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SSC DETECTOR SOLENOID DESIGN NOTE #175

TITLE: Conceptual Safety Analysis Report (CSAR) for the SDC Superconducting Solenoid - First Draft

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SUMMARY: This design note contains the guidelines for preparing the CSAR, the preliminary hazard list, the first draft of the text portion of the CSAR, and the first draft of the conceptual safety analysis forms.

Please forward your comments on the solenoid CSAR to Ron or Andy.

PHYSICS RESEARCH
ES&H ENGINEERING

SSC LABORATORY

Physics Research Division

Hazard Analysis Process Guidance

For Preperation of

Conceptual Safety Analysis Report

(CSAR)

R F Lavelle

Physics Research Division

Conceptual Safety Analysis Procedure

1.0 PURPOSE

The purpose of this practice is to establish a uniform process for conducting hazard analyses and risk assessments of technical system designs and operations. This document is intended to assist design engineers and system safety engineers when they are evaluating the adequacy of design safety and operational safety. One of the first steps of the hazard analysis process is to conduct a detailed hazard analysis of all segments of system/subsystem designs and operations. Hazard analyses should facilitate early identification of hazards, not routinely encountered by the public, for their prevention, elimination and control. Risk assessment and mitigation actions are dependent upon a thorough hazard analysis and safety review process. The hazard analysis process documents specific hazards, risks and mitigation actions (planned or implemented) to prevent or eliminate hazards. Any unacceptable residual hazards, which may require corrective or mitigation action, shall also be identified and documented for hazard tracking and risk resolution. Detailed hazard analyses are required prior to preparing a Safety Analysis Reports (SAR).

2.0 SCOPE

Department of Energy (DOE) Order 5481.1B Safety Analysis and Review System specifies safety analysis and hazard prevention, elimination, and control requirements. Hazards which can cause death, injury, or occupational illness, or damage to facilities, systems, subsystems or equipment shall be identified. Risks shall be assessed, and mitigation actions shall be taken to reduce hazards to acceptable risk levels. The hazard analysis addresses the adequacy of the preventive or mitigative design features and administrative controls provided to limit the probability of adverse occurrence or the severity of a hazard. The precedence of corrective actions to resolve risk include, but are not limited to:

1) Design safety features
2) Safety and warning devices
3) Safety procedures
4) Safety training
5) Safety equipment
6) Development of administrative controls or restrictions to prevent injury to personnel and damage to equipment.

3.0 DEFINITIONS

Accident - A mistake, error, unusual occurrence or event having safety implications, or leading to an unsafe condition or event. (see Mishap)

Effect on System - The detrimental effects inflicted on the system or personnel.

Effects of Recommended Action - The effects of the action in lowering risk.

Hazard - Any existing or potential condition that can result in a mishap or accident.

Hazard Description - A brief description of the hazard and cause.

Hazard Severity - A qualitative assessment of the worst potential consequence, defined by the degree of injury, occupational illness, property damage, and/or equipment damage/effects.

Hazard Probability - The likelihood that a hazard will occur.

Hazard Tracking and Risk Resolution System - A method of ensuring severe hazards/risks are documented, tracked, communicated and resolved in a timely manner.

Mishap - An unplanned event or series of events that result in death, injury, occupational illness, or damage to or loss of equipment or property. (see "accident")

Preliminary Safety Analysis Report (PSAR) - Documentation of Safety Analysis started during the concept exploration and design planning phases or earliest life cycle phase of the program so that safety considerations are included in tradeoff studies and design alternatives.

Recommended Action - The action required to eliminate or control the hazard.

Remarks - Any relevant comments relating to the hazard.

Risk - A quantitative or qualitative expression of possible loss in terms of hazard severity and hazard probability that a hazard will cause harm and the consequences of that event.

Risk Assessment - An evaluation of the hazard severity and probability and the determination of acceptability/unacceptability based upon mitigation actions to reduce risks.

Risk Zone - A classification of low, medium or high risk: 1 is high and unacceptable; 2 requires management evaluation, decisions, approval; 3 is low and is acceptable risk)

Safety Analysis Report (SAR) - A comprehensive safety assessment. A documented process to systematically identify systems and operational hazards, to describe and analyze the adequacy of the measures taken to eliminate, control, or mitigate identified hazards, and evaluate potential mishaps and their associated risks. SARs identify hazards, assess risks and means for their elimination and control, and document the approval for various stages of facility design, construction and operation.

Status - Status of actions to implement the recommended, or other, hazard controls.

System Safety - The systematic application of proven engineering and management processes to optimize safety within the constraints of operational effectiveness, time, and cost throughout all phases on the system life cycle.

System Safety Engineering - An engineering and management discipline requiring specialized professional knowledge and skills in planning, implementing and applying scientific and engineering principles, criteria, and techniques to identify and eliminate hazards, or reduce the risk associated with hazards.

System Event(s) Phase - Phase of operation (maintenance, testing, beam on, all, *etc.*).

System/Subsystem/Unit - The particular part of the system that is analyzed.

4.0 PRACTICE

4.1 Hazard Analysis Requirements

Safety analysis and review requirements are presented in DOE Order 5481.1B. Prior to preparation of the SAR, a comprehensive safety hazard analysis shall be conducted and included as a major integral part of the SAR. The hazard analysis shall be initiated during the earliest phases of the life cycle of the operation to facilitate early hazard identification, elimination or control. It shall be conducted and provided by the line organization with immediate operating responsibility — with assistance from the PRD Divisional Environmental, Safety, and Health (ES&H) Department and the System Safety Engineering Group.

4.2 Hazard Analysis Criteria and Guidelines

When evaluating hazards and determining adequate mitigation action, safety design and operational requirements should be investigated by the design engineer. The following guidelines will assist the design engineer in establishing the order of precedence for satisfying system safety requirements and resolving identified hazards.

1) **Design for Minimum Risk.** From the first, design to eliminate hazards. If a hazard cannot be prevented or an identified hazard cannot be eliminated, reduce the associated risk to an acceptable level (as defined by DOE Orders).
2) **Incorporate Safety Systems and Safety Devices.** If the design cannot reduce risk to an acceptable level, provide the use of inherent safety systems and/or fixed, automatic protective safety design features or devices. Testability provisions shall be made for periodic functional checks of safety devices and safety systems when applicable.

3) **Provide Warning Devices.** When neither design, safety systems or safety devices can effectively eliminate identified hazards or adequately reduce associated risk, devices shall be designed and used to detect the condition and to produce an adequate warning signal to alert personnel of the hazard. Human factors considerations shall be included in the design schemes to prevent confusion and human errors. Warning signals and their application shall be designed to minimize the probability of incorrect personnel reactions to the signals, alarms, cues, or other methods which shall be standardized between the different types of systems, whenever possible..

4) **Develop Safety Procedures and Safety Training.** Where it is impractical to eliminate hazards through design selection or adequately reduce the associated risk with safety and warning devices, procedures and training shall be used. Considerations for training and procedures shall be validated and verified by working groups and safety committees. To provide inadequate training or to write procedures which are not followed or enforced will have negative results. Training must be thorough. Procedures must have a step-by-step checklist with the applicable precautions, warnings, and notes on operating limitation and emergency procedures. Procedures are to be clear and must be task-oriented. Procedures may include the use of personnel protective equipment. Special Safety procedures shall be written. Both technical and safety training shall be provided to cover all tasks which have been determined to be potentially catastrophic or critical. Tasks and activities judged to be critical by DOE or PRD ES&H Management may require certification of personnel proficiency.

The following is provided to assist the engineer responsible for conducting hazard analysis of technical systems designs and operations. Some general system safety design criteria, requirements, and guidelines are:

1) Eliminate identified hazards or reduce associated risk through design, including material selection or substitution. When potentially hazardous materials must be used, select those with the least risk throughout the life cycle of the system.
2) Isolate hazardous substances, components, and operations from other activities, areas, personnel, and incompatible materials.
3) Locate equipment so that access during operations, servicing, maintenance, repair, or adjustment minimizes personnel exposure to hazards.
4) Minimize risk resulting from excessive environmental conditions (*e.g.*, ODH, radiation, high electrical voltage/current, energy sources, hazardous chemicals, toxic substances, temperature, pressure, noise, cutting edges,sharp points and falling objects)
5) Design to minimize risk created by human error in operation and support of the system. Ensure human factors, human-machine interface, and ergonomic designs are included to minimize equipment damage and injury to personnel.
6) Consider alternate approaches to minimize risk from hazards that cannot be eliminated. Such approaches include safety interlocks, redundancy, fail-safe design, system protection, fire suppression, protective devices, monitors, and alarms.

7) Protect the power sources of controls and critical components of systems and subsystems. Designs for disabling energy sources shall be provided and tested. This includes OSHA lockout and tagout provisions.
8) Design software controlled or monitored functions to minimize inadvertent initiation of hazardous events or mishaps.
9) If residual hazards still exist or alternate designs cannot eliminate the hazard, provide warning and caution notes in assembly, operations, maintenance, and servicing instructions. Where applicable place distinctive placarded warnings or distinctive markings on hazardous components, materials, equipment, and facilities to ensure personnel and equipment protection. Develop detailed safety procedures and ensure they are validated and verified.
10) Review design criteria for inadequate or potentially overly restrictive requirements regarding safety. (Ensure conformance to safety requirements)
11) Scenarios for safety-critical hardware should be incorporated into software logic (much easier, cheaper and more reliable than hardware safeguards).
12) Software-controlled functional sequences affecting system safety should require a minimum of two independent procedures for initiation.

When establishing design safety requirements, the potential for human error shall be considered. Human Factors Engineering designs shall provide work environments which foster personnel safety and health, and reduce the potential for human error. The designs of facilities and technical systems requiring human operational interface shall reflect human engineering, life support, and biomedical factors affecting human performance, including when applicable:

1) Satisfactory ambient atmospheric conditions, ventilation, pressure, temperature and humidity that will include safeguards against uncontrolled variations beyond acceptable limits.
2) Acoustic noise, vibration, impact shock, and visual safeguards against uncontrolled variations beyond safe limits.
3) Protection against thermal, toxicological, chemical, radiological, mechanical, electrical, electromagnetic, oxygen depleting, and other man-machine interface hazards.
4) Adequate space for personnel and their equipment to safely perform operation and maintenance tasks with little difficulty.
5) Adequate physical, visual, auditory, and other communication link between personnel, and personnel and their equipment, under both normal and emergency conditions.
6) Efficient arrangement of operation and workspace equipment, controls, and displays. Operator controls and procedures should not be confusing. User friendly designs, color coding (Red —Warning, Yellow —Caution, and Green — Advisory), and logical arrangements are encouraged to eliminate confusion and misinterpretation, and to minimize the always-present potential for human error.
7) Provisions for personnel safety in confined spaces, hazardous spaces, large uncontrolled spaces, or other hazardous areas. Provisions may include a personnel access safety system, egress system, evacuation system, including life safety code requirements, safe and adequate passageways, hatches, ladders, stairways, platforms, elevators, or other provisions for ingress, egress, passage, niches, protective shelter, barriers, or other "safe spaces" for humans under normal, adverse, and emergency conditions.

8) Adequate emergency systems designed to alert or warn personnel of hazardous or dangerous conditions. Design systems which provide warnings or caution cues that are easily distinguished from the normal or routine communication systems.

9) Provide adequate placarded warning systems, signs, labels, restrictions, safety notes, and directions etc. which are universally and easily understood by all operator and maintenance personnel. In cases that warrant, redundant bilingual signs or procedures (DANGER HIGH VOLTAGE, ACTUNG HOCKSPANNUG, ATTENTION! HAUTE TENSION) or international placards may be required.

10) During safety training courses, human error considerations, "Murphy's Law" precautions and other possible ways of preventing accidents should be presented and discussed with trainees.

4.3 DOE Design Safety Criteria for Risk Reduction

First, second, and third priority DOE Orders addressing ES&H topics that are applicable to SSC Maintenance and Operation contract, will be used for safety applications. Several of the first priority orders are applicable to System Safety. Aspects of other DOE order are also applicable to the SSC contract, such as applicable safety sections of DOE Order 6430.1A (General Design Criteria). When determining design safety criteria and requirements, the cognizant engineer will use these and other required safety documents and engineering standards.

Many design standards and guidelines, such as applicable sections of ANSI, IEEE and ASME codes for a broad variety of equipment and systems design, will have safety related criteria that will be evaluated as required to determine applicability to the PRD designs. From a System Safety perspective, many industrial codes and standards are acceptable design criteria. Some may not be directly applicable or suited to the specific technology of the PRD Division. These will be evaluated on a case-by-case basis to determine if the design criteria is applicable, and if so, will the criteria be considered as requirements or as flexible guidelines in applicable areas of safety technology. Use of many specific engineering standards and commercial codes outside of DOE may help ensure that best engineering practices and safety design practices are followed.

4.4 Risk Assessment

The Risks Assessment Matrix, Appendix B, is provided to assist in the hazard analysis process. It is designed in accordance with DOE 5481.1B, which authorizes the use of MIL-STD-882B. It is to be used to classify hazards by severity, frequency of occurrence, risk levels of acceptability or unacceptability. This matrix is to be used by the engineer when analyzing and assessing the risk of each identified hazard. The risk of each specific hazard must clearly be documented. Hazards which fall in the medium to high level of risk must be reduced to a low level of risk. The SAR must clearly show the corrective action taken to reduce risk to acceptable levels. In no cases shall unacceptable risks be permitted. Should there be a dispute as to the acceptability of risk, a course of action will be determined by the appropriate Laboratory ES&H Official and Division Associate Director.

