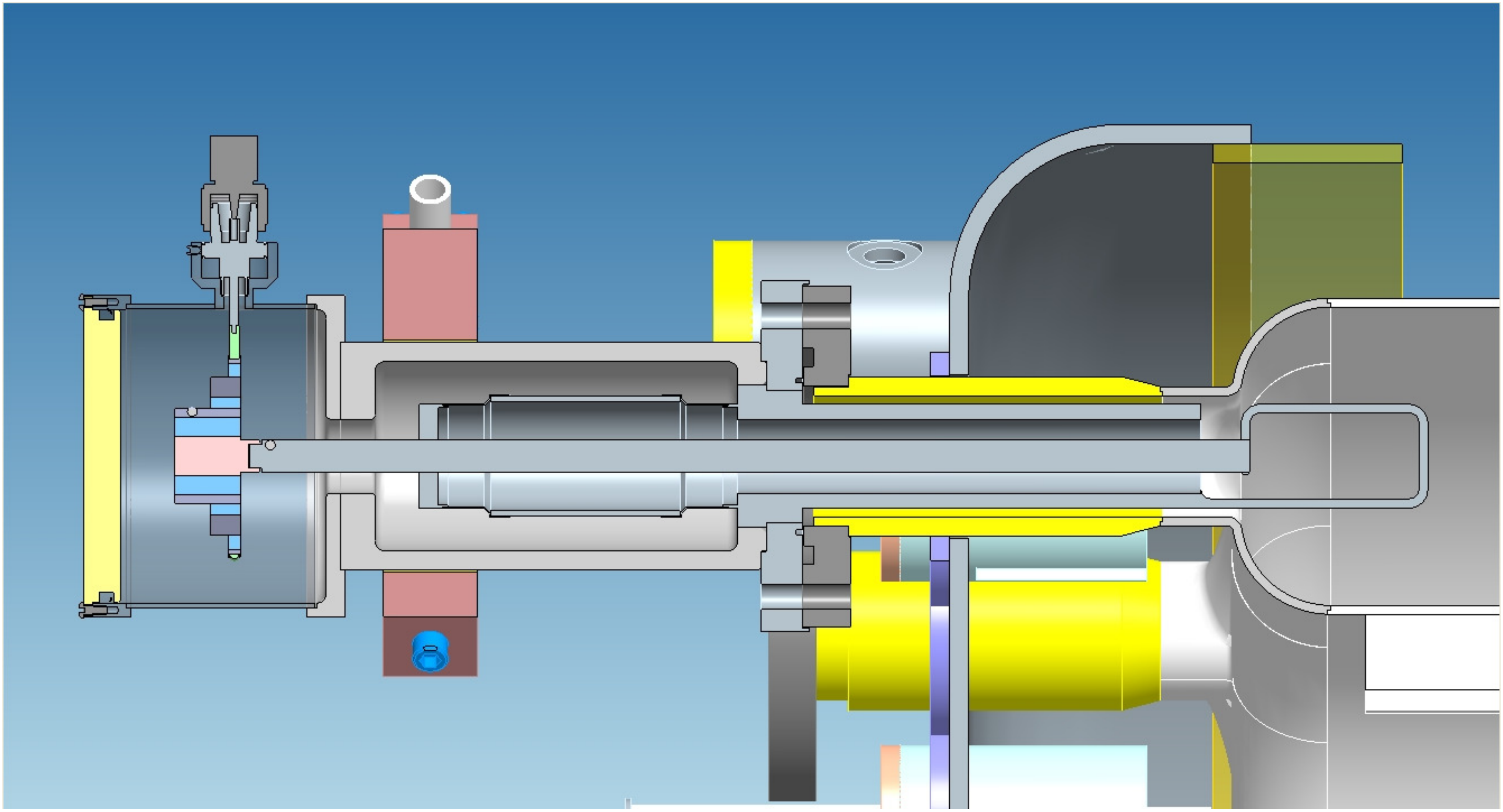
RHIC 56 MHz

HOM Damper
Fundamental Power Coupler
Fundamental Damper
Pick-ups

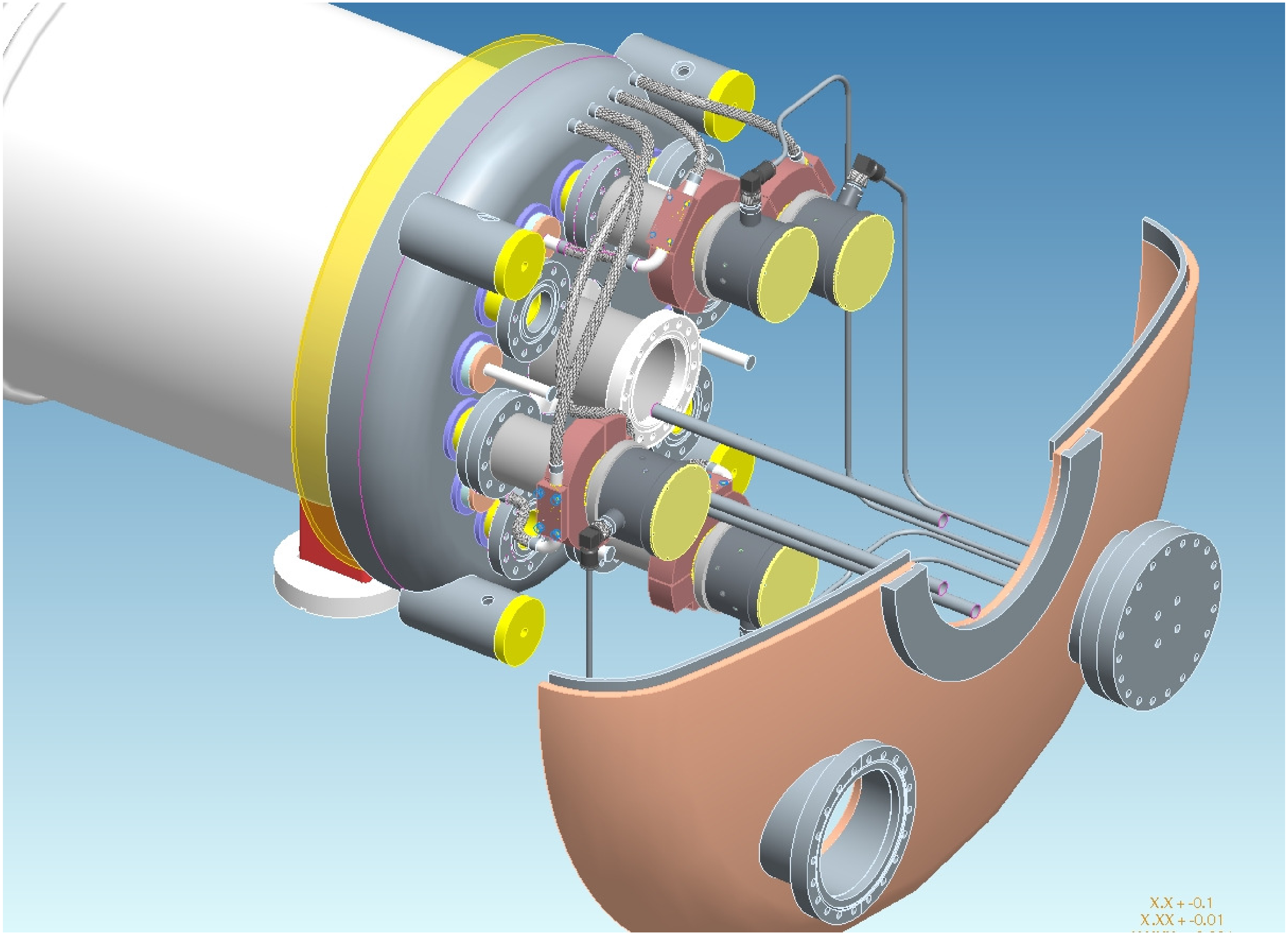
S. Bellavia

March 8th, 2011

Higher Order Mode (HOM) Damper

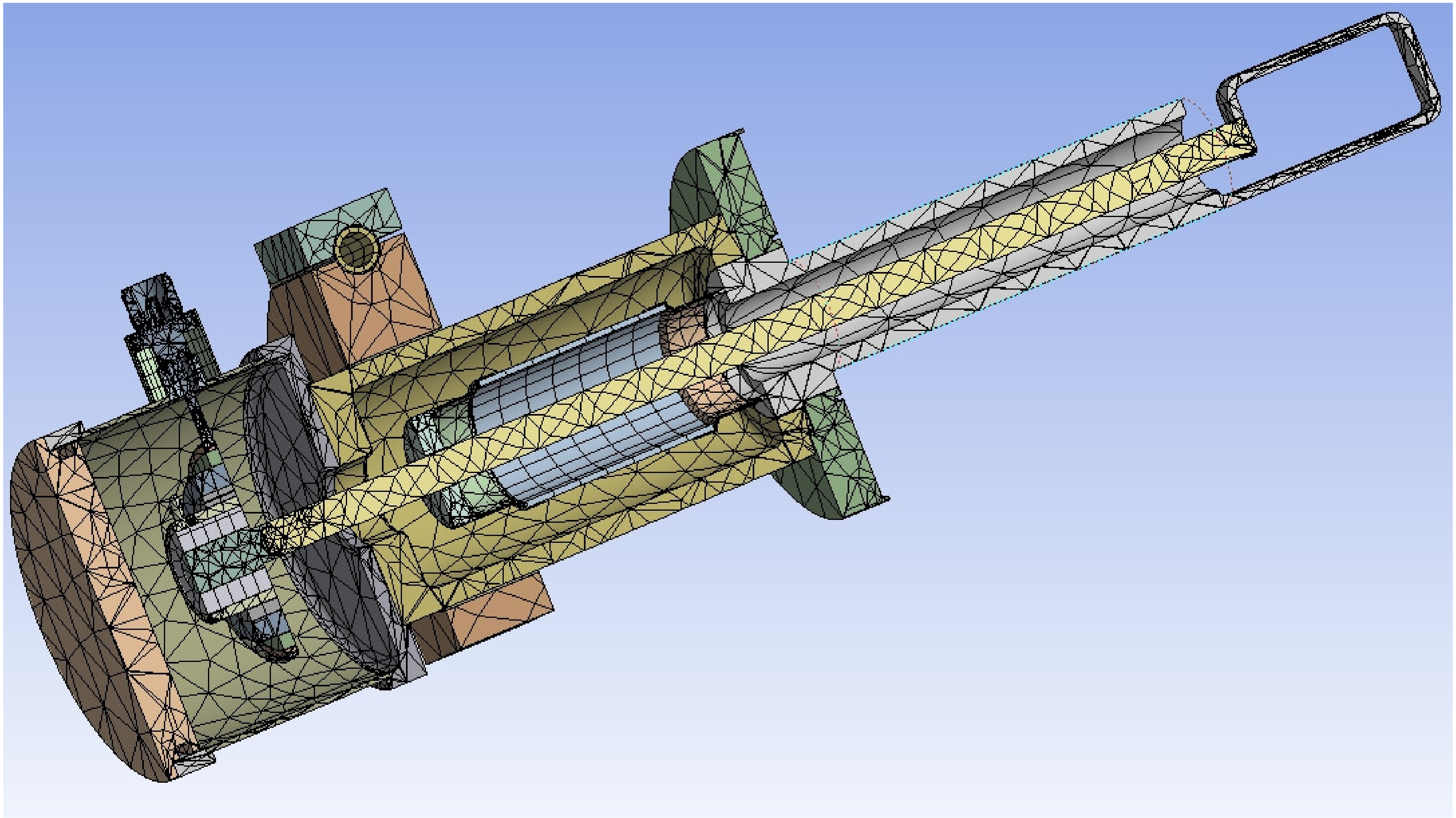


Higher Order Mode (HOM) Damper



HOM Thermal-Electric Performance

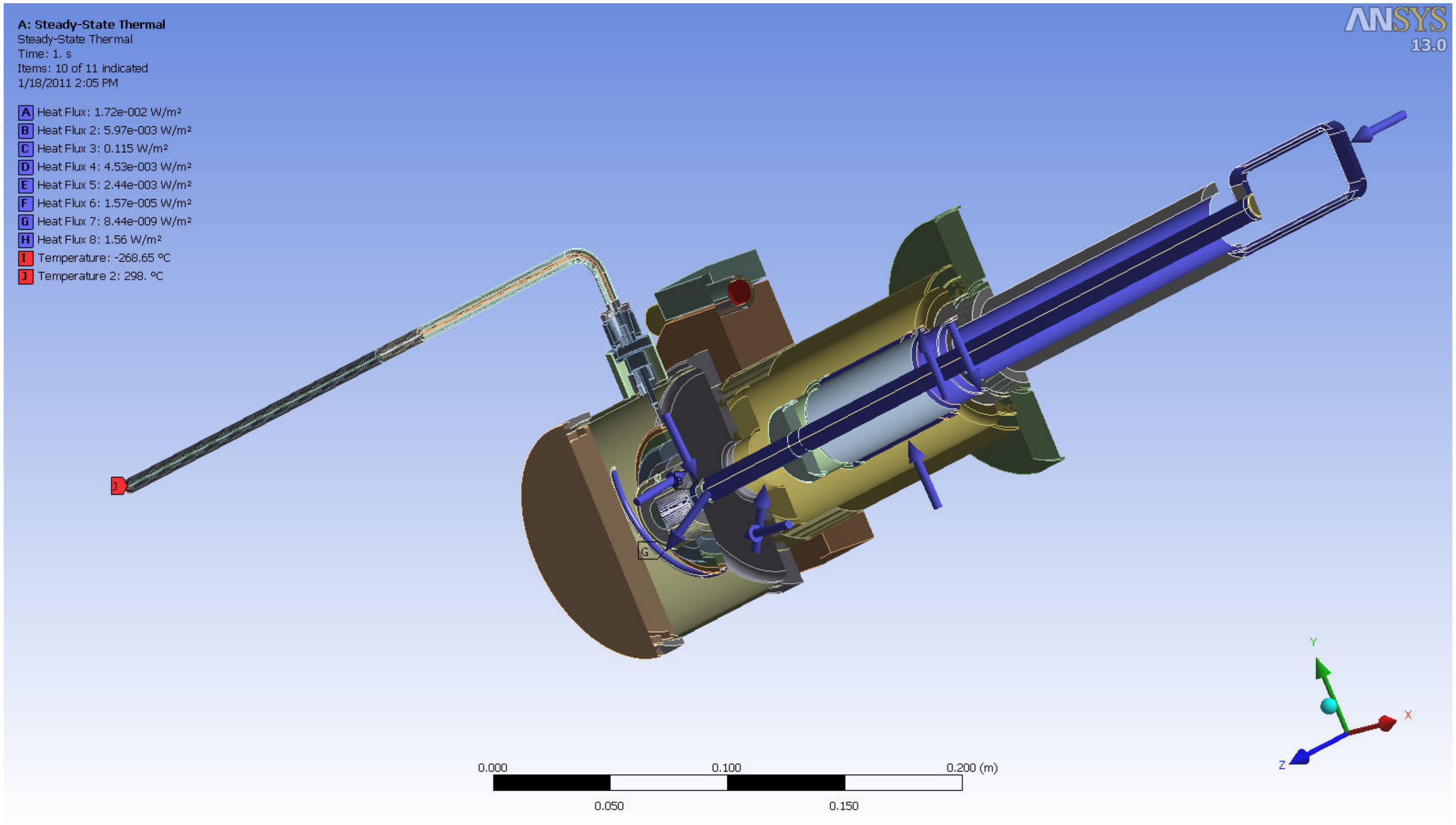
Solid Model Assembly in Pro-E, Finite Element Model built in ANSYS 13.0



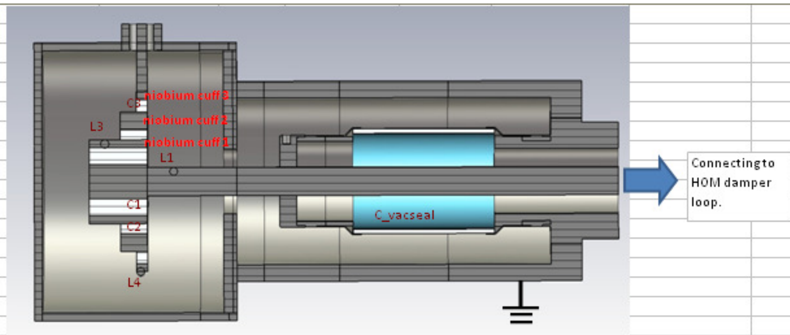
HOM Thermal-Electric Performance (cont.)

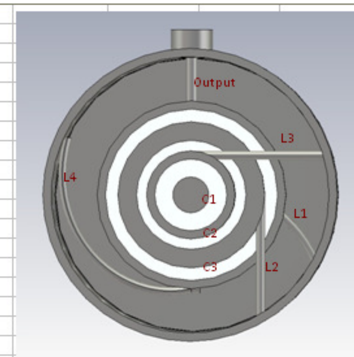
Boundary Conditions:

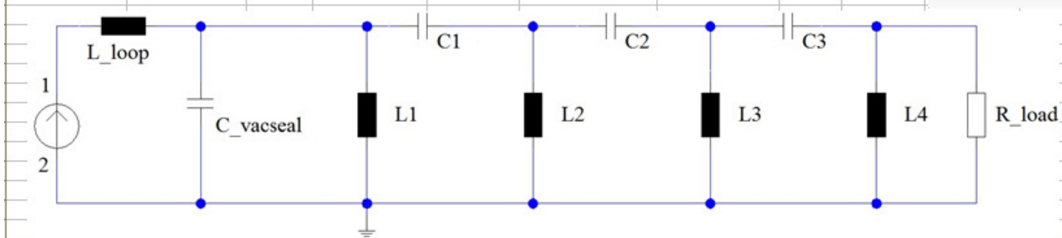
- Surface RF Currents
- Dielectric (Joule) Heating of Sapphire
- Heat Leak from Ambient



HOM Thermal-Electric Performance (cont.)







