Design & Development of BI-TL-300 Equipment as a Type B(U) Transportation cask

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BI-TL-300 : Blood Irradiator –Tungsten Lead-300 ml of Blood

Irradiators:

A facility or an equipment containing sealed radioactive sources and associated systems used for delivering a prescribed dose to a specific target in a preset time

CLASSIFICATION OF IRRADIATORS

IAEA Safety Series 107

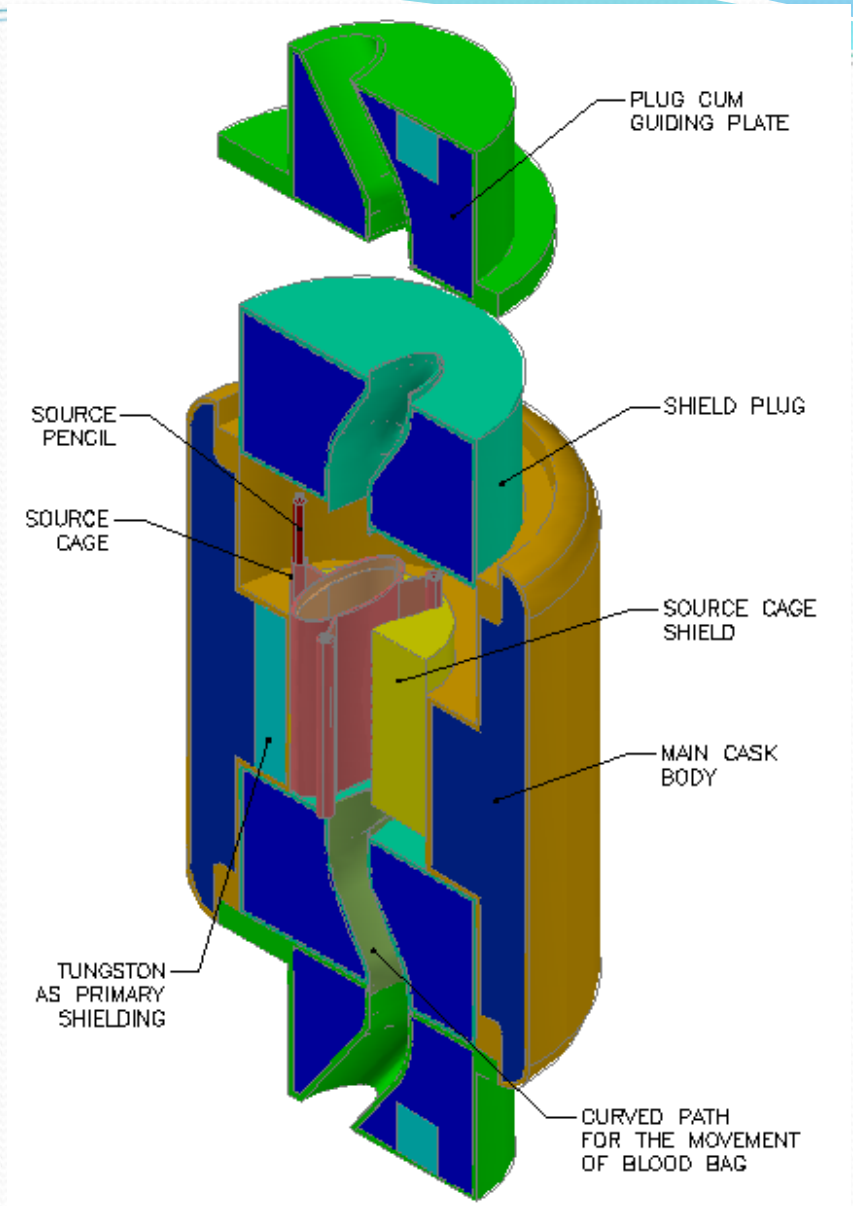
- Category I - Dry source storage
  no human access
- Category II - Dry source storage
  controlled human access
- Category III - Wet source storage
  no human access
- Category IV - Wet source storage
  controlled human access

Function of Blood Irradiator:

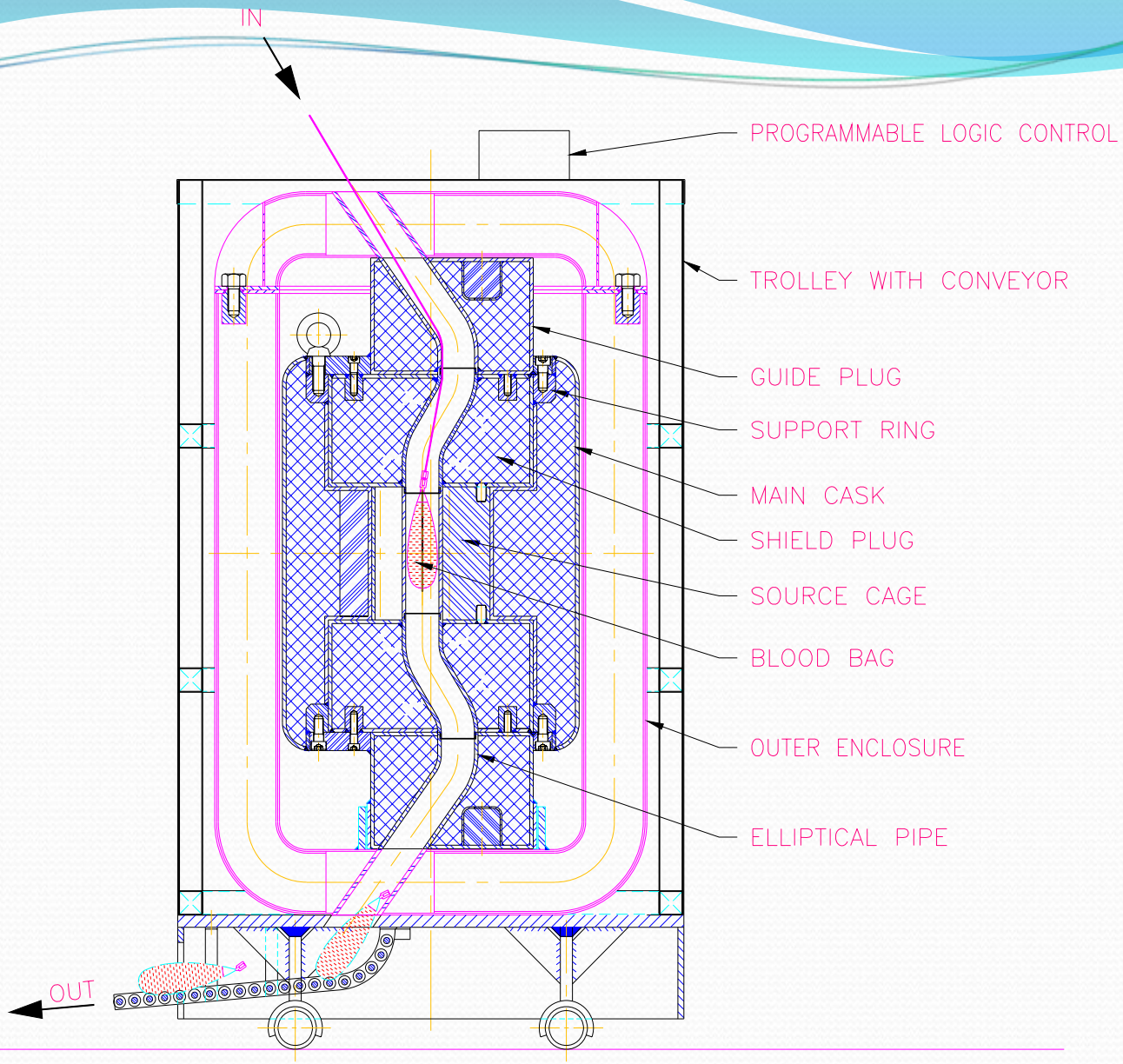
To Irradiate blood and its components to prevent Graft Vs Host disease in immune deficient patient

Purpose of the work:

To qualify the equipment as a Type B(U) transportation package



General Feature of the BI-TL-300



Sectional view of the BI-TL-300

Salient Features of the Blood Irradiator (BI-TL-300)

- Self shielded and safe
- Compact and light as Tungsten is used as primary shield
- Dose Uniformity Ratio
- Less mechanical components hence less maintenance
- PLC based automatic decay correction for accurate dose delivery
- Display of Irradiation temperature

Specification of the Package

Cask Overall Dimensions	ϕ 717 x 1185 (h) mm.
Weight of Package	1,760 Kg.
Weight of Lead in Package	1100 Kg.
Size of cavity of source	ϕ 196 x 218 (h) mm.
Cobalt-60 content	275 Ci (10.17 TBq)

Design Requirement Type B (U)

Irradiator(Category-I):

- 25Gy -30Gy Dose to Blood Bag
- 20mR/hr at the surface of the Irradiator

Shielding Requirement:

- 2mSv/hr at the surface of the cask
- 10mSv/hr at 1m from the surface after accident conditions

Structural Requirement:

Normal Conditions of Transport:

- Water spray test
- Free drop test
- Staking test for a period of 24 hr
- Penetration test

Accident Conditions of transport:

- Mechanical Tests
  - 9m drop test on unyielding target
  - 1m punch test
- Thermal Test
  - 800 °C Fire Test for 30 minutes
    - 15m Water Immersion Test for 8hrs

Codes Followed

Irradiators:

- IAEA Safety Series 107,1992
- IAEA Safety Series SSG-8, 2010, Radiation safety of Gamma, Electron, and X-ray irradiation facility
- ANSI-N- 47.3, Safe design and use of self contained dry source storage Gamma Irradiators.

