GGT-000007

GEM Detector Safety Analysis Report (SAR)

(Draft Submittal)

Kent Swarts
SSC Laboratory

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Abstract:

This document delineates the safety aspects of the GEM detector TDR design. It identifies hazards, the associated risk and provides mitigating actions that eliminate or reduce the risk of identified hazards.

GEM SAFETY ANALYSIS REPORT

Draft Submittal

April 1993

PREPARED:

Kent Swarts,
System Safety Engineer

Ronn Woolley,
System Safety Engineer

Disclaimer

This document is intended to provide a safety analysis of the TDR design for the GEM detector. As such it does not necessarily reflect the future final design nor does it entirely describe the extent of risks for hazards identified. The document will be updated to incorporate design evolution and changes as they occur.

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1.0 INTRODUCTION

1.1 Purposes

In compliance with SSCL policy for Environmental Safety and Health (ES&H) as expressed by the ES&H Manual, this Safety Analysis Report (SAR) documents personnel, system and operating hazards, quantifies the risk of identified hazards, and describes the adequacy of measures taken to eliminate, control and reduce risk. The document also describes how the design of the detector and associated technical facilities will ensure compliance with regulations or, if compliance is not possible, seek to demonstrate that other measures will provide equivalent levels of safety.

1.2 Scope

This document establishes the detector safety analysis baseline commensurate with the Technical Design Report (TDR). SSCL practices mandate this SAR as a single step process for safety analysis reporting for complying with Department of Energy (DOE) orders. The document will undergo revision and refinement as the detector design progresses.

1.3 Analysis Methodology

Safety analysis and review requirements are defined in DOE order 5481.1B. An ongoing safety hazard analysis of the GEM detector is being conducted. The hazard analysis was initiated in conjunction with the GEM Letter of Intent approval to facilitate early hazard identification and elimination or control. Analyses are conducted by the GEM ES&H group with support from the cognizant detector subsystems design groups. The GEM ES&H group coordinates analyses and provides to engineers the initial technical safety input. Engineers in turn provide additional data analysis. Safety then compiles results for the SAR.

Hazard Analysis Criteria

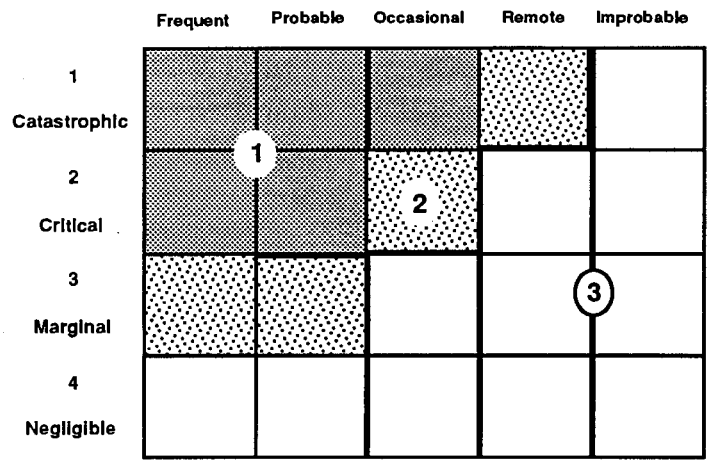
Hazard analysis criteria is based upon SSCL Practice D10-000003, Hazard Analysis Instructions. The identification of hazards is the mutual responsibility of the system safety and cognizant engineers and is based upon first distinguishing operating modes, next defining failure mechanisms which lead to hazardous states, and then quantifying the risk associated with each anticipated hazardous event. Operating modes are defined as any discretely defined periods during the life cycle of a system, or fabrication, usage or manipulation of a device. The various periods considered include those listed in Table 1-1. Hazardous event consequences include personnel injury, loss of or severe damage to equipment, and critically unsafe operations or environments.

Table 1-1 The Various Detector Stages.

Operating Mode	Applicability
Storage	During fabrication & in hall
Fabrication	Applies to manufacture of major subcomponents and modules
Assembly	Tasks performed at support buildings on major components and subsystems
Installation/align/check-out	Tasks performed in experimental hall
Test (fabrication validation) soft/hardware (verify, QA)	All phases - component thru subsystem, In calibration hall, etc.
Experiment operation	Detector, support facilities, environment
Maintenance	Planned, unplanned and emergency
Special operations	Confined spaces, radiation handling, waste management, etc.
Subcontractor-affected operations	Comply with requirements as specified

The risk assessment matrix is central to risk mitigation. It is illustrated in Fig. 1-1, Risk Assessment Matrix. Through the categorization of hazards according to the magnitude of an effect and applying the probable frequency that a hazard might occur, an assessment of the risk is established. The underlying basis for categorizing an identified hazard is the worst-case, credible failure scenario as it relates inherently to mechanical or electrical stress, environmental conditions, the presence of radiation, man-machine interfaces, and software display and control.

Once hazards are identified and classified according to risk, then mitigation action or reduction criteria are applied. Classification of risk and its reduction are defined to the level consistent with the current design of the major systems and components as presented in the TDR. Those hazards categorized as possessing unacceptable risk (contained in the Zone 1 area) are receiving risk mitigation already.



Level	Descriptive Word	Definition
A	Frequent	Likely to occur repeatedly during life cycle of system
B	Probable	Likely to occur several times in life cycle of system
C	Occasional	Likely to occur sometime in life of system.
D	Remote	Not likely to occur in life cycle of system
E	Improbable	Possibility of occur -rence is close to 0.

1 HIGH Imperative to suppress risk to lower level

2 MEDIUM Operations requires written, time waiver endorsed by Mgmt

3 LOW Operation permissable

Note: PERSONNEL must not be exposed to hazard zones 1 & 2

	Severity of Consequences					
1	Catastrophic	Death	>500K	> 4 months	Data never recoverable or primary program objectives lost	Long-Term (5 yrs or greater) environmental damage or requiring $500K or more to correct and/or in penalties
2	Critical	Severe injury or severe occupational illness	100K to 500K	2 weeks t 4 months	Repeat of last program	Medium-term (1-5 yrs) environmental damage or requiring $100K-500K to correct and/or in penalties
3	Marginal	Minor injury or minor occupational illness	1K to 100K	1 day to 2 weeks	Repeat of last period	Short-term (less than 1 yr) environmental damage or requiring $1K-100K to correct and/or in penalties
4	Negligible	No injury o illness	< 1 K	< 1 day	Repeat data point or data requires minor manipulation or computer rerun	Minor environmental damage that readily can be repaired or requiring less than $ 1K to correct and/or in penalties

Fig. 1-1 Risk assessment Matrix. Hazards are categorized relative to risk. The higher the risk, the more engineering and mitigation emphasis it is given.

Risk Management—Hazard and Risk Reduction Criteria

Based upon the analysis results, the analyst determined possible design options and control mechanisms. Choice of risk reduction design options was governed by order-of-precedence criteria. The following order-of-precedence is specified by the GEM Detector Program Management Plan.

1. Design for minimum risk: The primary means to reduce risk is to eliminate the hazard through design. Alternatively, if the hazard cannot be eliminated, then design will reduce the risk to an acceptable level as specified by SSCL Policy and DOE Orders.

2. Incorporate safety systems and devices: If the design cannot feasibly reduce risk to an acceptable level, inherent safety devices or systems which provide effective, reliable protection will be incorporated. Testability of the device or system will be considered as a major factor related to it's fail-safe performance.

3. Provide warning devices: When neither design, safety systems or devices can adequately reduce associated risk, warning devices will be used to detect the condition and to produce an adequate visual or auditory signal (occasionally tactile response). This alerts personnel to the presence of risk thus allowing hazard avoidance or minimizing the probability of incorrect reactions, response or initiation of a hazardous sequence.

4. Safety procedures and training: Safety procedures and training will be used to supplement application of all other mitigation techniques. In no event will training be used in lieu of the other means.

Applicability of Standards, Codes and Industry Design Safety Practices

DOE Orders addressing ES&H and general design criteria are applicable to GEM design and subsequent operation. Related design standards and guidelines also specify similar criteria. Appendix A, Reference Documents, lists the criteria used by the GEM program for meeting regulatory requirements and reducing the risk of inherent hazards.

1.4 Organization and Responsibility

Organization

SSCL Safety is organized to meet the objectives stated in the SSCL ES&H Manual. Organizations and reporting criteria are established by the manual and by SSCL practices. GEM ES&H is organized pursuant to the charter of the Physics Research Division and the GEM Detector Project Management Plan. The PRD Project Management Plan and GEM ES&H Implementation Plan specify the organizational and functional interfaces among GEM, SDC, EFD and ASD to address commonalty in approach to minimize variation among safety systems.

Responsibility

The SSCL ES&H Manual specifies safety policy and subsequently the responsibility of the organization outlined. The Physics Research Division Director is responsible for the safety of the experiments, halls and other factors and for demonstrating compliance to requirements. This in turn has been delegated to the GEM Project Manager who is responsible for implementing the safety program for the experiment and for informing GEM management of

hazards, mitigation and status. The GEM ES&H group is tasked to perform safety activities for the experiment, coordinate hazard analysis, track and resolve identified hazards and report status to GEM management.

2.0 SYSTEM DESCRIPTION

2.1 DETECTOR SYSTEM DESCRIPTION

The main physics goals of GEM involve high p_t physics, directed at the discovery and study of the Higgs sector, and the new physics beyond the standard model. The common signatures for these topics are leptons, jets and missing $\not{E}_t$. GEM detector design goals are to achieve clean identification of these signatures, to make precise measurements for maximum sensitivity to narrow resonances, and to reduce backgrounds. Particular emphasis is given to precise photon and lepton measurements. In addition, we have concentrated on maintaining significant capability at high luminosity at 10^{34} cm^{-2} s^{-1}. A technical description of the detector, subsystems and support equipment is available in the TDR. The following provides a brief overview to indicate the motivation for safety design.

A key design concept of GEM has been to place the magnet coils outside all detector elements. A main advantage of this design is that the intervening materials in the tracker, calorimeter and muon detectors are minimized. Also, the large free-bore of the magnet and the small radius of the inner tracker result in a large lever-arm, yielding enhanced muon momentum resolution.

The design of GEM is based on a large superconducting solenoid. The magnet design parameters for field, radius, and length have been optimized on the basis of cost and performance. The magnet has a nominal field strength of 8000 Gauss (G), an inner diameter of 18 m, and a length of 30.8 m. The conductor is the standard niobium-titanium superconducting alloy enclosed in a stainless steel tube which is filled with liquid helium (LHe). The stainless steel tube is surrounded by an aluminum stabilizer. The magnet has no return yoke. Thus, the fringe field is mitigated locally as needed. Finally, iron forward field shapers are incorporated at the ends of the magnet to shape the field for better momentum resolution in the forward direction. Because of its very large size, it must be constructed at the site.

Muons provide signatures for a wide range of important new physics topics accessible to the SSC. To explore these topics, the GEM muon subsystem is designed for precision measurement. In addition, it is well shielded by the thick calorimeter and general shielding for neutrons and other backgrounds. Muon momentum is measured using the sagitta method in three superlayers between the calorimeter and the magnet where each superlayer is comprised of cathode strip chambers. The muon subsystem contains both a barrel and two endcap sections. Another consideration that affects the design of the muon system is chamber occupancy. To keep the rates in the muon system at levels that can be handled, both for triggering and reconstructing.

The shielding of the GEM muon system by the calorimeter provides a quiet

environment with respect to direct leakage. However, another important shielding problem is that from neutrons produced by particles from the proton collision striking the forward calorimeter and the faces of the final quadrupoles. The shielding designs presented in the TDR have been optimized to maintain tolerable rates for efficient operation of the muon system up to the intended luminosity.

The electromagnetic calorimeter design is based on the noble liquid accordion sampling technique developed over the past several years in R&D programs carried out in the United States and at CERN. Liquid krypton is proposed in the barrel electromagnetic calorimeter and liquid argon in the similar endcaps. The precision electromagnetic calorimeter uses both a barrel and endcap sections. Each section (barrel and endcap) are enclosed in separate vacuum cryostats. To improve resolution, detection and improve muon identification, an absorber barrel using a copper-scintillating tile calorimeter section is employed. In the forward direction, a small calorimeter with a liquid argon electromagnetic section and liquid scintillating copper or tungsten calorimeter is inserted at about 3.4 m from the interaction point.

The central tracker as its name implies, is located immediately around the interaction point of the beam line and inside the other subsystems. Technologies and materials have been chosen so that the central tracker survives to a luminosity of 10^{33} cm^{-2} s^{-1} which also implies that the tracker must be designed for low occupancies. There is an inner silicon tracker section and an outer section of interpolating pad chambers. The silicon section consists of silicon strip ladders arranged in layers. In the forward region, the silicon sensors form disks with the strips projecting radically inward toward the beam axis. The outer tracker consists of 8 layers of interpolating pad chambers arranged in superlayers.

Appendix B, Utilities Systems Safety Overview, provides an overview of the utilities that will be used by the detector. The overview is intended to inform the reader of the general aspects of the utilities, the safety considerations and interfaces. Since these technical systems are evaluated from a safety point of view by other SSCL groups, the issues are not discussed herein. Detector to utility interface issues are discussed in the particular subsystem section.

The rest of the sections presents the analysis and review of the safety of the detector, subsystems and support equipment. The focus of hazard assessment at this point is on the major elements comprising the detector which include: the detector system and subsystem interfaces, support equipment interfaces and detector interfaces with the facility. As previously stated, the current assessment predominantly identifies catastrophic and critical hazards and risks.

3.0 MAGNET AND FORWARD FIELD SHAPER

3.1 Overview

The magnet is a large superconducting solenoid assembly with field shaping in the forward region. It consists of three major subassemblies. Two half-length cylindrical coil assemblies that are placed end-to-end and concentric around the beam line. In each forward region of the muon subsystem a ferromagnetic forward field shaper (FFS) is used to enhance low angle muon resolution. The FFSs, conical in shape, are axial surrounding the beam line and mount to end support structures. The magnet does not have a return yoke and therefore produces a fringe field.

Magnet

The magnet specification requires that the functional design provide specific magnetic field strength and shape. Table 3-1, Field Strength, indicates the nominal magnetic field strengths at various locations centered from the magnet. The locations chosen are relevant to personnel health and system operation. Safety effects and proposed mitigation are addressed in "SSC GEM Magnetic Field Safety & Health Effects", TN-91-19 (Woolley, 1991).

Table 3-1. Field Strengths at Pertinent Locations.

Field Location	Strength (Gauss)
Radially in from the magnet circumference (greatest B)	~ 8,000 G
At the outer envelope of the magnet	~1,000 - 2,000 G
Perimeter of the hall and the lowest levels of the shafts	~100 -200 G
Electronics shaft levels 1 to 3 field decreases	100 to 50 G
Site surface 51.5 m from IP	~ 48 G
100 m above the beam line (~50 m above the surface)	~10 G (pacemaker limit)
110 m above the beam line (~61 m above surface)	1-3 G
IR-5 site perimeter	<5 G

The two magnet assemblies consist of several major subassemblies - coils, vacuum vessel, thermal shields, and structural members. Each magnet half is independently mounted to the floor at reinforced mounting locations and the mounting structure provides the place to which the transporter will be attached. Each coil is supercooled to achieve a nominal operating temperature of 4.5 K by convection flow of LHe through the coil winding. The solenoidal

magnet is encased in the liquid nitrogen cooled cryostat vacuum vessel. The primary safety concerns associated with the magnet are quenching, electrical hazards and cryogen leaks.

A quench occurs when the coil transitions from a superconducting state to a resistive state. The causes which could lead to a transition potential are LHe loss or pressure changes, loss of thermal protection by the vacuum vessel or thermal insulation, or voltage or resistance changes in the circuit. Local disturbances in the form of heat or sudden wire motion are also causes of quenching. The probable occurrence is low, but the event effects on the magnet and other subsystems can be potentially catastrophic if prevention and protection means are not inherent in design. The magnet design incorporates various means to prevent quench.

