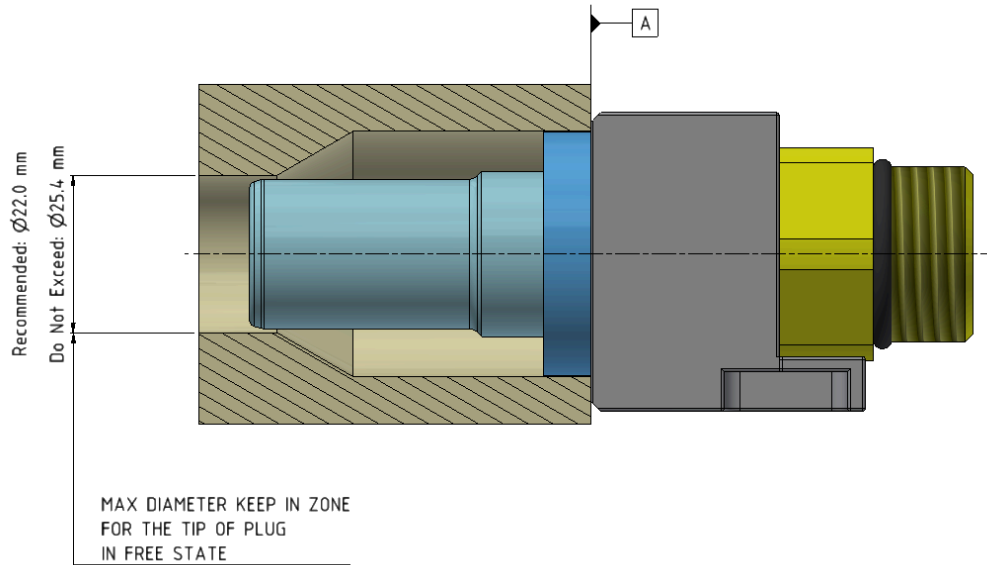


Figure 6.3.1 Allowable Plug Skew in Free State

### 6.3.2 Socket Self-Centering

A jig design that references the fixed shoulder on the socket to verify centering during testing is recommended. See below for the requirement.

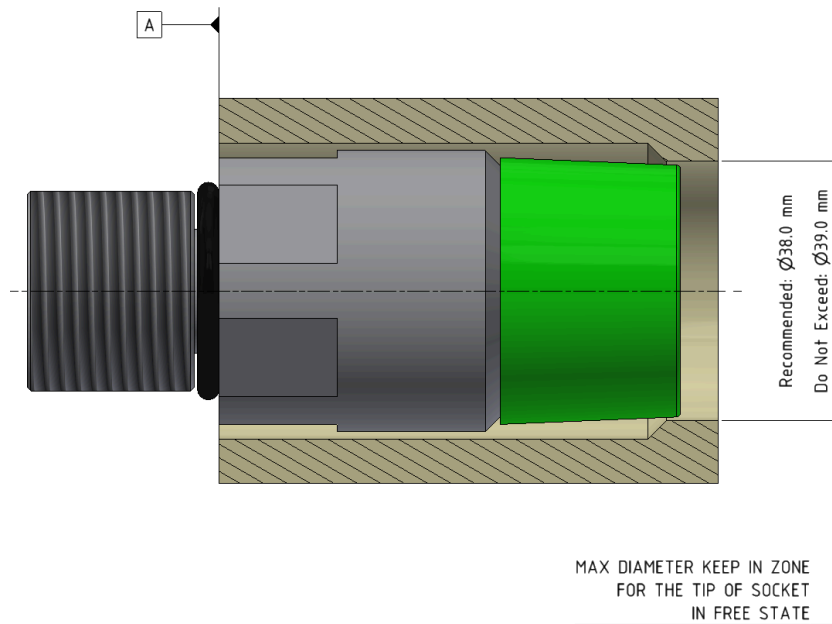


Figure 6.3.2 Allowable Socket Skew in Free State

## 6.4 Pivot Angle

The plug and socket pivoting bodies shall pivot relative to Datum A & B to a minimum angle outlined in the table below.

**Table 6.4 Rotation Range**

Parameter	Angle (degrees)
Plug Valve Rotation Angle	3.7° min.
Socket Valve Rotation Angle	3.8° min.

## 6.5 Mate & De-Mate Forces

### 6.5.1 Dynamic Mate Force vs. Mate Distance (with Fluid)

The maximum mate & de-mate speed is 310 mm/s; testing is performed at 330 mm/s to add confidence in meeting the specification. The dynamic mate & de-mate force vs. distance requirements at 330 mm/s is 667N.

Dynamic testing is also performed at a lower speed of 38 mm/s (tested to 40mm/s for confidence) to simulate a typical speed when an ejector is used. For testing a pair of valves at 40 mm/s with & without fluid flow, the force requirements are provided in Figure 6.5.1.1 below. The start of the boundary curves include approximately 1.5 mm buffer to the left where the alignment forces typically start to account for test fixture variability. The values apply to aligned, radial offset, and combined radial and angular offset conditions per the fixture guideline. Two force curves are provided in the figure, one for mate force during connection and the other for de-mate force during disconnection. The boundary curves encompass force requirements in two mating conditions:

- (1) With fluid flow at 36 LPM and 75PSIG, details in Test 7.1-12
- (2) Fluid static pressure of 75PSIG on each side of the connection (no fluid flow), details in Test 7.1-11

The mate distance represents the mating distance between Datum A on the socket and Datum A on the plug (see Figure 4.4.1). During testing an average speed of 40 mm/s is maintained during mate cycles. There is a deceleration to the minimum mate distance, it stops at minimum mate distance, then accelerates to full de-mate. The deceleration at the end of stroke and acceleration during the de-mate stroke is  $5000 \text{ mm/s}^2 \pm 10\%$ .

