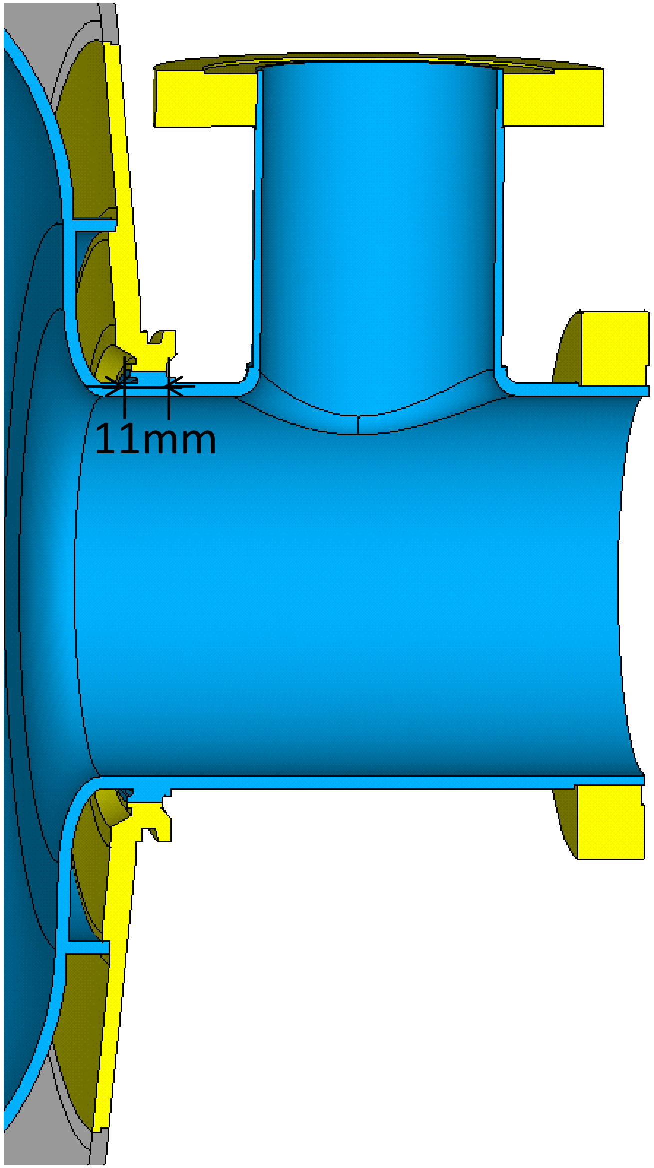
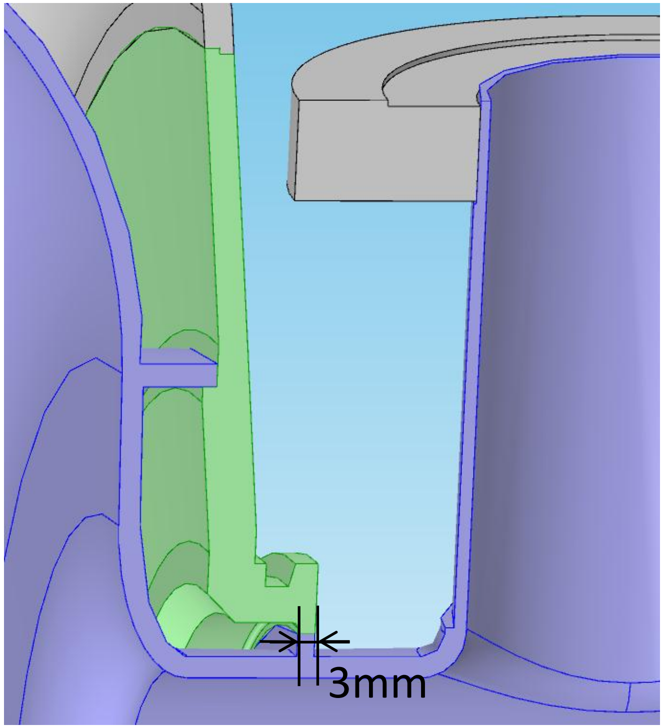
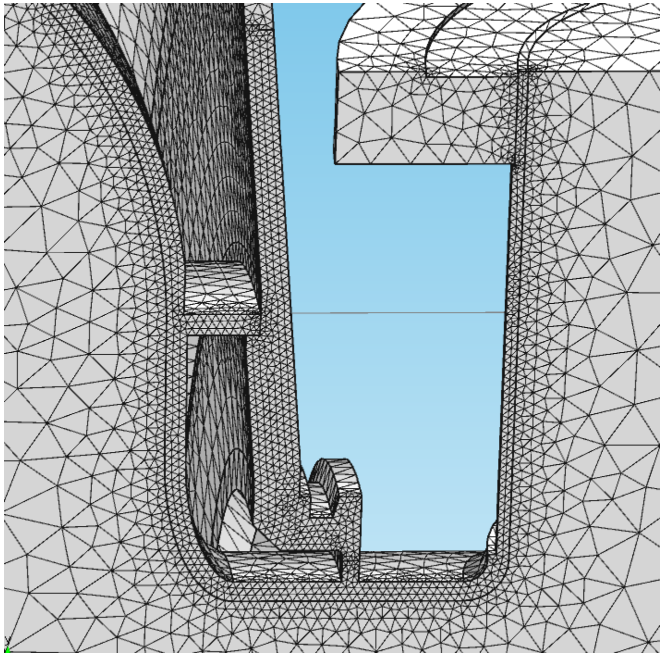
UPDATE ON ANALYSES OF THE 5 CELL 650 MHz CAVITY

