

# **Alpha Magnetic Spectrometer 02 (AMS-02) Experiment/Vacuum Case (VC) Payload Integration Hardware (PIH) Interfaces**

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**Engineering Directorate**

**February 2005  
Revision C**



National Aeronautics and  
Space Administration

**Lyndon B. Johnson Space Center**  
Houston, Texas

# Alpha Magnetic Spectrometer 02 (AMS-02) Experiment/Vacuum Case (VC) Payload Integration Hardware (PIH) Interfaces

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## PREFACE

This Interface Control Document (ICD) represents the interface agreement between the Alpha Magnetic Spectrometer – 02 (AMS-02) Experiment and the Vacuum Case Payload Integration Hardware (PIH) for the version of the payload to be operated on the International Space Station (ISS) for a minimum of three (3) years. The mission baseline is 1000 days of operational time (24,000 hours) in full deep space view.

A precursor flight (AMS-01) was accomplished on the Space Shuttle during the STS-91 flight and was addressed in an ICD similar to this document. The AMS on STS-91 was operated for approximately 8.5 days during the flight.

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## ACRONYMS AND ABBREVIATIONS

ACC	ANTI-COINCIDENCE COUNTER
AMS	ALPHA MAGNETIC SPECTROMETER
CM	COLD MASS
CMR	COLD MASS REPLICA
DOE	DEPARTMENT OF ENERGY
ESCG	ENGINEERING AND SCIENCES CONTRACT GROUP
ETH	EIDGEROSSISCHE TECHNISCHE HOCHSCHULE
GHE	GROUND HANDLING EQUIPMENT
GSE	GROUND SUPPORT EQUIPMENT
GSFC	GODDARD SPACE FLIGHT CENTER
ICD	INTERFACE CONTROL DOCUMENT
ISS	INTERNATIONAL SPACE STATION
JSC	LYNDON B. JOHNSON SPACE CENTER
LSR	LOWER SUPPORT RING
MIT	MASSACHUSETTS INSTITUTE OF TECHNOLOGY
NASA	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
PIH	PAYLOAD INTEGRATION HARDWARE
PM	PHOTO MULTIPLIER
SCL	SPACE CRYOMAGNETICS LTD.
SFHe	SUPERFLUID HELIUM
STA	STRUCTURAL TEST ARTICLE
STE	SPECIAL TEST EQUIPMENT
TBD	TO BE DETERMINED
TCS	THERMAL CONTROL SYSTEM
USR	UPPER SUPPORT RING
USS	UNIQUE SUPPORT STRUCTURE
VC	VACUUM CASE

## **1.0 INTRODUCTION**

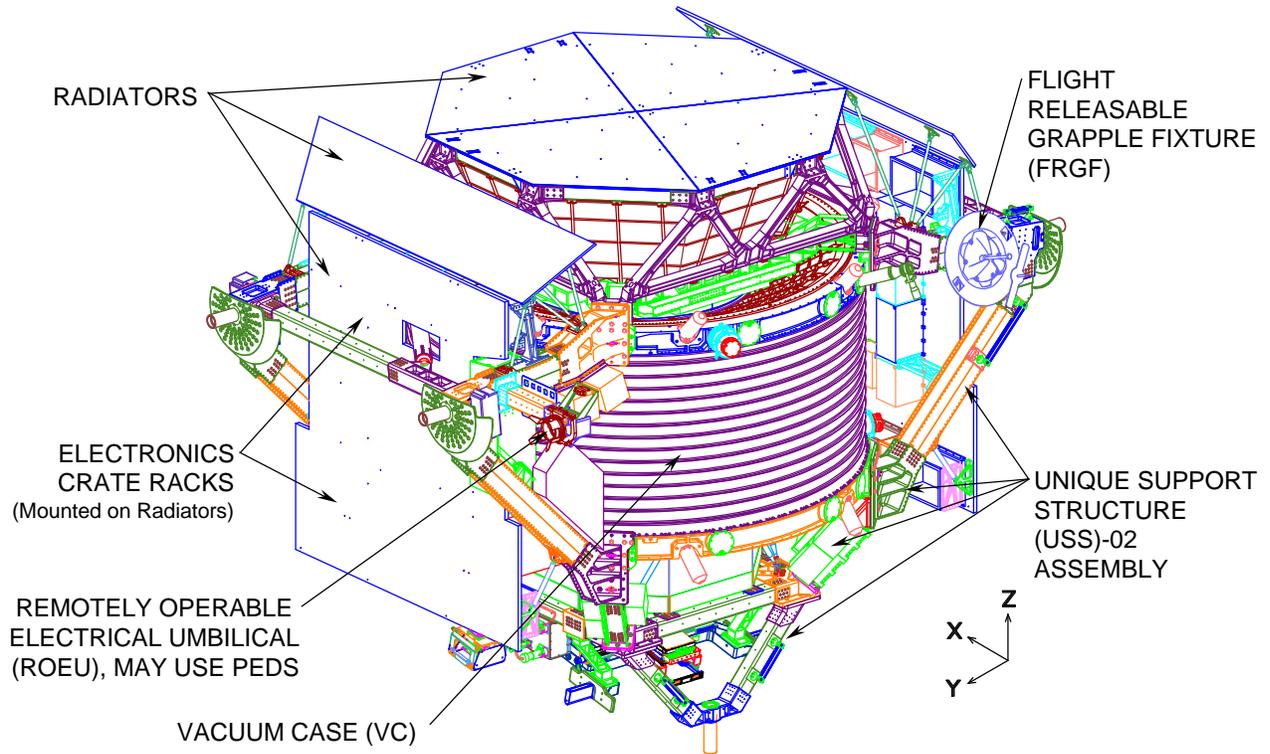
### **1.1 General**

In this Interface Control Document (ICD) “AMS” will refer to the total complement of activities, hardware, software, test, integration and operation of the Alpha Magnetic Spectrometer – 02 (AMS-02). The flight hardware is referred to as the “AMS Payload” and is comprised of two parts: the “AMS Experiment” provided by the international AMS Experiment Collaboration and the “AMS Payload Integration Hardware (PIH)” provided by the JSC Engineering Directorate with the support of the Engineering and Sciences Contract Group (ESCG).

This ICD pertains only to the version of the AMS (AMS-02) that will be installed and operated on the International Space Station (ISS). The acronym “AMS-01” will be used for references to the precursor flight version that flew on STS-91.

### **1.2 AMS Payload Description**

The AMS Experiment is a state-of-the-art particle physics detector containing a large, cryogenic superfluid helium superconducting magnet that will be designed, constructed, tested and operated by an international team organized under United States Department of Energy (DOE) sponsorship. The AMS Payload is shown in Figure 1.2-1. The AMS Experiment will use the unique environment of space to advance knowledge of the universe and potentially lead to a clearer understanding of the universe’s origin. Specifically, the science objectives of the AMS are to search for cosmic sources of antimatter (i.e., anti-helium or heavier elements) and dark matter.



**Figure 1.2-1 AMS-02 Payload and Experiment**

### 1.3 Document Purpose

This ICD is only to define the interfaces between the PIH Vacuum Case and the Eidgenössische Technische Hochschule (ETH) Cryomagnet and the AMS-02 Tracker and the Anti-Coincidence Counter (ACC).

## 2.0 MECHANICAL REQUIREMENTS

This section describes the mechanical and physical interfaces associated with the PIH Vacuum Case, ETH/Space Cryomagnetics Limited (SCL) Cryomagnet and the AMS-02 Tracker and ACC.

### 2.1 Coordinate System

The AMS-02 payload and AMS-02 experiment coordinate axis systems are identical and are shown in Figures 2.1-1 and 2.1-2. Dimensions are in inches. The AMS-02 origin is at the geometric center of the Vacuum Case and Tracker. All coordinate systems shown in this document are based on the right hand rule.

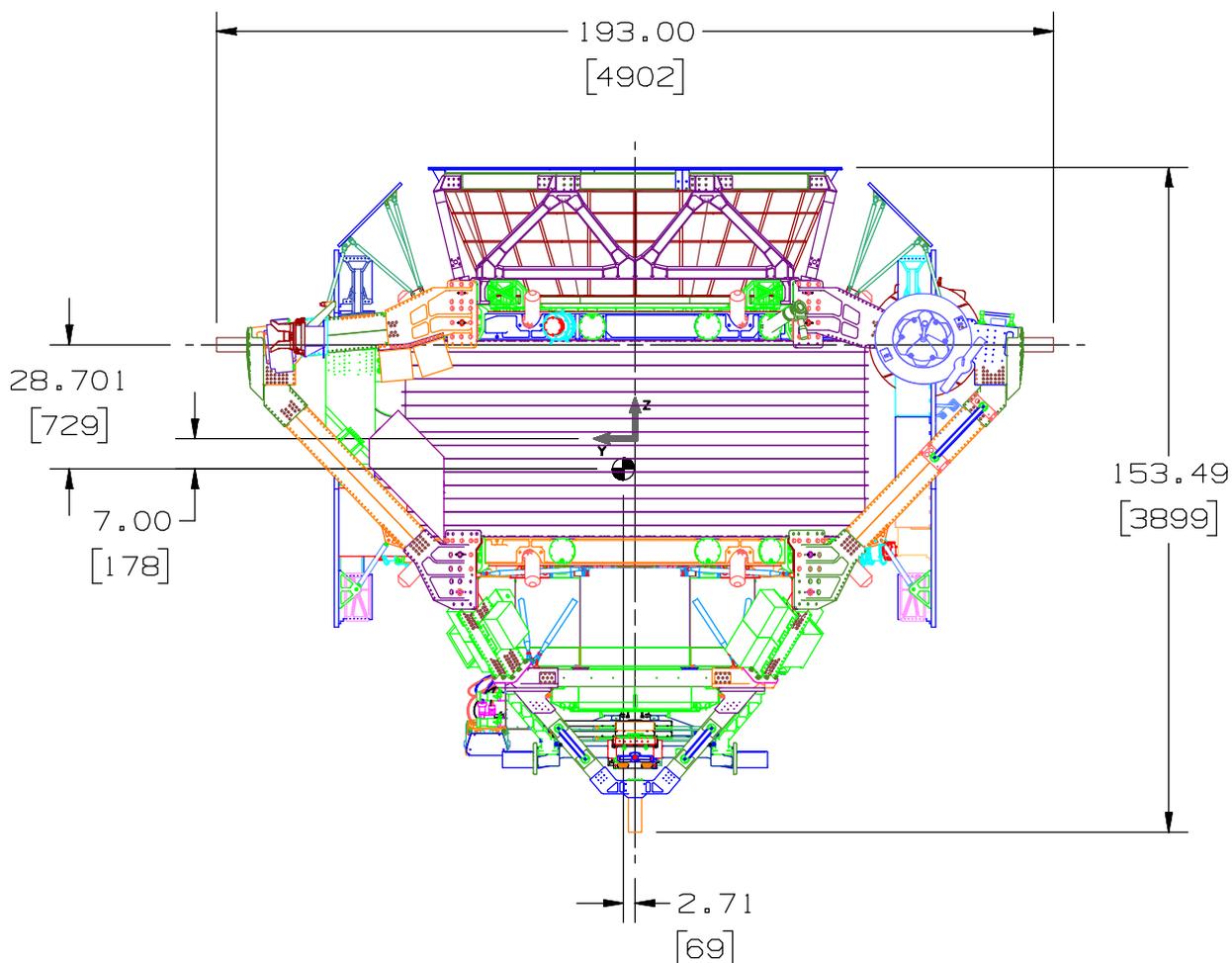


Figure 2.1-1 AMS-02 Payload and Experiment Coordinate Axis and Origin (1 of 2)

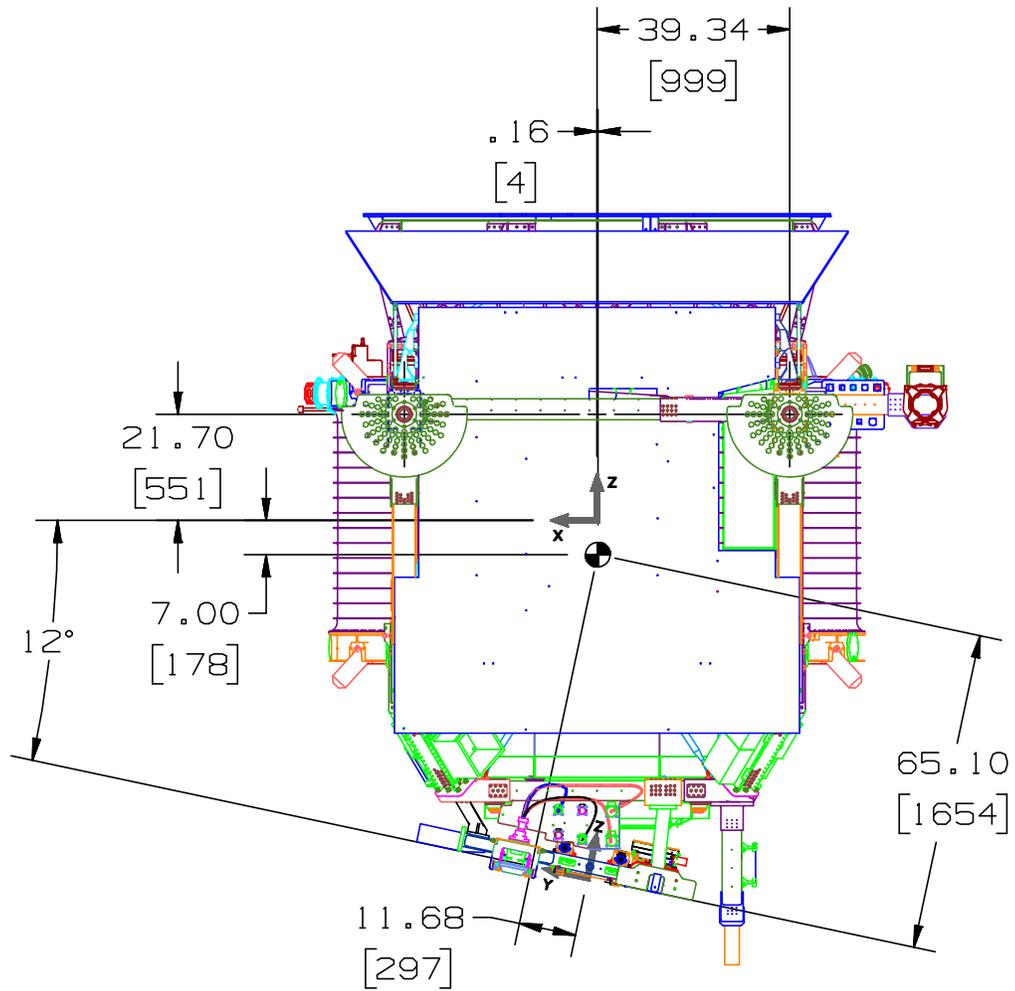
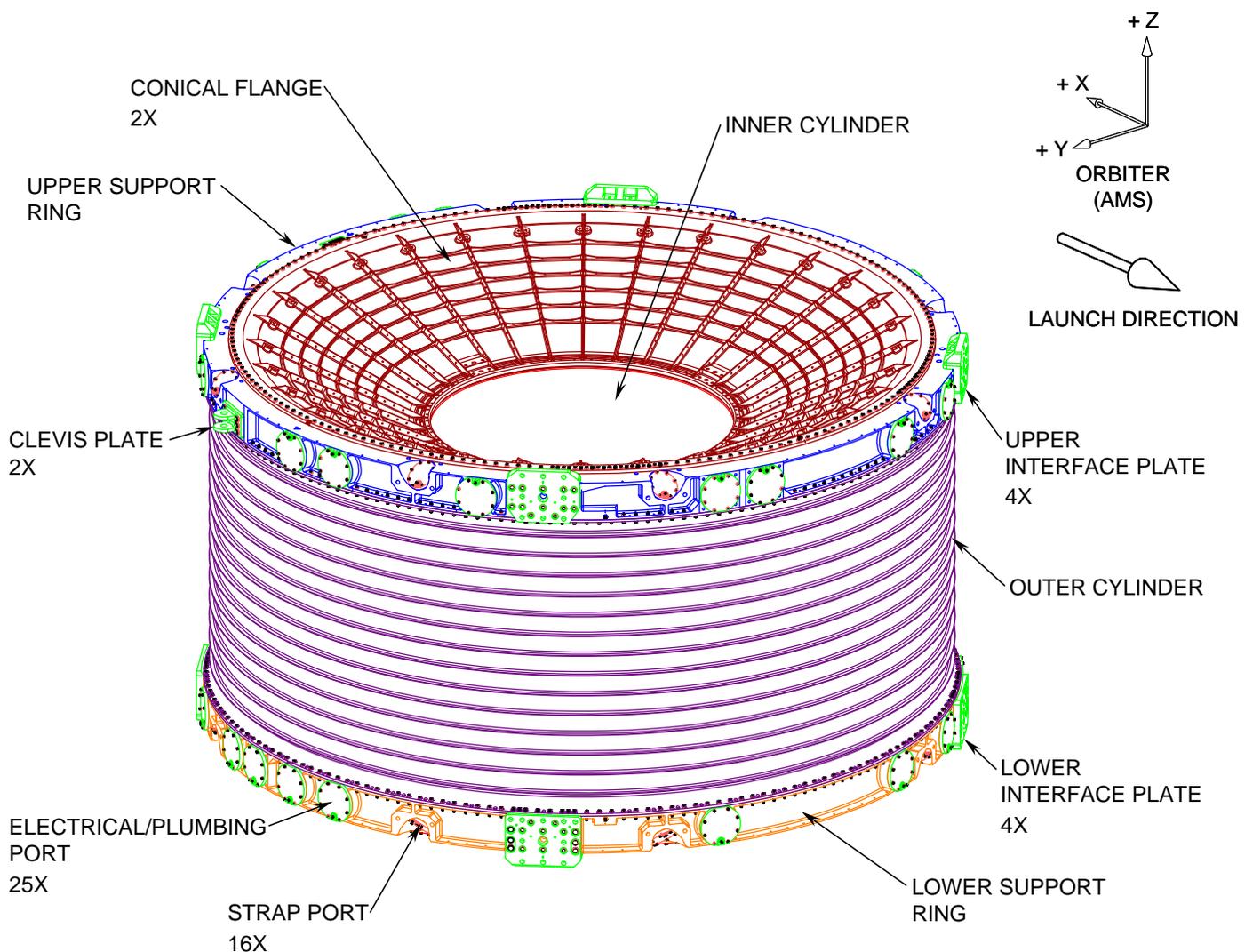


Figure 2.1-2 AMS-02 Payload and Experiment Coordinate Axis and Origin (2 of 2)

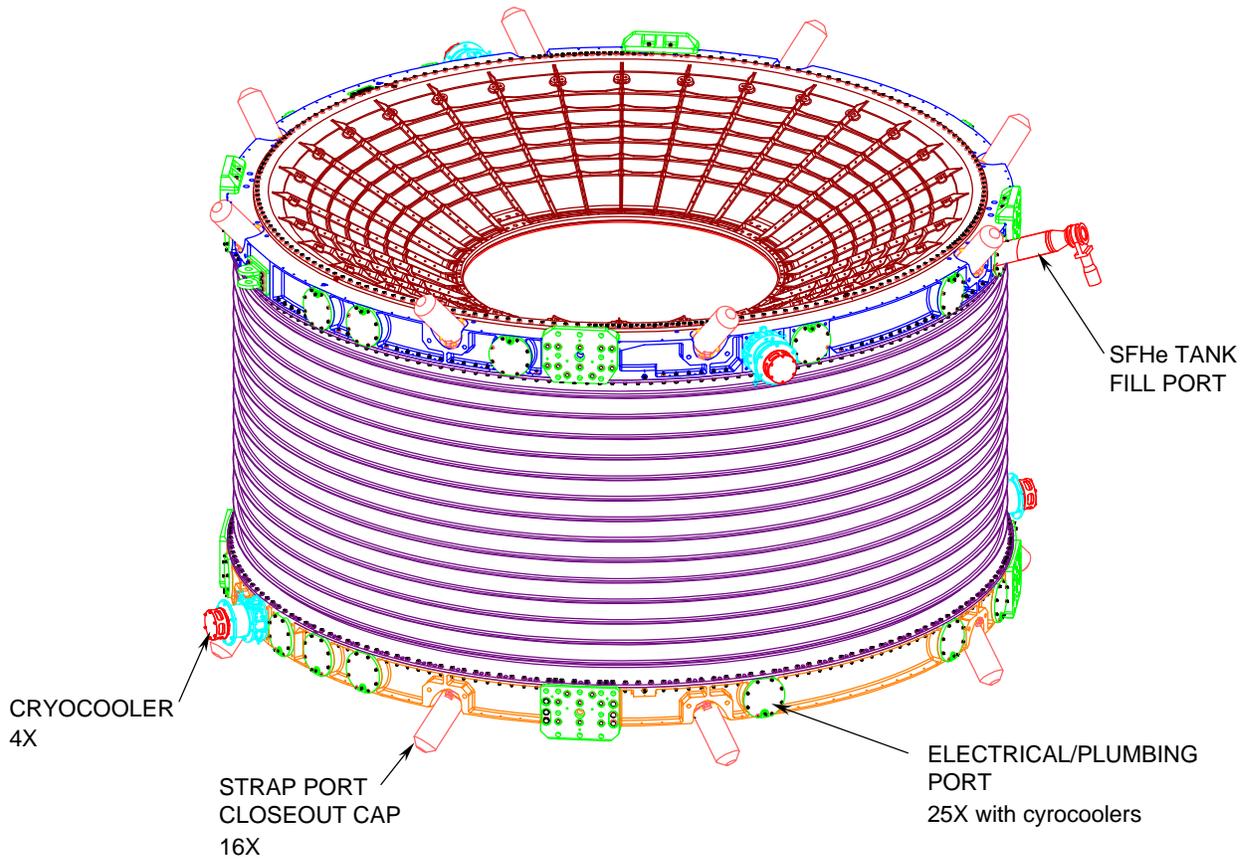
## 2.2 AMS Experiment to Vacuum Case Interfaces

### 2.2.1 Cryomagnet System to Vacuum Case (VC)

The Cryomagnet Vacuum Case is being developed by NASA/ESCG and will interface to the Cryomagnet, Super Fluid Helium Tank, and a Cryogenic System internally. It will also interface to the Tracker, Anti-Coincidence Counter (ACC), and various other experiment hardware externally. Figure 2.2.1-1 shows the overall Vacuum Case Assembly and Figure 2.2.1-2 shows a section view of the Vacuum Case Assembly. Details of the inner joint, outer joint, and O-ring grooves are shown in Figures 2.2.1-3, 2.2.1-4, and 2.2.1-5, respectively.