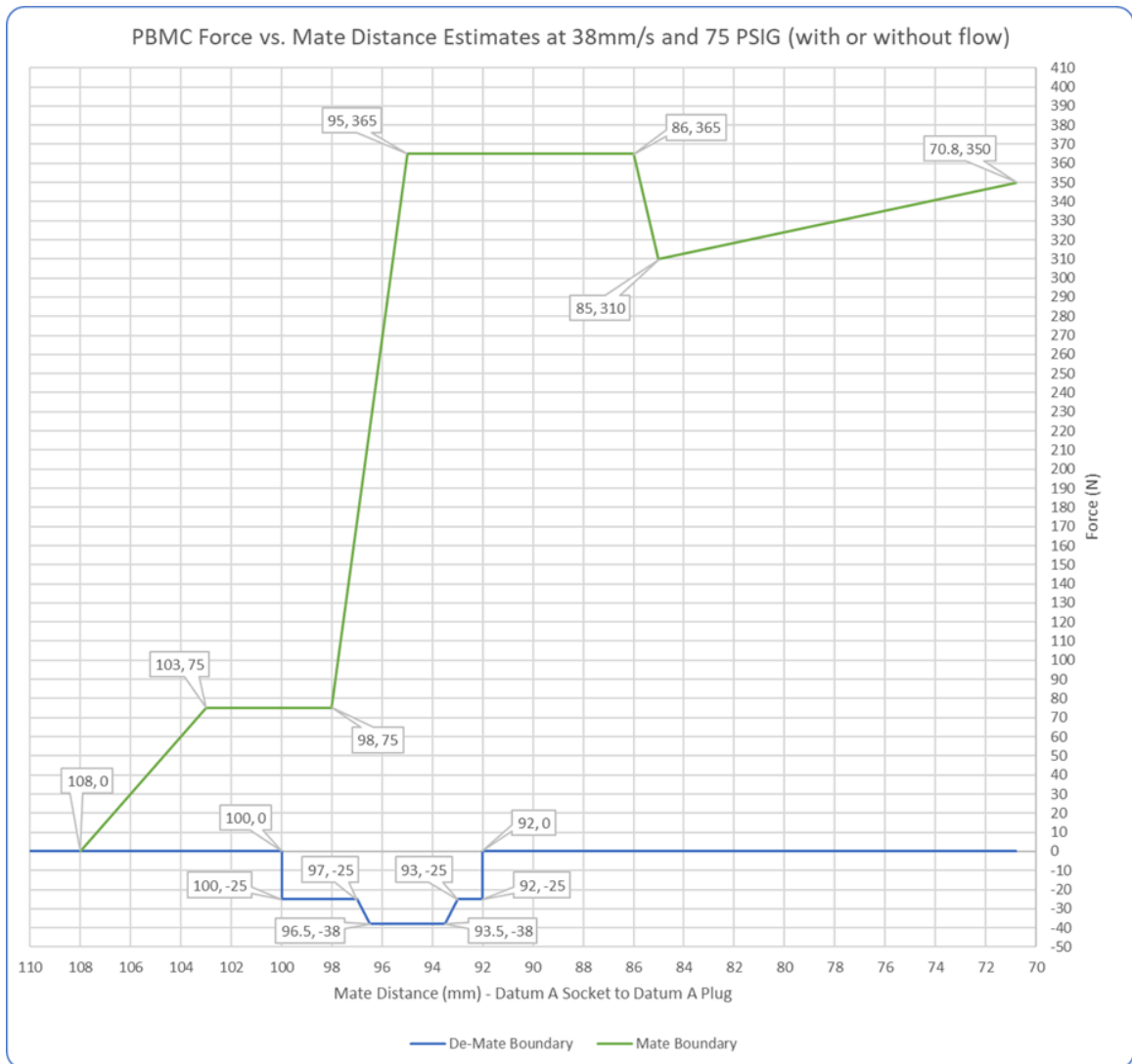


Figure 6.5.1 Dynamic Mate and Demate Forces

### 6.5.2 Static Force vs. Mate Distance (with Fluid)

The static mate force requirements are provided below with fluid at 75 PSIG. This must be met in aligned, radial offset, and combined radial and angular offset. Note additional points beyond the working range in Section 6.1, +1.6 mm above the maximum connection distance and -1.2 mm less than the minimum connected distance, are listed in the graph as well for test margin (no specific spring force requirements at those mate distances).

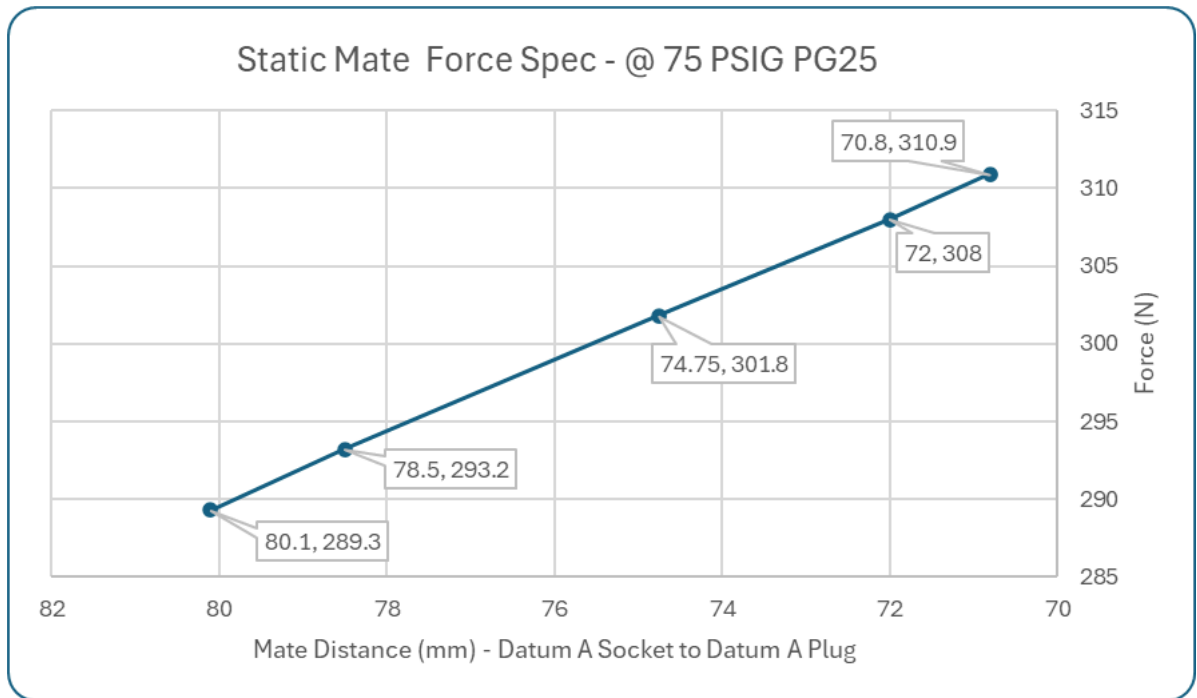


Figure 6.5.2 Max. Static Force (Force vs. Mate Distance)

To help ensure reasonable interoperability force variation between suppliers, listed below in Table 6.5.2 are requirements for the maximum plug and socket spring forces for certain components. Note the additional point +1.6mm beyond the maximum working range (80.1mm) is also shown as reference. A connection distance of 74.75mm is provided for reference as well.

**Table 6.5.2 Static Force Requirements for the Valves**

Item	Mate Distance (mm)				
	(80.1)	78.5	(74.75)	72	(70.8)
Socket Spring Force (N)	NR	64.4	68.9	72.1	NR
Plug Spring Force (N)	NR	42.2	46.3	49.3	NR
Fluid Force @ 75PSIG Force (N)	146.6	146.6	146.6	146.6	146.6
Friction Force (N)	40	40	40	40	40
Total Force (N)	289.3	293.2	301.8	308.0	310.9

### 6.5.3 Maximum Static Mate Force (Dry)

The dry static mate force requirements are provided below. See Section 7 for test details. This must be met in aligned, radial offset, and combined radial and angular offset in the default tube routing conditions. The mate distance represents the mating distance between Datum A on the socket and Datum A on the plug (ref. Section 6.1). Note additional points beyond the working range in Section 6.1 are listed in the graph as well for test margin. There are no specific spring force requirements at those margined mate distances.

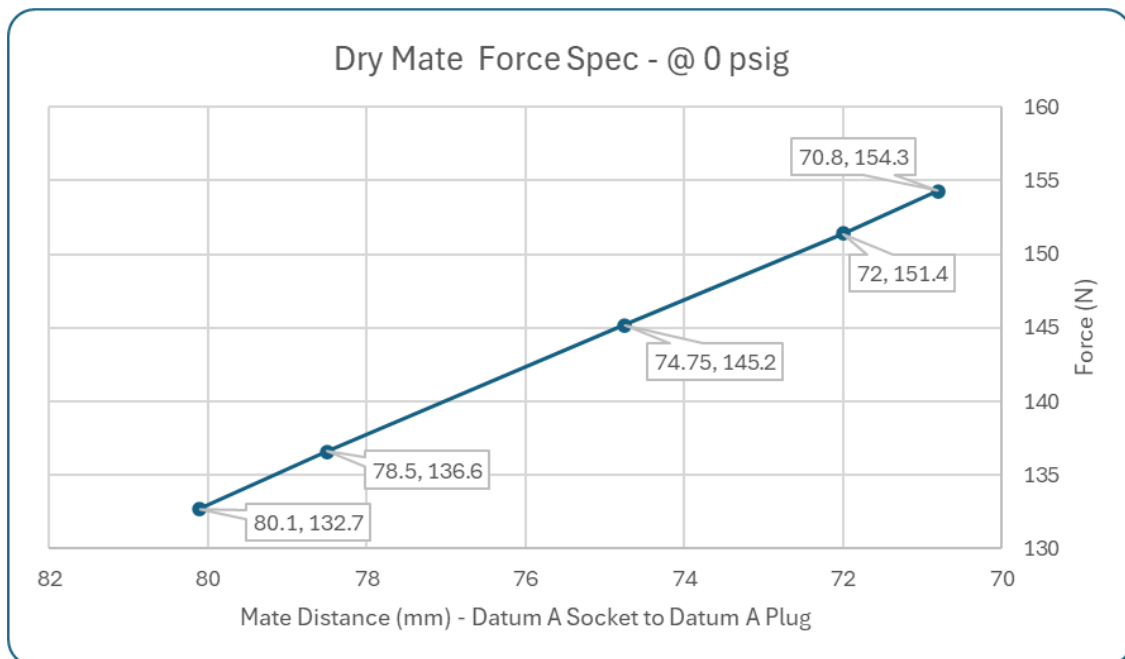


Figure 6.5.3 Static Mate Force Dry vs. Mate Distance

### 6.6 Radial Force

The plug and socket both pivot respective to their mounting datums in order to accommodate radial and angular misalignment between the manifold and chassis during the mating process. Both valve designs have features with springs that force the plug and socket to self-center when unmated to ensure a reliable gather of the valves during connection. The maximum allowable radial forces created between the valves during mating is outlined in the table below. This value must be met when tested in all conditions outlined in Section 7. System designers should consider the impact of these forces in their application.

**Table 6.6 Radial Force Requirements**

Parameter	Mate
Radial Force	38N maximum, per valve set (one socket and one plug)
Mating Distance for Requirement	From initial contact to minimum mate distance

Testing of the radial force shall be done in a test fixture across various mate distances between the initial contact to minimum mate distance.

