Design Of Cold Support Post -for Cryomodules

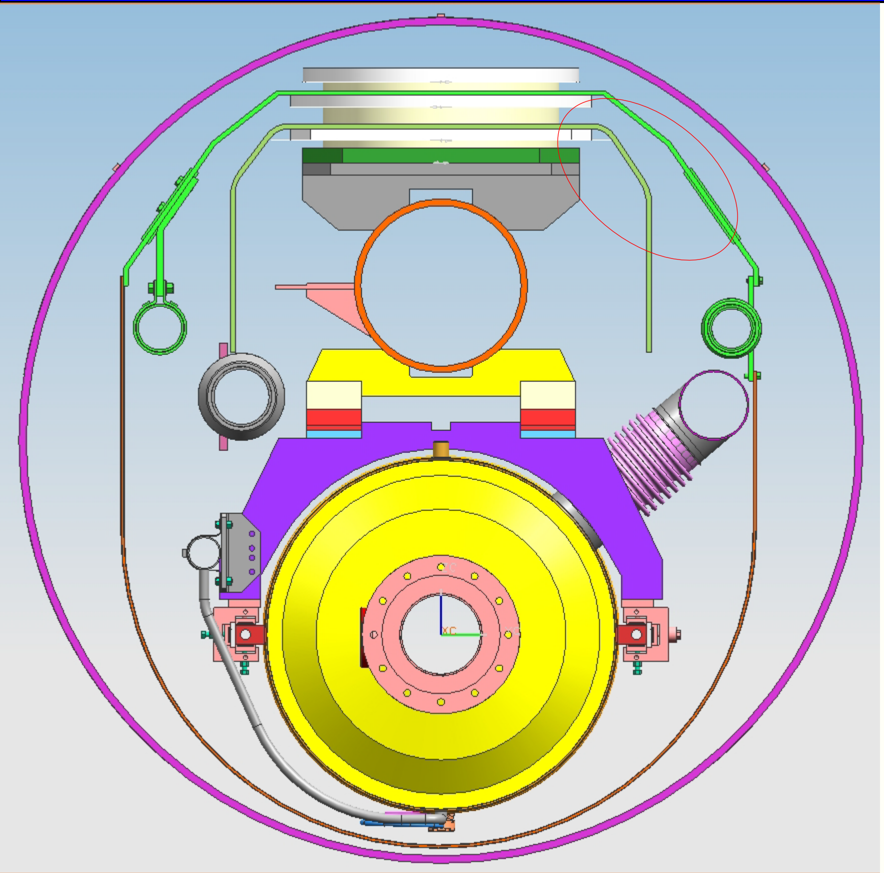
- Rupul Ghosh
- S.Gilankar
- Prashant Khare
- A Laxminarayan
- P.K.Kush

