DESIGN CRITERIA FOR THE NPDGAMMA LIQUID HYDROGEN TARGET GAS HANDLING SYSTEM VERSION 2

Version June-13-2005

Loction: TA-53, bldg MPF-30/ER2, FP12
Organization: P-23
Date: Latest update on June 13, 2005

1 System Description

The NPDGamma Collaboration has built a 21-liter liquid para-hydrogen (LH_2) target for the $\vec{n} + p \rightarrow d + \gamma$ experiment. The NPDGamma has been commissioned in 2004 and in 2005 and aims to have its 1st production phase at the Lujan Center in flight path 12 in fall 2005. The LH_2 target including the gas handlin system was built and preliminarily tested at Indiana University and then moved to Los Alamos where it was reassembled for testing in the building MPF-35 at TA-53. The target is still in MPF-35, and to date, we have tested (without cryogenics) the cryostat, instrumentation, and the preliminary implementation version of the gas handling system.

A plan is to fully test the target system in MPF-35, this includes also hydrogen operation. For this, the target must pass tests and reviews. We have to demonstrate that the target meets all safety requirements. After a succesfull operation in MPF-35 the target will be installed in the FP12 cave for the NPDGamma production.

The LH_2 target system, its design, operation, and safety is described in the Engineering Document [1].

One of the target components is the hydrogen gas handling system. The gas handling system (GHS) is needed for to deliver hydrogen gas from the supply manifold that has pressurized storage cylinders, to the cryostat while conditioning the gas and regulating and metering its flow rate. GHS is described in the Engineering Document [1]. The discussion in the Document won't be duplicated here. The diagram of the gas handling system is shown in Attachment A. Attachment B shows the loaction of the GHS on the FP12. The GHS is enclosed to an aluminum box with a 8" diameter ventilation pipe attached that in a case of a hydrgen gas leak, will safely conduct the hydrogen outside of the building.

The design criteria for the ventilation line of the enclosure are given in other documet [2]. The design criteria for the enclosure is given in [**?**].

The design of the gas handling system and the enclosure should meet requirements given by
- NFPA-50, *Standard for Gaseous hydrogen Systems at Consumer Sites*
- NFPA-70, *The National Electrical Code*
- NFPA-497, *Classification of Flammable Liquids, Gases or Vapors and Hazardous Locations*
- DOE 420.1A, *Facility Safety, Section 4.2 "Fire protection"*
- LIR 402-910-01, *LANL Fire Protection Program, Section 6.1*

Due to unavoidable reasons, it is not possible to meet all the requirements given by these and other documents. Where we cannot meet the requirements, we have done our best to mitigate the consequences. For example, the particular requirement of concern is that the GHS does not in its final location have the required 15' setback from conventional electrical equipment. By enclosing the GHS and venting the enclosure, a boundary is established isolating the GHS from the ignition hazards associated with electrical equipment. This also addresses the requirements of NFPA-50A, *Standard for Gaseous Hydrogen Systems at Consumer Sites* although again strict compliance is not achieved due to operational requirements and space constraints. Our system falls within the category of 400 to 3500 SCF of hydrogen within the code. The GHS should meet the following of those requirements:
- Electrical equipment within the cabinet will meet the requirements for Class 1.

Since it is clear that we cannot be in compliance with all the code requirements, we have instituted a number of adminstrative and engineering controls that should bring us to achieve equivalent compliance;

- GHS can only be operated by trained and authorized personnel - formal training and qualification of operations staff are defined and authorized by the line management.
- We will have extensive and approved operating procedures.
- We will have extensive procedures for leak testing. The procedures have to be approved.
- We will have a continuos monitoring of hydrogen levels in the enclosure.
- We will have controls that automatically stops hydrogen flow in the GHS and dumps the contents of the system upon detection of hydrogen in the enclosure.
- We will have an automatic shut down of electrical power in the enclosure in the event of detection of hydrogen in the enclosure.
- We are using welded joints as many places as possible but if other type of joints are needed, we will use either VCR or CF type joints.
- All the components of the GHS will be thoroughly pressure tested to 1.2xMAWP.
- The GHS is protected for over pressures by three pressure relief valves, RV101, RV102, and RV103.
- The layout of the GHS pannel has to be clear and components and their functions easily identified.

- The hydrogen gas flow rate in the GHS is limited to about 10 SLM.

Purpose of this document is to give design criteria for the gas handling system and identify associated main hazards.

2 Hazard Description, Consequencies, and Mitigation

1. Hazard: Hydrogen burning inside piping in the GHS.

   Concequeses: Pressure build-up and rupture of a component in the GHS and a possile hydrogen gas leak to the enclosure.