The cable and the cable-in-conduit design precludes sudden wire motion in normal modes, and structural members prevent movement of coil windings. External heat is kept away by various means. The vacuum vessel provides inherent prevention and protection. It will maintain 10^{-5} torr base pressure to provide thermal separation between the supercooled magnet and the room environment. Additionally, thermal radiation shields inserted between the coil and both the inner and outer vacuum vessel, and placed at both ends of the half coil assembly.

The power requirement for magnet is 20 Vdc at 50.2 kA. Line power is provided separately from other electronics and located in the surface utility building. Routing is through the utility shaft to the magnet using air-cooled resistive busses. The design incorporates both a normal charge/discharge cycle and a 5 minute emergency discharge capability provided by switching an external dump resistor into the circuit. In the event of a quench, the energy will be dissipated in the coil and in the 0.02 ohm dump resistor (DR), where the ratio of the energy dissipated in the coil and the DR is equal to the ratio of their resistance. The dump circuit discharge time constant of ~100 seconds. The voltage across the DR will rise to 1000 V and buss-to-ground voltage will be 500V; therefore stringent safety protection must be employed. The DR will be located in the surface utility building, and will be protected against accidental personnel contact with interlocked shielding.

FFS

The FFS is a cone composed of layers of steel plates with a bore through which the beam line passes. It bolts to a large endplate structure which abuts the muon support structure (The FFS is mechanically independent from the magnet assembly). The FFS endplate assembly is transportable. Total floor load component, handling and installation are safety items receiving attention.

3.2 Hazards and Mitigation

During the magnet conceptual design phase, safeguards are being incorporated to control hazards. The magnet design follows applicable DOE orders and SSCL policies, codes,

engineering standards, and safety design criteria. Reliability and safety requirements also influenced the design. Design standards, such as NEC, ASME, and ANSI are being employed, along with OSHA and EPA rules. These include the control of hazardous energy as required by OSHA Standard CFR 1990.147 for sources of significant stored energy including electrical, mechanical, hydraulic, pneumatic, or thermal.

In general, safety systems are designed into the magnet for the purposes of monitoring electrical, thermal, and dynamic conditions. Other circuitry provides quench, pressure change, flow change and electrical fault detection. Safety systems consider critical failure modes and provide either redundant or alternative monitoring or detection methods.

Hazard categories applicable to the current magnet design are listed below. Following the list are hazard analysis report sheets for the categories listed.

• Cryogen	3.0-1 & 3.0-2
• Electrical	3.0-3 thru 3.0-16
• Magnetic Field	3.0-17 thru 3.0-19
• Mechanical	3.0-20, thru 3.0-25
• Thermal	3.0-25

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Cr Magnet

Reference No: 002

System/Subsystem/Unit

Magnet, helium circuits

System Event(s) Phase

Test and operation

Hazard Description

Any leak in the internal helium circuits of the coil will decrease the vacuum value, increase the helium consumption and finally increase the pressure inside the vacuum vessel.

Effect on System

Heating of magnet above 4.5 K requirement. Quench and possible structural damage.

Risk Assessment

Severity: I Catastrophic Probability: C Occasional Risk: 1 Imperative to suppress

Recommended Action

Provisions will be taken to insure good vacuum conditions in case of small helium leaks. The vacuum vessel will be equipped with relief devices which will be designed to keep the internal pressure within specified design limits. Helium flow and pressure will be monitored. Vacuum pressure will be monitored. Abnormal conditions will activate a dump of the magnet energy.

Effect of Recommended Action:

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Remarks

Status

Open

Conducted by _____ **Date** 02-16-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Cr Magnet

Reference No: 082

System/Subsystem/Unit

Magnet, superconductor

System Event(s) Phase

Operation at 8000 G.

Hazard Description

Loss of liquid helium at the interface between the power lead and conductor can potentially result in an extreme temperature rise, arcing and quenching.

Effect on System

Possible deformation of coil, damage to bus, helium leaks and secondary damage.

Risk Assessment

Severity: I Catastrophic Probability: C Occasional Risk: 1 Imperative to suppress

Recommended Action

Pressure tests on the conductor and coil are to be made to see that it meets requirements prior to final assembly. Helium supply system will have safety valves, regulation and fault detection.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Magnet

Reference No: 075

System/Subsystem/Unit

Magnet

System Event(s) Phase

Operation during superconducting phase

Hazard Description

During the operation of the magnet, if the quench detection circuitry fails, the quench procedure may not proceed as desired (planned) resulting in an uncontrolled situation.

Effect on System

Magnet and other system items could be severely damaged.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

1. Provide redundant detection circuitry and possibly parallel mechanisms using different detection techniques. 2. Provide redundant DC interrupters installed to divert current to FDR circuit. 3. Direct wiring between magnet and alarm for at least one detection circuit. (Other is presumed to go through the safety - slow control - system.)

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Status

Open.

Conducted by _____ **Date** 02-19-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Magnet

Reference No: 007

System/Subsystem/Unit

Magnet

System Event(s) Phase

Tests and Operational

Hazard Description

Quench occurrence causing deformation of the coils and allied structures.

Effect on System

Possible loss or damage of magnet and secondary damage to other system components.

Risk Assessment

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Recommended Action

Design takes into consideration a quench occurrence which drives dump velocity, circuit design and materials selections. As a local quench will induce a flux variation, the flux loop detection system may be considered as a redundant safety device. Design limits will be provided in the specification package.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

Further analysis and evaluation required. Refer to Magnet Engineering Design document, TN-92-116.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: EL Magnet

Reference No: 073

System/Subsystem/Unit

Magnet, cable in conduit

System Event(s) Phase

Test, and operation.

Hazard Description

Instability of the conductor due to design, construction or assembly deficiency leading to quench or shorting of leads at the interface to the conductor.

Effect on System

Quench or shorting may cause damage to the magnet or other elements of the detector. As a minimum, system operating time will be lost.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

Tests must be performed on several loops and, as far as possible, in real conditions of operation. Possibility of quench must be analyzed and tested.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

The possibilities for having a quench are multiple, the cable in conduit technology offers the best stability (temperature variation) against quench. There are some other unknown possible means to quench such as flux variation or relative movement of conduit metal. These are covered in other records.

Status

Open

Conducted by _____ **Date** 02-22-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: EI Magnet

Reference No: 033

System/Subsystem/Unit

Magnet, coil (halves)

System Event(s) Phase

Tests and Operational

Hazard Description

Short in the coil windings due to design, materials, processes or handling causing a hot point which if not spread in a reasonable time could locally damage the conductor.

Effect on System

Possible severe damage and secondary effects.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

The design, the materials and each step of the process must be inspected to assure that the hazard doesn't occur. Test at each level of fabrication will be made for continuity and resistance. The coils will be subjected to test simulating operations prior to installation.Thermal cycles are to be avoid as far as possible.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

Insulating material, including bonding and assembly will be environmentally tested prior to use in magnet - assembly.

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: EI Magnet

Reference No: 008

System/Subsystem/Unit

Magnet, coil sensors

System Event(s) Phase

Tests and operation.

Hazard Description

Defective sensors or sensor wiring located on the magnets fail to detect or correctly measure unacceptable or abnormal conditions during operation.

Effect on System

Quench resulting in damage.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

The sensors and sensor circuits monitoring the electrical supply are to be redundant in design using dual sensors if necessary. Each sensor device used in the detection circuits will be subjected to environmental testing and burn-in prior to installation into the system. A check list will be prepared for use to verify senor status during maintenance, operations and after quench.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Magnet

Reference No: 009

System/Subsystem/Unit

Magnet, coils and electrical supply

System Event(s) Phase

During power on when magnet is in superconducting state - test, operation.

Hazard Description

A current and field margin too low on the superconductor can lead to quench problems and the control of the conductor will be more difficult.

Effect on System

Quench resulting in damage.

Risk Assessment

Severity: III Marginal Probability: B Probable Risk: 2 Waiver required

Recommended Action

Tests on the samples must show a safety factor of 2 for In(nominal current)/Ic (critical current) and a similar safety factor for the useful field to the critical field. Tests will be made during manufacture to verify these values.

Effect of Recommended Action:

Severity: III Marginal Probability: E Improbable Risk: 3 Operation permissible

Remarks

If during manufacture it is shown that some parts of the superconductor do not meet these specifications, the possibility exists replace the nonconforming part.

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Magnet

Reference No: 081

System/Subsystem/Unit

Magnet, control systems

System Event(s) Phase

Operation, test, checkout, maintenance

Hazard Description

Magnet control is anticipated to be from the control center by computer interface and by manual controls. Automatic and manual functions are not well defined nor well differentiated. (Detection requirements - redundancy in detection and control - for safety is a concern.) Inadvertent mishap resulting in unknown state(s).

Effect on System

Damage to the detector or injury to personnel, if present in hall.

Risk Assessment

Severity: II Critical Probability: B Probable Risk: 1 Imperative to suppress

Recommended Action

1. Control plan - activities for software control and direct or manual control. 2. Software plan, software reviews and validation/verification. 3. Safety interface definition and requirements are to be input to plans.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Safety will be actively involved in control system design. Safety will provide specifications to Engineering and Program Management. An assessment of the GCS will be made as part of requirements.

Status

Open.

Conducted by _____ **Date** 02-19-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: EI Magnet

Reference No: 076

System/Subsystem/Unit

Magnet, DC Power Supply

System Event(s) Phase

During power ON to magnet.

Hazard Description

Supply current increases too rapidly (run away) producing an excessive condition in the magnet. If the condition occurred it could result in excessive heating and therefore quench.

Effect on System

Possible damage to magnet.

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

1. Over current limiting and voltage regulation in power supplies. 2. Voltage/current monitor circuitry.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Status

Open

Conducted by _____ **Date** 02-21-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Magnet

Reference No: 010

System/Subsystem/Unit

Magnet, electrical

System Event(s) Phase

Tests and operational

Hazard Description

Any resistive status in the coil circuits will initiate a voltage across coil terminals, and between terminals and ground that can result in a quench . At a certain level arcs could occur between conductor parts and ground.

Effect on System

Damage vacuum structures, damage to coils, damage to electronics, personnel hazards during test.

Risk Assessment

Severity: I Catastrophic Probability: B Probable Risk: 1 Imperative to suppress

Recommended Action

Various design alternatives, safeguards, protection and procedures to produce redundant, tiered safety are being investigated. Electrical design, safety and reliability engineering are working together.

Effect of Recommended Action:

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Remarks

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Magnet

Reference No: 077

System/Subsystem/Unit

Magnet, electrical (grounding)

System Event(s) Phase

Power on during test or operational phases. Magnet uses 20Vdc at 50.2 KA.

Hazard Description

Inadequate ground connections in the dump circuit or its failure to discharge correctly during quench. Other causes can include corrosion and contamination.

Effect on System

1) Possible structural damage to the magnet, or excessive heat with possible damage to the dump circuit. 2) Eddy currents may adversely affect the operation or performance of other equipment and safety systems.

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

Generally, include adequate circuit connection requirements - size, redundancy, and procedure. Evaluate the effects of eddy current on detector and hall equipment.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Status

Open

Conducted by _____ **Date** 02-21-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Magnet

Reference No: 012

System/Subsystem/Unit

Magnet, fast dump resistor circuit

System Event(s) Phase

Tests and Operational

Hazard Description

1) Open circuit in the fast dump resistor (FDR) or magnet circuit when in operation will result in an arc or short. 2) Arc between bus bars from moisture, corrosion or contamination, if they are not protectively covered.

Effect on System

Possible loss of system or probable damage of internal magnet parts. Arcs in the vacuum vessel will probably pierce the vessel with undesired effects.

Risk Assessment

Severity: I Catastrophic Probability: B Probable Risk: 1 Imperative to suppress

Recommended Action

The FDR must be designed using techniques and components which will permit the coil energy to be discharged by means of the FDR without undue thermal problems. The materials for the coil and vendor components utilized must be tested prior to installation. Additionally, FDR circuitry will be kept to a minimum length to avoid unnecessary terminations. Quality control procedures and inspections will be mandated for components assembly, maintenance & after each fast dump. Insulation or barriers will be used on busses. NEC rules for circuits over 600 volts will be followed.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

When designing the FDR, side issues such as combustion, heat, & dump circuit cooling must be considered.

Status

Open

Conducted by _____ **Date** 02-22-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Magnet

Reference No: 013

System/Subsystem/Unit

Magnet, instrumentation - liquid helium and nitrogen, temperature, conditions (not including electrical supply which is covered in another record)

System Event(s) Phase

Operational

Hazard Description

In the event that an abnormal condition existed within the magnet, and a failure of a temperature sensor in one of the liquid gas flow circuits, on the coil or on the thermal shields, or a failure in the detection circuitry associated with electrical supply, an unknown state could occur to which an operator response may not be taken or taken inaccurately.

Effect on System

Possible damage of the coil or magnet.

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

Sensors will be redundant. Control procedures will be put in place concerning detection instrument test and will be a part of the maintenance program.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Design is moving from concept to detail. Also see magnet record #8.

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Magnet

Reference No: 014

System/Subsystem/Unit

Magnet, power Supply

System Event(s) Phase

Tests and Operational

Hazard Description

Failure of the regulator on the power supply which furnishes energy to the superconducting coil. The possibility of a quench exists if the operating current is allowed to reach a critical current output.

Effect on System

Damage to system/magnet

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

The regulator on supply power will be a redundant. In case of a failure of the primary field the control electronics will cause a discharge of the coil. There will also be coil quench detection system which will activate two circuit breakers in the coil supply and permit discharge of the energy into the FRD. Quality control procedures and inspections will be mandated for component assembly and maintenance operations before and after the system is tested.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

When selecting/designing the power supply the regulator and fail-safe circuits should have dual safeguards circuits.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Magnet

Reference No: 015

System/Subsystem/Unit

Magnet, quench electronics protection

System Event(s) Phase

Power on in superconducting state - test, operation

Hazard Description

A relative resistivity ratio too low can result in the instability of the conductor in case of quench with overheating problems. The resistivity can be too low if the yield strength of supports is sufficiently high.

Effect on System

Damaged equipment

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

Resistivity of circuit must be verified experimentally on initial samples and on samples during fabrication. The RRR value of GEM conductor must be tested on several loops before construction of GEM magnet

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

Find alternatives to reduce risk, if verification does not provide adequate results.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Ma Magnet

Reference No: 047

System/Subsystem/Unit

Detector, magnetic field

System Event(s) Phase

Operation and other magnet power on phases. During operation the magnetic field generated varies as a function of the distance from the magnet.

Hazard Description

Hazards include: 1) Ferromagnet displacement - Primarily of articles left in the near fringe field.
2) Affect electrical equipment operation - transformers, receivers, etc.
3) Personnel health hazards - primarily pace-maker inoperability

Effect on System

Two system effects are: System shutdown or inoperability or fault operability; and damage by displaced items or to equipment.
Personnel effects are: Health effects (documented in SSCL reports).

Risk Assessment

Severity: I Catastrophic Probability: B Probable Risk: 1 Imperative to suppress

Recommended Action

System : 1) Shielding of electronics shaft to reduce field, 2) use of non-ferrous materials, 3) use of control and switches which do not rely on motors, transformers, etc. 3) monitoring of levels in the hall and on surface.
Health: 1) PASS, 2) limit entry of high risk people, 3) work rules for hall 4) and others as discussed in SSCL documentation.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

A continuing effort is being made to fully understand all risks and deal with the hazards. An ongoing hazard investigation and communication with other labs for lessons learned is being coordinated.

Status

Currently open and ongoing.

Conducted by Engineering **Date** 02-17-93
Closed by **Date**

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Ma Magnet

Reference No: 078

System/Subsystem/Unit

Magnet

System Event(s) Phase

Power to the Magnet

Hazard Description

Electromagnetic interference with controls, instrumentation. Magnetic field intensity may affect electromechanical equipment in the hall and/or electronics rooms or lower utility shaft.

Effect on System

Erroneous operation and unknown states with a possible damage to equipment.

Risk Assessment

Severity: III Marginal Probability: C Occasional Risk: 3 Operation permissible

Recommended Action

Shielding, grounding and alternative parts/circuit analysis to minimize and quantify effects. Various equipment item specifications will have magnetic field operating requirements in them. Testing and QA will verify suitability of performance.

