FESHM 5031.1 PIPING ENGINEERING NOTE FORM

Prepared by: Terry Tope and Herman Cease Preparation Date: 7.31.08

Piping System Title: DES Lab A LN2 Test Piping System

Lab Location: Lab A Lab Location code:

Purpose of system / System description: Pump liquid nitrogen thru a cooling loop.

Piping System ID Number:

Appropriate governing piping code: B31.3

Fluid Service Category (if B31.3): Category-D / Normal / Category-M / High Pressure (circle one)

Fluid Contents: liquid nitrogen

Design Pressure: 150 psig max Design Temperature: 77 K

Piping Materials: 304/304L & 316/316L stainless steels

Drawing Numbers (PID's, weldments, etc.): 4900.000-ME-436389

Designer/Manufacturer: Herman Cease/PPD/MD

Test Pressure: 165 psig Test Fluid: nitrogen gas Test Date:

Statements of Compliance

Piping system conforms to FESHM 5031.1, installation ***is not*** exceptional: Yes / No

Piping system conforms to FESHM 5031.1, installation ***is*** exceptional and has been designed, fabricated, inspected, and tested using sound engineering principles: Yes / No

Reviewer's Signature: ______________________ Date: ____________

D/S Head's Signature: ______________________ Date: ____________

ES&H Director's Signature: ______________________ Date: ____________
(if exceptional)

Director's Signature or Designee: ______________________ Date: ____________
(if exceptional)

Pipe Characteristics

Size: 1" pipe, ¾" tube, ¾" pipe   Length: ~ 100 ft.   Volume: < 0.5 ft^3

Relief Valve Information

Type: spring loaded   Manufacturer: Circle Seal

Set Pressure: 150 psig   Relief Capacity: 400 SCFM

Relief Design Code: BPV Code, Section VIII, Division 1

Is the system designed to meet the identified governing code? (Yes) / No

Fabrication Quality Verification

System Documentation

Process and Instrumentation diagram appended? (Yes) / No

Process and Instrumentation component list appended? (Yes) / No

Is an operating procedure necessary for safe operation? Yes / (No)
If 'yes', procedure must be appended.

Exceptional Piping System

Is the piping system or any part of it in the above category? Yes / (No)
If "Yes", follow the requirements for an extended engineering note for Exceptional Piping Systems.

Quality Assurance

List vendor(s) for assemblies welded/brazed off site: N/A

List welder(s) for assemblies welded/brazed in-house: Welding: Leonard Harbacek.
Brazing: N/A

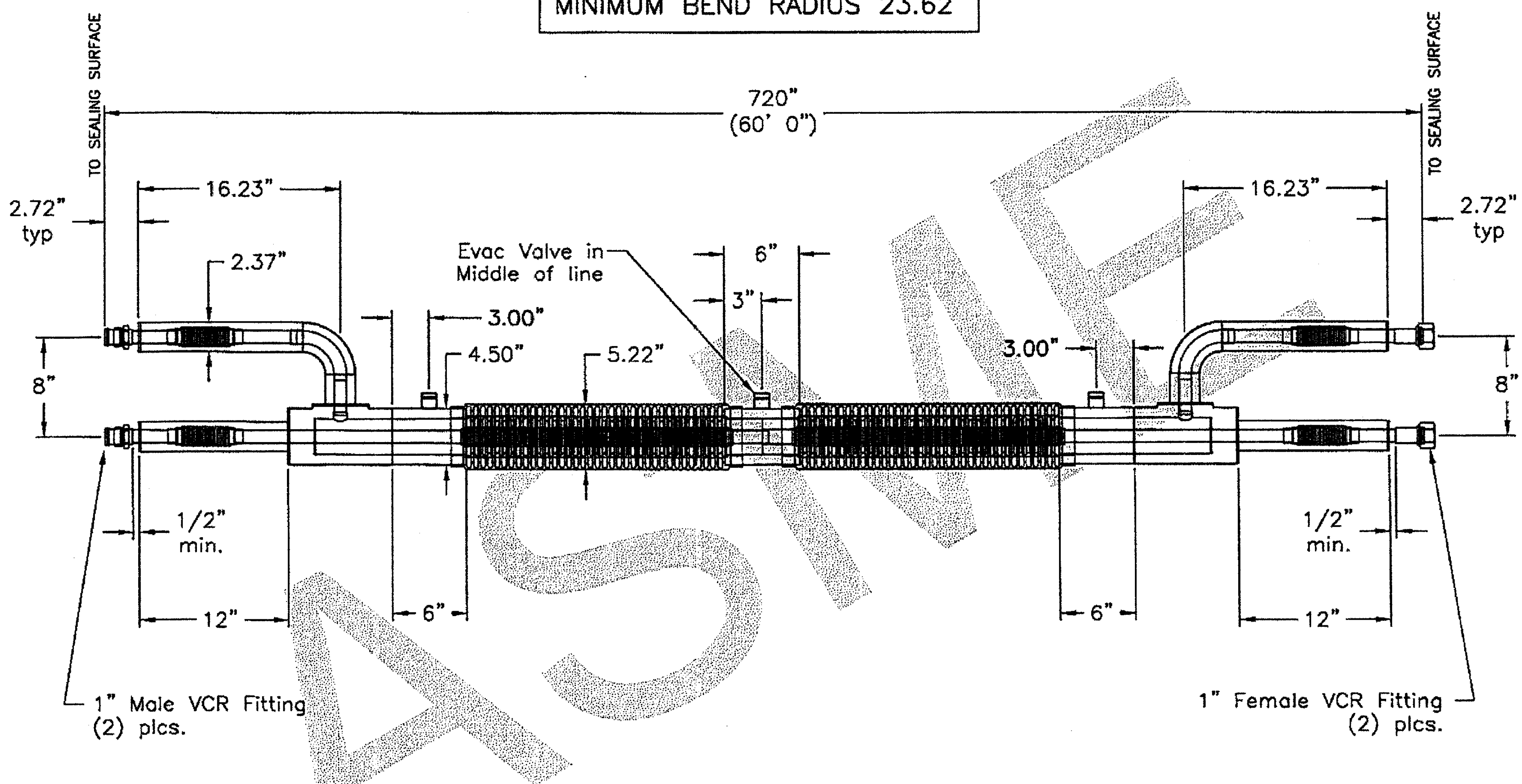
Append welder qualification records for in-house welded/brazed assemblies.

