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Failure Mode Effects Analysis for the RHIC Cryogenic Distribution System First Sextant Test Configuration

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December 1996

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U.S. Department of Energy
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AD/RHIC/RD–108

RHIC PROJECT

Brookhaven National Laboratory

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Abstract

The RHIC Cryogenic Distribution System previously has been analyzed and documented in the RHIC Cryogenic System Safety Analysis Report, September 6, 1994 and the RHIC SAD. These reports address the Cryogenic Distribution System for the completed Collider. The Collider is not completed for the First Sextant Test, thus the Cryogenic Distribution System must be modified for the First Sextant Test. Additionally, some components were not identified or designed at the time of the original report, and could not be analyzed. Finally, some minor modifications have been made to the configuration originally analyzed in 1994. This report specifically addresses all of the differences in the Cryogenic Distribution System configuration for the RHIC First Sextant Test, and updates the analysis of those components whose design has been finalized or changed from the originally analyzed configuration.

Background

RHIC Cryogenic System Description

The Cryogenic System and its operation are best described by the Process and Instrumentation Drawings (P&IDs). If one is unfamiliar with the RHIC Cryogenic System it would be useful to read the first three pages of the Cryogenic Section of the RHIC Design Manual before starting with the P&IDs. The Overall System Block Diagram, RD3A995006 refers to the other major drawings and depicts their relative positions in the system. Keeping in mind the functions described in the Design Manual, one can follow the flow paths through the P&IDs.

The details of the design for each of the major subsystems are contained in the Final Design Report for that subsystem. These reports document the design criteria, a summary of the design features, procurement/fabrication plans, testing and installation plans, pre-operations testing plans and a summary of all pertinent documentation for the subsystem. The Final Design Report(s) for each subsystem will be part of the QA file which is retained for the life of the accelerator.

Refrigeration for providing 4 Kelvin supercritical helium gas required for RHIC is produced by a 25 kW Helium Refrigerator. The helium is distributed by means of piping and valve boxes, both of which are vacuum jacketed, plus ancillary warm piping and valves. This system carries the helium to and from the Cryogenic Building, passing out-of-doors into the valves boxes located in a Service Building located at 6 o'clock, which are the primary interface points to the

superconducting magnets. The cryogenic loop for the completed Collider continues through the magnets and the five remaining Service Buildings located near the Experimental Areas around the Collider.

The Service Buildings are metal frame, pre-engineered structures. The volume of these buildings varies from 75,000 to 113,000 cubic feet. All Service Buildings contain the same types of equipment, specifically the power supplies for the Collider magnets and two cryogenic valve boxes with the piping to connect them to the ring. Each building has a different mix of power supplies and cryogenic equipment. The volume of air flow in the roof fan design for cooling and venting is chosen to meet the local requirements of each building, and to maintain a RHIC Oxygen Deficiency Hazard (ODH) Class 0 classification for personnel. Each building also contains a computer room. This room is completely partitioned off by a 1 hour fire rated enclosure from the remainder of the building and is air conditioned with air drawn from outside the building.

The Cryogenic System mechanical design was governed by the ASME Pressure Vessel Code, Section VIII and the ASME Refinery Piping Code, B31.3. Design, fabrication and testing was performed in accordance with these codes. Proprietary computer codes were used for stress calculations to aid design compliance with the codes. All stress calculations, typically part of the cognizant engineer's responsibility, have an independent engineering check as part of the Collider Ring Division QA program.

Where vessels or piping are to operate at cryogenic temperatures the material used is chosen to retain ductility at cryogenic temperatures. Cracks or other flaws which might somehow be initiated do not propagate to catastrophic size because of the material ductility and because even a small leak is soon evident when the insulating vacuum fails and causes a large increase in the heat load, possibly resulting in an aborted run. The heat load would increase by a factor of about two when the vacuum spoils from 1×10^{-4} to 3×10^{-3} Torr.

All pressure vessels and pressure piping have been pressure checked in conformance with the relevant code requirements. Table 3-8 in the RHIC Design Manual gives the pressure ratings of the major subsystems. Because many of the vessels and piping have vacuum insulating systems, the maximum design working pressure in every case, where it is applicable, takes into account this extra loading. The heat exchangers in the refrigerator, pressure vessels in the Main Compressor System and some of the other seminal equipment have been hydrostatically tested to 150% of the design pressure. The other equipment has been pneumatically pressure tested to 125% of the design pressure. The piping has been pneumatically tested to 110% of the design pressure in accordance with ASME B31.3.

Previous Cryogenic System Reviews and Analyses

In addition to the review process required by the QA program and routine DOE Project Reviews, the Cryogenic System was the subject of two other significant reviews. In March 1992, an external committee, the *RHIC Cryogenic System Technical Review*, reviewed the conceptual design of the system. Their comments were factored into the design. The committee who conducted the *Independent Safety Review of RHIC* (December 2-3, 1992) also included the Cryogenic System in its deliberations.

The Project policy for the safety review of cryogenic systems is contained in RHIC SEAPPM 5.2.1. The P&IDs and the Active Components List were the basis for a Failure Modes and Effects Analysis (FMEA) which was completed for this system and documented in the RHIC Cryogenic System Safety Analysis Report, September 6, 1994 and the RHIC SAD. These analyses lists the identified hazards which may result from the failure of each item of equipment in the system and assesses the risk of that event. Where this analysis resulted in action items recommended to eliminate or control the hazard, these actions have been incorporated into the design.

The original FMEA was performed in conjunction with the design effort for the Cryogenic System Valve Boxes. The Cryogenic System Valve Boxes are the centralized controls for the distribution of cryogen at the end of each sextant. At the 6 o'clock junction, the Cryogenic System Valve Box functions were expanded to include the interface between the RHIC Refrigerator and the Collider Ring and to include the ring helium circulators. The system makes extensive use of remotely operated valves which may be controlled from the Cryogenic System Main Control Room. These valves are air-operated via solenoid controls, with the de-energized state relying upon spring force for motive power. Thus, an initial de-energized state was assigned in order to conduct the initial analysis. Once RHIC commences operation, the Cryogenic System should operate in the cold state for a majority of the year, with, at most, annual shut-downs for maintenance. The initial valve state was chosen such that failures of the valves will not cause an interruption of Collider operations, where possible, but ring operation is sacrificed if a failure mode will adversely affect refrigerator operation.

The original design and analysis effort included a review of the helium recovery system to determine its adequacy during a power failure. The result was a modification of the piping around the Thermax heaters, thus allowing the direction of cold helium escaping from a warming sextant to warm storage. This modification system permits recovery of cold gas to warm storage by pressure equalization alone.

Cryogenic System Hazards

There are two primary hazards to personnel posed by the Cryogenic Distribution System. One hazard is the pressure piping which has a maximum working pressure of 275 psi. Pressure relief valves and rupture disks protect the system from exceeding this pressure. All major piping was analyzed to the requirements of ANSI B31.1, Power Piping requirements. The vessels are built in accordance with the ASME Pressure Vessel Code, Section VIII. Interfaces between components and process piping are welded wherever possible. Flanged connections, where required, use o-ring seals. All piping subject to thermal cycling has been stress-analyzed. All design and testing accomplishments assure that pressure vessel failure will not occur for all phases of operation of the Cryogenic System.

The second hazard is the Oxygen Deficiency Hazard (ODH) posed by uncontrolled release of helium. Dual sensors to detect an ODH condition in the Service or Support Buildings that house valve boxes shall be operating when helium is present in them. The sensors are located at the highest point of the sloped building ceiling. In the event of a release of helium, the fixed oxygen deficiency sensors will alarm to indicate a low oxygen level (18%). The outputs of the building

sensors respond locally with audible alarms and warning lights, as well to the PASS System that controls access gates and emergency ventilation. The PASS System also provides annunciation of the alarms in the Cryogenic and Main Control Rooms. The buildings are equipped with an automatic emergency ventilation system that activates with the ODH alarm.

First Sextant Test Cryogenic Distribution System Modifications

The Cryogenic Distribution System for the RHIC First Sextant Test consists of the Sextant 5 Blue and Yellow Magnet Systems between D0 magnets, with the 4 o'clock and 6 o'clock valve boxes on each end. The valve boxes are capped on the output sides intended to go to Sextants 3 and 7. Similarly, ambient temperature return piping is capped at the 4 o'clock and 6 o'clock ends. The Magnet circulation loop is accomplished in each ring by routing magnet flow from the magnet lines in the 4 o'clock valve box to the Utility line, back through the Utility lines in the magnet enclosures to the 6 o'clock valve boxes, where the magnet flow is directed back to the Magnet line upstream of the lead pots. Heat shield flow is common for the entire First Sextant Test configuration. Primary flow enters the 6 o'clock Yellow valve box and flows through the Yellow Sextant 5 magnet enclosure into the 4 o'clock Yellow valve box. Flow is then jumpered to the 4 o'clock Blue valve box via the two inch manual valve ports for the evacuation header. Heat shield return flow is then routed from the 4 o'clock Blue valve box, through the Blue Sextant 5 magnet enclosure into the 6 o'clock Blue valve box, where it is returned to the refrigerator. Cooling of the 6 o'clock Blue valve box heat shield is accomplished by a small flow through the 6 o'clock Blue valve box heat shield modulating valve directly to the heat shield return.

Procedure

The object of a Failure Mode Effects Analysis is to identify all possible modes of failure within a system or sub-system design so that the resultant effects can be eliminated at the earliest possible time. The system must remain safe for all reasonable postulated equipment failures or operator errors. The analysis is used to assess existing high risk items and the systems or sub-systems in the design stage. The analysis will then provide us with the information needed to minimize hazardous effects due to component failure. To provide assurance that all of the subsystems of the RHIC cryogenic system were covered, the analysis was carried out in concert with the design effort for the First Sextant Test. The end result of an FMEA is increased reliability and safety.

This FMEA is intended to cover the RHIC Cryogenic Distribution System and components as configured for the First Sextant Test. The broad categories included in this analysis are the cold helium distribution system associated with the ring magnets, including the cryogenic valves, relief valves, check valves, vacuum valves, temperature sensors, pressure sensors, liquid level sensors, filters, interlocks, and circulators. Systems that are not a direct part of the Cryogenic System, i.e. magnet power supplies, quench protection devices, etc. are outside the scope of this FMEA

The failure of a component of a subsystem, causing a complete failure of the subsystem, would be viewed as a component failure of the system. For example, a vacuum failure of one of the valve

boxes would be viewed as a failure of the valve box for the system FMEA. This FMEA reviewed the failure modes and effects of a component failure in subsystems, and in addition studied the effect of total failure modes of the subsystems and their effect on the Cryogenic system as a whole.