**Figure 2.2.1-1 Vacuum Case Assembly (NASA Delivered)**



**Figure 2.2.1-2 Vacuum Case Assembly (With Misc. Port Attachments)**

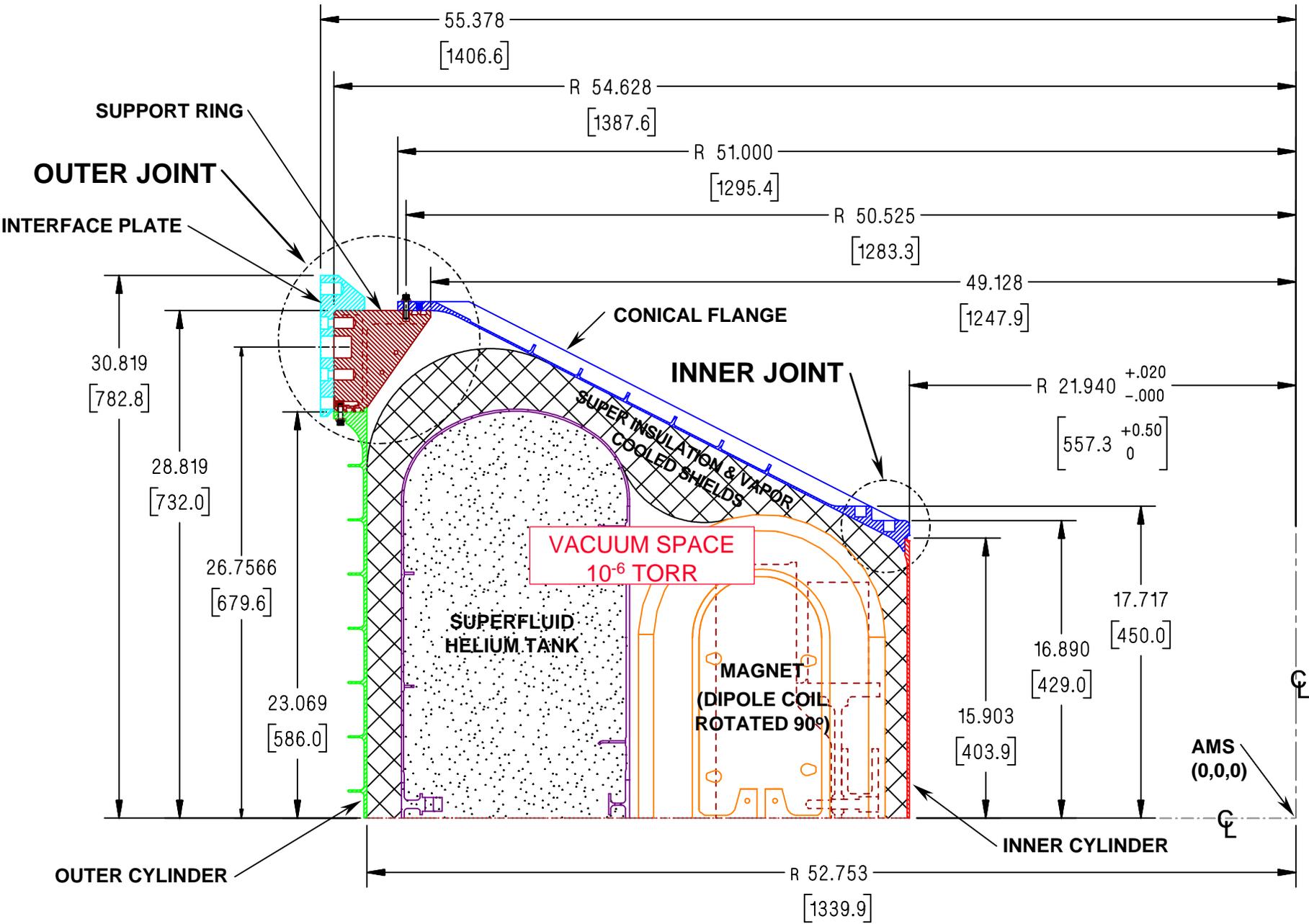


Figure 2.2.1-3 Vacuum Case Cross-Section

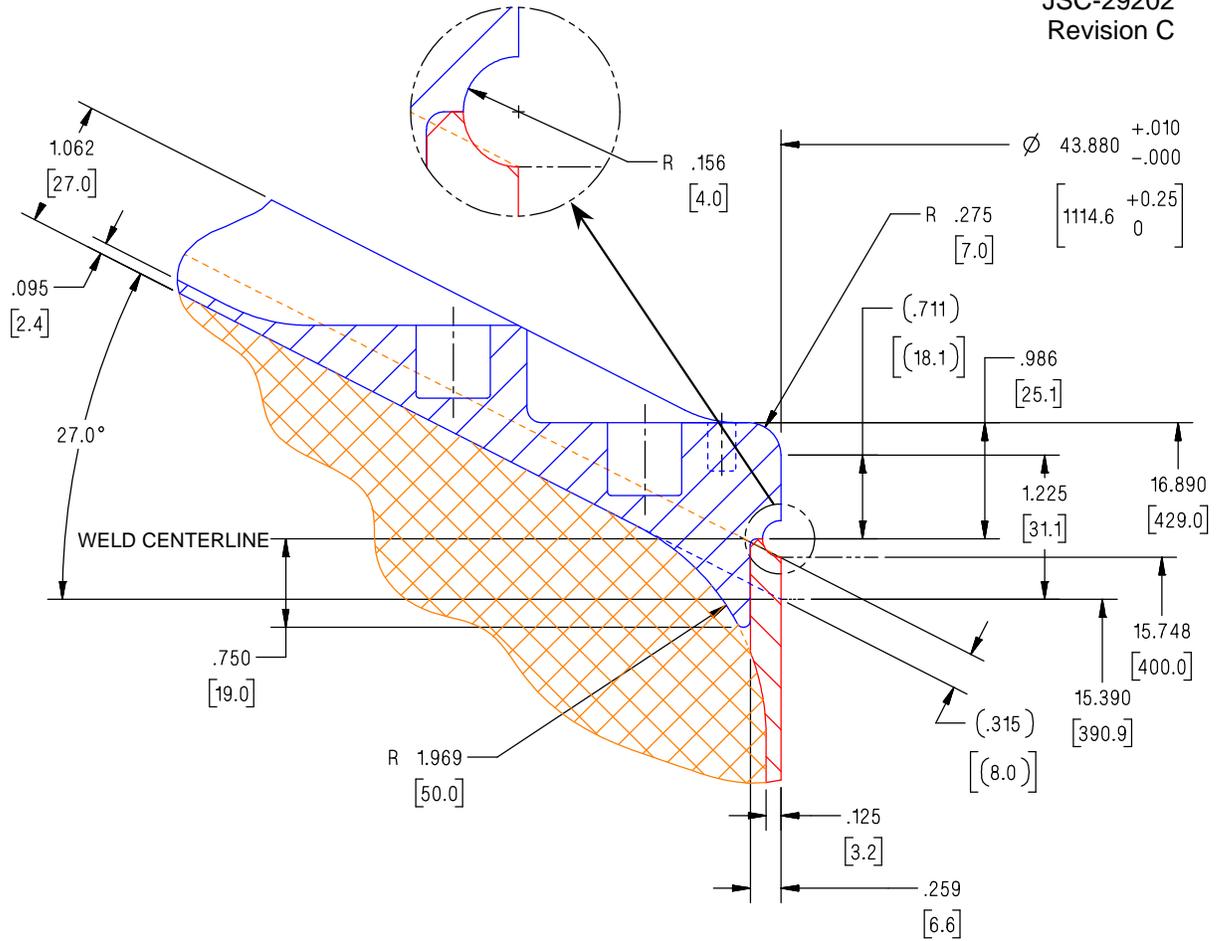


Figure 2.2.1-4 Inner Joint Detail

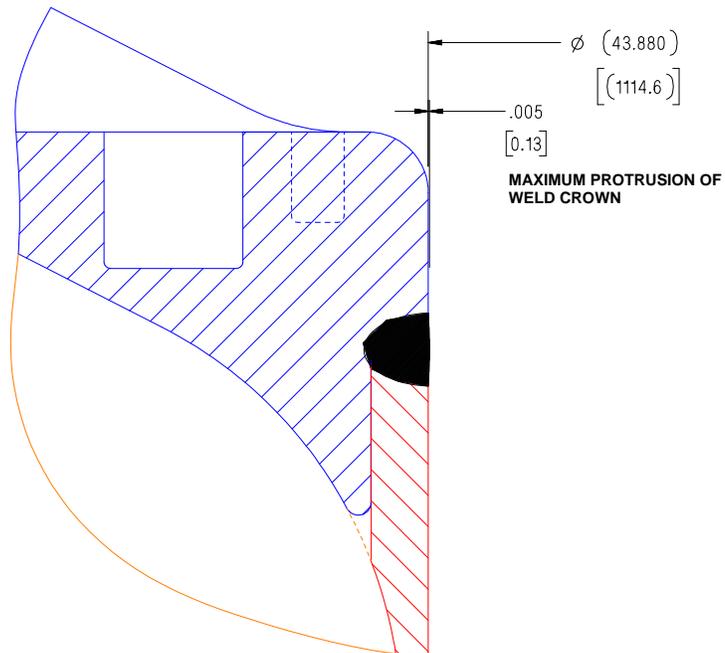


Figure 2.2.1-5 Closeout Weld

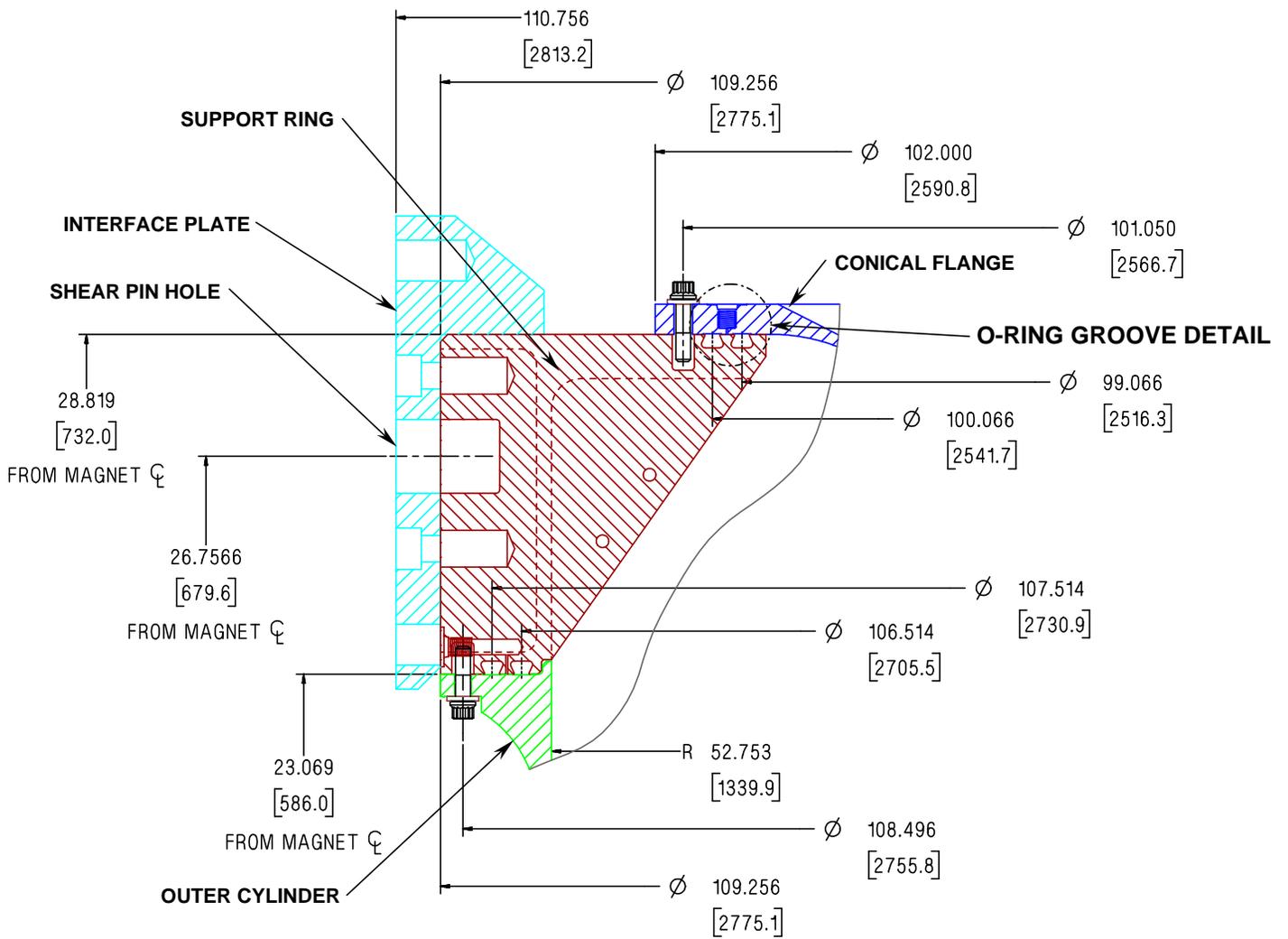
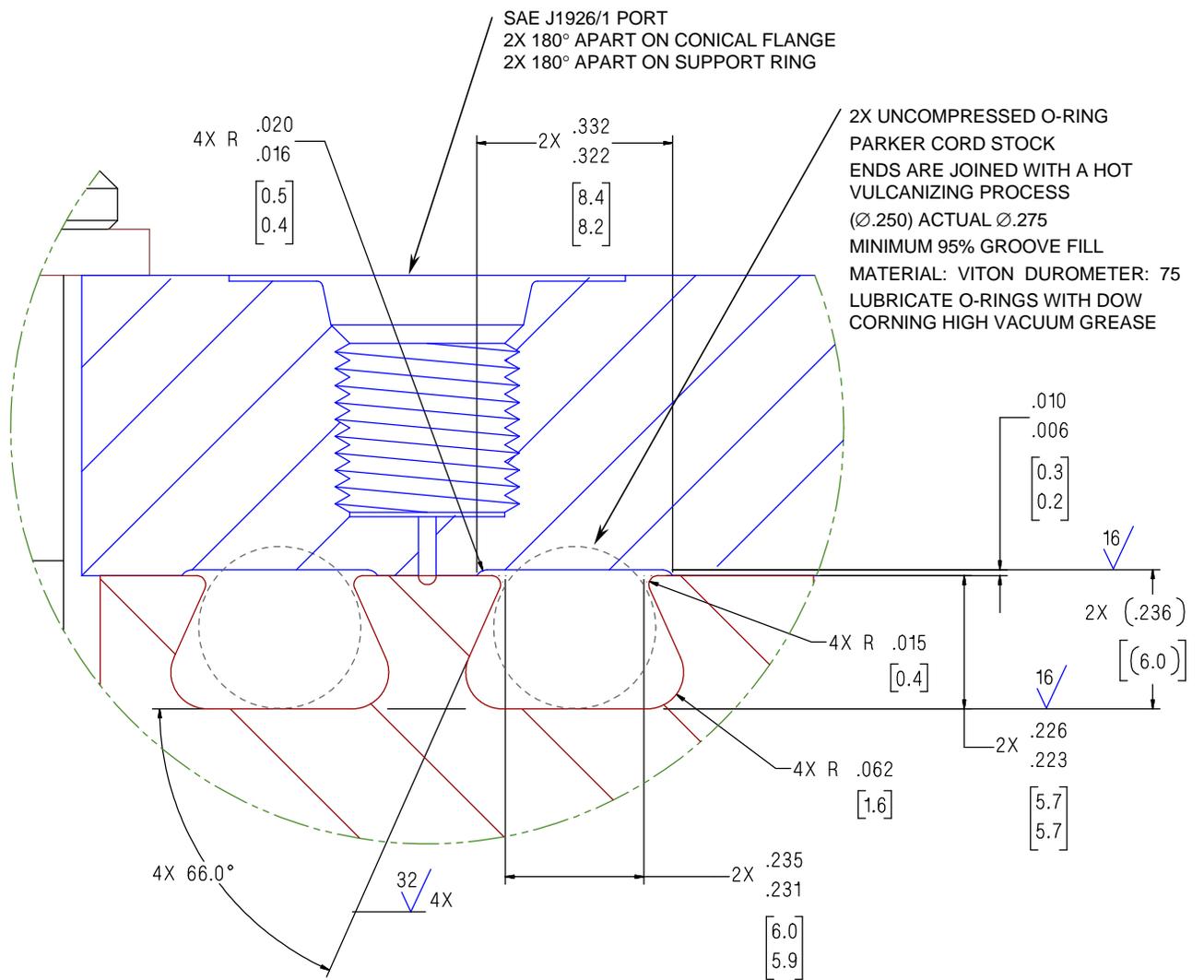


Figure 2.2.1-6 Outer Joint Detail



**Figure 2.2.1-7 O-Ring Groove Detail**

## 2.2.2 Temporary Seal

A temporary seal will be used prior to the final closeout weld in order to test the Vacuum Case and Cold Mass. This seal is shown in Figure 2.2.2-1 and will be at both ends of the VC. The temporary seal will be provided by ETH/SCL.

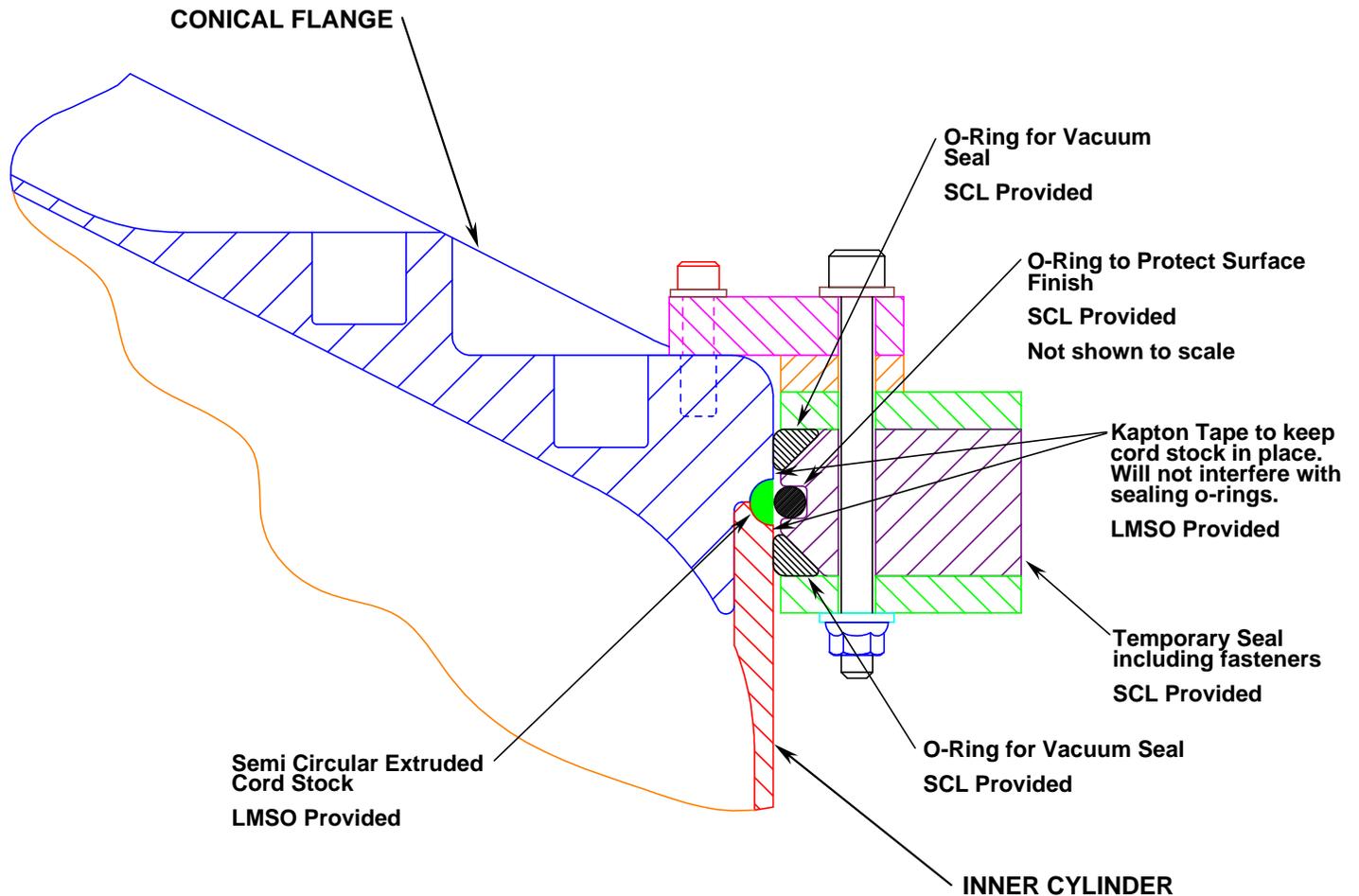


Figure 2.2.2-1 Temporary Seal

### 2.2.3 Magnet Support System

The Cryomagnet, Super Fluid Helium Tank, and Cryosystem are all supported to the Vacuum Case through the Magnet Support System. The Magnet Support System is comprised of 16 non-linear composite straps that connect to the Vacuum Case as shown in Figures 2.2.3-1 through 2.2.3-7. The Closeout Cap (provided by ETH/SCL) for these straps is shown in Figure 2.1.3-8.

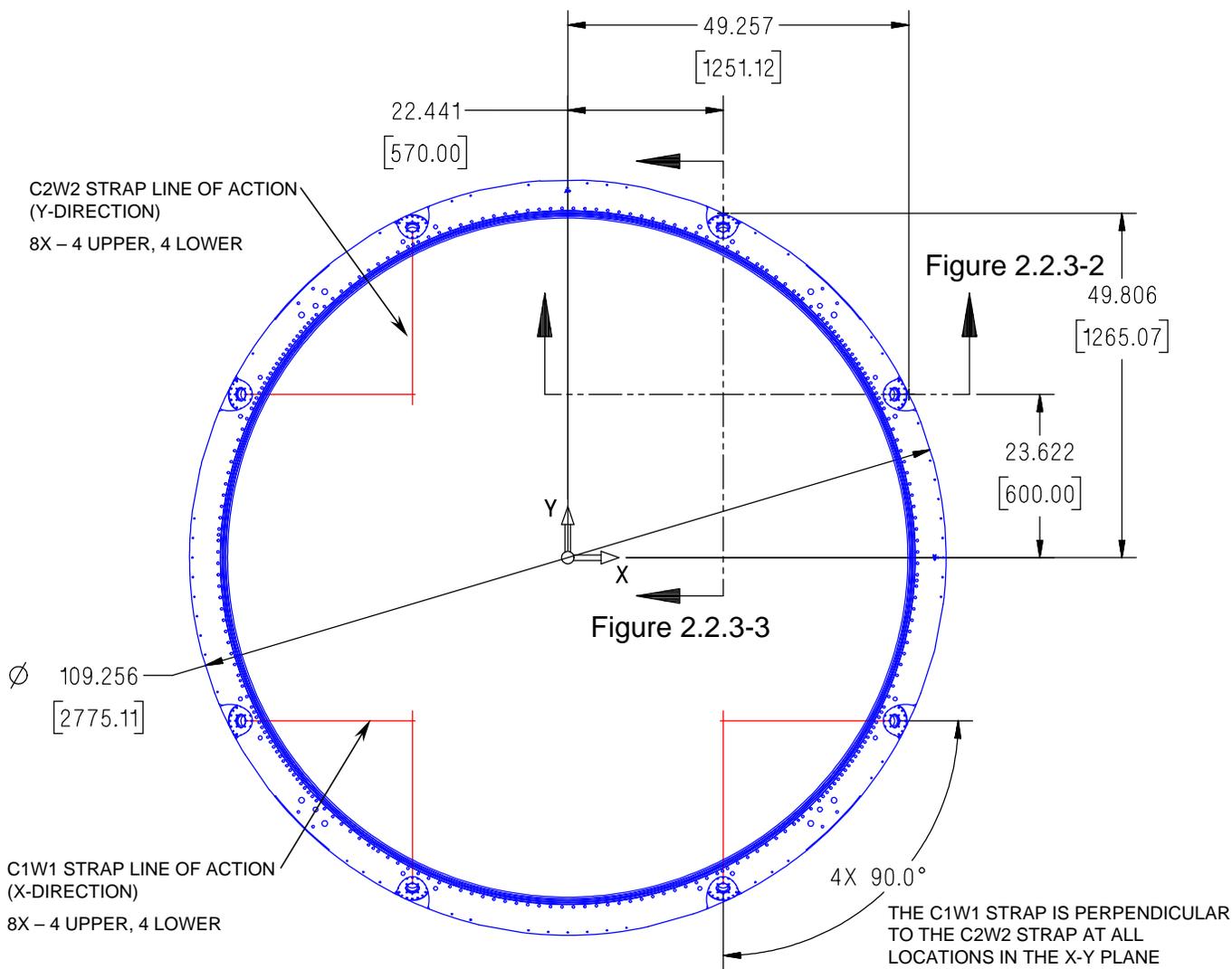


Figure 2.2.3-1 Support Strap Locations

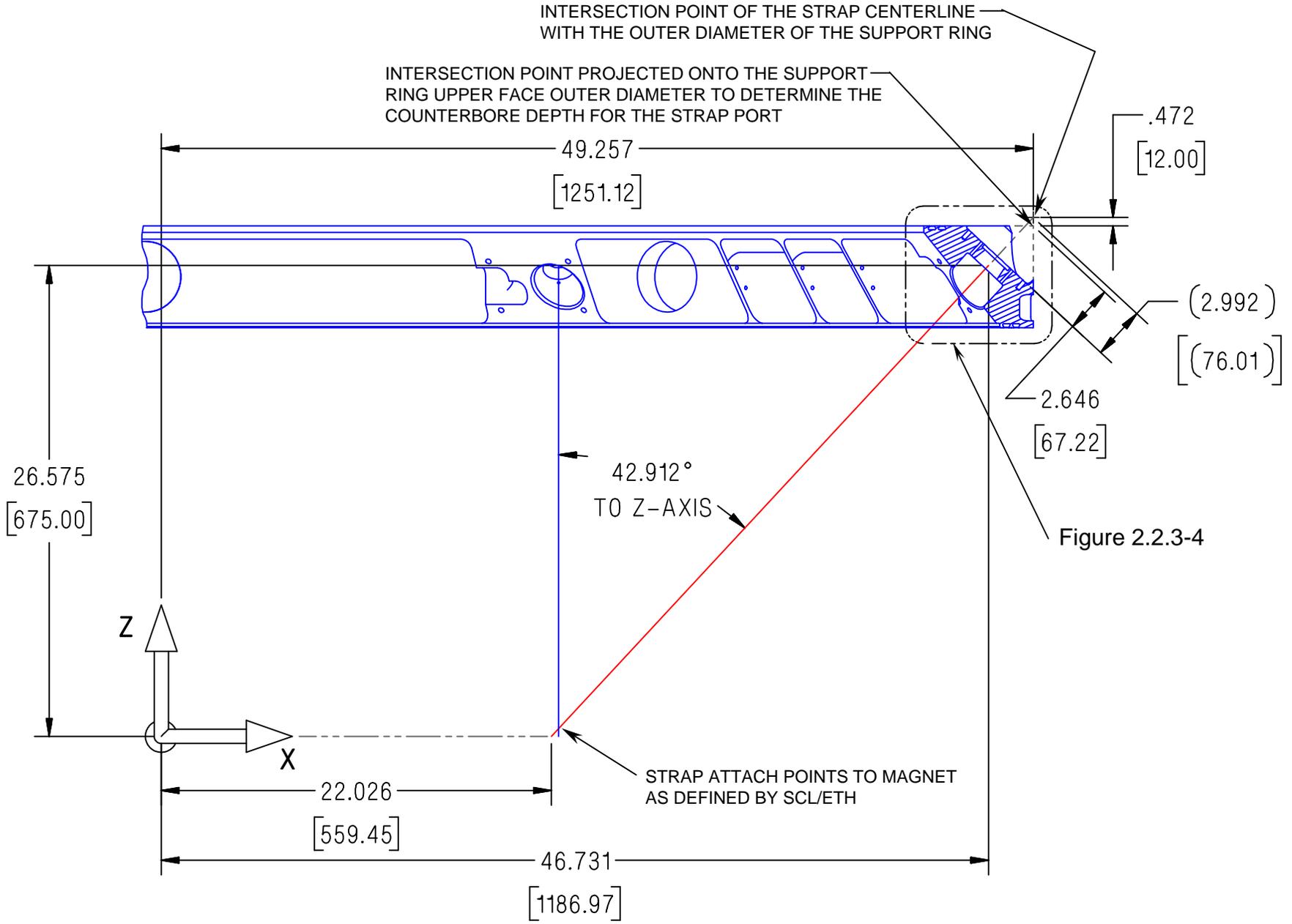


Figure 2.2.3-2 Section Thru Strap Port C1W1 (X-direction)

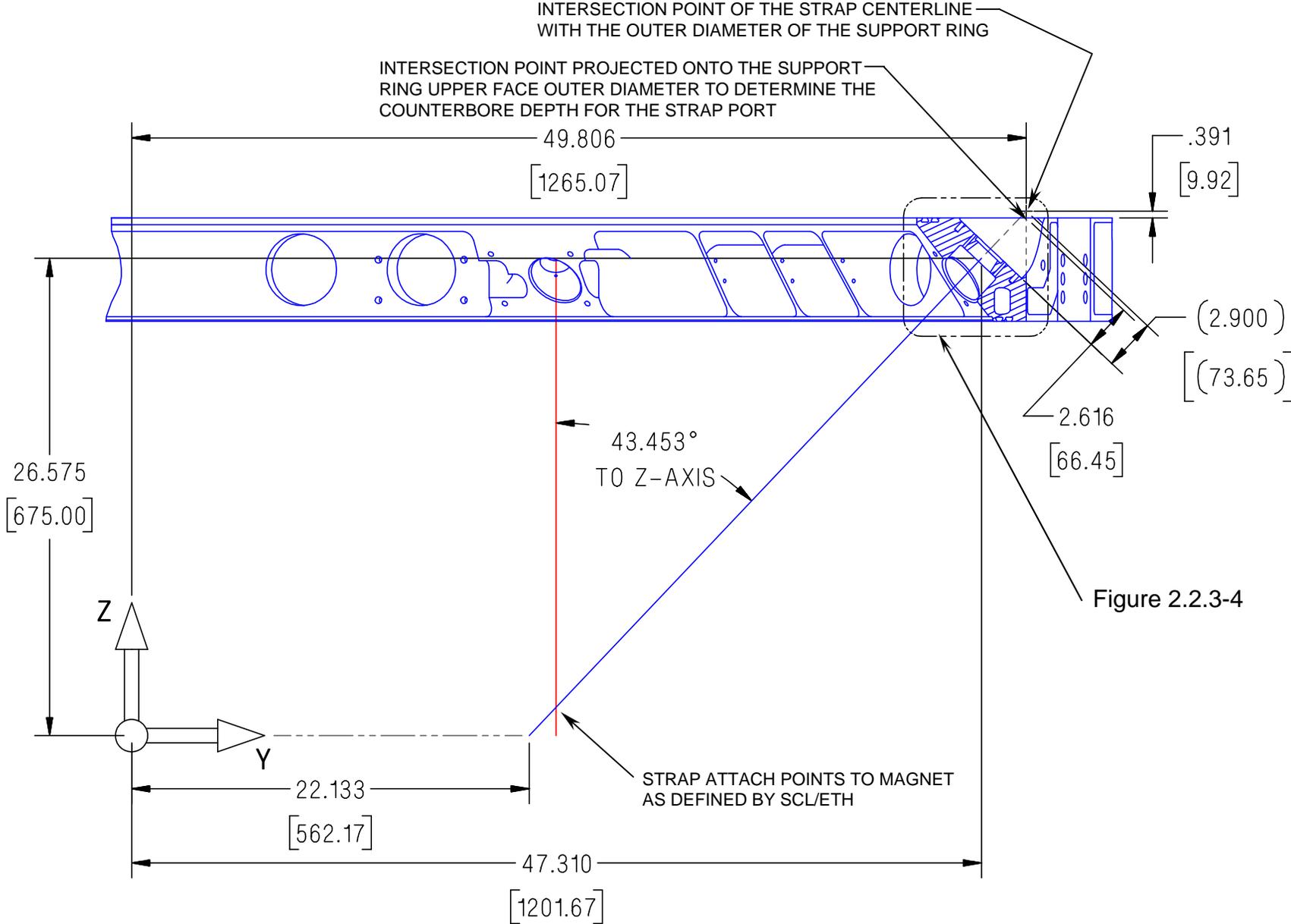


Figure 2.2.3-3 Section Thru Strap Port C2W2 (Y-direction)

NOTE: Strap angle shown is generic. Specific feed-thru angles are defined in Figures 2.2.3-2 and 2.2.3-3.