See attached document entitled "DES Lab A LN2 Test Piping System Engineering Note."

Append all quality verification records required by the identified code (e.g. examiner's certification, inspector's certification, test records, etc.)

See attached document entitled "DES Lab A LN2 Test Piping System Engineering Note."

MAWP
150 psi



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	INITIALS	DATE
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ENG		
PROD		

Drawing #:

Part #: D010TVJAVCR-720

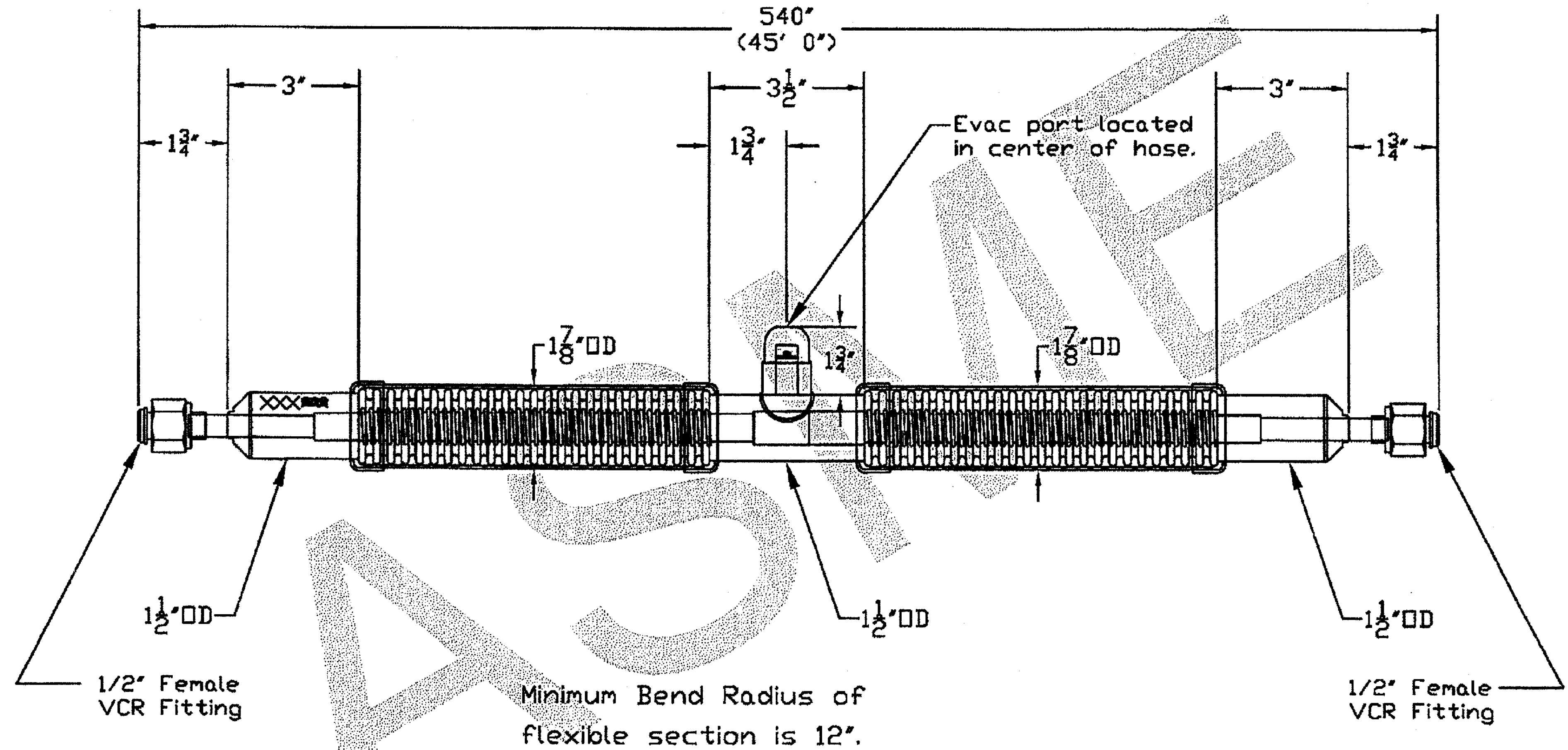
Cryogen: LN2

** NOT FOR USE WITH LIQUID OXYGEN **

REVISION B

DATE

MAWP
200 psi



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DO NOT SCALE DRAWING DIMENSIONS IN INCHES		
	INITIALS	DATE
CAD	LRobison	8/16/07
ENG		
PROD		

Drawing #:	REVISION
Part #: D005BVJPSVCR-540	DATE
Cryogen: LN2	
** NOT FOR USE WITH LIQUID OXYGEN **	

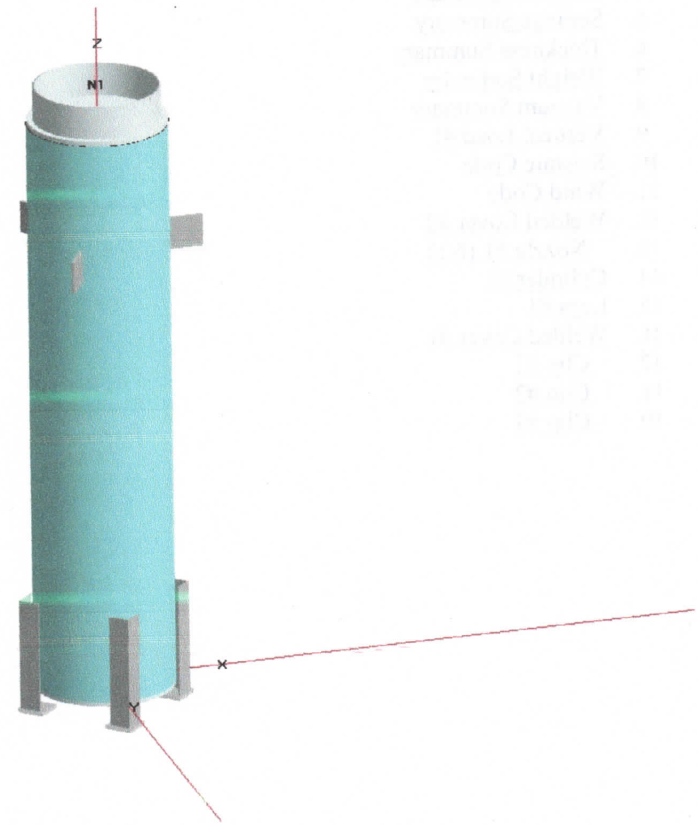
DE Camera Liquid Nitrogen System Valve and Instrument List