Note:

1. The currents from different modes are out of phase. Therefore, the summation should be over the power, not the current. The first 5 modes from the cavity are listed here for their contribution to the total power is up to 97.5%.

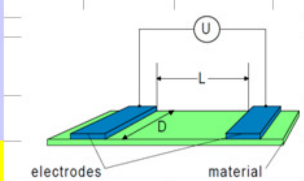
2. The current value given by MWS simulation corresponds to the AC voltage source with 1V amplitude showing in the right most picture. The real current is scaled with the square root of power ratio to the resistor load (same current as output conductor).

   example: I_real = sqrt(P_tot[A32]/(I_MWSouterconductor[I35]^2*50Ohm))*I_MWS[column I]

3. The current flow through conductors and inductors are all on the surface, through the sapphire tubes are all through the bulk. Surface resistivity of niobium and RF impedance of sapphire for EACH corresponding frequency should be used to calculate the power. Heat dessipated on the niobium cuffs should be neglegible.

4. Surface resistivity is defined as: Rho = (U/L)/(I/D), parameters are as shown on the right. http://www.trekinc.com/pdf/1005_Resistivity_Resistance.pdf

5. yellow backround cells are approximate value.



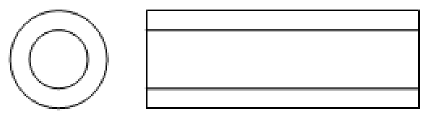
frequency [MHz]	components	ID [m]	OD [m]	tot length [m]	cross section area [m^2]	surface area [m^2]	material	current from MWS sim [A]	real current [A]	surface resistivity [Ohm]	Total resistance [Ohm]	power [W]	tot power [W]	W/mm²
56.231	inner conductor	0	0.0108	0.3	9.16088E-05	0.01017876	niobium	0.0186	26.22306025	1.00E-08	8.84E-08	6.0802E-05		5.973E-09
	outer conductor	0.0124	0.0174	0.16	0.000117024	0.00623292	niobium	0.0186	26.22306025	1.00E-08	4.11E-08	2.8243E-05		4.531E-09
total coupled	damper loop	0	a=0.02, b=0.003	0.1835	0.00006	0.00367	niobium	0.0186	26.22306025	1.00E-08	9.18E-08	6.3092E-05		1.719E-08
power	Inductor 1	0	0.003175	0.051	7.9173E-06	0.000508702	niobium	0.024	33.83620677	1.00E-08	5.11E-08	5.8538E-05		1.151E-07
contribution from	Inductor 2	0	0.003175	0.04	7.9173E-06	0.000398982	niobium	0.0035	4.934446821	1.00E-08	4.01E-08	9.7643E-07		2.447E-09
this frequency [W]:	Inductor 3	0	0.003175	0.032	7.9173E-06	0.000319186	niobium	0.00028	0.394755746	1.00E-08	3.21E-08	4.9993E-09		1.566E-11
0.000322	Inductor 4	0	0.003175	0.079	7.9173E-06	0.00078799	niobium	6.50E-06	0.009163973	1.00E-08	7.92E-08	6.6512E-12		8.441E-15
	niobium cuff 1	0.026	0.032	0.021	0.000273319	0.00211115	niobium	0.0035	4.934446821	1.00E-08	2.11E-11	5.1404E-10		2.435E-13
	niobium cuff 2	0.0396	0.0532	0.0102	0.000991235	0.001704754	niobium	0.00028	0.394755746	1.00E-08	1.70E-11	2.6566E-12		1.558E-15
	niobium cuff 3	0.0624	0.0684	0.0041	0.00061638	0.000881028	niobium	6.50E-06	0.009163973	1.00E-08	8.81E-12	7.3987E-16		8.398E-19
	sapphire vac seal	3.6322	4	5.3848	2.204709374	67.66739248	sapphire	2.65E-03	3.736081165	1.00E-08	6.77E-07	9.4452E-06		1.396E-13
	sapphire tube 1	0.013	0.026	0.021	0.000398197	0.00171531	sapphire	0.00323	4.553789495	1.00E-08	1.72E-11	3.557E-10		2.074E-13
	sapphire tube 2	0.032	0.0396	0.0102	0.000427382	0.001268952	sapphire	0.00028	0.394755746	1.00E-08	1.27E-11	1.9774E-12		1.558E-15
	sapphire tube 3	0.0532	0.0624	0.0041	0.000835287	0.000803745	sapphire	6.80E-06	0.009586925	1.00E-08	8.04E-12	7.3872E-16		9.191E-19
	output conductor	0	0.04	0.023	0.001256637	0.002890265	niobium	1.80E-06	0.002537716	1.00E-08	2.89E-11	1.8613E-16	0.000221102	6.44E-20

Dielectric Heating of HOM Sapphire Break

Solving for capacitance.

$$C = \frac{\varepsilon A}{s}$$

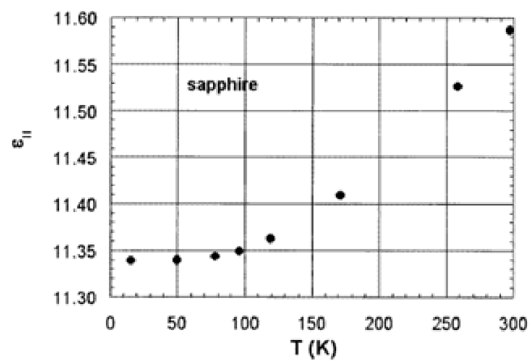
Note:
free space permittivity = ε_0 = 8.85 pF/m



$$A = \frac{\pi\left(D_o^2 - D_i^2\right)}{4}$$

For Sapphire break, D_o = 40mm (.0400m), D_i = 36.3mm (.0363m), length, S = 50mm (.05m)

$$A = \frac{\pi\left((.0400)^2 - (.0363)^2\right)}{4} = 2.217x10^{-4}m^2$$



For Sapphire break, Dielectric Strength (relative permittivity) ≈ 11.34,

$$C = \frac{(11.34)(8.85\times10^{-12})(2.217\times10^{-4})}{(.05)}$$

C = 4.45 x 10^{-13} farads, or .445 pF

Dielectric Heating of Sapphire Break (cont.)

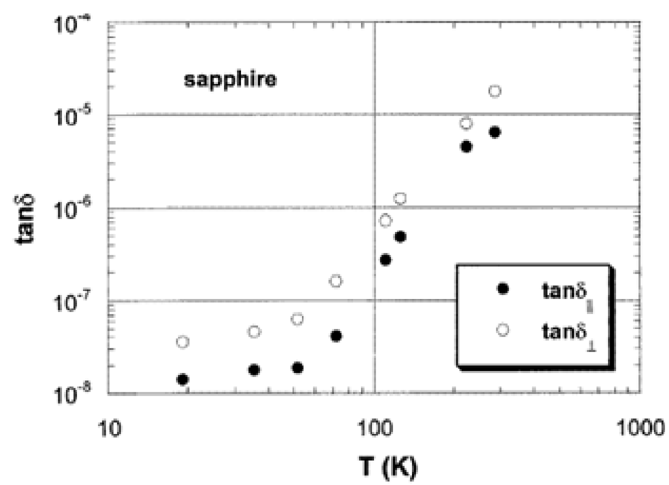
$$U = \frac{CV^2}{2}$$ stored energy

Assuming 40KV @ 56MHz:

$$U = \frac{(4.45\times10^{-13})(40\times10^{3})^2}{2}$$

U = 3.56 x 10^{-4} Joules

Power, P = ωU tan(δ)



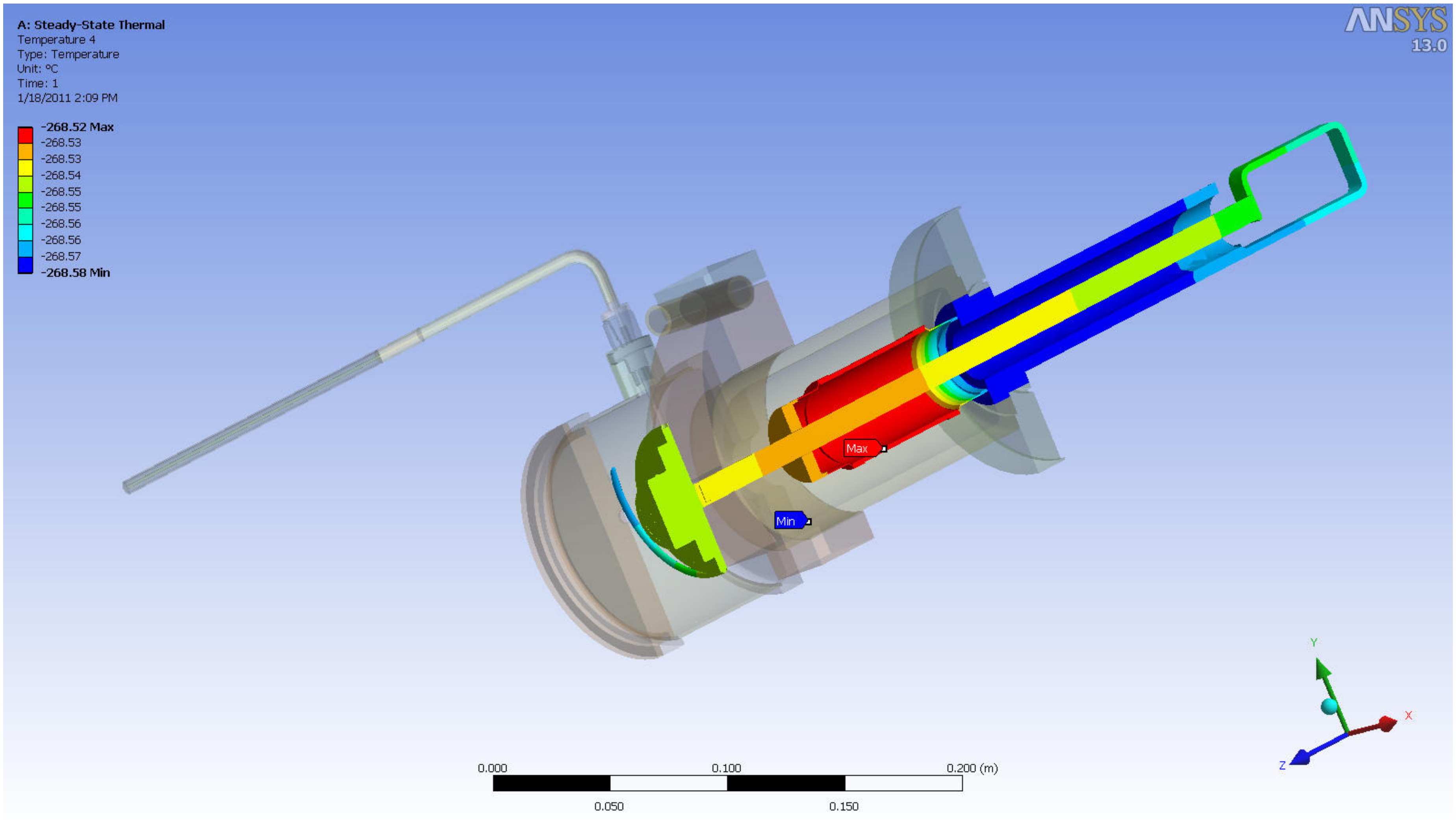
Let Loss tangent ≈ 1x10^{-7}

$$P = (2\pi)(56\times10^{6})(3.56\times10^{-4})(1\times10^{-7})$$

P = .0125 Joules/sec = .0125 Watts

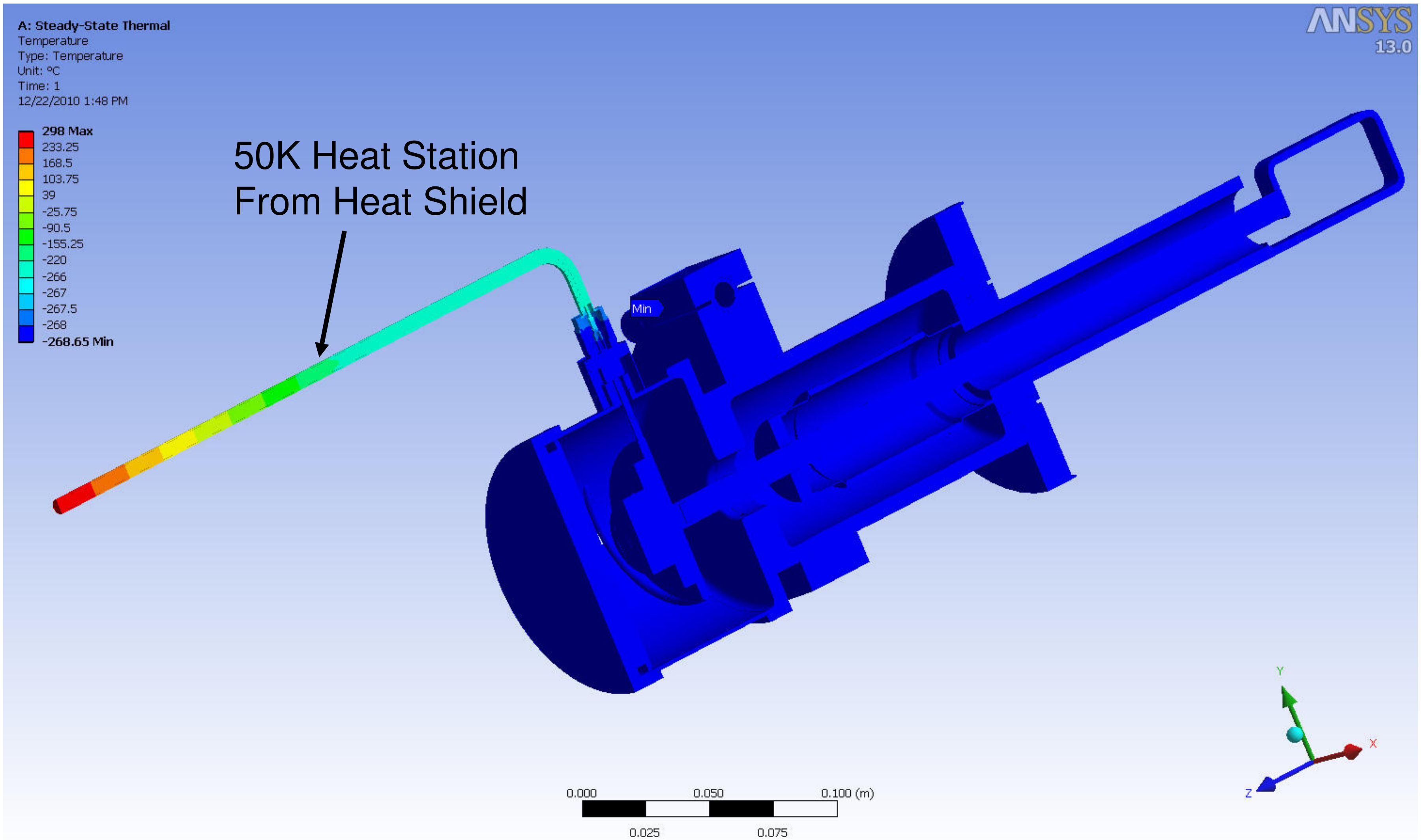
HOM Thermal Performance (cont.)

Internal Components



HOM Thermal Performance (cont.)