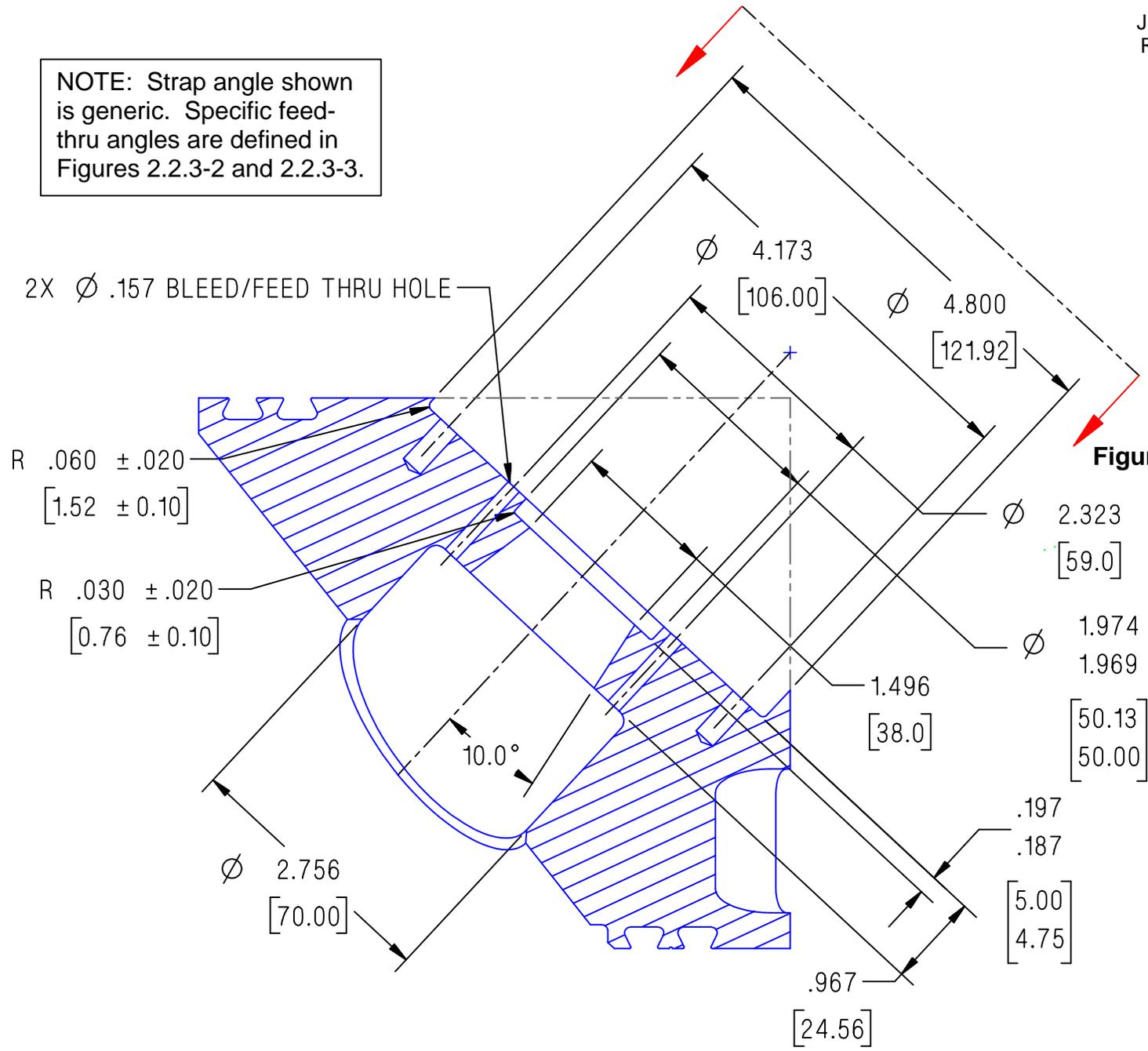
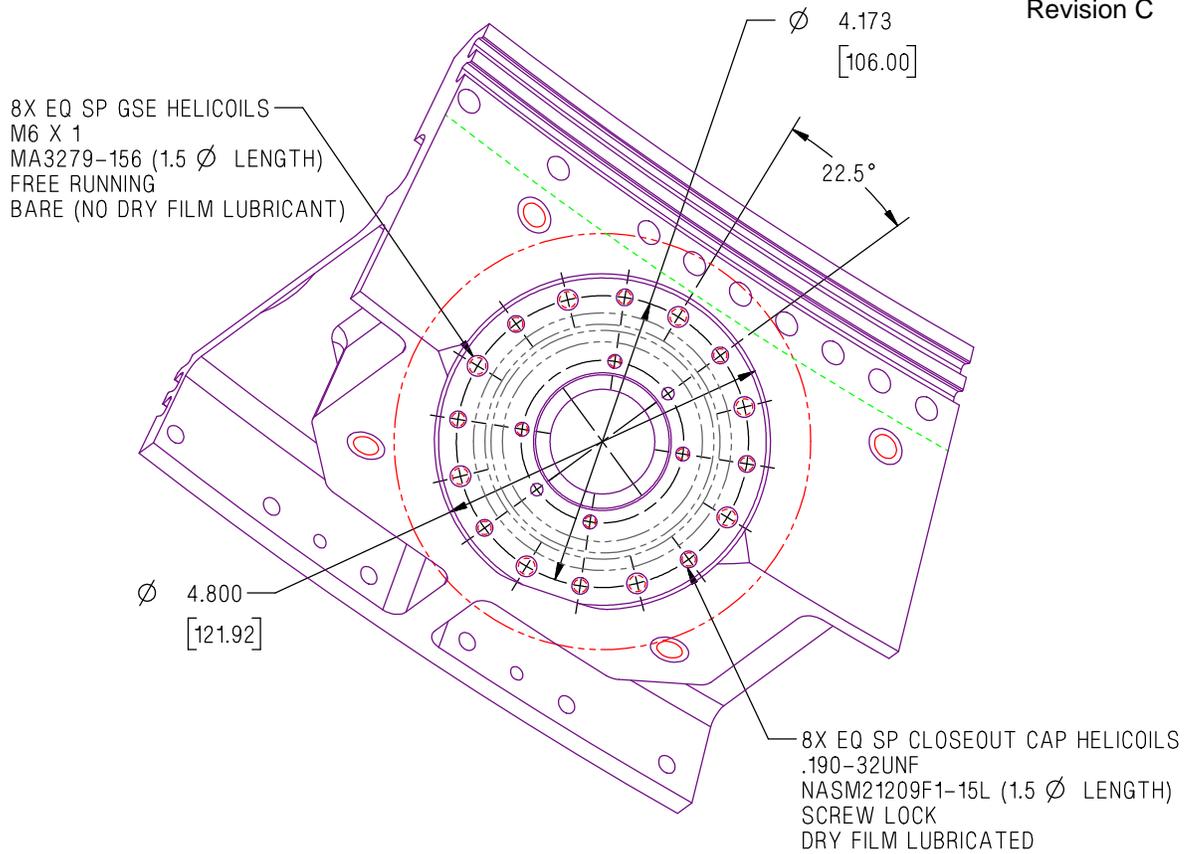
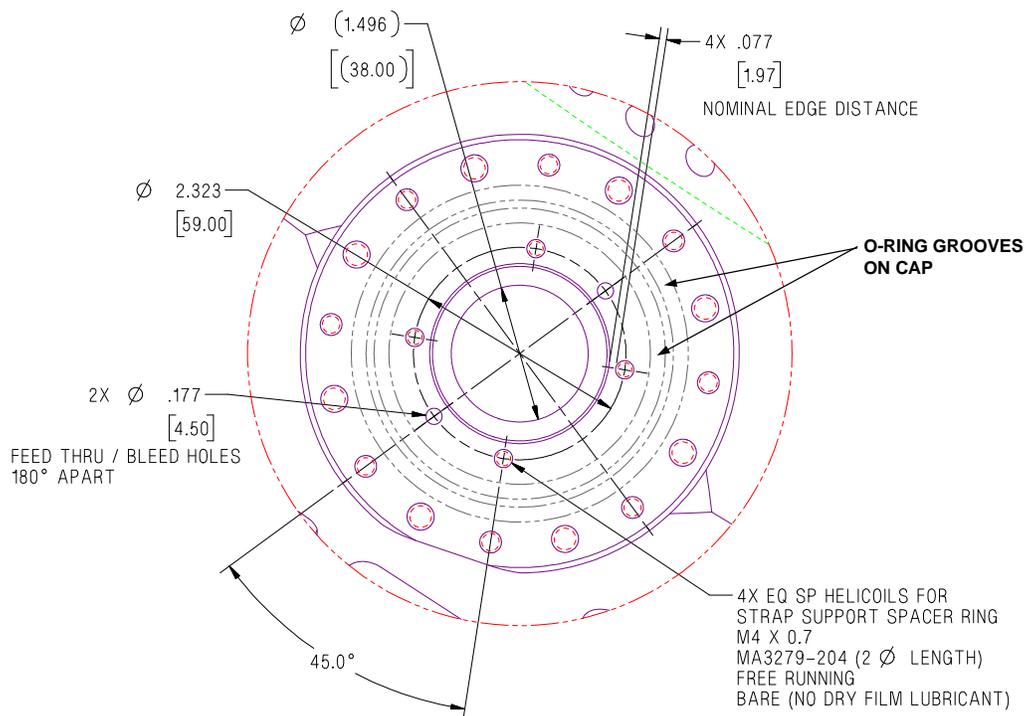


Figure 2.2.3-4 Strap Feed-Thru Detail



**Figure 2.2.3-5 Strap Feed-Thru Face View**



**Figure 2.2.3-6 Strap Feed-Thru Detail View**

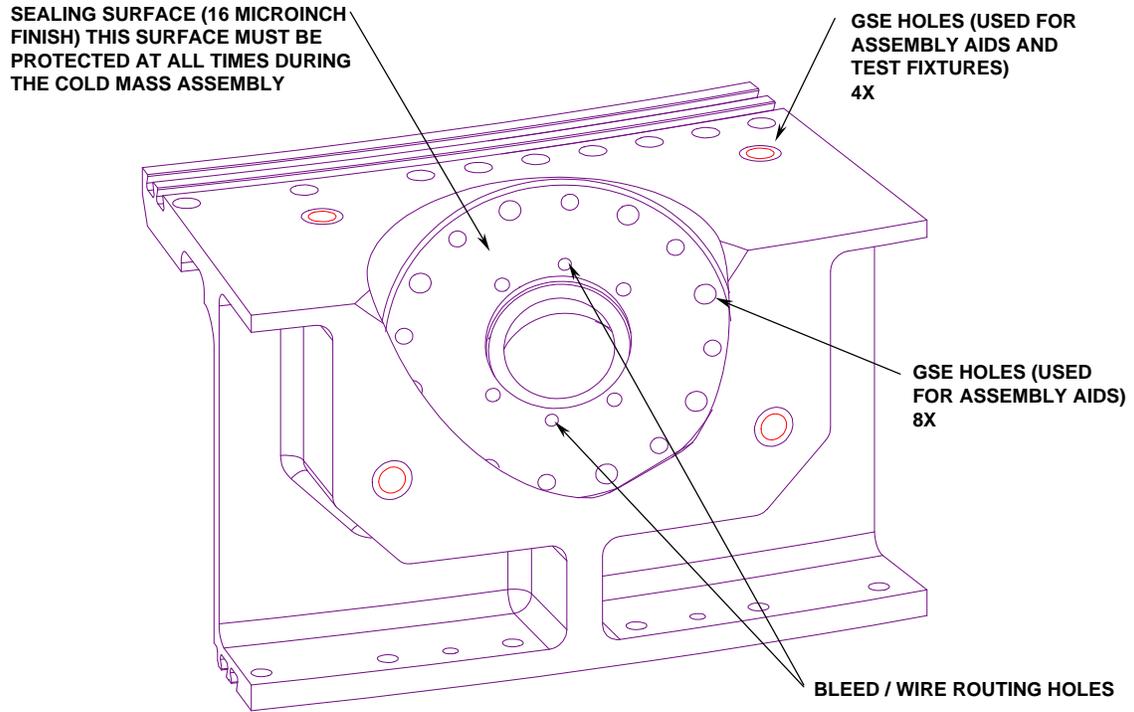


Figure 2.2.3-7 ISO View of Strap Port

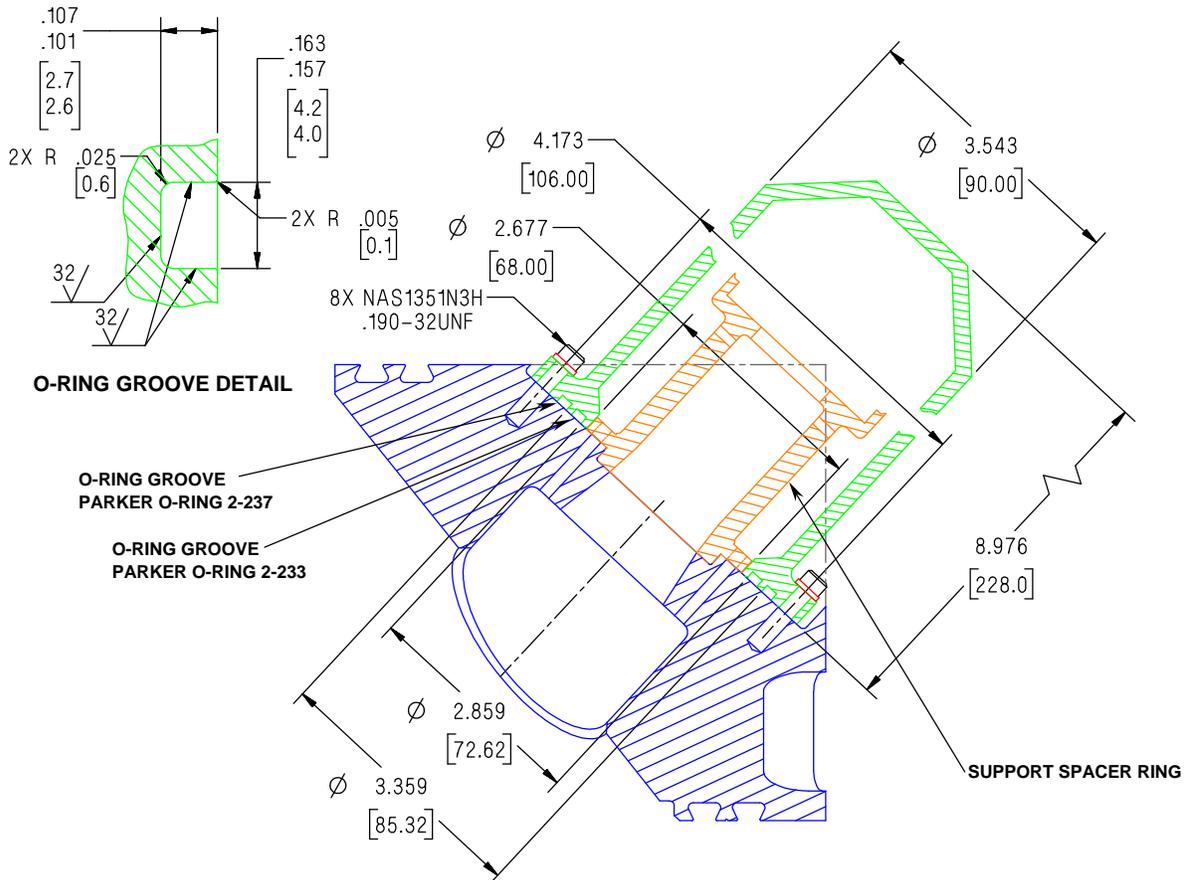


Figure 2.2.3-8 Strap Closeout Cap (Provided by ETH/SCL)

## **2.2.4 Feed-Thru Port Locations**

There are numerous plumbing lines and electrical cables that need to penetrate the Vacuum Case. All of the ports will be in the upper and lower support rings of the Vacuum Case. The orientations are shown in Figures 2.2.4-1, 2.2.4-2 and 2.2.4-3. Temporary port closeout covers (flat plates) will be provided by ESCG/NASA in order to perform vacuum leak checks prior to the installation of the final port closeout covers and caps. All Plumbing and Electrical flight closeout covers and caps will be provided by ETH/SCL. The temporary port closeout covers provided by ESCG/NASA will be available for flight closeout on ports that do not require any feedthru cables or tubes.

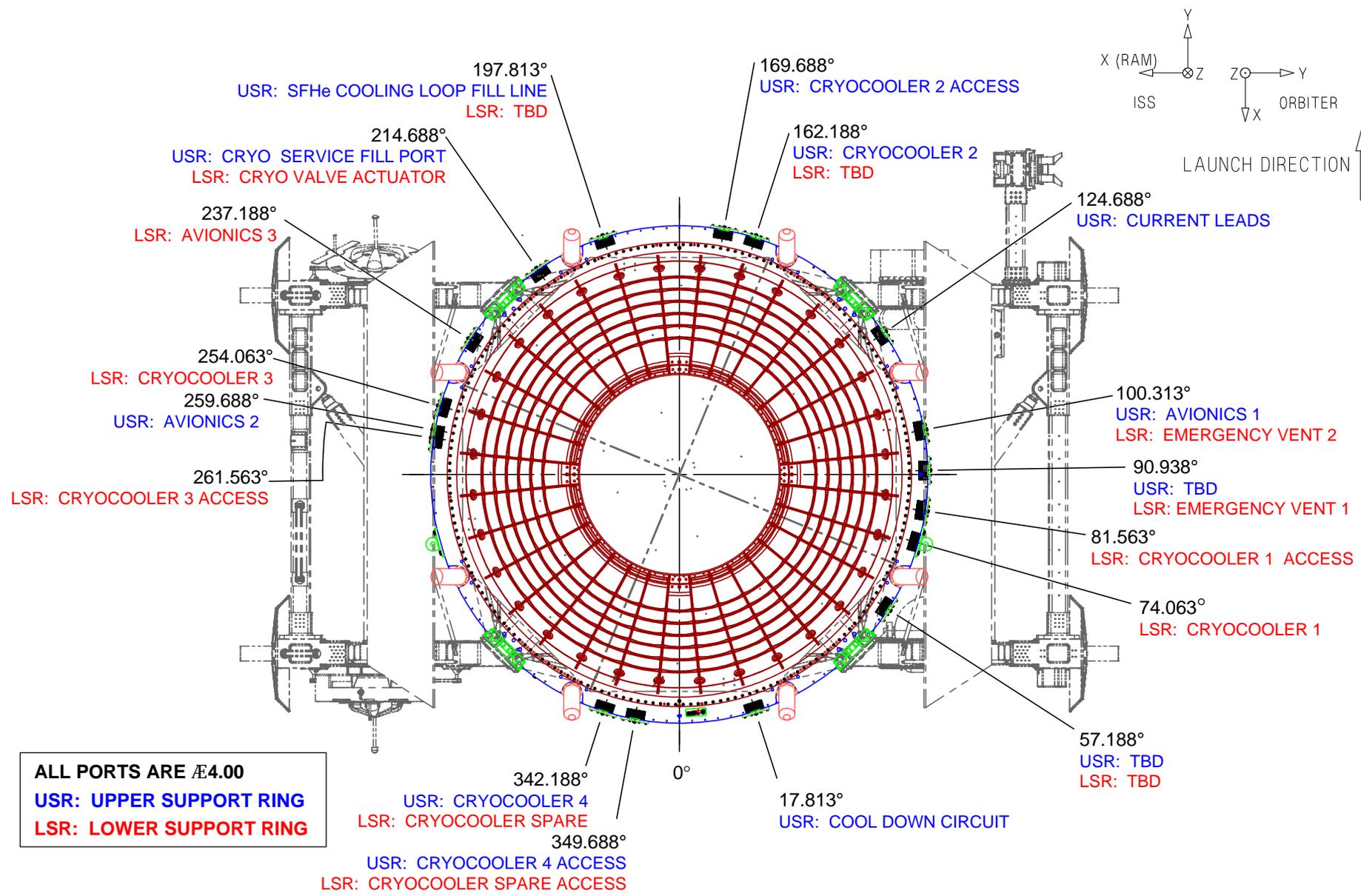


Figure 2.2.4-1 Plumbing and Electrical Port Locations

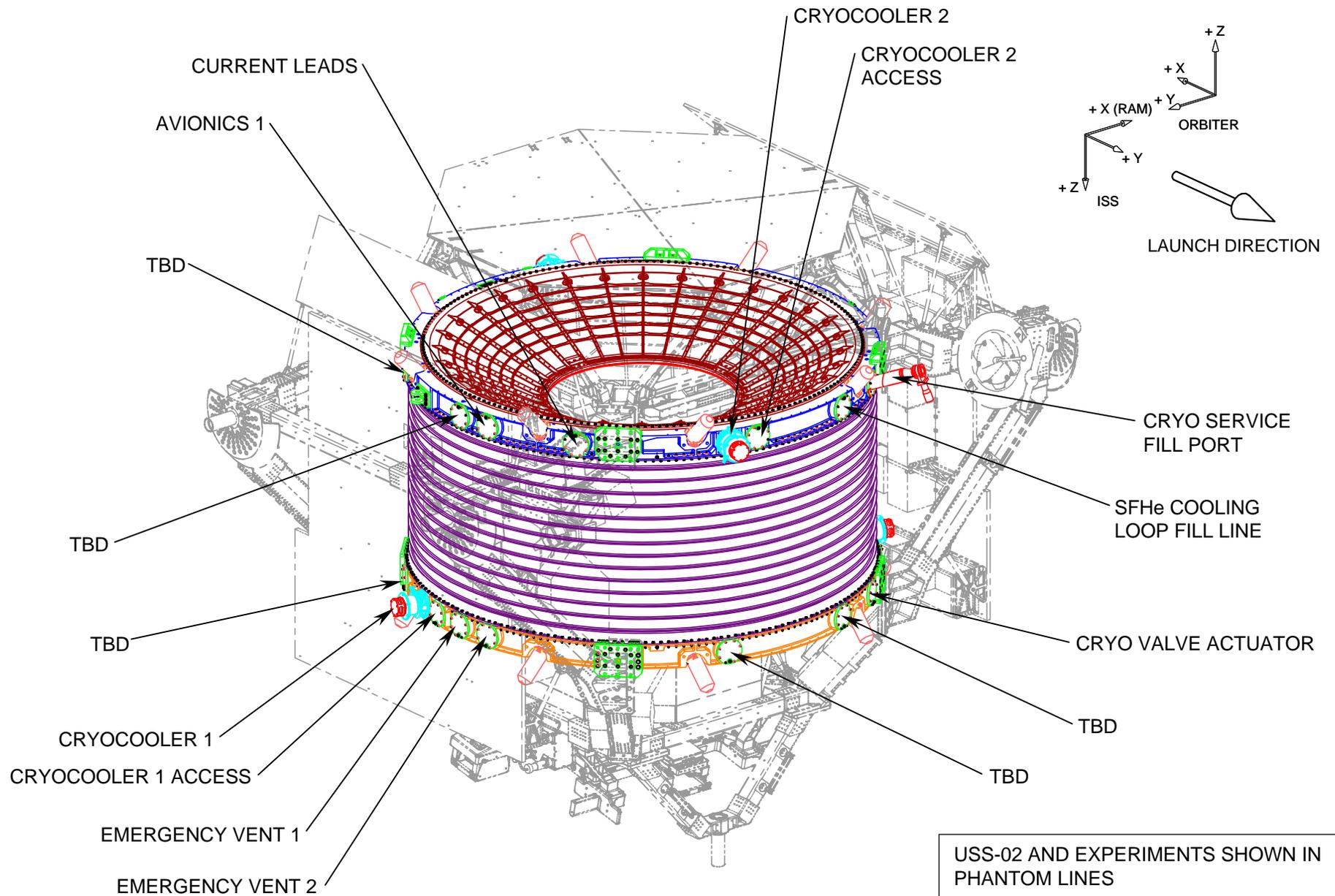


Figure 2.2.4-2 Port Locations – Front ISO View

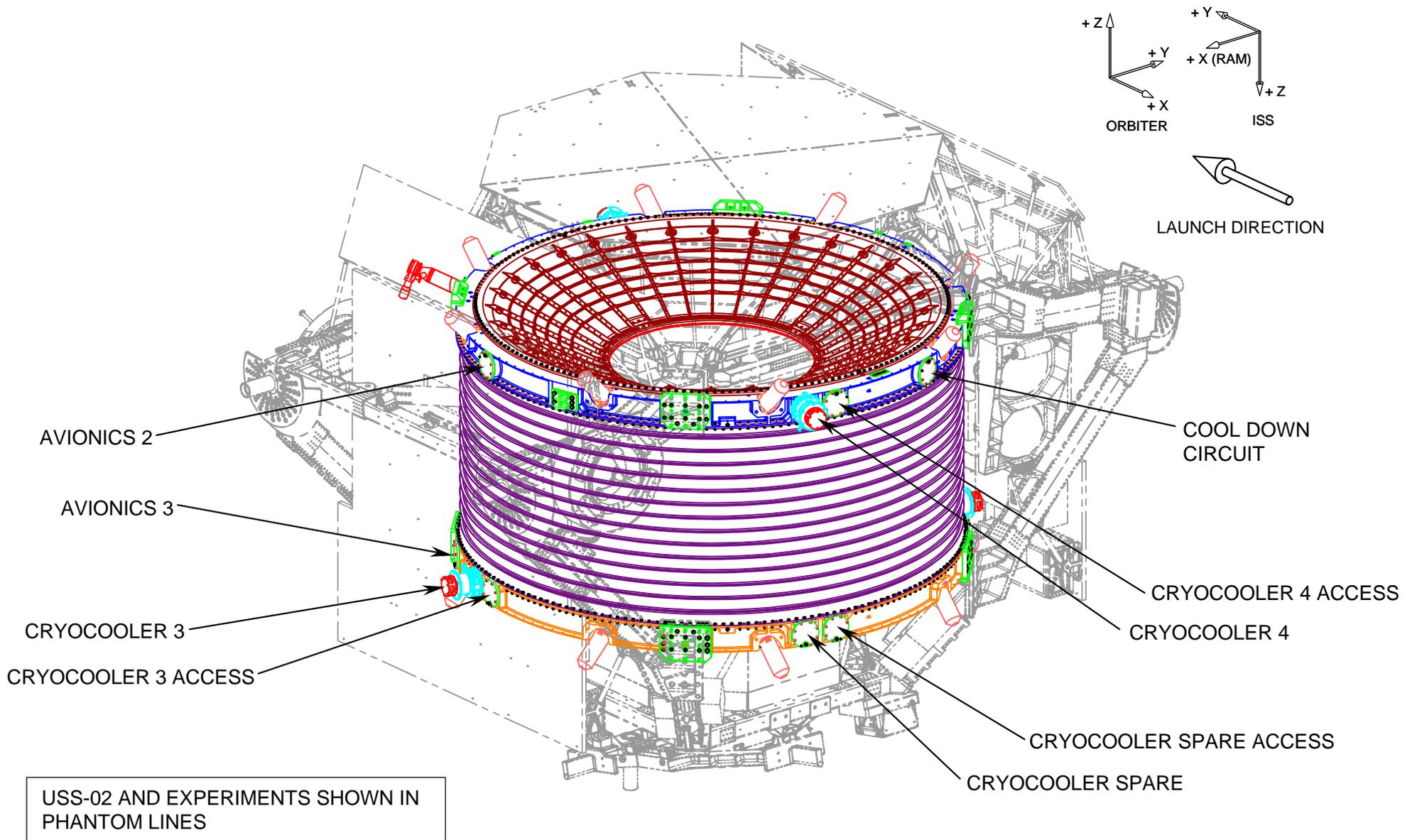
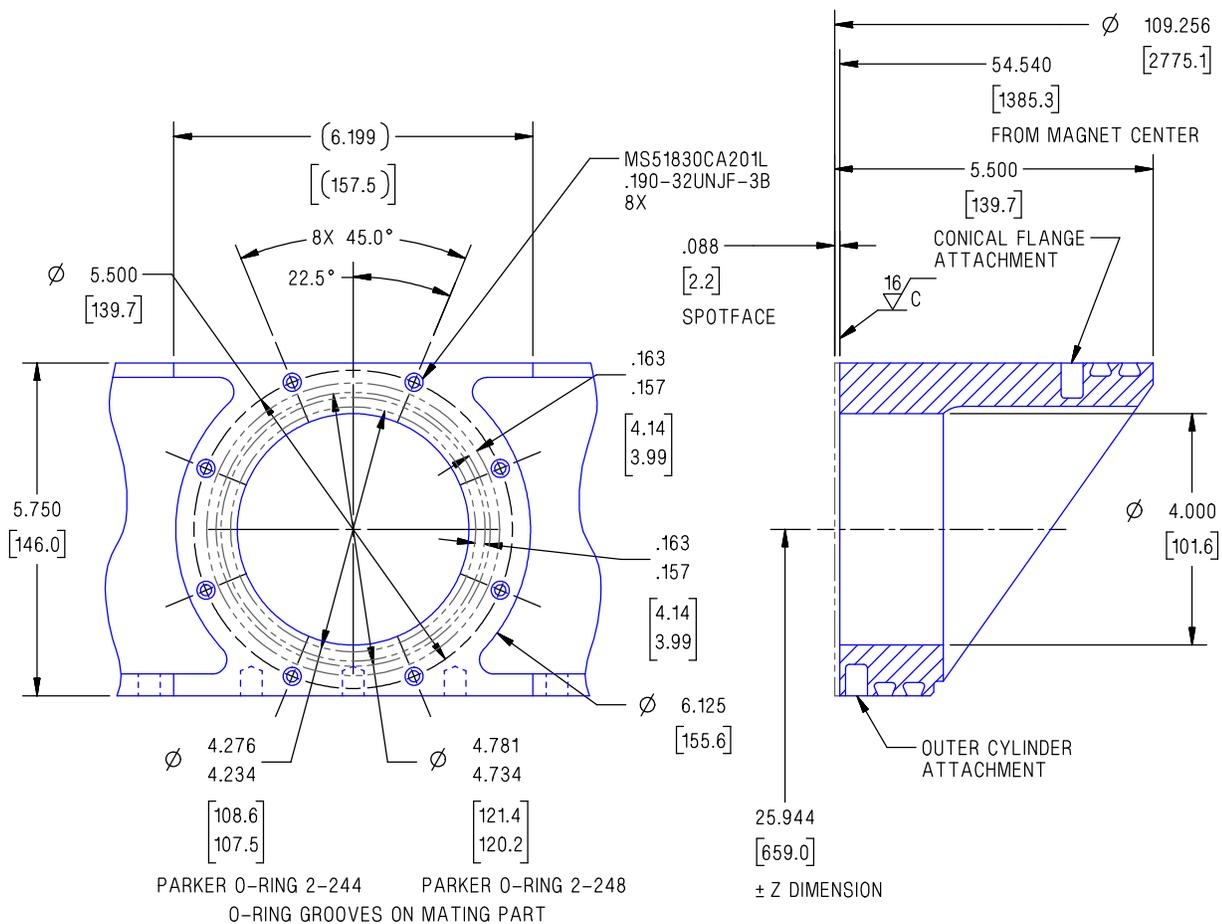


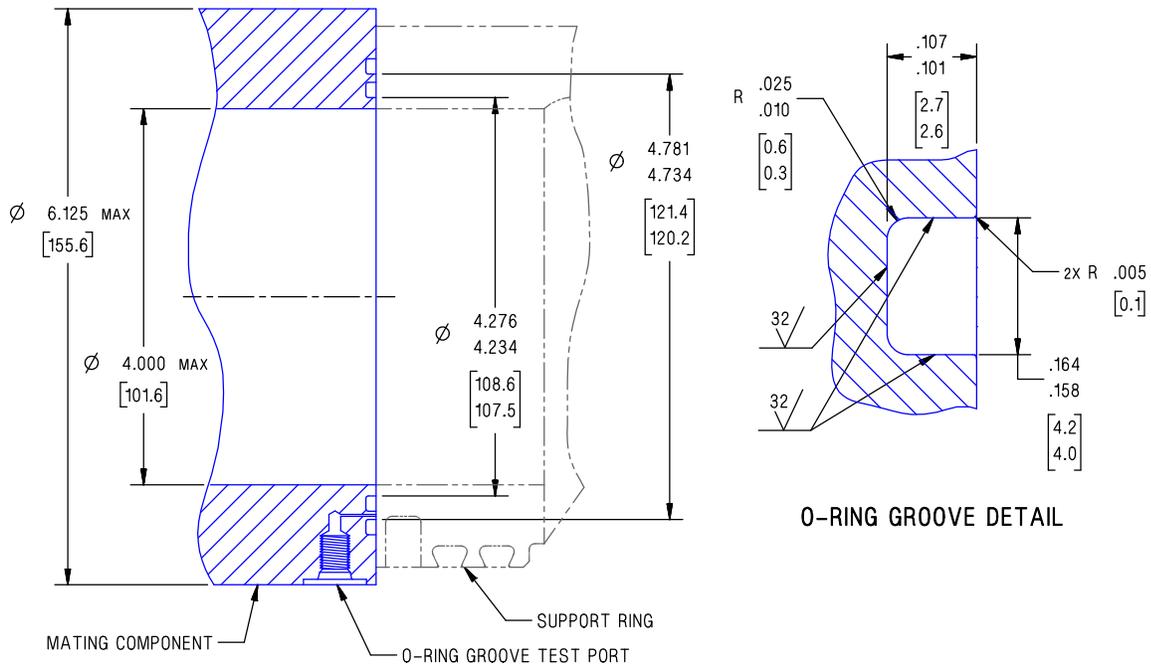
Figure 2.2.4-3 Port Locations – Back ISO View

## 2.2.5 Plumbing and Electrical Feed-Thru Ports

The plumbing and electrical feed-thru port is shown in Figure 2.2.5-1. The mating surface of the hardware that will attach to this port is shown in Figure 2.2.5-2. All mating hardware will incorporate a test port between the o-ring grooves so that each o-ring can be tested individually for vacuum integrity. ESCG/NASA will provide temporary closeout plates for the plumbing/electrical ports. The final flight closeout ports or caps will be provided by ETH/MIT/SCL/GSFC. The temporary port closeout covers provided by ESCG/NASA will be available for flight closeout on ports that do not require any feedthru cables or tubes.