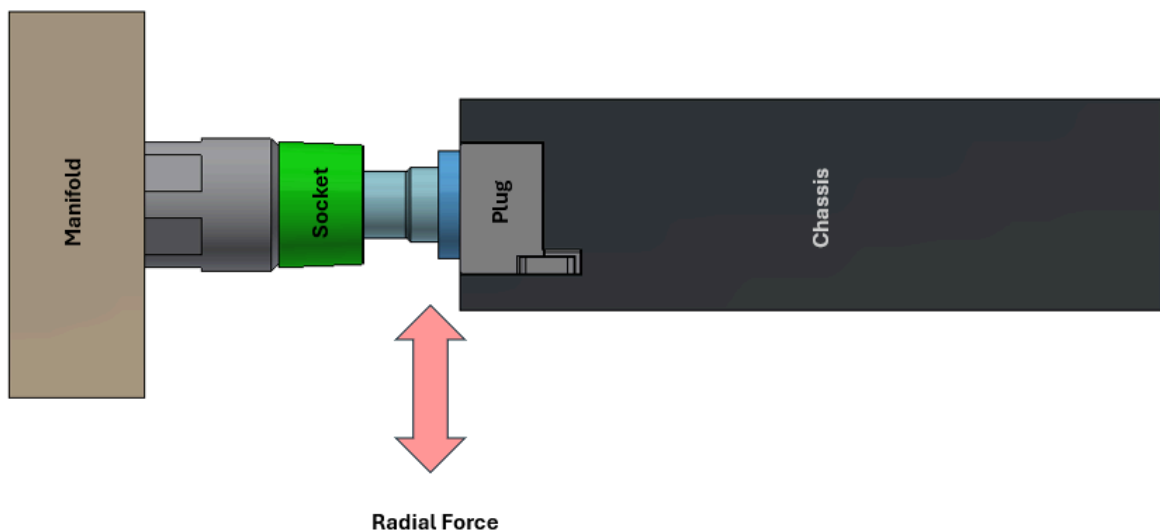


Figure 6.6 Concept of Radial Force

### 6.7 Mate Cycle Durability

Testing is required in several conditions and summarized in Table 6.7 below. More details are provided in Table 7.1 and the fixture requirements document. The values in Table 6.7 include margin for speed and cycle count for confidence.

The maximum mate & de-mate speed is 310 mm/s. During testing at 310 mm/s, the mate & de-mate forces shall not exceed 667N.

The valves are also tested at a lower speed of 38 mm/s that represents typical mate speed of a module using an injector lever to mate the module into the system.

The valve mate cycle durability is to be tested in several working conditions including:

1. Dry, without fluid

2. Static with fluid, but no flow
3. With fluid, at rated flow & maximum working pressure
4. With fluid, at elevated flow

A summary of the requirements and conditions for mate cycle durability are provided below. In some cases, a serialized valve pair is required to be tested in multiple tests. See Table 7.0 for details. Note that the testing listed below is performed with additional margin above the speeds than listed below for added confidence.

**Table 6.7 Summarizes all Durability - Mate Cycles**

Test	Alignment Condition*	Flow Direction	Mate & De-mate Speed	# of Cycles	Force Requirements
Mate Cycle Dry	4 alignment conditions	n/a	330 mm/s	12 cycles per condition* (4x), 48 total*	See Test in Table 7.1
Mate Cycle With Fluid Static (no Flow)	4 alignment conditions	n/a	330 mm/s	40 per condition* (4x), 160 total	See Test in Table 7.1
Mate Cycle With Fluid Static (no Flow)	4 alignment conditions	n/a	40 mm/s	314 per condition* (4x), 1256 total	Figure 6.5.1.1
Mate Cycle With Fluid at Rated Flow	4 alignment conditions	both	40 mm/s	157 per flow direction/alignment condition* (8x), 1256 total	Figure 6.5.1.1
Elevated Flow Mate Cycle Test	Aligned only & 2 flow directions, 2 conditions total	both	40 mm/s	20 cycles per flow direction/alignment condition* (2x), 40 total mate cycles	Figure 6.5.1.1

\* Conditions: (1) Aligned (2) Radial Offset (3) Combined, Plug Rotated (4) Combined, Socket Rotated. See PBMC Fixture & Test Guideline for additional context and illustrations of these test conditions.

## **6.8 Flow vs. Pressure Drop**

The requirements outlined in Figure 6.8 below shall be met at any mate distance within the working range outlined in Section 6.1. Figure 6.8 outlines the lower to upper range of acceptable pressure drop for different flow rates. The valves must meet the requirement in both plug-to-socket and socket-to-plug flow directions. This requirement must be met by all vendors to be considered to have met the specification. Same supplier and interoperability testing with all suppliers and all combinations shall be tested. For more details see Table 7.1, Test 7.1-1.

Note that the testing outlined in Table 7.1, Test 7.1-1, is to be performed at slightly margined values to account for test tolerance, valve manufacturing tolerances, and provide confidence in meeting the requirements. The lower to upper range in Fig. 6.8 represents the complete data set as measured across all supplier test sites. Testing variation of all supplier combinations at a single test site was shown to be reduced (in comparison). Test conditions are as follows:

- Fluid supply temperature: 35°C
- Fluid: 25% propylene glycol water mixture

See the Test Fixture Guidelines and Procedures document for tare information.

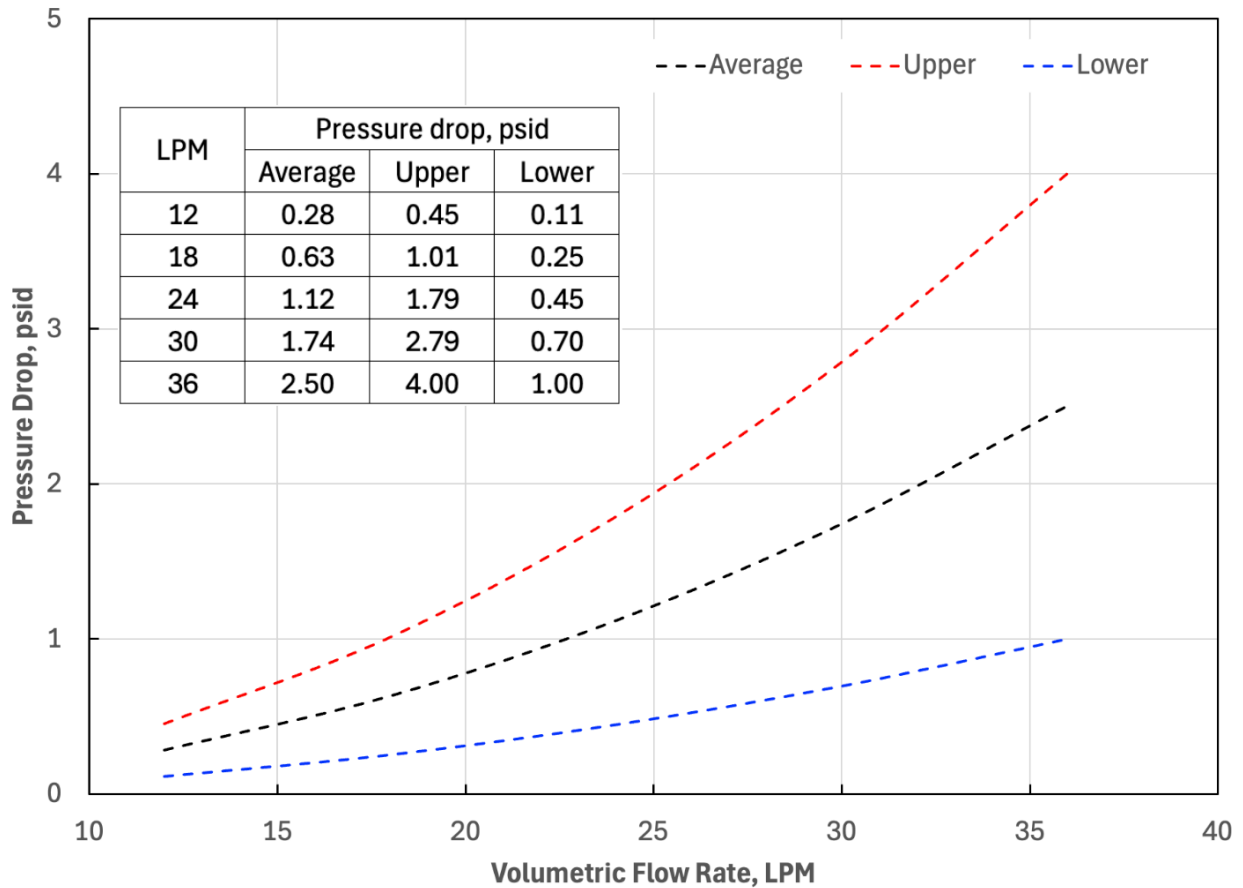


Figure 6.8: Target differential pressure vs. flow curves

## 7. Test Requirements

Most tests listed below require the testing of valve combinations with same and mixed supplier valves (interoperability) as well as multiple samples of each plug-socket combination. There are also safety test requirements in Section 9. Test levels below are generally tested with margin above the specifications listed in various other sections of this specification. For a design to be considered to have met the requirements specification:

- (1) The valve design must be tested and pass all tests below including those requiring supplier interoperability
- (2) To ensure reliable performance between valve designs, suppliers should perform interoperability testing per the table below. During the OCP submission process to OCP, the summary shall include a list of the suppliers valve designs that were tested for interoperability. Adopters may drive the requirements in terms of suppliers to be tested for

interoperability. All suppliers should make their valves available for testing.