Tag	Name	Fluid	Size	Description	Range / Set Point	Manufacturer	Model Number	Psig max	Signal	Excitation	Notes	PLC
SC	6104			Speed Control for LN pump	230VAC	Barber Nichols	VF-S11-2004-PM-WN	external				output
VV	6105	V	1"	Vacuum pump out port		ACME Cryo	93-2542-02431	~atm			CVI V 1046 pump out	
SV	6200	LN2	3/4" MNPT	Fill port, trapped volume relief	-320 F to 400F	Circle Seal	K5120B-6M-150	3600			150 PSIG set point	
FI-MV	6201	N2	1/8" NPT	Fill Port, Manual shutoff valve	0-20scfh	Dwyer	RMA	100			Valve is part of flow meter	
PRV	6202	N2	1/4" NPT	Instrument Line, Boil-Off Regulator	75-175 psig	Cash-Acme	1/4" FRM 100 psi	600			use inlet coil to warm gas before relief	
MV	6204	LN2	1/2" FNPT	Fill Port,		Rego	T9454	600			cryo-short stem valve	
MV	6205	LN2	1/2" FNPT	Drain Port, Manual Shutoff Valve		Rego	T9454	600			cryo-short stem valve	
PI	6206	LN2	1/4" NPT	Drain Port, Pressure Indicator	0-200 psig	US Gage	47101	250+			2" Dial Size, use inlet coil to warm gas	
LT	6207	LN2	1/4" NPT	Level Transmitter	0-100%	Teragon	LP7	500	4-20 mA	24 VDC		input
MV	6208	LN2	1/2" FNPT	Fill Try Cock, Manual valve		Rego	T9454	600			cryo-short stem valve	
PI	6209	N2	1/4" NPT	200L reservoir Pressure Indicator	0-200 psig	US Gage	47101	250+			2" Dial Size	
TE	6210	N2		Temperature Element, Condenser Temperature	-452 to 500 deg F	Omega	SA1-RTD-B	no diff. pres	RTD		100 Ohm 3-wire RTD, surface mount	input
TE	6211	N2		Temperature element, Top Reservoir Gas Temperature	-452 to 500 deg F	Omega	SA1-RTD-B	no diff. pres	RTD		100 Ohm 3-wire RTD, surface mount	input
SV	6213	LN2	1 1/2" NPT	Reservoir Positive pressure main relief	150 psig	Anderson Greenwood	81BF1216-G- 150 psig	500			ASME code stamp	
RD	6214	LN2	2" NPT	Reservoir Positive pressure 2nd main relief	165 psig	FIKE	2" SRL Flange Rupture Disk SS	165			ASME code stamp	
PT	6215	N2	1/4" NPT	Pressure Transmitter, Vessel pressure	0-200 psia	NOSHOK	615-200-1-1-2-6	200	4-20 mA			
MV	6216	N2	1/4" weld	Instrument Isolation Valve		Swagelok	SS-4BK-TW	1000				
F	6217	N2	1/4" VCR	Instrument Regulator In line Filter		Nupro	FW	6000				
SV	6218	N2	1/4" MNPT	Instrument line trapped volume	100 psig	Circle Seal	5123B-2MP-100	3600				
FT	6301	LN2	3/4" AN-flare	Supply line, Flow Transmitter	0.75 to 5 gpm	Sponsler	SP3/8-CB-NL-B-4	600+	4-20 mA			input
MV	6302	LN2	1" NPT	Supply Line manual valve		Mcmaster/Goddard	49415K34	600			-325F to 100F Long stem globe valve	
MV	6303	LN2	1" NPT	Return Line, Manual valve near reservoir		Mcmaster/Goddard	49415K34	600			-325F to 100F Long stem globe valve	
SV	6304	LN2	3/4" MNPT	Return line, trapped volume relief near reservoir	-320 F to 400F	Circle Seal	K5120B-6M-150	3600			150 PSIG set point	