The FMEA is component orientated. Each component of the system was reviewed for each possible failed state to evaluate its possible safety consequences to the system. For this analysis, the following P&IDs were used:

- 6:00 Blue Ring P&ID 3A995086F, Check Print October 16, 1996
- 6:00 Yellow Ring P&ID 3A995066F, Check Print October 16, 1996
- 4:00 Blue Ring P&ID 3A995084E, Check Print October 16, 1996
- 4:00 Yellow Ring P&ID 3A995064E, Check Print October 16, 1996

A safety analysis work sheet was used as a record of the specific failures. The work sheets included information on system or subsystem modes in order to evaluate the components effect as a function of mode. The work sheets contain specific information as follows:

- The description of failure.
- The effect of this failure on the system.
- The means for failure detection.

The general procedure for the analysis was:

- Identify the major systems and subsystems that in an event of failure will greatly affect the operation of the cryogenic system or could present a hazardous situation to personnel.
- Determine potential failure modes of equipment and systems.
- Review or establish operating procedures so that mode dependency can be established.
- Study and list each component in the analysis work sheets and enter all required information.

The results were compiled into a data base which combined similar failure mode effects to make a more manageable report. This report is provided in Appendix A.

Results and Discussion

There were 88 functionally-distinct categories for 708 components that were analyzed. There are no single-point failures which would result in personal injury or major system damage. There were 26 functional categories of components which would restrict or inhibit cryogen flow or increase heat leak to a point that, for a worst case situation, the magnets would be insufficiently cooled and may quench. Four of these categories are prevented by forcing the valve to the desirable state — in two categories, the valves are locked open, and in another two categories the valve operators are dome-loaded closed. Additionally, all magnets will have a quench protection system which will de-energize power supplies and activate an energy absorbing system, and the RHIC magnets all are capable of absorbing their own energy without the potential for damage. Pressure transducers for the Cryogenic System had not been defined at the time of the initial analysis, but design criteria was established that all transducers shall have a capacity at least equal to the Cryogenic System design pressure of 275 psi. The transducers have been procured and

installed, and all are rated for 300 psia. Nine functional categories of components have the potential for loss of helium gas inventory. This worst case assumes no intervention. However, a sizable gas leak would be readily detected by Cryogenic System operators, and there are sufficient controls remaining intact to prevent a significant loss of inventory.

Three functional categories of components may affect the speed of the cryogenic circulators. The speed control software incorporates several independent overspeed detection methods and two circuits to prevent electrical overspeed of the circulator. Three more functional categories of failures will result in loss of lead cooling flow. The power supplies monitor voltage and will de-energize upon sensing a harmful increase in lead resistance. Finally, a single category of components, a relief valve, could result in a failure of piping or adjacent components which may carry cryogen. The relief valve protects the volume between two valves which interconnect adjacent process lines. The relief valve provides overpressure protection for the case where this small volume is closed while cold, then subjected to warming. However, one of the valve pairs is normally open, thereby venting the volume to a process line. The volume also includes pressure sensing, providing detection for the increasing pressure. Further, this event can only occur when the volume is filled with cryogen, then warmed. Again, the volume will normally be open during warm-up to release this gas. The valves and the volume reside inside the valve box vacuum tank which will provide containment in the event of bursting. There is no hazard from helium release because of the small volume involved.

APPENDIX A

Failure Mode Effects Analysis

for the

RHIC Cryogenic Distribution System

First Sextant Test Configuration

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Date: Friday, December 20, 1996

Item: 1

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Contaminants may cause valves downstream of affected filter to leak.	Minor helium leak. Minor increase in refrigerator output.
Clogged	No flow. Heat shield temperature increase with magnet temperature rise and subsequent magnet quench. Filter will collapse and fail at low Delta P. See Open. Pump & Purge will minimize condensables.	Elevated pressure/temperature. Temperature indicators and Magnet quench.

Affected Components:

Component #	Ring	Box	Nomenclature
F4469H	B	4	FILTER H 6
F4474H	B	4	FILTER H 2
F4616H	B	6	FILTER H 4
F6425H	Y	4	FILTER H 6
F6430H	Y	4	FILTER H 2
F6753H	Y	6	FILTER H 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 2

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Contaminants may cause valves downstream of affected filter to leak. Short/open on Magnet electrical circuits. Circulator failure.	Minor helium leak. Minor increase in refrigerator output.
Clogged	No flow. Magnet temperature rise and subsequent magnet quench. Filter will collapse and fail at low Delta P. See Open. Pump & Purge will minimize condensables.	Elevated pressure/temperature. Temperature indicators and Magnet quench.

Affected Components:

Component #	Ring	Box	Nomenclature
F4467H	B	4	FILTER M 6
F4470H	B	4	FILTER U 6
F4609H	B	6	FILTER M 8
F4614H	B	6	FILTER M 4
F4617H	B	6	FILTER U 4
F6423H	Y	4	FILTER M 6
F6426H	Y	4	FILTER U 6
F6746H	Y	6	FILTER M 8
F6751H	Y	6	FILTER M 4
F6754H	Y	6	FILTER U 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 3

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Contaminants may cause valves downstream of affected filter to leak.	Minor helium leak. Minor increase in refrigerator output.
Clogged	Increased pressure drop may reduce flow. Utility Line provides alternate path. Recooler temperature increase with Magnet temperature rise and magnet quench. Filter will collapse and fail at low Delta P. See Open. Pump & Purge will minimize condensables.	Elevated pressure/temperature. Temperature indicators and Magnet quench.

Affected Components:

Component #	Ring	Box	Nomenclature
F4471H	B	4	FILTER R 6
F4618H	B	6	FILTER R 4
F6427H	Y	4	FILTER R 6
F6755H	Y	6	FILTER R 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 4

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Contaminants may cause valves downstream of affected filter to leak.	Minor helium leak. Minor increase in refrigerator output.
Clogged	Possible minor increase in heat load in 4 o'clock valve box. Minor increased refrigerator load.	Low level indication in 4 o'clock recooler. Elevated temperature indication.

Affected Components:

Component #	Ring	Box	Nomenclature
F4468H	B	4	FILTER S 6
F4615H	B	6	FILTER S 4
F6424H	Y	4	FILTER S 6
F6752H	Y	6	FILTER S 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Date: Friday, December 20, 1996

Item: 5

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Increased refrigerator demand. Refrigerator imbalance caused by unmodulated Supply gas going into Return. Refrigerator shutoff from ring.	Normally closed valve. Increasing liquid level. Increased refrigerator load.
Closed	Possible minor increase in heat load in valve box, minor increase in refrigerator load.	Normally closed valve. Low level indication. Elevated temperature indication.

Affected Components:

Component #	Ring	Box	Nomenclature
H4409A	B	4	J T 225watt RECOOLER
H6451A	Y	4	J T 225watt RECOOLER

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 6

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Normally open valve. Visual detection. Normal operations.
Closed	Possible minor increase in heat load in valve box, minor increase in refrigerator load. Valve locked in open position.	Normally open valve. Visual detection. Low level indication. Elevated temperature indication.

Affected Components:

Component #	Ring	Box	Nomenclature
H4401A L	B	4	ISOLATION S
H4501A L	B	6	ISOLATION S 4
H6401A L	Y	4	ISOLATION S
H6601A L	Y	6	ISOLATION S 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 7

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Normally open valve. Visual detection. Normal operations.
Closed	No impact. Line downstream is capped. Line open to leadpot upstream via superconductor bus, protected by relief valve. Valve locked in open position.	Normally open valve. Visual detection. Valve locked in open position.

Affected Components:

Component #	Ring	Box	Nomenclature
H4400A L	B	4	ISOLATION M
H6400A L	Y	4	ISOLATION M

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 8

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Normally open valve. Visual detection. Normal operations.
Closed	Potential for cold gas in closed volume. Protected by relief valve. May be relieved by other valve operation. Valve locked in open position.	Normally open valve. Visual detection. Elevated pressure indication.

Affected Components:

Component #	Ring	Box	Nomenclature
H4403A L	B	4	ISOLATION U
H6403A L	Y	4	ISOLATION U

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Date: Friday, December 20, 1996

Item: 9

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position. Valve locked in open position.	Normally open valve. Visual detection. Normal operations.
Closed	Recooler return blocked. Increased recooler pressure vaporizes bath. Gas warms and pressurizes Supply line. Valve locked in open position.	Normally open valve. Visual detection. Decreasing liquid level indication. Elevated temperature/pressure indication.

Affected Components:

Component #	Ring	Box	Nomenclature
H4404A L	B	4	ISOLATION R
H6404A L	Y	4	ISOLATION R

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 10

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Contaminants may cause valves upstream of affected filter to leak. Unlikely due to no flow on capped end of line.	Minor internal helium leak. Minor increase in refrigerator output.
Clogged	Potential for cold gas in closed volume. Protected by relief valve. May be vented manually. Unlikely due to no flow on capped end of line.	Elevated/inconsistent pressure.

Affected Components:

Component #	Ring	Box	Nomenclature
F4473H	B	4	FILTER S 2
F4475H	B	4	FILTER U 2
F4476H	B	4	FILTER R 2
F4610H	B	6	FILTER S 8
F4611H	B	6	FILTER H 8
F4612H	B	6	FILTER U 8
F4613H	B	6	FILTER R 8
F6429H	Y	4	FILTER S 2
F6431H	Y	4	FILTER U 2
F6432H	Y	4	FILTER R 2
F6747H	Y	6	FILTER S 8
F6748H	Y	6	FILTER H 8
F6749H	Y	6	FILTER U 8
F6750H	Y	6	FILTER R 8

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 11

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
N/A	No longer a separate component. Integrated with lead control.	

