E866 Liquid Hydrogen Target
Safety Report Index

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

SYSTEM DESCRIPTION FOR THE E866 TARGETS

June 4, 1996

The E866 target system is located in the ME6 beam hall of the Meson Area Detector 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 "50 Watt" APD refrigerators. The compressed helium gas is supplied from the Mycom compressors in the Meson Cryo Building. Standard pump carts are used for the vacuum systems and purging equipment. The target control system includes a TI405 Series Programmable Logic Controller. 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 E866 target tent 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.

E866 TARGET TRANSPORT TABLE
June 4, 1996

The E866 motion table was originally purchased for use in E665. Although the E866 target location has conditions less stringent than those at E665, we will reuse the table for the new target system in the Meson Area Detector Building, ME6 beamline. Following are the original specifications for the table. Drawings referenced below can be made available upon request.

E665 TARGET TRANSPORT TABLE:

This is the specification for a target transport table for experiment E665. The table moves in order to align different targets with the beam in the Muon lab. The table will be in a stray magnetic field from a large analysis magnet. The stray field in the area of the motion table is estimated at 200 Gauss. Ferromagnetic materials should be used only where necessary for structural reasons or for the drive mechanism. The table will support three hydrogen targets and a metal target structure that can rotate any of seven different metal target systems into the beam. The target setup is shown on drawing 2727.665-MD-58117 and 2727.665-MD-58118. The SELLER will supply the target table, drive motors, and motor controller for the metal target structure.

The target table is required to move from any one target beam position to any other target position in less than 35 seconds. The maximum motion distance of the table necessary is 32 inches. The accuracy of positioning is +/- 1 mm repeatedly in the direction of motion. The metal target drive motor may operate simultaneously. The acceleration and velocity profile must be adjustable from the motor controller. The motor controller will be programmed from a Fermilab supplied IBM compatible PC.

The table base plate must be drilled by the SELLER to hold the Fermilab supplied target systems. The base plate must be made from 6061-T6 aluminum and capable of supporting 800 lbs. of weight excluding the drilled base plate required by the design. Drawing 2727.665-MD-58119 shows the hole drilling pattern for the base plate.

The specific equipment list (or equivalent) is as follows:

QTY	DESCRIPTION
1	Anaheim Automation #DPF21SB1 2-axis programmable step motor controller, driver and power supply
2	Anaheim Automation #34D311S Nema 34 frame step motors
1	Anaheim Automation #AA1709 RS232/RS422 bi-directional

converter

1 Anaheim Automation #ENC-15 4-axis encoder feedback board

1 Veeder-Root #650800-010 8mm 5-24 VDC, NPN output, proximity switch for metal target wheel home sensor

1 Daedal #008-1369 single axis motor driven slide 24" wide x 32" travel rail table with 24" x 46" carrier plate and 4 linear guide rails: 4 bearings per rail: 0.200" lead rolled ball screw 1.125" diameter; home and limit switches; 1000 line encoder mounted on the drive screw opposite the motor

The quote must include the price for one day of training at Fermilab for programming the controller. A SELLER who proposes different equipment from the recommended list above must show a listing of the differences in specifications between the proposed equipment and our recommended equipment.

E-866 VALVE AND INSTRUMENTATION LIST						
DESIGNATION	FUNCTION	MANUFACTURER	MODEL	RANGE/MAX WORKING PRESS.	SIZE/OUTPUT	NOTES
CHECK VALVES						
CV-101-D	PV-D2VV vent to tent	Circle Seal	280T-4PP-1	1 psig cracking pressure	1/2"	Teflon seals
CV-01-H	PV-H2VV vent to tent	Circle Seal	280T-4PP-1	1 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	1 psid cracking pressure	1/4"	
ELECTRIC VALVES						
EV-01-He	Fill/Empty valve solenoid, H2 system	Skinner	V53DB2150, 110 VAC	150 psid	1/4"	3-way, Normally Closed
EV-02-He	Helium unloader valve, H2 system	Worcester	Mod 10 / 75, 110 VAC	2500 psid	1"	3-way
EV-101-He	Fill/Empty valve solenoid, D2 system	Skinner	V53DB2150, 110 VAC	150 psid	1/4"	3-way, Normally Closed
EV-102-He	Helium unloader valve, D2 system	Worcester	Mod 10 / 75, 110 VAC	2500 psid	1"	3-way
EV-D2VV	Vent Valve solenoid	Skinner	V53DB2150, 110 VAC	150 psid	1/4"	3-way, Normally Closed
EV-D2SUP	H2 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	Target fill valve solenoid	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"	2-way, Normally Closed
EXCESS FLOW VALVES						
EFV-101-D	Excess flow valve on D2 circuit	Nupro	6L-E4LE-FR4-VR4	225 psig	1/4"	Burst Press = 12,000 psi
EFV-01-H	Excess flow valve on H2 circuit	Nupro	6L-E4LE-FR4-VR4	225 psig	1/4"	Burst Press = 12,000 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	Vacuum 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	Vacuum Research	LP4, 120VAC	Vacuum Valve	4"	Normally Closed
FILTERS						
F-01-He	Helium supply particulate filter	Balston	Housing PN 27/35	800 psig	1" NPT	Filter Element PN 3/200-35-DX, 0.1 μ
F-01-N	Air compressor filter	Campbell-Hausfield	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"	

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E-866 VALVE AND INSTRUMENTATION LIST							
DESIGNATION	FUNCTION	MANUFACTURER	MODEL	RANGE/MAX WORKING PRESS.	SIZE/OUTPUT	NOTES	
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	Cold 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-00-He	Helium discharge primary supply valve	Worcester	1" 4466TSW	2500 psig	1"		
MV-01-He	Post regulator shutoff, H2 system	Nupro	B-4HK2	1000 psig	1/4"		
MV-02-He	Pre pump cart shutoff, H2 system	Hoke	4151M4B	600 psig	1/4"		
MV-04-He	Helium supply manual vent, H2 system	Nupro	SS-4BK-VCO	1000 psig	1/4"		
MV-05-He	Post vent shutoff valve, H2 system	Nupro	B-4HK2	1000 psig	1/4"		
MV-06-He	Helium discharge header valve, H2 sys.	Worcester	1" 4466TSW	2500 psig	1"		
MV-08-He	Helium suction header valve, H2 sys.	Worcester	1.5" 4466TSW	2000 psig	1.5"		
MV-09-He	PT-COMPSUCH shutoff valve	Nupro	B-4HK2	1000 psig	1/4"		
MV-10-He	PT-COMPSUCH pumpout valve	Nupro	B-4HK2	1000 psig	1/4"		
MV-11-He	PT-COMPDISH shutoff valve	Nupro	B-4HK2	1000 psig	1/4"		
MV-12-He	PT-COMPDISH pumpout valve	Nupro	B-4HK2	1000 psig	1/4"		
MV-13-He	RV-03-He shutoff valve, VV supply sys.	Linde	vendor supplied	3000 psig	1/4"		
MV-101-He	Post regulator shutoff, D2 system	Nupro	B-4HK2	1000 psig	1/4"		
MV-102-He	Pre pump cart shutoff, D2 system	Hoke	4151M4B	600 psig	1/4"		
MV-104-He	Helium supply manual vent, D2 system	Nupro	SS-4BK-VCO	1000 psig	1/4"		
MV-105-He	Post vent shutoff valve, D2 system	Nupro	B-4HK2	1000 psig	1/4"		
MV-106-He	Helium discharge header valve, D2 sys.	Worcester	1" 4466TSW	2500 psig	1"		
MV-108-He	Helium suction header valve, D2 sys.	Worcester	1.5" 4466TSW	2000 psig	1.5"		
MV-111-He	PT-COMPDISD shutoff valve	Nupro	B-4HK2	1000 psig	1/4"		
MV-112-He	PT-COMPDISD 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 system	Hoke	4151M4B	600 psig	1/4"		
MV-03-N	PT-PN2SUP pumpout valve	Nupro	SS-4P4T4	3000 psig	1/4"		
MV-04-N	PT-PN2SUP isolation valve	Nupro	SS-4P4T4	3000 psig	1/4"		
MV-05-N	Filter/dryer isolation valve	Nupro	SS-4P4T4	3000 psig	1/4"		
MV-06-N	Air compressor drain valve	Nupro	SS-4P4T4	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 isolation	Nupro	SS-4P4T4	3000 psig	1/4"		
MV-09-N	Air compressor isolation valve	Nupro	SS-4P4T4	3000 psig	1/4"		
MV-10-N	Pump cart isolation valve	Nupro	SS-4P4T4	3000 psig	1/4"		
MV-102-N	Pre pump cart shutoff valve, D2 system	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 system	Hoke	4151M4B	600 psig	1/4"		
MV-101-V	Rough line bleed valve, D2 system	Hoke	4151M4B	600 psig	1/4"		B
MV-102-V	Fore pump vent valve, D2 system	Hoke	4151M4B	600 psig	1/4"		

E-866 VALVE AND INSTRUMENTATION LIST							
DESIGNATION	FUNCTION	MANUFACTURER	MODEL	RANGE/MAX WORKING PRESS.	SIZE/OUTPUT	NOTES	
MV-103-V	Vacuum shutoff to EV-01-He, D2 system	Hoke	4151M4B	600 psig	1/4"		
PNEUMATIC 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	3000 psi max inlet
RV-102-D	Pump cart D2 regulator	Air Products	E11-N141A	0 to 25 psig	1/4"	NOP = 3 psig	400 psi max inlet
RV-01-H	Hydrogen cylinder regulator	Victor	VTS 452B	2 to 40 psig	1/4"	NOP = 10 psig	3000 psi max inlet
RV-02-H	Pump cart H2 regulator	Air Products	E11-N141A	0 to 25 psig	1/4"	NOP = 3 psig	400 psi max inlet
RV-01-He	Helium cylinder regulator, H2 system	Harris	93-350A	0 to 350 psig	1/4"		3000 psi max inlet
RV-02-He	Helium supply regulator, H2 system	Grove	202G		1"		3500 psi max inlet
RV-03-He	Vent valve actuator regulator	Linde	UPG-3-150	0 to 150 psig	1/4"	NOP = 110 psig	3000 psi max inlet
RV-04-He	Vent valve sleeve regulator	Air Products	E11-N141A	0 to 25 psig	1/4"	NOP = 3 psig	400 psi max inlet
RV-101-He	Helium cylinder regulator, D2 system	Harris	93-350A	0 to 350 psig	1/4"		3000 psi max inlet
RV-102-He	Helium supply regulator, D2 system	Grove	202G		1"		3500 psi max inlet
RV-01-N	Nitrogen cylinder regulator	Linde	UPG 3 150 580	0 to 150 psig	1/4"	NOP = 105 psig	3000 psi max inlet
RV-02-N	Pneumatic air compressor regulator	Matheson	3590	2 to 100 psig	1/4"	NOP = 60 psig	3000 psi max inlet
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 line 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-He	Helium gas supply relief, H2 system	Nupro	B-8CPA2-3	300 psig	1/2"		
SV-02-He	Refrig. supply relief valve, H2 system	Nupro	B-8CPA2-3	90 psig	1/2"		
SV-03-He	Helium gas supply line relief, VV system	Nupro	B-8CPA2-3	130 psig	1/2"		
SV-101-He	Helium gas supply relief, D2 system	Nupro	B-8CPA2-3	300 psig	1/2"		
SV-102-He	Refrig. supply relief valve, D2 system	Nupro	B-8CPA2-3	90 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	Refrigerator 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	Refrigerator 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	
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FLOW DEVICES							

E-866 VALVE AND INSTRUMENTATION LIST							
DESIGNATION	FUNCTION	MANUFACTURER	MODEL	RANGE/MAX WORKING PRESS.	SIZE/OUTPUT	NOTES	
FT-D2SUP	Hydrogen 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-01-He	Compressor total flow, H2 system	Hastings	L-200SF	0 to 286 scfm He	0 to 5.0 volts		
FI-01-He	Compressor flow readout, H2 system	Hastings	Model NALL, type HS-10S	0 to 286 scfm He	0 to 5.0 volts		
FE-101-He	Compressor total flow, D2 system	Hastings	L-200SF	0 to 286 scfm He	0 to 5.0 volts		
FI-101-He	Compressor flow readout, D2 system	Hastings	Model NALL, type HS-10S	0 to 286 scfm He	0 to 5.0 volts		
FE-ODHFAN	ODH fan flow	Annubar	AIR-26 for 3" circ. duct				
FIS-ODHFAN	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	Refrigerator 2 heater	Minco	H4A20W115	0-20 Watts	0 to 10.0 volts		
HTR-101-OIL	Diffusion Pump heater, D2 target sys.	NRC Diffusion Pump	vendor supplied			Pump Model # 0159	
HTR-01-H	Refrigerator 1 heater	Minco	H4A20W115	0-20 Watts	0 to 10.0 volts		
HTR-01-Oil	Diffusion Pump heater, H2 target sys.	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-He	1" He suction header pressure	FIXDMACS					
PI-02-He	1" He discharge header pressure, H2 tgt	FIXDMACS					
PI-03-He	RV-01-He inlet pressure, H2 tgt	US Gauge		0 to 4000 psig			
PI-04-He	RV-01-He outlet pressure, H2 tgt	US Gauge		0 to 500 psig			
PI-05-He	RV-03-He inlet pressure	NKS Nagano		0 to 4000 psig			
PI-06-He	RV-03-He outlet pressure	NKS Nagano		0 to 200 psig			
PI-07-He	RV-04-He outlet pressure	US Gauge		neg. 30 in Hg to 30 psig			
PI-102-He	1" He discharge header pressure, D2 tgt	FIXDMACS					
PI-103-He	RV-01-He inlet pressure, D2 tgt	US Gauge		0 to 4000 psig			
PI-104-He	RV-01-He outlet pressure, D2 tgt	US Gauge		0 to 500 psig			
PI-01-N	RV-01-N inlet pressure	NKS Nagano		0 to 4000 psig			B
PI-02-N	RV-01-N outlet pressure	NKS Nagano		0 to 200 psig			

E-866 VALVE AND INSTRUMENTATION LIST						
DESIGNATION	FUNCTION	MANUFACTURER	MODEL	RANGE/MAX WORKING PRESS.	SIZE/OUTPUT	NOTES
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-COMPDISH	1" He discharge header pressure, H2 tgt	Setra	C206	0 to 500 psig	4 to 20 mA	
PT-COMPDISD	1" He discharge header pressure, D2 tgt	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 Controller.	Beckman	7200	Set pt range = 0 to 50 psia	0 to 120 volts	range dependent on PT-D2VENT
PIC-01-H	Hydrogen Pressure Indicating Controller	Beckman	7200	Set pt range = 0 to 50 psia	0 to 120 volts	range dependent on PT-H2VENT
SWITCHES						
ISL-FPD	Current switch low	SSAC	ECS41BC	adjustable 2 to 20 Amps	12VDC	on D2 system Fore Pump
ISL-RPD	Current switch low	SSAC	ECS41BC	adjustable 2 to 20 Amps	12VDC	on D2 system Rough Pump
ISL-FPH	Current switch low	SSAC	ECS41BC	adjustable 2 to 20 Amps	12VDC	on H2 system Fore Pump
ISL-RPH	Current switch low	SSAC	ECS41BC	adjustable 2 to 20 Amps	12VDC	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	Allen-Bradley	100 Ω Carbon Resistor	100 to 300 Ω	2 to 6 Volts	1/8 Watt
TE-D2FLDWN	Deuterium flask bottom	Allen-Bradley	100 Ω Carbon Resistor	100 to 300 Ω	2 to 6 Volts	1/8 Watt
TE-R2CPOT	Refrigerator 2 condenser	Allen-Bradley	100 Ω Carbon Resistor	100 to 300 Ω	2 to 6 Volts	1/8 Watt
TE-R2D2RET	Deuterium flask inlet	Allen-Bradley	100 Ω Carbon Resistor	100 to 300 Ω	2 to 6 Volts	1/8 Watt
TE-R2STG1	Refrigerator 2, Stage 1	Minco	100 Ω Platinum Resistor	0 to 100 Ω		
TE-R2STG2	Refrigerator 2, Stage 2	Allen-Bradley	100 Ω Carbon Resistor	100 to 300 Ω	2 to 6 Volts	1/8 Watt
TE-D2SVEXH	D2 AGCO safety valve exhaust	Minco	S651PDX24A	100 Ω Platinum Resistor		RTD Thermal Ribbon
TE-DPD	D2 system Diffusion pump temperature	Minco	S201PD	100 Ω Platinum Resistor		
TE-H2FLUP	Hydrogen flask top	Allen-Bradley	100 Ω Carbon Resistor	100 to 300 Ω	2 to 6 Volts	1/8 Watt
TE-H2FLDWN	Hydrogen flask bottom	Allen-Bradley	100 Ω Carbon Resistor	100 to 300 Ω	2 to 6 Volts	1/8 Watt
TE-R1CPOT	Refrigerator 1 condenser	Allen-Bradley	100 Ω Carbon Resistor	100 to 300 Ω	2 to 6 Volts	1/8 Watt
TE-R1H2RET	Hydrogen flask inlet	Allen-Bradley	100 Ω Carbon Resistor	100 to 300 Ω	2 to 6 Volts	1/8 Watt
TE-R1STG1	Refrigerator 1, Stage 1	Minco	100 Ω Platinum Resistor	0 to 100 Ω		

B

E-866 VALVE AND INSTRUMENTATION LIST							
DESIGNATION	FUNCTION	MANUFACTURER	MODEL	RANGE/MAX WORKING PRESS.	SIZE/OUTPUT	NOTES	
TE-R1STG2	Refrigerator 1, Stage 2	Allen-Bradley	100 Ω Carbon Resistor	100 to 300 Ω	2 to 6 Volts	1/8 Watt	
TE-H2SVEXH	H2 AGCO safety valve exhaust	Minco	S651PDX24A	100 Ω Platinum Resistor		RTD Thermal Ribbon	
TE-DPH	H2 system Diffusion pump temperature	Minco	S201PD	100 Ω Platinum Resistor			
TEMPERATURE INDICATORS							
TI-101-DP	TE-DPD readout device	FIXDMACS		neg. 200°C to 850°C		0.25mA excitation current	
TI-101-D	TE-D2FLUP readout device	FIXDMACS		15K to 300K		0.25mA excitation current	
TI-102-D	TE-D2FLDWN readout device	FIXDMACS		15K to 300K		0.25mA excitation current	
TI-103-D	TE-R2CPOT readout device	FIXDMACS		15K to 300K		0.25mA excitation current	
TI-104-D	TE-R2D2RET readout device	FIXDMACS		15K to 300K		0.25mA excitation current	
TI-105-D	TE-D2SVEXH readout device	FIXDMACS		neg. 200°C to 850°C		0.25mA excitation current	
TI-110-D	TT-R2VPT readout device	FIXDMACS		14K to 28K		H2 VPT	
TI-111-D	TT-R2VPT pressure gauge	US Gauge		0 to 100 psia		H2 VPT	
TI-101-He	TE-R2STG1 readout device	FIXDMACS		neg. 200°C to 850°C		0.25mA excitation current	
TI-102-He	TE-R2STG2 readout device	FIXDMACS		15K to 300K		0.25mA excitation current	
TI-01-DP	TE-DPH readout device	FIXDMACS		neg. 200°C to 850°C		0.25mA excitation current	
TI-01-H	TE-H2FLUP readout device	FIXDMACS		15K to 300K		0.25mA excitation current	
TI-02-H	TE-H2FLDWN readout device	FIXDMACS		15K to 300K		0.25mA excitation current	
TI-03-H	TE-R1CPOT readout device	FIXDMACS		15K to 300K		0.25mA excitation current	
TI-04-H	TE-R1H2RET readout device	FIXDMACS		15K to 300K		0.25mA excitation current	
TI-05-H	TE-H2SVEXH readout device	FIXDMACS		neg. 200°C to 850°C		0.25mA excitation current	
TI-10-H	TT-R1VPT readout device	FIXDMACS		14K to 28K		H2 VPT	
TI-11-H	TT-R1VPT pressure gauge	US Gauge		0 to 100 psia		H2 VPT	
TI-01-He	TE-R1STG1 readout device	FIXDMACS		neg. 200°C to 850°C		0.25mA excitation current	
TI-02-He	TE-R1STG2 readout device	FIXDMACS		15K to 300K		0.25mA excitation current	
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	

B

TITLE

E866 Target Control Program

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DATE: 08-13-96
VERSION:

Date ______________

TARGET INSTALLATION LOG

E-866 - Liquid Hydrogen Target System

	By	Date	
1.	______	______	Target placed 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.	______	______	Helium, 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 larger.
18.	______	______	Plug pump cart into 220 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.	________	________	Helium cylinder installed with RV-01-He for supply to RV-02-He.
4.	________	________	Helium cylinder installed with RV-03-He to purge PV-H2VV stem sleeve.
5.	________	________	Hydrogen cylinder installed with RV-01-H for liquid hydrogen target purge and fill.

LH_2 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.

Note: Steps 10 and 11 should be performed in step 17 of Target Starting Procedure during initial startup of system.

10.	________	________	Open Hydrogen 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.
11.	________	________	Set RV-02-H to 3 psig (RV-01-H may then be set to 10 psig). Note pressure ________
12.	________	________	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.
13.	________	________	Start Air Compressor and open MV-05-N. Set pressure to 60 psig (RV-02-N). Note pressure ________
14.	________	________	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.
15.	________	________	Open MV-13-He and set RV-04-He to 3 psig. Note pressure ________

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16. ________ ________ Open Helium cylinder used for controlling RV-02-He set pressure. Set pressure to 90 psig.
Note pressures ________ ________
Close cylinder valve. Test for leakage as above. Reopen cylinder valve if no leaks are present. Note that this set pressure will vary depending on operating conditions. Normal operating pressure will be about 200 to 220 psig.

17. ________ ________ Install covers over cylinder regulators where necessary.

18. ________ ________ Hydrogen detector in place.

19. ________ ________ Housekeeping in area around target is good.

20. ________ ________ 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 fore 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 PE-FPVACH in 2 minutes.

7. ________ Open fore line valve 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 supply 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. ________ Start the hydrogen system compressor flow and refrigerator: To begin the compressor flow, close MV-04-He, MV-12-He and MV-10-He. Open MV-01-He, MV-05-He, MV-00-He, MV-06-He, MV-11-He, MV-08-He and MV-09-He. Using RV-01-He, set RV-02-He to allow 90 psig to the refrigerator (watch PT-COMPDISH) with EV-02-He open to the refrigerator (During a restart, EV-02-He needs to be opened to SV-02-He in order to vent the supply pressure to the refrigerator. Set RV-02-He to 90 psig and then reopen EV-02-He to the refrigerator). Now start the refrigerator. Gradually bring the supply pressure from 90 psig to 220 psig using RV-02-He. Note time and pressure in the logbook.

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-H2FLUP and TE-H2FLDWN.

26. ________ Continue to fill the target for 15 minutes after TE-H2FLUP sees liquid.

27. ________ Close the hydrogen supply valve, PV-H2SUP, and the hydrogen fill valve, PV-H2FILL. Close the hydrogen cylinder supply valve.

28. ________ Turn on temperature controller and gradually adjust until target pressure stabilizes at 14.7 psia.

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

30. ________ Pump out the cold trap by opening EP-H2PURGE and PV-H2FILL. Evacuate cold trap until warm.

31. ________ 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 MV-06-He, MV-08-He (and MV-00-He if desired). Vent helium from the refrigerator helium circuit through MV-12-He.

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

7. ________ Confirm that the hydrogen cylinder supply valve is closed.

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

NOTE: BACKFILLING OF CIRCUIT MUST OCCUR IN THIS ORDER TO AVOID CRUSHING TARGET FLASK.

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

10. ________ Close fore line valve EP-FORVLVH; turn off power to fore pump.

11. ________ Turn off power to roughing pump.

12. ________ Uncap and open roughing line vent valve at pump cart, MV-01-V, to vent the vacuum space to atmosphere.

13. ________ Turn off electric circuits at the pump cart.

14. ________ Close all gas cylinder valves connected to the target system.

15. ________ 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-HIVACH. 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.

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Date _______________

TARGET INSTALLATION LOG

E-866 - Liquid Deuterium Target System

	By	Date	
1.	_______	_______	Target placed 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.	_______	_______	Helium, 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 deuterium 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 larger.
18.	_______	_______	Plug pump cart into 220 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 Deuterium line with Helium gas. Reconnect Deuterium 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.	________	________	Helium cylinder installed with RV-101-He for supply to RV-102-He.
4.	________	________	Helium cylinder installed with RV-03-He to purge PV-D2VV stem sleeve.
5.	________	________	Deuterium cylinder installed with RV-101-D for liquid deuterium target purge and fill.

LD_2 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.

Note: Steps 10 and 11 should be performed in step 17 of Target Starting Procedure during initial startup of system.

10. ________ ________ 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.

11. ________ ________ Set RV-102-D to 3 psig (RV-101-D may then be set to 10 psig).
Note pressure ________

12. ________ ________ 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.

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

14. ________ ________ 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.

15. ________ ________ Open MV-13-He and set RV-04-He to 3 psig.
Note pressure ________

16. ________ ________ Open Helium cylinder used for controlling RV-102-He set pressure. Set pressure to 90 psig.
Note pressures ________ ________
Close cylinder valve. Test for leakage as above. Reopen cylinder valve if no leaks are present. Note that this set pressure will vary depending on operating conditions. Normal operating pressure will be about 200 to 220 psig.

17. ________ ________ Install covers over cylinder regulators where necessary.

18. ________ ________ Flammable Gas Detector in place.

19. ________ ________ Housekeeping in area around target is good.

20. ________ ________ All warning signs in area prominently displayed and unobstructed.

TARGET STARTING PROCEDURE

1. ________ Close hand valve, MV-101-V, at roughing pump port vent and cap; Close hand valve, MV-102-V, at fore pump port vent and cap.

2. ________ Close MV-103-V, EV-101-He and MV-102-He. MV-102-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 PE-FPVACD in 2 minutes.

7. ________ Open fore line valve 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-RUFVLVD 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 Deuterium. 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 deuterium supply line and cold trap are pumped out to 30 microns, close purge valve, EP-D2PURGE. Open deuterium supply valve EP-D2SUP (deuterium fill valve, EP-D2FILL, is already open). Be sure the deuterium pressure is set to 3 psig with the pressure regulator RV-102-D.

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

21. ________ Close deuterium 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: To begin the compressor flow, close MV-104-He, MV-112-He and MV-10-He. Open MV-101-He, MV-105-He, MV-00-He, MV-106-He, MV-111-He, MV-108-He and MV-09-He. Using RV-101-He, set RV-102-He to allow 90 psig to the refrigerator (watch PT-COMPDISD) with EV-102-He open to the refrigerator (During a restart, EV-102-He needs to be opened to SV-102-He in order to vent the supply pressure to the refrigerator. Set RV-102-He to 90 psig and then reopen EV-102-He to the refrigerator). Now start the refrigerator. Gradually bring the supply pressure from 90 psig to 220 psig using RV-102-He. Note time and pressure in the logbook.

24. ________ Refrigerators have reached 20 K when the refrigerator vapor pressure, TT-R2VPT, 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-D2SUP, and the deuterium fill valve, PV-D2FILL. Close the deuterium cylinder supply valve.

28. ________ Turn on temperature controller and gradually adjust 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 26 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 MV-106-He, MV-108-He (and MV-00-He if desired). Vent helium from the refrigerator helium circuit through MV-112-He.

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

7. _______ Confirm that the deuterium cylinder supply valve is closed.

8. _______ 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 TARGET FLASK.

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

10. _______ Close fore line valve EP-FORVLVD; turn off power to fore pump.

11. _______ Turn off power to roughing pump.

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

13. _______ Turn off electric circuits at the pump cart.

14. _______ Close all gas cylinder valves connected to the target system.

15. _______ 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 deuterium. 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.

~~E831~~ 866 EMERGENCY PROCEDURES E

E

D. Allspach, J. Peifer

July 22, 1996

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 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 building through the ventilation exhaust ducting. No operator action needs to be taken to ensure the safety of the target. No one 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 estimated by looking at the temperatures of the upper and lower resistors in each target; TE-H2FLUP, TE-H2FLDWN, TE-D2FLUP and TE-D2FLDWN.

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. Perform required maintenance to air compressor system.
3. Change nitrogen cylinder if necessary. Re-establish vacuum 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. For E866, each liquid target has a single refrigerator cooling it. There are two liquid targets in the tent. Since there is no refrigerator redundancy, a loss of refrigeration may cause the target to warm up and vent through the vent valve (or relief valve) in the tent.
3. 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.

E. LOSS OF ODH FAN IN THE ME6 BEAMHALL

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

1. If the ODH 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.

E866 EMERGENCY PROCEDURES

D. Allspach, J. Peifer
July 22, 1996

A. LOSS OF AC POWER

Indications: -All equipment shuts down
-Controls continue working with Uninterruptible Power System

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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 building through the ventilation exhaust ducting. No operator action needs to be taken to ensure the safety of the target. No one 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 estimated by looking at the temperatures of the upper and lower resistors in each target; TE-H2FLUP, TE-H2FLDWN, TE-D2FLUP and TE-D2FLDWN.

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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.

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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. Perform required maintenance to air compressor system.
3. Change nitrogen cylinder if necessary. Re-establish vacuum 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. For E866, each liquid target has a single refrigerator cooling it. There are two liquid targets in the tent. Since there is no refrigerator redundancy, a loss of refrigeration may cause the target to warm up and vent through the vent valve (or relief valve) in the tent.
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E. LOSS OF ODH FAN IN THE ME6 BEAMHALL

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

1. If the ODH 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.

E-866 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	SV-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 pressure 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-01-He	Open	Redundant equipment, MV-02-He is kept closed	Safe	Normally not used, power supply is disconnected
EV-01-He	Closed	Normal operating position	Safe	
EV-02-He	Open	Normal operating position	Safe	Cryo-cooler receives He gas at RV-02-He setpoint
EV-02-He	Closed	Refrigerator would not get He for cooling	Safe	Position used to limit He supply pressure to 90 psig during startup of cooler
EV-101-He	Open	Redundant equipment, MV-102-He is kept closed	Safe	Normally not used, power supply is disconnected
EV-101-He	Closed	Normal operating position	Safe	
EV-102-He	Open	Normal operating position	Safe	Cryo-cooler receives He gas at RV-102-He setpoint
EV-102-He	Closed	Refrigerator would not get He for cooling	Safe	Position used to limit He supply pressure to 90 psig during startup of cooler
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; during 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; during 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 operation 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 H2 during fill	Safe	Normal during fill; during 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 H2 during fill	Safe	Normal during fill; during 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 operation 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

F

E-866 FAILURE MODE AND EFFECT ANALYSIS

DESIGNATION	FAILURE OR ERROR CODE	HAZARD/EFFECT	HAZARD CLASS	REMARKS/ RECOMMENDATIONS
EFV-01-H	Open	Normal during fill	Safe	
EFV-01-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 diff. pump, diff. 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	Diff. 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-RUFVLVH	Open	Rough pump evacuates target vacuum jacket	Safe	Normal during vacuum jacket pump down
EP-RUFVLVH	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 diff. pump, diff. 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	Diff. Pump can not pump on target vacuum jacket	Safe	High vacuum won't be achieved
FILTERS				
F-01-He	Plugged	Helium cannot be supplied to cryo-coolers	Safe	No refrigeration to targets, liquid will evaporate and vent
F-01-N	Plugged	Air is not supplied to pneumatic valves from the air compressor	Safe	Nitrogen gas from back-up 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 cool down 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	

E-866 FAILURE MODE AND EFFECT ANALYSIS

DESIGNATION	FAILURE OR ERROR CODE	HAZARD/EFFECT	HAZARD CLASS	REMARKS/ RECOMMENDATIONS
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 overpressure
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 H2 flow into refrigerator or foul the condenser plate, increasing cool down 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 would 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-00-He	Open	Normal operating position	Safe	Helium is supplied to cryo-coolers
MV-00-He	Closed	Pressurized helium is not supplied to cryo-coolers	Safe	H2/D2 cannot be liquefied
MV-01-He	Open	Normal operating position	Safe	
MV-01-He	Closed	RV-02-He would close, refrigerator would not get He for cooling	Safe	Operational problem, SV-03-H protects target from overpressure
MV-02-He	Open	Redundant equipment, EV-01-He and MV-03-V are closed	Safe	Normally not used
MV-02-He	Closed	Normal operating position	Safe	
MV-04-He	Open	RV-02-He would close, refrigerator would not get He for cooling	Safe	Operational problem, SV-03-H protects target from overpressure
MV-04-He	Closed	Normal operating position	Safe	
MV-05-He	Open	Normal operating position	Safe	
MV-05-He	Closed	RV-02-He would close, refrigerator would not get He for cooling	Safe	Operational problem, SV-03-H protects target from overpressure

E-866 FAILURE MODE AND EFFECT ANALYSIS

DESIGNATION	FAILURE OR ERROR CODE	HAZARD/EFFECT	HAZARD CLASS	REMARKS/ RECOMMENDATIONS
MV-06-He	Open	Normal operating position	Safe	
MV-06-He	Closed	Refrigerator would not get He for cooling	Safe	Operational problem, SV-03-H protects target from overpressure
MV-08-He	Open	Normal operating position	Safe	
MV-08-He	Closed	Helium would not exit to suction header, refrigerator would not cool	Safe	Operational problem, SV-03-H protects target from overpressure
MV-09-He	Open	Normal operating position	Safe	
MV-09-He	Closed	PT-COMPSUC would measure incorrect pressure	Safe	
MV-10-He	Open	Helium would vent instead of returning to suction header	Safe	Close MV-09-He
MV-10-He	Closed	Normal operating position	Safe	
MV-11-He	Open	Normal operating position	Safe	
MV-11-He	Closed	PT-COMPDISH would measure incorrect pressure	Safe	
MV-12-He	Open	He would vent, refrigerator would not get He for cooling	Safe	Operational problem, SV-03-H protects target from overpressure
MV-12-He	Closed	Normal operating position	Safe	
MV-13-He	Open	Normal operating position	Safe	
MV-13-He	Closed	H2/D2 Vent Valves would close, tgt pressures increase to SV-03-H and SV-103-D set points	Safe	
MV-101-He	Open	Normal operating position	Safe	
MV-101-He	Closed	RV-102-He would close, refrigerator would not get He for cooling	Safe	Operational problem, SV-103-D protects target from overpressure
MV-102-He	Open	Redundant equipment, EV-101-He and MV-103-V are closed	Safe	Normally not used
MV-102-He	Closed	Normal operating position	Safe	
MV-104-He	Open	RV-102-He would close, refrigerator would not get He for cooling	Safe	Operational problem, SV-103-D protects target from overpressure
MV-104-He	Closed	Normal operating position	Safe	
MV-105-He	Open	Normal operating position	Safe	
MV-105-He	Closed	RV-102-He would close, refrigerator would not get He for cooling	Safe	Operational problem, SV-103-D protects target from overpressure
MV-106-He	Open	Normal operating position	Safe	
MV-106-He	Closed	Refrigerator would not get He for cooling	Safe	Operational problem, SV-103-D protects target from overpressure
MV-108-He	Open	Normal operating position	Safe	
MV-108-He	Closed	Helium would not exit to suction header, refrigerator would not cool	Safe	Operational problem, SV-103-D protects target from overpressure
MV-111-He	Open	Normal operating position	Safe	
MV-111-He	Closed	PT-COMPDISD would measure incorrect pressure	Safe	
MV-112-He	Open	He would vent, refrigerator would not get He for cooling	Safe	Operational problem, SV-103-D protects target from overpressure
MV-112-He	Closed	Normal operating position	Safe	
MV-01-N	Open	Normal operating position	Safe	
MV-01-N	Closed	Back-up 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

E-866 FAILURE MODE AND EFFECT ANALYSIS

DESIGNATION	FAILURE OR ERROR CODE	HAZARD/EFFECT	HAZARD CLASS	REMARKS/ RECOMMENDATIONS
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 and 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	Vacuum would be lost, D2 will vent
MV-101-V	Closed	Normal operating position	Safe	Normally not used
MV-102-V	Open	If cap is removed, air would enter vacuum jacket and enter between fore and 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 set point	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 and 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-01-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 set point	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	

E-866 FAILURE MODE AND EFFECT ANALYSIS

DESIGNATION	FAILURE OR ERROR CODE	HAZARD/EFFECT	HAZARD CLASS	REMARKS/ RECOMMENDATIONS
RV-02-H	Open	Normal operating position	Safe	
RV-02-H	Closed	Target would not get H2 for fill	Safe	
RV-01-He	Open	Normal operating position	Safe	
RV-01-He	Closed	RV-02-He would close, refrigerator would not get He for cooling	Safe	Operational problem, SV-03-H protects target from overpressure
RV-02-He	Open	Normal operating position	Safe	Provides cryo-cooler with He gas
RV-02-He	Closed	Refrigerator would not get He for cooling	Safe	Operational problem, SV-03-H protects target from overpressure
RV-03-He	Open	Normal operating position	Safe	
RV-03-He	Closed	H2/D2 Vent Valves would close, target pressures may increase to SV-03-H and SV-103-D set pressures	Safe	
RV-04-He	Open	Normal operating position	Safe	
RV-04-He	Closed	Air may displace He in Vent Valve stems	Safe	Frozen air may cause Vent Valves to stick open or closed.
RV-101-He	Open	Normal operating position	Safe	
RV-101-He	Closed	RV-102-He would close, refrigerator would not get He for cooling	Safe	Operational problem, SV-103-D protects target from overpressure
RV-102-He	Open	Normal operating position	Safe	Provides cryo-cooler with He gas
RV-102-He	Closed	Refrigerator would not get He for cooling	Safe	Operational problem, SV-103-D protects target from overpressure
RV-01-N	Open	Normal operating position	Safe	
RV-01-N	Closed	Back-up 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	Back-up 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	Hydrogen 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-He	Open	Helium supply would vent	Safe	Pneumatic supply to RV-02-He is severely depleted
SV-01-He	Closed	Normal operating position	Safe	

F

E-866 FAILURE MODE AND EFFECT ANALYSIS

DESIGNATION	FAILURE OR ERROR CODE	HAZARD/EFFECT	HAZARD CLASS	REMARKS/ RECOMMENDATIONS
SV-02-He	Open	He supply pressure to the cryo-cooler is limited to 90 psig	Safe	This requires EV-02-He to be in its closed position where RV-02-He does not supply the cryo-cooler and the cryo-cooler He inlet line is open to SV-02-He
SV-02-He	Closed	Normal operating position	Safe	
SV-03-He	Open	He supply to H2/D2 Vent Valves would vent	Safe	Vent Valves will not operate, SV-03-H and SV-103-D protect targets
SV-03-He	Closed	Normal operating position	Safe	
SV-101-He	Open	Helium supply would vent	Safe	Pneumatic supply to RV-102-He is severely depleted
SV-101-He	Closed	Normal operating position	Safe	
SV-102-He	Open	He supply pressure to the cryo-cooler is limited to 90 psig	Safe	This requires EV-102-He to be in its closed position where RV-102-He does not supply the cryo-cooler and the cryo-cooler He inlet line is open to SV-102-He
SV-102-He	Closed	Normal operating position	Safe	
SV-01-N	Open	Pneumatic back-up 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	

F

From: RDIV::ALLSPACH 29-JUL-1996 15:22:21.28
To: ELLERMEIER,FNAL::SMART,FNAL::TOMMY
CC: PEIFER,ALLSPACH
Subj: trapped volume in the refrigerator

In response to the concern raised in relation to the refrigerator helium trapped volume:

Scenario: The helium supply and return manual isolation valves are closed, the refrigerator stops, the 3-way valves are in their normal operating position and the refirgerator starts to warm. What happens to the gas in the refrigerator?