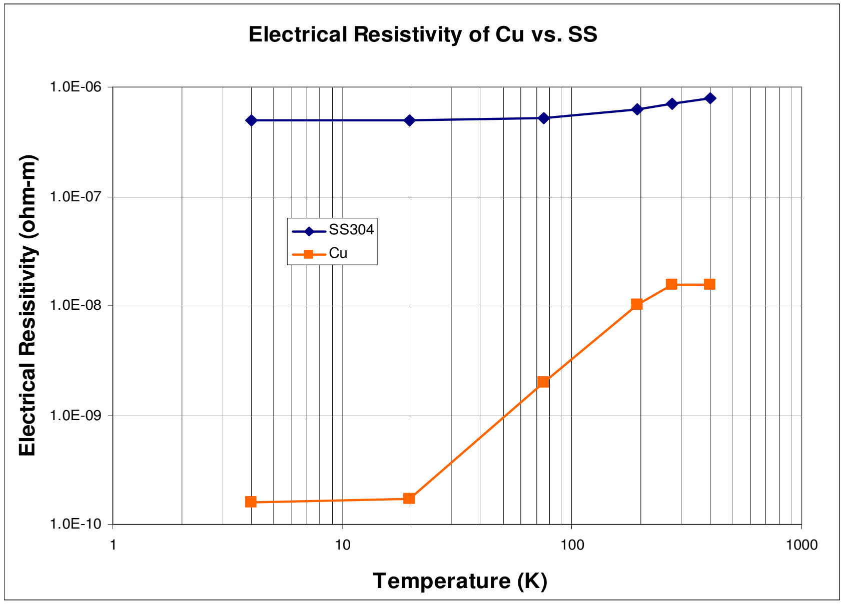
Assembly with Heat-Stationed Cable

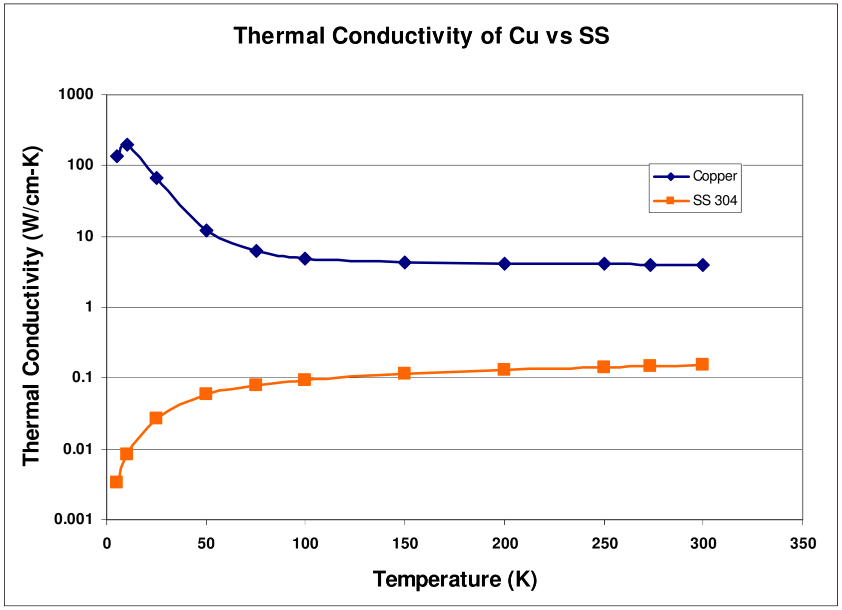


HOM Cable

Joule Heating vs. Thermal Conductivity

OFHC Copper vs. 304 Stainless Steel





Cable Joule Heating Due to RF Current

Skin depth:

$$\delta = \sqrt{\frac{2\rho}{\omega\mu}}$$

$$\omega = 2\pi f$$

$\mu_r = \frac{\mu}{\mu_0}$ **so that,** $\mu = \mu_r \mu_0$

$$\delta = \sqrt{\frac{1}{\pi\mu_0}}\sqrt{\frac{\rho}{\mu_r f}}$$

$\mu_0 = 4\pi \times 10^{-7}$ **N/amps^2 or Henries/meter or ohm-sec/m**

Finally,

$$\delta = 503.292121\sqrt{\frac{\rho}{\mu_r f}}$$

δ = skin depth (m)
ρ = resistivity (Ohm-m)
μ_r = relative permeability (-)
f = frequency (Hz)

AC Electrical Resistance:

$$R_{ac} = \frac{\rho L}{A_c}$$

R_{ac} = Resistance (ohms)
L = Length (m)
A_c = Effective cross-sectional area of conductor due to skin depth

For the outside of a cylindrical conductor:

$$A_c = \pi\left[r_o^2 - (r_o - \delta)^2\right]$$

For the inside of a cylindrical conductor:

$$A_c = \pi\left[(r_i + \delta)^2 - r_i^2\right]$$

Heat = I^2R_{ac}

And Heat Flux,

$$HF = \frac{I^2 R_{ac}}{A_s}$$

HF = Heat Flux (W/m^2)
I = current (amps)
As = surface area (m^2)

Note, for significant temperature differences: ρ = ρ(T)

So that the Heat Flux due to skin-effect (Joule) Heating:

For the outside of a cylindrical conductor:

$$HF = \frac{I^2\rho(T)L}{2\pi^2 r_o L\left[r_o^2 - \left(r_o - 503.29\sqrt{\frac{\rho(T)}{\mu_r f}}\right)^2\right]}$$

For the inside of a cylindrical conductor:

$$HF = \frac{I^2\rho(T)L}{2\pi^2 r_o L\left[\left(r_i + 503.29\sqrt{\frac{\rho(T)}{\mu_r f}}\right)^2 - r_i^2\right]}$$

Note, the Length drops out and the final formulation is:

For the outside of a cylindrical conductor:

$$HF = \frac{(I^2/2\pi^2 r_o)\rho(T)}{\left[r_o^2 - \left(r_o - 503.29\sqrt{\frac{\rho(T)}{\mu_r f}}\right)^2\right]}$$

For the inside of a cylindrical conductor:

$$HF = \frac{(I^2/2\pi^2 r_i)\rho(T)}{\left[\left(r_i + 503.29\sqrt{\frac{\rho(T)}{\mu_r f}}\right)^2 - r_i^2\right]}$$

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MECHANICAL CHARACTERISTICS

Outer Conductor Diameter, inch (mm)	0.250+/-0.002 (6.35+/-0.0508)
Dielectric Diameter, inch (mm)	0.209 (5.309)
Center Conductor Diameter, inch (mm)	0.0641+/-0.001 (1.628+/-0.0254)
Maximum Length, feet (meters)	20 (6.1)
Minimum Inside Bend Radius, inch (mm)	0.5 (12.7)
Weight, pounds/100 ft. (kg/100 meters)	9.14 (13.6)

ELECTRICAL CHARACTERISTICS

Impedance, ohms	50+/-0.5
Frequency Range GHz	DC-19
Velocity of Propagation %	70
Capacitance, pF/ft. (pF/meter)	29 (95.1)

Typical Insertion Loss, dB/ft. (dB/meter) and Average Power Handling, Watts CW at 20 degrees Celsius and Sea level

Frequency	Insertion Loss	Power
0.5 GHz	0.29 (0.93)	285.2
1.0 GHz	0.42 (1.33)	200.8
5.0 GHz	0.96 (3.04)	88.2
10.0 GHz	1.32 (4.38)	61.5
20.0 GHz	0.00 (0.00)	0

Corona Extinction Voltage, VRMS @ 60 Hz	3000
Voltage Withstand, VRMS @ 60 Hz	7000

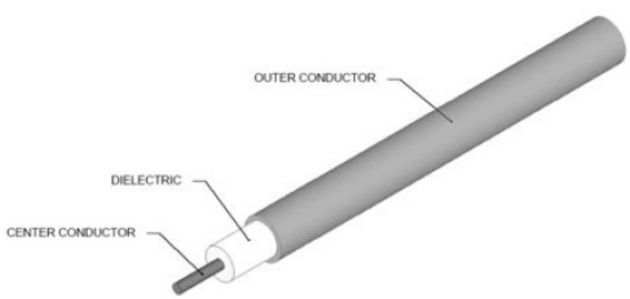
ENVIRONMENTAL CHARACTERISTICS

Outer Conductor Integrity Temperature, Deg Celsius	250
Maximum Operating Temperature, Deg Celsius	230

MATERIALS

Outer Conductor	304 Stainless Steel
Dielectric	PTFE
Center Conductor	304 Stainless Steel

CUTAWAY



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MECHANICAL CHARACTERISTICS

Outer Conductor Diameter, inch (mm)	0.0865+/-0.001 (2.197+/-0.0254)
Dielectric Diameter, inch (mm)	0.066 (1.676)
Center Conductor Diameter, inch (mm)	0.0201+/-0.0005 (0.511+/-0.0127)
Maximum Length, feet (meters)	20 (6.1)
Minimum Inside Bend Radius, inch (mm)	0.125 (3.175)
Weight, pounds/100 ft. (kg/100 meters)	1.25 (1.86)

ELECTRICAL CHARACTERISTICS

Impedance, ohms	50+/-1.0
Frequency Range GHz	DC-61
Velocity of Propagation %	70
Capacitance, pF/ft. (pF/meter)	29 (95.1)

Typical Insertion Loss, dB/ft. (dB/meter) and Average Power Handling, Watts CW at 20 degrees Celsius and Sea level

Frequency	Insertion Loss	Power
0.5 GHz	0.31 (1.02)	143.1
1.0 GHz	0.44 (1.46)	100.8
5.0 GHz	1.02 (3.33)	44.3
10.0 GHz	1.46 (4.79)	30.9
20.0 GHz	2.11 (6.94)	21.5

Corona Extinction Voltage, VRMS @ 60 Hz	1500
Voltage Withstand, VRMS @ 60 Hz	5000

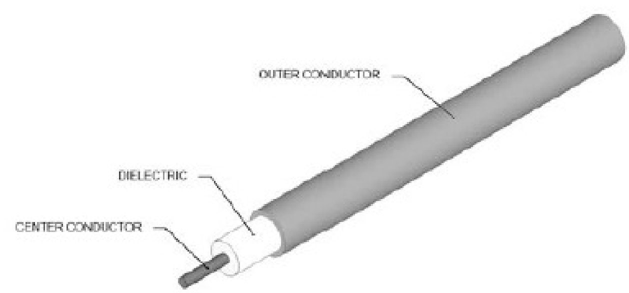
ENVIRONMENTAL CHARACTERISTICS

Outer Conductor Integrity Temperature, Deg Celsius	225
Maximum Operating Temperature, Deg Celsius	200

MATERIALS

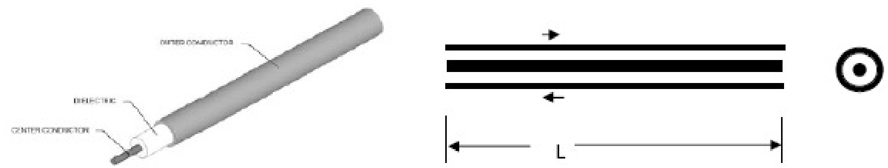
Outer Conductor	304 Stainless Steel
Dielectric	PTFE
Center Conductor	SPCW

CUTAWAY

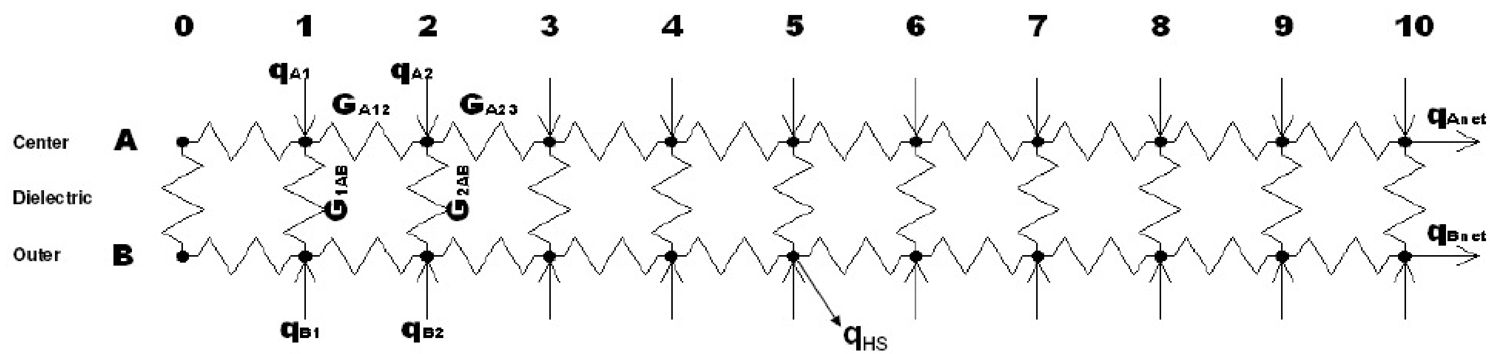


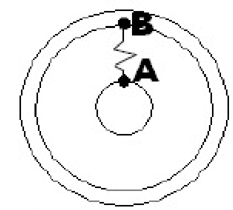
Model for Calculations

Thermal Conduction, Cooling and Joule Heating of Coaxial Cable



Break Conductor into 10 sections to account for themal & electrical conductivity change with temperature





$$G_{iAB} = \frac{2\pi K_D}{\ln(r_B / r_A)}$$

Where $G_{Aij} = (K_iA_i/X_i + KiAi/Xi + KiAi/Xi) = 1/R_{Aij}$ and $G_{iAB} = 2\pi K_D / \ln(r_B/r_A) = 1/R_{iAB}$

T_{A1} $G_{A01}(T_{A0}-T_{A1})+G_{1AB}(T_{B1}-T_{A1})+G_{A12}(T_{A2}-T_{A1})+q_{A1}=0$

T_{A2} $G_{A12}(T_{A1}-T_{A2})+G_{2AB}(T_{B2}-T_{A2})+G_{A23}(T_{A3}-T_{A2})+q_{A2}=0$

T_{A10} $G_{A910}(T_{A9}-T_{A10})+G_{10AB}(T_{B10}-T_{A10})+q_{A10}-q_{Anet}=0$

T_{B1} $G_{B01}(T_{B0}-T_{B1})+G_{1AB}(T_{A1}-T_{B1})+G_{B12}(T_{B2}-T_{B1})+q_{B1}=0$

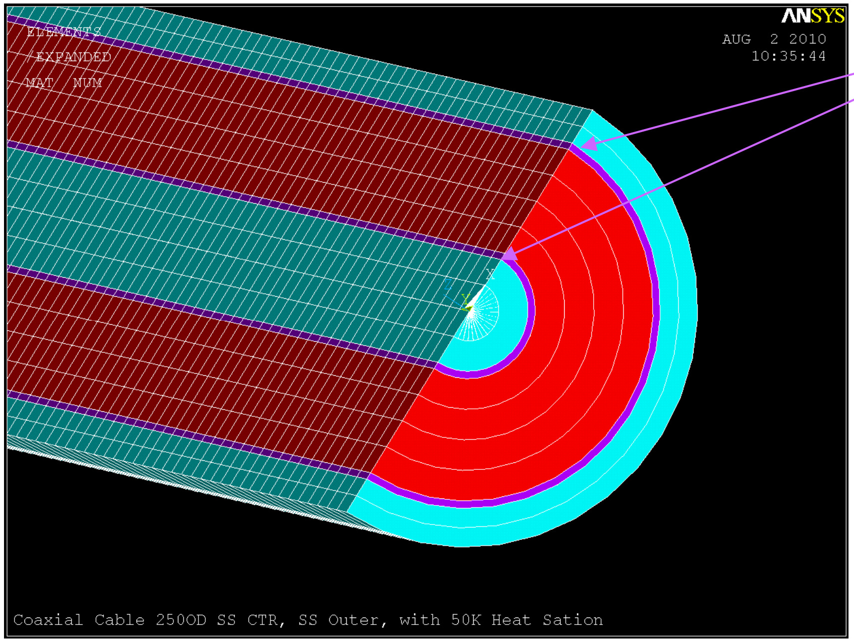
T_{B2} $G_{B12}(T_{B1}-T_{B2})+G_{2AB}(T_{B2}-T_{A2})+G_{B23}(T_{B3}-T_{B2})+q_{B2}=0$

T_{B10} $G_{B910}(T_I$

Thus 20 equations, 20 unknowns: **Note: $G_i = f(T_i)$**

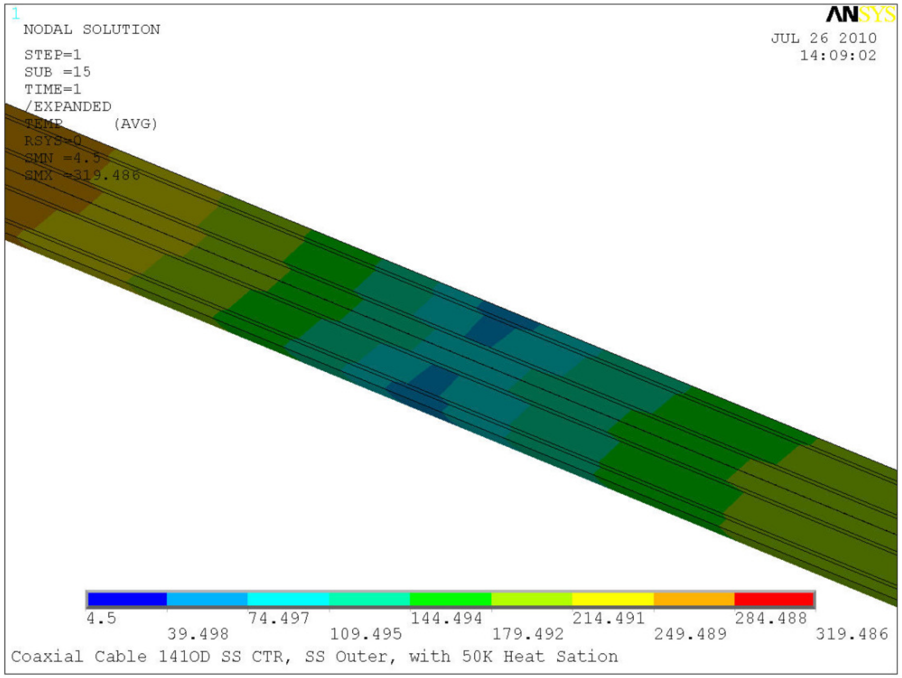
Thus, have 20 simultaneous equations of the form: **A X = C**, where **X** is the Temperature Vector being sought

FEA Model(s)