Effect of Recommended Action:

Severity: III Marginal Probability: D Remote Risk: 3 Operation permissible

Remarks

This hazard item will provide the focus for final closure of field issues relating to equipment.

Status

Open.

Conducted by _____ **Date** 02-21-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Ma Magnet

Reference No: 072

System/Subsystem/Unit

Magnet

System Event(s) Phase

Power applied to magnet 1) during operation in the hall or 2) during testing above ground.

Hazard Description

The size of the magnetic field may interfere with aircraft or vehicle instruments. The field is indicated to be about 3 G at 61 meters above the surface when powered to 8000 G.

Effect on System

Effects may cause an unsafe condition to very low flying aircraft or vehicles in the immediate area - as indicated to be within the SSCL IR5 perimeter.

Risk Assessment

Severity: III Marginal Probability: B Probable Risk: 2 Waiver required

Recommended Action

Further analysis will be done prior to assembly of coils at SSCL; however, current analysis suggests that no problem will exist. If the final analysis indicates the a potential for hazard, results will be coordinated with the SSCL and FAA.

Effect of Recommended Action:

Severity: III Marginal Probability: D Remote Risk: 3 Operation permissible

Remarks

Status

Open.

Conducted by _____ **Date** 03-29-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Magnet

Reference No: 074

System/Subsystem/Unit

Magnet, cryostats

System Event(s) Phase

Tests, operation

Hazard Description

During quench the pressure is estimated to reach 400 atm and a temperature rise of 100 K. The stainless steel casing is used to contain the pressure.

Effect on System

If the steel doesn't provide sufficient margin, damage could occur.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

Are the 100 K or 300K properties of stainless steel used? Engineering analysis will consider combined stresses of hoop, internal quench pressure and thermal rise, when considering design and process methods.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

See Wes Cradock's comments from 3/23.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Magnet

Reference No: 048

System/Subsystem/Unit

Magnet, Forward Field Shaper (FFS)

System Event(s) Phase

Assembly, handling, integration in hall and operation. The FFS are about 1000 tons each - one at each end of the detector - consist of 2 ferromagnetic cones cantilevered on support structure.

Hazard Description

Weight and size increase probability of handling, or other accident or mishap.
Structural loads and forces are extremely high on FFS which increase risk of failure.

Effect on System

Critical damage during assembly. Other effects are catastrophic damage to system, or injury.

Risk Assessment

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Recommended Action

Actions include: 1) Engineering - loads analyses, materials analyses, structural/other modeling, and design reviews, 2) Process control requirements specification preparation, 3) Failure modes analysis, 4) establish work operation procedures and training needs.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

Continuing effort. Open.

Status

Open

Conducted by Engineering **Date** 02-17-93
Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Magnet

Reference No: 079

System/Subsystem/Unit

Magnet, half coils and FFSs

System Event(s) Phase

Assembly and installation, or maintenance during which these massive assemblies are being moved by crane or transport systems.

Hazard Description

Occurrences - mishaps, failures or handling - in which an assembly can be damaged. Cause may be due to operator errors, failure of fixtures and tooling or crane failure.

Effect on System

Loss or damage of magnet or FFS.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

1. Approved rigging procedure. 2. Certified workers and multiple control observers. 3. Verified drawings for fixtures and tooling.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Issue has been communicated to EFD Safety for assessment of crane requirements.

Status

Open.

Conducted by _____ **Date** 02-21-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Magnet

Reference No: 054

System/Subsystem/Unit

Magnet, support structures

System Event(s) Phase

During the time that the muon system is mounted on the legs of the magnet structure.

Hazard Description

The two detector subsystems are extremely heavy. The barrel muon assemblies sits on the magnet support legs which due to the weight and size adds significant load. Design analysis is not complete as to the total load under operating (normal and abnormal) and vibration (earthquake) conditions.

Effect on System

In the event of a failure, the magnet and muon systems could be severely damaged and damage to the other subsystems sitting inside the muon could be damaged. (All sources considered.)

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

Provide a dynamical analysis of the loads and forces to demonstrate an adequate safety margin. Material and manufacturing processes will be reviewed against design analyses.

Effect of Recommended Action:

Severity: III Marginal Probability: D Remote Risk: 3 Operation permissible

Remarks

Incorporating analyses in design to provide an adequate safety margin for a worst case vibration load scenario - during lifting or earthquake - can reduce both the severity and probability of the hazard.

Status

Open, elemental analysis due by July 1993.

Conducted by _____ **Date** _____

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Magnet

Reference No: 026

System/Subsystem/Unit

Magnet, thermal radiation shield assy

System Event(s) Phase

Operation

Hazard Description

Sudden flux variation will potentially initiate a quench , will overheat metallic circuits which have no break circuits. This is the case of the thermal shields and intercepts.

Effect on System

Damage from overheating of metallic circuits.

Risk Assessment

Severity: III Marginal Probability: B Probable Risk: 2 Waiver required

Recommended Action

The design and the installation of the thermal shields and intercepts will provide enough circumferential breaks to avoid these overheating problems.

Effect of Recommended Action:

Severity: III Marginal Probability: E Improbable Risk: 3 Operation permissible

Remarks

Status

Open

Conducted by G.Leskens **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Magnet

Reference No: 034

System/Subsystem/Unit

Magnet, vacuum subsystems

System Event(s) Phase

Operational

Hazard Description

Mechanical instability of the outer vacuum shell or the inner vessel in case of overpressure after vacuum loss and pressure coming from He internal leaks.

Effect on System

Mechanical damage, with permanent deformations and breakdown.

Risk Assessment

Severity: I Catastrophic Probability: B Probable Risk: 1 Imperative to suppress

Recommended Action

Vacuum structures will be constructed and tested following the ASME codes in taking into consideration the relative external pressure of 10 hp. and an internal pressure of 270 hp. in case of He leaks inside the vacuum volume. This pressure safety margin will be the relief pressure of the safety overpressure devices.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

Is the vessel constructed to ASME PVC Section VIII, Div. 2?

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Th Magnet

Reference No: 046

System/Subsystem/Unit

Magnet

System Event(s) Phase

Operation at superconducting temperatures

Hazard Description

Quench of magnet occurrence can be due to the loss of cooling in the two sources. Causes include LHe cooling failure, or mechanical failure in vacuum, thermal shielding or LN2 line.

Effect on System

Possible critical damage to magnet, muon and other detector elements. Containment design when working correctly will reduce a catastrophic event to critical.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

Engineering actions to prevent quench are: voltage/current regulation, design margins and redundancy of subassembly items - nitrogen coolant, vacuum, and helium cooling systems. Monitor/detect for quench conditions/symptoms for each design element is fundamental. Safety systems include quench dump circuit, safety protection of circuits.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

Design is ongoing with both analysis and testing being done to support design. Reliability, safety and engineering are involved in studying modes, effects and mitigation.

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

4.0 MUON SYSTEM

4.1 Overview

The muon subsystem resides inside the large solenoid magnet and is divided into two regions, the barrel region and two endcap regions. The muon spectrometer is comprised of three superlayers of muon tracking chambers. Each superlayer consists of layers cathode strip chambers (CSCs) used for both tracking and triggering. The barrel region contains two sections where CSCs are rectangular while the endcap CSCs are trapezoidal as they are configured radially.

The barrel region CSCs are arranged into two nominally identical measurement modules. The modules are merged with ring support structures that assemble to form a monolithic barrel region structure. This monolith design minimizes moments placed on the joints due to tensile or compressive loads thereby providing structural safety margin. The monolithic structure will be inserted into the magnet and supported on four stable mounting points - two at the end rings and two at the Central Detector Support (CDS). At the outer ends, the barrel muon support structure will serve as the mounting site for the endcap muon support structures and will provide the interface to the magnet legs for supporting the entire weight of each half of the muon spectrometer.

The structure required for supporting the endcap muon chambers consists of three wheel structures which support the three super layers of chambers, and two conical trusses which tie the three wheel assemblies together. Basic construction techniques used in these support structures will be identical to those in the barrel region section. When assembled and aligned in the hall the endcap assembly will be attached to the barrel region structure utilizing a four-point mounting system capable of orienting the entire endcap into the desired attitude with respect to the interaction point. Hazards such as structural integrity of the chamber assembly supports are adequately addressed in the current design package. Structural analysis has been performed upon the muon chambers supports, which include a yield stress safety factor of 1.5 in the design.

The main safety issues relate to performing maintenance or other work inside the system. The risks include confined space hazards, radiation activation levels requiring special procedures, and working at significant heights for maintenance and installation. Various detection and monitoring capabilities are planned, and we will respond to the potential for oxygen deficiency in normal and confined spaces. Support structures will be used for elevated or difficult-position work. The strategy and method to safely facilitate access into the muon regions for chamber maintenance, etc. are currently being developed.

The CSCs use a mixture of 50% CO2, 30% Argon and 20% fluorocarbon (non-O-depleting) as the drift gas. The gas could leak at very low levels which could interfere with ODH (oxygen deficiency hazard) sensor operation, thus gas detection is planned for the area. Since the chambers are predominantly made from plastics an electrical fire could result in ignition of the hydrocarbons.

4.2 Hazards and Mitigating Actions

During the muon conceptual design phase, safeguards are being incorporated to control hazards. The design follows applicable DOE orders and SSCL policies, codes, engineering standards, and safety design criteria. Reliability and safety requirements also influence the design. Design standards, such as NEC, ASME, and ANSI are being employed.

Hazard categories applicable to the current design are listed below. Following the list are hazard analysis report sheets for the categories listed.

- Ingress/Egress 4.0-1
- Electrical 4.0-2 & 4.0-3
- Fire 4.0-4
- Mechanical 4.0-5 thru 4.0-8
- Oxygen Deficiency 4.0-9
- Pressure 4.0-10

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: EG Muon

Reference No: 037

System/Subsystem/Unit

Muon subsystem

System Event(s) Phase

Installation (alignment, test), operation and periodic maintenance.

Hazard Description

The interior of the muon subsystem is confined by structural members, electrical lines, gas delivery lines and water for cooling. There is a requirement for access to the interior (barrel & endcap), however, the design does not provide adequate means for ingress nor if a person were inside and an emergency occurred, could the person be brought out.

Effect on System

Possible death of an individual and probable secondary damage to the muon. Radiation effects are unquantifiable at this time (4/93)

Risk Assessment

Severity: I Catastrophic Probability: C Occasional Risk: 1 Imperative to suppress

Recommended Action

Design will consider safety requirements for ingress/egress and emergency removal of a person from inside. The space inside (barrel & endcaps) will be classified as Confined Workspace and will be suitably protected.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

GEM ES&H will monitor design and provide engineering guidance. Radiation studies are ongoing and will be monitored.

Status

Open

Conducted by _____ **Date** 03-30-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Muon

Reference No: 051

System/Subsystem/Unit

Muon, electronics subassemblies

System Event(s) Phase

Operation and maintenance.

Hazard Description

Electrical fire and shock due to shorts in high voltage (3000-5000) cables or equipment.

Effect on System

Critical damage to detector or injury to personnel.

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

For fire hazard: 1) Limit plastics, 2) keep plastics away from electrical contacts and related sources, 3) detection and mitigation in accordance with the SSCL fire protection program. Halogen free plastics, norms should be adopted at the level of the SSCL. For electrical items: 1) provide voltage monitoring, 2) voltage regulation and 3) automatic shutdown in abnormal conditions.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Muon

Reference No: 052

System/Subsystem/Unit

Muon subsystem, electronics and electrical

System Event(s) Phase

Power ON.

Hazard Description

High current electrical shorts or personnel contact. Causes include failures or errors at distribution panels, busses or cables.

Effect on System

Damage to muon and/or electronics causing shut down of the operation, or personnel shock resulting probable death.

Risk Assessment

Severity: I Catastrophic Probability: C Occasional Risk: 1 Imperative to suppress

Recommended Action

Follow grounding, parts derating (overload) precautions, monitor for circuit faults, correct labeling and interlocks. Lock out and tag out procedures will be enforced, and technical measures will be taken to provide interlocks.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: FE Muon

Reference No: 018

System/Subsystem/Unit

Muon, CSCs

System Event(s) Phase

All operating phases during which power is applied to the muon subsystem after installation.

Hazard Description

Structural materials and adhesives may produce hazardous decomposition products during combustion. However, combustion of the adhesive would be highly unlikely as it is not flammable and would require an external source of heat to facilitate decompostion. Cables, signal and H.V. are vectors for fire transmission. Electrical ignition is the source.

Effect on System

Hazardous decomposition products introduced into the detector and hall, and probable chamber damage.

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

If the amount of combustible materials is large enough to warrant an inerting system, inerting the muon volume with nitrogen can be done. This is one alternative for fire suppression that is being investigated.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Muon

Reference No: 049

System/Subsystem/Unit

Muon, CSCs

System Event(s) Phase

Operation

Hazard Description

During severe weather a sudden pressure drop could cause CSCs to rupture, since they tend to act as barometric cells.

Effect on System

1. Damage to CSCs and 2. Release of a significant amount of gas into the detector and environment.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

Pressure regulation for large gradients will provide positive means to safe the system. Gas detection will be put in strategic locations in the muon subsystem. Redundancy of valves, etc. will be considered for critical parameters in the design.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Muon

Reference No: 035

System/Subsystem/Unit

Muon, structures

System Event(s) Phase

Assembly, installation, operation and maintenance

Hazard Description

The stresses within the modules are primarily due to the weight of the structures themselves. However, additional hardware may be attached to the structures which if not considered in the design could result in hazardous conditions.

Effect on System

Mechanical failures or breakage.

Risk Assessment

Severity: III Marginal Probability: D Remote Risk: 3 Operation permissible

Recommended Action

Finite element analysis and actual structural test data will be used to eliminate the possibility of mechanical failures. Analysis will investigate the stresses in the metal parts of the structure as well as the stresses on the adhesive joints. It is also desirable to produce modules that are sufficiently rigid so that they can be mounted on the magnet using pure kinematic supports, thus eliminating the possibility of stresses being induced on the modules due to to magnet deflections.

Effect of Recommended Action:

Severity: III Marginal Probability: E Improbable Risk: 3 Operation permissible

Remarks

Further analysis is currently ongoing.

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Muon

Reference No: 050

System/Subsystem/Unit

Muon, structures

System Event(s) Phase

Assembly, transportation and handling and installation.

Hazard Description

Structures including barrel and endcap have significant loads due to the weight and geometry of the muon. A failure of a joint or vibration or other stress could cause damage to the muon subsystem.

Effect on System

Possible damage or loss of subsystem, release of drift gas and/or secondary damage to other subsystems.

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

Dynamic structural analysis to show worst case loads such as when access is needed to the interior or under vibration or transport induced stresses. Safety margins for worst case load will provide confidence of robust structural integrity. Design needs to include access means in both regions to show highest loading.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Structural design analysis indicates a sufficient safety margin exists during operational phases.

Status

Open.

Conducted by _____ **Date** 03-30-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: SDC
Item Category: Me Muon

Reference No: 043

System/Subsystem/Unit

Muon subsystem

System Event(s) Phase

Operational

Hazard Description

There is a possibility that x-ray techniques will be used during alignment of the muon subsystem both during assembly and during installation. Power and time may cause overexposure to radiation of personnel in area. (This could apply equally to laser alignment, but would depend on the power level.

Effect on System

Affect the health of individuals exposed to radiation above minimums.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

X-ray techniques will be used as a lower priority alternative to other means of alignment. Standard x-ray procedures will be used, including the clearing of the area of all personnel not directly involved in the alignment procedure. Other constraints on the facility and access will apply.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: OD Muon

Reference No: 036

System/Subsystem/Unit

Muon, gas subsystem

System Event(s) Phase

Operation, Maintenance and other times when gas (C02/CF4) is in use and when people might access the muon subsystem.

Hazard Description

A major leak of the drift gas due to inadvertently breaking a major supply/return line, or alternatively fatigue or defect in a line. If people are in the vicinity, then a potential exhists for ODH.

Effect on System

Personnel could be asphyxiated if sufficient gas leaked and there was insufficient ventilation.