Margherita Merio

RIGHT CAVITY END MODIFICATION





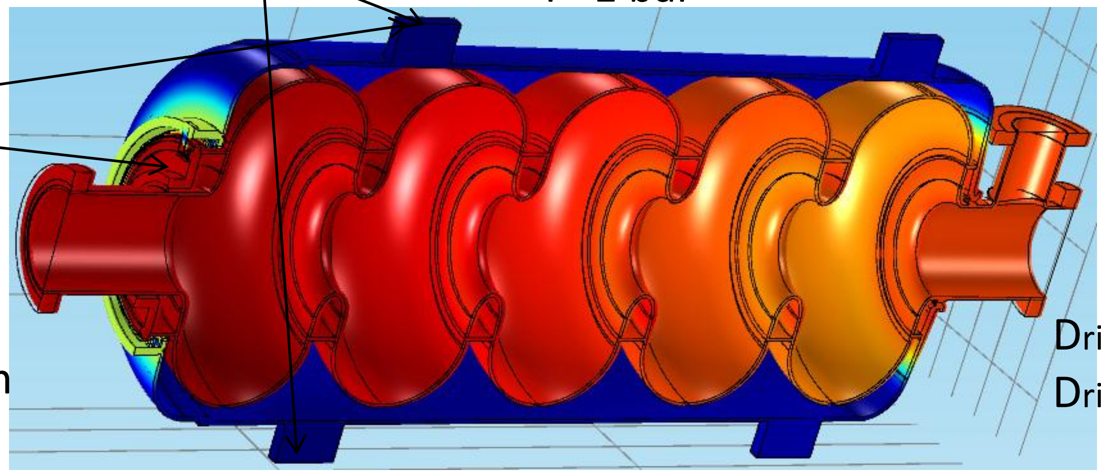


CAVITY BOTH ENDS MODIFIED, NO STIFFNESS

FIXED

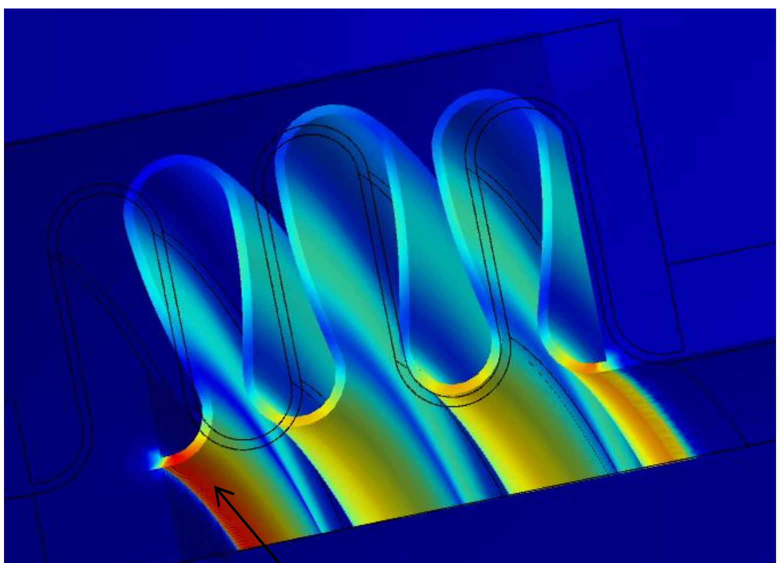
SPRING CONSTANT
0kN/mm

P=1 bar

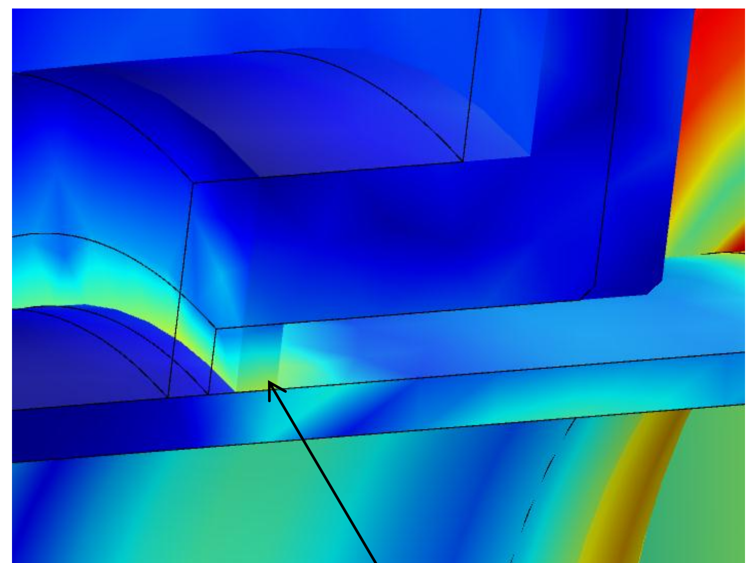


D_{left}~100µm, 4mm
D_{left}~137µm,3.7mm

D_{right}~87µm, 4mm
D_{right}~100µm, 3.7mm

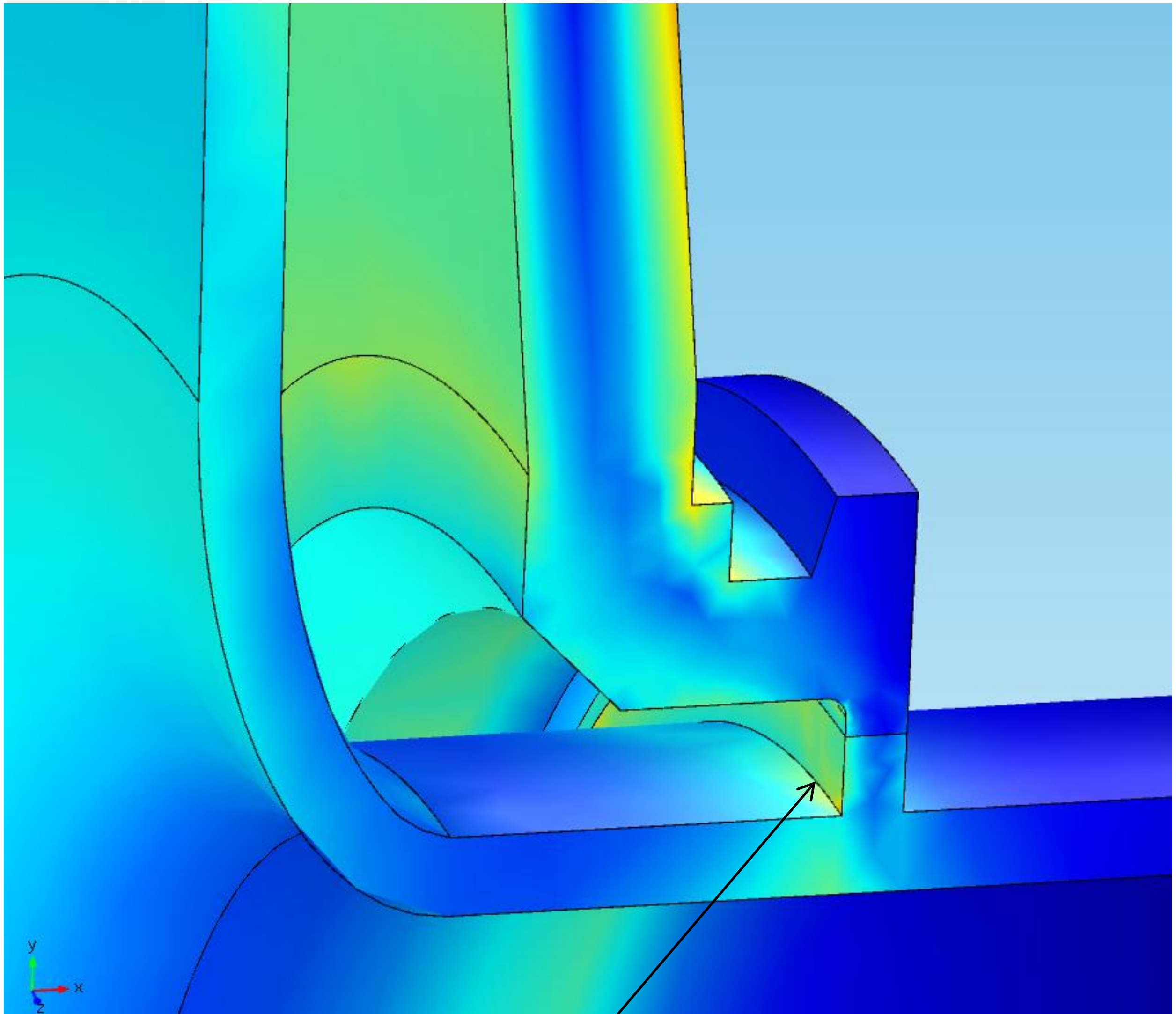


σ_{max} ~ 63MPa/66MPa (4mm/3.7mm)



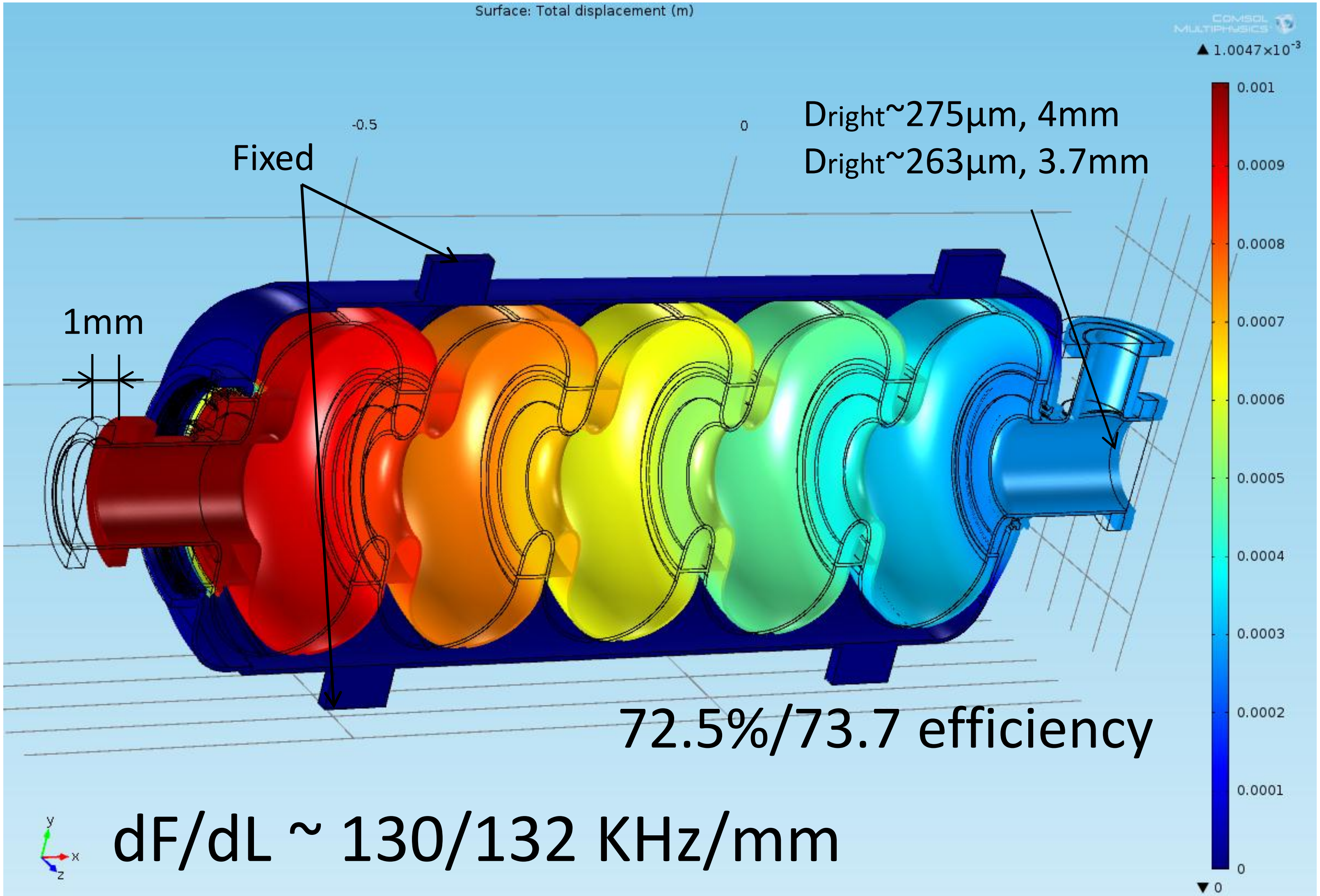
σ_{max} ~ 3/4.5MPa (4mm/3.7mm)