PI	6305	LN2	1/4" NPT	Supply line pressure indicator near reservoir	0-200 psig	US Gage	47101	250+			2" Dial Size, use inlet coil to warm gas	
SV	6306	LN2	3/4" MNPT	Supply line trapped volume relief near reservoir	-320 F to 400F	Circle Seal	K5120B-6M-150	3600			150 PSIG set point	
MV	6307	LN2	1/2" FNPT	Return Line port		Rego	T9454	600			cryo-short stem valve	
MV	6310	LN2	3/4" Class 150 Flange	Manual Control Valve, bypass near reservoir	60 degree	Worcester	C5166PM150-A60	Class 150			Manual cryo control valve	
SV	6311	LN2	3/4" MNPT	Supply line trapped volume relief reservoir check valve	-320 F to 400F	Circle Seal	K5120B-6M-150	3600			150 PSIG set point	
CV	6312	LN2	1" NPT	Check valve supply line	Swing Lift	Powell	CL#200	class 200				

PHPK Technologies

2111 Builders Place

Columbus, Ohio 43204



COMPRESS Pressure Vessel Design Calculations

Item:	DES Vessel Vacuum Jacket
Revision	A
Customer:	Fermi National Accelerator Laboratory
Diameter/Thk	20" Std Wt Pipe (.375" Wall)
Design Pressure	Full Vacuum / 3 psig
Revision Date	July 30, 2007

Table Of Contents

Engineering Notes

The support legs analyzed in these calculations vary somewhat from the actual design which is shown on drawing 07-1963-0500. This software uses standard pre-designed configurations for vessel legs, skirts, saddles, lugs, etc. that are widely accepted in the pressure vessel industry and the ASME pressure vessel code. When particular support requirements are invoked that vary from these, such as the case in this vessel, the supports are analyzed as close as possible with conservative judgement. In this case the support design is conservative due to the fact that the actual legs do not extend below the bottom of the vessel. In addition, the rectangular tube (fork lift staves) provide increased rigidity due to the integral attachment to the vessel, the legs and the floor (or base). Also, we have incorporated cap plates on the top of the legs which are welded all around. This practice has been proven to enhance the strength of open structures and provides for more uniformly distributed stresses into the vessel wall.

Nozzle Schedule

Nozzle mark	Service	Size	Materials								
			Nozzle	Impact	Norm	Fine Grain	Pad	Impact	Norm	Fine Grain	Flange
N1	Nozzle #1	18" Std Weight	SA-312 TP304 Wld pipe	No	No	No	N/A	N/A	N/A	N/A	N/A

Nozzle Summary

Nozzle mark	OD (in)	t_n (in)	Req t_n (in)	A_1?	A_2?	Shell			Reinforcement Pad		Corr (in)	A_a/A_r (%)
						Nom t (in)	Design t (in)	User t (in)	Width (in)	t_{pad} (in)		
N1	18.00	0.3750	0.3750	Yes	Yes	0.7500*	0.5480		N/A	N/A	0.0000	100.0

t_n: Nozzle thickness

Req t_n: Nozzle thickness required per UG-45/UG-16

Nom t: Vessel wall thickness

Design t: Required vessel wall thickness due to pressure + corrosion allowance per UG-37