4.5 Hazard Analysis Forms and Instructions

Appendix A shows the Hazard Analysis form, which will be used to document specific hazards, effects, risks, safety features, mitigation actions, recommended actions, etc. The following instructions, and the sample forms shown in Appendix C, are provided to assist the cognizant engineer while analyzing system designs and operations for hazards:

1) **SYSTEM/SUBSYSTEM/UNIT.** Enter the part of the system that this analysis is concerned with, *e.g.*, Cryogenic Control Valve #12, HV Power Supply #4, Pulse Generator, Switch.
2) **OPERATIONAL PHASE.** Enter the phase of operation (maintenance, testing, data operations, all phases, *etc.*)
3) **HAZARD DESCRIPTION.** Enter a description of the hazard and cause, *e.g.*, Radiation leakage from LINAC, Power Supply #2 failure, shorted wire, thermo-accoustical oscillation and failure, failure to provide lockout/tagout provisions, corroded electrical contact.
4) **RISK ASSESSMENT PRIOR TO ABATEMENT.** Enter qualitative or quantitative risk for each hazard. The classification of hazard severity and the probability of occurrence, such as II/C (Critical/Occasional), Risk 2-Medium can be obtained from the risk assessment matrix (Appendix B).
7) **RECOMMENDED ACTION.** Enter the cost effective corrective action required to eliminate, control, or mitigate the hazard. Sufficient technical detail is required. Include alternate designs/cost impact where appropriate. Actions can include, but are not limited to, design safety features, safeguards and redundancies, incorporate safety devices, warning/alert devices, safety procedures and precautions, training, safety equipment, safety note, restrictions, and administrative controls.
8) **RISK ASSESSMENT AFTER ABATEMENT.** Enter the effect of the recommended action on the assigned risk assessment. Show hazard/risk reduction to acceptable level, *i.e.*, II/C to II/E or III/C. If actions will result in cost, schedule, and/or performance penalties, then these considerations shall be addressed.
9) **REMARKS.** Enter any information relating to the hazard not covered in other blocks, for example, applicable documents, previous failure data, such as Failure Mode Effects and Criticality Analysis (FMECA) on similar systems, or administrative direction, such as Safety Manuals, OSHA, Design Criteria, DOE Orders, requirements, standards and guidelines.

5.0 RESPONSIBILITIES

The SSC Laboratory ES&H Manual clearly spells out the safety policy of the Laboratory Director and the safety responsibility of Supervisors. The Associate Director of each division is responsible for the design safety of systems (hardware, software, personnel, procedures). The ES&H Oversight Office is responsible for ensuring compliance with DOE requirements. The ES&H System Safety Group is responsible for coordinating the safety hazard analysis and review effort and assisting in the development of methodologies and techniques required for development of the SAR.

6.0 REFERENCES

DOE Order 5481.1B	Safety Analysis and Review System
DOD MIL-STD-882B	System Safety Program Requirement

7.0 RECORDS

7.1 Work in Progress

Completed Hazard Analysis documentation, developed by line division personnel performing the analysis, will be returned to the ES & H System Safety Engineering Group. The ES & H system safety group will maintain a file of all identified hazards, which may be attached or reformatted for inclusion in the Safety Analysis Report (SAR). The SAR will be submitted as an official safety document to DOE.

7.2 Approved Documents

Documents that have been approved for use at the Laboratory will be stored in Centralized Document Control. The release records and status of these documents will reside in the Document Control System.

8.0 ATTACHMENTS

Appendix A — Blank Hazard Analysis Form (make copies of and use)
Appendix B — Risk Assessment Matrix
Appendix C — Preliminary Hazard List

SDC Detector • Conceptual Safety Assessment Form • SSCL Physics Research Division

Subsystem and Location	Date _____ Rev _____ Attachments YES NO

Operational Phase

Hazard Description

Risk Assessment Prior to any Abatement Strategy

Current Recommended Action

Risk Assessment After Implementation of Recommended Action

Remarks

APPENDIX B. RISK ASSESSMENT MATRIX

	A Frequent	B Probable	C Occasional	D Remote	E Improbable	F Impossible
1 Catastrophic						
2 Critical						
3 Marginal						
4 Negligible						

Severity of Consequences

	Descriptive Word	Personal Illness/ Injury	Equipment Loss(s)	Test Unit Downtime	Data Compromise	Environmental Effect
1	Catastrophic	Death	>500K	> 4 months	Data never recoverable or primary program objectives lost	Long-Term (5yrs 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 to 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 mimor 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 or illness	< 1 K	< 1day	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

Probability of Mishap

Level	Descriptive Word	Definition
A	Frequent	Likely to occur repeatedly during life cycle of syst.
B	Probable	Likely to occur several times in life cycle of syst.
C	Occasional	Likely to occur sometime in life of system.
D	Remote	Not likely to occur in life cycle of system.
E	Improbable	Possi. of occurance cannot be distinguished from 0.
F	Impossible	Physically impossible to occur

Risk Zones

Code		Action
1	High	Imperative to suppress risk to lower level
2	Med	Operation requires written, time-lt waiver endorsed by Mgmt
3	Low	Operation permissible

Note: PERSONNEL must not be exposed to hazards in Risk Zones 1 and 2

* Adapted from MIL-STD-882B

APPENDIX C. PRELIMINARY HAZARD LIST

The following is a limited list of potential hazards that may be encountered within the PRD particle detectors. The list is intended for "mind jogging" purposes only as a start of a hazard analysis. Some systems may have hazards not listed in that appendix.

D.1 Oxygen Deficiency Hazards (and similar air hazards)

Cryogenic spills displacing/depleting oxygen
Liquid Nitrogen Leak
Liquid Helium Leak
liquid Argon leak
Leak of gaseous Argon or other detector gases at IR region
Methane leakage through tunnel walls
Fire, smoldering, smoke from combustible products
Electrical insulation fire and smoke
Failure of ventilation equipment - loss of fresh air supply
Chemicals - asphyxiant, air is contaminated or displaced
Failure of ODH monitor
Other similar hazards such as Carbon Monoxide
Leak of supplied gas in laboratory spaces
Diesel engine fumes in MAAS

D.2 Fire Hazards

Electrical
Solvents and combustible materials
Unauthorized materials, chemicals
Improper storage of flammable materials
Leakage and lack of spill containment
Unauthorized smoking
Improper housekeeping
Carelessness or lack of adequate safety practices in laboratory
Failure to recognize fire hazard
Spark producing tools around combustibles
Chemical reactions
Spontaneous Combustion
Explosion
Lightning or other natural occurrence
Welding
Equipment failure such as compressor seize causing friction
Support equipment failure
Electrical carts - motors and battery pact
Human Errors
Burns and secondary effects
Carbon monoxide, smoke and human injury
Malfunctioning smoke detectors
Malfunctioning sprinkler system

Inadequate fire detection/suppression system
Failure to properly inspect and detect discrepancies
Failure to prevent, eliminate or control potential fire hazards
Large quantities of flammable liquids and gases in detector areas
Smoke contamination of breathable air
Vaporization of flammable liquids upon heating

D.3 Electrical Hazards

Inadequate design or human error leading to shock or electrocution
Electrical shock or body burns
Lack of personnel clearance around electrical equipment
Lack of adequate grounding and leakage current
Breaking of grounds by excavation
Burning off grounds by short circuits
Stray voltage
Quench and damaging effects
Faulty or malfunctioning equipment
Failure to follow procedures
Overloads
Shorts
Low voltage/low current signal wires short which don't trip CB
Circuit contamination, metallic or moisture
Electrical faults producing noxious fumes or ozone
Lack of main power emergency shutoff design
115v disrespect
Lack of clearly labeling pertaining to high voltage or current loads
High voltage
Extremely high current and power
Remote operation/control of equipment
Failure to properly de-energize or tag and lockout
Failure to use physical barriers and warning signs to alert personnel
Failure to use insulating gloves or protective gear or equipment
Unauthorized use
Defeating interlocks or protective barriers
Failure to inspect and verify safeguard operation
Unqualified personnel
Working alone with electrical circuits
Wrong components or maintenance errors
Wrong polarity hookup, i.e., electrolytic capacitors or wiring
Inadequate insulation
Inadequate repairs, modifications
Lack of proper inspections
Failure to positively de-energize circuits
Failure to follow written procedures/violation of safety rules
Mis-wiring and other human errors
Frayed, damaged or worn electrical cords, cables or wiring
Failure of emergency lighting to energize during power outage
Loss of Emergency Warning Systems power
Loss of Safety Interlock System power
Failure of hazard detectors and warning device circuits

Failure of power supplies
Charged capacitor shock hazard - after power has been removed
Hazards associated with various type capacitors and configurations

Rupture of capacitor (combustible dielectric materials) and fire
Inadequate/improper grounding or lack of grounding hooks
Inadequate fuse protection
Dense packing in cable trays and potential overheat hazards
Chaffing wire bundles/shorts from insulation deterioration
Insulation damage from corrosion, reactions, heat, radiation, etc.
Cable tray damage
Improperly keyed connectors - not murphy proof
RF, microwave, electromagnetic leakage
Inductor, electromagnets and coil hazards - such as induced voltage
Inadequate electronic cooling scheme - damage to equipment
Inadequate radiation shielding
Inadequate surge protectors, isolators or buffer schemes/devices
"Sneak" circuits
Electromagnetic Interference and magnetic field hazards
Electromagnetic radiation hazards
Personnel with bioelectronic implants - EM exposure hazards
Poor human factors design (such as inadequate space) hazards
Potential fire ant damage
Improper grounding and bonding design (grounding points/hooks)
Failure to follow proper procedures
Lack of guards, shields or placarded warnings, or inadequate barriers
Inadequate design - violation of NEC or other applicable codes
Lightning charge
Moisture in equipment or in vicinity - shock/equipment damage
Battery hazards - acid, corrosion, burns, explosion
Lack of alarms, signals, lights, placards and warnings
Maintenance/test personnel wearing metal objects or jewelry
Failures of electrical safeguards, back-up devices or interlocks
Using inadequate lock-and-tag procedures before maintenance
Failure to strictly abide by lockout/tagout - 29 CFR 1910.147
Failure to design to appropriate code (NEC, ANSI, IEEE, ISA, NFPA)

D.4 Radiation Hazards

Presence of ionizing radiation
Inadequate shielding
Exposure beyond ALARA
Residual exposure - particularly in ACC beam transfer areas
Handling of materials
Inadequate barriers
Accidental misalignment or misdirection of beam
Spill of radioactive liquid or release of radioactive gas
Failure to wear monitor in required spaces
Radon and other sources escaping into tunnel
Improper labeling, storage and handling
Failure to recognize radiation hazards

Failure to know time, distance and shielding
Failure to abide by safe procedures and protection
Depleted uranium for calorimetry
Contamination spread
Improper or inadequate training
Potential for creating mixed waste

D.5 Materials Handling Hazards

Magnet damage during transport/handling
Cranes, hoists, slings, guides - lack of integrity
Lack of protective safeguards
Lack of training on procedures
Ignorance or intentional shortcuts
Violating proper handling procedures
Chemical spills
Improper procedures
Improper containers and secondary containment
Lifting objects
Falling objects, projectiles, missiles
Moving objects
Hazardous tools, equipment and machinery
Hazards - lifts, cranes, hoists, slings, lifting fixtures and equipment
Elevator hazards associated with unsecured or too heavy load
Transportation
Cryogenics dewars, valves, controls and handling procedures
Use of toxic Beryllium for vacuum vessels
Improper use of vehicles and facilities for transport/storage
Excess quantities and logistics hazards
Use of elevators for transporting hazardous materials
Violation of OSHA and laws
Environmental issues
Storage of lead, mercury and other toxic materials
Materials logistics (Transport, storage, transfer, control, use)
Argon logistics
Helium logistics
Nitrogen logistics
Flammable materials logistics
Inadequate response equipment

D.6 Hazardous Machinery/Crane Hazards

Human error
Powerline contact
Overloading
Outrigger failure (soft ground and structural)
Two-Blocking
Pinchpoint
Unguarded moving parts
Unsafe hooks

Obstruction of Vision
Sheave-caused cable damage
Cable kinking
Side pull
Boom buckling (from striking objects)
Access to cab, bridges, and/or runways
Control confusion (nonuniform location
Turntable Failure
Removeable or extendable counterweight systems
Travel Upset
Two-wheel/Four-wheel steer

Loss of stowed jib boom
Boom toppling over
Boom disassembly
Boom toppling over
Inadvertent loss of load
Conductive cable for a remote control
Unsafe walkway
Exposed electrical trolley
Absence of lockout systems during repairs
Inadequate stops
Poor operator vision
Load loss
Elevating tower cranes
Footing failure
Worn, uninspected, defective, rejected or wrong hardware
Failure to plan for effective crane safety
Operator and/or crew unaware of obvious/impending hazards
Human factors associated with crane operator performance
Complacency

D.7 Cryogenics Related Hazards

Oxygen Deficiency Hazards to personnel
Lack of training, knowledge and understanding
Frostbite and skin injury - vision impairment due to vapor (fog)
Bodily burns upon contact with liquid
Facial, eyes and lung damage
Improper handling, transport or storage of dewars
Safety violations in small laboratories
Improper procedures and precautions
Lack of protective equipment when handling
Failure to carry ODH monitor in required areas
ODH monitor failures/improper or lack of verification checks
ODH monitor battery is dead or cell is dead
Lack of adequate ventilation/poor ventilation design

D.8 Flooding Hazards

Water leakage through walls
Water from surface
Water from flood
Water from pipe rupture or leak
Construction in flood plain

D.9 Other Personnel Hazards

Traffic hazards
Trapped - difficult egress
Lack of adequate lighting
Falls from equipment
Potential for falls down ventilation shaft
Slips on wet surfaces or floors

Slip/fall on ladders, stairs and other access equipment
Lack of non-skid at needed surface locations
Collision with fixed or moving objects (vehicles)
Open shafts
Confined spaces
Head injury/lack of protective equipment for tasks
Eye injury/lack of protective shields and equipment for tasks
Failure to wear safety glasses or Laser glasses for tasks
Ear injury/lack of protective equipment for tasks or from noise
Foot/toe injury/lack of protective equipment for tasks
Hand injury/lack of protective equipment for mechanical tasks
Electrical shock injury/lack of protective equipment for tasks
Back injury/lack of lifting equipment or safe lifting procedures
Worn, untested or uncalibrated tools and equipment
Misuse of hoist, slings, chains, ropes and unsafe lifting devices
Blockage of passageways and exits
Improperly designed passageways and exits
Improper storage of equipment, solvents, chemicals or parts
Lack of good housekeeping
Violation of standard safety rules
Rattlesnakes in construction areas

D.10 Other Mechanical Hazards

Stairs, catwalks, handrails, ledges, elevators
Machinery and rotating parts
Pressurized tanks, containers and Lines
Elevators - Many potential personnel hazards (See Elevator World)
Moving vehicles - carts, forklifts
Sharp edges
Hot surfaces, flames and potential explosives
Welding - Lack of proper procedures and safeguards
Welding/Brazing - eye and skin burns, fumes and combustion

Materials grinding, cutting, drilling, fabrication/construction
Lack of training or precautions when using portable hand tools
Special hand tool hazards - power driven nail guns, axes, picks, etc.
Weapons