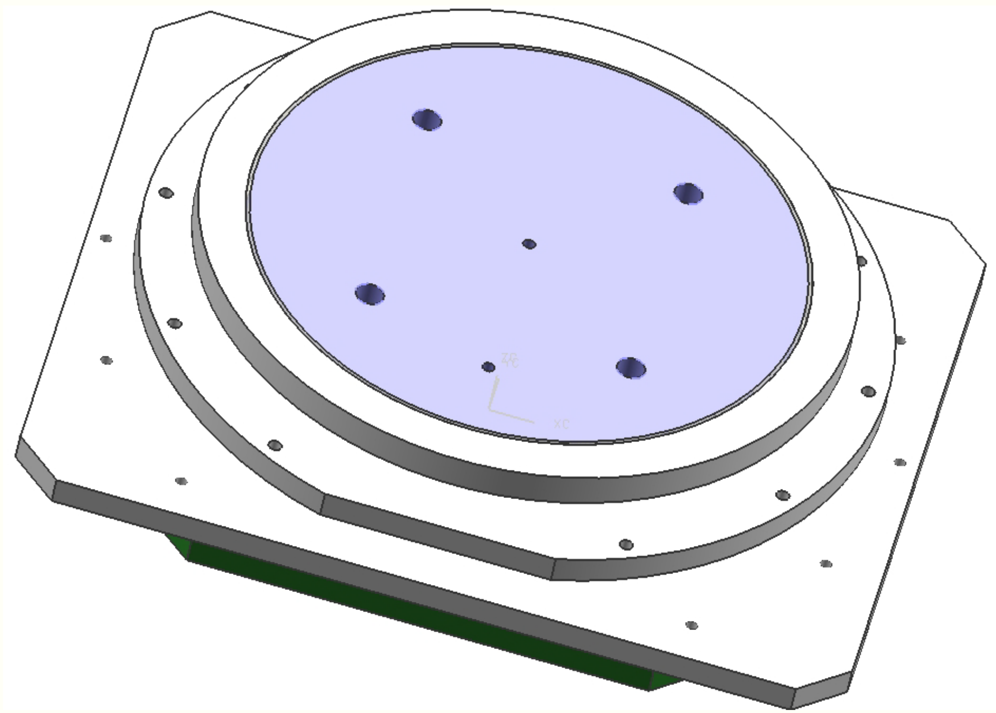
Design Note on Cryogenic support Post

1.Purpose of this design Note
   a. To get the calculations verified
   b. To get the drawings verified
   c. To seek inputs on different protoptype tests
   d. To seek advise on the tubes that we are planning to procure

2. Cryogenic Support post functions
3. Calculations made to determine the dimensions
4. Prototyping Plan
5. Querries

Drawing of the new CSP



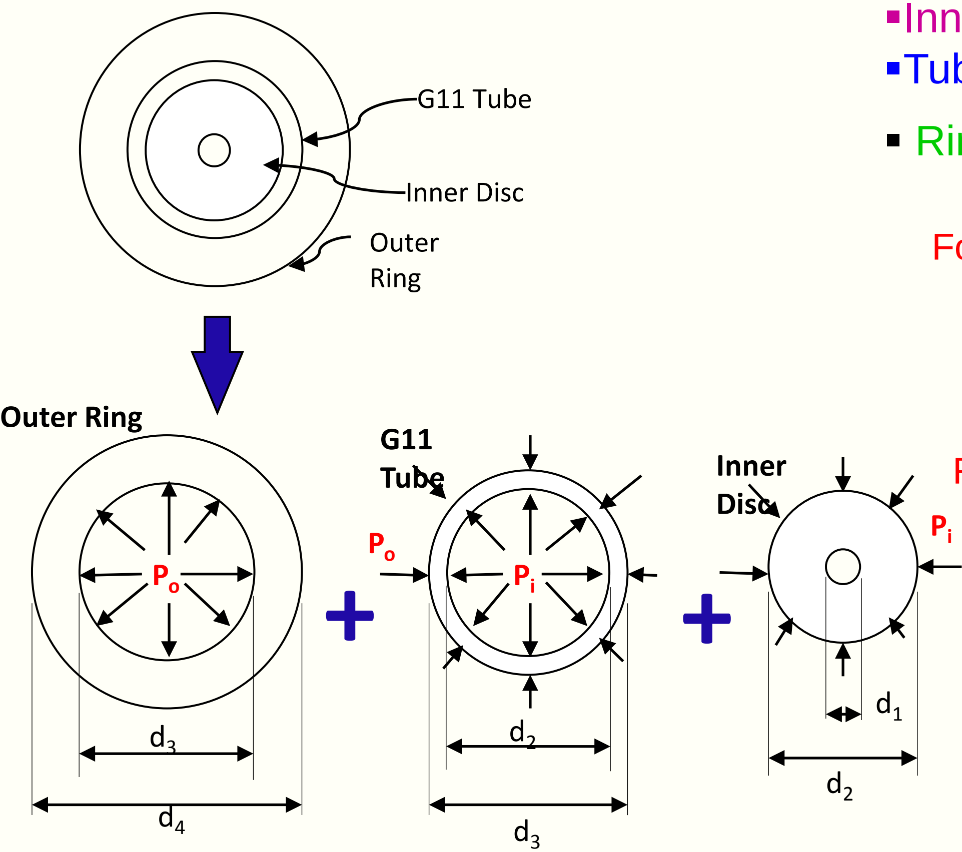


To create more space

- Support post length reduced
- Thermal shield Shape Changed

Support Post Analysis

Support Post modelled as Three Component Compound Cylinder



- Inner disc under internal pressure
- Tube under both internal and external pressure
- Ring under internal pressure

