

Title:

FAILURE MODES and EFFECTS ANALYSIS

FAILURE MODES and EFFECTS ANALYSIS

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY

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TECHNICAL DIRECTOR

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PROJECT MANAGER

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AUG 07 1996

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1	SFT - 7/3/96	<i>D. McWilliams</i>	Revised per LIGO TDM No. 10, ISSUE PER DFD 0.1.93
0	SFT - 4/19/96	<i>AB</i>	Issue for FDR per DEO # 0120
REV LTR	BY—DATE	APPD—DATE	DESCRIPTION OF ACTION

PROCESS SYSTEMS INTERNATIONAL, INC				SPECIFICATION		
INITIAL APPROVALS	PREPARED BY	DATE	APPROVED BY	DATE	Number	Rev
	<i>SF Teth</i>	<i>4-19</i>	<i>D. McWilliams</i>	<i>5-1-96</i>	A V049-2-094	1

LIGO-E960111-01-V

Title:

FAILURE MODES and EFFECTS ANALYSIS

Following is a general revision of the Failure Modes and Effects Analysis with an emphasis on:

1. Reliability
2. System Wide Effects (Listed as "Ultimate Effect" on the FMEA sheets)

SPECIFICATION

Number

A V049-2-094

Rev

1

To: Dave McWilliams

From: Stephen Toth

Date: July 2, 1996

Subject: Revised LIGO FMEA

Attached is the revised LIGO FMEA sheets for your review.

Rev.
 Prepared by:
 Reviewed by:

LIGO Vacuum Equipment
 Failure Modes and Effects Analysis

P&I Number: V049-0-002
Node: 1
System: Annulus Vacuum System
Date: 6/24/96

Node 1 is the Annulus ion pump and the connections from the double "O" rings seals on the 104" and 4 - 60" flanges.
 This P&I represents 11 BSC's, Washington BSC 2,4,5,6,7,8,9, and Louisiana BSC 2,4,5. The numbers below reflect WBSC2.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
1		75 liter/second ion pump	1A: Ion pump shuts down on high current caused by premature operation on pumpdown.	Pump down ceases. Restart turbopump, complete pump down to acceptable pressure for ion pump, and restart ion pump.	No significant effect.
			1B: Ion pump fails mechanically or electrically	Loss in Annulus Vacuum Pumping. Indication of loss of pump operation by current readings on LIGO control system.	Increase in leakage from atmosphere into the LIGO vacuum equipment until the annulus ion pump is replaced. The ion pump can be replaced, turbopumped, and brought back online without the chamber vacuum being broken. No significant effect.
			1C: Ion pump shuts down due to high pressure caused by annulus leak from atmosphere.	Once the ion pump fails to restart due to high current, an auxiliary turbocart can be attached to the 2 1/2" AVHV and the turbocart pressure gauges used to confirm the loss of vacuum.	LIGO Operations will determine the timing of helium leak checking the annulus "O" ring seal. If the seal cannot be fixed externally by tightening bolts, etc. The BSC will have to be isolated and the "O" ring repaired or replaced.
					The overall repair operation will result in a loss of operating time to effect the repairs and bring the BSC and other chambers in the isolatable section back to vacuum.

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					Estimated leakage rate per "O" ring seal from atmospheric pressure is 1×10^{-5} Torr-liter/sec. This would be the rate if either the inner or outer ring failed.

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LIGO Vacuum Equipment
 Failure Modes and Effects Analysis

P&I Number: V049-0-002
Node: 2
System: Beam Splitter Chamber
Date: 6/24/96

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
3	WBSC2	Beam Splitter Chamber	3A: Any flange leak or leak in a feed through	Loss in vacuum is indicated on the Cold Cathode or Pirani gauge.	LIGO Operations will determine the timing of helium leak checking the chamber and repairing the leak.
					The overall repair operation will result in a loss of operating time to effect the repairs and bring the BSC and other chambers in the isolatable section back to vacuum.
			3B: During manual "Back to Air" operation the operator fully opens the larger supply valve.	The pressure will rise to the "Back to Air" supply header pressure of 1 psig. The supply header pressure is further limited by a relief valve set at 2 psig. The pressure can be bled out of the system by opening the 1 1/2" Aux. Turbo Pumpout Port.	None
			3C: Opening of the 2 1/2" RGA Port valve, the 1 1/2" Aux. Turbo Pumpout Port valve, or the 14" Air Shower Connection with the BSC under vacuum.	The BSC and other sections of the vacuum enclosure connected to it would rapidly pressurize with contamination of the vacuum enclosure. The rapid air flow into the open valve might cause injury to personnel nearby.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.

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4	Gauge Pair on WBSC2	A Gauge Pair consists of a Cold Cathode gauge and a Pirani gauge both with local and remote readouts.	4A: Either gauge can fail during pumpdown	There are two options: 1. The section can be isolated, brought back to atmospheric pressure and the gauge replaced, or 2. The gauges on the Turbo Cart could be used to monitor pressure during pumpdown.	Minor loss in operating time with no long term effects.
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 Failure Modes and Effects Analysis

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P&I Number: V049-0-003
Node: 3
System: Annulus Vacuum System
Date: 6/25/96

Node 3 is the Annulus ion pump and the connections from the double "O" rings seals on the 104" and 4 - 60" flanges. and Louisiana BSC 1 and 3. The numbers below reflect WBSC1.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
5		75 liter/second ion pump	5A: Ion pump shuts down on high current caused by premature operation on pumpdown.	Pump down ceases. Restart turbopump, complete pump down to acceptable pressure for ion pump, and restart ion pump.	No significant effect.
			5B: Ion pump fails mechanically or electrically	Loss in Annulus Vacuum Pumping. Indication of loss of pump operation by current readings on LIGO control system.	Increase in leakage from atmosphere into the LIGO vacuum equipment until the annulus ion pump is replaced. The ion pump can be replaced, turbopumped, and brought back online without the chamber vacuum being broken. No significant effect.
			5C: Ion pump shuts down due to high pressure caused by annulus leak from atmosphere.	Once the ion pump fails to restart due to high current, an auxiliary turbocart can be attached to the 2 1/2" AVHV and the turbocart pressure gauges used to confirm the loss of vacuum.	LIGO Operations will determine the timing of helium leak checking the annulus "O" ring seal. If the seal cannot be fixed externally by tightening bolts, etc. The BSC will have to be isolated and the "O" ring repaired or replaced.
					The overall repair operation will result in a loss of operating time to effect the repairs and bring the BSC and other chambers in the Corner Vertex Section back to vacuum.

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					Estimated leakage rate per "O" ring seal from atmospheric pressure is 1×10^{-5} Torr-liter/sec. This would be the rate if either the inner or outer ring failed.
6		"O" Ring Seals on the 104" top section and the 4 - 60" ports and interconnecting piping.	6A: "O" Ring seals fails, or leakage in a piping item (flex hose, flange)	Same as Failure Mode 5C above	Same as Failure Mode 5C above

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P&I Number: V049-0-003
Node: 4
System: Beam Splitter Chamber
Date: 6/24/96

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
7	WBSC1	Beam Splitter Chamber	7A: Any flange leak or leak in a feed through	Loss in vacuum is indicated on the Cold Cathode or Pirani gauge located on adjacent BSC (WBSC2).	LIGO Operations will determine the timing of helium leak checking the chamber and repairing the leak.
					The overall repair operation will result in a loss of operating time to effect the repairs and bring the BSC and the other chambers in the Corner Vertex Section back to vacuum.
			7B: Opening of the 2 1/2" RGA Port valve, the 1 1/2" Aux. Turbo Pumpout Port valve, or the 14" Air Shower Connection with the BSC under vacuum.	The BSC and other sections of the vacuum enclosure connected to it would rapidly pressurize with contamination of the vacuum enclosure. The rapid air flow into the open valve might cause injury to personnel nearby.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.