Risk Assessment

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Recommended Action

Design concept is still being determined. System design will route major gas lines through areas which reduces the probability of breakage, install sufficient quantity of gas sensors to detect amounts of leakage to parts per million. The interior of the muon will be classified as a Confined Workspace, but the specific class will remain open until design is complete for muon ICDs. There will also be oxygen sensors in the detector interior. (See Ingress/Egress hazard.)

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

GEM ES&H will provide confined workspace requirements before the GEM baseline is frozen.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Pr Muon

Reference No: 053

System/Subsystem/Unit

Muon, gas subsystem

System Event(s) Phase

Most operating phases when gases are under pressure in detector.

Hazard Description

Failure of joints, valves, or safety devices allowing overpressure and leakage - low or gross.

Effect on System

Damage of subsystem by overpressurization. ODH in local area could be increase risk above level 0.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

Safety design practices and code standards are to be integrated in design. Detection alternatives such as IR, mass/gas spectrometry - are being investigated for general and manual usage depending on phase.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Working groups on detectors and facilities are actively pursuing.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

5.0 CALORIMETER

5.1 Overview

The calorimeter is composed of five major sections. They are the barrel noble liquid calorimeters, the endcap liquid calorimeters, the forward calorimeters, the barrel scintillating calorimeter and passive absorber. The barrel liquid calorimeter is composed of two functional elements, termed the electromagnetic (EM) calorimeter and hadronic (HAD) calorimeter. Both components use liquid krypton as the sampling medium. Additionally, the two sections are contained in a cryostat which has an inner liquid vessel and an outer vacuum vessel. The endcap will also have both EM and HAD sections contained in a cryostat, but will use a different geometry for the vessels. The endcap sampling medium will be liquid argon. Internally to the liquid vessels, the barrel calorimeter electronics are cooled (heat dissipation) using liquid argon and the endcap calorimeter electronics utilize liquid nitrogen. The forward calorimeter is composed of EM and HAD sections. The last active detection section is the barrel scintillating calorimeter which surrounds the barrel liquid section. Finally, there is a passive absorber section used outside of the endcap and forward calorimeters.

A primary safety concern of the calorimeter is the risk that results from the use of large quantities of liquid argon (LAr) and liquid krypton (LKr) as ionization media. A significant leak in either the supply (in the hall), or in the detector lines or cryostats. Potential causes for leakage include broken lines, mechanical stress failure or fatigue, liquid regulation failure, or secondary effects from a failure in another item. Safety features of these liquid systems are mechanical safety margins, redundancy in regulation, and detection, and extensive monitoring. Delivery lines will be vacuum-jacketed and insulated with redundant shut-off valves in case of emergency. The lines and valves will be leak-monitored and generate a shutdown, with evacuation alarms if people are in the hall. Strict quality control will be adhered to in the design, assembly, operation, and testing of the liquid systems. The vacuum vessels will be protected against overpressure by fabricating and inspecting the cryostats using the guidelines of ASME PVC, section VIII.

The calorimeter surrounds the tracker subsystem and is contained inside the muon subsystem. The calorimeter detectors will be supported at the center by the CDS. The calorimeter will be installed in a minimum of two stages (i.e., barrel sections followed by the forward/endcap sections).

Electronics subsystems associated with the calorimeter subsystem consist of preamps imbedded within the noble liquid calorimeters, photomultiplier (PM) tubes in the scintillating calorimeter; and the electronics racks. All are considered low-voltage except for the PM tubes (2-3,000 Vdc).

Other potential safety issues associated with the calorimeter are:

- loss of vacuum in the cryostat,
- cooling-loop over pressurization,
- high current electrical shorts and personnel shock,
- supply or return cryogenic pipes leaking, and
- use of combustible doped liquid scintillator or fibers.

Hazards and Mitigation

The most significant hazard category of the calorimeter is the use of significant amounts of cryogenic liquids. Since the liquids are used as both ionizing mediums (LKr & LAr) and for cooling (LAr & LN2), the design of control and monitoring systems for storage and delivery, and mechanical design and fabrication of vessels are critical to hazard prevention and risk abatement. Table 5-1 shows information about the cryogenic liquids that is related to precepts for the measure safety design.

Table 5-1 Physical properties of argon and krypton related to safety design.

Property	LAr	LKr
Boiling point K°	87.29	119.8
One mole kg.	0.03995	0.0838
Relative density/air	1.38	2.89
Triple point		
Temperature °K	83.78	115.77
Pressure mbar	687.5	731.5
Critical T in °K	150.72	209.4
Critical pressure Bar	48.64	54.9

One concern determining the direction of the hazard analysis of these cryogens is that the two elements in gaseous form are heavier than air. This poses challenges in control and hazard prevention that the other liquids don't. Analyses will make use of the physical data when determining ODH, spill effects and related risks. In the event of a major release, containment of the liquid and management of the rate of vaporization are critical to limit the potential of ODH and give people enough time to evacuate the area. (Preliminary calculations indicate that an

unconfined spill will vaporize depleting the oxygen to a two meter depth within 15 to 30 seconds. HVAC will not appreciably remove sufficient quantity of gas to reduce the OD hazard within the boil-off period of time. Each component of the liquid systems – dewars, lines, cryostats and supporting equipment – will be examined to determine potential failure scenarios, to establish the maximum credible leak for each circumstance, and to analyze associated risks and to determine mitigation for each. The analyses outputs will provide additional safety design guidance and provide specific methodology for monitoring, fault detection and alarm.

Hazard categories applicable to the current design are listed below. Following the list are hazard analysis report sheets for the categories listed.

• Electrical	5.0-1
• Fire	5.0-2 & 5.0-3
• Mechanical	5.0-3 thru 5.0-10
• Oxygen Deficiency	5.0-11
• Pressure	5.0-12
• Radiation	5.0-13 & 5.0-14

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Calorimeter

Reference No: 004

System/Subsystem/Unit

Calorimeter, electronics and electrical systems - readout, power, bias and support.

System Event(s) Phase

All operating phases

Hazard Description

High voltage low current or low voltage high current shorts in the circuits, lines or busses due to design, fatigue, or damage during assembly.

Effect on System

Damage to the detector or shock to personnel.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

Electrical circuits will meet NEC code, cabling will meet SSCL design criteria, electrical test will be performed and reviewed by QA. Voltage/current sources and lines will be separated in runs and at points where connections are made. Power will be monitored and regulated at supplies. Internal sensing of abnormal conditions will be done. Connectors will be differentiated so that cross connection of power types will not be possible.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

Ongoing analyses will be conducted until designs for the calorimeter are firm.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: FE Calorimeter

Reference No: 058

System/Subsystem/Unit

Calorimeter, barrel scintillator, photomultiplier tubes

System Event(s) Phase

During phases when ignition sources are present such as power ON or welding.

Hazard Description

Scintillator is made from pure hydrocarbon plastic which in large amounts presents a fire hazard. Ignition source could cause combustion of the plastic.

Effect on System

Severe damage due to secondary effect of another event.

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

An enclosure of the scintillator is being used. Incipient smoke/fire detection will be used. Route sources such as electrical contacts away from areas. Nitrogen environment will also fight against scintillator
oxidation.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Final materials have not been selected, monitor design baseline.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: FE Calorimeter

Reference No: 056

System/Subsystem/Unit

Calorimeter, forward hadronic

System Event(s) Phase

Operational phases.

Hazard Description

Combustible material - possible mineral oil - is in design baseline. Secondary fire potential if material comes in contact with ignition source.

Effect on System

Damage to the detector.

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

Monitor for final design of competing materials. Detection/inspections for leaks, electrical fault detection and prevention through segregation of sources from combustible materials is imperative.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Limited reduction potential until design is "frozen".

Status

Open

Conducted by _____ **Date** 02-17-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Calorimeter

Reference No: 083

System/Subsystem/Unit

Calorimeter, cryostats - barrel & endcap

System Event(s) Phase

Operation, maintenance and other phases during which the vessels are under vacuum and filled with noble liquids.

Hazard Description

A failure occurs in the vacuum vessel or in the liquid vessel causing rupture and release of cryogenic liquids to the detector. (Both LKr & LAr are heavier than air.)

Effect on System

Two effects are considered. 1) A major cryogenic liquid spill could have structural or secondary effects on the other calorimeter cryostats or on other systems - muon or tracker, and 2) There would be copious amounts of liquid released into the hall, which if not contained, could cause a severe ODH. (The tracker butane delivery system is particularly at risk.)

Risk Assessment

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Recommended Action

Vacuum vessels (including the liquid liner) will be thoroughly inspected using radiographic, etc. techniques and 100% inspection of welds, joints and torque to bolts. Design analyses will be used to provide sufficient design margins to show that each vessel - inner & outer - is able to withstand a rupture of the other. In-place inspections will be used. The butane delivery system risk associated with with hazard is covered in the tracker section.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

Cryogen containment using thermal insulation will be used in order to control the evaporation. Also, spills may be routed to safe areas within the hall for disposal. Both will be used to reduce severe ODH. An analysis of spill evaporation velocity is needed.

Status

Open.

Conducted by _____ **Date** 03-31-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Calorimeter

Reference No: 028

System/Subsystem/Unit

Calorimeter, gas/liquid subsystems, relief valve or rupture disk.

System Event(s) Phase

Filling detector vessel, purging detector vessel, operation, maintenance while filled.

Hazard Description

Relief valve or rupture disk fails to open on demand.

Effect on System

Equipment failure, pressure build-up with probable burst.

Risk Assessment

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Recommended Action

Design recommendations and plan: Redundancy using combination of relief and check valves and rupture disk.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

Redundancy significantly reduces the severity of a possible failure and makes the risk close to negligible.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Calorimeter

Reference No: 086

System/Subsystem/Unit

Calorimeter, liquid and vacuum vessels

System Event(s) Phase

All times during which liquids are in the cryostats.

Hazard Description

There will be numerous feedthroughs in the vacuum and liquid vessels walls. Each feedthrough, containing multiple cables or nitrogen/argon cooling lines, will have a vacuum separate from the cryostat. In the event of failure or defect, a cryogen leak could occur.

Effect on System

Damage to subsystems or ODH effects.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

Design will provide safety tolerance, provide detection, ensure limitation of failure or defect effects of the immediate area. Detection and pressure monitoring will be provided for each feedthrough area. General gas detection and ODH monitoring will be performed.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

See also record no. 85.

Status

Open.

Conducted by _____ **Date** 03-31-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Calorimeter

Reference No: 027

System/Subsystem/Unit

Calorimeter, liquid nitrogen and argon cooling subsystems.

System Event(s) Phase

All

Hazard Description

Equipment failure from overheating caused by loss of cooling, i.e. LAr in the endcap or LN2 in the barrel, due to mechanical failure in the supply system, regulation or control valves.

Effect on System

Major damage to electronics.

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

Detection for both flow rate and coolant loss, coupled to tiered shutdown of the calorimeter system will be used. Redundant regulation and safety circuitry is planned for critical areas. Valve/regulation design will provide the ability for the system to go to a safe state if a fault occurs. More actions are being evaluated as design progresses.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Calorimeter

Reference No: 029

System/Subsystem/Unit

Calorimeter, liquid nitrogen, argon and krypton

System Event(s) Phase

Phases during which personnel will be in the area - maintenance, preparation for operation and hall support.

Hazard Description

A cryogenic spill could occur as a result of filling operations of the detector or dewars, or a leak could occur resulting from failure of a vessel, line or procedural error (personnel or other) during the time the cryostats are vacuum purged and filled.

Effect on System

Severe injury to personnel or ODH in a localized area.

Risk Assessment

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Recommended Action

ODH monitor, leak detection, maximum design stress limits, procedures, protective equipment, and monitor through the GCS are being considered for minimizing a failure or mishap.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

In the detector area confined space requirements are being evaluated as to their applicability during various phases or operating modes.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Calorimeter

Reference No: 084

System/Subsystem/Unit

Calorimeter, noble and nitrogen liquid relief, control, regulation and safety systems.

System Event(s) Phase

All phases during which cryogens are in lines or vessels.

Hazard Description

In the event of a failure of a liquid delivery system (includes LKr, LAr, LN2) due to the inoperability of pressure relief, sensing of an abnormal condition or random event, a significant amount of liquid could be spilled. Pressure in the LN2 lines could occur causing a rupture.

Effect on System

Two possible effects are considered. 1) OD or freezing of personnel in the area. 2) Secondary effects including damage of vessels or lines within the calorimeter with further release of liquids.

Risk Assessment

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Recommended Action

Liquids used by the cryostats will be provided through redundant systems which each have regulation and safety monitoring and control. Pressure sensing of lines and vessels will be performed. Monitoring for ODH and gas leaks is planned. Regulation and safety systems will be interfaced to the GCS.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

See record number 83 for discussion on cryogenic spill containment.

Status

Open.

Conducted by _____ **Date** 03-31-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Calorimeter

Reference No: 030

System/Subsystem/Unit

Calorimeter, structural members of barrel calorimeter (support frame, ties, etc.)

System Event(s) Phase

All phases of operation assembly and installation

Hazard Description

Structural failure of supports, transfer lines, or other mechanical items.

Effect on System

Possible equipment damage; potential personnel injury.

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

Most items of this nature are covered by code requirements and failure of this kind is rare. The major design concerns deal with non-coded areas of this detector. Supports, transfer lines, and mechanical equipment will be designed in compliance with recognized engineering practices. FEM will be used to evaluate loading, bending and other stresses.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Further define items covered by code or not.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: OD Calorimeter

Reference No: 041

System/Subsystem/Unit

Calorimeter, noble liquid systems and liquid nitrogen

System Event(s) Phase

All operations of the detector during which gas is being supplied or held in detector

Hazard Description

Nominal leak or major accidental spill of one of the liquids exposing personnel to local ODH and cryogenic freezing on contact of skin or by inhalation.

Effect on System

Severe injury to personnel.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

Gas leak detection throughout the hall, detector and support dewars will be used. Study to determine confined space requirements is being conducted. Gas detection will be mandatory at all times when personnel are in the area.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

Design & safety systems options are being studied. Multiple paths will be used for accident prevention.

Status

Open

Conducted by _____ **Date** 02-16-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Pr Calorimeter

Reference No: 057

System/Subsystem/Unit

Calorimeter, vacuum/liquid vessels

System Event(s) Phase

Structural, stress or other failure during operation.

Hazard Description

Cracks, explosion/implosion due to over/under pressure in vessels or lines associated with failure or fatigue or other mechanical events are possible. In the event of a vessel failure, other portions of the detector will be subject to secondary hazards.

Effect on System

Catastrophic damage to calorimeter and other assemblies.

Risk Assessment

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Recommended Action

Design to ASME boiler and pressure vessel standards. Maintain close process/procedure control during assembly to calorimeter, during movement, handling and integration. Feedthrough connections are to conform to industry/military standards for vessel type (to be further defined). Must be carefully tested in cryo environment. Vacuum vessel must be protected by safety relief devices. Provision will be taken to evacuate vessel in the event of cryogenic leaks.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

Analysis is ongoing since design concept still has some alternatives being evaluated.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Ra Calorimeter

Reference No: 085

System/Subsystem/Unit

Calorimeter, EM and HAD calorimeters

System Event(s) Phase

All phases.

Hazard Description

Radioactive isotopes may be used for calibration. Radiation hazards associated with the handling, proximity to work and disposal are considered. (Amounts are small so that activation is not an issue.)

Effect on System

Radiation effects of exposure to personnel.

Risk Assessment

Severity: III Marginal Probability: C Occasional Risk: 3 Operation permissible

Recommended Action

Identification of sources and locations of the isotope will be made on vessels and other relevant locations and will be included in engineering drawings. Safe handling measures will be required along with removal/replacement procedures.

Effect of Recommended Action:

Severity: III Marginal Probability: D Remote Risk: 3 Operation permissible

Remarks

This issue will be followed during design to determine types, amounts and locations, if used.

Status

Open.

Conducted by _____ **Date** 03-31-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Ra Calorimeter

Reference No: 087

System/Subsystem/Unit

Calorimeter, passive absorber materials and absorber material in active detectors

System Event(s) Phase

During life of system after beam ON.

