NCSX

Diagnostic Port Flange Weld Stress Resulting From Loss of Power Fault Condition in NCSX Vacuum Vessel

NCSX-CALC-12-005-00

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Prepared by:

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P. L. Goranson, ORNL

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 2004.12.13 13:50:26 -05'00'

K Freudenberg, ORNL Engineer

Introduction

The NCSX Vacuum Vessel (VV) utilizes gas tracing tubes on the exterior vessel wall and electrical resistance heaters on the port extension walls to provide heating during bakeout and standby operation of the vessel. Insulation is provided to limit the heat losses from the vessel system to the cryostat and modular coils, both of which are maintained at cryogenic temperature. The VV flanges are 304 stainless steel and the port extension pipes are Inconel 625. The thermal design basis stipulates that the flanges and VV be maintained at a minimum of 20 C during standby and operation and the flanges not exceed 150 C during bake out of the VV. This is to avoid excessive stress in the weld joints joining the flanges to the port extensions, due to mismatch in the coefficient of thermal expansion. Analyses were performed using ANSYS to determine the stress in the large non-circular Port 4 during bakeout, the results referenced in DAC NCSX-CALC-12-006-00, Port 4 Weld Stress During Bakeout. The stress was found to be acceptable, but no fault conditions were studied. A criteria was established that the Port 4 weld would never be permitted to see an excursion in temperature exceeding 150 degrees Kelvin, in other words it would never exceed 150 C or fall below 163 K (referred to as the critical temperature in the graphs).

A fault condition addressed by the VV FMECA is a situation in which all power to the VV gas tracing and resistance heaters is lost. During CD3 the outer port extensions will not be installed and the port flanges will terminate within the cryostat. This could result in cooldown of the VV and ports to the Cryostat temperature of 80 K, since it is a large cool mass and warms only very slowly.

The analysis in this DAC includes hand calculations to determine the approximate time for the VV to cool to 80 K and the weld stress resulting in the Conflat flanges. The goal is to determine whether some sort of emergency backup system is required to protect the VV flanges from a loss of power during CD3.

Performance Requirements and Criteria

The NCSX VV Systems Requirements Document, NCSX-BSPEC-12-00
requires that:

- The vacuum vessel and interior components must be baked at 350 C and maintained at a minimum of 20 C before and after operational shots.
- During bakeout, the port extensions are to be maintained at 150 C at the flanges ends and 350 C at vessel end, with gradient between.
- The cryostat and modular coils are maintained at 80 K during both bakeout and standby operation.

Methodology
The analysis was done as a spreadsheet in MICROSOFT EXCEL representing the vessel and ports as simple areas conducting heat across insulating layers to constant temperature heat sinks. Input variables to the spreadsheet were insulation thicknesses, conductivity, vessel temperatures, and surface areas. The outputs were the heat loss from the vessel body and port extensions to the cryostat and coil bodies. The port cooling balance was done with finite differences, iterating along the port length until the boundary conditions [temperatures] were met. The output was the net loss and time to temperature. The Conflat flanges and port extensions were represented as thick-wall tubes. The analysis determined the net interference between the parts at cool down and the pressure needed to fit the parts over each other, i.e. compress the inner tube and expand the outer. The pressure was then used to calculate the tensile, compressive, and shear stresses at the interface.

Assumptions
The worst case will be the largest port:
12 inch OD Conflat flange
10 inch OD port extension
0.25 inch thick wall

The Heat balance and port losses were taken from NCSX Vacuum Vessel Heat Balance Analysis NCSX-CALC-123-03-00.

