Cryostat Acceptance strategy

O. Beltramello – 30.01.2018

What do we want to ensure ?

- the cryostat structure withstands the commissioning, operating and exceptional load cases

- the cryostat and all penetrations are leak-tight

Note : the slab sizing and testing is not part of this discussion

Reminder .. the basis:

October 2015 - MoU signed between CERN and Fermilab, Design, Fabrication, Installation and Testing of the LBNF/DUNE and SBN Membrane Cryostats - EDMS 1554082

Reference for the design, manufacturing and testing of all membrane cryostats of LBNF/DUNE and SBN programs.

The main points are:

- US ANSI/AISC 360 (latest edition) “Specification for Structural Steel Buildings” applies to the design and construction of the support structure.

- the warm steel supporting structure design is performed per the European standard for steel structure design and construction EN1993 - EUROCODE 3 (equivalent to ANSI/AISC 360).

- the design approach is to generate a detailed FEA model of the vessel and to perform a detail stress analysis of each component.

- the level of safety per ASME Boiler and Pressure Vessel Code, Section VIII, Div. 2. is demonstrated to comply with the U.S. DOE 10 CFR 851.

Reminder .. the basis:

October 2015 - MoU signed between CERN and Fermilab, Design, Fabrication, Installation and Testing of the LBNF/DUNE and SBN Membrane Cryostats - EDMS 1554082

Prior to each testing campaign:

✓a risk assessment is performed to verify personnel and equipment safety during the tests.

✓the respective authorities of the host laboratory performs an internal review.

Their approval is mandatory prior to each test.

1. **Destructive tests for the weakest structural part** of the steel frame in order to validate the FEA model and the structure mechanical behavior.

2. Prior to the Liquid Argon filling process, **a pneumatic test** is performed at a testing pressure PT:
PT = 1.15 x Maximum Allowable Working Pressure = 1.15 x 350 mbar.

3. **Fill of the cryostat with liquid argon in incremental steps** until the service level.

- **Structural analysis method (see Andrea talk)**

The structural analysis of the vessel have been performed following the MoU requirements.

The sizing loads are:

- operational : self weight + LAr hydrostatic load + 350 mbar overpressure
- exceptional : seismic load case

- **We follow a strict quality insurance plan: fabrication and QC (see Dimitar talk)**

The fabrication follows EN 1090 for all QC

- Welding procedures
- Welders qualification
- Material certificates, etc…

- **Leak testing is performed locally for the external membrane, the primary and secondary membrane (see Filippo talk).**

Proposed structural testing methods

1. Destructive tests for the most critical structural part of the steel frame (7 tests) for the worst loading cases **(see Dimitar talk)** :

- performed remotely from the cavern and under control.
- anticipated from the installation to correct if required the design
- validate the FEA model (**local worst behavior**) and the worst connections cases. **(see Dimitar talk).**

No risk for personnel, no risk for the cryostat, no risk for the detector

2. During the cryostat filling and commissioning, the gas pressure in the vessel is maintained below 150 mbar, the sizing loads can never be exceeded **(see Johan talk).**

3. Filling of the cryostat with liquid argon in incremental steps until the service level.
This is complementary of step1of the qualification process.

It verifies the **global model** of the cryostat and the general behavior of the structure under the worst load case.
In particular, **it qualifies the bottom part of the structure**.

The structural behavior (deformations and strains) of the warm structure is checked during the whole filling process:

- Height of the liquid = service height (96% of LAr)
- Overpressure of LAr gas in the remaining volume at 350 mbars.

Compensatory safety measures while filling the cryostat

1. The cryostat is instrumented with deformation and strain gages at strategic locations, and IR cameras.

2. In case of any abnormal behavior of the structure:
   - filling is stopped
   - the cryogen is transferred to an available adjacent cryostat or drained

3. Oxygen deficiency monitors are installed all around the vessel linked to evacuation of the SURF undergrounds.

4. Exceptional access to the bottom part of the cavern during filling process with specific safety measures (ODH portable, 2 persons rules, oxygen masks)

We disregard the pneumatic tests because:

It is not required by any code (the vessel is not a pressure vessel)

It **will NOT qualify the most loaded part of the vessel structure and connections. Then what would be** the criteria for test acceptance as the test will not load at maximum the most critical areas ?

It will NOT remove the risk of an issue during the filling with LAr as the static head will load highly the bottom connections.

It is not required for leak tightness testing as it is covered by other methods.

It is dangerous for personnel as inspections are required during the test

It is dangerous for the vessel, for the detectors and for the surrounding infrastructures:

We estimated a stored energy of:

E= 420 MJoules equivalent to 100 Kg of TNT
With missiles estimated at > 300 meters