REPORT OF THE np → dγ LIQUID HYDROGEN TARGET REVIEW COMMITTEE

The Committee met at the Lujan Neutron Scattering Center of the Los Alamos National Laboratory on November 29-30, 2005.

The Committee members were:

- James Knudson, LANL, Chair
- Mikell Seely, TJNL
- Dallas Hill, LANL
- James Kilmer, FNL
- Allen Crabtree, ORNL

Experiment collaboration members present:

- David Bowman, LANL, Experiment Spokesman
- Seppo Pentilla, LANL, Project Manager
- Mike Snow, Indiana University
- Hermann Nann, Indiana University

Los Alamos facility staff present

- Paul Lewis, Lujan Center Experimental Area Manager
- Jane Lataille, LANL Fire Protection Office

CHARGE

The Committee will report to the LANSCE-Lujan Group Leader, Alan Hurd.

The Committee is asked to:

Provide an independent review of the hydrogen safety aspects of the Liquid Hydrogen Target System of the NPDGamma experiment on flight path 12 (FP-12) at LANSCE with priorities of protecting people (highest), protecting equipment and providing reliable operation.

Specifically, the committee is to review the target system as installed in MPF-35 (the "Shed") where the first hydrogen operation is planned. This review should primarily focus on the safety of the as-built system in MPF-35, and secondly to review the design of the target and its operation after its transfer to FP12.

Provide an overall assessment of and recommendations for improvement of proposed hardware, procedures and facilities, including such aspects as design, controls, instrumentation, interlocks, safety systems, ease of operation and reliability.

Review a list of possible failures and comment whether each was adequately represented and consequences correctly assessed, if the proposed mitigation method was adequate, if there was a better mitigation method and if any failures had been overlooked.

DISCUSSION

The committee is pleased with the changes that the collaboration has made to the design of the target, particularly the elimination of thin windows on the cryostat, which collectively make the worst-case scenario of a hydrogen spill into the cave highly unlikely.

The collaboration plans to operate the target at positive pressure, rather than at sub-atmospheric pressure as was in the original design. This change, which was recommended at the previous review, will reduce the likelihood of developing problems from small leaks during extended operating periods.

Helium passivation of the vent lines is a further change that the Committee agrees makes a significant positive impact on the safety and reliability of the target. Detecting helium in the vacuum space is an unambiguous signal of potential trouble, and will allow the operators to intervene before more drastic events can occur. The effects of small leaks through check and relief valves that are backed with helium gas will be minimal compared to having air behind these valves.

The Committee is encouraged that the collaboration has taken steps to establish a quality assurance (QA) plan that incorporates (1) control of the critical design drawings and documents and (2) a change control method. Once the collaboration decides to freeze the design, continued diligence is required to ensure that uncontrolled changes, however small and seemingly unimportant, do not compromise the design or operation of the target.

The Committee concludes that the worst-case accident that could occur is the loss of the entire hydrogen charge into the cave at the end of FP-12 as a result of the rupture of the cryostat and the vacuum vessel. It is not clear to the Committee how well the cave would survive the subsequent fire. However, given the robust construction of each of these vessels and of the cave itself, this event is expected to be highly unlikely.

In the Committee's opinion the most credible accident involves physical contact between the target and the ER-2 crane. The collaboration has taken steps to mitigate this problem through the use of barriers and shielding. Even so, it is the Committee's opinion that venting the entire hydrogen inventory out of the top of the target in such an accident, while certainly undesirable, would not be a catastrophic event due to the rapid dispersion of the hydrogen into the large volume of ER-2.

The next credible accident to consider is the rupture of the cryostat into the vacuum vessel, which remains intact. The Committee finds that the rupture disks installed into the relief chamber are sufficiently large to handle this event.

SUMMARY OF REVIEW FINDINGS

It is the opinion of the Committee that the collaboration has designed and constructed a target that will accomplish the goals of the experiment safely and reliably. The Committee recommends that a few minor details, listed below, be completed, after which hydrogen operations may proceed. We have separated these recommendations into sections referring to initial operations in the Shed (MPF-35) and the eventual operations in ER-2. The Committee was satisfied that the target designers have considered the failure modes and have developed appropriate methods of mitigation.

The Committee also makes one recommendation to the Lujan Center in the third section below.

RECOMMENDATIONS

1. Approval to proceed with hydrogen operations in the Shed:

    a. Barriers (shield blocks would be adequate) should be placed strategically around the Shed to prevent a vehicle from striking the target.

    b. Leave building doors open when operating with hydrogen.

    c. Ensure that the gas handling system is leak-tight before operating with hydrogen. A helium leak-check is sufficient.

    d. Install a sign on the outer wall of the shed reading "Caution: Hydrogen in use; authorized personnel only", or some other appropriate wording, to warn casual observers.

    e. Use of the flow restrictors planned for the ER-2 hydrogen manifold is strongly encouraged for the Shed operations as well.

    f. Prepare an as-built P&ID specifically for the Shed operations.

    g. Ensure adequate monitoring of the target takes place at all times during hydrogen operations.

    h. Create a development plan for the target that tests various fault situations. One such fault situation would be for the GHS to go sub-atmospheric while the target is being condensed because a combination of regulator and flow restrictor settings do not supply gas at an adequate rate. Any leaks in the GHS would then result in contamination of the target with air.

2. Approval to proceed with hydrogen operations on FP-12 in ER-2:

    a. The committee views with favor the decision by the collaboration to replace the existing gas panel with one featuring welded construction and a minimum number of demountable joints. A robust, reliable and leak-tight GHS is essential to the safe and successful operation of the target. As in point 2.h. above, the possibility of sub-atmospheric conditions in the gas panel dictates particular diligence on this issue.

    b. Consider installing a low-pressure relief valve in parallel with the rupture disks that protect the vacuum vessel.

    c. Ensure that the operating procedure includes methods of dealing with fault scenarios such as loss of a heater or a drop in the pressure in the cryostat.

    d. Develop an operating strategy and interlock system that minimizes the number of situations that require rapid venting of the hydrogen.

    e. Erect barriers to ensure that the hydrogen bottles and manifold are protected

    f. Prepare a response to the presence of hydrogen in the cave.

    g. Consider operating combustible gas detectors in pairs to reduce false positive indications.

3. For the Lujan Center:

    a. Ensure that all operators of the ER-2 crane are made aware of the hazards presented by the presence of the hydrogen target at FP-12.