For Inner Interface, Final Disc OD = Final G11 ID

Eqn (1) $\text{Decrease in Disc OD} + \text{Increase in G11 ID} = \text{Interference bwn Disc \& G11}$

For Outer Interface, final G11 OD = Final Ring ID

Eqn (2) $\text{Increase in G11 OD} - \text{Clearance bwn G11 \& Ring} = \text{Increase in Ring ID}$

Two Eqns are Solved for Contact Pressures P_i, P_o

Contact Pressures Develop due to Elastic Resistance of materials and Interference

Disc and Ring Can Support Load due to Contact Pressure and Friction at the Interfaces

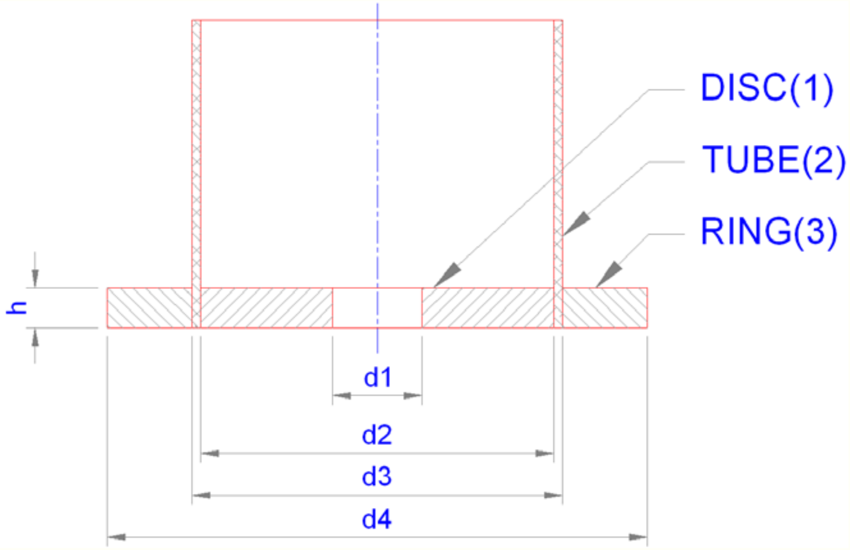
Load Bearing Capacity

$$F_i = f\pi d_2 h P_i$$
$$F_o = f\pi d_3 h P_o$$

F_i Max Axial Load Carried by Inner Joint
F_o Max Axial Load Carried by Outer Joint

P_i Contact Pressure at Inner Joint
P_o Contact Pressure at Outer Joint

'f' -- Coefficient of Friction between G11 Tube and Disc/Ring



$$P_i = \frac{P_o(K_4 + K_5) + \delta_o}{K_6}$$

$$P_o = \frac{\delta_i K_6 - \delta_o(K_1 + K_2)}{(K_4 + K_5)(K_1 + K_2) - K_6 K_3}$$

$$K_1 = \frac{d_2}{E_1}\left[\frac{d_2^2 + d_1^2}{d_2^2 - d_1^2} - \mu_1\right] \quad K_2 = \frac{d_2}{E_2}\left[\frac{d_3^2 + d_2^2}{d_3^2 - d_2^1} + \mu_2\right] \quad K_3 = \frac{d_2}{E_2}\left[\frac{2\, d_3^2}{d_3^2 - d_2^2}\right]$$

$$K_4 = \frac{d_3}{E_2}\left[\frac{d_3^2 + d_2^2}{d_3^2 - d_2^2} - \mu_2\right] \quad K_5 = \frac{d_3}{E_3}\left[\frac{d_4^2 + d_3^2}{d_4^2 - d_3^2} + \mu_3\right] \quad K_6 = \frac{d_3}{E_2}\left[\frac{2\, d_2^2}{d_3^2 - d_2^2}\right]$$