Collateral Provided and will be included with this specification include:

- (1) "PBMC Test Fixture Guidelines and Procedures"
- (2) "PBMC Reference Test Guideline"
- (3) "PBMC Test Submission Template" suggested template for submitting to OCP the high level summary of test results included, list of all tests, supplier combinations tested, and serial numbers
- (4) "PBMC Supplemental Test Data" - a reference detailed test report template to enable suppliers to document detailed test results consistently.

More details on the fixture guideline and test guideline are provided later in this section.

Note that certain groups of tests require one serialized pair to be used and details are summarized in table 7.0 below.

**Table 7.0 Summary of Tests Requiring The Same Serialized Pair**

Test	Serialized Pair Info	Sample Qty.
7.1-6 Elevated Flow Test, Connected 7.1-7 Elevated Flow Mate Cycle Test	Same serialized pair for this group of tests	See table 7.1
7.1-8 Static Force vs. Mate Distance, Dry 7.1-9 Static Force vs. Mate Distance, Wet 7.1-10 Mate Cycles, Dry 7.1-11 Mate Cycles, Wet, Static 7.1-12 Mate Cycles, Wet, w/Flow 7.1-13 Radial Force, Mate Cycles, Dry 7.1-14 Radial Force, Mate Distance, Wet, Static 7.1-15 Radial Force, Mate Cycles, Wet, Static 7.1-16 Radial Force, Mate Cycles, Wet, w/Flow	Same serialized pair for this group of tests	See table 7.1
7.1-22 Operating Temperature Testing 7.1-23 Operating Humidity Testing	Same serialized pair for this group of tests	See table 7.1
7.1-24 Non-Operating Temperature 7.1-25 Non-Operating Humidity	Same serialized pair for this group of tests	See table 7.1

Additional Information:

- Unless specified otherwise, all tests listed below are to be executed at accepted ambient temperature and relative humidity levels.

- Pre-conditioning, and functional verification of samples used as part of the test shall be completed.
- Post test, functional verification & inspection of the samples shall be completed on all tests
- The testing that requires the test fixture shall use a fixture manufactured per requirements in the PBMC Test Fixture Guidelines and Procedures
- The PBMC Reference Test Guideline is a sample of the test plan and test order document that was used during testing is supplied with the collateral; if additional valves (new supplier) are to be tested, the matrix would need to grow to ensure all combinations are tested to the appropriate quantities
- The testing below references the PBMC Test Fixture Guidelines and Procedures document. This document provides detailed fixture requirements and test procedures used to test and validate the valves meet the various requirements.

**General Pass/Fail Criteria**

The valves must not bind, leak, exhibit damage to external or internal parts, have any degradation in performance beyond the requirements, meet any additional requirements listed in a particular test, and meet any requirements in any reference test specification listed in the “Reference Standard” column below for that test.

**Table 7.1 Minimum Test Requirements**

Test # & Description	Requirements	Reference Standard
7.1-1 <i>Pressure Drop Test</i>	<ul style="list-style-type: none"> <li>● Ambient Temperature: 20°C ± 3°C</li> <li>● Fluid Temperature: 35°C</li> <li>● Fluid Type: PG25</li> <li>● Must meet Figure 9.8.1 curve at any mate distance between 78.5mm &amp; 72mm, but also measure at 80.1mm (margin) and 70.8mm (margin) to verify extreme ends of stroke are met when accounting for tolerances of design and fixture</li> <li>● Flow rates: measured at 18, 24, 30, 36, &amp; 42 LPM.</li> <li>● Requirements are listed in Figure 6.8</li> <li>● Same supplier and interoperability testing required, minimum 3 samples of each same supplier and interop combination</li> </ul>	ISO 18869:2017, Section 13  Conditions at left supersede any conflict with the referenced standard.  Reference PBMC Fixture & Test Guideline
7.1-2 <i>Air Inclusion</i>	<ul style="list-style-type: none"> <li>● Pressure: Atmospheric , Ambient Temperature: 20C ± 3C</li> <li>● Fluid Temperature: 20C ± 3C</li> <li>● Fluid: PG25 or water</li> <li>● Requirements per Table 6.0</li> <li>● Same supplier and interoperability testing required, minimum 2 samples of each combination</li> </ul>	ISO 18869:2017, Section 11
7.1-3 <i>Spillage</i>	<ul style="list-style-type: none"> <li>● Pressure: 0 &amp; 80 PSIG, Ambient Temperature: 20C ± 3C</li> <li>● Fluid Temperature: 20C ± 3C, Fluid type: water</li> <li>● Max. spillage: per Table 6.0</li> <li>● All performed with vertical orientation and using graduated cylinder per ISO Standard listed</li> <li>● Provide test results for both pressure levels</li> <li>● Same supplier and interoperability testing required, minimum 3 samples of each same supplier and interop combination</li> </ul>	ISO 18869:2017, Section 12
7.1-4 <i>Hydrostatic Pressure, Coupled</i>	<ul style="list-style-type: none"> <li>● Pressure: 300 PSIG</li> <li>● Duration: 3 minutes</li> <li>● Ambient Temperature: 50C+3C/-0C</li> <li>● Fluid Temperature: 50C+3C/-0C</li> <li>● Fluid: water or PG25</li> <li>● Valves shall be allowed to stabilize at 50C for 1 hour to ensure fluid, tubing and valves are at temperature prior to starting pressure test</li> <li>● Same supplier and interoperability testing required, minimum 2 samples of each same supplier and interop combination</li> </ul>	ISO 18869:2017, Section 18.3  Reference PBMC Fixture & Test Guideline Section 14 for fixture layout & design.
7.1-5 <i>Hydrostatic Pressure, Un-coupled</i>	<ul style="list-style-type: none"> <li>● Pressure: &gt;300 PSIG - test to this pressure (not to burst)</li> <li>● Duration: 3 minutes</li> <li>● Ambient Temperature: 50C+3C/-0C</li> <li>● Fluid Temperature: 50C+3C/-0C</li> <li>● Fluid: water or PG25</li> </ul>	ISO 18869:2017, Section 18.2.  Reference PBMC Fixture

	<ul style="list-style-type: none"> <li>Valves shall be allowed to stabilize at 50C to ensure fluid, tubing and valves are at temperature before testing</li> <li>Same supplier, minimum 3 samples</li> </ul>	& Test Guideline
7.1-6 <i>Elevated Flow Test, Connected, Closed Loop</i>	<ul style="list-style-type: none"> <li>Surge flow test in both flow directions (1) plug to socket &amp; (2) socket to plug. Increase flow up to 200% of rated flow (72 LPM). Testing should be done in both directions at min. connected distance 78.5mm.</li> <li>1 cycle</li> <li>Static Pressure not to exceed 75PSI during test</li> <li>See Test Fixture &amp; Test Requirements Document for more details on test procedure (including flow ramp up rates)</li> <li>Test to be done with PG25</li> <li>Fluid temperature 50°C</li> <li>Same supplier and interoperability testing required, a minimum of 2 samples of each same supplier and interop combination</li> </ul>	ISO 18869 section 17  Reference PBMC Fixture & Test Guideline
7.1-7 <i>Elevated Flow, Mate Cycle Test, Open Loop</i>	<ul style="list-style-type: none"> <li>This test is conducted to ensure that the seals of the valves can withstand mating/un-mating under higher pressure / flowrate conditions without washing out and creating a leak.</li> <li>Although this test tests for seal durability, for guidance on use in an open loop scenario, such as during filling or draining a server – contact the valve supplier for guidance. In an open loop scenario, extreme pressure drop and fluid velocity across a valve set can induce a seal washout event. As such, fill and drain practices should follow a progressive introduction of flow and pressure within the specification of the valve.</li> <li>Connection test with flow, simulating a minimally pressurized open loop connection.</li> <li>Set test up with <b>76 psi</b> on one side of the connection when disconnected and 1 psi on the outlet side of connection.</li> <li>Flow Rate: 54LPM minimum, 72LPM preferred</li> <li>Fluid: PG25</li> <li>Fluid temperature 50°C+/-5°C</li> <li>Connection / disconnection at 40 mm/s</li> <li>20 cycles in each flow direction, from fully demated to minimum mate distance per Table 6.1</li> <li>Same supplier and interoperability testing required, a minimum of 2 samples of each same supplier and interop combination</li> <li>See Test Fixture &amp; Test Requirements Document for more details on test procedure</li> </ul>	Reference PBMC Fixture & Test Guideline Section
7.1-8 <i>Static Force vs. Mate Distance, (Dry)</i>	<ul style="list-style-type: none"> <li>Pressure: N/A (Dry)</li> <li>Ambient Temperature: 20C ± 3C</li> <li>Fluid: N/A (Dry)</li> <li>Alignment Conditions: <ol style="list-style-type: none"> <li>Aligned</li> <li>Radial: 5.25mm offset</li> <li>Combined: 2.6 deg &amp; 5.1mm radial plug rotated</li> <li>Combined: 2.6 deg &amp; 5.1mm radial socket rotated</li> </ol> </li> <li>Measure Static force at Mate Distances 80.1 (margin), 78.5, 78, 77, 76, 74.75, 74, 73, 70.8 (margin), in the exact order listed and stopping at each distance, with each plug &amp; socket pair</li> <li>Dwell at each distance for 1 sec</li> </ul>	Reference PBMC Fixture & Test Guideline