User t: Local vessel wall thickness (near opening)

A_a: Area available per UG-37, governing condition

A_r: Area required per UG-37, governing condition

Corr: Corrosion allowance on nozzle wall

*: Head minimum thickness after forming

Pressure Summary

Pressure Summary for Chamber bounded by Welded Cover #1 and Welded Cover #2

Identifier	P Design (psi)	T Design (°F)	MAWP (psi)	MAP (psi)	MAEP (psi)	T_e external (°F)	MDMT (°F)	MDMT Exemption	Total Corrosion Allowance (in)	Impact Test
Welded Cover #2	3.0	120.0	92.00	92.00	92.00	120.0	-320.0	Note 1	0.000	No
Cylinder #1	3.0	120.0	485.43	485.43	175.22	120.0	-155.0	Note 2	0.000	No
Welded Cover #1	3.0	120.0	53.03	53.03	53.03	120.0	-155.0	Note 3	0.000	No
Legs #1	3.0	120.0	3.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Clip #1	3.0	120.0	3.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Clip #2	3.0	120.0	3.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Clip #3	3.0	120.0	3.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nozzle #1 (N1)	3.0	120.0	49.60	49.60	49.12	120.0	-320.0	Note 4	0.000	No

Chamber design MDMT is -20.00°F
Chamber rated MDMT is -155.00°F @ 3.00 psi

Chamber MAWP hot & corroded is 3.00 psi @ 120.0°F

Chamber MAP cold & new is 49.60 psi @ 70.0°F

Chamber MAEP is 49.12 psi @ 120.0°F
Vacuum rings did not govern the external pressure rating.

Notes for MDMT Rating:

Note #	Exemption	Details
1.	Impact test exempt per UHA-51(g)(coincident ratio = 0.03261)	
2.	Material is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.00626)	
3.	Head is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.05658).	
4.	Impact test exempt per UHA-51(g)(coincident ratio = 0.00464)	

Design notes are available on the Settings Summary page.

Settings Summary

COMPRESS Build 6252

Units: U.S. Customary

Datum Line Location: 0.00" from bottom seam

Design

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Design or Rating:	Get Thickness from Pressure
Minimum thickness:	1/16" per UG-16(b)
Design for cold shut down only:	No
Design for lethal service (full radiography required):	No
Design nozzles for:	Design P, find nozzle MAWP and MAP
Corrosion weight loss:	100% of theoretical loss
UG-23 Stress Increase:	1.20
Skirt/legs stress increase:	1.0
Minimum nozzle projection:	1.5000"
Juncture calculations for $\alpha > 30$ only:	Yes
Preheat P-No 1 Materials > 1.25" and <= 1.50" thick:	No

Butt welds are tapered per Figure UCS-66.3(a).

Hydro/Pneumatic Test

Shop Hydrotest Pressure:	1.3 times vessel MAWP
Test liquid specific gravity:	1.00
Maximum stress during test:	90% of yield

Required Marking - UG-116

UG-116 (e) Radiography:	None
UG-116 (f) Postweld heat treatment:	None

Code Interpretations

Use Code Case 2547:	No
Apply interpretation VIII-1-83-66:	Yes
Apply interpretation VIII-1-86-175:	Yes
Apply interpretation VIII-1-83-115:	Yes
Apply interpretation VIII-1-01-37:	Yes
Disallow UG-20(f) exemptions:	No

UG-22 Loadings

UG-22 (a) Internal or External Design Pressure :	Yes
UG-22 (b) Weight of the vessel and normal contents under operating or test conditions:	Yes

UG-22 (c) Superimposed static reactions from weight of attached equipment (external loads):	Yes
UG-22 (d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs:	Yes
UG-22 (f) Wind reactions:	Yes
UG-22 (f) Seismic reactions:	Yes

Note: UG-22 (b),(c) and (f) loads only considered when supports are present.

Thickness Summary

Component Identifier	Material	Diameter (in)	Length (in)	Nominal t (in)	Design t (in)	Joint E	Load
Welded Cover #2	SA-240 304	0.00 ID	0.75	0.7500*	0.3028	1.0000	External
Cylinder #1	SA-53 E/B Wld pipe	20.00 OD	90.00	0.3750	0.1200	1.0000	External
Welded Cover #1	SA-36	0.00 ID	0.63	0.6250*	0.3324	1.0000	External

Nominal t: Vessel wall nominal thickness

Design t: Required vessel thickness due to governing loading + corrosion

Joint E: Longitudinal seam joint efficiency

* Head minimum thickness after forming

Load

internal: Circumferential stress due to internal pressure governs

external: External pressure governs

Wind: Combined longitudinal stress of pressure + weight + wind governs

Seismic: Combined longitudinal stress of pressure + weight + seismic governs

Weight Summary

Component	Weight (lb) Contributed by Vessel Elements						
	Metal New*	Metal Corroded*	Insulation & Supports	Lining	Piping + Liquid	Operating Liquid	Test Liquid
Welded Cover #2	7.95	7.95	0.00	0.00	0.00	0.00	44.29
Cylinder #1	588.87	588.87	0.00	0.00	0.00	0.00	945.51
Welded Cover #1	51.48	51.48	0.00	0.00	0.00	0.00	0.00
Legs #1	39.53	39.53	0.00	0.00	0.00	0.00	0.00
TOTAL:	**687.83**	**687.83**	**0.00**	**0.00**	**0.00**	**0.00**	**989.80**

* Shells with attached nozzles have weight reduced by material cut out for opening.