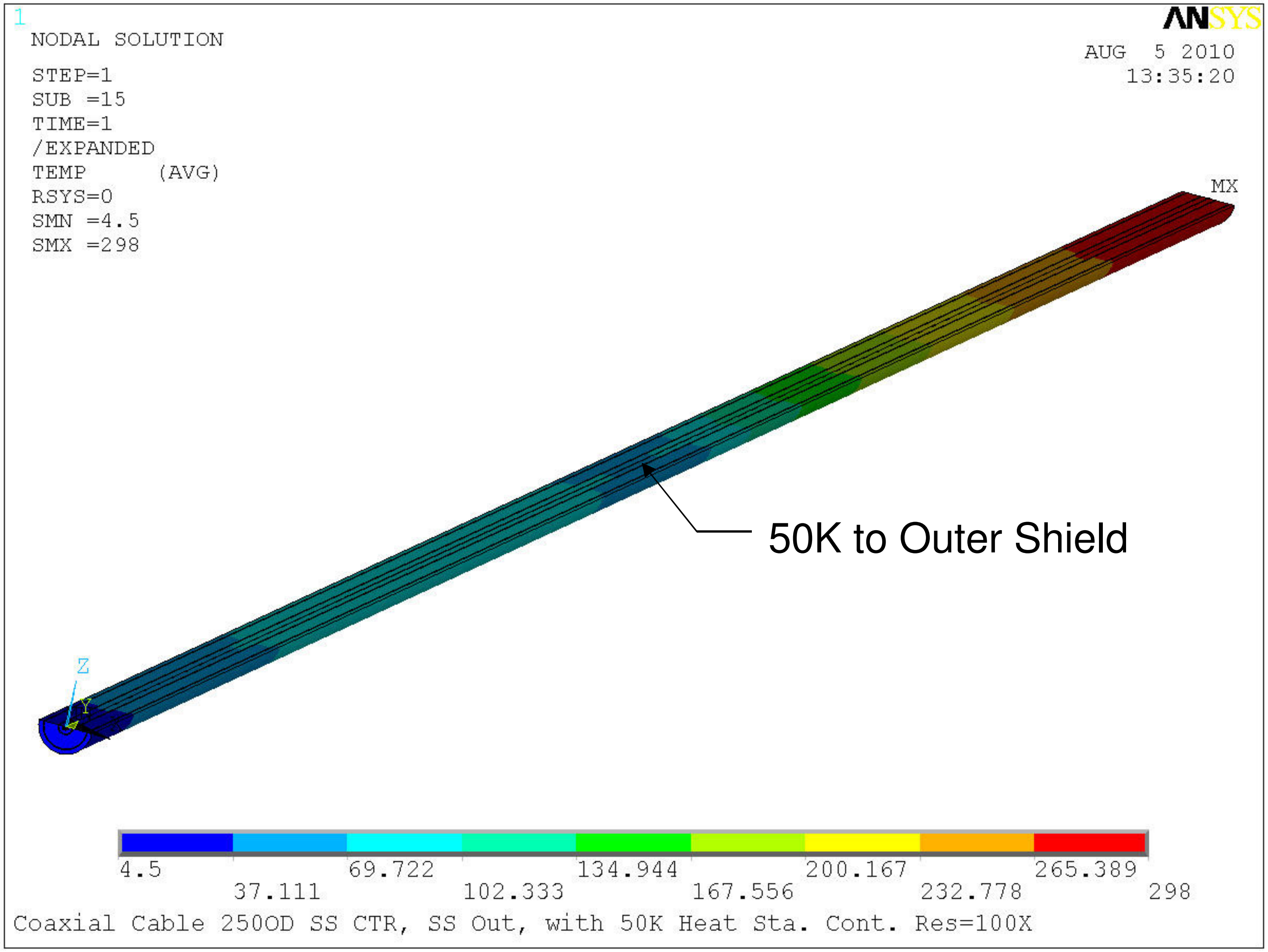
These regions made 100X more thermally resistive than PTFE to simulate contact resistance

SS Conductors, Heat Station with Effect of Contact Resistance

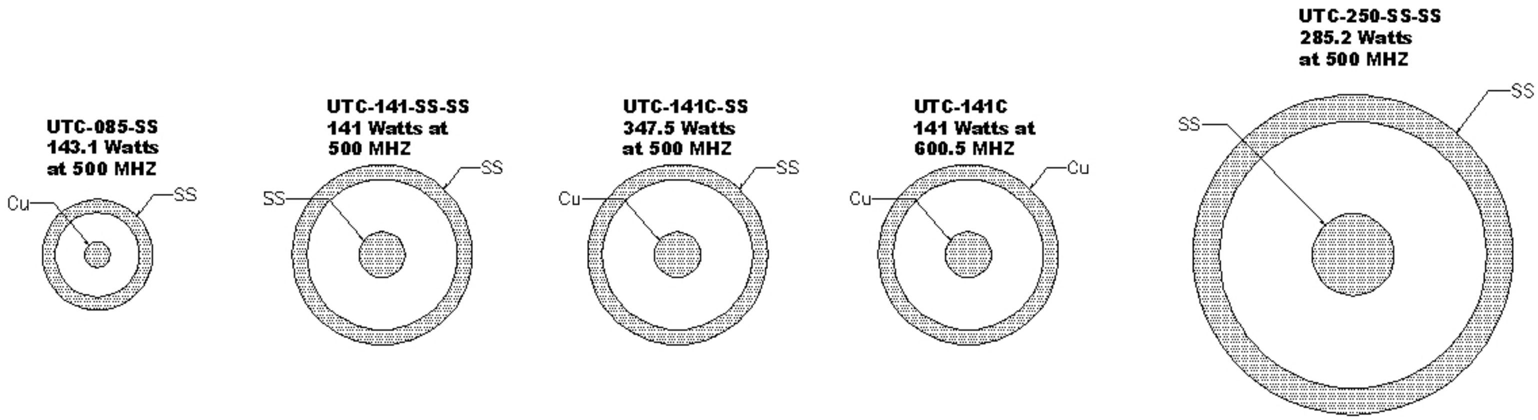


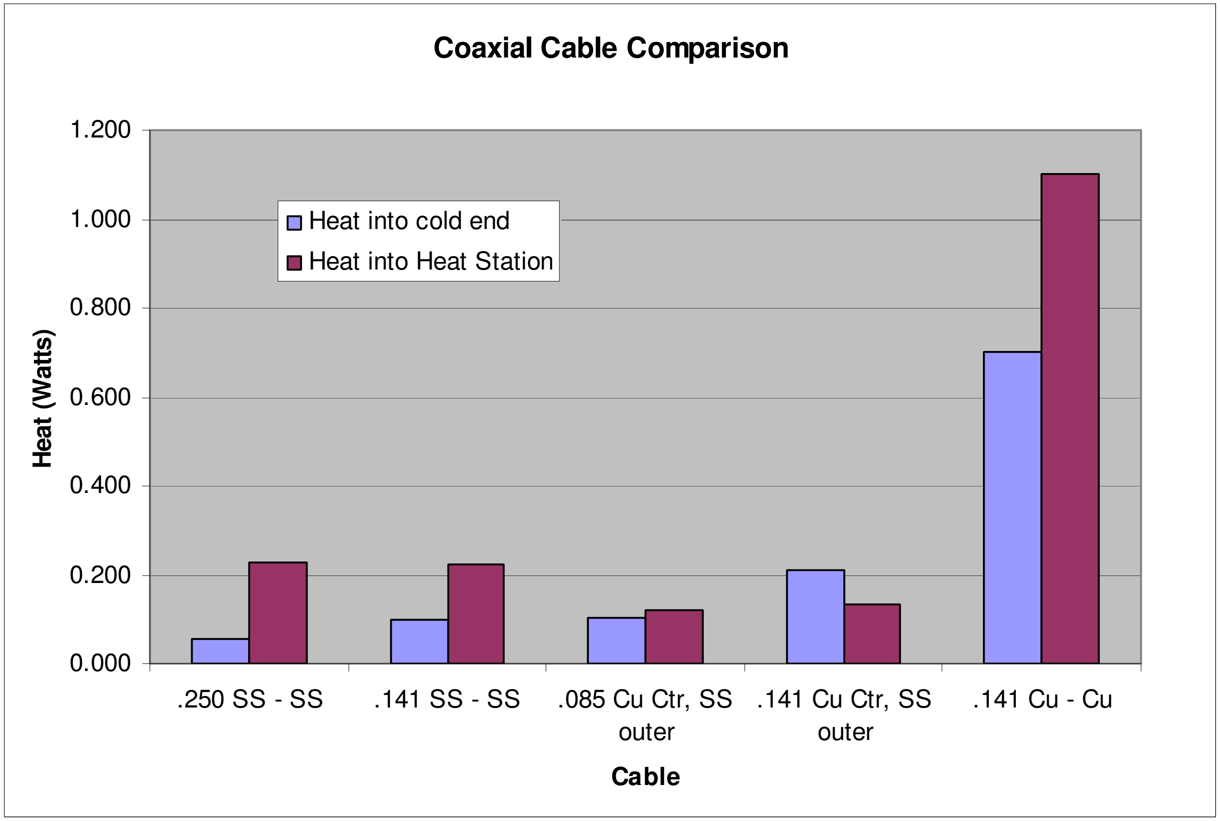
FEA Results

For 250 SS Cable - FEA performed on many types and sizes

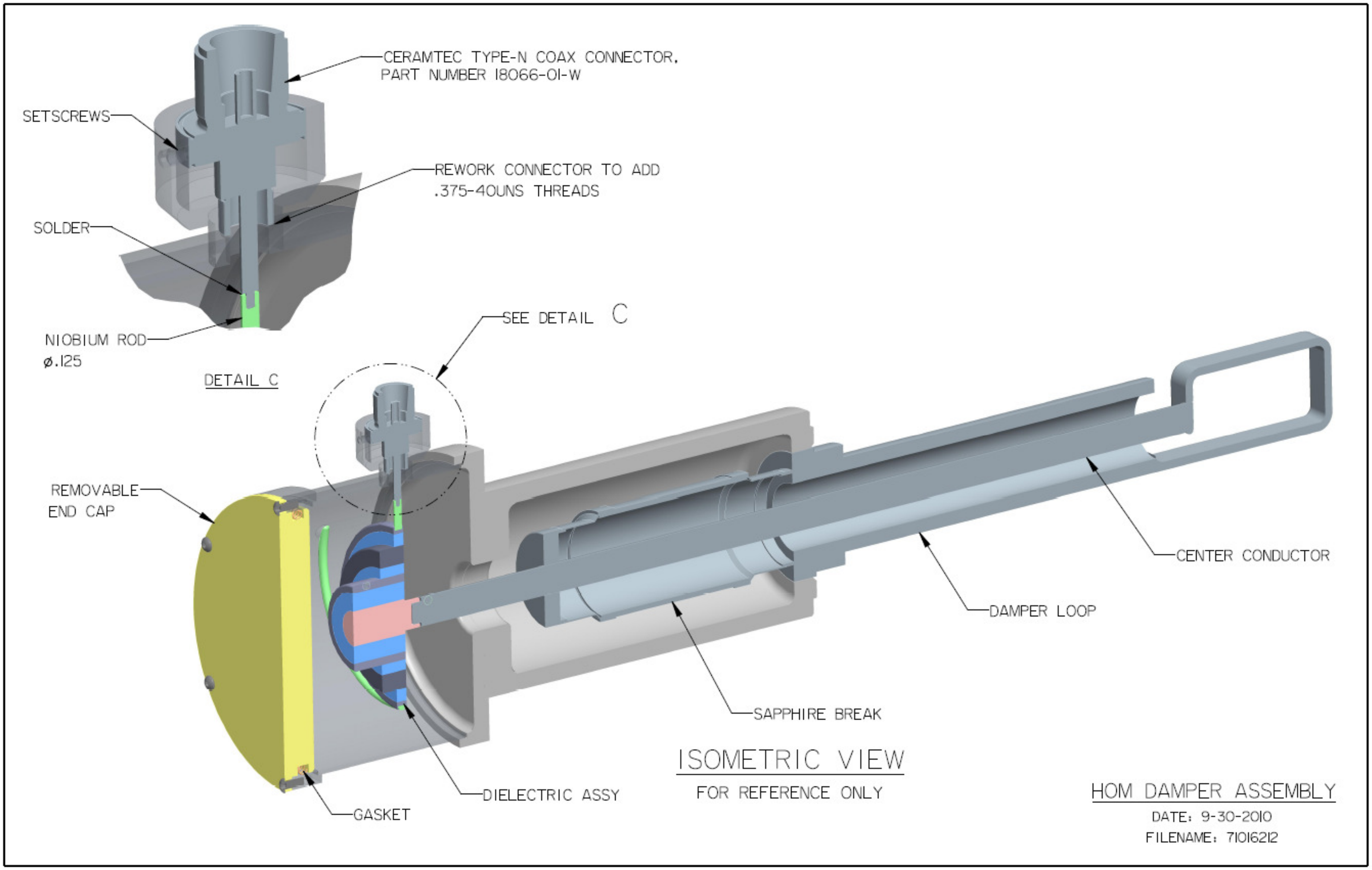


FEA Results Summary

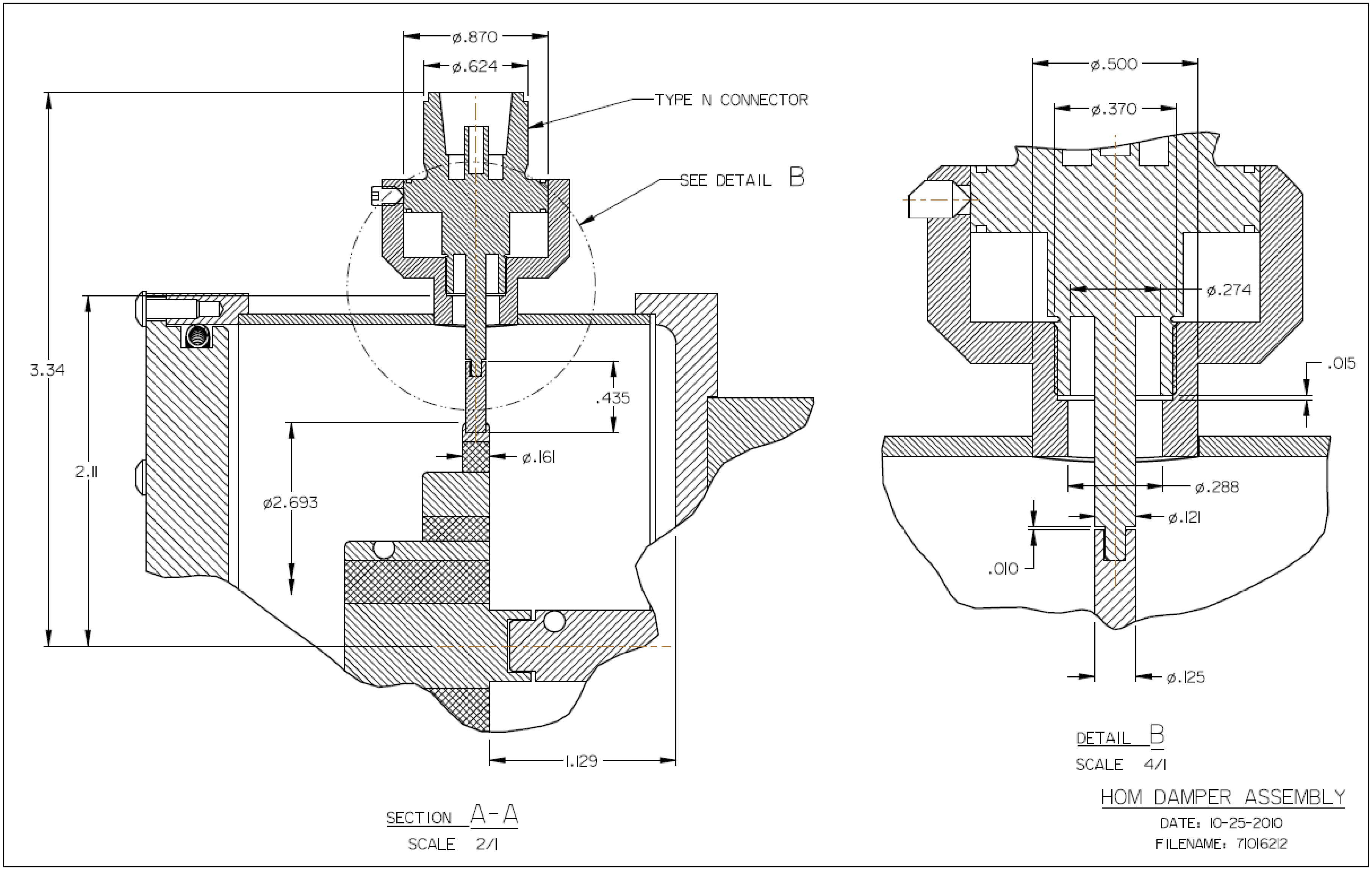




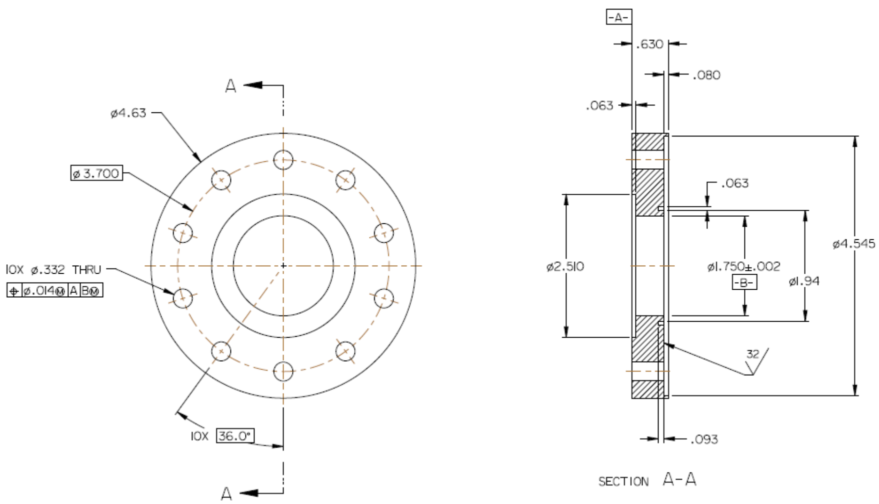
HOM Cable-Connector Assembly



HOM Cable-Connector (cont.)