Hazard Description

The absorption requirements of the calorimeter pose a materials activation issue. The significance of the hazard will depend on total exposure and the final amount of passive shielding used in other areas of the hall as protection to the GEM detector.

Effect on System

Effects are: 1) Radiation exposure of personnel working near exposed areas. 2) High radiation levels in short time periods after "beam -OFF."

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

Radiation levels and effects will be defined. Physics will determine the most sensitive materials and locations (based on fluences and exposure) and provide maps of high activation (above regulatory standards for minimal exposure sources). Design shall provide protection. Policy and procedures will be formulated dealing with removal/replacement and access requirements.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

Note that the risk is some what arbitrary at this time since evaluations of radiation levels and fluences are not complete and therefore design is not firm.

Status

Open.

Conducted by _____ **Date** 03-31-93

Closed by _____ **Date** _____

6.0 TRACKER

6.1 Overview

The tracker is the innermost detector subsystem. It surrounds the beam pipe in the region of the interaction point and it consists of two assemblies - the silicon microstrip inner tracker and the interpolating pad chamber outer tracker of which both assemblies include barrel sections and radial subassemblies. The tracker essentially functions in two capacities. First it detects gammas, electrons and muons at high energy (p_t), and secondly, it provides reconstruction of the charged tracks, secondary vertex finding and tracking at low momenta. The tracker is designed to operate in a 1 Mrad radiation field, a high magnetic field, and for a minimum life of 10 years at 10^{33} cm^{-2} s^{-1}. The design also considers minimizing the radiation length of materials.

The inner tracker consists of a barrel and two radial sections. The major structural assembly to which the silicon tracker electronics assembly attaches is a space frame structure. The inner tracker in turn will be attached to the outer tracker. The electronics are isothermally cooled by butane using evaporative phase-change technology as a thermosiphon system. A leakage-containing gas enclosure is used for safety reasons. The enclosure is comprised of an inner beryllium gas shell (immediately surrounding the beam pipe) and an outer composite envelope (around the silicon tracker perimeter) which consists of a two wall truss design through which gaseous nitrogen will flow. The cooling system design incorporates safety features to restrict the flow of butane to the environment, to detect butane leaks virtually anywhere in the loop, to prevent combustion by nitrogen blanketing external to the gas enclosure, and to use structural boundaries for containment of gases within a limited volume. If butane is detected, electronics will be shut-off and the immediate area immersed with nitrogen. Also, filling and emptying for maintenance will require careful analysis of the probability of spills and other credible accidents. A HAZOP-type risk analysis for handling of LPG is anticipated and will be made by specialists.

The outer tracker consists of the structural members of the barrel and endcaps, interpolating pad chambers, electronics, and cooling. The structure with an enclosure houses the other subassemblies, provides attachment points for the inner tracker and in turn mounts kinematically to the detector calorimeter structural subassembly. The electronics consist of the interpolating pad chambers, circuit assemblies, and connections. The electronics are cooled with water. Water leaks within the tracker could cause shorting or loss of water cooling could produce overheating of electronics resulting in potential secondary hazards.

The IPC gas mixture uses CO_2/CF_4 at slightly above the atmospheric pressure. The gas system is in a circulation loop. A purification system will measure and eliminate contaminants

such as water, oxygen, hydrocarbon, and oil. Gas systems designs are conventional. The supply and purification systems will be situated at surface level, the supply and return lines to the outer tracker will go in the experimental hall.

Electronics for both the silicon microstrips and interpolating pad chambers sections are connected to fastbus data acquisition for signal input and output and to the GCS for monitor and operations. The silon microstrip section uses low voltage low current supply while the IPCs use both high and low current. Support equipment includes power and bias voltage supplies, detectors for various purposes and associated cable harnesses.

6.2 Hazards and Mitigation

Fire Protection

Since the inner tracker is cooled with butane, even with the proposed mitigating actions, fire or overheating problems cannot be completely eliminated, therefore early warning fire (VESDA-type) and infrared flammable gas leak detection systems will be installed in the tracker volume. Reactions from these detection systems will be human intervention initially followed by automatic power shut-off, evacuating of the liquid and gaseous butane, and subsequent purging of these volumes. Incipient detection systems will be installed and an initial low-level alarm will alert the supervisor to take corrective actions, while a higher-concentration alarm will provide automatic power shut-off and emergency purging in the tracker volume.

Identified Hazards

Hazard categories applicable to the current design are listed below. Following the list are hazard analysis report sheets for the categories listed.

- Electrical 6.0-1 & 6.0-2
- Fire 6.0-3 thru 6.0-7
- Mechanical 6.0-8 thru 6.0-14
- Pressure 6.0-15

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Tracker

Reference No: 061

System/Subsystem/Unit

Tracker, electrical (power supply)

System Event(s) Phase

During power ON phases

Hazard Description

Electrical transmission and distribution of DC power and electronics possessing high currents may cause arcing and burning in the event of short or crossconnection.

Effect on System

Possible damage, shutdown of detector, arcing, interference and shock are considered.

Risk Assessment

Severity: III Marginal Probability: B Probable Risk: 2 Waiver required

Recommended Action

Engineering analyses, failure/damage mode analyses, reliability predictions and radiation effects analyses are required to provide design means to reduce risk.

Effect of Recommended Action:

Severity: III Marginal Probability: D Remote Risk: 3 Operation permissible

Remarks

Effort is ongoing.

Status

Open

Conducted by _____ **Date** 02-17-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Tracker

Reference No: 060

System/Subsystem/Unit

Tracker, electronics parts and materials

System Event(s) Phase

All phases

Hazard Description

Sophisticated materials to minimize weight and radiation length, and to meet performance may lead to electrical failure caused by random events or the fact that some electronic piece parts are new designs. Failures could lead to arcing, burning or ignition of butane if occurring in the microstrips. However, butane requires oxygen as a source.

Effect on System

Possible damage to tracker and if damage affected enclosures, it could cause secondary damage to beam pipe or calorimeter.

Risk Assessment

Severity: III Marginal Probability: C Occasional Risk: 3 Operation permissible

Recommended Action

Engineering analyses, failure modes analysis, parts/materials control program, extensive testing program and design reviews (working groups) are means to reduce and eliminate risk through design. Safety systems will provide circuit monitoring, power monitoring and temperature monitoring.

Effect of Recommended Action:

Severity: III Marginal Probability: D Remote Risk: 3 Operation permissible

Remarks

Status

Open

Conducted by _____ **Date** 02-17-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Fe Tracker

Reference No: 020

System/Subsystem/Unit

Tracker, butane enclosure housing

System Event(s) Phase

All operations

Hazard Description

A vacuum (substantial pressure drop) in the containment vessel due to a failure or accident in the supply system causes it to buckle allowing butane to escape the enclosure. (The gas enclosure is designed for 0.2 psi min.)

Effect on System

Damaged equipment, potential for fire in the presence of an ignition source. Possible secondary damage to beam pipe in IP region.

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

The detector startup and shutdown procedures have been modified so that the maximum pressure difference across the detector housing at any time is 0.2 bar. The detector housing will be carefully designed with a factor of safety in compliance with industry standards for vacuum vessels.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Further evaluation required to quantify hazard.This analysis must be reverified because conflict exists in the pressure to be considered inside the tracker. Vapor pressure is unknown. Vacuum must also be considered for purge reason, which requires a technical decision.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Fe Tracker

Reference No: 019

System/Subsystem/Unit

Tracker, butane system

System Event(s) Phase

When butane is in transfer lines or in the detector and condenser. Ambient temperature nitrogen flow - inner tracker

Hazard Description

Failure of the ambient nitrogen flow could impair protection if a butane leak occurred in the cooling system outside the detector.

Effect on System

Equipment damage.

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

Design control with provision to shutdown electronics and purge system of butane in the event of a nitrogen flow system failure.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Interlocked system should operate whether or not there is a detectable butane leak.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Fe Tracker

Reference No: 021

System/Subsystem/Unit

Tracker, butane system

System Event(s) Phase

All phases

Hazard Description

Structural failure of supports, transfer lines, or other mechanical equipment.

Effect on System

Damage equipment, and possible fire in the presence of an ignition source.

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

Most items of this nature are covered by code requirements and failure of this kind is rare. The major design problems will be in non-coded areas of the detector. Supports, transfer lines, and mechanical equipment will be designed in compliance with appropriate design codes. Safety systems will consider the requirements for pressure monitoring and leak detection and failure modes analysis to determine fail safe conditions.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Fe Tracker

Reference No: 022

System/Subsystem/Unit

Tracker, butane system

System Event(s) Phase

All phases of operation, but particularly during operation

Hazard Description

Failure of the automatic data acquisition and control system (ADACS), especially during a butane transfer or detector operation. Failure of ADACS to provide proper feedback or to warn of discrepancies in system. With presence of oxygen and ignition source a fire could result.

Effect on System

Equipment damage

Risk Assessment

Severity: III Marginal Probability: C Occasional Risk: 3 Operation permissible

Recommended Action

Design includes: Nitrogen gas inerting of complete subsystem, isolation of butane, detectors at strategic locations, and detection tied to GCS (includes fire prevention).

Effect of Recommended Action:

Severity: III Marginal Probability: D Remote Risk: 3 Operation permissible

Remarks

Design criteria in place

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Fe Tracker

Reference No: 024

System/Subsystem/Unit

Tracker, housing

System Event(s) Phase

Butane charging,charging and shutdown

Hazard Description

Slow leaks around fittings in the gas enclosure housing which if combined with oxygen and an ignition source could pose a fire/explosion hazard. These leaks could form due to thermal expansions and contractions of the containment vessel during startup and shutdown. The tracker is nested inside layers of other detectors making access to fix any leaks difficult.

Effect on System

Possible fire hazard during startup or shutdown and operation.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

Flow dry nitrogen gas through the space between the silicon detector and the outer detector to sweep away any butane that may flow out of the detector. The nitrogen flow rate should be sufficient to allow 8 circulation changes per hour in the area of the detector. The hydrocarbon concentration in the inerting nitrogen should be monitored with air hydrocarbon sensor.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

Further evaluate hazard and consequences - postulation needs further clarification Safety system design will delineate detection and monitoring strategy and items.

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Tracker

Reference No: 039

System/Subsystem/Unit

Tracker, butane refrigeration

System Event(s) Phase

Butane charging and during operation

Hazard Description

Mechanical or electrical failure of the condenser refrigeration system. Without pressure relief there is a gradual pressurization of the detector housing up to 2 bars at 20 degree C. The pressurization rate depends on the heat leak to the detector housing from the environment and whether the detector electronics are still operating. Mechanical and electrical failure may occur.

Effect on System

Possible damage or loss of equipment.

Risk Assessment

Severity: I Catastrophic Probability: C Occasional Risk: 1 Imperative to suppress

Recommended Action

Use redundant pressure relief valves to prevent detector housing overpressurization. Establish a control system driven electronics shutdown and butane removal/nitrogen replacement procedure. Will require a software FMECA. Design the detector housing for this pressure.

Effect of Recommended Action:

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Remarks

Conflicts exist on the pressure to be taken in consideration.

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Tracker

Reference No: 091

System/Subsystem/Unit

Tracker, butane system.

System Event(s) Phase

Operation

Hazard Description

During pump down and conditioning of the beam pipe vacuum, the NEG pump will be on and at a high (400+F) temperature. If butane escapes around the O-ring or permanent seal between the inner enclosure (beryllium) wall and outer enclosure, the unit is a point source for ignition.

Effect on System

Possible fire/explosion.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

This is the most critical area for butane leakage. Design will consider alternative means to prevent leakage such as double seals, alternative materials, high stress safety margin. Safety systems will provide for butane detection in the low ppm (LEL = 1.9%), and if butane is detected, then nitrogen inertion will be used in tracker annular spaces where butane could collect.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

Status

Open.

Conducted by _____ **Date** 03-20-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Tracker

Reference No: 040

System/Subsystem/Unit

Tracker, IPC tracker, cooling water subassemblies.

System Event(s) Phase

All operations of the detector

Hazard Description

Pipes bursting inside the detector or the outer tracker or leaks at joints with water released into equipment.

Effect on System

Damaged equipment.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

Pipes will be designed for a specific pressure according to the appropriate Federal Codes. Routine inspections will be in accordance with SSC Laboratory and DOE Policy and procedures. Consider using underwater pressure system similar to the L3. If a water pressurization system is used, it is desirable that pipes be metallic and welded or brazed. Mechanical fittings are not acceptable for use in the tracker volume.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

Further study of potential damage of water leaks will be conducted.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Tracker

Reference No: 062

System/Subsystem/Unit

Tracker, IPC tracker, drift gas.

System Event(s) Phase

All phases during which the tracker is filled with gas.

Hazard Description

A failure or damage or random event causing rupture of the outer gas containment shell. (Gas is C02/CF4).

Effect on System

Possible critical damage.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

Need design baseline to evaluate alternative safety mechanisms. Similar actions as recommended for calorimeter will assist to eliminate risk.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Tracker

Reference No: 089

System/Subsystem/Unit

Tracker, kinematic mounts

System Event(s) Phase

All phases.

Hazard Description

If the mounts that internally mount items or the mounts that tie the tracker to the calorimeter fail or do not perform as designed, a hazard potential to the tracker and possibly calorimeter exist. Alternatively, deformation or misalignment of the tracker subsystem could occur.

Effect on System

Possible moderate damage. Loss of ability to meet physics goals. Any mounting failure will cause severe interruption of testing and lead to undue amounts of down time.

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

Dynamic analysis will be performed and prototype build and test will be performed.

Effect of Recommended Action:

Remarks

Status

Open.

Conducted by _____ **Date** 03-31-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Tracker

Reference No: 059

System/Subsystem/Unit

Tracker, materials

System Event(s) Phase

All phases of usage

Hazard Description

Sophisticated materials to minimize weight, to maximize radiation length, to have material property compatibility and to meet interface requirements may lead to mechanical failure induced by various causes.

Effect on System

Severe damage to tracker, beam pipe or calorimeter.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

Engineering analyses, failure modes analysis, parts/materials control program, extensive testing program and design reviews (working groups) are means to reduce and eliminate risk through design. The correct design pressure must be decided.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

The design pressure 5 mb seems too low. Vapor pressure should be taken in consideration.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Tracker

Reference No: 090

System/Subsystem/Unit

Tracker, nitrogen inerting (of inner tracker)

System Event(s) Phase

All phases during which butane is loaded in the system.

Hazard Description

A failure in the nitrogen supply would significantly reduce the ability to inert the areas around the butane enclosure which if a butane leak occurred could prevent the concentration from being reduced below the LEL (1.9%).

Effect on System

Possible damage and fire.

Risk Assessment

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Recommended Action

Nitrogen lines and supply will be mechanically protected, will have redundant pressure regulation and detected fault conditions will be tied to the emergency removal of butane from the system. The nitrogen and butane lines are specification compliant and double jacketed.

Effect of Recommended Action:

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Remarks

Status

Open.

Conducted by _____ **Date** 03-01-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Pr Tracker

Reference No: 088

System/Subsystem/Unit

Tracker, IPC tracker gas system.

System Event(s) Phase

Operation.

Hazard Description

An under/over pressure in the closed loop system could result in gas being vented into the detector or hall. An example condition would be a failure of a relief valve.

Effect on System

Damage to the detector and gas supply loop, and possible ODH, but is not considered critical due to amounts and locations.

Risk Assessment

Severity: III Marginal Probability: C Occasional Risk: 3 Operation permissible

Recommended Action

The primary means to mitigate the risk is the intended use of redundancy in valves, regulation devices and where lines will be routed. Gas leak detection will be used.

Effect of Recommended Action:

Severity: III Marginal Probability: E Improbable Risk: 3 Operation permissible

Remarks

Status

Open.

Conducted by _____ **Date** 03-31-93

Closed by _____ **Date** _____

7.0 ELECTRONICS

7.1 Safety Overview

The detector utilizes several different types of electronics: DC power supplies for the detector (excluding the magnet, reviewed in Section 3.0); data acquisition associated with the physics system; safety and control operations associated with the global control system; and other support electronics. Electronics are located in the operations center, on the detector, in the hall, and in electronics shaft and its access tunnels.

