Comments from the SNS Cryostat Design Review -- 11 - 12 February 2010

Tom Peterson, Fermilab

15 February 2010

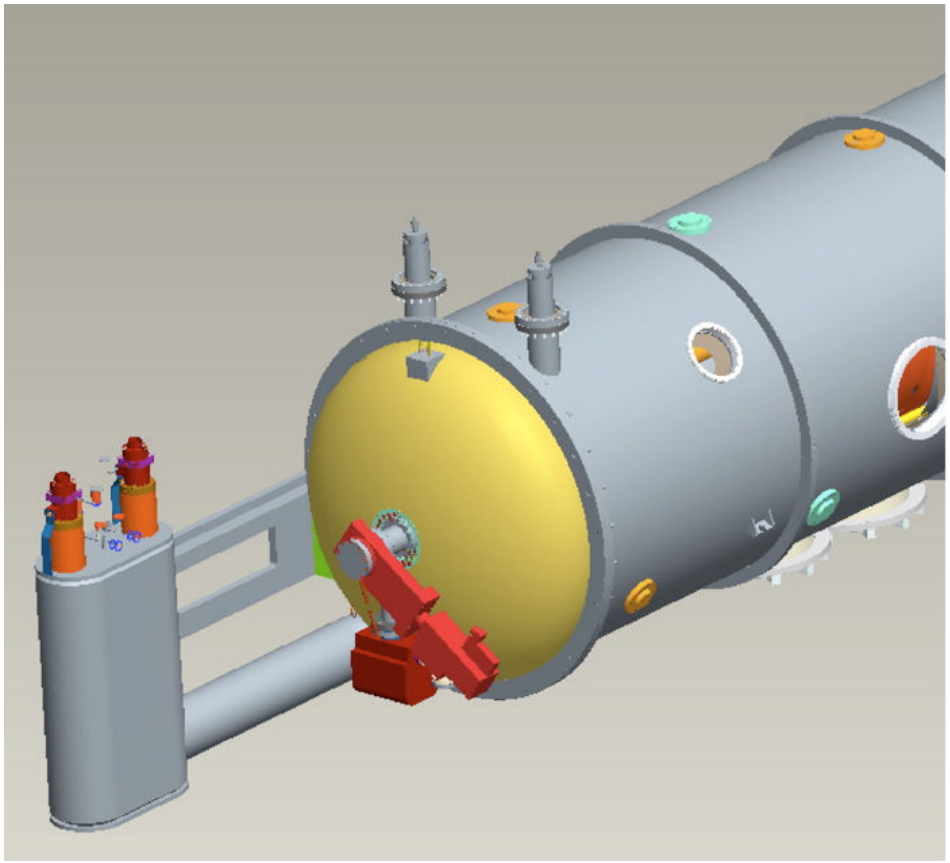
Safety and compliance issue

- 10CFR851 (Code of Federal Regulations), dated Feb 9, 2006, governs "the conduct of contractor activities at DOE sites".
- Part 4, the "Pressure Safety" section says, "Contractors must ensure that all pressure vessels, boilers, air receivers, and supporting piping systems conform to [the applicable ASME pressure vessel and piping codes]".
- "When national consensus codes are not applicable (because of pressure range, vessel geometry, use of special materials, etc.), contractors must implement measures to provide equivalent protection and ensure a level of safety greater than or equal to the level of protection afforded by the ASME or applicable state or local code."