CAVITY BOTH ENDS MODIFIED, NO STIFFNESS



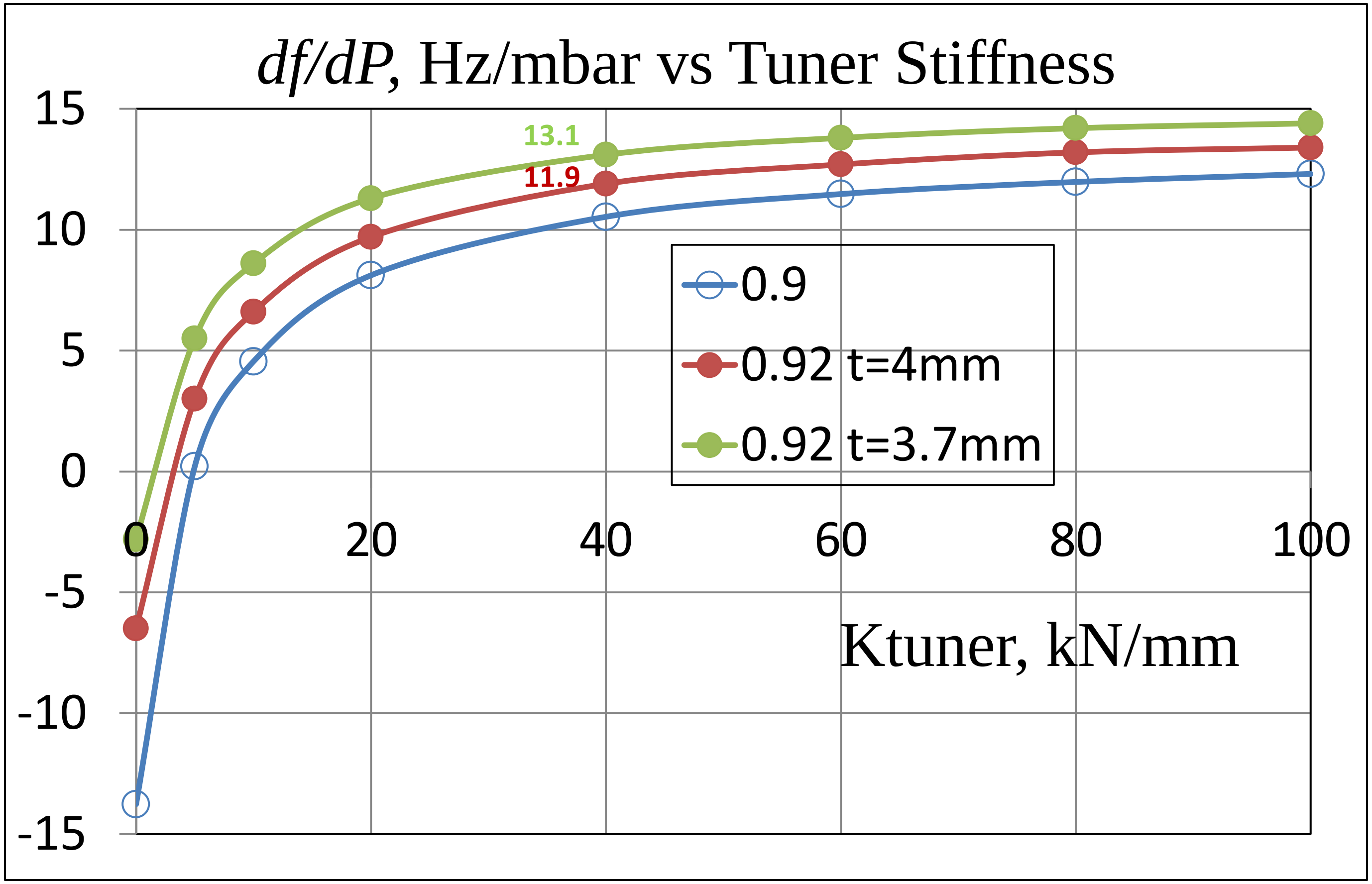
σ_{max} ~ 13MPa t=3.7mm)

Tuning: Efficiency and dF/dL β=0.92 T=4 vs. 3.7mm



TOTAL F=6.4/6.0kN applied, Field flatness ~1.5%

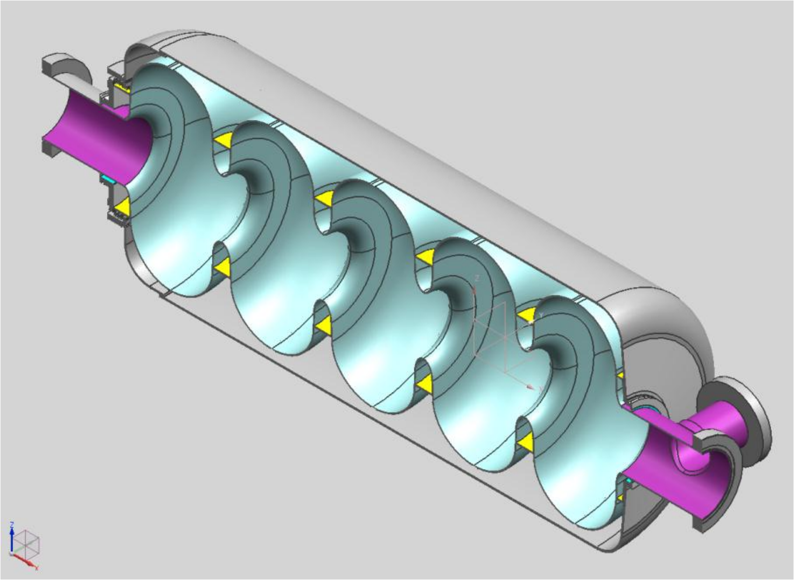
df/dP vs. Tuner Stiffnes, new helium vessel design

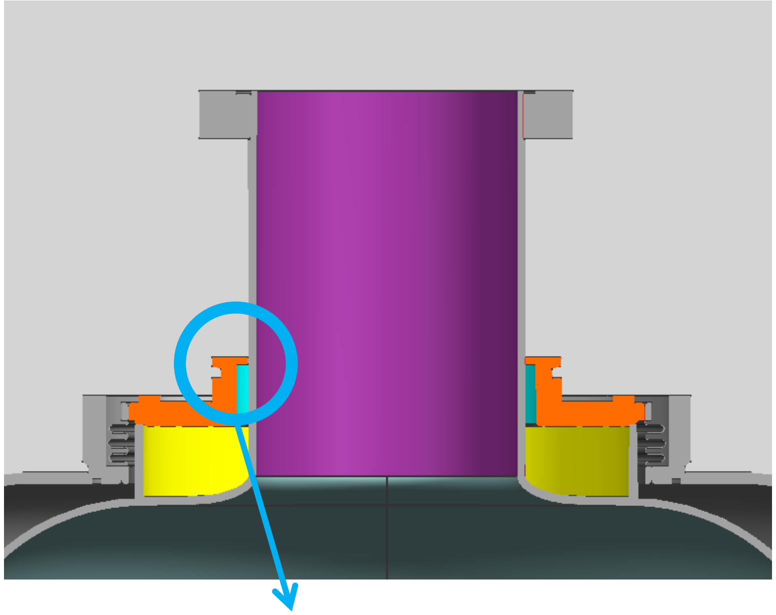


Modern cryogenic systems achieve rms pressure stability ~0.2 mbar → df/dP < 3Hz

Updated Model

Changes with respect to the model presented on Wednesday 8/7:
- Niobium 3.7 mm
- Welding Nb to Ti-45Nb at the bellow side





- Linear structural analyses to update the stress results in the "new" model
- Welding verification

Analyses Performed:

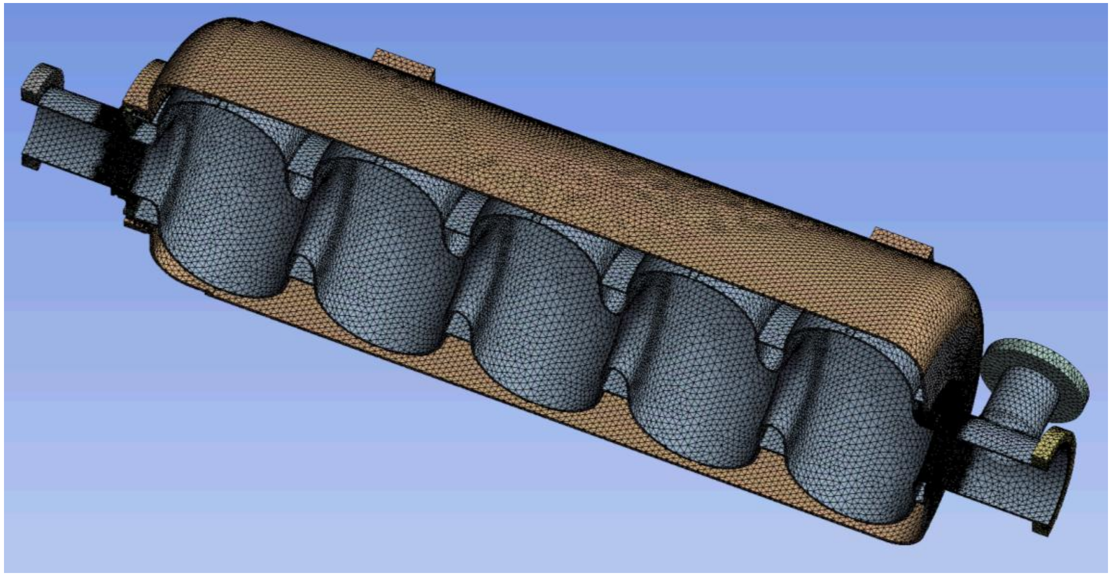
- Pressure and self weight of the system @ RT
- Pressure, self weight of the system and tuner displacement 1 mm@ RT
- Cooldown, pressure and self weight of the system @ CT
- Cooldown, pressure, self weight of the system and tuner displacement @ CT