**Figure 2.2.5-1 Plumbing/Electrical Port**



**Figure 2.2.5-2 Mating Component for Plumbing/Electrical Port**

## 2.2.6 Cryocooler Interfaces and Ports

Four cryocoolers will be mounted to the Vacuum Case Upper and Lower Rings. The current mounting location (Figures 2.2.4-1, 2, and 3) and ports are shown in Figure 2.2.6-2. Figure 2.2.6-1 shows a front and back ISO view the port. The cryocooler access port is identical to the cryocooler port and allows access to the cold head once the cryocooler is installed. The ports are essentially the same as the 4 inch diameter ports shown in Figure 2.2.5-1 and 2 with the addition of the 4 mounting holes at the corners on the outside and the inside. The VC design includes enough ports to actually mount five cryocoolers, but the fifth location will only be used in a contingency event. ESCG/NASA will provide temporary closeout plates for the cryocooler ports. The final flight closeout ports or caps will be provided by ETH/MIT/SCL/GSFC. All cryocoolers and flight closeout caps will incorporate a test port between the o-ring grooves so that each o-ring can be tested individually for vacuum integrity. The temporary port closeout covers provided by ESCG/NASA will be available for flight closeout on ports that do not require any feedthru cables or tubes.

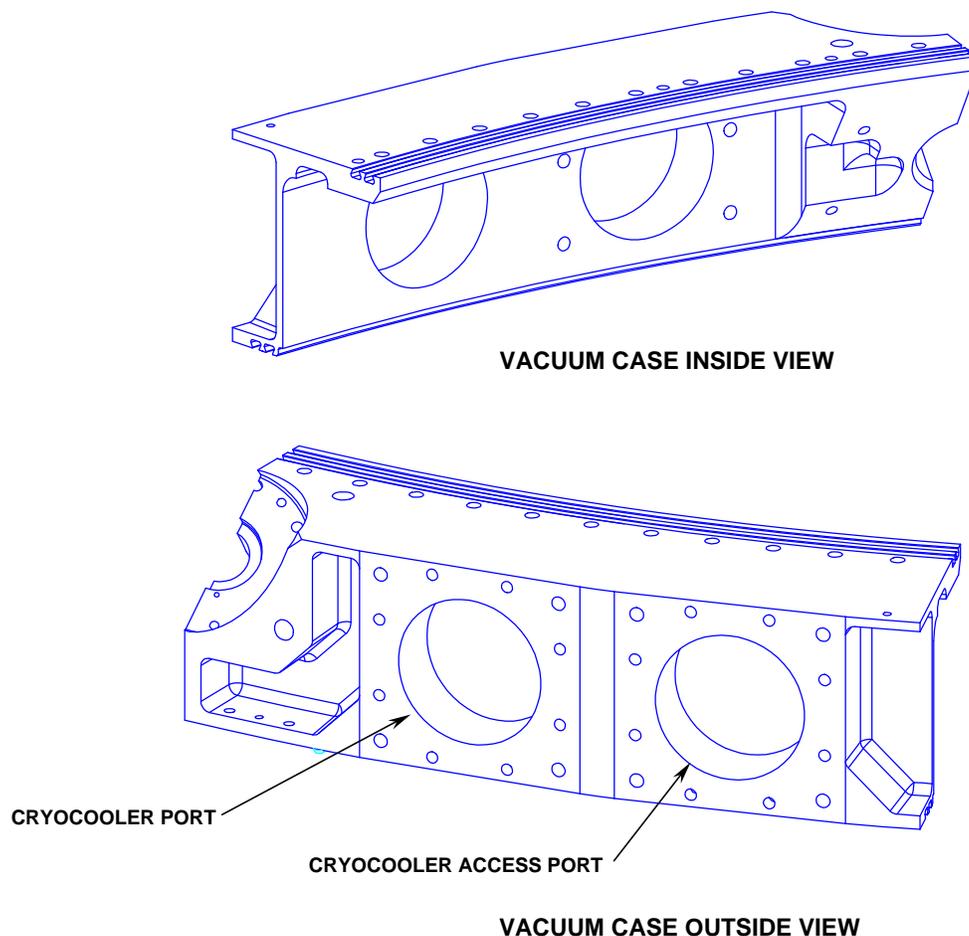


Figure 2.2.6-1 Cryocooler Port ISO Views

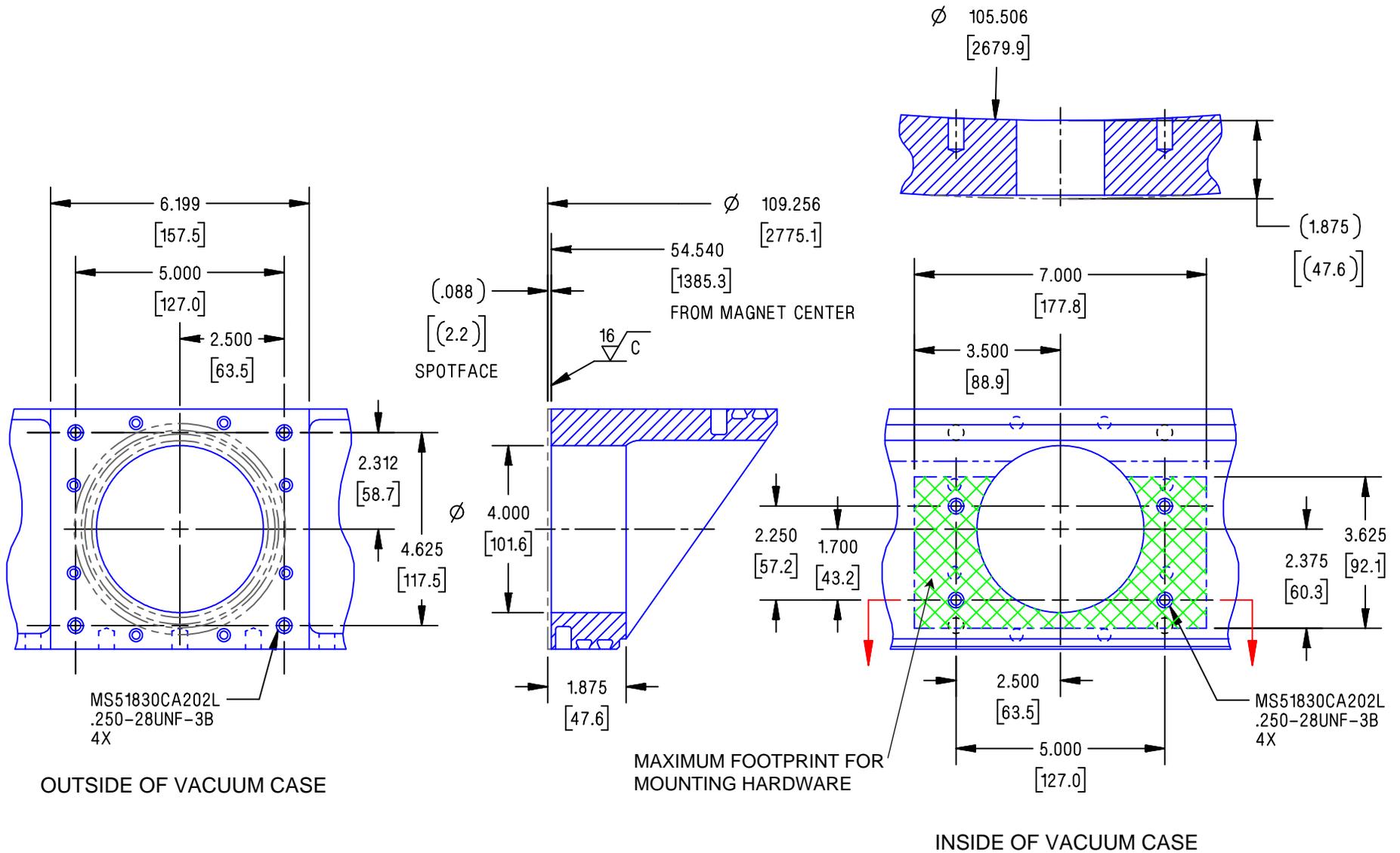
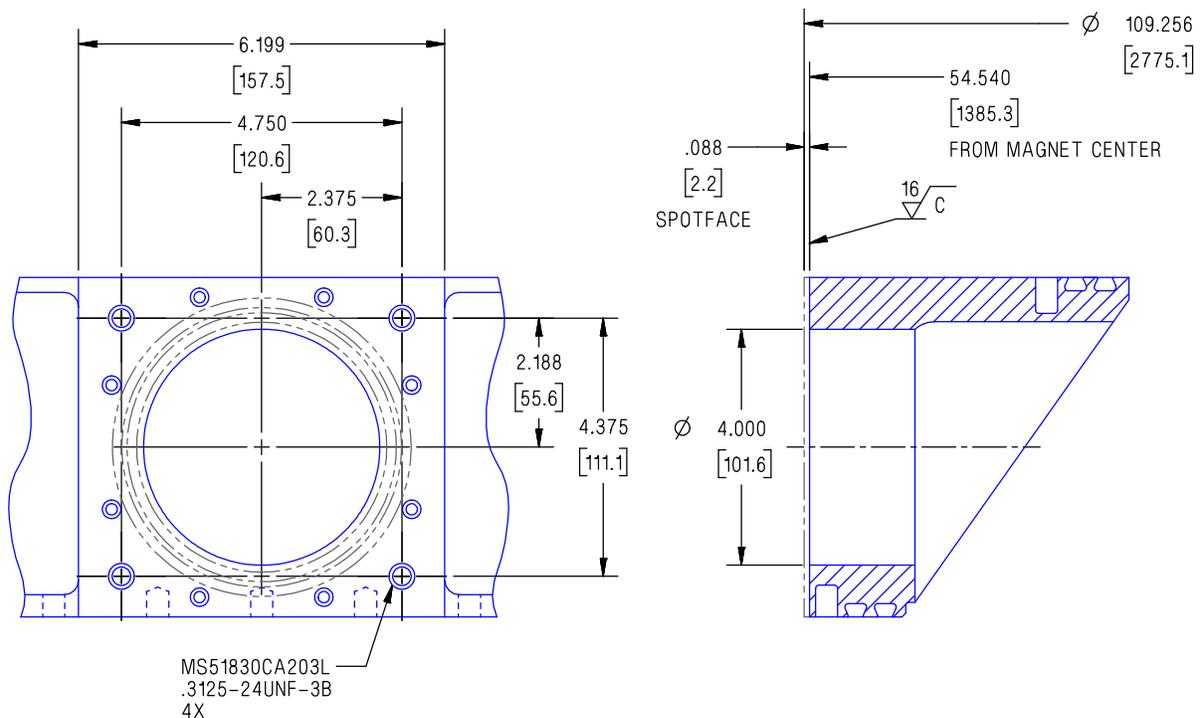


Figure 2.2.6-2 Cryocooler Interfaces and Ports

## 2.2.7 Cryo Service Port

A cryo service port will be mounted to the Vacuum Case Upper Ring. The current mounting location (Figures 2.2.4-1, 2, and 3) and port are shown in Figure 2.2.7-1. The cryo service port is used to service the cryogenic system on the ground. The ports are essentially the same as the 4 inch diameter ports shown in Figure 2.2.5-1 and 2 with the addition of the 4 mounting holes at the corners on the outside. The VC design includes enough ports to actually mount five cryocoolers, but the fifth location will only be used in a contingency event. ESCG/NASA will provide temporary closeout plates for the cryocooler ports. The final flight closeout ports or caps will be provided by ETH/MIT/SCL. The cryo service port will incorporate a test port between the o-ring grooves so that each o-ring can be tested individually for vacuum integrity.



**Figure 2.2.7-1 Cryo Service Port**

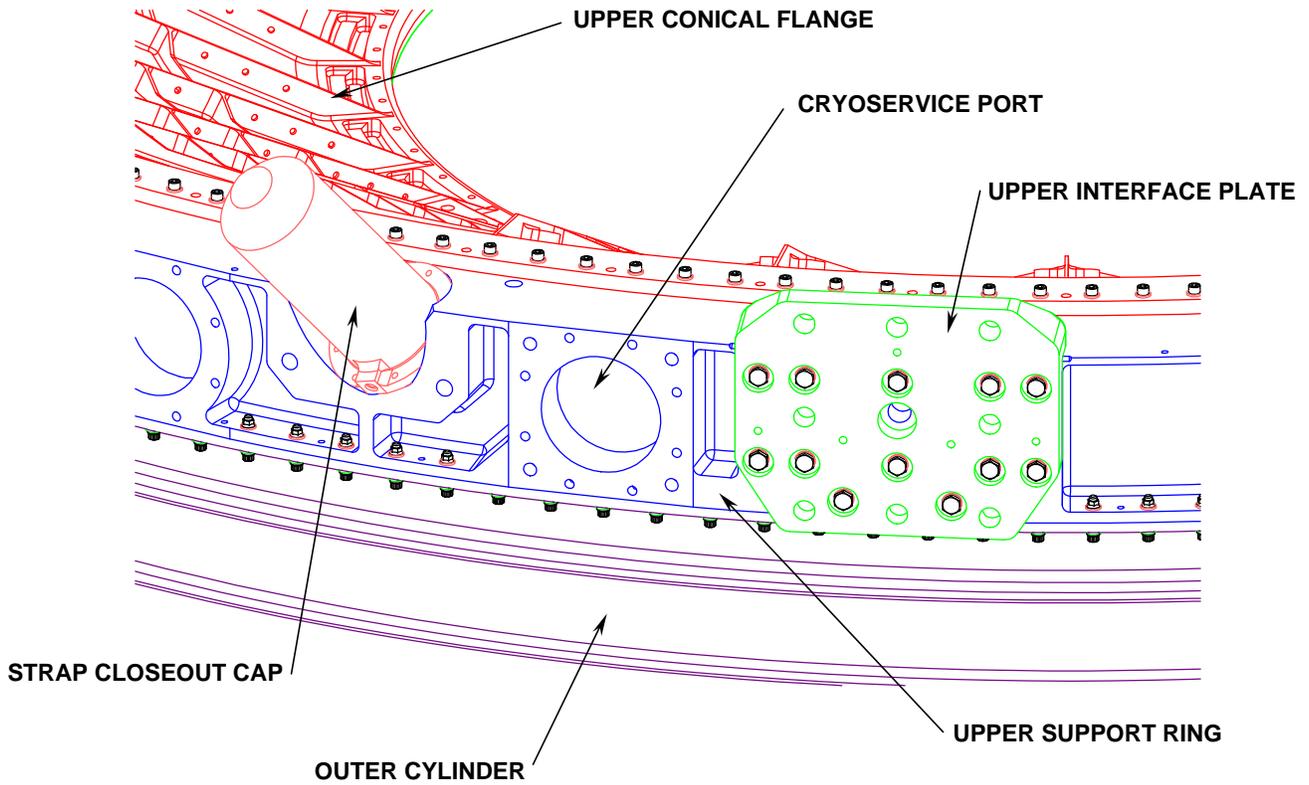


Figure 2.2.7-2 Cryo Service Port Layout – Front ISO View

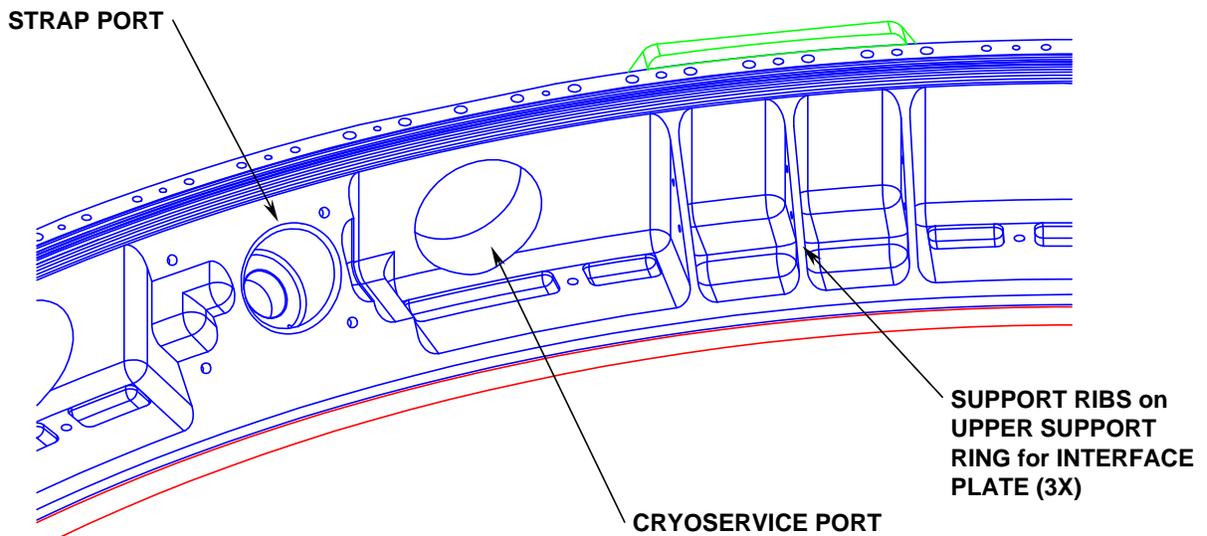


Figure 2.2.7-3 Cryo Service Port Layout – Back ISO View

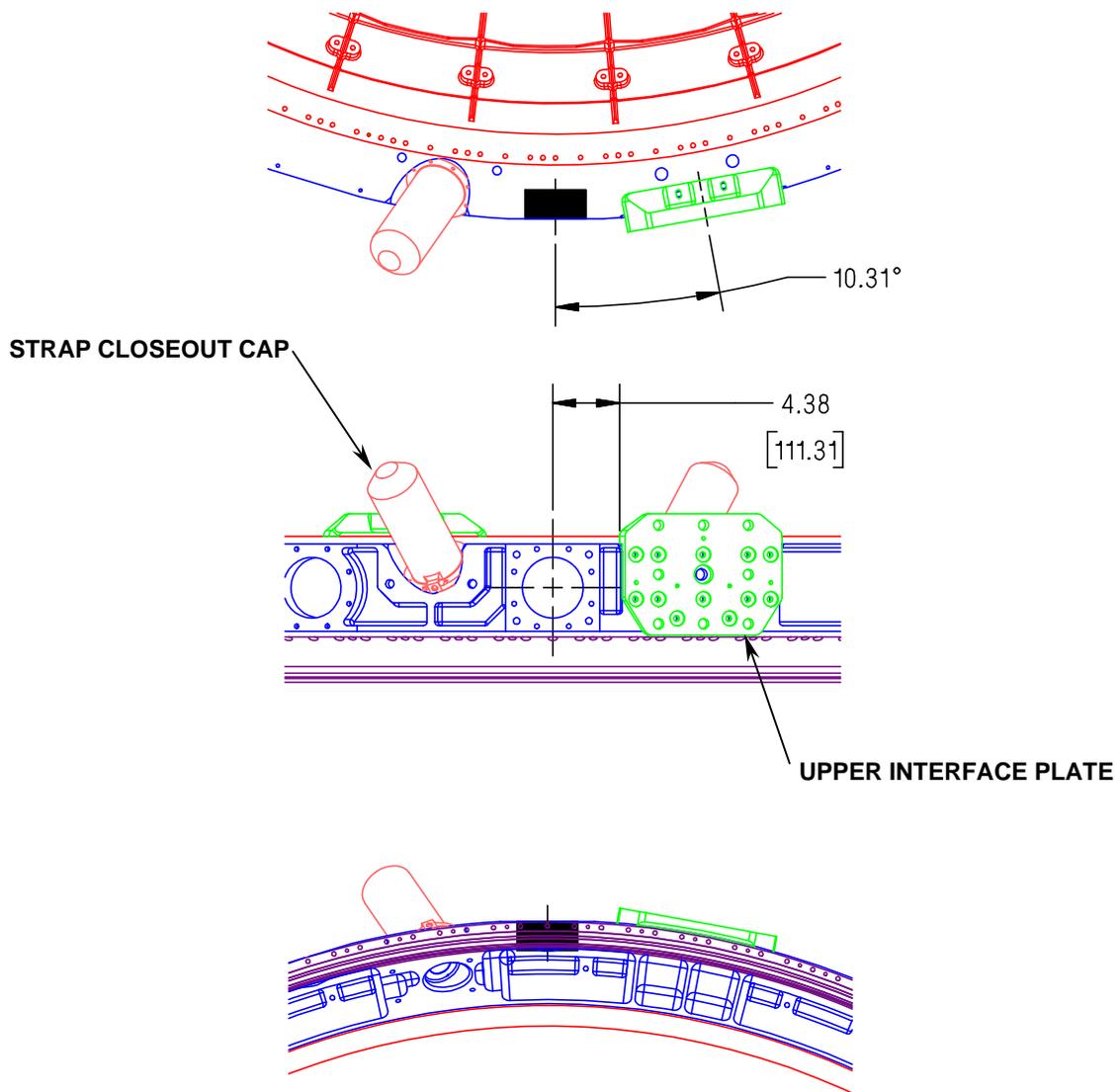


Figure 2.2.7-4 Cryo Service Port Layout

## 2.2.8 Keep In/Out Zones

Due to space station envelopes, shipping constraints and interfaces to other experiments, several keep in/out zones have been established. Figures 2.2.8-1 and 2.2.8-2 show the keep in zone for the cold mass hardware around the Upper and Lower Support Rings. The keep in zones extend through the thickness of each Support Ring and include the strap closeout caps protruding out of the zone. Figures 2.2.8-1 through 2.2.8-4 also show the keep out zone for the Vacuum Case to USS-02 assembly. This area must remain clear until the Vacuum Case is installed. After that, cable routing can cross this area. The area between the Support Ring interface to the Outer Cylinder on both ends can also be used for cable routing and is shown in Figure 2.2.8-4. Figure 2.2.8-5 shows the cryocooler keep in zone for the locations outside of the USS-02. The keep in zone for the Cryo Service Port is shown in Figure 2.2.8-6. This keep in zone will include both flight and ground configurations. Because of the numerous cable routings from all of the experiments, all cable routings and protrusions must be coordinated with ESCG, SCL, and MIT.

All hardware that attaches to the VC must meet the requirements in the Thermal ICD.