HOM Hex Seal



From: Doug Holmes [mailto:doug_holmes@mail.aesys.net]
Sent: Friday, January 14, 2011 11:11 AM
To: McIntyre, Gary T
Subject: Line load for Hex seals

Mac,
We like to shoot for a minimum of 1,000 lbs/inch load on the hex seals. This is why we use the A286 high strength bolts and nuts. Belleville washers are also used to make sure you maintain the load throughout temperature cycling. I have attached a presentation by John Mammosser that has some testing information on the subject (slides 14-16).
Regards,
Doug

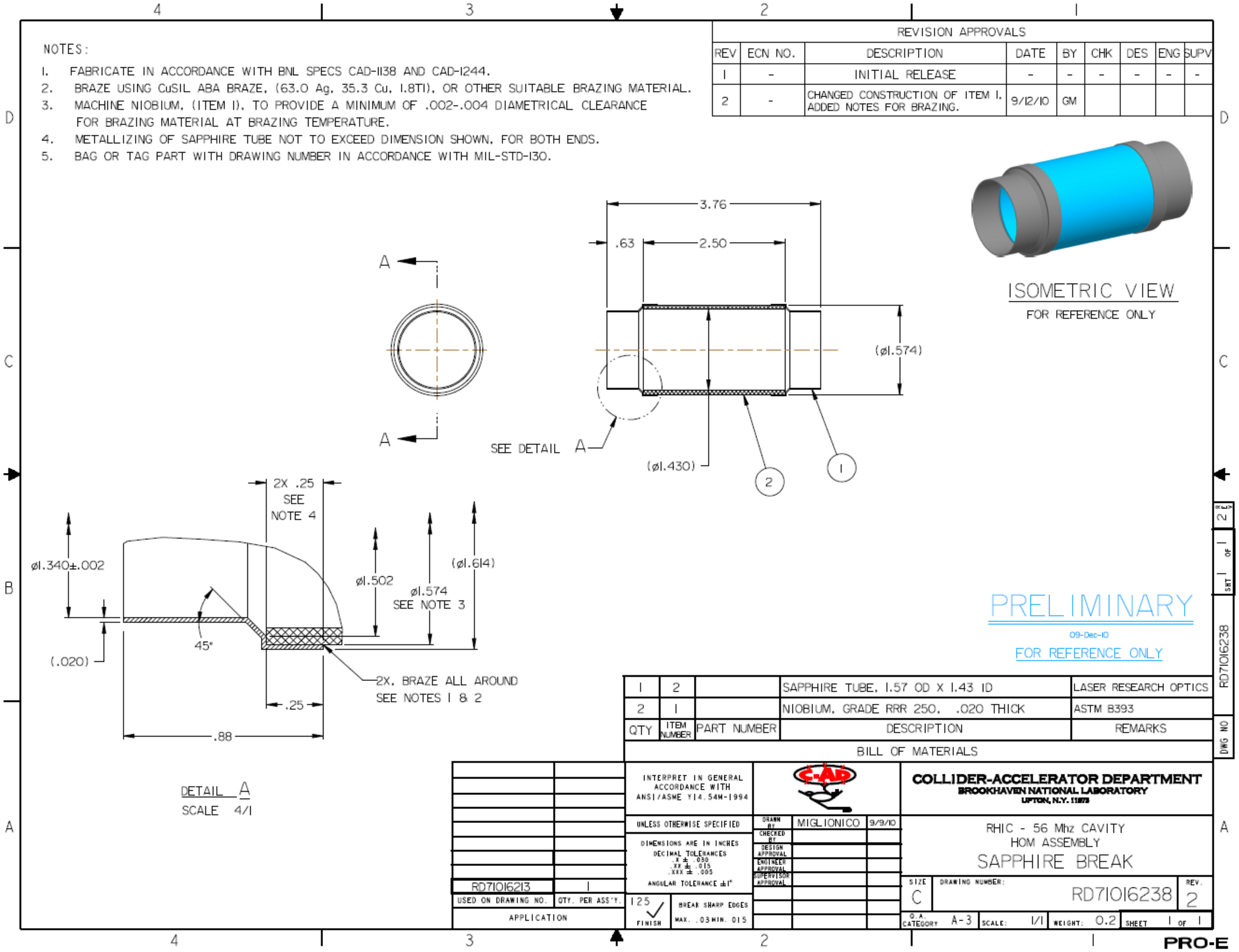
=====================================
Doug Holmes, Senior Engineering Specialist
Advanced Energy Systems, Inc.
27 Industrial Blvd, Unit E
Medford, NY 11763
Ph: 631-345-6264x106
Fx: 631-345-0458
email: doug_holmes@mail.aesys.net
=====================================

10 x 5/16-24 SS Bolts, Torqued to 113.1 in-lbs results in 1809.6 lbf (80% of yield)

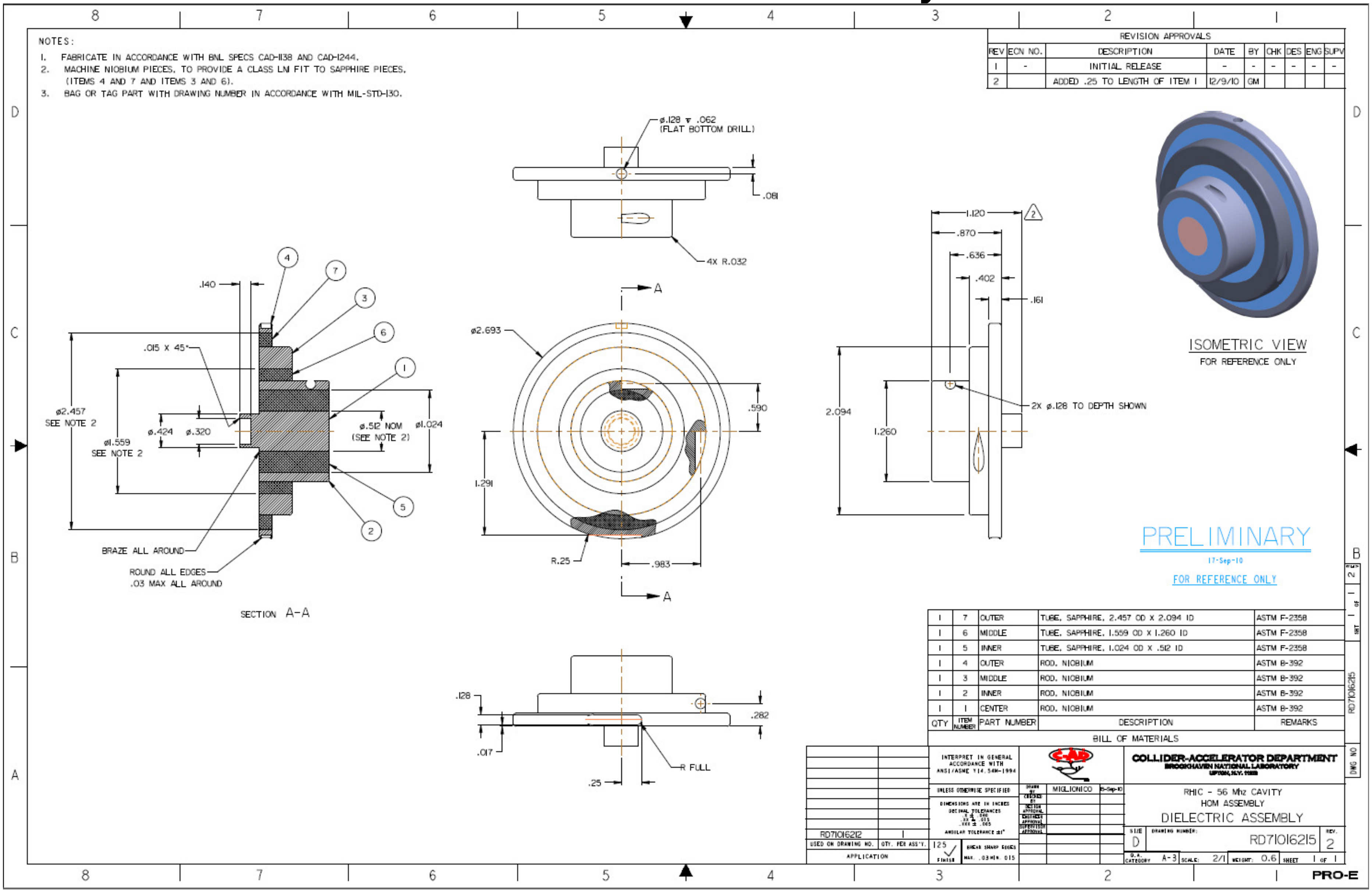
Bolt Circle = π x 3.700 = 11.62 inches

Linear Sealing Load = 10 x 1809.6 / 11.62 = 1557 lb_f/inch

HOM Design / Fabrication (cont.)



HOM Filter Assembly

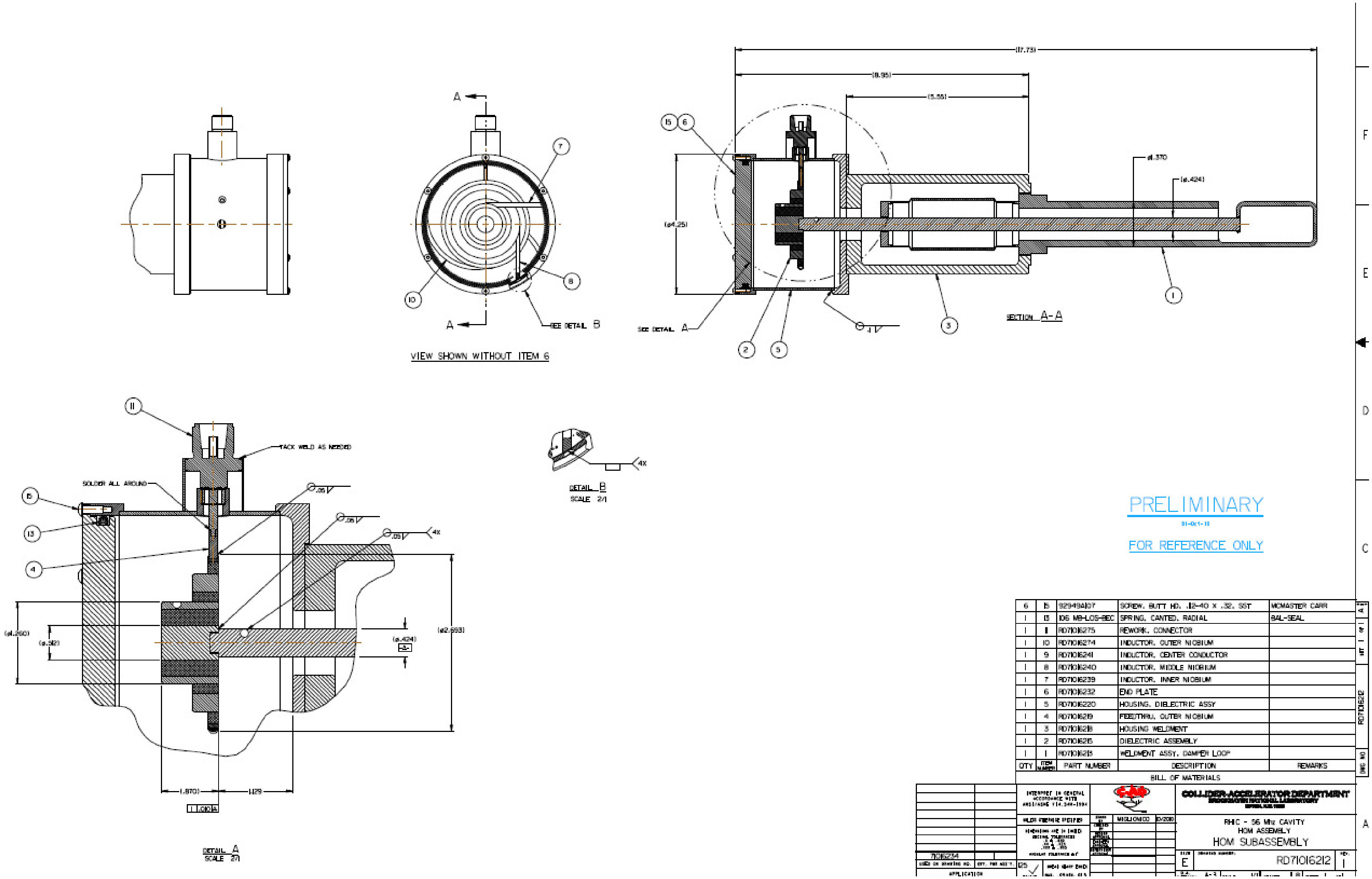


REV	ECN NO.	DESCRIPTION	DATE	BY	CHK	DES	ENG	SUPV
1	-	INITIAL RELEASE	-	-	-	-	-	-
2		ADDED .25 TO LENGTH OF ITEM 1	12/9/10	GM				

QTY	ITEM NUMBER	PART NUMBER	DESCRIPTION	REMARKS
1	7	OUTER	TUBE, SAPPHIRE, 2.457 OD X 2.094 ID	ASTM F-2358
1	6	MIDDLE	TUBE, SAPPHIRE, 1.559 OD X 1.260 ID	ASTM F-2358
1	5	INNER	TUBE, SAPPHIRE, 1.024 OD X .512 ID	ASTM F-2358
1	4	OUTER	ROD, NIOBIUM	ASTM B-392
1	3	MIDDLE	ROD, NIOBIUM	ASTM B-392
1	2	INNER	ROD, NIOBIUM	ASTM B-392
1	1	CENTER	ROD, NIOBIUM	ASTM B-392

BILL OF MATERIALS

HOM Design / Fabrication

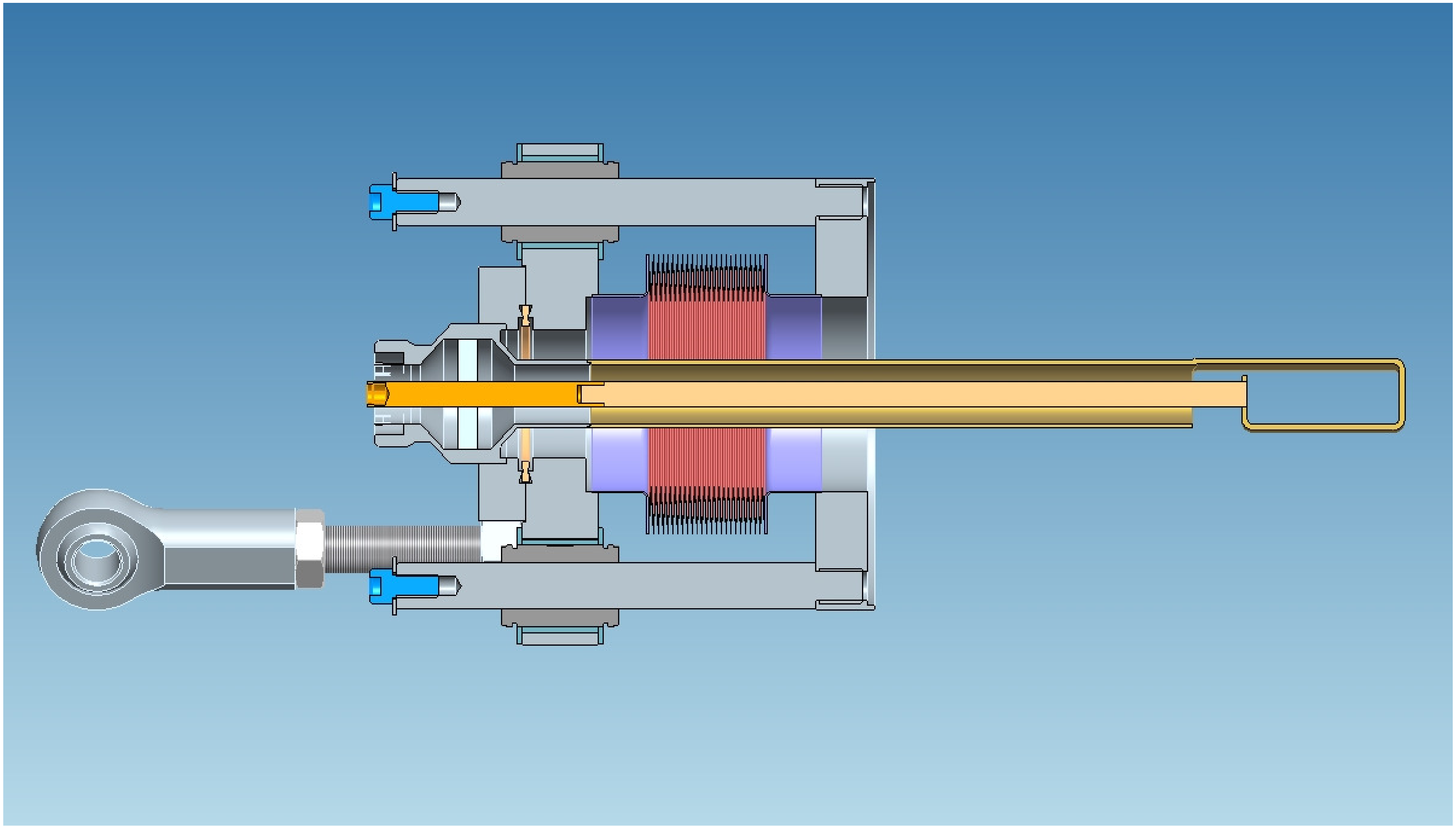


HOM Schedule

- March 11 - Release of Drawings
- March 16 - Deadline for responses to RFP (pinned 2/23) for building entire HOM assembly
  - Phase 1 – Prototype / First Article (20 weeks – Aug ‘11)
  - Phase 2 – 6 follow-on HOM’s (16 weeks – Dec ‘11)

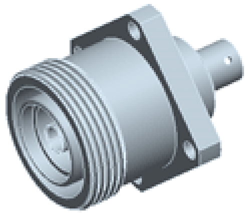
- Alternate Approach:
  - supply vendor with sapphire tubes and machined niobium parts for brazing (12 weeks – June ‘11)
  - purchase and receive brazed assemblies (8 weeks – Aug ‘11)
  - arrange machining of niobium components (8 weeks – Aug ’11)
  - send out machined parts and brazed assemblies for pre-cleaning, welding and final cleaning, (8 weeks – Sep ’11)
  - Receive Final HOM’s (12 weeks – Dec ’11)

