AGENDA AND DESCRIPTION OF SYSTEM

The committee met at the Indiana University Cyclotron Facility (IUCF), Bloomington, Indiana, on December 4-5, 2001. The charge to the committee was given by the LANSCE-12 Group Leader, Alan Hurd:

The Committee is asked to report to the LANSCE-12 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 np->dγ experiment 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 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 is adequately represented and consequences correctly assessed, if the proposed mitigation method is adequate, if there is a better mitigation method, and if any failures have been overlooked.
- 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
- James Kilmer, Fermi National Laboratory
- Trevor Lucas, Oak Ridge National Laboratory
- Mike Seely, Jefferson National Laboratory
- William Schneider, retired, formerly with Brookhaven and Jefferson National Laboratories

Indiana University faculty, staff and students present:

- Mike Snow, IU Physics Department faculty
- Hermann Nann, IU Physics Department faculty
- Igor Kusnetsov, IUCF postdoctoral fellow
- Bill Lozowski, IUCF staff, target expert
- Mike Gericke, IU Physics Department graduate student

Los Alamos facility staff present:

- Dan Seely, LANL LANSCE-FM, TA-53 Facility Manager
- Roger Klaffky, LANL LANSCE-12, Lujan Facility Experimental Area Manager
- Seppo Penttilä, LANL P-23, NPDGamma Project Manager
- Jeff Schinkel, LANL P-23, Group Safety Officer

- Jan Novak, retired from LANL, Laboratory consultant for cryogenics

The meeting began with welcoming remarks by IUCF director John Cameron, who discussed the changes occurring to that facility as a result of the conversion of IUCF from an NSF facility to a state-supported medical treatment facility. This change has opened other opportunities and facilitatedexperiments at other facilities in user mode; hence the participation of the IU team in NPDGamma.

The review began with presentations of the present status of the $\vec{n}p \rightarrow d\gamma$ experiment, NPDGamma, the requirements and limitations placed on the target by the needs of the experiment, facility requirements, target safety and design, and details of the design of several safety-related components of the target.

Seppo Penttilä, the Project Manager for NPDGamma, described the present status of the experiment. The collaboration was scheduled beam time during Fall 2001 to develop beam monitoring equipment, the neutron spin flipper, and the CsI detector. This work has been progressing satisfactorily. The collaboration expects to begin work on building the shielding enclosure beginning January 2002, with target fabrication beginning at about the same time. The plan for commissioning the target in Los Alamos calls for this to happen in May 2003. At the request of the DOE, the collaboration is implementing full project management for the construction and operation of the experiment.

The design goals for the target were given by Mike Snow of IUCF. In order to meet the physics goals of the experiment, the target must:

- Capture >50% of the incident neutrons while shielding the gamma detectors (this implies a low-Z target)
- Maintain the neutron spin
- Introduce no systematic effects from polarized-neutron capture on other materials present
- Introduce no noise effects above $\sqrt{N_\gamma}$ from fluctuations in target pressure, temperature or density (implies that bubbles must be suppressed)
- Minimize the magnetic interactions between the target and the polarized neutrons that could affect the overall level of polarization
- Be safe and reliable to operate

SUMMARY OF REVIEW FINDINGS

The sense of the committee is that the basic target design concept is sound and that the target would work as proposed by the collaboration and would likely meet the criteria required of the experiment. A number of details are still to be worked out, and the committee should be consulted when all of the final decisions have been made. With the basic design under control, the committee was able to put a significant emphasis on operational considerations for this target; where it was generally felt that the most likely source of difficulty that will arise from the operation of this target will be from operator error. No other significant failure modes were identified by the committee.

First and foremost, the committee agrees that a quality assurance (QA) plan should be established as required by the management plan being implemented. The QA program will need to meet the requirements of the relevant DOE orders while ensuring that the resulting system also meets the intent of the electrical and fire codes, and ANSI B31.3 for the system piping. The committee requests that the designers provide a statement describing how the various vessels will meet the intent of the ASME pressure vessel Code standards along with LANL requirements.