'E' -- Young's Modulus
'μ' -- Poisson's Ratio of Materials

δ_i Diametral Interference between Tube and Inner Disc
δ_o Diametral Clearance between Tube and Outer Ring

Load bearing Capacity of Prototype

Poisson's Ratio Al 6061T6c Disc	μ_1 =	0.33
Poisson's Ratio G11 Tube	μ_2 =	0.2
Poisson's Ratio Al 6061T6c Ring	μ_3 =	0.33

Young's Modulus Al 6061T6 Disc,	E_1 =	70Gpa
Young's Modulus G11 Tube,	E_2 =	28Gpa
Young's Modulus Al 6061T6 Ring,	E_3 =	70Gpa

ID of Al Disc, d_1 =	10mm
ID of G11Tube, d_2 =	57.02mm
OD of G11Tube, d_3 =	63.02mm
OD of Al Disc, d_4 =	92mm
Thickness of Disc/Ring, h	15mm

Diametral Interference b/w Disc and Tube, δ_i	0.12 mm
Diametral Clearance b/w Disc and Tube, δ_o	0.02 mm

Friction Coeff b/w Al 6061T6 Disc/Ring and G11 Tube 0.3

Max Axial Load taken by Inner Joint F_i = 2700 Kg

Max Axial Load taken by Outer Joint F_o = 2361 Kg

Contact pressure at Inner Joint P_i = 32.8 MPa

Contact Pressure at Outer Joint P_o = 26 MPa

Stresses Developed due to Shrink Fitting

Radial and Circumferential Stresses Developed at ID & OD of Disc, Tube and Ring material

Inner Disc Al 6061T6

Stresses at Disc ID		*Stresses at Disc OD*	
Radial	0MPa	Radial	-32.8MPa
Circumferential	-67.7MPa	Circumferential	-35MPa

Tube G11

Stresses at G11 ID		*Stresses at G11 OD*	
Radial	-32.8MPa	Radial	-26MPa
Circumferential	42.7MPa	Circumferential	36MPa

Outer Ring Al 6061T6

Stresses at Ring ID		*Stresses at Ring OD*	
Radial	-26MPa	Radial	0MPa
Circumferential	70MPa	Circumferential	46MPa

Allowable Stress G11	62Mpa
Allowable Stress Al6061 T6	70MPa
Allowable Stress SS304	130Mpa

Check Feasibility for Cryogenic Shrink Fitting

- Inner Disc to be Cooled with LN_2
- Calculate OD of Disc after Cooling
- Find Effective Diametral Clearance available for making the Assembly

Effective Diametral Clearance for Assembly = ID of G11 Tube – OD of Disc after Cooling

- If Effective Diametral Clearance Is Not Enough
  Reduce the Interference between Tube and Disc

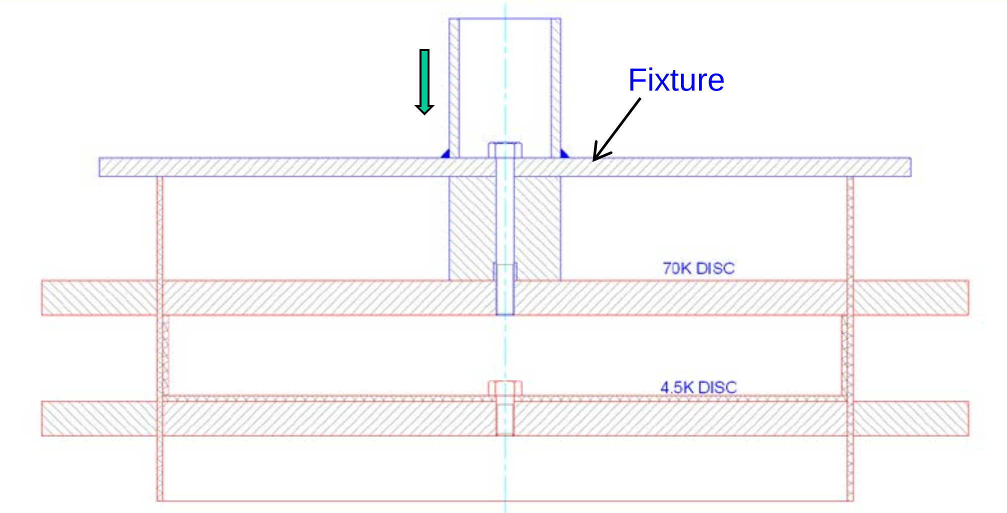
ID G11 Measured	Diametral Interference	OD Al Disc before Shrink Measured	Al shrinkage upto 80 K	OD Al Disc after Shrink Calculated	Effective Diametral Clearance for Assembly
57.02mm	0.12 mm	57.14 mm	0.21 mm	56.93 mm	0.09 mm