High voltage

The potential high voltages to be used are 1– 5 KVdc. The main hazard is that of electrocution, where current is sufficient to produce ventricular fibrillation. In the case of low current, personnel might experience the temporary loss of motor skills leading to falls, unconsciousness, and secondary accidents or damage. Also, stored energy in devices is important safety consideration since experience has shown that potentials ≥ 10 joules can cause physiological effects.

It is important for the design of high voltage installations to know the current that personnel will be working on and the exposure duration. There is a limit which permits us to separate high voltage equipment into two classifications. These limits are taken from data on human effects contained in the IEC (International Electrical Commission) publication 479-1. The threshold values given are a safe current limit at 10 mA with an exposure duration maximum of 20 msec. These values are intended for AC currents, which may be more harmful than DC currents. In cases where potential exposure is ≤10 mA, the requirements will be to avoid direct contact with live parts and to provide labeling of all the circuits (i.e., "Warning High Voltage ≥ 120 Volts"). At ≥10 mA total inaccessibility of high voltage sources will be achieved by enclosures and interlocks. During maintenance electrical lock and tag out methods will be used in addition to interlocks, as warranted.

Also, several fires in HEP have occurred where the current produced by a high voltage supply is to high for the rated capacity of the equipment. Power cable rating is being considered and fire retardant cables will be used. Cable runs will have smoke and early warning detection.

Operations Protection

The operations center, located in the south end of the south assembly building, is proposed to contain the on-line, off-line and global control system. Safety has provided input to the requirements package and will continue active participation in design, construction and test. Code compliance with NEC and FCC regulations is verifiable in current design. Heat dissipation design appears to be adequate and contains a safety margin. Power distribution design provides protection to prevent shock and circuit breakers, etc. having safety margins. Communications — busses, cables, networks — incorporate safe design practices. Because the center will house a high number of physicists, operators, and technical staff, human factors engineering will be an intensive area for design support to prevent accidents or mishaps. Equipment accessibility and availability will be a high priority.

Crates and Rack protection

The design makes use of standard racks having water and air cooling, electronic fault protection, fire protection and control, and fault diagnostics. When high current lugs are a part of a connector and data lugs are situated beside them, any improper handling of the card during connection creates the potential to cause a short circuit. Therefore each card should have a separate connector for the card supply, and this should be installed in parallel to the data connector. Each card and its supply will be overcurrent protected. Temperature sensors will be installed at strategic points in the ventilation stream at the top level of each crate and in each supply. Water flow and temperature sensors will be installed. Fire detection systems and fire suppression systems are prescribed.

For maintenance reasons, power supplies, crates, and cooling systems will be physically separated. Racks will incorporate human factors (ergonomic) design, and prescribe dimension and weight limitations to prevent injury from lifting, to make use of standard connectors, spacing and labeling, and to allow ease of maintenance.

Electronics Room

The three levels of electronics rooms located within the electronics shaft will require application of perimeter magnetic field shielding, attenuating the field down to a level where rack and crate functions are unaffected. Equipment in the hall will have to have local protection and possibly designs which are fault tolerant to the field.

Electronics rooms contain numerous high voltage, high current power sources and loads, and a very high density of cables. Attention to electrical safety design issues, compliance

to code requirements and usage of industry standard practices will be followed to minimize risk to people and equipment. Design issues address cable size, routing and protection, prevention of cross-connection, and human factors requirements associated with electronic items, racks, controls, and anthropometric measures.

Electronics Fire Protection

Several fire protection system strategies for the cable shaft electronics rooms (~30' × 40') are currently being evaluated. For computer type room occupancies safety codes require effective, approved room fire suppression and below-floor smoke detection, as a minimum. Based upon the total risk, we will consider a conservative approach where each rack will have dedicated detection and shutdown capabilities complimented by a room suppression system.

For incipient smoke-detection the choices are laser-particle-counters, Very Early Smoke Detection Apparatus (VESDA) and smoke detectors. Additionally, smoke detectors (high-quality UL/FM approved) with annunciator panel system mounted above and below the floor can be used. Anticipated fire suppression systems choices are: non-CFC or CO_2 gas suppressant or pre-action water sprinkler system.

The racks in the electronics rooms and hall will be installed in rows normally one row per detector subsystem. This is important in case of automatic response actions due to a local or a detector fire detection system alarm. Segregation provides the ability to cut power on the affected subsystem or conversely avoids having to cut power on other electronics not involved.

Experience has shown that in the event of cooling problems, temperature increases very quickly in cards. Sensors will be installed in the water cooling, each fan will be monitored for good operation, and temperature will be monitored at the top level of each crate and rack. Temperature increases in crates will pass an alarm to the GCS which will trigger cut out of power to the involved crate. For safety reason, each row will be covered inside the row by an early warning fire detection system. The role of this system is to give a first alarm for manual intervention and afterwards an alarm for automatic cut out of the supply involved.

In summary, special attention will be provided to the strategic design of this electronics protection. Early warning devices will give indications to the GCS and supervisor on duty. Human intervention is the first step for correction of minor problems; however, automatic actions will be required for the serious conditions. This could entail a full disconnection of the power depending of the situation of the alarm. The alarm structure relating to fire detection and prevention is being considered by safety and control system engineers.

7.2 Hazards and Mitigation

Hazard categories applicable to the current design are listed below. Following the list are hazard analysis report sheets for the categories listed.

- Electrical 7.0-1 thru 7.0-5

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Electronics

Reference No: 006

System/Subsystem/Unit

Electornics and electricl, distribution panels and racks/crates - detector, hall or shafts.

System Event(s) Phase

All operations of the detector.

Hazard Description

High voltage, personnel injury or death, damage/loss of equipment.

Effect on System

Equipment damage, or death of personnel.

Risk Assessment

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Recommended Action

High voltage warning signs will be placed on the distribution panels, cable ways and other relevant items. Maintenance crews and operation personnel will be trained in high voltage procedures in accordance with SCC Laboratory procedures and policies. Electrical protective devices will be incorporated during the system installation. Equipment interlocks. IEEE rules will be followed.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

Design is not complete.

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Electronics

Reference No: 065

System/Subsystem/Unit

Electronics and electrical subsystems, racks, crates, cable ways, and other items.

System Event(s) Phase

All phases are considered where human factors, egress and lifting/moving and repair are of paramount significance.

Hazard Description

Human factors errors, mishaps and other unsafe events are directly related to design considerations, work environment - area, lighting, lifting, etc. - controls, connector and mechanical interfaces and more.

Effect on System

Most effects are personnel injury - including loss of life, lost time and significant system down time. Damage is frequently moderate based on military type applications.

Risk Assessment

Severity: I Catastrophic Probability: B Probable Risk: 1 Imperative to suppress

Recommended Action

Use MIL-STD-1472, MIL-STD-454, MIL-STD-470, industry standards and public domain references for meeting requirements. Safety and reliability work closely with engineering to eliminate most hazards. Evolve human factors design with detail designs.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

Status

Open

Conducted by _____ **Date** 02-17-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Electronics

Reference No: 066

System/Subsystem/Unit

Electronics, controls, computers, and support equipment

System Event(s) Phase

Items located in operation/control center in south assembly building. Human factors design issues related to man-machine interfaces, maintenance and other considerations where human error can occur.

Hazard Description

Hazards such as operator error, misinformation being supplied leading to erroneous actions may be caused by awkward console controls, software bugs and presentation, low illumination and anthropometric errors.

Effect on System

Severity is critical for many of the hazards. Risk without mitigation is high.

Risk Assessment

Severity: II Critical Probability: B Probable Risk: 1 Imperative to suppress

Recommended Action

Use MIL-STD-1472, MIL-STD-454, MIL-STD-470, industry standards and public domain references for meeting requirements. Safety and reliability will work closely with engineering to eliminate hazards. Evolve human factors design with detail designs and the use of mock-ups, validation and verification are planned.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

Status

Open

Conducted by _____ **Date** 02-17-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Electronics

Reference No: 063

System/Subsystem/Unit

Electronics, subsystems

System Event(s) Phase

All phases

Hazard Description

Multiple and widely disparate hazards are considered. At this preliminary or design concept phase specific hazards applicable to individual equipment items are not available. Refer to the PSAR, paragraph 3.5 for a list of specific hazards of electrical and electronics equipment.

Effect on System

Most severe of the kinds of effects aniticipated are categorized as critical either with respect to damage or personnel.

Risk Assessment

Severity: II Critical Probability: B Probable Risk: 1 Imperative to suppress

Recommended Action

Actions to take are: 1) reliability predictions, 2) maintainability predictions/assessment, 3) failure modes analysis (of box interfaces) and 4) damage mode analyses. Engineering analyses of designs are being conducted to fully understand specific inputs and outputs, etc. Recommendations are to be determined once design has been assessed. Nevertheless the proposals written in the SAR are valid.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

Engineers are involved in design, analysis and providing safety. Experience has shown that hazardous risk can be reduced to remote by prudent design following industry, military and regulatory standards. Other issues relating to electromagetic susceptability are covered in a separate item.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Electronics

Reference No: 064

System/Subsystem/Unit

Electronics, subsystems and support equipment

System Event(s) Phase

All phases. Equipment considered is located in hall or electronics shafts.

Hazard Description

Electromagnetic susceptibility hazards - EMI, EMC - due to proximity of various types of equipment items, complexity of racks/crates, cable runs/types, and grounding and other recognized sources.

Effect on System

Most probable effects are 1) inoperability or operation errors, 2) false alarms, 3) circuit/part damage and 4) loss of safety systems.

Risk Assessment

Severity: II Critical Probability: C Occasional Risk: 2 Waiver required

Recommended Action

Further study is needed to identify sources, and effects. A detector grounding, etc. plan should be implemented. EMI/EMC testing and qualification program should be initiated.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

Significant reductions in severity and risk can be realized. Various groups are working issues.

Status

Open

Conducted by _____ **Date** 02-17-93

Closed by _____ **Date** _____

8.0 BEAM PIPE

8.1 Overview

A beryllium vacuum beam tube will penetrate through the center of the silicon tracker and be attached to steel extensions on either end. The steel beam tubes will extend on through the calorimeter and FFS joining the collider beam tubes at the collimator. The beryllium beam tube must be constructed for a minimum radiation length to support physics. A vacuum level of between 1×10^{-7} and 1×10^{-8} torr will be required at the interaction region.

Potential hazards can affect personnel and experimental equipment. The failure of the beam pipe would result in significant detector down time. The length of down time and equipment damage depend on the severity of the failure. A failure in the beryllium pipe could result in the release of airborne beryllium oxides which are known to be a hazardous material to personnel. Further, catastrophic pipe failure could damage adjacent detector subsystems. At this point, safety and design engineers are developing a safety margin requirement that will provide adequate prevention of accidents or hazards and still meet physics needs.

8.2 Hazards and Mitigation

Hazard categories applicable to the current design are listed below. Following the list are hazard analysis report sheets for the categories listed.

- Mechanical 8.0-1

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Beam Pipe

Reference No: 068

System/Subsystem/Unit

Detector, beam pipe

System Event(s) Phase

During calibration (cal hall) or during operation when vacuum is applied to the ring and/or experiment.

Hazard Description

Accidental damage to or structural failure of the beryllium beam tube during the time that vacuum is pulled. (Other portions of the pipe are susceptible, but have higher yields and strength.)

Effect on System

Catastrophic damage due to implosion by 1) external damage such as latent failure from impact or 2) loss of vacuum locally such as weld stress crack, or due to explosion from shock wave emanating in the ring. Secondary damage can be foreseen to the tracker.

Risk Assessment

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Recommended Action

Recommendations will be forthcoming when radiation analyses, physics analyses and other supporting evaluations are complete. Initial recommendations include: any vacuum loss must trigger a beam dump, valves (N/O) will close, power removed from detector. Pipe integrity is to be inspected at each major planned maintenance.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

Further define explosion. What is velocity of shock wave? Where are the closest safety valves going to be located? What is time between a vacuum loss and when the valves close? What is effect of beam bunches that cross during the interim?

Status

Open.

Conducted by _____ **Date** 02-22-93

Closed by _____ **Date** _____

9.0 CENTRAL DETECTOR SUPPORT & STRUCTURES

9.1 Overview

As its name implies, the central detector support (CDS) is located at the center of the GEM detector as a large mounting structure for various items. The CDS is comprised of a large low carbon steel cross beam supported by two angled legs on each end (resembles a saw-horse in shape). The purpose of the CDS is to support and provide coarse alignment for the calorimeters and central tracker independently from the rest of the detector. Functionally the CDS provides a load path for the axial magnetic forces, and provides support and coarse alignment for the calorimeter and tracker independent from the rest of the detector. Also, utilities and other items such as electric cables, data bus hardware, electronics equipment, etc. will travel through the CDS. The CDS is designed to DOE UCRL 15-910, Design and Evaluation for DOE Facilities Subjected to Natural Phenomena Hazards, and other standard engineering design codes.

9.2 Hazards and Mitigation

Potential hazards associated with the CDS system are: 1) buckling and load stresses; 2) maintenance activities requiring access method definition; and 3) contact with gross or prolonged cryogenic spill causing either buckling[1]; or embrittlement with fatigue cracking. Safety considerations include stress and Vibrational effects analysis to determine or verify design limits for loads and evaluate hazard potential and to determine the center of gravity. Analysis will be completed prior to release of the assembly's drawing package.

The response of detector structures and supports to vibrations anticipated in the experimental hall[2] have not been indicated to exceed the specified alignment tolerances. Support structures are designed to meet load limits through useful life when subjected to the hall vibrations over operating and non-operating temperature ranges. Structures and supports will be designed to handle various hypothesized static and seismic loads by utilizing factors of safety specified in the GEM design documentation package and ANSI standards. (Maximum ground accelerations are anticipated to be 0.08g vertical and 0.12g horizontal[3].) Low frequency vibrations generated by cryogenic equipment operation are not expected to cause problems. Other loads imposed by transportation and rigging will be addressed through studies and analyses to meet sufficient factors of safety.

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1 GEM TN-92-224 Structural Analysis of the GEM Central Detector Support.

2 SSC-SR-1043, "Field Measurements and Analysis of Underground Vibrations at the SSC Site."

3 3.7B, Seismic Criteria, of the Commanche Peak (a power plant operated by Texas Utilities near the SSCL) Steam Electric Station Final Safety Analysis Report.

Hazard categories applicable to the current design are listed below. Following the list are hazard analysis report sheets for the categories listed.

- Mechanical 9.0-1 & 9.0-2

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me CDS

Reference No: 031

System/Subsystem/Unit

CDS

System Event(s) Phase

Assembly (surface) and installation (in hall).

Hazard Description

Because of the weight and size handling and assembly will be difficult with increased probability of accident or mishap.

Effect on System

Effect is severe injury or catastrophic damage.

Risk Assessment

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Recommended Action

Design considerations includes: 1) Approved operating procedures - assembly, weld, crane, lift, etc., 2) rigid attention to design codes - particularly UCRL 15910, 3) identify hazard/failure modes of various operating modes, and 4) safety training to correspond to effects identified.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

Follow design process, and documentation with respect to the recommended actions.

Status

Open.

Conducted by _____ **Date** 02-17-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me CDS

Reference No: 032

System/Subsystem/Unit

CDS

System Event(s) Phase

All phases after placement into the hall.

Hazard Description

The CDS fails structurally - loads or other mechanical stresses. Mechanism is hypothesized as design inherent. (For induced damage see CDS record #31.)

Effect on System

Catastrophic damage as the tracker and calorimeter are connected directly to the CDS and the CDS provides central functional load path for the magnet subsystem.

Risk Assessment

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Recommended Action

Based on current engineering design status recommendations are: 1) Identify failure modes; 2) continue to verify design - dynamic models, compliance to specifications, and 3) peer reviews or design reviews. FEM will be used.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

Each recommendation item is in progress.

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

10.0 ASSEMBLY, INSTALLATION AND UPGRADES

10.1 Safety Overview

At this point in the design of the detector, assembly and integration are conceptually defined. Facilities, fixtures, tools and support mechanism along with processes are not well defined. Therefore, this section currently highlights general issues. Also, this section will receive extensive additions and accordingly will evolve with detail design.