D.11 Chemical and Environmental Pollutant Hazards

Acids, chemicals, solvents, toxic agents and hazardous liquids
Heavy metals - such as lead
Non-confined radioactive materials
Improper handling, storage, packaging, transport and disposal
Improper waste management
Lack of proper labeling
Spills
Releases
Lack of containment
Chemical reactions
Toxicity
Reactivity
Corrositivity
Failure to know hazards and mitigation factors
Failure to protect self/others when using hazardous materials
Failure to inspect, inventory and control
Failure to have hazardous materials data sheet on file
Failure to use proper precautions
Failure to recognize health hazards
Improper use of pesticides
Improper or inadequate ventilation
Application of coatings with inadequate ventilation
Lack of respiratory protective equipment
Toxicity in smoke or fumes of materials
Skin, eyes and mucous membrane hazardous reactions
Severe injury, occupational illness or death to personnel
Ignition
Spontaneous combustion or autoignition sources
Fire
Deflagration
Detonation
Lack of personnel protective clothing, face shields/safety devices
Transfer of vapors to other areas via ventilation system

D.12 Construction Hazards

Heavy equipment hazards (more than you can shake a stick at)
Local community impact hazards
Earth cave in/collapse during construction
Failure to constrain earth by pilings and tiebacks near crews
Heavy rainfall flooding during excavation
Natural groundwater bursts and flooding
Dewatering hazard

Transportation and logistics hazards
Materials handling
possibility of hitting gas, electrical, utility lines
Tunnel egress
Environmental construction hazards - air pollution, water pollution

D.13 Accelerator/Magnet Hazards (Potential Equipment Damage)

3 g to magnet during handling causes severe (costly) damage
Resistivity changes state/increases during operation
Quench and ramifications
Short circuit to ground
Heater to coil short due to insulation breakdown
Improper construction/fabrication of magnet
Charred insulation
Shorted turns
Impurities and contamination in Kapton insulation
Insulation flowing at room temperature
Thermal expansion/contraction wear
Insufficient electrical insulation for shielding radiation
Insulation damaged or deteriorated
Rubbing of insulation during pulsing (ramping of magnets)
Overpressure
Cryostat rupture due to quench
Cryostat leak due to poor quality
Exterior vacuum vessel rupture damage and cryogenic leak
Max Quench damage to system

D.14 Vacuum Vessel/Cryostat Structural Hazards

Improper loads
Inadequate structural supports
Broken suspension and mounting hardware
Flaws in connecting ring
Poor quality welds at joints may cause leaks
Mounting/structural post wear
Mounting strength weakened to to stress and loads
Structural and mounting hardware out of tolerance
Thermal cycling weakening structural integrity
Structural loads and stresses weakening structural integrity
Anchor saddle assembly premature wear or out of tolerance
Tie bar stresses, loads and wear
Crack in vacuum vessel
Valve failure
Valve stuck open
Valve stuck closed
Vacuum service port leaking
Vacuum service port contaminated or plugged
Cold pipe(s) clogged or inadequate liquid helium or liq. nitrogen flow
Cracked stainless steel pipe/liquid leak

Cracked aluminium pipe/gaseous leak
Gaseous helium or nitrogen - pipe clogged and restricted flow
Fluid leaks in cryostat
80K or 20k shield is cracked or improperly installed
80K or 20 blanket insulation deteriorate/heat-up and quench
Cold mass blanket torn, contaminated and poor insulation
Cryostat fiducial/o... of tolerance and resultant damage
Half shell cracked or out of tolerance
Yoke lamination material flaw
Yoke is misaligned and loads lead to quench
End yoke and lamination binding
End yoke and main coil lead interference
End yoke quality/material flaws and potential for quench
End plate structural defects/poor welds
Pressure relief (rupture disk) failure
Improper re-seat of valves
High pressure elliptical end structural defects and quench
Bus bar assembly resistance increase and quench
Bus bar electrically shorts to yoke lamination and quench
Bus bar open - no electrical power
Breakdown of Kapton insulation or poor insulation of bus leads
Bus lead shorts to cold mass and short to ground damage/quench
Beam tube crack, contamination, vacuum leak
Beam tube contaminated, plugged, blocked -FOD
Beam tube damaged, improperly installed/aligned
Beam collides with beam tube - burn through and quench
Beam tube - sliding RF joint malfunctions/degradations
Bumper strip structural or insulation flaws
Superconducting cable heat, hot spots, shorts and quench
Superconducting cable insulation breakdown, coil short and quench
Superconducting cable has a short to ground/cryostat and quench
Superconducting cable damage, open strands
Superconducting cable heat quench/secondary damage to equipment
Kapton insulation, coil turns short and quench
Improper wrapping of insulation (quality) and quench
Quench heater resistance change and quench
Warm up heater - unregulated temperature
Collar lamination - manufacturing or material flaws
Collar lamination - assembly errors, material tolerance change
Pole tab shims out of tolerance
Collaring shoes out of tolerance
Collar keys out of tolerance or shears
Collet body - insufficient support of coil
Collet sleeve - insufficient support of coil
Voltage tap - shorts or opens
Coil ramp splices - poor continuity or open splice
Cold mass Fudicial - improper alignment
Beam tube bellows - crack, wear and vacuum leak
Differential bellows - crack, wear and liquid helium leak
Liquid helium cold mass lead bellow pipe failures and quench
20k bellows pipes and return bellows failures and quench
80k bellows pipes and return bellows failures and quench

Thermal insulation failures, malfunctions and quality factors
Primary electrical connection failures
Radiation hazards
High current hazards

From: FNAL::FAST 18-FEB-1992 16:04:47.38
To: STEFANIK
CC: FAST
Subj: for you

PRELIMINARY HAZARD LIST--SDC SOLENOID

R.W. Fast, Jan 24, 1992

1. Superconductor
   - 1.1 Breaks in SC strands
   - 1.2 Poor bond between SC and Al
   - 1.3 Poor quality SC--short sample too low
   - 1.4 Current or field margin too low at operating current
   - 1.5 RRR too low
   - 1.6 Yield strength too low
   - 1.7 Inadequate amount of Al
   - 1.8 Inadequate amount of SC

2. Coil Winding
   - 2.1 Insulation damage--turn-to-turn short
   - 2.2 Insulation damage--coil-to-OSC(ground) short
   - 2.3 Insulation damage--coil-to-other ground short
   - 2.4 Radiation damage to insulation--shorts develop later
   - 2.5 Inadequate radial winding preload
   - 2.6 Inadequate axial winding preload
   - 2.7 Improper mixing or curing of epoxy between coil and OSC
   - 2.8 High resistance in conductor splice

3. LHe Cooling Tube on Outer Support Cylinder (OSC)
   - 3.1 Tube spacing on OSC too large
   - 3.2 Inadequate tube routing at ends of OSC
   - 3.3 Tube diameter incorrectly sized for flow required
   - 3.4 Tube wall thickness inadequate for maximum pressure after quench
   - 3.5 Tube material incorrect for fabrication and service
   - 3.6 Improper welding of tube to OSC
   - 3.7 Max quench pressure in tube incorrectly calculated
   - 3.8 Tube has leak into vacuum annulus during assy/test in Japan
   - 3.9 Tube has leak into vacuum annulus after installation in detector hall (DH)
   - 3.10 TAOs in dead headed lines, eg lines to RVs

4. Coil-Cold Mass
   - 4.1 Inadequate or absence of LHe sink on ID
   - 4.2 Inadequate or improperly applied MLI on ID
   - 4.3 Inadequate or improperly applied MLI on OD

5. Thermal Intercepts and Shields
   - 5.1 Thermal short between cold mass and 80-K shields
   - 5.2 Inadequate cooling of shields--shield temperature higher than expected; tube size, routing inadequate
   - 5.3 Failure to break circumferential electrical circuit in shields
   - 5.4 Improperly applied MLI on shield--''black crack''
   - 5.5 Temp of 80-K intercepts higher than expected; inadequate heat

transfer
5.6 Placement of 80-K intercepts on supports incorrect
5.7 Temp of 4.5-K intercepts higher than expected
5.8 Inadequate pressure rating of tubes
5.9 Leak in 80-K circuit--discovered during assy at vendor

5.10 Leak--discovered during test in Japan
5.11 Leak--discovered after installation in detector hall

6. Cold-mass Supports, Radial and Axial
6.1 Off-balance forces inadequately known; poor assumptions in calculations
6.2 Support attachments to OSC(cold) or vac vessel(warm) structurally inadequate; poor welding
6.3 Supports over designed for actual force
6.4 Supports under designed for actual force
6.5 Improper choice of support system materials--metallics
6.6 Improper choice of materials--composites
6.7 Incomplete or erroneous heat load calculation for supports
6.8 Support fails at or below operating current--during test in Japan
6.9 Support fails after installation in detector hall
6.10 Radiation damage to composite support elements

7. Cryostat Vacuum Vessel--Inner Vacuum Shell (IVS)
7.1 Thickness of IVS inconsistent with expected overpressure and desired safety factor on collapse
7.2 Venting area in chimney inadequate for external pressure rating
7.3 Vacuum relief improperly set or sized
7.4 Vacuum leak in IVS--discovered during assy and test in Japan
7.5 Irrepairable leak in IVS--discovered after installation in DH
7.6 Thermal short between IVS and inner thermal shield
7.7 Collapse of IVS following cryogen leak or warm-up
7.8 Poor welding of pieces to form shell

8. Cryostat Vacuum Vessel--Outer Vacuum Shell (OVS)
8.1 Collapse of OVS at operating pressure (vacuum)
8.2 Failure of OVS following cryogen leak
8.3 Vacuum leak in OVS--discovered during assy and test in Japan
8.4 Vacuum leak in OVS--discovered after installation in DH
8.5 Honeycomb or isogrid prove unsatisfactory for OVS
8.6 Poor welding of pieces to form shell

9. Chimney, Service Port, Field Joint
9.1 Electrical short to ground of lead-in bus in chimney
9.2 Electrical short between lead-in bus in chimney
9.3 Inadequate cooling of lead-in bus in chimney
9.4 Inadequate cooling of lead-in bus at bottom of chimney in cryostat
9.5 Inadequate cooling of lead-in bus below LHe pot in service port
9.6 He leak in ceramic electrical feed-thru at bottom of pot in service port
9.7 Al-SS transition couplings on cryogen lines leak
9.8 Thermal short between lead-in bus and thermal shield
9.9 Higher than expected heat load to conductor/He pipe at stand-offs
9.10 Pump/vent space restricted or blocked with MLI--discovered after assy and test in Japan
9.11 Pump/vent space restricted or blocked with MLI--discovered after

installation in DH
9.12 Leak in vacuum jacket pipe, Al-SS joint, or SS bellows--discovered during assy and test in Japan
9.13 Leak in vacuum jacket--discovered after making field joint in DH
9.14 Improperly made-up conductor field joints

9.15 Leak at field joints in He or LIN pipes
9.16 Inadequate allowances for thermal longitudinal contraction of conductor/He pipe in chimney
9.17 Cold He leak in chimney
9.18 Failure of phase separator LHe vessel in service port
9.19 Heat leak of vapor-cooled leads (VCL) higher than expected
9.20 High resistance joint between lead-in bus and VCL, initially or developes later
9.21 Poor solder joint at bottom of VCL
9.22 Pressure drop of VCL for desired flow rate higher than expected
9.23 VCL loses cooling flow at operating current

10. Instrumentation
10.1 Open voltage tap(s)
10.2 Voltage tap causes electrical short from coil to ground
10.3 Redundant voltage tap found to be open when needed
10.4 Inoperable temp sensor in flow circuit
10.5 Inoperable temp sensor on cold mass
10.6 Inoperable temp sensor on thermal shields or intercepts
10.7 Unbelievable reading from temp sensor
10.8 Instrumentation lead-in wires cause 80 to 4.5-K thermal short
10.9 Lead-in wires not adequately heat sunk
10.10 Redundant sensor found inoperable when needed

11. Relief Devices
11.1 He circuit--size inadequate for flow, pressure setting incorrect
11.2 Trapped volume reliefs omitted
11.3 Vacuum vessel--size inadequate, setting inconsistent with actual flow path
11.4 He relief fails to open at set pressure
11.5 Vacuum relief fails to open at set pressure
11.6 Vacuum relief fails to reseat
11.7 He relief fails to reseat

12. Electrical Equipment
12.1 Open DC circuit between coil and Fast Dump Resistor (FDR)
12.2 Power supply runs away in current
12.3 FDR gets hot following quench
12.4 High-resistance joint between copper bus and VCL
12.5 Current sensor on magnet does not read accurately
12.6 Current sensor on magnet fails

13. Discharge and Quench
13.1 Voltage taps circuits open--unbalance voltage not seen at input to quench detector circuit
13.2 Quench detector circuit fails to see unbalance voltage indicating quench
13.3 Other fast discharge detection circuits fail to see signals
13.4 Quench circuit or other fast discharge circuit fails to send signal to Fast Dump Switch (FDS)

13.5 Open control cable, FDS does not receive signal to open
13.6 FDS fails to open on quench signal received
13.7 FDS fails to open on fast discharge signal received
13.8 Temp following quench exceed 100 K, but less than 250 K
13.9 Temp following quench exceeds 250 K

13.10 Voltage across terminals exceeds test hi-pot value on quench
13.11 Room temp bus arcs to ground on quench
13.12 Coil or SC lead-in bus arcs to ground inside cryostat
13.13 Magnet quenches during a fast discharge
13.14 DC circuit fails hi-pot test

14. Operational Hazards not covered elsewhere
14.1 Coil fails to reach design current during test in Japan
14.2 Coil fails to reach design current during first test in DH
14.3 Coil fails to reach design current during subsequent running
14.4 Cryostat developes He leak after running for some time
14.5 Temp sensor readings drift in time
14.6 System heat leak greater than expected/calculated
14.7 Cannot get adequate LHe flow through coil cooling circuit
14.8 Shield/intercept temps higher than expected
14.9 Temp or quality of LHe not to spec
14.10 Temp, quality or flow of LIN/GHe not to spec

15. Oxygen Deficiency Hazards
15.1 Relief devices discharge into DH
15.2 VJ cryogenic liquid line ruptures, followed by VJ failure
15.3 Cryogen line in cryostat ruptures, failure or large leak in vac vessel
15.4 Active He or LIN U-tube pulled
15.5 Non-VJ GHe or GN line ruptures or has large leak

7.3 SUPERCONDUCTING SOLENOID

7.3.1 System Description

The superconducting solenoid magnet, pictured in figure 7.3-1, located between the central tracking chamber and the hadron calorimeter, provides the magnet field for the SDC detector.