Specs of Tube for Purchase

Tube Material --G11 (NEMA LI 1)
OD 300 mm, Thickness 2.5 mm

Property	Value	Test Method
Flexural Strength	350 MPa	ISO 178
Compressive Stress Axial	250 MPa	ISO 604
Density	1.8 g/cm3	IEC 1183-A
Water Absorption	0.3 mg/cm3	IEC 62-1

Sketch of Fixture under Development

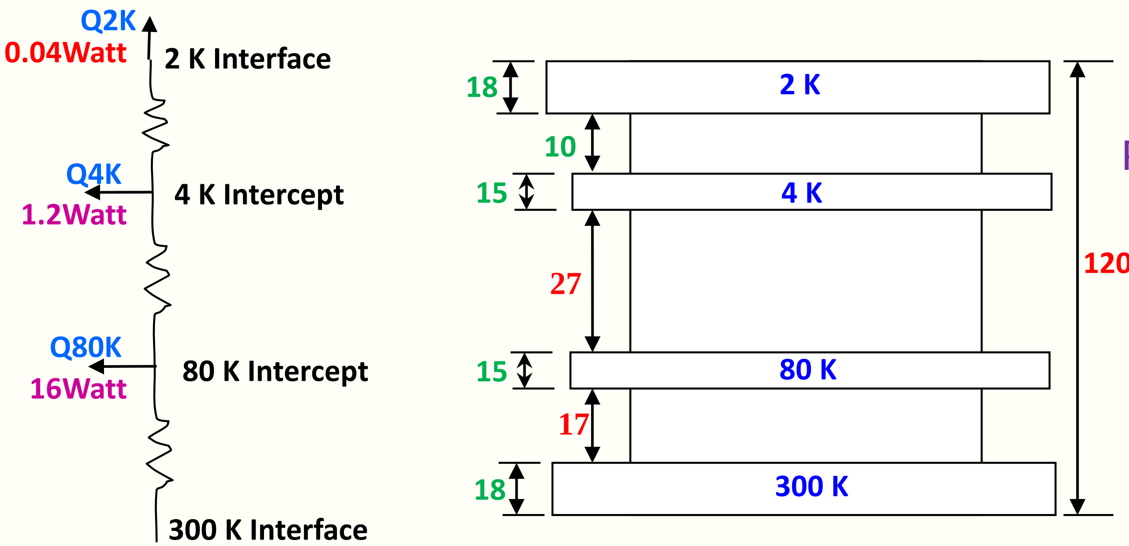


Initially 4.5 K Disc /Ring Assembled

Next, 70 K Disc/Ring Assembled with the Fixture Shown

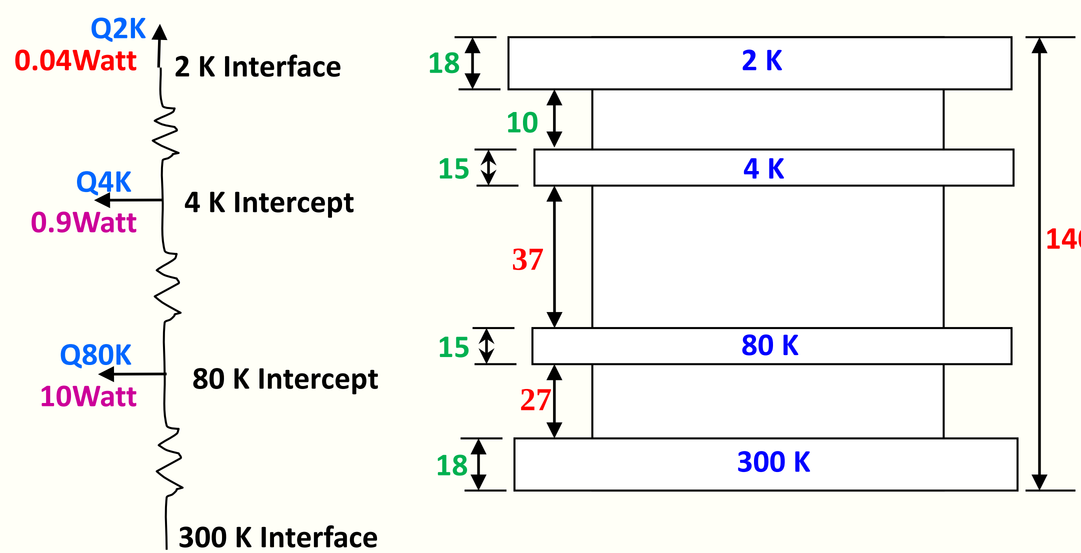
300 K and 1.8 K Disc/Ring Assembled at the End