Affected Components:

Component #	Ring	Box	Nomenclature
FE4000H	Y	6	FLOW CONTROL ELEMENT 9
FE4001H	Y	6	FLOW CONTROL ELEMENT 8
FE4002H	Y	6	FLOW CONTROL ELEMENT 7
FE4003H	Y	6	FLOW CONTROL ELEMENT 6
FE4005H	B	6	FLOW CONTROL ELEMENT 11
FE4006H	B	6	FLOW CONTROL ELEMENT 10
FE4007H	B	6	FLOW CONTROL ELEMENT 9
FE4008H	B	6	FLOW CONTROL ELEMENT 8
FE4009H	B	6	FLOW CONTROL ELEMENT 7
FE4012H	B	6	FLOW CONTROL ELEMENT 6
FE4013H	Y	6	FLOW CONTROL ELEMENT 5
FE4014H	Y	6	FLOW CONTROL ELEMENT 4
FE4015H	Y	6	FLOW CONTROL ELEMENT 2
FE4016H	Y	6	FLOW CONTROL ELEMENT 1
FE4017H	Y	6	FLOW CONTROL ELEMENT 10
FE4080H	B	6	FLOW CONTROL ELEMENT 5
FE4081H	B	6	FLOW CONTROL ELEMENT 4
FE4082H	B	6	FLOW CONTROL ELEMENT 3
FE4083H	B	6	FLOW CONTROL ELEMENT 2
FE4084H	B	6	FLOW CONTROL ELEMENT 1
FE4465H	B	4	FLOW CONTROL ELEMENT B10
FE4466H	B	4	FLOW CONTROL ELEMENT B9
FE4467H	B	4	FLOW CONTROL ELEMENT B8
FE4468H	B	4	FLOW CONTROL ELEMENT B7
FE4469H	B	4	FLOW CONTROL ELEMENT B6
FE4470H	B	4	FLOW CONTROL ELEMENT A11
FE4471H	B	4	FLOW CONTROL ELEMENT A9
FE4472H	B	4	FLOW CONTROL ELEMENT A8
FE4473H	B	4	FLOW CONTROL ELEMENT A6
FE4474H	B	4	FLOW CONTROL ELEMENT A5
FE4475H	B	4	FLOW CONTROL ELEMENT A4
FE4476H	B	4	FLOW CONTROL ELEMENT A2
FE4477H	B	4	FLOW CONTROL ELEMENT A1
FE6465H	Y	4	FLOW CONTROL ELEMENT 10
FE6466H	Y	4	FLOW CONTROL ELEMENT 9

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Component #	Ring	Box	Nomenclature
FE6467H	Y	4	FLOW CONTROL ELEMENT 8
FE6468H	Y	4	FLOW CONTROL ELEMENT 7
FE6469H	Y	4	FLOW CONTROL ELEMENT 6
FE6470H	Y	4	FLOW CONTROL ELEMENT 5
FE6471H	Y	4	FLOW CONTROL ELEMENT 4
FE6472H	Y	4	FLOW CONTROL ELEMENT 3
FE6473H	Y	4	FLOW CONTROL ELEMENT 2
FE6474H	Y	4	FLOW CONTROL ELEMENT 1
FE6475H	Y	4	FLOW CONTROL ELEMENT 11
SPARE1	Y	6	FLOW CONTROL ELEMENT 11
SPARE3	B	4	FLOW CONTROL ELEMENT B11

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 12

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
None	Shaped pipe. Has no normally anticipated failure modes.	

Affected Components:

Component #	Ring	Box	Nomenclature
FE4010H	Y	6	VENTURI FLOW 200 g/sec He @ 4k
FE4011H	B	6	VENTURI FLOW 200 g/sec He @ 4k

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 13

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Continuous lead flow. Increased refrigerator heat load.	Minor helium leak. Minor increase in refrigerator output.
Closed	No lead cooling. Power supply shutdown by voltage monitoring circuit.	Power supply shutdown or elevated lead voltage.

Affected Components:

Component #	Ring	Box	Nomenclature
H4455E	B	4	LEAD CONTROL B10
H4456E	B	4	LEAD CONTROL B9
H4458E	B	4	LEAD CONTROL B7
H4459E	B	4	LEAD CONTROL B6
H4461E	B	4	LEAD CONTROL A9
H4466E	B	4	LEAD CONTROL A5
H4467E	B	4	LEAD CONTROL A4
H4469E	B	4	LEAD CONTROL A1
H4514E	B	6	LEAD CONTROL 10
H4518E	B	6	LEAD CONTROL 9
H4523E	B	6	LEAD CONTROL 7
H4548E	B	6	LEAD CONTROL 5
H4551E	B	6	LEAD CONTROL 2
H4552E	B	6	LEAD CONTROL 1
H6453E	Y	4	LEAD CONTROL 10
H6455E	Y	4	LEAD CONTROL 8
H6456E	Y	4	LEAD CONTROL 7
H6458E	Y	4	LEAD CONTROL 5
H6459E	Y	4	LEAD CONTROL 4
H6460E	Y	4	LEAD CONTROL 3
H6472E	Y	4	LEAD CONTROL 2
H6473E	Y	4	LEAD CONTROL 1
H6613E	Y	6	LEAD CONTROL 9
H6614E	Y	6	LEAD CONTROL 8
H6618E	Y	6	LEAD CONTROL 7
H6619E	Y	6	LEAD CONTROL 6
H6626E	Y	6	LEAD CONTROL 5
H6627E	Y	6	LEAD CONTROL 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Component #	Ring	Box	Nomenclature
H6628E	Y	6	LEAD CONTROL 2
H6629E	Y	6	LEAD CONTROL 1
H6631E	Y	6	LEAD CONTROL 10
SPARE14	Y	6	LEAD CONTROL 11

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 14

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Minor increase in refrigerator heat load.	Minor helium leak. Minor increase in refrigerator output.
Closed	Line bursts, with loss of insulating vacuum (internal line) or pressure indicator failure (external line). Internal line burst will cause helium to escape into Power Supply building through vacuum tank relief valve.	Elevated pressure/temperature. Temperature indicators and Magnet quench. Detectable only with individual test.

Affected Components:

Component #	Ring	Box	Nomenclature
H3076R	Y	6	RELIEF H6702A~H6745A H 8
H3077R	Y	6	RELIEF H6740A~H6600A
H3078R	Y	6	RELIEF H6616A~H6716A S BYPASS
H3079R	Y	6	RELIEF H6609M~H6705M S
H3080R	Y	6	RELIEF H6603A~H6703A U
H3081R	Y	6	RELIEF H6604A~H6704A R
H3082R	Y	6	RELIEF H6602A~H6610A H 4
H3088R	Y	6	CIRCULATOR C3018 RELIEF
H3090R	B	6	CIRCULATOR C3019 RELIEF
H3091R	B	6	RELIEF H4602A~H4645A H 8
H3092R	B	6	RELIEF H4641A~H4500A
H3093R	B	6	RELIEF H4516A~H4616A S BYPASS
H3094R	B	6	RELIEF H4503A~H4603A U
H3095R	B	6	RELIEF H4534M~H4614A S
H3096R	B	6	RELIEF H4502A~H4510A H 4
H3097R	B	6	RELIEF H4504A~H4604A R
H3104R	Y	6	RELIEF H6720A~H6721A
H3105R	Y	6	RELIEF H6610A~H6611A
H3106R	Y	6	RELIEF H6615A~H6616A
H3107R	Y	6	RELIEF H6715A~H6716A
H3108R	Y	6	RELIEF H6620A~H6621A
H3109R	B	6	RELIEF H4620A~H4621A
H3110R	B	6	RELIEF H4510A~H4511A
H3111R	B	6	RELIEF H4515A~H4516A
H3112R	B	6	RELIEF H4615A~H4616A
H3113R	B	6	RELIEF H4520A~H4521A
H3114R	Y	6	RELIEF H6636A~H6736A R BYPASS
H3115R	Y	6	RELIEF H6701A~H6705M

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Component #	Ring	Box	Nomenclature
H3231R	B	6	RELIEF H4536A~H4636A R BYPASS
H3232R	B	6	RELIEF H4501A~H4534M
H3235R	B	6	RELIEF H4600A~H4618M
H4413R	B	4	RELIEF H4407M~H4400A
H4419R	B	4	RELIEF H4405M~H4401A
H4446R	B	4	RELIEF H4415A~H4416A
H4447R	B	4	RELIEF H4410A~H4411A
H4448R	B	4	RELIEF H4420A~H4421A
H6413R	Y	4	RELIEF H6400A~H6405M
H6423R	Y	4	RELIEF H6420A~H6421A
H6442R	Y	4	RELIEF H6415A~H6416A
H6443R	Y	4	RELIEF H6410A~H6411A
H6444R	Y	4	RELIEF H6401A~H6426M
H6471R	B	6	RELIEF H4500A~H6733M
H6642R	Y	6	RELIEF H6600A~H6623M
H6805R	Y	6	RELIEF H6601A~H6609M
H6807R	Y	6	RELIEF H6700A~H6707M
H6813R	B	6	RELIEF H4601A~H4614M

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 15

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Flow through Vent to atmosphere. Unacceptable leak, with depletion of helium inventory.	Elevated temperature/low pressure. Frosted valve.
Closed	No impact. Relief on opposite end of magnet string is adequate	Detectable only with individual test.

Affected Components:

Component #	Ring	Box	Nomenclature
H3083R	Y	6	RELIEF LINE M 4
H3084R	Y	6	RELIEF LINE S 4
H3085R	Y	6	RELIEF LINE H 4
H3086R	Y	6	RELIEF LINE U 4
H3087R	Y	6	RELIEF LINE R 4
H3098R	B	6	RELIEF LINE M 4
H3099R	B	6	RELIEF LINE H 4
H3100R	B	6	RELIEF LINE S 4
H3102R	B	6	RELIEF LINE R 4
H3103R	B	6	RELIEF LINE U 4
H4436R	B	4	RELIEF LINE M 6
H4437R	B	4	RELIEF LINE S 6
H4438R	B	4	RELIEF LINE H 6
H4439R	B	4	RELIEF LINE U 6
H4440R	B	4	RELIEF LINE R 6
H4441R	B	4	RELIEF LINE M 2
H4442R	B	4	RELIEF LINE S 2
H4443R	B	4	RELIEF LINE H 2
H4444R	B	4	RELIEF LINE U 2
H4445R	B	4	RELIEF LINE R 2
H4609R	B	6	RELIEF LINE M 8
H4610R	B	6	RELIEF LINE S 8
H4611R	B	6	RELIEF LINE H 8
H4612R	B	6	RELIEF LINE U 8
H4613R	B	6	RELIEF LINE R 8
H6432R	Y	4	RELIEF LINE M 6
H6433R	Y	4	RELIEF LINE S 6
H6434R	Y	4	RELIEF LINE H 6

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Component #	Ring	Box	Nomenclature
H6435R	Y	4	RELIEF LINE U 6
H6436R	Y	4	RELIEF LINE R 6
H6437R	Y	4	RELIEF LINE M 2
H6438R	Y	4	RELIEF LINE S 2
H6439R	Y	4	RELIEF LINE H 2
H6440R	Y	4	RELIEF LINE U 2
H6441R	Y	4	RELIEF LINE R 2
H6746R	Y	6	RELIEF LINE M 8
H6747R	Y	6	RELIEF LINE S 8
H6748R	Y	6	RELIEF LINE H 8
H6749R	Y	6	RELIEF LINE U 8
H6750R	Y	6	RELIEF LINE R 8

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 16

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Headers open to warm Return. Vent checkvalve prevents flow.	Detectable only with individual test.
Closed	No impact. Headers open to Return.	Detectable only with individual test.

Affected Components:

Component #	Ring	Box	Nomenclature
H4623R	B	6	VENT RELIEF 8
H6452R	Y	4	VENT RELIEF 6
H6723R	Y	6	VENT RELIEF 8

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 17

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Full Scale High	No impact. Instrumentation only with redundant sensors.	Temperature indication unreasonably high.
Full Scale Low	No impact. Instrumentation only with redundant sensors.	Zero temperature indication.