Niobium						
	E [GPa]	Yield [MPa]	Ultimate [MPa]	Int th contr 293 K - 1.88 K	Poisson Ratio	Allowable Stress [MPa]
293 K	104.8	38	114		0.38	**25**
1.88 K	104.8	317	600	0.0014	0.38	**127**

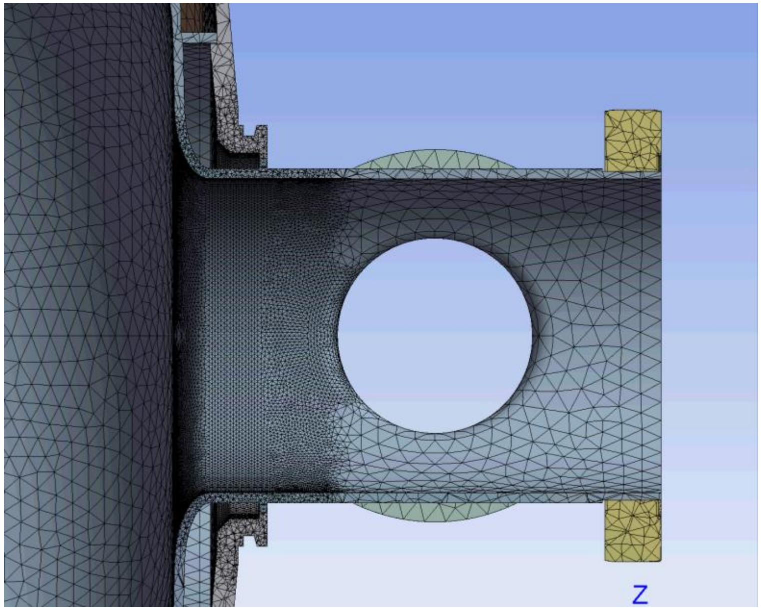
Ti-45Nb						
	E [GPa]	Yield [MPa]	Ultimate [MPa]	th contr 293 K - 1.88 K	Poisson Ratio	Allowable Stress [MPa]
293 K	62	475	N/A		0.347	**316**
1.88 K	62	544	N/A	0.0019	0.347	**362**

Ti grade 2						
	E [GPa]	Yield [MPa]	Ultimate [MPa]	th contr 293 K - 1.88 K	poisson ratio	Allowable Stress [MPa]
293 K	106.8	275	344		0.32	**98**
1.88 K	106.8	834	1116	0.0015	0.32	**318**

Finite Element Model



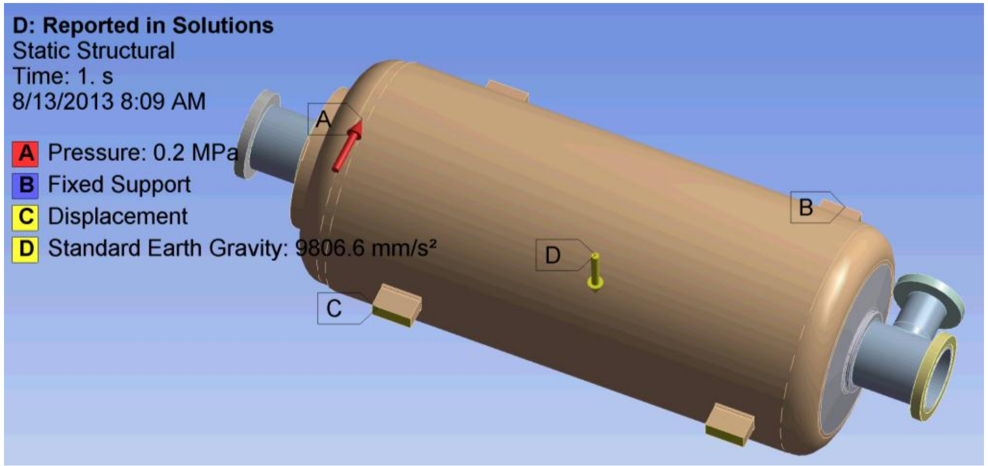
Number of elements $\approx 10^6$



Mesh Refined in the contact region where welds needed to be checked

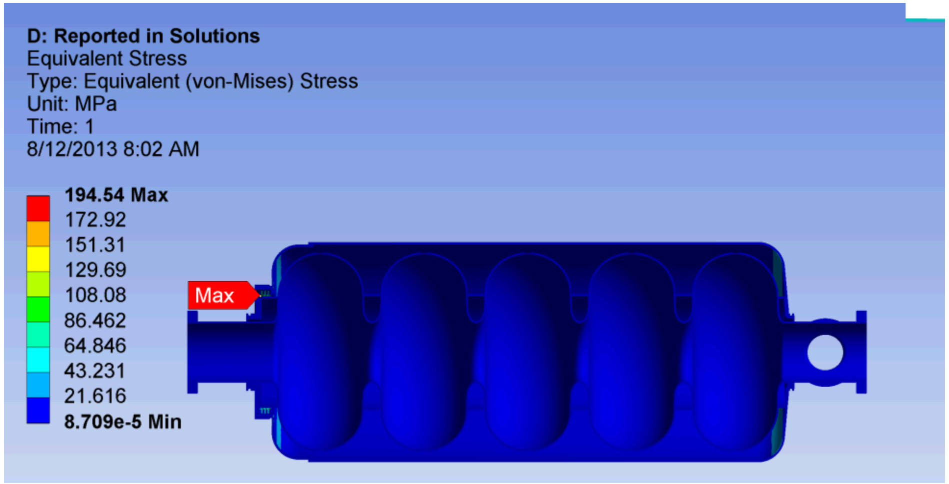
2 bar pressure and weight of the system @ RT

Loads And Boundary Conditions



- 2 bar pressure
- Acceleration of gravity

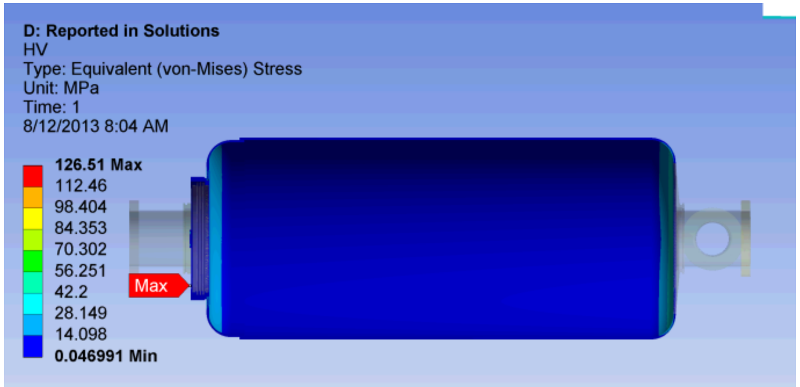
Von Mises Stress Plot



Equivalent Stress in each component below the yield limit of the material

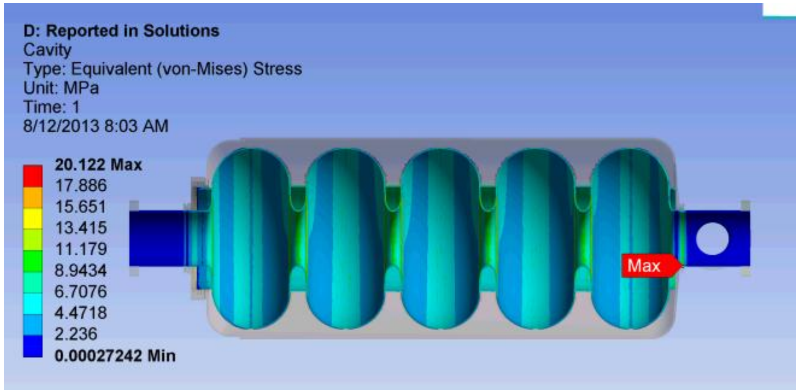
Von Mises Stress Plot for each material and component

