LBNF Project Manager's Final Design Review – Closeout

Cryostat #1 Steel Support Structure (Warm Structure)
21-22 August 2017 at Sanford Underground Research Facility in Lead, SD
Review Committee: Mike Andrews (FNAL), Kevin Fahey (FNAL), Tim Hart (LBNL), Jim Niehoff (FNAL), Tom Nicol (FNAL) - chair, Russ Rucinski (FNAL), David Taylor (SURF)

Executive Summary

The warm structure for detector #1 is the focus of this review. A significant engineering effort has been undertaken by engineering professionals at CERN in arriving at an optimized design for the structure. The presentations and material presented show that the design complies with design rules and will meet its function as the structural support for the membrane cryostat and the load of the DUNE detector.

Charge

The Long Baseline Neutrino Facility (LBNF) Cryostat for Detector #1 will provide the cryostat for the first of four Deep Underground Neutrino Experiment (DUNE) liquid argon time-projection chamber (TPC) modules. The cryostat is composed of two major elements: the membrane cryostat interior (cold vessel) that contains the liquid argon, and the steel support structure (warm structure) external to the membrane.

The cold primary membrane vessel is made of a stainless-steel liner that contains the cryogenic liquid and gas. This liner maintains leak tightness and is corrugated to provide strain relief due to temperature-related expansion and contraction. The insulation is composed of two layers of polyurethane foam, providing a thermal barrier between the membrane at the liquid cryogen temperature and the steel support structure at ambient temperature; a secondary barrier located between the layers of insulation is a physical protection that contains the liquid argon in case of a failure of the first membrane. The surrounding cryostat warm steel structure support consists of large vertical beams alternating with a framework of smaller structural members and a steel plate liner, also acting as vapor barrier to prevent the moisture from entering the insulation space.

The steel support structure provides support for all internal and external loads acting on the cryostat, including hydrostatic pressure, gas pressure, thermal, weight, and seismic loads. The loads from the liquid head and the gas pressure are transferred from the cold vessel stainless steel membrane vessel to the steel support structure through the insulation. The top steel frames will serve also as a support structure for the detector and the internal cryogenics.

This external, independent review is of the final design of the Cryostat #1 steel support structure, which is 18.9m wide x 17.8m high x 65.8m deep, and will be installed a mile underground at the Sanford Underground Research Facility in Lead, SD, in a to-be-excavated chamber. The design has been optimized to reduce weight and connection complexities and facilitate modular fabrication and installation. It includes the feedback from the construction of several smaller prototypes built at CERN in the last couple of years. The design has been done by CERN and documentation is provided by the engineering team for this review.

Ancillary steel structures are associated with the cryostat and are also part of this design review. Access/egress stairways and platforms are integral to the four sides of the steel support structure. An independent mezzanine, supported from the chamber roof and side walls, supports cryogenic equipment and covers part of the area above the cryostat. Platforms supported from the top cryostat steel support structure members support detector equipment and provide walkways to access that equipment as well as the mezzanine.

The review will look at the analysis and design of the steel support structure to answer these charge questions:

1. Does the design meet the functional and performance requirements?
    - ***Yes.***
2. Does the design conform to interface agreements?
    - ***Yes, transportation of components in and around the work area, the ability to handle mechanical loads, and dimensional requirements of installation in the cavern appear to be well understood, but some agreements on logistics for storage, above ground transportation, etc. are still works in progress. The project has plans to hire a full-time logistics professional to assist in these issues. This will be crucial to meet the November goal of defining penetrations in the warm structure roof.***
3. Does the layout of the stairways, walkways, and platforms meet life safety requirements?
    - ***Not yet. Partial plans exist in the mechanical design of the steel structure, e.g. manholes, access holes, etc., but the system of ladders and walkways is incomplete.***
4. Are design, fabrication, and assembly drawings and specifications complete, or if not yet, is there a plan to complete them prior to the production readiness review (currently scheduled for Sep 2018)?
    - ***The committee was presented with examples of specifications, models, and drawings and there is a plan leading to completion by the production readiness review schedule for next year.***
5. Has the installation process been considered in the design and is it accommodated satisfactorily?
    - ***Yes, we were presented with a credible plan for assembly. This will likely be modified over time, but the potential problems and other issues seem to be well understood. There are plans for a future installation review.***
6. Will the planned destructive testing validate the finite element analysis model and structure mechanical behavior?
    - ***Yes.***
7. Are the design and the testing plan adequate to satisfy the required codes and standards?
    - ***Yes, for the steel structure, the design is adequate to satisfy the required codes. Plans for weld testing also satisfies the required codes. Testing proposed for all the various mechanical joints ensures an adequate design, but is not required by the code.***
    - ***For pressure testing, no. A membrane cryostat pressure test is required by the existing MOU and FESHM. The steel structure is part of the membrane cryostat so FESHM chapter 5031.7 "Membrane Cryostats" applies as does the Memorandum of Understanding "Design, Fabrication, Installation and Testing of LBNF/DUNE and SBND Cryostats", EDMS 1554082 v1. Both documents require a pressure test prior to filling with liquid argon. CERN takes exception to the pressure testing requirement. LBNF management and the authority having jurisdiction will need to resolve this exception or accept responsibility for pressure testing.***

Recommendations:

- Resolve the penetration issues between the top of the cryostat, detector, and cryogenic equipment before November.
- LBNF management and the authority having jurisdiction will need to resolve the disagreement that CERN has to performing a pressure test prior to operations. CERN states that a pressure test could be done if CERN's responsibility is removed for all project consequences of a failure during the test.
- Prior to procuring and manufacturing the warm vessel, the egress ports, ladders, handrails, guardrails, and toe boards to and from the bottom of floor of the cavern should be finalized. This includes appropriate trap door access, ladder access, railings, signage, lighting, and additional handrails, guardrails, and toe boards at intermediate levels of the warm vessel. This design also includes a means to extract an injured worker. This design should be reviewed and approved by the LBNF ES&H Manager.
- Verify that the base of the structure can adequately support the structure's weight, including the leveling legs, the concrete floor, and the grout placed below the steel beams.
- Verify that the welding specifications call for weld electrodes that have ductility properties, for example low hydrogen content and Charpy V-notch toughness.