E906 Target Safety Document

Contents

A. Introduction
B. Valve and Instrument Summary
C. Interlock List
D. Operating Procedures
E. Emergency Procedures
F. Failure Mode and Effect Analysis
G. What-If Analysis
H. ODH Analysis
I. Design Calculations/Material Specifications
J. Tent Design and Conditions for Entry
K. Performance Tests
L. Safety Correspondence
M. Call-In List

- Flow Diagrams are located in the sleeves attached to the front and back covers of this binder

A. INTRODUCTION

This document is the E906 Target System Safety Report. The E906 Experiment is a successor experiment to, and will re-use many of the designs/components that were used for, the E866 Experiment. For parts of the system where components are directly re-used, this document will refer directly to the E866 Target System Safety Report. Locations where changes have been made will be pointed out before referring to the E866 Target System Safety Report.

The E906 target system is located in the SeaQuest beam hall inside the NM4 building. The target system is composed of three stainless steel flasks. The stainless steel flasks are 2.2 liters each in volume with dimensions of 20 inches long by 3 inches in diameter. One flask holds liquid deuterium, one holds liquid hydrogen, and one is evacuated for a control. The hydrogen and control flasks share the same insulating vacuum space. The vacuum containers are built from aluminum with their beam windows using a titanium alloy.

The liquid deuterium and liquid hydrogen targets are controlled to a pressure slightly above atmospheric, i.e. about 14.7 psia. The interior of the control flask is common with the insulating vacuum space and thus its pressure is equivalent to that of the insulating vacuum. The primary safety relief valves protecting the liquid deuterium and liquid hydrogen flasks have a set point of 10 psig.

The various targets are moved into the beam position by a custom-built motion table by Daedel. Controls for the table are made by Anaheim Automation. The three targets are moved horizontally into and out of the beam. A complete specification is enclosed for the motion system.

The cryogenic targets are cooled by Cryomech refrigerators. The compressor is connected to the coldhead of the refrigerator through helium-filled metal flexible lines. Standard pump carts are used for the vacuum systems and purging equipment. The target control system includes a Siemens APACS Programmable Logic Controller (PLC). Controls for the motion table are in a separate half rack. These controls can be locked locally to prevent the motion of the table. This will be necessary for tent access periods.

The E906 tent design is based on that used for the E866 experiment, and includes a ventilation system to exhaust any leaking hydrogen outdoors. The two liquid flasks are in different vacuum spaces to reduce the potential for releasing 4.4 liters of H2/D2 instead of a single flask failure releasing only 2.2 liters. The vent duct has a powered fan for ventilating the tent.

I. E906 Target Transport Table

The E906 motion table will re-use the table used for the E866 experiment, and the basic setup, therefore, will be identical to theE866 experiment. However, the motor used to drive the target table will be that of a higher torque than that used for the E866 experiment. The list below shows the items that are newly procured for the E906 target table:

1 Anaheim Automation 42D212S 1575 oz-in torque stepper motor

1 Anaheim Automation PLC601USB single axis stepper motor controller

1 Anaheim Automation #CPL-KTR-14GS-0.375-2.0 shaft coupling

1 Anaheim Automation CPL-KTR-14GS-0.625-2.1 shaft coupling

1 Anaheim Automation CPL-KTR-SPDR-14GS-98R coupling spider

For all other items relating to the target motor table, refer to page 3 of the E866 Safety Report.

Designation	Function	Manufacturer	Model	Range/Max working Press.	Size/Output	Notes
Check Valves						
CV-101-D	PV-D2VV vent to tent	Circle Seal	28OT-4PP-1	1 psig cracking pressure	1/2"	Teflon Seals
CV-01-H	PV-H2VV vent to tent	Circle Seal	28OT-4PP-1	2 psig cracking pressure	1/2"	Teflon Seals
CV-01-N	N2 gas supply check valve	Nupro	CP	1 psid cracking pressure	1/4"	
CV-02-N	Air supply check valve	Nupro	CP	2 psid cracking pressure	1/4"	
Electric Valves						
EV-D2VV	Vent Valve solenoid	Skinner	V53DB2150, 110 VAC	150 psid	1/4"	3-way, Normally Closed
EV-D2SUP	D2 Supply valve solenoid	Skinner	V53DB2150, 110 VAC	150 psid	1/4"	3-way, Normally Closed
EV-D2FILL	Target fill valve solenoid	Skinner	V53DB2150, 110 VAC	150 psid	1/4"	3-way, Normally Closed
EV-RPVENTD	Rough pump vent valve	Skinner	V53DB2150, 110 VAC	150 psid	1/4"	3-way, Normally Closed
EV-FPVENTD	Forepump vent valve	Skinner	V53DB2150, 110 VAC	150 psid	1/4"	3-way, Normally Closed
EV-H2VV	Vent Valve solenoid	Skinner	V53DB2150, 110 VAC	150 psid	1/4"	3-way, Normally Closed
EV-H2SUP	H2 Supply valve solenoid	Skinner	V53DB2150, 110 VAC	150 psid	1/4"	3-way, Normally Closed
EV-H2FILL		Skinner	V53DB2150, 110 VAC	150 psid	1/4"	3-way, Normally Closed
EV-RPVENTH	Rough pump vent valve	Skinner	V53DB2150, 110 VAC	150 psid	1/4"	3-way, Normally Closed
EV-FPVENTH	Forepump vent valve	Skinner	V53DB2150, 110 VAC	150 psid	1/4"	3-way, Normally Closed
EV-WTRDRN	Air compressor water drain	Skinner	V58DB2150, 110 VAC	150 psid	1/4"	3-way, Normally Closed
EXCESS FLOW VALVES						
EFV-101-D	Post RV-101-D shutoff	Nupro	6L-E4LE-FR4-VR4	225 psig	1/4"	Burst Press. = 12000 psi
EPV-01-H	Pre pump cart shutoff valve	Nupro	6L-E4LE-FR4-VR4	225 psig	1/4"	Burst Press. = 12000 psi
ELECTRO-PNEUMATIC VALVES						
EP-D2PURGE	Deuterium circuit purge valve	Skinner	V5D34435, 120VAC	150 psid	1 1/8"	3-way, Normally Closed
EP-RUFVLVD	Rough pump shutoff valve	Skinner	V5D34435, 120VAC	150 psid	1 1/8"	3-way, Normally Closed
EP-FORVLVD	Forepump shutoff valve	Skinner	V5D34435, 120VAC	150 psid	1 1/8"	3-way, Normally Closed
EP-HIVACD	High Vacuum shutoff valve	Vacuumm Research	LP4, 120VAC	Vacuum Valve	4"	Normally Closed
EP-H2PURGE	Hydrogen circuit purge valve	Skinner	V5D34435, 120VAC	150 psid	1 1/8"	3-way, Normally Closed
EP-RUFVLVH	Rough pump shutoff valve	Skinner	V5D34435, 120VAC	150 psid	1 1/8"	3-way, Normally Closed
EP-FORVLVH	Forepump shutoff valve	Skinner	V5D34435, 120VAC	150 psid	1 1/8"	3-way, Normally Closed
EP-HIVACH	High Vacuum shutoff valve	Vacuumm Research	LP4, 120VAC	Vacuum Valve	4"	Normally Closed
FILTERS						
F-01-N	Air compressor filter	Campbell-Hausfeld	PA212100Av	vendor supplied	1/4"	

MANUAL VALVES

MV-101-D	Post RV-101-D shutoff	Nupro	B-4HK2	1000 psig	1/4"
MV-102-D	Pre pump cart shutoff valve	Matheson	103	3000 psig	1/4"
MV-104-D	Cold trap inlet valve	Nupro	6L-LD8 2293	300 psig	1/2"
MV-105-D	Cold trap bypass valve	Nupro	6L-LD8 2293	300 psig	1/2"
MV-106-D	Cold trap outlet valve	Nupro	6L-LD8 2293	300 psig	1/2"
MV-107-D	Cold trap purge valve	Nupro	SS-4BK-VCO	1000 psig	1/4"
MV-108-D	TT-R2VPT charge valve	Nupro	B-4HK2	1000 psig	1/4"
MV-110-D	PT-D2SUP shutoff valve	Nupro	B-4HK2	1000 psig	1/4"
MV-111-D	PT-D2SUP pumpout valve	Nupro	B-4HK2	1000 psig	1/4"
MV-112-D	PT-D2VENT shutoff valve	Nupro	B-4HK2	1000 psig	1/4"
MV-113-D	PT-D2VENT pumpout valve	Nupro	B-4HK2	1000 psig	1/4"
MV-01-H	Post RV-01-H shutoff	Nupro	B-4HK2	1000 psig	1/4"
MV-02-H	Pre pump cart shutoff valve	Matheson	103	3000 psig	1/4"
MV-04-H	Cold trap inlet valve	Nupro	6L-LD8 2293	300 psig	1/2"
MV-05-H	Cold trap bypass valve	Nupro	6L-LD8 2293	300 psig	1/2"
MV-06-H	Cold trap outlet valve	Nupro	6L-LD8 2293	300 psig	1/2"
MV-07-H	Dold trap purge valve	Nupro	SS-4BK-VCO	1000 psig	1/4"
MV-08-H	TT-R1VPT charge valve	Nupro	B-4HK2	1000 psig	1/4"
MV-10-H	PT-H2SUP shutoff valve	Nupro	B-4HK2	1000 psig	1/4"
MV-11-H	PT-H2SUP pumpout valve	Nupro	B-4HK2	1000 psig	1/4"
MV-12-H	PT-H2VENT shutoff valve	Nupro	B-4HK2	1000 psig	1/4"
MV-13-H	PT-H2VENT pumpout valve	Nupro	B-4HK2	1000 psig	1/4"
MV-01-N	Post nitrogen regulator shutoff	Linde	NA	3000 psig	1/4"
MV-02-N	Pre pump cart shutoff valve, H2 syste	Hoke	4151M4B	600 psig	1/4"
MV-03-N	PT-PN2SUP pumpout valve	Nupro	SS-4PAT4	3000 psig	1/4"
MV-04-N	PT-PN2SUP isolation valve	Nupro	SS-4PAT4	3000 psig	1/4"
MV-05-N	Filter/dryer isolation valve	Nupro	SS-4PAT4	3000 psig	1/4"
MV-06-N	Air compressor drain valve	Nupro	SS-4PAT4	3000 psig	1/4"
MV-07-N	Compressor water drain hand valve	Campbell-Hausfield	vendor supplied	NA	1/4"
MV-08-N	Vent Valve pneumatic supply isolatio	Nupro	SS-4PAT4	3000 psig	1/4"
MV-09-N	Air compressor isolation valve	Nupro	SS-4PAT4	3000 psig	1/4"
MV-10-N	Pump cart isolation valve	Nupro	SS-4PAT4	3000 psig	1/4"
MV-102-N	Pre pump cart shutoff valve, D2syste	Hoke	4151M4B	600 psig	1/4"
MV-01-V	Rough line bleed valve, H2 system	Hoke	4151M4B	600 psig	1/4"
MV-02-V	Fore pump vent valve, H2 system	Hoke	4151M4B	600 psig	1/4"
MV-03-V	Vacuum shutoff to EV-01-He, H2 syst	Hoke	4151M4B	600 psig	1/4"
MV-101-V	Rough line bleed valve, D2 system	Hoke	4151M4B	600 psig	1/4"
MV-102-V	Fore pump vent valve, D2 system	Hoke	4151M4B	600 psig	1/4"
MV-103-V	Vacuum shutoff to EV-01-He, D2 syst	Hoke	4151M4B	600 psig	1/4"