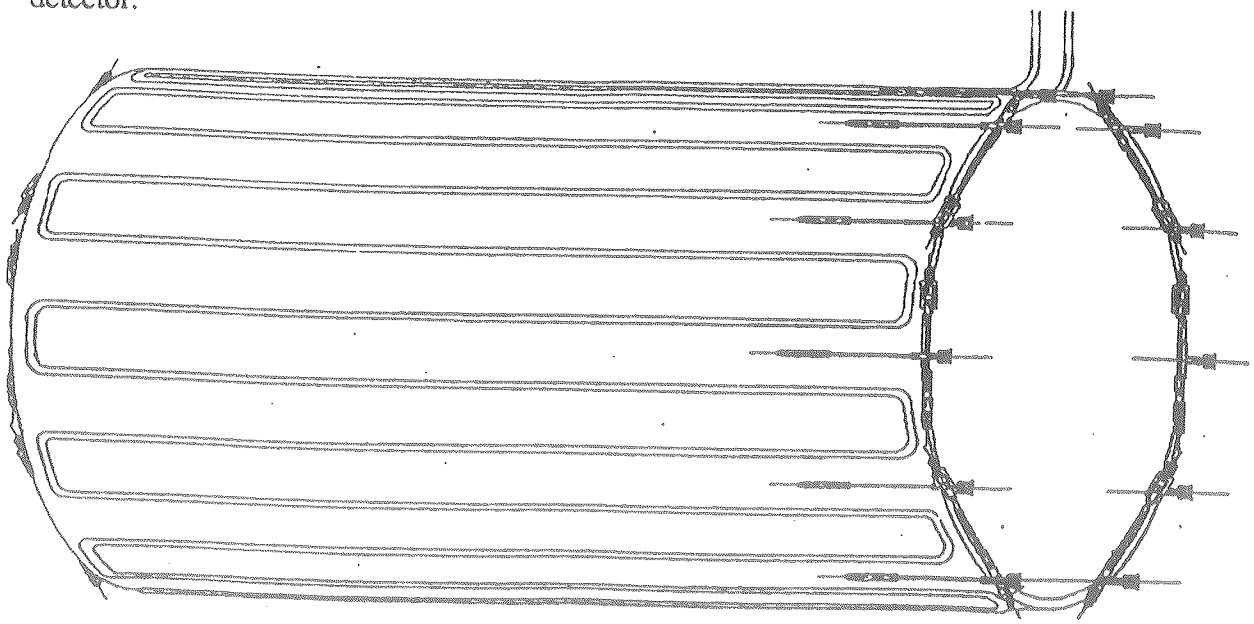

Figure 7.3-1 Superconducting solenoid in relation to overall detector

The service port, located directly above the chimney (north) end of the magnet outside the muon detector, is the interface between the superconducting solenoid magnet and the SSCL cryogenic system. The chimney runs vertically upward from the magnet and connects to the bottom of the service port. The superconducting power leads and cryogen lines on the magnet extend through the detector inside the chimney and terminate in the service port. The power supply and control system hardware are located in the cryogenic system utility building.

7.3.1.1 Superconducting Solenoid Magnet Components and Their Functions

1. Aluminum stabilized superconductor conducts the energizing current without electrical resistance when operating below its critical temperature for the operating current and magnetic field. It consists of cabled niobium-titanium/copper (Nb-Ti/Cu) superconducting filaments centered in an aluminum stabilizer.

2. Kapton or glass tape and epoxy is used for the turn-to-turn electrical insulation.

3. A single-layer solenoid generates the magnetic field. It is wound with the electrically insulated, aluminum stabilized superconductor. The turns are bonded together with epoxy.

4. The use of pure aluminum quench propagation strips bonded with epoxy to the inside surface of the solenoid is being considered. These strips might be needed to limit the maximum hot spot temperature during a quench.

5. An aluminum outer support cylinder restrains the solenoid in the radial direction so it doesn't move outward when subjected to the radial forces generated by the magnetic field. The solenoid is bonded with epoxy to the inside surface of the support cylinder. An end ring is bolted to each end of the support cylinder. The radial supports attach to the end rings.

6. An aluminum helium cooling tube is welded to the outer support cylinder. Helium flowing in this tube cools the solenoid and the outer support cylinder.

7. Axial and radial supports transmit magnetic and gravitational loads from the solenoid to the external support bars that are attached to the hadron calorimeter. The supports consist of slender rods of composite material with metallic end pieces. Radial supports are installed on both ends of the solenoid. The axial supports are installed only on the chimney end of the solenoid. Each of these supports attaches to the outer support cylinder (cold end) and to the cryostat annular bulkhead (warm end) at the same end of the solenoid as the support. Each support has a thermal intercept to reduce heat leak from the warm end of the support to the outer support cylinder.

8. Gaseous helium- or liquid nitrogen-cooled aluminum shields reduce radiation heat transfer to the liquid helium environment. A cylindrical shield is installed between the outer support cylinder and the cryostat outer vacuum shell, and another cylindrical shield is installed between the inside surface of the solenoid and the cryostat inner vacuum shell. Each cylindrical shield consists of aluminum tubes welded to a thin aluminum cylinder. Flat shields are installed at each end of the solenoid between it and the cryostat end walls. Each flat shield consists of an aluminum tube welded to a thin aluminum ring that is attached to the ends of the cylindrical shields.

9. Multilayer insulation (MLI) between the cryostat vacuum vessel and the thermal radiation shields, and between the thermal radiation shields and the outer support cylinder/solenoid assembly. MLI is used in a vacuum environment to reduce heat transfer from warm to cold surfaces.

10. Composite supports for the thermal radiation shields. These supports are attached to the flat end shields and the cryostat annular bulkhead.

11. Temperature, pressure and position sensors, and strain gauges. This instrumentation used to monitor all operations, provides useful information, including rate of cooldown, mechanical and thermal stresses, temperature distribution, and vacuum level.

12. Voltage taps are used to measure voltage differences along the length of the solenoid.

13. Quench heaters are used to initiate a quench for testing purposes.

14. The aluminum cryostat vacuum vessel consists of an outer vacuum vessel, an inner vacuum vessel, and an annular bulkhead on each end. All of the components are installed inside the vacuum vessel. The vacuum environment

maintained in this vessel is needed to thermally insulate the cryogenic components of the solenoid from the room-temperature environment.

15. External support bars connect the superconducting solenoid magnet to the hadron calorimeter. Bolts are used to attach these composite bars to the annular bulkheads on the cryostat vacuum vessel and to the calorimeter.

7.3.1.2 Chimney Components and Their Functions (Figure 7.3-2)

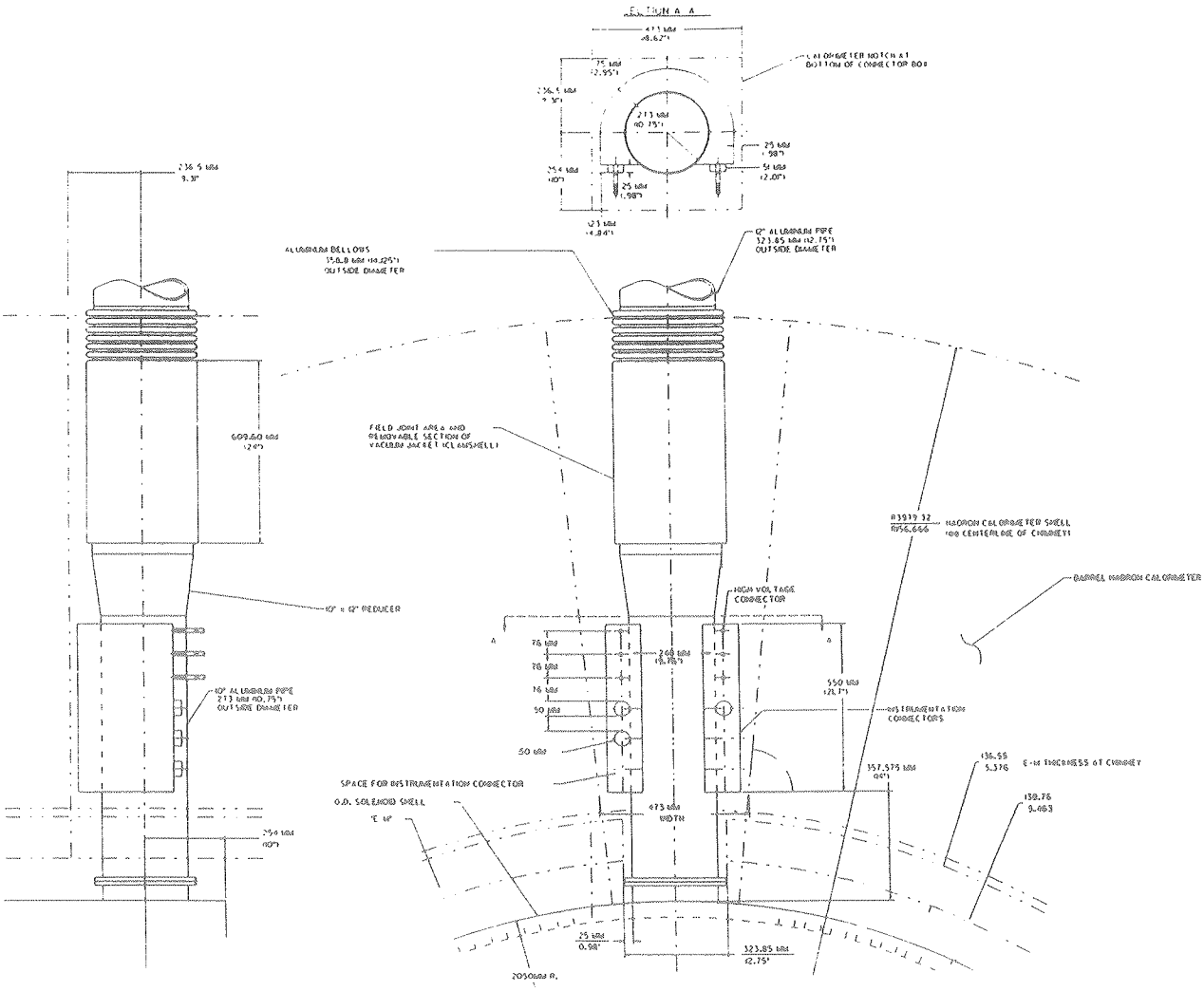

Figure 7.3-2 Chimney Components

1. Superconducting leads for the supply and return of the solenoid DC energizing current. The leads are fabricated with the superconductor and electrical insulation described above for the superconducting solenoid magnet.

2. Tubing for the supply and return of cryogens needed to operate the superconducting solenoid magnet.

3. A gaseous helium- or liquid nitrogen-cooled, cylindrical aluminum shield reduces radiation heat transfer to the current leads and cryogen tubing. The shield surrounds these components.

4. Spacers attach to the leads and tubes to keep them centered inside the radiation shield.

5. Multilayer insulation (MLI) between the chimney vacuum jacket and the thermal radiation shields. MLI is used in a vacuum environment to reduce heat transfer from warm to cold surfaces. The annular space between the outer MLI surface and the vacuum jacket is the flow path between the cryostat vacuum vessel and the service port. This flow path is needed to pump down the cryostat vacuum vessel, to vent boiloff gas in the event of a cryogen leak in the cryostat vacuum vessel, and to pump a small helium leak in the cryostat vacuum vessel.

6. Temperature and position sensors, and strain gauges. This instrumentation, used to monitor all operations, proudly useful information, including rate of cool down, mechanical and thermal stresses, and temperature distribution.

7. Voltage taps are used to measure voltage differences along the length of the solenoid.

8. A vacuum jacket encloses all of the above components in a vacuum environment. The vacuum environment is needed to thermally insulate the cryogenic components from the room-temperature environment. The vacuum jacket is stainless steel except for a short section between the cryostat vacuum vessel and the electrical connector box. It has a sliding sleeve for access to the field joints in the cryogen lines, the superconducting leads, and the thermal shield.

9. Hermetic electrical connectors for instrumentation wiring from the solenoid magnet and chimney. The connectors have stainless steel bodies that are welded to ports in the connector box.

10. Hermetic electrical connectors for the voltage taps on the solenoid magnet and chimney. The connectors have stainless steel bodies that are welded to ports in the connector box.

11. A connector box provides a place to mount the hermetic electrical connectors and to store slack wiring.

12. An aluminum-to-stainless steel transition piece makes it possible to join the aluminum chimney nozzle on the cryostat vacuum vessel to the stainless steel chimney vacuum jacket.

13. Stainless steel bellows provide flexibility in the chimney vacuum jacket to accommodate relative motion between the muon iron, the chimney, and the cryostat vacuum vessel.