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P&I Number: V049-0-004
Node: 5
System: Annulus Vacuum System
Date: 6/25/96

Node 5 is the Annulus ion pump and the connections from the double "O" rings seals on the 2 - 84" and 2 - 60" flanges. This P&I represents all 19 HAM's, Washington 1-13, and Louisiana 1-6. The numbers below reflect WHAM1.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
8		75 liter/second ion pump	8A: Ion pump shuts down on high current caused by premature operation on pumpdown.	Pump down ceases. Restart turbopump, complete pump down to acceptable pressure for ion pump, and restart ion pump.	No significant effect.
			8B: Ion pump fails mechanically or electrically	Loss in Annulus Vacuum Pumping. Indication of loss of pump operation by current readings on LIGO control system.	Increase in leakage from atmosphere into the LIGO vacuum equipment until the annulus ion pump is replaced. The ion pump can be replaced, turbopumped, and brought back online without the chamber vacuum being broken. No significant effect.
			8C: Ion pump shuts down due to high pressure caused by annulus leak from atmosphere.	Once the ion pump fails to restart due to high current, an auxiliary turbocart can be attached to the 2 1/2" AVHV and the turbocart pressure gauges used to confirm the loss of vacuum.	LIGO Operations will determine the timing of helium leak checking the annulus "O" ring seal. If the seal cannot be fixed externally by tightening bolts, etc. The HAM will have to be isolated and the "O" ring repaired or replaced.
					The overall repair operation will result in a loss of operating time to effect the repairs and bring the HAM and other chambers in the isolatable section back to vacuum.

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					Estimated leakage rate per "O" ring seal from atmospheric pressure is 1×10^{-5} Torr-liter/sec. This would be the rate if either the inner or outer ring failed.
9		"O" Ring Seals on the 2 - 84" and the 2 - 60" ports and interconnecting piping.	9A: "O" Ring seals fails, or leakage in a piping item (flex hose, flange)	Same as Failure Mode 8C above	Same as Failure Mode 8C above

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 Failure Modes and Effects Analysis

P&I Number: V049-0-004
Node: 6
System: Horizontal Access Module
Date: 6/26/96

Node 6 is the Horizontal Access Module.
 This P&I represents all 19 HAM's, Washington 1-13, and Louisiana 1-6. The numbers below reflect WHAM1.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
10	WHAM1	Horizontal Access Module	10A: Any flange leak or leak in a feed through	Loss in vacuum is indicated on the Cold Cathode or Pirani gauge located BSC in the same isolatable section (WBSC2).	LIGO Operations will determine the timing of helium leak checking the chamber and repairing the leak.
					The overall repair operation will result in a loss of operating time to effect the repairs and bring the HAM and the other chambers in the Isolatable Section back to vacuum.
			10B: Opening of the 2 1/2" RGA Port valve, the 1 1/2" Aux. Turbo Pumpout Port valve, or the 14" Air Shower Connection with the HAM under vacuum.	The HAM and other sections of the vacuum enclosure connected to it would rapidly pressurize with contamination of the vacuum enclosure. The rapid air flow into the open valve might cause injury to personnel nearby.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.

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LIGO Vacuum Equipment
 Failure Modes and Effects Analysis

P&I Number: V049-0-005
Node: 7
System: Large Gate Valves
Date: 6/26/96

This P&ID depicts the pneumatic and motor driven 44" and 48" gate valves.
 There are 8 - 44" pneumatic gate valves, Washington 5-8, and Louisiana 3-6.
 There are 8 - 48" and 16 - 44" electric gate valves, Wasnington 1-4, and 9-20. and Louisiana 1,2 and 7-12.
 The equipment and instrument numbers reflect WGV5 for pneumatic and WGV1 for electric.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
11		25 liter/second ion pump on one of the Pneumatic Gate Valves	11A: Ion pump shuts down on high current caused by premature operation on pumpdown.	Pump down ceases. Restart turbopump, complete pump down to acceptable pressure for ion pump, and restart ion pump.	No significant effect.
			11B: Ion pump fails mechanically or electrically	Loss in Annulus Vacuum Pumping. Indication of loss of pump operation by current readings on LIGO control system.	Increase in leakage from atmosphere into the LIGO vacuum equipment until the annulus ion pump is replaced. The ion pump can be replaced, turbopumped, and brought back online without the chamber vacuum being broken. No significant effect.
			11C: Ion pump shuts down due to high pressure caused by annulus leak from atmosphere.	Once the ion pump fails to restart due to high current, an auxiliary turbocart can be attached to the 1 1/2" AVHV and the turbocart pressure gauges used to confirm the loss of vacuum.	LIGO Operations will determine the timing of helium leak checking the annulus "O" ring seal. If the seal cannot be fixed externally by tightening bolts, etc., the gate valve will have to be isolated and the "O" ring repaired or replaced.
					This operation requires closing the gate valve and the next large gate valve on the side where the leak is detected.

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					The overall repair operation will result in a loss of operating time to effect the repairs and bring the HAM and other chambers in the isolatable section back to vacuum.
					Estimated leakage rate per "O" ring seal from atmospheric pressure is 1×10^{-5} Torr-liter/sec. This would be the rate if either the inner or outer ring failed.

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P&I Number: V049-0-005
Node: 8
System: Large Gate Valves
Date: 6/27/96

The large gate valves, whether pneumatic or electric are driven from the computer. Since the opening of one of these valves exposes an atmospheric section to high vacuum and vice versa we recommend and plan to configure the controls such that they can only be operated from the control room. At the valve itself there is a lockout with a keyed padlock which prevents opening even if the computer initiates it. LIGO operating procedures will stress the critical nature of the lockout / tagout function. The lockout feature of the valves is also used in the open position.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
12	WGV5	44" Pneumatic Gate Valve	12A: Valve Fails to Close, caused by instrument air failure, failure of drive mechanism, or failure to open lockout.	Failure to isolate a section when desired - causes a delay in isolating a section either for pumpdown to vacuum, repressurization, or cryopump regeneration.	Minor loss in operating time - No long term effect.
			12B: Valve Fails to Open, caused by instrument air failure, failure of drive mechanism, damage to drive mechanism caused by excessive differential pressure, failure to open lockout, or failure of the latching mechanism to release.	Failure to open a section when desired - causes a delay in opening a section either for work to be performed at atmospheric pressure or return to operation of the interferometer and cryopump.	Minor loss in operating time - No long term effect.
			12C: Valve is Closed with the Laser on	Damage to the valve and possibly other equipment	Major loss in operating time to remove the valve for repair or replacement, repair instrument damage and remove contamination from the adjacent area followed by a bakeout of a large section of the vacuum enclosure.

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			12D: Valve fails to fully close or open as indicated by limit switches, or false signal from limit switches indicating failure to open or close.	Same as 12A and 12B	Minor loss in operating time - No long term effect.
			12E: Valve is opened at an inappropriate time	Section containing equipment and personnel under atmospheric pressure is exposed to vacuum causing injury or death and damage to equipment on both sides of valve.	Major loss in operating time to repair instrument damage followed by a bakeout of a large section of the vacuum enclosure.

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P&I Number: V049-0-005
 Node: 9
 System: Large Gate Valves
 Date: 6/27/96

This P&ID depicts the pneumatic and motor driven 44" and 48" gate valves.
 There are 8 - 44" pneumatic gate valves, Washington 5-8, and Louisiana 3-6.
 There are 8 - 48" and 16 - 44" electric gate valves, Washington 1-4, and 9-20. and Louisiana 1,2 and 7-12.
 The equipment and instrument numbers reflect WGV5 for pneumatic and WGV1 for electric.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
13		25 liter/second ion pump on one of the Electric Gate Valves	13A: Ion pump shuts down on high current caused by premature operation on pumpdown.	Pump down ceases. Restart turbopump, complete pump down to acceptable pressure for ion pump, and restart ion pump.	No significant effect.
			13B: Ion pump fails mechanically or electrically	Loss in Annulus Vacuum Pumping. Indication of loss of pump operation by current readings on LIGO control system.	Increase in leakage from atmosphere into the LIGO vacuum equipment until the annulus ion pump is replaced. The ion pump can be replaced, turbopumped, and brought back online without the chamber vacuum being broken. No significant effect.
			13C: Ion pump shuts down due to high pressure caused by annulus leak from atmosphere.	Once the ion pump fails to restart due to high current, an auxiliary turbocart can be attached to the 1 1/2" AVHV and the turbocart pressure gauges used to confirm the loss of vacuum.	LIGO Operations will determine the timing of helium leak checking the annulus "O" ring seal. If the seal cannot be fixed externally by tightening bolts, etc., the gate valve will have to be isolated and the "O" ring repaired or replaced.
					This operation requires closing the gate valve and the next large gate valve on the side where the leak is detected.

