SAFETY MANAGEMENT FOR THE CRYOGENIC SYSTEM OF SUPERCONDUCTING RF SYSTEM

S.P. Kao, C.R. Chen, F.Z. Hsiao, J.P. Wang,
National Synchrotron Radiation Research Center,
101 Hsin-Ann Road, Hsinchu Science Park, Hsinchu 30076, Taiwan, R.O.C.

Abstract

The installation of the helium cryogenic system for the superconducting RF cavity and magnet were finished in the National Synchrotron Radiation Research Center (NSRRC) at the end of October 2002. The first phase of this program started commissioning at the end of 2004. This is the first large scale cryogenic system in Taiwan. The major hazards to personnel are cryogenic burn and oxygen deficient. To avoid the injury to the operators and meet the requirements of local laws and regulations, some safety measures must be adopted. This paper will illustrate the methods of risk evaluation and the safety control programs taken at NSRRC to avoid and reduce the hazards from the cryogenic system of the superconducting RF cavity and magnet system.

SYSTEM INTRODUCTION

A helium cryogenic system with cooling capacity of 450W at 4.5K was set up in NSRRC at the end of 2002. This helium system is dedicated to provide the cooling ability for 500 MHz superconducting radio frequency (SRF) cavity which is a key item of the upgrade project to enhance beam current and stability of the electron storage ring.

Major components of the cryogenic system are installed at three areas including the platform, the compressor room and the gas yard. Figure 1 shows the layout of these three areas [1,2].

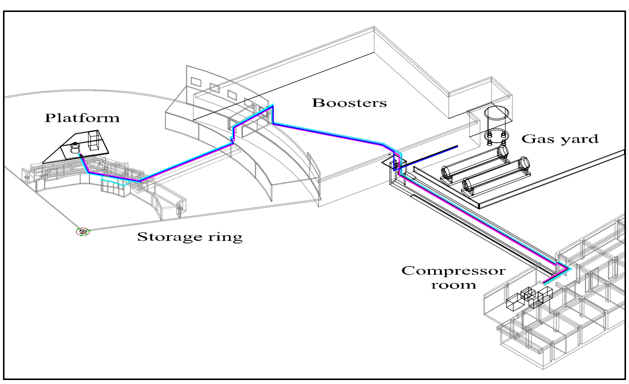

Figure 1: Location of the cryogenic system.

The 10kW refrigerator, the 2000L dewar and the distribution valve box are located on the platform with 2.8m height above experiment floor. The space under the platform is a shielding room for cavity test before its final installation into the storage ring.

The main compressor and its oil removal module, various frequency drivers for the main compressor, the recovery compressor and its oil removal module are installed in the compressor room located at the basement of the utility building. The compressor room is constructed with soundproof wall and vibration isolation floor to decrease noise and vibration.

In the gas yard, a nitrogen storage tank with a capacity of 20000L is installed and two $100m^3$ helium gas storage tanks are located nearby. A local grounding network for pressure transmitters is installed on the foundation of the nitrogen tank and helium tanks. Another grounding network is constructed for the nitrogen tank to prevent a lightning strike.

RISK ANALYSIS

Various methods for hazard identification can be used such as safety review, checklist analysis, what-if analysis, fault tree analysis and HazOp (Hazard and Operability) studies. Among these, HazOp has been the most popular method.

After preliminary hazard analysis, helium cryogenic system and LN_2 system are the two major parts with high priority to do HazOp studies.

The HazOp studies considered many system parameters such as pressure, temperature, flow rate, level etc. It also applied a set of "guide" words.

During a series of HazOp meetings, we focused on specific portions of the process called "nodes" firstly, and then the HazOp team studied the piping and instrumentation diagrams (P&IDs) to find out the causes and consequences of every abnormal deviation.

The assessment sequence for the entire HazOp process includes [3]:

- Defining the information, needs and objectives of the HazOp
- The HazOp study itself
- Approval of the HazOp
- Review of the HazOp
- Recording and reporting of the overall study

A flow chart of the helium cryogenic system is presented in figure 2 [2]. For brief example, we focused on the node 1022, which is the main dewar and its P&ID is shown in figure 3. Some of the HazOp worksheets are reported in table 1.