Assume that the supply pressure to the refrigerator is 220 psig. Assume that the return pressure is 2 psig.

The pressure inside the refrgerator is at some intermediate pressure, but assume 220 psig.

The void volume in the 20K portion of the frig is about 4 in^3.
The void volume in the 80K portion of the frig is about 50 in^3.

The mass that may escape the refrigerator is calculated to be 0.017 pounds.

The refrigerator valve will lift as the helium gas inside the heat exchanger warms. It will lift at a pressure just greater than 220 psig, since it is the supply pressure that loads the valve and creates the seal required to prevent any blowby.

The supply pressure will remain at 220 psig as the frig warms, and the gas "relieved" from the frig vents into the suction pipe.

The volume of the suction pipe is about 80 liters. When you add the mass of helium that can escape from the frig to the mass already in the suction pipe at 2 psig, one finds that the suction pipe will reach about 10.5 psig. This pressure is safe for the piping and instrumentation which make up the suction line.

E866 WHAT-IF ANALYSIS

July 22, 1996

The what-if analysis for the 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 numbered 0 through 99 are part of the hydrogen system and tags 100 and greater are part of the deuterium system. The only exception are some nitrogen and helium valves which are shared by both systems (See P&I Diagrams to confirm valve/instrument functions).

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. 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.

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 15 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.

Results of failure:
a. Any hydrogen/deuterium pumped by the vacuum system will be vented into the very large Meson Detector Building.
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 Meson Detector 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 Meson Detector 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 1/4" 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 A. C. 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.

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.

7. Restoration of A.C. 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, reseated. If the pressure in the target is near 14.3 psia then the valve must be reseated and the target repurged before filling. This scenario is now much less likely since the addition of PV-H2VV / PV-D2VV.

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 pneumatic pressure is less than 20 psig EP-H2PURGE / EP-D2PURGE, EP-RUFVLVH / EPRUFVLVD, 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:

a. 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 subatmospheric.

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.

E866 ODH Analysis

July 25, 1996
D. Allspach

Meson Detector Building

Fluids to be in use with the E866 Target System include deuterium, helium, hydrogen and nitrogen. The hydrogen and deuterium cylinders are to located outdoors near the Detector Building south-east entryway. The cylinders of non-flammable gas will be located inside the Meson Detector Building. They will be positioned immediately east of the ME6 beamhall near the targets. At any given time, three helium cylinders and one nitrogen cylinder will be in use. 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, helium or hydrogen gas supply system were to leak gas indoors, the gas would escape into the very large Meson Detector 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 area east of the ME6 beamhall would reduce the oxygen concentration by less than 1%. The Building is thus ODH class 0.

ME6 Beamhall

The target cryo-coolers use helium from compressors located in the Meson Cryo Building. Helium supply and return lines for each target system approach the target tent from inside the ME6 beamhall. The cryo-coolers are located inside the hydrogen secondary containment. Other helium line components are located outside the tent but inside the ME6 beamhall. Since this is a somewhat confined area, a more detailed analysis is performed. An exhaust fan, to be running continuously, will pull air from the ceiling of the beamhall near the upstream side of the tent and exhaust into the Meson Detector Building above the ME6 beamhall. The ODH fan flowrate is 100 cfm. Fresh air is taken in through the beamhall entryway a few yards upstream of the target tent.

Referencing chapter 5064 of the ESH Manual, the following failures to the helium lines which could possibly create an ODH condition in the ME6 beamhall are considered.

(1)	Pipes < 3 inch diameter rupture:	$P_1 = 1x10^{-9}$ / Hr
(2)	Gaskets leak/rupture:	$P_2 = 3x10^{-7}$ / Hr
(3)	Valves leak/rupture:	$P_3 = 1x10^{-8}$ / Hr
(4)	Exhaust fan debilitating power outage:	$P_4 = 1x10^{-4}$ / Hr

These failures and a combination of a fan power outage with any one other failure are considered in the computation of a total fatality rate. From ESH page 5064TA-1:

$$\phi_{total} = \phi_1 + \phi_2 + \phi_3 + \phi_4 + \phi_{1/4} + \phi_{2/4} + \phi_{3/4}$$

$$\phi_{total} = P_1F_1 + P_2F_2 + P_3F_3 + P_4F_4 + P_1P_4F_{1/4} + P_2P_4F_{2/4} + P_3P_4F_{3/4}$$

where:

ϕ = the ODH fatality rate per hour
P_i = the expected rate of the i^{th} event per hour
F_i = the fatality factor for the i^{th} event

The fatality rates are calculated as follows:

1. Pipe rupture. It has been calculated that a complete severing of the helium supply line would send slightly less than 1000 scfm helium into the beamhall. A severing of the helium return line would send about 200 scfm helium into the hall. A conservative approach could assume either flow to continue indefinitely which would result in the fatality factor $F_i = 1$. The fatality rate of this event is therefore,

$$\phi_1 = P_1F_1 = \left(1\text{x}10^{-9}\right)(1.0) = 1.0\text{x}10^{-9}\ /\ \text{Hr}$$

2. Gaskets leak/rupture. Assuming a flowrate of 5 scfm helium in this case would be very conservative. The fatality factor F_2 is calculated for Case B of ESH 5064TA: Exhaust fan draws contaminated atmosphere from the confined volume with the ventilation rate greater than the spill rate (Q>R).

$$C_r(t) = 0.21\left\{1 - \frac{R}{Q}\left[1 - e^{(-Qt/V)}\right]\right\}$$

where:
C_r = oxygen concentration during release
Q = exhaust rate = 100 cfm
R = spill rate into confined volume = 5 cfm
t = time
V = confined volume

Consider the oxygen concentration after much time has past since the leak began. Then "t" goes to infinity. The oxygen concentration is calculated to be 19.95%. Given this value we realize that $F_2 = 0$. Therefore,

$$\phi_2 = P_2 F_2 = (3x10^{-7})(0) = 0 / Hr$$

3. Valve leak/rupture. A complete rupture of a valve in this system is very unlikely as the helium supply is relieved at a pressure far below the rated working pressure of all the valves in this system. Also, a pressure test of the helium circuit will prove its adequacy. Assume that a valve may leak at the same rate as for the gasket leak which results in $F_3 = 0$. The fatality rate is then,

$$\phi_3 = P_3 F_3 = (1x10^{-8})(0) = 0 / Hr$$

4. A power outage to the fan in itself cannot cause a reduced Oxygen environment, giving it a fatality rate of 0.

1. & 4. concurrently: The fatality factor in this case is $F_{1/4} = 1$. Our two occurrence rates are:

$P_1 = 1x10^{-9} / Hr$
$P_4 = 1x10^{-4} / Hr$

The fatality rate in this case is:

$$\phi_{1/4} = P_1 P_4 F_{1/4} = (1x10^{-9})(1x10^{-4})(1.0) = 1x10^{-13} / Hr$$

2. & 4. concurrently: Conservatively assume that, even though a gasket leak is small, at some point $F_{2/4} = 1$. The occurrence rate for the gasket leak/rupture is:

$P_2 = 3x10^{-7} / Hr$

The fatality rate in this case is:

$$\phi_{2/4} = P_2 P_4 F_{2/4} = (3x10^{-7})(1x10^{-4})(1.0) = 3x10^{-11} / Hr$$

3. & 4. concurrently: Again, conservatively assume that at some point $F_{3/4} = 1$. The occurrence rate is:

$P_3 = 1x10^{-8} / Hr$

Then,

$$\phi_{3/4} = P_3 P_4 F_{3/4} = (1x10^{-8})(1x10^{-4})(1.0) = 1x10^{-12} / Hr$$

It is very unlikely that more than one component such as a gasket or valve will leak at a given point in time. A single occurrence is considered for each type of probable failure. The total fatality rate for the E866 target system is thus computed as follow:

$$\phi_{total} = \phi_1 + \phi_2 + \phi_3 + \phi_4 + \phi_{1/4} + \phi_{2/4} + \phi_{3/4}$$

$$\phi_{total} = (1x10^{-9}) + (1x10^{-13}) + (3x10^{-11}) + (1x10^{-12})$$

$$\phi_{total} = 1.03x10^{-9}$$

Given the 100 cfm ventilation fan described, the ME6 beamhall in the area around the target system remains an ODH class 0 as the total fatality rate is less than 10^{-7} / Hr (see Table 5 of ESH 5064TA-9).

Inside the Tent

The *Tent Design* safety document indicates that the tent exhaust fan has a capacity of 1300 cfm. There are components on the portion of the helium circuit inside the tent which have failure rates as those outside the tent were shown to have above. The worst condition would be that discussed for a complete severing of the helium supply line which results in a flow of slightly less than 1000 cfm. The failure rate for this event is low and the tent exhaust fan has a ventilation rate which is higher than this failure rate. In the case of a line rupture, the helium supply and return lines of the failing target should be isolated before entering the tent. Any other leaks would be less than 5 cfm which is very small compared to the ventilation rate. In all cases the following rules, related to ODH concerns, will be in effect for any and all tent accesses. The following list is not intended to be a comprehensive list of requirements for tent access (see also *Tent Access Procedures*).

(1) The exhaust fan must be in the MANUAL ON mode. The control switch must be tagged out.
(2) Verify normal helium flow and suction and discharge pressures.
(3) No one may enter the tent while the flammable gas detector is in alarm.
(4) No one may enter the tent during a power outage or if the tent exhaust fan is inoperable.

Following these ODH control measures keep the tent an ODH class 0 location.

E866 Hydrogen Safety Analysis

July 11, 1996

D. Allspach

If hydrogen or deuterium were to leak outside the tent it will vent through the ODH exhaust fan into the Meson Detector 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 Meson Detector Building and mix perfectly with air, its explosive equivalent is = 1.2 lbs of TNT.

It is unlikely that any hydrogen will escape from the tent as the system is built according to the 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 exhausted 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 outside of the east wall of the ME6 beamhall near the location of the liquid targets. The hydrogen and deuterium cylinders will be located outside, near the entryway at the southeast corner of the Detector building. 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 operations crew will be able to contact one. The operations crew will have access to a copy of the E866 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 Detector 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.

PRESSURE VESSEL ENGINERING NOTE
PER CHAPTER 5031

Prepared by: Filip Rysanek
Preparation date: 20-Sept-96

1. Description and Identification
Fill in the label information below:

This vessel conforms to Fermilab ES&H Manual Chapter 5031

Vessel Title Air Compressor Receiving Tank

Vessel Number RD# 10038 — Obtain from Safety Officer

Division/Section

Vessel Drawing Number NA

Maximum Allowable Working Pressure (MAWP) 150 PSIG

Working Temperature Range -20 °F 450 °F

Contents Air

Designer/Manufacturer Campbell Hausfield

Test Pressure (if tested at Fermi) Acceptance Date: ______ — Document per Chapter 5034 of the Fermilab ES&H Manual

______ PSI, Hydraulic ______ Pneumatic ______

Accepted as conforming to standard by [signature]

of Division/Section Research Date: 9/30/96 — Actual signature required

NOTE: Any subsequent changes in contents, pressures, temperatures, valving, etc., which affect the safety of this vessel shall require another review.

Reviewed by: Harry F. Carter Date: 9/25/96

Director's signature (or designee) if the vessel is for manned areas but doesn't conform to the requirements of the chapter.

______ Date: ______

Amendment No.:	Reviewed by:	Date:

Lab Property Number(s): N/A

Lab Location Code: MDB (obtain from safety officer)

Purpose of Vessel(s): Pneumatic Air Supply

Vessel Capacity/Size: 20 Gallons Diameter: 14 inches Length: 32 inches

Normal Operating Pressure (OP) 110-125 PSIG

MAWP-OP = 25 PSIG

List the numbers of all pertinent drawings and the location of the originals.

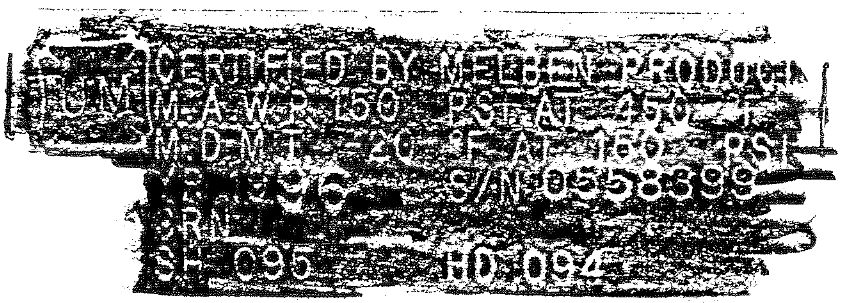
Drawing #	Location of Original
N/A	

2. Design Verification

Does the vessel(s) have a U stamp? Yes X No_____. If "Yes", fill out data below and skip page 3; if "No", fill out page 3 and skip this page.

Staple photo of U stamp plate below.

Copy "U" label details to the side



CERTIFIED BY MELBEN PRODUCTS
M.A.W.P. 150 PSI AT 450 °F
MD.MT. -20 °F AT 150 PSI
YR 1996 S/N 0558399
CRN
SH095 HD.094

Copy data here:

Certified by Melben Products

M.A.W.P 150 Psi at 450 ^{0}F

MDMT -20 ^{0}F at 150 PSI

YR 1996 S/N 0558399

CRN

SH 095 HD .094

Provide ASME design calculations in an appendix. On the sketch below, circle all applicable sections of the ASME code per Section VIII, Division I. (Only for non-coded vessels)

Summary of ASME Code

Item	Reference ASME Code Section	CALCULATION RESULT (Required thickness or stress level vs. actual thickness calculated stress level)		
			vs	
			vs	
			vs	
			vs	
			vs	

3. System Venting Verification Provide the system schematic in the Appendix.

Is it possible to isolate the relief valves by a valve from the vessel?

Yes___ No_X_

If "Yes", the system must conform to code rules. Provide an explanation on the appended schematic. (An isolatable vessel, not conforming to code rule is non-compliant under this chapter.)

Is the relief cracking pressure set at or below the M.A.W.P.?

(A "No" response violates this chapter.)

Is the pressure drop of the relief system at maximum anticipated flow such that vessel pressure never rises above the following? (UG 125)

Yes_X_ No_____ 110% of MAWP (one relief)
116% of MAWP (multiple reliefs)
121% of MAWP (unexpected heat source)

Provide test or calculational proof in the Appendix.
(Non-conforming pressure rises is non-compliant under this Chapter.)

List of reliefs and settings:

Manufacturer	Model #	Set Pressure	Flow Rate	Size
Campbell Hausfield	SP25	140 psig	47 scfm air	1/4"

Does the primary relief device follow UG-129? Yes_X_ No_____
(A "No" response is non-compliant under this chapter)

4. Operating Procedure

Is an operating procedure necessary for the safe operation of this vessel?

Yes_____ No_X_ (If "Yes", it must be appended)

5. Welding Information

Has the vessel been fabricated in a non-code shop? Yes_____ No_X_

If "Yes", append a copy of the welding shop statement of welder qualification (Procedure Qualification Record, PQR) which references the Welding Procedure Specification (WPS) used to weld this vessel.

6. <u>Exceptional, Existing, Used and Unmanned Area Vessels</u>

Is this vessel or any part thereof in the above categories?
Yes_____ No__X__

If "Yes", follow the Engineering Note requirements for documentation and append to Note.

Verification of Relief Valve Sizing

The only inlet into the vessel is an air compressor which is rated to provide 6.5 scfm air at 90 psig. This number will decrease as the pressure increases. Since the ASME stamped relief valve has a rated flow of 47 scfm at 110% of the 140 psig set pressure, it will be more than adequate to relieve the tank.

E-866 Stainless Steel Flask Stress Calculations

D. Allspach

October 17, 1995

The following calculations yield the maximum allowable working pressures of a flask constructed using 0.003 in. thick 304 Stainless Steel for the cylindrical shell and 0.002 in. thick 304 Stainless Steel for the hemispherical heads. The Maximum Allowable Stress, S_a, used in these calculations is taken as 18,800 psi. The allowable stress is calculated as 1/4 of the ultimate tensile strength of the material. Regarding the joint efficiency, please reference the *E866 Stainless Steel Flask Joint Testing* document.

Circumferential Stress on Cylinder Under Internal Pressure:
Formula taken from ASME Boiler and Pressure Vessel Code, Sec. VIII, Div. 1, UG-27(c,1).

$E = 1.0$	Joint Efficiency
$t = 0.003$ in.	Stainless Steel Thickness
P	Maximum Allowable Working Pressure
$R = 1.5$ in.	Flask Radius

$$P = S_aEt/(R + 0.6t)$$

$$P = (18{,}800)(1)(0.003)/[1.5 + (0.6)(0.003)]$$

$$P = 37.6 \text{ psid}$$

Longitudinal Stress on Cylinder Under Internal Pressure:
Formula taken from ASME Boiler and Pressure Vessel Code, Sec. VIII, Div. 1, UG-27(c,2).

$$P = 2S_aEt/(R - 0.4t)$$

$$P = (2)(18{,}800)(1)(0.003)/[1.5 - (0.4)(0.003)]$$

$$P = 75.3 \text{ psid}$$

Each of these allowable pressures exceed the suggested MAWP of 25 psid for target flasks by the Target Guidelines. Thus, 0.003 in. thick 304 S.S. is acceptable for the cylindrical portion of the flask.

Hemispherical Heads with Pressure on Concave Side:
Formula taken from ASME Boiler and Pressure Vessel Code, Sec. VIII,

Div. 1, UG-32(f).

$E = 1.0$	Joint Efficiency
$t = 0.002$ in.	Stainless Steel Thickness
P	Maximum Allowable Working Pressure
$L = 1.5$ in.	Inside Crown Radius

$$P = 2S_aEt/(L + 0.2t)$$

$$P = (2)(18{,}800)(1)(0.002)/[(1.5) + (0.2)(0.002)]$$

$$P = 50.1 \text{ psid}$$

This allowable pressure exceeds the suggested MAWP of 25 psid for target flasks by the Target Guidelines. Thus, 0.002 in. thick 304 S.S. hemispherical heads are acceptable for this flask.

Flask Maximum Allowable Working Pressure:

Calculation	Maximum Pressure
Circumferential	37.6 psid
Longitudinal	75.3 psid
Heads	50.1 psid
MAWP	**37.6 psid**

Stress due to Liquid Weight and Table Motion:

Both the liquid hydrogen and liquid deuterium targets are located on a linear motion table (see Fermilab drwg. # 9205.100-MD-58662). The table is driven by a stepping motor and has the following calculated maximum velocity and acceleration.

Stepping motor steps per revolution = 200
Controller maximum half-steps per second = 20,000
(10,000 steps/sec)/(200 steps/rev) = 50 revolutions per second
Threaded drive shaft has five threads per inch = 5 rev/inch of linear motion
Maximum table speed = (50 rev/sec)/(5 rev/inch) = 10 inches per second

Assume table is moving at top speed and power fails. Assume table stops in 0.2 seconds.

$$a = \frac{V_f - V_i}{\Delta t} = -50 \text{ in/sec}^2 = -4.167 \text{ ft/sec}^2$$

As liquid deuterium is heavier than liquid hydrogen, the following calculations assume liquid deuterium in the flask. The liquid deuterium weight inside the flask is roughly 1 pound.

$F = ma = (1 \text{ lb}/32.2 \text{ ft/sec}^2)(4.167 \text{ ft/sec}^2) = 0.13 \text{ lbf}$

For a thin cylinder, $I = \pi R^3 t = 0.0318 \text{ in}^4$
where, $R = 1.5$ inches
$t = 0.003$ inches

Also, $c = 1.5$ inches.

The bending moment can be calculated from Roark and Young, Table 3, case 1a. M = 2.16 in-lbs. The bending stress in the horizontal plane on the flask due to deceleration of the targets from top speed to zero in 0.2 seconds is the following:

$$\textit{Stress due to Table Motion} = \sigma = \frac{M}{I/c} = \frac{2.16}{\left(0.0318/1.5\right)} = 102 \text{ psi}$$

The weight distribution of the liquid deuterium over the length of the flask is 0.05 lb/in, where the weight is about 1 lb and the total flask length is 20 inches. From Roark and Young, Table 3, case 2a, the maximum bending moment can be determined. This stress on the flask is in the vertical direction.

$$M_{max} = \frac{-w_a l^2}{2} = \frac{(0.05)(16.625)^2}{2} = 6.91 \text{ in-lbs; where, } w_a = 0.05 \text{ lb/in}$$
$$l = 16.625 \text{ inches}$$

$$\textit{Stress due to Liquid (Deuterium) Weight} = \sigma = \frac{M}{I/c} = \frac{6.91}{\left(0.0318/1.5\right)} = 326 \text{ psi}$$

The combined effect of these two conditions is 342 psi directed 72.6 degrees downward from the horizontal plane. Thus, the additional stress imposed on the flask due to the conditions of table motion and liquid weight is insignificant.

INVOICE

27810

E-866

THIN METAL SALES, INC.
15047 Sierra Bonita Lane
Chino, CA 91710
(909) 393-2273

Fermilab
P.O. Box 500
ATTN: Accounting
Batavia, IL 60510

SHIPPED TO

Fermilab
Kirk Road & Wilson Street
ATTN: Receiving
Batavia, IL 60510

INVOICE DATE	DATE SHIPPED	OUR ORDER NO	YOUR ORDER NO	TERMS	F.O.B.	SALESPERSON	SHIPPED VIA
03/20/95	03/20/95	24823	S47040	Net 30	Chino	FER05	UPS

QUANTITY ORDERED	QUANTITY SHIPPED	DESCRIPTION	PRICE	AMOUNT
	5 lb	.002 x 24½" T304 Annealed Stainless		

954351

Specification: ASTM-A-240-94A, ASTM-A-666-94A,T302 AMS-5516L Size: 0.00200
Specification: T304 AMS-5513F Type: T302/304

Heat# 864141 Mill Source: ALLEGHENY

Condition	ANNEALED
Rockwell	KN 125
Ultimate Tensile (psi)	105,000
Yield Strength @ .2% offset (psi)	46,000
Percent Elongated in 2 inches	40%
Bend Test	OK
ASTM Grain Size	8
Embrittlement Test	OK

Co	C	Mn	P	S	Si	Cr	Ni	Mo
	.06	1.86	.026	.0005	.44	18.39	9.17	.40

Al	Cu	Ti	Cb&Ta	N2	O2	Fe	V	Sn
	.41			.05				

We certify this to be a true and just copy of the chemical and mechanical properties as recorded in our company files.

THIN METAL SALES, INC.

R.F. Briggs, Jr.
Quality Manager

954351

E-866

INVOICE

27810

THIN METAL SALES, INC.
15047 Sierra Bonita Lane
Chino, CA 91710
(909) 393-2273

SHIPPED TO

Bill to	Shipped to
Fermilab P.O. Box 500 ATTN: Accounting Batavia, IL 60510	Fermilab Kirk Road & Wilson Street ATTN: Receiving Batavia, IL 60510

INVOICE DATE	DATE SHIPPED	OUR ORDER NO	YOUR ORDER NO	TERMS	F.O.B	SALESPERSON	SHIPPED VIA
03/20/95	03/20/95	24823	S47040	Net 30	Chino	FER05	UPS

QUANTITY ORDERED	QUANTITY SHIPPED	DESCRIPTION	PRICE	AMOUNT
	5 lb	.002 x 24½" T304 Annealed Stainless		
	5 lb	.003 x 24½" T304 Annealed Stainless		

944179

pecification: T302 AMS-5516L
pecification: T304 AMS-5513F
Type: T302/304
Size: 0.00300

eat# 862622
Mill Source: ALLEGHENY

ondition	ANNEALED
ockwell	KN 120
ltimate Tensile (psi)	88,000
ield Strength @ .2% offset (psi)	32,000
ercent Elongated in 2 inches	45%
end Test	OK
STM Grain Size	8
mbrittlement Test	OK

Co	C	Mn	P	S	Si	Cr	Ni	Mo
	.05	1.87	.28	.001	.47	18.45	9.13	.35

Al	Cu	Ti	Cb&Ta	N2	O2	Fe	V	Sn
	.40			.04				

e certify this to be a true and just copy of the chemical and mechanical roperties as recorded in our company files.

THIN METAL SALES, INC.

R.F. Briggs, Jr.
Quality Manager

RFBriggs Jr

.79

Stainless Steel Flask Relief Sizing

D. Allspach
February 16, 1995

The stainless steel target flask is relieved by an Anderson Greenwood relief valve. The flask surface area must first be calculated in order to obtain the rate of heat flow to the vessel. From this rate of heat transfer, and the heats of vaporization of H_2 and D_2, the mass flow rate of the vaporizing H_2 or D_2 can be calculated, as well as the corresponding pressure drop in the lines. The relief valve may be sized for this flow rate.

Vessel Dimensions:

R = 1.5 in	Cylinder Radius
B = 20.0 in	Vessel Length (Total)
h = 0.75 in	Depth of ellipsoidal head
L = 18.5 in	Cylinder Length
S	Surface Area of one head
A	Vessel Surface Area
K	Radius of dished head
V	Vessel Volume
Y	Volume of one head
MR = 3.0 in	Principle Radius of Head
mR = 0.75 in	Knuckle Radius

The formulas below are taken from C.B.I. Bulletin #594.

$K = M - [(M-1)(M+1-2m)]^{1/2}$
$M = 2.0, \ m = 0.5$
$K = 0.586$

$S = \pi R^2[1+K^2(2-K)]$
$S = 10.5$ sq. in.
$A = 2\pi RL + 2S$
$A = 195 \text{ in}^2 = 1.35 \text{ ft}^2$

$Y = (2/3)\pi KR^3$
$Y = 4.14 \text{ in}^3$
$V = \pi R^2 L + 2Y$
$V = 139 \text{ in}^3 = 2.28$ liters

Required Mass Flow Rate :

$q' = 3500$ Btu/(hr-ft^2)	Heat Flux to Vessel (<u>Cryogenic Systems</u>, Barron)
$S = 1.35$ ft^2	Vessel Surface Area
Q	Heat Transfer Rate to Vessel
$\Delta H' = 434.2$ J/g	H_2 Heat of Vaporization
$\Delta H'' = 314.6$ J/g	D_2 Heat of Vaporization
m'	Mass Flow Rate

$Q = q'S$

$Q = 4725$ Btu/hr $= 1384$ W

$m' = Q/\Delta H$

$m'(H_2) = 3.2$ g/s $= 25$ lbs/hr

$m'(D_2) = 4.4$ g/s $= 35$ lbs/hr

Required Relief Valve Orifice :

Symbols and formula from Anderson Greenwood catalog, "Series 80 Relief Valves", p. 6.

$W(H_2) = 25$ lbs/hr	Mass Flow Rate (m') of H_2
$W(D_2) = 35$ lbs/hr	Mass Flow Rate (m') of D_2
$T = 530$ °R	Absolute Temperature
$M(H_2) = 2.0$	Molecular Weight of H_2
$M(D_2) = 4.0$	Molecular Weight of D_2
$Z = 1.0$	Compressibility
$K = 0.816$	Valve Discharge Coefficient
$P1 = 25.7$ psia	Pressure at Valve Inlet
$C = 356$	Gas Constant
A	Required Area of Orifice

$A = W(TZ)^{1/2}/CKP1(M)^{1/2}$

$A(H_2) = 0.055$ in^2

$A(D_2) = 0.053$ in^2

An Anderson-Greenwood type 83 relief valve with a 3/8 inch orifice diameter (0.110 in^2 orifice area) will be sufficient for each target.

Actual Flow Capacity of Relief Device: (Subsonic flow formula)

W	Mass Flow Rate
$P_1 = 25$ psia	Valve Inlet Pressure
$P_2 = 15$ psia	Valve Outlet Pressure
$M(H_2) = 2.0$	Molecular Weight of Hydrogen
$M(D_2) = 4.0$	Molecular Weight of Deuterium
$T = 530$ °R	Flow Temperature

$Z = 1$	Compressibility
$A = 0.110$ sq. in.	Valve Orifice Area
$K = 0.816$	Valve Coefficient of Discharge
$k = 1.404$	Ratio of Specific Heats
m'	Actual Mass Flow Capacity of Relief Device

$W = (735)AKP_1(M)^{1/2}[(k/(k-1))((P_2/P_1)^{(2/k)} - (P_2/P_1)^{((k+1)/k)})]^{1/2}/(TZ)^{1/2}$
$W(H_2) = 48.8$ lbs/hr $= 6.15$ g/s H_2
$W(D_2) = 68.6$ lbs/hr $= 8.64$ g/s D_2

Note: The following calculations show the pressure drops through the vent lines for the actual flow capacity of the relief device.

Pressure Drop in Line from Flask to Cond. Pot:
Assuming cold line (Saturation temperature of H_2 or D_2)
1/2 in. stainless tubing of length 3.0 ft; I.D. = 0.402 in = 1.02 cm
Neglect the change in height (since it is small) and minor losses (since there are no sharp bends). The properties below are for 25 psia and saturated vapor.