Evaluation of the detector assembly and installation processes indicates that specific safety systems will need to be provided. Subsystems or portions of them will be assembled in surface buildings; final assemble and integration will be done in the experimental hall. The primary hazards are those associated with handling and transport of the massive detector subsystems and components. Assembly, work area and personnel hazards will be identified. Mitigation will be implemented in detector design, by special fixtures, through quality requirements in manufacturing process/procedure documents and shop orders. Joining processes used in the assembly of components require special safety precautions. Processes that create a safety hazard will be controlled. Sources generating toxic fumes or noise will be segregated, managed and mitigated in accordance with SSCL ES&H manual requirements.

Cranes, assembly support fixtures, vehicle/rail transports, hall grease pad and the hydraulic transport system will be analyzed to identify hazards and load capacity safety factors. Hazard reduction methods will be incorporated in designs and purchase specifications for each equipment type. All suspension or support structures will incorporate code design stress recommendations. Where massive detector parts require integrated assembly, preference will be to provide permanent load supports as opposed to temporary scaffolds or lengthy suspension by crane or hoist.

Safety measures that protect people and hardware in the surface buildings will be adapted and installed within the underground hall and shafts. During installation, support structures will be constructed to design stress levels that can safely support the load. All handling, scaffolding, support and transport equipment will comply with SSCL ES&H, OSHA and other regulations.

Occasionally, the installation shaft radiation shielding concrete blocks will be removed and replaced. While the blocks are removed a safety net or cover will be placed within the shaft, close to the surface level. Also, a barrier will be placed around the shaft opening.

In the hall and on the surface, installation equipment and materials will be placed so as not to block emergency egress pathways. Personnel access safety equipment will be designed according to human factors guidelines and will be present during installation. During the

installation process, the safety rules governing access to confined spaces will apply. Although the magnet does not present a confined space hazard, it does define the perimeter of a closed (or partially closed) volume depending on the operational mode. Thus, work space and ingress/egress will be referenced to the magnet. The issue of work environment and ingress/egress within the space when subsystems are installed inside is being analyzed by GEM Safety. Preliminary workspace and ingress/egress requirements have been provided to the project engineers.

Safety system controls will be applied to mitigate physical agents (e.g., cold & heat stress, ionizing radiation, static magnetic fields, noise, lasers, light and ultraviolet and near-infrared radiation) during detector installation. Lighting will be ≥ 50 foot-candles at the floor and ventilation will be ≥ 2 air changes per hour under normal hall occupation conditions.

10.2 Hazards and Mitigation

Hazard categories applicable to the current design are listed below. Following the list are hazard analysis report sheets for the categories listed.

• Biological	10.0-1
• Egress	10.0-2
• Electrical	10.0-3 & 10.0-4
• Environmental	10.0-5
• Fire	10.0-6
• Gravity	10.0-7
• Mechanical	10.0-8 & 10.0-9
• Oxygen Deficiency	10.0-10
• Radiation	10.0-11

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Bi Detector

Reference No: 001

System/Subsystem/Unit

Detector and support equipment

System Event(s) Phase

During all phases.

Hazard Description

No biological hazards have been identified.

Effect on System

Risk Assessment

Severity: IV Negligible Probability: E Improbable Risk: 3 Operation permissible

Recommended Action

No action required

Effect of Recommended Action:

Severity: IV Negligible Probability: E Improbable Risk: 3 Operation permissible

Remarks

Status

Closed.

Conducted by _____ **Date** 02-15-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Eg Detector

Reference No: 003

System/Subsystem/Unit

Detector & subsystems

System Event(s) Phase

Installation & all phases thereafter.

Hazard Description

Difficult ingress and egress in and around the detector and its subassemblies.

Effect on System

Possible injury to personnel and/or damage to equipment

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

Alternative options for design, procedures and other mitigation are being studied.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

In particular, see muon subsystem record #37.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Detector

Reference No: 016

System/Subsystem/Unit

Detector, cabling (Various), optical fibers

System Event(s) Phase

Operating - Power On

Hazard Description

Potential combustible cabling may be used due to performance requirements, which in the event of fire would potentially propagate the fire.

Effect on System

Loss of system or severe damage.

Risk Assessment

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Recommended Action

Fire prevention, alarm and suppression systems are to be installed. Where code or fire retardant cable cannot be used, a thorough investigation of effects and fire detection will be made with recommendations for risk reduction.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

An interim specification has been released for cables and optical fibers that should result in minimizing the quantity of noncompliant cable used. ES&H is participating in the review of the procedure.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: El Detector

Reference No: 067

System/Subsystem/Unit

Detector, Global Control System (GCS)

System Event(s) Phase

All phases during which the GCS is used to monitor, detect, interact with other control systems, or communicate with emergency systems.

Hazard Description

GCS provides the central point for hall, detector and subsystem monitoring, fault detection, failure isolation and control and communication with mitigation systems and emergency activities. Inoperation, incorrect detection, transmission, interface with operators or other safety critical operations could lead to significantly hazardous events.

Effect on System

Catastrophic damage and/or loss of life.

Risk Assessment

Severity: I Catastrophic Probability: C Occasional Risk: 1 Imperative to suppress

Recommended Action

Incorporate redundancy in detection and controls, multiple levels of confirmation verification, use the following documents as guidelines : MIL-STD-1472, Human Factors, MIL-STD-2167 Software Configuration/quality Mgt, MIL-STD-882 (300 series tasks) Safety, and lessons learned for additional data. Perform fault tree analysis on safety critical controls.For alarm transmission (level C) hard wired system will assure the redundancy

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

Ongoing analyses. Design is conceptual with further refinements as scheduled in GEM PMP.

Status

Open.

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: En Detector

Reference No: 055

System/Subsystem/Unit

Detector, subsystems

System Event(s) Phase

Mixed hazardous waste

Hazard Description

Potential for personnel contact, handling and storage hazards. Various materials used in detector subsystems such as muon and calorimeter.

Effect on System

Toxic and radioactive materials

Risk Assessment

Severity: II Critical Probability: B Probable Risk: 1 Imperative to suppress

Recommended Action

Various working groups in engineering and ES&H are aware of the issues. Recommendations are to be determined.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

Continuing efforts are underway within several groups - ASD and PRD.

Status

Open.

Conducted by _____ **Date** 02-16-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Fe Detector

Reference No: 017

System/Subsystem/Unit

Detector, Materials

System Event(s) Phase

Phases during which a spark could be generated such as during welding/brazing.

Hazard Description

Fire and toxic fumes from combustion of materials which are flammable/combustible.

Effect on System

Loss or major damage of system. Personnel injury.

Risk Assessment

Severity: I Catastrophic Probability: C Occasional Risk: 1 Imperative to suppress

Recommended Action

Fire alarm, suppression and prevention systems will be installed; limit combustible materials. Other mitigation TBD. Compile and continuously monitor list of hazardous materials.

Effect of Recommended Action:

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Remarks

Investigation of complete fire detection, and suppression system is ongoing.

Status

Open

Conducted by _____ **Date** 02-16-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Gr Detector

Reference No: 025

System/Subsystem/Unit

Detector

System Event(s) Phase

Installation, maintenance, and inspection.

Hazard Description

The detector is over 20 meters tall. Therefore, 1) it is possible for personnel to fall. 2) Falling objects are also considered as a potential hazard.

Effect on System

Personnel injury and system damage.

Risk Assessment

Severity: I Catastrophic Probability: B Probable Risk: 1 Imperative to suppress

Recommended Action

Guard rails will be required on all walkways and scaffolds being used to build and maintain the detector to minimize the possibility of persons falling or being injured from items. Handling procedures are to be made.

Effect of Recommended Action:

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Remarks

Further risk reduction is required.

Status

Open

Conducted by _____ **Date** 02-23-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Detector

Reference No: 038

System/Subsystem/Unit

Detector and subsystems and support equipment.

System Event(s) Phase

Installation, maintenance & shutdown

Hazard Description

Creation of pinch points when major subassemblies, or their subassemblies are positioned during the various phases.

Effect on System

Damage to structures, electrical, vacuum, gas, liquid lines, etc.

Risk Assessment

Severity: III Marginal Probability: B Probable Risk: 2 Waiver required

Recommended Action

Multiple approach including design of interfaces, special fixtures - aligning, transport, handling - procedural precautions, and safety procedures for identified critical areas.

Effect of Recommended Action:

Severity: III Marginal Probability: D Remote Risk: 3 Operation permissible

Remarks

Status

Open

Conducted by _____ **Date** 02-16-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Me Detector

Reference No: 069

System/Subsystem/Unit

Detector and support equipment, items and services in hall.

System Event(s) Phase

Low frequency vibration of system caused by earthquake.

Hazard Description

Vibration of structures, supports, gas and other pipes, cable trays and interference among mechanical joints and interfaces. Earthquake caused. (Note that the SSCL is located in an earthquake zone zero.)

Effect on System

Possible damage.

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

Design for vibration levels as documented in Seismic Criteria of Commanche Peak and other current SSCL related analyses. Current analyses of engineering data indicates compliance to criteria.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

Final review prior to design release will close item.

Status

Conducted by _____ **Date** 02-22-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: OD Detector

Reference No: 042

System/Subsystem/Unit

Detector, liquids & gases

System Event(s) Phase

Phases during which ODH could be a hazard in the hall. (ODH in the detector is in record #'s 36 &41.)

Hazard Description

Within the experimental hall, the primary hazard associated with gas systems is from an uncontrolled release that is not confined to the detector.

Effect on System

Potential asphyxiation or cryogen burns.

Risk Assessment

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Recommended Action

ODH sensing and warning system to prevent personnel exposure to undetected ODH environments in both the hall and detector. HVAC air exchange is planned to be increased in case of detected decrease in hall oxygen content. An alarm with emergency evacuation of personnel will be used. If the release is a liquid, several abatement methods are being evaluated for abatement.

Effect of Recommended Action:

Severity: II Critical Probability: E Improbable Risk: 3 Operation permissible

Remarks

ODH design and analysis are ongoing. SSCL has specific procedures for monitoring, control, prevention and compliance. HVAC failure modes with respect to this hazard need to be identified.

Status

Open

Conducted by _____ **Date** 02-16-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Ra Detector

Reference No: 045

System/Subsystem/Unit

Detector and equipment in immediate area

System Event(s) Phase

Operational life cycle after beam ON.

Hazard Description

Radiation embrittlement - induced structural failure.

Effect on System

To be determined; however, failures could lead to catastrophic events.

Risk Assessment

Severity: I Catastrophic Probability: D Remote Risk: 2 Waiver required

Recommended Action

Radiation analysis, design, cause/effect studies are ongoing. Limited recommendations have been made. Also, determine susceptible materials and concentrate analysis on those.

Effect of Recommended Action:

Severity: I Catastrophic Probability: E Improbable Risk: 3 Operation permissible

Remarks

Ongoing with radiation working group, research, and consulting.

Status

Open

Conducted by _____ **Date** 02-16-93

Closed by _____ **Date** _____

11.0 RADIATION & RADIOACTIVE MATERIALS

11.1 Safety Overview

Personnel Radiation Safety

At accelerators there are two major sources of radiation to workers; direct (prompt) or radiation from induced radioactivity. Experience has shown that the largest proportion of the collective dose equivalent arises from work carried out on activated components. The protection of people from radiation is controlled by regulations which prescribe limits to radiation exposure and in some cases set out specific radiation control practices. Given the trends shown in various orders and guidance documents, it is prudent for institutions such as the SSCL to adopt practices in radiation control that will result in personnel exposure to levels well below the current regulatory limits. The SSCL has adopted a policy on radiation protection which sets challenging administrative control levels and design goals for those exposed occupationally and also members of the public.

Persons who are routinely exposed to radiation as a consequence of their work are designated as "Radiation Workers." These persons will receive specific training in radiation control principles and practice and be monitored so as to provide a record of their radiation dose history. Most of the SSCL site is shielded to give radiation levels which would permit normal occupancy by members of the public. Thus anyone who works only in these "open" areas does not need to be a radiation worker.

Activation

The radioactivation in the detector and low beta quadrupoles predominantly occurs in a zone very near the beam pipe. Parts of the detector and collimator/shield (and the quadrupoles) near the beam tube may be sufficiently activated from collider operation that they will become radioactive. This radioactivation can provide high risk, even after the beam is off, to those who need to work near the beam. To mitigate this hazard, the residual activity must be measured and unsafe areas will be identified by barriers or other recognized means before workers are allowed access to the detector or its components.

Equipment and technical support systems which are located within the hall (or calibration hall) will become activated to an extent. If these systems are not required within the area, they will be remoted away from the area. If their location within the hall is required, local shielding may be applied, if analyzed and found to be necessary.

Other activation issues which have been worked resulting in standards for

environmental impact and design include air and ground-water activation and definition of "controlled areas" outside the hall.

Shielding

Shielding will be applied to attenuate radiation levels at or above the surface in accordance with the SSCL Environmental Impact Statement. In the hall, the following areas will be shielded: utility and cable shafts; accelerator tunnel/hall interface; collimators; all non-radiation hard subsystems; and electronics rooms.

Hazardous Mixed Waste Handling

Generation of mixed hazardous waste within the IR-5 site will be strictly limited. A method of disposal of radioactive wastes and hazardous wastes will be in place prior to start-up. Disposal of mixed hazardous wastes will be planned for, prior to their generation. The SSCL policy is to eliminate these where possible, and to minimize waste where generation is unavoidable. SSCL is not allowed to store or permanently dispose of any of these wastes on site. Transportation to approved sites also will be arranged to meet appropriate regulations.

11.2 Hazards and Mitigation

In the event of a fire the HVAC system to introduces outside air thus ejecting smoke and air from the hall. If a fire occurred, a particular concern is the magnitude of airborne radioactivity that could potentially released to the environment without the hold up time normally used to allow normal decay. This scenario will be studied for determining alternative means to effect a safe and environmentally sound solution. Results will affect fire protection and suppression.

The best protection against overexposure is radiation monitoring. All radiation workers are required to wear personal radiation monitors in controlled areas. In addition all controlled areas will be monitored using appropriate installed monitor systems. Proper procedures will be in place prior to operation to ensure that operations staff are fully aware of the radiation levels that exist in the halls at all times when occupancy is requested so to ensure that all operations are conducted in the safest possible manner.

Hazard categories applicable to the current design are listed below. Following the list are hazard analysis report sheets for the categories listed.

- Radiation 11.0-1 thru 11.0-3

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Ra Radiation

Reference No: 044

System/Subsystem/Unit

Detector (Activated Material)

System Event(s) Phase

All phases after beam ON.

Hazard Description

Fire in the hall or detector may release radiation or irradiated debris into the outside environment.

Effect on System

Effects are being studied.

Risk Assessment

Severity: III Marginal Probability: D Remote Risk: 3 Operation permissible

Recommended Action

This issue is being studied as part of the radiation analyses. Results of the analyses will be used to define requirements and design safety abatement.

Effect of Recommended Action:

Severity: III Marginal Probability: E Improbable Risk: 3 Operation permissible

Remarks

Coordination with central radiation physics is planned.

Status

Open

Conducted by _____ **Date** 02-16-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Ra Radiation

Reference No: 071

System/Subsystem/Unit

Detector, parts and materials

System Event(s) Phase

Hazard Description

Radio activation of parts and materials used for detector.

Effect on System

Effects are still being determined. Radioactivation leads to hazardous waste and handling.

Risk Assessment

Severity: II Critical Probability: B Probable Risk: 1 Imperative to suppress

Recommended Action

Few specific recommendations have been made at this point. Various studies by SSCL and other laboratories are providing input to engineering and ES&H on issues and their resolution. Determine the list of susceptible materials.

Effect of Recommended Action:

Severity: II Critical Probability: D Remote Risk: 3 Operation permissible

Remarks

Ongoing process with several working groups.