	<ul style="list-style-type: none"> <li>• Must not exceed mate forces in Figure 6.5.3</li> <li>• Must meet self-centering requirements in section 6.3</li> <li>• Minimum 2 samples of each same supplier and interop combination</li> </ul>	
<p>7.1-9 <i>Static Force vs. Mate Distance, Mated Pair, (Wet)</i></p>	<ul style="list-style-type: none"> <li>• Pressure: 75PSIG (both sides pressurized for tests)</li> <li>• Ambient Temperature: 20C ± 3C</li> <li>• Fluid Temperature: 50C</li> <li>• Fluid: PG 25</li> <li>• Plug &amp; socket valve shall be checked for compliance to self-centering in Section 6.3 prior to starting, during test and after last cycle for each test</li> <li>• Alignment Conditions:             <ol style="list-style-type: none"> <li>1. Aligned</li> <li>2. Radial: 5.25mm offset</li> <li>3. Combined: 2.6 deg &amp; 5.1mm radial plug rotated</li> <li>4. Combined: 2.6 deg &amp; 5.1mm radial socket rotated</li> </ol> </li> <li>• See fixture guideline section for fixture set-up for this test</li> <li>• Measure Static force at Mate Distances 80.1 (margined), 78.5, 78, 77, 76, 74.75, 74, 73, and 70.8 (margined) with each plug &amp; socket pair</li> <li>• Dwell at each distance for 1 sec</li> <li>• Must not exceed mate forces in Figure 6.5.2</li> <li>• Same supplier and interoperability testing required, minimum 2 samples of each same supplier and interop combination</li> <li>• Measurements taken before all tests and after all cycle tests</li> </ul>	<p>Reference PBMC Fixture &amp; Test Guideline</p>
<p>7.1-10 <i>Mate Cycles, Mated Pair, (Dry)</i></p>	<ul style="list-style-type: none"> <li>• Pressure: 0 PSI (no fluid), PG25 post-test check</li> <li>• Ambient Temperature: 20C ± 3C</li> <li>• Fluid Temperature: not applicable (dry)</li> <li>• Fluid: not applicable (dry)</li> <li>• Velocity: Run at 330 mm/s ± 40 mm/s</li> <li>• 12 cycles per set-up below (4 tests)</li> <li>• Plug &amp; socket valve shall be checked for compliance to self-centering in Section 6.3 prior to starting, during test and after last cycle for each test</li> <li>• Alignment Conditions:             <ol style="list-style-type: none"> <li>1. Aligned</li> <li>2. Radial: 5.25mm offset</li> <li>3. Combined: 2.6 deg &amp; 5.1mm radial, plug pivoted and radial offset</li> <li>4. Combined: 2.6 deg &amp; 5.1mm radial, socket pivoted and radial offset</li> </ol> </li> <li>• Must not exceed 667N during any portion of mate/de-mate cycle.</li> <li>• See Note 1 for mate cycle description.</li> <li>• Same supplier and interoperability testing required, minimum 2 samples of each same supplier and interop combination</li> <li>• Upon completion of above, valves to be tested with fluid at 75PSI to ensure no leaks or functional issues (both unmated and mated)</li> </ul>	<p>Reference PBMC Fixture &amp; Test Guideline</p>

	<ul style="list-style-type: none"> <li>● Plug &amp; socket valve shall be checked for compliance to self-centering in Section 6.3 prior to starting, during test and after last cycle for each test</li> <li>● Measurements taken to verify below max</li> </ul>	
<p><i>7.1-11 Mate Cycles (wet) with Static Pressure</i></p>	<ul style="list-style-type: none"> <li>● Ambient Temperature: 20C ± 3C</li> <li>● Fluid Temperature: 50C</li> <li>● Pressure: 75 PSI (both sides pressurized for tests)</li> <li>● Fluid: PG25</li> <li>● Velocity: Run at             <ul style="list-style-type: none"> <li>(1) 40 mm/s ± 2 mm/s</li> <li>(2) 330 mm/s ± 4mm</li> </ul> </li> <li>● See Note 1 for mate cycle description.</li> <li>● For 40 mm/s , 314 cycles per alignment condition, 1256 total</li> <li>● For 330 mm/s, 40 cycles per alignment condition, 160 total</li> <li>● Plug &amp; socket valve shall be checked for compliance to self-centering in Section 6.3 prior to starting, during test and after last cycle for each test</li> <li>● Alignment conditions:</li> <li>● 40 mm/s test:             <ol style="list-style-type: none"> <li>1. Aligned: 314 total cycles</li> <li>2. Radial: 5.25mm offset, 314 total cycles,</li> <li>3. Combined: 2.6 deg &amp; 5.1mm radial, 314 total cycles, plug pivoted and radial offset</li> <li>4. Combined: 2.6 deg &amp; 5.1mm radial, 314 total cycles, socket pivoted and radial offset</li> <li>5. Monitor to ensure peak values are not exceeded.</li> <li>6. Measure mate, de-mate, and axial forces during the test at a minimum of 6 cycles throughout the testing in each condition. Monitor to ensure peak values are not to exceed. Measure force and develop curve for mate &amp; de-mate for at least 2 cycles per condition (1 at the end).</li> <li>7. No damage, binding or leaks, must meet mate and de-mate curves in Figure 6.5.1 for all test cycles.</li> <li>8. Same supplier and interoperability testing required, minimum 2 samples of each same supplier and interop combination</li> </ol> </li> <li>● For 330 mm/s tests:             <ol style="list-style-type: none"> <li>1. Aligned: 40 total cycles</li> <li>2. Radial: 5.25mm offset, 40 total cycles,</li> <li>3. Combined: 2.6 deg &amp; 5.1mm radial, 40 total cycles, plug pivoted and radial offset</li> <li>4. Combined: 2.6 deg &amp; 5.1mm radial, 40 total cycles, socket pivoted and radial offset</li> <li>5. no binding nor exceed 667N during testing, pass all functional tests during and after completion, and show no sign of damage or leaks. No force measurements requirement.</li> </ol> </li> </ul>	<p>Reference PBMC Fixture &amp; Test Guideline</p>