Results

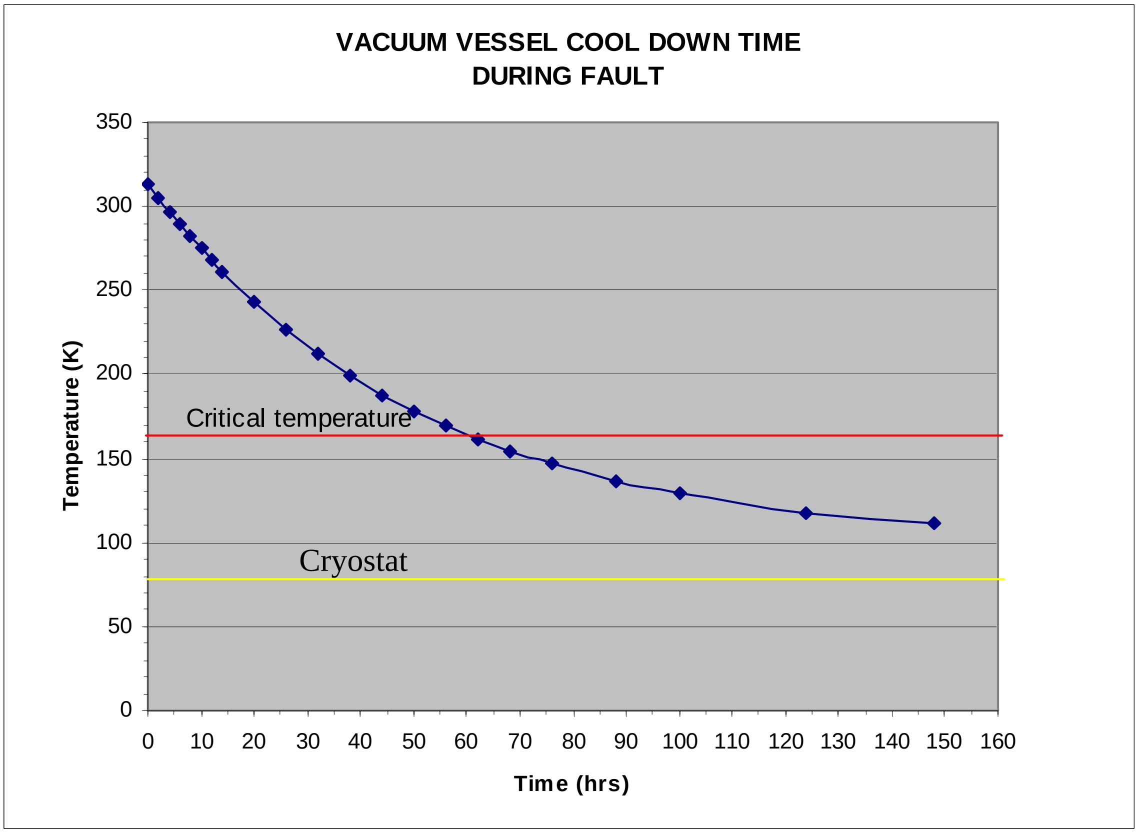
Cool down time
Cool down of the VV from an operation temperature to 80 K is shown in Figure 1. It shows that there will be approximately 60 hours to take appropriate action after loss of power to the systems, before the VV temperature drops to the critical temperature of 163 K.

Flange stresses

Stress at flange interface

Inconel tube	10925	psi compression
Cf stainless flange	3105	psi tension
Weld	1832	psi shear
Max stress is in inner tube	11485	psi compression

Figure 1 Cool down of vacuum vessel after loss of power to heating systems



Conclusions:

The stresses are very low and it is probable that the CF welds can safely survive an excursion down to 80 K. The AWS allowable for carbon steel static weld stress is 13600 psi. This takes into account residual stress due to welding.

In reality, the Port 4 flange is outside the cryostat and it is unlikely that its flange temperature can fall to anything approaching 163 K; the 163 K limit, therefore, is not meaningful.

Caveat:

There is an additional (bending) stress term due to the CF being a disk, not a tube, which loads the inner tube along its edge rather than its entire surface. This stress can probably can be neglected since the loading is very modest and there is an additional reinforcing weld around the outside of the CF which serves to reduce the bending.