RECOMMENDATIONS FOR THE TARGET DESIGN

1. Operational considerations:

A number of issues arose regarding target operations that the committee felt the need to comment about:

- The committee was concerned that the presence of the 10 kW heater called for in the present design is a potential source of trouble. It is intended to assist in the rapid venting of hydrogen in the event of an abnormal situation, but the (conservative) calculations of the design team indicate that there is little benefit to be gained in turning on this heater over such other solutions as spoiling the insulating vacuum or simply turning off the cryo-coolers. The committee viewed the consequences of an unplanned or inadvertent activation of this heater while the target flask is empty, causing severe damage to the vessels, to outweigh the small benefit gained in the venting scenario. The committee recommends that the design team investigate alternative methods of initiating the rapid vent.

- While some members of the committee have successfully operated sub-atmospheric cryogenic systems, no one was aware of a hydrogen target being operated in this fashion. To the best of the committee's understanding the sub-atmospheric operating principle presented did not appear to work. It was the committee's conclusion that operating at less than one atmosphere invites a host of difficulties should leaks develop, despite the large size of the proposed vent lines. The committee recommends that the target philosophy be modified so that the target operates at greater than 1.25 bar rather than at sub-atmospheric pressures, and that the collaboration give a clear explanation of the operating principles involved. If the return line from the target is returned to the main manifold at a point below the gas feed/vent connection, the liquid will subcool and a small heater can be used to control its operating temperature. With subcooling of about 4K, boiling in the target is unlikely and the outer refrigerated radiation shield should no longer be required.

- Considerable discussion revolved around the possibility of using a storage tank to contain the charge of hydrogen, rather than relying on a manifold and rack of up to six hydrogen bottles. Given the expected 48-hour cooldown time to fill this target, it was felt that a storage tank would be advantageous in that bottle changes at all hours would be eliminated, and, given a clean tank, that overall cleanliness of the charge could be better maintained. Recognizing that some serious logistical details would need to be worked out, the committee recommends that the use of a storage tank large enough to contain the entire hydrogen inventory be investigated. The inclusion of such a tank would have consequences on other parts of the system, and perhaps also other parts of the Lujan facility, that would have to be thought through. Additionally, the committee suggests that a warm buffer or ballast tank would ease the cooldown process by smoothing out the fast pressure transients that would likely occur during cooldown.

2. Relief setpoints:

The committee and the design team spent a significant amount of time discussing the choice of set points for the relief valves on the both the hydrogen flask and the helium jacket. These settings appear to be far above the operating pressure, be it either less than or greater than one atmosphere, and are greater than the crush pressure of the vacuum jacket. Recognizing that the final settings could be affected by whether or not a storage tank is chosen, the committee wishes to see a thorough description of the philosophy and rationale behind the eventual relief valve settings. The committee recommends that relief valve pressure settings be included with the piping schematics so that values will be unambiguous.

3. Vent line sizing:

The size of the hydrogen vent line was one topic revisited by the committee in its concluding discussions. This discussion is also a consequence of the lack of understanding on the committee's part concerning the basic principles of operation proposed. It was not immediately clear that venting hydrogen would warm sufficiently to be buoyant when it reaches the end of the vent stack. Clearly the design team needs to perform new calculations of the vent line conductance once the vent line design is finalized. The committee recommends that the design team review the size of the vent line considering the following points concerning the cold gas in the line;

- The ortho-hydrogen to para-hydrogen ratio of recondensing gas may be sufficiently changed from the target liquid as to make maintaining the desired ortho/para ratio difficult. However, operating the system with sub-cooled liquid, as suggested, would improve control of the ortho/para ratio since the constant body of fluid is not required to condense and re-condense.

- The heat leak back into the target flask needs to be of manageable proportions.

5. Pressure vessels:

Significant work remains to be done on the design of the hydrogen pressure vessel. The committee is satisfied that the present plan of bolting the upstream/downstream dome to the aluminum body of the vessel will work, and is also satisfied with the progress made at correcting the deficiencies with the entrance head pointed out by the analysis performed by ARES Corporation. The design team is encouraged to review the stiffening around the penetrations into the vessel for the fill and vent lines. The committee would like to see more analysis of the entire vessel, including the interactions between the vessel and its supports, the flange designs and of the outer vessels as well. The committee agrees with the design team that the transfer of the target to Los Alamos should be done with the target disassembled and properly packed. The design team is encouraged to perform a vibration analysis of the components during shipping to preclude damage.

6. Testing:

The committee was concerned that the testing plan for the target is not complete. It does, however support the present idea that testing with inert liquid be done at IUCF in order to debug the gas handling system before everything is shipped to Los Alamos for final testing with hydrogen. The committee requests the opportunity to review the testing plan prior to implementation.