$\rho(H_2) = .00216$ g/cc	Density of H_2
$\rho(D_2) = .00375$ g/cc	Density of D_2
$\mu(H_2) = 1.25 \times 10^{-5}$ g/cm-s	Viscosity of H_2
$\mu(D_2) = 1.55 \times 10^{-5}$ g/cm-s	Viscosity of D_2
v	Velocity
f	Friction Factor
$D = 1.02$ cm	Inner Diameter of tubing
$\varepsilon = 0.0015$ mm	Roughness of Drawn Tubing
$\Delta P1$	Pressure Drop from Vessel to Cond. Pot
$L = 91.4$ cm	Length of Pipe
$m'(H_2) = 6.15$ g/s	Actual Mass Flow Capacity of Valve
$m'(D_2) = 8.64$ g/s	Actual Mass Flow Capacity of Valve

$Re = \rho v D/m = 4m'/D\pi\mu$
$Re(H_2) = 6.14 \times 10^5 >> 2300$, therefore, Turbulent.
$Re(D_2) = 6.96 \times 10^5 >> 2300$, therefore, Turbulent.
$f(H_2) = 0.0146$ (From Moody Chart, $\varepsilon/D = 0.000147$)
$f(D_2) = 0.0145$ (From Moody Chart, $\varepsilon/D = 0.000147$)

$v = 4m'/\pi\rho D^2$
$v(H_2) = 3484$ cm/s
$v(D_2) = 2820$ cm/s

$\Delta P = \rho v^2 f L/2D$
$\Delta P1(H_2) = 1715$ Pa = 0.25 psi
$\Delta P1(D_2) = 1937$ Pa = 0.28 psi

Pressure Drop in Line from Cond. Pot to Relief Valve:
1/2 inch stainless tubing, 3.5 ft long; I.D. = 1.02 cm. Find the temperature of the fluid in this length of bare tubing for P = 25 psia:

$q' = 3500$ Btu/(hr-ft^2) = 1.1 W/cm^2	Heat Flux to Uninsulated Tube
$A = \pi(0.5$ in)(42 in) = 66 in^2 = 426 cm^2	Outside Surface Area of Tube
$Q = 467$ W	Heat Transfer to Tube
$m'(H_2) = 6.15$ g/s; $\Delta h = Q/m' = 76$ J/g	Energy Increase of Hydrogen
$m'(D_2) = 8.64$ g/s; $\Delta h = Q/m' = 54$ J/g	Energy Increase of Deuterium
$h_1(H_2) = 198.5$ J/g	Saturated Vapor Enthalpy of H_2
$h_1(D_2) = 196.9$ J/g	Saturated Vapor Enthalpy of D_2
$h_2(H_2) = 198.5 + 76 = 275$ J/g	Enthalpy of H_2 at Relief Valve
$h_2(D_2) = 196.9 + 54 = 251$ J/g	Enthalpy of D_2 at Relief Valve
$T(H_2) = 29$ K	Temperature of H_2 at Relief Valve
$T(D_2) = 37$ K	Temperature of D_2 at Relief Valve

To be slightly conservative, assume that the temperature of both the H_2 and D_2 flowing through the tube is at 50 K. Neglect the change in height (since it is small) and minor losses (since there are no sharp bends). The properties below are for 25 psia and 50 K.

$\rho(H_2) = 0.8479$ E-3 g/cc	Density of H_2
$\rho(D_2) = 0.169$ E-2 g/cc	Density of D_2
$\mu(H_2) = 1.53$ E-5 g/cm-s	Viscosity of H_2
$\mu(D_2) = 2.14$ E-5 g/cm-s	Viscosity of D_2
v	Velocity
f	Friction Factor
$D = 1.02$ cm	Inner Diameter of tubing
$\varepsilon = 0.0015$ mm	Roughness of Drawn Tubing
$\Delta P2$	Pressure Drop from Vessel to Cond. Pot
$L = 107$ cm	Length of Pipe
$m'(H_2) = 6.15$ g/s	Actual Mass Flow Capacity of Valve
$m'(D_2) = 8.64$ g/s	Actual Mass Flow Capacity of Valve

$Re = \rho v D/\mu = 4m'/D\pi\mu$
$Re(H_2) = 5.02 \times 10^5 \gg 2300$, therefore, Turbulent.
$Re(D_2) = 5.04 \times 10^5 \gg 2300$, therefore, Turbulent.

$f(H_2) = 0.015$ (From Moody Chart, $\varepsilon/D = 0.000147$)
$f(D_2) = 0.015$ (From Moody Chart, $\varepsilon/D = 0.000147$)

$v = 4m'/\pi\rho D^2$
$v(H_2) = 8876$ cm/s
$v(D_2) = 6257$ cm/s

$\Delta P = \rho v^2 fL/2D$
$\Delta P2(H_2) = 5256$ Pa = 0.76 psi
$\Delta P2(D_2) = 5206$ Pa = 0.76 psi

Total Pressure Drop in Line:
$\Delta P_{total}(H_2) = \Delta P1 + \Delta P2 = 1.01$ psi
$\Delta P_{total}(D_2) = \Delta P1 + \Delta P2 = 1.04$ psi

These pressure drops are less than the 2.0 psi blowdown of the relief valve. The valve blowdown is set at 20% of the valve set pressure.

Vacuum Jacket Stresses

D. Allspach
March 6, 1995

The cylindrical portion of the vacuum vessel housing the target flask has a 5 inch outer diameter, a length of about 15.5 inches and a wall thickness of 0.125 inches. On the upstream end of the cylindrical shell is attached a heavy wall aluminum target transition block. A flange is located on the downstream end. Reference Fermilab drawing # 2727.866-MD-58635. These vessel components are made of 6061-T6 Aluminum Alloy.

Cylindrical Shell, Internal Pressure: Formulae are obtained from the ASME Boiler and Pressure Vessel Code, Sec. VIII, Div. 1, UG-27.

$t = 0.125$ in.	Actual Shell Thickness
$E = 0.6$	Weld Efficiency
$S = 10{,}500$ psi	Maximum Allowable Stress for Drawn Seamless Tube
$R = 2.375$ in.	Inside Shell Radius
$P_{min} = 15$ psid	MAWP of Vessel (Target Guidelines, II.D.1.c.(i))
P	Actual Maximum Allowable Pressure

Circumferential Stress: UG-27(c,1)

$P = SEt / (R + 0.6t)$

$P = (10{,}500)(0.6)(0.125)/[2.375 + (0.6)(0.125)]$

$P = 321$ psid

Longitudinal Stress: UG-27(c,2)

$P = 2SEt / (R - 0.4t)$

$P = (2)(10{,}500)(0.6)(0.125)/[2.375 - (0.4)(0.125)]$

$P = 677$ psid

Cylindrical Shell, External Pressure: Formulae and variables obtained from the "ASME Boiler and Pressure Vessel Code", Sec. VIII, Div. 1, UG-28 and App. 5.

$D_o = 5.0$ in.	Outer Shell Diameter
$L = 15.5$ in.	Length of Shell
$t = 0.125$	Shell Thickness
A	Factor Obtained from Fig. 5-UGO-28.0
B	Factor Obtained from Fig. 5-UNF-28.30
P	Max. Allowable External Pressure
$E = 10.0$ E6 psi	Modulus of Elasticity

Cylindrical Shell, External Pressure (cont.):

$D_o / t = 40 > 10$ therefore, use UG-28(c,1).

Step 1: $L / D_o = 3.1$; $D_o / t = 40$.
Steps 2-3: From Fig. 5-UGO-28.0, A = 0.0016
Steps 4-5: From Fig. 5-UNF-28.30, B = 7,500
Step 6:

$P = 4Bt / 3D_o$
$P = (4)(7500)(0.125)/[(3)(5.0)]$
P = 250 psid

Maximum Allowable Working Pressures:

Calculation	Internal Press.	External Press.
Shell	-------	250 psid
Shell, Circumferential	321 psid	-------
Shell, Longitudinal	677 psid	-------
MAWP, External	**------**	**250 psid**
MAWP, Internal	**321 psid**	**-------**

The Maximum Allowable External Pressure is 250 psid. This is greater than the 7.5 psid required external pressure when using the ASME allowable stress. Thus, the Fermilab ES&H Manual Chapter 5033, "Vacuum Vessel Safety", which requires a minimum collapse pressure of 30 psid (15 psid collapse pressure with a safety factor of two) is satisfied; therefore, the vessel meets Fermilab's vacuum vessel external pressure requirement.

The Maximum Allowable Internal Pressure is 321 psid. This is greater than the 15 psid minimum required by "The Design, Fabrication, Testing, Installation, and Operation of LH_2 Targets", II.D.1.c.(i); therefore, the vessel meets Fermilab's vacuum vessel internal pressure requirement.

Titanium Window Stress

D. Allspach
February 14, 1995

The E866 target beam windows are to be fabricated from a titanium alloy, Ti 15-3 (Ti-15V-3Cr-3Sn-3Al). The downstream flange and a flange on the transition block hold the thin metal windows in position. The "beam diameter" of each window is 4.25 inches (diameter to calculate window thickness = 4.5 inches).

Window Thickness: Fermilab ES&H Manual Chapter 5033, "Vacuum Vessel Safety", references the Mechanical Safety Subcommittee Guidelines for the Design of Thin Windows at Fermilab (TM-1380). Formulas in this memo are taken from Roark and Young for combined bending and diaphragm stresses for circular plates (Chapter 10 of the Fifth Edition). Our flanges have a 1/8 inch edge radius as is required by paragraph II.E.2.a. of the Target Guidelines. Thus, 1/4 inch (2 x 1/8 inch) is added to the "beam diameter" for the calculations below. Edge conditions are fixed and held.

$S_u = 121{,}100$ psi	Minimum Ultimate Strength
$S_y = 107{,}000$ psi	Minimum Yield Strength
$q = 15$ psid	Actual pressure applied to window
$E = 13.4$ E6 psi	Minimum Modulus of Elasticity
$\upsilon = 0.3$	Poisson's ratio
$a = 2.25$ inches	Window radius
t	Window thickness
y	Window deflection

Using t = 0.0055 inches in the formula below, iterations are performed to find the deflection, y, such that the calculated window thickness, $t_{calculated}$, is equal to 0.0055.

$$t_{calculated} = \sqrt[4]{\frac{qa^4(1-\upsilon^2)}{E[(5.33)(y/t)+(2.6)(y/t)^3]}}$$

It is found that for y = 0.122 inches, t = 0.0055 inches. Note that y > t / 2, thus the above formula for diaphragms is valid.

$y = 0.122 > t/2 = 0.00275$ inches

Given the thickness and deflection, the edge and center stresses are found.

Stress at Edge:

$$\sigma_{edge} = E\left(\frac{4}{1-\upsilon^2}\right)\left(\frac{y \times t}{a^2}\right) + E(0.476)\left(\frac{y}{a}\right)^2$$

$$\sigma_{edge} = 26{,}570 \text{ psi}$$

Stress at Center:

$$\sigma_{center} = E\left(\frac{2}{1-\upsilon}\right)\left(\frac{y \times t}{a^2}\right) + E(0.976)\left(\frac{y}{a}\right)^2$$

$$\sigma_{center} = 43{,}560 \text{ psi}$$

As found above, the maximum stress is at the center of the window. Given the certified ultimate tensile strength we find this material offers a safety factor of 2.8. Also, we see that the maximum stress is about 40% of the certified yield strength.

It is of interest to compare these safety factors with those the Target Guidelines require for mylar and those which are required in Vacuum Vessel Safety. Paragraph II.E.1.b.(i) of the Guidelines note that the allowable strength for a circular mylar window is to be taken as 2/3 of the yield strength. (Note that, based on tensile testing of mylar at Fermilab, an allowable strength based on 2/3 of the yield strength is approximately equivalent to a safety factor of 2.5 based on the ultimate strength). Vacuum Vessel Safety requires that the smaller of 0.5(ultimate strength) or 0.9(yield strength) be taken as the allowable strength. In consideration of these methods of determining the allowable strength, we find that, for Ti 15-3, using 0.5(ultimate strength) results in the smallest value. It is thus relevant to speak of the safety factor for the E866 windows relative to the ultimate strength of the material. Note that our safety factor of 2.8 exceeds that required for mylar in the Target Guidelines and that required for Vacuum Vessel Safety.

Paragraph II.E.3.a. of the Guidelines require that testing be completed on windows in order to verify their strength. This is viewed as a very important requirement. As a result, testing beyond the requirements of the Guidelines is planned to understand how the Ti 15-3 will perform under various conditions. See safety report insert *Titanium Window Testing*. However, the required burst pressure of 75 psid (implying a safety factor of 5 based on the ultimate strength) for materials other than mylar is an excessively stringent requirement opposing the goal of building a target system conducive to obtaining physics data at a reasonably efficient rate. We propose that this point in the Guidelines be revised (please see insert titled *Proposal for Revision to Target Guidelines Paragraph II.E.3.a. and Other Related Paragraphs*). For the case at hand, we propose, given the information in this document and others supporting it and positive testing results, that Ti 15-3 windows at 0.0055 inch thickness be approved for use in the E866 experiment.

Following is additional information which indicates positive performance of Ti 15-3 for use as E866 vacuum windows.

<u>*Failure Scenario:*</u>
In the case of a flask failure the following conditions exist:

(1) The vacuum container will increase in pressure to a maximum of about 3.5 psig.

(2) The parallel plate reliefs will open, venting hydrogen/deuterium into the tent. The tent exhaust fan will start automatically. H_2/D_2 will be vented outdoors.

(3) The initial level of H_2/D_2 in the vacuum container will be such that it will cool the titanium windows to cryogenic temperatures.

<u>*Thermal Stress:*</u>
Following is an analysis of the window stress due to thermal contraction in the case of a flask failure. From "Cryogenic Engineering" by B. A. Hands, Fig. 4.5, page 98, we see that the thermal contraction of Titanium from room temperature to 20K is 0.15%. Given the Modulus of Elasticity we can find the stress applied to the window due to this thermal contraction.

$$\sigma_{thermal} = \varepsilon E = 0.0015 in / in \times 13.4 E6 psi = 20,100 psi$$

This stress is calculated assuming the aluminum flanges holding the windows do not shrink. If uniform contraction is assumed, the actual window thermal stress will be less than that calculated above. In fact, the thermal contraction of aluminum from room temperature to 20K is slightly greater than that of titanium.

This problem was modeled by our Engineering Analysis Group. The model assumes that the edges of the windows are fixed and held (as in TM-1380), they are exposed to cryogenic temperatures and are subsequently loaded to 15 psid. The maximum combined stress on a window under these conditions was found to be about 65,000 psi. Upon examination of the Titanium alloy properties we find that both S_y and S_u increase significantly with lowered temperature. This combined stress value is about 30% of S_y at liquid hydrogen temperature.

If an actual flask failure were to occur, the differential pressure across the window will decrease (from 15 psid external pressure to 3.5 psid internal pressure) as noted above. This decrease in pressure differential will cause the stress component due to pressure to decrease. The combined stress value of 65,000 psi is thus conservative.

The elongation of Ti 15-3 is reduced by approximately 50% when it is cooled from room temperature to liquid hydrogen temperature. The elongation of the Ti 15-3 material is certified at 14.3% at room temperature. Actual elongation calculated for the E866 vacuum windows with 15 psid is less than 0.5%.

The case of a flask failure is not expected to cause the vacuum windows to fail. Thus, the analysis indicates that 0.0055 inch thick titanium alloy vacuum windows are suitable for the E866 targets.

CERTIFICATE OF TEST

2/1/95 No. 01

ARNOLD

THE ARNOLD ENGINEERING COMPANY
A subsidiary of SPS Technologies

PRECISION ROLLING MILL

300 West Street Marengo, Illinois 60152
Marengo (815) 568-2471
FAX (815) 568-2477

Sold To
Fermi Labs
P.O. BOX 500 Acct. Dept.
Batavia, IL 60510

Ship To
Receiving Dept.
Kirk & Batavia Roads

Our Order No. R3072
Customer Order No. S25580
Order Date 1/31/95
Date Shipped 2/1/95
Requested Shipping Instructions
UPS

End Use	Partial or Complete	Quantity Shipped	Description
85710	C	1 Lot (3.0 lbs.)	15-3-3 Titanium, Annealed .0055 x 10.125 x as rolled width x coil AMS 4914 with standard AECo exceptions

CHEMICAL ANALYSIS

MATERIAL AS IS

No. — Lot No.	C	Mn	P	Sn	Si	Cr	Ni	Mo	~~XXXXX~~ Y	~~XXXXX~~ Va	Al	Fe	~~XXXXX~~ Ti	N	H
T6230H	.011	.11		2.6		2.8			*.10	15.4	3.0	.12	75.94	.016	.003

*DENOTES LESS THAN

PHYSICAL PROPERTIES

	Properties in As-Ordered Condition					Heat Treatable Conditions			
Lot No:	Yield Strength	Tensile Strength	Elong %	Hardness	Grain Size	Yield Strength	Tensile Strength	Elong %	Hardness
T6230H	107,000	121,100	14.3%	15T915	ASTM#6.5				

Subscribed and sworn to before me

__________Day of________________19__________

We hereby certify that the chemical analysis and physical or mechanical tests reported above are correct as contained in the records of the company.

By George W. Nelson

GEORGE W. NELSON
APPLICATION ENGINEER

FORM ARM-632-43-006

SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL®
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard

SAE AMS 4914A

Issued 1 APR 1984
Revised 1 JUL 1992
Superseding AMS 4914

TITANIUM ALLOY COLD ROLLED SHEET AND STRIP
15V - 3Al - 3Cr - 3Sn
Solution Heat Treated

1. SCOPE:

1.1 Form:

This specification covers a titanium alloy in the form of sheet and strip.

1.2 Application:

These products have been used typically for parts to be formed in the solution heat treated condition and subsequently precipitation heat treated requiring high strength-to-weight ratio and stability up to 550 °F (288 °C) in the precipitation heat treated condition, but usage is not limited to such applications.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2242 Tolerances, Corrosion and Heat Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Sheet, Strip, and Plate
MAM 2242 Tolerances, Metric, Corrosion and Heat Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Sheet, Strip, and Plate
AMS 2249 Chemical Check Analysis Limits, Titanium and Titanium Alloys
AMS 2750 Pyrometry
AMS 2809 Identification, Titanium and Titanium Alloy Wrought Products

2.2 ASTM Publications:

Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM E 8 Tension Testing of Metallic Materials
ASTM E 8M Tension Testing of Metallic Materials (Metric)
ASTM E 112 Determining the Average Grain Size
ASTM E 120 Chemical Analysis of Titanium and Titanium Alloys
ASTM E 290 Semi-Guided Bend Test for Ductility of Metallic Materials

2.3 U.S. Government Publications:

Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

3. TECHNICAL REQUIREMENTS:

3.1 Composition:

Shall conform to the percentages by weight shown in Table 1, determined by wet chemical methods in accordance with ASTM E 120, by spectrochemical methods, or by other analytical methods acceptable to purchaser.

TABLE 1 - Composition

Element	min	max	
Vanadium	14.0	16.0	
Chromium	2.5	3.5	
Tin	2.5	3.5	
Aluminum	2.5	3.5	
Iron	--	0.25	
Oxygen	--	0.13	
Carbon	--	0.05	
Nitrogen	--	0.05	(500 ppm)
Hydrogen	--	0.015	(150 ppm)
Residual Elements, each (3.1.1)	--	0.10	
Residual Elements, total (3.1.1)	--	0.40	
Titanium	remainder		

3.1.1 Determination not required for routine acceptance.

3.1.2 (R) Check Analysis: Composition variations shall meet the requirements of AMS 2249.

3.2 Melting Practice:

3.2.1 (R) Alloy shall be multiple melted; the final melting cycle shall be under vacuum. The first melt shall be by consumable electrode, nonconsumable electrode, electron beam, or plasma arc melting practice. The subsequent melt or melts shall be made using consumable electrode practice with no alloy additions permitted in the last consumable electrode melt.

3.2.1.1 (R) The atmosphere for nonconsumable electrode melting shall be vacuum or shall be argon and/or helium at an absolute pressure not higher than 1000 mm of mercury.

3.2.1.2 (R) The electrode tip for nonconsumable electrode melting shall be water-cooled copper.

3.3 Condition:

Hot rolled with subsequent cold reduction, solution heat treated, descaled, and leveled, having a surface appearance comparable to a commercial corrosion-resistant steel No. 2D finish (See 8.2).

3.4 (R) Heat Treatment:

Product shall be solution heat treated by heating to a temperature within the range 1450 to 1500 °F (788 to 816 °C), holding at the selected temperature within ±25 °F (±14 °C) for 3 to 30 minutes, and cooling at a rate which will produce product meeting the requirements of 3.5 (See 8.3). Pyrometry shall be in accordance with AMS 2750.

3.5 Properties:

The product shall conform to the following requirements:

3.5.1 As Solution Heat Treated:

3.5.1.1 Tensile Properties: Shall be as shown in Table 2 for product 0.125 inch (3.18 mm) and under in nominal thickness, determined in accordance with ASTM E 8 or ASTM E 8M with the rate of strain maintained at 0.003 to 0.007 inch/inch/minute (0.003 to 0.007 mm/mm/minute) through the yield strength and then increased so as to produce failure in approximately one additional minute. When a dispute occurs between purchaser and vendor over the yield strength values, a referee test shall be performed on a machine having a strain rate pacer, using a rate of 0.005 inch/inch/minute (0.005 mm/mm/minute) through the yield strength and a minimum crosshead speed of 0.10 inch (2.5 mm) per minute above the yield strength.

TABLE 2 - Tensile Properties

Property	Value
Tensile Strength	102 - 137 ksi (703 - 945 MPa)
Yield Strength at 0.2 % Offset	100 - 126 ksi (689 - 869 MPa)
Elongation in 2 Inches (50.8 mm) or 4D	12%

3.5.1.1.1 (R) Tensile property requirements for product over 0.125 inch (0.32 mm) in nominal thickness shall be as agreed upon by purchaser and vendor.

3.5.1.2 Bending: Product 0.125 inch (3.18 mm) and under in nominal thickness shall withstand, without evidence of cracking when examined at 20X magnification, bending in accordance with ASTM E 290 through an angle of 105 degrees around a diameter equal to the bend factor times the nominal thickness of the product, using either V-block, U-channel, or free bend procedure with axis of bend parallel to the direction of rolling. Only one of these tests will be required in routine inspection. In case of dispute, results of bend tests using the V-block procedure shall govern.

TABLE 3 - Bending

Nominal Thickness Inch	Nominal Thickness Millimeters	Bend Factor
Up to 0.070, incl	Up to 1.78, incl	4
Over 0.070 to 0.125, incl	Over 1.78 to 3.18, incl	5

3.5.1.2.1 Bending requirements for product over 0.125 inch (3.18 mm) in nominal thickness shall be as agreed upon by purchaser and vendor.

3.5.1.3 Surface Contamination: The product shall be free of any oxygen-rich layer, such as alpha case, or other surface contamination, determined by the bend test of 3.5.1.2 or other method acceptable to purchaser.

3.5.2 After Precipitation Heat Treatment:

4.4 Reports:

The vendor of the product shall furnish with each shipment a report showing the results of tests for chemical composition of each heat and for the hydrogen content and tensile and bending properties and grain size of each lot, and stating that the product conforms to the other technical requirements. This report shall include the purchase order number, lot number, AMS 4914A, size, and quantity.

4.5 (R) Resampling and Retesting:

If any specimen used in the above tests fails to meet the specified requirements, disposition of the product may be based on the results of testing three additional specimens for each original nonconforming specimen. Failure of any retest specimen to meet the specified requirements shall be cause for rejection of the product represented. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY:

5.1 (R) Identification:

Shall be in accordance with AMS 2809.

5.2 Packaging:

5.2.1 (R) The product shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the product to ensure carrier acceptance and safe delivery.

5.2.2 For direct U.S. Military procurement, packaging shall be in accordance with MIL-STD-163, Commercial Level, unless Level A is specified in the request for procurement.

6. ACKNOWLEDGMENT:

A vendor shall mention this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS:

Product not conforming to this specification, or to modifications authorized by purchaser, will be subject to rejection.

8. NOTES:

8.1 Marginal Indicia:

The (R) symbol is used to indicate technical changes from the previous issue of this specification.

8.2 Commercial corrosion-resistant steel finishes are defined in ASTM A 480/A 480M.

8.3 For nominal thicknesses under 0.1875 inch (4.762 mm), air cooling from the solution heat treatment temperature is usually satisfactory. Fan air circulation is recommended for thicknesses 0.1875 to 0.375 inch (4.762 to 9.52 mm), inclusive. Quenching, usually in water, may be required for thicknesses over 0.375 inch (9.52 mm).

8.4 Definition of "Oil Can":

An excess of material in a localized area of a sheet which causes the sheet to buckle in that area. When the sheet is placed on a flat surface and hand pressure applied to the buckle, the buckle will spring through to the opposite surface or spring up in another area of the sheet.

8.5 Dimensions and properties in inch/pound units and the Fahrenheit temperatures are primary; dimensions and properties in SI units and the Celsius temperatures are shown as the approximate equivalents of the primary units and are presented only for information.

8.6 For direct U.S. Military procurement, purchase documents should specify not less than the following:

Title, number, and date of this specification
Form and size of product desired
Quantity of product desired
Level A packaging, if required (See 5.2.2).

8.7 Products meeting the requirements of this specification have been classified under Federal Supply Classification (FSC) 9535.

PREPARED UNDER THE JURISDICTION OF AMS COMMITTEE "G".

3.6 Quality:

The product, as received by purchaser, shall be uniform in quality and condition, sound, and free from "oil cans" (See 8.4) of depth in excess of the flatness tolerances, ripples, and foreign materials and from imperfections detrimental to usage of the product.

3.7 Tolerances:
(R)

Shall conform to all applicable requirements of AMS 2242 or MAM 2242.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:
(R)

The vendor of the product shall supply all samples for vendor's tests and shall be responsible for performing all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to the requirements of this specification.

4.2 Classification of Tests:

Tests for all technical requirements are acceptance tests and shall be performed on each heat or lot as applicable.

4.3 Sampling and Testing:
(R)

Shall be in accordance with the following; a lot shall be all product of the same nominal size from the same heat processed at the same time and in the same heat treatment batch.

4.3.1 Composition: One sample from each heat, except that for hydrogen determinations one sample from each lot obtained after thermal and chemical processing is completed.

4.3.2 Tensile Properties, Bending, Grain Size, and Surface Contamination:
(R) Not less than one sample from each lot.

4.3.2.1 Specimens for tensile tests of widths 9 inches (229 mm) and over shall be taken and tested in both the longitudinal and transverse directions; for widths under 9 inches (229 mm), specimens shall be taken in longitudinal direction.

4.3.2.2 For V-block or U-channel bend tests, specimen width shall be not less than 10 times the nominal thickness or 1 inch, (25 mm), whichever is greater. For free bend tests, minimum specimen width shall, when possible, be not less than 10 times the nominal thickness; maximum width need not be greater than 1 inch (25 mm).

E866 VACUUM JACKET VOLUME

November 13, 1995
D. Allspach

The volume of the vacuum jacket can make the target safer by allowing the liquid from the target to fill the vacuum space and vaporize without overwhelming the vent. The dimensions and volumes of the various components of the target are identified below.

Component	Dimensions	Volume
Refrigerator Vacuum	dia=13" length=22.5"	2986.5 cu.in.
Connector Box: Top	dia = 9" length=5.25"	334 cu.in.
Conn. Box: Bottom Flange	dia=7" length=0.75"	28.9 cu.in.
Refrigerator Support	dia=3.75" length=8.5"	93.9 cu.in.
Transition Block	dia=8" length=5.25"	263.9 cu.in.
Tgt. Vacuum Jacket	dia=4.75" length=15.5"	274.7 cu.in.
Two Window Flanges	dia=4.25" length=2x0.5"	14.2 cu.in.
TOTAL Volume inside the vacuum shell is:		3996.1 cubic inches
Support Ring	ID=3" OD=3.25" length=1.5"	1.84 cu.in.
Tubing	OD=50" length≈50"	3.13 cu.in.
Support Spider Ring	ID=2.69" OD=3.69" t=0.5"	2.5 cu.in.
Support Spider Tripod	rectangular solid w/ 3 legs	2.07 cu.in.
Refrigerator	Various cylindrical elements	288 cu.in.
TOTAL Volume of components inside the vacuum shell is:		297.5 cubic inches
	TOTAL VACUUM VOLUME IS:	3698.6 cubic inches =
		60.6 liters

The volume of the flask is calculated in the document *Stainless Steel Flask Relief Sizing* as 2.3 liters. Compare the total vacuum volume of the target to the flask volume:

$$V_{tgt\ vac}/V_{flask} = 26.35$$

The volumetric ratio of hydrogen saturated vapor @ one atmosphere to liquid hydrogen is about 52. The target vacuum to flask volume is smaller than the vapor to liquid ratio which is requested in the Target Guidelines. The vacuum relieving system must then see some part of the fluid from a flask failure being vented at the full equivalent vent rate for a heat load of 20 watts/sq.cm. The vent system must be capable of that vent rate. See the safety document titled *Vacuum Jacket Relief.*

Vacuum Jacket Relief

D. Allspach

December 21, 1994

The following calculations show that the parallel plate relief devices attached to the liquid target vacuum jackets are capable of accommodating the flow rate required in the case of a flask failure. The liquid spills into the vacuum container, subsequently vaporizing and venting through the vacuum container's parallel plate reliefs. Note that each vacuum container has two parallel plate relief devices installed on it.

The surface area of the vacuum container that would be in contact with the H_2 or D_2 after a flask rupture was found to be 873 cm^2.

$A_s = 873\ cm^2$	Area available for heat transfer
$\dot{Q} = 20\ W/cm^2$	Heat flux, Target Guidelines, Section II.D.3.a.
$Q = \dot{Q}A_s = 1.746\ E4\ W$	Rate of heat flow to H_2 or D_2
$\Delta h_H = 445\ J/g$	Latent heat of hydrogen
$\Delta h_D = 321\ J/g$	Latent heat of deuterium
$\dot{m} = Q/\Delta h$	Mass flow rate
$\dot{m}_H = 39.2\ g/s = 0.086\ lbm/s$	
$\dot{m}_D = 54.4\ g/s = 0.12\ lbm/s$	

Calculation of Required Area of Rupture Disc:

$k = 1.4$	Ratio of specific heats (hydrogen and deuterium)
$P_e = 14.7$ psia	Exit pressure
$P_o = 18.2$ psia	Upstream pressure
$D = 2$ in.	Parallel plate relief pipe diameter
$K = 0.62$	Coefficient (FIKE Technical Bulletin TB 8102)
$M_H = 2$	Molecular weight of hydrogen
$M_D = 4$	Molecular weight of deuterium
$t = 60^oF$	Gas temperature
$C1 = 0.0792$	Constant (FIKE TB 8102, Table 1)
a	Required rupture disc area
A	Parallel plate flow area

$P_e/P_o = 0.81 > 0.528$, thus flow is subsonic.

J

Submitted by: D. Allspach Approved by: RD/MSD Department: James R. Kilmer

LH$_2$ Target Safety Panel: Tom L. Ellerman
Verbal OK Tom Pete

PROCEDURE FOR ACCESS TO THE E866 TENT FOR INSTALLATION/REMOVAL OF COPPER FOIL

D. Allspach, J. Peifer / December 16, 1996

Only hydrogen target experts are allowed in the tent when a hydrogen or deuterium target is full in order to tune a refrigerator. For the purpose of tent entry, this is whenever either of a target's flask resistors read 80K or less. An operator or target expert must monitor the operation of the target systems looking for unexpected conditions during the execution of this procedure. In particular, the H2 detector must be checked in case of target leakage, status of the tent exhaust fan flow must be checked, the vent pressure of each target is to be monitored closely and proper helium flow and suction and discharge pressures must be verified. If the targets are running as expected, the task to tune a refrigerator may proceed with the condition that a hydrogen target expert perform the work inside the tent. Note that no one may enter the tent while the flammable gas detector is in alarm, nor during a power outage, nor if the tent exhaust fan is inoperable. The operator monitoring the systems must maintain communication with the expert inside the tent. If unexpected or unsafe conditions are observed during the tent access, the observation must be communicated to the person inside the tent. Communication will occur between an operator or another target expert who will enter the ME6 beamhall (but remain outside of the tent) in order to also meet controlled access requirements. This will occur via walkie-talkies. Note that the operator in the controls area must be outside of the control room when activating the walkie-talkie. No walkie-talkies may be taken into the tent. If trouble is communicated, the operation must be terminated and the tent must be vacated. No changes may be made at the target control rack during a tent access. The steps listed below must be adhered to.

STEPS TO BE TAKEN WHEN INSTALLING/REMOVING THE FOIL

1. Make sure the magnet current is off for the ME6AN1 Magnet.
2. Before entering the tent, move the target system all the way to the east (this is the LH$_2$ Target position).
3. LOCK OUT the motion table power supply with a padlock.
4. Turn on the tent exhaust fan and leave fan controller switch in the manual-on position. TAG OUT this fan controller switch.
5. Carry no tools into the tent. Carry no nonessential objects into the tent such as pagers, tape measures, keys, etc.
6. Climb up the ladder on the west side of the SWIC.
7. Protect each target's upstream beam windows with a suitable material.
8. Install or remove copper foil on vacuum beam-pipe flange as required. The operator monitoring the target systems will warn of unexpected or unsafe target conditions. Before completing the job make sure no loose metal objects are left in the tent.
9. Remove the beam window protection from the targets.
10. Exit the tent, securing the flaps.
11. Unlock the motion mechanism.
12. Clear the tent area before trying to move the targets.
13. Check the motion mechanism for proper operation.
14. Untag the fan controller switch and set it to the automatic position.
15. Recharge the ME6AN1 magnet as required.

Note that for purposes of this procedure, the following personnel are considered target experts: Joe Davids, Mike McKenna and Jim Peifer. The operator must be made familiar with the current operating conditions of the target systems.

D. Allspach

LH$_2$ Target Safety Panel: W.M. Smart 9/30/96

PROCEDURE FOR ACCESS TO THE E866 TENT FOR EXPANDER WORK

D. Allspach, J. Peifer / September 30, 1996

Only hydrogen target experts are allowed in the tent when a hydrogen or deuterium target is full in order to perform work on an expander. For the purpose of tent entry, this is whenever either of a target's flask resistors read 80K or less. An operator or target expert must monitor the operation of the target systems looking for unexpected conditions during the execution of this procedure. In particular, the H2 detector must be checked in case of target leakage, status of the tent exhaust fan flow must be checked, the vent pressure of each target is to be monitored closely and proper helium flow and suction and discharge pressures must be verified. If the targets are running as expected, the expander work may proceed with the condition that a hydrogen target expert perform the task. Note that no one may enter the tent while the flammable gas detector is in alarm, nor during a power outage, nor if the tent exhaust fan is inoperable. The operator monitoring the systems must maintain communication with the expert inside the tent. If unexpected or unsafe conditions are observed during the tent access, the observation must be communicated to the person(s) inside the tent. Communication from the person monitoring the system will be maintained with a second person entering the ME6 Beamhall (to also meet controlled access requirements) via walkie-talkies. Note that the operator in the controls area must be outside of the control room when activating the walkie-talkie. If two people are required inside the tent for the task, the second person must be a target expert. If only one person is required for the task, the second person may be a target expert or an operator and will remain just outside the tent maintaining communication with the expert inside the tent. If trouble is communicated, the operation must be terminated and the tent must be vacated. No changes may be made at the target control rack during a tent access. The steps listed below must be adhered to.

STEPS TO BE TAKEN WHEN WORKING ON AN EXPANDER

1. Make sure the magnet current is off for the ME6AN1 Magnet.
2. Before entering the tent, move the target system all the way to the east (this is the LH$_2$ Target position).
3. LOCK OUT the motion table power supply with a padlock.
4. Turn on the tent exhaust fan and leave fan controller switch in the manual-on position. TAG OUT this fan controller switch.
5. Only tools required for the expander work may be taken into the tent. Carry no nonessential objects into the tent such as pagers, tape measures, keys, etc.
6. Climb up the ladder on the west side of the SWIC.
7. Protect each target's upstream beam windows with a suitable material.
8. Perform required expander work. The operator monitoring the target systems will warn of unexpected or unsafe target conditions.
9. All tools must be accounted for when leaving tent. Before completing the job make sure no loose metal objects are left in the tent.
10. Remove the beam window protection from the targets.
11. Exit the tent, securing the flaps.
12. Unlock the motion mechanism.
13. Clear the tent area before trying to move the targets.
14. Check the motion mechanism for proper operation.
15. Untag the fan controller switch and set it to the automatic position.
16. Recharge the ME6AN1 magnet as required.

