Engineering Department

LHC CRAB Cavity Measurements Meeting

Integration of the 4-Rod LHC CRAB cavity for RF measurements at 4.5K in SM18

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- Until now, two test environments are foreseen:
  - SM18 - test cryostat;
  - SPS;

All mechanical calculations done until now assess only this test environment

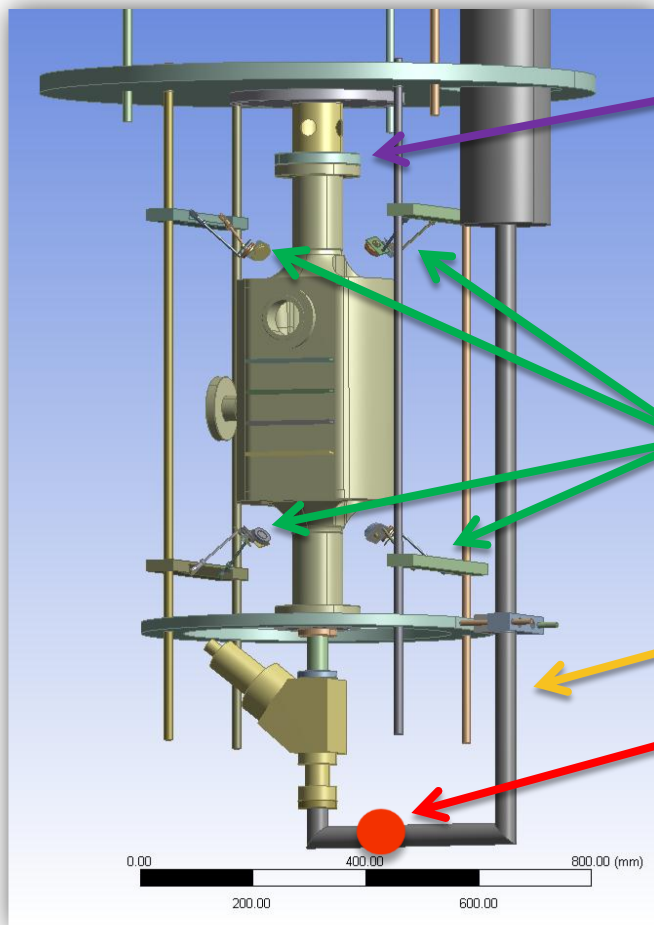
Table 1 – Pressure conditions for each test environment

Test environment	*Safety valve set-point*	*Maximum allowable pressure (PS)*	*Test pressure (1.43xPS)*
SM18 Test cryostat	1.5bar±0.15 *(abs)	1.5bar (abs)	2.1bar (abs)
SPS	1.8bar±0.15* (abs)	1.8bar (abs)	2.6 bar (abs)

*This tolerance for the set pressure of safety valves is defined by EN ISO 4126-1

Cryostat for 4.5K RF Measurements in SM18
-Design & Materials-

Cryostat for 4.5K RF Measurements in SM18 -Design-



Fixed extremity (bolted)

Quench detectors

Vacuum line

Bellow (not shown)

Integration of prototype cavity for test in SM18

Cryostat for 4.5K RF Measurements in SM18 -Materials-

- Materials:
  - Cavity body: unalloyed Niobium
  - Connections: AISI 300-Series Stainless Steel (flanges in AISI 316LN)

Typical physical and mechanical properties:

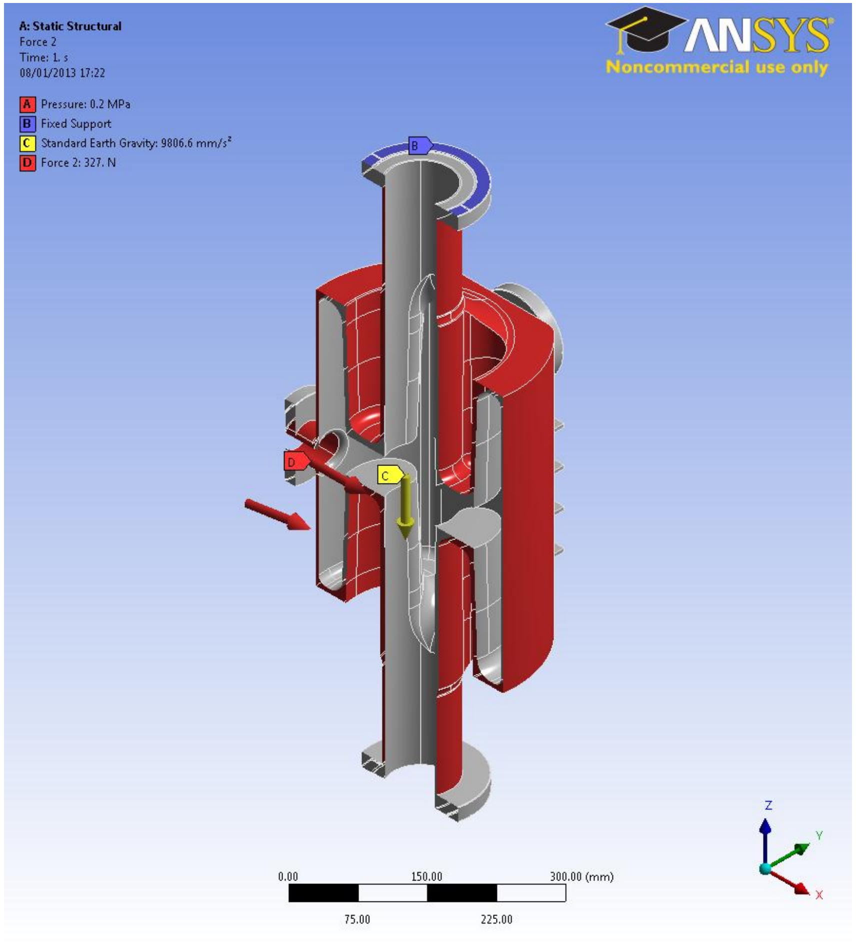
*Physical and mechanical properties of unalloyed Niobium at room temperature** *-Reactor grade Type 1, UNS R04200-*				
Density (kg/m^3)	Young's modulus (GPa)	Poisson's ratio	Yield strength $RP_{0.2}$ (MPa)	Max allowable stress $RP_{0.2}/SF$ (MPa)
8600	100	0.4	75	70
Stainless steel AISI 316LN (1.4429 – round bar)**				
8000	200	0.3	$RP_{1.0}$ =315MPa	$RP_{1.0}/SF$=300MPa

*Data from GRANTA'S CES Selector 2012 Database
**Data from EN 10088-1 Annex A, EN 13155-3 Annex O, EN 10021:2006, EN 10088-3:2005