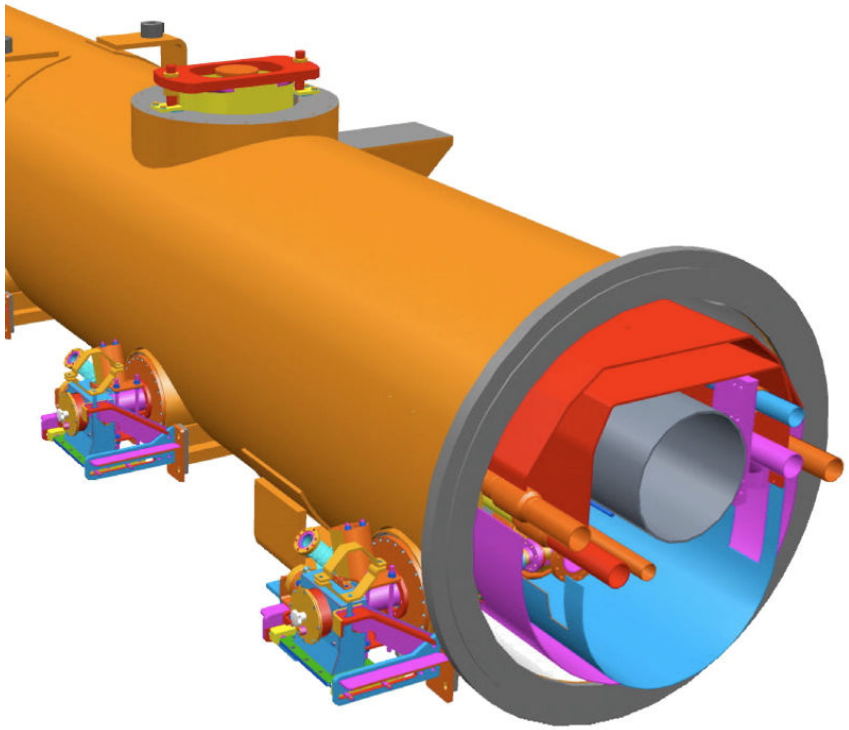
Pressure boundary

- Fermilab is presently taking the approach of analyzing and certifying the individual helium vessel/cavity assemblies
  - While used for its superconducting properties, niobium ends up also being treated as a material for pressure vessels.
- **An alternative solution being developed at SNS -- treat the stainless steel vacuum vessel as the "pressure boundary"**
  - Fermilab rules also require vacuum vessel to generally follow ASME code rules but not be code-stamped
  - Differences for SNS involve
    - Pressure rating of vacuum vessel (higher internal pressure)
    - Stricter adherence to code for vacuum vessel (code-stamped)
    - ASME approved relief valves on the vacuum vessel
    - Pressure boundary at the ends of the insulating vacuum system

SNS vs TTF cryomodule



SNS (like CEBAF):
self-contained vacuum vessel



TTF: vacuum vessel string.
End boxes and bellows would become part of vacuum/pressure closure

Some comments from review

- We like the use of the vacuum vessel as the pressure boundary
  - However, it would be more difficult for our TTF-style cryomodule
- Venting from vacuum vessel requires accommodating flow around thermal shields with possible plugging from MLI
- Code approved reliefs are required for vacuum vessel in order to meet code
  - A code case allowing non-UV stamped reliefs is up for consideration
- Oak Ridge has an ASME code vessel expert (John Swezy) who has provided help with interpretation of the code and code cases
- SNS also called upon a National Fire Protection Code expert to provide advice regarding whether NFPA 68: "Standard on Explosion Protection by Deflagration Venting" applies to the vacuum vessel.
  - The answer is NO

Some key ASME code cases

- VIII-1-89-82 (Feb 15, 1989)
  - Non-metallic tubes (not coded) in heat exchanger OK with shell side code-designed for maximum tube pressure
- VIII-1-89-147 (Sep 19, 1989) and VIII-1-89-163 (Dec 4, 1989)
  - Proprietary inner chamber (not coded) within outer vessel OK with outer vessel code-designed for more severe temperature and pressure than inner chamber
- VIII-80-56 (Jun 25, 1980)
  - For tubes in a heat exchanger with higher pressure than the shell side, " . . . the possibility of a tube failure must be considered in determining the capacity of relief devices to prevent overpressure. Otherwise the maximum allowable working pressure of one chamber need not influence the determination of the maximum allowable working pressure for internal pressure of another chamber of a combination unit."