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					The overall repair operation will result in a loss of operating time to effect the repairs and bring the HAM and other chambers in the isolatable section back to vacuum.
					Estimated leakage rate per "O" ring seal from atmospheric pressure is 1×10^{-5} Torr-liter/sec. This would be the rate if either the inner or outer ring failed.

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P&I Number: V049-0-005
Node: 10
System: Large Gate Valves
Date: 8/27/96

The large gate valves, whether pneumatic or electric are driven from the computer. Since the opening of one of these valves exposes an atmospheric section to high vacuum and vice versa we recommend and plan to configure the controls such that they can only be operated from the control room. At the valve itself there is a lockout with a keyed padlock which prevents opening even if the computer initiates it. LIGO operating procedures will stress the critical nature of the lockout / tagout function. The lockout feature of the valves is also used in the open position.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
14	WGV1	48" Electric Gate Valve	14A: Valve Fails to Close, caused by power failure, failure of drive mechanism, or failure to open lockout.	Failure to isolate a section when desired - causes a delay in isolating a section either for pumpdown to vacuum, repressurization, or cryopump regeneration.	Minor loss in operating time - No long term effect.
			14B: Valve Fails to Open, caused by power failure, failure of drive mechanism, damage to drive mechanism caused by excessive differential pressure, failure to open lockout, or failure of the latching mechanism to release.	Failure to open a section when desired - causes a delay in opening a section either for work to be performed at atmospheric pressure or return to operation of the interferometer and cryopump.	Minor loss in operating time - No long term effect.
			14C: Valve is Closed with the Laser on	Damage to the valve and possibly other equipment	Major loss in operating time to remove the valve for repair or replacement, repair instrument damage and remove contamination from the adjacent area followed by a bakeout of a large section of the vacuum enclosure.

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			14D: Valve fails to fully close or open as indicated by limit switches, or false signal from limit switches indicating failure to open or close.	Same as 14A and 14B	Minor loss in operating time - No long term effect.
			14E: Valve is opened at an inappropriate time	Section containing equipment and personnel under atmospheric pressure is exposed to vacuum causing injury or death and damage to equipment on both sides of valve.	Major loss in operating time to repair instrument damage followed by a bakeout of a large section of the vacuum enclosure.

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LIGO Vacuum Equipment
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P&I Number: V049-0-006
Node: 11
System: 80K Cryopump LN2 and GN2 Supply
Date: 6/27/96

At each cryopump there is a dedicated LN2 supply dewar located outside the building. The cryopump regeneration system consists of an ambient vaporizer also located outside the building, a hand control valve, a flow indicator, and an electric heater to warm the gas.

The storage dewar includes a pressure building coil and all the normal pressure relief protection.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
15	LV-100	LN2 Level Control Valve	15A: Valve fails closed	Failure to make up liquid to the cryopump with loss of effectiveness and eventual release of adsorbed water vapor.	None
				LAL-100 indicates problem, valve can either be repaired or HV-194 can be used to supply make-up manually.	
			15B: Valve fails open	The cryopump reservoir overfills spilling LN2 out the vent.	None
				LAH-100 indicates problem, the manual block valve closed and LV-100 repaired or HV-194 can be used to supply make-up manually.	
16	WDW1	LN2 Dewar and associated vendor supplied valving and pressure building coil.	16A: Vessel or line rupture caused by overpressure	Vessel is protected against rupture by RV 106 and rupture disk RD 106. Potentially blocked in liquid lines are protected by RV 108, 112, 132, and 136.	None - Vessel rupture can be eliminated as a failure mode

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			16B: RV fails to reseal after relief	Partial loss of LN2 inventory. Block valve can be closed and valve repaired. Makeup rate to the Cryopump is low enough that it can be cut off for a short period of time without detrimental effects to the system.	None
17		Ambient Vaporizer	17A: Outside surface covered with ice limiting effectiveness.	Inability to vaporize sufficient LN2 for regeneration. Regeneration can be stopped until the vaporizer can be derimed or regeneration can be done at a lower rate.	None
18		Electric Heater	18A: Heater burns out. Protection is by hard wired TSH-103.	Inability to heat the gas above ambient. This would slow regeneration.	None
			18B: JC-103 fails with low output.	Inability to heat the gas above ambient. This would slow regeneration.	None
			18C: TIC-103 fails with high output	TAH-103 alerts LIGO operators who can the cut the power to the heater.	Although the inner annulus may be heated above its' design temperature, there is no source of significant overpressure since the annulus is open to the atmosphere so vessel rupture caused by overheat is not a failure mode. None

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LIGO Vacuum Equipment
 Failure Modes and Effects Analysis

P&I Number: V049-0-006
Node: 12
System: 80K Cryopump
Date: 6/27/96

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
19	WCP1	80 K Cryopump	19A: Leakage from atmosphere, either through a faulty weld or through the Relief Valve.	Failure to maintain vacuum, each cryopump has a gauge pair which will indicate loss of vacuum. The leak can either be repaired with the cryopump in service or the cryopump can be isolated and the leak repaired.	Minor loss in operating time to isolate the Cryopump, leak check, and bring the cryopump back online since each cryopump is designed to be isolated for regeneration.
			19B: Rupture or leak from LN2 reservoir into the cryopump while the cryopump is isolated for regeneration.	Overpressure of the cryopump shell. Protection is provided by relief device on the cryopump shell.	Major loss in operating time to isolate the cryopump, effect repairs on the internal annulus, clean and decontaminate the repaired area, rebake the isolatable section containing the cryopump and return to vacuum.
			19C: Rupture or leak from LN2 reservoir into the cryopump during normal operation	Failure to maintain vacuum, each cryopump has a gauge pair which will indicate loss of vacuum.	Major loss in operating time to isolate the cryopump, effect repairs on the internal annulus, clean and decontaminate the repaired area, rebake the isolatable section containing the cryopump and return to vacuum.

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P&I Number: V049-0-010
Node: 13
System: Washington Site Left End Station
Date: 6/27/96

Node 13 includes all the normally connected equipment. The BSC chamber covered on P&ID V049-0-002, WIP11, and WCP7.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
20	WIP11	2500 liter/sec ion pump and its' associated 14" gate valve.	13A: Ion pump shutdown on high current caused by premature operation during pumpdown of the pump itself or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect
			13B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the ion pump replaced without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.
21	WCP7	80 K Cryopump (Short)	21A: Leakage from atmosphere or LN2 side.	Loss of vacuum, possible contamination. PI-424 A or B will indicate leak. The cryopump can be isolated with WGV17 and 18 and repaired.	Major or minor loss in operating time depending on source of leak. See Node 12 "80 K Cryopump" for details.
22	PI 424 A or B	Gauge Pair on Cryopump	22A: Either gauge fails electrically	Loss in the ability to read the vacuum level. Either an RGA can be attached to read the pressure or operation may continue without this information until it's convenient to isolate the cryopump and replace the gauges.	None

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23	WGV18	Large Motor Operated Gate Valve	23A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			23B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			23C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			23D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
24	WGV17	Large Motor Operated Gate Valve	24A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			24B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			24C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"

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			24D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
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P&I Number: V049-0-010
Node: 14
System: Washington Site Left End Station
Date: 6/27/96

Node 14 includes the turbo pumping equipment and the clean air supply system equipment. The Turbo Cart and its' Turbo Backing Pump Cart are self-protected. See Hazards Analysis sheets for the Turbo Carts. The unit shuts down on loss of seal gas to the backing cart, loss of cooling water flow shuts it down on high temperature, power failure, etc.