Cryostat for 4.5K RF Measurements in SM18
-Calculations-

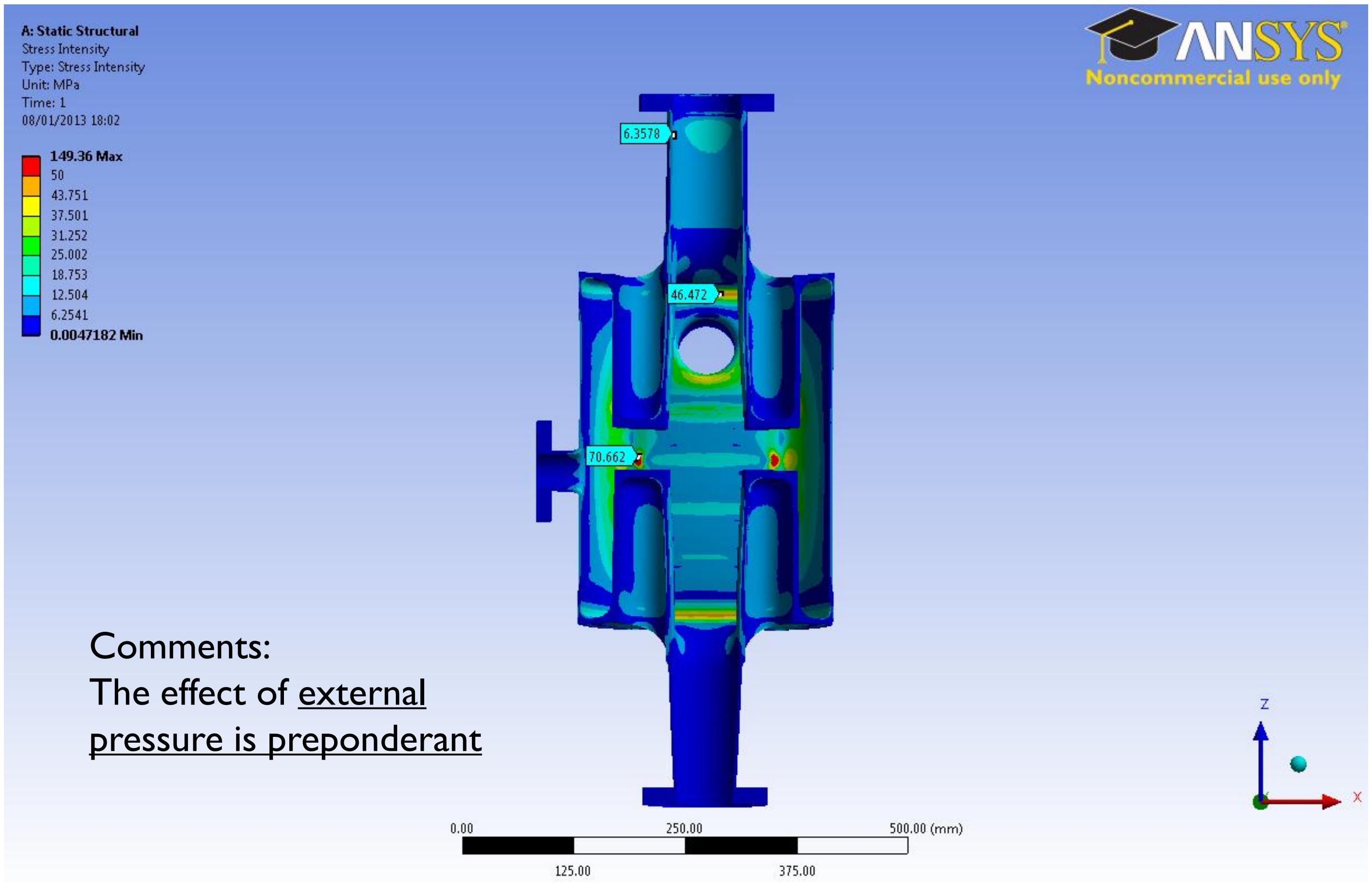
Cryostat for 4.5K RF Measurements in SM18 -Calculations-

- **Assumptions:**
  - Stainless Steel (SS) flanges perfectly bonded to cavity body
- **Boundary conditions:**
  - External pressure: 0.2MPa
  - Self-weight
  - Hold by top flange
  - Compensation of non-symmetry with external force of 327N (D)
- **Material model:**
  - Elastic, Isotropic (see slide 6)



Cryostat for 4.5K RF Measurements in SM18 -Calculations-

- ## Results:
  - Stress intensity plot



Comments:
The effect of <u>external pressure is preponderant</u>

Cryostat for 4.5K RF Measurements in SM18
-Calculations-

Additional effort: bellow on vacuum line

Cryostat for 4.5K RF Measurements in SM18 -Calculations-

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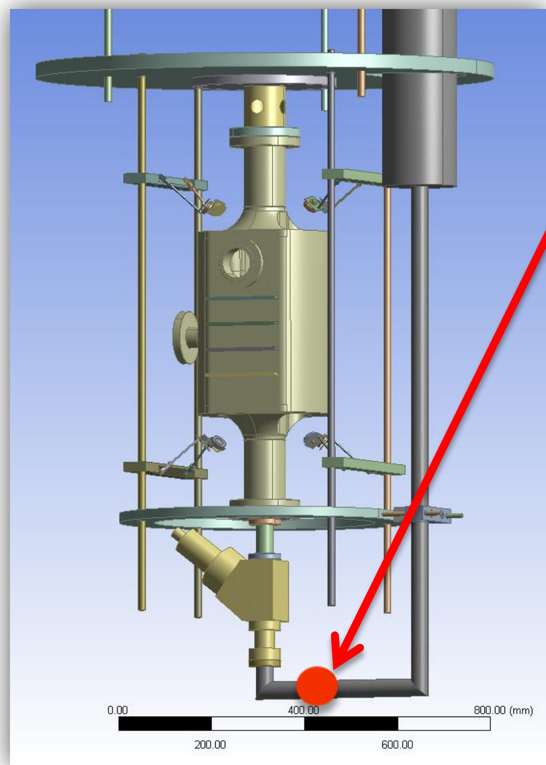