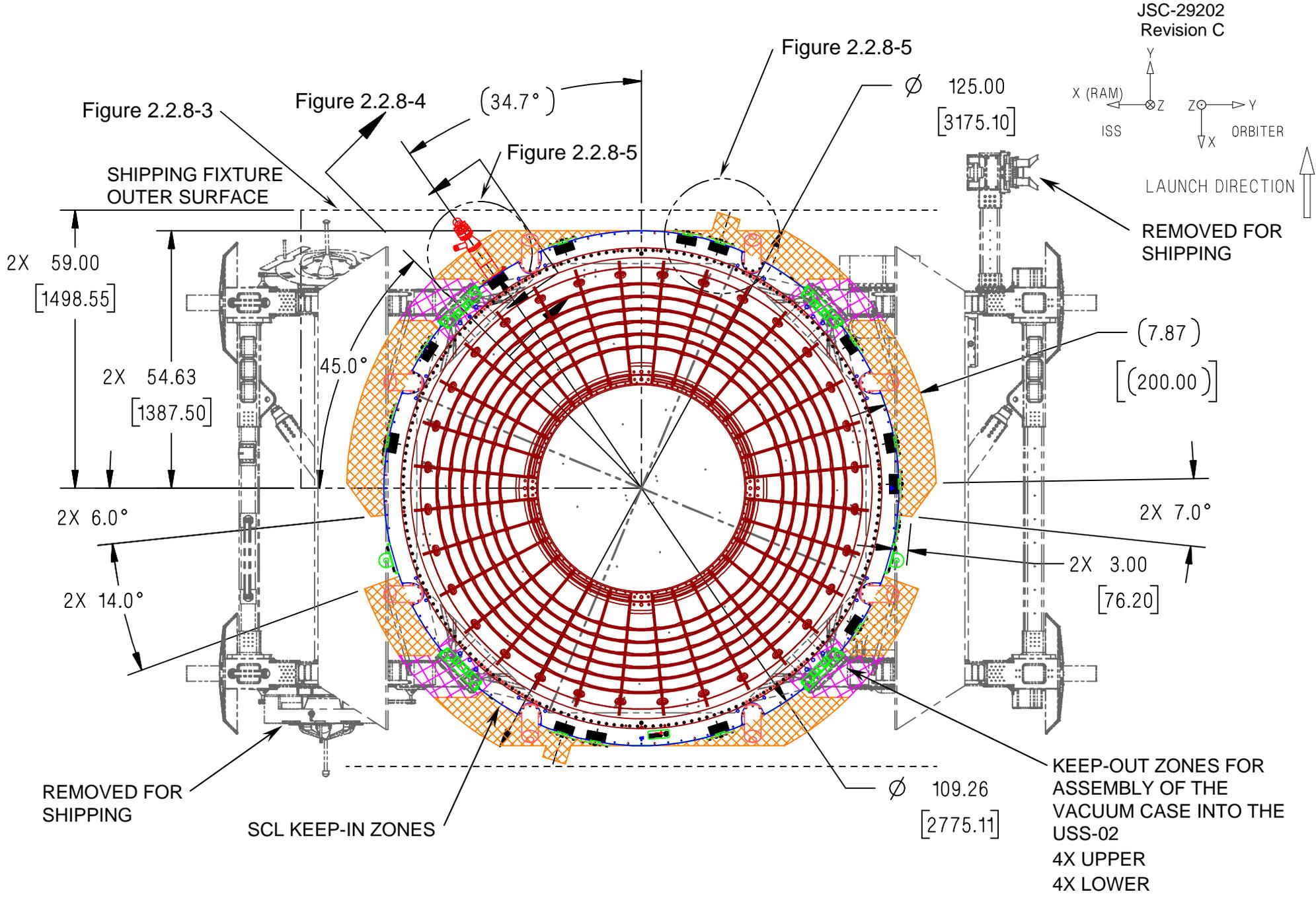


Figure 2.2.8-1 Keep In/Out Zones for the Upper Support Ring

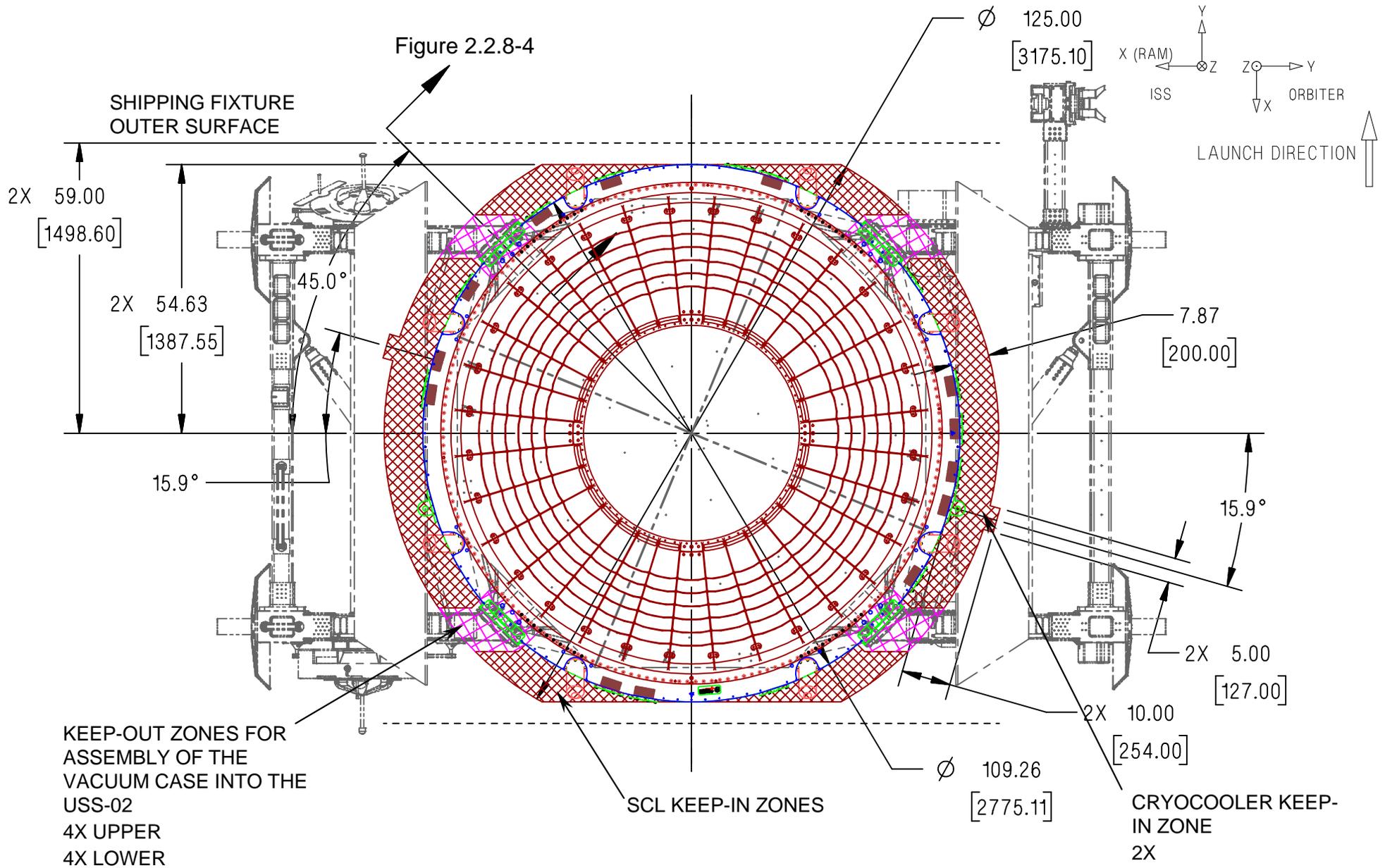


Figure 2.2.8-2 Keep In/Out Zones for the Lower Support Ring

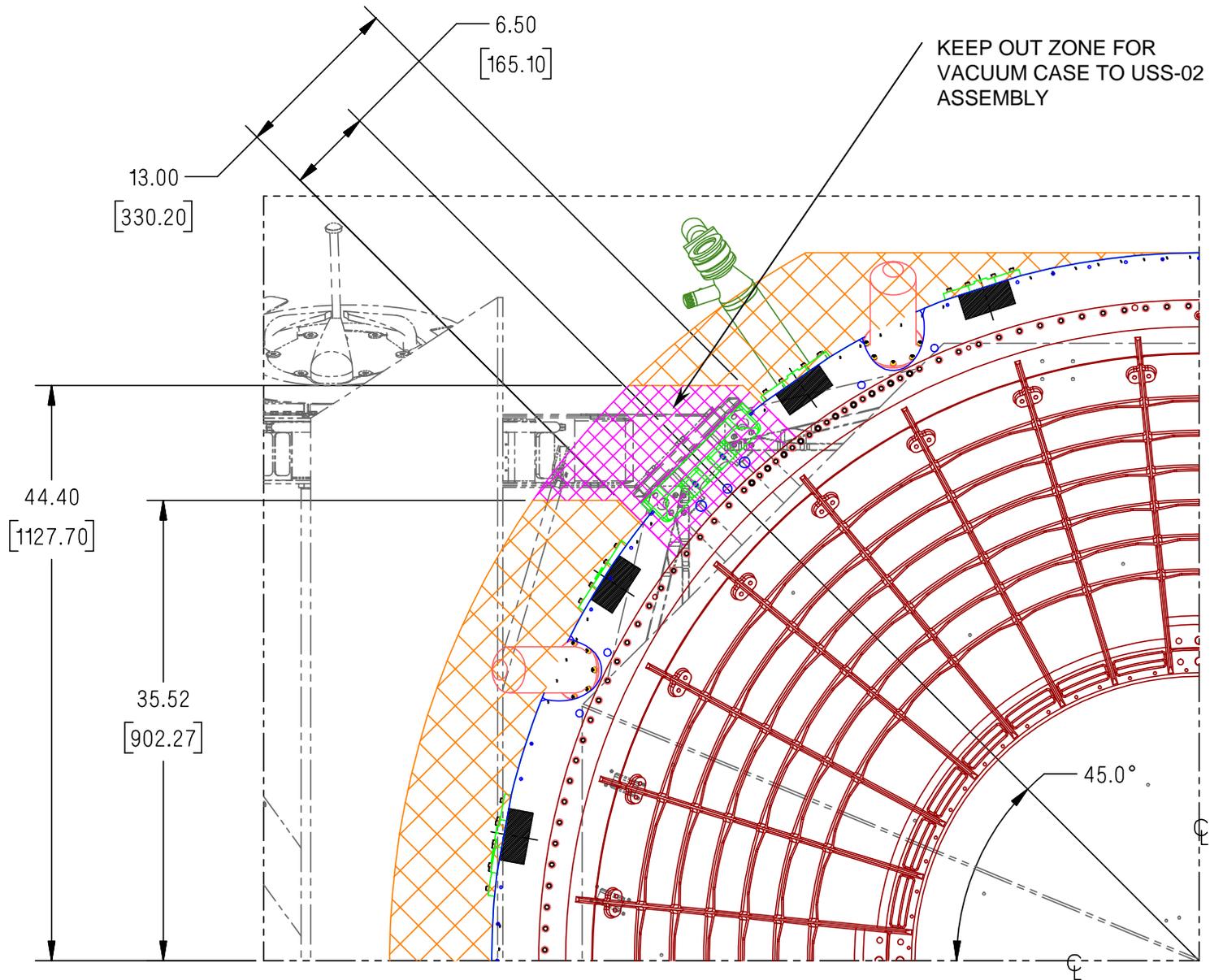
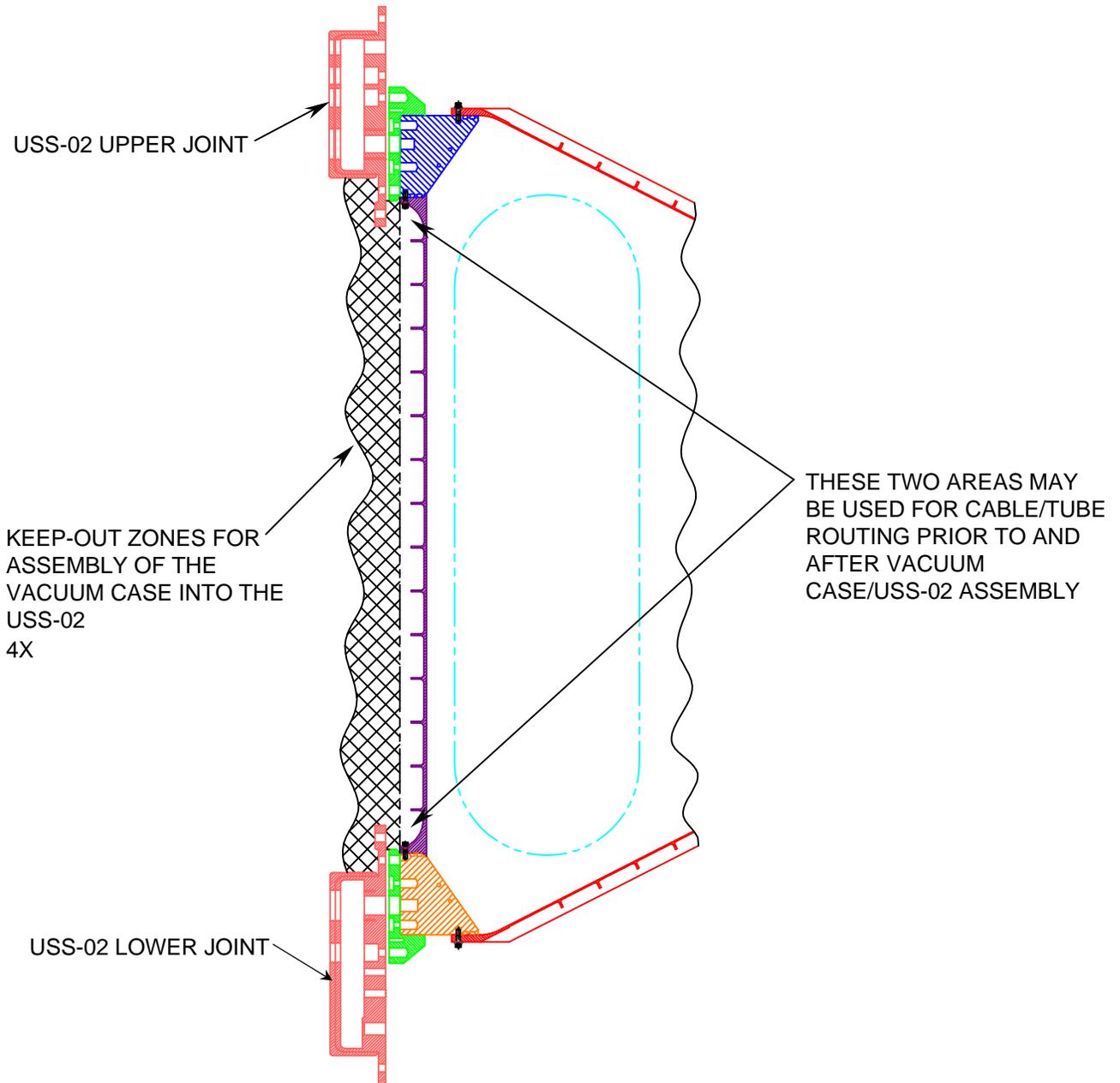
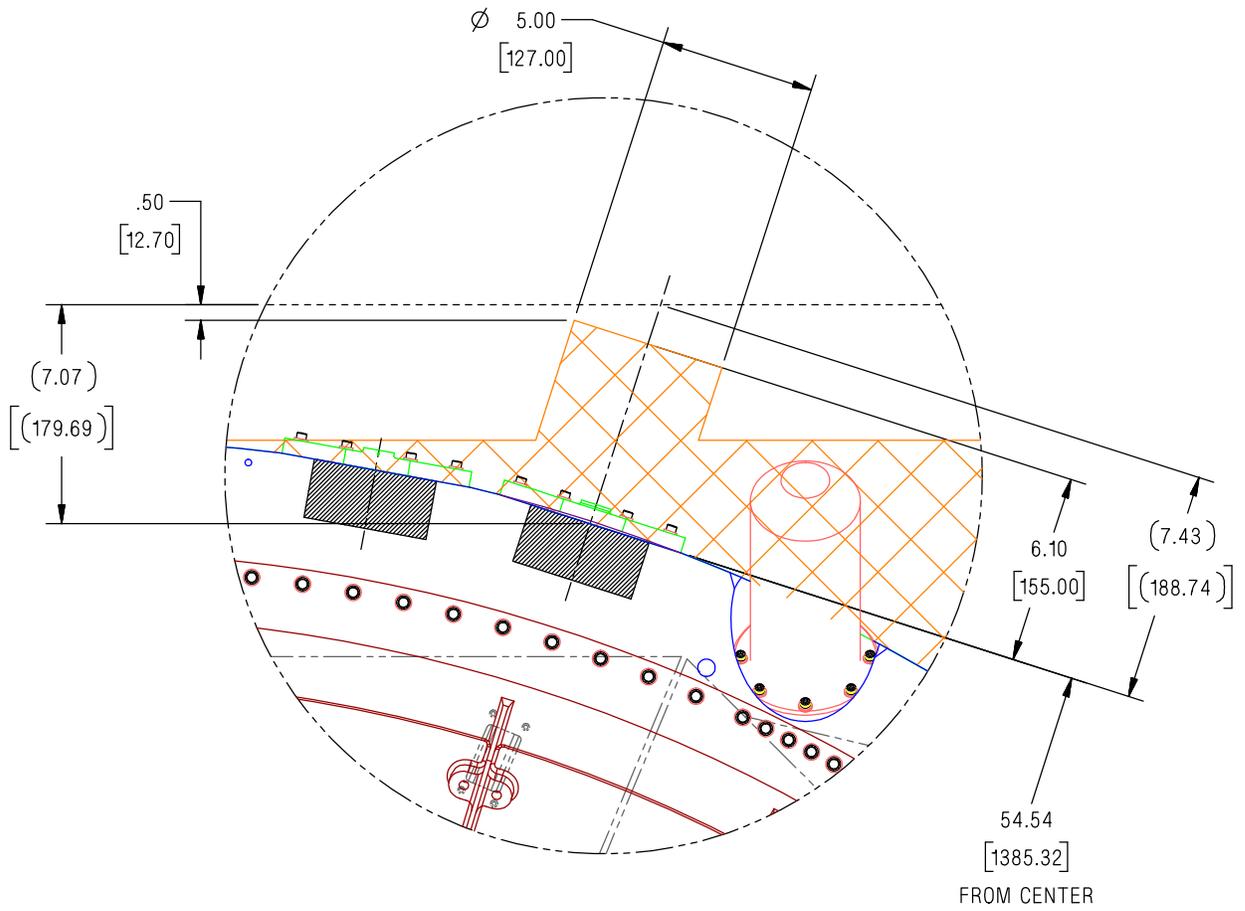


Figure 2.2.8-3 Detail View of the Keep Out Zone for the VC/USS-02 Assembly



**Figure 2.2.8-4 Section View of Keep Out Zone for the VC/USS-02 Assembly**



**Figure 2.2.8-5 Keep In Zone for the Cryocoolers**

Figure 2.2.8-7

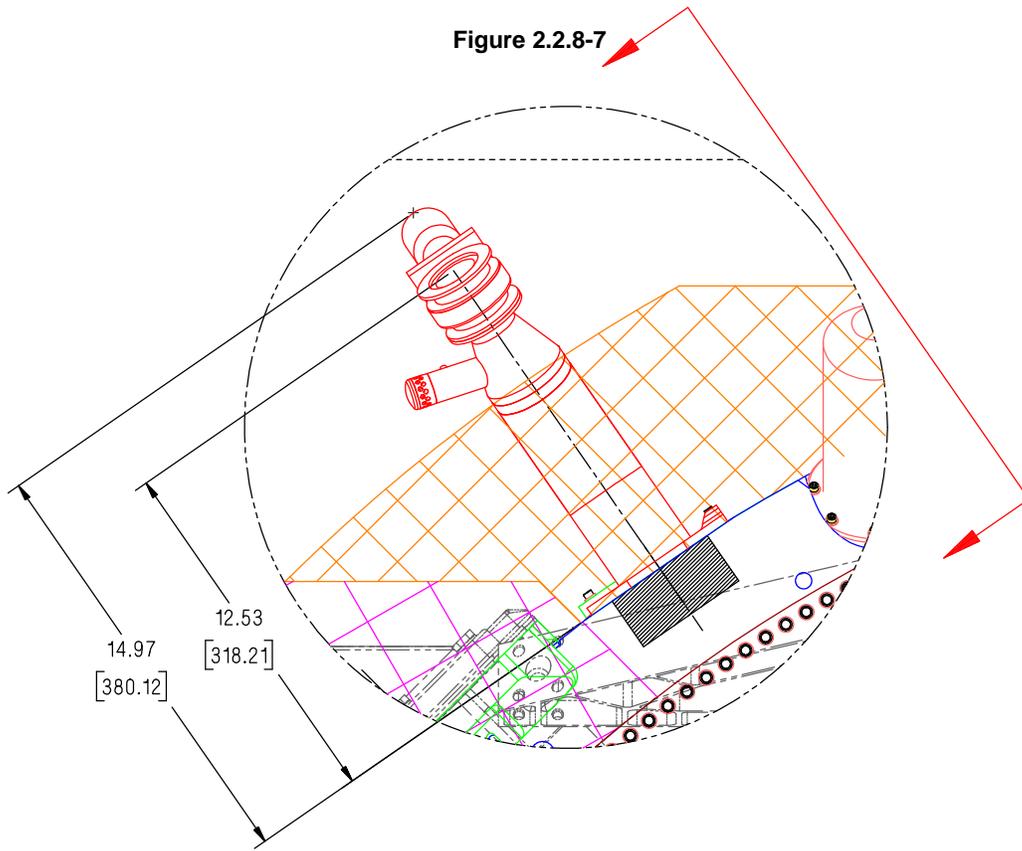


Figure 2.2.8-6 Keep In Zone for the Cryo Service Port Top View

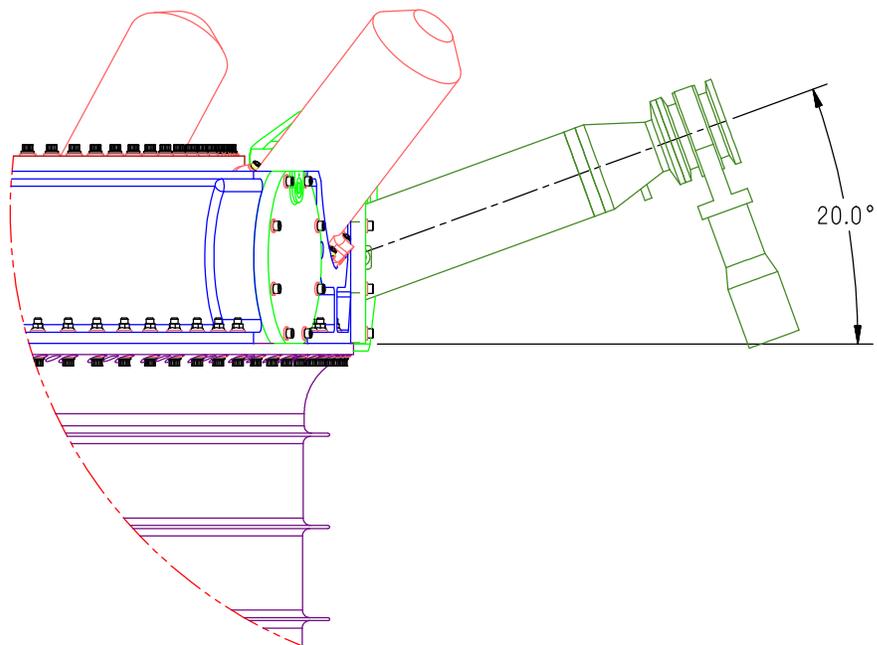


Figure 2.2.8-7 Keep In Zone for the Cryo Service Port Side View

Figure 2.2.8-9

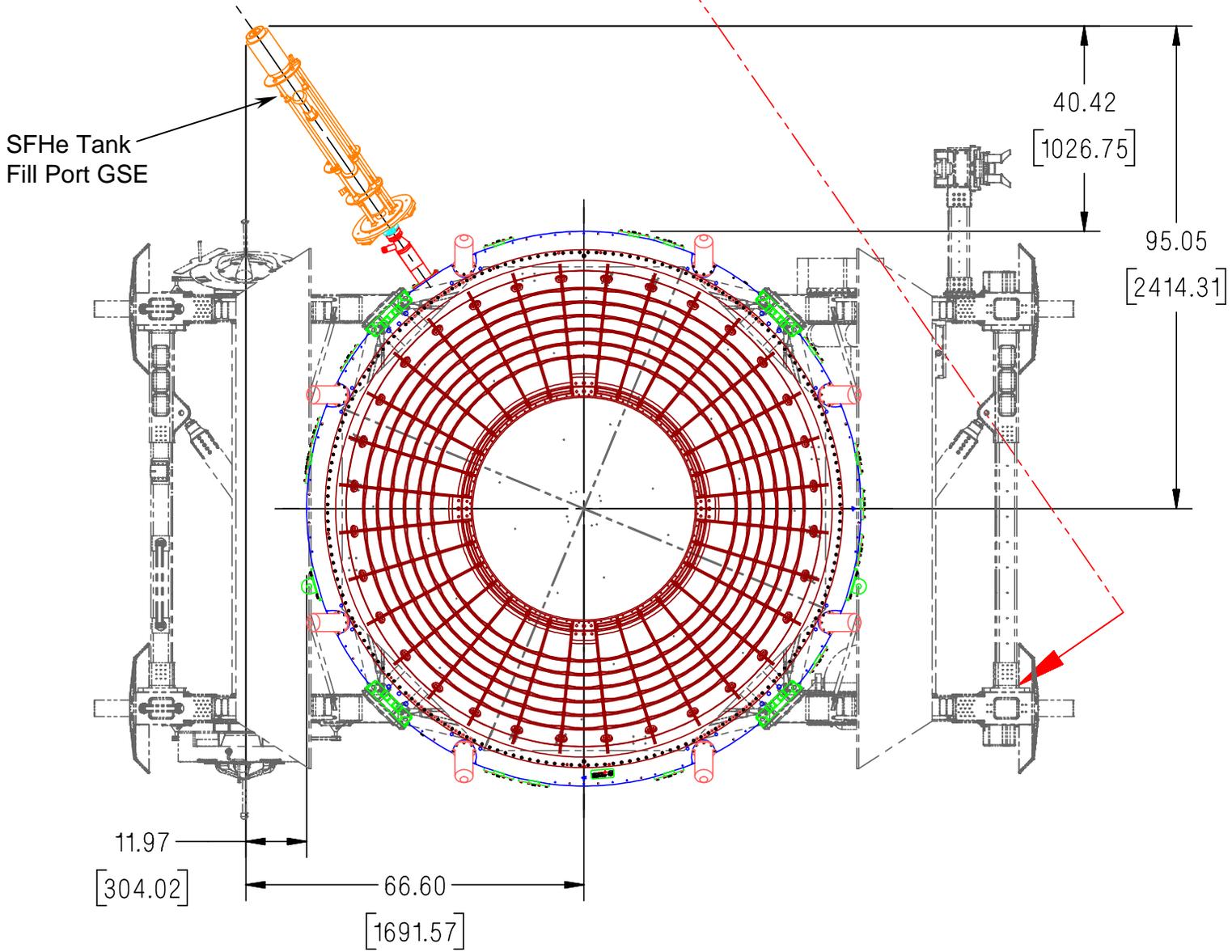


Figure 2.2.8-8 Keep In Zone for the Cryo Service Port GSE Top View

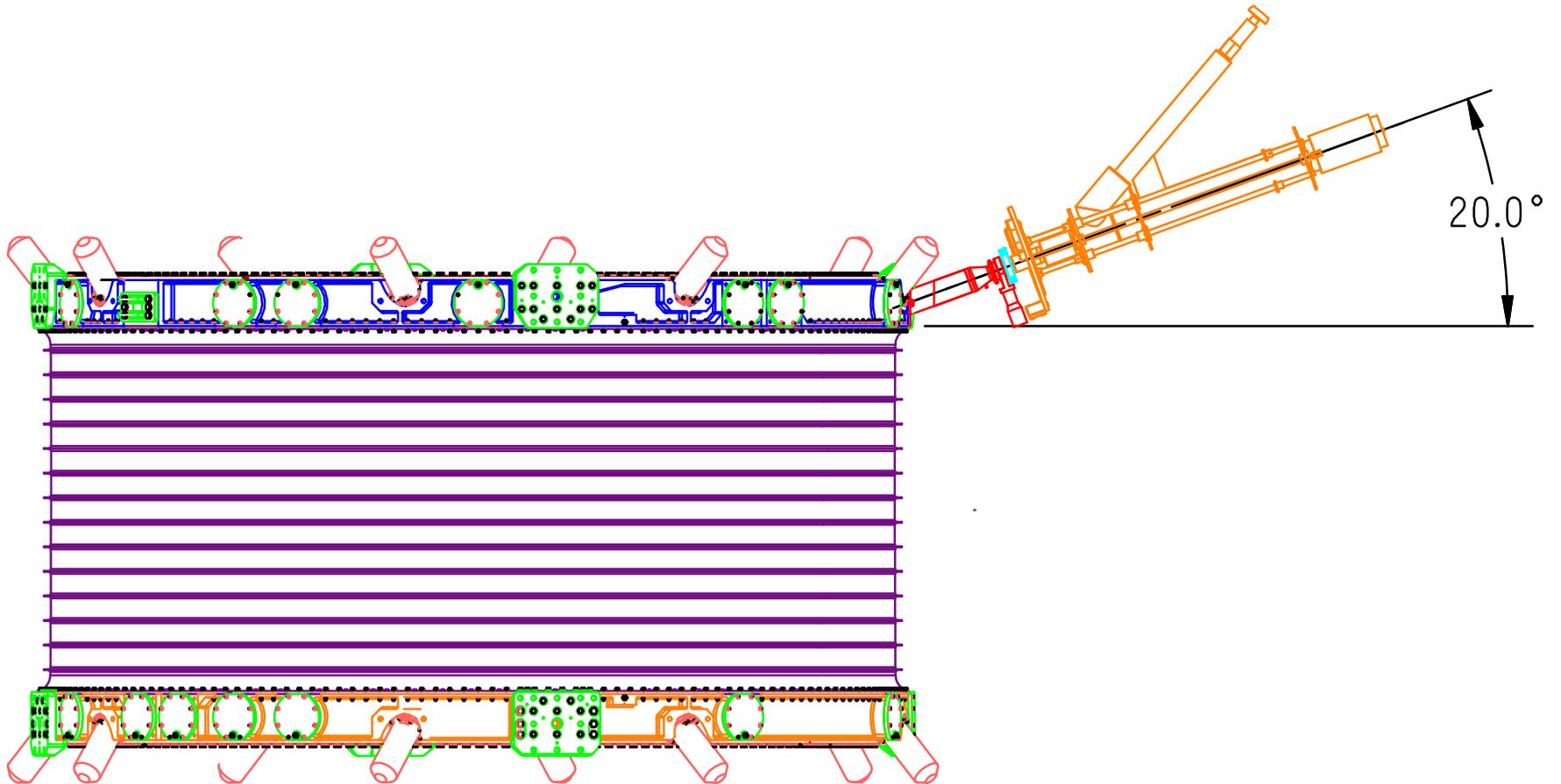
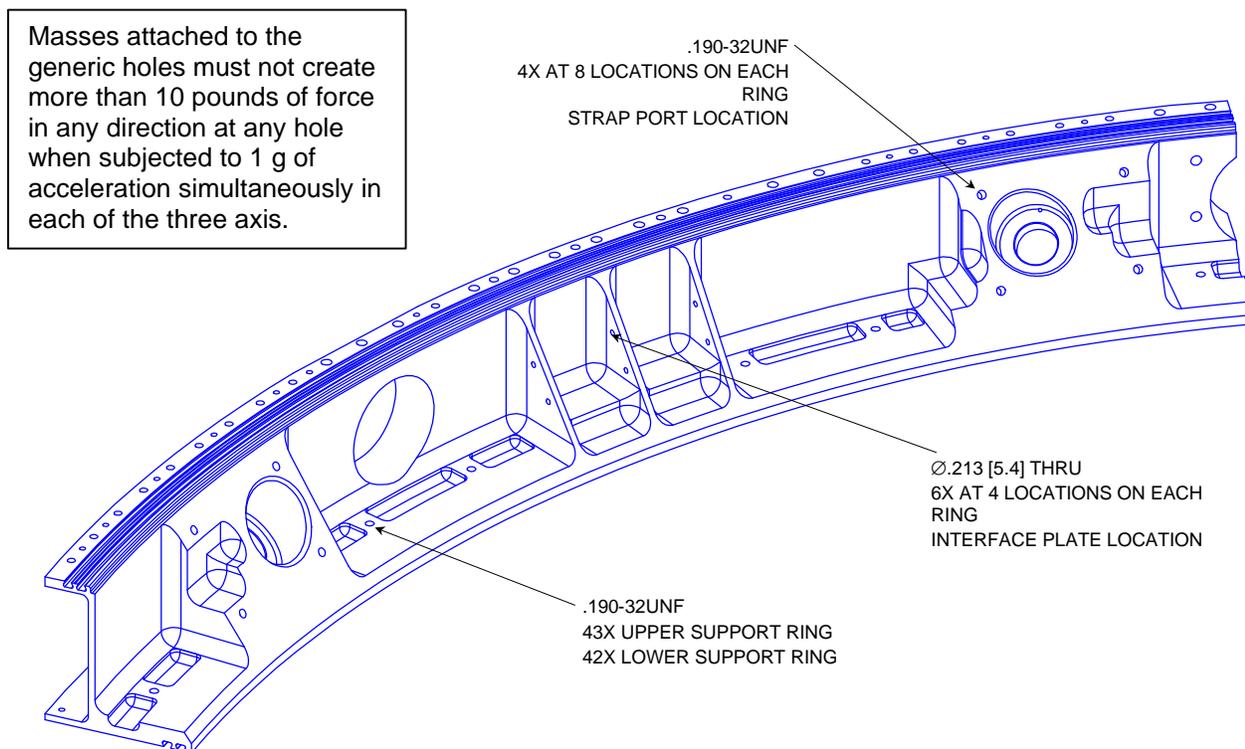


Figure 2.2.8-9 Keep In Zone for the Cryo Service Port GSE Side View

## 2.2.9 Generic Bolt Pattern Interfaces on Inside of VC

Inside the Vacuum Case Upper and Lower Support Rings, a generic hole pattern has been incorporated, as shown in Figure 2.2.9-1, to allow the AMS-02 experiment team to mount additional lightweight hardware internal to the vacuum space. The pattern consists of numerous inserts for #10 bolts. The maximum allowable load for each of these #10 bolts is 10 lb under a 1g acceleration in each axis. The pattern includes a bolt approximately every 6 inches around the circumference on both the top and bottom ring. There are additional bolt inserts near the strap feed-thru ports as shown in Figures 2.2.9-2 through 2.2.9-4.