An intrinsically safe wiring setup has been designed such that it is physically impossible to operate more than one turbo pump cart with a single backing pump.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
25	WTC5	Turbopump cart and associated connections	25A: Pump shuts down for any of a number of reasons; loss of utility, suction pressure above allowable due to leak or insufficient roughing.	Delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.
26	HV 420 / 421	10" Pump out port valve	26A: Valve opened to atmosphere with vacuum in the tube or cryopump. These are manual gate valves with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of these valves.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.
27	WTC5B	Turbo pump backing cart	27A: Pump shuts down for any of a number of reasons; loss of utility, signal from turbo cart controller.	Shutdown of turbo cart and delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.

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28	WCA400	Class 100 Clean Air Supply System	28A: System shutdown, either compressor out or drier beds won't switch. Three signals go to the LIGO computer for monitoring, Compressor running signal, Compressor Common Alarm, Drier Beds Common Alarm.	A-1: During turbo pumping this would cause shutdown of the Turbo Backing Pump on loss of seal air.	Minor loss in operating time. No long term effect.
				A-2: During back to air operation the receiver could be sucked down to vacuum damaging it.	Loss in operating time. This would require replacement of receiver. A vacuum relief valve should be included on the receiver to avoid this situation.
				A-3: During purge operation through air showers loss of flow would allow contamination of optics with moisture should the outage persist long enough to drop the receiver pressure.	None
29	PCV-426	First stage letdown valve	29A: Fail open	Increase downstream pressure to PCV-427. If PCV-427's response is not fast enough the clean air supply header pressure will increase limited by PSV-425 which will relieve at 2 psig.	None
			29B: Fail closed	Loss of clean air flow tripping the turbo or cutting off air shower flow.	None
30	PCV-427	Second stage letdown valve	30A: Fail open	The clean air supply header pressure will increase limited by PSV-425 which will relieve at 2 psig.	None
			30B: Fail closed	Loss of clean air flow tripping the turbo or cutting off air shower flow.	None

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34	WCP3	80 K Cryopump (Short)	34A: Leakage from atmosphere or LN2 side.	Loss of vacuum, possible contamination. PI-244 A or B will indicate leak. The cryopump can be isolated with WGV9 and 10 and repaired.	Major or minor loss in operating time depending on source of leak. See Node 12 "80 K Cryopump" for details.
35	PI 244 A or B	Gauge Pair on Cryopump	35A: Either gauge fails electrically	Loss in the ability to read the vacuum level. Either an RGA can be attached to read the pressure or operation may continue without this information until it's convenient to isolate the cryopump and replace the gauges.	None
36	WGV12	Large Motor Operated Gate Valve	36A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			36B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			36C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			36D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
37	WGV11	Large Motor Operated Gate Valve	37A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"

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P&I Number: V049-0-011
Node: 16
System: Washington Left Mid Station
Date: 6/28/96

Node 16 includes the turbo pumping equipment and the clean air supply system equipment.
 The Turbo Cart and its' Turbo Backing Pump Cart are self-protected. See Hazards Analysis sheets for the Turbo Carts.
 The unit shuts down on loss of seal gas to the backing cart, loss of cooling water flow shuts it down on high temperature, power failure, etc.

An intrinsically safe wiring setup has been designed such that it is physically impossible to operate more than one turbo pump cart with a single backing pump.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
40	WTC3	Turbopump cart and associated connections	40A: Pump shuts down for any of a number of reasons; loss of utility, suction pressure above allowable due to leak or insufficient roughing.	Delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.
41	HV 240 / 241 / 242	10" Pump out port valves	41A: Valve opened to atmosphere with vacuum in the tube or cryopump. These are manual gate valves with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of these valves.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.
42	WTC3B	Turbo pump backing cart	42A: Pump shuts down for any of a number of reasons; loss of utility, signal from turbo cart controller.	Shutdown of turbo cart and delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.

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43	WCA200	Class 100 Clean Air Supply System	43A: System shutdown, either compressor out or drier beds won't switch. Three signals go to the LIGO computer for monitoring, Compressor running signal, Compressor Common Alarm, Drier Beds Common Alarm.	A-1: During turbo pumping this would cause shutdown of the Turbo Backing Pump on loss of seal air.	Minor loss in operating time. No long term effect.
				A-2: During back to air operation the receiver could be sucked down to vacuum damaging it.	Loss in operating time. This would require replacement of receiver. A vacuum relief valve should be included on the receiver to avoid this situation.
				A-3: During purge operation through air showers loss of flow would allow contamination of optics with moisture should the outage persist long enough to drop the receiver pressure.	None
44	PCV-261	First stage letdown valve	44A: Fail open	Increase downstream pressure to PCV-284. If PCV-284's response is not fast enough the clean air supply header pressure will increase limited by PSV-260 which will relieve at 2 psig.	None
			44B: Fail closed	Loss of clean air flow tripping the turbo or cutting off air shower flow.	None
45	PCV-284	Second stage letdown valve	45A: Fail open	The clean air supply header pressure will increase limited by PSV-260 which will relieve at 2 psig.	None
			45B: Fail closed	Loss of clean air flow tripping the turbo or cutting off air shower flow.	None

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P&I Number: V049-0-012
 Node: 17
 System: Washington Site Left Beam Manifold
 Date: 6/28/96

Node 17 includes all the normally connected equipment; WCP1, WBSC8, WIP5, and WGV 5 and 6.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
46	WIP5	2500 liter/sec ion pump and its' associated 14" gate valve.	46A: Ion pump shutdown on high current caused by premature operation during pumpdown of the pump itself or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect
			46B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the ion pump replaced without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.
47	WCP1	80 K Cryopump (Long)	47A: Leakage from atmosphere or LN2 side.	Loss of vacuum, possible contamination. PI-114 A or B will indicate leak. The cryopump can be isolated with WGV5 and 6 and repaired.	Major or minor loss in operating time depending on source of leak. See Node 12 "80 K Cryopump" for details.
48	PI 114 A or B	Gauge Pair on Cryopump	48A: Either gauge fails electrically	Loss in the ability to read the vacuum level. Either an RGA can be attached to read the pressure or operation may continue without this information until it's convenient to isolate the cryopump and replace the gauges.	None

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49	WGV5	Large Pneumatic Gate Valve	49A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			49B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			49C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			49D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
50	WGV6	Large Pneumatic Gate Valve	50A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			50B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			50C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"

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			50D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
51	HV 146 / 147 / 148	10" Pump out port valves	51A: Valve opened to atmosphere with vacuum in the tube or cryopump. These are manual gate valves with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of these valves.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.

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P&I Number: V049-0-013
 Node: 18
 System: Washington Site Vertex Section
 Date: 6/28/96

Node 18 is the entire P&ID. The vertex section is one large isolatable section with only two large gate valves. There are no cryopumps in the vertex section. The FMEA information for the HAM's and BSC's is found on the FMEA sheets for P&ID's V049-0-002, 003 and 004.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
52	WIP1	2500 liter/sec ion pump and its' associated 14" gate valve.	52A: Ion pump shutdown on high current caused by premature operation during pumpdown of the pump itself or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect
			52B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the ion pump replaced without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.
53	WIP2	2500 liter/sec ion pump and its' associated 14" gate valve.	53A: Ion pump shutdown on high current caused by premature operation during pumpdown of the pump itself or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect

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			53B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the Ion pump replaced without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.
54	WIP3	2500 liter/sec ion pump and its' associated 14" gate valve.	54A: Ion pump shutdown on high current caused by premature operation during pumpdown of the pump itself or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect
			54B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the Ion pump replaced without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.
55	WIP4	2500 liter/sec ion pump and its' associated 14" gate valve.	55A: Ion pump shutdown on high current caused by premature operation during pumpdown of the pump itself or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect
			55B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the Ion pump replace without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.