PNEUMATIV VALVES						
PV-D2SUP	D2 Supply valve to target	Nupro	SS-4BK-NC, Series 1	1000 psig	1/4"	Normally Closed
PV-D2FILL	D2 Target Fill Valve	Nupro	SS-4BK-NC, Series 1	1000 psig	1/4"	Normally Closed
PV-D2VV	D2 Target Vent Valve	Nupro	SS8UWVCRTFT2-4C	2500 psig	1/2"	Normally Closed
PV-H2SUP	H2 Supply valve to target	Nupro	SS-4BK-NC, Series 1	1000 psig	1/4"	Normally Closed
PV-H2FILL	H2 Target Fill Valve	Nupro	SS-4BK-NC, Series 1	1000 psig	1/4"	Normally Closed
PV-H2VV	H2 Target Vent Valve	Nupro	SS8UWVCRTFT2-4C	2500 psig	1/2"	Normally Closed
REGULATORS						
RV-101-D	Deuterium cylinder regulator	Victor	VTS-452B	2 to 40 psig	1/4"	NOP = 10 psig
RV-102-D	Pump cart D2 regulator	Air Products	E11-N141A	0 to 25 psig	1/4"	NOP = 3 psig
RV-01-H	Hydrogen cylinder regulator	Victor	VTS-452B	2 to 40 psig	1/4"	NOP = 10 psig
RV-02-H	Pump cart H2 regulator	Air Products	E11-N141A	0 to 25 psig	1/4"	NOP = 3 psig
RV-01-N	Nitrogen cylinder regulator	Linde	UPG 3 150 580	0 to 150 psig	1/4"	NOP = 105 psig
RV-02-N	Pneumatic air compressor regulator	Matheson	3590	2 to 100 psig	1/4"	NOP = 60 psig
SAFETY VALVES						
SV-101-D	D2 Supply line relief	Nupro	B-8CPA2-3	110 psig	1/2"	
SV-102-D	Target D2 supply relief	Nupro	B-8CPA2-3	10 psig	1/2"	
SV-103-D	Target D2 vent lilne relief	Anderson-Greenwood	83MB68-6	10 psig	3/8" orifice	
SV-104-D	D2 Cold trap relief valve	Nupro	B-8CPA2-3	50 psig	1/2"	
SV-01-H	H2 Supply line relief	Nupro	B-8CPA2-3	110 psig	1/2"	
SV-02-H	Target H2 supply relief	Nupro	B-8CPA2-3	10 psig	1/2"	
SV-03-H	Target H2 vent line relief	Anderson-Greenwood	83MB68-6	10 psig	3/8" orifice	
SV-04-H	H2 Cold trap relief valve	Nupro	B-8CPA2-3	50 psig	1/2"	
SV-01-N	Nitrogen gas supply relief	Circle Seal	5159B-4MP	140 psig	1/2"	
SV-02-N	Air compressor relief	Campbell-Hausfield	SP25	140 psig	1/4"	Code Stamped
SV-01-V	Refrigirator can relief, H2 system	Fermilab design	parallel plate	lift pressure <= 3.5 psid	2"	
SV-02-V	Target vacuum relief, H2 system	Fermilab design	parallel plate	lift pressure <= 3.5 psid	2"	
SV-101-V	Refrigirator can relief, D2 system	Fermilab design	parallel plate	lift pressure <= 3.5 psid	2"	
SV-102-V	Target vacuum relief, D2 system	Fermilab design	parallel plate	lift pressure <= 3.5 psid	2"	
ANALYZERS						
AE-01	Flammable gas detector	Controls Instruments	B3SNR005			
AIS-01	Detector indication switch	Controls Instruments		0 to 100% of LEL	12VDC	Set Pt = 1% H2 in air = 25% of LEL
FLOW DEVICES						
FT-D2SUP	Deuterium gas supply flow	MKS	0558C-050L-GV-SPCAL-H2	0 to 50 slpm H2	0 to 5.0 volts	
FT-H2SUP	Hydrogen gas supply flow	MKS	0558C-050L-GV-SPCAL-H2	0 to 50 slpm H2	0 to 5.0 volts	
FE-ODHFAN	ODH fan flow	Annubar	AIR-26 for 3" circ. duct			
FIS-OOHFAN	ODH fan flow indication	Annubar	EFW	0 to 100 actual CFM air		electronic relay on-off
FE-TENTFAN	Tent fan flow	Annubar	AIR-26 for 10" circ. duct			
FIS-TENTFAN	Tent fan flow indication	Annubar	EFW	0 to 1500 actual CFM air		electronic relay on-off

HEATERS					
HTR-101-D	Regrigerator 2 heater	Minco	H4A20W115	0-20 Watts	0 to 10.0 volts
HTR-101-OIL	Diffusion Pump heater, D2 target syst	NRC Diffusion Pump	vendor supplied		Pump Model # 0159
HTR-01-H	Regrigerator 1 heater	Minco	H4A20W115	0-20 Watts	0 to 10.0 volts
HTR-01-OIL	Diffusion Pump heater, H2 target syst	NRC Diffusion Pump	vendor supplied		Pump Model # 0159
POWER TRANSMITTER					
JT-HTRD	D2 tgt. refrigerator heater power	Ohio Semitronics	PC5-103E-Y24	0 to 100 Watts	4 to 20 mA
JT-HTRH	H2 tgt. refrigerator heater power	Ohio Semitronics	PC5-103E-Y24	0 to 100 Watts	4 to 20 mA
PRESSURE ELEMENTS					
PE-RPVACD	Rough pump vacuum	Fredericks Televac	2A	0 to 1000 micron	0 to 7 volts
PE-FPVACD	Forepump vacuum	Fredericks Televac	2A	0 to 1000 micron	0 to 7 volts
PE-INSULVACD	Insulating Vacuum Pressure	Fredericks Televac	7B	10-3 to 10-8 Torr	Power supply not installed in rack
PE-RPVACH	Rough pump vacuum	Fredericks Televac	2A	0 to 1000 micron	0 to 7 volts
PE-FPVACH	Forepump vacuum	Fredericks Televac	2A	0 to 1000 micron	0 to 7 volts
PE-INSULVACH	Insulating Vacuum Pressure	Fredericks Televac	7B	10-3 to 10-8 Torr	Power supply not installed in rack
PRESSURE INDICATORS					
PI-101-D	PT-D2SUP readout device	FIXDMACS			
PI-102-D	RV-101-D inlet pressure	US Gauge		0 to 4000 psig	
PI-103-D	RV-101-D outlet pressure	US Gauge		0 to 60 psig	
PI-107-D	RV-102-D outlet pressure	Air Products supplied		neg. 30 in Hg to 30 psig	
PI-01-H	PT-H2SUP readout device	FIXDMACS			
PI-02-H	RV-01-H Inlet pressure	US Gauge		0 to 4000 psig	
PI-03-H	RV-01-H outlet pressure	US Gauge		0 to 60 psig	
PI-07-H	RV-02-H outlet pressure	Air Products supplied		neg. 30 in Hg to 30 psig	
PI-01-N	RV-01-N inlet pressure	NKS Nagano		0 to 4000 psig	
PI-02-N	RV-01-N outlet pressure	NKS Nagano		0 to 200 psig	
PI-04-N	RV-02-N outlet pressure	US Gauge		0 to 100 psig	
PI-05-N	Air supply pressure at H2 pumpcart	US Gauge		0 to 100 psig	
PI-06-N	Air compressor supply pressure	US Gauge		0 to 200 psig	
PI-105-N	Air supply pressure at D2 pumpcart	US Gauge		0 to 100 psig	
PI-01-V	PT-01-V readout device, H2 tgt	MKS Instruments	PDR-C-2C-BCD	0 to 10 mmHg	
PI-02-V	PT-02-V readout device, H2 tgt	MKS Instruments	PDR-C-2C-BCD	0 to 1000 mmHg	
PI-03-V	Insulating vacuum, H2 tgt	Fredericks Televac	7B	10-3 to 10-8 Torr	
PI-101-V	PT-01-V readout device, D2 tgt	MKS Instruments	PDR-C-2C-BCD	0 to 10 mmHg	
PI-102-V	PT-02-V readout device, D2 tgt	MKS Instruments	PDR-C-2C-BCD	0 to 1000 mmHg	
PI-103-V	Insulating vacuum, D2 tgt	Fredericks Televac	7B	10-3 to 10-8 Torr	