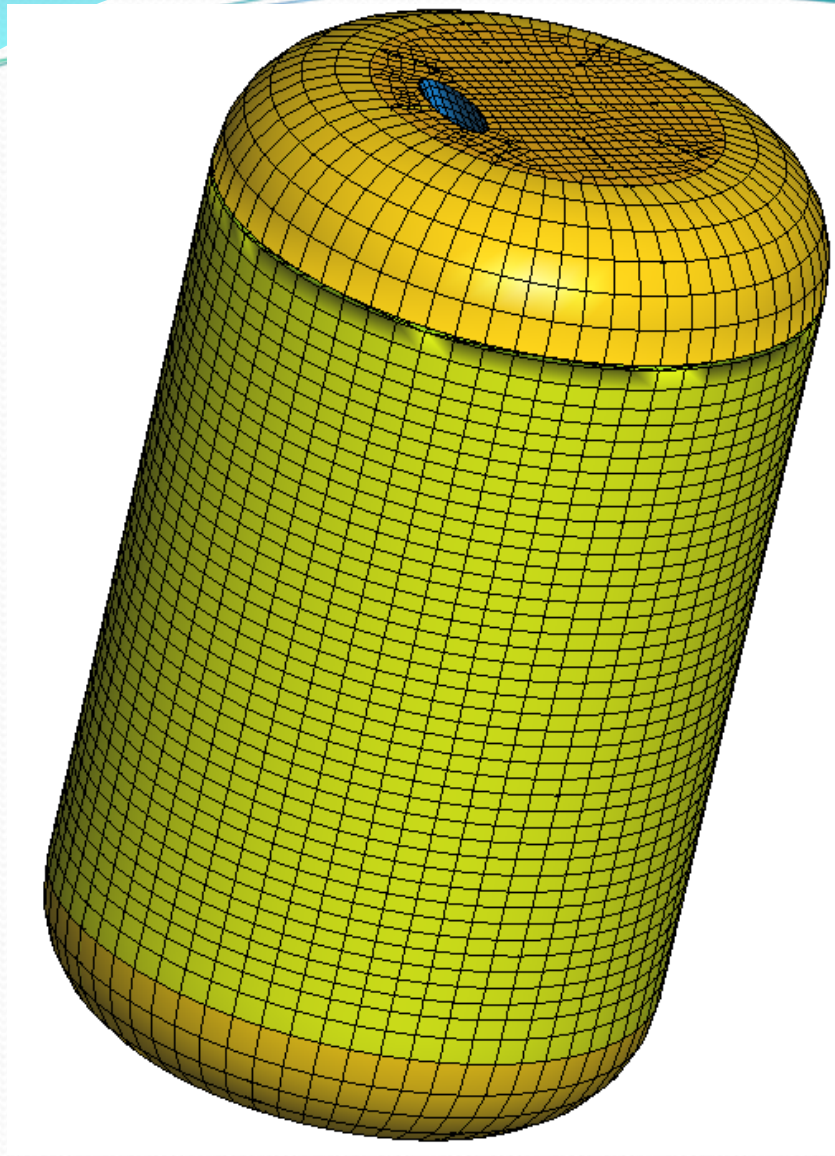
Transportation Cask

- IAEA Code TS-R-1, 2009, Safe transport of Radioactive material
- IAEA Code TS-G-1.1(Rev 1), 2008, Advisory material for the IAEA regulation for the safe transport of radioactive material
- AERB/Sc/TR-1, 1986, Safe transport of Radioactive material
- ASME, Sec III, Div 1, Appendix – F, Rules for Evaluation of Service Loadings with Level D Service Limits, 1994

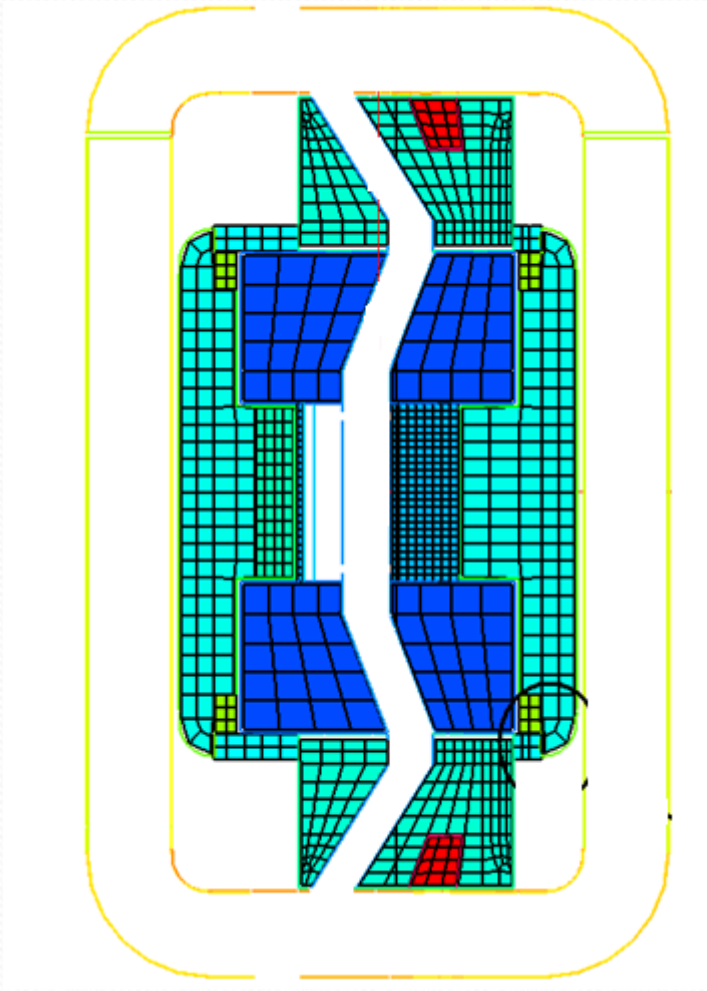
Finite Element Analysis:
Software Package used: A non linear FE code PAM-CRASH

Finite Element Model
Model: FEMAP v-8.0
Plates: 3D, 4 noded bilinear shell element
Lead: 8 noded 3D brick element
Tungsten: 8 noded 3D brick element
Bolts: One dimensional beam element

The Cask model consists of
45420 nodes
26910 shell elements
13692 solid elements
40 beam elements



FE Model of the cask with shock absorber



Sectional view of FE Model of the cask

Material properties used for analysis

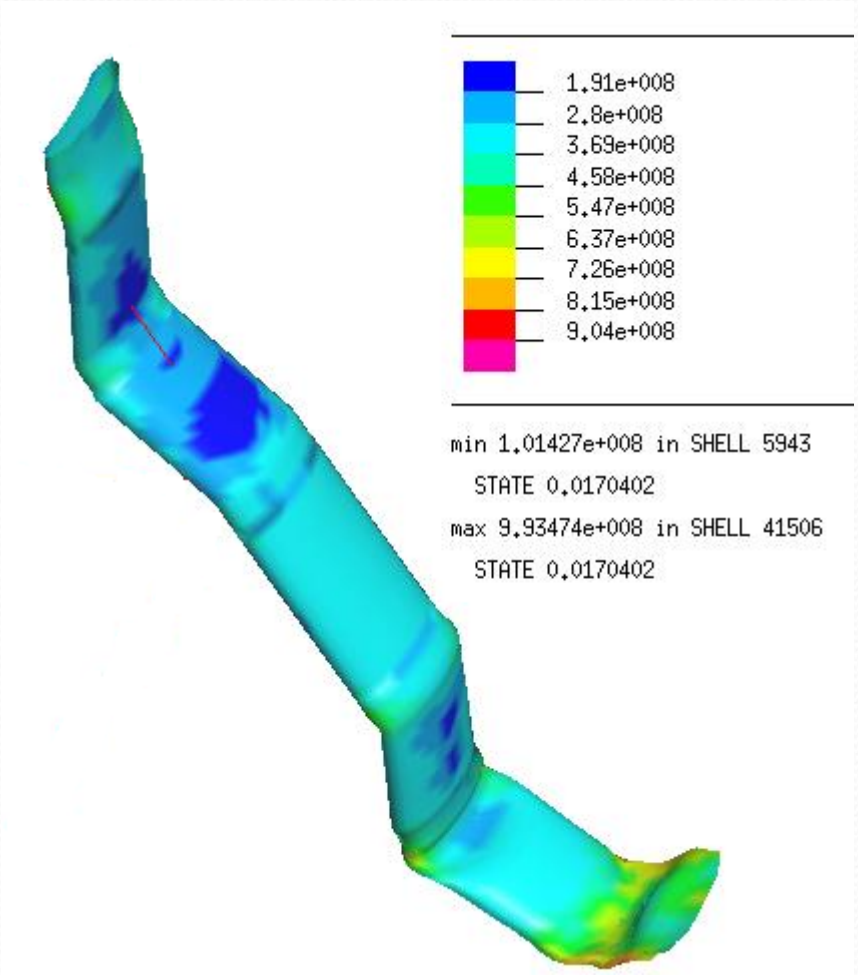
Sr. No.	Properties	Steel (SS 304L)	Tungsten	Lead	Bolt SA 540 Gr B24
1	Material law	Bilinear Elastic-Plastic	Bilinear Elastic-Plastic	Bilinear Elastic-Plastic	Bilinear Elastic-Plastic with 1% plastic strain
2	Density	7800 kg/m³	18500 kg/m³	11350 kg/m³	7800 kg/m³
3	Young's modulus	200E9 N/m²	310 E9 N/m²	Not Used	200E9 N/m²
4	Poisson's ratio	0.3	0.28	Not Used	0.3
5	Yield stress	170 E6 N/m²	586 E6 N/m²	3.2 E6 N/m²	1035E6 N/m²
7	Ultimate stress	485 E6 N/m²	758 E6 N/m²	Not Used	1140E6N/m²