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56	HV 109	10" Pump out port valves	56A: Valve opened to atmosphere with vacuum in the tube or cryopump. These are manual gate valves with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of these valves.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.
57	HV 145	6" Pump out port valve	57A: Valve opened to atmosphere with vacuum in the tube or cryopump. These are manual gate valves with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of these valves.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.
58	WGV1	Large Motor Operated Gate Valve	58A: Valve fails to close	Inability to isolate vertex section for pumpdown or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			58B: Valve fails to open	Inability to return vertex section to operation. Valve can be repaired and the valve	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			58C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"

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			58D: Valve opened with pressure on one side or one of the BSC's or HAM's open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
59	WGV2	Large Motor Operated Gate Valve	59A: Valve fails to close	Inability to isolate vertex section for pumpdown or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			59B: Valve fails to open	Inability to return vertex section to operation. Valve can be repaired and the valve	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			59C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			59D: Valve opened with pressure on one side or one of the BSC's or HAM's open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
60	WTC2	Turbopump cart and associated connections	60A: Pump shuts down for any of a number of reasons; loss of utility, suction pressure above allowable due to leak or insufficient roughing.	Delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.
61	WRC2	Roughing pump cart and associated connections	61A: Pump shuts down for any of a number of reasons.	Delay in rough pumping the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.

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P&I Number: V049-0-014
Node: 19
System: Washington Site Diagonal Section
Date: 6/28/96

Node 19 is the entire P&ID. The diagonal section is one large isolatable section with only two large gate valves. There are no cryopumps in the diagonal section. The FMEA information for the HAM's and BSC's is found on the FMEA sheets for P&ID's V049-0-002 and 004.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
62	WIP7	2500 liter/sec ion pump and its' associated 14" gate valve.	62A: Ion pump shutdown on high current caused by premature operation during <i>pumpdown of the pump itself</i> or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect
			62B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the ion pump replaced without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.
63	WIP8	2500 liter/sec ion pump and its' associated 14" gate valve.	63A: Ion pump shutdown on high current caused by premature operation during pumpdown of the pump itself or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect

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			63B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the ion pump replaced without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.
64	HV 174	10" Pump out port valves	64A: Valve opened to atmosphere with vacuum in the tube. This is a manual gate valve with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of this valve.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.
65	HV 160	6" Pump out port valves	65A: Valve opened to atmosphere with vacuum in the tube. This is a manual gate valve with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of this valve.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.
66	WGV3	Large Motor Operated Gate Valve	66A: Valve fails to close	Inability to isolate diagonal section for pumpdown or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			66B: Valve fails to open	Inability to return diagonal section to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			66C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"

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			66D: Valve opened with pressure on one side or one of the BSC's or HAM's open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
67	WGV4	Large Motor Operated Gate Valve	67A: Valve fails to close	Inability to isolate diagonal section for pumpdown or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			67B: Valve fails to open	Inability to return diagonal section to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			67C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			67D: Valve opened with pressure on one side or one of the BSC's or HAM's open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
68	WCT1	Turbopump cart and associated connections	68A: Pump shuts down for any of a number of reasons; loss of utility, suction pressure above allowable due to leak or insufficient roughing.	Delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.

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69	WRC1	Roughing pump cart and associated connections	69A: Pump shuts down for any of a number of reasons.	Delay in rough pumping the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.
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P&I Number: V049-0-015
Node: 20
System: Washington Site Right Beam Manifold
Date: 6/28/96

Node 20 includes all the normally connected equipment; WCP2, WBSC7, WIP6, and WGV 7 and 8.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
70	WIP6	2500 liter/sec ion pump and its' associated 14" gate valve.	70A: Ion pump shutdown on high current caused by premature operation during pumpdown of the pump itself or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect
			70B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the Ion pump replaced without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.
71	WCP2	80 K Cryopump (Long)	71A: Leakage from atmosphere or LN2 side.	Loss of vacuum, possible contamination. PI-134 A or B will indicate leak. The cryopump can be isolated with WGV7 and 8 and repaired.	Major or minor loss in operating time depending on source of leak. See Node 12 "80 K Cryopump" for details.
72	PI 134 A or B	Gauge Pair on Cryopump	72A: Either gauge fails electrically	Loss in the ability to read the vacuum level. Either an RGA can be attached to read the pressure or operation may continue without this information until it's convenient to isolate the cryopump and replace the gauges.	None

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73	WGV7	Large Pneumatic Gate Valve	73A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			73B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			73C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			73D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
74	WGV8	Large Pneumatic Gate Valve	74A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			74B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			74C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"

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			74D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
75	HV 176 / 177 / 178	10" Pump out port valves	75A: Valve opened to atmosphere with vacuum in the tube or cryopump. These are manual gate valves with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of these valves.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.

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P&I Number: V049-0-016
 Node: 21
 System: Washington Site Right Mid Station
 Date: 6/28/96

Node 21 includes all the normally connected equipment; WCP5, WBSC5, WIP10, WCP6, and WGV 13,14,15, and 16.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
76	WIP10	2500 liter/sec ion pump and its' associated 14" gate valve.	76A: Ion pump shutdown on high current caused by premature operation during pumpdown of the pump itself or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect
			76B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the Ion pump replaced without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.
77	WCP5	80 K Cryopump (Short)	77A: Leakage from atmosphere or LN2 side.	Loss of vacuum, possible contamination. PI-344 A or B will indicate leak. The cryopump can be isolated with WGV13 and 14 and repaired.	Major or minor loss in operating time depending on source of leak. See Node 12 "80 K Cryopump" for details.
78	PI 344 A or B	Gauge Pair on Cryopump	78A: Either gauge fails electrically	Loss in the ability to read the vacuum level. Either an RGA can be attached to read the pressure or operation may <i>continue without this information until it's convenient to isolate the cryopump and replace the gauges.</i>	None

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79	WCP6	80 K Cryopump (Short)	79A: Leakage from atmosphere or LN2 side.	Loss of vacuum, possible contamination. PI-345 A or B will indicate leak. The cryopump can be isolated with WGV15 and 16 and repaired.	Major or minor loss in operating time depending on source of leak. See Node 12 "80 K Cryopump" for details.
80	PI 345 A or B	Gauge Pair on Cryopump	80A: Either gauge fails electrically	Loss in the ability to read the vacuum level. Either an RGA can be attached to read the pressure or operation may continue without this information until it's convenient to isolate the cryopump and replace the gauges.	None
81	WGV13	Large Motor Operated Gate Valve	81A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			81B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			81C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			81D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
82	WGV14	Large Motor Operated Gate Valve	82A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"

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			82B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			82C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			82D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
83	WGV15	Large Motor Operated Gate Valve	83A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			83B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			83C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			83D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"

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84	WGV16	Large Motor Operated Gate Valve	84A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			84B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			84C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			84D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"

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P&I Number: V049-0-016
Node: 22
System: Washington Site Right Mid Station
Date: 6/28/96

Node 22 includes the turbo pumping equipment and the clean air supply system equipment.
 The Turbo Cart and its' Turbo Backing Pump Cart are self-protected. See Hazards Analysis sheets for the Turbo Carts.
 The unit shuts down on loss of seal gas to the backing cart, loss of cooling water flow shuts it down on high temperature, power failure, etc.

An intrinsically safe wiring setup has been designed such that it is physically impossible to operate more than one turbo pump cart with a single backing pump.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
85	WTC4	Turbopump cart and associated connections	85A: Pump shuts down for any of a number of reasons; loss of utility, suction pressure above allowable due to leak or insufficient roughing.	Delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.
86	HV 340 / 341 / 342	10" Pump out port valves	86A: Valve opened to atmosphere with vacuum in the tube or cryopump. These are manual gate valves with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of these valves.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.
87	WTC4B	Turbo pump backing cart	87A; Pump shuts down for any of a number of reasons; loss of utility, signal from turbo cart controller.	Shutdown of turbo cart and delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.