PRESSURE TRANSMITTERS						
PT-D2SUP	Deuterium supply pressure	Setra	205-2	0 to 50 psia	0 to 5 Volts	
PT-D2VENT	Deuterium jacket pressure	Setra	205-2	0 to 50 psia	0 to 5 Volts	
PT-H2SUP	Hydrogen supply pressure	Setra	205-2	0 to 50 psia	0 to 5 Volts	
PT-H2VENT	Hydrogen jacket pressure	Setra	205-2	0 to 50 psia	0 to 5 Volts	
PT-COMPSUC	1.5" He suction header low pressure	Setra	C206	0 to 25 psig	4 to 20 mA	
PT-COMPOISH	1" He discharge header pressure, H2 t	Setra	C206	0 to 500 psig	4 to 20 mA	
PT-COMPOISD	1" He discharge header pressure, D2 t	Setra	C206	0 to 500 psig	4 to 20 mA	
PT-PN2SUP	Pneumatic supply pressure	Setra	C206	0 to 500 psig	4 to 20 mA	
PT-01-V	Insulating Vacuum Pressure, H2 tgt	MKS Instruments	122AA-00010A	0 to 10 mmHg	0 to 10 volts	
PT-02-V	Insulating Vacuum Pressure, H2 tgt	MKS Instruments	122AA-01000AB	0 to 1000 mmHg	0 to 10 volts	
PT-101-V	Insulating Vacuum Pressure, D2 tgt	MKS Instruments	122AA-00010A	0 to 10 mmHg	0 to 10 volts	
PT-102-V	Insulating Vacuum Pressure, D2 tgt	MKS Instruments	122AA-01000AB	0 to 1000 mmHg	0 to 10 volts	
PRESSURE CONTROLLER						
PIC-101-D	Deuterium Pressure Indicating Control	Beckman	7200	Set pt range = 0 to 50 psia	0 to 120 volts	range dependent on PT-D2VENT
PIC-01-H	Hydrogen Pressure Indicating Controll	Beckman	7200	Set pt range = 0 to 50 psia	0 to 120 volts	range dependent on PT-D2VENT
SWITCHES						
ISL-FD	Current switch low	SSAC	ECS41BC	adjustable 2 to 20 Amps	12 VDC	on D2 system Fore Pump
ISL-RPD	Current switch low	SSAC	ECS41BC	adjustable 2 to 20 Amps	12 VDC	on D2 system Rough Pump
ISL-FPH	Current switch low	SSAC	ECS41BC	adjustable 2 to 20 Amps	12 VDC	on H2 system Fore Pump
ISL-RPH	Current switch low	SSAC	ECS41BC	adjustable 2 to 20 Amps	12 VDC	on H2 system Rough Pump
PS-01-N	Air compressor ON-OFF	Condor	MDR 21/11	160 psig		110/135 psig set pts.
TEMPERATURE ELEMENTS						
TE-D2FLUP	Deuterium flask top	Lakeshore	CX-1030-SD cernox	50 to 700 Ohms (4-300K)		
TE-R2CPOT	Refrigerator 2 condenser	Lakeshore	CX-1030-SD cernox	50 to 700 Ohms (4-300K)		
TE-R2D2RET	Deuterium flask inlet	Lakeshore	PT102 Platinum RTD	10 to 200 Ohms (14-300K)		
TE-D2SVEXH	D2 AGCO safety valve exhaust	Lakeshore	PT102 Platinum RTD	10 to 200 Ohms (14-300K)		
TE-H2FLUP	Hydrogen flask top	Lakeshore	CX-1030-SD cernox	50 to 700 Ohms (4-300K)		
TE-R1CPOT	Refrigerator 1 condenser	Lakeshore	CX-1030-SD cernox	50 to 700 Ohms (4-300K)		
TE-R1H2RET	Hydrogen flask inlet	Lakeshore	PT102 Platinum RTD	10 to 200 Ohms (14-300K)		
TE-H2SVEXH	H2 AGCO safety valve exhaust	Lakeshore	PT102 Platinum RTD	10 to 200 Ohms (14-300K)		
TEMPERATURE TRANSMITTERS						
TT-R2VPT	Refrigerator 2, VPT	Setra	204	0 to 100 psia	0 to 5 Volts	H2 VPT
TT-R1VPT	Refrigerator 1, VPT	Setra	204	0 to 100 psia	0 to 5 Volts	H2 VPT

D. OPERATING PROCEDURES

TARGET INSTALLATION LOG

E906 – Liquid Hydrogen Target System

The basic design of the E906 Liquid Hydrogen Target System will be identical to that of the E866 Experiment, with the exception that the E906 cryocooler will not need an external helium source during operation.

	By	Date	
1.	_____	_____	Target place into position in beam line.
2.	_____	_____	H2 Pump Cart in position.
3.	_____	_____	Ground connection to target.
4.	_____	_____	Foreline connected to target.
5.	_____	_____	Purge line connected to target.
6.	_____	_____	Roughing line connected to target.
7.	_____	_____	Refrigerator gas lines connected and leak checked.
8.	_____	_____	Hydrogen, & Nitrogen lines connected to pump cart.
9.	_____	_____	Deutsch connector installed on cryostat.
10.	_____	_____	Transducer cable connected to both transducers.
11.	_____	_____	Discharge gauge connected (gauge powered only when hydrogen is not present)
12.	_____	_____	Auxiliary cable connected to manipulator.
13.	_____	_____	Refrigerator cables connected.
14.	_____	_____	Pump cart control cable connected.
15.	_____	_____	Transducer control cable connected.
16.	_____	_____	Diffusion pump and high vacuum valve cable connected.
17.	_____	_____	220 Volts 3 phase 60 amp disconnect checked for 15 amp fuses. Replace fuses if they are longer.
18.	_____	_____	Plug pump cart into 200 volt receptacle.
19.	_____	_____	Connect pump cart cable to control rack.
20.	_____	_____	Connect transducer cable to control rack.
21.	_____	_____	Connect MKS gauge cable to control rack.
22.	_____	_____	Connect refrigerator cable to control rack.
23.	_____	_____	Connect temperature control cable to control rack.
24.	_____	_____	Connect Hydrogen detector cable to control rack.

25. _____ _____ Connect Hydrogen detector cable to Hydrogen head and mount head.
26. _____ _____ Tie down all cables and lines, check for interference with manipulators, correct where necessary.
27. _____ _____ Do general housekeeping around target area.
28. _____ _____ Install guard over cables and lines when necessary.
29. _____ _____ Remove guard on target windows when appropriate.
30. _____ _____ Install rotating warning lights in vicinity of target and in pump cart area.
31. _____ _____ Install warning signs at designated locations.
32. _____ _____ Leak test all gas connections with Nitrogen or Helium. Test Hydrogen line with Helium gas. Reconnect Hydrogen when tests are completed. Secure all cylinders and tag properly.

COMMENTS:

Control Console

	By	Date	
1.	_____	_____	All cables connected to rack.
2.	_____	_____	Power on to programmable logic controller.
3.	_____	_____	Power on to graphics panel.
4.	_____	_____	Power to Flammable Gas Detector. Test alarm whooper and reset.
5.	_____	_____	Check housekeeping in area around control console.

Cylinders and System Regulators Installation Note: Keep cylinder valves closed at this time.

1.	_____	_____	Nitrogen cylinder installed with RV-01-N for pneumatic air backup.
2.	_____	_____	Air compressor installed with RV-02-N for pneumatic air supply.
3.	_____	_____	Check compressor helium pressure.
4.	_____	_____	Hydrogen cylinder installed with RV-01-H for liquid hydrogen target purge and fill.

LH2 TARGET STARTING/RESTARTING CHECK LIST

Target Area

	By	Date	
1.	_____	_____	Physical damage to equipment.
2.	_____	_____	Physical damage to lines.
3.	_____	_____	Physical damage to cables.
4.	_____	_____	Alignment check.
5.	_____	_____	Target windows intact.
6.	_____	_____	Vacuum pump oil level normal.
7.	_____	_____	All lines connected to target and pump cart.
8.	_____	_____	Rotating lights turned on.
9.	_____	_____	Target power on. Both disconnects and all circuit breakers on.
10.	_____	_____	Nitrogen pressure is OK.
11.	_____	_____	Air compressor is operational.

Note: Steps 12 and 13 should be performed in step 17 of Target Starting Procedure during initial startup of system.

12. _____ _____ Open cylinder, set pressure to 5 psig (RV-01-H). Note pressures_____ _____. Close cylinder valve. High pressure gauge must show no noticeable drop for 5 minutes. If no leaks are present, reopen cylinder valve.

13. _____ _____ Set RV-02-H to 3 psig (RV-01-H may then be set to 10 psig). Note Pressure _____.

14. _____ _____ Open Nitrogen cylinder, set pressure to 50 psig (RV-01-N). Note pressures_____ _____ Close cylinder valve. Test for leakage as above. Reopen cylinder valve if no leaks are present.

15. _____ _____ Start Air Compressor and open MV-05-N. Set pressure to 60 psig (RV-02-N). Note pressure _____.

16. _____ _____ Open Helium cylinder to supply PV-H2VV. Set pressure to 110 psig (RV-03-He). Note pressures_____ _____. Close cylinder valve. Test for leakage as above. Reopen cylinder valve if no leaks are present.

17. _____ _____ Open MV-13-He and set RV-04-He to 3 psig. Note pressure _____

18. _____ _____ Install covers over cylinder regulators where necessary.

19. _____ _____ Hydrogen detector in place.

20. _____ _____ Housekeeping in area around target is good.

21. _____ _____ All warning signs in area prominently displayed and unobstructed.

TARGET STARTING PROCEDURE

1. _____ Close hand valve, MV-01-V, at roughing pump port vent and cap; Close Hand valve, MV-02-V, at for pump port vent and cap.

2. _____ Close MV-03-V, EV-01-He and MV-02-He. Mv-02-He is to be capped.

3. _____ Check oil level in vacuum pumps.

4. _____ Note Pneumatic Supply Pressure on pump cart gauge, PI-05-N, _____ psig. Pneumatic valves should be positioned as follows: MV-01-N, MV-02-N, MV-04-N and MV-05-N should be open. MV-03-N and MV-07-N should be closed.

5. _____ Turn on roughing pump. Pressure should reach 20 microns on PE-RPVACH in 2 minutes.

6. _____ Turn on foreline pump. Pressure should reach 20 microns on PE-FPVACH in 2 minutes.

7. _____ Open fore line valves EP-FORVLVH.

8. _____ Open roughing valve EP-RUFVLVH to target insulating vacuum.

9. _____ Turn on power to diffusion pump.

10. _____ Open high vacuum valve, EP-HIVACH. The HIVAC valve on/off switch will blink until target insulating vacuum pressure is low enough for it to open. EP-RUFVLVH closes automatically. This occurs at 200 microns.

11. _____ Be sure that MV-04-H, MV-06-H, MV-10-H and MV-12-H are open.

12. _____ Be sure that MV-05-H, MV-07-H, MV-11-H and MV-13-H are closed.

13. _____ Vent valve hand switch, HS-VVH, must be in the AUTO position.

14. _____ Note that MV-08-H is a part of the hydrogen VPT which reads the temperature of the condensing pot. It is not a part of the hydrogen supply circuit. After proper charging of the VPT bulb, MV-08-H is closed.

15. _____ Open purge valve EP-H2PURGE; open target fill valve PV-H2FILL. Note that the PLC interlocks will not allow PV-H2SUP and EP-H2PURGE to be open at the same time.

16. _____ Notify operations center that ME6 target is being purged to Hydrogen. Secure the target tent and the area around the target. Close access gates if provided. Start controlled access into area.

17. _____ Be sure MV-01-H and MV-02-H are open.

18. _____ Perform steps 10 and 11 of the Target Starting/Restarting Check List now. Verify that EFV-01-H is positioned correctly.

19. _____ After the hydrogen supply line and cold trap are pumped out to 30 microns, close purge valve, EP-H2PURGE. Open hydrogen suppy valve EP-H2SuP (hydrogen fill valve, EP-H2FILL, is already open). Be sure the hydrogen pressure is set to 3 psig with the pressure regulator RV-02-H.

20. _____ Target pressure read on pressure transducer PT-H2VENT should reach approximately 17.5 psia.

21. _____ Close hydrogen supply valve PV-H2SUP. Open purge valve EP-H2PURGE; Wait for PE-RPVACH to reach 30 microns. Pump and purge the circuit three times as indicated in steps 19, 20 and 21. End the pump and purge procedure by leaving PV-H2SUP open and EP-H2PURGE closed.

