April 23: Cryomodule/ Cryogenics

Time	Title	Presented by
8:00	CF&S Technical Area WebEx Meeting	Marc Ross et al.,
9:00	Cryomodule: functional parameters and interfaces	N. Ohuchi/H.Carter
9:30	**Plug-compatibility** (for cavity and cryomodule, HLRF): -Interfaces (CAD-work boundary condition) of plug-compatible design - (expected) Compatibility of ILC and Project-X cryomodules -Parameters tables for interfaces	 D. Mitchell S. Nagaitsev H. Hayano and N. Ohuchi
10:45	Break	
11:00	Discussions Conclusion/Consensus (Table filled) and Further study required	Led by Ohuchi and Carter
12:30	Lunch	
13:30	**Helium vessel issues for dressed cavities** Introduction, comments helium vessel issues JLab report (Nb-stainless joint, pressure vessel issues) Brief comments on cryomodule "crash test" at DESY Comments and discussions for further works	 T. Peterson Ed Daly L. Lilje H. Nakai, K.Jensch
15:00	Break	
15:30	**Thermal optimization for cryomodule/cryogenics** -5 K shield study at TTF cryomodule design -5 K shield study at STF cryomodule design -Lowering radiation shield (80K) temperature Discussions and conclusion/consensus	 P. Pierini N. Ohuchi N. Ohuchi led by Ohuchi/Peterson)
18:00	SCRF dinner ??	

Some Comments on Helium Vessel Issues for Dressed Cavities

Tom Peterson

23 April 2008

Causes of cavity helium bath pressure excursions

- Worst case location is probably always the cavity helium vessels in the string far from the cryogenic plant
- Purification and cool-down flow
- Warm-up flow
- Compressor failure (e.g., power outage)
- Control and/or valve failures
- Loss of insulating vacuum while cold
- Loss of cavity vacuum while cold

Peak warm pressure

- Compressor suction set pressure
  - 1.2 bar
- Control margin
  - +/- 0.2 bar
- Relief set pressure margin
  - 0.3 bar (a judgment here, would like 0.5 bar)
- Suction relief set pressure
  - 1.7 bar
- Pressure drop from far string
  - 0.1 bar
- Peak warm pressure
  - 1.8 bar (note that 0.5 bar set P margin ==> 2.0 bar)
- We have selected 2.0 bar warm design P

Peak cold pressures - analysis

- Film boiling of helium with 60 K surface is about 2.5 W/sq.cm.
- Heat flux of 10's of KW to liquid helium
- Mass flows of many kg/sec, very dynamic and non-steady situation
- Pressure drops to vent may result in peak pressures of 3 - 4 bar locally
  - Even if vent opened at much lower pressure
- TTF, TESLA, and XFEL analyses have been done, as well as for many other systems
- Test data are necessary to validate analyses

Peak cold pressures in TTF/ILC

- Analyses of TTF and TESLA back in the early 1990's indicated that worst-case loss of vacuum might lead to pressures near 4 bar cold
- Input parameters
  - Heat flux as limited by
    - Rate of air inleak
    - Suface heat transfer
  - Total surface area involved
    - Can be limited by vacuum breaks, fast valves
  - Initial conditions
    - Note that 4.5 K just after filling is the worst case!

Peak cold pressures - tests

- Loss of vacuum to air
  - "Safety Aspects for the LHe Cryostats and LHe Containers," by W. Lehman and G. Zahn, ICEC7, London, 1978
    - "3.8 W/sq.cm. for an uninsulated tank of a bath cryostat"
    - "0.6 W/sq.cm. for the superinsulated tank of a bath cryostat"
  - "Loss of cavity vacuum experiment at CEBAF," by M. Wiseman, et. al., 1993 CEC, Advances Vol. 39A, pg 997.
    - Maximum sustained heat flux of 2.0 W/sq.cm.
  - LEP tests and others have given comparable (2.0 to 3.8 W/sq.cm.) or lower heat fluxes
  - New! "Crash" tests at CMTB at DESY

Dressed cavity vessels as pressure vessels

- Helium vessels (generally) fall under the scope of pressure vessel codes
- Standard pressure vessel codes are difficult to apply
  - Non-standard materials
  - Various heat and chemical treatments
  - Non-standard weld/braze joints
- It would be nice to compile some generally applicable material information

Request for information

1. What room-temperature yield stress, ultimate stress, and/or "allowable" stress, do we use in analysis and documentation for dressed SRF cavities, and based on what sources of information?

2. Similarly, what low temperature mechanical properties do we use for the various materials, and based on what sources of information?

3. How do we address the uncertainties in niobium properties that result from the various heat and chemical treatments?

4. How will we qualify joint designs, such as welds and/or braze joints, including welds between dissimilar materials.

Estimating allowable stress

- For our Niobium, RRR = ~300, after forming and heat treating at 800 C, conservatively assume:
  - Ultimate Stress ST: 95 MPa
  - Yield Stress SY: 50 MPa
- Allowable stress per ASME Pressure Vessel Code, Section VIII, Division 1, formula
  - Lowest of either ST/3.5 or 2/3 x SY, with another 0.85 factor for welded pipe or tube. So ST x 0.85/3.5 = 95 x 0.85/3.5 = 23 MPa determines our allowable stress.

Summary of room temperature mechanical properties for pressure vessel analysis

	Tensile strength ST (MPa)	Yield strength SY (MPa)	Allowable (MPa)
Example Š 3.9 GHz cavity Niobium as received	150	~50	
RRR 300 Nb after forming, welding, BCP, 800 C heat treating from literature	115	~50	
Nb assumed for Fermilab analysis	95	~50	
Allowable for Nb per ASME code formula (for welded pipe or tube, ST/3.5 x 0.85)			23
KEKB cavity parent Nb material	162		34
KEKB cavity welded Nb part	118		30
Titanium grade 2 from ASME, Section 8, Div 1, tables			83
NbTi (45% Nb, from ATI Wah Chang)	546	480	
Allowable for NbTi per ASME code formula (for welded pipe or tube, ST/3.5 x 0.85)			133