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88	WCA300	Class 100 Clean Air Supply System	88A: System shutdown, either compressor out or drier beds won't switch. Three signals go to the LIGO computer for monitoring, Compressor running signal, Compressor Common Alarm, Drier Beds Common Alarm.	A-1: During turbo pumping this would cause shutdown of the Turbo Backing Pump on loss of seal air.	Minor loss in operating time. No long term effect.
				A-2: During back to air operation the receiver could be sucked down to vacuum damaging it.	Loss in operating time. This would require replacement of receiver. A vacuum relief valve should be included on the receiver to avoid this situation.
				A-3: During purge operation through air showers loss of flow would allow contamination of optics with moisture should the outage persist long enough to drop the receiver pressure.	None
89	PCV-361	First stage letdown valve	89A: Fail open	Increase downstream pressure to PCV-384. If PCV-384's response is not fast enough the clean air supply header pressure will increase limited by PSV-360 which will relieve at 2 psig.	None
			89B: Fail closed	Loss of clean air flow tripping the turbo or cutting off air shower flow.	None
90	PCV-384	Second stage letdown valve	90A: Fail open	The clean air supply header pressure will increase limited by PSV-360 which will relieve at 2 psig.	None
			90B: Fail closed	Loss of clean air flow tripping the turbo or cutting off air shower flow.	None

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P&I Number: V049-0-017
Node: 23
System: Washington Site Right End Station
Date: 6/28/96

Node 23 includes all the normally connected equipment. The BSC chamber covered on P&ID V049-0-002, WIP12, WCP8, WGV19 and WGV20.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
91	WIP12	2500 liter/sec ion pump and its' associated 14" gate valve.	91A: Ion pump shutdown on high current caused by premature operation during pumpdown of the pump itself or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect
			91B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the ion pump replaced without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.
92	WCP8	80 K Cryopump (Short)	92A: Leakage from atmosphere or LN2 side.	Loss of vacuum, possible contamination. PI-524 A or B will indicate leak. The cryopump can be isolated with WGV19 and 20 and repaired.	Major or minor loss in operating time depending on source of leak. See Node 12 "80 K Cryopump" for details.
93	PI 524 A or B	Gauge Pair on Cryopump	93A: Either gauge fails electrically	Loss in the ability to read the vacuum level. Either an RGA can be attached to read the pressure or operation may continue without this information until it's convenient to isolate the cryopump and replace the gauges.	None

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94	WGV19	Large Motor Operated Gate Valve	94A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			94B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			94C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			94D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
95	WGV20	Large Motor Operated Gate Valve	95A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			95B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			95C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"

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			95D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
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P&I Number: V049-0-017
Node: 24
System: Washington Site Right End Station
Date: 6/28/96

Node 24 includes the turbo pumping equipment and the clean air supply system equipment. The Turbo Cart and its' Turbo Backing Pump Cart are self-protected. See Hazards Analysis sheets for the Turbo Carts. The unit shuts down on loss of seal gas to the backing cart, loss of cooling water flow shuts it down on high temperature, power failure, etc.

An intrinsically safe wiring setup has been designed such that it is physically impossible to operate more than one turbo pump cart with a single backing pump.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
96	WTC6	Turbopump cart and associated connections	96A: Pump shuts down for any of a number of reasons; loss of utility, suction pressure above allowable due to leak or insufficient roughing.	Delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.
97	HV 520 / 521	10" Pump out port valve	97A: Valve opened to atmosphere with vacuum in the tube or cryopump. These are manual gate valves with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of these valves.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.
98		Turbo pump backing cart	98A: Pump shuts down for any of a number of reasons; loss of utility, signal from turbo cart controller.	Shutdown of turbo cart and delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.

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99		Class 100 Clean Air Supply System	99A: System shutdown, either compressor out or drier beds won't switch. Three signals go to the LIGO computer for monitoring, Compressor running signal, Compressor Common Alarm, Drier Beds Common Alarm.	A-1: During turbo pumping this would cause shutdown of the Turbo Backing Pump on loss of seal air.	Minor loss in operating time. No long term effect.
				A-2: During back to air operation the receiver could be sucked down to vacuum damaging it.	Loss in operating time. This would require replacement of receiver. A vacuum relief valve should be included on the receiver to avoid this situation.
				A-3: During purge operation through air showers loss of flow would allow contamination of optics with moisture should the outage persist long enough to drop the receiver pressure.	None
100	PCV-526	First stage letdown valve	100A: Fail open	Increase downstream pressure to PCV-527. If PCV-527's response is not fast enough the clean air supply header pressure will increase limited by PSV-525 which will relieve at 2 psig.	None
			100B: Fail closed	Loss of clean air flow tripping the turbo or cutting off air shower flow.	None
101	PCV-527	Second stage letdown valve	101A: Fail open	The clean air supply header pressure will increase limited by PSV-525 which will relieve at 2 psig.	None
			101B: Fail closed	Loss of clean air flow tripping the turbo or cutting off air shower flow.	None

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P&I Number: V049-0-018
Node: 25
System: Washington Site Corner Station Mechanical Room
Date: 6/28/96

Node 25 includes the turbo and roughing backing pump carts and the clean air supply system equipment in the mechanical room. The Turbo Backing Pump Cart and Roughing Backing pump cart are self-protected. See Hazards Analysis sheets for the Turbo Carts and Roughing Pump Carts. The units shut down on loss of seal gas to the backing cart, loss of cooling water flow shuts them down on high temperature, power failure, etc.

An intrinsically safe wiring setup has been designed such that it is physically impossible to operate more than one turbo pump cart or roughing pump cart with a single backing pump.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
102	WRC1B	Roughing pump backing cart	102A: Pump shuts down for any of a number of reasons; loss of utility, signal from turbo cart controller.	Shutdown of roughing pump cart and delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.
103	WRC2B	Roughing pump backing cart	103A: Pump shuts down for any of a number of reasons; loss of utility, signal from turbo cart controller.	Shutdown of roughing pump cart and delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.
104	WTC1B	Turbo pump backing cart	104A: Pump shuts down for any of a number of reasons; loss of utility, signal from turbo cart controller.	Shutdown of turbo pump cart and delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.

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105	WTC2B	Turbo pump backing cart	105A: Pump shuts down for any of a number of reasons; loss of utility, signal from turbo cart controller.	Shutdown of turbo pump cart and delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.
106	WCA100	Class 100 Clean Air Supply System	106A: System shutdown, either compressor out or drier beds won't switch. Three signals go to the LIGO computer for monitoring, Compressor running signal, Compressor Common Alarm, Drier Beds Common Alarm.	A-1: During turbo pumping this would cause shutdown of the Turbo Backing Pump on loss of seal air.	Minor loss in operating time. No long term effect.
				A-2: During back to air operation the receiver could be sucked down to vacuum damaging it.	Loss in operating time. This would require replacement of receiver. A vacuum relief valve should be included on the receiver to avoid this situation.
				A-3: During purge operation through air showers loss of flow would allow contamination of optics with moisture should the outage persist long enough to drop the receiver pressure.	None
107	PCV-184	First stage letdown valve	107A: Fail open	Increase downstream pressure to PCV-198. If PCV-198's response is not fast enough the clean air supply header pressure will increase limited by PSV-175 which will relieve at 2 psig.	None
			107B: Fail closed	Loss of clean air flow tripping the turbo or cutting off air shower flow.	None

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108	PCV-198	Second stage letdown valve	108A: Fail open	The clean air supply header pressure will increase limited by PSV-175 which will relieve at 2 psig.	None
			108B: Fail closed	Loss of clean air flow tripping the turbo or cutting off air shower flow.	None

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P&I Number: V049-0-020
Node: 32
System: Louisiana Site Left End Station
Date: 7/2/96

Node 32 includes all the normally connected equipment. The BSC chamber covered on P&ID V049-0-002, LIP5, and LCP3.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
147	LIP5	2500 liter/sec ion pump and its' associated 14" gate valve.	147A: Ion pump shutdown on high current caused by premature operation during pumpdown of the pump itself or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect
			147B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the ion pump replaced without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.
148	LCP3	80 K Cryopump (Short)	148A: Leakage from atmosphere or LN2 side.	Loss of vacuum, possible contamination. PI-724 A or B will indicate leak. The cryopump can be isolated with LGV9 and 10 and repaired.	Major or minor loss in operating time depending on source of leak. See Node 12 "80 K Cryopump" for details.
149	PI 724 A or B	Gauge Pair on Cryopump	149A: Either gauge fails electrically	Loss in the ability to read the vacuum level. Either an RGA can be attached to read the pressure or operation may continue without this information until it's convenient to isolate the cryopump and replace the gauges.	None

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150	LGV9	Large Motor Operated Gate Valve	150A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			150B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			150C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			150D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
151	LGV10	Large Motor Operated Gate Valve	151A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			151B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			151C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"

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			151D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
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P&I Number: V049-0-020 Rev. 1
Node: 33
System: Louisiana Site Left End Station
Date: 4/17/96

Node 33 includes the turbo pumping equipment and the clean air supply system equipment.
 The Turbo Cart and its' Turbo Backing Pump Cart are self-protected. See Hazards Analysis sheets for the Turbo Carts.
 The unit shuts down on loss of seal gas to the backing cart, loss of cooling water flow shuts it down on high temperature, power failure, etc.

