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CHARGE AND SYSTEM OVERVIEW

An internal Laboratory committee met at the Lujan Center auditorium on December 3, 2004 to review the 10% designs for the vent and ventilation lines of the liquid hydrogen target being built by the NPDGamma collaboration. This target is to be tested first in building MPF-35 before being installed in the experiment located at flight path 12 (FP12) in the Lujan Center Experimental Room 2 (ER-2), MPF-622. The charge to the committee was given by the LANSCE-12 Group Leader, Alan Hurd:

> The Committee will report to the LANSCE-12 group leader, Alan Hurd.
> The Committee is asked to;
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> - Provide an independent review of the hydrogen and fire safety aspects of the two separate vent lines required to test and operate the Liquid Hydrogen Target System of the np->dγ experiment, first in the Shed (TA-53-MPF-35) and secondly on flight path 12 at LANSCE with priorities of protecting people (highest), protecting equipment and providing reliable operation.
> - Provide an overall assessment of and recommendations for improvement of the proposed hardware, including such aspects as design and construction.
> - Comment on whether all physical phenomena or physical behaviors with significant safety or operational consequences had been adequately considered.
> - Comment on any other safety or operational issues observed.

The committee members were:

- James Knudson, LANL LANSCE-7, Chair
- J. Patrick Kelley, LANL LANSCE-7, LANL Cryogenic Liquid Safety Committee member
- Dallas Hill, LANL ESA-AET, Hydrogen Review Committee and LANL Cryogenic Liquid Safety Committee member

The experiment was represented by

- Seppo Penttilä, LANL P-23, Project Manager for NPDGamma
- Mike Snow, Indiana University
- Hermann Nann, Indiana University
- Todd Jankowski, ESA-AET

Other Laboratory stakeholders were represented by

- Roger Cardon, FM-MSE
- Frances Aull, LANSCE-10
- Jane Lataille, LANL Fire Marshal's office
- Ron Nelson, LANSCE-12
- Scott Walker, HSR-1
- Josh Long, LANSCE-3
- Ben Etuk, ENG-DECS

The review began with an overview of the experiment and its status by Seppo Penttilä. The experiment is designed to measure the parity-violating asymmetry in the reaction $\vec{n}p \rightarrow d\gamma$ with a sensitivity of 10% in the predicted value of 5×10^{-8}. The beam line on FP12 is complete and the collaboration has checked out their detector systems by measuring several parity-violating asymmetries with the neutron beam. The liquid hydrogen (LH_2) target is the last major component of the experiment to be installed and is now the highest priority of the experiment. The team plans to test the target in MPF-35 before installing it in FP-12; hence each location requires a vent line from the target and a ventilation line from a tent enclosing the target apparatus. In order for the target to be installed in FP-12 for 2005 beam operations

the exterior work on the ER-2 stacks must be complete by the time beam is first delivery to the Lujan Center at the end of January, 2005 in order to avoid working in the 1L target beam spill exclusion area.

Mike Snow discussed the design and safety features of the LH_2 target. The design goals, driven by physics as well as safety considerations, are:

- Safety: be safe to operate and be in compliance with codes
- Maximize absorption of the polarized cold neutrons. This dictates the target size of 30cm diameter and 30cm length.
- Minimize neutron depolarization. This requires that para-hydrogen at temperatures $\leq$ 17K.
- Suppress formation of bubbles and minimize in-leakage. This dictates an operating pressure of slightly greater than one atmosphere.
- Negligible attenuation of gammas. This requires the use of low-Z materials in the vicinity of the neutrons.
- 6Li- rich neutron shield.
- Cryostat must be non-magnetic.

Previous reviews of the target design have yielded the following guidance:

- No release of hydrogen into the experimental cave should occur following a failure of the main vacuum system or target vessel.
- Design the target for "triple containment" of the LH_2.
- Be able to safely and rapidly vent the LH_2 on command in emergency situation.

Hermann Nann presented a discussion of the calculations that formed the basis of the sizes of the vent lines. He made his calculations without taking credit for the thermal insulation installed in the vacuum vessel, which is certainly very conservative for sizing the vent pipes, but is not for determining vent times. The conclusions he reaches are

- a 1.5-inch (ID) target vessel relief line will handle a mass flow rate of 0.2 lb/s with a 43 psia pressure rise; and
- a 4-inch (ID) relief line from the vacuum vessel will handle a mass flow rate of 0.5 ob/s with a 23 psia pressure rise.

Todd Jankowski presented the results of an independent calculation from first principles of the behavior of the system following a target vessel failure. His results predict that at 4.5 seconds after the rupture the system pressure is reduced to 13.5 psia and that roughly 2/3 of the initial hydrogen charge has been vented.