Ti – Helium Vessel



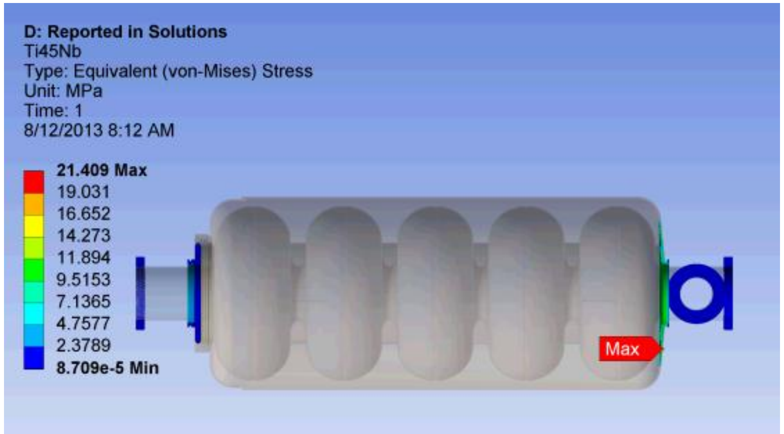
$$\sigma_{Ti} < 275\ MPa$$ ✓

Niobium – Cavity



$$\sigma_{Nb} < 38\ MPa$$ ✓

Ti-45Nb – 'Transition Elements'

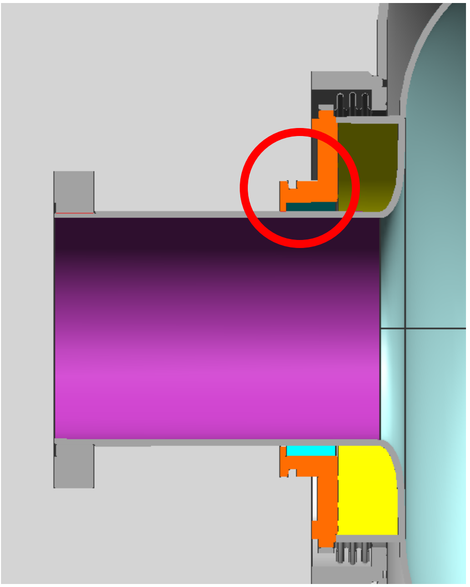


$$\sigma_{Ti} < 475\ MPa$$ ✓

Welds Proposed

Pressure and weight of the system @ RT

Weld Bellow Side



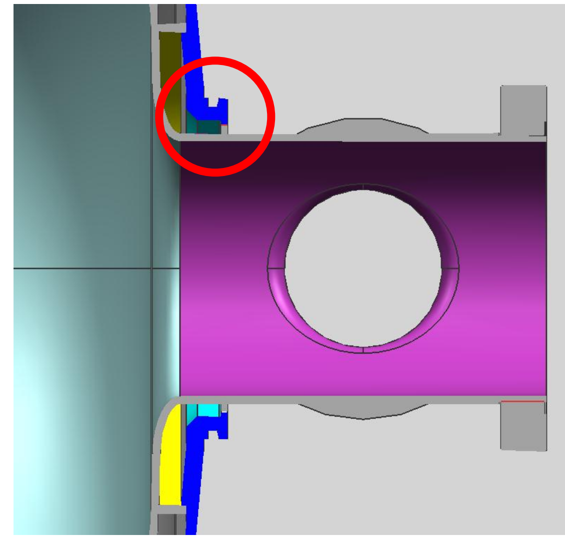
Weld Efficiency ε 0.65
Allowable Stress of Nb @ RT: 16 MPa
Allowable Stress of Ti-45Nb @ RT: 316 MPa

Material	s 1 [MPa]	s 2 [MPa]	s 3 [MPa]	s tot [MPa]	S x ε [MPa]	Eff stot/(4Sε)
Nb	16	8	7	31	16	0.469
Ti-45Nb	14	6	3	23	205	0.028

Part 5, Div 2 – Local Analyses

$$\sigma_1 + \sigma_2 + \sigma_3 < 4\sigma_{all}\varepsilon$$

Weld Ring Side

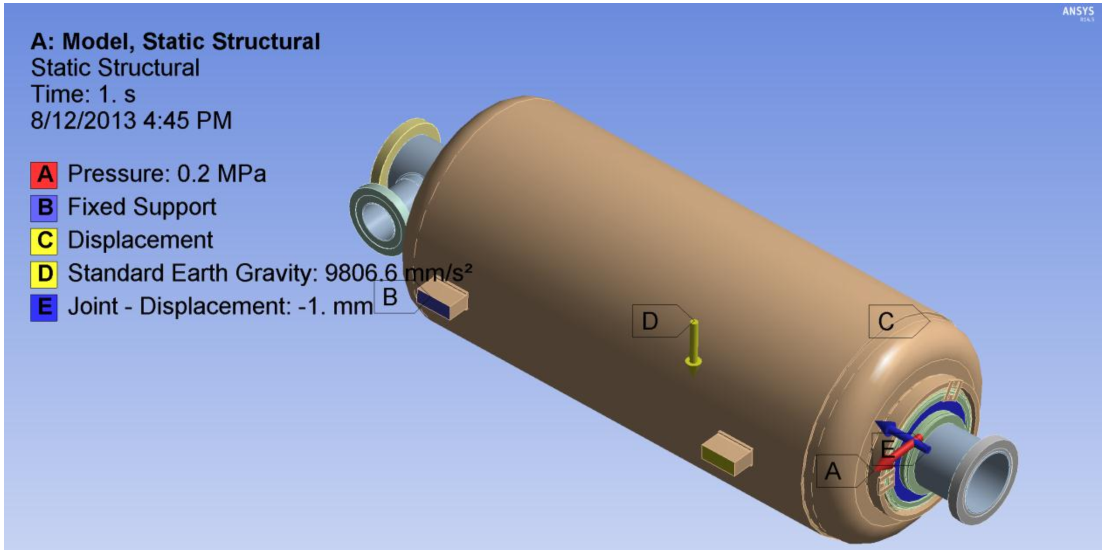


Weld Efficiency ε 0.65
Allowable Stress of Nb @ RT: 16 MPa
Allowable Stress of Ti-45Nb @ RT: 316 MPa

Material	s 1 [MPa]	s 2 [MPa]	s 3 [MPa]	s tot [MPa]	4S x ε [MPa]	Eff stot/(4Sε)
Nb	14	10	0	24	16	0.369
Ti-45Nb	13	8	1	22	205	0.026

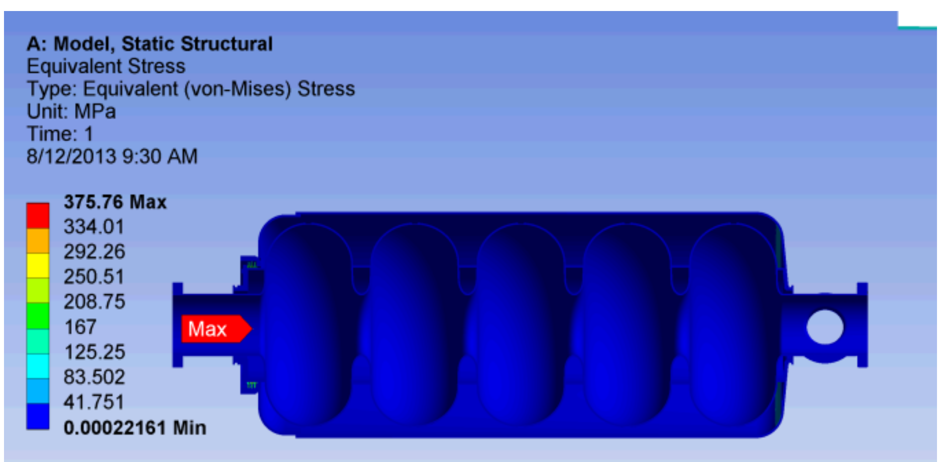
2 bar pressure, weight of the system and tuner displacement of 1 mm@ RT

Loads And Boundary Conditions



- 2 bar pressure
- Acceleration of gravity
- Tuner displacement: 1mm

Von Mises Stress Plot



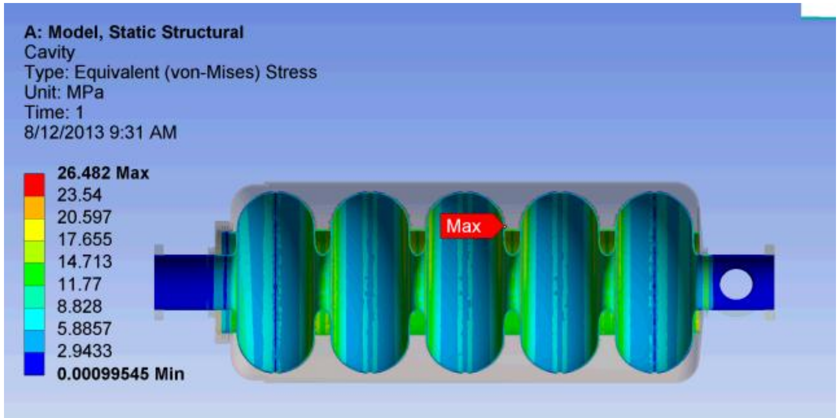
Equivalent Stress in each component below the yield limit of the material