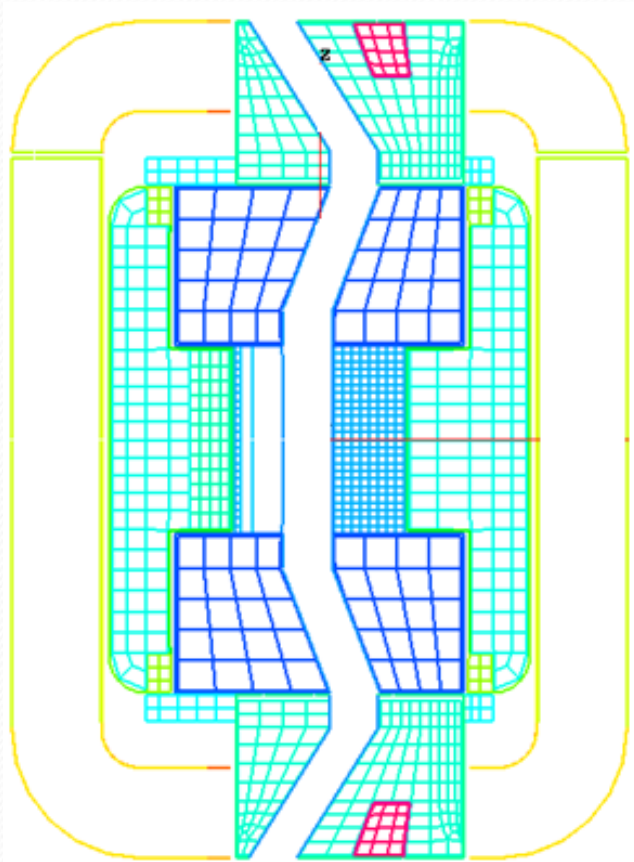
Approximations/ Assumptions made in the FEM Model

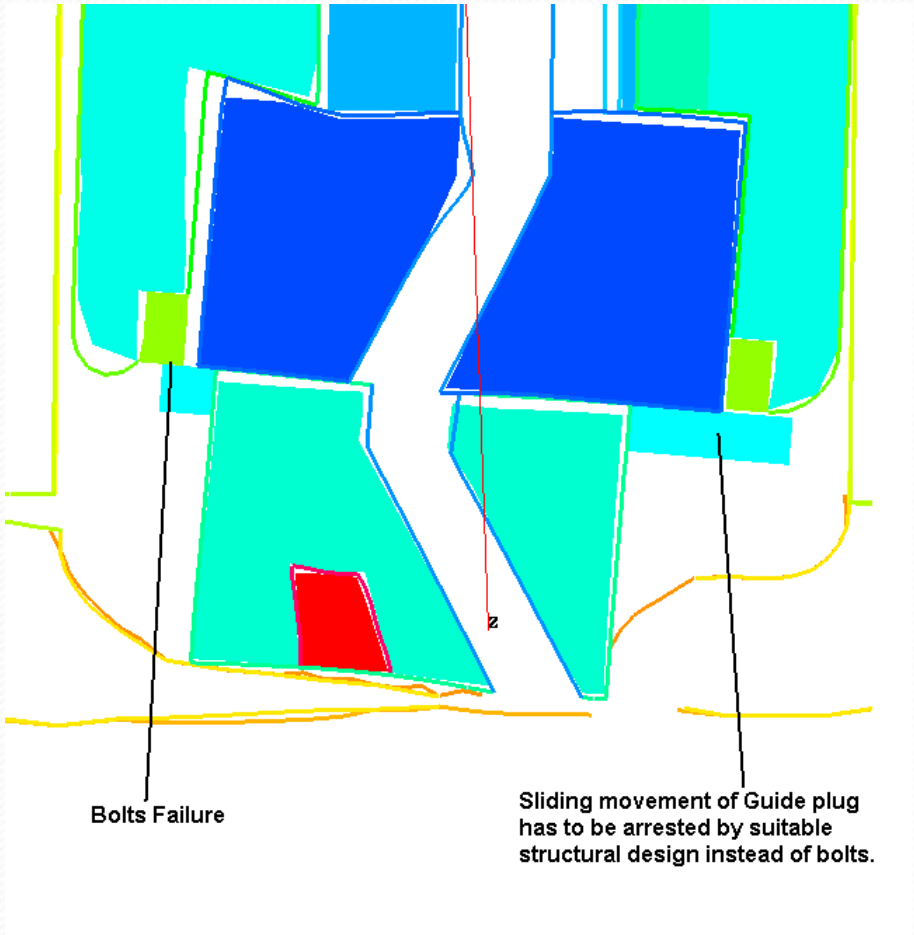
- For all the simulations, material properties are considered at room temperature.
- The target is assumed to be a perfectly rigid wall without friction.
- The interfaces such as steel-lead, steel-steel etc. are assumed to be frictionless.
- The structural welds are not considered in the model and uniform base material is modeled across any structural joints.
- The bolt response is assumed to be elastic and 1% plastic.
- All the simulations are carried out for first impact; the second impact on rebound is ignored.
- The elastic-plastic material properties are assumed to be bilinear