An intrinsically safe wiring setup has been designed such that it is physically impossible to operate more than one turbo pump cart with a single backing pump.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
152	LTC3	Turbopump cart and associated connections	152A: Pump shuts down for any of a number of reasons; loss of utility, suction pressure above allowable due to leak or insufficient roughing.	Delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.
153	HV 720 / 721	10" Pump out port valve	153A: Valve opened to atmosphere with vacuum in the tube or cryopump. These are manual gate valves with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of these valves.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.
154	LTC3B	Turbo pump backing cart	154A: Pump shuts down for any of a number of reasons; loss of utility, signal from turbo cart controller.	Shutdown of turbo cart and delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.

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155	LCA700	Class 100 Clean Air Supply System	155A: System shutdown, either compressor out or drier beds won't switch. Three signals go to the LIGO computer for monitoring, Compressor running signal, Compressor Common Alarm, Drier Beds Common Alarm.	A-1: During turbo pumping this would cause shutdown of the Turbo Backing Pump on loss of seal air.	Minor loss in operating time. No long term effect.
				A-2: During back to air operation the receiver could be sucked down to vacuum damaging it.	Loss in operating time. This would require replacement of receiver. A vacuum relief valve should be included on the receiver to avoid this situation.
				A-3: During purge operation through air showers loss of flow would allow contamination of optics with moisture should the outage persist long enough to drop the receiver pressure.	None
156	PCV-726	First stage letdown valve	156A: Fail open	Increase downstream pressure to PCV-727. If PCV-727's response is not fast enough the clean air supply header pressure will increase limited by PSV-725 which will relieve at 2 psig.	None
			156B: Fail closed	Loss of clean air flow tripping the turbo or cutting off air shower flow.	None
157	PCV-727	Second stage letdown valve	157A: Fail open	The clean air supply header pressure will increase limited by PSV-725 which will relieve at 2 psig.	None
			157B: Fail closed	Loss of clean air flow tripping the turbo or cutting off air shower flow.	None

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			110C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			110D: Valve opened with pressure on one side.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"

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P&I Number: V049-0-022
Node: 27
System: Louisiana Site Left Beam Manifold
Date: 6/28/96

Node 27 includes all the normally connected equipment; LCP1, LGV 3 and 4. as well as the turbo cart (LTC1) and roughing pump cart (LRC1).

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
111	LCP1	80 K Cryopump (Long)	111A: Leakage from atmosphere or LN2 side.	Loss of vacuum, possible contamination. PI-614 A or B will indicate leak. The cryopump can be isolated with LGV3 and 4 and repaired.	Major or minor loss in operating time depending on source of leak. See Node 12 "80 K Cryopump" for details.
112	PI 614 A or B	Gauge Pair on Cryopump	112A: Either gauge fails electrically	Loss in the ability to read the vacuum level. Either an RGA can be attached to read the pressure or operation may continue without this information until it's convenient to isolate the cryopump and replace the gauges.	None
113	PI 680 A or B	Gauge Pair on 72" Beam Tube	113A: Either gauge fails electrically	Loss in the ability to read the vacuum level when this section is isolated from the	None
114	LGV3	Large Pneumatic Gate Valve	114A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			114B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"

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			114C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			114D: Valve opened with pressure on one side or BSC open to clean room (BSC in Vertex section).	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
115	LGV4	Large Pneumatic Gate Valve	115A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			115B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			115C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			115D: Valve opened with pressure on one side or BSC open to clean room (BSC in Vertex section).	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"

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116	HV 647 / 648	10" Pump out port valves	116A: Valve opened to atmosphere with vacuum in the tube or cryopump. These are manual gate valves with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of these valves.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.
117	HV 646	6" Pump out port valve	117A: Valve opened to atmosphere with vacuum in the tube. These are manual gate valves with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of these valves.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.
118	LTC1	Turbopump cart and associated connections	118A: Pump shuts down for any of a number of reasons; loss of utility, suction pressure above allowable due to leak or insufficient roughing.	Delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.
119	LRC1	Roughing Pump cart and associated connections	119A: Pump shuts down for any of a number of reasons.	Delay in rough pumping the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.

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P&I Number: V049-0-023 Rev. 1
 Node: 28
 System: Louisiana Site Vertex Section
 Date: 4/16/96

Node 28 is the entire P&ID. The vertex section is one large isolatable section with only two large gate valves. There are no cryopumps in the vertex section. The FMEA information for the HAM's and BSC's is found on the FMEA sheets for P&ID's V049-0-002, 003 and 004.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
120	LIP1	2500 liter/sec ion pump and its' associated 14" gate valve.	120A: Ion pump shutdown on high current caused by premature operation during pumpdown of the pump itself or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect
			120B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the Ion pump replaced without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.
121	LIP2	2500 liter/sec ion pump and its' associated 14" gate valve.	121A: Ion pump shutdown on high current caused by premature operation during pumpdown of the pump itself or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect

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			121B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the ion pump replaced without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.
122	LIP3	2500 torr-liter/sec ion pump and its' associated 14" gate valve.	122A: Ion pump shutdown on high current caused by premature operation during pumpdown of the pump itself or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect
			122B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the ion pump replaced without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.
123	LIP4	2500 torr-liter/sec ion pump and its' associated 14" gate valve.	123A: Ion pump shutdown on high current caused by premature operation during pumpdown of the pump itself or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect
			123B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the ion pump replaced without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.

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124	HV 609	10" Pump out port valve	124A: Valve opened to atmosphere with vacuum in the tube. This is a manual gate valve with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of this valve.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.
125	HV 645	6" Pump out port valve	125A: Valve opened to atmosphere with vacuum in the tube. This is a manual gate valve with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of this valve.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.
126	LGV1	Large Motor Operated Gate Valve	126A: Valve fails to close	Inability to isolate vertex section for pumpdown or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			126B: Valve fails to open	Inability to return vertex section to operation. Valve can be repaired and the valve	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			126C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			126D: Valve opened with pressure on one side or one of the BSC's or HAM's open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"

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127	LGV2	Large Motor Operated Gate Valve	127A: Valve fails to close	Inability to isolate vertex section for pumpdown or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			127B: Valve fails to open	Inability to return vertex section to operation. Valve can be repaired and the valve	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			127C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			127D: Valve opened with pressure on one side or one of the BSC's or HAM's open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
128	LTC2	Turbopump cart and associated connections	128A: Pump shuts down for any of a number of reasons; loss of utility, suction pressure above allowable due to leak or insufficient roughing.	Delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.
129	LRC2	Roughing pump cart and associated connections	129A: Pump shuts down for any of a number of reasons.	Delay in rough pumping the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.