Component	Weight (lb) Contributed by Attachments								
	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays & Supports	Rings & Clips	Vertical Loads
	New	Corroded	New	Corroded					
Welded Cover #2	0.00	0.00	36.13	36.13	0.00	0.00	0.00	0.00	0.00
Cylinder #1	0.00	0.00	18.06	18.06	0.00	0.00	0.00	10.61	1,095.00*
Welded Cover #1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Legs #1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL:	**0.00**	**0.00**	**54.19**	**54.19**	**0.00**	**0.00**	**0.00**	**10.61**	**1,095.00***

* This number includes vertical loads which are not present in all conditions.

Vessel operating weight, Corroded: 1,848 lb
Vessel operating weight, New: 1,848 lb
Vessel empty weight, Corroded: 1,848 lb
Vessel empty weight, New: 1,848 lb
Vessel test weight, New: 1,742 lb

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New: 753 lb
Center of Gravity: 43.96"

Vessel Capacity

Vessel Capacity** (New): 113 US gal
Vessel Capacity** (Corroded): 113 US gal
**The vessel capacity does not include volume of nozzle, piping or other attachments.

Vacuum Summary

Component	Line of Support	Elevation above Datum (in)	Length Le (in)
Welded Cover #2	-	90.75	N/A
-	1/3 depth of Welded Cover #2	90.00	N/A
Cylinder #1 Top	-	90.00	90.00
Cylinder #1 Bottom	-	0.00	90.00
-	1/3 depth of Welded Cover #1	0.00	N/A
Welded Cover #1	-	-0.63	N/A

Note
For main components, the listed value of 'Le' is the largest unsupported length for the component.

Vertical Load #1

Load Orientation:	Vertical Load
Elevation above datum:	45.00"
Direction angle:	0.00 degrees
Distance from center of vessel:	0.00"
Magnitude of force:	1095.00 lb

Present when operating:	Yes
Included in vessel lift weight:	No
Present when vessel is empty:	Yes
Present during hydrotest:	No

Seismic Code

Method of seismic analysis: **UBC 1997 building mounted**
Seismic Zone: 4
R_p Factor (Table 16-O): $R_p = 3.0000$
Soil profile: (Table 16-Q): SD
Importance Factor: $I_p = 1.0000$
Near Source Factor (Table 16-S): Na = 1.0000
Component Amplification Factor: $a_p = 1.0000$
x/h Ratio 1.0000
Vertical Accelerations Considered: Yes
Force Multiplier: = 0.3333
Minimum Weight Multiplier: = 0.6500

Vessel Characteristics

Vessel height: 7.8958 ft
Vessel Weight:
Operating, Corroded: 1,848 lb
Empty, Corroded: 1,848 lb
Vacuum, Corroded: 1,848 lb

Period of Vibration Calculation

Fundamental Period, T:
Operating, Corroded: 0.016 sec (f = 62.6 Hz)
Empty, Corroded: 0.016 sec (f = 62.9 Hz)
Vacuum, Corroded: 0.016 sec (f = 62.6 Hz)

The fundamental period of vibration T (above) is calculated using the Rayleigh method of approximation:

$T = 2 * PI * Sqr(\{Sum(W_i * y_i^2)\} / \{g * Sum(W_i * y_i)\})$, where

W_i is the weight of the i^{th} lumped mass, and
y_i is its deflection when the system is treated as a cantilever beam.

Seismic Shear Reports:

Operating, Corroded
Empty, Corroded
Vacuum, Corroded

Base Shear Calculations

Seismic Shear Report: Operating, Corroded

Component	Elevation of bottom above base (in)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Seismic shear at Bottom (lbf)	Bending Moment at Bottom (lbf-ft)
Welded Cover #2	94.00	28.0	0.3788	52.06	1.62
Cylinder #1 (top)	4.00	29.2	0.0537	771.05	3,305.57

Legs #1	0.00	29.0	0.0002	774.45	3,563.33
Cylinder #1 (bottom)	4.00	29.2	0.0537	2.70	0.28
Welded Cover #1	4.00	29.2	0.3788	2.43	0.06