Results & Discussion

Stress Contour in the bent pipe

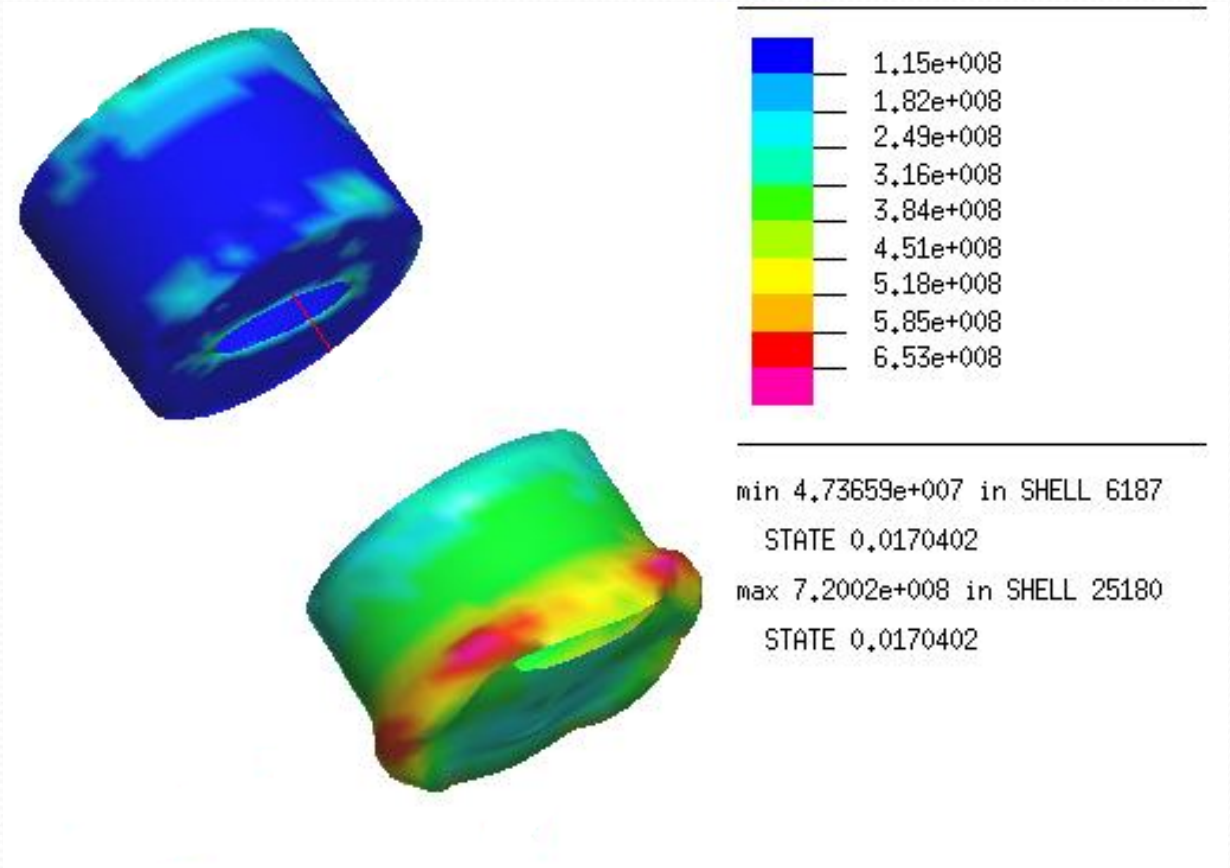


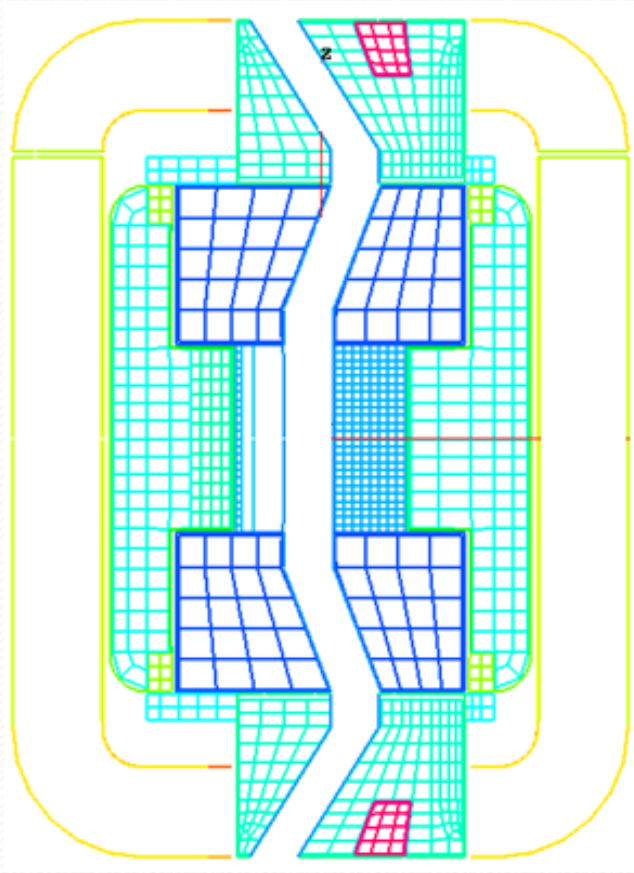




Bolts failed due to sliding movement of guide plug

Stress Contours in the shield plug

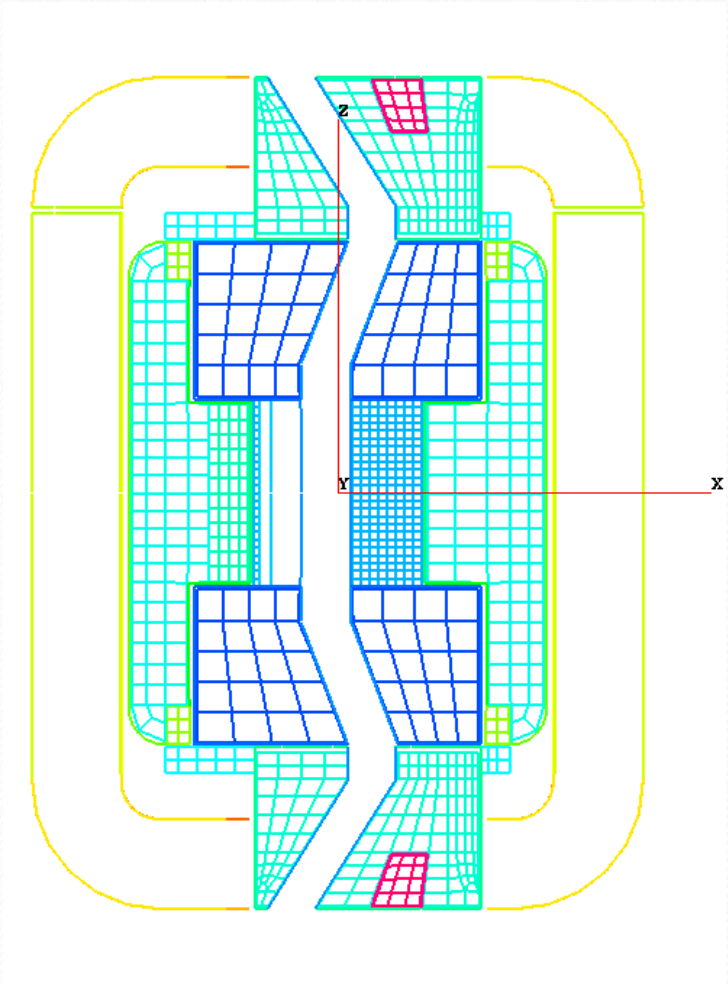




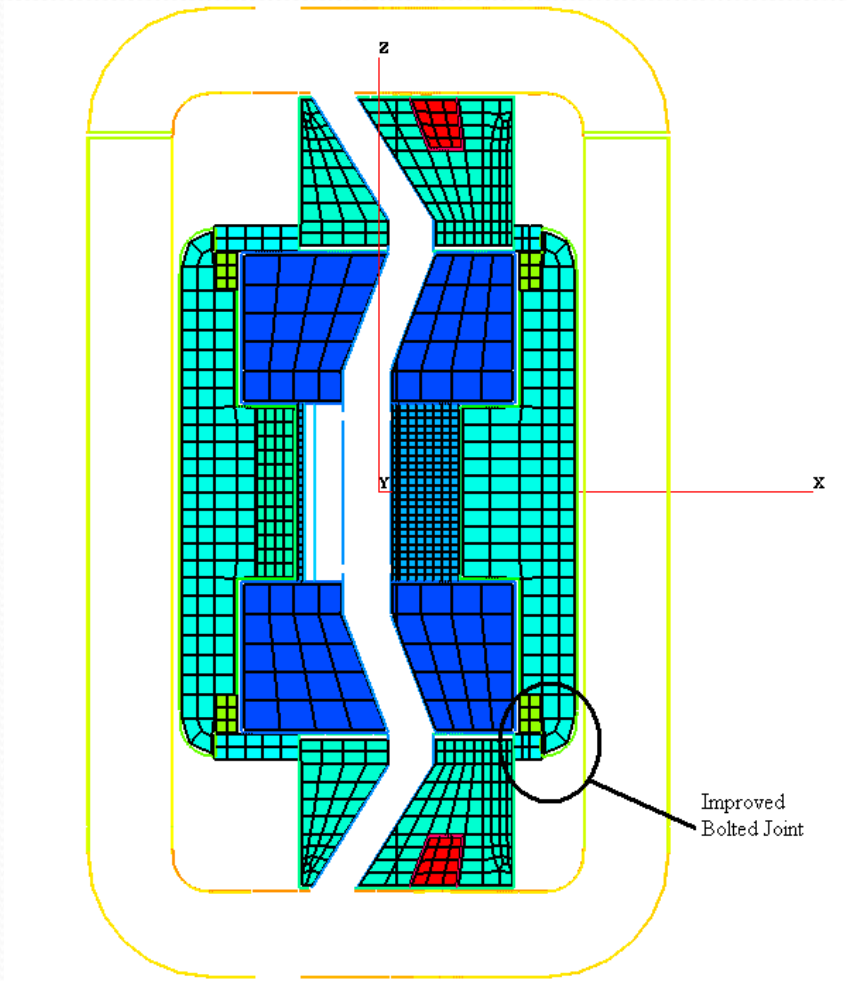
Design Modification

- The shock absorber was extended in such a way that it covers the complete cask.
- Thickness of shock absorber pipe was increased to 8.1 mm.
- Thickness of bent pipe was increased to 8 mm from 4 mm.
- Structural modification to restrict sliding movement between guide plug and cask main body.
- Thickness of guide plug was increased to 12 mm from 6 mm
- Higher strength bolts are used.
- The bent pipe was considered in separate pieces