22. _____ Cool down the Hydrogen cold trap.

23. _____ Refrigerators have reached 20 K when the refrigerator vapor pressure, TT-R1VPT, reaches 15 psia.

24. _____ Monitor progress of the target on the upper and lower resistors, TE-H2FLUP and TE-H2FLDWN.

25. _____ Continue to fill the target for 15 minutes after TE-H2FLUP sees liquid.

26. _____ Close the hydrogen supply valve, PV-H2SUP, and the hydrogen fill valve, PV-H2FILL. Close the hydrogen cylinder supply valve.

27. _____ Turn on temperature controller and gradually ajust until target pressure stabilizes at 14.7 psia.

28. _____ Close MV-06-H (MV-05-H is already closed). Remove the cold trap from the liquid nitrogen.

29. _____ Pump out the cold trap by opening EP-H2Purge and PV-H2Fill. Evacuate cold trap until warm.

30. _____ After trap is warm, close EP-H2PURGE, and PV-H2FILL. Open MV-06-H.

TARGET SHUTDOWN PROCEDURE

1. _____ Turn off the hydrogen system refrigerator.

2. _____ Turn off temperature controller.
3. _____ The liquid inside the hydrogen/ target flask is empty when the hydrogen upper and lower resistor temperatures exceed 23 K. These include TE-H2FLUP and TE-H2FLDWN.
4. _____ The Hydrogen circuit will continue to hold some amount of hydrogen gas unless complete shutdown is required for certain target maintenance.

For complete target shutdown, do the following:

5. _____ Close PV-H2SUP. Open PV-H2FILL and EP-H2PURGE. Pump out the target Hydrogen circuit. The hydrogen gas is vented through the roughing pump.

6. _____ Confirm that the hydrogen cylinder supply valve is closed.

7. _____ Hook up a helium cylinder to MV-07-H and backfill the Hydrogen circuit with Helium to 1 psig.

NOTE: BACKFILLING OF CIRCUIT <u>MUST</u> OCCUR IN THIS ORDER TO AVOID CRUSHING THE TARGET FLASK.

8. _____ Close high vacuum valve EP-HIVACH; turn off diffusion pump heater power. Allow 20 minutes for diffusion pump to cool down.

9. _____ Close fore line valve EP-FORVLVH; turn off power to fore pump.

10. _____ Turn off power to roughing pump.

11. _____ Uncap and open roughing line vent valve at pump cart, MV-101-V, to vent the vacuum space to atmosphere.

12. _____ Turn off electric circuits at the pump cart.

13. _____ Close all gas cylinder valves connected to the target system.

14. _____ Disable the Hydrogen detector as necessary for welding/brazing repairs.

Date _____ By _____

TARGET RESTART AFTER POWER OUTAGE OCCURS

1. _____ After power is restored, open hydrogen system roughing valve EP-RUFVLVH and fore valve EP-FORVLVH.

2. _____ Open high vacuum valve EP-HIVAC. When pressure in the insulating vacuum is low enough, EP-HIVACH will open and EP-RUFVLVH will automatically close.

3. _____ After system analysis by a hydrogen target expert, turn on compressor flow and refrigerator if permitted.

4. _____ Check the hydrogen circuit upper and lower resistors as some hydrogen may need to be added to the hydrogen circuit.

5. _____ If required, open PV-H2SUP and PV-H2FILL to add hydrogen. Use the cold trap while adding hydrogen as instructed in the TARGET STARTING PROCEDURE.

6. _____ Close PV-H2FILL and PV-H2SUP.

7. _____ Turn on the heater controller and be sure the set pressure is 14.7 psia.

TARGET INSTALLATION LOG

E906 – Liquid Deuterium Target System

The basic design of the E906 Liquid Deuterium Target System will be identical to that of the E866 Experiment, with the exception that the E906 cryocooler will not need an external helium source in order to operate the refrigerator.

	By	Date	
1.	_____	_____	Target place into position in beam line.
2.	_____	_____	D2 Pump Cart in position.
3.	_____	_____	Ground connection to target.
4.	_____	_____	Foreline connected to target.
5.	_____	_____	Purge line connected to target.
6.	_____	_____	Roughing line connected to target.
7.	_____	_____	Refrigerator gas lines connected and leak checked.
8.	_____	_____	Deuterium, & Nitrogen lines connected to pump cart.
9.	_____	_____	Deutsch connector installed on cryostat.
10.	_____	_____	Transducer cable connected to both transducers.
11.	_____	_____	Discharge gauge connected (gauge powered only when hydrogen is not present)
12.	_____	_____	Auxiliary cable connected to manipulator.
13.	_____	_____	Refrigerator cables connected.
14.	_____	_____	Pump cart control cable connected.
15.	_____	_____	Transducer control cable connected.
16.	_____	_____	Diffusion pump and high vacuum valve cable connected.
17.	_____	_____	220 Volts 3 phase 60 amp disconnect checked for 15 amp fuses. Replace fuses if they are longer.
18.	_____	_____	Plug pump cart into 200 volt receptacle.
19.	_____	_____	Connect pump cart cable to control rack.
20.	_____	_____	Connect transducer cable to control rack.
21.	_____	_____	Connect MKS gauge cable to control rack.
22.	_____	_____	Connect refrigerator cable to control rack.
23.	_____	_____	Connect temperature control cable to control rack.
24.	_____	_____	Connect Hydrogen detector cable to control rack.
25.	_____	_____	Connect Hydrogen detector cable to Hydrogen head and mount head.
26.	_____	_____	Tie down all cables and lines, check for interference with manipulators, correct where necessary.

27. _____ _____ Do general housekeeping around target area.
28. _____ _____ Install guard over cables and lines when necessary.
29. _____ _____ Remove guard on target windows when appropriate.
30. _____ _____ Install rotating warning lights in vicinity of target and in pump cart area.
31. _____ _____ Install warning signs at designated locations.
32. _____ _____ Leak test all gas connections with Nitrogen or Helium. Test Hydrogen line with Helium gas. Reconnect Hydrogen when tests are completed. Secure all cylinders and tag properly.

COMMENTS:

Control Console

	By	Date	
1.	_____	_____	All cables connected to rack.
2.	_____	_____	Power on to programmable logic controller.
3.	_____	_____	Power on to graphics panel.
4.	_____	_____	Power to Flammable Gas Detector. Test alarm whooper and reset.
5.	_____	_____	Check housekeeping in area around control console.

Cylinders and System Regulators Installation Note: Keep cylinder valves closed at this time.

1.	_____	_____	Nitrogen cylinder installed with RV-01-N for pneumatic air backup.
2.	_____	_____	Air compressor installed with RV-02-N for pneumatic air supply.
3.	_____	_____	Check compressor helium pressure.
4.	_____	_____	Hydrogen cylinder installed with RV-01-H for liquid deuterium target purge and fill.

LD2 TARGET STARTING/RESTARTING CHECK LIST

Target Area

By Date

1. _____ _____ Physical damage to equipment.
2. _____ _____ Physical damage to lines.
3. _____ _____ Physical damage to cables.
4. _____ _____ Alignment check.
5. _____ _____ Target windows intact.
6. _____ _____ Vacuum pump oil level normal.
7. _____ _____ All lines connected to target and pump cart.
8. _____ _____ Rotating lights turned on.
9. _____ _____ Target power on. Both disconnects and all circuit breakers on.
10. _____ _____ Nitrogen pressure is OK.
11. _____ _____ Air compressor is operational.

Note: Steps 12 and 13 should be performed in step 17 of Target Starting Procedure during initial startup of system.

12. _____ _____ Open Deuterium cylinder, set pressure to 5 psig (RV-101-D). Note pressures_____ _____ . Close cylinder valve. High pressure gauge must show no noticeable drop for 5 minutes. If no leaks are present, reopen cylinder valve.

13. _____ _____ Set RV-02-H to 3 psig (RV-101-D may then be set to 10 psig). Note Pressure _____

14. _____ _____ Open Nitrogen cylinder, set pressure to 50 psig (RV-01-N). Note pressures_____ _____ Close cylinder valve. Test for leakage as above. Reopen cylinder valve if no leaks are present.

15. _____ _____ Start Air Compressor and open MV-05-N. Set pressure to 60 psig (RV-02-N). Note pressure _____

16. _____ _____ Open Helium cylinder to supply PV-D2VV. Set pressure to 110 psig (RV-03-He). Note pressures_____ _____ Close cylinder valve. Test for leakage as above. Reopen cylinder valve if no leaks are present.

17. _____ _____ Open MV-13-He and set RV-04-He to 3 psig. Note pressure _____

18. _____ _____ Install covers over cylinder regulators where necessary.

19. _____ _____ Flammable Gas Detector in place.

20. _____ _____ Housekeeping in area around target is good.

21. _____ _____ All warning signs in area prominently displayed and unobstructed.

TARGET STARTING PROCEDURE

5. _____ Close hand valve, MV-101-V, at roughing pump port vent and cap; Close Hand valve, MV-102-V, at for pump port vent and cap.

2. _____ Close MV-103-V, EV-101-He and MV-102-He. Mv-02-He is to be capped.

3. _____ Check oil level in vacuum pumps.

4. _____ Note Pneumatic Supply Pressure on pump cart gauge, PI-105-N, _____ psig. Pneumatic valves should be positioned as follows: MV-01-N, MV-102-N, MV-04-N and MV-05-N should be open. MV-03-N and MV-07-N should be closed.

5. _____ Turn on roughing pump. Pressure should reach 20 microns on PE-RPVACD in 2 minutes.

6. _____ Turn on foreline pump. Pressure should reach 20 microns on PE-FPVACD in 2 minutes.

7. _____ Open fore line valves EP-FORVLVD.

8. _____ Open roughing valve EP-RUFVLVD to target insulating vacuum.

9. _____ Turn on power to diffusion pump.

10. _____ Open high vacuum valve, EP-HIVACD. The HIVAC valve on/off switch will blink until target insulating vacuum pressure is low enough for it to open. EP-RUFVLVH closes automatically. This occurs at 200 microns.

11. _____ Be sure that MV-104-D, MV-106-D, MV-110-D and MV-112-D are open.

12. _____ Be sure that MV-105-D, MV-107-D, MV-111-D and MV-113-D are closed.

13. _____ Vent valve hand switch, HS-VVD, must be in the AUTO position.

14. _____ Note that MV-108-D is a part of the hydrogen VPT which reads the temperature of the condensing pot. It is not a part of the deuterium supply circuit. After proper charging of the VPT bulb, MV-108-D is closed.

15. _____ Open purge valve EP-D2PURGE; open target fill valve PV-D2FILL. Note that the PLC interlocks will not allow PV-D2SUP and EP-D2PURGE to be open at the same time.

16. _____ Notify operations center that ME6 target is being purged to Hydrogen. Secure the target tent and the area around the target. Close access gates if provided. Start controlled access into area.