Heat In-Leak through Support Post Compared with earlier situation

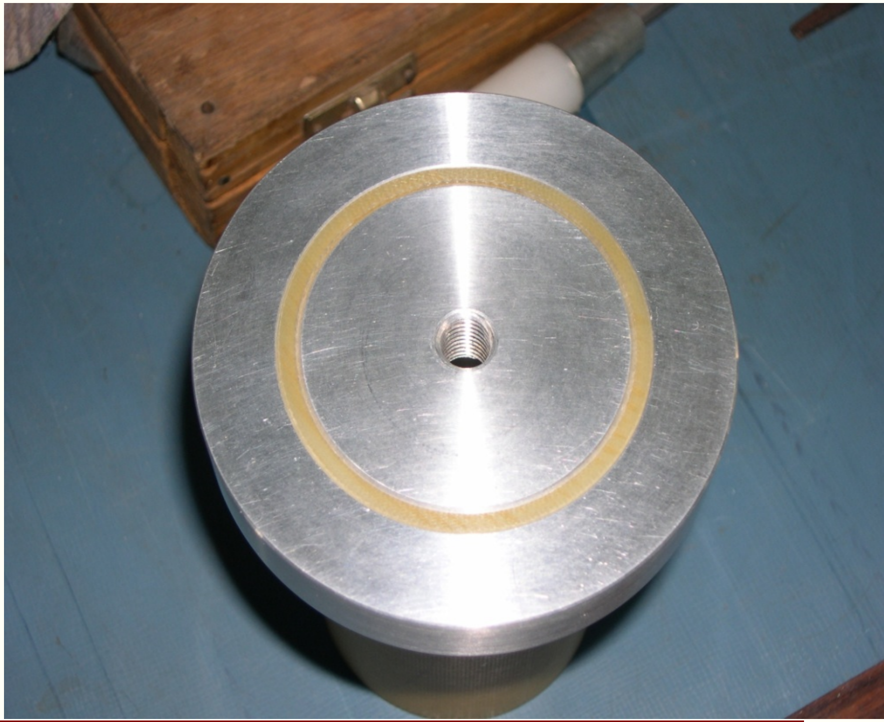


