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RHIC PROJECT

Brookhaven National Laboratory

Failure Mode and Effects Analysis RHIC Cyrogenic Liquid Storage Area

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1.0 INTRODUCTION

1.1 GENERAL

The object of a Failure Mode and Effect Analysis (FMEA) is to identify all the postulated modes of failure, within a system or sub-system design, so that hazards from the resultant effects can be eliminated or control to an acceptable level of risk at the earliest possible time. The system must remain safe for all reasonable postulated equipment failures or operator errors. The analysis shall be used to assess existing high risk items and the systems or sub-systems, in the design stage. The analysis will then provide us with the information needed to minimize hazardous effects due to component failure. The end result of an FMEA is increased reliability and safety.

1.2 OUTLINE

To provide assurance that all of the subsystems of the RHIC cryogenic system were covered, the analysis was carried out in concert with the design effort when possible.

1.2.1 The cognizant engineer (CE) involved in the design of their respective subsystem or component has considered the potential failure modes and their effects on the subsystem or component.

1.2.2 The failure of a component of a subsystem, causing a complete failure of the subsystem, would be viewed upon as a component failure of the system. For example, a vacuum failure of one of the valve boxes would be viewed as a failure of the valve box for the system FMEA.

1.2.3 This FMEA will review the failure modes and effects of a component failure in subsystems, and in addition will study the effect of total failure modes, of the subsystems, and their effect on the Cryogenic system as a whole.

1.2.4 The FMEA is primarily component orientated. Each component of the system should be reviewed in each possible failed state, for each mode of operation, to evaluate its possible safety consequences to the system. When the FMEA is applied to a process, with different modes of operation, the steps or operating procedures have been carefully formulated or reviewed. In addition a safety analysis worksheet, with operating mode indicated, is used as a record of the specific failures. The worksheets will include information on system or subsystem modes in order to evaluate the components effect as a function of mode.

2.0 SCOPE

2.1 GENERAL

2.1.1 This FMEA is intended to cover the RHIC cryogenic Liquid Storage Area (LSA) facility and components.

2.2 SYSTEMS AND COMPONENTS FOR ANALYSIS

2.2.1 The system and components reviewed for this study are those added to the RHIC cryogenic system to provide a reserve volume of liquid helium for various operating conditions. The system is identified by RHIC Helium Storage P & ID drawing RD3A995073.

2.3 COMPONENTS REVIEWED

2.3.1 Types of components that are covered in this study include: storage dewars, valves, relief valves, burst disks, sensors (pressure, differential pressure, temperature, etc.) and gauges.

2.3.1.1 The major components which make up the LSA include the following:

- The liquid helium stowage dewars (designated Dewer #1, Dewer #2 and Dewer #3),
- The liquid nitrogen dewer (designated Dewer #4),
- The distribution system associated with the liquid nitrogen system and the helium dewars,
- The distribution system between the cryogenic supply header and the helium dewars,
- The distribution system between the cryogenic return header and the helium dewars,
- The distribution system between the cryogenic cooldown return header and the helium dewars,
- Bulk fill and Local withdrawal piping.

2.4 SYSTEMS OR SUBSYSTEMS NOT COVERED

2.4.1 Systems and component that are located on the cryogenic refrigeration and distribution system side of the LSA isolation valves have been analyzed by other analyses and will not be included in this FMEA.

2.5 SYSTEM DESCRIPTION

2.5.1 Liquid Helium Dewars

Three (3) 11,000 gallon dewars provide a storage volume for Liquid Helium (LHe) during cooldown and warmup operations of the RHIC system. The dewars contain a LHe vessel, surrounded by a Liquid Nitrogen (LN_2) shield, enclosed in a vacuum insulation. For inventory control, each LHe dewer contains a Differential Pressure Transducer (DPT) for liquid level indication along with a force transducer. Both indications are available through the cryogenic

computer control system. Each LHe volume of the dewer is protected from over pressurization by use of a duel branch pressure relief valve and burst disk configuration. A 3-way ball valve is used to align the dewer to either one branch or the other. In the event of a relief valve failing to reseat or a burst disk opening, that branch can be isolated to minimize the loss of LHe without loss of over pressure protection. LHe pressure indication is available through the cryogenic computer control system. Vacuum pressure is available locally.