Finite Element Model of the Modified Cask

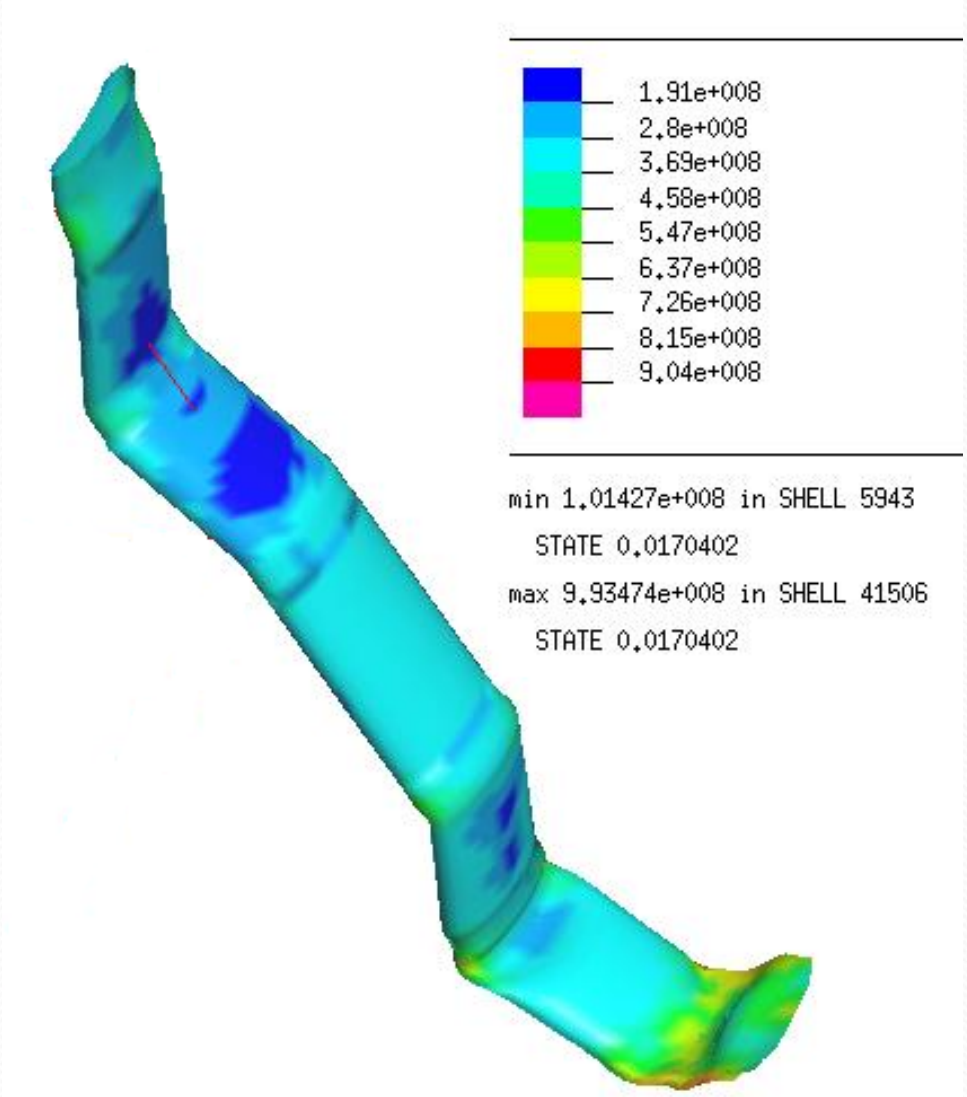


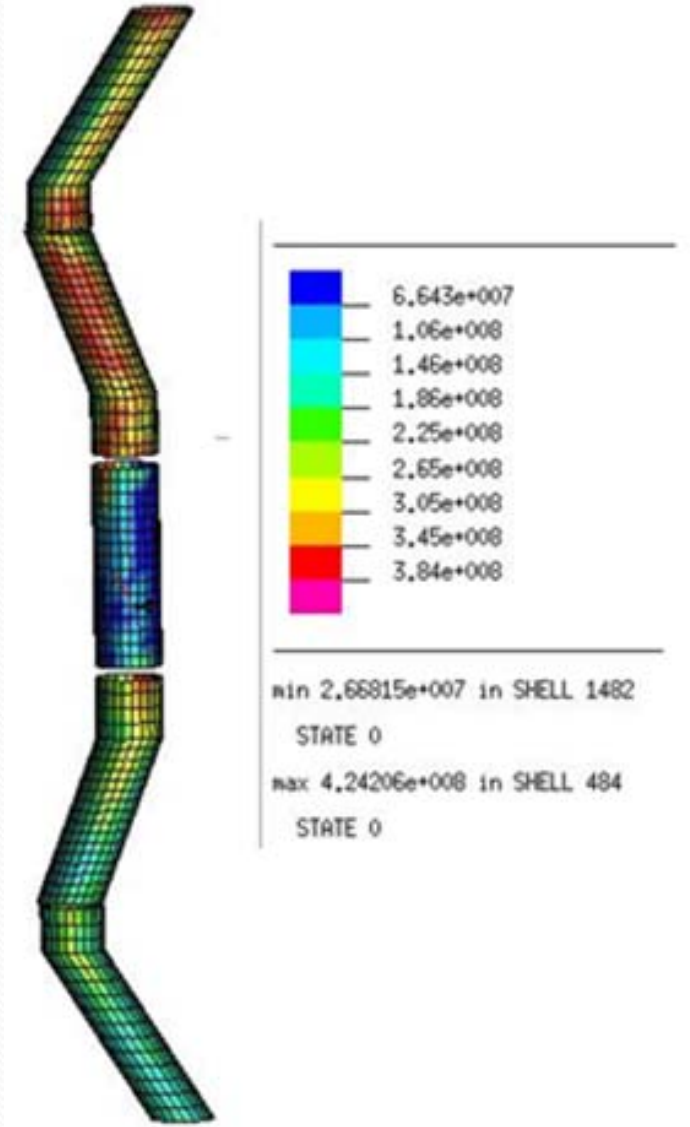
Before Modification

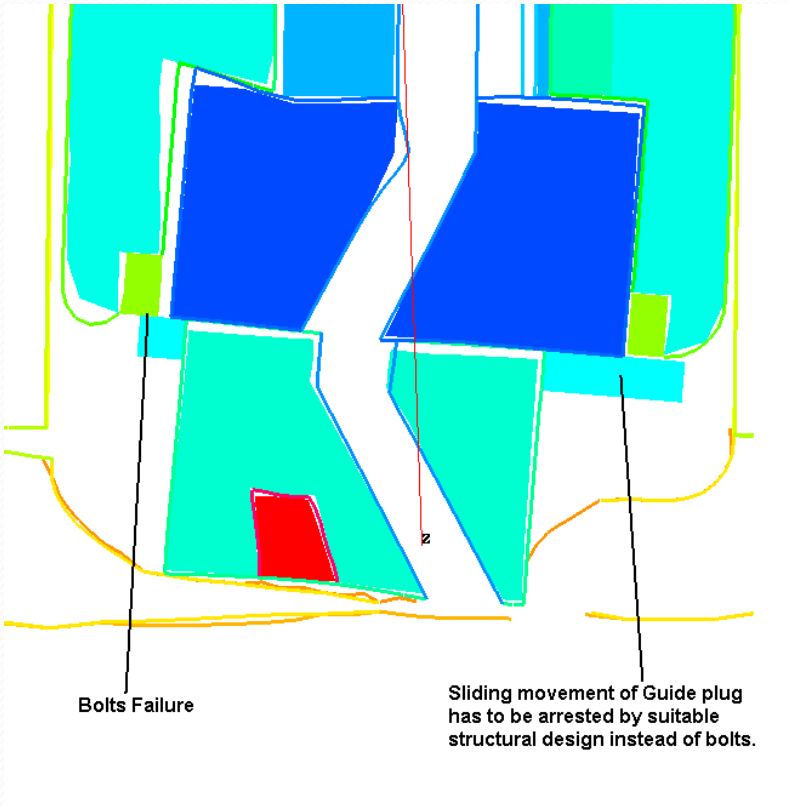


After Modification

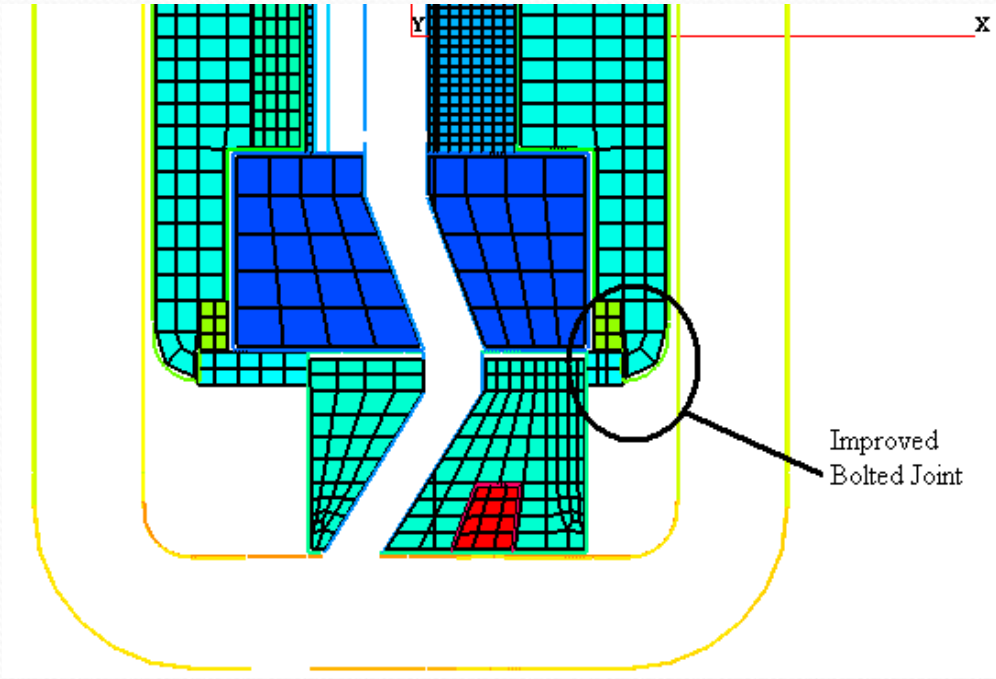
Stress Contours in the bent pipe after modification