Note that for purposes of this procedure, the following personnel are considered target experts: Joe Davids, Mike McKenna and Jim Peifer. The operator must be made familiar with the current operating conditions of the target systems.

Submitted by: D. Allspach Approved by: RD/MSD Department: K L [illegible]

LH_2 Target Safety Panel: W. Smart 9/26/96

PROCEDURE FOR ACCESS TO THE E866 TENT FOR REPAIRING/REPLACING INSTRUMENTATION

D. Allspach, J. Peifer / September 26, 1996

Only hydrogen target experts are allowed in the tent when a hydrogen or deuterium target is full in order to repair/replace instrumentation. For the purpose of tent entry, this is whenever either of a target's flask resistors read 80K or less. An operator or target expert must monitor the operation of the target systems looking for unexpected conditions during the execution of this procedure. In particular, the H2 detector must be checked in case of target leakage, status of the tent exhaust fan flow must be checked, the vent pressure of each target is to be monitored closely and proper helium flow and suction and discharge pressures must be verified. If the targets are running as expected, the task to repair/replace instrumentation may proceed with the condition that a hydrogen target expert perform the work inside the tent. Note that no one may enter the tent while the flammable gas detector is in alarm, nor during a power outage, nor if the tent exhaust fan is inoperable. The operator monitoring the systems must maintain communication with the expert inside the tent. If unexpected or unsafe conditions are observed during the tent access, the observation must be communicated to the person inside the tent. Communication will occur between an operator or another target expert who will enter the ME6 beamhall (but remain outside of the tent) in order to also meet controlled access requirements. This will occur via walkie-talkies. Note that the operator in the controls area must be outside of the control room when activating the walkie-talkie. If trouble is communicated, the operation must be terminated and the tent must be vacated. No changes may be made at the target control rack during a tent access. The steps listed below must be adhered to.

STEPS TO BE TAKEN WHEN REPAIRING/REPLACING INSTRUMENTATION

1. Make sure the magnet current is off for the ME6AN1 Magnet.
2. Before entering the tent, move the target system all the way to the east (this is the LH_2 Target position).
3. LOCK OUT the motion table power supply with a padlock.
4. Turn on the tent exhaust fan and leave fan controller switch in the manual-on position. TAG OUT this fan controller switch.
5. Only tools required to repair/replace the instrumentation may be carried into the tent. Carry no nonessential objects into the tent such as pagers, tape measures, keys, etc.
6. Climb up the ladder on the west side of the SWIC.
7. Protect each target's upstream beam windows with a suitable material.
8. Perform required instrumentation repair/replacement. The operator monitoring the target systems will warn of unexpected or unsafe target conditions.
9. All tools must be accounted for when leaving tent. Before leaving the tent, make sure no loose metal objects are left inside the tent.
10. Remove the beam window protection from the targets.
11. Exit the tent, securing the flaps.
12. Unlock the motion mechanism.
13. Clear the tent area before trying to move the targets.
14. Check the motion mechanism for proper operation.
15. If re-entry into the tent is desired at this time, begin again at step 2 of this procedure and follow all steps except step 4. If no re-entry is desired, continue with step 16.
16. Untag the fan controller switch and set it to the automatic position.
17. Recharge the ME6AN1 magnet as required.

Note that for purposes of this procedure, the following personnel are considered target experts: Joe Davids, Mike McKenna and Jim Peifer. The operator must be made familiar with the current operating conditions of the target systems.

Submitted by: D. Allspach Approved by: RD/MSD Department: R L [illegible] 7-26-96

LH_2 Target Safety Panel: N. M. Smart 7/26/96

PROCEDURE FOR ACCESS TO THE E866 TENT FOR REFRIGERATOR TUNING

D. Allspach, J. Peifer / July 25, 1996

Only hydrogen target experts are allowed in the tent when a hydrogen or deuterium target is full in order to tune a refrigerator. For the purpose of tent entry, this is whenever either of a target's flask resistors read 80K or less. An operator or target expert must monitor the operation of the target systems looking for unexpected conditions during the execution of this procedure. In particular, the H2 detector must be checked in case of target leakage, status of the tent exhaust fan flow must be checked, the vent pressure of each target is to be monitored closely and proper helium flow and suction and discharge pressures must be verified. If the targets are running as expected, the task to tune a refrigerator may proceed with the condition that a hydrogen target expert perform the work inside the tent. Note that no one may enter the tent while the flammable gas detector is in alarm, nor during a power outage, nor if the tent exhaust fan is inoperable. The operator monitoring the systems must maintain communication with the expert inside the tent. If unexpected or unsafe conditions are observed during the tent access, the observation must be communicated to the person inside the tent. Communication will occur between an operator or another target expert who will enter the ME6 beamhall (but remain outside of the tent) in order to also meet controlled access requirements. This will occur via walkie-talkies. Note that the operator in the controls area must be outside of the control room when activating the walkie-talkie. No walkie-talkies may be taken into the tent. If trouble is communicated, the operation must be terminated and the tent must be vacated. No changes may be made at the target control rack during a tent access. The steps listed below must be adhered to.

STEPS TO BE TAKEN WHEN TUNING A REFRIGERATOR

1. Make sure the magnet current is off for the ME6AN1 Magnet.
2. Before entering the tent, move the target system all the way to the east (this is the LH_2 Target position).
3. LOCK OUT the motion table power supply with a padlock.
4. Turn on the tent exhaust fan and leave fan controller switch in the manual-on position. TAG OUT this fan controller switch.
5. Carry no tools into the tent. Carry no nonessential objects into the tent such as pagers, tape measures, keys, etc.
6. Climb up the ladder on the west side of the SWIC.
7. Protect each target's upstream beam windows with a suitable material.
8. Perform refrigerator tuning. The operator monitoring the target systems will warn of unexpected or unsafe target conditions. Before completing the job make sure no loose metal objects are left in the tent.
9. Remove the beam window protection from the targets.
10. Exit the tent, securing the flaps.
11. Unlock the motion mechanism.
12. Clear the tent area before trying to move the targets.
13. Check the motion mechanism for proper operation.
14. Untag the fan controller switch and set it to the automatic position.
15. Recharge the ME6AN1 magnet as required.

Note that for purposes of this procedure, the following personnel are considered target experts: Joe Davids, Mike McKenna and Jim Peifer. The operator must be made familiar with the current operating conditions of the target systems.

CONDITIONS FOR ACCESS TO THE ME6 BEAMHALL

D. Allspach, J. Peifer

July 25, 1996

(1) Note that the ME6 BeamHall will remain interlocked (controlled access required) whenever there is liquid in either of the hydrogen or deuterium targets. For these purposes, this is whenever either of a target's flask resistors read 80K or less.

(2) Flashing Blue light indicates hydrogen and/or deuterium is present inside the target flasks. This is a normal running condition.

(3) A whooper is located inside the beamhall. An alarm from the whooper indicates hydrogen or deuterium is detected by the flammable gas detector. The ME6 beamhall must be vacated immediately if the whooper is in alarm. The Operations Center and FIRUS are contacted automatically when an alarm occurs.

(4) **No unauthorized personnel are allowed inside the Target Tent.** Only Liquid Hydogen Target Experts are allowed to enter the tent with an approved access procedure.

(5) An ODH fan is installed to constantly ventilate the ME6 beamhall in the area of the Target Tent. The ODH fan maintains an ODH Class Zero in the beamhall. Before access is granted to the ME6 beamhall, normal operation of the ODH Fan Flow must be verified. If the ODH Fan Flow status is OK, no other special precautions are required. If the ODH Fan Flow is in alarm, access may still be granted, but ODH Class 1 rules must be followed.

J

From: RDIV::ALLSPACH 31-JUL-1996 12:25:30.04
To: GERARDI
CC: PEIFER,FNAL::RLS,ALLSPACH
Subj: ME6 beamhall

Hello Mike,

We have a liquid hydrogen/deuterium target system in the ME6 beamhall as you are aware. A secondary containment (or tent) surrounds the liquid targets. The tent includes a large window.

I have been informed that you are doing the Search and Secure Maps for this area. As in the past, I want to remind you that access to the target tent is strictly prohibited except by target experts (those named on the call-in list for this system) only with an approved procedure. Search and Secure teams are at no time allowed inside the tent and are to rely on the window provided when doing the search and secures.

Please contact me if you have any questions regarding this.

Thank you, Del

E866 Tent Design

D. Allspach, J. Brusoe

July 3, 1996

The E866 tent houses two independent liquid target systems. Materials the tent is constructed of include herculite and lexan. Steel angles support the target table and unistrut is used for the tent framing. A working platform made of aluminum is located immediately upstream of the target table. The 10 inch diameter vent ducting used for tent ventilation is made of sheet metal. A fan with a capacity of about 1300 cfm air for our ducting system is used to ventilate the tent when required. Ducting exhaust is vented outdoors on the project east side of the Meson Area Detector Building. The outlet of the ducting will be protected in order to prevent undesirable outdoor conditions from affecting the intended function of the ventilation system. Fresh air intake will be provided with ducting which is extended from the bottom of the tent to about one foot above the floor level.

Operation of the fan is controlled with our new TI405 programmable logic controller. The fan will turn on under the following conditions: (1) target insulating vacuum pressure high coupled with low target temperature or (2) detection of hydrogen/deuterium by the flammable gas detector located at the top of the tent. Notification of a flammable gas detector alarm is sent to the target controls rack, FIXDMACS and FIRUS. FIXDMACS notifies the operators that the ventilation fan is running and also verifies that there is flow in the ventilation ducting.

The following calculations find the pressure drop across the ventilation ducting that would be produced by a target flask rupture. It is assumed that the liquid from the flask evaporates inside the target vacuum volume and is then vented through the vacuum system parallel plate relief devices as cold vapor. It is also assumed that the hydrogen/deuterium does not ignite. The pressure drop across the ventilation system is first found for the case with the fan off.

<u>Pressure Drop Across Tent Ventilation Ducting</u>

The ventilation system is modeled as 60 ft. of 10 in. diameter commercial steel piping with four regular 90° elbows. The highest possible volumetric flow rate is found using the parallel plate relief rate (see 866 safety document *Vacuum Jacket Relief*) and the density of hydrogen and deuterium at room temperature.

$\rho(H_2)$	$= 0.08233$ kg/m^3	Density of Hydrogen at 70° F
$\rho(D_2)$	$= 0.1645$ kg/m^3	Density of Deuterium at 70° F
$m'(H_2)$	$= 0.0392$ kg/sec	H_2 Mass Flow Rate through Parallel Plate Relief
$m'(D_2)$	$= 0.0544$ kg/sec	D_2 Mass Flow Rate through Parallel Plate Relief
$Q(H_2)$	$= m'(H_2) / \rho(H_2)$	
$Q(H_2)$	$= 0.476$ m^3/sec = 1009 cfm	Volumetric Flow Rate of Hydrogen
$Q(D_2)$	$= m'(D_2) / \rho(D_2)$	
$Q(D_2)$	$= 0.331$ m^3/sec = 702 cfm	Volumetric Flow Rate of Deuterium
L	= 60 ft	Actual Length of Pipe
D	= 0.833 ft	Diameter of Pipe
A	= 0.545 ft^2	Area of Pipe
K	= 0.15	Resistance Coefficient for Regular 90° Elbow
L_e	$= KD/f = 7.14$ ft	Equivalent Length for one 90° Elbow
$4L_e$	= 28.6 ft	Total Equivalent Length for four 90° Elbows
V	$= Q/A = 31$ ft/sec	Fluid Velocity in Pipe (H_2 Yields Highest Velocity)
ε/D	= 0.00018	Relative Roughness of Commercial Steel Pipe
g	= 32.2 ft/sec^2	Acceleration of Gravity
Δz	= 18 ft	Elevation Change

Since the flow of air, hydrogen, or deuterium would all be turbulent flow, the numbers for air will be used in the following calculations since they provide the lowest Reynolds number, and thus the highest friction factor. This yields the highest possible pressure drop.

ρ(air) = 0.072 lb/ft^3		Density of air at STP
μ(air) = 1.2 x 10^{-5} lb/sec ft		Viscosity of air at STP

$$Re = \frac{\rho V D}{\mu} = \frac{0.072\frac{lb}{ft^3}\cdot 31\frac{ft}{sec}\cdot 0.833\,ft}{1.2x10^{-5}\frac{lb}{sec\cdot ft}} = 1.54x10^5$$

$f = 0.0175$ — Friction Factor from Moody Diagram. Note: This value of f is used in above calculation of L_e.

$$\Delta p = \left[f\left(\frac{L+4L_e}{D}\right)\cdot\frac{V^2}{2} + g\Delta z\right]\cdot\rho$$

$\Delta p = 0.64"\ H_2O$ — Pressure Drop with Fan Off

Since the tent returns to atmospheric pressure after the fan turns on, this 0.64" H_2O is the highest positive pressure the target tent will see. This value will be considered in calculating the stresses seen by the tent.

Time Required to Vent the Target and Tent:

Target venting times calculated below are based on one target failure. As each target system is independent of the other, the failure of one system will not affect the operation of the other. It is highly improbable that both systems will fail simultaneously.

m(H_2)	= 163 g	Target Hydrogen Mass Content
m(D_2)	= 398 g	Target Deuterium Mass Content
T(H_2)	= m(H_2)/m'(H_2) = 4.16 sec	Time Required to Relieve Hydrogen
T(D_2)	= m(D_2/m'(D_2) = 7.32 sec	Time Required to Relieve Deuterium
V(H_2)	= 70 ft^3	Volume (at 70° F) of Discharged H_2 from Rupture
V(D_2)	= 85 ft^3	Volume (at 70° F) of Discharged D_2 from Rupture
V(tent)	= 380 ft^3	Volume of Target Tent (72"x94" floor x 97" high)

With our fan (volumetric discharge rate of 1300 cfm operating at a static pressure of approximately 0.85" H_2O):

t	= V(tent)/1300 cfm = 17.5 sec	Time Required to Replace Target Tent Air with Fan
t	= V(H_2)/1300 cfm = 3.2 sec	Time Required to Vent Hydrogen with Fan
t	= V(D_2)/1300 cfm = 3.9 sec	Time Required to Vent Deuterium with Fan

By comparing the amount of time required to discharge the hydrogen/deuterium through a target parallel plate relief in the case of a flask rupture to the time required to vent the equivalent room temperature volume of hydrogen/deuterium with the fan, it is seen that the ventilation capacity of the fan is more than adequate. Note: The 0.85" H_2O static pressure is found by repeating the Δp calculation above given the characteristics of the fan. The tent fresh-air intake ducting has a resistance much less than 0.85" H_2O, thus the greatest negative pressure the tent will see is less than this value.

In order for the pressure drop across the ventilation system to be accurate, the pressure drop through each of the two inlet ducts must be negligible. Therefore, the pressure drop was calculated. The inlet ducts contain dry air at one atmosphere flowing at a rate of 650 SCFM. Each inlet duct is assumed to accommodate one half of the ventilation fan flow of 1300 SCFM. The calculations are shown below.

$$vf = 650\frac{ft^3}{min} \qquad \text{Cross Sectional Area} = 6" \text{ X } 18"$$

$$\text{Cross Sectional Area } (A) = 108 \text{ in}^2 \qquad \text{Wetted Perimeter}(P) = 4 \text{ ft}$$

$$\text{Length } (L) = 4 \text{ ft} \qquad \text{Density } (\rho) = 1.21\frac{kg}{m^3}$$

$$\text{Kinematic viscosity } (\nu) = 1.606 \text{ E-5 } \frac{m^2}{sec}$$

$$\text{Velocity}(v) = \frac{vf}{A} = \frac{650 \text{ ft}^3}{min} * \frac{1}{108 \text{ in}^2} * \frac{1 \text{ min}}{60 \text{ sec}} * \frac{144 \text{ in}^2}{1 \text{ ft}^2} = 14.44\frac{ft}{sec}$$

$$\text{Hydraulic Radius}(Rh) = \frac{A}{P} = \frac{108 \text{ in}^2}{48 \text{ in}} = 2.25 \text{ in}$$

$$\text{Hydraulic Diameter}(Dh) = 4Rh = 9 \text{ in} = .75 \text{ ft}$$

$$D_{eff} = .64 * Dh = .64 * .75ft = .48 \text{ ft}$$

$$R_{eff} = \frac{v * D_{eff}}{\nu} = \frac{14.44 \text{ ft}}{sec} * \frac{48 \text{ ft}}{} * \frac{1 \text{ sec}}{1.606 \text{ E-5 } m^2} * \frac{1 \text{ m}^2}{3.281^2 \text{ ft}^2} = 40{,}091.33$$

$$\varepsilon = \text{Roughness}, \quad \frac{\varepsilon}{D_{eff}} = \frac{.00015}{.48} = 3.125E-4 \rightarrow f = .023$$

$$\Delta P = \rho g h_f = \rho g\left(f * \frac{L}{Dh} * \frac{v^2}{2g}\right)$$

$$\Delta P = \frac{1.21 \text{ kg}}{m^3} * \frac{32.2 \text{ ft}}{sec^2} * .023 * \frac{4 \text{ ft}}{.75 \text{ ft}} * \frac{14.44^2 \text{ ft}^2}{sec^2} * \frac{sec^2}{2 * 32.2 \text{ ft}} = 15.47$$

$$\Delta P = 15.47\frac{kg - ft^2}{m^3 - sec^2} * \frac{1 \text{ in } H_2O - in^2}{.0362 \text{ lbf}} * \frac{1 \text{ N - sec}^2}{1 \text{ kg - m}} * \frac{1 \text{ ft}^2}{144 \text{ in}^2} * \frac{.3048^4 \text{ m}^4}{1 \text{ ft}^4}$$

$$\Delta P = .2552\frac{\text{in } H_2O - N}{lbf} * \frac{1 \text{ lbf}}{4.448 \text{ N}} = .00574 \text{ in } H_2O$$

The results show that by having a .00574 in H20 pressure drop through the inlet ducts, the previous calculations are accurate.

Power Failure Scenario:

In the case of a power failure, the targets will begin to vent into the tent. The fan will not start under this condition. As the duct opening is located near the top of the tent, virtually all of the hydrogen gas will enter the ducting. There are no ignition sources inside the tent nor in the ducting. The flammable gas detector is on battery backup power and thus continues to operate. When commercial power is restored, the fan starts and vents any trapped hydrogen. Access into the tent is not allowed while the flammable gas detector is in an alarm status.

During operations, when the target is purged, there is some hydrogen vented into the tent from the roughing pump exhaust. This is typically less than one cubic foot of gas. A "slow" leak of hydrogen from a target will eventually be seen by a low liquid level in the target flask. In either of these conditions, the flammable gas detector will indicate that hydrogen exists in the tent.

Target Table Motor Safety:

The motors used in the motion system are size 34 stepping motors (induction type) supplied by Anaheim Automation. Manufacturer specifications indicate that at full capacity the maximum motor case temperature will not exceed 100 degrees Celsius. These specifications are acceptable for a Class 1, Division 2, Group B area. The "National Electrical Code", indicates in article 501-8 paragraph (b) that "in Class 1, Division 2 locations, the installation of open or nonexplosion proof enclosed motors, such as squirrel-cage induction motors without brushes, switching mechanisms, or similar arc-producing devices shall be permitted." The paragraph further adds that "it is important to consider the temperature of the internal and external surfaces which may be exposed to the flammable atmosphere." As indicated by M. G. Zabetakis in "Safety With Cryogenic Fluids" on page 36, table IV, the autoignition temperature of hydrogen in air is 500 degrees Celsius. Having a maximum motor case temperature of 100 degrees Celsius, the motor is not a potential autoignition source for the hydrogen gas.

E866 Target Table Support Analysis Summary

D. Allspach
July 12, 1996

An analysis of the Target Table Support System has been performed by Zhijing Tang of the RD/MSD Engineering Analysis Group. See the attached document titled "E866 Table Support" and Addendum 1.

The total load requiring support is taken as 1000 pounds. This is assumed due to a total weight of the target table and target system roughly equal to 750 lbs and allowance for a person standing on the table. The analysis is performed for a quarter of the support system due to its symmetries.

The final design of the support system utilizes two steel L5x5x1/2 inch angles supporting the table as indicated in the sketch shown on the second page of the attached report. Original calculations were performed for L5x3x1/2 angle. The addendum shows that the deflection is increased by 0.001 inch due to the design change. The stresses remain insignificant.

A maximum deflection to the steel angles is reported as about 0.010 inch with maximum stresses at about 4000 psi. Maximum deflection to the aluminum target table is at 0.022 inch with maximum stress at about 2000 psi. The deflections and stresses are low and are considered very adequate as a support system for the E866 liquid hydrogen targets.

J

E866 Target Table Support

Zhijing Tang
December 8, 1994

The E866 Table support is initially designed to use aluminum I beams. Since the space between the table and ground is to be used as a pathway, increasing its clearance will be desirable. Hence steel angles are selected to support the table, and finite element model is used to verify its adequacy.

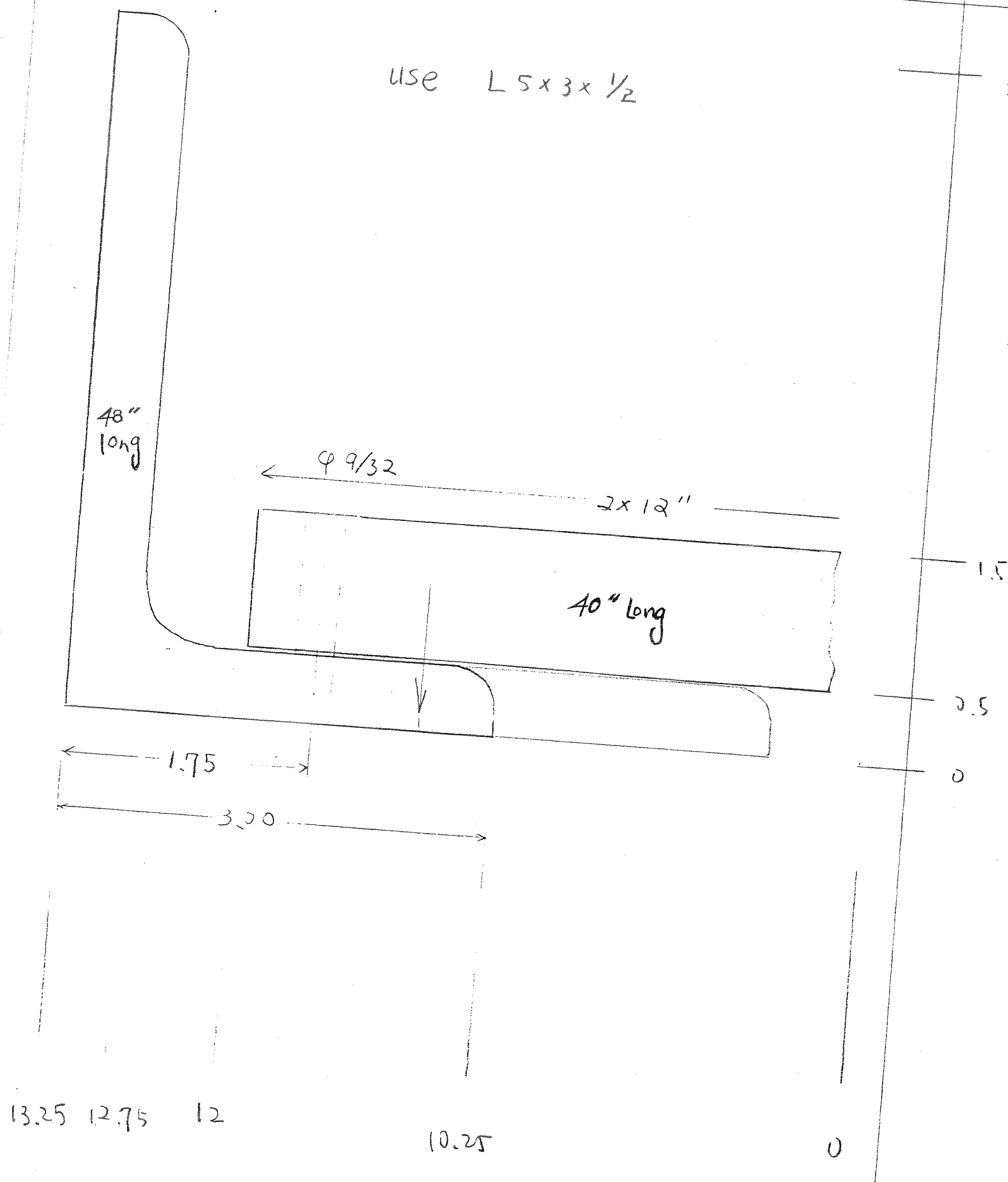
Steel angle L5×3×1/2 is connected to the aluminum table base as shown in Fig.1. Assume symmetry, only a quarter of the structure is modeled. The total load is 1000/4 = 250 lb.

Four cases are run for different load distributions. 1) All load in the center; 2) Load divided at three places along z axis; 3) Load divided among nine places. All three cases give the deflection of the steel angle of about 0.01 inch. The stress is very small, less than 4000 psi maximum.

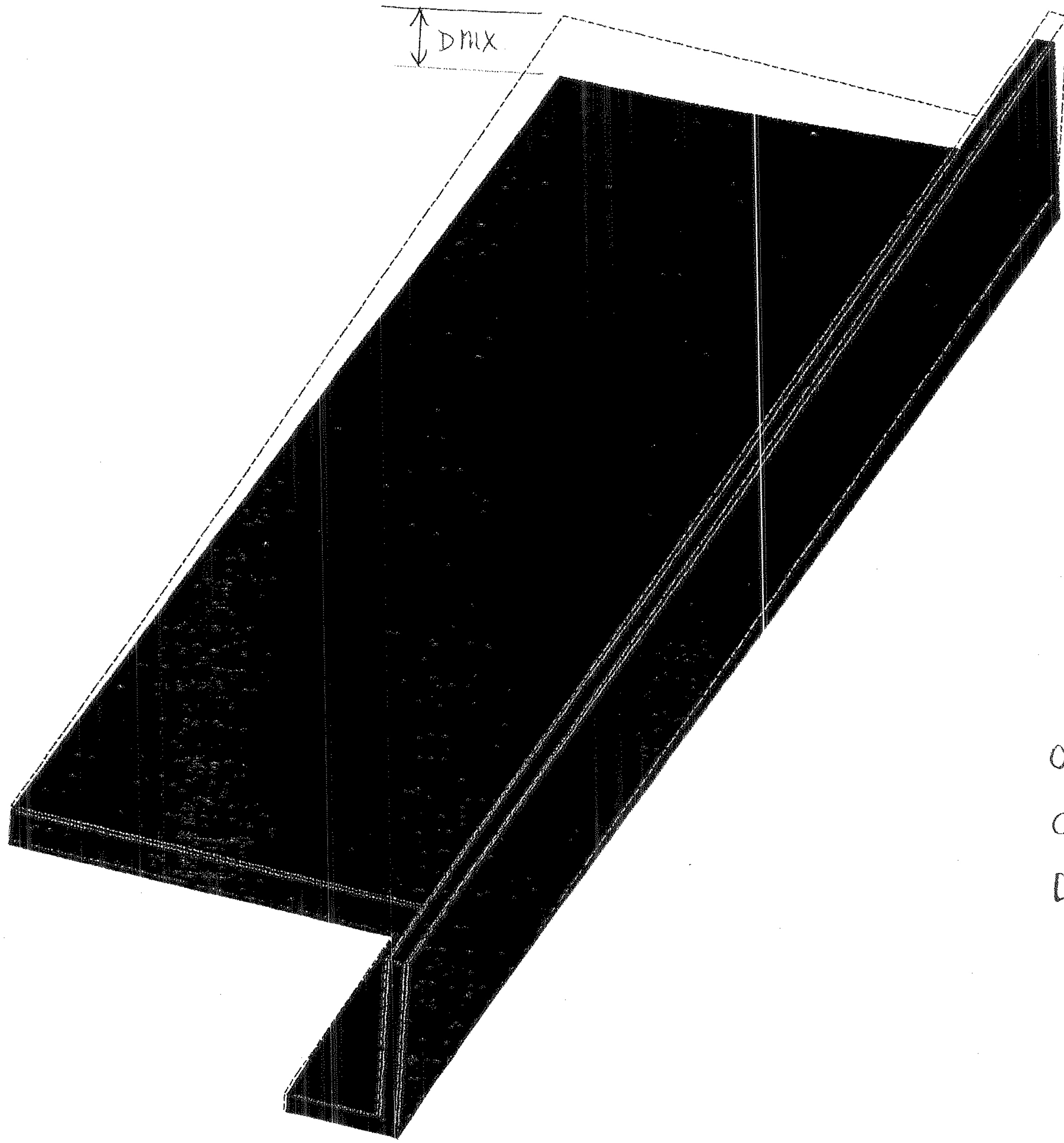
Conclusion: we can use two L5×3×1/2 steel angles to support the target table.

3.

use L 5 x 3 x 1/2



Case 1



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DEC 7 199
10:26:24
PLOT NO. 6
DISPLACEMENT
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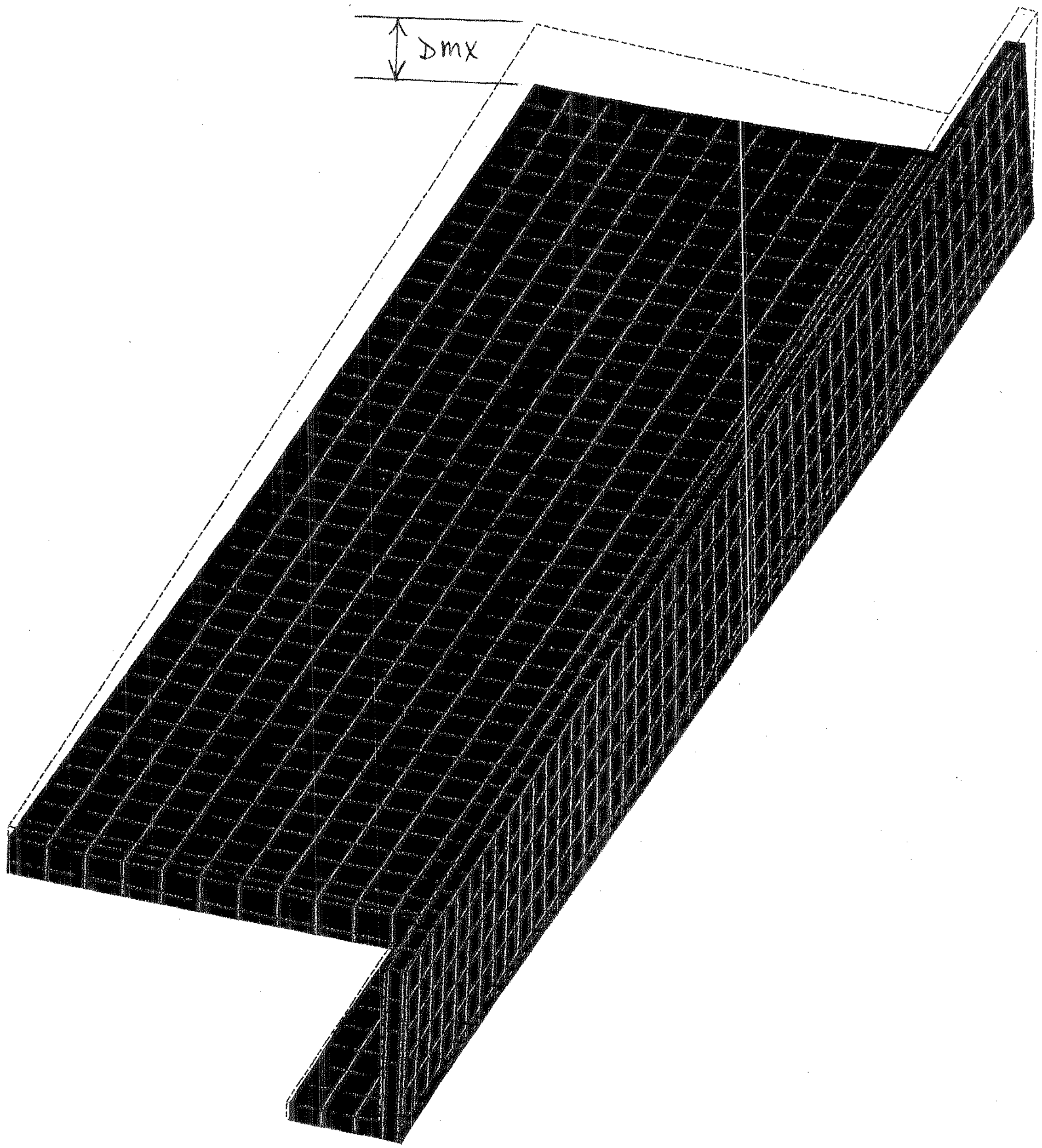
SUB =1
TIME=1
RSYS=0
DMX =0.022101 inche
SEPC=27.272

DSCA=79.326
XV =1
YV =2
ZV =3
DIST=17.532
XF =6.665
YF =1.906
ZF =24.018
CENTROID HIDDEN
EDGE

deflection under
concentrated
center load

Table support

Case 2



ANSYS 5.0
DEC 7 1994
14:05:52
PLOT NO. 2
DISPLACEMENT
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SUB =1
TIME=1
RSYS=0
DMX =0.014349 inches
SEPC=27.175