17. _____ Be sure MV-101-D and MV-102-D are open.

18. _____ Perform steps 10 and 11 of the Target Starting/Restarting Check List now. Verify that EFV-101-D is positioned correctly.

19. _____ After the hydrogen supply line and cold trap are pumped out to 30 microns, close purge valve, EP-D2PURGE. Open hydrogen suppy valve EP-D2SUP (hydrogen fill valve, EP-D2FILL, is already open). Be sure the deuterium pressure is set to 3 psig with the pressure regulator RV-02-H.

20. _____ Target pressure read on pressure transducer PT-D2VENT should reach approximately 17.5 psia.

21. _____ Close hydrogen supply valve PV-D2SUP. Open purge valve EP-D2PURGE; Wait for PE-RPVACD to reach 30 microns. Pump and purge the circuit three times as indicated in steps 19, 20 and 21. End the pump and purge procedure by leaving PV-D2SUP open and EP-D2PURGE closed.

22. _____ Cool down the Deuterium cold trap.

23. _____ Start the deuterium system compressor flow and refrigerator.

24. _____ Refrigerators have reached 20 K when the refrigerator vapor pressure, TT-R1VPT, reaches 15 psia.

25. _____ Monitor progress of the target on the upper and lower resistors, TE-D2FLUP and TE-D2FLDWN.

26. _____ Continue to fill the target for 15 minutes after TE-D2FLUP sees liquid.

27. _____ Close the deuterium, supply valve, PV-H2SUP, and the deuterium fill valve, PV-D2FILL. Close the deuterium cylinder supply valve.

28. _____ Turn on temperature controller and gradually ajust until target pressure stabilizes at 14.7 psia.

29. _____ Close MV-106-D (MV-105-D is already closed). Remove the cold trap from the liquid nitrogen.

30. _____ Pump out the cold trap by opening EP-D2Purge and PV-D2Fill. Evacuate cold trap until warm.

31. _____ After trap is warm, close EP-D2PURGE, and PV-D2FILL. Open MV-106-D.

TARGET SHUTDOWN PROCEDURE

1. _____ Turn off the deuterium system refrigerator.
2. _____ Turn off temperature controller.
3. _____ The liquid inside the deuterium target flask is empty when the deuterium upper and lower resistor temperatures exceed 23 K. These include TE-D2FLUP and TE-D2FLDWN.
4. _____ The Deuterium circuit will continue to hold some amount of deuterium gas unless complete shutdown is required for certain target maintenance.

For complete target shutdown, do the following:

5. _____ Close PV-D2SUP. Open PV-D2FILL and EP-D2PURGE. Pump out the target Deuterium circuit. The deuterium gas is vented through the roughing pump.

6. _____ Confirm that the deuterium cylinder supply valve is closed.

7. _____ Hook up a helium cylinder to MV-107-D and backfill the Deuterium circuit with Helium to 1 psig.

NOTE: BACKFILLING OF CIRCUIT <u>MUST</u> OCCUR IN THIS ORDER TO AVOID CRUSHING THE TARGET FLASK.

8. _____ Close high vacuum valve EP-HIVACD; turn off diffusion pump heater power. Allow 20 minutes for diffusion pump to cool down.

9. _____ Close fore line valve EP-FORVLVD; turn off power to fore pump.

10. _____ Turn off power to roughing pump.

11. _____ Uncap and open roughing line vent valve at pump cart, MV-101-V, to vent the vacuum space to atmosphere.

12. _____ Turn off electric circuits at the pump cart.

13. _____ Close all gas cylinder valves connected to the target system.

14. _____ Disable the Hydrogen detector as necessary for welding/brazing repairs.

Date _____ By _____

TARGET RESTART AFTER POWER OUTAGE OCCURS

1. _____ After power is restored, open deuterium system roughing valve EP-RUFVLVD and fore valve EP-FORVLVD.

2. _____ Open high vacuum valve EP-HIVACD. When pressure in the insulating vacuum is low enough, EP-HIVACD will open and EP-RUFVLVD will automatically close.

3. _____ After system analysis by a deuterium target expert, turn on compressor flow and refrigerator if permitted.

4. _____ Check the deuterium circuit upper and lower resistors as some deuterium may need to be added to the deuterium circuit.

5. _____ If required, open PV-D2SUP and PV-D2FILL to add hydrogen. Use the cold trap while adding deuterium as instructed in the TARGET STARTING PROCEDURE.

6. _____ Close PV-D2FILL and PV-D2SUP.

7. _____ Turn on the heater controller and be sure the set pressure is 14.7 psia.

E. E906 Emergency Procedures

A. LOSS OF AC POWER

Indications:

- All equipment shuts down.

- Controls continue working with Uninterruptible Power System

1. All vacuum valves close. Vacuum pumps stop. Compressors and refrigerators s stop. Insulating vacuum starts to spoil.

2. Depending on the amount of time the power is off, the hydrogen and deuterium will vaporize. Hydrogen and deuterium will be vented to the atmosphere outside of the builing through the ventilation exhaust ducting. No operator action needs to be taken to ensure the safety of the target. No on is allowed inside the tent while power is off.

3. When power returns, the vacuum system will try to automatically restore the insulating vacuum for the target. If flammable gas detector is in alarm, the ventilation fan will begin running.

4. If the power has been off for only a few minutes, the compressors and refrigerators may be restarted to restore the targets to full operation. A small loss of hydrogen/deuterium will not affect the operation of the targets.

5. A long power outage will mean a larger loss of hydrogen/deuterium from the targets. It will be necessary to refill them. The amount of hydrogen/deuterium to add may be estimate by looking at the temperatures of the upper and lower resistors in each target; TE-H2FLUP, TE-H2FLDWN, TE-D2FLUP and TE-D2FLDWN.

6. The UPS will keep the control system alive, which will open pressure valves PV-H2VV/PV-D2VV in order to allow the venting of hydrogen and deuterium through CV-01-H/CV-01-D. In the event that the control system shuts down and the above pressure valves are not opened, the gas will be vented through safety valves SV-03-H/SV-03-D.

7. The target motion controller should be restarted once the hydrogen/deuterium flasks are filled.

8. The heater power supply should be restarted once hydrogen/deuterium flasks are filled.

B. HYDROGEN/DEUTERIUM LEAK

Indications:

- Hydrogen reading on the flammable gas detector.
- Visual sighting

1. A flammable gas alarm is sent to FIXDMACS via our programmable logic controller. The O.D. operators are notified of FIXDMACS alarms. The alarm is also sent to FIRUS. An alarm on the flammable gas detector alone will not require the fire department to respond. However, if coupled with a spoiled insulating vacuum pressure, the fire department will respond to assess the situation. No one is allowed inside the target tent while the flammable gas detector is in alarm.
2. The target is surrounded by a tent. The tent is vented outdoors through a large fan. A flammable gas detector near the ceiling of the tent will start the fan when the detector is in alarm. The fan is also started whenever the insulating vacuum pressure is high and the targets are cold.
3. In any situation where a hydrogen leak has occurred, the entire system must be rechecked for system integrity before restarting the target. One should not confuse venting of a target through its vent valve or relief valve with a leak in the system.

C. LOSS OF AIR/NITROGEN FOR VALVES

Indications:

- Air compressor stops running.
- PT-PN2SUP goes into alarm.
- Back-up nitrogen cylinder is found empty.
- Valves don’t respond.
- Insulating vacuum spoils.

1. Loss of air/nitrogen will cause all vacuum valves except the high vacuum valve to close. The high vacuum valve will remain in its previous position.

2. Change nitrogen cylinder. Re-establish vacuum system.
3. Perform required maintenance to air compressor system.
4. Check target operation indicators. Hydrogen may need to be added. Refill as necessary.
5. Loss of air/nitrogen does not cause a safety problem, but only poor operation.

D. LOSS OF REFRIGERATION

Indications:

- Heater power demand decreases.
- Target pressures start to rise.

1. Check for vacuum problems.
2. After the target with the poor refrigeration has been shut down and emptied, repairs to that refrigerator may be performed while the other target is full, provided a written procedure is provided to the safety panel and is approved by them, prior to performing the work.
3. Each liquid target (hydrogen and deuterium) has its own cryocooler. Loss of refrigeration on one would not translate to a loss of refrigeration on the other. A loss of refrigeration on one target may cause that target to warm up and vent through the vent

E. LOSS OF THE ODH FAN IN THE SEAQUEST BEAMHALL

Indications:

- Alarm on FIXDMACS to O.D. operators
- Power Outage
- Failure of the flow sensing device

1. If the OH fan for the ME6 hall has failed, the fan should be replaced. A spare fan is available.
2. In the case that the fan is not operational, access to the beamhall near the targets is allowed, but the area is considered an ODH class 1 area. ODH class 1 rules must be followed until the fan is again operational.