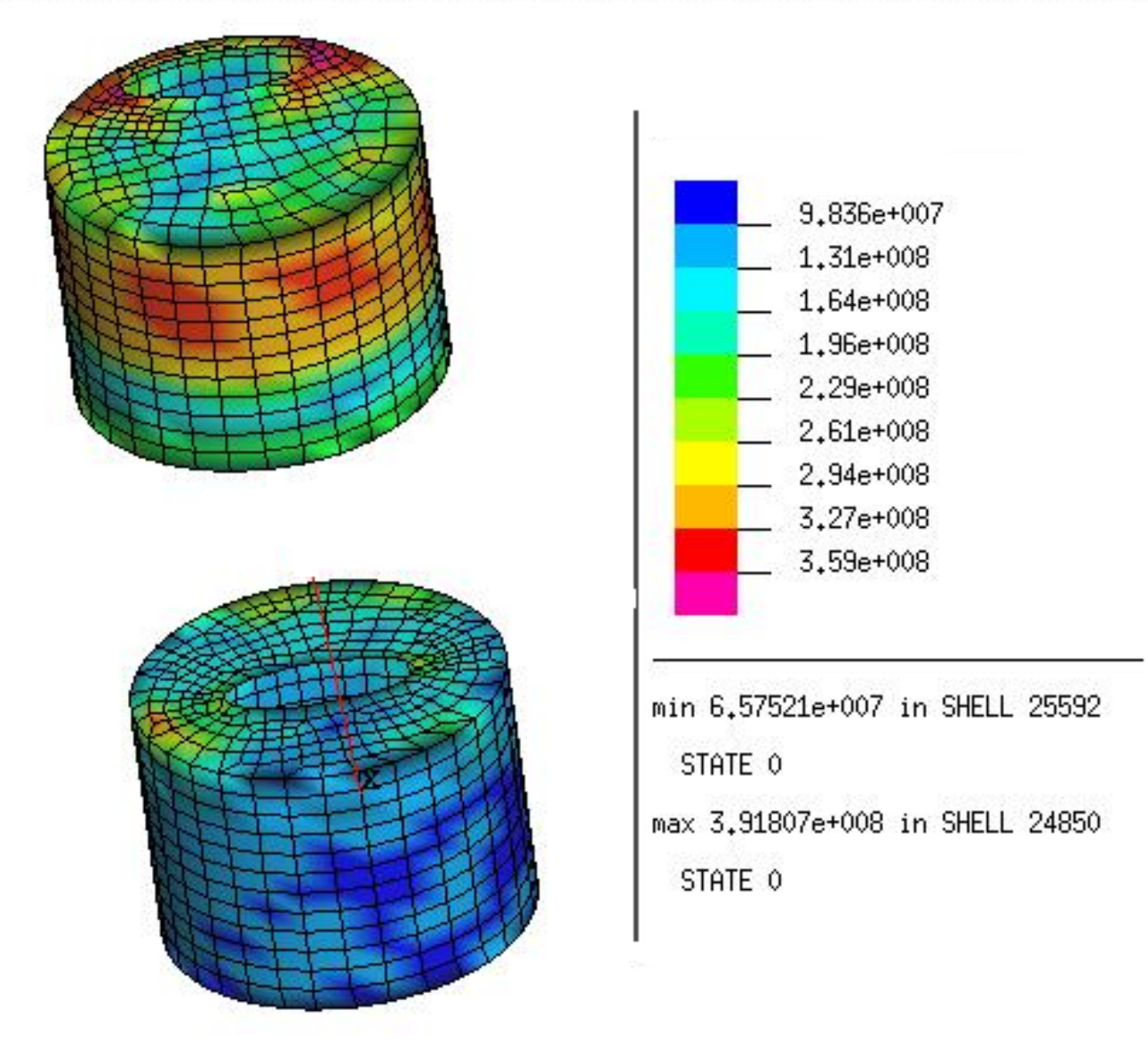


Failure of bolt due to sliding movement of guide plug



Improved structural design

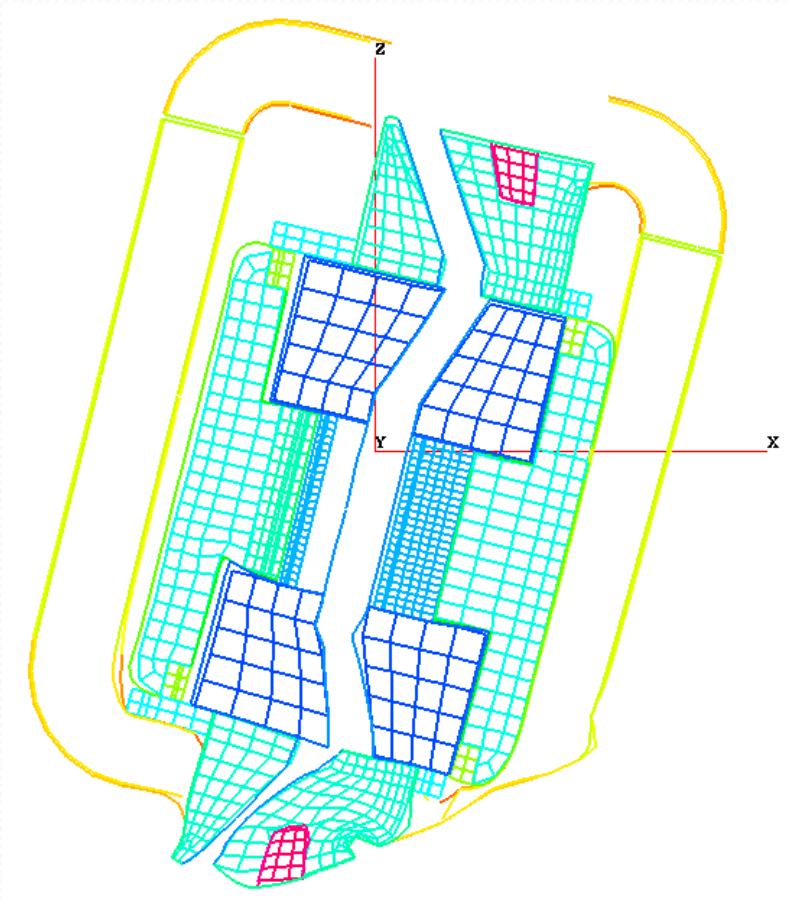
Stress Contours in the steel casing of shield plug after Modification



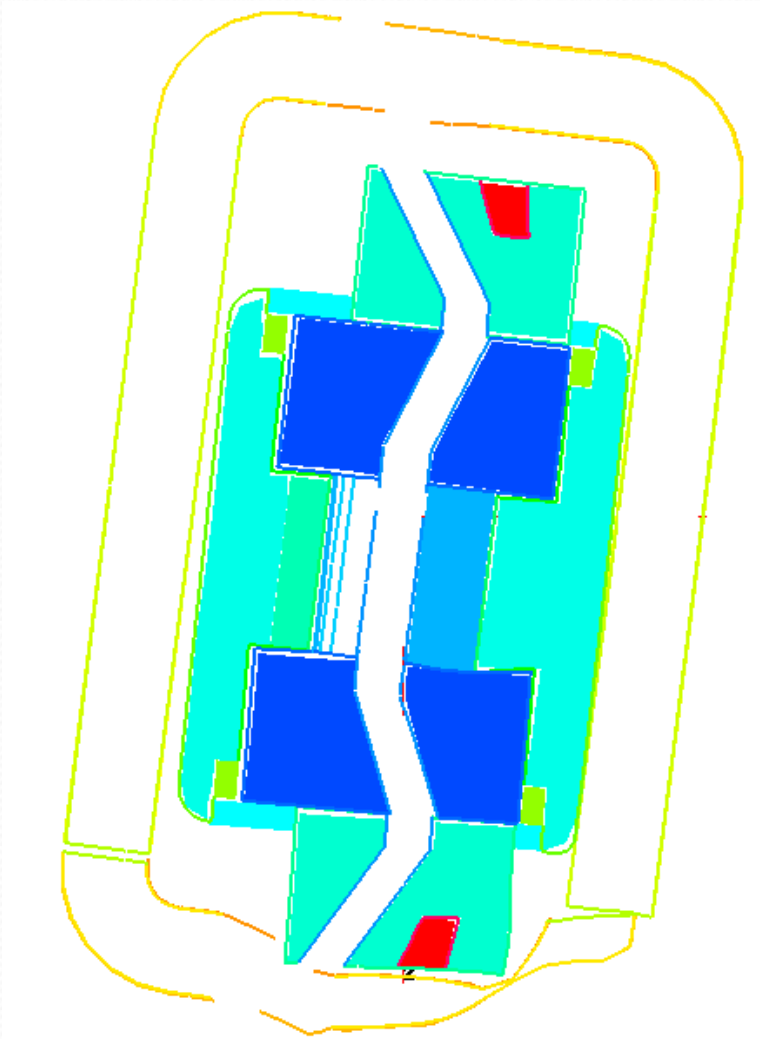
Summary of Stress Intensity of the Optimized Cask

Component / Material	Stress Limit (MPa)	Observed Maximum S.I. (MPa)		
		End Drop	Horizontal Drop	Corner Drop
Outer shell of main cask	485	398.6	440.0	392.4
Inner shell of main cask	485	386.2	379.4	377.7
Steel casing of guiding plug	485	391.8	439.0	402.5
Steel casing of shield plug	485	383.8	383.8	384.6
Bent pipe	485	424.2	436.4	415.3