Status

Open

Conducted by _____ **Date** 02-22-93

Closed by _____ **Date** _____

HAZARD ANALYSIS REPORT

Project Name: GEM
Item Category: Ra Radiation

Reference No: 080

System/Subsystem/Unit

Detector, radiation Analysis of Detector and Hall

System Event(s) Phase

All phases after beam ON during system life cycle.

Hazard Description

At this stage, hazards are grouped and described generally. Since radiation will affect most portions of the detector, hall, and air, there are activation, handling, personnel and emergency . Detector activation hazards are documented in section 10.0 of the SAR.

Effect on System

Exposure effects on personnel.

Risk Assessment

Severity: III Marginal Probability: A Frequent Risk: 2 Waiver required

Recommended Action

The TDR provides an analysis of radiation. The safety chapter provides an overview of safety implications and systems. Since analysis is ongoing, this SAR item will track progress. It is the goal to provide an ultimate risk which has a probability of occurrence of improbable.

Effect of Recommended Action:

Severity: III Marginal Probability: E Improbable Risk: 3 Operation permissible

Remarks

Monitor and update.

Status

Open.

Conducted by _____ **Date** _____

Closed by _____ **Date** _____

12.0 FIRE HAZARD AND PROTECTION

12.1 Hazard Description

Experience in HEP shows that fires often have a long process in their development, except if flammable gas mixtures are used. Inquiries at CERN indicate that the main causes for the fire development for 90% of the fires, were the lack of fail-safe equipment design, the lack of early warning fire detection and inadequate or unsuitable suppression equipment.

The main source of fire, with the exception of induced fires from external works as welding process, is from condensed power in electronics. The principal vectors are plastics materials, optic fibers and cables. When electric and electronic installations are not correctly protected against internal defects at each level, overheating and fire result. This is a concern for high power electronics. Electronics issues and protection are evaluated in section 7.0.

A related concern is the location and mounting position of high power electronics. A significant quantity of electronics crates is situated very close to the detector. The density of electronics and proximity of electronics to each other and minimal accessibility increase the potential for a hazard. Closely tied to the risk is the added difficulty to take external actions. Again, status monitoring and early detection are employed.

12.2 Detection and Protection

Until recently, the goals for fire detection and extinguishing, rules and regulations were to save human life, to protect buildings, surrounding installations, but rarely the equipment. The technology at the time for fire detection and extinguishing systems was not able to give good coverage for protection. Now the philosophy is changing due to the fact that the cost of equipment is so high. Equipment system protection is becoming more practical since the technology in fire protection has improved and can meet the unique and often complex requirements of equipment. At CERN a technology based protection philosophy is being used with success. Prevention techniques based on current capabilities and experience (lessons learned) are being employed to the GEM experiment.

General features include:

- Equipment must be designed to be fail-safe as far as possible, and that a system failure will trigger an automatic action to put the system in a safe state.
- Circuits from supplies, power distribution and preamps must be individually protected against over current, and protection must cut power of the circuits involved.

- Temperature sensors must be put at strategic points, and sensors must have two functions. One is to advice at a low level of overheating to allow early actions based on intervention procedures. The second is to provide automatic cut out if the temperature continues to increase.

- If automatic actions do not operate for any reason, the last barrier consists of early warning smoke detection systems which will take the necessary cut out actions for total power to the detector involved.

The next group of subsections illustrate specific areas that will be encountered in the protection of the detector's subsystems in order to achieve a unified or complete system.

Tracker Protection

Early detection and tiered warning is particularly pertinent for the tracker. The problem is the inability to access internal electronics in order to take maintenance actions

In the tracker volume oxygen (O_2) monitoring will be installed, its action is to interlock the power supplies in case of O_2 indication in the tracker, condenser and pipe volume. An indication, in operation, will trigger an emptying procedure of the liquid butane from the condenser, and will trigger N_2 inertion inside the tracker volume, condenser and pipes. Power to the tracker supplies will also be cut.

Calorimeter

As the equipment will be situated in the muon volume, early warning detection systems will be installed in the muon space. Also, due to the density of the subsystem and the amount of passive absorber within it, detection and protection will be installed in most of the spaces throughout. Location will depend on sources and vectors.

Muon Spectrometer

Technical protection will follow the general approach already described. The front-end muon electronics on each chamber will be enclosed by covers to contain fire and limit oxygen. Additionally it may be reasonable to flow nitrogen through the covers which will cool the heat coming from preamps and facilitate measuring the pollution given by any overheating, aerosols and smoke (augment early fire detection).

Cables and Optical Fibers.

As far as possible cables and optical fibers will be installed in ducts to avoid spreading of a fire. They will be chosen taking into consideration low smoke emission, toxicity, fire resistance, low opacity of smoke and resistance to radiation.

Cables and optical fibers entering in the control rooms will be sealed by fire barriers. The distribution inside the rooms will be made in such a way that vertical cable ways will be limited and that the distribution in racks never cuts the ventilation stream.

12.3 Fire Suppression

Fire suppression for the detector and ancillary technical systems or hardware is driven by the problems to be encountered in materials selected, by technologies used and by its overall design. Since the design is an evolutionary process, fire suppression design will correspondingly evolve. Suppression will be an integrated system within the detector, will support the physics requirements and meet objectives and regulations. The following provides a synopsis of suppression options for detector subsystems:

- Inner tracker: butane evacuation, power off followed by N_2 inertion,
- Outer tracker: operating gas CO_2/CF_4, with emergency N_2 inertion,
- Muon chamber volume: high expansion foam, nitrogen inertion or water mist,
- Muons chambers electronics: emergency N_2 inertion,
- Crates: water mist, halon replacement (if and when available) and/or water deluge

Outside the detector fire suppression for the immediate area and support equipment items include:

- High expansion foam,
- Water for cable ways and ducts,
- High pressure water mist or gas inertion inside racks and crates,
- Room sprinklers or non-CFC gas.

These recommended solutions are the best today, but can be modified depending on future development of the detector. Operationally, fire suppression systems must have the capability to be automatically or manually initiated with the possible exceptions of the tracker, calorimeter and muon which have minimal accessibility and therefore, initiated automatically.

13.0 CALIBRATION HALL TESTING

Many of the same safety measures described for the tracker, calorimeter and muon spectrometer will apply to test beam work in the calibration hall. A separate study is being performed for the safety aspects of the calibration hall, the GEM detector subsystems which will be tested, and required support equipment. The documentation generated from that study will be incorporated herein. As hazards are identified, analysis and tracking sheets will be made part of this SAR.

Hazard categories applicable to the current design are listed below. Following the list are hazard analysis report sheets for the categories listed.

No hazards distinct from those affecting the detector, have been identified through March 1993.

APPENDIX A: REFERENCE DOCUMENTS

1.0 APPLICABLE DOCUMENTS

The following form an integral part of this document either for preparation, design, or operating compliance. Unless otherwise stated, the document date of issue at the time of the GEM letter of agreement is to be used unless otherwise specified or amended.

1.1 Department of Energy Orders

DOE 4700.1	Project Management System
DOE 5400.2	Environmental Compliance Issue Coordination
DOE 5400.1	General Environmental Protection Plan
DOE 5480.1b	Environment, Safety, and Health Program for Department of Energy Operations
DOE 5480.4	Environmental Protection, Safety, and Health Protection Standards
DOE 5480.7	Fire Protection
DOE 5481.1b	Safety Analysis and Review System
DOE 5483.1a	Occupational Safety and Health Program for DOE Contractor Employees Government Owned Contractor Operated Facilities
DOE 6430.1a	General Design Criteria

1.2 Federal Codes

29CFR1910	Code of Federal Regulations, Occupational Safety and Health Standards
29CFR1926	Code of Federal Regulations, Occupational Safety and Health Standards f Construction

1.3 National Consensus Standards and Codes

ANSI Z117.1	Safety Requirements for Confined Spaces
NFPA 101	Code for Safety to Life from Fire in Buildings and Structures
NFPA 70	National Electric Code
NFPA 58	Standard for Storage and Handling of Liquefied Petroleum Gas
ASME	Boiler and Pressure Vessel Code, Section VIII, Division 1
UL #83	
ASME	Code for Pressure Piping B31. 2 & 3

ASTM	Metric E380-89a
ASCE	Building 7-1988
NFPA 58	Flammable Gas Storage
NFPA 59A	Std for the Production, Storage and Handling of LNG Article 501, Class 1 Div 2
CGA	Pressure Standard S-1,2 Relief Device
CGA	Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections
CGA	Guide to the Preparation and Precautionary Labeling and Marking of Compressed Gas Containers
CGA	Safe Handling of Cryogenic Liquids P-12
CGA	Pressure Relief Device Std S-1,2
49 CFR	Part 193 LNG Facilities.

1.4 Other Guidance Documentation

DOE EV-0051/1	Electrical Safety Criteria for Research and Development Activities
MIL-STD-882B	System Safety Program Requirements
MIL-STD-1472	Human Factors Engineering for System & Equipment

1.5 References

1 Calibration Hall draft PSAR document GEM TN-92-230.

2 Alignment Chapter of Baseline 2 document.

3 Graham R. Stevenson, "Activation at Accelerators, CERN Divisional Report", TIS-RP/90-10/CF (1990)

4 R. H. Thomas and G. R. Stevenson, "Radiological Safety Aspects of the Operation of Proton Accelerators", Technical Report Series No. 283, IAEA, Vienna (1988)

APPENDIX B: UTILITY SYSTEMS SAFETY OVERVIEW

Utility safety is only discussed in summary below because it is the topic of evaluation and reporting by Experimental Facilities Department (EFD). It is the purpose of this SAR to indicate that utility interfaces with the detector are safeguarded so we can evaluate related safety mechanisms for the detector with assurance that they don't unnecessarily duplicate, conflict or counteract those features of utility safety. If a hazard potential exists from a specific utility we need that awareness so it can be dealt with correctly in the GEM design.

GEM ES&H maintains working group sessions with EFD ES&H to keep abreast of issues and provide input. Further, we provide EFD identified hazards of the detector which may affect their utility design and safeguards. Other safety disciplines such as fire protection are treated similarly. This category of hazards are addressed in sections 3 and 4, herein.

1.0 Water Systems

Cooling pond/tower water is used as a primary medium to meet equipment cooling requirements. The majority of the heat rejected to the cooling water systems will be transferred to the atmosphere by means of evaporation and heat exchangers. Systems include cooling pond water, low conductivity water (LCW and LTLCW) and chilled water. Water systems are described in the GEM Experimental Facilities User requirements (GEFUR) GCT-000001C, February 3, 1993. Water systems incorporate check valves, relief valves, filters, pumps and other safety devices to ensure proper utilization and operation thus ensuring equipment overheat protection. water will be channeled to protective areas for cooling and disposal.

2.0 Heating Ventilation and Air Conditioning (HVAC)

The HVAC is important for proper detector operation during run times and during maintenance or other operations. Several systems are used to guarantee hall, shaft and detector supply requirements are met. Separate ventilation from the HVAC provides conditioned air to the interior of the detector. During shut down periods this air serves both to remove any gases escaping in the detector and to supply fresh air for occupancy.

The HVAC is a conditioning, environmental control and safety system. During beam-off operation, the HVAC assures that the atmosphere in the hall environment has sufficient oxygen mixed with outside air to dilute any escaping gases from the detector. Outside air makeup is 25% of the supply air; exhausts up to 25% of the air supplied to the hall. During beam-on operation, the ventilation system is used as a cooling medium for heat sources in the hall. Effectively, no outside air is introduced to avoid exhausting activated hall air. An air venting portion of the HVAC is designed to exhaust the bottom of the pit if any of the heavier than air gases in the detector are released. If a fire or oxygen deficiency occurred, the HVAC can

double airflow and convert to 100% outside air for rapid air replacement. Also, a common vent is designed to collect non-flammable gases such as discharged nitrogen and helium.

3.0 GEM Gas Systems

GEM gas systems—a separate system for each usage requirement—provide gas mixing if needed and flow pressures/regulation to each detector subsystem to meet individual chamber technical specifications. The proposed gases which the systems will use are listed in Table 1-1. Gas systems provide each chamber the required pressure, flow rate, temperature, purity and gas constituent ratios.

Table 1-1 Gases proposed for GEM experiment.

Gas Supplied	Function	GEM Subsystem	Remarks
Nitrogen	Inerting of butane	Tracker	For fire inertion and suppression
Ar, CO_2 & CF_4	Drift	Muon subsys	For CSCs
CO_2 & CF_4	Mixed, drift	Outer tracker	50% each

Gas system design is based on the type of gas specified, flow, storage, recalculation, and other needs of the experiment. Therefore, safety specifications are provided for each system as regulations and standards differ. All systems will be electrostatically grounded and be constructed using materials and parts which provide a design safety factor.

To minimize ODH and other environmental concerns, gas bulk storage will be above ground and supply is routed through the utility shaft. The supply and return piping network will join the gas mixing, storage, analyzer, pressurization and control systems. Specification compliant lines and connectors will be used at the interface between the utilities and the GEM. Safety specific features are being incorporated in designs. Monitoring mechanisms will interface with the overall detection and control system.

4.0 Electrical Systems

There are 3 isolated power feeders from the substation for the GEM IR5 site. One of these feeders supplies clean power to the operation center, electronics rooms in the shaft and electronics in the experimental hall. Clean power will be provided from step-down transformers located above ground. Power is routed to four 208/120V isolation transformers to electronics rooms. In turn, power in each electronics room will be distributed to the individual equipment rack. Each rack will be further isolated with a rack-mount isolation transformer. Experimental hall/detector power is rated at 208/120V and will be provided by one isolation transformer for each GEM experiment subsystem.

Conventional electrical systems for power, lighting, convenience receptacles are not discussed herein as the ES&H issues are covered by EFD and comply with codes.

Electrical work, systems and equipment will be designed and installed in compliance with governing electric, fire and safety codes and will conform to applicable industry standards.

5.0 Cryogenic Systems

The cryogenic system for GEM consists of five subsystems as described:

- LKr Subsystem. The LKr subsystem functions as the ionizing medium in the barrel calorimeter. It consists of storage containers, transfer lines, temperature conditioning equipment, and safety devices required to maintain the krypton in its environmental stable condition. Additionally, this supply has a purification unit since the subsystem is closed loop.

- LAr Subsystem. The LAr subsystem function as the ionizing medium in the endcap calorimeters consists of storage containers, transfer lines, temperature conditioning equipment, and safety devices required to maintain the argon in the proper condition.

- Two LN_2 Subsystems. One complex serves the purposes of cooling the calorimeter barrel and endcaps and condensing and controlling the temperature of the argon and the krypton. The other supply is used to cool both the radiation shield in the superconducting coil cryostat and the helium refrigerator/liquefier. Both supplies contain storage, valves, lines and safety devices to eliminate or reduce hazards.

- LHe Subsystem: The He refrigerator/liquefier cryogenic system is used to support both the superconducting magnet and visible light photon counters within the detector. The LHe flow rate to the solenoid is 90 g/s. High and low pressure gaseous helium storage tanks and liquid helium storage dewars are located and in the hall.

The vent line for the vapors of these systems will be piped directly to the common vent system. Bulk storage for nitrogen and argon will be above ground. Krypton will be stored in the hall. Helium storage options are still being investigated.

The cryogenic subsystem will be designed in accordance with ASME pressure vessels codes. Pressure relief valves, filters, control panel monitoring and operational system procedures will be required. System tests and acceptance will be performed prior to operation. ODH monitoring will be in the hall and facilities that contain the cryogenic systems. ODH monitoring will be tied to the safety control system and GCS.

6.0 Vacuum System

There are two vacuum subsystems required to support the calorimeter. One provides vacuum to evacuate the insulating spaces around the cryostat and the insulating spaces in the cryogen transfer lines. The other provides vacuum to evacuate the interior of the cryostat prior to filling with argon or krypton.

- Insulating Vacuum Subsystem. A separate insulating vacuum systems for each cryostat will be used.

- Calorimeter Vacuum and Purge Subsystem. The pump and purge system to be installed to evacuate the modules has much more rigorous requirements on its performance than the insulating vacuum system. Purity of the noble liquid and no back streaming of oil are the concerns in this instance. High quality mechanical pumps with in line filtration to reduce oil back streaming and particulate back flow will be used.