Affected Components:

Component #	Ring	Box	Nomenclature
TI3705H	Y	6	CALIBRATED SNSR L. P. OUT
TI3706H	Y	6	CALIBRATED SNSR CIRC IN
TI3707H	Y	6	CALIBRATED SNSR CIRC OUT
TI3709H	B	6	CALIBRATED SNSR L. P. OUT
TI3710H	B	6	CALIBRATED SNSR CIRC IN
TI3711H	B	6	CALIBRATED SNSR CIRC OUT
TI3713H	Y	6	CALIBRATED SNSR RECL OUT
TI3714H	B	6	CALIBRATED SNSR RECL OUT
TI3804H	B	6	CAL. SNSR CIRC C3019 OUTLET
TI3806H	Y	6	CAL. SNSR CIRC C3018 OUTLET
TI4002H	B	6	SNSR RECLR LIQUID LI4001
TI4454H	B	4	CALIBRATED SNSR RECL IN
TI4464H	B	4	CALIBRATED SNSR RECL OUT
TI4470H	B	4	SNSR RECLR LIQUID LI4452
TI4471H	B	4	CALIBRATED SENSOR S 6
TI4472H	B	4	CALIBRATED SENSOR H 6
TI4473H	B	4	CALIBRATED SENSOR U 6
TI4474H	B	4	CALIBRATED SENSOR R 6
TI4475H	B	4	CALIBRATED SENSOR S 2
TI4476H	B	4	CALIBRATED SENSOR H 2
TI4477H	B	4	CALIBRATED SENSOR U 2
TI4478H	B	4	CALIBRATED SENSOR R 2
TI4479H	B	4	CALIBRATED SNSR R IN~6
TI4480H	B	4	CALIBRATED SNSR U IN~6
TI4481H	B	4	CALIBRATED SNSR H IN~6
TI4482H	B	4	CALIBRATED SNSR S IN~6
TI4483H	B	4	CALIBRATED SNSR M IN~6
TI4600H	B	6	CALIBRATED SENSOR S 8

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Component #	Ring	Box	Nomenclature
TI4601H	B	6	CALIBRATED SENSOR H 8
TI4602H	B	6	CALIBRATED SENSOR U 8
TI4603H	B	6	CALIBRATED SENSOR R 8
TI4604H	B	6	CALIBRATED SENSOR S 4
TI4605H	B	6	CALIBRATED SENSOR H 4
TI4606H	B	6	CALIBRATED SENSOR U 4
TI4607H	B	6	CALIBRATED SENSOR R 4
TI4608H	B	4	CALIBRATED SNSR S INLET
TI4609H	B	4	CALIBRATED SNSR R OUTLET
TI4610H	B	4	CALIBRATED SNSR CR OUTLET
TI4611H	B	4	CALIBRATED SNSR HG INLET
TI4612H	B	4	CALIBRATED SNSR HR OUTLET
TI6475H	Y	4	CALIBRATED SNSR RECL IN
TI6476H	Y	4	CALIBRATED SNSR RECL OUT
TI6477H	Y	4	SNSR RECLR LIQUID LI6477
TI6483H	Y	4	CALIBRATED SENSOR S 4
TI6484H	Y	4	CALIBRATED SENSOR H 4
TI6485H	Y	4	CALIBRATED SENSOR U 4
TI6486H	Y	4	CALIBRATED SENSOR R 4
TI6487H	Y	4	CALIBRATED SENSOR S 2
TI6488H	Y	4	CALIBRATED SENSOR H 2
TI6489H	Y	4	CALIBRATED SENSOR U 2
TI6490H	Y	4	CALIBRATED SENSOR R 2
TI6491H	Y	4	CALIBRATED SNSR R IN^6
TI6492H	Y	4	CALIBRATED SNSR U IN^6
TI6493H	Y	4	CALIBRATED SNSR H IN^6
TI6494H	Y	4	CALIBRATED SNSR S IN^6
TI6495H	Y	4	CALIBRATED SNSR M IN^6
TI6605H	Y	6	SNSR RECLR LIQUID LI4000
TI6700H	Y	6	CALIBRATED SENSOR S 8
TI6701H	Y	6	CALIBRATED SENSOR H 8
TI6702H	Y	6	CALIBRATED SENSOR U 8
TI6703H	Y	6	CALIBRATED SENSOR R 8
TI6704H	Y	6	CALIBRATED SENSOR S 4
TI6705H	Y	6	CALIBRATED SENSOR H 4
TI6706H	Y	6	CALIBRATED SENSOR U 4
TI6707H	Y	6	CALIBRATED SENSOR R 4
TI6708H	Y	4	CALIBRATED SNSR S INLET
TI6709H	Y	4	CALIBRATED SNSR R OUTLET
TI6710H	Y	4	CALIBRATED SNSR CR OUTLET
TI6711H	Y	4	CALIBRATED SNSR HG INLET
TI6712H	Y	4	CALIBRATED SNSR HR OUTLET

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 18

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Pressure indicator failure. Minor cold gas leak. Minor increase in refrigerator heat load. Can be shut off with manual valve.	Visual detection. Frosted Component. Minor helium leak. Minor increase in refrigerator output.
Closed	No impact. Instrumentation only. Burst pressure over 300 psia.	Static pressure indication, inconsistent with other adjacent pressures.
Full Scale High	No impact. Instrumentation only, with adjacent sensors available.	High/Full scale pressure indication.
Full Scale Low	No impact. Instrumentation only with adjacent sensors available.	Zero/Low pressure indication.

Affected Components:

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Component #	Ring	Box	Nomenclature
PI3704H	Y	6	PRESSURE TRANSDUCER H~U 8
PI3705H	Y	6	PRESSURE TRANSDUCER S BYPASS 8
PI3706H	Y	6	PRESSURE TRANSDUCER S BYPASS 4
PI3707H	Y	6	PRESSURE TRANSDUCER H~U MID
PI3708H	Y	6	PRESSURE TRANSDUCER H~U 4
PI3709H	B	6	PRESSURE TRANSDUCER H~U 8
PI3710H	B	6	PRESSURE TRANSDUCER S BYPASS 8
PI3711H	B	6	PRESSURE TRANSDUCER S BYPASS 4
PI3712H	B	6	PRESSURE TRANSDUCER H~U MID
PI3713H	B	6	PRESSURE TRANSDUCER H~U 4
PI3718H	B	6	PRESSURE TRANSDUCER M 4
PI3719H	B	6	PRESSURE TRANSDUCER S 4
PI3720H	B	6	PRESSURE TRANSDUCER H
PI3721H	B	6	PRESSURE TRANSDUCER U
PI3722H	B	6	PRESSURE TRANSDUCER R
PI3723H	B	4	PRESSURE TRANSDUCER M 2
PI3724H	B	4	PRESSURE TRANSDUCER S 2
PI3725H	B	4	PRESSURE TRANSDUCER H
PI3726H	B	4	PRESSURE TRANSDUCER U
PI3727H	B	4	PRESSURE TRANSDUCER R
PI3738H	Y	6	PRESSURE TRANSDUCER M MID
PI3739H	Y	6	PRESSURE TRANSDUCER S 8
PI3740H	Y	6	PRESSURE TRANSDUCER S MID
PI3741H	Y	6	PRESSURE TRANSDUCER CIRC BYPASS
PI3742H	B	6	PRESSURE TRANSDUCER M MID
PI3743H	B	6	PRESSURE TRANSDUCER S MID
PI3744H	B	6	PRESSURE TRANSDUCER CIRC BYPASS
PI3745H	B	6	PRESSURE TRANSDUCER S 8
PI4448H	B	4	PRESS TRANSDUCER VENT HEADER
PI4449H	B	4	PRESSURE TRANSDUCER S~H
PI4450H	B	4	PRESSURE TRANSDUCER H~U 6
PI4451H	B	4	PRESSURE TRANSDUCER M 6
PI4452H	B	4	PRESSURE TRANSDUCER H~U 2
PI4453H	B	4	PRESSURE TRANSDUCER S 6
PI6057H	Y	6	PRESSURE TRANSDUCER M 4
PI6058H	Y	6	PRESSURE TRANSDUCER S 4
PI6059H	Y	6	PRESSURE TRANSDUCER H
PI6060H	Y	6	PRESSURE TRANSDUCER U
PI6061H	Y	6	PRESSURE TRANSDUCER R
PI6067H	Y	6	PRESS TRANSDUCER VENT HEADER
PI6068H	B	6	PRESS TRANSDUCER VENT HEADER
PI6413H	Y	4	PRESSURE TRANSDUCER S~H
PI6414H	Y	4	PRESS TRANSDUCER VENT HEADER
PI6418H	Y	4	PRESSURE TRANSDUCER H~U 6
PI6423H	Y	4	PRESSURE TRANSDUCER S 6
PI6424H	Y	4	PRESSURE TRANSDUCER M 6
PI6425H	Y	4	PRESSURE TRANSDUCER H~U 2
PI6426H	Y	4	PRESSURE TRANSDUCER M 2

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Component #	Ring	Box	Nomenclature
PI6427H	Y	4	PRESSURE TRANSDUCER S 2
PI6428H	Y	4	PRESSURE TRANSDUCER H
PI6429H	Y	4	PRESSURE TRANSDUCER U
PI6430H	Y	4	PRESSURE TRANSDUCER R

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 19

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position. Leakage during Pressure Indicator replacement.	Manual valve. Visual detection. Escaping gas during pressure indicator removal.
Closed	No pressure indication or constant pressure indication. No hazard; relief valves safe system.	No pressure indication or constant pressure indication.