Deformation of the cask under 9m corner drop

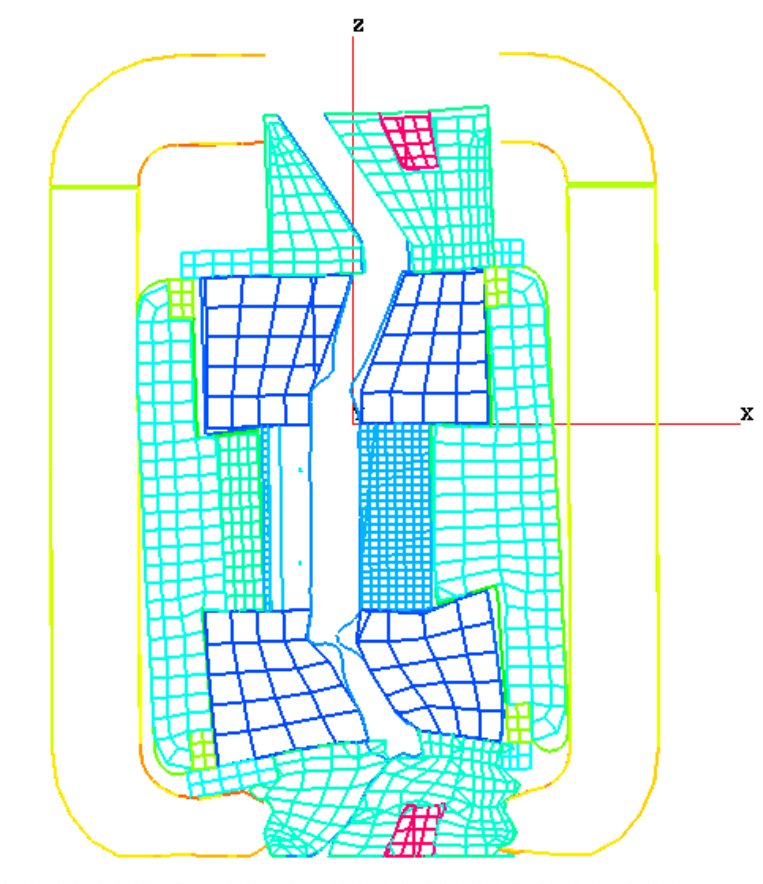


Before Modification

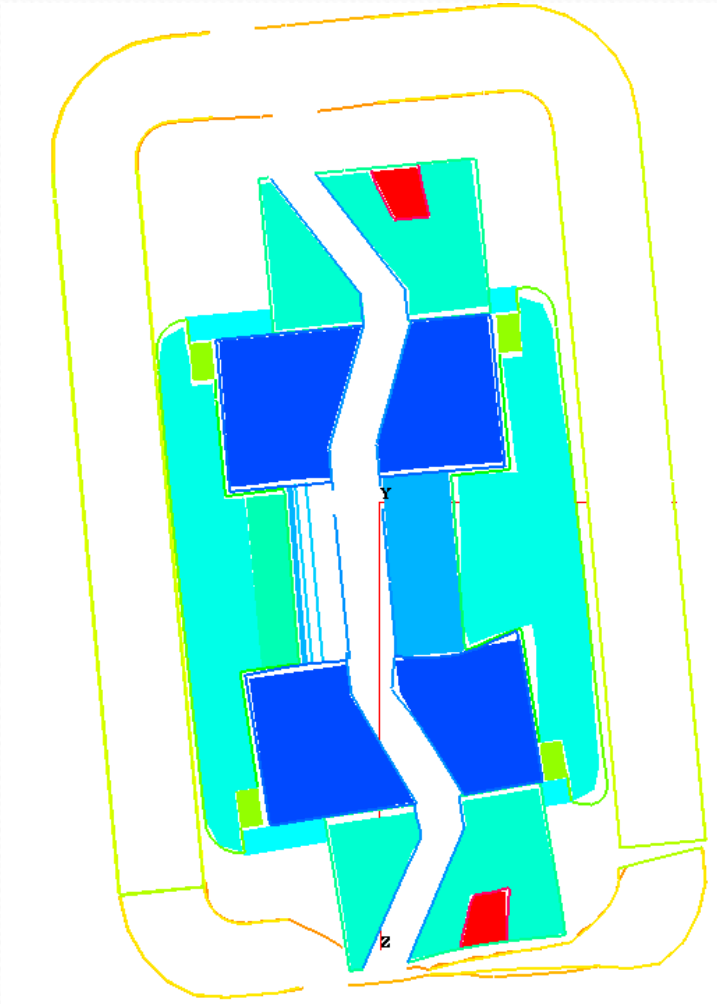


After Modification

Deformation of the cask under 9m end drop

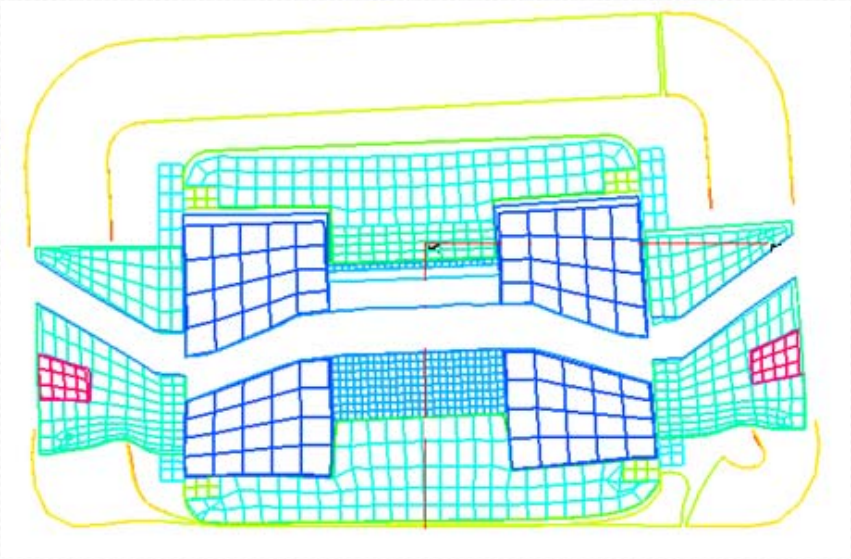


Before Modification

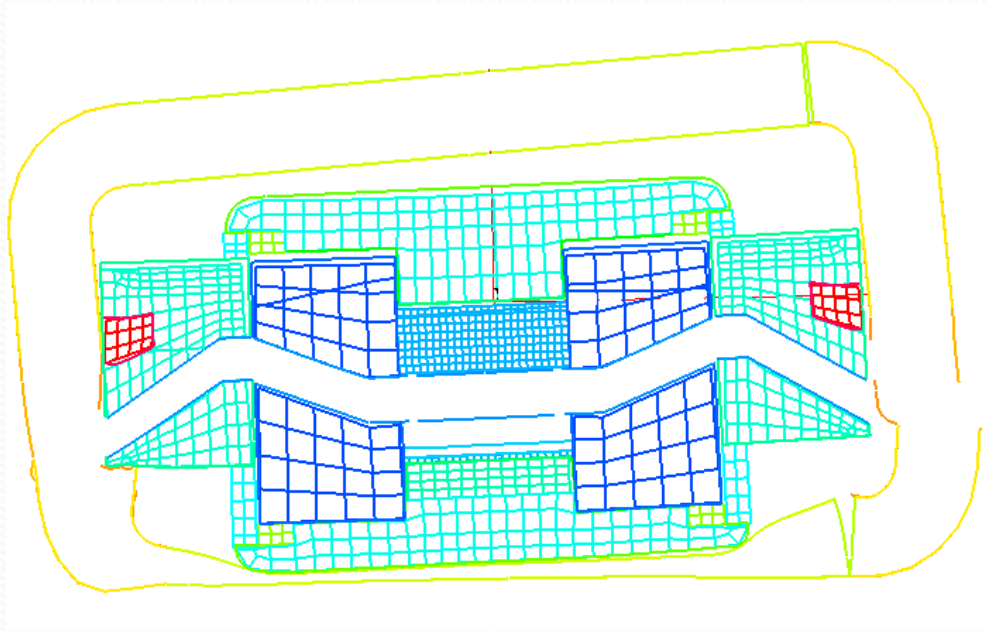


After Modification

Deformation of the cask under 9m horizontal drop



Before Modification



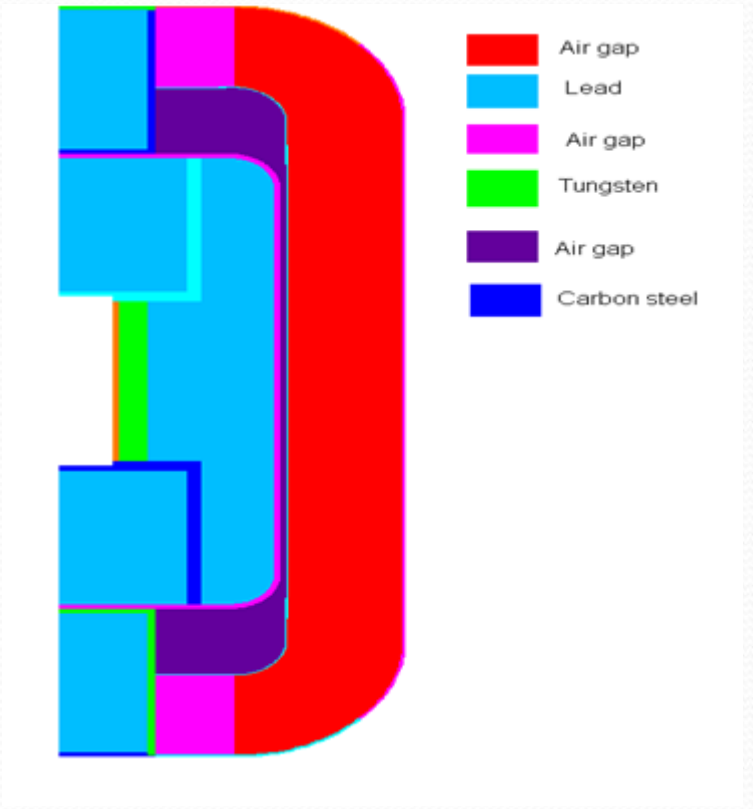
After Modification

Thermal Analysis

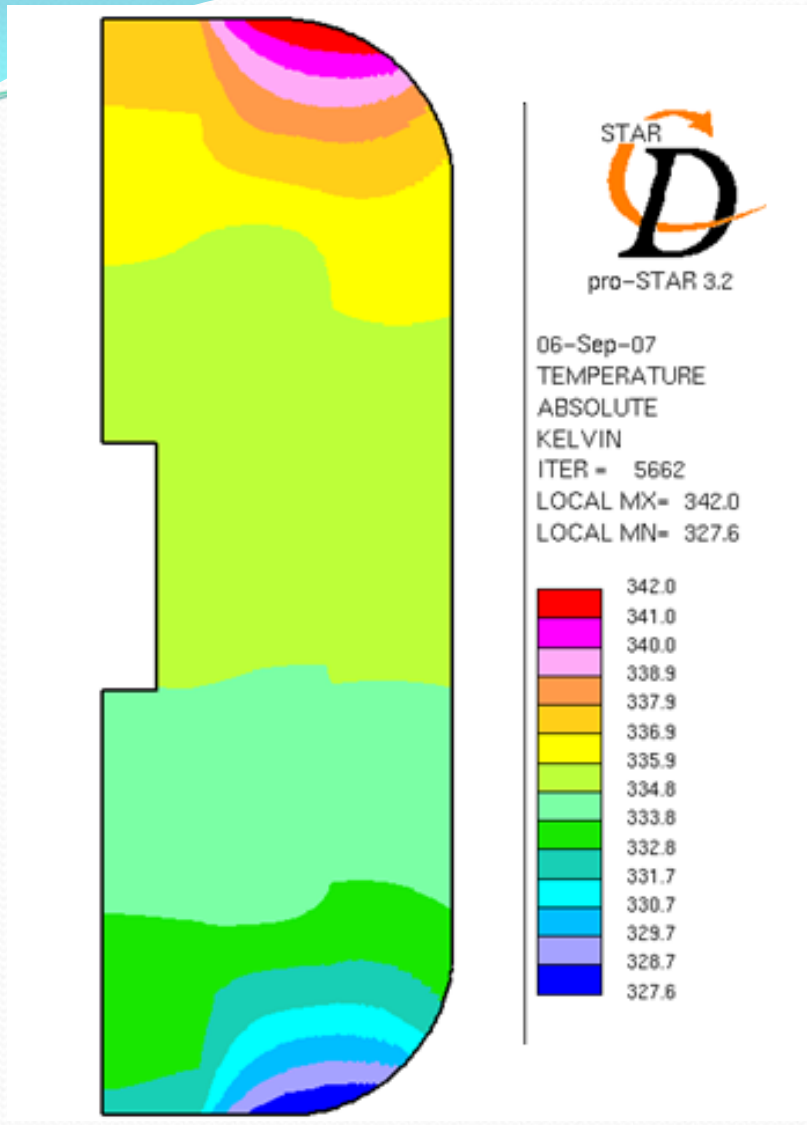
Code used for thermal analysis
pro- STAR 3.2

Assumptions made in the model

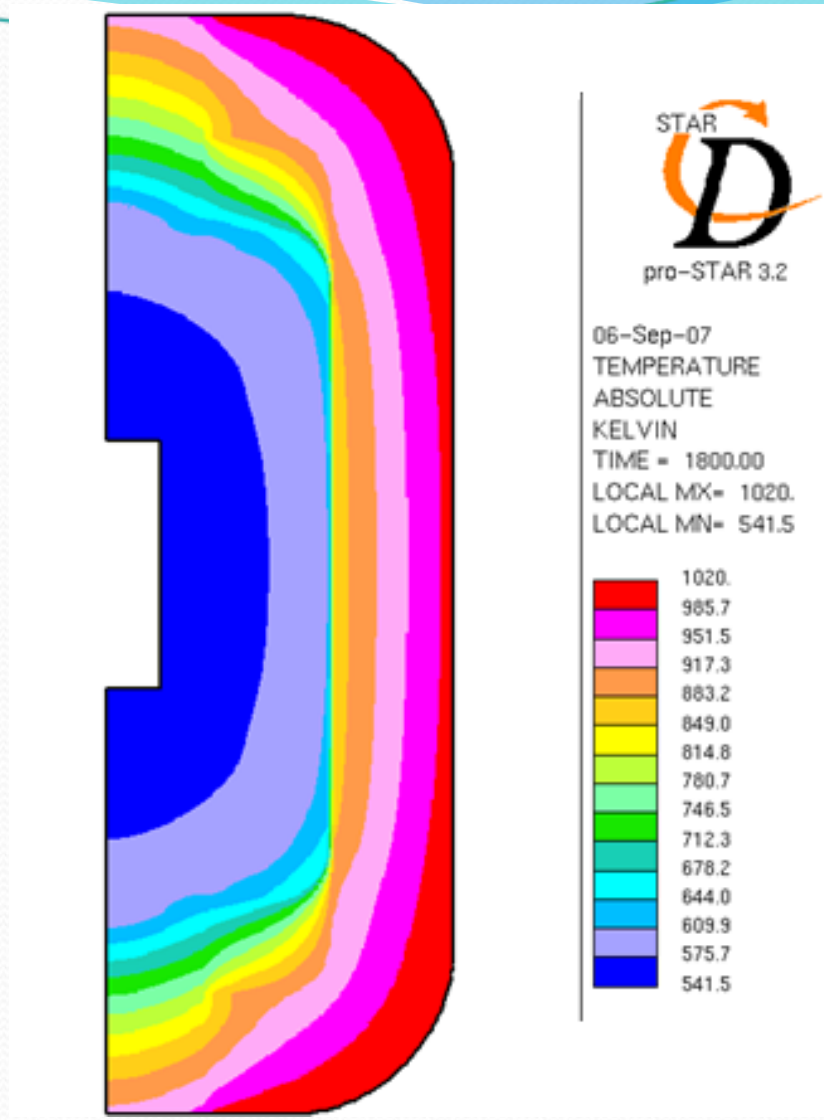
- Axisymmetric model has been assumed.
- Bent Pipe details are not modeled.
- Elliptical pipe was assumed to be circular with a mean diameter of 203mm.
- Pipes are not modeled in the cabinet.