Dewer #1 and Dewer #2 are the same Cryenco model dewar. Dewer #3 is a Gardner model. The Cryenco dewars include a self contain small LN_2 dewer for volume control. Dewer #3 does not have an independent LN_2 dewer and relies directly on LN_2 from the LN_2 stowage dewer. The Cryenco LN_2 dewer has a DPT for level detection. Overpressure protection is provided by pressure relief valve in parallel with a check valve. The LN_2 dewer is insulated by a vacuum vessel, protected by a pressure relief valve. Overpressure in the LN_2 shield of the Gardner Dewer is provided by a float controller, vented to atmosphere by two (2) check valves in parallel. The Cryenco dewar has internal electrical heaters in the LHe vessel. The Gardner dewer has a heat exchanger in the LHe vessel which is not expected to be used by the system. Each dewer uses a burst disk (Cryenco @ 5 psig, Gardner @ 0.25 psig) for vacuum vessel overpressure protection. t

2.5.2 Liquid Nitrogen Dewars Distribution lines

A 20,000 gallon Cryenco LN_2 dewar (Dewer #4) provides a storage volume of LN_2 for shielding of the LHe dewars. The dewar is also protected from overpressure by use of a duel branch pressure relief valve and burst disk configuration. A 3-way ball valve is used to align the dewer to either one branch or the other as in the LHe dewars. The dewar is enclosed in a vacuum insulation. The dewer uses dual burst disks (@ 10 psig) for vacuum vessel overpressure protection. A DPT is used for liquid level indication, available through the cryogenic computer control system. Pressure indication is also available through the cryogenic computer control system. Vacuum and nitrogen pressures are available locally. A series of manual and digitally controlled pneumatic valves allow LN_2 feed to the LHe dewars and well as LN_2 dewar operations. The LN_2 header can be isolated at both the outlet of the LN_2 dewar and inlets of the LHe dewars.

2.5.2 Liquid Helium Dewars and Cryogenic Systems Distribution lines

Each LHe dewar is connected to cryogenic system Supply (S), Cooldown Return (CR) and Return (R) at the 6:00 VJRR. These headers have been designed to the same operating pressure as the cryogenic system. Relief valves are used for over pressure protection. The Return header is configured so at each LHe dewar, flow can be at the top, branched off the same port as the Cooldown Return, or at the bottom, identified as LHe. Digitally controlled pneumatic valves provide isolation for each line at both the VJRR and at each dewar. At the isolation valve at the VJRR, each line has temperature indicators on either side of the valve and a pressure indicator (available through the cryogenic computer control system) on the LSA side of the valve. At the VJRR, digitally control valves allow cross flow between the Return/LHe header and the Cooldown Return header or the Supply header. The Supply header has a flow element/DPT system to measure the amount of flow to or from the Supply header to the LSA. The Supply

header can also be cross connected by use of digitally control valves with the Cooldown Return header at Dewar #1 and Dewar #2.

3.0 PROCEDURE

3.1 INTRODUCTION

3.1.1 To properly prepare an FMEA that includes the effects on the process and the potential hazards to personnel, we must systematically identify and analyze all of the possible faults.

3.2 GENERAL PROCEDURE FOR ANALYSIS

3.2.1 Identify the major systems and subsystems that in an event of failure will greatly affect the operation of the cryogenic system or could present a hazardous situation to personnel.

3.2.2 Meet with cognizant personnel, to discuss potential failure modes of equipment and systems. Compile this information (see appendix).

3.2.3 Review or establish operating procedures so that mode dependency can be established.

3.2.4 Study and list each component, in the analysis worksheets, and enter all required information. Since this is not a complex system, causes for failures have been omitted. See appendix.