7. Gas handling system:

The committee was concerned that the conceptual design for the gas handling system is too vulnerable to operator error and disruption of target operations, especially during cooldown. The committee specifically identified the residual gas analyzer (RGA) as a potential source of trouble in that a valve line-up error or even leaky valves could cause either hydrogen or helium to enter the isolation vacuum. The committee recommends that the design team investigate alternative methods of installing or operating the RGA to prevent the former scenario. This should eliminate the cross-connect and move the RGA from one part of the system to the other. Two RGAs could be used to avoid the cross connection, or a dedicated pumping system designed for RGA to pump continuously. The proposed design also showed a palladium leak downstream of the cold trap; some concern was raised by the committee that the palladium would catalyze hydrogen and residual oxygen into water that would then plug the system. The committee recommends that the final design have the palladium filter upstream of the cold trap. The design presented to the committee was incomplete, with some potentially trapped volumes lacking pressure relief. Therefore, the committee requests that a new gas handling design that addresses these issues be developed, and a detailed full piping diagram be created to full engineering standards. Finally, the committee suggests that the eventual operating procedures that will be written include straightforward checks of system integrity such as rate-of-rise tests.

8. Code compliance:

Fire and electrical code issues are serious hurdles for operators of liquid hydrogen targets to overcome, as these codes do not address the special circumstances of these systems. The project must obtain the agreement of the appropriate authorities at Los Alamos before operating this target. The committee agrees that the construction of a tent to enclose the portion of the gas handling system located above the shielding cave is the best solution for isolating the hydrogen system from sparking electrical equipment. The committee felt that the potential for the ER-2 overhead crane to cause difficulties with the gas handling system can be minimized through the use of appropriate administrative controls on crane operations. The design team is encouraged to pursue this approach with the Los Alamos fire protection authorities. The suggested construction method of using Herculite (a self-extinguishing coated fabric) over a Unistrut framework with a vented fan drawing air through the enclosure has been used successfully by most of the committee members at their home institutions. Since final acceptance of this system will be made by LANL, the committee does not need to be involved in any further review of this subject beyond being assured that a tent is implemented.

9. Facility interface issues:

A discussion of facility interface issues covered areas that will require extensive interaction between the project and the relevant authorities at LANL. The potential exists for impacting the requirements of the authorization bases of actinide experiments and of the 1L Target Facility. It is clearly in the best interests of the experiment that any such negative interactions between the experiment and its neighbors in ER-2 be eliminated. The committee is of the opinion that the best way to achieve this goal is to develop the safest, most reliable target possible consistent with meeting the physics goals of the experiment. It will be up to the collaboration to convince the appropriate LANL and DOE authorities that the target design does indeed pose no threat to other experiments and to the facility. The failure table prepared for the engineering document that describes this target will be a key component of these discussions.

10. Change control:

Change control is part of the larger issue of quality assurance (QA) that must be addressed by the project. The basis for all QA will be the Engineering Document, once finalized, being prepared by the project, and the assembly drawings. Any deviations from this basis, for whatever reasons, will be subject to the change control process. While the full details of this will be part of the project management plan, the committee recommends the following broad details be included in the change control process:

1. When a change is identified, the Target Work Package Leader sends a written change request to the Project Leader. The change request will include sufficient detail to describe the change and full justification for the request.

2. A Target Change Control Board (TCCB) consisting of J.D. Bowman (Experiment Spokesman), J. Knudson (Review Committee Chair), S. Penttilä (Project Manager), and J. Schinkel (P-23 Group Safety Officer) will review the change.

3. The TCCB will either approve the change or recommend that it be forwarded to an appropriate level for further review and approval. The hierarchy of levels might be: TCCB, LANSCE Facility, LANL LH_2 Safety Committee, LANL management, DOE.

The TCCB will function mostly as a screening committee.

The committee requests that a final readiness review of the target be completed prior to the start of operations.

11. Approval to proceed with target fabrication:

Given the fact that a multi-institution collaboration is interacting with a DOE facility in this effort, the committee recommends that the following steps be undertaken before proceeding with fabrication of the target:

- A detailed response to this report is prepared and accepted by Alan Hurd, LANL LANSCE-12 Group Leader.

- A complete set of assembly drawings for the target and its support structure is prepared, signed off by IUCF authorities, and approved by the appropriate LANL authorities.

- That the Committee reviews the drawings and concurs with the detailed response to this report.