Other design issues

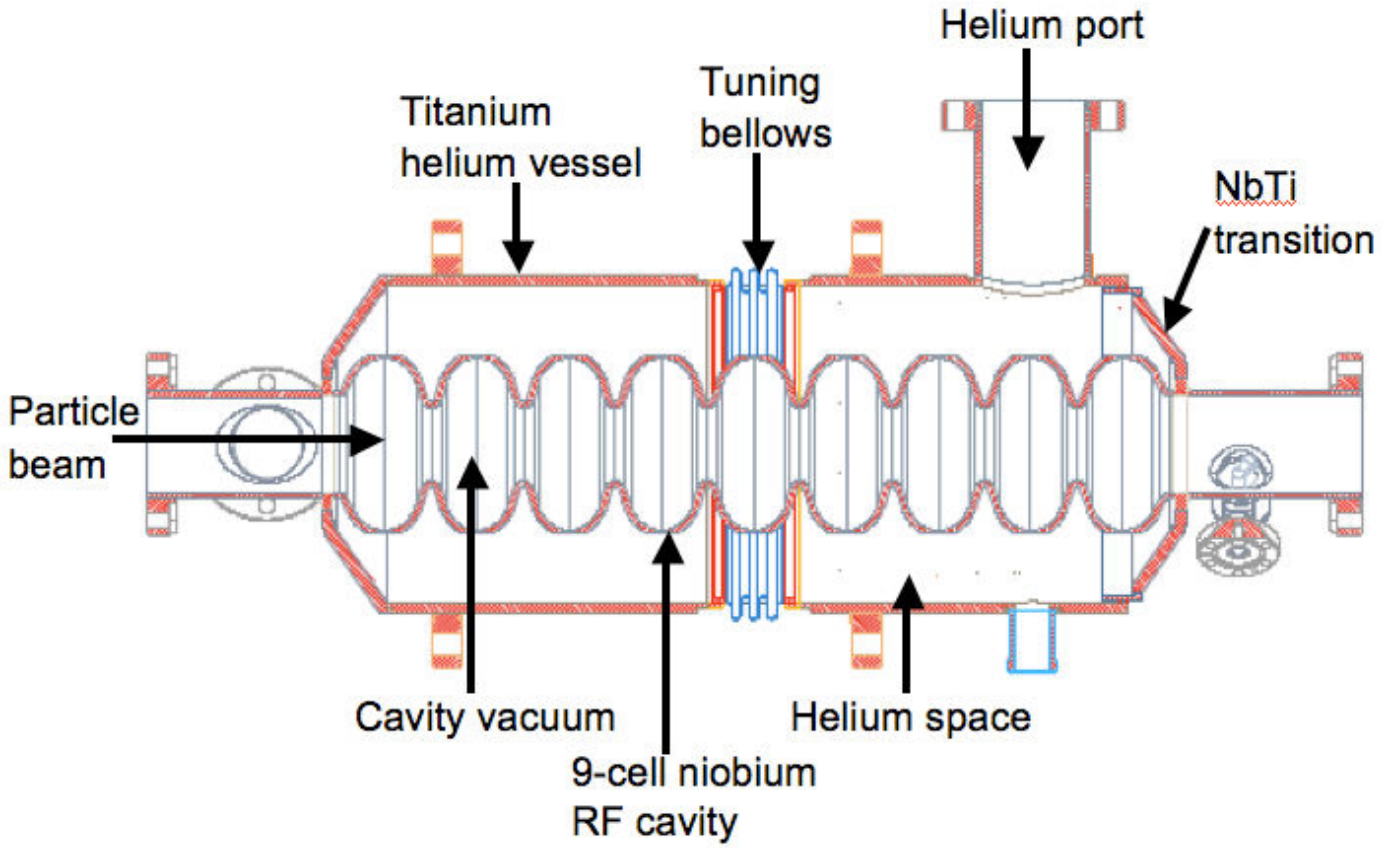
- The independent vacuum vessels with bayonet cryogenic connections allow each cryomodule to be warmed and/or replaced separately (maximal segmentation)
- SNS cryomodule cold mass support structure is an internal frame, “space frame”, not a helium pipe
- CEBAF and SNS cryomodules have large static heat load
  - About 25 W for 4 cavities (larger cavities, larger couplers, but still seems high)
  - TTF about 3 - 4 W for 8 cavities
- The counterflow cooling of the input coupler outer conductor with helium does not seem to work well
  - Possibly several problems including inadequate heat exchanger and unstable flow
- Designers should consider some of the SNS cryomodule features for a 650 MHz cryomodule for Project X

Background Information

Fermilab's approach to dressed cavity pressure vessel compliance

Features of a dressed RF cavity

Niobium cavity under external pressure.
Helium vessel sees internal pressure.



Conclusions for code compliance

				ASME Sec VIII, Div 1	
Yield strength (YS)	Tensile strength (TS)	approx RRR	heat treatment	allowable stress	
				Take the smaller of:	
				2/3 x YS	TS/3.5
MPa	MPa			(MPa)	(MPa)
38	130	300	825 C, 2.4 hr	**25**	37

- The last line in this table is our conclusion from our literature search.
- TS/3.5 = 130/3.5 = 37 MPa. YS x 2/3 = 38 x 2/3 = 25 MPa. Therefore, the allowable stress for 800 C baked niobium is S = 25 Mpa (3600 psi).

Low temperature allowable stress

- The low temperature (5 kelvin or below) allowable stress is based on the tensile strength due to the brittle nature of the low temperature material.
  - Yes, the lack of low temperature ductility is not good for a pressure vessel material
  - Low stresses and no impact or shock loading
  - Experience has shown no mechanical problems at low temperature
- A conservative result, allowing for some variability of samples, is 600 MPa/3.5 = 171 MPa, over six times the room-temperature value.

We had only used this code case

Interpretation: VIII-1-89-82

Subject: Section VIII, Division 1, UG-19

Date Issued: February 15, 1989

File: BC89-056

Question: For Section VIII, Division 1 construction and certification, if nonmetallic, non-Code tubes are used in heat exchangers of the fixed tubesheet, floating head or U-tube types, whereby the operating pressure on the tube side is greater than the operating pressure, fluid and mix effects on the shell side, but the shell and associated pressure relief devices are designed to withstand the highest design pressure associated with the tube side, and the outside pressure boundary parts are treated as a single chambered vessel making UG-19 inapplicable, may such a single chambered vessel be stamped as complying with Section VIII, Division 1?

Reply: Yes.