Affected Components:

Component #	Ring	Box	Nomenclature
H3075M	Y	6	ISOLATION PI6067H
H3234M	B	6	ISOLATION PI3743H
H3236M	B	6	ISOLATION PI3744H
H4414M	B	4	ISOLATION PI4451H
H4423M	B	4	ISOLATION PI4448H
H4429M	B	4	ISOLATION PI4453H
H4657M	B	6	ISOLATION PI6068H
H6407M	Y	4	ISOLATION PI6424H
H6419M	Y	4	ISOLATION PI6414H
H6425M	Y	4	ISOLATION PI6425H
H6427M	Y	4	ISOLATION PI6426H
H6428M	Y	4	ISOLATION PI6427H
H6429M	Y	4	ISOLATION PI6428H
H6446M	Y	4	ISOLATION PI6429H
H6447M	Y	4	ISOLATION PI6430H
H6640M	Y	6	ISOLATION PI3738H
H6724M	Y	6	ISOLATION PI6057H
H6725M	Y	6	ISOLATION PI6058H
H6727M	Y	6	ISOLATION PI3740H
H6729M	Y	6	ISOLATION PI3741H
H6734M	B	6	ISOLATION PI3742H
H6741M	Y	6	ISOLATION PI3704H
H6742M	Y	6	ISOLATION PI3707H
H6743M	Y	6	ISOLATION PI3706H
H6744M	Y	6	ISOLATION PI3705H
H6751M	Y	6	ISOLATION PI3714H
H6753M	Y	6	ISOLATION PI3708H
H6754M	B	6	ISOLATION PI3709H

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Component #	Ring	Box	Nomenclature
H6755M	B	6	ISOLATION PI3712H
H6756M	B	6	ISOLATION PI3711H
H6757M	B	6	ISOLATION PI3710H
H6758M	B	6	ISOLATION PI3716H
H6760M	B	6	ISOLATION PI3713H
H6763M	Y	6	ISOLATION PI3739H
H6770M	B	4	ISOLATION PI3723H
H6771M	B	4	ISOLATION PI3724H
H6772M	B	4	ISOLATION PI3725H
H6773M	B	4	ISOLATION PI3726H
H6774M	B	4	ISOLATION PI3727H
H6775M	B	6	ISOLATION PI3718H
H6776M	B	6	ISOLATION PI3719H
H6777M	B	6	ISOLATION PI3720H
H6778M	B	6	ISOLATION PI3721H
H6779M	B	6	ISOLATION PI3722H
H6787M	Y	6	ISOLATION PI6059H
H6788M	Y	6	ISOLATION PI6060H
H6789M	Y	6	ISOLATION PI6061H
H6793M	Y	4	ISOLATION PI6413H
H6794M	Y	4	ISOLATION PI6418H
H6795M	Y	4	ISOLATION PI6423H
H6814M	B	6	ISOLATION PI3745H
H6910M	B	4	ISOLATION PI4449H
H6911M	B	4	ISOLATION PI4450H
H6912M	B	4	ISOLATION PI4452H

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 20

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Normally open valve. Visual detection. Normal operations.
Closed	No circulation. Magnet temperature rises with subsequent magnet quench.	Normally open valve. Elevated pressure/temperature. Temperature indicators and Magnet quench.

Affected Components:

Component #	Ring	Box	Nomenclature
H4500A L	B	6	ISOLATION M 4
H4641A	B	6	ISOLATION CIRCULATOR OUT
H4642A	B	6	ISOLATION CIRCULATOR IN
H6600A L	Y	6	ISOLATION M 4
H6739A	Y	6	ISOLATION CIRCULATOR IN
H6740A	Y	6	ISOLATION CIRCULATOR OUT

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 21

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Manual valve. Visual detection. Normal operations.
Closed	Incorrect flow indication. No impact. Instrumentation only.	Manual valve. No flow indication. Visual detection.

Affected Components:

Component #	Ring	Box	Nomenclature
H6752M	Y	6	ISOLATION DELTA P IN
H6759M	B	6	ISOLATION DELTA P IN

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 22

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Manual valve. Visual detection. Normal operations.
Closed	Incorrect flow indication. No impact. Instrumentation only.	Manual valve. High flow indication. Visual detection.

Affected Components:

Component #	Ring	Box	Nomenclature
H6731M	B	6	ISOLATION DELTA P OUT
H6761M	Y	6	ISOLATION DELTA P OUT

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 23

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Normally open valve. Visual detection. Normal operations.
Closed	No flow. Heat shield temperature increase with Magnet temperature rise and subsequent magnet quench.	Normally open valve. Visual detection. Elevated pressure/temperature. Temperature indicators and Magnet quench.

Affected Components:

Component #	Ring	Box	Nomenclature
H4402A L	B	4	ISOLATION H
H6402A L	Y	4	ISOLATION H
H6602A L	Y	6	ISOLATION H 4
H6745A	Y	6	ISOLATION H 4 Linear Plug

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 24

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Normally closed valve. Visual detection. Normal operations.
Closed	No circulation. Magnet temperature rises with subsequent magnet quench.	Normally closed valve. Elevated pressure/temperature. Temperature indicators and Magnet quench.

Affected Components:

Component #	Ring	Box	Nomenclature
H4406A	B	4	CROSSOVER M~U 6
H4503A L	B	6	ISOLATION U 4
H4603A	B	6	ISOLATION U 8
H4606A	B	6	CROSSOVER M~U 8
H6406A	Y	4	CROSSOVER M~U 6
H6603A L	Y	6	ISOLATION U 4
H6703A	Y	6	ISOLATION U 8
H6706A	Y	6	CROSSOVER M~U 8

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 25

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Manual valve. Visual detection.
Closed	Possible minor increase in heat load in valve box, minor increase in refrigerator load.	Manual valve. Visual detection. Elevated pressure.

Affected Components:

Component #	Ring	Box	Nomenclature
H4405M L	B	4	MANUAL ISOLATION S
H4534M L	B	6	MANUAL ISOLATION S 4
H6426M L	Y	4	MANUAL ISOLATION S
H6609M L	Y	6	MANUAL ISOLATION S 4

Failure Mode Effects Analysis

Item: 26

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Manual valve. Visual detection.
Closed	No flow. Magnet temperature rises with power supply shutdown possible.	Manual valve. Visual detection. Elevated pressure/temperature. Temperature indicators and Magnet quench.

Affected Components:

Component #	Ring	Box	Nomenclature
H6623M L	Y	6	MANUAL ISOLATION M
H6733M L	B	6	MANUAL ISOLATION M

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 27

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Manual valve. Visual detection.
Closed	Other end capped. Potential for cold gas in closed volume. Protected by relief valve. May be relieved by other valve operation.	Manual valve. Visual detection. Elevated pressure.

Affected Components:

Component #	Ring	Box	Nomenclature
H4614M L	B	6	MANUAL ISOLATION S 8
H6705M L	Y	6	MANUAL ISOLATION S 8

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 28

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Flow from Heat Shield to Supply. Recooler empties. Magnet temperature rise with eventual magnet quench. Can be reconfigured.	Normally closed valve. Elevated pressure/temperature; zero recooler level. Temperature indicators and Magnet quench.
Closed	No impact. Normal operating position.	Normally closed valve. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
H4615A	B	6	CROSSOVER S~B~HG 8
H6715A	Y	6	CROSSOVER S~B~HG 8

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 29

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Return line opened to Cooldown Return, through Thermax heaters, to Main Compressor Suction. Main Compressor Suction may operate at a higher pressure; needs to be evaluated. If at higher pressure, increased heat load, with magnet quench.	Normally closed valve. Visual detection. Elevated pressure/temperature. Magnet quench.
Closed	No impact. Normal operating position.	Normally closed valve. Visual detection.

Affected Components:

Component #	Ring	Box	Nomenclature
H4536A	B	6	BYPASS R 4
H4636A	B	6	BYPASS R 8
H6636A	Y	6	BYPASS R 4
H6736A	Y	6	BYPASS R 8

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 30

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
N/A	Valve removed for First Sextant Test. Connects Blue to Yellow Heat Shield lines.	

Affected Components:

Component #	Ring	Box	Nomenclature
H4477M	B	4	PUMPOUT H 2
H6482M	Y	4	PUMPOUT H 2

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 31

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Pressure/gas make-up for magnet line.	Normally closed valve. Visual detection. Magnet line same pressure as supply line.
Closed	No magnet line pressure/gas make-up. Possible circulator failure.	Normally closed valve. Low magnet line pressure. Erratic circulator speed. Elevated pressure/temperature. Temperature indicators and Magnet quench.

Affected Components:

Component #	Ring	Box	Nomenclature
H4524A	B	6	REF SUPPLY M Linear Plug
H6607A	Y	6	REF SUPPLY M Linear Plug

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Date: Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 32

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Full Scale High	Inadequate flow to recoolers. Recooler level declines with possible minor increase in heat load in valve box, minor increase in refrigerator load.	Elevated pressure/temperature; high liquid level indication.
Full Scale Low	Opens recooler J-T valve. Increased refrigerator demand. Refrigerator imbalance caused by unmodulated Supply gas going into Return. Refrigerator shutoff from ring.	Constant low liquid level output. Minor increase in refrigerator output.

Affected Components:

Component #	Ring	Box	Nomenclature
LI4000H	Y	6	SUPERCON LEVEL PROBE
LI4001H	B	6	SUPERCON LEVEL PROBE
LI4452H	B	4	SUPERCON LEVEL PROBE
LI6477H	Y	4	SUPERCON LEVEL PROBE

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Date: Friday, December 20, 1996

Item: 33

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
N/A	Flow control not connected for First Sextant Test. Lead not installed.	

Affected Components:

Component #	Ring	Box	Nomenclature
SPARE16	B	4	LEAD CONTROL B11

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 34

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Visual detection. Normal operations.
Closed/No output	No circulation. Magnet temperature rises with power supply shutdown possible.	Elevated pressure/temperature. Temperature indicators and Magnet quench.

Affected Components:

Component #	Ring	Box	Nomenclature
C3018H	Y	6	CIRCULATOR @ 5ATM
C3019H	B	6	CIRCULATOR @ 5ATM

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 35

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Full Scale High	High flow indication may cause operator to lower circulation. Magnet temperature rises with subsequent magnet quench. Is not used to control circulator speed.	Elevated pressure/temperature/speed. Temperature indicators and Magnet quench.
Full Scale Low	No flow indication may cause operator to command maximum circulator speed. Potential for circulator shutdown by overspeed protection system. Is not used to control circulator speed.	No/low flow indication with high circulator speed. Circulator speed alarm and/or shutdown.

Affected Components:

Component #	Ring	Box	Nomenclature
DPT3007H	Y	6	DELTA P TRANSDUCER
DPT3008H	B	6	DELTA P TRANSDUCER

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 36

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Maximum speed output	No impact; instrumentation only. May cause operator to lower circulation. Magnet temperature rises with subsequent magnet quench.	Elevated pressure/temperature/speed with low flow. Temperature indicators and Magnet quench.
Minimum speed output	No impact; instrumentation only. May cause operator to increase circulation. Circulator may shutdown by overspeed protection system.	Constant low speed indication and command mismatch.

Affected Components:

Component #	Ring	Box	Nomenclature
ST4647H	B	6	5k~15kRPM C3019 TRANSDUCER
ST6746H	Y	6	5k~15kRPM C3018 TRANSDUCER

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 37

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Minor heat load increase with Magnet temperature rise.	Manual valve. Visual detection. Elevated magnet temperature. Minor increase in refrigerator output. Frosted valve.
Closed	No impact. Normal operating position.	Manual valve. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
H4559M	B	6	CIRCULATOR C3019 INLET PUMPOUT
H6799M	Y	6	CIRCULATOR C3018 INLET PUMPOUT
H6823M	B	6	CIRCULATOR C3019 WARMUP
H6826M	B	6	CIRCULATOR C3019 OUTLET PUMPOUT
H6894M	Y	6	CIRCULATOR C3018 WARMUP
H6895M	Y	6	CIRCULATOR C3018 OUTLET PUMPOUT

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 38

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
N/A	Flow control and manual valve not connected on inlet; no lead to connect gas. Inlet capped. Upstream side connected to warm return. No hazard.	Visual detection. Leak detection.