DSCA=122.37
XV =1
YV =2
ZV =3
DIST=17.559
XF =6.673
YF =1.889
ZF =24.024
CENTROID HIDDEN

deflection of the model

Table support

Case 1

ANSYS 5.0
DEC 7 1994
10:25:35
PLOT NO. 5
DISPLACEMENT
STEP=1
SUB =1
TIME=1
RSYS=0
DMX =0.022101
SEPC=22.966

DSCA=33.059
ZV =1
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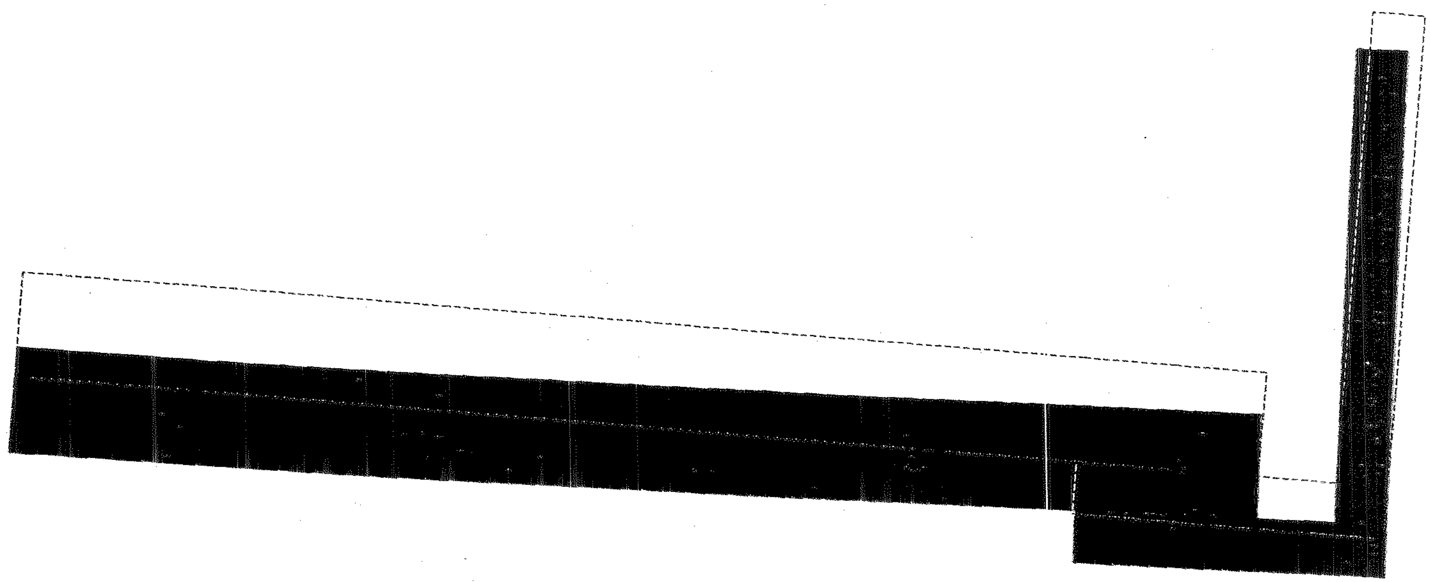
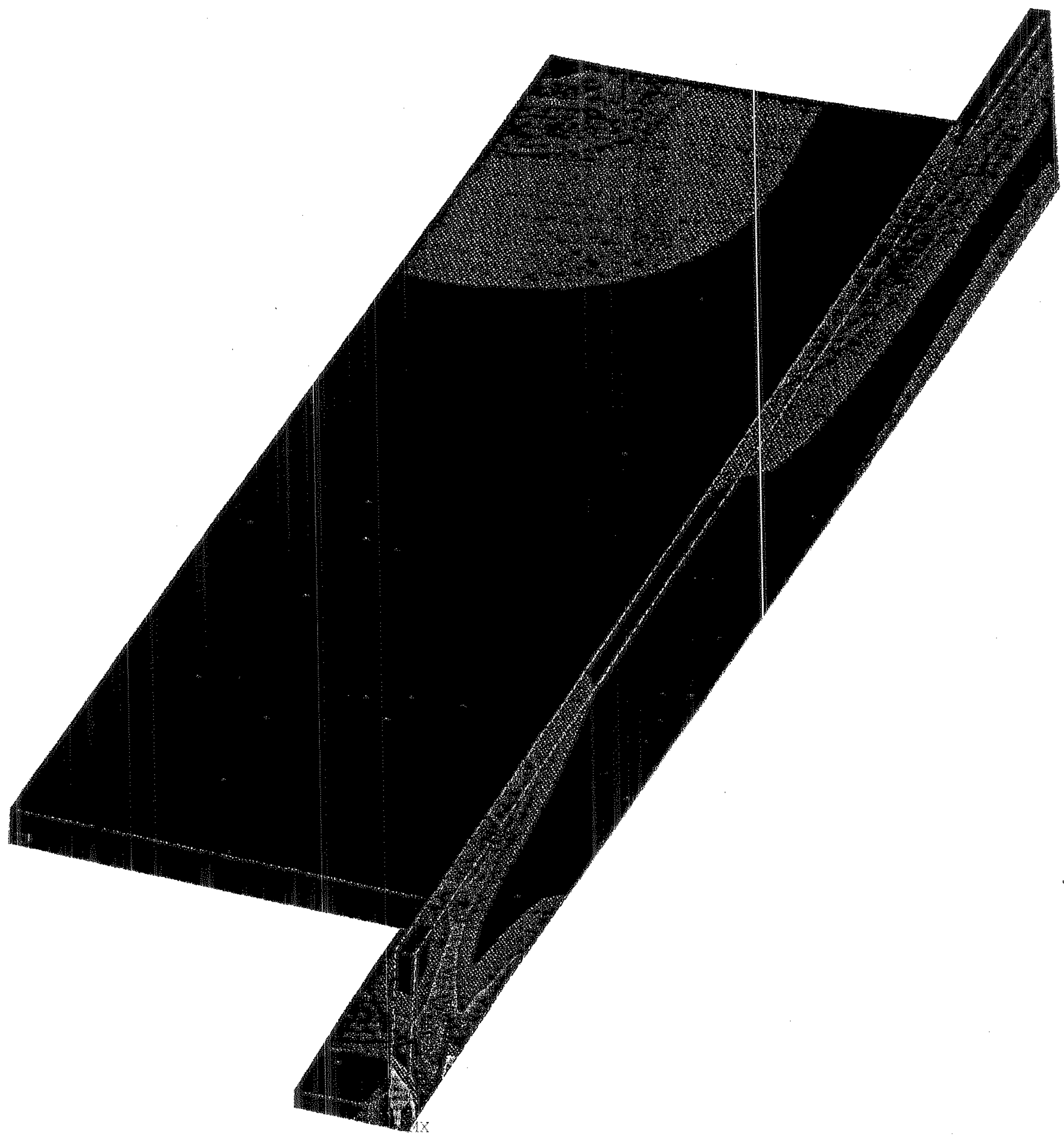
XF =6.642
YF =2.092
ZF =0.502306
CENTROID HIDDEN
EDGE



deflection under concentrated center load (end view)

Table support

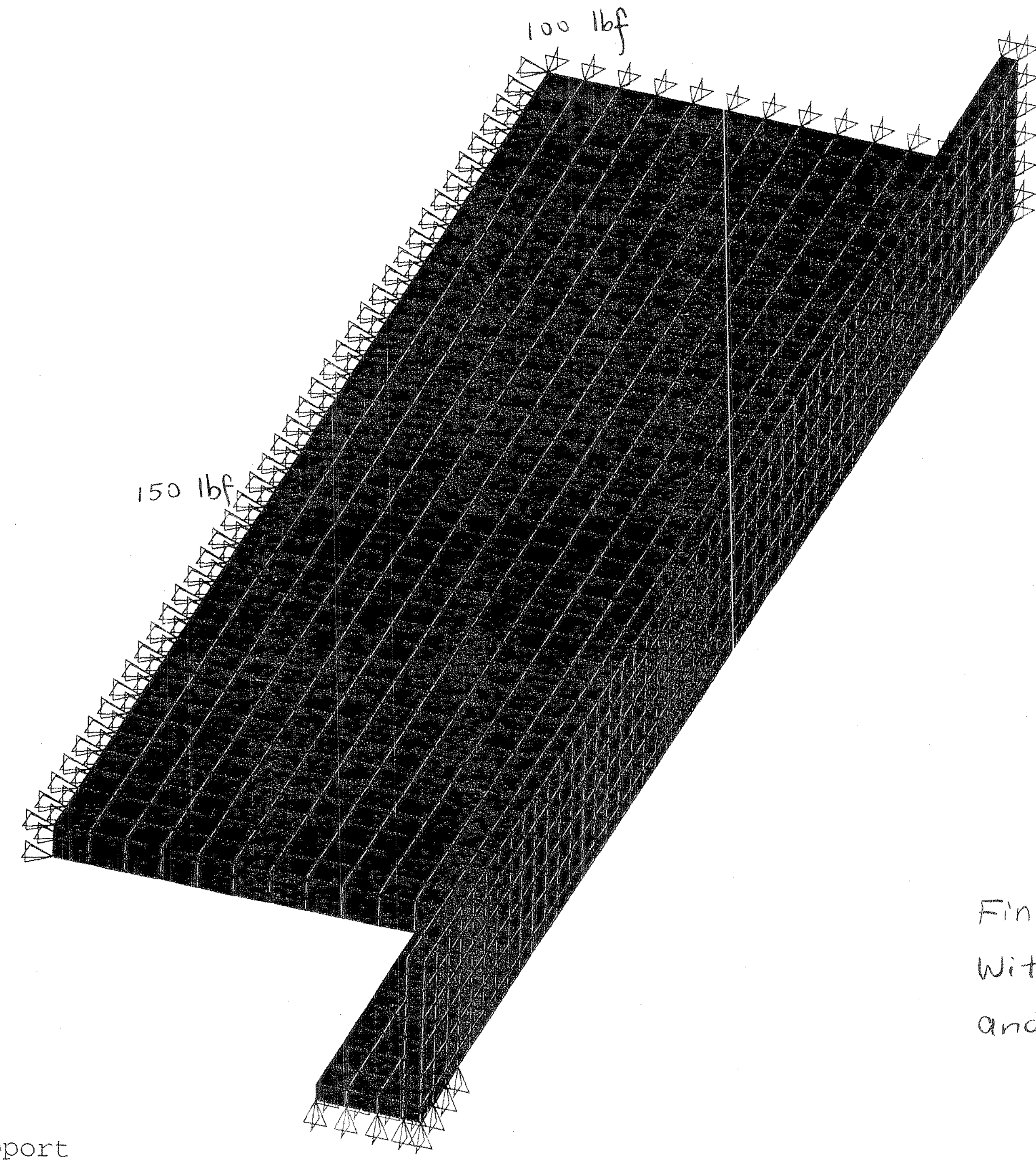
Case 1



Stress Contours

Table support

Case 2



ANSYS 5.0
DEC 7 1994
14:01:59
PLOT NO. 1
ELEMENTS
TYPE NUM
U
F

XV =1
YV =2
ZV =3
DIST=16.943
XF =6.625
YF =2.5
ZF =24
CENTROID HIDDEN

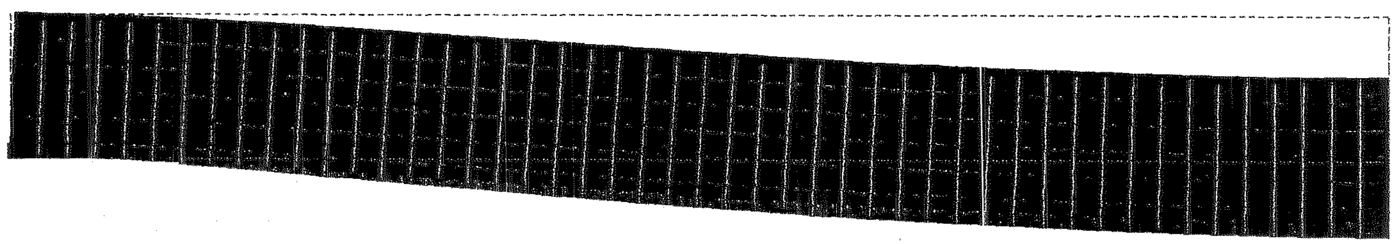
Finite Element model
With boundary conditions
and Loads

Table support

Case 2

ANSYS 5.0
DEC 7 1994
14:27:38
PLOT NO. 1
DISPLACEMENT
STEP=1
SUB =1
TIME=1
RSYS=0
DMX =0.010032
SEPC=29.424

DSCA=263.711
XV =1
DIST=26.456
XF =11.866
YF =1.209
ZF =24.051
CENTROID HIDDEN



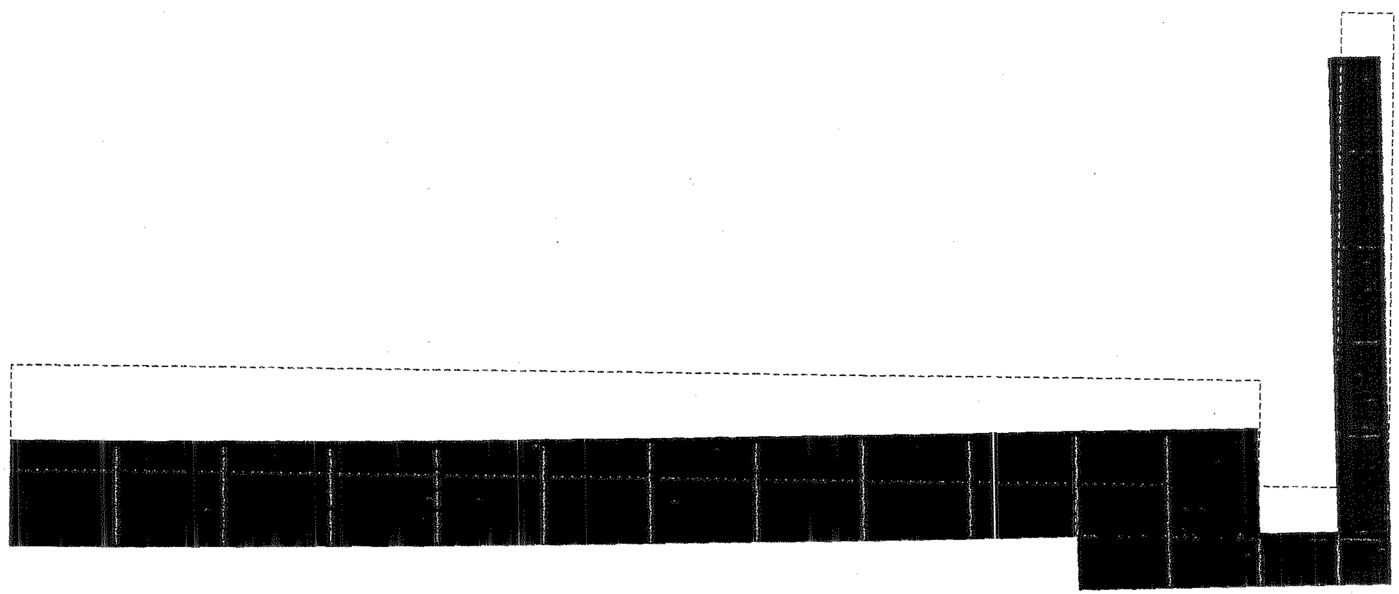
deflection of
steel angle
(end view)

Table support

Case 2

ANSYS 5.0
DEC 7 1994
14:07:14
PLOT NO. 3
DISPLACEMENT
STEP=1
SUB =1
TIME=1
RSYS=0
DMX =0.014349
SEPC=20.47

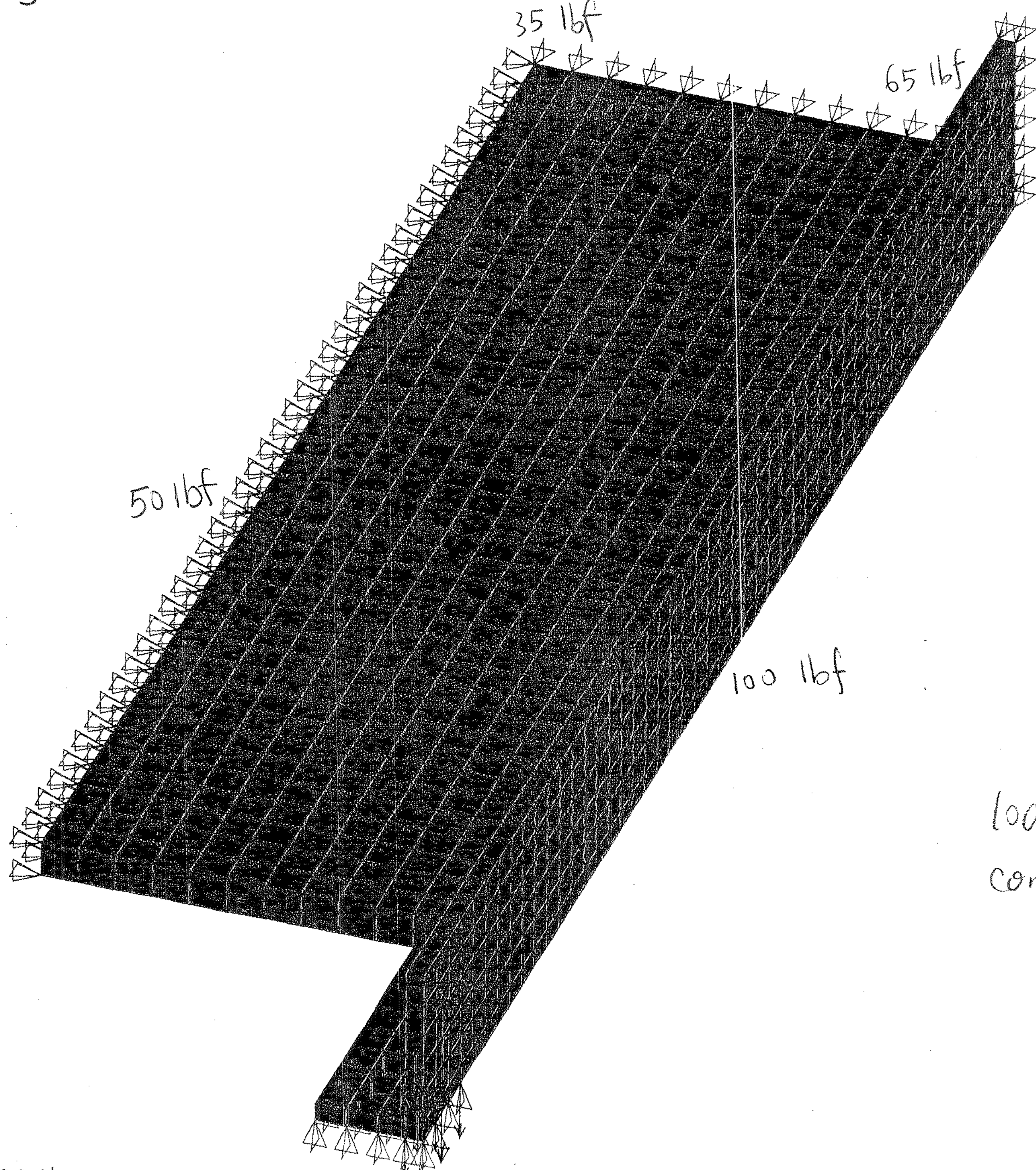
DSCA=50.908
ZV =1
DIST=7.305
XF =6.641
YF =2.039
ZF =0.501399
CENTROID HIDDEN



Central cross sectiona
view of deflection
(angle and table)

Table support

Case 3



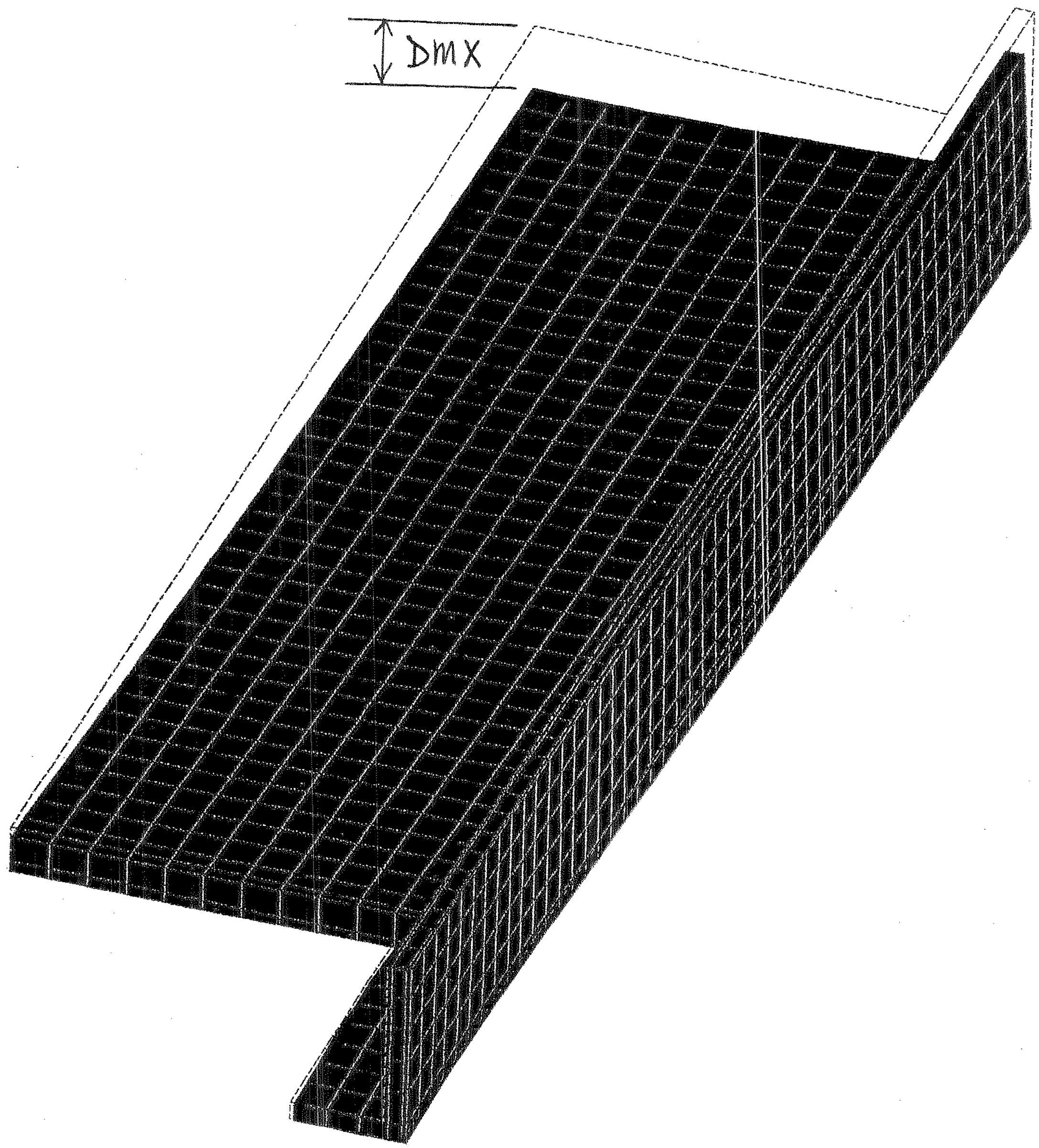
ANSYS 5.0
DEC 8 1994
09:39:58
PLOT NO. 4
ELEMENTS
TYPE NUM
U
F
NFOR
RFOR

XV =1
YV =2
ZV =3
DIST=16.943
XF =6.625
YF =2.5
ZF =24
CENTROID HIDDEN

loads and boundary conditions for case 3.

Table support

Case 3



ANSYS 5.0
DEC 8 1994
09:39:15
PLOT NO. 3
DISPLACEMENT
STEP=1
SUB =1
TIME=1
RSYS=0
DMX =0.011536 inches
SEPC=29.188

DSCA=158.49
XV =1
YV =2
ZV =3
DIST=18.284
XF =6.727
YF =1.172
ZF =24.054
CENTROID HIDDEN

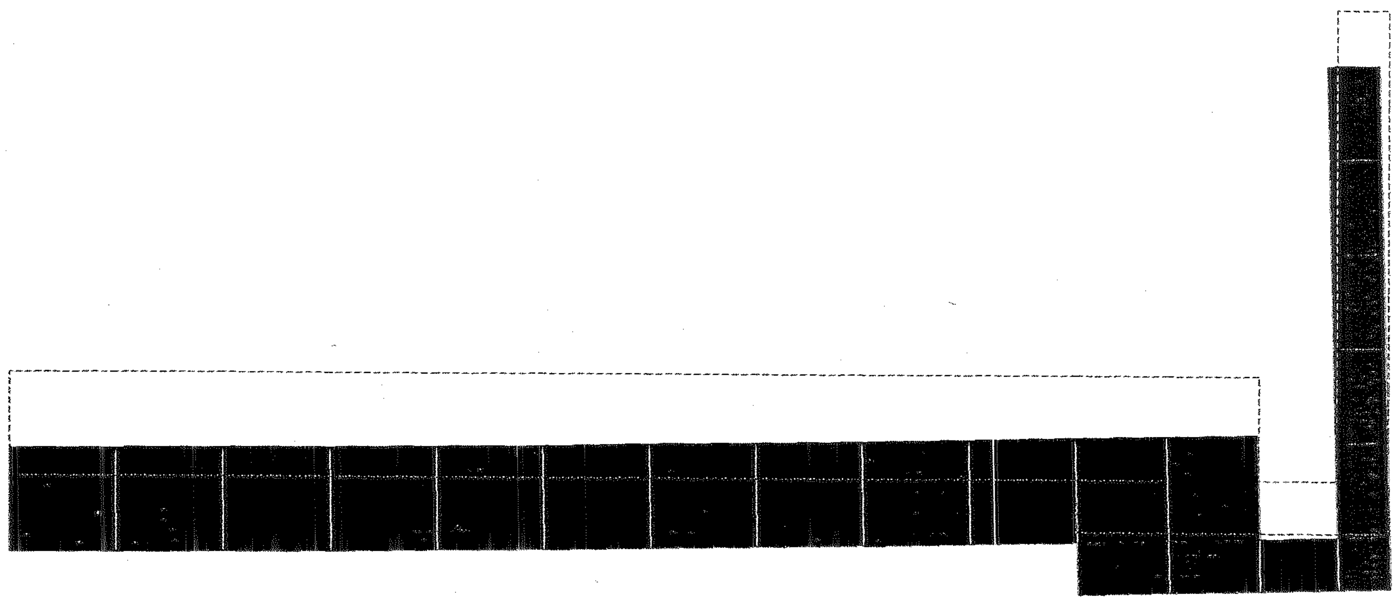
deflection for case 3

Table support

Case 3

ANSYS 5.0
DEC 8 1994
09:38:37
PLOT NO. 1
DISPLACEMENT
STEP=1
SUB =1
TIME=1
RSYS=0
DMX =0.011536
SEPC=20.985

DSCA=63.279
ZV =1
DIST=7.3
XF =6.636
YF =1.939
ZF =0.500867
CENTROID HIDDEN



cross sectional view of the deflect for case 3 (angle and table)

Table support

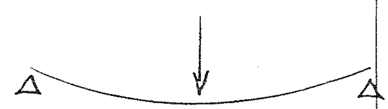
J

About E866 Target Table support

There are two changes in the E866 target table support: 1) use angle L5×5×½ instead of L5×3×½, 2) the support position is 2½" from the wall instead of 1¾"

1) $I = 11.3\ in^4$ for L5×5×½

$I_0 = 9.45\ in^4$ for L5×3×½



As a beam, the deflection is inversely proportional to I, Therefore,

$$y = \frac{I_0}{I} y_0 = \frac{9.45}{11.3} 0.011 = 0.009''$$

$$\Delta y = y - y_0 = -0.003''$$

2) The deflection is proportional to l^3, Therefore

$$y = \left(\frac{l}{l_0}\right)^3 y_0 = \left(\frac{2.5}{1.75}\right)^3 \cdot 0.002 = 0.006''$$

$$\Delta y = y - y_0 = 0.004''$$

The overall net effect is $\Delta y = 0.001''$ increase in the maximum deflection.

E-866 Test Report

Type of Test: Test of Target Table Wall Support Brackets

Date: 7-2-96

Test Coordinator: Joe Davids

Witness: Jim Semen

Items to be tested: Wall Support Brackets

Scope of Test: It is the purpose of this test to insure that the Wall Support Brackets will adequately support the target table and the liquid hydrogen target system. Total weight is roughly 750 pounds.

Procedure: Stack brick weights on each wall bracket to a total weight of 300 lbs. (Weight is distributed to four brackets. This load is $750 \div 4 = 188$ lbs. Test is performed at load $\geq 125\%$ of 188 lbs = 234 lbs required.)

Results: Each wall bracket satisfactorily held the 300 lb force applied to it.

J

E866 Target Tent Analysis

D. Allspach
July 15, 1996

A good portion of the liquid hydrogen target system secondary containment (the tent) is fabricated of the flexible material Herculite. Specifically, it is Herculite Staph-Chek Anstat 20. This is acceptable according to the Guidelines Paragraph II.G.1.c.(i). Unistrut channel is used as the tent frame.

As in the previous fixed target run, we will provide a wall made of a transparent material in order for the Search and Secure teams to check that no personnel are inside the tent before turning on beam. The accepted transparent material used is Lexan polycarbonate sheet type 9034.

An analysis of the wall supporting the Lexan has been performed by Zhijing Tang of the RD/MSD Engineering Analysis Group. A grid has been designed for the relatively rigid (as compared to Herculite) Lexan material to assure integrity of the wall. The grid framing is made of Unistrut with the Lexan attached to the outside of the grid. This is done since a release of hydrogen starts the tent exhaust fan immediately and a slight differential pressure is created between the inside and outside of the tent with the lower pressure on the inside of the tent.

Following is the information from Z. Tang's analysis: The wall is made of 1/4 inch thick Lexan, supported by a Unistrut frame. The Lexan 9034 has the following material properties: $E= 0.34\times10^6$ psi, $\upsilon= 0.38$. Unistrut used is P4001, which is steel ($E= 29\times10^6$ psi), size 1.625" x 1.625", cross section properties $A= 0.460\ in^2$, $I= 0.108\ in^4$. The grid size is 19.8" x 22.0". The design pressure of 2" water is used (72.3×10^{-3} psi).

The frame is supported at the sides as well as the bottom, leaving the top free. The calculated displacement is shown in Figure 1. The maximum displacement is 0.269 inches. The maximum stress in the Lexan is about 150 psi. The maximum stress in the Unistrut is about 6840 psi. These values are acceptable.

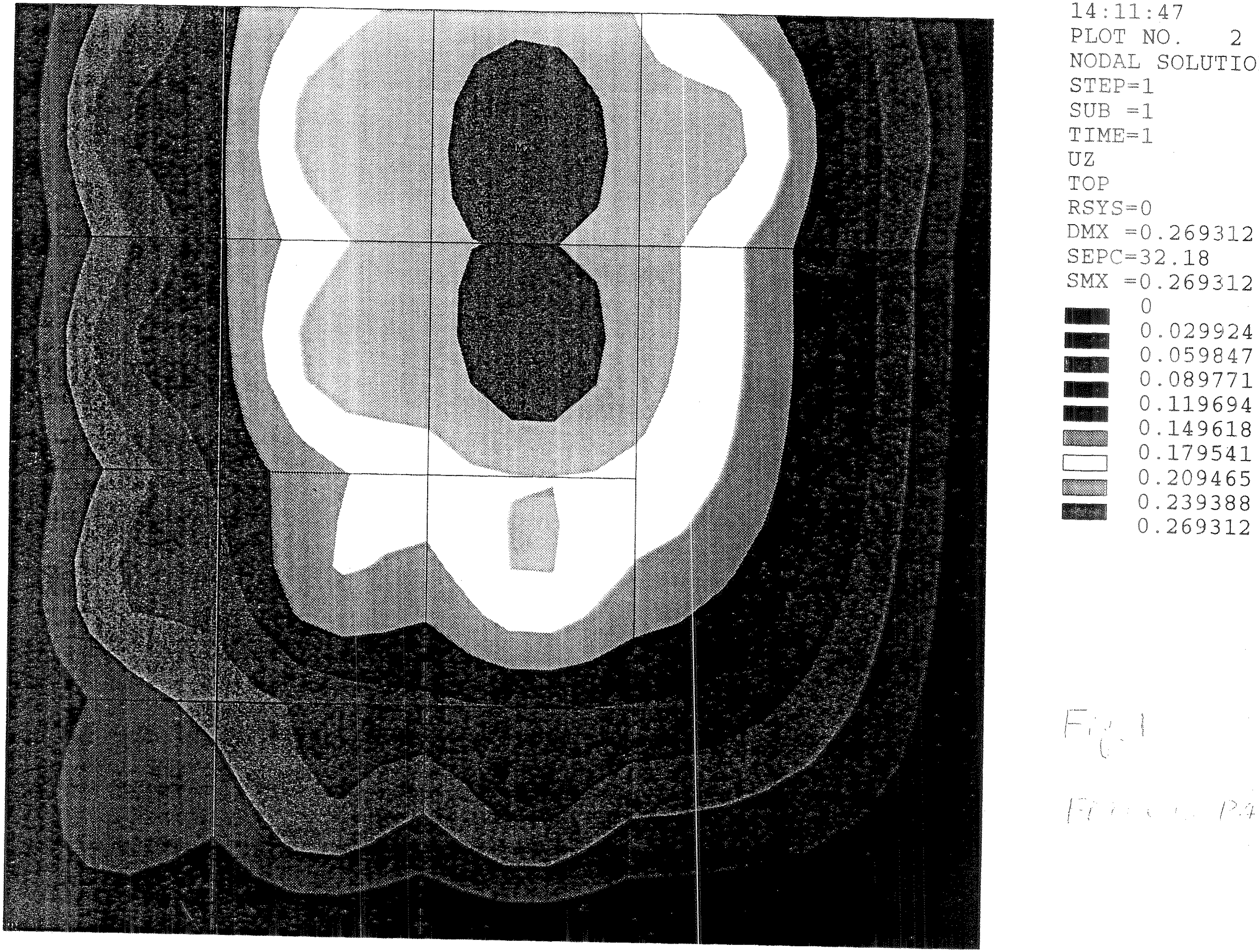


Fig. 1

E-866 Window

E866 Tent Beam Window

D. Allspach
July 15, 1996

Only one target tent beam window is required for the E866 secondary containment. It is located on the downstream wall of the target tent. To avoid radiation damage to the target tent beam window, we have chosen aluminum foil rather than mylar or kapton. See Guidelines paragraph II.C.1.b.(iii) as applied to targets.

The aluminum window will be circular having a diameter of 4.375 inches and a thickness of 0.001 inches. Inner edges of the flanges holding the window in place include a 0.06 inch radius. Both flanges are 0.25 inch aluminum plate.

The attached calculations show that for a pressure differential of 2" H_2O, the deflection is about 0.03 inches and the maximum stress is at the center with a value of about 2200 psi. These values are acceptable.

SUBJECT: Tent Beam Window

NAME: Del Allspach

DATE: 7-10-96

REVISION DATE

Mechanical Properties of Aluminum Foil: AL000420

$E = 10.9\,E6$ psi
$\nu = 0.345$
$S_y = 16{,}000$ psi ; $S_a' = (0.9)(16{,}000) = 14{,}400$ psi
$S_u = 18{,}900$ psi ; $S_a' = (0.5)(18{,}900) = 9450$ psi ←

$S_a = 9{,}450$ psi.