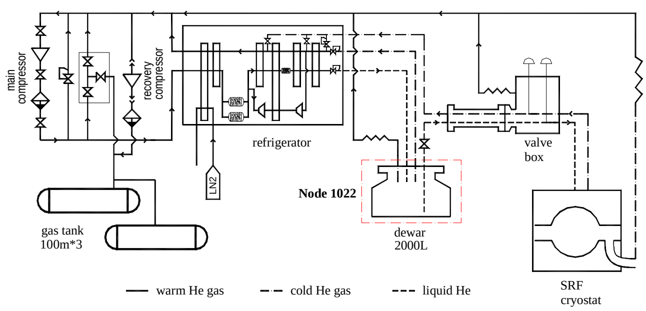

Figure 2: Flow chart of the helium cryogenic system.

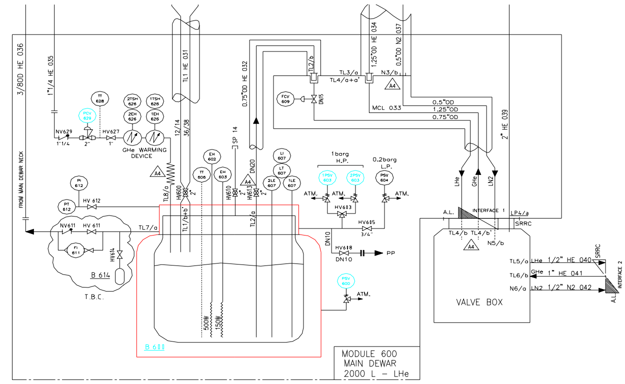

Figure 3: The P&ID of main dewar.

Table 1: HazOp worksheet for the helium cryogenic system

- Process unit: LHe supply system
- Node description: 1022 – Main dewar (capacity: 2000L, operation pressure: 0.4barg, operation temp: -268℃, pressure setting of high pressure safety valve 1PSV603/2PSV603: 1barg)
- Piping / Equipment No: B 600 (Setting of pressure safety valve PSV603: 1barg, pressure setting of interlayer safety valve PSV600: 0.2barg)
- Design purpose: LHe storage (outer and inner vessel are stainless, vacuum pumping)
- Draw No: C1088A005-A

No.	Deviation	Causes	Consequences	Safeguards	Severity categories	Probability levels	Risk levels	Recommendations
1022.1	High pressure	1. High source pressure 2. Fire outside 3. Bad vacuum 4. Long idle time (vaporize naturally)	Dewar breaks	1. Dewar has high pressure safety valve 1PSV603/2PSV603 2. Regular maintenance 3. Daily inspection 4. Hot work control 5. Fire hydrant and extinguisher indoor 6. High pressure alarm 7. High pressure relief valve PCV629 pressure setting: 0.5barg	2	D	4	1. Personnel training 2. Emergency response drill
1022.2	Low pressure	1. Excessive back end use 2. Low source pressure	No specific hazard is found					
1022.3	Vacuum	No possible cause is found						
1022.4	High temp	1. Fire outside 2. Bad vacuum bad (leakage caused by error crane operation)	Dewar breaks	1. Dewar has high pressure safety valve 1PSV603/2PSV603 2. Regular maintenance 3. Daily inspection 4. Hot work control 5. Fire hydrant and extinguisher indoor 6. High pressure alarm 7. High pressure relief valve PCV629 pressure setting: 0.5barg 8. Fence	2	C	3	1. Personnel training 2. Emergency response drill 3. SOP of crane operation 4. To set up alarm in danger area and interlock of the crane
1022.5	Low temp	No possible cause is found						
1022.6	High level	1. Level gauges failure 2. Heater failure (can't heat LHe to gasify)	No specific hazard is found					
1022.7	Low level	1. Level gauge failure 2. Heater failure (can't heat LHe to gasify) 3. Excessive back end use	No specific hazard is found					
1022.8	No level	No possible cause is found						
1022.9	Leakage	1. Hit outside 2. Aging, corrosion 3. Bad welding 4. High pressure safety valve 1PSV603/2PSV603 discharge abnormal	Personnel frostbite	1. Fence 2. Regular maintenance 3. Manufacturer's quality assurance 4. Regular valve test	2	D	4	1. Hazard labelling 2. Personnel control 3. Tags on tube and valve 4. Flow direction signs

OXYGEN DEFICIENCY HAZARDS

After careful HazOp evaluation, we identified the following four possible situations that may lead to oxygen deficiency hazard (ODH) resulted from the cryogenic system.

