NCSX

Design Basis Analysis

Vacuum Vessel Support Rod Analysis

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I have reviewed this calculation and, to my professional satisfaction, it is properly performed and correct. I concur with analysis methodology and inputs and with the reasonableness of the results and their interpretation.

Reviewed by:

Kevin D. Freudenberg 2005.04.19 16:32:36 -04'00'

K. Freudenberg Engineer

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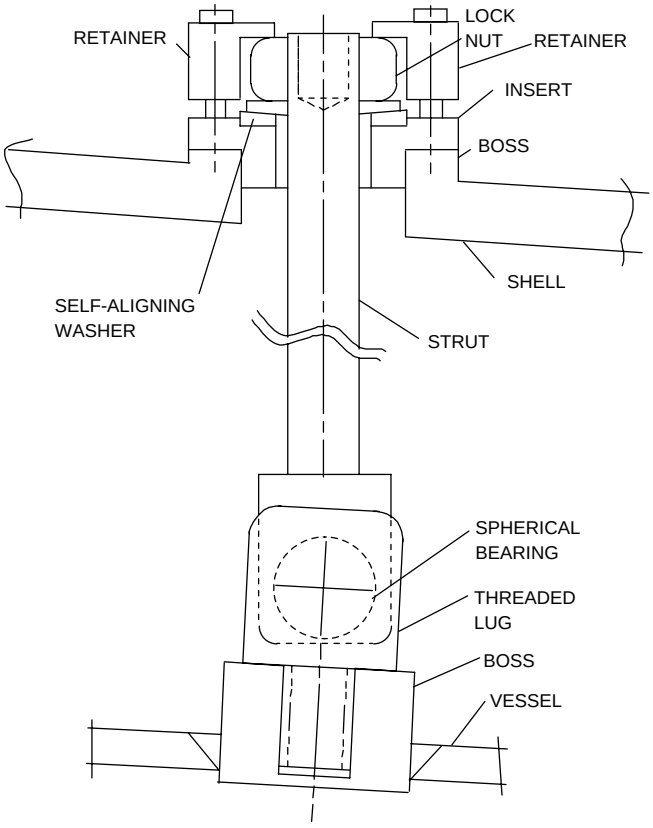
Introduction
The Vacuum Vessel Subassembly (VVSA) utilizes six threaded support rods to suspend the VVSA from the interior of the Modular Coil (MC) shell structure. Lateral supports mounted on the Neutral Beam Transition Duct position the VVSA and react off-center loads to the MC structure. Two internally threaded bosses are built into each of the VVSA assemblies near the Neutral Beam. Corresponding boss features are built into the shell such that the support rods will be vertical when the MC Shell and VVSA are at room temperature.
VV wall stresses have been analyzed by a separate DAC.

Design Description – Per figure
A threaded clevis screws into boss at the VV end.
A commercial rod end and spherical bearing attaches rod to clevis.
A nut and self-aligning washer on the threaded rod supports the load at the MC.

Performance Requirements and Criteria
No credit is given for lower hangers which could be used to preload the VV and reduce dynamic loads.
A safety factor of three based on ultimate, during normal operation is acceptable.



VESSEL HANGER CONCEPT

Methodology
Hand calculations were done to determine simple tensile and shear stresses in the components based on static gravity and magnetic loads.

Assumptions

1. Rod thread

3/4-10UNC
Stress area = 0.313 in^2
Minor dia = 0.6309 in

The design utilizes a minimum thread engagement of 1.5 diameters, which assures full tensile capability for the rod, therefore, thread shear is not an issue and is not analyzed here.

2. Vessel weight = 24000 lbs

3. All six supports are loaded equally in pure tension.

4. Material properties

6Al-4V titanium alloy properties from MIL-T-81556
Yield is 150 ksi
Tensile is 160 ksi
Yield at 350 C is 60%
Tensile at 350 C is 70%
Yield at 80 K is 160%
Tensile at 80 K is 155%

Inconel 625 properties from AMS 5666
Tensile at room is 120 ksi, 105.6 ksi at 350 C.
Yield at room is 60 ksi, 42 ksi at 350 C.

G-10 insulation
Material compressive strength is rated at 60 ksi.

5. VV is never at 350 C during plasma operation. Reduced allowable due to temperature are not applicable during magnetic loading.

6. Dynamic disruption load, from Dahlgren, is two times static load.

Results

1. Tensile stress at thread root.

Tensile stress(static) = 12,800 psi (S = Vessel Weight/6/rod area)
Dynamic tensile stress = 25,600 psi (twice static load, see 6 above in assumptions)
Safety factor, based on ultimate, during disruption is 6.25.

2. Clevis threads

Stress is same as in rod but strength of I625 is less than titanium alloy.
Safety factor, based on ultimate during disruption and room temperature is 4.7.
Safety factor based on ultimate during static load and 350 C is 8.25.

3. Weld joint in VV boss.

Boss dia = 2 in
Weld depth = 0.375 in
Weld area = 2.36 in^2

Assume:
Weld metal not inspected radio graphically has efficiency of 50%.
A full penetration weld through 3/8 wall.

Reference: VV Structural Analysis NCSX-CALC-12-007-00, for welded Inconel 625 pressure vessel.

Allowable at 150 C is 33.4 ksi.
Allowable at 350 C is 30.4 ksi.

Results

Tresca Shear stress
Sstatic = 1694 psi
Sdynamic = 3389 psi
Safety factor is 19.7 during operation.
Safety factor is 9.8 during disruption

4. G-10 Insulation Bearing Stress

A G-10 electrical insulation is used under the spherical washer seat
OD = 2.28", ID = 1.38" area = 2.59 in^2
Temperature ranges from room temperature down to 80K.
Static compressive stress = 1546 psi

5. Rod End
The rod end is a commercial design rated at 29,300 lbs ultimate load, a safety factor of 3.7 during disruption events.

Summary
All of the components are conservatively stressed and there is ample room for increase in the system weight during upgrade operation, when internal plasma facing components will be added.
The critical component in the assembly is the commercial rod end with a safety factor of 3.7 during disruption.