Von Mises Stress Plot for each material and component

Ti – Helium Vessel

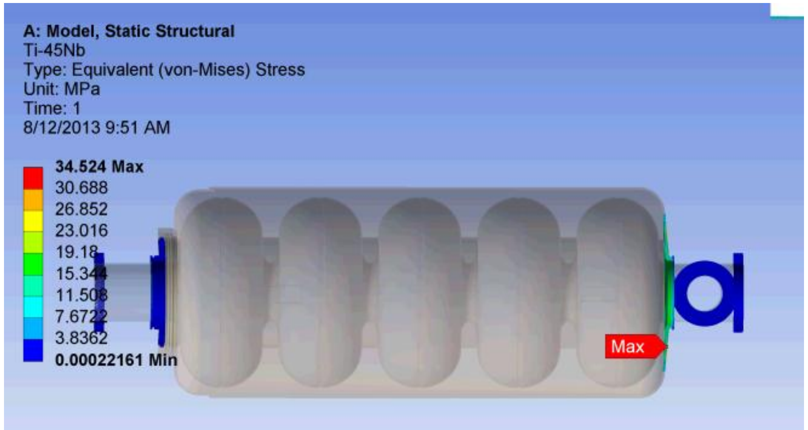
$$\sigma_{Ti} < 275\ MPa$$

Niobium – Cavity



$$\sigma_{Nb} < 38\ MPa$$

Ti-45Nb – 'Transition Elements'

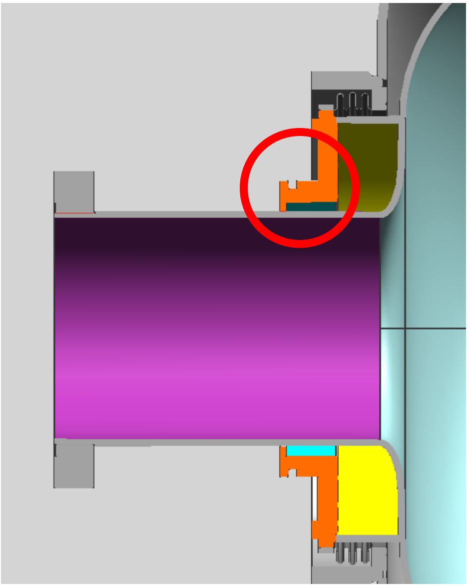


$$\sigma_{Ti} < 475\ MPa$$

Welds Proposed

Pressure, weight and tuner @ RT

Weld Bellow Side



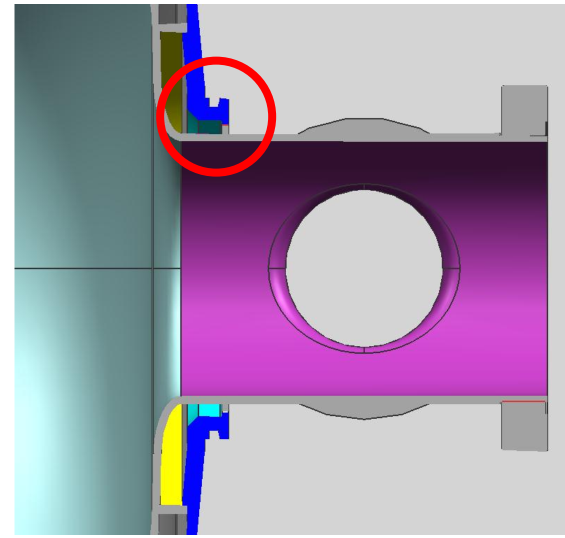
Part 5, Div 2 – Local Analyses

$$\sigma_1 + \sigma_2 + \sigma_3 < 4\sigma_{all}\varepsilon$$

Weld Efficiency ε 0.65
Allowable Stress of Nb @ RT: 16 MPa
Allowable Stress of Ti-45Nb @ RT: 316 MPa

Material	s 1 [MPa]	s 2 [MPa]	s 3 [MPa]	s tot [MPa]	S x ε [MPa]	Eff stot/(4Sε)
Nb	14	6	5	25	16	0.39
Ti-45Nb	13	5	3	21	205	0.03

Weld Ring Side

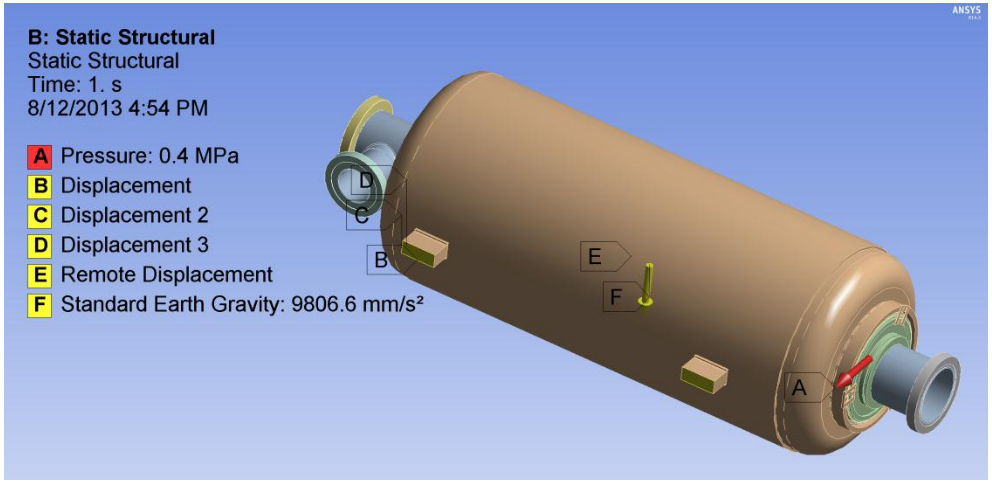


Weld Efficiency ε 0.65
Allowable Stress of Nb @ RT: 16 MPa
Allowable Stress of Ti-45Nb @ RT: 316 MPa

Material	s 1 [MPa]	s 2 [MPa]	s 3 [MPa]	s tot [MPa]	S x E [MPa]	Eff stot/(4Sε)
Nb	20	14	-1	33	16	0.51
Ti-45Nb	18	11	1	30	205	0.04

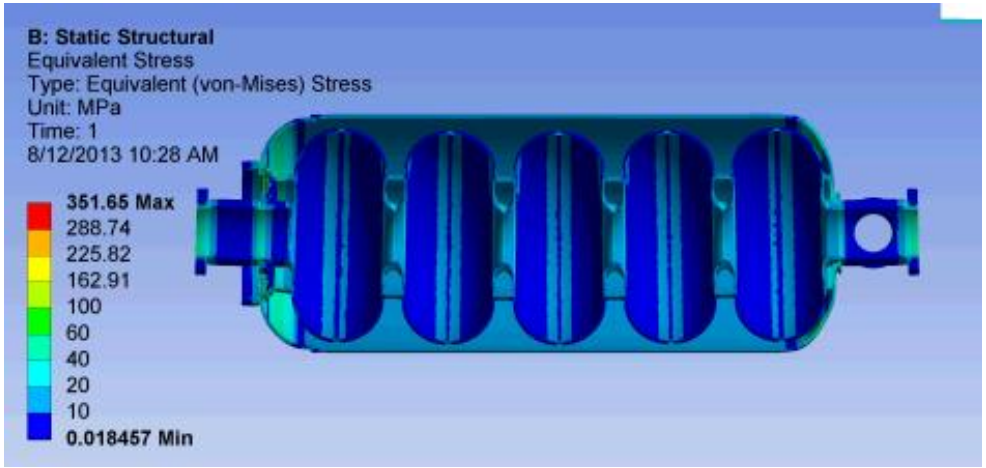
Cooldown, 4 bar pressure and weight of the system @ CT

Loads And Boundary Conditions



- Cooldown to 2 K
- 4 bar pressure
- Acceleration of gravity

Von Mises Stress Plot

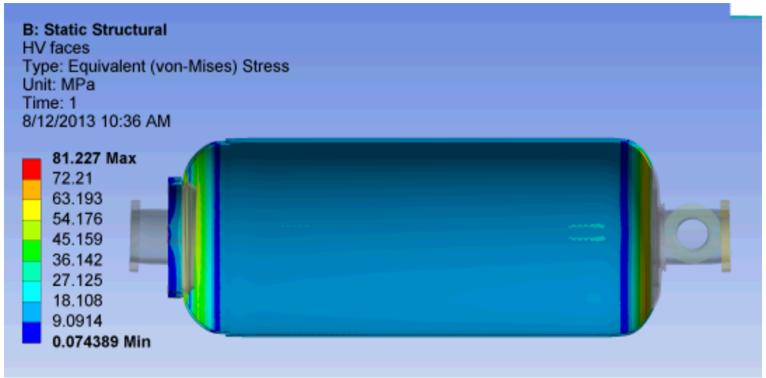


✓

Equivalent Stress in each component below the yield limit of the material

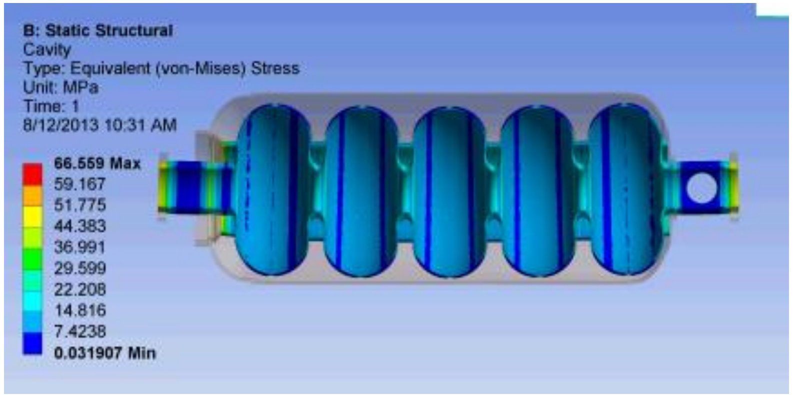
Von Mises Stress Plot for each material and component