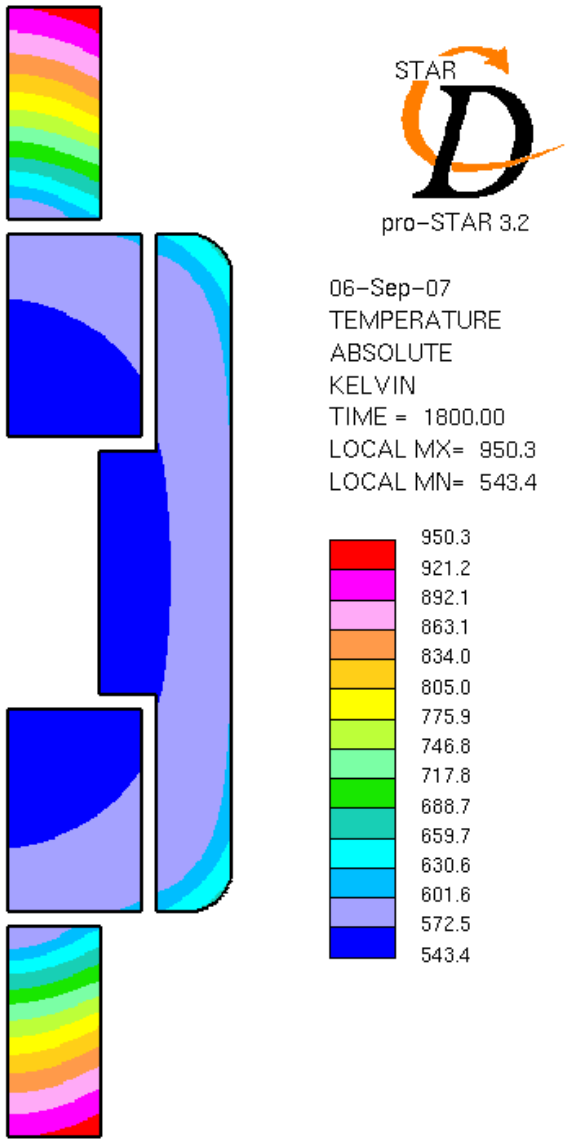
Analysis model



Temperature contours during normal Conditions of transport



Temperature contours after 800° C fire test



Temperature contours in the lead region at the end of fire test (30 minutes)

Conclusion

- By suitable modification in the design of the cask structure, stresses in the closure bolts were brought under safe limits.
- The impact limiter gets completely deformed demonstrating significant energy absorption by the impact limiter.
- Stresses generated in the cask are well within limit and meeting the regulatory requirement.
- Deformation observed in the main cask are minor.
- Partial lead melting occurred in the outer periphery which is insignificant.
- The cask maintains its structural integrity in the 9m drop and 800°C fire test.
- Experimental test of the cask is also planned to be carried out.

THANK YOU