<p><i>7.1-12 Mate Cycles With Flow</i></p>	<ul style="list-style-type: none"> <li>● This test is meant to recreate the real world scenario of connecting / disconnecting a filled server into a filled system.</li> <li>● Ambient Temperature: 20C ± 3C</li> <li>● Fluid Temperature: 50C</li> <li>● Flow Rate: 36 LPM, 2 directions</li> <li>● Pressure: 75 PSIG</li> <li>● Differential Pressure: 45PSI</li> <li>● Fluid: PG25</li> <li>● Velocity: Run at 40 mm/s ± 2 mm/s</li> <li>● See Note B for mate cycle description</li> <li>● One serialized pair to be used for testing (the same pair as in tests 7.1-11, 7.1-12, 7.1-13)</li> <li>● Plug &amp; socket valve shall be checked for compliance to self-centering in Section 6.3 prior to starting, during test and after last cycle for each test</li> <li>● Alignment conditions: see details below (1256 total cycles)             <ol style="list-style-type: none"> <li>1. Aligned: 314 total cycles, 157 in each flow direction</li> <li>2. Radial: 5.25mm offset, 314 total cycles, 157 in each flow direction</li> <li>3. Combined: 2.6 deg &amp; 5.1 mm radial, 314 total cycles, 157 in each flow direction, plug pivoted and radial offset</li> <li>4. Combined: 2.6 deg &amp; 5.1mm radial, 314 total cycles, 157 in each flow direction, socket pivoted and radial offset</li> </ol> </li> <li>● See Note 1 for mate cycle definition</li> <li>● Measure mate, de-mate, radial forces during test at a minimum of 6 cycles throughout the test in each condition, 3 first cycles &amp; 3 last cycles (while still monitoring peak forces throughout). Note test cycle count will be slightly more due to these measurements in each condition.</li> <li>● Same supplier and interoperability testing required, minimum 2 samples of each same supplier and interop combination</li> <li>● No damage, binding or leaks</li> <li>● Forces must be below the mate &amp; de-mate curves in Figure 6.5.1</li> </ul>	<p>Reference PBMC Fixture &amp; Test Guideline</p>
<p><i>7.1-13 Radial Force, Mate Distance, Dry, Static</i></p>	<ul style="list-style-type: none"> <li>● Pressure: 0 PSIG</li> <li>● Ambient Temperature: 20C ± 3C</li> <li>● Fluid: N/A (Dry)</li> <li>● Test Conditions: Installed in panel or fixture, (1) dry without tubing installed</li> <li>● Measure force required to pivot plug and socket</li> <li>● Must meet requirements in Table 6.6</li> <li>● Alignment conditions: see details below             <ul style="list-style-type: none"> <li>○ Aligned</li> <li>○ Radial only: 5.25mm offset</li> <li>○ Combined: 2.6 deg &amp; 5.1mm radial, plug pivoted and radial offset</li> </ul> </li> </ul>	<p>Reference PBMC Fixture &amp; Test Guideline</p>

	<ul style="list-style-type: none"> <li>o Combined: 2.6 deg &amp; 5.1mm radial, socket pivoted and radial offset</li> <li>● Measure Static force at Mate Distances 80.1 (margined), 78.5, 78, 77, 76, 74.75, 74, 73, 70.8 (margined), with each plug &amp; socket pair</li> <li>● See Note 1 for mate cycle definition</li> <li>● Same supplier and interoperability testing required, minimum 2 samples of each same supplier and interop combination</li> <li>● measure &amp; monitor peak forces throughout testing, to be measured during test 7.1-8</li> </ul>	
<p>7.1-14 <i>Radial Force, Mate Distance, Wet , Static</i></p>	<ul style="list-style-type: none"> <li>● Pressure: 75 PSIG</li> <li>● Ambient Temperature: 20C ± 3C</li> <li>● Fluid: PG25</li> <li>● Test Conditions:</li> <li>● Measure force required to pivot plug and socket</li> <li>● Must meet requirements in Table 6.6</li> <li>● Alignment conditions: see details below <ul style="list-style-type: none"> <li>o Aligned</li> <li>o Radial only: 5.25mm offset</li> <li>o Combined:2.6 deg &amp; 5.1mm radial, plug pivoted and radial offset</li> <li>o Combined: 2.6 deg &amp; 5.1mm radial, socket pivoted and radial offset</li> </ul> </li> <li>● Measure Static force at Mate Distances 80.1 (margined), 78.5, 78, 77, 76, 74.75, 74, 73, 70.8 (margined), with each plug &amp; socket pair</li> <li>● Minimum three cycle measurement to develop curve for each condition at the beginning and end of the cycles</li> <li>● See Note 1 for mate cycle definition</li> <li>● Same supplier and interoperability testing required, minimum 2 samples of each same supplier and interop combination</li> <li>● measure &amp; monitor peak forces throughout testing, to be measured during test 7.1-9</li> </ul>	<p>Reference PBMC Fixture &amp; Test Guideline</p>
<p>7.1-15 <i>Radial Force, Mate Cycles, Wet, Static fluid pressure</i></p>	<ul style="list-style-type: none"> <li>● Pressure:75 PSI</li> <li>● Ambient Temperature: 20C ± 3C</li> <li>● Fluid: PG25</li> <li>● Test Conditions: see fixture guidelines fixture set-up for this test</li> <li>● Velocity: Run at 40 mm/s ± 2 mm/s</li> <li>● See Note B for mate cycle description.</li> <li>● Measure force required to pivot plug and socket</li> <li>● Must meet requirements in Table 6.6</li> <li>● Alignment conditions: see details below <ul style="list-style-type: none"> <li>o Aligned</li> <li>o Radial: 5.25mm offset,</li> <li>o Combined: 2.6 deg &amp; 5.1mm radial, plug pivoted and radial offset</li> <li>o Combined: 2.6 deg &amp; 5.1mm radial, socket pivoted and radial offset</li> </ul> </li> </ul>	<p>Reference PBMC Fixture &amp; Test Guideline</p>

	<ul style="list-style-type: none"> <li>● Same supplier and interoperability testing required, minimum 2 samples of each same supplier and interop combination</li> <li>● measure &amp; monitor peak forces throughout testing, to be measured during 7.1-11</li> </ul>	
<p>7.1-16 <i>Radial Force, Mate Cycles, Wet, with flow</i></p>	<ul style="list-style-type: none"> <li>● Pressure:75 PSI</li> <li>● Ambient Temperature: 20C ± 3C</li> <li>● Fluid: PG25</li> <li>● Test Conditions: see fixture guidelines fixture set-up for this test</li> <li>● Velocity: Run at (1) 40 mm/s ± 2 mm/s</li> <li>● See Note 1 for mate cycle description.</li> <li>● measure mate, radial forces during test at a minimum of 2 cycles throughout the test in each condition</li> <li>● Must meet requirements in Table 6.6</li> <li>● Alignment conditions: see details below               <ul style="list-style-type: none"> <li>○ Aligned: socket to plug flow</li> <li>○ Aligned: plug to socket flow</li> <li>○ Radial: 5.25mm offset, socket to plug flow</li> <li>○ Radial: 5.25mm offset, plug to socket flow</li> <li>○ Combined:2.6 deg &amp; 5.1mm radial, plug to socket flow, socket pivoted and radial offset</li> <li>○ Combined: 2.6 deg &amp; 5.1mm radial, socket to plug flow, socket pivoted and radial offset</li> <li>○ Combined: 2.6 deg &amp; 5.1mm radial, plug to socket flow, plug pivoted and radial offset</li> <li>○ Combined: 2.6 deg &amp; 5.1mm radial, socket to plug flow, plug pivoted and radial offset</li> </ul> </li> <li>● Same supplier and interoperability testing required, minimum 2 samples of each same supplier and interop combination</li> <li>● measure &amp; monitor peak forces throughout testing, to be measured during 7.1-12</li> </ul>	<p>Reference PBMC Fixture &amp; Test Guideline</p>
<p>7.1.1-17 <i>Centering Verification</i></p>	<ul style="list-style-type: none"> <li>● Testing to be performed with no fluid and at 75PSIG with fluid (water or PG25)</li> <li>● Fluid &amp; Ambient Temperature: 20C ± 3C</li> <li>● (1) pivot valves (plug and socket) tips to angle stops in at least 4 orthogonal directions</li> <li>● Valve shall return to be within the zone outlined in Figure 6.3</li> <li>● (2) check centering after mate cycle testing in each of the 34mate conditions (dry and wet) during cycle testing listed in this table</li> <li>● All centering verification to be performed using a go/no-go gauge outlined in Section 6.3.</li> <li>● During the measurement, no part of the tip of the valves shall touch the gauge tools.</li> <li>● Minimum 2 samples, same supplier</li> </ul>	