E906 FAILURE MODE AND EFFECT ANALYSIS

DESIGNATION	FAILURE OR ERROR CODE	HAZARD/EFFECT	HAZARD CLASS	REMARKS/RECOMMENDATIONS
Check Valves				
CV-101-D	Open	Target D2 vents when PV-D2VV is open	Safe	PV-D2VV prevents backflow of air if CV-101-D is stuck open
CV-101-D	Closed	Target pressure may increase to SV-103-D set point (10 psig)	Safe	PSV-103-D would relieve any excess pressure
CV-01-H	Open	Target H2 vents when PV-H2VV is open	Safe	PV-H2VV prevents backflow of air if CV-01-H is stuck open
CV-01-H	Closed	Target pressuure may increase to SV-03-H set point (10 psig)	Safe	SV-03-H would relieve any excess pressure
CV-01-N	Open	Pneumatic air from compressor may leak through RV-01-N vent	Safe	Supply pressure to pneumatic valves will not go below RV-01-N setting
CV-01-N	Closed	Normal operating position	Safe	Maintains a pressure of 60 psig (RV-02-N setting) to pneumatic valves
Electric Valves				
EV-D2VV	Open	Opens PV-D2VV, Target is vented	Safe	Operates when target pressure exceeds 7 psig
EV-D2VV	Closed	PV-D2VV would close, target pressure may increase to SV-103-D set point	Safe	SV-103-D relieves target when pressure exceeds 10 psig
EV-D2SUP	Open	PV-D2SUP would open, supplying target with D2 during fill	Safe	Normal during fill; durion operation, all D2 supply is off
EV-D2SUP	Closed	Normal during operation	Safe	Target cannot fill
EV-D2FILL	Open	PV-D2FILL would open, supplying target with D2 during fill	Safe	Normal during fill; durion operation, all D2 supply is off
EV-D2FILL	Closed	Normal during operation	Safe	Target cannot fill
EV-RPVENTD	Open	Rough pump is vented to air	Safe	EP-RUFVLVD must be closed to prevent loss of vacuum
EV-RPVENTD	Closed	Normal operating position	Safe	Rough pump operation proceeds normally
EV-FPVENTD	Open	Fore pump is vented to air	Safe	EP-FORVLVD must be closed to prevent loss of vacuum
EV-FPVENTD	Closed	Normal operating position	Safe	Fore Vacuum system opeartion proceeds normally
EV-H2VV	Open	Opens PV-H2VV, Target is vented	Safe	Operates when target pressure exceeds 7 psig
EV-H2VV	Closed	PV-H2VV would close, target pressure may increase to SV-03-H set point	Safe	SV-03-H relieves target when pressure exceeds 10 psig
EV-H2SUP	Open	PV-H2SUP would open, supplying target with D2 during fill	Safe	Normal during fill; durion operation, all H2 supply is off
EV-H2SUP	Closed	Normal during operation	Safe	Target cannot fill
EV-H2FILL	Open	PV-H2FILL would open, supplying target with D2 during fill	Safe	Normal during fill; durion operation, all H2 supply is off
EV-H2FILL	Closed	Normal during operation	Safe	Target cannot fill
EV-RPVENTH	Open	Rough pump is vented to air	Safe	EP-RUFVLVH must be closed to prevent loss of vacuum
EV-RPVENTH	Closed	Normal operating position	Safe	Rough pump operation proceeds normally
EV-FPVENTH	Open	Fore pump is vented to air	Safe	EP-FORVLVH must be closed to prevent loss of vacuum
EV-FPVENTH	Closed	Normal operating position	Safe	Fore Vacuum system opeartion proceeds normally
EXCESS FLOW VALVES				
EFV-101-D	Open	Normal during fill	Safe	
EFV-101-D	Closed	Target will not fill; High flow may have caused valve to close	Safe	D2 line may have leak
EFV-101-H	Open	Normal during fill	Safe	
EFV-101-H	Closed	Target will not fill; High flow may have caused valve to close	Safe	H2 line may have leak
ELECTRO-PNEUMATIC VALVES				
EP-D2PURGE	Open	Rough pump would pump on D2 tubing	Safe	Since during normal operation, PV-D2FILL and PV-D2SUP are closed, there would be little effect. Used in clean-up of system during start-up
EP-D2PURGE	Closed	Normal operating position	Safe	
EP-RUFVLVD	Open	Rough pump evacuates target vacuum jacket	Safe	Normal during vacuum jacket pump down
EP-RUFVLVD	Closed	Normal operating position	Safe	Rough pump is isolated after rough vacuum has been achieved in the target
EP-FORVLVD	Open	Normal operating position	Safe	Fore pump pumps on diffusion pump outlet
EP-FORVLVD	Closed	Forepump wouldn't pump on diffusion pump, diffusion pump would not operate	Safe	Fore/High Vacuum system will not pump on target insulating vacuum
EP-HIVACD	Open	Normal operating position	Safe	Diffusion pump maintains high vacuum in target vacuum jacket
EP-HIVACD	Closed	Diffusion pump can not pump on target vacuum jacket	Safe	High vacuum won't be achieved

EP-H2PURGE	Open	Rough pump would pump on H2 tubing	Safe	Since during normal operation, PV-H2FILL and PV-H2SUP are closed, there would be little effect. Used in clean-up of system during start-up
EP-H2PURGE	Closed	Normal operating position	Safe	
EP-RUPVLVH	Open	Rough pump evacuates target vacuum jacket	Safe	Normal during vacuum jacket pump down
EP-RUPVLVH	Closed	Normal operating position	Safe	Rough pump is isolated after rough vacuum has been achieved in the target
EP-FORVLVH	Open	Normal operating position	Safe	Fore pump pumps on diffusion pump outlet
EP-FORVLVH	Closed	Forepump wouldn't pump on diffusion pump, diffusion pump would not operate	Safe	Fore/High Vacuum system will not pump on target insulating vacuum
EP-HIVACH	Open	Normal operating position	Safe	Diffusion pump maintains high vacuum in target vacuum jacket
EP-HIVACH	Closed	Diffusion pump can not pump on target vacuum jacket	Safe	High vacuum won't be achieved
FILTERS				
F-01-N	Plugged	Air is not supplied to pneumatic valves from the air compressor	Safe	Nitrogen gas from backup cylinder provides pressure to valves
MANUAL VALVES				
MV-101-D	Open	Normal operating position during target fill	Safe	
MV-101-D	Closed	D2 cylinder not supplying gas for target fill	Safe	
MV-102-D	Open	Normal during fill	Safe	
MV-102-D	Closed	No D2 supplied to target	Safe	
MV-104-D	Open	Normal operating position	Safe	Used during target fill
MV-104-D	Closed	D2 would not enter adsorber	Safe	
MV-105-D	Open	Contaminated D2 would enter target	Safe	Frozen N2, O2 or H2O may reduce D2 flow into refrigerator or foul the condenser plate, increasing cooldown time
MV-105-D	Closed	Normal operating position	Safe	
MV-106-D	Open	Normal operating position	Safe	Used during target fill
MV-106-D	Closed	D2 would not exit adsorber	Safe	
MV-107-D	Open	D2 would vent, target would not fill	Safe	Functions as pumpout port for adsorber regeneration
MV-107-D	Closed	Normal operating position	Safe	
MV-108-D	Open	TT-R2VPT would read incorrect temperature	Safe	VPT would vent to atm
MV-108-D	Closed	Normal operating position	Safe	
MV-110-D	Open	Normal operating position	Safe	
MV-110-D	Closed	PT-D2SUP would measure incorrect pressure	Safe	Compare to PT-D2VENT reading
MV-111-D	Open	Target D2 would vent, target would not fill	Safe	Close MV-110-D
MV-111-D	Closed	Normal operating position	Safe	
MV-112-D	Open	Normal operating position	Safe	
MV-112-D	Closed	PT-D2VENT would measure incorrect pressure, target control is inaccurate	Safe	SV-103-D protects target from overpressures
MV-113-D	Open	Target D2 would vent	Safe	Close MV-112-D
MV-113-D	Closed	Normal operating position	Safe	
MV-01-H	Open	Normal operating position during target fill	Safe	
MV-01-H	Closed	H2 cylinder not supplying gas for target fill	Safe	
MV-02-H	Open	Normal during fill	Safe	
MV-02-H	Closed	No H2 supplied to target	Safe	
MV-04-H	Open	Normal operating position	Safe	Used during target fill
MV-04-H	Closed	H2 would not enter adsorber	Safe	
MV-05-H	Open	Contaminated H2 would enter target	Safe	Frozen N2, O2 or H2O may reduce D2 flow into refrigerator or foul the condenser plate, increasing cooldown time
MV-05-H	Closed	Normal operating position	Safe	
MV-06-H	Open	Normal operating position	Safe	Used during target fill
MV-06-H	Closed	H2 would not exit adsorber	Safe	
MV-07-H	Open	H2 would vent, target would not fill	Safe	Functions as pumpout port for adsorber regeneration
MV-07-H	Closed	Normal operating position	Safe	
MV-08-H	Open	TT-R1VPT would read incorrect temperature	Safe	VPT would vent to atm

MV-08-H	Closed	Normal operating position	Safe	
MV-10-H	Open	Normal operating position	Safe	
MV-10-H	Closed	PT-H2SUP woudl measure incorrect pressure	Safe	Compare to PT-H2VENT reading
MV-11-H	Open	Target H2 would vent, target would not fill	Safe	Close MV-10-H
MV-11-H	Closed	Normal operating position	Safe	
MV-12-H	Open	Normal operating position	Safe	
MV-12-H	Closed	PT-H2VENT would measure incorrect pressure, target control is inaccurate	Safe	SV-03-H protects target from overpressure
MV-13-H	Open	Target H2 would vent	Safe	Close MV-12-H
MV-13-H	Closed	Normal operating position	Safe	
MV-01-N	Open	Normal operating position	Safe	
MV-01-N	Closed	Backup pneumatic N2 gas supply is isolated	Safe	Air compressor supplies gas to pneumatic valves
MV-02-N	Open	Normal operating position	Safe	
MV-02-N	Closed	Pneumatic air valves would close, stopping H2 flow and vacuum pumping	Safe	Loss of pumping on insulating vacuum, H2 flow would stop during fill
MV-03-N	Open	Pneumatic air supply is vented to atmosphere	Safe	Loss of pumping on insulating vacuum, H2/D2 flow would stop during fill
MV-03-N	Closed	Normal operating position	Safe	
MV-04-N	Open	Normal operating position	Safe	
MV-04-N	Closed	PT-PN2SUP would no longer function	Safe	Low Air/Nitrogen pressure alarms will not function
MV-05-N	Open	Normal operating position	Safe	
MV-05-N	Closed	Air compressor supply to pneumatic valves is isolated	Safe	Nitrogen gas cylinder supplies gas to pneumatic valves
MV-07-N	Open	Pressurized air is vent from compressor storage tank	Safe	May have a loss of pumping on insulating vacuum and H2/D2 flow may stop if in fill mode
MV-07-N	Closed	Normal operating position	Safe	
MV-102-N	Open	Normal operating position	Safe	
MV-102-N	Closed	Pneumatic air valves would close, stopping H2 flow and vacuum pumping	Safe	Loss of pumping on insulating vacuum, D2 flow would stop during fill
MV-01-V	Open	If cap is removed, air would enter vacuum jacket	Safe	Vacuum would be lost, H2 will vent
MV-01-V	Closed	Normal operating position	Safe	Normally not used
MV-02-V	Open	If cap is removed, air would enter vacuum jacket and enter between fore anc diffusion pump	Safe	Normally not used, EP-HIVACH closes and EP-RUFVLVH opens
MV-02-V	Closed	Normal operating position	Safe	
MV-03-V	Open	Redundant equipment, EV-01-He and MV-02-He are closed	Safe	Normally not used
MV-03-V	Closed	Normal operating position	Safe	
MV-101-V	Open	If cap is removed, air would enter vacuum jacket	Safe	Normally not used
MV-101-V	Closed	Normal operating position	Safe	
MV-102-V	Open	If cap is removed, air would enter vacuum jacket and enter between fore anc diffusion pump	Safe	Normally not used, EP-HIVACD closes and EP-RUFVLVD opens
MV-102-V	Closed	Normal operating position	Safe	
MV-103-V	Open	Redundant equipment, EV-101-He and MV-102-He are closed	Safe	Normally not used
MV-103-V	Closed	Normal operating position	Safe	
PNEUMATIC VALVES				
PV-D2SUP	Open	Normal during fill, redundant equipment during operation	Safe	All D2 sources are closed during operation
PV-D2SUP	Closed	Normal operating position	Safe	
PV-D2FILL	Open	Normal during fill and Target pump down, redundant during operation	Safe	All D2 sources are closed during operation
PV-D2FILL	Closed	Normal operating position	Safe	
PV-D2VV	Open	Target D2 may vent	Safe	CV-101-D may prevent D2 from venting since D2 pressure is not much greater than atmospheric pressure
PV-D2VV	Closed	Target pressure may increase to SV-103-D setpoint	Safe	SV-103-D would relieve any excess pressure
PV-H2SUP	Open	Normal during fill, redundant equipment during operation	Safe	All H2 sources are closed during operation
PV-H2SUP	Closed	Normal operating position	Safe	
PV-H2FILL	Open	Normal during fill land Target pump down, redundant during operation	Safe	All H2 sources are closed during operation
PV-H2FILL	Closed	Normal operating position	Safe	
PV-H2VV	Open	Target H2 may vent	Safe	CV-101-H may prevent H2 from venting since H2 pressure is not much greater than atmospheric pressure