0-7803-8859-3/05/$20.00 ©2005 IEEE

Abnormal Discharge of LHe System

In the storage ring, all exits of safety valves are connected to specific exhaust pipes to discharge to the atmosphere. This will unlikely cause an ODH. If the dewar breaks and helium gas is completely released because of heat or fire accident, the air space of the experiment floor (44089 m^3) is able to safely dilute the helium gas of 1600m^3.

Abnormal Discharge of He Compressor System

The compressor room is a confined space. All exits of safety valves except the helium compressor are connected to specific pipes to discharge to the atmosphere. When oil separator's pressure of the helium compressor is too high, these release valves will discharge helium to the room. The maximum discharge rate is 0.26m^3/sec. The discharge rate of the exhaust system is 4.16m^3/sec that is large enough to provide adequate ventilation to avoid ODH in the compressor room.

If the exhaust system was shutdown because of power failure, there is another backup venting system connected to uninterruptible power-system (UPS) and the emergency power system to introduce fresh air from outdoors. In the worst scenario that both venting system are failed, the delay time for the compressor room of 316m^3 in volume to reduce oxygen concentration from 18% to 14% is about 243 seconds. This delay time is sufficient to evacuate from the compressor room whose diagonal size is 17m.

Abnormal Discharge of He Pipeline System

The underground transport tunnel housing He pipeline is a potential area that may cause ODH when severe He leakage occurs. Ventilation well is designed to minimize possible ODH. If the ventilation well failed during a He leakage accident, the delay time to compel oxygen from 18% to 14% is 184 seconds. People should have enough time to evacuate from either door of both ends 47.5m apart.

Abnormal Discharge of LN_2 Transfer Line

The maximum flow rate of the LN_2 transfer line to experiment floor is 130L/hr. In case LN_2 is leaking at full flow rate and completely vaporized, the oxygen concentration in the experiment floor will decrease 0.2% every hour. There are hours of time to respond to the alarm triggered by oxygen detector and close the valve before oxygen concentration decrease to dangerous level.

SAFETY MANAGEMENT

From the HazOp studies, we have identified the major hazards including high flow, extreme low temperatures, high temperature, high pressure, leakage and oxygen deficiency. To prevent the occurrence of hazard, safety management for the cryogenic system of SRF system should include engineering controls, administrative controls, personal protective equipment and emergency procedures.

Engineering Controls

- Design of cryogenic systems
- Preventing oxygen deficiency
- Preventing system overpressure
- Oxygen enrichment
- Inspection of cryogenic system
- Fire protection system
- Annual test of safety valves & oxygen detectors

Administrative Controls

- Safety documents
- Personnel training
- Process safety assessment
- Emergency action plan
- Audit plan
- Sign, tags and labels
- SOP for receipt, use and storage

Personal Protective Equipment (PPE)

- Hand, eye and face shield protection
- Respiratory equipments
- Ears plugs or muffs

Emergency Procedures

- Frostbite
- Cryogen spill and oxygen deficiency

SUMMARY

For the cryogenic system, the HazOp studies have been helpful to identify and to predict possible incidents. We identified 48 possible incidents in the helium cryogenic system, 10 possible incidents in the LN_2 system. We have improved safety control to prevent these potential accidents.

Required by Taiwan regulations, we have submitted safety reports to the authority for approval in year 2003. After document reviews, the authority conducted an on-site inspection focusing on the engineering and administrative controls. At the end of 2004, our operation approval was granted officially.

REFERENCES

[1] F.Z., Hsiao, et al., "The pilot-runs of the helium cryogenic system for the TLS superconducting cavity", PAC'03, p. 2402-2404.

[2] F.Z., Hsiao, et al., "The Liquid Helium Cryogenic System for the Superconducting Cavity in SRRC", PAC'01, p. 1604-1606.

[3] Kennedy R., Kirwan B., "Development of a Hazard and Operability-based method for identifying safety management vulnerabilities in high risk systems", *Safety Science*, Volume: 30, Issue: 3, December, 1998, p. 249-274.

0-7803-8859-3/05/$20.00