<p>7.1-18 <i>Plug &amp; Socket Rotation</i></p>	<ul style="list-style-type: none"> <li>● Test are performed dry only</li> <li>● Reference Figure 16 in fixture guideline</li> <li>● Socket &amp; Plug shall have a minimum rotation capability outlined in table 6.4</li> <li>● Centering verification to be performed using a go/no-go gauge referencing Datum A &amp; B of each valve. The gauge shall be rotated 360 degrees to verify rotation capability in all directions.</li> <li>● Minimum 2 samples, same supplier</li> </ul>	<p>Reference PBMC Fixture &amp; Test Guideline</p>
<p>7.1-19 <i>Thread Strength</i></p>	<ul style="list-style-type: none"> <li>● Perform torque test on the socket into manifold port at 120% of the maximum values for the socket and plug (screws), for material and port design reference manifold spec., For valve, no stripping of threads, no damage to socket or plug interfaces, and no leaks allowed.</li> <li>● Plug test torque value for M3 screws :             <ul style="list-style-type: none"> <li>○ 10 in-lbs [1.13 N-m] into the all threaded hole locations to using standard zinc plated steel screw</li> </ul> </li> <li>● Plug port interface test             <ul style="list-style-type: none"> <li>○ 36 N-m ([26.6 ft-lb] test level, to be tested with stainless</li> </ul> </li> <li>● Socket port interface test             <ul style="list-style-type: none"> <li>○ 72 N-m [53.1 ft-lb] test level, to be tested with stainless</li> </ul> </li> <li>● No stripping of damage to threads</li> <li>● Minimum 3 samples, same supplier</li> </ul>	
<p>7.1-20 <i>Pivot Movement &amp; External Torque Test.</i></p>	<p><b>Plug Valve Torque &amp; Movement Test:</b></p> <ul style="list-style-type: none"> <li>● Fluid water or PG25</li> <li>● Fluid &amp; Ambient Temperature: 20C ± 3C</li> <li>● Test Pressure (1) 1PSI &amp; (2) 75PSI</li> <li>● For each fluid pressure, apply 6Nm torque to adaptor rod on swivel at 0, 90, 180 and 270 degrees , 4 times per angle</li> <li>● Minimum 3 samples, same supplier</li> <li>● No leaks or functional damage</li> </ul> <p><b>Socket Valve Movement Test:</b></p> <ul style="list-style-type: none"> <li>● Fluid water or PG25</li> <li>● Test Pressure (1) 1PSI &amp; (2) 75PSI</li> <li>● For each fluid pressure, by hand pivot socket pivoting body to its maximum angle in multiple directions at 0, 90, 180 and 270 degrees , 4 times per angle</li> <li>● Minimum 3 samples, same supplier</li> <li>● No leaks or functional damage</li> </ul>	<p>Reference PBMC Fixture &amp; Test Guideline Section 19</p>

<p>7.1-21 <i>Packaging</i></p>	<ul style="list-style-type: none"> <li>● <b>(2A OR 2B) Single Parcel</b> <ol style="list-style-type: none"> <li>1. For packages <math>\leq</math> 150lbs follow Section 2A</li> <li>2. For packages <math>&gt;</math> 150lbs follow Section 2B</li> <li>3. Random Vibration, Performed in shipping box. All six of the container sides will be tested for 30 minutes/side for Single Containers. (Total 180 mins)</li> <li>4. Drop - Sequence for Single Containers on 1 corner, 3 edges, 6 flats. Drop heights should follow ASTM Packaged Product Test Procedure. Drop Height based on guidelines listed in spec. Test sequence per specification.</li> <li>5. Compression - Apply and hold force= <math>W \times (S-1) \times F</math>. No damage to package.                      W: total weight of packaged product                      S: total number of packaged products in a stack                      F: compensating factor; a minimum of 4 (all this is in the spec but listed for reference)</li> </ol> </li> <li>● <b>(3E) Palletized Package:</b> <ol style="list-style-type: none"> <li>1. Use section 3E</li> <li>2. Vibration - 60 mins on bottom side for Palletized Containers.</li> <li>3. Drop – Sequence for Palletized Containers:                             <ol style="list-style-type: none"> <li>a. Opposite edge with a wooden fixture 4 inch in height.</li> <li>b. 8 inches off the surface and drop for 4 edges.</li> </ol> </li> </ol> </li> <li>● <b>Post Test Functional Requirements:</b> <ol style="list-style-type: none"> <li>1. Hydrostatic pressure test as outlined in test 7.1.5</li> </ol> </li> <li>● No physical damage from visual inspection during chamber and post test, including but not limited to no leakage, rust or oxidation, etc.</li> </ul>	<p>ISTA 2A/2B/3E</p>
<p>7.1-22 <i>Operating Temperature Testing</i></p>	<ul style="list-style-type: none"> <li>● <b>Test Conditions:</b> <ol style="list-style-type: none"> <li>1. Ambient: 62°C, 15%RH: 16hrs; Fluid temp 62°C <math>\pm</math> 2°C</li> <li>2. Ambient: -5°C: 16hrs; Fluid temp -5°C <math>\pm</math> 2°C</li> <li>3. Air Ramp Rates: 10°C/hr &amp; 20%RH/hr max. (humidity control at -5°C not required)</li> <li>4. Fluid Ramp rate: 10°C/hr max ramp</li> </ol> </li> <li>● Socket and plug assemblies mated within range in Table 6.1</li> <li>● Fluid: PG25 with minimum 80 PSIG</li> <li>● <b>Post Test Functional Requirements (to be performed after both 7.1-22 &amp; 7.1-23 are completed):</b> <ol style="list-style-type: none"> <li>1. Hydrostatic pressure test as outlined in test 7.1-5</li> <li>2. Dry the valves and perform helium leak test per ASTM E493, leak rate requirement: <math>1 \times 10^{-5}</math> mbar-L/S. Perform test on valves individually at 75psi. Perform for 10 to 30 seconds once the above leak rate is achieved.</li> </ol> </li> <li>● Same supplier and interoperability testing required, a minimum of one sample of each same supplier and interop combination required</li> <li>● <b>Pass/Fail:</b> Pass test and post tests listed above and no physical damage from visual inspection, including but not limited to no leakage,</li> </ul>	

	meets helium leak test, passes hydrostatic pressure test, no rust or oxidation, etc.	
7.1-23 <i>Operating Humidity Testing</i>	<ul style="list-style-type: none"> <li>● Test Conditions:             <ol style="list-style-type: none"> <li>1. 40C, 93%RH: 16hrs</li> <li>2. 40C, 10%RH: 16hrs</li> <li>3. Fluid Temp for all tests: 23 ± 10C during dwell; Fluid Ramp rate: 10C/hr max ramp</li> <li>4. Air Ramp Rates: 10C/hr &amp; 20%RH/hr max</li> </ol> </li> <li>● Socket and plug assemblies mated within range in Table 6.1</li> <li>● Fluid: PG25 with minimum 80 PSIG</li> <li>● Post Test Functional Requirements ( to be performed after both 7.1-22 &amp; 7.1-23 are completed):             <ol style="list-style-type: none"> <li>1. Hydrostatic pressure test as outlined in test 7.1-5</li> <li>2. Dry the valves and perform helium leak test per ASTM E493, leak rate requirement: 1x10<sup>-5</sup> mbar-L/S. Perform test on valves individually at 75psi. Perform for 10 to 30 seconds once the above leak rate is achieved.</li> </ol> </li> <li>● Same supplier and interoperability testing required, a minimum of one sample of each same supplier and interop combination required</li> <li>● Pass/Fail: Pass test and post tests listed above and no physical damage from visual inspection, including but not limited to no leakage, meets helium leak test,passes hydrostatic pressure test, no rust or oxidation, etc.</li> </ul>	
7.1-24 <i>Non-Operating Temperature</i>	<ul style="list-style-type: none"> <li>● Test Conditions:             <ol style="list-style-type: none"> <li>1. 72C,15%RH: 72hrs, 20C/hr &amp; 20%RH/hr max</li> <li>2. -42C: 72hrs, 20C/hr max</li> </ol> </li> <li>● Post Test Functional Requirements ( to be performed after both 7.1-24 &amp; 7.1-25 are completed):             <ol style="list-style-type: none"> <li>1. Hydrostatic pressure test as outlined in test 7.1-5</li> <li>2. Dry the valves and perform helium leak test per ASTM E493, leak rate requirement: 1x10<sup>-5</sup> mbar-L/S. Perform test on valves individually at 75psi. Perform for 10 to 30 seconds once the above leak rate is achieved.</li> </ol> </li> <li>● Same supplier only, one pair of valves required, samples for nonoperating temperature and nonoperating humidity to be the same exact parts (serial no)</li> <li>● Pass/Fail: Pass test and post tests listed above and no physical damage from visual inspection, including but not limited to no leakage, meets helium leak test,passes hydrostatic pressure test, no rust or oxidation, etc.</li> </ul>	
7.1-25 <i>Non-Operating Humidity</i>	<ul style="list-style-type: none"> <li>● Test Conditions:             <ol style="list-style-type: none"> <li>1. 40C, 95% RH: 120hrs, 20% RH/hr max</li> <li>2. 40C, 5% RH: 96hrs, 20% RH/hr max</li> </ol> </li> <li>● Post Test Functional Requirements ( to be performed after both 7.1-24 &amp; 7.1-25 are completed):             <ol style="list-style-type: none"> <li>1. Hydrostatic pressure test as outlined in test 7.1-5</li> </ol> </li> </ul>	