Fundamental Power Coupler



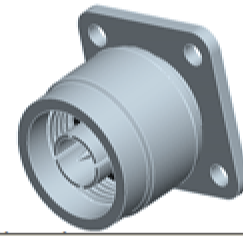
Fundamental Power Coupler Connector

7/16 DIN



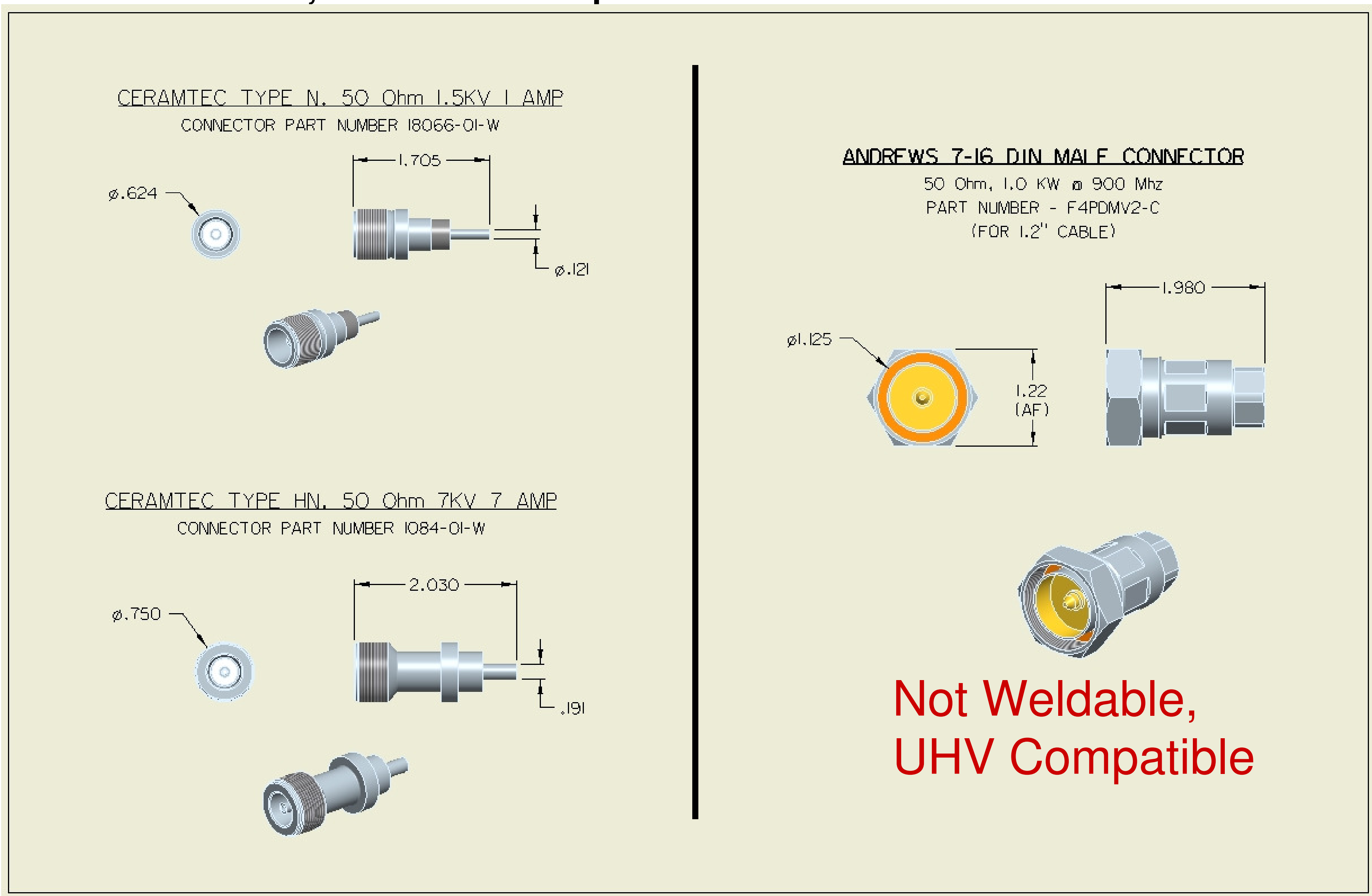
Electrical	
Impedance	50 Ω
Frequency Range	DC - 7.5 GHz
Return Loss	30 dB @ DC - 1.0 GHz (3 ft. assembly) 28 dB @ 1.0 - 2.0 GHz 21 dB @ 2.0 - 3.0 GHz
RF-Leakage	125 dB minimum
Voltage Rating (at sea level)	≥ 813 Vrms (depending on cable)
Average (Peak) Power Maximums	3.0 kW (13.2 kW)
Contact Resistance	center contact: ≤ 0.4 mΩ outer contact: ≤ 1.5 mΩ
Insulation Resistance	5,000 MΩ minimum
Insertion Loss Maximum	0.05 dB @ 1 GHz
Dielectric Withstanding Voltage	2,300 Vrms (at sea level)
3rd order Inter-Modulation Distortion	-120 dBm/ - 165 dBc typical (+43 dBm carriers)
Mechanical	
Mating	M29 x 1.5 threaded coupling nut
Attachment Method (inner/outer)	captivated/compression
Coupling Torque, min./max.	15/20 lb-ft (20/28 N-m)
Coupling Nut Retention force	225 lbs (1000N) min.
Assembly Torque (body/clamp nut)	positive stop, 18/20 lb-ft (25/30 N-m)
Durability (matings)	500 cycles min. (DIN 47275, 2/10.82 section 2.10)
Environmental	
Temperature Range	-65°C to +165°C
Thermal Shock	IEC 68, part 2-14, test Na
Immersion	IEC 529, IP68
Corrosion	IEC 68, part 2-1, test Ka
Vibration	IEC 68, part 2-6
Mechanical Shock	IEC 68, part 2-27
Material	
Male Contact	Brass
Female Contact	Beryllium copper
Other Metal Parts	Brass per ASTM-B16, silver or white bronze plated
Insulator	PTFE per ASTM-D1457
Gasket	Silicone rubber (weatherproof), ZZ-R-75
Protective Coating	Clear chromate (on silver plating)

Type N



Electrical	
Impedance	50 Ω
Frequency Range	11.0 GHz
Return Loss	33 dB (1-2 GHz) 28 dB (2-3 GHz)
Operating Voltage	Maximum 707 rms
Dielectric Withstanding Voltage	2,000 vdc
Insulation Resistance	5,000 MΩ minimum
Insertion Loss	.05 frequency GHz
Shielding Effectiveness	Minimum 125 dB
Peak Power	Maximum 10 kW
Average Power	Maximum .60 kW
3rd Order IM Product	Typical -125 dBm (-168 dBc)
Mechanical	
Mating	MIL-STD-348
Inner Attachment Method	Solder or captivated
Outer Attachment Method	Compression
Assembly Torque	18/22 lb-ft (25/30 N-m)
Coupling Torque	15.00 lb-in (1.70 N-m)
Coupling Nut Retention Force	100.00 lbs (444.80 N)
Connector Durability	500 cycles, 12 cycles/minute
Material	
Body	Brass, silver plated
Outer Contacts	Brass, silver plated
Inner Contacts	Beryllium copper, gold plated
Other Metal Parts	Brass, silver plated
Insulators	TFE
Gaskets	Silicone rubber
Environmental	
Temperature Range	Operating: -40°C to +150°C Storage: -70°C to +100°C
Thermal Shock	MIL-STD-202, method 107, test condition A-1
Immersion	IEC 529, IP68
Vibration	MIL-STD-202, method 204, test condition B
Corrosion	MIL-STD-202, method 101, test condition B
Mechanical Shock	MIL-STD-202, method 213, test condition I

Fundamental Power Coupler
Weldable, UHV Compatible Connector / Window



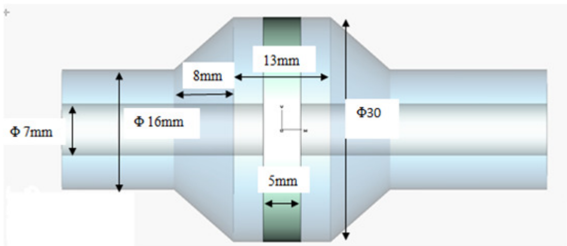
Custom Power Coupler (cont.)

Concept Modeled in MW Studio

Final design of Feed through for 56MHz and 700MHz

Wencan Xu, Update on Feb.4, 2011

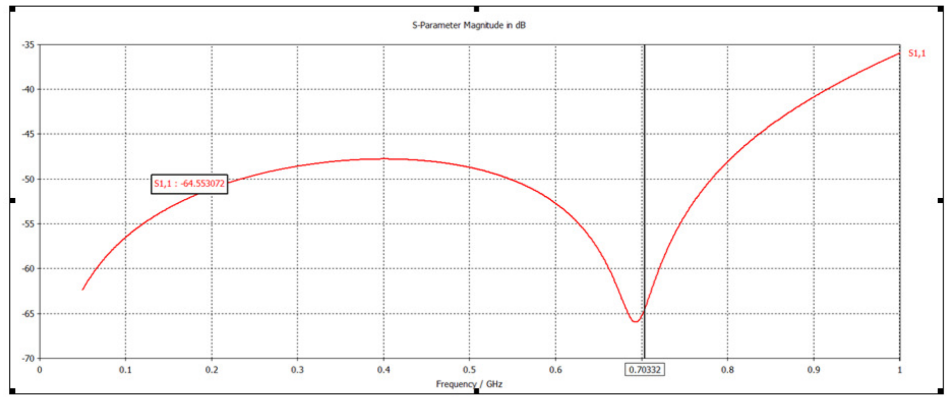
1. Geometry and material parameters



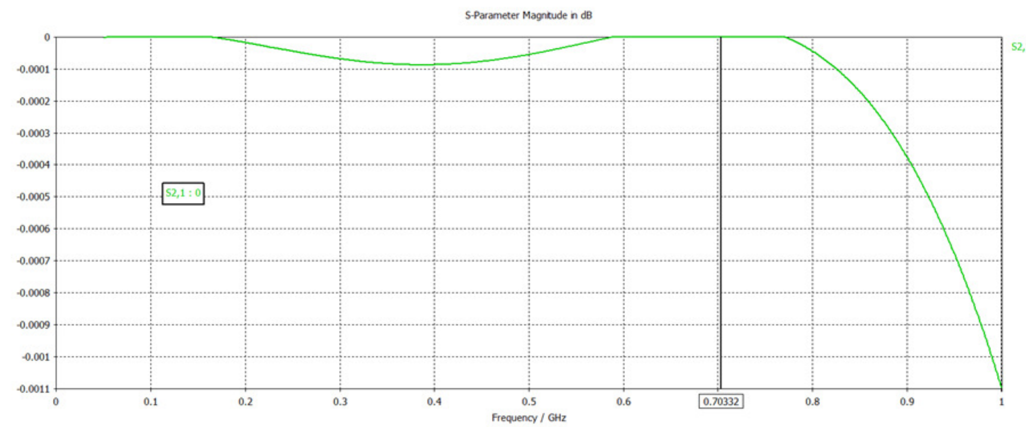
Material	Alumina (96%) (loss free)
Type	Normal
Epsilon	9.4
Mue	1
Rho	3800 [kg/m^3]
Young's Mod.	300 [kN/mm^2]
Poiss.Ratio	0.22
Thermal Exp.	7 [1e-6/K]

Performance

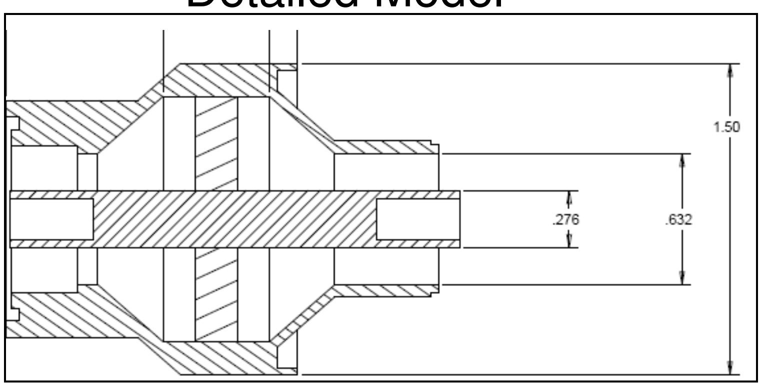
S 1,1 = 10* log ($P_{reflected}/P_{incident}$) in db



S 2,1 = ($V_{transmitted}/V_{incident}$)