Use membrane formulas:

$$t = \sqrt[4]{\frac{3 w a^4 (1-\nu^2)}{16 E\left[\left(\frac{y}{t}\right) + .488\left(\frac{y}{t}\right)^3\right]}}$$

t = thickness = 0.001"
y = deflection
a = radius = 2.188"
w = 0.0723 psi (2" H_2O)

Iterate with t = 0.001 to find y.

y	t
0.004	0.005
0.010	0.0027
0.020	0.0016
0.030	0.0012

For t = 0.001", the deflection is about 0.03". *

ENGINEERING NOTE | KD/MSD | E866 | | 2/2

SUBJECT: Tent Beam Window

NAME: Del Allspach

DATE: 7-10-96

REVISION DATE:

Stress @ edge:

$$f = 4.40\,E\left(\frac{yt}{a^2}\right) + 0.476\,E\left(\frac{y}{a}\right)^2$$

$$f = 1276 \text{ psi} < F_{allowable} = 9450 \text{ psi}$$ ✱

Stress @ center:

$$f = 2.86\,E\left(\frac{yt}{a^2}\right) + 0.976\,E\left(\frac{y}{a}\right)^2$$

$$f = 2195 \text{ psi} < F_{allowable} = 9450 \text{ psi.}$$ ✱

ENGINEERING NOTE | RD/MSD | 2400

SUBJECT: Tent Beam Window - Addendum 1

NAME: Del Allspach

DATE: 7-19-96

REVISION DATE

Iteration to find the deflection, y, to a more precise degree than shown on page 1/2 of the document, "Tent Beam Window", yields the following results.

$y = 0.0372$ inches

$f_{edge} = 1872$ psi $< F_{allowable}$

$f_{center} = 3317$ psi $< F_{allowable}$.

This shows that 0.001 inch aluminum foil is acceptable for our application.

K K

Fermilab

Date 7-15-96

EXHIBIT B

Pressure Testing Permit*

Type of Test: [ ] Hydrostatic [X] Pneumatic

Test Pressure: 375 psig Maximum Allowable Working Pressure: 300 psig

Items to be Tested E866 Helium Discharge Pneumatic Control lines.

Location of Test Meson Detector Building Date and Time 7-30-96, 8:30 AM

Hazards Involved Pressurized tubing & piping components

Safety Precautions Taken Signs indicating test at all entry areas to test apparatus. All personnel outside of test areas until $p \leq 4/5$ P_{max} = 300 psig

Special Conditions or Requirements Keep a log of each step, including the task, person, and time completed in the test. see Fermi drwg 2727.866-MD-58896

Test Coordinator Del Allspach Dept/Date RD/MSD

Division/Section Safety Officer [signature] Dept/Date RD ES&H 17 July 96

Division/Section Head Bruce B Bull Dept/Date RD D 7/18/96

Results No leaks were seen. Test completed successfully. -DA.

Witness [signature] Dept/Date RD/THERM 7/30/96

(Safety Officer or Designee)

* Must be signed by division/section safety officer and division/section head prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.

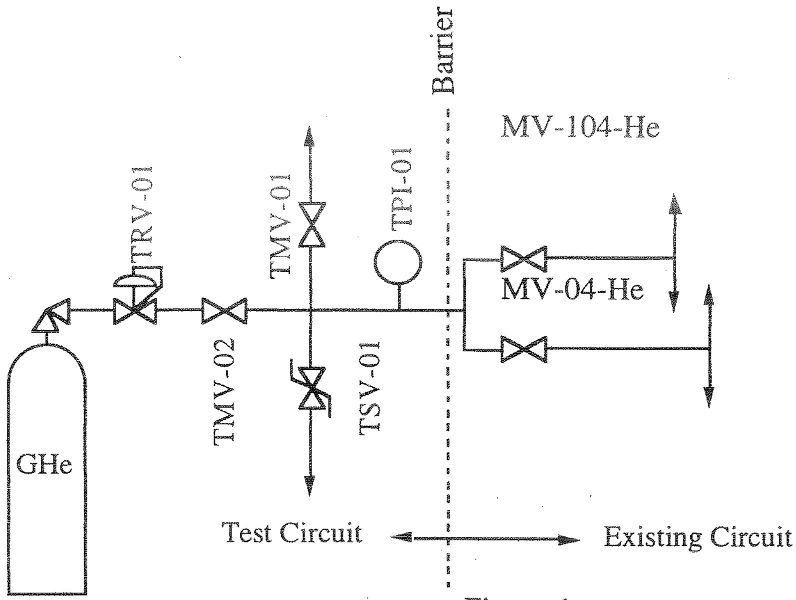


Figure 1.

Designation	Description	Mfg./model	Max. Pressure	Notes
TMV-01	exhaust manifold valve	Nupro B-4HK2	1000	bellows valve
TMV-02	TRV-01's manual valve	Whitey B-1VM4	3000	
TRV-01	pressure regulator	Matheson 2-580	3000	50-650 psig del. pressure range
TPI-01	Test pressure gauge		60 psig	0-600psig range
TSV-01	Safety relief valve	Circle Seal 5159 B4MP		setpoint = 413 psig

Test Setup Valve and Instrument List

6. All personnel involved will be outdoors at the test setup, with no one remaining in the test area. Warnings pertaining to the pressure test will be posted around all components being tested, thus keeping away uninvolved personnel.

7. If a leak is detected during any part of the test (step 8)
   a. Immediately reduce the test pressure to 1/2 of the current pressure reading.

   b. Accurately locate the leak.

   c. Depressurize the system before attempting any adjustments or repairs.

   d. Continue with the test.

8. Proceed with the test:
   a. The maximum test pressure will be 1.25 times the maximum allowable working pressure:

$$P_{max.test} = (1.25)(300 \text{ psig}) = 375 \text{ psig}$$

b. Following UG-100, increase the test pressure to 1/2 the maximum test pressure using TRV-01 and pressure gauge TPI-01.

$P_{1/2} = (0.5)(375)$ psig = 188 psig

c. The test pressure should now be increased in steps of 1/10 of the maximum test pressure, until the maximum test pressure is reached. At each step, close off TMV-02, hold the pressure for approximately 1 minute, and observe the system for failures.

$P_{1/10} = (0.1)(375) = 38$ psi

d. Close TMV-02 and hold the maximum test pressure (375) for 15 minutes to test for a pressure drop indicating leakage. No observable pressure drop should be observed.

e. Using TRV-01 and, if necessary, the test manual vent valve (TMV-01), reduce the test pressure to 4/5 of the maximum test pressure.

$P_{4/5} = (0.80)(375$ psig$) = 300$ psig

f. At this reduced pressure, test personnel may enter the room to examine the lines for any small leaks. If leaks do exist, follow step 7.

9. At the completion of the test, reduce the pressure to atmospheric pressure using TMV-01.

10. Unplug SV-01-He and SV-101-He.

11. Close valves MV-104-He and MV-04-He.

12. Remove test setup.

E-866 Pressure Test Relief Valve Sizing

F.Rysanck July 15, 1996

The Fermilab ES&H manual requires that a test setup include "a relief valve of proper capacity and a set cracking pressure that does not exceed 110% of the maximum test pressure" This setup contains a Circle Seal relief valve which has been sized to limit system pressure to 110% of the cracking pressure 413 psig (454 psig) in any circumstance.

The gas source (cylinder) has a Matheson 2-580 pressure regulator for controlling the helium test pressure. According to the Matheson catalog, it has a maximum flow rate of:

$$V_{max} = 5200 \text{ SCFH air} = 86.7 \text{ SCFM air}$$

A Circle Seal 5159 B-4MP is connected in such a way that it cannot be isolated from the system (see "... Pressure Test" Figure 1). From the Circle Seal Catalog, it is found that the relief valve's capacity at 110% of the 413 psig set pressure is:

$$V_{max} > 400 \text{ SCFM air},$$

which satisfies the Fermilab ES&H manual standard.

K

Fermilab

Date 7-15-1996

EXHIBIT B

Pressure Testing Permit*

Type of Test: [ ] Hydrostatic [X] Pneumatic

Test Pressure: 375 psig Maximum Allowable Working Pressure: 300 psig

Items to be Tested E866 Helium Discharge lines.

Location of Test Meson Detector/Cryo Bldgs Date and Time 7-30-96, 9:30 AM

Hazards Involved Pressurized tubing & piping components

Safety Precautions Taken Signs indicating test at all entry areas to test apparatus All personnel outside of test area until p ≤ 4/5 Pmax = 300 psig

Special Conditions or Requirements Keep a log of each step, including the task, person, and time completed in the test. see Fermi drwg 2727.866-MD-58896

Test Coordinator [signature] Dept/Date RD/MSD

Division/Section Safety Officer [signature] Dept/Date RD ES&H 18 July 96

Division/Section Head [signature] Dept/Date RDO 7/18/96

Results No leaks were seen. Test completed successfully. -DA

Witness [signature] Dept/Date RD/THERM 7-30-96
(Safety Officer or Designee)

* Must be signed by division/section safety officer and division/section head prior to conducting test. It is the responsibility of the test coordinator to obtain signatures.

1 K

E-866 Helium Discharge Header Pressure Test

F.Rysanek / July 15, 1996

The helium supply from the Meson Cryo Central compressors is relieved at 300 psig. Because these lines feed the Discharge Header, 300 psig is the maximum pressure the Header could reach. As described in Fermilab ES&H 5031.1, since this is above 150 psig, a pressure test is required. A pneumatic test will be performed instead of a hydrostatic because the system is not easily dried.

Prior to the test, a Research Division Safety Officer will review the system for compliance with applicable codes and to confirm that all appropriate safety measures have been taken. Also prior to the test, a Pressure Testing Permit, as required by chapter 5034, will be completed and signed by appropriate personnel. The test will be performed in compliance with the ASME Boiler and Pressure Vessel Code Section VIII, UG-100 standard.

UG-100 requires a test pressure at least equal to 1.25 times the system's maximum operating pressure, in this case 300 psig. Since there are pneumatic regulators in the system, a pressure test of the pneumatic control lines must be completed before continuing with the Discharge header test. (see E-866 Helium Discharge Pneumatic Control Pressure Test)

Pressure Test Procedure

1. If the system is above atmospheric pressure, relieve the excess pressure by opening manual valve MV-112-He and MV-12-He.

2. Make sure that the following manual valves are open
   a. MV-111-He
   b. MV-11-He
   c. MV-106-He
   d. MV-06-He
   e. MV-00-He
   f. FH2 Targ. manifold valves (MCC)

   Be sure that RV-102-He and RV-02-He are fully open throughout the test by maintaining a pressure in the pneumatic control lines that is slightly higher than the test pressure.

3. Be sure that EV-102-He and EV-02-He are in the normal operating position.

4. Be sure that MV-700-H and MV-701-H (MCC-Helium Valves) and MV-12-He are closed.

5. Connect the rest of the setup as shown in Figure 1. This setup contains a gas cylinder of Helium, TRV-01 to control the test pressure, TPI-01 to read the test pressure, a relief valve capable of venting the maximum flow rate from TRV-01 (see E866 Pressure Test Relief Valve Sizing), and two manual valves. TPI-01 is a pressure gauge with a full scale range between 1.5 to 4 times the maximum test pressure.

$$(1.5)(375) = 563 \text{ psig} < P_{range} = 600 < (4.0)(375) = 1500 \text{ psig}$$

TPI-01 is visible to the pressure controlling operator at all times. TSV-01 has a set pressure of 110% of the maximum test pressure:

$$P_{TSV\text{-}01} <= (1.10)(375) \text{ psig} = 413 \text{ psig}$$
$$P_{TSV\text{-}01} = 413 \text{ psig}$$

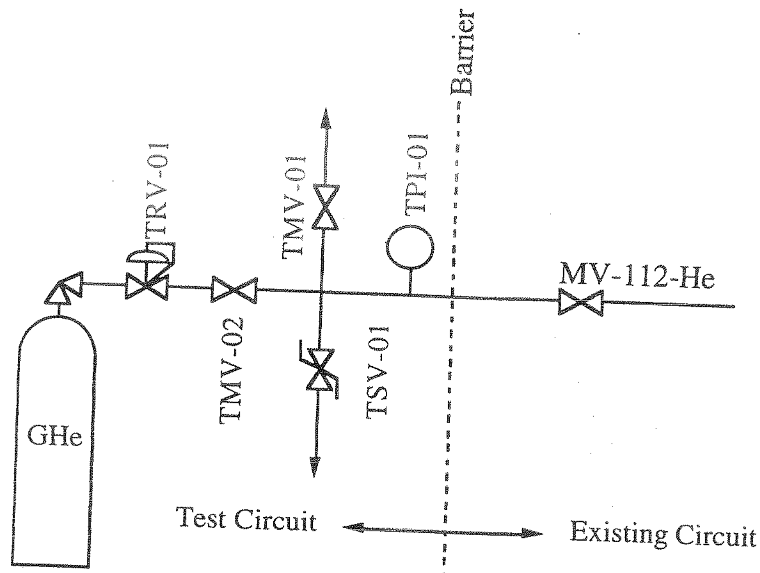


Figure 1.

Designation	Description	Mfg./model	Max. Pressure	Notes
TMV-01	exhaust manifold valve	Nupro B-4HK2	1000	bellows valve
TMV-02	TRV-01's manual valve	Whitey B-1VM4	3000	
TRV-01	pressure regulator	Matheson 2-580	3000	50-650 psig del. pressure range
TPI-01	Test pressure gauge		60 psig	0-600psig range
TSV-01	Safety relief valve	Circle Seal 5159 B4MP		setpoint = 413 psig

Test Setup Valve and Instrument List

6. All personnel involved will be outdoors at the test setup, with no one remaining in the test area. Warnings pertaining to the pressure test will be posted around all components being tested, thus keeping away uninvolved personnel.

7. If a leak is detected during any part of the test (step 8)
   a. Immediately reduce the test pressure to 1/2 of the current pressure reading.

   b. Accurately locate the leak.

   c. Depressurize the system before attempting any adjustments or repairs.

   d. Continue with the test.

8. Proceed with the test:
   a. The maximum test pressure will be 1.25 times the maximum allowable working pressure:

$$P_{max.test} = (1.25)(300 \text{ psig}) = 375 \text{ psig}$$

b. Following UG-100, increase the test pressure to 1/2 the maximum test pressure using TRV-01 and pressure gauge TPI-01. Use PT-COMP-DISH to make sure that the entire system is being pressurized. At the same time, in the pneumatic control lines, maintain a pressure higher than the current test pressure to ensure that RV-102-He and RV-02-He are completely open.

$P_{1/2} = (0.5)(375)$ psig = 188 psig

c. The test pressure should now be increased in steps of 1/10 of the maximum test pressure, until the maximum test pressure is reached. At each step, close off TMV-02, hold the pressure for approximately 1 minute, and observe the system for failures.

$P_{1/10} = (0.1)(375) = 38$ psi

d. Close TMV-02 and hold the maximum test pressure (375) for 15 minutes to test for a pressure drop indicating leakage. No observable pressure drop should be observed.

e. Using TRV-01 and, if necessary, the pressure relieving manual test valve (TMV-01), reduce the test pressure to 4/5 of the maximum test pressure.

$P_{4/5} = (0.80)(375$ psig$) = 300$ psig

f. At this reduced pressure, test personnel may enter the room to examine the lines for any small leaks. If leaks do exist, follow step 7.

9. At the completion of the test, reduce the pressure to atmospheric pressure using TMV-01.

10. Depressurize the pneumatic control lines to close RV-02-He and RV-102-He.

11. Close MV-112-He.

12. Unplug the connection at MV-112-He.

13. Remove the test setup.

E-866 Pressure Test Relief Valve Sizing

F.Rysanek July 15, 1996

The Fermilab ES&H manual requires that a test setup include "a relief valve of proper capacity and a set cracking pressure that does not exceed 110% of the maximum test pressure" This setup contains a Circle Seal relief valve which has been sized to limit system pressure to 110% of the cracking pressure 413 psig (454 psig) in any circumstance.

The gas source (cylinder) has a Matheson 2-580 pressure regulator for controlling the helium test pressure. According to the Matheson catalog, it has a maximum flow rate of:

$$V_{max} = 5200 \text{ SCFH air} = 86.7 \text{ SCFM air}$$

A Circle Seal 5159 B-4MP is connected in such a way that it cannot be isolated from the system (see "... Pressure Test" Figure 1). From the Circle Seal Catalog, it is found that the relief valve's capacity at 110% of the 413 psig set pressure is:

$$V_{max} > 400 \text{ SCFM air,}$$

which satisfies the Fermilab ES&H manual standard.

PRESSURE PIPING SYSTEMS
(Formerly Fermilab Engineering Standard SD-38)

INTRODUCTION

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

SCOPE

This chapter includes all piping systems that fall under the scope of ASME/ANSI B31 code series. This includes the following:

Section 1	Power Piping B31.1
Section 2	Fuel Gas Piping B31.2
Section 3	Chemical Plant & Petroleum Refinery Piping B31.3
Section 4	Liquid Petroleum Transportation Piping Systems B31.4
Section 5	Refrigeration Piping B31.5
Section 8	Gas Transmission and Distribution Piping B31.8

SPECIAL RESPONSIBILITIES

The division/section head who controls the area of operations where the piping system resides is responsible for carrying out the requirements of this chapter. He shall arrange for the review of the piping system by a qualified person.

The ES&H Section shall audit the divisions and sections on their compliance to this chapter. They will also maintain an open master file of all pressure piping system reviews.

The Mechanical Safety Subcommittee shall serve the division/section heads and ES&H Section in a consulting capacity on all piping system matters.

POLICY

1. All pressure piping systems built and used at Fermilab shall be in accordance with this chapter and the ASME/ANSI B31 code series.

2. Implementation of Policy

   a. *Documentation*: A document shall be prepared by an engineer or designer for some existing or new pressure piping systems at Fermilab, whether purchased or in-house built. Its purpose is to allow a reviewer to check the design and installation and to inform a future user of the pressure piping systems parameters. The document shall include design calculations for the pressure piping systems and manufacturer's compliance to the ANSI/ASME standard for purchased pressure piping systems. The document shall also include precautions and operation procedures necessary for the safe use of the pressure piping system.

PROCEDURES AND REQUIREMENTS FOR DESIGN, FABRICATION, INSPECTION AND TEST

1. Purchased Pressure Piping Systems: All pressure piping systems purchased by Fermilab or its experimenters shall be made (designed and fabricated) in accordance with the *"Policy"* section of this chapter.

2. In-House Built Pressure Piping Systems: All pressure piping systems built at Fermilab or experimenter's shops shall be designed in accordance with the *"Policy"* section of this chapter.

3. Existing Pressure Piping Systems In Service: All such pressure piping systems must be in accordance with the *"Policy"* section of this chapter.

4. Used Pressure Piping Systems: Used pressure piping systems shall be classified as an existing pressure piping system and will have their previous service taken into account during the review process. Questionable pressure piping systems or those with unknown histories shall be retested per the *"Proof Test"* section of this chapter.

5. Proof Test: All pressure piping systems shall be pressure tested as described per Fermilab ES&H Manual Chapter 5034.

6. Welding/Brazing Information (Fermilab or Experimenter's Welding/Brazing Shops Only): Welding executed at Fermilab shall be done in a manner equivalent to a welding/brazing procedure supplied by the Fermilab Weld Shop. Purchased pressure piping systems should be welded according to the ANSI/ASME piping standard.

7. Component Identification: Components should be labeled to correspond to an up-to-date piping and instrument diagram. Labels are to be permanent, securely attached and easy to read. Each component label should list a unique component number for that system. Guidance may be obtained from DOE Order 5480.19, Chapter XVII, "Equipment and Piping Labeling."

4. Pressure testing shall be performed as per ASME Sec VIII, UG-99 or UG-100. Using an inert liquid or gas, the vessel shall be stressed in excess of the maximum allowable working pressure (1.5 times in hydrostatic tests and 1.25 times in pneumatic tests).

5. All pressure tests shall be directed by a qualified engineer and observed by the division/section safety officer or designee.

6. A report shall be prepared for all pressure vessel tests. The report shall include the time, date, location, an equipment layout drawing, test data, conditions, personnel present and pressure readings. The layout shall show all system components and their pressure ratings. See attached "Exhibit A" for suggested set up for pressure testing, and also "Exhibit B" for test report format.

7. The completed report shall be filed with the Engineering Note in the ES&H Section Pressure Vessel Master File (MS119) and a copy maintained by the division/section.

8. A technical appendix which provides a detailed discussion of required documentation, safety precautions, equipment and materials, and test procedures is attached.

(j) Before applying pressure, the test equipment shall be examined to see that it is tight and that all low-pressure filling lines and other appurtenances that should not be subjected to the test pressure have been disconnected.

(k) The test pressure for enameled vessels shall be at least equal to, but need not exceed, the maximum allowable working pressure to be marked on the vessel.

(l) Vessels which are to be galvanized may be pressure-tested either before or after galvanizing.

(m) Homogeneously lead-lined vessels may be pressure tested before or after completion of all lead lining, including nozzles.

UG-100 PNEUMATIC TEST[33] (SEE UW-50)

(a) Subject to the provisions of UG-99(a)(1) and (a)(2), a pneumatic test prescribed in this paragraph may be used in lieu of the standard hydrostatic test prescribed in UG-99 for vessels:

(1) that are so designed and/or supported that they cannot safely be filled with water;

(2) not readily dried, that are to be used in services where traces of the testing liquid cannot be tolerated and the parts of which have, where possible, been previously tested by hydrostatic pressure to the pressure required in UG-99.

(b) Except for enameled vessels, for which the pneumatic test pressure shall be at least equal to, but need not exceed, the maximum allowable working pressure to be marked on the vessel, the pneumatic test pressure shall be at least equal to 1.25 times the maximum allowable working pressure to be stamped on the vessel multiplied by the lowest ratio (for the materials of which the vessel is constructed) of the stress value S for the test temperature of the vessel to the stress value S for the design temperature (see UG-21). In no case shall the pneumatic test pressure exceed 1.25 times the calculated test pressure as defined in 3-2.

(c) The metal temperature during pneumatic test shall be maintained at least 30°F above the minimum design metal temperature (see UG-20) to minimize the risk of brittle fracture.

(d) The pressure in the vessel shall be gradually increased to not more than one-half of the test pressure. Thereafter, the test pressure shall be increased in steps of approximately one-tenth of the test pressure until the required test pressure has been reached. Then the pressure shall be reduced to a value equal to four-fifths of the test pressure and held for a sufficient time to permit inspection of the vessel.

The visual inspection of the vessel at four-fifths of the required test pressure may be waived provided:

(1) a suitable gas leak test is applied;

(2) substitution of the gas leak test is by agreement reached between Manufacturer and Inspector;

(3) all welded seams which will be hidden by assembly be given a visual examination for workmanship prior to assembly;

(4) the vessel will not contain a "lethal" substance.

[33] In some cases it is desirable to test vessels when partly filled with liquids. For such vessels a combined hydrostatic and pneumatic test may be used as an alternative to the pneumatic test of this paragraph, provided the liquid level is set so that the maximum stress including the stress produced by pneumatic pressure at any point in the vessel (usually near the bottom) or in the support attachments, does not exceed 1.5 times the allowable stress value of the material multiplied by the applicable joint efficiency. After setting the liquid level to meet this condition, the test is conducted as prescribed in (b) and (c) above.

Air or gas is hazardous when used as a testing medium. It is therefore recommended that special precautions be taken when air or gas is used for test purposes.

UG-101 PROOF TESTS TO ESTABLISH MAXIMUM ALLOWABLE WORKING PRESSURE

(a) General

(1) The maximum allowable working pressure for vessels or vessel parts for which the strength cannot be computed with a satisfactory assurance of accuracy (see U-2) shall be established in accordance with the requirements of this paragraph, using one of the test procedures applicable to the type of loading and to the material used in construction.

(2) Provision is made in these rules for two types of tests to determine the internal maximum allowable working pressure:

(a) tests based on yielding of the part to be tested. These tests are limited to materials with a ratio of minimum specified yield to minimum specified ultimate strength of 0.625 or less.

(b) tests based on bursting of the part.

(3) Safety of testing personnel should be given serious consideration when conducting proof tests, and particular care should be taken during bursting tests in (m) below.

(b) The tests in these paragraphs may be used only for the purpose of establishing the maximum allowable working pressure of those elements or component parts for which the thickness cannot be determined by means of the design rules given in this Division. The maximum allowable working pressure of all other elements or component parts shall not be greater than that determined by means of the applicable design rules.

K

E866 STAINLESS STEEL FLASK JOINT TESTING

D. Allspach
October 11, 1995

Introduction:

A series of tests were completed to evaluate the strength of overlapped soft soldered joints for stainless steel 0.002 inch and 0.003 inch thick material. The testing consisted of performing tensile tests on several samples following Appendix II of the LH2 Target Guidelines. The difference in our testing was the use of stainless steel samples which had overlapped soft soldered joints at the center of the test sample.

Several samples were made with variation in overlap width, soldering methods and comparison of the flux which has been on the shelf since the past fixed target run to some newly purchased flux (same type). Some samples without a joint were tested as well in order to establish some reference data. Also, a calculation was performed to predict how great of a shear stress we should expect the joint to withstand before failing. For a 0.5 inch overlapped joint, the result is a value higher than the strength of the stainless steel. We thus expect that the samples will fail at a stress greater than or equal to the allowable stress of the stainless steel (18,800 psi) times four (= 75,200 psi) , which is the ASME code estimated ultimate stress of the stainless steel material.

Summary of test results:

Testing summary below includes overlapped joint samples which were produced with 60/40 solder and MA stainless steel flux from Lake Chemical Co., Chicago, IL as recommended in the Target Guidelines. Joints were made using a soldering iron as is done in the production of target flasks.

0.002 inch thick stainless steel test samples

Average tensile strength of five samples without a joint = 93,000 psi
Tensile strength of strongest sample without a joint = 95,800 psi
Tensile strength of weakest sample without a joint = 86,600 psi

Average tensile strength of five samples with a 0.5" joint = 98,300 psi
Tensile strength of strongest sample with a 0.5" joint = 104,800 psi
Tensile strength of weakest sample with a 0.5" joint = 93,800 psi

0.003 inch thick stainless steel test samples

Average tensile strength of three samples without a joint = 93,000 psi
Tensile strength of strongest sample without a joint = 94,100 psi
Tensile strength of weakest sample without a joint = 91,600 psi

Average tensile strength of five samples with a 0.5" joint = 90,200 psi
Tensile strength of strongest sample with a 0.5" joint = 91,800 psi
Tensile strength of weakest sample with a 0.5" joint = 88,900 psi

Discussion:

Attached, please find the tensile test data of the 0.002 inch and 0.003 inch samples (with and without a joint). In most cases, the failure occurred in the base material rather than in the joint. In all cases, the failure occurred at a stress clearly exceeding 75,200 psi. Thus, the test results indicate that using 0.5 inch overlapped joints in the target flasks will not de-rate their expected strength. Using 0.5 inch overlapped joints, we have consistently produced solder joints with a strength exceeding the material strength assumed (18,800 psi x safety factor of 4) in the flask design calculations. A joint efficiency equal to one (1) is thus valid in the flask stress design calculations.

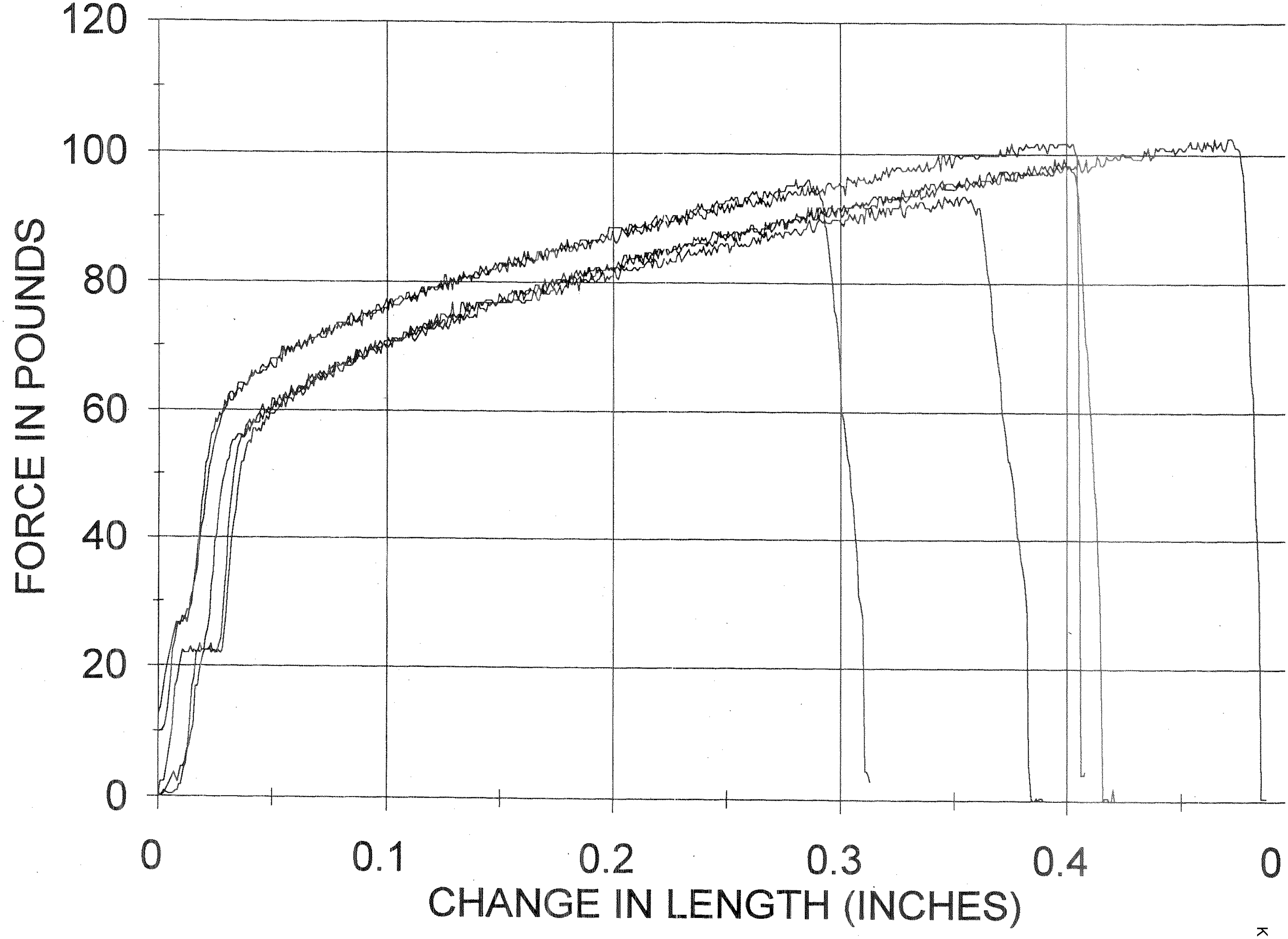
K

E866 Flask Materi. Tensile Test Results

Sample #	Width (inches)	Cross Section (sq. in.)	Break Point (pounds)	Tensile (psi)	Break Type
	Test A - 1/2" overlap of 0.002" thick T304 Annealed Stainless Steel				
1	0.494	0.000988	103.6	104858	base mat'l at edge of overlap
2	0.516	0.001032	103	99806	base mat'l away from joint
3	0.506	0.001012	99.7	98518	base mat'l away from joint
4	0.495	0.00099	93.6	94545	base mat'l away from joint
5	0.512	0.001024	96.1	93848	base mat'l away from joint
	Test B - One piece sample of 0.002" thick T304 Annealed Stainless Steel				
6	0.506	0.001012	95.1	93972	
7	0.501	0.001002	93.6	93413	
8	0.505	0.00101	96.5	95545	
9	0.508	0.001016	88	86614	
10	0.518	0.001036	99.3	95849	
	Test E - One piece sample of 0.003" thick T304 Annealed Stainless Steel				
21	0.48	0.00144	135.6	94167	
22	0.491	0.001473	137.5	93347	
23	0.481	0.001443	132.3	91684	
	Test I - 1/2" overlap of 0.003" thick T304 Annealed Stainless Steel				
39	0.504	0.001512	139	91813	base mat'l away from joint
40	0.51	0.00153	136	88934	base mat'l away from joint
41	0.506	0.001518	136	89869	joint seam
42	0.51	0.00153	138	90350	joint seam
43	0.508	0.001524	137	90053	base mat'l at edge of overlap