Mike Snow showed the results of testing of Conflat flanges performed at Indiana to determine the suitability of these items to function while pressurized. The issue here is that the Conflat flange is designed to be a vacuum flange, and the manufacturer does not rate them for pressure service. Conflat flanges have metal o-rings and have more bolts than most other flanges, giving them the potential for being very strong. The target designers wish to use them under pressure. Various size flanges were leak tested warm and also after being cold soaked and rewarmed. A further test was made where a small leak was introduced into a flange which was cold-soaked in order to test whether such a leak would plug when exposed to air. The Indiana team concludes that Conflats may be used in the system. Other facilities, such as Jefferson Laboratory, are making similar tests.

Seppo Penttilä described the ventilation plans for MPF-35 and ER-2. An important safety feature of the gas handling system will be a flow restrictor that will limit total hydrogen flow to the target to a maximum of 10 SLM. This means that 500 SLM (or 18 cfm) of air flow will be required in the enclosure to keep hydrogen concentrations below 2%, or half of the lower explosive level (LEL).

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SUMMARY OF REVIEW FINDINGS

Acknowledging the fact that this review was of 10% designs, the committee was satisfied that the collaboration is on the path to final solutions and designs that will meet the various sets of requirements that are involved with these vents (structural code, fire code, electrical code). The committee encourages the collaboration to press ahead with finalizing the design and commencing with fabrication and installation. While there is some risk that an important issue could arise at the next level of review, the committee considers this risk to be small.

RECOMMENDATIONS

The committee was very interested in the results of the testing of Conflat flanges done at Indiana, and concurs that this is the proper route for validating the use of these items in the target assembly. The Indiana tests did not subject the flanges to pressures much beyond the MAWP of the target system and so the committee is concerned that there is a risk that the tests stopped just short of inducing failure in the flanges. Testing to failure would be extremely useful information if the Indiana team can do so safely with an appropriate set up. Otherwise, testing to at least twice the system MAWP would suffice to establish a comfortable safety factor.

A further point to follow up on is to repeat the cold tests of the Conflats, this time watching for leaks the entire time while the flanges warm from liquid nitrogen temperature to room temperature. Experience at the 1L Target Facility showed that Conflats would leak badly when undergoing a temperature gradient, yet would be tight when cold or warm.

Recent LANL experience with Conflats shows that regularly checking of the tightness of the fasteners should be part of a preventive maintenance program. Using Belleville washers, rather than lock washers, has shown to be a useful method of helping to keep the fasteners tight.

Additionally, the committee repeats earlier recommendations that welding be the preferred method for connecting components of the both the vent lines and the gas handling system, and that use of connectors such as Conflat flanges or VCR fittings be minimized. VCR fittings remain the connectors of choice where non-welded joints are unavoidable.

The committee recommends that the fill line from the hydrogen supply bottles to the target be armored, and that the vent line from the cryostat also be armored.

The committee was impressed with the results of the first-principle calculations by Jankowski. We request that the following related questions be investigated:

- The calculations of Jankowski should be extended to see how long it takes to vent the entire hydrogen charge.
- What is the effect on vent times and flow rates of the first rupture disk opening only partially?
- What is the effect on vent times and flow rates of the failure of the first rupture disk to open?
- What is the appropriate K factor for the rupture disk?

The committee expects to see a formal, documented review of the stack drawings at the 70 – 80 % level. This can be done as part of the regular meetings that the local stakeholders have been having.

The committee will also want to see the as-built details of the ventilation systems at the time of the experiment readiness review.

The committee strongly suggests that the microswitches installed on the gas handling panel in MPF-35 be rendered safe (non-sparking) by cutting their cables if they are not removed.

The committee recognizes the progress made on establishing change control for the target system and encourages the collaboration to keep up this effort. One important aspect of change control is the use of materials certification and making this information readily available to the collaboration. Making scans of these documents available on the collaboration's web site would be worthwhile.

The committee will welcome the opportunity to look over the target operation procedures as they are developed beyond the rough draft stage.

The committee would like the collaboration to investigate further the following issues:

- Is 10 SLM really the worst-case scenario for dumping hydrogen into the target cave?
- Work with the 1L Target Team to determine if the installation of the ER2 vent stacks creates an Unresolved Safety Question (USQ) for the 1L Target Facility. Any USQ issues that result will need to be dealt with by the 1L Target Team.
- Conduct a Failure Modes and Effects Criticality analysis on the helium system used to purge the joints and welds.
- Investigate the use of pressurized helium to force out the hydrogen charge as opposed to the proposed argon dump in the event of an emergency vent.
- Conduct an oxygen deficiency/depletion hazard analysis for the helium bottles used in MPF-35.
- Investigate the consequences of the heat load from a fire directly under the cryostat to be certain that the loss of the cryostat will not exacerbate the effects of the fire. The committee recognizes that the target need not be designed to survive such an extreme event.