   Mitigation: The GHS is designed to handle any emergy situation safley. The piping and components of the GHS can tolerate high pressures. MAWP of the pipe downstream of the Pd membrane purifier (PRFR) is xyz psi. MAWP of the pipe upstream of the Pd membrane purifier is abc psi. Each section is protected by a pressure relief valve. Use of welded joints but if required VCR or CF joints have to be used. Components and piping thoroughly pressure tested. Hydrogen gas flow rate in the GHS limited to about 10 SLM. The GHS can only be operated by trained and authorized personnel - formal training and qualification of operations staff are approved and authorized by line management. Have extensive approved operating procedures. Have extensive approved procedures for leak testing of the system. We will have Controls that automatically stops the hydrogen flow in the GHS and dumps safely the content of the system upon detection of hydrogen in the enclosure. Shut down of electrical power in the enclosure in the event upon detection of hydrogen in the enclosure. The fire will burn out because of the hydrogen supply is stopped. The enclosure prevents the fire to spread. The layout of the GHS has to be clear to minimize operator error.

2. Hazard: Hydrogen leaking out from the GHS into the enclosure.

   Concequences: Fire

   Mitigation: The ventilation rate of the enclosure will prevent the hydroegn content in the enclosure to reach the LEL level, see [2]. If there is a fire outside the GHS, the enclosure will contain the fire. The fire will burn out because of the hydrogen supply is stopped automatically. To prevent hydrogen leaks in the GHS welded joints are used and if reuired only VCR or CF joints canbe used to replace the welded joints. The components and piping of the GHS will be pressure tested. Hydrogen gas flow rate in the GHS is limited to about 10 SLM. The ventilation of the enclosure can handle this size of leak without that hydrogen contnet reached the LEL level in the enclosure. We will have extensive approved procedures for operating the GHS and leak testing of the GHS. We will have Controls that automatically stops the hydrogen flow in the GHS and dumps the content of the system upon detection of hydrogen in the enclosure. There

will be a shut down of electrical power in the enclosure in the event upon detection of hydrogen in the enclosure.

3. Hazard: Air leak into the GHS.

   Consequences: Fire inside the GHS or in the target.

   Mitigation: See hazard above "Hydrogen burning inside pipe." The leaked air is condensed in the cold trap. When the target filled, hydrogen left in the GHS is pumped out and the GHS backfilled with helium. The cold trap is isolated with valves V125 and V117. When warming up the condensed air vaporizes and can cause an overpressure in the trap. The pressure relief valves RV102 and RV103 will protect the system. Before new hydrogen gas is introduced to the GHS, it is carefully pumped and leak checked. To prevent air leaks welded joints are used but if required only VCR or CF joints can be used as replacement. We will have extensive approved procedures for operating and leak testing of the GHS.

4. Hazard: Blocked cold trap or OPC during the target fill. Requires operator's action during the target fill.

   Consequences: No hydrogen flow. Probability of operator error increased.

   Mitigation: We will use ultra pure hydrogen gas. In addition, the gas has to go through the Pd-membrane purifier and cold OPC and cold trap. It is very unprobable that there is any impurities left to block the OPC or cold trapp. To get air into the GHS so that it could block the OPC or trap, is possible only if there is a leak after the PRFR, Pd membrane purifier. In a case of a blockage, the target filling will be stopped and the cold trap valves closed and cold trap warmed up, and cleaned according to the approved procedure.

5. Hazard: Cold trap and OPC will run out of LN_2.

   Consequenses: Dirt that was trapped in the cold trap gets into the cryostat. In the cryostat the dirt will be again condensed on cold surfaces of the cryostat. When cryostat is warmed up a possibility of air-hydrogen admixture at the LEL level or higher exists..

   Mitigation: Monitoring of the LN_2 amount in the dewar and have an alarm if level goes to low. Use ultra pure hydrogen gas. To prevent leaks welded joints used but if required VCR or CF joints can be uswed too. Extensive approved procedures for operating the GHS and leak checking of the system. An extensive approved procedure to warm up the cryostat and cleaning it.

3 Design Requirements

1. The main hydrogen line sized so that hydrogen throughput at 1 atm is at least 20 SLM.

Figure 1: A schematic of the gas handling system. This is how I imagine laying things out, with the three main lines parallel and unbent.

2. MAWP downstream of the Pd membrane purifier xyz psi. MAWP of upstream of the Pd membrane purifier is abc psi.
3. Sections of the GHS protected by pressure relief valves with properly set relief points.
4. Leak rate: Helium leak rate less than $1x10^{-9}$ atm cm^3/s. (???)
5. Layout of the main line and compoents have to be clear, the main hydrogen line has to be separated from the rest of the GHS so that it is easy to indentify.
6. Valves used in the hydrogen line and connecting lines have to be easily reconizable. It has to be visualy easy to see if a valve is open or closed - on/off type valves with lever-type handles.
7. No electricity inside the enclosure besides a few low volatage pressure gauges.
8. Careful electrical grounding of GHS, its components, and the enclosures.

References

[1] NPDGamma Liquid Hydrogen Target Engineering Document, V2.0. Available at web site www.iucf.indiana.edu/U/lh2target/export-files/

[2] Design Criteria for Ventilation of the Enclosure of the NPDGamma Liquid Hydrogen Target Gas Handling System on Fligh Path 12 at ER2. Dated Decemeber 1, 2004. Available at web site www.iucf.indiana.edu/U/lh2target/export-files/

[3] encl) Design Criteria for the Enclosure of the NPDGamma Liquid Hydrogen Target Gas Handling System on Fligh Path 12 at ER2. Not yet available.