7.3.1.1.3 Service Port Components and Their Functions (Figure 7.3-3)

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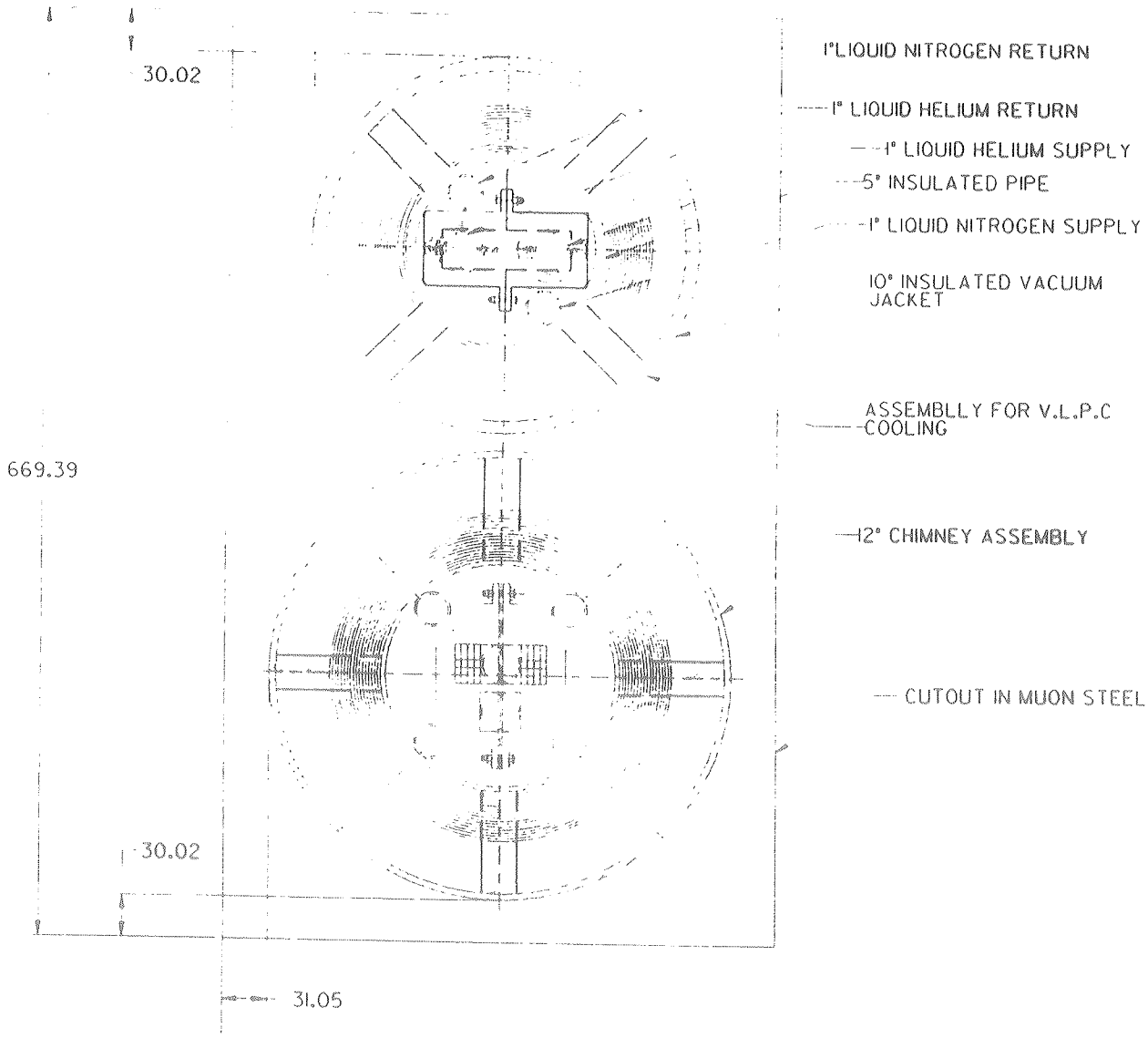

Figure 7.3-3 Service port schematic

1. A phase separator provides the flow of helium gas needed by the vapor-cooled leads. The two-phase flow of helium from the solenoid magnet enters this stainless steel vessel through its top head.

2. Vapor-cooled leads are the transition pieces between the superconducting leads on the solenoid magnet and the power supply circuit. The superconducting leads enter through the bottom of the phase separator and attach to the vapor-cooled leads at a point below the liquid helium level. The vapor-cooled leads exit through the top of the phase separator and terminate outside the top head of the service port.

3. Double ceramic seals are used to seal and electrically insulate each phase separator/superconducting lead penetration.

4. Bayonet connections for the cryogenic lines penetrate through the top head of the service port. These bayonets are used to connect the solenoid magnet to the SSCL cryogenic system.

5. Aluminum-to-stainless steel transition pieces make it possible to join the aluminum tubing runs on the solenoid magnet to the stainless steel bayonets. Only aluminum tubing is used in the solenoid magnet.

6. A gaseous helium- or liquid nitrogen-cooled cylindrical aluminum shield reduces radiation heat transfer to the current leads, cryogen tubing, and phase separator. The shield surrounds these components.

7. Multilayer insulation (MLI) between the outer vacuum jacket and the thermal radiation shields. MLI is used in a vacuum environment to reduce heat transfer from warm to cold surfaces.

8. Temperature and pressure sensors. This instrumentation, used to monitor all operations, provides useful information, including rate of cool down, temperature distribution, and vacuum level.

9. A vacuum jacket encloses all of the above components in a vacuum environment. The vacuum environment is needed to thermally insulate the cryogenic components from the room-temperature environment. The vacuum jacket is the stainless steel outer shell of the service port.

10. Process safety-relief valves limit the pressure in the two-phase helium cooling circuit (helium cooling tube on the outer support cylinder). These valves are located on both the supply and return lines for this circuit.

11. A relief device for the solenoid magnet system is designed to limit the pressure in the cryostat vacuum vessel in the event of an accidental flow of cryogen from a ruptured or leaking line.

12. Process safety-relief valves protect trapped volumes in the helium and nitrogen piping circuits.

13. A turbomolecular vacuum pump will be used to pump down the solenoid system and provide continuous high-vacuum pumping in the event of a small helium leak. This pump is attached to a port on the vacuum jacket.

14. A high-vacuum valve isolates the solenoid system from the turbomolecular vacuum pump.

15. Hermetic electrical connectors for instrumentation wiring form the service port and chimney. The connectors have stainless steel bodies that are welded to ports in the vacuum jacket.

16. A purge box encloses the vapor-cooled leads outside the service port. This box is supplied with a continuous inert gas flow to prevent moisture condensation or frost from forming on the leads.

17. A support structure stands on the muon iron.

7.3.1.4 Power Supply Circuit Components and Their Functions

1. A 10,000-ampere power supply energizes the superconducting solenoid magnet. It is located in the cryogenic system utility building on the surface and is equipped with a voltage filter.

2. A fast dump resistor quickly extracts part of the energy stored in the superconducting solenoid magnet during a quench or other emergency requiring a fast discharge. Manual initiation of a fast discharge (fast dump) will quench the solenoid magnet. The fast dump resistor is located near the service port.

3. A diode might be placed in series with the fast dump resistor to prevent current flow through it during normal operations. Current would flow through the dump resistor only during a quench.

4. Fast dump switches open the supply and return bus to initiate a fast discharge of the superconducting solenoid magnet. These switches are located near the power supply.

5. A slow dump resistor slowly extracts the energy stored in the superconducting solenoid magnet. Slowly discharging the solenoid magnet (slow dump) eliminates eddy-current loss in the support cylinder and avoids a quench during shutdown. The slow dump resistor is located near the power supply.

6. A slow dump switch opens the supply bus to initiate a slow discharge of the superconducting solenoid. This switch is installed in parallel with the slow dump resistor.

7. A water-cooled copper bus connects the superconducting solenoid magnet to the power supply. This bus has a short section of copper cable to facilitate its connection to the vapor cooled leads.

8. Direct current, current transformers (DCCT) measure the current at various points in the power supply circuit.

7.3.1.5 Control System

The control system is treated as a single entity in the safety assessment report for the superconducting solenoid magnet. The control system reads the instrumentation in the solenoid and power supply systems, displays and prints all measure points, implements the fail-safe control and alarm logic, performs operations with the measured points, controls the power supply and dump switches, and is linked to both the control system for the SSCL cryogenic system and to the SSCL communication network.

7.3.2 Hazards and Mitigations

7.3.2.1 Particular hazards

Particular hazards, risk assessment and mitigating actions for each component, are given in the conceptual safety analysis matrix. The forms are summarized in this section.

The risk assessment assigned to each hazard after implementation of the recommended actions based on best engineering judgment and the known experience gained from existing, thin, superconducting solenoids throughout the world. This assessment does not always fall in risk zone 3 with respect to the equipment loss, test unit downtime and data compromise categories. This is especially true for remote and occasional probabilities associated with critical and catastrophic consequences. Personnel are not exposed to hazards in risk zone 1 and 2 by the SSCL.

Major particular hazards for the superconducting solenoid are:

New design concepts and advances in existing technology will be utilized to design and build the SDC superconducting solenoid. The general mitigating actions for potential hazards posed by this approach include: careful design, testing of individual components, quality control and proving the design ideas by building, operating and testing a prototype superconducting solenoid.

2 - The E/M ratio, i.e., the ratio of the stored energy to the cold mass for the superconducting solenoid, is a useful parameter to gauge the relative transparency of the solenoid. The relative transparency and average coil temperature after a quench increase as the E/M ratio increases. The E/M ratio for existing thin superconducting solenoids is 5.5 or less. The E/M ratio for the SDC superconducting solenoid is 7.5. The 7.5 E/M ratio is a significant technological advancement for superconducting solenoids. General mitigating actions for the potential hazards posed by this advancement include: designing for the temperatures generated by open circuit quenches (a quench with the solenoid disconnected from the power supply circuit), designing for the electromagnetic and static loads, and proving the design in the prototype solenoid.

3 - The superconducting solenoid is designed to operate at or below its maximum allowable energizing current. The energizing current can exceed the maximum value if the power supply is oversized. Excessive current could occur if the power supply malfunctions or by operator error. This is a hazard because the stored energy and the electromagnetic forces will exceed their limits if the current exceeds its maximum allowable value. General mitigating actions include not oversizing the power supply, having the control system monitor for power supply malfunctions and initiate corrective actions, and to design the superconducting solenoid considering the maximum amount of energy that can be stored in it.

4 - Energy release in case of quench is a hazard. Quench is the abrupt transition from the superconducting state to the resistive state. The energy is dissipated by joule heating in the circuits, in proportion to the resistance of each circuit (coil, support cylinder, fast dump resistance). The possibility of coil overheating, hot points, and local quench could lead to the destruction of the coil if the stored energy is released locally. This could happen if the quench velocity is too low and if the heat generated in this local transition is not spread over the whole coil.

7.3.2.2 General hazards

General hazards apply to many or all components and systems. They are discussed in this section rather than being noted on the conceptual safety assessment forms. Applicable Codes and Standards are specified in section 4.0.

General hazards for the superconducting solenoid system are:

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1 - Oxygen deficient environment for personnel caused by the release of helium or nitrogen from the solenoid system. An unventilated, confined space is a notable, potential oxygen deficient environment because of the lack of ventilation. General mitigating actions include limiting the release rate, ODH (Oxygen Deficiency Hazard) training, and providing ventilation, oxygen monitors (both fixed and individually carried units), individual air supply packs, and ODH alarm devices in the experimental hall.

2 - General cryogenic hazards to personnel. These hazards include: exposure to cryogenic temperatures resulting in freezing damage to bodily tissue, frostbite (cryogenic burns), hypothermia, vision impairment caused by fog formation, and oxygen deficient environments that can result in injuries, asphyxia or death. General mitigating actions include training, use of protective wear, safety procedures and safe work practices.

3 - General electrical safety hazards. General mitigating actions include designing, installing and testing the power supply and control systems in accordance with applicable design codes and standards, and good engineering practice.

4 - Magnetic field hazards to personnel. This hazard includes health and work hazards. Work hazards arise because of the force of attraction exerted on metallic objects, such as tools and equipment, by the magnetic field. General mitigating actions include magnetic field safety training, magnetic field survey, and safety procedures and safe work practices for working around the energized solenoid magnet.

5 - Safety and operating performance hazards associated with a component or part that does not comply with its design specification. Mitigating actions include inspecting and testing an item to assure compliance with its specification, and rejection of unacceptable items (quality control). Inspection and testing requirements that are to be performed by a supplier are defined in the design specification. Inspection includes: nondestructive methods (such as: visual, leak testing, radiographic, checking dimensions, etc.), and destructive methods. Testing includes: mechanical loading, pneumatic/hydrostatic, and determining operating performance.

6 - High stress in components caused by thermal, pressure, magnetic, weight and acceleration loads. The general mitigating action is to limit stresses in components to allowable values by designing them for the forces to which they will be subjected. Allowable stress values are established by following applicable design codes and standards, and good engineering practice.

6.1 - Thermal stresses will develop in a component that is restrained from moving when subjected to a temperature change. Thermal stress will also occur in an interconnecting component if it is restrained from moving in response to thermal movements of the components it connects. The mitigating action includes designing components and systems with sufficient flexibility to limit thermal stress to allowable values.

6.2 - An overpressure condition exists in a component when it is pressurized above its design value. Exposure of a trapped volume to a source of pressure greater than its design value, or pressurizing a component faster than the pressurizing medium can be vented from it are examples of components at overpressure conditions. The pressurizing medium for both of these examples can originate from another component in the system, an external source, or uncontrolled vaporization or expansion of a fluid inside the component. The mitigating action includes installing relief devices to limit pressures to design values.

6.3 - The magnetic field produced by the superconducting solenoid causes forces to be developed in the superconducting solenoid magnet, the detector and objects/equipment in areas outside the detector.

6.4 - Gravity causes the weight load.

6.5 - Acceleration forces occur during shipping, installation and seismic events.

7 - Materials of construction not suited for the intended service. General mitigating actions include establishing suitability (e.g., for the operating temperature, radiation exposure, etc.) based on previous experience, code data, material specifications or tests, and verifying physical properties and chemistry by obtaining the material test report or certificate of compliance for the material, by using the material identification marking system specified by the applicable material specification, or by testing.

8 - Accidental exposure of non-cryogenic materials to cryogenic temperatures. Materials that are not suitable for cryogenic temperatures can be damaged by exposure to cryogens. This hazard occurs when a cryogen accidentally escapes the cryogenic system and contacts a non-cryogenic material. The mitigating action is to prevent accidental contact by protecting the non-cryogenic material with a barrier or by changing a component's location.

9 - Hazards caused by equipment/instrumentation malfunctions, power failure, or equipment/instrumentation/operator errors. The general mitigating action is to design all systems to fail safe, to alarm abnormal process conditions and to initiate corrective or shutdown actions.

10 - Loss of insulating vacuum. Insulating vacuums can be lost or degraded by leaks that develop or by inadvertently opening a valve. This hazard results in increased heat leak to the cryogenic system and to the pressurization of vacuum enclosures. Increasing the heat leak can lead to an overpressure condition in a component because it can cause uncontrolled vaporization or expansion of liquid cryogens. Increasing heat leak to the superconducting solenoid magnet can cause it to quench, as discussed on the conceptual safety assessment forms. Pressurizing a vacuum enclosure can result in an overpressure condition. Mitigating actions include the actions noted under the high stress hazard for an overpressure condition and under operating malfunctions/errors.

2.1.3 Conceptual Safety Assessment Forms

The conceptual safety assessment forms are summarized below:

2.2 Interfacing systems

The superconducting solenoid system has the following interfaces with the detector and experimental hall:

1 - The external support bars for the superconducting solenoid magnet bolt to the hadron calorimeter.

2 - The cryostat vacuum vessel and the hadron calorimeter.