Present Configuration

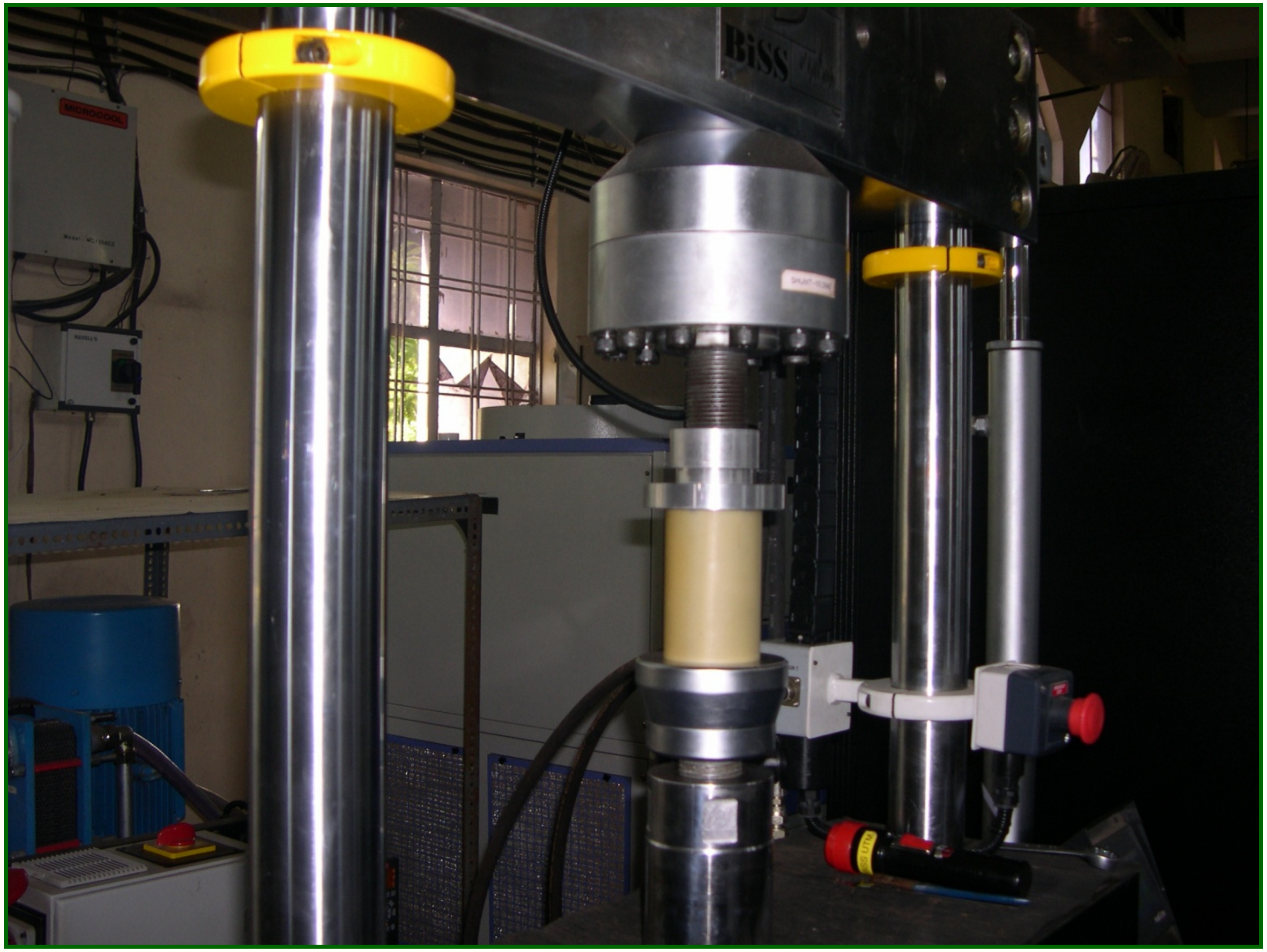
OD of G11 Tube 300 mm
Tube Thickness 2.5 mm