**Figure 2.2.9-1 ISO View Section of Generic Holes for CM**

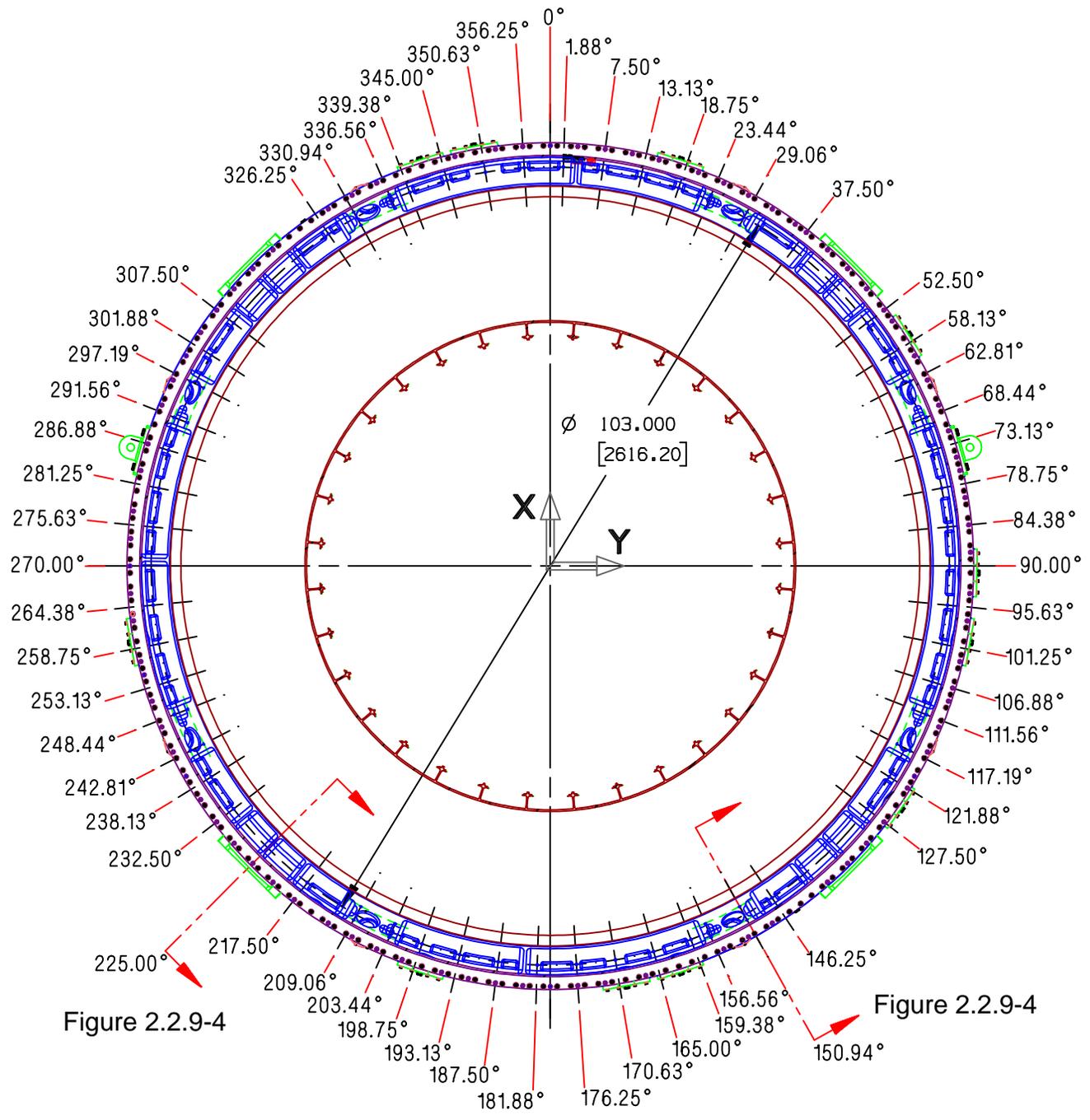


Figure 2.2.9-2 Upper Support Ring Generic Hole Pattern for CM

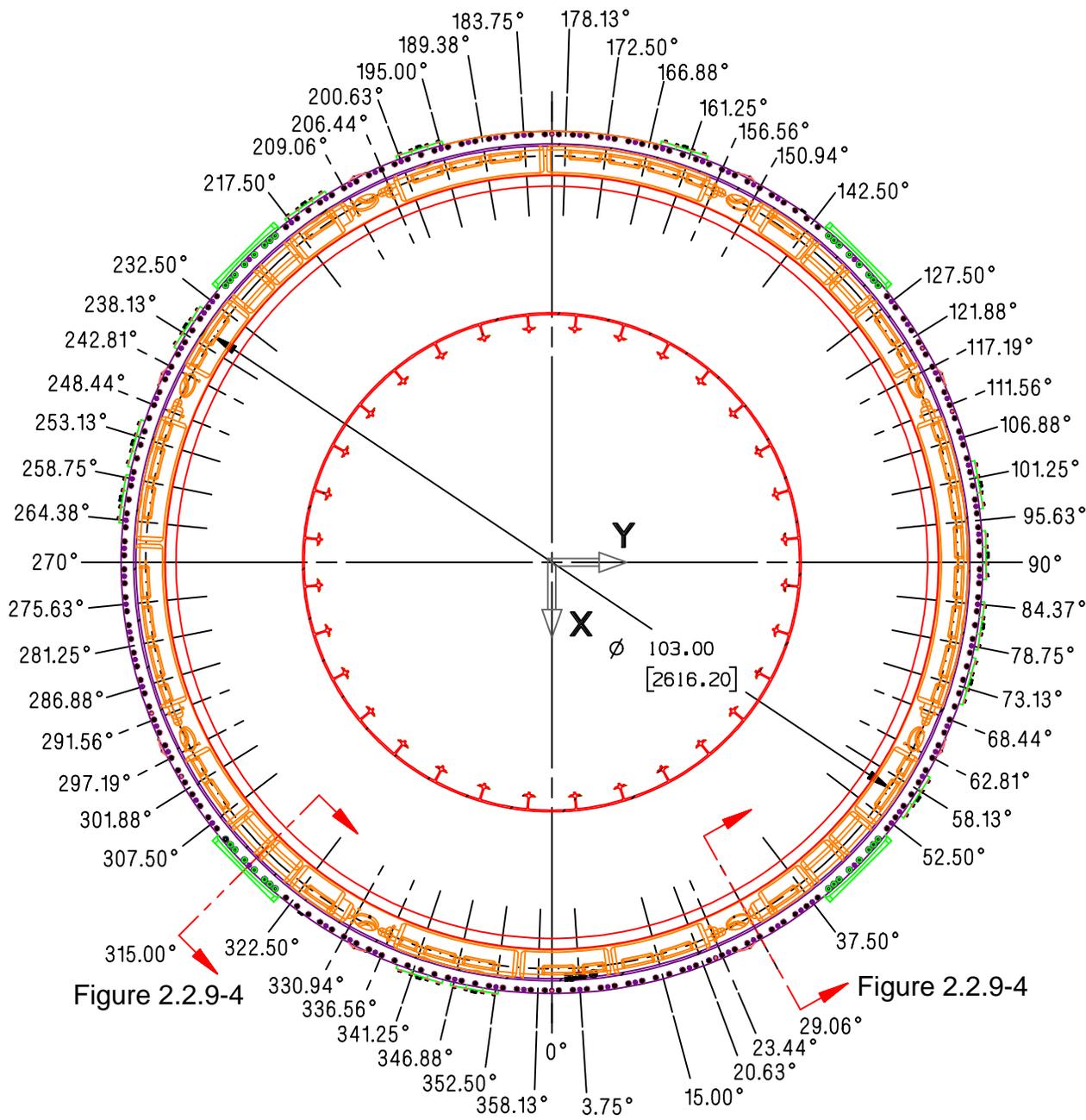
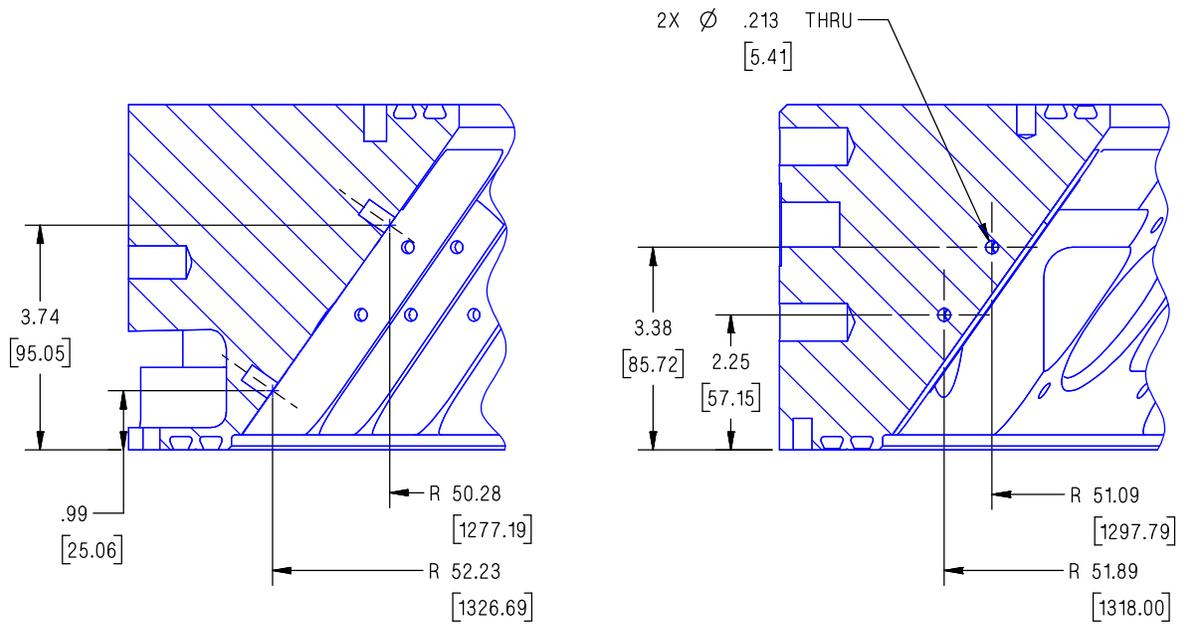


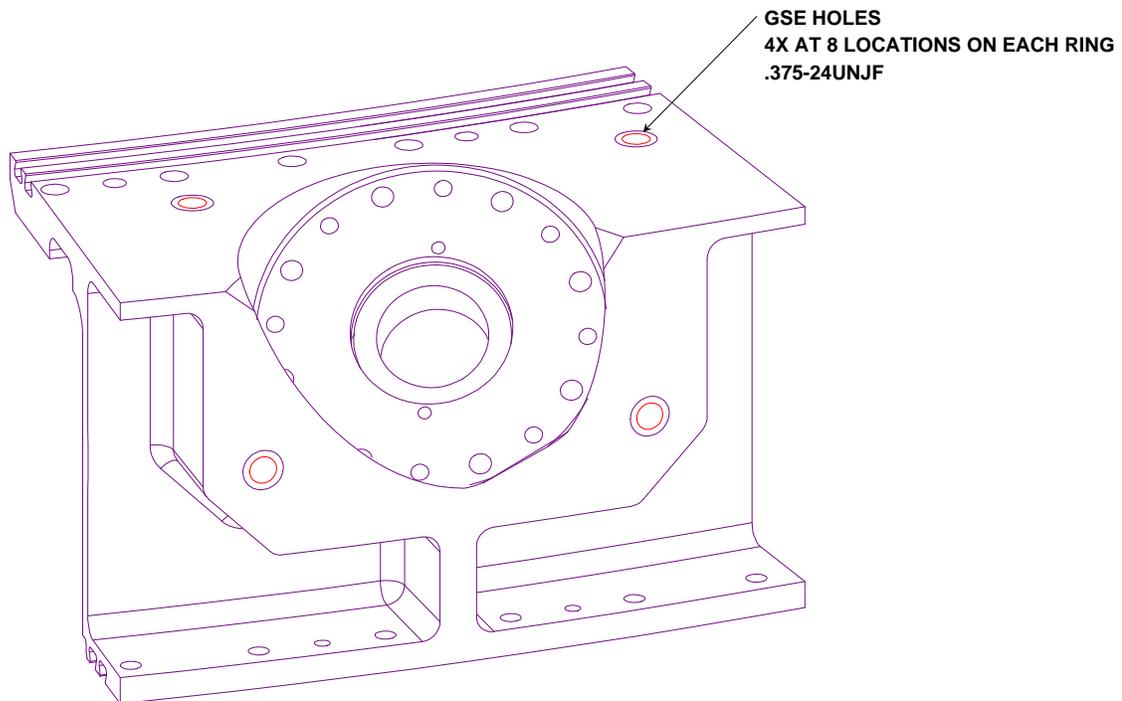
Figure 2.2.9- 3 Lower Support Ring Generic Hole Pattern for CM



**Figure 2.2.9-4 Detail Views of Generic Hole Pattern for CM**

### 2.2.10 GSE Holes at Strap Locations

A set of holes has been incorporated on the outside of the VC around each strap port. These holes are for supporting the strap preload operation during the installation of the CM into the VC. These holes are in addition to the holes that are located on the strap closeout cap mating surface. Figures 2.2.10-1 through 2.2.10-4 detail these hole locations.



**Figure 2.2.10-1 ISO View of Strap GSE Holes**

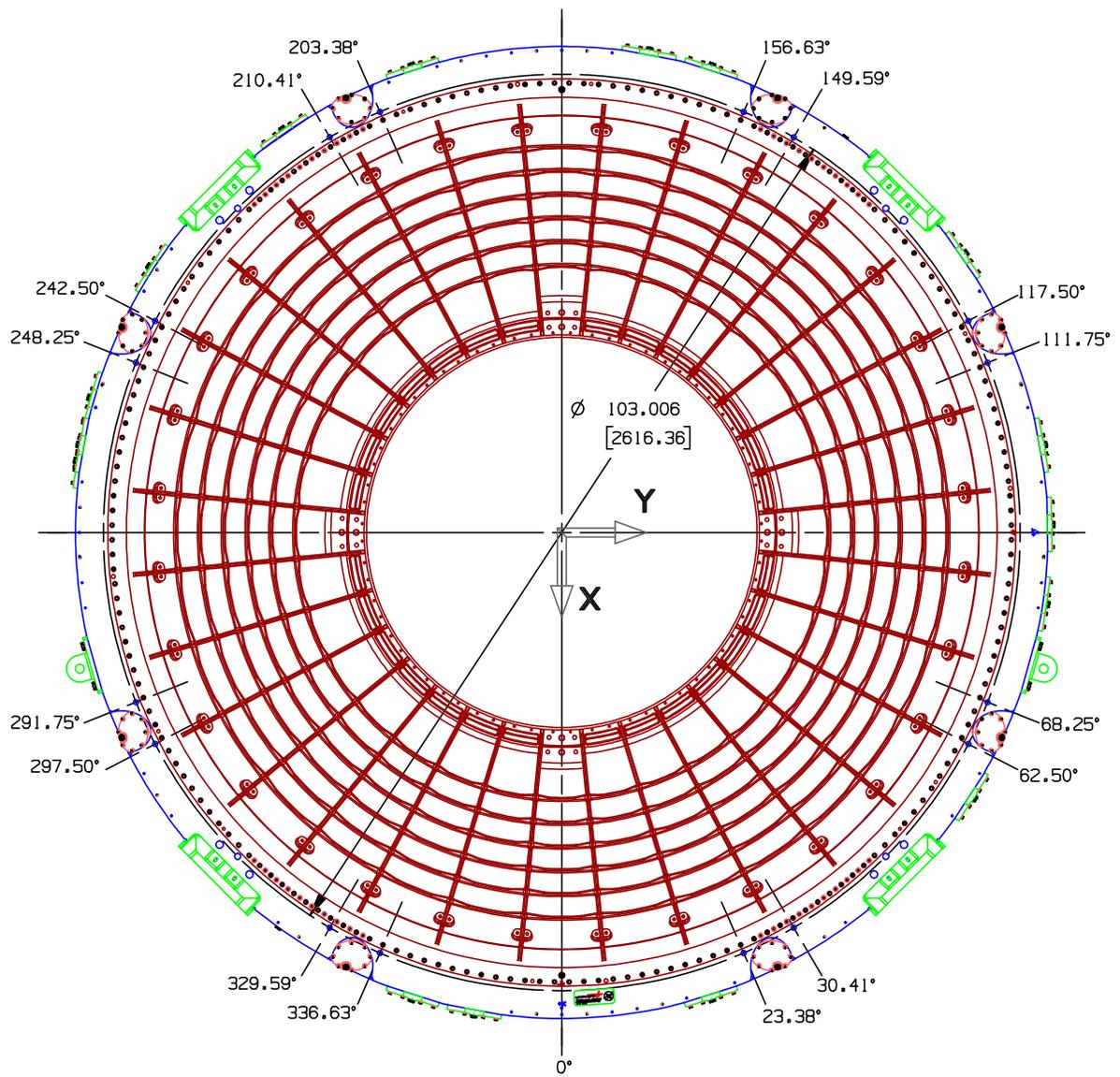
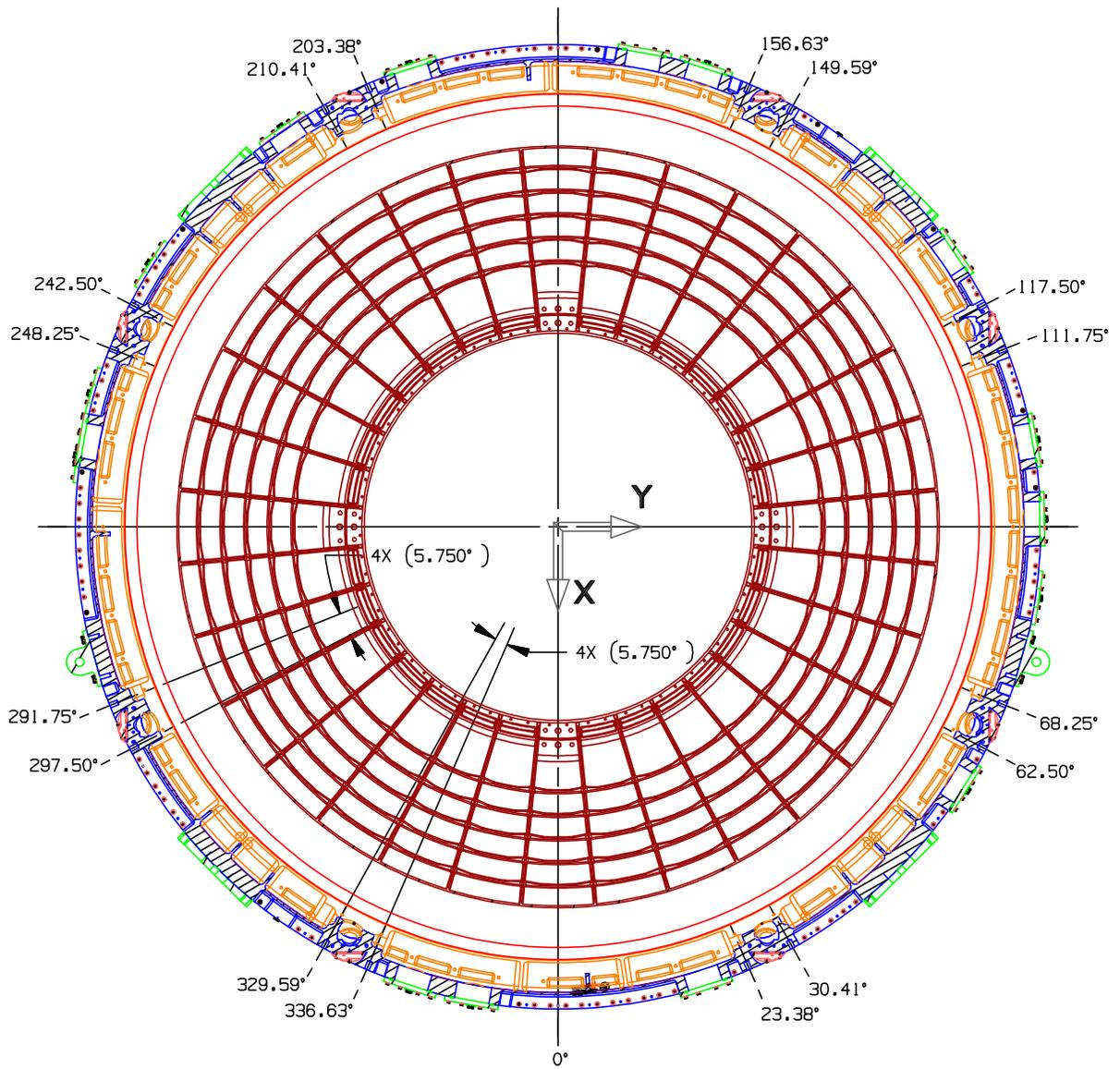
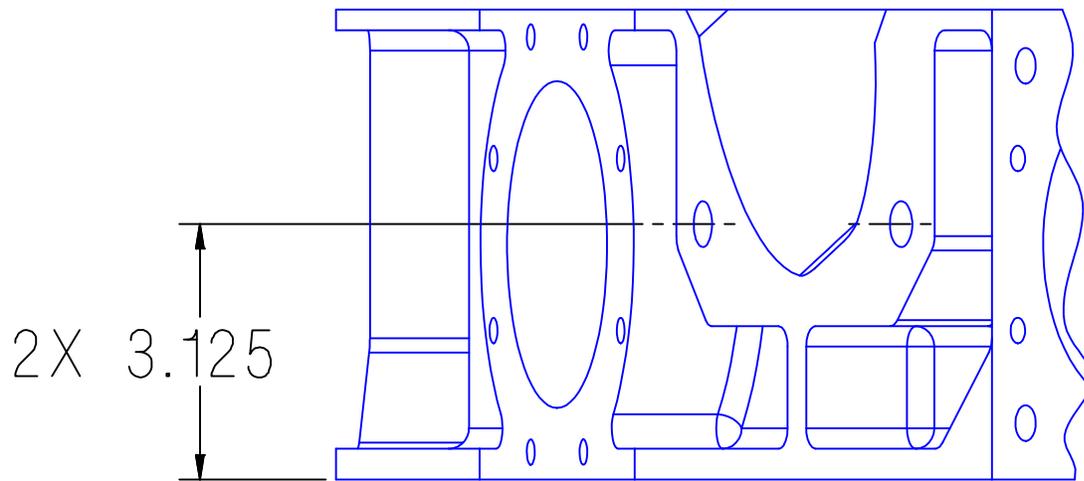


Figure 2.2.10-2 Top/Bottom View of Hole Locations



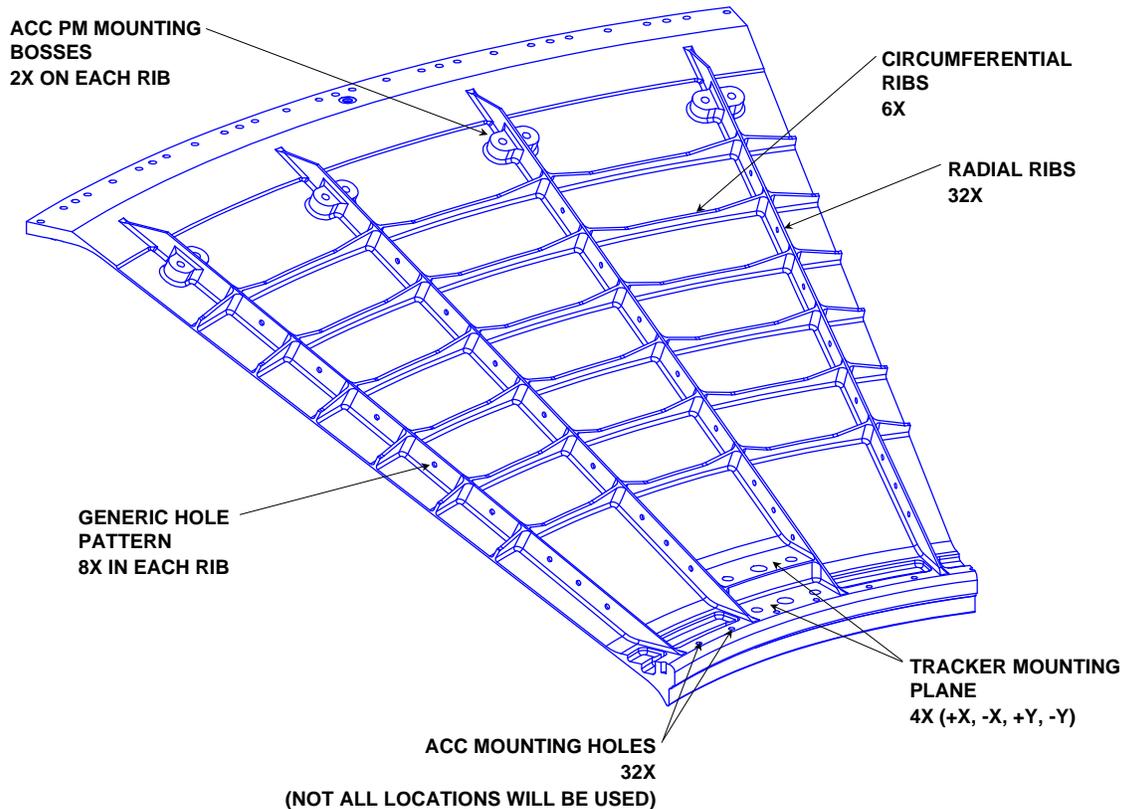
**Figure 2.2.10-3 Section View of Side Hole Locations**



**Figure 2.2.10-4 Detail View of Side Holes**

## 2.2.11 Experiment Interfaces to Vacuum Case

The Tracker and Anti-Coincidence Counter mount to the inner diameter of the Vacuum Case Conical Flanges. An ISO view section of the Conical Flange with the interfaces is shown in Figure 2.2.11-1.



**Figure 2.2.11-1 ISO View Showing Experiment Interfaces on Conical Flange**

### 2.2.11.1 Tracker Support Feet

The Tracker Support Feet are mounted to the Vacuum Case as shown in Figures 2.2.11.1-1 and 2.2.11.1-2.

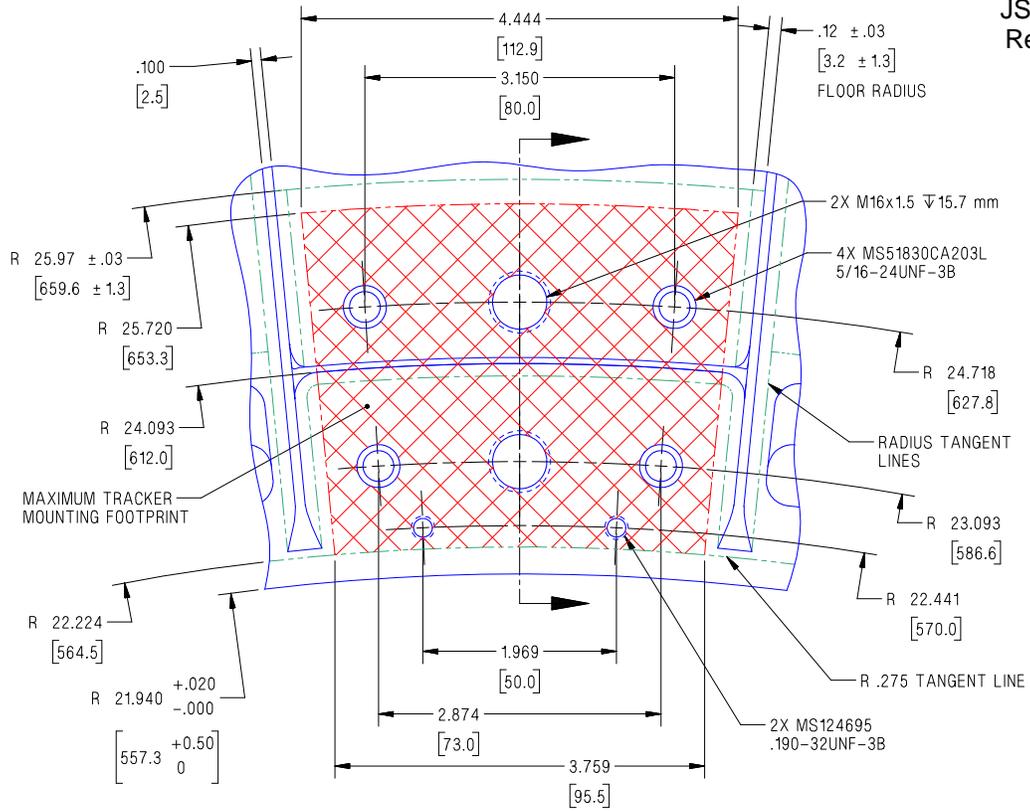


Figure 2.2.11.1-1 Tracker Mounting Pattern

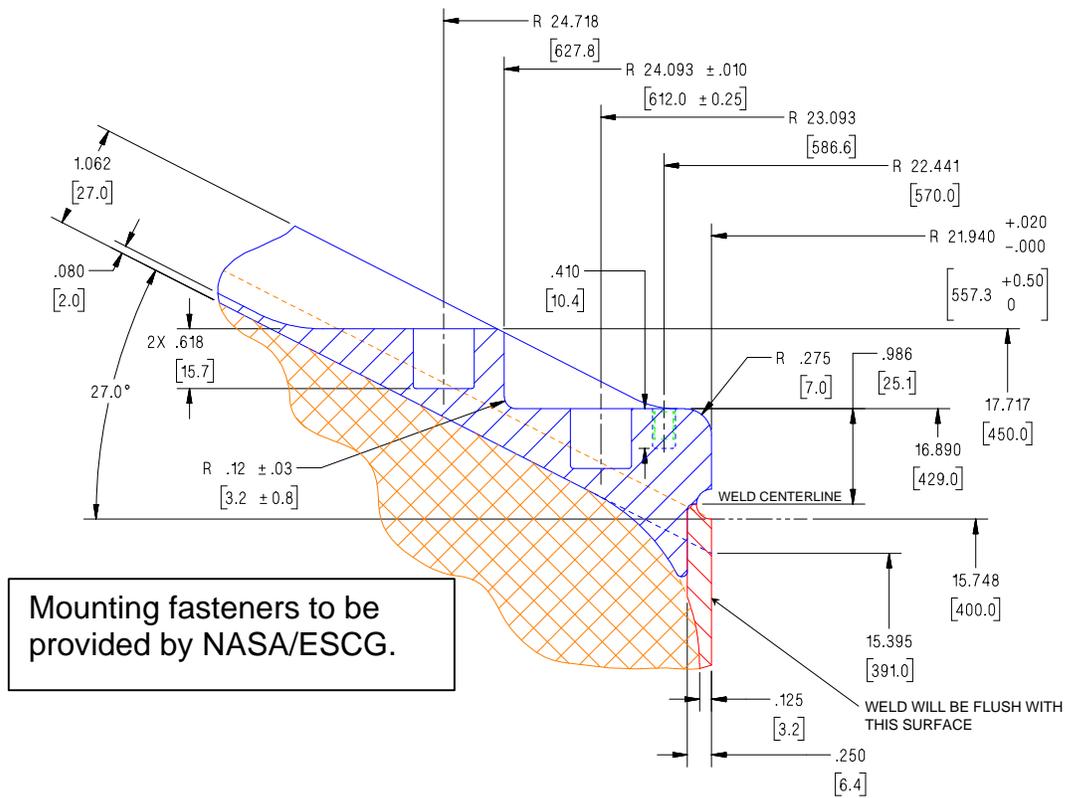


Figure 2.2.11.1-2 Tracker Mounting Cross-Section

### 2.2.11.2 Anti-Coincidence Counter Support Feet

The ACC support feet mount to the inner diameter of the upper and lower conical flanges of the Vacuum Case. These mounting locations are shown in Figure 2.2.11.2-1. The hole pattern shown in Figure 2.2.11.2-1 exists between each of the conical flange ribs, but the ACC will only utilize the pattern between every other pocket. The additional bolt inserts can be used for other mounting as required by the experiment.