3 - The cryostat vacuum vessel and the central tracking chamber.

4 - The chimney runs vertically upwards through the hadron calorimeter, the space between the calorimeter and muon iron, the muon iron and the muon detectors. The chimney field joint is located in the hadron calorimeter.

5 - Instrumentation wiring from the connector box at the base of the chimney follows the same route as the chimney to exit the detector.

6 - The support structure for the service port and chimney stands on the muon iron.

7 - The muon system under the service port and its piping.

8 - The water-cooled copper bus and instrumentation wiring run from the service port, across the muon system and to the cryogenic system utility building on the surface.

9 - The solenoid system has several process related interfaces with the experimental hall: helium vented from the helium cooling tube relief valves located on the service port, helium and nitrogen vented from trapped volume relief valves located on the service port, helium vented from the solenoid magnet system relief device located on the service port, helium and nitrogen occasionally vented from the system (e.g., removing a u-tube, flow purging piping/tubing runs), lubricated vacuum pump exhaust, turbomolecular vacuum pump exhaust, nitrogen flowing out of the purge box around the vapor cooled leads located atop the service port, and accidental discharge of cryogens.

10 - The magnetic field produced by the superconducting solenoid magnet.

CONCEPTUAL SAFETY ASSESSMENT REPORT
CSAR
SDC DETECTOR

SUPERCONDUCTING COIL.

Superconductor. 1 **Date:**

Operational Phase: construction

Hazard Description:

Breaks in the superconducting wires, poor bond between the SC wires and the aluminium support, inadequate amount of aluminium or SC wires gives a *poor quality* which may result , if the defects are not detected, in the impossibility to reach the superconductive status, or depending on the defect, in problems like bad safety factor between the I (nominal current) and I_C (critical current), quench problems, overheating of the coil structure in case of quench.

Risk Assessment Prior to any Abatement Strategy:

2 B 1

Current Recommended Actions:

Controls during fabrication . These control consist of X ray control, quality measurements of the aluminium support, quality and quantity control of the SC wires, dimensional controls.

Risk Assessment after Implementation of Recommended Actions:

2 E 3

Remarks:

CONCEPTUAL SAFETY ASSESSMENT REPORT
CSAR
SDC DETECTOR

SUPERCONDUCTING COIL

Superconductor 2 | Date:

Operational Phase: Tests on sample and conductor

Hazard Description:

A RRR (relative resistivity ratio) too low can result in the *instability* of the conductor in case of quench with overheating problems. The RRR can be too low if the Yield strength of the aluminium support is too high.

Risk Assessment Prior to any Abatement Strategy:

2 C 2

Current Recommended Actions:

The RRR must be verified experimentally on initial samples and on samples during fabrication. The RRR must be conform to the specifications > 600.

Risk Assessment after Implementation of Recommended Actions:

3 E 3

Remarks:

The RRR > 600 is a compromise but it is situated in the lower limit where the temperature after quench doesn't not depend of the RRR. This must be proved in the future on the prototype coil. As example similar magnets as CDF, ALEPH have a RRR > 1000, and Zeus >800.

CONCEPTUAL SAFETY ASSESSMENT REPORT
CSAR
SDC DETECTOR

SUPERCONDUCTING COIL

Superconductor 3 | **Date:**

Operational Phase: Tests on sample during superconductor manufacture

Hazards Description:

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

Risk Assessment Prior to any Abatement Strategy:
3 B 2

Current Recommended Actions:

The tests on the samples must show a safety factor of 2 for I(nominal current)/ Ic (critical current) and a safety factor of ? on the field / the critical field. Samples will be taken during manufacture to verify these values.

Risk Assessment after Implementation of Recommended Actions:
3 E 3

Remarks:

If during supraconductor manufacture it is shown that some parts do not reach the specifications, possibility exists to make replacement of the non conformed part.

CONCEPTUAL SAFETY ASSESSMENT REPORT
CSAR
SDC DETECTOR

SUPERCONDUCTING COIL
Coil winding 1 | Date:
Insulation

Operational Phase: Winding
Hazard Description: coil inoperative due to shorts

Turn to turn , coil to OSC ground or other ground shorts during winding and curing will render the coil totally inoperative

Risk Assessment Prior to any Abatement Strategy:

1 B 1

Current Recommended Actions:

The axial and radial preload for the winding is essential and will be controled permanently.

The epoxy resin will be mixed following the vendor specifications, the curing of the epoxy will be made in taking into account the required temperature and humidity.

During winding and curing the electrical tests like dielectric tests and wire to ground resistance tests will be performed

Risk Assessment after Implementation of Recommended Actions:

1 E 3

Remarks:

CONCEPTUAL SAFETY ASSESSMENT REPORT
CSAR
SDC DETECTOR

SUPERCONDUCTING COIL
Coil winding 2
Curing | **Date:**

Operational Phase: Operation

Hazard Description: Radiation damage to the epoxy resin.

The epoxy resin which make the liaison between the super conductor and the outer support cylinder could be damaged by the radiation effect.

The result of this will be cracks in the resin, diminution of the dielectric characteristics.

Risk Assessment Prior to any Abatement Strategy:

2 C 2

Current Recommended Actions:

The choice of the epoxy resin will be made in taking into account the curing due to radiation effects.

Tests before the choice will be made in radiation environment, to see if at the cumulate rate of radiation, equivalent to the cumulate rate in SDC (at coil level), the mechanical and electrical characteristics are acceptable.

Risk Assessment after Implementation of Recommended Actions:

2 E 3

Remarks:

10 years is the operational time for SDC experiment and subsystems.

CONCEPTUAL SAFETY ASSESSMENT REPORT
CSAR
SDC DETECTOR

SUPERCONDUCTING COIL.

Electrical system. | **Date:** 02-14-1992.

Operational Phase: Operation

Hazards description: Coil damages.

The electrical system consists of an internal system which is the coil itself and an external system consisting with the supply , flywheel diode, fast and slow dump resistances, circuit breakers (dump switches) and control systems. (See figure.).

In case of coil quenching if the power supply does not detect the problem and does not take the necessary actions, as switching off its secondary circuit, and if the circuit breakers S2A and S2B (fast dump dump switches) stay closed, the coil, which will be in resistive state , will probably overheat.

The catastrophic credible situation is an open circuiting of the electrical circuits when the coil is in operation. The critical circuits are those between the coil and the fast dump resistance.

This situation can happen if the electrical construction of the circuits is poor, for example the bolting and bad weldings on the busses.
The non operation of the S1 circuit breaker (slow dump switch), necessary for slow discharge, and the non operation of the switching off the power supply in the same operation can also reach a problem with the coil.

Risk Assessment Prior to any Abatement Strategy:

I A 1

Current recommended actions:

In case of non operation of the quench detection system in the supply, a redundancy will exists with the two S2A and S2B circuits breakers (fast dump switches) which are connected together to open at the same time.

To avoid the opencircuiting of the electrical circuits, strict control procedures will be made for inspection after each operation on the electrical circuits, the use of check lists will be mandatory.

The position of the fast dump resistance will be as close as possible to the SDC experiment to increase the control possibility and avoiding connections.

In case of flammable gas inside SDC, the operational temperature of the dump resistance must be below the autoignition temperature of the flammable gas.

Risk Assessment after Implementation of recommended Actions:

1 E 3

Remarks:

CONCEPTUAL SAFETY ASSESSMENT REPORT
CSAR
SDC DETECTOR

SUPERCONDUCTING COIL
Electrical subsystem 1 | **Date:**
Fast dump resistance

Operational Phase: Tests, Operation

Hazard Description: Opencircuit, coil and vacuum structure damages

FDR (Fast Dump resistance) is foreseen to discharge quickly the coil in case of quench. The choice of the FDR is a compromise between the time constant and the maximum admissible voltage in the coil in case of quench. The operational voltage is 4oo V (200 V to the ground as the middle point of the coil is connected to the ground) , the FDR Resistance is 5o m.ohm, the time constant 45 sec.

In case of opencircuiting of the COIL-FDR circuits the voltage increase COIL/ Ground will be such that an arc will occur between the Coil and the ground potential structures, the vacuum tank will be pierced and the *coil damage (due to overheating)* could be total without any repair possibility.

The opencircuiting could occur if loose connections burn , if the FDR circuits between the busses stay open after a maintenance period for example.

Opencircuit could occur also for the following reasons :

- Voltage taps causes electrical short from coil to ground.
- Electrical short to ground of lead in bus in chimney
- Electrical short between lead-in bus in chimney

Risk Assessment Prior to any Abatement Strategy:

1 B 1

Current Recommended Actions:

The FDR must be chosen in such a way that the maximum whole Coil energy can be discharge in the FDR without overheating problems.

The position of FDR will be as close as possible to the coil to avoid too long circuits.

The circuits will be inspected and controlled to avoid loose connections. The inspections will be performed after each fast dump and after any maintenance operation. Check lists will be issued.

For the electrical installations inside the chimney , strict controls and measurements will be made before closing the volume. Procedures will be enforced.

Risk Assessment after Implementation of Recommended Actions:

1 E 3

Remarks: The maximum operating temperature of the FDR will be chosen in taking into account the auto ignition temperature of the flammable gas used in the SDC experiment.

CONCEPTUAL SAFETY ASSESSMENT REPORT
CSAR
SDC DETECTOR

SUPERCONDUCTING COIL
Electrical subsystem 2
Electrical Supply | **Date:**

Operational Phase: Operation

Hazard Description: Supply runaway, quench.

If the power supply runs away the operational current will reach the critical current and the *quench* possibility increases. The energy to be discharged will increase.

Risk Assessment Prior to any Abatement Strategy:

3 B 2

Current Recommended Actions:

It will be a redundancy in the current measurements and actions. One system will operate the regulation of the supply secondary part , an other one will trigger the primary part of the supply and the coil energy will be discharge in the SDR.

In case one of the previous systems fail, the coil quench detection system will trigger the opening of the two circuit breakers in the coil supply and the energy will be discharged in the FDR.

Risk Assessment after Implementation of Recommended Actions:

3 E 3

Remarks:

CONCEPTUAL SAFETY ASSESSMENT REPORT
CSAR
SDC DETECTOR

SUPERCONDUCTING COIL
Electrical subsystem 3 | **Date:**
FDR , QUENCH

Operational Phase: Operation

Hazard Description: Opencircuit of the coil fast discharge circuit after fusion of the FRD

Overheating of the FRD could lead to fusion of the resistance and lead to the opencircuiting of the safety circuits (see Electrical subsystem2). This event could happen if, for any reason , the power supply runs away to a current critical value which reaches a quench, but the stored energy will be the energy relative to this current value , if we assume that the nominal current reaches the critical current before quench, that means 16000 A, then if the FRD was not correctly dimensioned for this value it will burn.

Risk Assessment Prior to any Abatement Strategy:

1 B 1

Current Recommended Actions:

Dimension of the FDR must be adapted to the maximum possible stored energy .

Risk Assessment after Implementation of Recommended Actions:

1 E 3

Remarks:

CONCEPTUAL SAFETY ASSESSMENT REPORT
CSAR
SDC DETECTOR

SUPERCONDUCTING COIL
Electrical Subsystem 4
COIL Sensors | **Date:**

Operational Phase: Operation

Hazard Description: magnet out of control

The sensors on the magnet (*quench detectors,* temperature in various places on the outer cylinder, *coil voltage* , amps in the middle point line ------) indicate the status of the coil. Defects or faults in the sensors could reach a non controlled state of the coil. The main sensors like quench and voltage sensors which must give an action on the electrical supply and the main fast dump circuit breakers are essential for the safety of the coil.

Risk Assessment Prior to any Abatement Strategy:

1B1

Current Recommended Actions:

Each sensor will be redundant and the electrical supply will be equiped with various detectors like overcurrent, overvoltage. These detectors will have the same actions as electrical shut off, FDR .

A flux loop will be installed around the coil, this system will detect any flux variation, but it will only operate when the coil will be at its nominal current.

Other systems like current devices in the coil circuit will also detect any abnormality in the current supply.

Risk Assessment after Implementation of Recommended Actions:

1 E3

Remarks:

CONCEPTUAL SAFETY ASSESSMENT REPORT
CSAR
SDC DETECTOR

SUPERCONDUCTING COIL
Electrical systems 5
Quench Detection | **Date:**

Operational Phase: Operation

Hazard Description: Quench , coil damages.

If a quench is not detected, the coil will be in conductive status and the electrical supply will continue to operate, the fast dump switches will stay closed. The coil will overheat and if no actions are taken or manually (Emergency switch) or by an other system, important damage to the coil could occur. If the cause of the quench is a hot point,
local damage to the superconductor could be envisaged. Also ,if after quench ,the final temperature exceeds 170° C irremediable damage could be found in the the liaison epoxy resin between the conductor and the outer cylinder.

Risk Assessment prior to any Abatement Strategy:

` 1 B 1

Current Recommended Actions:

The safety against quench depends of the reliability of the various quench detectors like unbalance voltage detector.
The control lines will be surveyed permanently.
The computer system will monitor the fast dump systems and the quench circuits.
A test plan will be issued to take care of the operation of the Fast Dump switches.
Other detectors will also detect anomalies, like temperature sensors, in various parts of the coil and will trigger a quench.

Risk Assessment after Implementation of Recommended Actions:

1 E 3

Remarks:

CONCEPTUAL SAFETY ASSESSMENT REPORT
CSAR
SDC DETECTOR

SUPERCONDUCTING COIL
Electrical subsystems 6 | **Date:**
Quench

Operational Phase: Operation

Hazard Description: Overheating due to Resistive state of the coil

Quench is an abnormal situation and should be avoided as far as possible. The effects of a quench will be an overheating of the coil structures with , if the temperature exceeds 250 C the epoxy resin could be damaged and the coil could be out of operation.

Quench may arise for the following reasons:

- Lack of cooling, the Superconductor instability increases and as the RRR (600) value is minimum, quench will occur.
- Nominal current reaches critical current.
- Current grows too fast to reach the nominal current
- Current decreases too quickly during normal coil discharge.
- magnetic flux variations
- quench or other critical sensor failures

Risk Assessment Prior to any Abatement Strategy:

1 A 1

Current Recommended Actions:

The coil will be designed for the temperatures generated by an open coil electrical circuit. This assumption will be tested on the prototype coil. These tests will permit to see if the E/M ratio (7.5) is the right choice.