	<p>2. Dry the valves and perform helium leak test per ASTM E493, leak rate requirement: <math>1 \times 10^{-5}</math> mbar-L/S. Perform test on valves individually at 75psi. Perform for 10 to 30 seconds once the above leak rate is achieved.</p> <ul style="list-style-type: none"> <li>• Same supplier only, one pair of valves required, samples for nonoperating temperature and nonoperating humidity to be the same exact parts (serial no)</li> <li>• Pass/Fail: Pass test and post tests listed above and no physical damage from visual inspection, including but not limited to no leakage, meets helium leak test, passes hydrostatic pressure test, no rust or oxidation, etc.</li> </ul>	
<p>7.1-26 <i>Salt Spray (Corrosion resistance)</i></p>	<ul style="list-style-type: none"> <li>• Test Conditions:             <ol style="list-style-type: none"> <li>1. Follow ASTM B117 spec</li> <li>2. Duration: 72 hrs</li> <li>3. The position of the part under test can be placed vertically or horizontally with thread cap on. Parts should be tested loose (socket and plug assemblies un-mated.)</li> </ol> </li> <li>• Post Test Functional Requirements:             <ol style="list-style-type: none"> <li>1. Hydrostatic pressure test as outlined in test 7.1-5</li> <li>2. <i>Dry the valves and perform helium leak test per ASTM E493, leak rate requirement: <math>1 \times 10^{-5}</math> mbar-L/S. Perform test on valves individually at 75psi. Perform for 10 to 30 seconds once the above leak rate is achieved.</i></li> </ol> </li> <li>• Same supplier only, minimum of one pair of valves required</li> <li>• Pass/Fail requirements: Pass post test hydrostatic and helium leak test listed above after the chamber test. Leakage is not allowed during post test. Sample continues to operate as intended as listed above. Cosmetic issues including rust or discoloration are acceptable as long as valve performance is not affected.</li> </ul>	<p>ASTM B117</p>

**Note: 1** A mate cycle is described as follows: starting from completely unmated then to 70.8 mm mate distance and back to completely un-mated

## 8. Cosmetic Guidelines

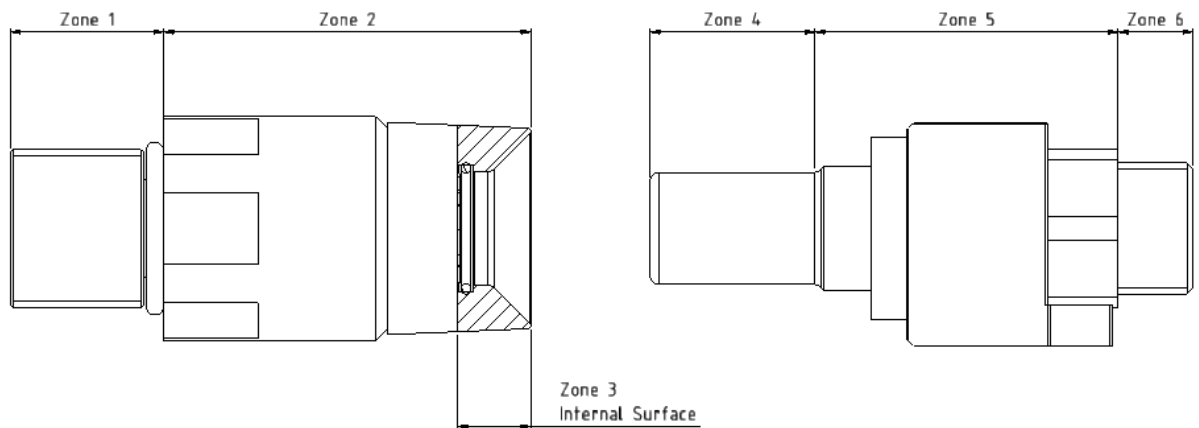
This section outlines the recommended product cosmetic acceptance criteria. These guidelines should be aligned across suppliers, integrators, and end users throughout the ecosystem. Common surface quality considerations are outlined below for reference.

This document is only applicable to products that are new, unused products and inspected immediately after the product has been unpackaged from the shipping packaging.

### 8.1 Visual Inspection

Recommended visual acceptance criteria for inspection of the various surfaces of the valves are provided below. Specific zones on the parts are provided below per Figure 8.1 and referenced in Table 8.2. Where no guidance is provided, acceptance criteria is left at the discretion of the valve supplier. General guidance for visual inspection includes the following:

- Zone 3 includes all visible internal surfaces of the socket from the front of the cone to the valve face, including the radius transitions  
Inspect for one full rotation (360°) of part, 2x magnification is recommended.
- Inspection lighting shall be performed under typical office lighting conditions (~700-1200LUX)
- TAPPI/ANSI T 564 chart may be used for defect size estimation
- Prior to inspection, any loose particles present may be removed via compressed filtered air
- Recommended that inspector wear nitrile or rubber gloves and a cleanroom cap



**Figure 8.1 Inspection Surface Zones**

## 8.2 Visual Attribute Criteria

Recommendations for criteria for common visual attributes are provided below in the table below.

**Table 8.2 - Visual Evaluation**

Visual Attribute	Description	Acceptance Criteria	Zone Specific
<b>Surface Imperfections</b>	Minor notch, impression or deformation of surface(s)	All defect sizes $\leq$ 0.3mm <sup>2</sup>	1, 3, 4, 6
		All defect sizes $\leq$ 1.0 mm <sup>2</sup>	2, 5
<b>Manufacturing Artifacts</b>	Resulting surface characteristics from typical fabrication processes, such as machining tool marks	Base material and as manufactured characteristics are acceptable per the prevailing surface (Ra) requirements	All
	Metal or plastic remnants from processing such as shavings or burrs	No residual debris from manufacturing present - loose or attached	All
<b>Compromised Material</b>	Foreign particulate/substance present or evidence of unintended <sup>1</sup> chemical reaction such as oxidation	No foreign materials, rust or other evidence of corrosion present	All
<b>Thread Profile</b>	Deformation or damage to termination thread that would prevent installation or compromise performance	Evaluate with applicable standard thread/plug gauge <sup>2</sup> or mating port	1, 6
<sup>1</sup> Intentional surface treatments such as passivation may result in a yellowing tint to stainless steel <sup>2</sup> Reference termination thread class for appropriate gauging			

## 9. Safety

Test items	Requirements	Reference	Criteria
Hydrostatic pressure (Normal operation)	Valve shall be designed to meet three times the maximum working pressure at normal operating condition (PSI to meet: 225PSI)	UL62368-1	During and after tests, there shall be no rupture, no leaks and no loosening of any connection or part.
Hydrostatic pressure (Abnormal operation)	Valve shall be designed to meet two times the maximum working pressure after single fault condition is applied (PSI to meet: 150)	UL62368-1	During and after tests, there shall be no rupture, no leaks and no loosening of any connection or part.
Flammability	Plastic parts shall meet UL94 flammability rating.	UL62368-1	V1 or higher

## 10. Environmental Regulatory Compliance and Design

- RoHS Directive (2015/863/EU and latest revisions); aims to reduce the environmental impact of EEE by restricting the use of certain substances during manufacture.
- REACH Regulation (EC) No 1907/2006; the risk assessment for the restriction of PFAS, and registration with the European Chemicals Agency (ECHA), evaluation, authorization and restriction of chemicals.
- WEEE Directive (2012/19/EU); aims to reduce the environmental impact of EEE by restricting the use of certain substances during manufacture.
- Substances of Concern In articles as such or in complex objects (Products): product shall not contain any substances regulated by EPA 40 CFR751

**Table 10.0 Environmental Specifications**

Condition	Specification
Operating Temperature	-5C to 60C with fluid*
Nonoperating Temperature	-40C to 70C, without fluid
Operating Humidity	10% to 93%, noncondensing, with fluid*
Nonoperating Humidity	5% to 95%, noncondensing, without fluid
Salt Spray	Per ASTM B117, without fluid

\* Testing performed with Dowfrost LC25. Usage of other fluids may affect this working range and will need to be tested by the end user.

## 11. Prescribed Materials

### 11.1 Non-Wetted Materials

- All components to be RoHs compliant and pass required testing listed elsewhere in this specification

### 11.2 Wetted Materials

- *Plug and socket components: SS303, SS304*
- Springs (Internal and external) any of the following: SS302, UNS S30203, SS304, UNS S30403, SS316, UNS S31603, SS321, UNS S32103, SS410, UNS17700
- All wetted stainless steel components to be passivated
- Seals to be EPDM
- All components to be RoHs compliant

## 12. References

1. ISO 18869:2017
2. UL62368-1 2nd edition
3. ASTM B117
4. ISTA 2A/2B/3E
5. PBMC Reference Test Guideline - included in collateral
6. PBMC Test Fixture Guidelines and Procedures - included in collateral
7. PBMC Test Submission Template - included in collateral
8. PBMC Supplemental Test Data - included in collateral