4.0 Methodology

The performance of an FMEA, a detailed study of the components identified by the LSA P & ID's and the how the system is to be used were completed. The detail operating procedures for the LSA still need to be developed using the results of the FMEA for guidance. The following assumptions were made for the FMEA:

A) *Only one independent failure will occur at a time.*

B) *The cryogenic control systems used including software have been verified.*

C) *The system only uses differential pressures to move fluids, no external pumps or compressors will be added.*

D) *The lose of use of the LSA is not a safety risk The purpose of the LSA is to provide an economical means of storing Liquid Helium. The addition of the system does not invalidate the results or conclusions of prior cryogenic system safety analyses or failure analyses.*

E) *LSA operation is not directly effected by different modes of cryogenic system operation outside of its function of either receiving or the supplying of Helium.*

5.0 Results

5.1 The Liquid Storage Area (LSA) and associated piping and control systems were analyzed to determine if failures or unintended operations could cause safety risks as defined by ES & H Standard 1.3.3. The Project policy for the safety review of cryogenic systems is contained in RHIC SEAPPM 5.2.1. The P & ID for the LSA was the basis for the FMEA. Safety issues identified in the FMEA are group and summarized.

5.1.1 Overpressure Protection:
All piping and dewars associated with the LSA were examined for protection from overpressure. The primary volume of all four (4) dewars have dual branch, redundant pressure relief valve, burst disk configuration. A 3-Way valve can be used to isolate one branch at a time, but it can not isolate both branches simultaneously. All factory set relief valves and burst disks are properly labeled. Adjustable relief valves have been tested and adjustment mechanism safety wired.

The cryogenic piping headers (Supply, Cooldown Return and Return/Liquid Helium), which are subjected to the 275 psi operating pressure of the cryogenic system, are design for that pressure and are protected by at least one pressure relief valve in all possible valve positions and system configurations. In the event of a failure of a relief valve to open, which is not the typical failure mode, these headers are isolated under normal system operations by pneumatically operated control valves. The characteristics of these valve are to unseat, under high differential pressures.

Pressure gauges, Differential Pressure Transducer and Pressure Transducers are able to be isolated from the system is a way that overpressure can develop. The safety concern would be if the piping could catastrophically rupture under these conditions. These components are not isolated during normal operation, which they are protected from overpressure. Isolation of these components would only be for specific testing or for removal. These components are attached to the system by use threaded fittings whose failure mode is to leak under high pressure (therefore venting high pressure). In addition, the volume of piping that could be affected has been minimized. These components failure mode under high pressure is to leak, typically through soft material such as bellows, also reducing pressure. Therefore, the risk of injury or damage from overpressure in these lines is low.

5.1.2 Loss of Cryogenic Fluids:
Each Dewar contains level and pressure indicators which can be read at cryogenic control stations. The LHe dewars also have pressure/weight transducers to inventory control. These redundant systems mitigate the risk of overfilling, causing a release of a cryogenic hazard (personnel/equipment contact with very cold temperatures). All dewars vent to open atmosphere, so no Oxygen Deficiency Hazard (ODH) condition be present. Only the pressure relief valves for the Supply, Cooldown Return and the Return/LHe distribution header are located in the VJRR. Since the volume of piping is significantly less than that of the cryogenic system, (which also has its relief valves in the VJRR), no ODH risk would result if the relief would vent as long as normal ventilation is present. Dewar overpressure protection includes a 3-way valve which can isolate on branch in the event of a burst disk rupture or a pressure relief valve failure to reseat. This will minimize the release of cryogenic fluids as well as reduce loss of inventory. All remotely operated

valves, including valves isolating the dewars from the distribution headers and the distribution headers from the primary cryogenic system (at the VJRR) are pneumatically operated valves which will close (normal state) upon the loss of control signal or pneumatic pressure.

5.2 Summary:

The FMEA for the LSA analyzed 189 components and their failure modes. The FMEA is document on worksheets, included as an appendix to this report. The worksheets include the following information: Component Number with its nomenclature, if it is a valve, the valve type, size and temperature/pressure setting if known; the normal function, the failure position, the effect of the failure with its associated risk, comments and if there is any redundancy associated with the component or system.

95 items were analyzed to have a routine risk, as defined by ES & H Standard 1.3.3. These would result in degraded system performance and maintenance actions. 92 items were identified as have a low risk. These items would have either the potential, in the worst case scenario, to release cryogenic fluid resulting in personnel injury or equipment damage or overpressurizing components.

For copies of:

RHIC Cryogenic System
Liquid Storage Area
Failure Modes and Effects Analysis
Worksheets

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