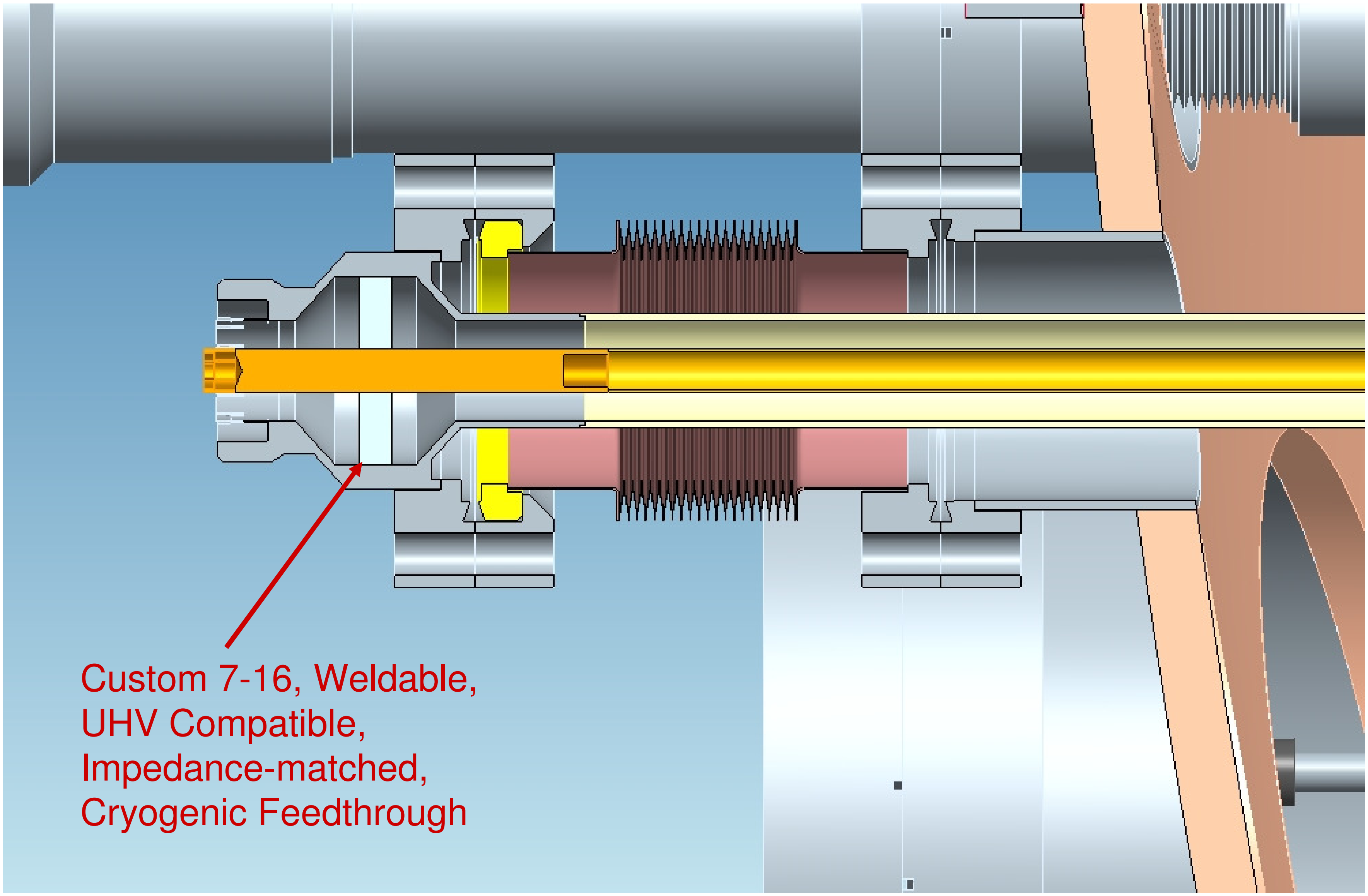


Detailed Model

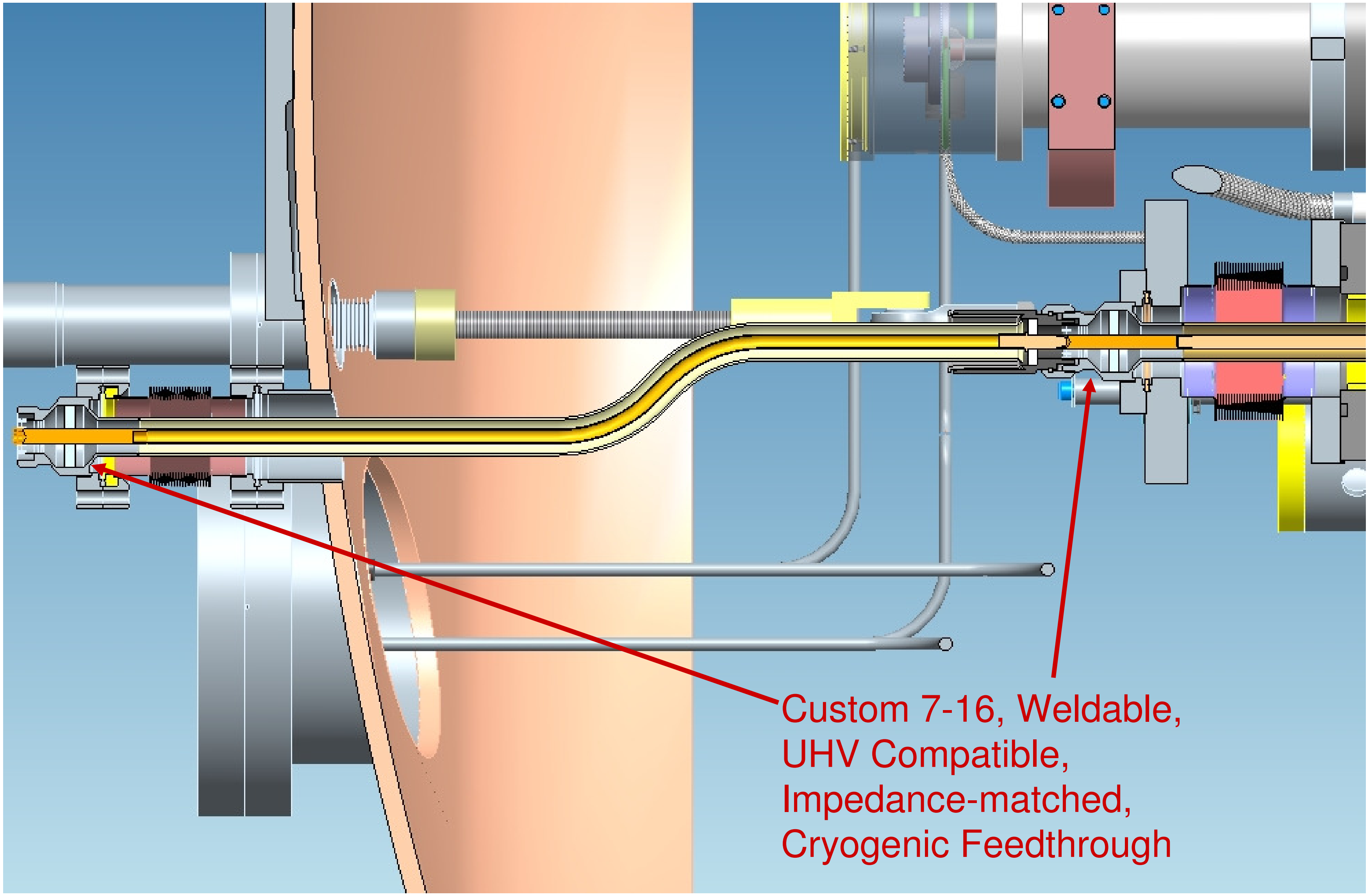


Ceramic with Dielectric Constant = 9.4

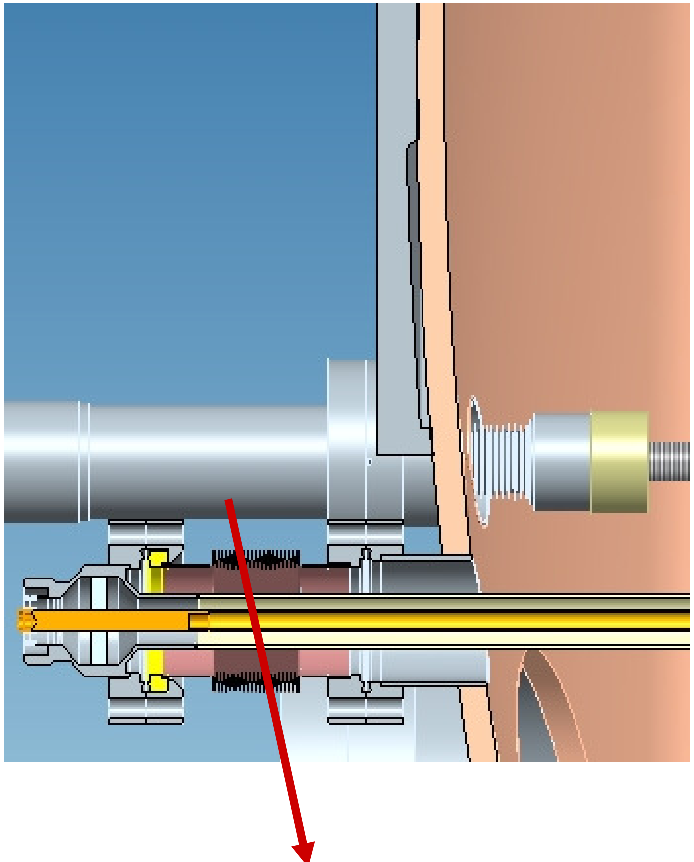
Fundamental Power Coupler (cont.)

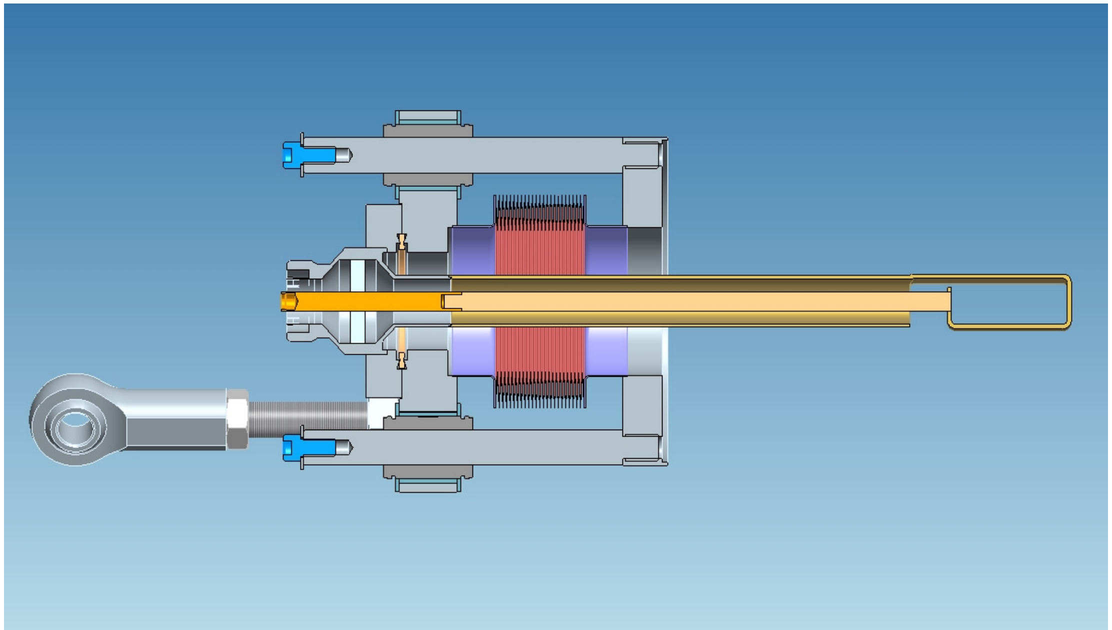


Fundamental Power Coupler (cont.)

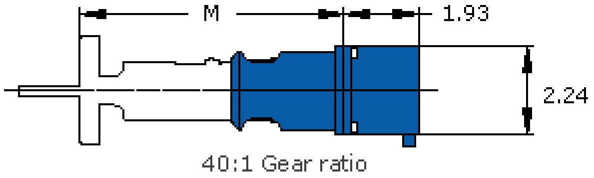


Fundamental Power Coupler Motion System

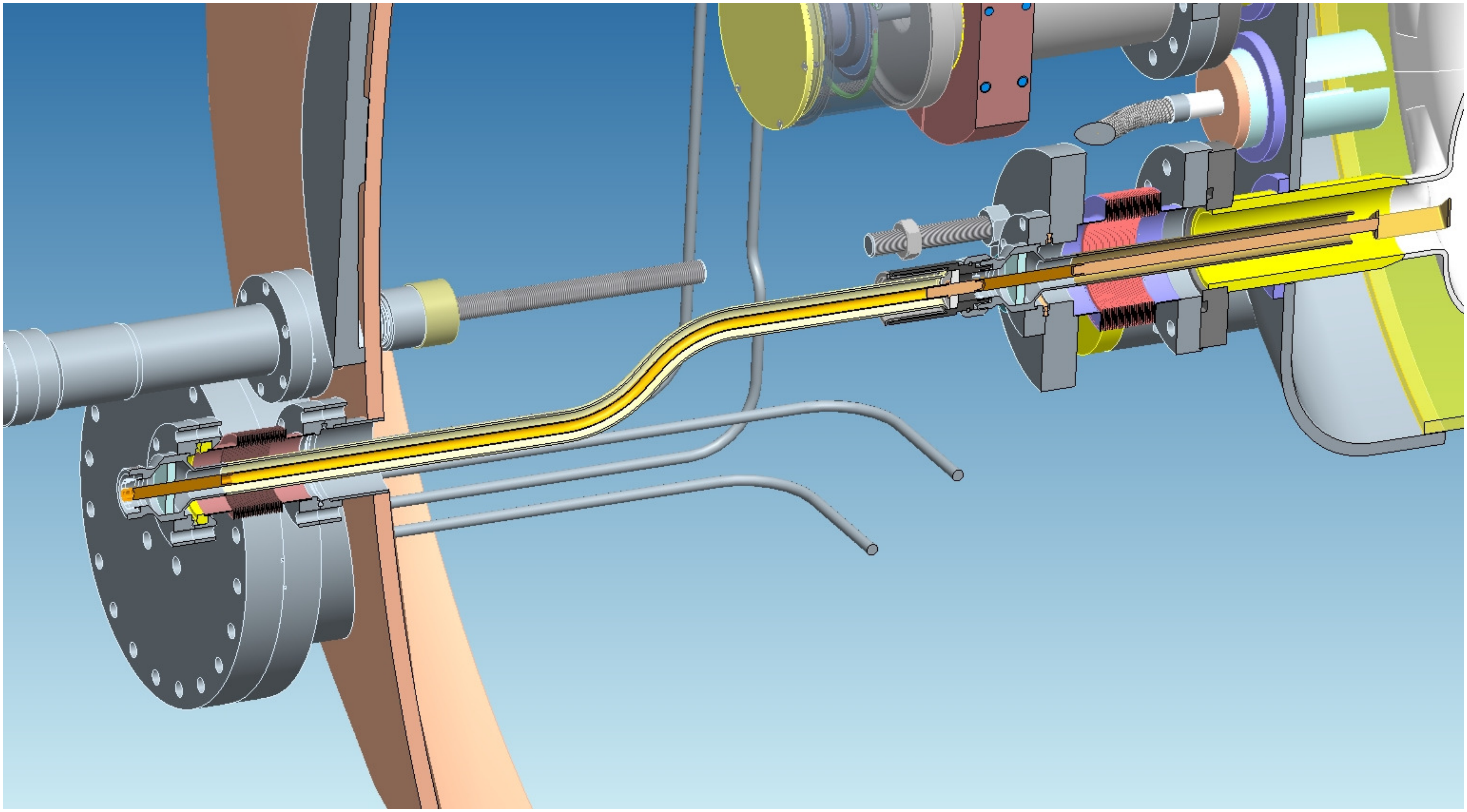




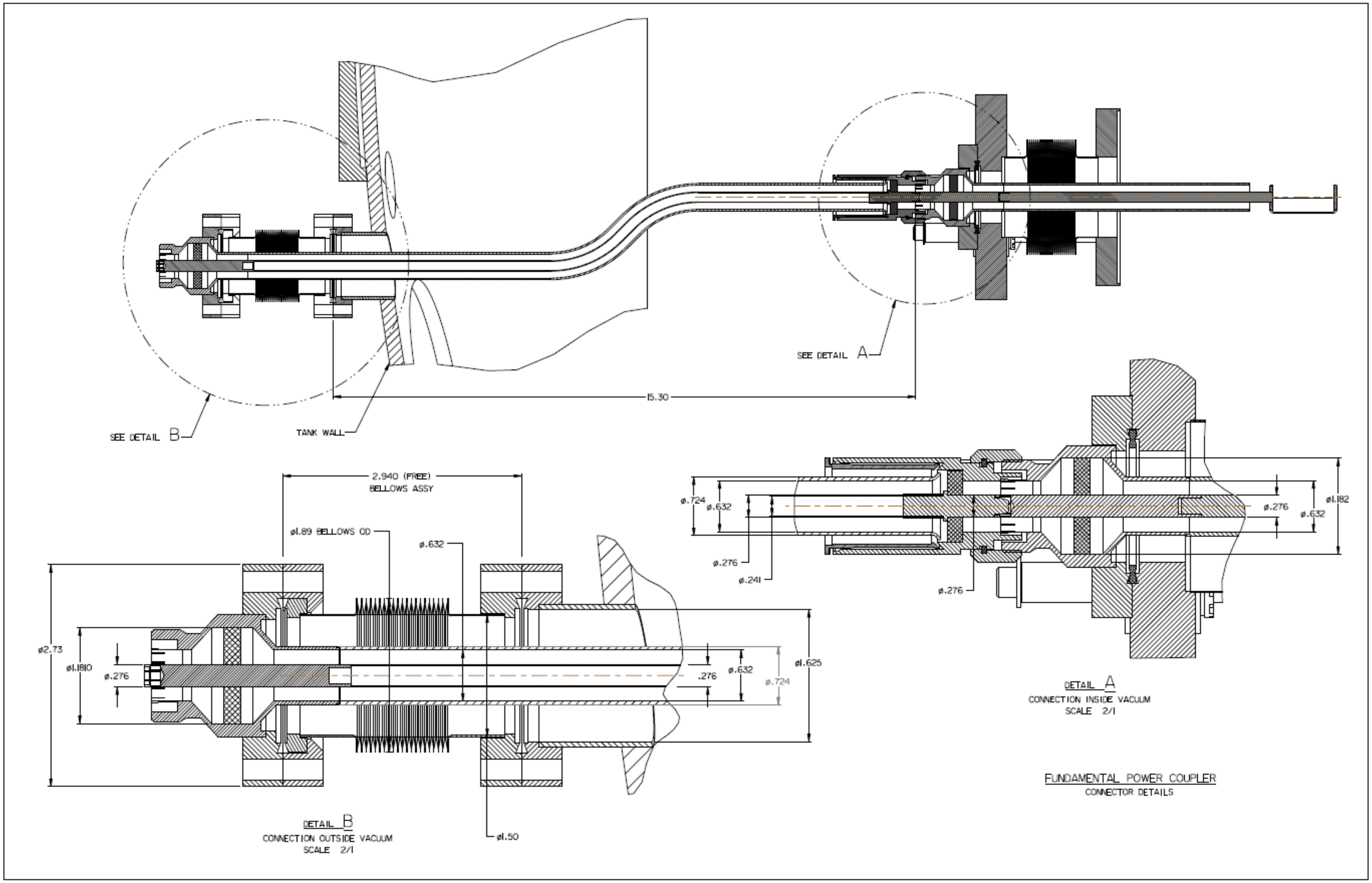
Option -03
Inline stepper motor   Add-On WT 2 lbs