Affected Components:

Component #	Ring	Box	Nomenclature
H4457E	B	4	LEAD CONTROL B8
H4460E	B	4	LEAD CONTROL A11
H4462E	B	4	LEAD CONTROL A8
H4465E	B	4	LEAD CONTROL A6
H4468E	B	4	LEAD CONTROL A2
H4485M	B	4	LEAD ISOLATION B8
H4488M	B	4	LEAD ISOLATION A11
H4490M	B	4	LEAD ISOLATION A8
H4491M	B	4	LEAD ISOLATION A6
H4494M	B	4	LEAD ISOLATION A2
H4513E	B	6	LEAD CONTROL 11
H4519E	B	6	LEAD CONTROL 8
H4547E	B	6	LEAD CONTROL 6
H4549E	B	6	LEAD CONTROL 4
H4550E	B	6	LEAD CONTROL 3
H4742M	B	6	LEAD ISOLATION 11
H4745M	B	6	LEAD ISOLATION 8
H4747M	B	6	LEAD ISOLATION 6
H4749M	B	6	LEAD ISOLATION 4
H4750M	B	6	LEAD ISOLATION 3
H6454E	Y	4	LEAD CONTROL 9
H6457E	Y	4	LEAD CONTROL 6
H6474E	Y	4	LEAD CONTROL 11
H6529M	Y	4	LEAD ISOLATION 9
H6532M	Y	4	LEAD ISOLATION 6
H6538M	Y	4	LEAD ISOLATION 11

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 39

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Significantly reduced circulation. Magnet temperature rises with subsequent magnet quench.	Normally open valve. Visual detection. Elevated pressure/temperature. Temperature indicators and Magnet quench.
Closed	No impact. Normal operating position.	Normally open valve. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
H4533A	B	6	CIRCULATOR TEST Linear Plug
H6606A	Y	6	CIRCULATOR TEST Linear Plug

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 40

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No flow indication.	Manual valve. Visual detection. Normal operations.
Closed	No impact. Normal operating position.	Manual valve. No flow indication. Visual detection.

Affected Components:

Component #	Ring	Box	Nomenclature
H6732M	B	6	DELTA P CROSSOVER
H6762M	Y	6	DELTA P CROSSOVER

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 41

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Normally open valve. Visual detection. Normal operations.
Closed	Loss of instrumentation. Bypass dead-headed by manual valve. Possible pipe contamination.	Normally open valve. Erroneous instrumentation. Visual detection.

Affected Components:

Component #	Ring	Box	Nomenclature
H4600A	B	6	MONITOR CIR BYPASS OUT~B~IN
H6700A	Y	6	MONITOR CIR BYPASS OUT~B~IN

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 42

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. No pressure source. Relief valve protects vacuum pump.	Manual valve. Visual detection.
Closed	No impact. Normal operating position.	Manual valve. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
H4656M	B	6	VACUUM ISOLATION 4
H6485M	Y	4	VACUUM ISOLATION 2
H6785M	Y	6	VACUUM ISOLATION 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 43

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Pumpout header closed off by manual valves, vented by check valve.	Manual valve. Visual detection.
Closed	No impact. Normal operating position.	Manual valve. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
H4482M	B	4	VACUUM~VENT 2
H4629M	B	6	VACUUM~VENT 4
H6470M	Y	4	VACUUM~VENT 2
H6786M	Y	6	VACUUM~VENT 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 44

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Vent header contaminated by air.	Checkvalve. Detectable only with individual test.
Closed	Loss of emergency venting and relief valve capacity. Adjacent magnet/valvebox relief valves have adequate capacity.	Checkvalve. Detectable only with individual test.

Affected Components:

Component #	Ring	Box	Nomenclature
H4009C	B	6	VENT CHECK 8
H4029C	Y	6	VENT CHECK 8
H4434C	B	4	VENT CHECK 6
H6445C	Y	4	VENT CHECK 6

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 45

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Flow from First Sextant Test magnet loop to Cooldown Return. If magnet loop pressure is higher than Cooldown Return, then cold gas flows through Thermax heaters to Main Compressor Suction. If Cooldown Return pressure is higher, then increased heat load.	Normally closed valve. Visual detection. Cold gas flow to Cooldown Return will result in frosted components. Warm gas flow to magnet loop will cause minor increase in refrigerator output.
Closed	No impact. Normal operating position.	Normally closed valve. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
H4537A	B	6	CROSSOVER CR~U 4
H4637A	B	6	CROSSOVER CR~U 8
H6637A	Y	6	CROSSOVER CR~U 4
H6737A	Y	6	CROSSOVER CR~U 8

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 46

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Flow from Heat Shield to Supply. Recooler level declines with Magnet temperature rise and subsequent magnet quench.	Normally closed valve. Valve dome loaded closed. Elevated pressure/temperature; zero recooler level. Temperature indicators and Magnet quench.
Closed	No impact. Normal operating position.	Normally closed valve. Valve dome loaded closed. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
H4416A	B	4	CROSSOVER H~B~S 6
H6416A	Y	4	CROSSOVER H~B~S 6

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Date: Friday, December 20, 1996

Item: 47

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Normally open valve. Visual detection. Normal operations.
Closed	Loss of instrumentation. Bypass dead-headed by automatic valve. Possible pipe contamination.	Normally open valve. Erroneous instrumentation. Visual detection.

Affected Components:

Component #	Ring	Box	Nomenclature
H4411A	B	4	CROSSOVER U~B~H 6
H4420A	B	4	CROSSOVER H~B~U 2
H4510A	B	6	CROSSOVER H~B~U MID
H4520A	B	6	CROSSOVER H~B~U 4
H4621A	B	6	CROSSOVER U~B~H 8
H6411A	Y	4	CROSSOVER U~B~H 6
H6420A	Y	4	CROSSOVER H~B~U 2
H6610A	Y	6	CROSSOVER H~B~U MID
H6620A	Y	6	CROSSOVER H~B~U 4
H6721A	Y	6	CROSSOVER U~B~H 8

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 48

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position. Valve locked in open position.	Manual valve. Visual detection. Valve locked in open position.
Closed	No impact. Line downstream is capped. Line open to leadpot upstream via superconductor bus, protected by relief valve. Valve locked in open position.	Manual valve. Visual detection. Valve locked in open position.

Affected Components:

Component #	Ring	Box	Nomenclature
H4407M L	B	4	MANUAL ISOLATION M
H6405M L	Y	4	MANUAL ISOLATION M

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 49

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Flow from Heat Shield to Supply. Recooler empties. Magnet temperature rise with eventual magnet quench.	Normally closed valve. Elevated pressure/temperature; zero recooler level. Temperature indicators and Magnet quench.
Closed	No impact. Normal operating position.	Normally closed valve. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
H4516A	B	6	CROSSOVER HG~B~S 4
H6616A	Y	6	CROSSOVER HG~B~S 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 50

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Normally open valve. Visual detection. Normal operations.
Closed	Loss of instrumentation. Bypass dead-headed by automatic valve. Possible pipe contamination.	Normally open valve. Visual detection. Erroneous instrumentation.

Affected Components:

Component #	Ring	Box	Nomenclature
H4616A	B	6	CROSSOVER HG~B~S 8
H6716A	Y	6	CROSSOVER HG~B~S 8

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 51

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Magnet pressure & temperature fluctuates.	Normally closed valve. Pressure and temperature fluctuations. Visual detection.
Closed	No impact. Normal operating position.	Normally closed valve. Visual detection.

Affected Components:

Component #	Ring	Box	Nomenclature
H4430A	B	4	CROSSOVER M~S 2
H4530A	B	6	CROSSOVER M~S 4
H4630A	B	6	CROSSOVER M~S 8
H6430A	Y	4	CROSSOVER M~S 2
H6630A	Y	6	CROSSOVER M~S 4
H6730A	Y	6	CROSSOVER M~S 8

Failure Mode Effects Analysis

Item: 52

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Magnet line pressure bleeds into Return. Magnet temperature rise and subsequent magnet quench.	Normally closed valve; valve is dome-loaded closed for test. Visual detection. Magnet line pressure drop and/or Return pressure increase. Increased demand on circulator/refrigerator. Temperature increase and magnet quench.
Closed	No impact. Normal operating position.	Normally closed valve; valve is dome-loaded closed for test. Visual detection.

Affected Components:

Component #	Ring	Box	Nomenclature
H4408A	B	4	CROSSOVER R~U 6
H4508A	B	6	BYPASS U 4
H4608A	B	6	BYPASS U 8
H6408A	Y	4	CROSSOVER R~U 6
H6608A	Y	6	BYPASS U 4
H6708A	Y	6	BYPASS U 8

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 53

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position. Bypass dead-headed by second automatic valve.	Normally open valve. Visual detection.
Closed	Loss of instrumentation.	Normally open valve. No pressure indication or constant pressure indication. Visual detection.

Affected Components:

Component #	Ring	Box	Nomenclature
H4415A	B	4	CROSSOVER S~B~H 6 Linear Plug
H6415A	Y	4	CROSSOVER S~B~H 6 Linear Plug

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 54

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Normally open valve. Visual detection. Normal operations.
Closed	Loss of instrumentation. Bypass dead-headed by automatic valve. Possible pipe contamination.	Normally open valve. Visual detection. Erroneous instrumentation.

Affected Components:

Component #	Ring	Box	Nomenclature
H4515A	B	6	CROSSOVER S~B~HG 4
H6615A	Y	6	CROSSOVER S~B~HG 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 55

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Flow from Heat Shield to Utility of magnet loop. Magnet temperature rise and subsequent magnet quench.	Normally closed valve; valve is dome-loaded closed for test. Visual detection. Elevated pressure/temperature. Temperature indicator or power supply lead monitoring alarms. Magnet quench.
Closed	No impact. Normal operating position.	Normally closed valve; valve is dome-loaded closed for test. Visual detection.

Affected Components:

Component #	Ring	Box	Nomenclature
H4410A	B	4	CROSSOVER H~B~U 6
H4421A	B	4	CROSSOVER U~B~H 2
H4511A	B	6	CROSSOVER U~B~H MID
H4521A	B	6	CROSSOVER U~B~H 4
H4620A	B	6	CROSSOVER H~B~U 8
H6410A	Y	4	CROSSOVER H~B~U 6
H6421A	Y	4	CROSSOVER U~B~H 2
H6611A	Y	6	CROSSOVER U~B~H MID
H6621A	Y	6	CROSSOVER U~B~H 4
H6720A	Y	6	CROSSOVER H~B~U 8

Failure Mode Effects Analysis

Item: 56

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Flow from Heat Shield Supply on return side of First Sextant loop bypassed to Heat Shield Return, stops Heat Shield flow. Heat Shield temperature increase with magnet temperature rise and subsequent magnet quench.	Normally closed valve. Visual detection. Elevated temperature/pressure. Temperature indicators and magnet quench.
Closed	Loss of flow to Yellow 6 o'clock valve box heat shield. Increased heat load.	Normally closed valve. Visual detection. Minor increase in refrigerator output.