Integration of prototype cavity for test in SM18

Bellow (not shown)

Analytical calculations:

3/10/2012

CRYOSTAT P/ TESTER CAVITÉ CRAB/LHC

$\Delta P = 2$ bar   Soufflet: DN 40 $F = \frac{\pi \times 40^2}{4} \times 0,2 = 250N$

Distance entre brides ≈ 800 mm → $M = 200$ N.m

Section tube: $\phi_{ext} = 90$ mm → $c = \phi_{ext}/2 = 45$ mm; $\phi_{int} = 84$ mm

$$I = \frac{1}{4}\pi \left(r_{ext}^4 - r_{int}^4 \right) = 776,7 \times 10^3 \text{ mm}^4$$

$$\sigma_{adm} = \frac{M \times c}{I} \rightarrow \sigma_{max} = \frac{200 \times 10^3 \text{ N.mm} \times 45 \text{ mm}}{776,7 \times 10^3 \text{ mm}^4} = 12 \text{ MPa}$$

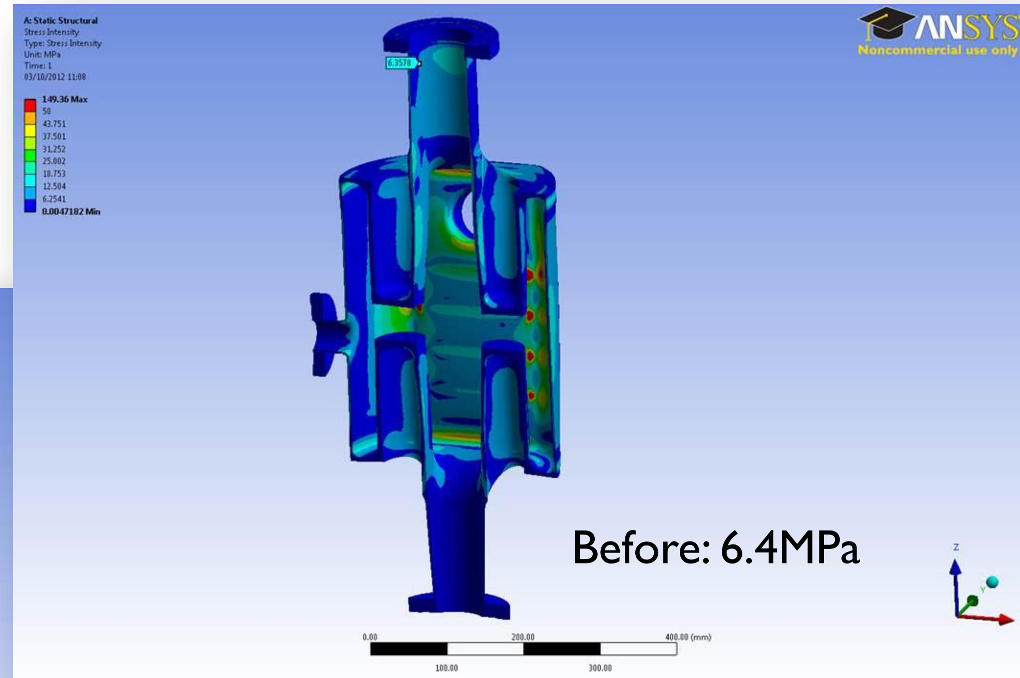
$$\tau_{max} = \frac{250}{\frac{\pi}{4}\left(90^2 - 84^2\right)} = 0,3 \text{ MPa}$$