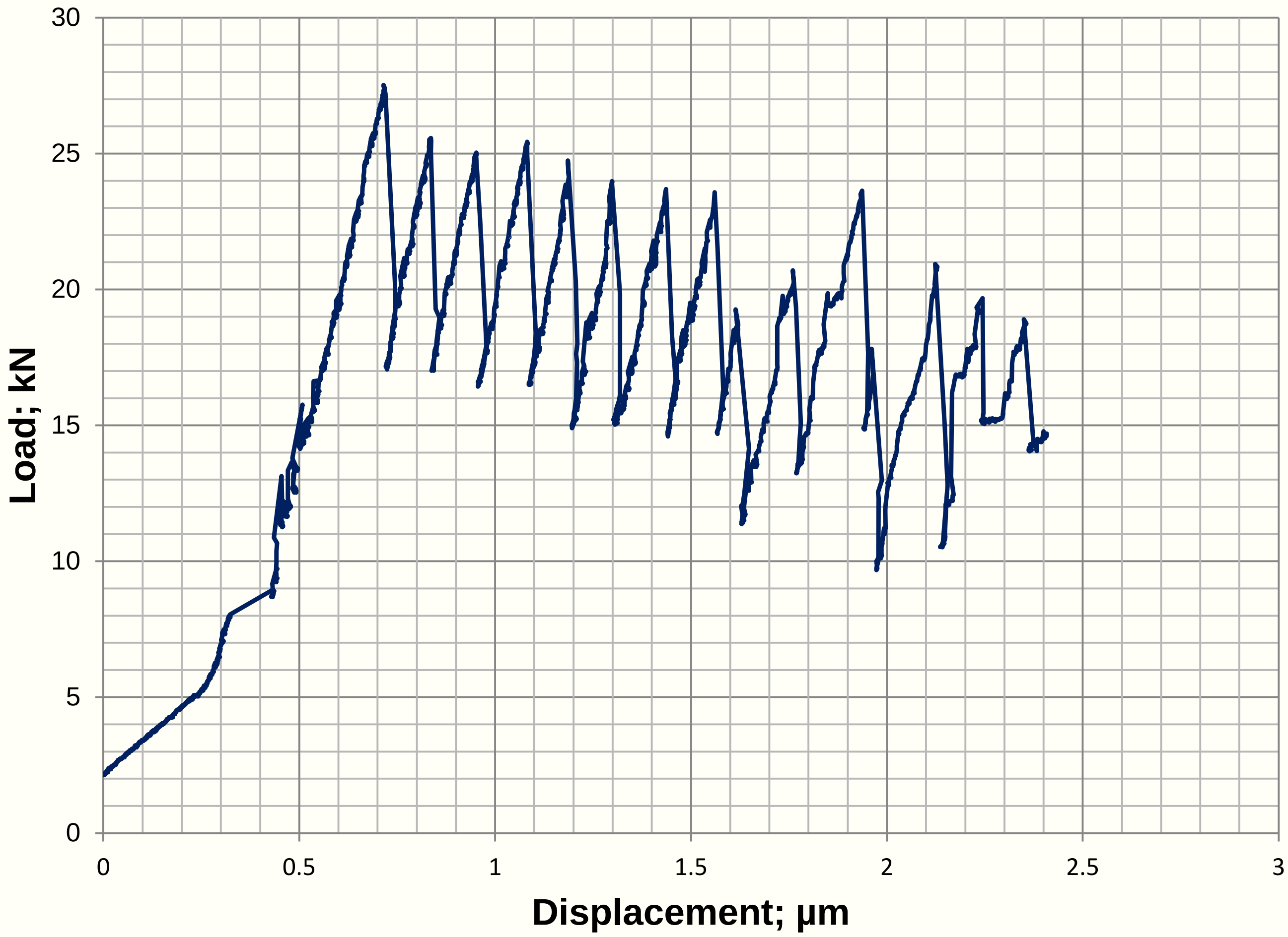
Prototype Fabrication



Prototype Testing



Prototype Test Result



Load Testing of Inner Joint

Querry

- **4K shield : In CW cryomodule,Is MLI Required if so then how will it be assembled**
- **Reason for Undulation in the Load v/s Displacement Plot.**