Affected Components:

Component #	Ring	Box	Nomenclature
H4645A	B	6	ISOLATION H 4 Linear Plug

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Date: Friday, December 20, 1996

Item: 57

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No circulation. Magnet temperature rises with power supply shutdown possible.	Manual valve. Visual detection. Elevated pressure/temperature. Temperature indicators and Magnet quench.
Closed	No impact. Normal operating position.	Manual valve. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
H4618M L	B	6	MONITOR CIR BYPASS IN~B~OUT
H6707M L	Y	6	MONITOR CIR BYPASS IN~B~OUT

Failure Mode Effects Analysis

Item: 58

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Manual valve. Visual detection. Normal operations.
Closed	No lead cooling. Power supply shutdown by voltage monitoring circuit.	Manual valve. Visual detection. No lead flow indication. Power supply shutdown.

Affected Components:

Component #	Ring	Box	Nomenclature
H4483M	B	4	LEAD ISOLATION B10
H4484M	B	4	LEAD ISOLATION B9
H4486M	B	4	LEAD ISOLATION B7
H4487M	B	4	LEAD ISOLATION B6
H4489M	B	4	LEAD ISOLATION A9
H4492M	B	4	LEAD ISOLATION A5
H4493M	B	4	LEAD ISOLATION A4
H4495M	B	4	LEAD ISOLATION A1
H4743M	B	6	LEAD ISOLATION 10
H4744M	B	6	LEAD ISOLATION 9
H4746M	B	6	LEAD ISOLATION 7
H4748M	B	6	LEAD ISOLATION 5
H4751M	B	6	LEAD ISOLATION 2
H4752M	B	6	LEAD ISOLATION 1
H6528M	Y	4	LEAD ISOLATION 10
H6530M	Y	4	LEAD ISOLATION 8
H6531M	Y	4	LEAD ISOLATION 7
H6533M	Y	4	LEAD ISOLATION 5
H6534M	Y	4	LEAD ISOLATION 4
H6535M	Y	4	LEAD ISOLATION 3
H6536M	Y	4	LEAD ISOLATION 2
H6537M	Y	4	LEAD ISOLATION 1
H6884M	Y	6	LEAD ISOLATION 9
H6885M	Y	6	LEAD ISOLATION 8
H6886M	Y	6	LEAD ISOLATION 7
H6887M	Y	6	LEAD ISOLATION 6
H6888M	Y	6	LEAD ISOLATION 5
H6889M	Y	6	LEAD ISOLATION 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System

Operation Mode: First Sextant Test

Component #	Ring	Box	Nomenclature
H6890M	Y	6	LEAD ISOLATION 2
H6891M	Y	6	LEAD ISOLATION 1
H6892M	Y	6	LEAD ISOLATION 10
SPARE4	Y	6	LEAD ISOLATION 11
SPARE7	B	4	LEAD ISOLATION B11

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 59

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Flow to local warm Return header. Minor refrigerator heat load increase.	Manual valve. Visual detection. Frosted valve. Minor increase in refrigerator output.
Closed	No impact. Normal operating position.	Manual valve. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
H3233M	B	6	MONITOR TUBE H4501A~H4534M
H3237M	B	6	MONITOR TUBE H4600A~H4618M
H4412M	B	4	MONITOR TUBE H4415A~H4416A
H4417M	B	4	MONITOR TUBE H4410A~H4411A
H4418M	B	4	MONITOR TUBE H4407M~H4400A
H4422M	B	4	MONITOR TUBE H4420A~H4421A
H4428M	B	4	MONITOR TUBE H4405M~H4401A
H4512M	B	6	MONITOR TUBE H4510A~H4511A
H4517M	B	6	MONITOR TUBE H4515A~H4516A
H4522M	B	6	MONITOR TUBE H4520A~H4521A
H4617M	B	6	MONITOR TUBE H4615A~H4616A
H4622M	B	6	MONITOR TUBE H4620A~H4621A
H6409M	Y	4	MONITOR TUBE H6000A~H6405M
H6412M	Y	4	MONITOR TUBE H6415A~H6416A
H6417M	Y	4	MONITOR TUBE H6410A~H6411A
H6422M	Y	4	MONITOR TUBE H6402A~H6426M
H6424M	Y	4	MONITOR TUBE H6420A~H6421A
H6612M	Y	6	MONITOR TUBE H6610A~H6611A
H6617M	Y	6	MONITOR TUBE H6615A~H6616A
H6622M	Y	6	MONITOR TUBE H6620A~H6621A
H6641M	Y	6	MONITOR TUBE H6600A~H6623M
H6717M	Y	6	MONITOR TUBE H6715A~H6716A
H6722M	Y	6	MONITOR TUBE H6720A~H6721A
H6726M	Y	6	MONITOR TUBE H6601A~H6609M
H6728M	Y	6	MONITOR TUBE H6700A~H6707M
H6735M	B	6	MONITOR TUBE H4500A~H6733M
H6764M	Y	6	MONITOR TUBE H6701A~H6705M
H6819M	B	6	MONITOR TUBE H4601A~H4614M

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 60

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Flow through Pumpout header relief valve to atmosphere. Unacceptable leak, with depletion of helium inventory.	Manual valve. Visual detection. Elevated temperature/low pressure. Frosted valve.
Closed	No impact. Normal operating position.	Manual valve. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
H4472M	B	4	PUMPOUT H 6
H4648M	B	6	PUMPOUT H 8
H4653M	B	6	PUMPOUT H 4
H6477M	Y	4	PUMPOUT H 6
H6711M	Y	6	PUMPOUT H 8
H6782M	Y	6	PUMPOUT H 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 61

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Flow through Pumpout header relief valve to atmosphere. Unacceptable leak, with depletion of helium inventory.	Manual valve. Visual detection. Elevated temperature/low pressure. Frosted valve.
Closed	No impact. Normal operating position.	Manual valve. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
H4470M	B	4	PUMPOUT M 6
H4475M	B	4	PUMPOUT M 2
H4646M	B	6	PUMPOUT M 8
H4651M	B	6	PUMPOUT M 4
H6475M	Y	4	PUMPOUT M 6
H6480M	Y	4	PUMPOUT M 2
H6709M	Y	6	PUMPOUT M 8
H6780M	Y	6	PUMPOUT M 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 62

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Flow through Pumpout header relief valve to atmosphere. Unacceptable leak, with depletion of helium inventory.	Manual valve. Visual detection. Elevated temperature/low pressure. Frosted valve.
Closed	No impact. Normal operating position.	Manual valve. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
H4474M	B	4	PUMPOUT R 6
H4479M	B	4	PUMPOUT R 2
H4650M	B	6	PUMPOUT R 8
H4655M	B	6	PUMPOUT R 4
H6479M	Y	4	PUMPOUT R 6
H6484M	Y	4	PUMPOUT R 2
H6713M	Y	6	PUMPOUT R 8
H6784M	Y	6	PUMPOUT R 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 63

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Flow through Pumpout header relief valve to atmosphere. Unacceptable leak, with depletion of helium inventory.	Manual valve. Visual detection. Elevated temperature/low pressure. Frosted valve.
Closed	No impact. Normal operating position.	Manual valve. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
H4471M	B	4	PUMPOUT S 6
H4476M	B	4	PUMPOUT S 2
H4647M	B	6	PUMPOUT S 8
H4652M	B	6	PUMPOUT S 4
H6476M	Y	4	PUMPOUT S 6
H6481M	Y	4	PUMPOUT S 2
H6710M	Y	6	PUMPOUT S 8
H6781M	Y	6	PUMPOUT S 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Date: Friday, December 20, 1996

Item: 64

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Flow through Pumpout header relief valve to atmosphere. Unacceptable leak, with depletion of helium inventory.	Manual valve. Visual detection. Elevated temperature/low pressure. Frosted valve.
Closed	No impact. Normal operating position.	Manual valve. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
H4473M	B	4	PUMPOUT U 6
H4478M	B	4	PUMPOUT U 2
H4649M	B	6	PUMPOUT U 8
H4654M	B	6	PUMPOUT U 4
H6478M	Y	4	PUMPOUT U 6
H6483M	Y	4	PUMPOUT U 2
H6712M	Y	6	PUMPOUT U 8
H6783M	Y	6	PUMPOUT U 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 65

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Increased refrigerator demand. Refrigerator imbalance caused by unmodulated Supply gas going into Return. Refrigerator shutoff from ring.	Normally open valve. Increasing liquid level. Increased refrigerator load.
Closed	No flow. Recooler level declines with magnet temperature rise and power supply shutdown possible.	Normally open valve. Elevated pressure/temperature; low level indication. Temperature indicators and Magnet quench.

Affected Components:

Component #	Ring	Box	Nomenclature
H4558A	B	6	J T 225watt RECOOLER
H6605A	Y	6	J T 225watt RECOOLER

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 66

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Vacuum header open to vent header. Lines not used for normal operations.	No detection.
Closed	No impact. Lines not used for normal operations. Low pressure relief for protection of vacuum pump.	No detection.

Affected Components:

Component #	Ring	Box	Nomenclature
H4560R	B	6	RELIEF VACUUM HEADER
H6414R	Y	4	RELIEF VACUUM HEADER
H6714R	Y	6	RELIEF VACUUM HEADER

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 67

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Not in use - Open	No impact. Bayonet capped. Normal operating position. Valve locked open.	Normally closed valve; valve locked open. Visual detection.
Not in use - Closed	Leakage will put cold gas into trapped volume. Burst line on warming. Loss of insulating vacuum (internal line burst).	Normally closed valve; valve locked open. Visual detection. High pressure indication in vacuum tank (internal line burst).

Affected Components:

Component #	Ring	Box	Nomenclature
H4425A	B	4	DETECTOR SUPPLY
H4625A	B	6	DETECTOR SUPPLY
H6462A	Y	4	DETECTOR SUPPLY
H6625A	Y	6	DETECTOR SUPPLY

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 68

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open/ Leaks	Flow of Supply gas to atmosphere. Can be shutoff with valve. Unacceptable leak, with depletion of helium inventory. Increased refrigerator load.	Elevated temperature/low pressure. Frosted fitting. Increased refrigerator output.
Closed	No impact. Normal operating position.	Normally closed. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
U0004H	B	4	1/2 IPS FEMALE BAYONET
U0005H	B	6	1/2 IPS FEMALE BAYONET
U0010H	Y	4	1/2 IPS FEMALE BAYONET
U0011H	Y	6	1/2 IPS FEMALE BAYONET

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 69

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position. Valve locked in open position.	Normally open valve. Visual detection. Normal operations.
Closed	Potential for cold gas in closed volume. Protected by relief valve. May be relieved by other valve operation. Valve locked in open position.	Normally open valve. Visual detection. Elevated pressure.