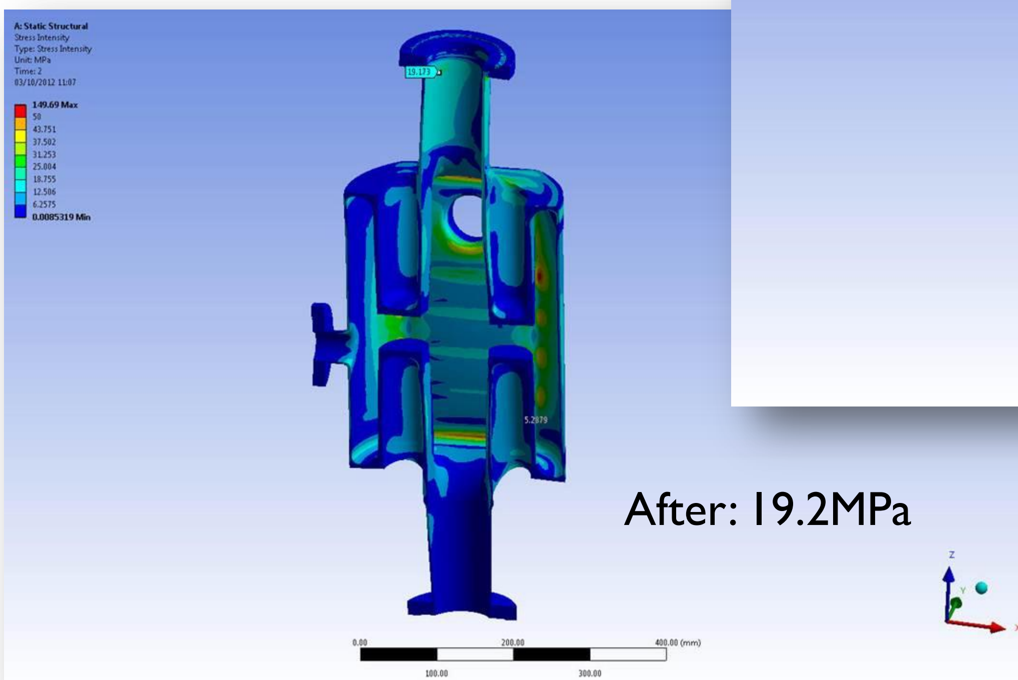
Normal stress increase due to isolated effort: 12MPa

Cryostat for 4.5K RF Measurements in SM18 -Calculations-

- Additional effort: bellow on vacuum line

Validation with a FE model:



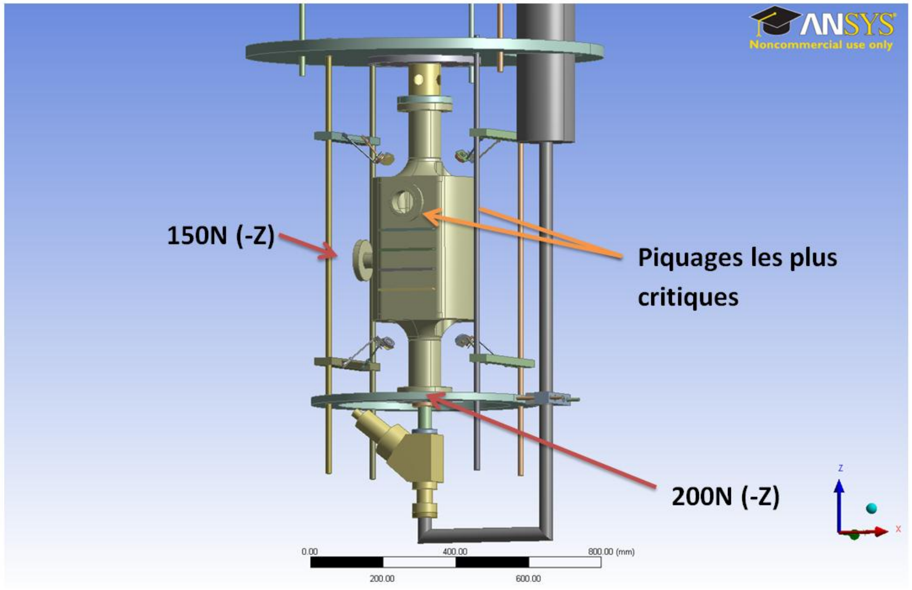


Effect due to isolated effort:
12.8MPa (validates analytical result)

Comments

First design: comments

- Comments
  - The effect of the external pressure of 0.2MPa is preponderant for the structural strength;
  - The cavity is expected to withstand the foreseen integration design;
  - Additionally, it is also expected to withstand the additional force coming from the bellow in series with the vacuum line;
  - Moreover, this design was found out to have enough strength to tolerate the following additional loads->