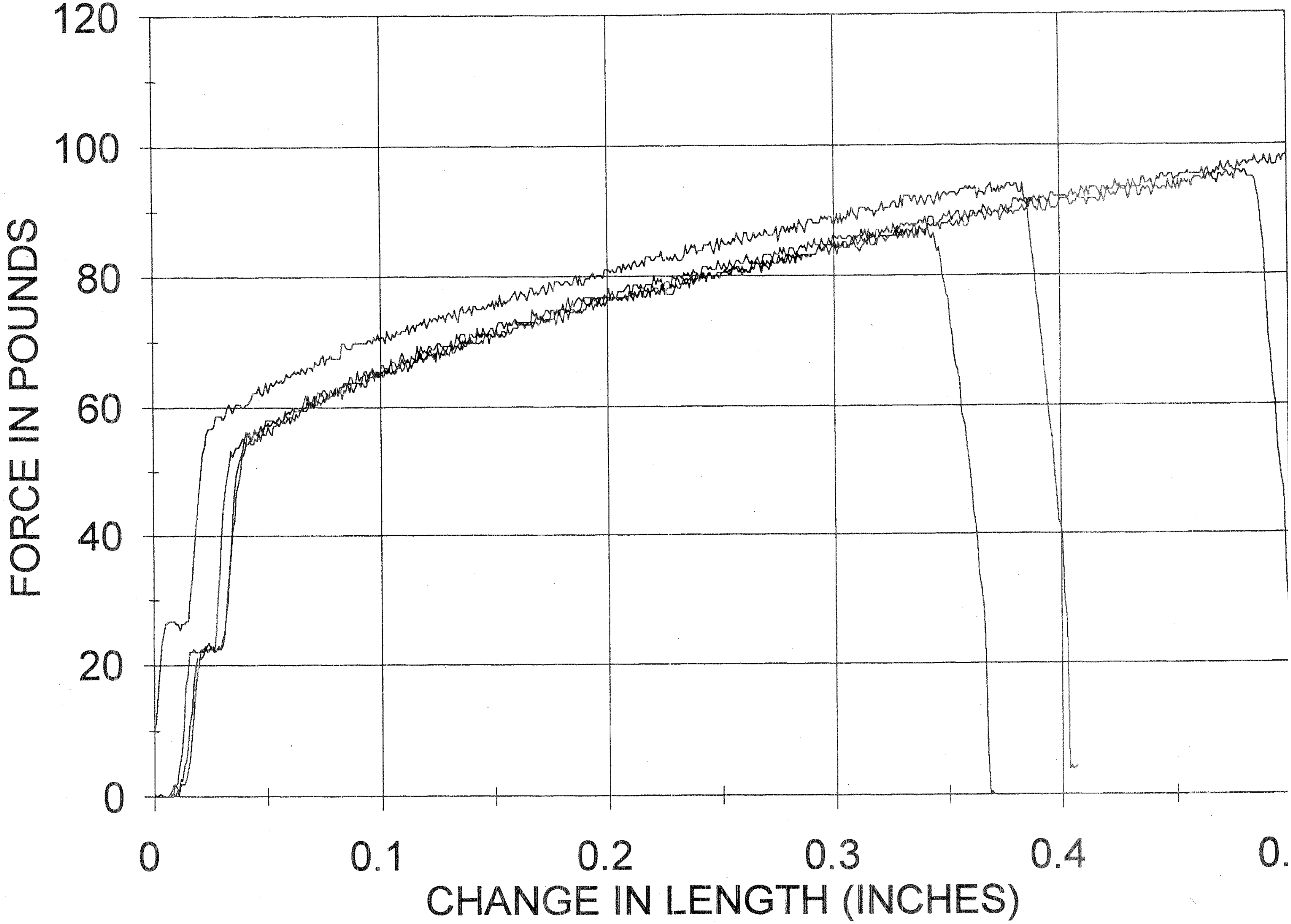
TEST A OVERLAP 'OLDERED W/ IRON

4-12-95



TEST B ONE PIECE SAMPLE

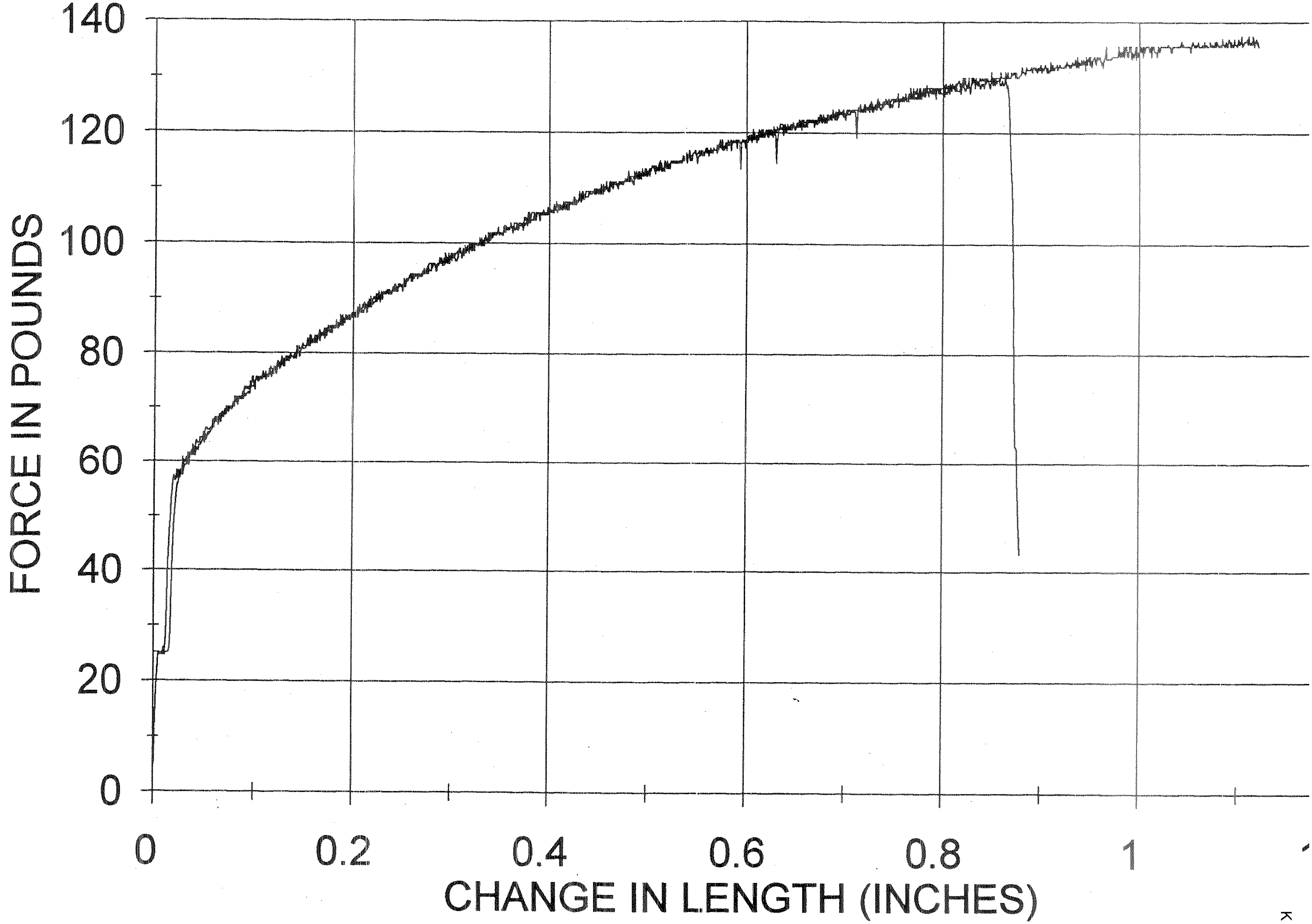
4-12-95



3 MIL S.S. ONE PIECE SAMPLES

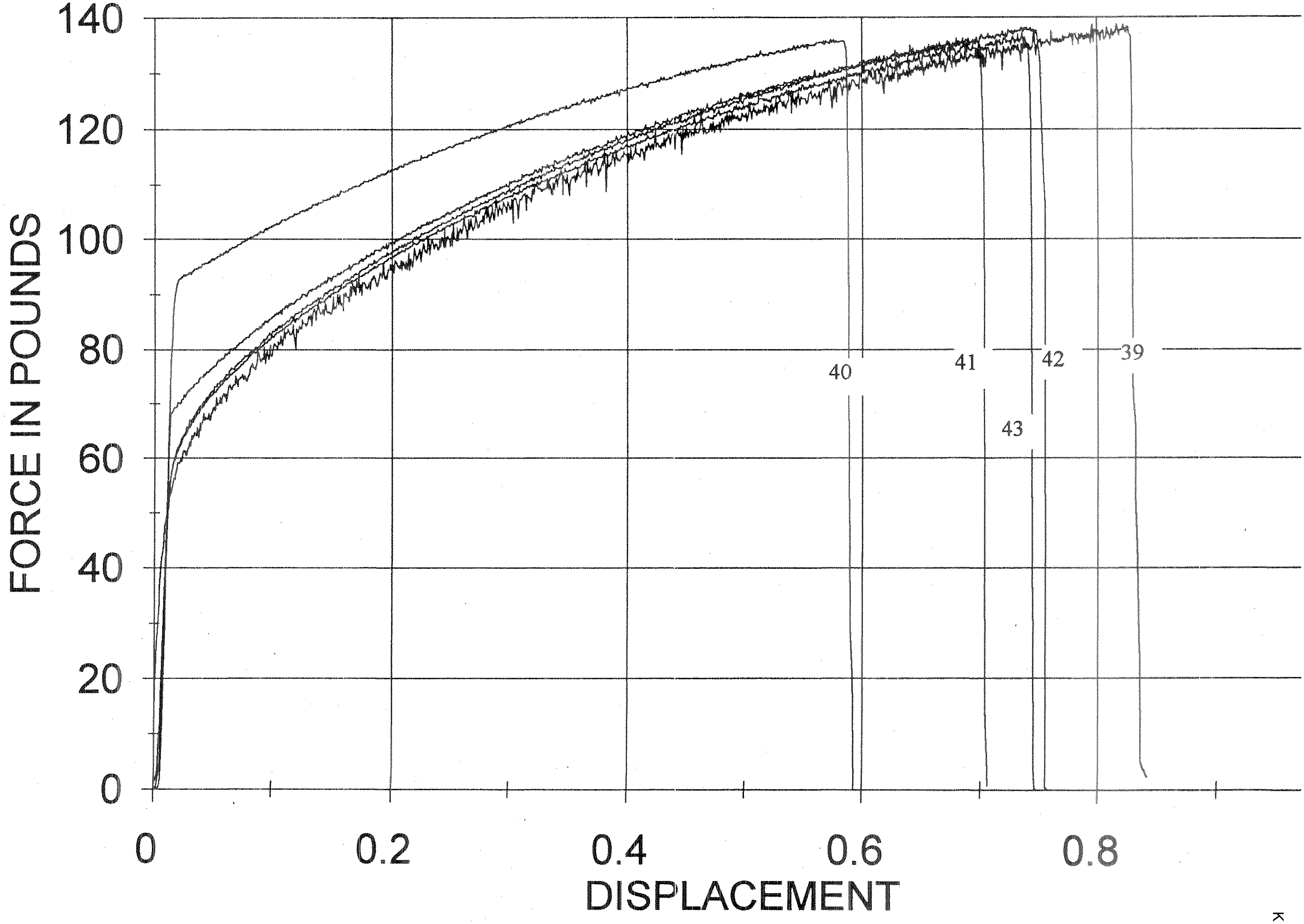
4-17-95

TEST E



TEST I - .5" OVERLAP (IRON & NEW FLUX)

07/26/95



K

K

Flask Pressure Testing Results

November 30, 1995
D. Allspach

Flask testing was performed at Lab 3 in accordance with the Target Guidelines Flask Testing procedures (Section II.C.3.). Excerpts recorded in the E866 Hydrogen Target Log Book by Mike McKenna are copied below for your reference. Three types of tests were completed:

(1) Liquid Nitrogen Pressure Test to 1.5 times the MAWP.

(2) Hydrostatic Burst Test.

(3) Pneumatic Tests to 1.25 times the MAWP.

(1) Log Book Notes: "This prototype flask (which was an inferior sample and had several material flaws) was, non-the-less, used for testing. The first test was a LN2 pressure test. See set up schematic and photos. The flask was filled about 2/3 with LN2 then pressurized to 40 psi and allowed to sit for several minutes. No adverse affects were seen."

The schematic is shown in Diagram 1 and the photos taken in this test are photos #1 and #2.

(2) Log Book Notes: "This same prototype flask was then tested hydrostatically to failure. Yield occurred at around 130 psi with ultimate failure at 143 psi."

The working schematic is shown in Diagram 2 and photo #3 shows the flask under pressure.

(3) Other than the prototype flask, five flasks were constructed for the E866 experiment. Three for planned use, leaving two spares. A room temperature pneumatic test was completed for each of the five. The testing was successful.

Log Book Notes: "Each flask was pressurized to 31 psi (1.25 x MAWP) and leak checked using the LEAK HUNTER."

K

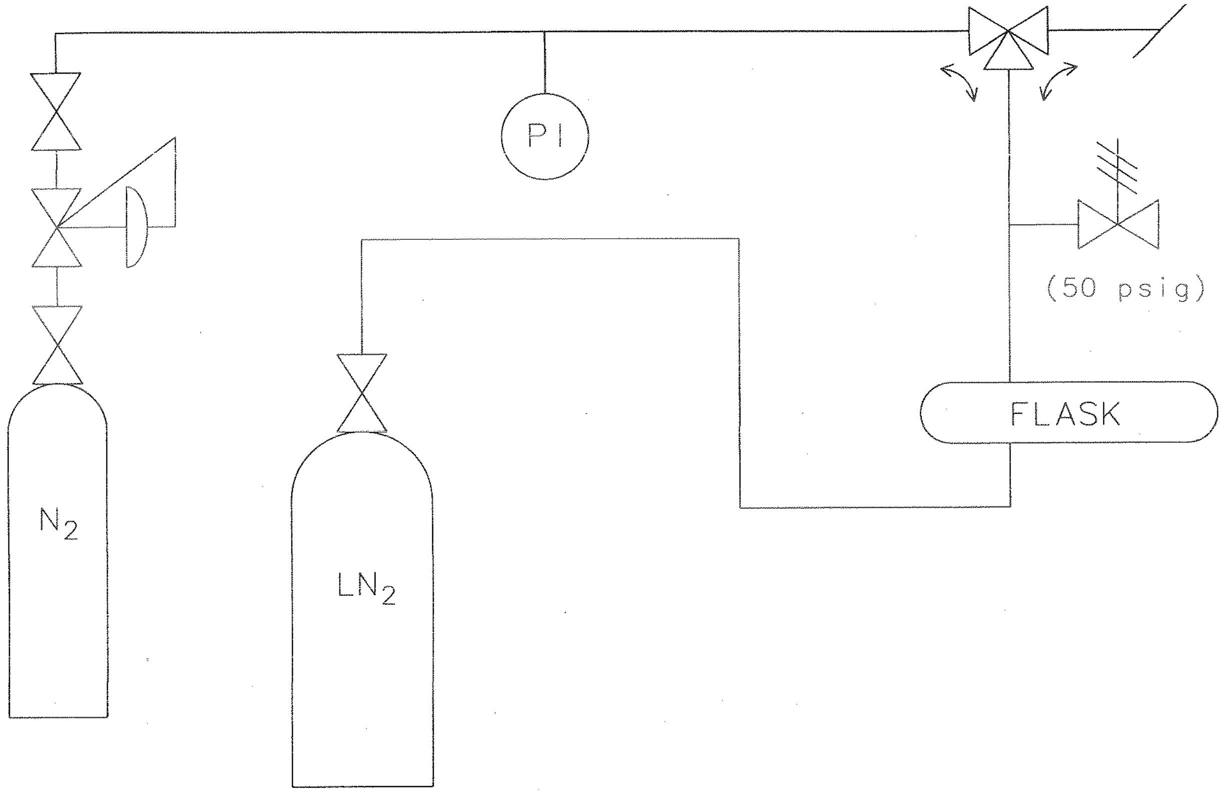


Diagram 1. LN_2 Pressure Test

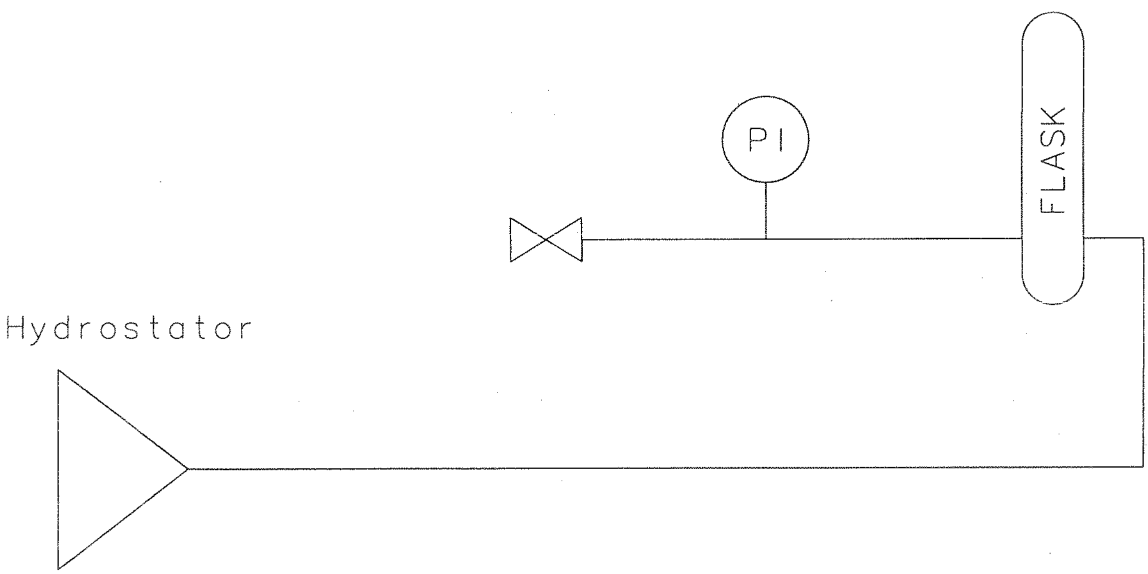


Diagram 2. Hydrostatic Burst Test

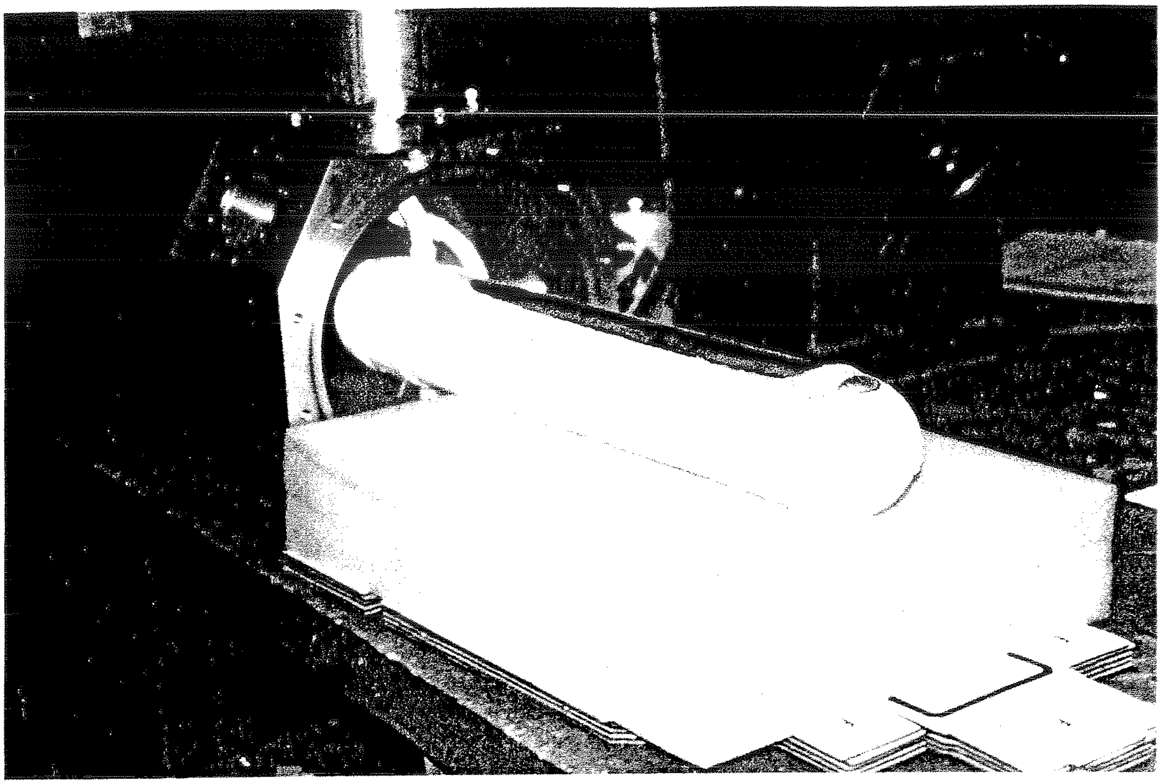


Photo # 1: LN2 Pressure Test

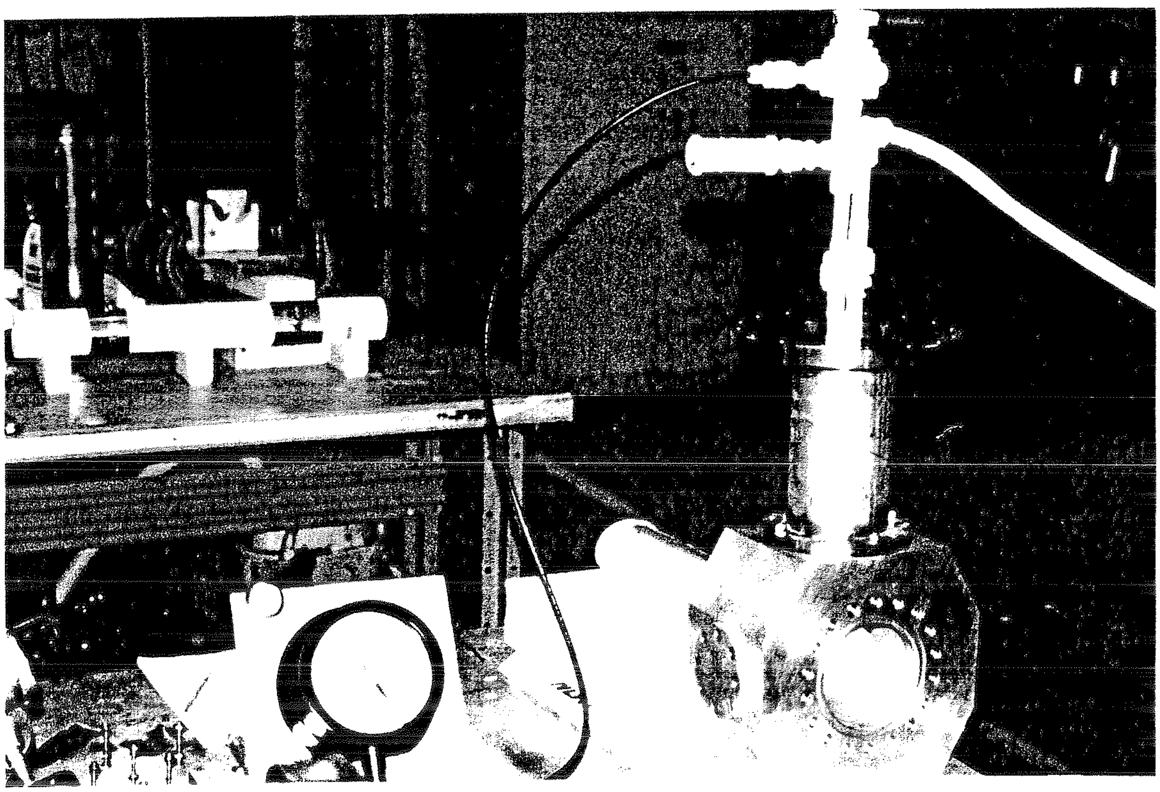


Photo # 2: LN2 Pressure Test

Photo # 3: Hydrostatic Burst Test

Titanium Window Testing Results

D. Allspach / J. Brusoe
October 18, 1995

A total of 25 sample 0.0055 inch thick Titanium 15-3 windows were tested to ensure that the design meets the safety requirements set for it. The tests were performed as described in the document titled "Titanium Window Testing" (please reference document appended at rear).

Test (1) is part of the general vacuum system pressure test. When the vacuum volume is completely assembled, it will be performed. Based on the results of tests (2), (3) and (4) which are described below, the windows will not be a problem in successfully performing test (1) in the future.

Tests (2) and (3) both use the same testing setup. A diagram of this setup is shown on page 3 of this report. The testing fixture for these tests is shown on page 4. Pictures of the actual setup are shown in Photo # 1 and Photo # 2 on page 5. An Anderson-Greenwood 1/2" relief valve with a set pressure of 150 psig was included in the testing setup.

The scope of test (2) was increased to include 10 samples. Samples 1 through 10 were tested at room temperature. Samples 1 through 5 involved starting at atmospheric pressure and then ramping the pressure to 150 psig (the safety relief valve set pressure) over a span of 1 to 2 minutes. Samples 6 through 10 involved cycling the pressure from vacuum to 15 psig three times before ramping the pressure to 150 psig. These first 10 test samples displayed evidence of yielding in a central circular region of about 2 to 3 inches in diameter and around the edge of the window where it mates with the flange. None of the samples bursted.

Samples 11 through 15 involved cooling each window with liquid nitrogen while increasing the pressure to 150 psig. These samples appeared to have the yielding where the window mates with the flange, but lacked the central circular yield region. None of the samples bursted.

Page 6 shows a diagram of the test setup used for test (4), samples 16 through 25. Note that five tests with two samples each are utilized in this testing procedure. Also, on page 5, Photo # 3 shows one test in progress. The level of the liquid can be seen on the window. The chart recorder showed that the highest pressure reached in these tests was about 1.5 psig, which occurred with window samples #20 and #21. Samples 16 through 25 showed no signs of any yielding. None of the samples bursted.

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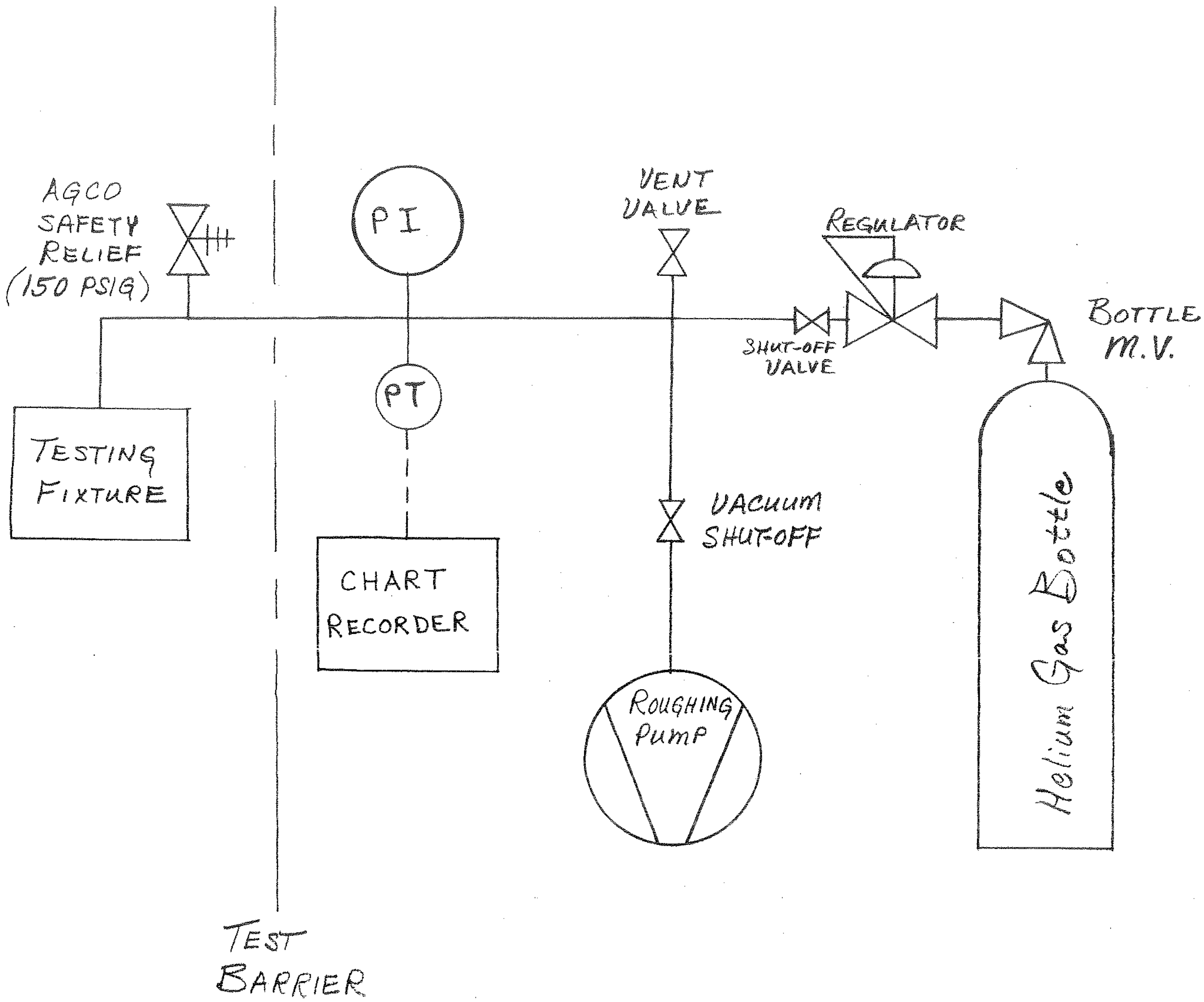
These tests showed that the 0.0055 inch thick Titanium 15-3 windows meet the safety requirements set for them. The windows were subjected to 150 psig at room temperature without any ruptures. Subsequent cryogenic tests showed that the low temperatures strengthened the windows. The windows have been shown to be safe to use in their designed role in E866.

SUBJECT: VACUUM WINDOW TESTING MANIFOLD - ½" tubing

NAME: DA

DATE: 3-7-95

REVISION DATE



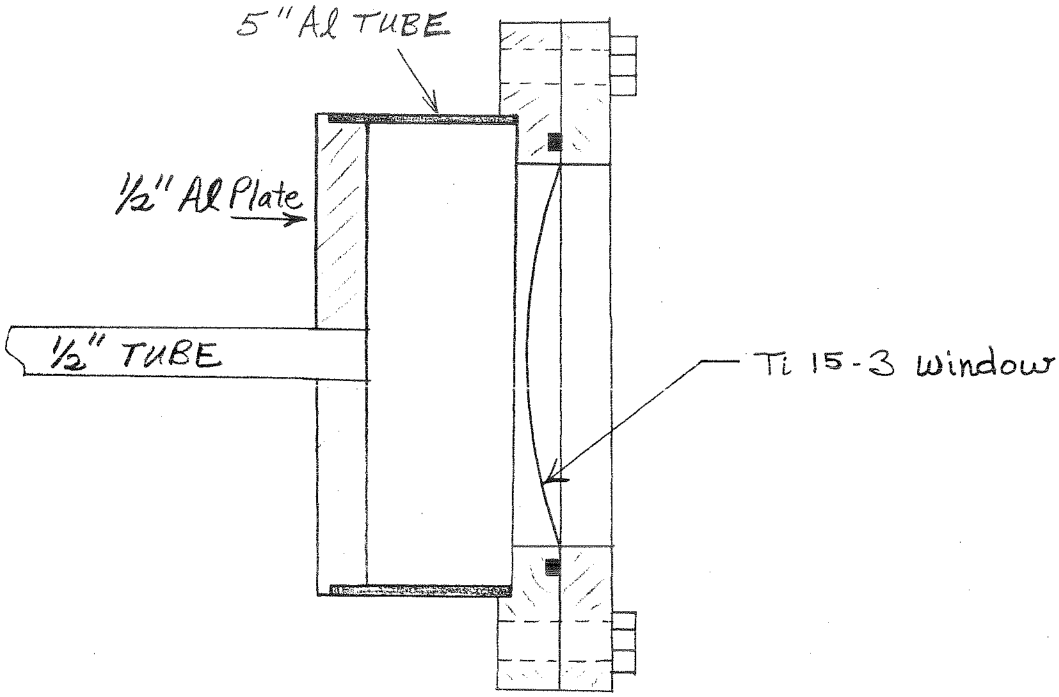
SUBJECT

VACUUM WINDOW BURST TEST FIXTURE

NAME DA

DATE 3-9-95

REVISION DATE



NOTE: 150 PSIG SAFETY RELIEF VALVE USED WITH THIS FIXTURE.

K

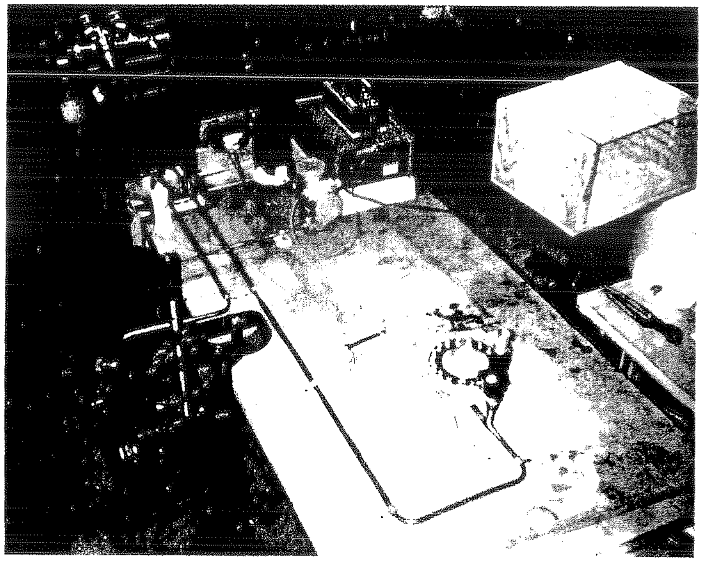


Photo # 1:
Ti 15-3 window test setup

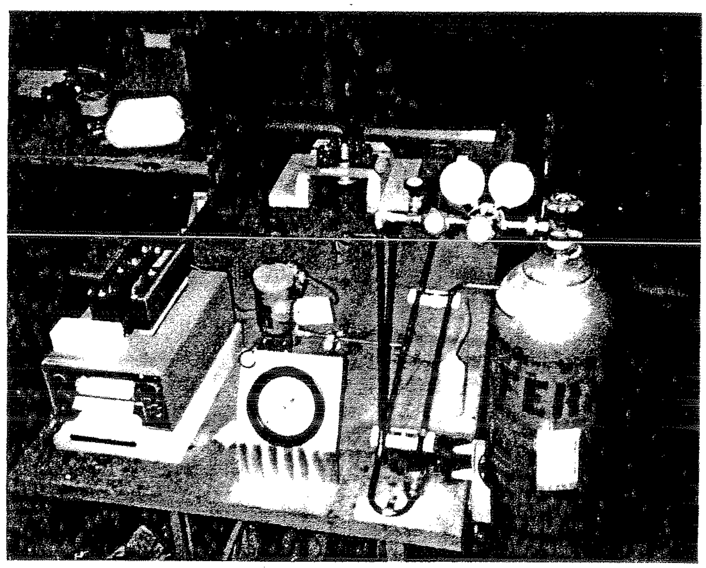


Photo # 2:
Ti 15-3 window test setup

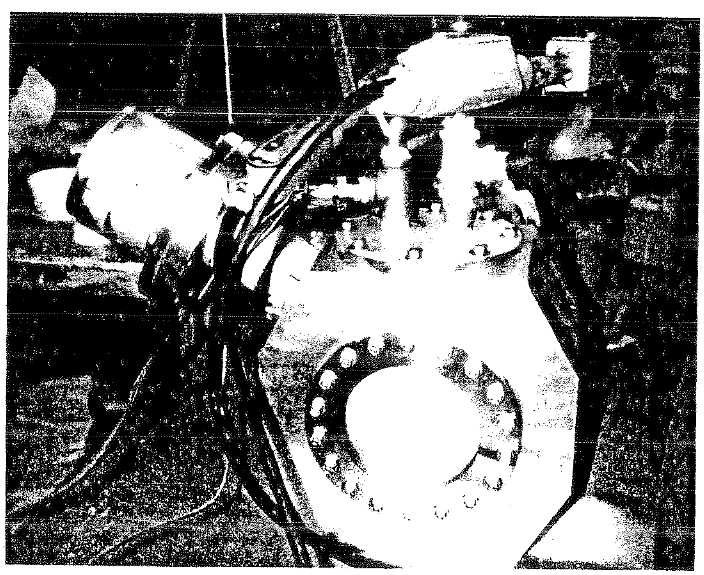


Photo # 3:
Simulated flask failure test

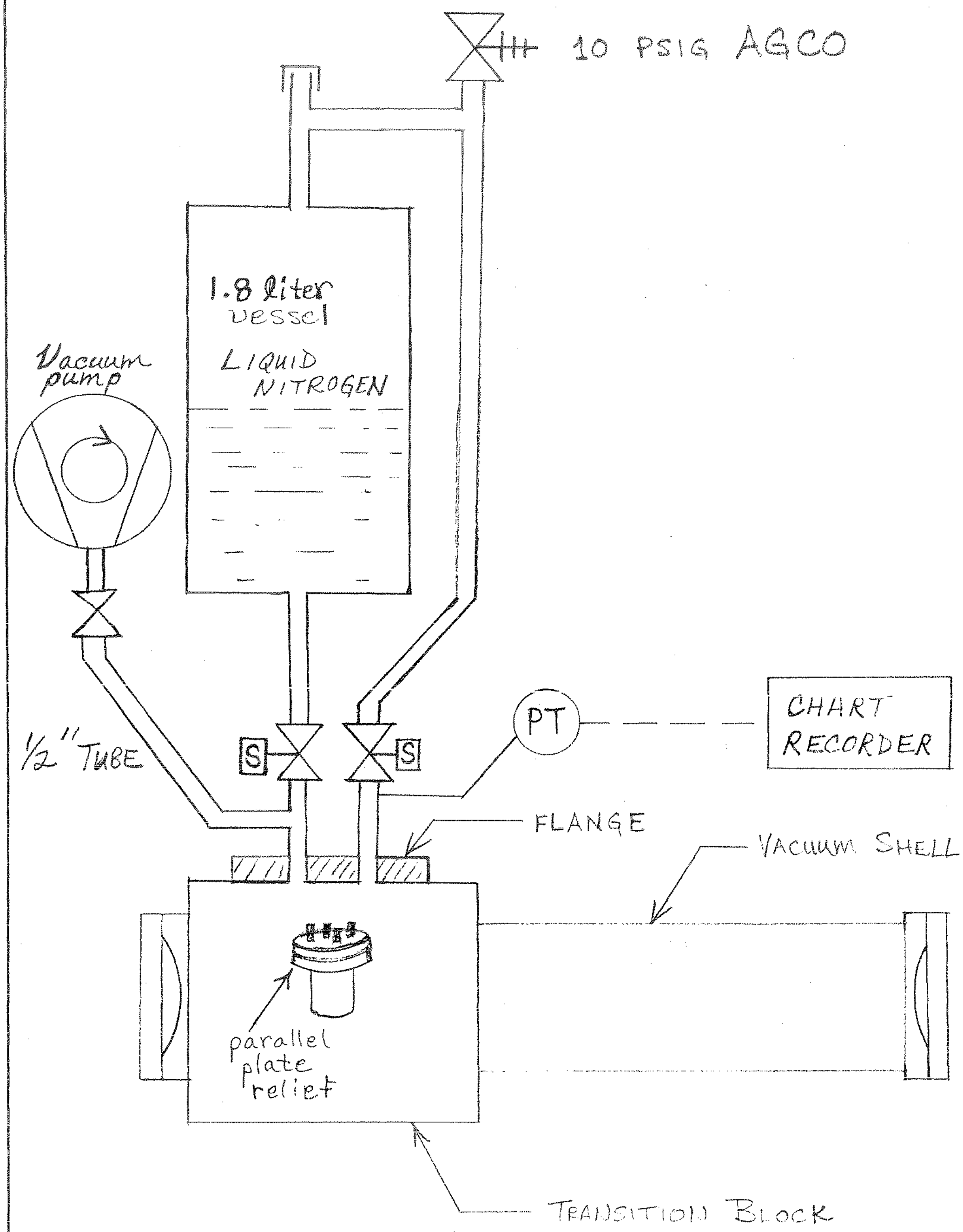
ENGINEERING NOTE | 866 | 6k

SUBJECT: VACUUM WINDOW TEST - FLASK FAILURE SIMULATION

NAME: DA

DATE: 3-21-95

REVISION DATE:



Titanium Window Testing

January 30, 1995 / D. Allspach, J. Peifer

The following tests will be conducted to verify the results of the titanium window stress calculations. Please reference "Titanium Window Stress" calculations for E866. Test data will be logged and the results documented and included in the E866 Target Safety Report.