Affected Components:

Component #	Ring	Box	Nomenclature
H4602A	B	6	ISOLATION H 8 Linear Plug
H6702A	Y	6	ISOLATION H 8 Linear Plug

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 70

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Flow from Heat Shield Supply bypassed to Heat Shield Return. Heat shield temperature increase with magnet temperature rise and subsequent magnet quench.	Normally closed valve. Visual detection. Elevated pressure/temperature. Temperature indicators and Magnet quench.
Closed	No impact. Normal operating position.	Normally closed valve. Visual detection.

Affected Components:

Component #	Ring	Box	Nomenclature
H4502A L	B	6	ISOLATION H 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 71

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Leaks	Helium leaks into valve box insulating vacuum. Loss of inventory. Unacceptable heat load. Magnet quench.	Pressure tested pressure vessel. Elevated Pressure/temperature. Magnet quench.

Affected Components:

Component #	Ring	Box	Nomenclature
LP1 A	Y	4	LEAD POT 32015127 01
LP1 E	B	6	LEAD POT 32015127 01
LP2 C	B	4	LEAD POT "a" 32015127 02
LP3 B	B	4	LEAD POT "b" 32015127 03
LP5 A	Y	6	LEAD POT 32015127 05

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 72

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position. Valve locked in open position.	Normally open valve. Visual detection. Normal operations.
Closed	Return line blocked. Increased 4 o'clock recooler pressure vaporizes bath. Gas warms and pressurizes supply line. Can be reconfigured.	Normally open valve. Visual detection. Elevated pressure/temperature. Decreasing liquid level.

Affected Components:

Component #	Ring	Box	Nomenclature
H4504A L	B	6	ISOLATION R 4
H6604A L	Y	6	ISOLATION R 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 73

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Significantly reduced circulation. Magnet temperature rises with subsequent magnet quench.	Normally closed valve. Visual detection. Elevated pressure/temperature. Temperature indicators and magnet quench.
Closed	No impact. Normal operating position.	Normally closed valve. Visual detection. Normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
H4506A	B	6	CROSSOVER M~U 4
H6638A	Y	6	CROSSOVER M~U 4

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 74

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
N/A	Valves removed and lines capped. Discharge line not connected between Compressor Building and 6 o'clock Service Building.	

Affected Components:

Component #	Ring	Box	Nomenclature
H4538A	B	6	WARM GAS TO S LINE
H4639A	B	6	WARM GAS TO S LINE
H6639A	Y	6	WARM GAS TO S LINE
H6738A	Y	6	WARM GAS TO S LINE

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 75

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position. Valve locked in open position.	Normally open valve. Visual detection. Normal operations.
Closed	Other end capped. Potential for cold gas in closed volume. Protected by relief valve. May be relieved by other valve operation. Valve locked in open position.	Normally open valve. Visual detection. Elevated pressure.

Affected Components:

Component #	Ring	Box	Nomenclature
H4601A	B	6	ISOLATION S 8
H4604A	B	6	ISOLATION R 8
H6701A	Y	6	ISOLATION S 8
H6704A	Y	6	ISOLATION R 8

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 76

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Normally open valve. Visual detection.
Closed	No lead flow in 4 O'clock lead pots. Power supply shutdown.	Normally open valve. Visual detection. Power supply shutdown.

Affected Components:

Component #	Ring	Box	Nomenclature
H6418A	Y	4	WARM RETURN ISOLATION 4~6

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 77

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Normally open valve. Visual detection.
Closed	No lead flow in Sextant. Power supply shutdown.	Normally open valve. Visual detection.

Affected Components:

Component #	Ring	Box	Nomenclature
H4638A	Y	6	WARM RETURN RING ISOLATION

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 78

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	No impact. Normal operating position.	Normally open valve. Visual detection.
Closed	No lead flow in 6 O'clock lead pots. Power supply shutdown.	Normally open valve. Visual detection.

Affected Components:

Component #	Ring	Box	Nomenclature
H6718A	Y	6	WARM RETURN ISOLATION 6~8

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 79

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
N/A	Valve not installed for First Sextant Test.	N/A

Affected Components:

Component #	Ring	Box	Nomenclature
H6719A	Y	6	WARM RETURN ISOLATION 8~6

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 80

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open- No Pump	Loss of valve box insulating vacuum. Unacceptable heat load. Temperature rise and subsequent quench.	Elevated pressure/temperature. Magnet quench. Visual detection.
Closed- No Pump	No impact. Normal operating position.	Visual detection. Vacuum indication.
Open- Pump Attached	No impact. Normal operating position.	Visual detection. Vacuum indications (Pump and valve box indicators compare).
Closed- Pump Attached	Pump cannot evacuate valve box. Continues spoilation of vacuum. Temperature rise and subsequent magnet quench.	Visual detection. Vacuum indication. Elevated temperature. Magnet quench.

Affected Components:

Component #	Ring	Box	Nomenclature
V4400M	B	4	INSULATING VAC ISOLATION B4
V4500M	B	6	INSULATING VAC ISOLATION B6
V6400M	Y	4	INSULATING VAC ISOLATION Y4
V6600M	Y	6	INSULATING VAC ISOLATION Y6

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 81

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Open	Normal operating position. Leakage during vacuum indicator replacement causing spoilation of vacuum.	Manual valve. Visual detection. In-rushing air during vacuum indicator removal.
Closed	Isolation of vacuum indicators. Erroneous insulating vacuum readings. May mask bad vacuum problem.	Manual valve. Visual detection.

Affected Components:

Component #	Ring	Box	Nomenclature
V4401M	B	4	ISOLATION VI4400V & VI4401V
V4501M	B	6	ISOLATION VI4500V & VI4501V
V6401M	Y	4	ISOLATION VI6400V & VI6401V
V6601M	Y	6	ISOLATION VI6600V & VI6601V

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 82

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Full Scale High	No impact. Indicates poor vacuum. Does not correlate with high vacuum indicator.	Compare with high vacuum indicator.
Full Scale Low	No impact. Normal operations.	Not detectable during normal operations.

Affected Components:

Component #	Ring	Box	Nomenclature
VI4401V	B	4	VACUUM TRANSDUCER B4
VI4501V	B	6	VACUUM TRANSDUCER B6
VI6401V	Y	4	VACUUM TRANSDUCER Y4
VI6601V	Y	6	VACUUM TRANSDUCER Y6

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 83

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Full Scale High	Indicates high vacuum. Will mask spoilation of vacuum.	Vacuum higher than possible or initially set, without vacuum pump attached.
Full Scale Low	Indicates poor vacuum, but temperatures remain acceptable and rough vacuum indicator remains full scale.	Mismatch in vacuum indicators.

Affected Components:

Component #	Ring	Box	Nomenclature
VI4400V	B	4	VACUUM TRANSDUCER B4
VI4500V	B	6	VACUUM TRANSDUCER B6
VI6400V	Y	4	VACUUM TRANSDUCER Y4
VI6600V	Y	6	VACUUM TRANSDUCER Y6

Failure Mode Effects Analysis

System: RHIC Cryogenic System
Operation Mode: First Sextant Test

Item: 84

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
N/A	Valve and associated piping has been deleted from the design, although it does appear on the P&IDs. This does not impact system safety or operation.	N/A

Affected Components:

Component #	Ring	Box	Nomenclature
H4427R	B	4	VENT RELIEF 6

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 85

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Full Scale High	Circulator speed limited to 5,000 RPM. No impact above 20 K, but limits heat removal capacity below 20 K and may prevent cooling to superconducting temperature.	Temperature indication unreasonably high. Elevated pressure/temperature. Magnet quench.
Full Scale Low	Speed limit for elevated temperature operation disabled. Overspeed protection provided by other interlocks. Cryogen provides lubrication for lower bearing. Speed above 5000 RPM above 20 K will accelerate bearing deterioration.	Zero temperature indication.

Affected Components:

Component #	Ring	Box	Nomenclature
TI3803H	B	6	CAL. SNSR CIRC C3019 INLET
TI3805H	Y	6	CAL. SNSR CIRC C3018 INLET

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Friday, December 20, 1996

Operation Mode: First Sextant Test

Item: 86

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Full Scale High	No impact. Interlock turns off heater in valve box. Heater not used for First Sextant Test.	Temperature indication unreasonably high.
Full Scale Low	No impact. Interlock would permit heater operation at elevated temperature or when circulator is turned off. Heater not used for First Sextant Test.	Zero temperature indication.

Affected Components:

Component #	Ring	Box	Nomenclature
TI3708H	Y	6	CALIBRATED SNSR RECL IN
TI3712H	B	6	CALIBRATED SNSR RECL IN

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Thursday, December 26, 1996

Operation Mode: First Sextant Test

Item: 87

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Full Scale High	Interlock closes circulator isolation valve. No circulation. Magnet temperature rises with power supply shutdown possible.	Temperature indication unreasonably high. Elevated pressure/temperature. Other temperature indicators and Magnet quench.
Full Scale Low	Interlock closes circulator isolation valve. No circulation. Magnet temperature rises with power supply shutdown possible.	Zero temperature indication. Elevated pressure/temperature. Other temperature indicators and Magnet quench.

Affected Components:

Component #	Ring	Box	Nomenclature
PI3714H	Y	6	PRESSURE TRANSDUCER CIRC IN
PI3716H	B	6	PRESSURE TRANSDUCER CIRC IN

Failure Mode Effects Analysis

System: RHIC Cryogenic System **Date:** Thursday, December 26, 1996

Operation Mode: First Sextant Test

Item: 88

Failure Modes and Effects:

Failure:	Failure Effect:	Failure Detection:
Full Scale High	Interlock closes circulator isolation valve. No circulation. Also closes Supply make-up. Magnet temperature rises with power supply shutdown possible.	Temperature indication unreasonably high. Elevated pressure/temperature. Other temperature indicators and Magnet quench.
Full Scale Low	Interlock closes circulator isolation valve. No circulation. Also opens Supply make-up to full open. Magnet temperature rises with power supply shutdown possible.	Zero temperature indication. Elevated pressure/temperature. Other temperature indicators and Magnet quench.

Affected Components:

Component #	Ring	Box	Nomenclature
PI3715H	Y	6	PRESSURE TRANSDUCER CIRC OUT
PI3717H	B	6	PRESSURE TRANSDUCER CIRC OUT