PV-H2VV	Closed	Target pressure may increase to SV-03-H setpoint	Safe	SV-03-H would relieve any excess pressure
REGULATORS				
RV-101-D	Open	Normal operating position	Safe	
RV-101-D	Closed	Target would not get D2 for fill	Safe	
RV-102-D	Open	Normal operating position	Safe	
RV-102-D	Closed	Target would not get D2 for fill	Safe	
RV-01-H	Open	Normal operating position	Safe	
RV-01-H	Closed	Target would not get H2 for fill	Safe	
RV-02-H	Open	Normal operating position	Safe	
RV-02-H	Closed	Target would not get H2 for fill	Safe	
RV-01-N	Open	Normal operating position	Safe	
RV-01-N	Closed	Backup N2 gas supply is isolated	Safe	Air compressor supplies the pneumatic valves
RV-02-N	Open	Normal operating position	Safe	
RV-02-N	Closed	Pneumatic air supply is isolated	Safe	Backup N2 gas cylinder supplies the pneumatic valves
SAFETY VALVES				
SV-101-D	Open	Deuterium is vented from supply	Safe	
SV-101-D	Closed	Normal operating position	Safe	
SV-102-D	Open	Deuterium is vented from supply line	Safe	D2 vents into tent; Flammable gas detector triggers tent exhaust fan; D2 is vented through ducting to the outdoors
SV-102-D	Closed	Normal operating position	Safe	
SV-103-D	Open	Deuterium is vented from target through the vent line	Safe	D2 vents into tent; Flammable gas detector triggers tent exhaust fan; D2 is vented through ducting to the outdoors
SV-103-D	Closed	Normal operating position	Safe	
SV-104-D	Open	Deuterium is vented from cold trap	Safe	Would typically only operate when the cold trap is isolated
SV-104-D	Closed	Normal operating position	Safe	
SV-01-H	Open	Hydrogen is vented from supply	Safe	
SV-01-H	Closed	Normal operating position	Safe	
SV-02-H	Open	Hydrogen is vented from supply line	Safe	H2 vents into tent; Flammable gas detector triggers tent exhaust fan; H2 is vented through ducting to the outdoors
SV-02-H	Closed	Normal operating position	Safe	
SV-03-H	Open	Hydogen is vented from target through the vent line	Safe	H2 vents into tent; Flammable gas detector triggers tent exhaust fan; H2 is vented through ducting to the outdoors
SV-03-H	Closed	Normal operating position	Safe	
SV-04-H	Open	Hydrogen is vented from cold trap	Safe	Would typically only operate when the cold trap is isolated
SV-04-H	Closed	Normal operating position	Safe	
SV-01-N	Open	Pneumatic backup N2 gas supply is vented	Safe	Air compressor supplies pneumatic valves
SV-01-N	Closed	Normal operating position	Safe	
SV-01-V	Open	Vacuum would not be achieved	Safe	Operational problem
SV-01-V	Closed	Normal operating position	Safe	
SV-02-V	Open	Vacuum would not be achieved	Safe	Operational problem
SV-02-V	Closed	Normal operating position	Safe	
SV-101-V	Open	Vacuum would not be achieved	Safe	Operational problem
SV-101-V	Closed	Normal operating position	Safe	
SV-102-V	Open	Vacuum would not be achieved	Safe	Operational problem
SV-102-V	Closed	Normal operating position	Safe	

G. E906 WHAT-IF ANALYSIS

The what-if analysis for both of the liquid target systems is included below. This is acceptable since the systems are identical. Valves associated with the hydrogen system are identified with an H in the tagname. Those associated with the deuterium system are identified with a D in the tagname. That is, EP-HIVACH is the HIVAC valve in the hydrogen system and EP-HIVACD is the HIVAC valve in the deuterium system. Furthermore, the tagnames identified numerically are distinguished as follows: Tags number 0 through 99 are part of the hydrogen system and tags 100 and greater are part of the deuterium system. The only exceptions are some nitrogen and helium valves which are shared by both system (see P&I Diagrams to confirm valve/instrument function).

1. Loss of Insulating Vacuum

Initiation:

a. Forepump belt failure
b. Forepump failure
c. Foreline hose rupture
d. Roughing line hose rupture
e. Diffusion pump failure
f. Vacuum leak in system

Automatic Responses:

a. If fore pressure as read on PE-FPVACH/PE-FPVACD exceeds 200 microns, diffusion pump heater turns off and EP-FORVLVH/EP-FORVLVD closes.
b. The cryocooler will be shutdown. The heater will continue to operate under PID control, although a cryocooler shutdown will lead to the eventual shutdown of the heater via PID.

Results of Failure:

a. Refrigerator remains on, supplying cooling to target.
b. Refrigeration will not be able to keep the target cool because of the condensing air heat load. At a pressure of 7 psig, the hydrogen vent valve, PV-H2VV/PV-D2VV, will open. When the pressure falls below 4 psig, it will close again. If PV-H2VV/PV-D2VV were to fail, SV-02-H/SV-102-D will open at a pressure of 10 psig to relieve the hydrogen/deuterium jacket.

c. Exhaust fan is started by the interlocks in the PLC program. FIXDMACS alarms and FIRUS alert appropriate personnel.

2. Cold flask failure, Cryostat windows intact

Initiation:

a. Flask overpressure
b. Cold leak in flask or plumbing

Automatic Responses:

a. When vacuum reaches 800 microns as measured on PT-01-V/PT-101-V, high vacuum valve EP-HIVACH/EP-HIVACD closes.
b. If fore pressure as read on PE-FPVACH/PE-FPVACD exceeds 200 microns, diffusion pump heater turns off and EP-FORVLVH/EP-FORVLVD closes.
c. When the vacuum jacket reaches 1.5 psia, RD-01-V/RD-101-V and RD-02-V/RD-102-V open and vent the hydrogen/deuterium to relieve the insulating vacuum jacket.
d. At 800 microns, both the cryocooler compressor and heater will be shutdown.

Results of failure:

a. Any hydrogen/deuterium pumped by the vacuum system will be vented into the Tent.
b. All hydrogen/deuterium from a flask failure is vented outside through the tent ventilation ducting.

3. Failure of H2/D2 supply cylinder valve or cylinder regulator

Initiation:

a. Leaking cylinder valve
b. Leaking cylinder regulator

Automatic responses:

None. No hydrogen detector will be used outside in the cylinder storage area for this experiment.

Results of failure:

Hydrogen/Deuterium gas will vent into the area outside where the cylinders are stored.

4. **Failure of H2/D2 supply line between cylinder regulator and PV-H2SUP**

Initiation:

a. Rupture of line.
b. Leak in line due to physical damage.
c. Leaking fittings in line.

Automatic responses:

The excess flow valve, EFV-01-H/EFV-101-D, will stop the flow of hydrogen/deuterium. The excess flow valves are located outdoors, near the supply cylinders.

Results of failure:

a. Supply lines for this experiment are copper tubing which run along the concrete shielding blocks. They are well protected against physical damage.
b. If a failure occurs during filling, hydrogen/deuterium would escape into the NM4 building. Small leaks would be undetected. A maximum of about 200 SCF of hydrogen/deuterium would be caught in the ceiling of Building from this failure.
c. The hydrogen/deuterium cylinder is valved off at all times except during filling limiting any amount of hydrogen/deuterium available during such a leak.

5. **Failure of H2/D2 supply line from pump cart to target.**

Initiation:

a. Leak in fittings.
b. Physical damage to lines.
c. Rupture of lines.

Automatic Responses:

a. Target hydrogen/deuterium pressure will drop to 14.3 psia regardless of heater controller setting.
b. If the leak is large enough or directly over the hydrogen detector, it will alarm to alert the operators of the problem. At most a leak will release 200 SCF of hydrogen into the NM4 building or the Tent. The tent is equipped with a ventilation fan with a capacity of 1300 cfm air.

Results of failure:

a. Supply line to the target is made of ¼" copper tubing with some fittings. The lines are routed along the wall and damage is unlikely.
b. The hydrogen detector in the ceiling of the tent may see the leak and warn the operators and FIRUS. The leak will be contained inside the tent and when the detector alarms, the ventilation fan will run.

6. Loss of AC Power

Initiation:

a. Power outage in area (scheduled or unscheduled)
b. Power outage on Main site.

Automatic Responses:

a. Uninterruptible Power System (UPS) allows control of PV-H2VV/PV-D2VV.
b. All other electronically controlled valves close.
c. All vacuum pumps, compressors, and refrigerators stop.
d. The proton beam will stop

Results of failure:

a. Insulating vacuum begins to spoil. No refrigeration is available.
b. Liquid in the targets begins to vaporize. Hydrogen/Deuterium is vented through PV-H2VV/PV-D2VV while UPS supplies backup power. SV-02-H/SV-102-D protects system from increasing in pressure higher than 10 psig.
c. The target motion table and controller stop.
d. Although the heater PID will continue to function on UPS, the heater power supply will shutdown.

7. Restoration of AC Power

Initiation:

a. Power restored to area.

Automatic Responses:

a. Vacuum system will attempt to restore itself.
b. Refrigerators and compressors remain off.

Results of failure:

a. Unless the power outage is of short duration and the refrigerators are restarted, all of the hydrogen/deuterium will be vented.
b. If there was considerable ice buildup on the flask, several hours may be needed to re-establish high vacuum.
c. Pressures in the target flask volumes must be checked to determine if SV-02-H/SV-102-D has lifted and, if so, re-seated. If the pressure in the target is near 14.3 psia, then the valve must be re-seated and the target re-purged before filling. This scenario is now much less likely since the addition of PV-H2VV/PV-D2VV.
d. The control system will attempt to restart itself if the duration of power loss was longer than what the UPS would have allowed. The control system PC remains off and will need to be restarted.
e. The heater controller will attempt to restart itself. However, the control system will not automatically restart the PID control.
f. The target table motor controller will attempt to restart itself. However, the control system will not automatically restart the pre-programmed motion control.

8. Loss of valve operating gas (air/nitrogen) pressure.

Initiation:

a. Leakage in the valves, lines, or fittings or excessive use of the valves. See also, E866 Emergency Procedures: Loss of Air/Nitrogen for Valves.