(1) As the MAWP of the vacuum container is equal to 15 psid internal, the windows will be tested as a part of the general vacuum system pressure testing. During this test the windows are required to sustain 22.5 psid.

(2) Five sample windows will be tested to determine their burst pressure. This test will be conducted at room temperature and will show the window burst pressure to be consistently greater than or equal to 37.5 psid.

(3) Five sample windows will be tested to determine their burst pressure at cryogenic conditions. The windows are to be pressurized while cooled with liquid nitrogen. The pressure differential will be slowly increased showing the window burst pressure to be consistently greater than or equal to 37.5 psid at cryo conditions.

(4) Five tests, each with two sample windows, will occur in which an amount of liquid nitrogen (determined as equivalent to the volume of liquid H_2/D_2 in an E866 flask, based on the expansion ratio from the saturated liquid to the saturated vapor state) will be released into the target flask vacuum container. The container will be under vacuum immediately prior to release of the liquid nitrogen. The test is to show that each window will survive a simulated flask failure.

Notes:

(a) Material to be tested shall be Titanium alloy, Ti 15-3, with a material thickness equal to 0.0055 inches. A manufacturer's material certification sheet showing composition, yield strength and ultimate strength of the titanium shall be obtained.

(b) The flange and mating surface which hold the window samples during testing are to be fabricated as specified for the actual E866 liquid targets.

(c) See "E866 Vacuum Jacket Relief" calculations which show the maximum internal pressure of the vacuum container in the case of a flask failure to be 3.5 psid.

Pneumatic Vent Valve Leak Testing

J. Brusoe / June 6, 1995
Revised: 10-19-95

The vent valve labeled PV-03-H on the E-866 P&I Diagram was leak tested at both room temperature and after being cooled with liquid nitrogen. The attached pages include photographs of the test in progress as well as a diagram of the testing setup. The testing procedure is described below. The results are summarized in the following table:

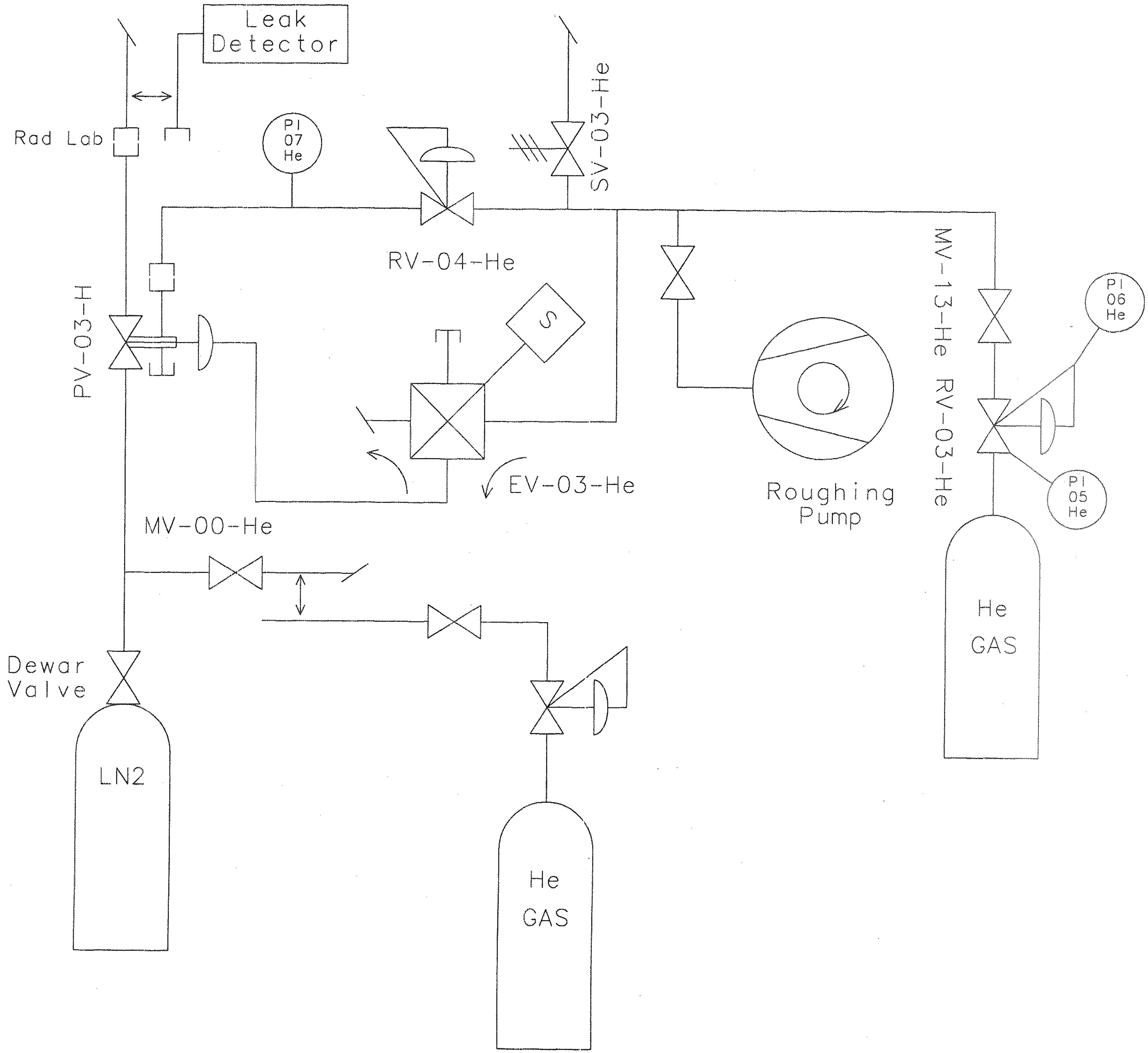
Leak Testing Results

Test Description	Vacuum Pressure
Room Temp. Test	2.5×10^{-9} Torr
1st Cold Test	9.9×10^{-9} Torr
2nd Cold Test	1.7×10^{-9} Torr
3rd Cold Test	1.2×10^{-9} Torr

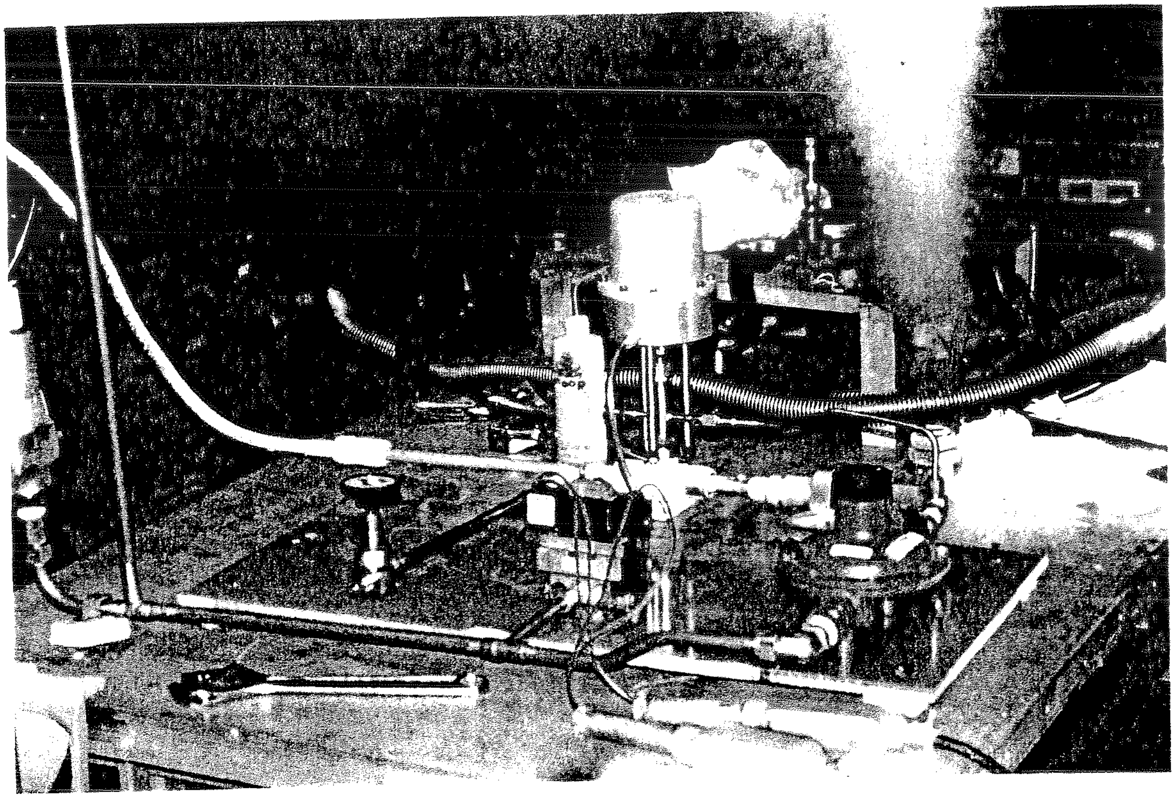
It is believed that the gradually improving results were from the valve and testing setup cleaning itself from successive exposures to vacuum, eventually leading to lower outgassing and thus a better vacuum.

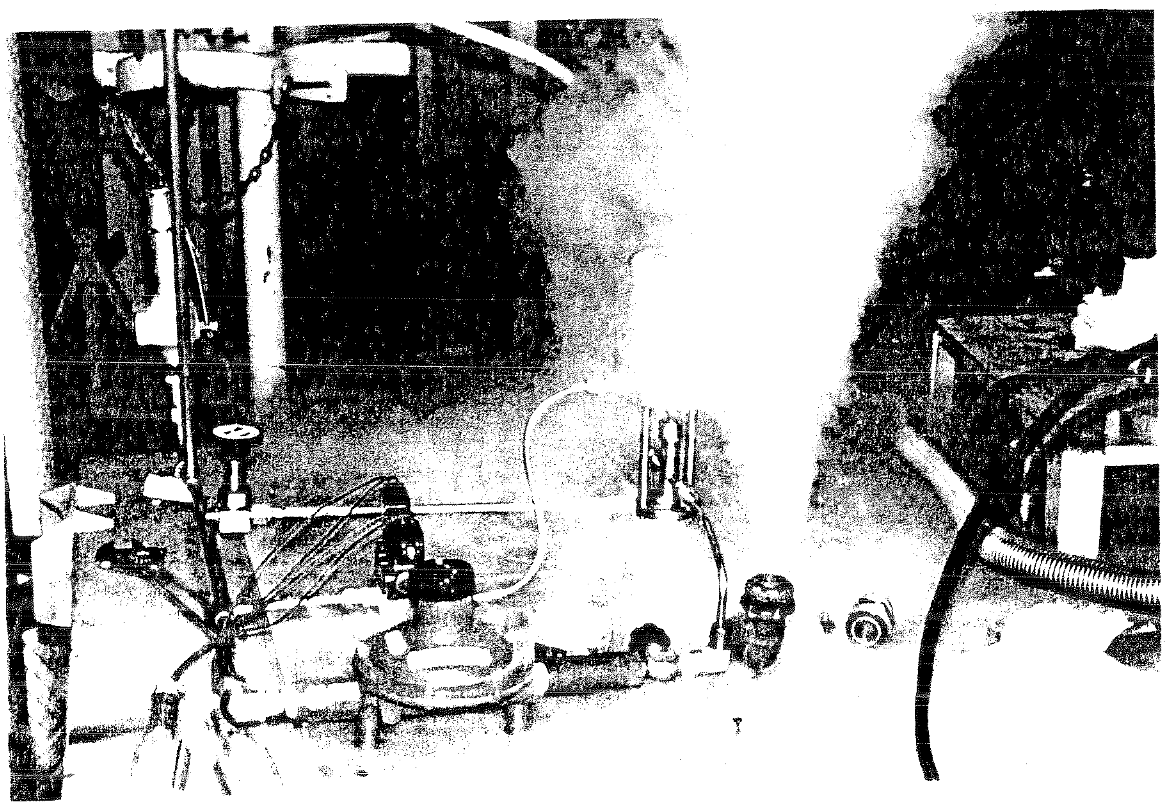
Testing Procedure

1. Purge the valve sleeve by flowing He through it for several minutes, then recap it.
2. Open PV-03-H, the vent valve that is being tested.
3. Open LN2 dewar valve and allow to flow until PV-03-H is cooled and liquid is coming out of the vent. Then tighten dewar valve down to a slow trickle of gas coming out of the vent. This prevents air from getting inside the system.
4. Apply heat gun to Rad Lab connection until it is warm enough to properly connect the leak testing equipment to it (connection is made in step 6).
5. Open MV-00-He while the portable helium gas bottle is still unattached. Close PV-03-H.
6. Connect leak testing equipment at the Rad Lab connection.
7. Turn LN2 dewar valve completely off.
8. Using MV-00-He, apply helium gas pressure to the upstream area of the vent valve using the portable helium gas bottle.
9. Conduct leak test.



Plotted Thu Oct 19 16:57:11 CDT 1995 by coops





L

Fermilab

December 11, 1996

TO: Wes Smart, LH_2 Target Panel Chairman
FROM: Del Allspach, Jim Peifer
SUBJECT: Safety Documentation for E866 and E831 LH_2 Targets

We are modifying the pneumatic air supply systems to better service the LH_2 Target systems at both E866 and E831. The modified systems include new air compressors and some new valves and instrumentation. The air system service has been expanded to include supplying the Vent Valve actuators (at E866: PV-H2VV and PV-D2VV; and at E831: PV-H2VV). Experience has shown that, during operation of the Vent Valves, the actuator temperature is not significantly reduced and thus does not require helium as its supply gas.

The air system operates below 150 psig, thus no part of the circuit includes pressure piping. The air tank is considered a pressure vessel, therefore the required documentation is provided for this vessel. Additionally, updated Flow Diagrams and Valve and Instrument Lists are provided.

The modifications to these air systems in no way threaten either the safety or operational integrity of the targets. The updated documentation is provided for your knowledge.

L

From: RDIV::SMART "Wesley M. Smart, smart@fnal.gov" 26-SEP-1996 20:54:4♦
To: ELLERMEIER,FNAL::TOMMY,FNAL::SARLINA,ALLSPACH,BALLER,FNAL::KILMER,PEIFER♦
CC: SMART
Subj: H2 Target Panel MInutes Sept. 26, 1996

3:00-3:30 PM Sept 26, 96

LIQUID HYDROGEN TARGET SAFETY REVIEW PANEL
Minutes

Present: Panel: Jim Ellermeier, Wes Smart
Thermal Systems Group: Del Allspach, Jim Peifer

Subject: E-866 Liquid H2/D2 Targets: New Tent Access Procedures

Del and Jim have submitted two new E-866 tent access procedures for approval; Expander Work (Sept. 25) and Repairing/replacing Instrumentation (Sept. 26). These both differ from the Refrigerator Tuning procedures we approved on July 26 in two respects:

1. Tools, but only those specifically needed for the job, are allowed to be brought into the tent. They must be accounted for when leaving the tent.

2. Walkie-talkies are allowed inside the tent. Del certified that the walkie-talkies the target group owns and will use are approved for class 1, division 1 service.

These two changes are acceptable to the panel, and the "Procedure for Access to the E866 Tent for Repairing/replacing Instrumentation" D. Allspach, J. Peifer/ September 26, 1996 was approved by the panel.

The Expander Work procedure was unclear on the role of the second person making the ME6 beamhall access. Del explained it would either be an operator or a second target expert. They would either remain just outside the tent or, if it was a target expert, could enter the tent and assist with the expander work. In either case this second person would be responsible for maintaining communication with the operator outside the beamhall at the target control area. This was acceptable to the panel, but we asked Del to make this role of the second person clear in the written procedure before we signed it.

Wesley M. Smart

L

From: RDIV::ALLSPACH 26-SEP-1996 08:35:39.45
To: SMART,ELLERMEIER,FNAL::TOMMY
CC: PEIFER,ALLSPACH
Subj: the expander work procedure

Hello, I am writing in response to the letter from Wes. I hope that my comments/explanations can be helpful. I am aware that there is not much time before the shutdown. Also, I am available to meet if this would be helpful.

(1) Subject: Tools; No comment.

(2) Subject: Walkie-talkies; Since the time the first 866 tent access procedure was written, I have come to the realization that the walkie-talkies the LH2 Target group has purchased for its use are approved for a class 1 div 1 area. Thus, there is not a reason they cannot be carried into the tent. I see no reason to revise the first procedure as tuning a refrigerator would never require more than one person in the tent to do the job.

(3) Subject:
The two man rule and communication; First, I would like to clarify a sentence in the procedure. The sentence, "Communication will occur between an operator or another target expert." refers to the second person entering the ME6 beamhall. A second person in this procedure is required (1) to meet controlled access rules, (2) to provide a means of communications without burdening the primary person carrying out the task inside the tent, and (3) perhaps assist the person inside the tent. Let me explain #3. Since the sentence says "operator or another target expert" we need to choose another target expert as the second person if the expander work requires two people in the tent. If only one person is required in the tent, the second person remains in the ME6 beamhall outside the tent and thus can be an operator.

Let me know if there are further questions.

Thanks, Del

L

From: RDIV::SMART "Wesley M. Smart, smart@fnal.gov" 25-SEP-1996 21:24:3♦
To: ELLERMEIER,FNAL::TOMMY,ALLSPACH
CC: SMART
Subj: New E866 Tent Access Procedure

25 Sept 96

Dear Jim and Tom;

Del Allspach has sent me a "Procedure for access to the E866 tent for expander work" for approval. He hopes to use it during a scheduled shutdown next week. It is similar to the procedure for E866 refrigerator tuning we approved last July, but has the following differences:

1. Tools, for the expander job only, are allowed in the tent. They must be accounted for when leaving the tent.

2. The sentence "No walkie-talkies may be taken into the tent" does not appear in this new procedure.

3. A controlled access to the ME6 beam hall requires two people. The July procedure required the second person to be an operator or a second target expert who would remain outside the tent and communicate between the expert in the tent and the operator at the target controls. The new procedure says nothing about who the second person is, where he goes, or what he does. (Both procedures state that only target experts are allowed inside the tent when a target is full.)

Copies of the new procedure for each of you are on top of the bookcase just on your left when you enter my office on 9W.

A copy of the July 25, 96 procedure should be in your E866 target book (section J). Please consider the above changes and let me know if you are willing to approve them or if we should meet with Del to discuss the procedure.

Thanks,
Wes

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I held a 30 minute safety meeting with the E-866 experimenters. At this meeting I explained the operation of their hydrogen target system and answered any question they asked. I also explained the safety rules and how they should react to a unscheduled release of hydrogen gas from the target.
The people who attended are listed on the attached sign in sheet.

9/4/96

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E-866 H2 Target Safety Talk

Date 9/4/96

Name	Badge #	Signature
Chuck Brown	2493	
TOM CAREY	V04178	
Paul Stankus	V03309	
Patrick McGaughey	V4177	
DAVID M. LEE	V08057	
Mike Leitch	V4156	
Donald D. Koetke	V5380	

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From: RDIV::ALLSPACH 9-AUG-1996 08:19:06.28
To: ELLERMEIER,FNAL::TOMMY,FNAL::SMART
CC: PEIFER,FNAL::RLS,RSTANEK,FNAL::KILMER,ALLSPACH
Subj: E866 Target system ventilation

The Target Tent exhaust system ducting at the outlet of the blower has been modified. The exhaust flowrate now exceeds 1250 cfm air. This satisfies and exceeds the required tent exhaust rate and the qualification for approval to operate the E866 target system is met.

- Del Allspach

From: Roger Dixon (8/2/96) Tom Peterson (8/2/96)
To: Tom Peterson
CC: Del Allspach, Bruce Baller, Jim Ellermeier, Bill Freeman, Jim Kilmer, Jim Peifer, TJ Sarlina, Rich S
BCC:
Priority: Normal
Date sent: 8/2/96 2:17 PM

Reply to: RE>E-866 H2 and D2 Targets

Operation of the E-866 liquid hydrogen and liquid deuterium targets is hereby approved subject to the qualification outlined below.

Roger L. Dixon

Date: 8/2/96 2:07 PM
To: Roger Dixon
From: Tom Peterson

To: Roger Dixon, Research Division Head
From: Tom Peterson, Liquid Hydrogen Target Safety Review Panel
Subject: Qualified Recommendation to Approve Operation of the E-866 H2 and D2 Targets

Based on our review of the documentation received from Del Allspach and Jim Peifer and our walkthrough of the target area on August 1, 1996, we recommend that you approve the E-866 liquid hydrogen and liquid deuterium targets for operation WITH ONE QUALIFICATION, which follows:
the volumetric flow of the tent exhaust vent fan should first be measured to be at least 1000 cfm air, equal to the maximum estimated hydrogen or deuterium volumetric venting rate. Some new measurements and/or modifications of the vent system may be required to satisfy this requirement.
Once Del Allspach is convinced that he has this exhaust flow rate from the tent, the Panel believes that operations may safely commence. There is no need to seek further approval from the H2 Target Panel for this system startup unless this venting requirement cannot be achieved.

cc:
D. Allspach
J. Ellermeier
J. Kilmer
J. Peifer
T. J. Sarlina
W. Smart
R. Stanek

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From: RDIV::SMART "Wesley M. Smart, smart@fnal.gov" 26-JUL-1996 20:28:5♦
To: ELLERMEIER,FNAL::TOMMY,FNAL::SARLINA,ALLSPACH,BALLER,FNAL::KILMER,PEIFER♦
CC: SMART
Subj: H2 Target Panel Minutes July 22 & 26, 1996

1:30-2:30 PM July 22, 96

LIQUID HYDROGEN TARGET SAFETY REVIEW PANEL
Minutes

Present: Panel: Jim Ellermeier, Tom Peterson, T.J. Sarlina, Wes Smart
Thermal Systems Group: Del Allspach, Jim Peifer

Subject: E-866 Liquid H2/D2 Targets: Walkthrough of Area

We viewed the target for E-866 in the ME6 Beamhall. While much of the installation is done, the job was not far enough along for us to complete our review and make a recommendation on operation. Another walkthrough will be scheduled (now planned for July 30) when installation is complete.

The following items were noted and will be checked during the next walkthrough:

1. Some valve tags missing on the refrigerators
2. Barriers to be installed to keep vehicles away from the H2 and D2 gas bottle area just outside the SE Meson Hall door.
3. Safety restraints are needed when working on top of the shielding blocks.

2:00-3:20 PM July 26, 96

LIQUID HYDROGEN TARGET SAFETY REVIEW PANEL
Minutes

Present: Panel: Jim Ellermeier, Tom Peterson, Wes Smart

Subject: E-866 Liquid H2/D2 Targets: Review of Documentation and Plans for Final Walkthrough

All required documentation has been received and it looks very good. Two minor errors will be pointed out to Del. The July 25, 1996 Procedure for Access to the E866 Tent for Refrigerator Tuning was reviewed and approved by the Panel. This procedure is very similar to the one used for E683 during the 1991 fixed target run.

The E-866 Piping and Instrumentation Diagram shows shutoff valves and no relief valve in the helium piping to each refrigerator. Unless there is a relief valve built into the refrigerator, but not shown on the P&I Diagram, each such cryogenic trapped volume will require the addition of a relief valve.

I will be away from the lab July 27 through August 12. We agreed the other members of the panel, with Tom Peterson as acting chairman could make the recommendation to operate E-866. However when Tom is also away from the lab (August 3 to 11), the remaining panel members would not make a major recommendation such as this.

Wesley M. Smart

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From: RDIV::ALLSPACH 25-JUL-1996 15:59:41.75
To: FNAL::SMART
CC: PEIFER,ALLSPACH
Subj: 866 safety approval

Wes,

(1) We will not be ready for a walkthru tomorrow. We will most likely be ready Monday or Tuesday. I will coordinate a time with Jim or Tom. If you have any comments on safety documents, please leave them with me, either directly or via another safety panel member. I will not likely be at the lab tomorrow afternoon.

(2) We will be installing intrinsically safe zenar diode barriers manufactured for switches. These are for the four switches installed by the experiment for detecting target table position. This is acceptable for class 1 Div II requirements in the tent.

(3) I am leaving addtional safety documents in your office.

- Del and Jim

FERMILAB ENGINEERING NOTE | E866 | L

SUBJECT: Safety Documentation

NAME: Del Allspach

DATE: 7-16-96

REVISION DATE:

To: Wes Smart, Safety Panel Chairman.

From: Del Allspach, Jim Peifer

Wes, Included are the following safety documents.

1) E866 ODH Analysis

2) Tent Documentation

   (a) Target Table Support Analysis

   (b) Wall Support Bracket Load Test Report

   (c) Target Tent Analysis

   (d) Tent Beam Window

I will be working on Procedures and the What-if analysis to complete the documentation. A pressure test of the helium supply piping remains to be completed as well.

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From: RDIV::SMART "Wesley M. Smart, smart@fnal.gov" 11-JUL-1996 21:18:5◆
To: ELLERMEIER,FNAL::TOMMY,FNAL::SARLINA,ALLSPACH,BALLER,FNAL::KILMER,PEIFER◆
CC: SMART
Subj: LH2 Target Panel Minutes July 11, 1996

1:30-2:30 PM July 11, 96

LIQUID HYDROGEN TARGET SAFETY REVIEW PANEL

Present: Panel: Jim Ellermeier, Tom Peterson, Wes Smart
Thermal Systems Group: Del Allspach, Jim Peifer

Subject: Installation and Review Status of E-866 Liquid H2/D2 Target

We met with Del Allspach and Jim Peifer to discuss the progress and schedule of the E-866 target installation and review. It has been requested that this target be ready to run by July 24.

The target is being installed at meson lab now, and Del expects this to be complete Friday July 19. Del provided a partial target book on July 3, which still requires several documents including:

- Operating Procedures
- Emergency Procedures
- What-If Analysis
- ODH Analysis
- Tent Conditions for Entry

Del will provide these as soon as he can, but is frequently being assigned other jobs during this experimental area startup period.

Del and Jim Peifer indicated they plan to use 1 mil Aluminum for the downstream tent beam exit window. This choice is acceptable to the panel.

A walkthrough of the E-866 is scheduled for Monday July 22. We will meet at the Ops. Center at 1:30 PM. Film badges and dosimeters are required for everyone. Jim Peifer plans to bring some extra dosimeters.

Wesley M. Smart

Fermilab

RD/Mechanical Support Department--MS#219
Wilson Hall 11th Floor--Ext. 3519

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July 3, 1996

TO: Del Allspach

FROM: Rich Stanek *Rich Stanek*

SUBJECT: Approval for Installation of the E866 Hydrogen Target

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Both Jim Peifer and yourself have informed me that the testing of the E866 hydrogen target system at Lab 3 was successful. I understand this to mean that the refrigerators were run and that some amount of liquid hydrogen was accumulated (targets did not need to be filled). The control system is also functional although not in its final state. Under these conditions, I approve the next stage of the project, namely installation of the target system in ME6. Please proceed with this work in the most expeditious manner.

Fermilab

February 19, 1996

TO: Rich Stanek, MSD Department Head
FROM: Del Allspach, Jim Peifer
SUBJECT: E866 LH_2 Target System Testing Request

This is to request permission to test the liquid hydrogen target system at Lab 3. The safety documentation for the design of the target has been approved (see attached memo). The approved documents supporting the target design are listed below:

DESIGN CALCULATIONS:		
(1)	E-866 Stainless Steel Flask Stress Calculations	Oct. 17, '95
(2)	Stainless Steel Flask Relief Sizing	Feb. 16, '95
(3)	Vacuum Jacket Stresses	Mar. 6, '95
(4)	Titanium Window Stress	Feb. 14, '95
(5)	Vacuum Jacket Volume	Nov. 13, '95
(6)	Vacuum Jacket Relief	Dec. 21, '94
TESTING RESULTS:		
(1)	Stainless Steel Joint Testing	Oct. 11, '95
(2)	Flask Pressure Testing Results	Nov. 30, '95
(3)	Titanium Window Testing Results	Oct. 18, '95
(4)	Pneumatic Vent Valve Leak Testing	Oct. 19, '95

The volume of the target is 2.2 liters. Before testing with hydrogen we will prepare the vacuum system and run a refrigerator capacity test with the Lab 3 compressor configuration. Our testing is expected to be completed within one normal working day ± a couple of hours. We want to primarily see that (1) the temperature control is acceptable, (2) interlocks to operate the heater behave correctly and (3) the vent valve operation is OK. The following safety precautions will be in place:

(1) Target will be placed inside the approved target testing tent
(2) Tent fan will run continuously
(3) Flammable gas detector will be operational inside the tent
(4) Target vent valve exhaust will be routed with hosing to a point above the refrigerators
(5) Testing area will be roped off
(6) Warning signs of *Hydrogen* and *No Ignition Sources* will be in place
(7) Our blue flashing light will be in operation
(8) Trained operators will be present while liquid hydrogen is present

I approve test operation of the E866 LH_2 target at Lab 3.
Rich Stanek 6/10/96

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Fermilab

19 Dec. 95

To: Del Allspach, RD/Cryo
From: Wes Smart, LH2 Target Safety Panel Chairman *Wes Smart*
Subject: E866 LH2 Target Design Approval

The panel meet on December 13, 1995 to discuss the E866 LH2 target flask design, drawing 9205.100-MD-58635 "E-866 Target Cross Section", and the six design calculations you submitted on December 1, 1995:

(1) E-866 Stainless Steel Flask Stress Calculations	Oct. 17, 95
(2) Stainless Steel Flask Relief Sizing	Feb. 16, 95
(3) Vacuum Jacket Stresses	Mar. 6, 95
(4) Titanium Window Stress	Feb. 14, 95
(5) Vacuum Jacket Volume	Nov. 13, 95
(6) Vacuum Jacket Relief	Dec. 21, 94

The Panel approved all the above documentation and the design of the E866 target flask. As you recall the design of the E866 vacuum jacket was approved by the panel at our February 17, 1995 meeting.

This memo documents the acceptance of the E866 LH2 target design by the LH2 Target Safety Panel, which is required by section IV.C. of the Guidelines for the Design, Fabrication, Testing, and Installation and Operation of LH2 Targets.

xc:
B. Baller
J. Ellermeier
J. Peifer
T. Peterson
R. Stanek

L

Fermilab

19 Dec. 95

To: Del Allspach, RD/Cryo
From: Wes Smart, LH2 Target Safety Panel Chairman *Wes Smart*
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xc:
B. Baller
J. Ellermeier
J. Peifer
T. Peterson
R. Stanek

CALL-IN LIST

July 3, 1996

The Fixed Target Physics Run beginning in 1996 will have two liquid hydrogen target systems in operation, E-831 and E-866. In order to maintain the safe and efficient operation of these targets, as well as other cryogenic systems, the RD Operations Department (OD) will provide 24 hour monitoring through its operating crew. With regard to the specifics of the liquid hydrogen targets, the operations crew members will be given introductory training on the operation of the systems along with a clear set of limits which define normal operating conditions. Additional training for the OD operators will be of both the formal and "on-the-job" variety. The safety manuals, which include operating procedures and flow schematics, will be available to aid them in learning about the systems. When a serious problem arises, the operating crew will have to contact a "hydrogen target expert" via a long range paging system. This on-call status will rotate among the people who have designed, fabricated, installed or operated hydrogen targets in the past and will assure that in the event of a system upset, a knowledgeable person will be contacted. At this time, the list of "hydrogen target system experts" is as follows:

Del Allspach
Joe Davids
Mike McKenna
Jim Peifer
Rich Schmitt (not included in the call-in rotation)

NOTE: The RD/MSD may add names to this list as additional training takes place and operational experience increases.