Ti – Helium Vessel



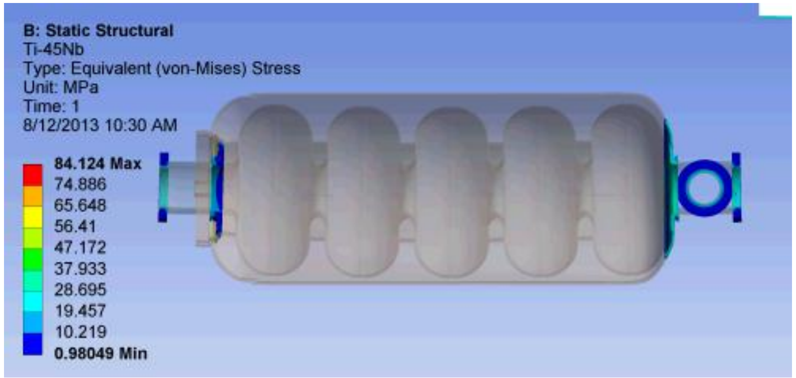
$\sigma_{Ti} < 834\ MPa$

Niobium – Cavity



$\sigma_{Nb} < 317\ MPa$

Ti-45Nb – 'Transition Elements'

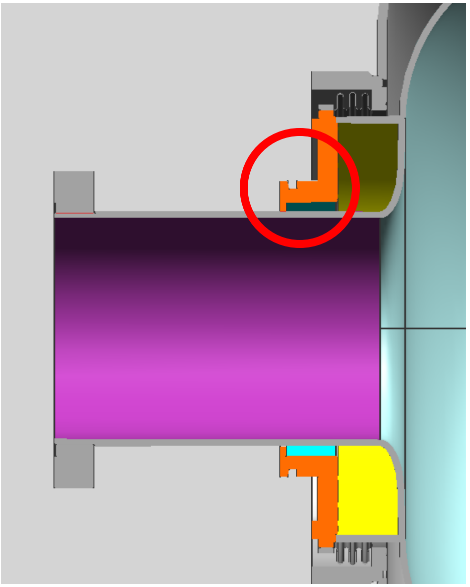


$\sigma_{Ti} < 544\ MPa$

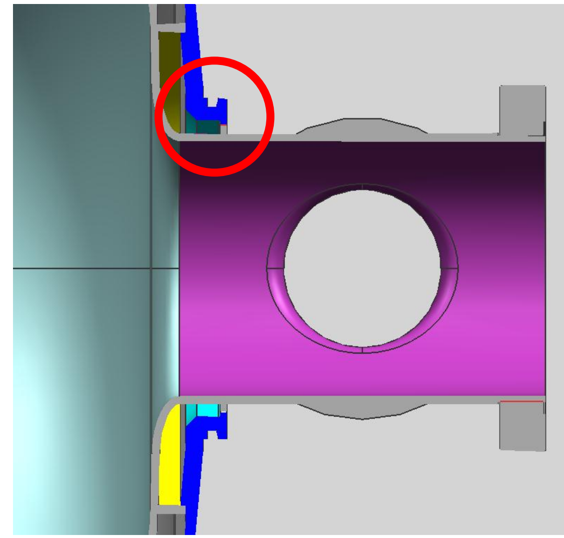
Welds Proposed

Cooldown, pressure and weight @ CT

Weld Bellow Side



Weld Ring Side



Part 5, Div 2 – Local Analyses

$$\sigma_1 + \sigma_2 + \sigma_3 < 4\sigma_{all}\varepsilon$$

Weld Bellow Side

Weld Efficiency ε	0.65
Allowable Stress of Nb @ RT:	127 MPa
Allowable Stress of Ti-45Nb @ RT:	362 MPa

Material	s 1 [MPa]	s 2 [MPa]	s 3 [MPa]	s tot [MPa]	S x ε [MPa]	Eff stot/(4Sε)
Nb	16	5	0	21	83	0.06
Ti-45Nb	24	23	-3	44	235	0.05

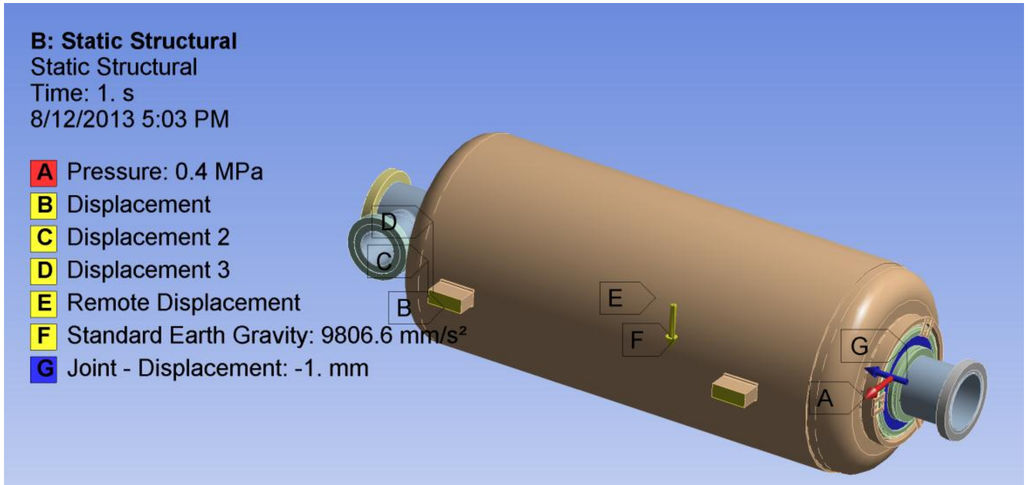
Weld Ring Side

Weld Efficiency ε	0.65
Allowable Stress of Nb @ RT:	127 MPa
Allowable Stress of Ti-45Nb @ RT:	362 MPa

Material	s 1 [MPa]	s 2 [MPa]	s 3 [MPa]	s tot [MPa]	S x E [MPa]	Eff stot/(4Sε)
Nb	18	-14	-16	-12	83	0.04
Ti-45Nb	33	31	0	64	235	0.07

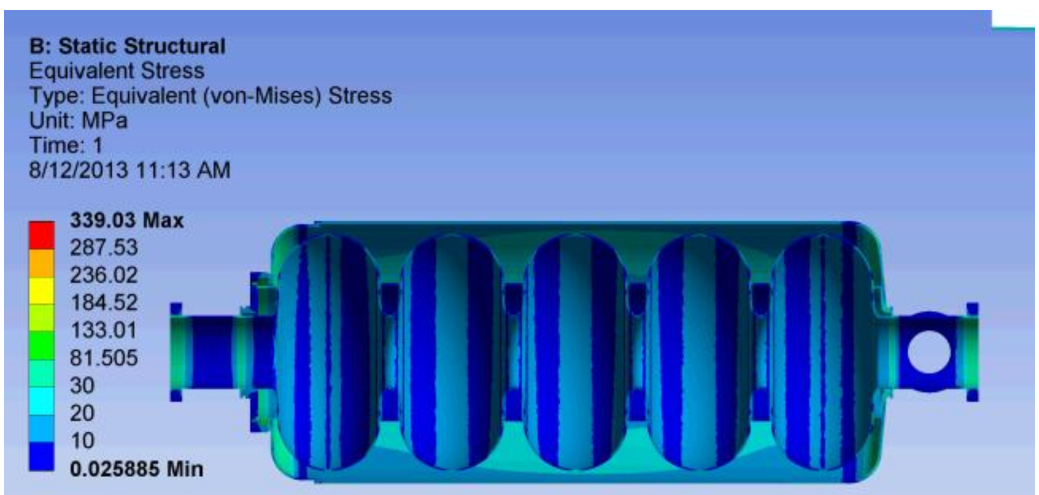
Cooldown, 4 bar pressure, weight of the system and tuner displacement of 1 mm @ CT

Loads And Boundary Conditions



- Cooldown to 2 K
- 4 bar pressure
- Acceleration of gravity
- Tuner displacement of 1 mm