The stability in temperature will be assured by the Helium supply system and to have more possibility the helium cooling systems will use a pumping system in place of thermosiphon technique. The Helium systems will have their own CSAR.

The maximum temperature reached by the coil structure after a quench must be calculated taking into account the E/M value, and the maximum possible stored energy .

Stability of the power supply is essential, this equipment will be equiped with all the control devices to limit the nominal value to 8000 amps. The supply system will have its own CSAR.

To avoid a too fast current growing , the Supply control system will be equiped with a system which prevent to exceed 4. 8 A/sec.

To avoid a too quick current decreasing, the SDR will be chosen for this purpose. The SDR of 2 mohm give a value of 3.8 A/sec which is less than the current growing value.

Here again the flux variation depends on the supply stability.

To avoid sensor failure there will be redundancy in the detection systems.

All these parameters will be confirmed with the coil prototype.

Risk Assessment after Implementation of Recommended Actions:

1 E 3

Remarks:

CONCEPTUAL SAFETY ASSESSMENT REPORT
CSAR
SDC DETECTOR

SUPERCONDUCTING COIL
Electrical subsystem 7
Quench Hot Points | **Date:**

Operational Phase: Tests and operation

Hazard Description: local destruction of the coil winding

If for any reason a local quench occurs , that means a local resistive point, fusion of this point can be reached if no actions are taken.

This situation becomes equivalent to an open circuit,(see CSAR Electrical subsystem no1)

Risk Assessment Prior to any Abatement Strategy:

1 A 1

Current Recommended Actions:

The Superconductor design takes in consideration the quench velocity which is fixed at (?)m/sec .

The quench detection system will operate in few msec (?) by the voltage measurement on voltage tabs.

As a local quench will make a flux variation, the flux loop detection system may be considerd as a redundant safety device.

<u>Possibly use quench propagation strips on the inside radius of the coil.</u>

Risk Assessment after Implementation of Recommended Actions:
1 E 3

Remarks:

CONCEPTUAL SAFETY ASSESSMENT REPORT
CSAR
SDC DETECTOR

SUPERCONDUCTING COIL
SDR

| Date:

Operational Phase: Operation
Hazard Description: Quench due to Supply and cryogenic failures

Power supply and cryogenic failures not detected can cause a fast dump and unwanted heat and mechanical stresses in the coil.

Risk Assessment Prior to any Abatement Strategy:

3 A 1

Current Recommended Actions:

All these anomalies will be detected and will operate the supply cut off and the opening of the switch which short circuits the SDR.

Risk Assessment after Implementation of Recommended Actions:

4 C 3

Remarks:

CONCEPTUAL SAFETY ASSESSMENT REPORT
CSAR
SDC DETECTOR

SUPERCONDUCTIVE COIL INSTRUMENTATION

| Date:

Operational Phase: Operation

Hazard Description: uncontrolled coil operation.

The goal of the instrumentation is permanently to give the status of the coil during charging , discharging and normal operation.

The following parameters will control the coil operation:

- Voltage in different places of the winding which must operate the fast discharge switches,
- Flux variation with the same effect.
- Coil Current
- Temperature sensors in the He flow circuits,
- Temperature sensors on the coil mass,
- Temperature sensors on thermal shields and intercepts

These last instrumentations are important to regulate the operating parameters before quench.

Failure of these instrumentations or wrong indications could reach an uncontrolled situation of the coil.

Failure of the quench detection systems can damage the coil.

Risk Assessment Prior to any Abatement Strategy:

1 B 1

Current Recommended Actions:

Coil status indicators will be redundant, strict checking procedures concerning the instrument readings will be enforced.

The necessary actions on SDR and FDR , He flow , current regulations will be controled and will be a part of a maintenance program.

Risk Assessment after Implementation of Recommended Actions:

2 D 3

Remarks:

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Apr 7, 1992 Rev: 0 Attachments: YES_, NO_X_

Subsystem: Superconducting solenoid magnet, Chimney, service port, field joint - No. 1
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

Inadequate cooling of the superconducting power leads in the service port, in the chimney, and at the entrance to the cryostat vacuum vessel. This hazard can cause the superconductor to return to the resistive state and consequently cause the solenoid to quench.

Risk Assessment Prior to any Abatement Strategy

2-A-1

Current Recommended Action

Provide adequate cooling for the superconducting power leads by attaching them to the helium supply line. Minimize the length of sections that are not in good thermal contact with the helium supply line. Short sections of the superconducting leads are not in contact with the supply line. This occurs where the leads run between the ceramic electrical feedthroughs (located in the bottom of the liquid helium reservoir) and the supply line in the service port, and at the entrance to the cryostat vacuum vessel between the outer support cylinder and the supply line. Use good engineering practice and reasonable contingencies.

Risk Assessment After Implementation of Recommended Action

2-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Apr 7, 1992 Rev: 0 Attachments: YES_, NO_X_

Subsystem: Superconducting solenoid magnet, Chimney, service port, field joint - No. 2
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

Thermal acoustic oscillations in dead ended branch lines, such as relief valve inlet lines, entending from liquid helium lines to the ambient environment.

Risk Assessment Prior to any Abatement Strategy

3-A-1

Current Recommended Action

Use the standard practice of installing a check valve in the branch line to prevent helium oscillation in it.

Risk Assessment After Implementation of Recommended Action

3-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Apr 7, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Chimney, service port, field joint - No. 3
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

Thermal short between the superconducting leads and a thermal shield. This hazard can cause the superconductor to return to the resistive state and consequently cause the solenoid to quench.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Install the superconducting leads with reasonable clearance from the thermal shields. Inspect for proper installation during fabrication.

Risk Assessment After Implementation of Recommended Action

1-D-2

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Apr 7, 1992 Rev: 0 Attachments: YES_ NO X

Subsystem: Superconducting solenoid magnet, Chimney, service port, field joint - No. 4
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

Higher than expected heat load at stand-offs for the superconducting leads. This hazard can cause the superconductor to return to the resistive state and consequently cause the solenoid to quench.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Design the stand-offs using good engineering practice and reasonable contingencies. Inspect for proper dimensions before fabrication and for proper installation during fabrication.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Apr 7, 1992 Rev: 0 Attachments: YES_ NO X

Subsystem: Superconducting solenoid magnet, Chimney, service port, field joint - No. 5
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

Inadequate allowances for differential movements of the vacuum jacket, cryogen lines and the superconducting leads. The movements are caused by thermal contraction to cryogenic temperatures and by position adjustments of the calorimeter and the muon iron. Parts of the vacuum jacket can be cooled down to cryogenic temperature by a cryogen leak. This hazard can cause structural damage.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Design the vacuum jacket, cryogen lines and the superconducting leads with sufficient flexibility to accommodate the identifiable thermal and position differential movements. Use good engineering practice and reasonable contingencies.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Apr 7, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Chimney, service port, field joint - No. 6
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

Pressure drop of a vapor cooled lead is higher than expected for the desired flow rate. This hazard can cause inadequate cooling of the lead.

Risk Assessment Prior to any Abatement Strategy

2-A-1

Current Recommended Action

Specify and design the vapor cooled leads using good engineering practice and reasonable contingencies. Measure the pressure drop during fabrication to make sure it is acceptable.

Risk Assessment After Implementation of Recommended Action

2-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Apr 7, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Chimney, service port, field joint - No. 7
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

A vapor cooled lead loses cooling flow or is not cooled adequately. This hazard will destroy the lead.

Risk Assessment Prior to any Abatement Strategy

2-A-1

Current Recommended Action

Install an exhaust gas return line to the surface for each lead. Provide a sight flow indicator in each of the return lines (in addition to the non-indicating flow sensors used to obtain a flow signal for the control system) to have positive flow indication for each lead. Monitor voltage drop across each lead and fast dump the solenoid if the resistance of a lead increases above a defined trip point.

Risk Assessment After Implementation of Recommended Action

2-E-3

Remarks

Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

and Location | Date: Apr 7, 1992 Rev: 0 Attachments: YES_, NO_X.

Superconducting solenoid magnet, Chimney, service port, field joint - No. 8
Center of the SDC detector, between the central tracking chamber and the
alorimeter - See attachment A.

Phase

and steady-state operation.

escription

path for pressure relief and vacuum pumping is partially or fully blocked with
insulation (MLI). This hazard will restrict flow in the chimney and can lead to an
e condition in the cryostat vacuum vessel. This condition can be caused by poor
or by gas flow.

sment Prior to any Abatement Strategy

ecommended Action

installed MLI during fabrication. Install a cover sheet (polyester, nylon or other
round the MLI to secure it.

ssment After Implementation of Recommended Action

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Cold mass supports, No. 1
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

The off-balance forces have not been calculated properly. This hazard can lead to over-designed support rods that increase heat leak or under-designed supports subject to failure. Excessive heat load at a cold support block can cause the solenoid to quench. Failure of the supports causes the solenoid to be inoperative. A support consists of the rod, attachment blocks and end pieces to connect the rod ro the attachments blocks.

Risk Assessment Prior to any Abatement Strategy

1-A-1 for under-designed supports. 1-A-1 for over-designed supports if the heat leak causes the solenoid to quench, otherwise 1-E-1 for over-designed supports.

Current Recommended Action

Calculate the off-balance forces using good engineering practice. Verify calculations by predicting the results measured in existing systems or in tests. Define upper limit on the operating current. Measure the actual forces as the solenoid is energized for the first time.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Cold mass supports, No. 2
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

Support attachment to the outer support cylinder (cold), to the vacuum vessel (warm) and joints between the support rod and its end pieces are structurally inadequate, resulting in support failure under load.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Design the support rods and attachment blocks for the off-balance forces using good engineering practice and reasonable contingency. Follow applicable code/standard. Load test each type of support (radial and axial) to verify the design. Inspect the fabrication process to ensure conformance to the design specification.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_, NO_X_

Subsystem: Superconducting solenoid magnet, Cold mass supports, No. 3
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

Support failure. The solenoid can not operate with failed supports. The supports must be redesigned and the magnet must be shipped back to the vendor for support replacement.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Design the support rods and attachment blocks for the off-balance forces using good engineering practice and reasonable contingency. Follow applicable code/standard. Load test each type of support (radial and axial) to verify the design. Inspect the fabrication process to ensure compliance with the design specification.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Cold mass supports, No. 4
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

Actual support heat load exceeds the design value. This hazard can cause the solenoid to quench.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Calculate support heat leak using good engineering practice and reasonable design contingencies. Perform a heat leak test on each type of support (radial and axial) to verify the design. Inspect the fabrication process to ensure conformance to the design specification.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Cold mass supports, No. 5
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

Radiation damage to composite support elements that lead to structural failure of the support.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Calculate the level of nuclear radiation to which the supports will be subjected. Establish the service life of composite materials exposed to the design level of nuclear radiation for the design loads, using reasonable contingencies. Utilize existing data and perform tests if necessary.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_, NO_X_

Subsystem: Superconducting solenoid magnet, Cryostat vacuum shell, No. 1
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Fabrication testing of the cryostat vacuum vessel by itself, testing of the completed solenoid magnet, or normal operation.

Hazard Description

The outer vacuum shell, OVS, collapses when the solenoid is evacuated for testing or service.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Design, fabricate, inspect and test the OVS using good engineering practice, the appropriate code/standard, and reasonable contingencies and safety factors. Use recommended knock-down factors for designs not covered by code/standards, such as isogrid and honeycomb. Perform inspections during the fabrication process to ensure compliance to the design specifications.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Cryostat vacuum shell, No. 2
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Fabrication testing of the cryostat vacuum vessel by itself, testing of the completed solenoid magnet, or normal operation.

Hazard Description

The inner vacuum shell, IVS, collapses when the solenoid is pressurized for test or service.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Design, fabricate, inspect and test the IVS using good engineering practice, the appropriate code/standard, and reasonable contingencies and safety factors. Use recommended knock-down factors for designs not covered by code/standards, such as isogrid and honeycomb. Perform inspections during the fabrication process to ensure compliance to the design specifications.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Cryostat vacuum shell, No. 3
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Fabrication testing of the cryostat vacuum vessel by itself, testing of the completed solenoid magnet, or normal operation.

Hazard Description

The outer vacuum shell, OVS, fails when the solenoid is pressurized for test or service.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Design, fabricate, inspect and test the OVS using good engineering practice, the appropriate code/standard, and reasonable contingencies and safety factors. Use recommended knock-down factors for designs not covered by code/standards, such as isogrid and honeycomb. Perform inspections during the fabrication process to ensure compliance to the design specifications.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_, NO_X_

Subsystem: Superconducting solenoid magnet, Cryostat vacuum shell, No. 4
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Fabrication testing of the cryostat vacuum vessel by itself, testing of the completed solenoid magnet, or normal operation.

Hazard Description

The inner vacuum shell, IVS, fails when the solenoid is evacuated for test or service.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Design, fabricate, inspect and test the IVS using good engineering practice, the appropriate code/standard, and reasonable contingencies and safety factors. Use recommended knock-down factors for designs not covered by code/standards, such as isogrid and honeycomb. Perform inspections during the fabrication process to ensure compliance to the design specifications.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_. NO_X.

Subsystem: Superconducting solenoid magnet, Cryostat vacuum shell, No. 5
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Fabrication testing of the cryostat vacuum vessel by itself, testing of the completed solenoid magnet, or normal operation.

Hazard Description

The annular bulk heads fail when the solenoid is evacuated for testing or service.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Design, fabricate, inspect and test the annular bulk heads using good engineering practice, the appropriate code/standard, and reasonable contingencies and safety factors. Use recommended knock-down factors for designs not covered by code/standards, such as isogrid and honeycomb. Perform inspections during the fabrication process to ensure compliance to the design specifications.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Cryostat vacuum shell, No. 6
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Fabrication testing of the cryostat vacuum vessel by itself, testing of the completed solenoid magnet, or normal operation.

Hazard Description

The annular bulk heads fail when the solenoid is pressurized for testing or service.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Design, fabricate, inspect and test the annular bulk heads using good engineering practice, the appropriate code/standard, and reasonable contingencies and safety factors. Use recommended knock-down factors for designs not covered by code/standards, such as isogrid and honeycomb. Perform inspections during the fabrication process to ensure compliance to the design specifications.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Cryostat vacuum shell, No. 7
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Fabrication testing of the cryostat vacuum vessel by itself, testing of the completed solenoid magnet, or normal operation.