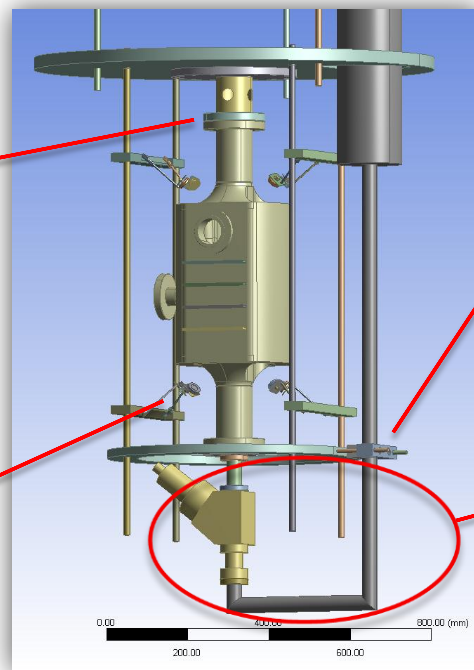
Final note: natural vibration modes can be triggered at low frequency…

Limitations and modifications being studied

- The following limitations were pointed out by the first tests:

Coupled load bearing / leak tightness interface: Bending efforts not compensated by the copper joint may have been in the origin of the observed leak…

Insufficient support for acoustic detectors?



Integration of prototype cavity for test in SM18

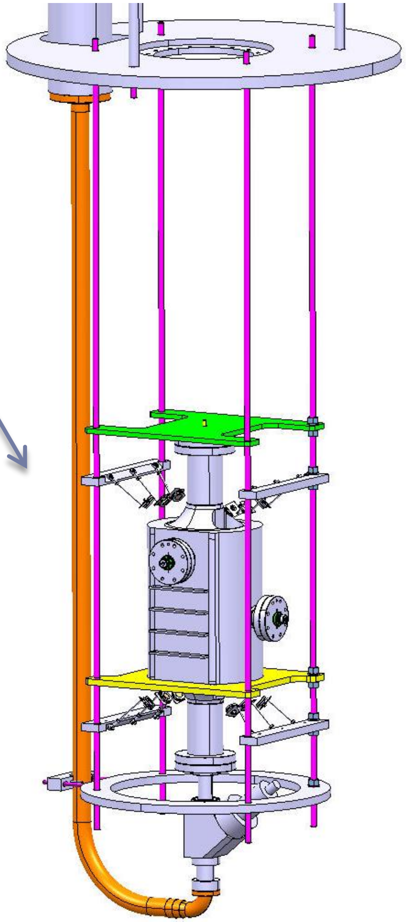
Over-constrained system not allowing significant adjustment

The position of the vacuum line coming from the top didn't allow to position correctly the vacuum valve: the in-line bellow was installed with significant deformation in order to compensate this positioning defect

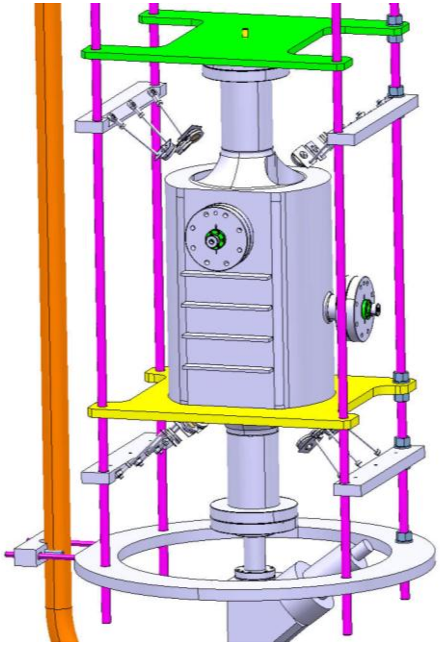
Modifications being studied

- The following upgrades are being studied:

Vacuum supplied through long metallic flexible (minimizes efforts, increases versatility)



Support system:
- Decoupling of structural/leak tightness boundaries;
- Fixed-sliding extremities allowing free expansion/contraction



Next:
Do acoustic detectors holding system need improvements?

Thank you for your attention