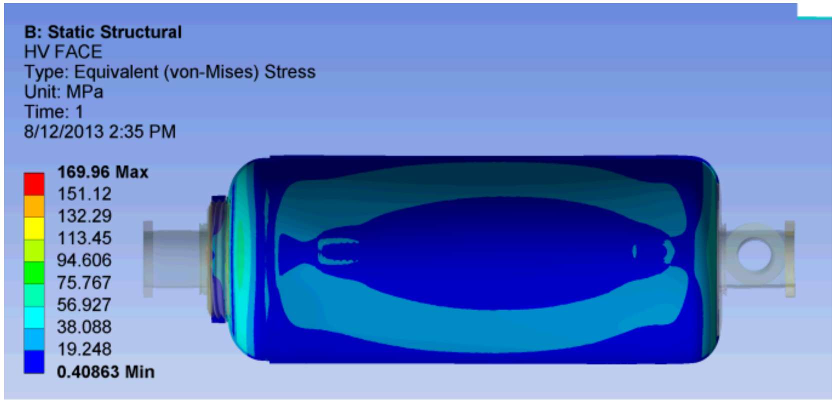
Von Mises Stress Plot



Equivalent Stress in each component below the yield limit of the material

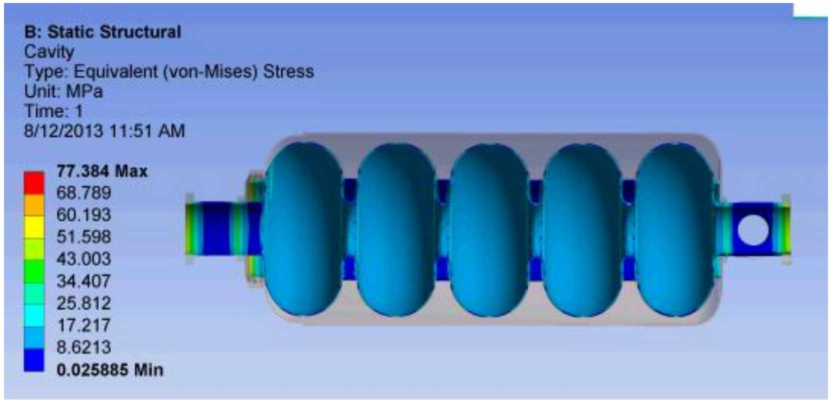
Von Mises Stress Plot for each material and component

Ti – Helium Vessel



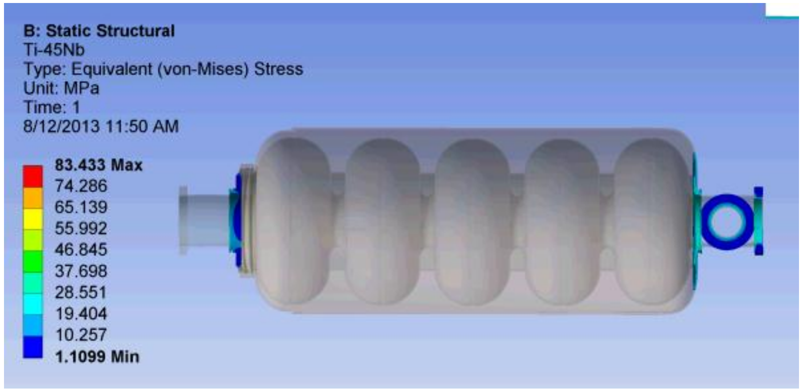
$\sigma_{Ti} < 834\ MPa$ ✓

Niobium – Cavity



$\sigma_{Nb} < 317\ MPa$ ✓

Ti-45Nb – 'Transition Elements'



$\sigma_{Ti} < 544\ MPa$ ✓

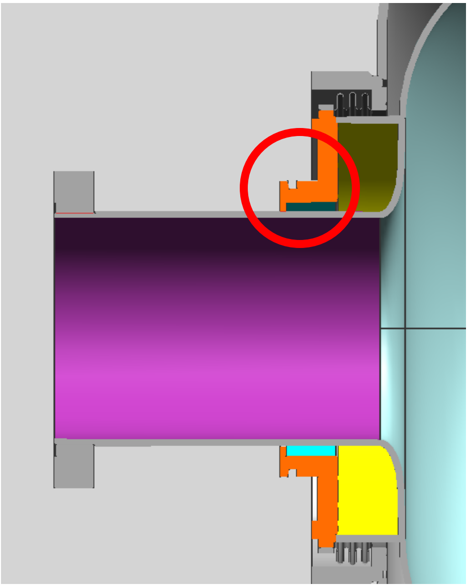
Welds Proposed

Cooldown, pressure, weight and tuner @ CT

Part 5, Div 2 – Local Analyses

$$\sigma_1 + \sigma_2 + \sigma_3 < 4\sigma_{all}\varepsilon$$

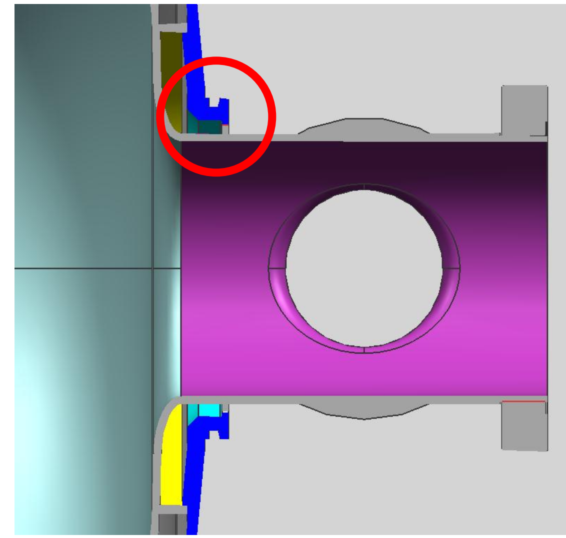
Weld Bellow Side



Weld Efficiency ε 0.65
Allowable Stress of Nb @ RT: 127 MPa
Allowable Stress of Ti-45Nb @ RT: 362 MPa

Material	s 1 [MPa]	s 2 [MPa]	s 3 [MPa]	s tot [MPa]	S x ε [MPa]	Eff stot/(4Sε)
Nb	-21	-50.6	-56.3	-127.9	2064	0.015
Ti-45Nb	27	25	-1.2	50.8	5883	0.002

Weld Ring Side



Weld Efficiency ε 0.65
Allowable Stress of Nb @ RT: 127 MPa
Allowable Stress of Ti-45Nb @ RT: 362 MPa

Material	s 1 [MPa]	s 2 [MPa]	s 3 [MPa]	s tot [MPa]	S x E [MPa]	Eff stot/(4Sε)
Nb	13.3	-15.8	-19	-21.5	2064	0.003
Ti-45Nb	31	30	-1.2	59.8	5883	0.003

…… Summing up ……

Pressure and self weight of the system @ RT

- Von Mises Stresses Below the yield ✓
- Welds ✓

Pressure, self weight of the system and tuner displacement 1 mm@ RT

- Von Mises Stresses Below the yield ✓
- Welds ✓

Cooldown, pressure and self weight of the system @ CT

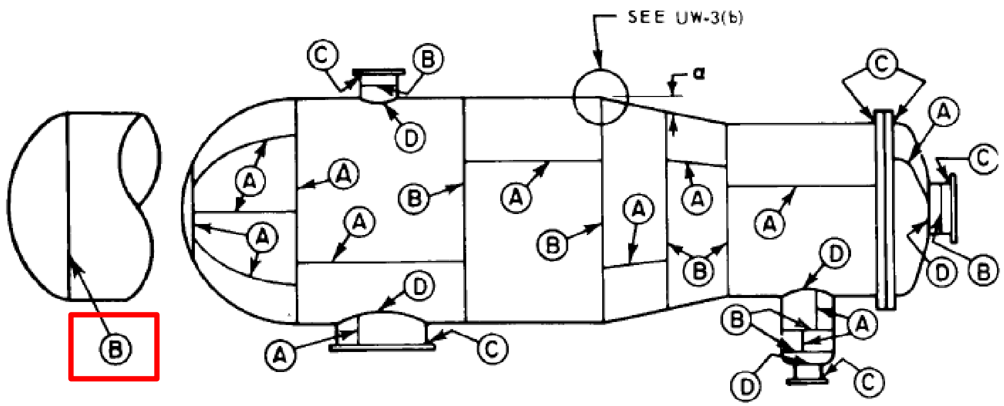
- Von Mises Stresses Below the yield ✓
- Welds ✓

Cooldown, pressure, self weight of the system and tuner displacement @ CT

- Von Mises Stresses Below the yield ✓
- Welds ✓

Observation on ASME Code on Welds. Div 1 – Part UW

FIG. UW-3 ILLUSTRATION OF WELDED JOINT LOCATIONS TYPICAL OF CATEGORIES A, B, C, AND D



07 TABLE UW-12
MAXIMUM ALLOWABLE JOINT EFFICIENCIES FOR ARC AND GAS WELDED JOINTS

Type No.	Joint Description	Limitations	Joint Category	Degree of Radiographic Examination (a) Full [Note (1)]	(b) Spot [Note (2)]	(c) None
(1)	Butt joints as attained by double-welding or by other means which will obtain the same quality of deposited weld metal on the inside and outside weld surfaces to agree with the requirements of UW-35. Welds using metal backing strips which remain in place are excluded.	None	A, B, C & D	1.00	0.85	0.70
(2)	Single-welded butt joint with backing strip other than those included under (1)	*(a)* None except as in (b) below	A, B, C & D	0.90	0.80	0.65
		(b) Circumferential butt joints with one plate offset; see UW-13(b)(4) and Fig. UW-13.1, sketch (i)	A, B & C	0.90	0.80	0.65