Fundamental Power Coupler
Final Design



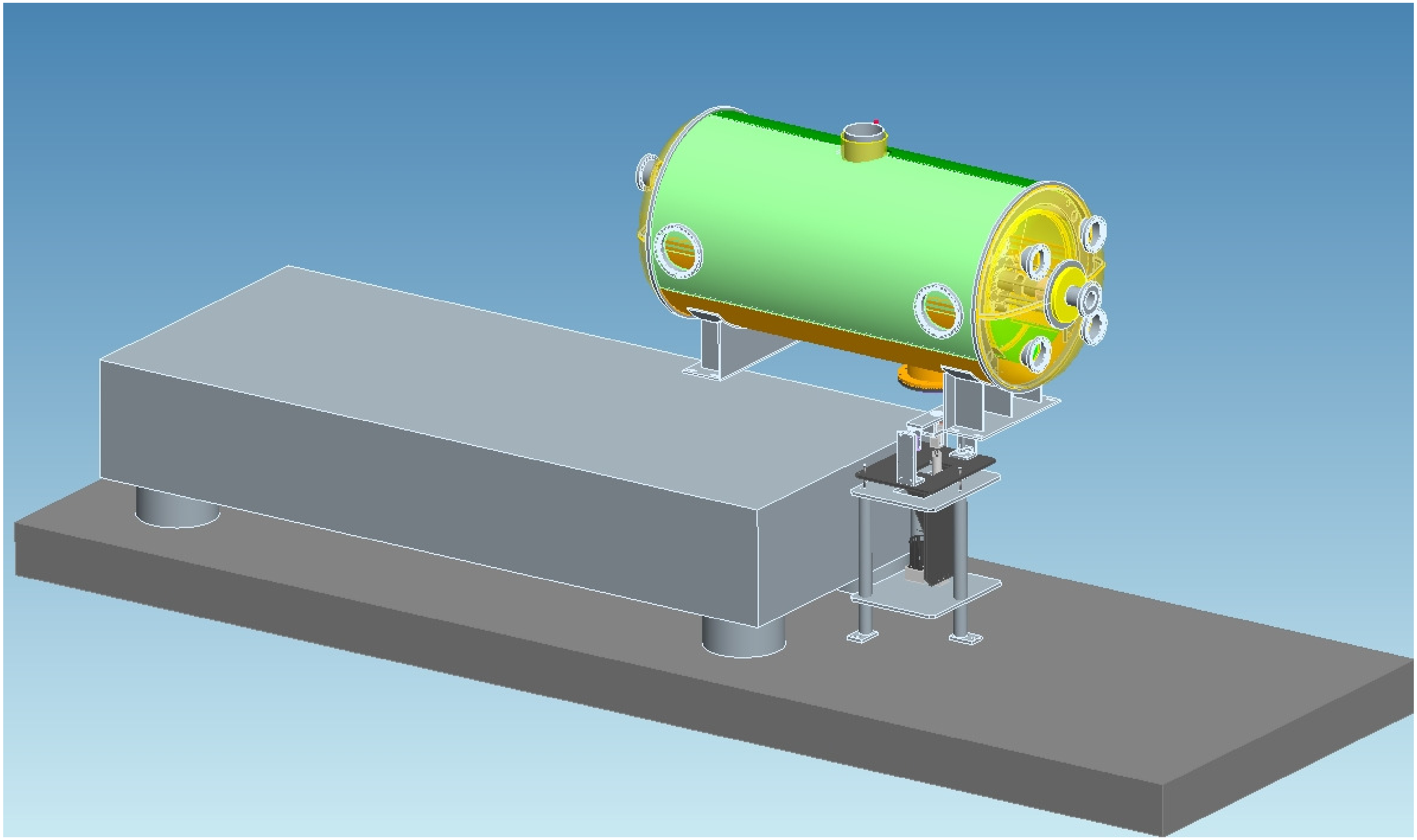
FPC Detailed Design



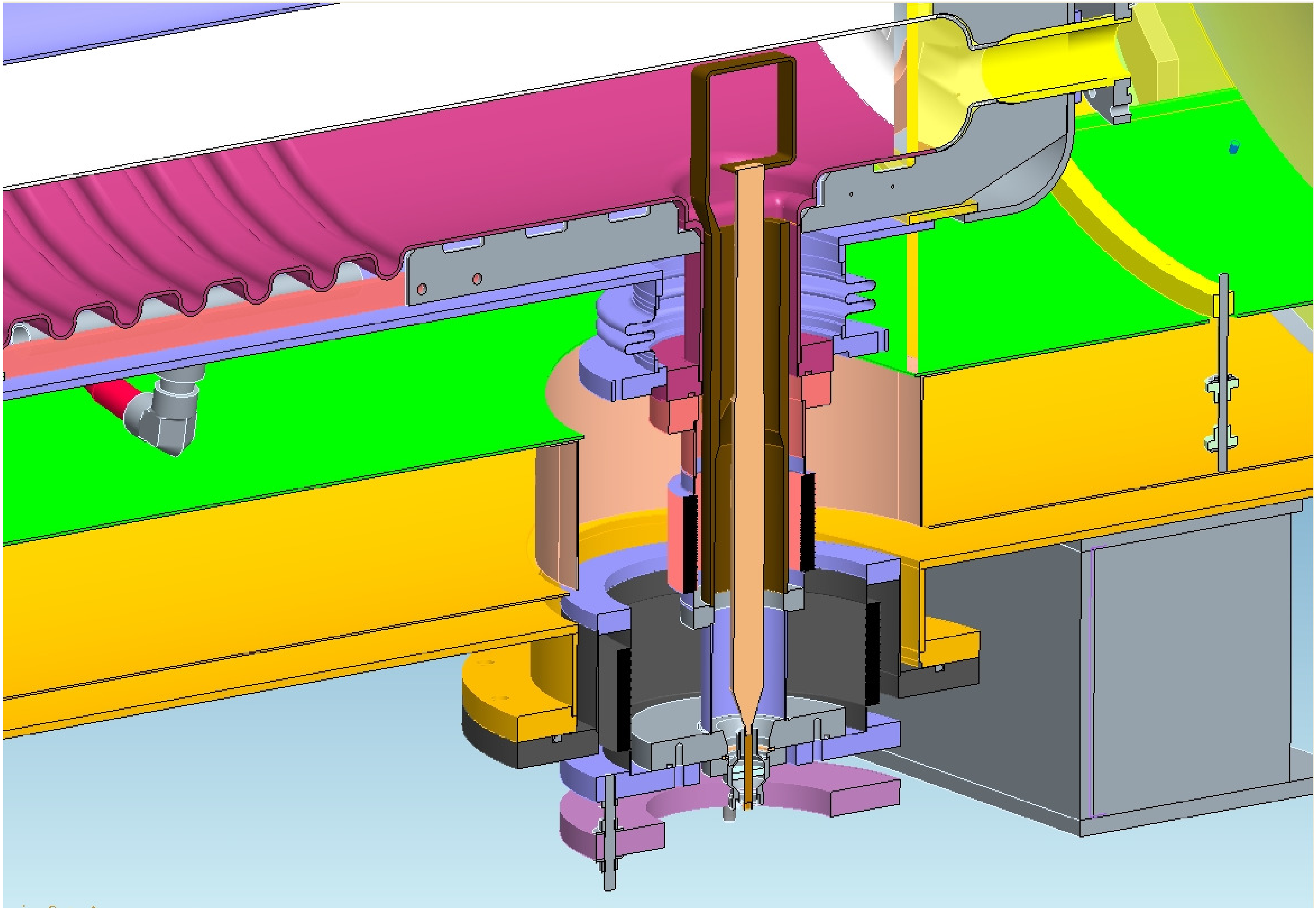
Fundamental Power Coupler Schedule

- March ‘11 – Design of Custom Feedthrough
  - P.O. for Fabrication – March ‘11
- March ‘11 –Thermal / Structural Analysis
- April ’11 –Detailed Design / Drawings for cavity side
- May ’11 – Detailed Design / Drawings for insulating vacuum / air side
- June ’11 – Design / Procurement of Motion System
- Jan ’12 All FPC and Motion System Procurement and Fabrication Complete

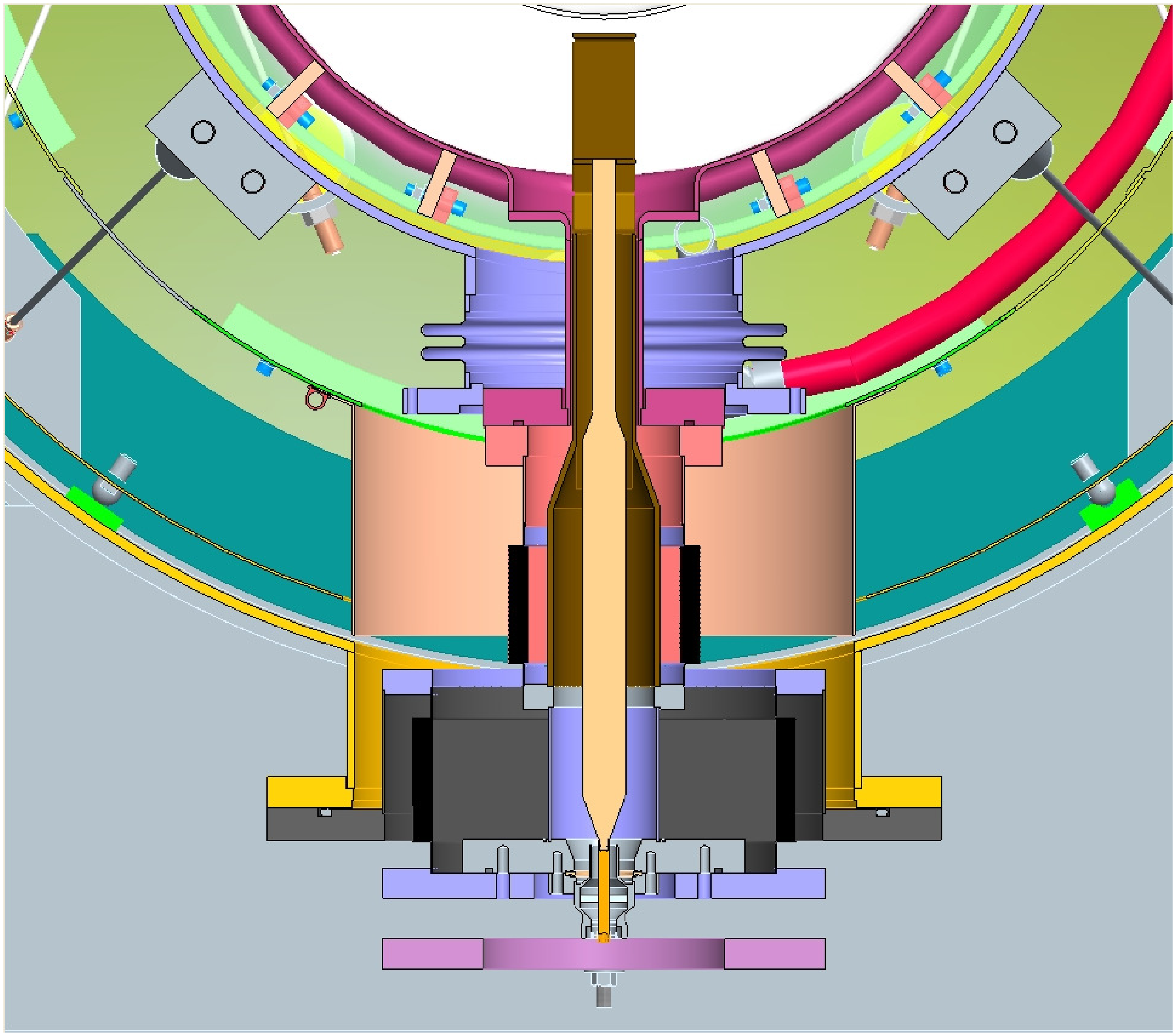
Fundamental Damper



Fundamental Damper (cont.)

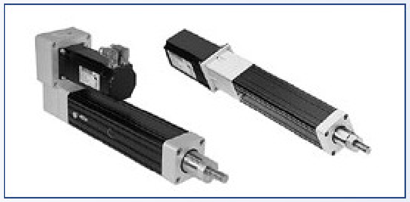


Fundamental Damper (cont.)



Fundamental Damper Motion System

EC5 Series

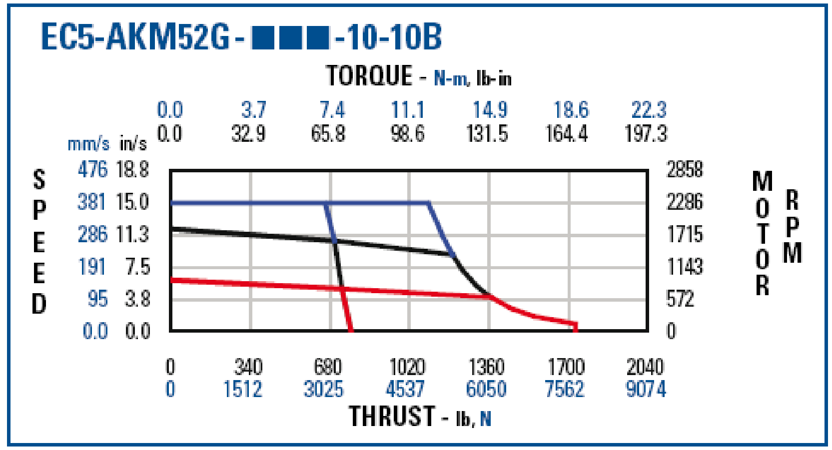


The EC5 Series of Electric Cylinder systems are our highest, robust linear motion package for very heavy thrust loads. Precision-rolled ball screw types yield quiet operation, low backlash, and high accuracy with a variety of motor to screw reduction types. Bearing and drive housings are made of durable construction material with optional environmental capabilities to meet most moisture or contaminant conditions. Special design minimizes the need for routine maintenance.

Available Motors:

- T41x Kollmorgen Hybrid Stepper motor (P7000 drive recommended)
- AKM42E, 42G, 52G, 52L, 52H Kollmorgen Brushless AKM Servomotors
- NEMA 34, 42 custom motor mount

MECHANICAL SPECIFICATIONS	Ball Screw Version
Max. Stroke Length, mm (in)	1500 (59.06)
Screw Lead, mm	32, 10 mm
Screw Diameter, mm	32
Unit Backlash, mm (in)	0.30 (0.12)
Dimensional Standard	Metric ISO6431 Std.
Bore Size, mm	100
Motor Mount	parallel or inline
PERFORMANCE SPECIFICATIONS	**Travel life standards of 25.4 km (1,000,000 in)**
Max. Thrust Force, N (lbf)	25,000 (5620)
Max. Velocity, m/s (in/s)	1.33 (52.5)
Max. Rated Duty Cycle	100
Std. Operating Temp Range, C° (F°)	-22 to 158 (-30 to +70)
Environment	IP54 Std. IP65 Opt.



Legend

- 25 km / 1 M " Life
- 460 Vac SD 6.3 /12.7 A
- 460 Vac S300 6.0 /12.0 A (Ip limit)
- 230 Vac S200 6.0 /18.0 A
- 115 Vac S200 6.0 /18.0 A

Sys	#	Electric Cylinder - AKM Servomotor	AKD Drive	Cont. Thrust @ Speed (lb @ in/sec)		Peak Thrust @ Speed (lb @ in/sec)		Max Thrust (lb)	Max System Speed (in/sec)	**Max Stroke for Max Speed (mm)	Cylinder Bore Size (EC)
	91	EC5-AKM52H-■■■-10-10B *	AKD-X00606	641	14.5	1130	13.1	1670	14.5	450	100

Fundamental Damper Motion System Costs

Motion System

Axis Inc.
210 Meister Avenue
Somerville, NJ 08876
(908) 429-0090
www.axisnj.com

CUSTOMER

Steve bellavia
Brookhaven National Labs
Building 911
Upton, NY 11973
Phone: (631)344-4646
bellavia@bnl.gov

QUOTATION

Quote Number:	17884
Quote Date:	05/05/2010
Expiration Date:	06/04/2010
Issued By:	Ed Mullen

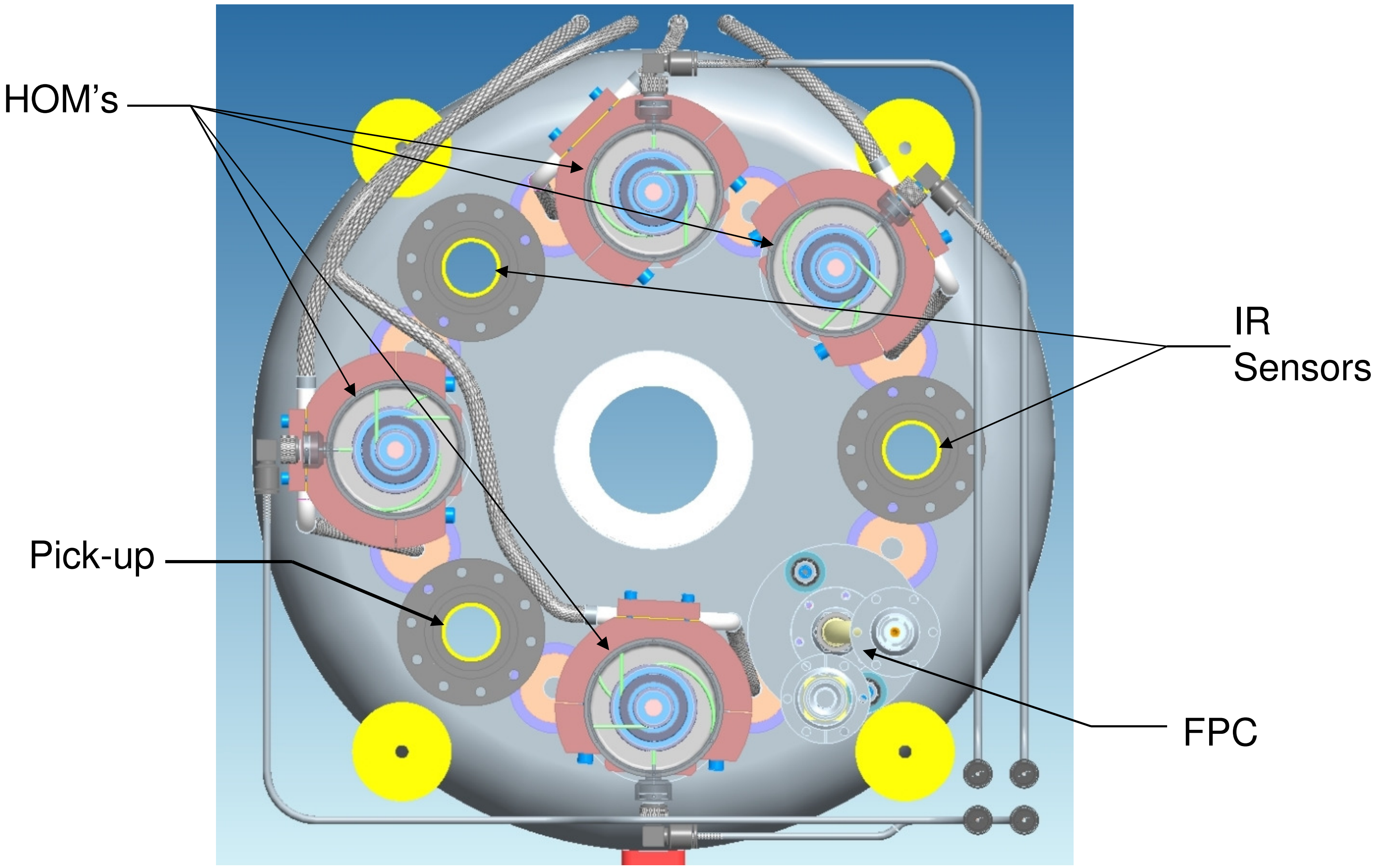
Part Number	Description	Manufacturer	Price	Qty.	Extend
EC5-AKM52H-C2DA-1010B-200-MF1-FC2-PB	EC5 Series Electric Cylinder. AKM Servomotor with dual intercontec connector, 24VDC motor-brake. Single turn absolute encoder feedback (512 LPR). 1:1 timing belt, 10mm lead (ballscrew), 200 mm stroke length. Rectangular front mounting flange. Clevis rod, motor cable, protective boot	Danaher	$7,135.00	1	$7,135.00
AKD-B00606-NAAN-000	base Drive AKD servo drive. 6 Amp continuous. 120/240 VAC	Danaher	$990.00	1	$990.00
CP-507CCAN10	Motor Power Cable 10M	Danaher	$349.00	1	$349.00
CF-SB7374N10	Motor Feedback Cable 10M	Danaher	$511.00	1	$511.00
P136	P136 MC206X (base unit with 1 step or 1 servo axis)	Trio Motion	$1,422.03	1	$1,422.03
P296	Ethernet Daughter Board	Trio Motion	$395.60	1	$395.60

Total: $10,802.63

Fundamental Damper Schedule

- March ‘11 – Design and Procurement of Custom Feedthrough
- April ‘11 – Thermal / Structural Analysis
- May ’11 – Detailed Design / Drawings
- Jan ’12 All Fundamental Damper and Motion System Procurement and Fabrication Complete
- Summer ’11 – Modification to RHIC floor area

Pick-Up



Pick-Up

- Aug ‘11 – Begin Thermal / Structural Analysis
- Sep ’11 – Begin Detailed Design / Drawings
- Jan ’12 – Pick-up complete