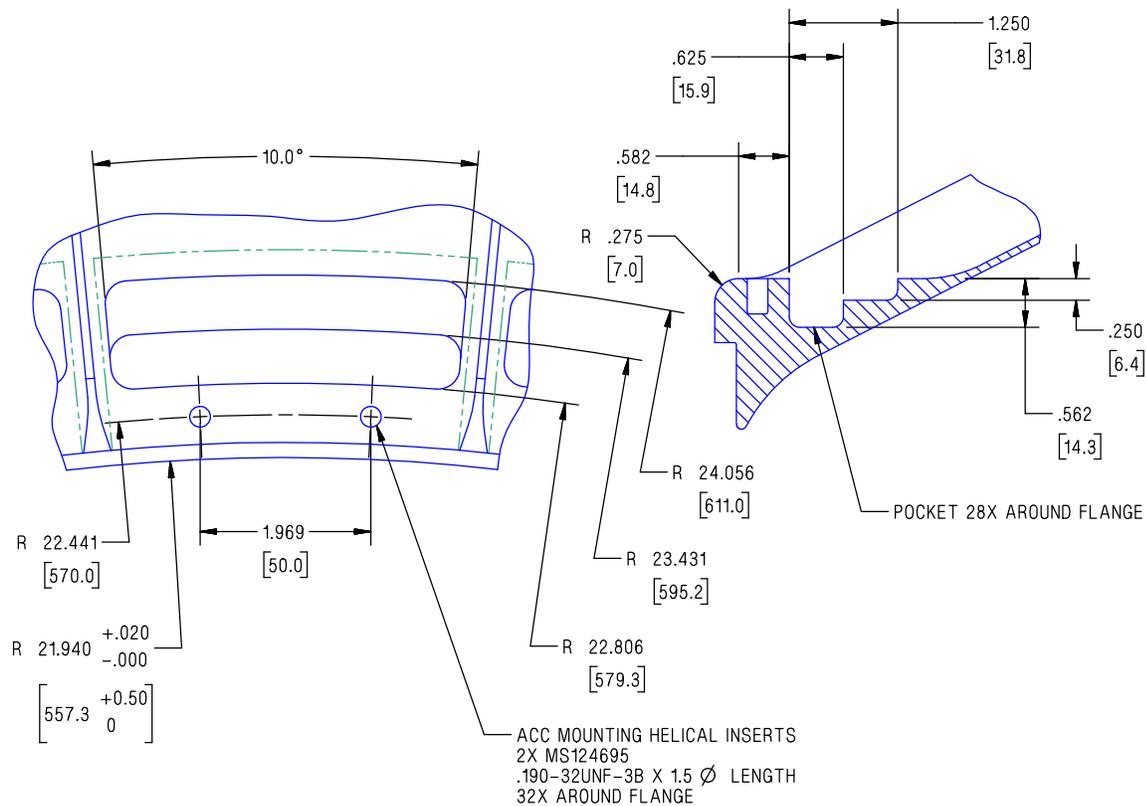


Figure 2.2.11.2-1 ACC Mounting Pattern

### 2.2.11.3 Generic Bolt Pattern Interfaces on Outside of VC

A generic bolt hole pattern exists on the Vacuum Case Conical Flange Ribs as shown in Figure 2.2.11.3-1. The maximum allowable force on each hole is 4.5 lbf. Additional generic bolt hole patterns will be incorporated into the upper and lower rings of the VC as shown in Figures 2.2.11.3-2 through 2.2.11.3-6. The maximum allowable force on each hole is 16 lbf. This pattern includes numerous #10 bolt inserts and thru holes at approximately 3 inch spacing around the circumference of both the upper and lower support rings and the upper and lower outer cylinder mating flanges. Several of the holes will need to be reserved to attach thermal blankets and other PIH. Details of this are TBD.

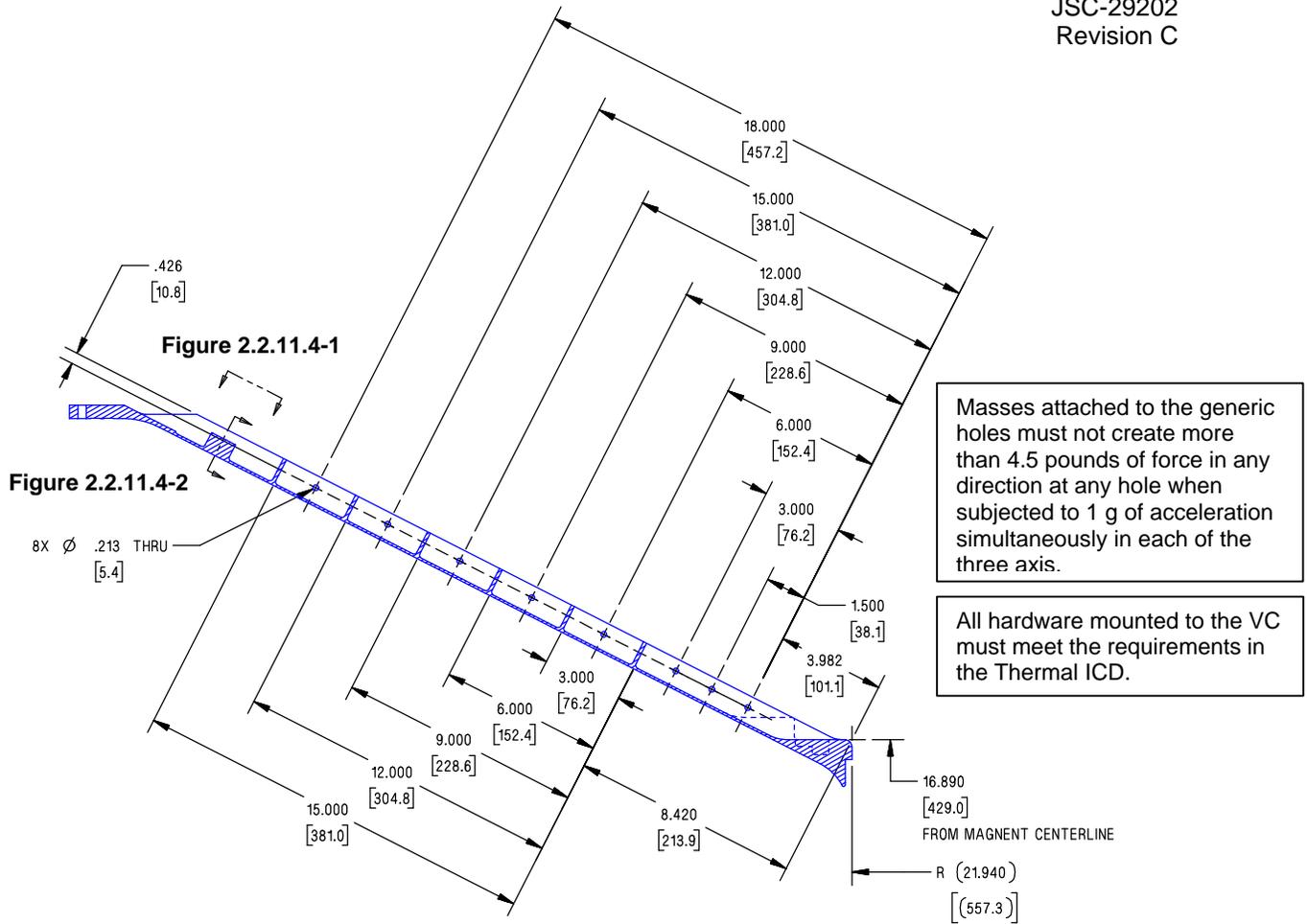


Figure 2.2.11.3-1 Generic Bolt Hole Pattern on Conical Flange Ribs

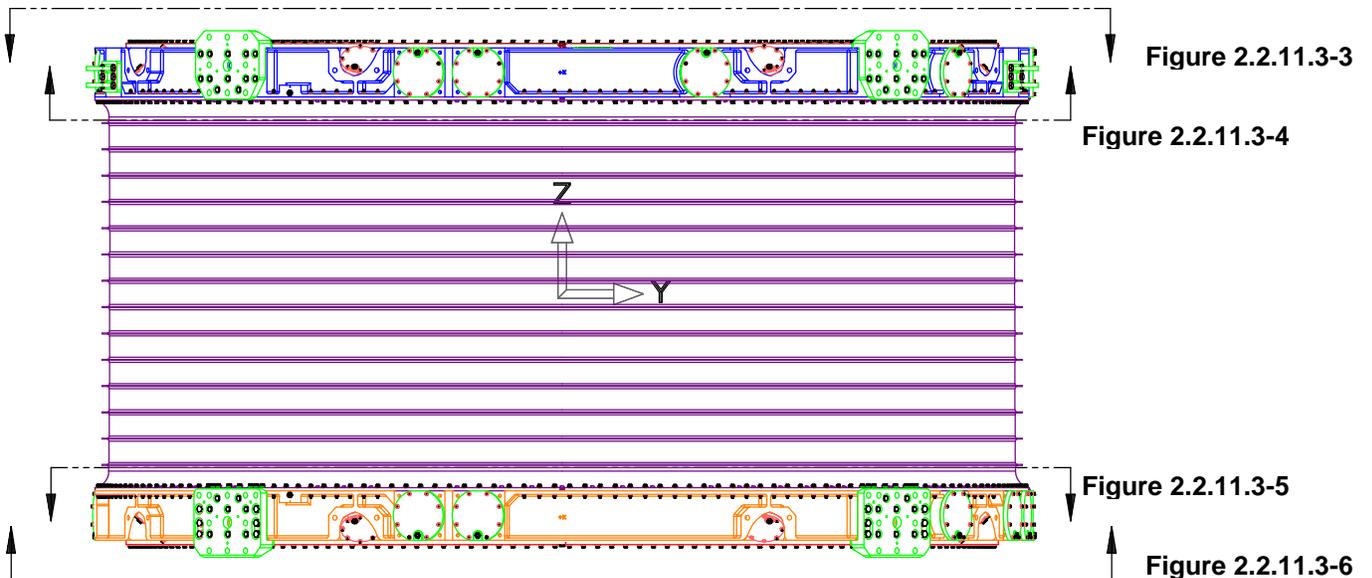


Figure 2.2.11.3-2 Generic Bolt Hole Pattern on Vacuum Case

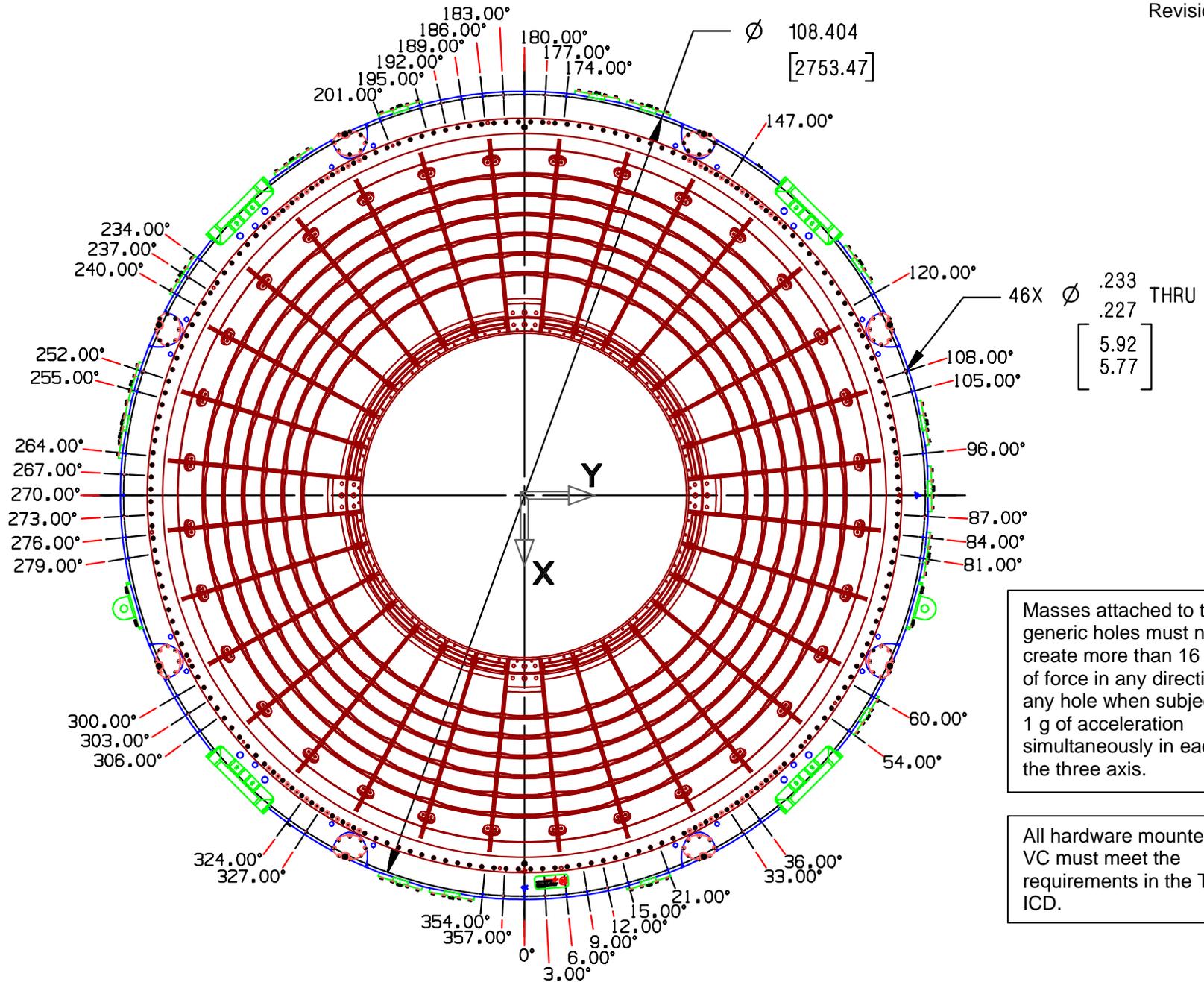


Figure 2.2.11.3-3 Generic Bolt Hole Pattern on VC Upper Support Ring

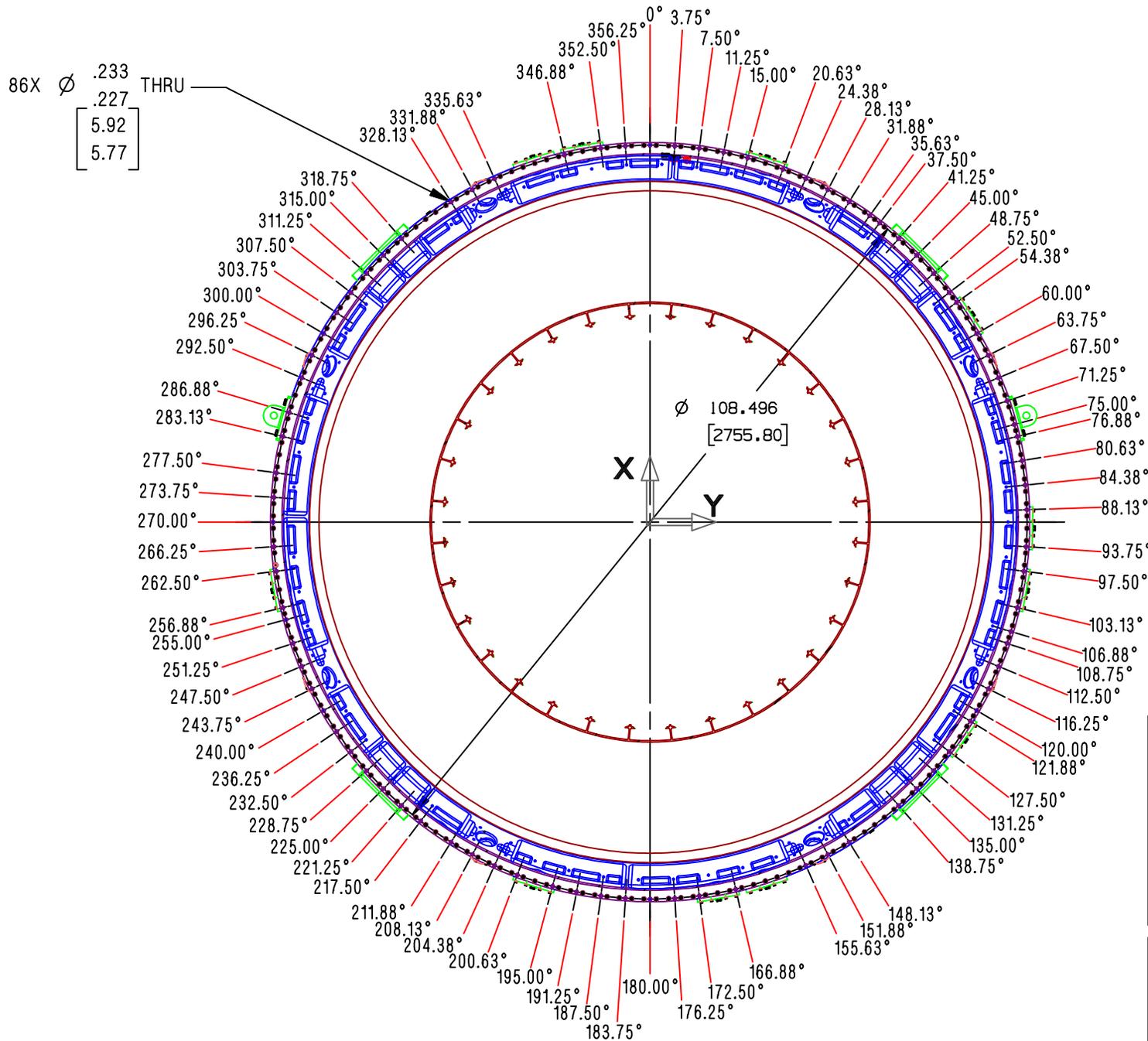
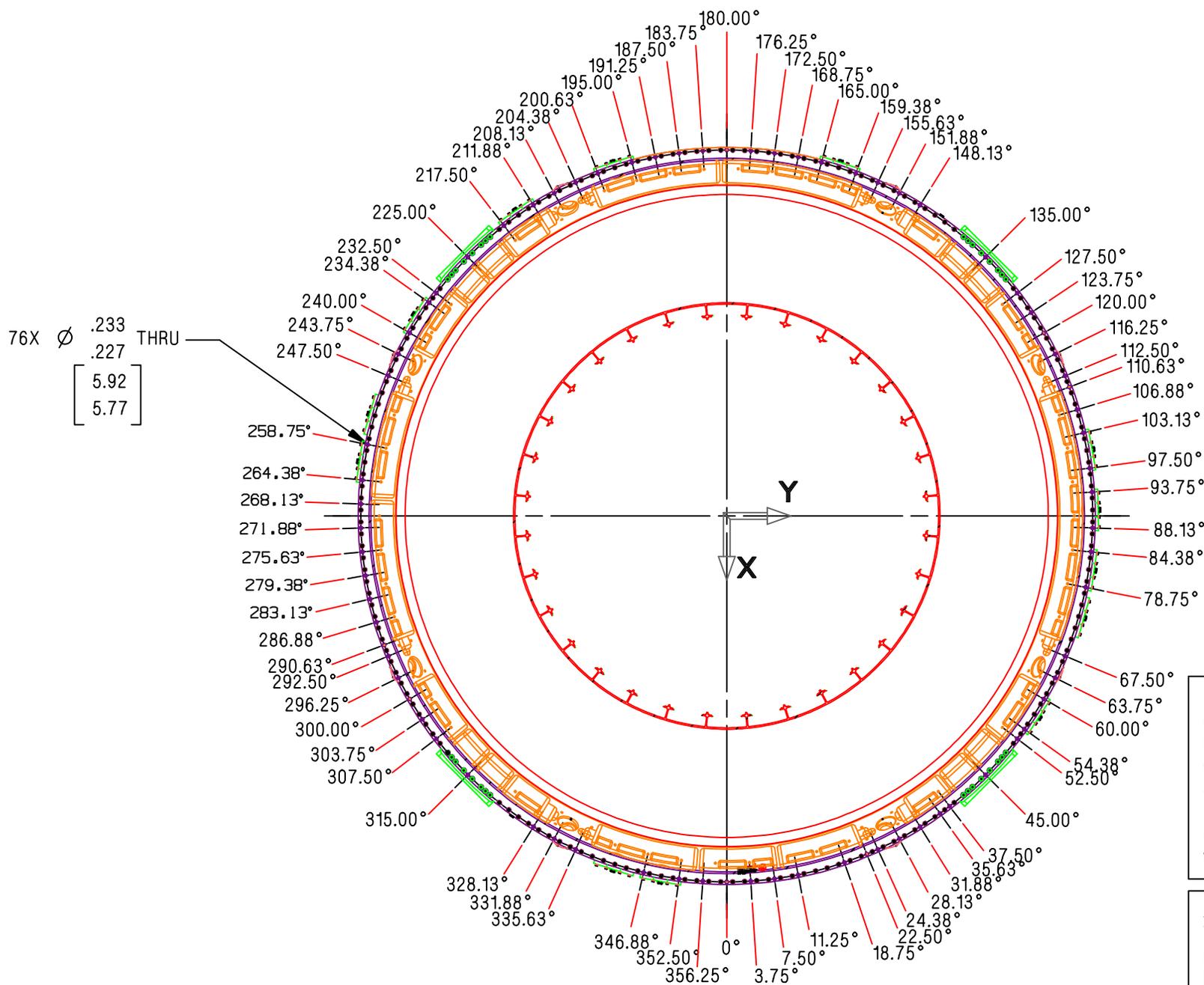


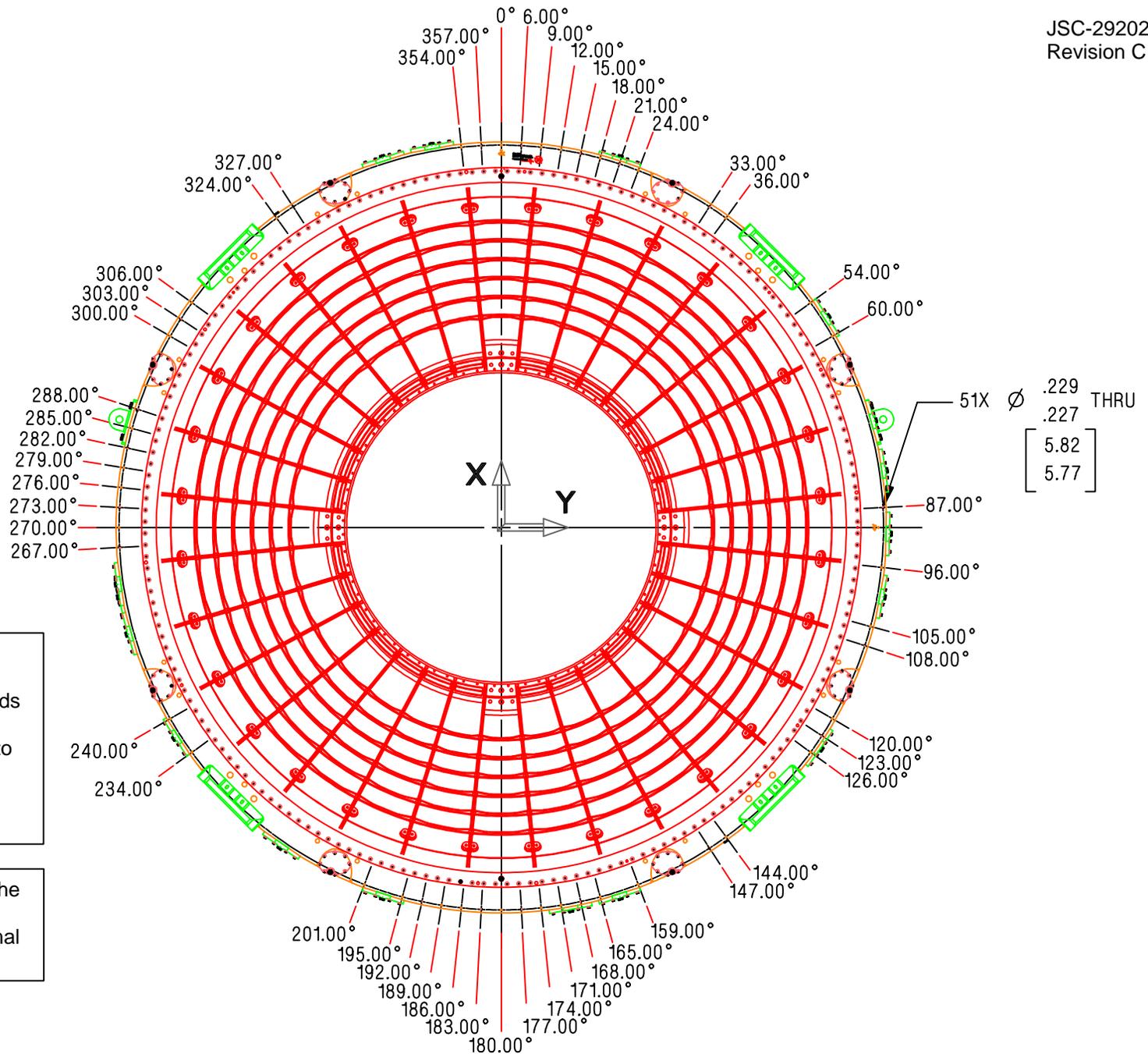
Figure 2.2.11.3-4 Generic Bolt Hole Pattern on VC Outer Cylinder Upper Flange



Masses attached to the generic holes must not create more than 16 pounds of force in any direction at any hole when subjected to 1 g of acceleration simultaneously in each of the three axis.

All hardware mounted to the VC must meet the requirements in the Thermal ICD.

Figure 2.2.11.3-5 Generic Bolt Hole Pattern on VC Outer Cylinder Lower Flange



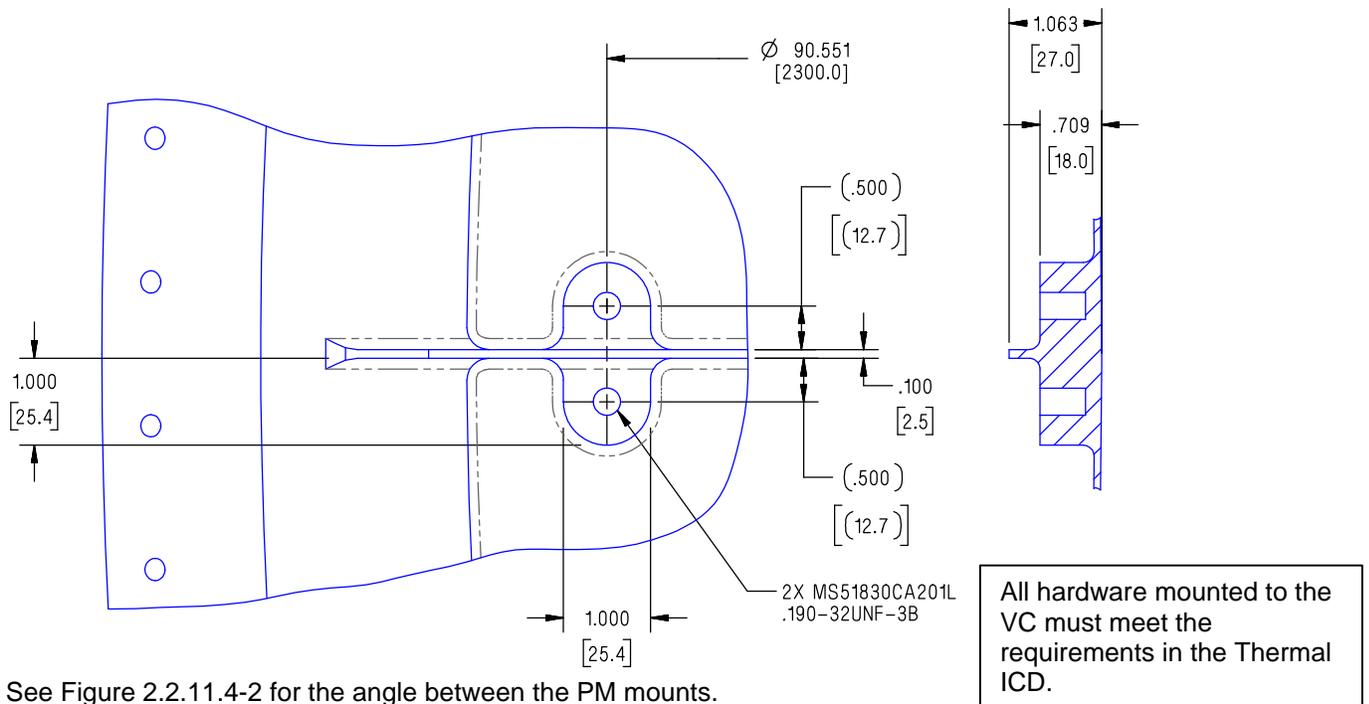
Masses attached to the generic holes must not create more than 16 pounds of force in any direction at any hole when subjected to 1 g of acceleration simultaneously in each of the three axis.