Hazard Description

Cover plates on the cryostat vacuum vessel fail when the solenoid is evacuated or pressurized for testing or service.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Design, fabricate, inspect and test the cover plates using good engineering practice, the appropriate code/standard, and reasonable contingencies and safety factors. Perform inspections during the fabrication process to ensure compliance to the design specifications. The cover plates are tested in their installed locations.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_, NO_X_

Subsystem: Superconducting solenoid magnet, Cryostat vacuum shell, No. 8
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Design, fabrication and testing.

Hazard Description

Both isogrid and honeycomb prove unsatisfactory for the outer vacuum shell, OVS.

Risk Assessment Prior to any Abatement Strategy

1-A-1 if the isogrid or honeycomb OVS is proven unsatisfactory after it is built; 3-C-3 if proven unsatisfactory during the design phase.

Current Recommended Action

Thoroughly study the isogrid and honeycomb OVS designs before fabrication. The study includes: design calculations by consultants and the SDC Solenoid Magnet Sub-Group, testing, and review of existing cylindrical structures and test data. Using solid plate for the OVS is a low risk alternative with respect to structural integrity.

Risk Assessment After Implementation of Recommended Action

1-A-1 decreases to 1-D-2.

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

ubsystem and Location | Date: Mar 18, 1992 Rev: 0 Attachments: YES_, NO_X_

ubsystem: Superconducting solenoid magnet, Cryostat vacuum shell, No. 9
ocation: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

perational Phase

esting and operation.

azard Description

ooldown of a small area on the outer or inner shell of the cryostat vacuum vessel to cryogenic emperature with a boiling liquid. There is a small probability that this hazard can result in a ocal failure of a shell which does not have a uniform cross sectional area.

isk Assessment Prior to any Abatement Strategy

-D-2

urrent Recommended Action

esign the outer and inner shells so cooldown of a local area with liquid cryogen will not cause failure. Route internal tubing runs to minimize the possibility of spraying liquid cryogen on e shells in the event of a tube rupture.

isk Assessment After Implementation of Recommended Action

-E-3

emarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: April 9, 1992 Rev: 0 Attachments: YES__ NO_X_

Subsystem: Superconducting solenoid magnet, Instrumentation - No. 1
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Test at vendor and test or service at the SSCL.

Hazard Description

Instrumentation failure and excessive sensor drift (for sensors that can not be removed and recalibrated or replaced). This hazard can lead to operational and diagnostic problems because needed data is not available.

Risk Assessment Prior to any Abatement Strategy

1-B-1

Current Recommended Action

Provide redundant sensors for critical measurements and monitor enough locations so that losing data from the sensors in several locations will not impede operation.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: April 9, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Instrumentation - No. 2
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Test at vendor and test or service at the SSCL.

Hazard Description

Open voltage tap. This hazard reduces the level of protection provided by the quench detection circuit.

Risk Assessment Prior to any Abatement Strategy

1-C-1

Current Recommended Action

Provide redundant taps and monitor enough locations so that losing the taps at one location will not impede operation.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: April 9, 1992 Rev: 0 Attachments: YES_, NO_X_

Subsystem: Superconducting solenoid magnet, Instrumentation - No. 3
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Test at vendor and test or service at the SSCL.

Hazard Description

The leads for temperature sensors are not adequately heat sunk. The hazard causes inaccurate temperature measurements.

Risk Assessment Prior to any Abatement Strategy

1-C-1

Current Recommended Action

Follow the standard practice for heat sinking the leads of temperature sensors. Inspect final installation during fabrication.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: April 9, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Instrumentation - No. 4
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Test at vendor and test or service at the SSCL.

Hazard Description

The instrumentation leads cause an 80 K to 4.5 K thermal short. This hazard can increase the heat load on a small area of the support cylinder and cause the solenoid to quench because cooling is not sufficient for the increased heat load.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Inspect installation during fabrication to minimize the probability of thermal shorts developing during final assembly.

Risk Assessment After Implementation of Recommended Action

1-D-2

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES__ NO_X_

Subsystem: Superconducting solenoid magnet, Outer support cylinder/coil - No. 1
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

The outer support cylinder is not cooled adequately. Inadequate cooling causes the coil or a small section of the coil (at an intercept for example) to operate at a temperature higher than the design value. This hazard can cause the solenoid to quench. Inadequate cooling can be caused by heat loads which exceed the design values (due to thermal shorts, incorrect intercept placement, poor insulation installation, e.g., black cracks and compression), by deficiencies in the cooling circuit (e.g., flow rate, quality, temperature, incorrect tube size/spacing/route/welded contact area), and incorrect intercept heat transfer surface area/strap size/thermal contact resistance, and insufficient shield thickness.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Design the cooling circuit (tube and intercepts) for the outer support cylinder using good engineering practice and reasonable contingencies. Inspect for proper MLI installation and for thermal shorts during fabrication and assembly. Check operating temperatures.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_ NO X

Subsystem: Superconducting solenoid magnet, Outer support cylinder/coil - No. 2
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

Wall thickness for the cooling tube on the outer support cylinder is inadequate for the maximum pressure generated during a quench. This hazard can cause the cooling tube to rupture.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Calculate the peak pressure during a quench by using published methods and by doing independent calculations. Verify calculations by comparing the results with test data. Calculate the cooling tube wall thickness using good engineering practice, the appropriate code/standard and reasonable contingencies. Pressure test the tubing during fabrication.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Outer support cylinder/coil - No. 3
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

Inadequate cooling of the inside surface of the solenoid. Thermal radiation is a normal heat load on this surface. Gas conduction is minimized and solid conduction (thermal shorts) must not occur. This hazard can cause the solenoid to quench.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Follow good engineering practice and use reasonable contingencies to calculate the heat transfer from the inside surface to the helium cooling tube. Operate at the vacuum required to minimize gas conduction. Design to eliminate solid conduction.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_, NO_X_

Subsystem: Superconducting solenoid magnet, Outer support cylinder/coil - No. 4
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

The multilayer insulation (MLI) used to insulate the cold mass is inadequate or improperly applied. Inadequate or improperly applied MLI increases the heat load on the helium cooling circuit above the design value. This hazard can cause the solenoid to quench.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Follow established practices for installing MLI and use reasonable contingency in the insulation heat load calculation.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: April 9, 1992 Rev: 0 Attachments: YES__ NO_X_

Subsystem: Superconducting solenoid magnet, Relief devices - No. 1
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Test at the vendor and test or service at the SSCL.

Hazard Description

Inadequate pressure relief capacity for the vacuum environment in the solenoid system. Inadequacies include a chimney which is not large enough for the identifiable flows (causes too much pressure drop), incorrect set/opening pressure for the relief device and high back pressure in discharge lines/headers. Sufficient pressure relief capacity is required to protect the solenoid system from an unacceptably high overpressure condition caused by a cryogen tube rupture or vaporization of an accumulation of solid air. This hazard can cause failure of the cryostat vacuum vessel.

Risk Assessment Prior to any Abatement Strategy

1-C-1

Current Recommended Action

Design the pressure relief system using good engineering practice and reasonable contingencies. Provide a low resistance flow path in the chimney so vapor can vent from the cryostat vacuum vessel to the relief device on the service port with a small pressure drop. Check relief device set point.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: April 9, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Relief devices - No. 2
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Test at the vendor and test or service at the SSCL.

Hazard Description

Inadequate pressure relief capacity for the cryogen lines in the solenoid system. Inadequacies include relief valves and inlet lines which are not large enough for the identifiable flows, relief valves with incorrect set/opening pressures and high back pressure in discharge lines/headers. Sufficient pressure relief capacity is required to protect the lines from an unacceptably high overpressure condition. This hazard can cause failure of a cryogen line.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Design the pressure relief system using good engineering practice and reasonable contingencies. Conduct safety reviews to ensure the system has relief devices where needed. Inspect fabrication and site construction work to verify all relief devices are properly installed. Check relief device set points.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: April 9, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Relief devices - No. 3
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Test at the vendor and test or service at the SSCL.

Hazard Description

Trapped volume relief valves are omitted in cryogen lines. This hazard can cause failure of a line with a trapped volume of cryogen liquid.

Risk Assessment Prior to any Abatement Strategy

1-B-1

Current Recommended Action

Conduct safety reviews to ensure the system has relief devices where needed. Inspect fabrication and site construction work to verify all relief devices are properly installed. Check relief device set points.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: April 9, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Relief devices - No. 4
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Test at the vendor and test or service at the SSCL.

Hazard Description

A relief device fails to open at the set pressure. This hazard can cause an overpressure condition in the protected component.

Risk Assessment Prior to any Abatement Strategy

1-D-2

Current Recommended Action

Use quality relief devices with proven performance. Check the set pressure of all relief devices using gas pressure (opens the relief device) on a periodic basis and adjust it to the proper value.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: April 9, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Relief devices - No. 5
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Test at the vendor and test or service at the SSCL.

Hazard Description

A relief device fails to reseat after opening. For the cryogen lines, this hazard can cause loss of cryogens during operation or an air leak during pumpout. For the solenoid system vacuum environment, it can cause an air leak which prevents establishing the insulating vacuum or it can result in a solid air accumulation.

Risk Assessment Prior to any Abatement Strategy

3-B-2

Current Recommended Action

Install relief devices so they are readily accessible for inspection and repair.

Risk Assessment After Implementation of Recommended Action

3-D-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: April 9, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Relief devices - No. 6
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Service at the SSCL.

Hazard Description

Cold fluid discharge, due to either process relieving conditions or leakage, from a relief device contacts and damages a component not suitable for exposure to cryogenic temperature.

Risk Assessment Prior to any Abatement Strategy

3-B-2

Current Recommended Action

Protect all components from relief valve discharges. This is accomplished by selecting good locations for relief devices, using discharge lines/manifolds and shielding nearby components.

Risk Assessment After Implementation of Recommended Action

3-D-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_, NO_X_

Subsystem: Superconducting solenoid magnet, Thermal intercepts and shields - No. 1
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

The thermal intercepts and shields are not cooled adequately. Inadequate cooling causes these components to operate at temperatures higher than design values and results in higher heat loads for the helium cooling circuit. This hazard can cause the solenoid to quench. Inadequate cooling can be caused by heat loads which exceed the design values (due to thermal shorts, incorrect intercept placement, poor insulation installation, e.g., black cracks and compression), by deficiencies in the cooling circuit (e.g., flow rate, quality, temperature, incorrect tube size/spacing/route/welded contact area), incorrect intercept heat transfer surface area/strap size/thermal contact resistance, and insufficient shield thickness.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Design the thermal intercepts and shields using good engineering practice and reasonable contingencies. Inspect for proper MLI installation and for thermal shorts during fabrication and assembly. Measure the heat leak to the liquid helium circuit and to the thermal shield, and check operating temperatures.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Thermal intercepts and shields - No. 2
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

Failure to break circumferential electrical circuit in the thermal shields. Eddy current heating will occur in the metallic thermal shields when the magnetic field changes if a longitudinal electrical break is not provided. It is a heat load that can be eliminated.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Use the standard practice of installing a longitudinal electrical break to prevent the voltage induced during charging from producing eddy currents in the circumferential direction.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_ NO X

Subsystem: Superconducting solenoid magnet, Thermal intercepts and shields - No. 3
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Energizing and steady-state operation.

Hazard Description

The cooling tube wall thickness for the thermal intercepts and shields is inadequate for the operating pressure. This hazard can cause the cooling tube to rupture.

Risk Assessment Prior to any Abatement Strategy

1-A-1

Current Recommended Action

Calculate the cooling tube wall thickness using good engineering practice, the appropriate code/standard and reasonable contingencies. Pressure test the tubing during fabrication.

Risk Assessment After Implementation of Recommended Action

1-E-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_. NO_X.

Subsystem: Superconducting solenoid magnet, Vacuum - No. 1
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Fabrication.

Hazard Description

Leaks in the cryogen piping (notably the aluminum-to-stainless steel transition pieces), liquid helium reservoir or ceramic electrical feedthroughs for the superconducting leads, or air leaks in the cryostat vacuum vessel, chimney or service port. Leaks are a hazard because they spoil the insulating vacuum and consequently cause the solenoid to be inoperative.

Risk Assessment Prior to any Abatement Strategy

2-B-1

Current Recommended Action

Helium leak check all components following standard practice. Repair all leaks.

Risk Assessment After Implementation of Recommended Action

2-D-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_, NO_X_

Subsystem: Superconducting solenoid magnet, Vacuum - No. 2
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Test at vendor.

Hazard Description

Leaks in the cryogen piping (notably the aluminum-to-stainless steel transition pieces), liquid helium reservoir or ceramic electrical feedthroughs for the superconducting leads, or air leaks in the cryostat vacuum vessel, chimney or service port. Leaks are a hazard because they spoil the insulating vacuum and consequently cause the solenoid to be inoperative.

Risk Assessment Prior to any Abatement Strategy

2-B-1

Current Recommended Action

Helium leak check all components following standard practice during fabrication. Repair all leaks before final assembly. Disassemble the magnet to repair leaks if necessary.

Risk Assessment After Implementation of Recommended Action

2-D-3

Remarks

SDC Detector - Conceptual Safety Assessment Form - SSCL Physics Research Division

Subsystem and Location	Date: Mar 18, 1992 Rev: 0 Attachments: YES_ NO_X_

Subsystem: Superconducting solenoid magnet, Vacuum - No. 3
Location: Center of the SDC detector, between the central tracking chamber and the calorimeter - See attachment A.

Operational Phase

Test or service at the SSCL.

Hazard Description

Leaks in the cryogen piping (notably the aluminum-to-stainless steel transition pieces), liquid helium reservoir or ceramic electrical feedthroughs for the superconducting leads, or air leaks in the cryostat vacuum vessel, chimney or service port. Leaks are a hazard because they spoil the insulating vacuum and consequently cause the solenoid to be inoperative.

Risk Assessment Prior to any Abatement Strategy

1-C-1

Current Recommended Action

Helium leak check all components following standard practice during fabrication. Repair all leaks before final assembly. Disassemble the magnet, if necessary, to repair leaks at the vendor's plant before initial shipment. Install a vacuum pump on the service port to maintain insulating vaccum in the event of a small leak. Repair leaks that can be reached through access openings, or by disassembling the service port or chimney at the SSCL. Return the magnet to the vendor for the repair of inaccessible leaks.

Risk Assessment After Implementation of Recommended Action

1-D-2 for a small leak that can be handled by the vacuum pump; 1-C-1 for larger leaks.

Remarks