Automatic Responses:

a. When the pneumatic pressure is less than 20 psig, EP-H2PURGE/EP-D2PURGE, EP-RUFVLVH/EP-RUFVLVD, and EP-FORVLVH/EP-FORVLVD close. Valves close due to force of actuator spring. EP-HIVACH/EP-HIVACD (high vacuum valve) remains in the open state.

b. PV-H2SUP/PV-D2SUP and PV-H2FILL/PV-D2FILL close. Valves close due to force of actuator spring.

Results of failure:

a. Vacuum in the target vacuum jacket will spoil, increasing heat load to the target.
b. Hydrogen/Deuterium may be vented from the target to the stack.

9. Failure of heater control circuit.

Initiation:

a. Open heater circuit in the target.
b. Failure of the pressure sensing circuit.
c. Failure of the heater controller.

Automatic responses:

None.

Results of failure:

a. If power output from the controller exceeds the desired power, target pressure will rise and target will vent if the pressure exceeds the vent valve or relief valve set pressures.
b. If power output from controller is less than the desired power, target pressure will decrease. An alarm on FIXDMACS will alert the operators if the target pressure begins to go sub-atmospheric.

10. Failure of pressure transducer circuit.

Initiation:

a. Failure of pressure transducers PT-H2SUP/PT-D2SUP, PT-H2VENT/PT-D2VENT.
b. Failure of readout circuits.

Automatic Responses:

a. If PT-H2SUP/PT-D2SUP increases above 5 psig, PV-H2SUP/PV-D2SUP will close. PT-H2VENT/PT-D2VENT is used for the input signal to the heater control and PV-H2VV/PV-D2VV action. The heater control will act on the erroneous signal. If the signal fails low, PV-H2VV/PV-D2VV will not open. If it fails high, PV-H2VV/PV-D2VV will open and vent hydrogen/deuterium.

Results of failure:

a. Target Pressure will be unknown. The heater circuit will act on the erroneous signal and the target will either rise or fall in pressure in response to the heater output. See section 9. If PV-H2VV/PV-D2VV does not open, the hydrogen/deuterium must

vent through SV-02-H/SV-102-D. Temperature sensors will be monitored for agreement with pressure transducers.

H. E906 ODH Analysis

NM4 Building

Fluids to be in use with the E906 Target System include deuterium, hydrogen, and nitrogen. The hydrogen and deuterium cylinders are to be located inside an explosion proof gas shed which is a part of the NM4 Building. The cylinders of non-flammable gas will also be located inside the gas shed. At any given time, one nitrogen cylinder will be in use. All transfer lines from the gas shed into the SeaQuest Beam Hall will be metal. A single spare cylinder of each of these gases may be stored locally. Each cylinder contains roughly 200 to 250 standard cubic feet of gas. The gas systems are not common and are therefore unlikely to be released simultaneously. If a deuterium, or hydrogen gas supply system were to leak gas indoors, the gas would escape into the very large SeaQuest Building. The volume of the gas inside the cylinders is small compared to the volume of the building and would not present an ODH condition. The nitrogen from one cylinder released and mixed uniformly inside the SeaQuest Hall would reduce the oxygen concentration by less than 1%. The Building is thus ODH class 0.

SEAQUEST BEAMHALL

Unlike the E866 Target System, there are no external helium lines/cylinders feeding the refrigerator. However, a metal flexible line containing helium will be connected between the compressor and the cryo-cooler coldheads. The amount of helium contained in these metal flexible lines is approximately 3.3 standard cubic feet of gas. In case of rupture of these lines, the reduction in oxygen concentration would be negligible.

INSIDE THE TENT

The E906 target system will re-use the E866 target tent. See Page 53 of the E866 Safety Report.

The following modifications should be made to the worst condition scenario:

The worst condition would be that discussed for a complete severing of the helium metal flexible lines which would result in the release of 3.3 SCF of gas. The failure rate for this event is low, and the tent exhaust fan has a ventilation rate of 1300 SCFM which is significantly higher than this failure rate. In the case of line rupture, the helium supply and return lines should be replaced.

Since the E906 target system will not use a helium supply to operate its refrigerators, part (2) of the requirements for tent access may be deleted while maintaining an ODH classification of 0.

E906 Hydrogen Safety Analysis

If hydrogen or deuterium were to leak outside the tent it will vent through the ODH exhaust fan into the NM4 Building. The amount of hydrogen from one of the targets mixed perfectly with air is equivalent to 0.36 lbs. Of TNT. This value is based on a TNT equivalent of 1 lb. TNT = 1 lb. H2 from NBS Report 10 734 "Explosion Criteria for Liquid Hydrogen Test Facilities", Hord. If a full cylinder were to vent into the NM4 Building and mix perfectly with air, its explosive equivalent is equal to 1.2 lbs of TNT.

It is unlikely that any hydrogen will escape from the tent as the system is built according to Fermilab Guidelines for LH_2 Targets. Thus any venting from the target flask or its vacuum shell is expected to be vented through the tent ventilation system and exhaust outdoors. All reliefs are adequately sized as is the ventilation ducting. Small leaks will not present this hazard immediately and target performance will suffer before this amount of hydrogen or deuterium would leak out and be discovered.

The vacuum pump carts and cold traps will be located along the east wall of SeaQuest Hall next to the beamline near the targets. The hydrogen and deuterium cylinders will be located outside the Hall on the ground level inside an explosion proof gas shed. In consideration of the presence of hydrogen, the Guidelines section II.F.2.a. is followed. We will take the following precautions in this regard:

(1) Warning signs will be posted alerting personnel of hydrogen gas in the area and that ignition sources are not allowed.

(2) The phone number and pager number of the operations crew will be posted. If a hydrogen target expert is required, the shift crew will be able to contact one. The shift crew will have access to a copy of the E906 LH_2 Target Safety Report which includes the Operating and Emergency Procedures.

(3) No combustibles or ignition sources will be allowed in the area of the hydrogen cylinders. No welding will be allowed within 33 feet without the Research Division Office approval.

(4) Cylinders will be properly secured. Only hydrogen cylinders in use will be kept at the entryway to the NM4 building. Full or empty bottles not in use will be promptly removed and stored in a designated storage area. Concrete bumpers will be installed to keep automobiles at a distance from the cylinders.

(5) The hydrogen supply lines have an excess flow valve installed outdoors. Each cylinder uses an appropriate pressure regulator. Each supply line also includes a relief valve set for 50 psig in order to protect the cold traps.

(6) Hydrogen supply lines will be leak checked at 90% of the circuit relief pressure.

(7) The hydrogen lines and ventilation exhaust ducting will be identified with labels.

(8) Hydrogen lines will be metallic and will be appropriately installed and supported.

I. DESIGN CALCULATIONS/MATERIAL SPECIFICATIONS

E906 STAINLESS STEEL FLASK STRESS CALCULATIONS

The E906 Target System will re-use the target flasks used for the E866 Target System. Refer to pp.63-72 of the E866 Safety Report.

VACUUM JACKET STRESSES

The E906 Target System will re-use the vacuum jacket used for the E866 Target System. For safety issues relating to its stress test, volume, and relief mechanism, refer to pp73-74, 87-8 of the E866 Safety Report.

TITANIUM WINDOW STRESS

The E906 Target System will re-use the titanium windows used for the E866 Target System. Refer to pp.75-86 of the E866 Safety Report.

J. TENT DESIGN AND CONDITIONS FOR ENTRY

PROCEDURE FOR ACCESS TO THE E906 TENT FOR INSTALLATION/REMOVAL OF COPPER FOIL, EXPANDER WORK, REPAIRING/REPLACING INSTRUMENTATION,

The procedure for access to the E906 Tent for installation/removal of the copper foil is the same as that for the E866 experiment. Refer to pp. 89-92 of the E866 target safety report.

The list of personnel considered target experts has been updated to consist of the following names:

CONDITIONS FOR ACCESS TO THE SEAQUEST BEAMHALL

The conditions for access to the SeaQuest Beamhall are the same as that for the ME6 Beamhall for E866. Refer to page 93 of the E866 target safety report.

E906 TENT DESIGN

The target tent design from the E866 target system will be re-used for the E906 Experiment. For tent design as well as power failure scenarios and target table motor safety, refer to pp.95-119 of the E866 Target Safety Report.

Changes between the E866 and E906 tents are as follows:

- The fan will be controlled by the APACS programmable logic controller.
- Ducting exhaust is vented outdoors on the east side of the SeaQuest Building.

K. PERFORMANCE TESTS

PERFORMANCE TESTS

Pressure test, relief valve test, stainless steel flask joint test, flask pressure testing, titanium window testing, pneumatic vent valve leak test were all performed prior to the E866 experiment, and all of the above items will be re-used for the E906 target.

Pressure Piping Test

This section defines procedures for designing, fabricating and testing pressure piping systems.

SCOPE

This chapter includes all piping systems that fall under the following subsystems:

1. Target internal piping
2. Target external existing piping
3. Target external new piping

Target Internal Piping

- All piping within the target vacuum jacket, including the condenser and the supply and relief pipes, will be pressure tested to 1.1 times the maximum allowable working pressure according to UG-100 of the ASME Boiler and Pressure Vessel Code, Section VIII Div.1 (hereafter called the Code).

Target External Existing Piping

Piping from the hydrogen, deuterium, and nitrogen cylinders to the target will make use of partially existing piping between the gas shed and the experimental hall.

- Existing piping will be pneumatically tested to 90% of the relief pressure.
- Any piping or system components with relief settings above 150 psig shall be tested at 1.25 times the relief pressure as per Chapter 5034 of the Fermilab ES&H Manual.
- A leak test using suitable means shall also be performed prior to operating the system.

Target External New Piping

- New external piping between the gas shed and the target will be tested to 1.1 times the relief pressure.
- Material certification and engineering notes for all joints, fittings, and piping will be documented on the "FESHM 5031.1 Piping Engineering Notes".
- All welding joints will be documented on the "Weld Inspection Form" by the weld inspector according to the "In-Process Weld Inspection Guidelines". A "Weld Inspection Form" will be required for each welder.
- A leak test using suitable means shall also be performed prior to operating the system.

E906 STAINLESS STEEL FLASK JOINT TESTING

The E906 target system will re-use the E866 target flask. Flask joint tests were performed for the E866 target system (refer to pp. 133-139 of the E866 Target Safety Report).

FLASK PRESSURE TESTING

The E906 target system will re-use the E866 target flask. Flask pressure tests were performed for the E866 target system (refer to pp. 140-143 of the E866 Target Safety Report).

TITANIUM WINDOW TESTING

New titanium windows will be built for the E906 target system. The design of the windows will be identical to those of the E866 Target System. Refer to p. 151 of the E866 Target Safety Report.

INTERLOCK SYSTEM TEST

Each interlock will be tested and documented for operability with a safety personnel on hand to witness its safe operation.