All hardware mounted to the VC must meet the requirements in the Thermal ICD.

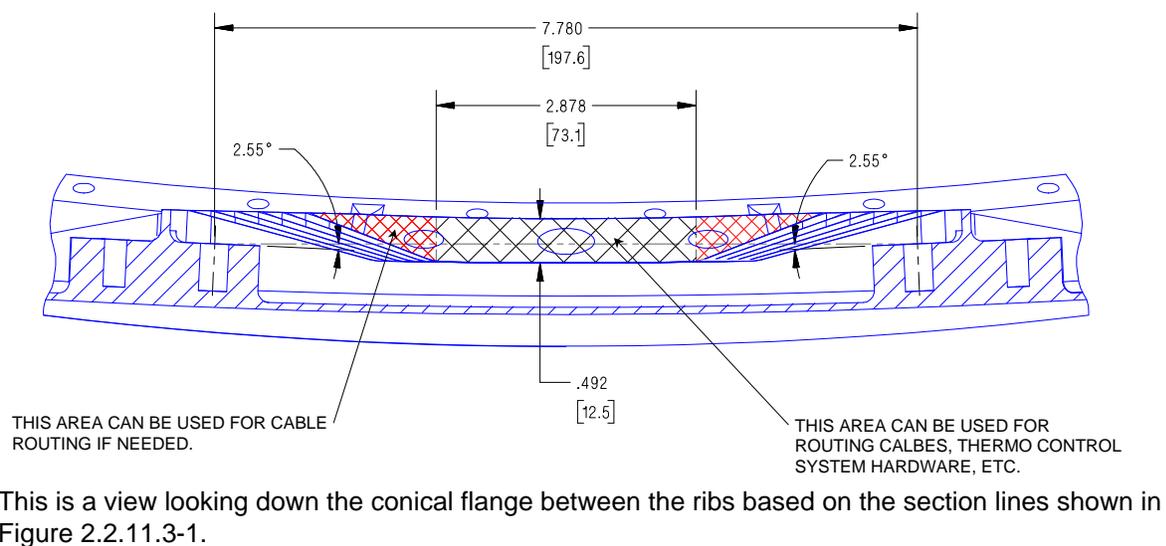
Figure 2.2.11.3-6 Generic Bolt Hole Pattern on VC Lower Support Ring

### 2.2.11.4 Anti-Coincidence Counter Photomultiplier Mounts

The ACC photomultipliers mount to the top and bottom conical flanges at the PM mounted locations as shown in Figure 2.2.11.4-1.



**Figure 2.2.11.4-1 ACC PM Mounting Locations**



**Figure 2.2.11.4-2 Keep-In Zone for ACC and Tracker Electrical/Plumbing Lines**

### **2.2.11.5 Thermal Control System Interface to Vacuum Case**

Although the TCS has not been determined at the time of the signing of this ICD, it is anticipated that the TCS will utilize the generic hole patterns on the upper and lower rings of the Vacuum Case. See Figures 2.2.11.3-2 through 2.2.11.3-6 for the generic hole pattern.

### **2.2.12 Structural Finish and Flatness**

All AMS-02 experiment structural interfaces shall have a surface finish of 125 micro-inches or better. Mounting surfaces shall not be painted, but shall be anodized or alodined aluminum. All vacuum sealing surfaces will be cleaned, polished and protected with a thin film of vacuum grease or equivalent.

### 3.0 ASSEMBLY REQUIREMENTS

#### 3.1 Assembly Procedure Between VC And Cold Mass

The assembly procedure of the Vacuum Case / Cold Mass (CMR or Flight Magnet) will be performed in England at ETH/SCL facilities. Figure 3.1-1 shows the assembly procedure for the Vacuum Case / Cold Mass.

**Figure 3.1-1 VC/Cold Mass Assembly Procedure (shown below)**

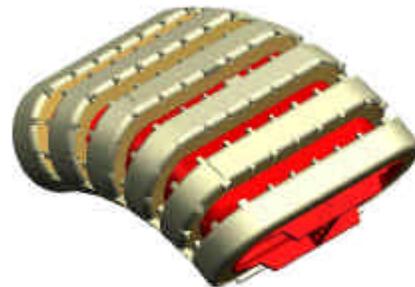
**Step 1:**

Fabricate and assemble all 12 racetrack coils and test each one individually



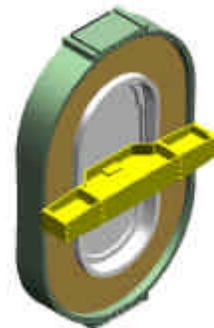
**Step 2:**

Assemble 6 together, twice. One for each side.



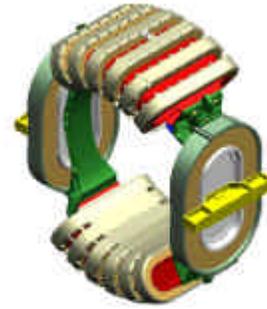
**Step 3:**

Fabricate and assemble 2 Dipoles and test each one Individually.



**Step 4:**

Assemble all coils together  
Including Racetrack End frames.

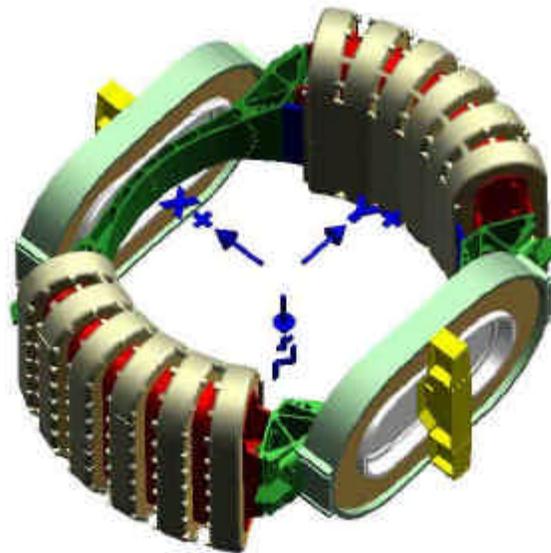


**Step 5:**

Complete all plumbing, up to helium vessel

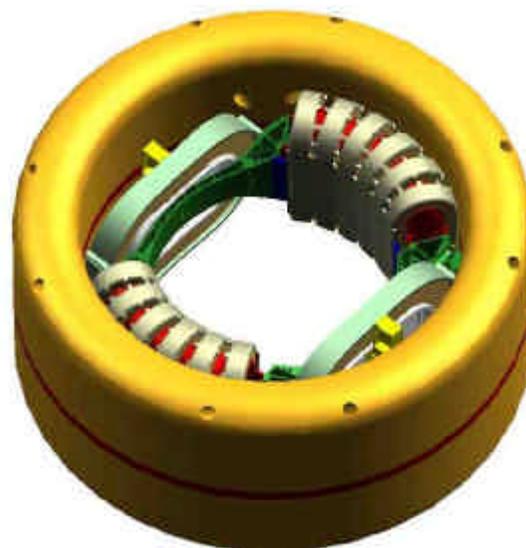
**Step 6:**

Turn to  $-z$  axis upwards



**Step 6:**

Fit helium vessel and  
Connect to coil pipework



**Step 7:**

Fit cold-warm supports (except warm end item)

**Step 8:**

Complete all 1.8 K instrumentation (this includes accelerometers on CMR)

**Step 9:**

Lift cold mass and put in assembly frame inverted ('top' is down).  
Transfer loads to four C1W1 supports (only)



**Step 10:**

Assemble all Pipework, Superinsulation, Radiation Shields, Radiation shield Supports, Current leads, Instrumentation; (access from above and below).

**Step 11:**

Fit from above the VC Lower Support Ring (shown in green), supported on Assembly Frame, with warm Bods in place (retracted).

**Step 12:**

Transfer load to 4 C2W2 supports.

**Step 13:**

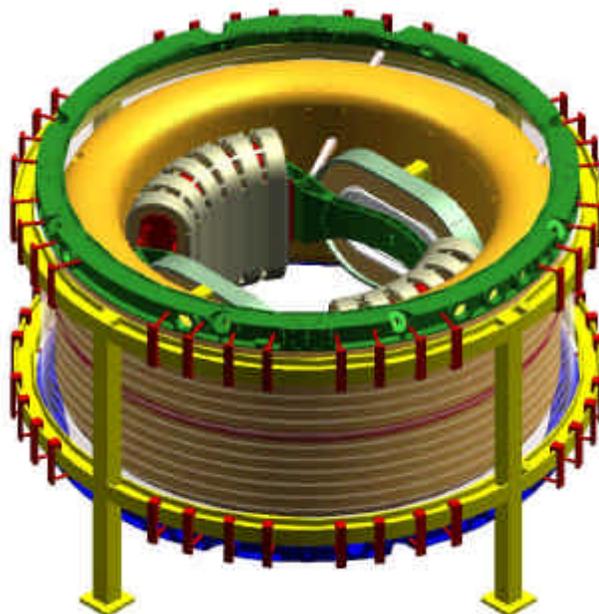
Re-tension 4 C1W1 supports to VC Lower Support Ring.  
Complete pipework etc to VC Lower Support Ring.

**Step 14:**

Lift whole cold mass via the VC Lower Support Ring and install in the pre-assembled (inverted) VC Outer Cylinder / VC Upper Support Ring.

**Step 15:**

Re-install VC / Cold mass into re-built Assembly Frame to allow tension loads to be reacted so as to retain circularity of VC Upper and Lower Support Rings.



**Step 16:**

Tension remaining cold to warm supports and complete pipework etc to VC Upper Support Ring.

**Step 17:**

Set up all CTW straps correctly to tension values based on the cold mass replica (CMR) assembly sequence.

**NOTE:** During the CMR assembly sequence, the cold mass will have been supported via a load cell to simulate zero g and all supports tensioned to the warm, zero 'g', preload. Load cell is then removed and the resulting tensions in all supports are recorded. These tensions are used during the assembly of the flight article.

**Step 18:**

Complete all work to internals of VC, fit cryocoolers.

**Step 19:**

Fit Upper Conical Flange of VC to underside of assembly.

**Step 20:**

Fit Inner Cylinder of VC.

**Step 21:**

Fit Lower Conical Flange of VC to top of assembly.

**Step 22:**

Fit temporary O-ring seal fixtures to Inner Cylinder, perform pressure test and leak test on all systems and operate cryosystem.

**Step 23:**

Rotate to where the z axis is horizontal and weld the Inner Cylinder to the Conical Flanges.

**Step 24:**

Pressure test and leak test Vacuum Case.

**Step 25:**

Complete external pipework and instrumentation.

### 3.1.1 Hardware

The hardware provided by each group and the description is shown in Table 3.1.1-1.

**TABLE 3.1.1-1 PROVIDED HARDWARE SUMMARY TABLE**

<b>HARDWARE</b>	<b>PROVIDER</b>	<b>DESCRIPTION</b>
Vacuum Case	ESCG/NASA-JSC	Structural Test Article (STA) and Flight Vacuum Case
Weld Fixture	ESCG/NASA-JSC	Used to support VC during welding of the inner cylinder to conical flange.
Temporary Port Closeout Covers	ESCG/NASA-JSC	Used to temporarily seal the VC (STA and Flight) during ground vacuum leak tests and proof pressure tests prior to the installation of the final closeout port covers or caps. Also used for flight spare ports
Hydra - Set	ESCG/NASA-JSC	Will be on loan to SCL for use in the VC/Cold Mass assembly process.
Plumbing and Electrical Feed Thru Port Covers and Caps, and Support Strap Closeout Caps	SCL/ETH	Used to seal the VC (STA and Flight) during ground vacuum leak tests and proof pressure tests after installation of cryosystem.
Cryocooler Feed Thru Port Covers / Cryocooler Support Bracket-Compliant Mount	ETH/MIT/ NASA-GSFC	Used to support the cryocoolers to the VC, to seal the cryocooler port, and to mechanically & thermally isolate the cryocoolers. Use temporary covers for spare ports.
Cryocoolers	ETH/MIT/ NASA-GSFC	Mount to the Upper and Lower Support Rings on the VC.
Cryocooler Heat Rejection System	TBD	Used to draw the heat away from the cryocooler warm end and distribute it to the AMS-02 Thermal Control System (TCS).
Cold Mass Replica (CMR) Assy.	SCL/ETH	The CMR will match the mass and inertia properties of the flight magnet to within $\pm 5\%$ . It will be installed in STA Vacuum Case.
Cold Mass Replica Straps	SCL/ETH	Flight identical non-linear straps to be used with STA VC and CMR. Must be capable of changing these straps to linear response during the modal and static testing of the AMS-02 payload. Details to be discussed.
STA SFHe Tank	SCL/ETH	To be used with STA Vacuum Case & CMR.
Pressure Gauge for the STA Acoustic Test	SCL/ETH	The pressure gauge will be used to check the pressure of the Vacuum Case before, during and after the acoustic test.
STA Cryosystem	SCL/ETH	To be used with STA Vacuum Case & CMR.

**TABLE 3.1.1-1 PROVIDED HARDWARE SUMMARY TABLE**

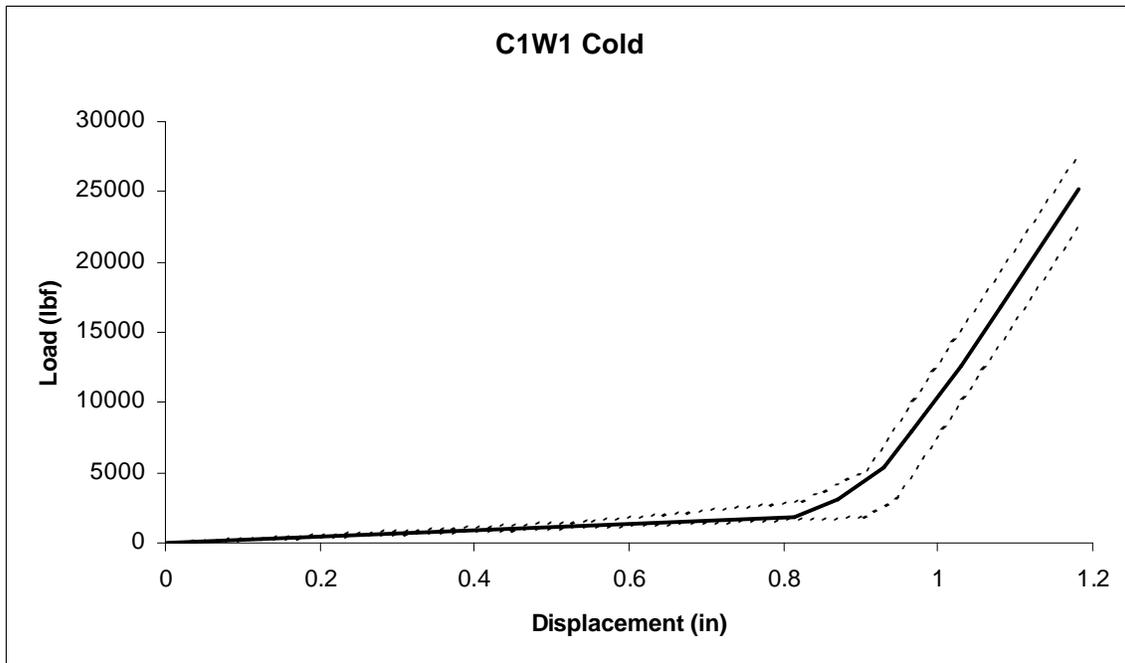
<b>HARDWARE</b>	<b>PROVIDER</b>	<b>DESCRIPTION</b>
Cryomagnet	SCL/ETH	To be used with the flight Vacuum Case and Flight SFHe Tank.
Flight SFHe Tank	SCL/ETH	To be used with flight Vacuum Case and Cryomagnet.
Flight Cryosystem	SCL/ETH	To be used with flight VC, flight Cryomagnet, and SFHe Tank
Flight Straps	SCL/ETH	Support the Flight SFHe Tank, the Flight Cryosystem, and the Cryomagnet.
Burst Disks: VC = 0.8 atm SFHe = 3.0 B	SCL/ETH	All burst disks for STA & Flight VC and STA & Flight SFHe will be provided by SCL/ETH as defined by the SCL/ETH cryogenic schematic.
Temporary O-ringed Seal for Inner Cylinder to Conical Flange Interface of VC	SCL/ETH	Will be used with the STA and Flight VC to perform vacuum leak checks. Must be provided to NASA/ESCG to perform this early testing on the VC before the VC arrives in England.
Ground Support Hardware for Magnet / Vacuum Case Assembly	SCL/ETH	-Must be capable of rotating complete magnet system. -Must be capable of maintaining the required shape of the VC during the assembly process.
Cryosystem GSE	SCL/ETH	To be used to support the filling an operations associated with helium or superfluid helium. This hardware will be used in England, Zurich, KSC, wherever the vibration testing occurs, and wherever the thermal vacuum testing occurs.

### 3.1.2 Strap System

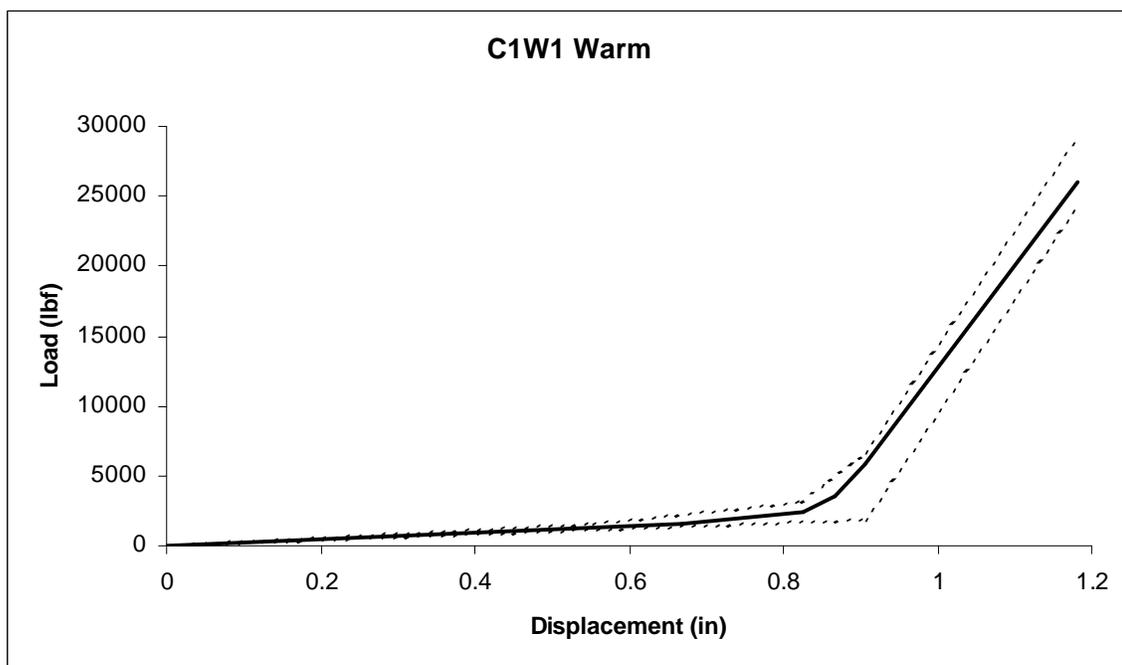
The Strap System is completely designed, built and tested by SCL / ETH. Since the design of this system affects the design of the Vacuum Case, the load verses deflection envelope shown in the following Figures will be adhered to. Any changes to these curves must be agreed to by all parties affected by the change.

**Table 3.1.2-1 Non-Linear Strap Load Data**

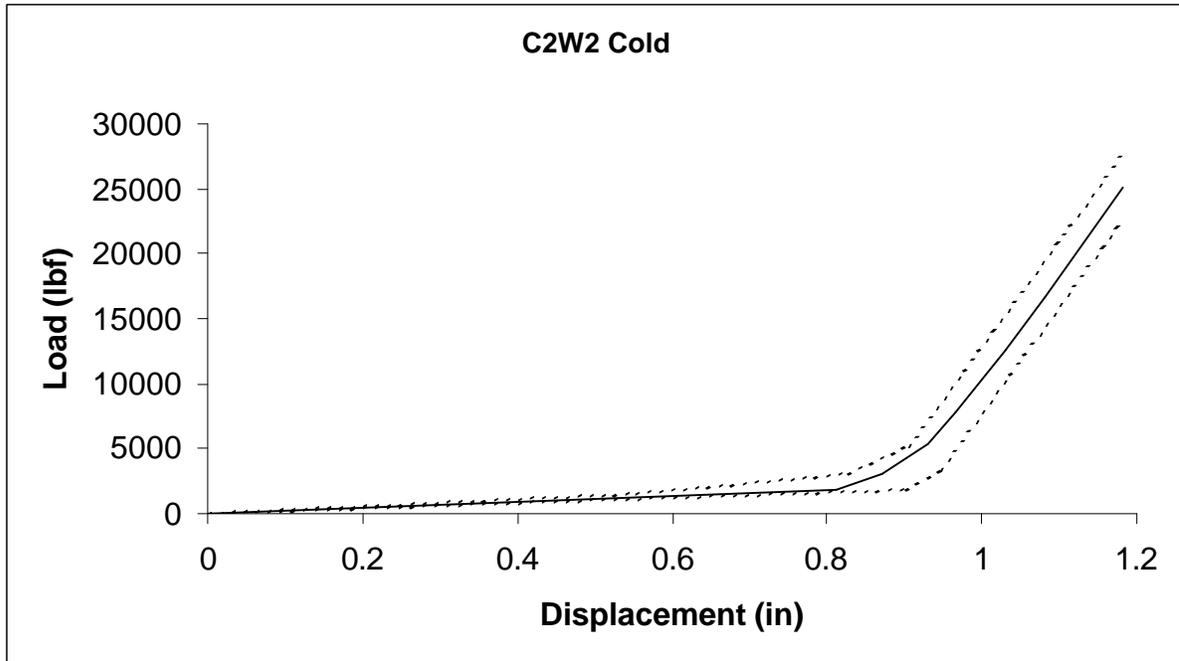
C1W1 Warm					
Nominal		Upper Bound		Lower Bound	
Deflection (in)	Load (lbs)	Deflection (in)	Load (lbs)	Deflection (in)	Load (lbs)
0	0	0	0	0	0
0.6693	1573	0.5512	1573	0.9055	1798
0.8268	2472	0.8268	3146	1.1811	24180
0.8661	3596	0.9055	6742		
0.9055	5843	1.1811	29124		
1.1811	26067				
C2W2 Warm					
Nominal		Upper Bound		Lower Bound	
Deflection (in)	Load (lbs)	Deflection (in)	Load (lbs)	Deflection (in)	Load (lbs)
0	0	0	0	0	0
0.2756	652	0.5512	1573	0.9055	1798
0.6693	1596	0.8268	3146	1.1811	24180
0.8268	2494	0.9055	6742		
0.8661	3618	1.1811	29124		
0.9055	5888				
1.1811	26247				
C1W1 Cold					
Nominal		Upper Bound		Lower Bound	
Deflection (in)	Load (lbs)	Deflection (in)	Load (lbs)	Deflection (in)	Load (lbs)
0	0	0	0	0	0
0.812992126	1797.753	0.5512	1573	0.9055	1798
0.87007874	3146.067	0.8268	3034	0.9449	3303
0.929133858	5393.258	0.9055	5236	1.1811	22472
0.966535433	7865.169	1.1811	27618		
1.029527559	12584.27				
1.080708661	16853.93				
1.1811	25228.84				
C2W2 Cold					
Nominal		Upper Bound		Lower Bound	
Deflection (in)	Load (lbs)	Deflection (in)	Load (lbs)	Deflection (in)	Load (lbs)
0	0	0	0	0	0
0.812992126	1779.069	0.5512	1573	0.9055	1798
0.87007874	3072.351	0.8268	3034	0.9449	3303
0.929133858	5311.167	0.9055	5236	1.1811	22472
0.966535433	7780.119	1.1811	27618		
1.029527559	12497.34				
1.080708661	16736.52				
1.1811	25058.7				



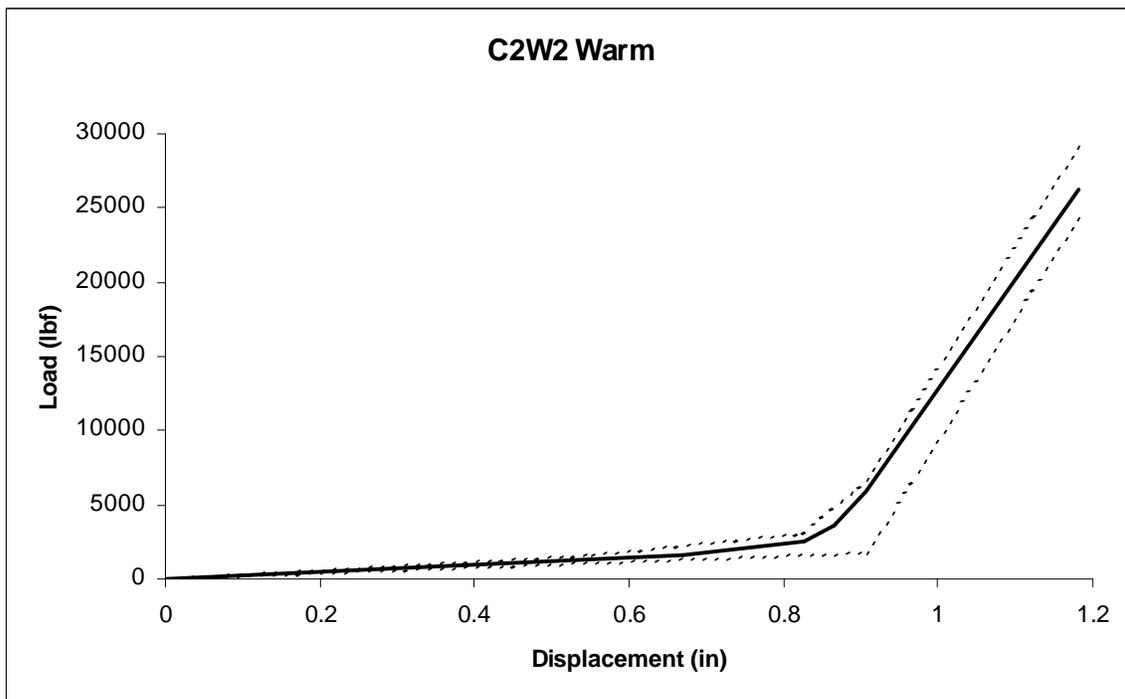
**Figure 3.1.2-1 Force Versus Deflection for C1W1 Strap - Cold**



**Figure 3.1.2-2 Force Versus Deflection for C1W1 Strap - Warm**



**Figure 3.1.2-3 Force Versus Deflection for C2W2 Strap - Cold**



**Figure 3.1.2-4 Force Versus Deflection for C2W2 Strap - Warm**

### **3.2 Assembly Procedure Between VC and ACC**

The assembly procedure of the Vacuum Case / ACC will be covered in the Integration Plan for the AMS experiment.

### **3.3 Assembly Procedure Between VC and Tracker**

The assembly procedure of the Vacuum Case / Tracker will be covered in the Integration Plan for the AMS experiment.

## **4.0 VACUUM CASE VACUUM AND PRESSURE TEST REQUIREMENTS**

### **4.1 Vacuum Test Requirements**

Both the STA and Flight Vacuum Cases will be vacuum leak checked with the temporary port covers and the temporary inner cylinder to conical flange interface seal (provided by SCL/ETH). The test will be considered successful once it shows that the VCs can hold a vacuum of  $1.0 \times 10^{-6}$  torr. The maximum leak/permeability rate shall be  $1.0 \times 10^{-7}$  std cc/sec and will be determined by using a helium leak detector attached to the vacuum space to measure a rate of helium molecules. This entire process will be listed in a Task Preparation Sheet (TPS) prepared by NASA/ESCG with input from ETH/SCL.

Once the cold mass (CMR or flight magnet) is installed inside the VC, the system will be vacuum leak checked with the final port covers and caps and the temporary inner cylinder to conical flange interface seal. If at this point there is a problem attaining an acceptable vacuum, NASA/ESCG will work with ETH/SCL to ensure that all of the NASA/ESCG seals have been installed properly. This may include checks of these seals through the test ports that have been built into the VCs. Since NASA/ESCG will have already shown that the VC can be held within an acceptable tolerance from the previous tests and will show that the large (>90 inches) o-rings are sealed utilizing the VC test ports, NASA/ESCG will assume no responsibility for an inability to achieve acceptable vacuum results after this point.

### **4.2 Proof Pressure Test Requirements**

Both the STA and Flight Vacuum Cases will be proof pressure tested as required by JSC-28792 (AMS-02 Structural Verification Plan).