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P&I Number: V049-0-024
Node: 29
System: Louisiana Site Right Beam Manifold
Date: 7/2/96

Node 29 includes all the normally connected equipment; LCP2, LGV 5 and 6.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
130	LCP2	80 K Cryopump (Long)	130A: Leakage from atmosphere or LN2 side.	Loss of vacuum, possible contamination. PI-634 A or B will indicate leak. The cryopump can be isolated with LGV5 and 6 and repaired.	Major or minor loss in operating time depending on source of leak. See Node 12 "80 K Cryopump" for details.
131	PI 634 A or B	Gauge Pair on Cryopump	131A: Either gauge fails electrically	Loss in the ability to read the vacuum level. Either an RGA can be attached to read the pressure or operation may continue without this information until it's convenient to isolate the cryopump and replace the gauges.	None
132	PI 670 A or B	Gauge Pair on 72" Beam Tube	132A: Either gauge fails electrically	Loss in the ability to read the vacuum level when this section is isolated from the	None
133	LGV5	Large Pneumatic Gate Valve	133A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			133B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"

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			133C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			133D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
134	LGV6	Large Pneumatic Gate Valve	134A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			134B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			134C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"
			134D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 8) "Large Gate Valves"

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135	HV 676 / 677 / 678	10" Pump out port valves	135A: Valve opened to atmosphere with vacuum in the tube or cryopump. These are manual gate valves with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of these valves.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.
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P&I Number: V049-0-025
Node: 30
System: Louisiana Site Right End Station
Date: 7/2/96

Node 30 includes all the normally connected equipment. The BSC chamber covered on P&ID V049-0-002, LIP6, and LCP4.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
136	LIP6	2500 liter/sec ion pump and its' associated 14" gate valve.	136A: Ion pump shutdown on high current caused by premature operation during pumpdown of the pump itself or the chamber. The ion pump controller protects the pump from damage due to high current draw.	Pumpdown ceases. Restart Turbopump, complete pumpdown to acceptable pressure for ion pump, and restart ion pump.	No significant effect
			136B: Ion pump fails mechanically or electrically.	Loss in ion pumping capacity. Ion pump failure will be indicated by current and voltage indication sent to the LIGO control system. System pressure will begin to rise.	The 14" GVHV can be closed and the ion pump replaced without breaking system vacuum. The new ion pump can then be turbopumped, started, and brought online.
137	LCP4	80 K Cryopump (Short)	137A: Leakage from atmosphere or LN2 side.	Loss of vacuum, possible contamination. PI-824 A or B will indicate leak. The cryopump can be isolated with LGV11 and 12 and repaired.	Major or minor loss in operating time depending on source of leak. See Node 12 "80 K Cryopump" for details.
138	PI 824 A or B	Gauge Pair on Cryopump	138A: Either gauge fails electrically	Loss in the ability to read the vacuum level. Either an RGA can be attached to read the pressure or operation may continue without this information until it's convenient to isolate the cryopump and replace the gauges.	None

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139	LGV11	Large Motor Operated Gate Valve	139A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			139B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			139C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			139D: Valve opened with pressure on one side or BSC open to clean room.	Damage to equipment, personnel injury or death. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
140	LGV12	Large Motor Operated Gate Valve	140A: Valve fails to close	Inability to isolate cryopump for regeneration or back to air operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			140B: Valve fails to open	Inability to return pump to operation. Valve can be repaired and the valve closed.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"
			140C: Valve closed with laser in operation	Damage to equipment and/or valve. Protection is by "two-key" lockout with both computer and physical lockout covered in operating procedures.	See Sheet V049-0-005 (Node 10) "Large Gate Valves"

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P&I Number: V049-0-025
Node: 31
System: Louisiana Site Right End Station
Date: 7/2/96

Node 31 includes the turbo pumping equipment and the clean air supply system equipment.
 The Turbo Cart and its Turbo Backing Pump Cart are self-protected. See Hazards Analysis sheets for the Turbo Carts.
 The unit shuts down on loss of seal gas to the backing cart, loss of cooling water flow shuts it down on high temperature, power failure, etc.

An intrinsically safe wiring setup has been designed such that it is physically impossible to operate more than one turbo pump cart with a single backing pump.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
141	LTC4	Turbopump cart and associated connections	141A: Pump shuts down for any of a number of reasons; loss of utility, suction pressure above allowable due to leak or insufficient roughing.	Delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.
142	HV 820 / 821	10" Pump out port valve	142A: Valve opened to atmosphere with vacuum in the tube or cryopump. These are manual gate valves with a pad lock for both lock open and lock closed. LIGO procedures will regulate the opening or closing of these valves.	Loss of vacuum, damage to equipment in the tube, contamination, injury or loss of life to personnel near the valve.	Major loss in operating time as the contaminated section might have to be baked out as well as pumped down.
143	LTC4B	Turbo pump backing cart	143A: Pump shuts down for any of a number of reasons; loss of utility, signal from turbo cart controller.	Shutdown of turbo cart and delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.

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144	LCA800	Class 100 Clean Air Supply System	144A: System shutdown, either compressor out or drier beds won't switch. Three signals go to the LIGO computer for monitoring, Compressor running signal, Compressor Common Alarm, Drier Beds Common Alarm.	A-1: During turbo pumping this would cause shutdown of the Turbo Backing Pump on loss of seal air.	Minor loss in operating time. No long term effect.
				A-2: During back to air operation the receiver could be sucked down to vacuum damaging it.	Loss in operating time. This would require replacement of receiver. A vacuum relief valve should be included on the receiver to avoid this situation.
				A-3: During purge operation through air showers loss of flow would allow contamination of optics with moisture should the outage persist long enough to drop the receiver pressure.	None
145	PCV-826	First stage letdown valve	145A: Fail open	Increase downstream pressure to PCV-827. If PCV-827's response is not fast enough the clean air supply header pressure will increase limited by PSV-825 which will relieve at 2 psig.	None
			145B: Fail closed	Loss of clean air flow tripping the turbo or cutting off air shower flow.	None
146	PCV-827	Second stage letdown valve	146A: Fail open	The clean air supply header pressure will increase limited by PSV-825 which will relieve at 2 psig.	None
			146B: Fail closed	Loss of clean air flow tripping the turbo or cutting off air shower flow.	None

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P&I Number: V049-0-026
Node: 34
System: Louisiana Site Corner Station Mechanical Room
Date: 7/2/96

Node 34 includes the turbo and roughing backing pump carts and the clean air supply system equipment in the mechanical room. The Turbo Backing Pump Cart and Roughing Backing pump cart are self-protected. See Hazards Analysis sheets for the Turbo Carts and Roughing Pump Carts. The units shut down on loss of seal gas to the backing cart, loss of cooling water flow shuts them down on high temperature, power failure, etc.

An intrinsically safe wiring setup has been designed such that it is physically impossible to operate more than one turbo pump cart or roughing pump cart with a single backing pump.

ITEM:	IDENTIFICATION	DESCRIPTION	FAILURE MODES	IMMEDIATE EFFECTS	ULTIMATE EFFECT
158	LRC1B	Roughing pump backing cart	158A: Pump shuts down for any of a number of reasons; loss of utility, signal from turbo cart controller.	Shutdown of roughing pump cart and delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.
159	LRC2B	Roughing pump backing cart	159A: Pump shuts down for any of a number of reasons; loss of utility, signal from turbo cart controller.	Shutdown of roughing pump cart and delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.
160	LTC1B	Turbo pump backing cart	160A: Pump shuts down for any of a number of reasons; loss of utility, signal from turbo cart controller.	Shutdown of turbo pump cart and delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.

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164	PCV-698	Second stage letdown valve	164A: Fail open	The clean air supply header pressure will increase limited by PSV-675 which will relieve at 2 psig.	None
			164B: Fail closed	Loss of clean air flow tripping the turbo or cutting off air shower flow.	None

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161	LTC2B	Turbo pump backing cart	161A: Pump shuts down for any of a number of reasons; loss of utility, signal from turbo cart controller.	Shutdown of turbo pump cart and delay in pumping out the system. The cause of pump shutdown needs to be corrected and the process restarted.	Minor loss in operating time. No long term effect.
162	LCA600	Class 100 Clean Air Supply System	162A: System shutdown, either compressor out or drier beds won't switch. Three signals go to the LIGO computer for monitoring, Compressor running signal, Compressor Common Alarm, Drier Beds Common Alarm.	A-1: During turbo pumping this would cause shutdown of the Turbo Backing Pump on loss of seal air.	Minor loss in operating time. No long term effect.
				A-2: During back to air operation the receiver could be sucked down to vacuum damaging it.	Loss in operating time. This would require replacement of receiver. A vacuum relief valve should be included on the receiver to avoid this situation.
				A-3: During purge operation through air showers loss of flow would allow contamination of optics with moisture should the outage persist long enough to drop the receiver pressure.	None
163	PCV-684	First stage letdown valve	163A: Fail open	Increase downstream pressure to PCV-698. If PCV-698's response is not fast enough the clean air supply header pressure will increase limited by PSV-675 which will relieve at 2 psig.	None
			163B: Fail closed	Loss of clean air flow tripping the turbo or cutting off air shower flow.	None