Seismic Shear Report: Empty, Corroded

Component	Elevation of bottom above base (in)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Seismic shear at Bottom (lbf)	Bending Moment at Bottom (lbf-ft)
Welded Cover #2	94.00	28.3	0.3788	52.06	1.62
Cylinder #1 (top)	4.00	29.4	0.0537	771.05	3,305.57
Legs #1	0.00	29.0	0.0002	774.45	3,563.33
Cylinder #1 (bottom)	4.00	29.4	0.0537	2.70	0.28
Welded Cover #1	4.00	29.4	0.3788	2.43	0.06

Seismic Shear Report: Vacuum, Corroded

Component	Elevation of bottom above base (in)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Seismic shear at Bottom (lbf)	Bending Moment at Bottom (lbf-ft)
Welded Cover #2	94.00	28.0	0.3788	52.06	1.62
Cylinder #1 (top)	4.00	29.2	0.0537	771.05	3,305.57
Legs #1	0.00	29.0	0.0002	774.45	3,563.33
Cylinder #1 (bottom)	4.00	29.2	0.0537	2.70	0.28
Welded Cover #1	4.00	29.2	0.3788	2.43	0.06

Vertical Acceleration Term, V_{Accel}

Factor is applied to dead load.
Compressive Side: $= 1.0 + V_{Accel}$

V_{Accel} Term is: greater of (Force Mult * Base Shear / Weight) or (Min. Weight Mult.)				
Force multiplier = 0.3333		Minimum Weight Multiplier = 0.6500		
Condition	**Base Shear (lbf)**	**Weight (lb)**	**Force Mult * Shear / Weight**	V_{Accel}
Operating, Corroded	774.25	1,848	0.1397	0.6500
Operating, New	774.25	1,848	0.1397	0.6500
Empty, Corroded	774.25	1,848	0.1397	0.6500
Empty, New	774.25	1,848	0.1397	0.6500
Vacuum, Corroded	774.25	1,848	0.1397	0.6500

Base Shear Calculations

<u>Operating, Corroded</u>
<u>Empty, Corroded</u>

Vacuum, Corroded

Base Shear Calculations: Operating, Corroded

V(32-1) = 4 * C_a * I_p * W_p = 4 * 0.4400 * 1.0000 * 1847.6378 = 3251.8425
V(32-2) = a_p * C_a * I_p * (1 + 3 * (x/h)) * W_p / R_p = 1.0000 * 0.4400 * 1.0000 * (1 + 3 * 1.0000) * 1847.6378 / 3.0000 = 1083.9475
V(32-3) = 0.70 * C_a * I_p * W_p = 0.7 * 0.4400 * 1.0000 * 1847.6378 = 569.0724
To obtain V, take the greater of V(32-2) and V(32-3).
Then take the lesser of this and V(32-1), and divide by 1.4, giving 774.25 lb

Base Shear Calculations: Empty, Corroded

V(32-1) = 4 * C_a * I_p * W_p = 4 * 0.4400 * 1.0000 * 1847.6378 = 3251.8425
V(32-2) = a_p * C_a * I_p * (1 + 3 * (x/h)) * W_p / R_p = 1.0000 * 0.4400 * 1.0000 * (1 + 3 * 1.0000) * 1847.6378 / 3.0000 = 1083.9475
V(32-3) = 0.70 * C_a * I_p * W_p = 0.7 * 0.4400 * 1.0000 * 1847.6378 = 569.0724
To obtain V, take the greater of V(32-2) and V(32-3).
Then take the lesser of this and V(32-1), and divide by 1.4, giving 774.25 lb

Base Shear Calculations: Vacuum, Corroded

V(32-1) = 4 * C_a * I_p * W_p = 4 * 0.4400 * 1.0000 * 1847.6378 = 3251.8425
V(32-2) = a_p * C_a * I_p * (1 + 3 * (x/h)) * W_p / R_p = 1.0000 * 0.4400 * 1.0000 * (1 + 3 * 1.0000) * 1847.6378 / 3.0000 = 1083.9475
V(32-3) = 0.70 * C_a * I_p * W_p = 0.7 * 0.4400 * 1.0000 * 1847.6378 = 569.0724
To obtain V, take the greater of V(32-2) and V(32-3).
Then take the lesser of this and V(32-1), and divide by 1.4, giving 774.25 lb

Wind Code

Building Code:	**UBC 1997**
Elevation of base above grade:	0.0000 ft
Increase effective outer diameter by:	0.0000 ft
Wind Force Coefficient C_q:	0.5600
Basic Wind Speed:, V:	45.0000 mph
Importance Factor:, I_w:	1.0000
Exposure category:	B

Vessel Characteristics

Vessel height, h:	7.8958 ft
Vessel Minimum Diameter	
Operating, Corroded:	1.6667 ft
Empty, Corroded:	1.6667 ft
Fundamental Frequency	
Operating, Corroded:	62.6354 Hz
Empty, Corroded:	62.8629 Hz
Damping coefficient, β	
Operating, Corroded:	0.0200
Empty, Corroded:	0.0200

Wind Deflection Reports:

Operating, Corroded
Empty, Corroded
Vacuum, Corroded

Wind Pressure Calculations

Wind Deflection Report: Operating, Corroded

Component	Elevation of bottom above base (in)	Effective OD (ft)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Platform wind shear at Bottom (lbf)	Total wind shear at Bottom (lbf)	bending moment at Bottom (lbf-ft)	Deflection at top (in)
Welded Cover #2	94.00	1.67	28.0	0.3788	0.00	0.46	0.01	0.0002
Cylinder #1 (top)	4.00	1.67	29.2	0.0537	0.00	54.53	203.93	0.0002
Legs #1	0.00	0.00	29.0	0.0002392	0.00	55.52	222.37	0.0000
Cylinder #1 (bottom)	4.00	1.67	29.2	0.0537	0.00	0.99	0.07	0.0000
Welded Cover #1	4.00	1.67	29.2	0.3788	0.00	0.38	0.01	0.0000

Wind Deflection Report: Empty, Corroded

Component	Elevation of bottom above base (in)	Effective OD (ft)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Platform wind shear at Bottom (lbf)	Total wind shear at Bottom (lbf)	bending moment at Bottom (lbf-ft)	Deflection at top (in)
Welded Cover #2	94.00	1.67	28.3	0.3788	0.00	0.46	0.01	0.0002
Cylinder #1 (top)	4.00	1.67	29.4	0.0537	0.00	54.53	203.93	0.0002

Legs #1	0.00	0.00	29.0	0.0002392	0.00	55.52	222.37	0.0000
Cylinder #1 (bottom)	4.00	1.67	29.4	0.0537	0.00	0.99	0.07	0.0000
Welded Cover #1	4.00	1.67	29.4	0.3788	0.00	0.38	0.01	0.0000

Wind Deflection Report: Vacuum, Corroded

Component	Elevation of bottom above base (in)	Effective OD (ft)	Elastic modulus E (10^6 psi)	Inertia I (ft^4)	Platform wind shear at Bottom (lbf)	Total wind shear at Bottom (lbf)	bending moment at Bottom (lbf-ft)	Deflection at top (in)
Welded Cover #2	94.00	1.67	28.0	0.3788	0.00	0.46	0.01	0.0002
Cylinder #1 (top)	4.00	1.67	29.2	0.0537	0.00	54.53	203.93	0.0002
Legs #1	0.00	0.00	29.0	0.0002392	0.00	55.52	222.37	0.0000
Cylinder #1 (bottom)	4.00	1.67	29.2	0.0537	0.00	0.99	0.07	0.0000
Welded Cover #1	4.00	1.67	29.2	0.3788	0.00	0.38	0.01	0.0000

Wind Pressure (WP) Calculations

Wind stagnation pressure q_s = 12.6000 psf
[Table 16-F, page 2-28]

Wind Pressure WP = $C_e * C_q * q_s * I_w$
= C_e * 0.5600 * 12.6000 * 1.0000
= 7.0560 * C_e

[Equation (20-1), page 2-7]

Design Wind Pressures

Height (')	C_e	WP (psf)
15.0	0.62	4.3747

Welded Cover #2

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Component: Welded Cover
Material specification: SA-240 304 (II-D p. 82, ln. 38)
Impact test exempt per UHA-51(g)(coincident ratio = 0.03261)

Internal design pressure: P = 3.0000 psi @ 120.00°F
External design pressure: P_e = 15.0000 psi @ 120.00°F

Static liquid head:

P_{th}=0.3474 psi(SG=1.0000, H_s=9.6250", Horizontal test head)

Corrosion allowance: Inner C = 0.0000" Outer C = 0.0000"

Design MDMT = -20.00°F
Rated MDMT = -320.00°F

No impact test performed
Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography: Category A joints - Seamless No RT

Estimated weight: New = 8.0 lb corr = 8.0 lb

Head outside diameter = 20.0000"
Cover thickness = 0.7500"

Factor C from Fig. UG-34, sketch (h)

Factor C = 0.33

Design thickness, (at 120.00 °F) UG-34 (c)(2)

t = d*Sqr(C*P/(S*E)) + Corrosion
= 19.25*Sqr(0.33*3/(20,000.00*1)) + 0
= 0.1354 in

Maximum allowable working pressure, (at 120.00 °F)

P = (S*E/C)*$(t/d)^2$ - P_s
= (20,000.00*1/0.33)*$(0.75/19.25)^2$ - 0
= 91.998 psi

Maximum allowable pressure, (At 70.00 °F)

P = (S*E/C)*$(t/d)^2$
= (20,000.00*1/0.33)*$(0.75/19.25)^2$
= 91.998 psi

Design thickness for external pressure, (at 120.00 °F) UG-34(c)(2)

t = d*Sqr(C*P_e/(S*E)) + Corrosion
= 19.25*Sqr(0.33*15/(20,000.00*1)) + 0
= 0.3028 in

Maximum allowable external pressure, (At 120.00 °F)

$P = (S*E/C)*(t/d)^2$
$= (20{,}000.00*1/0.33)*(0.75/19.25)^2$
$= 91.998$ psi

Nozzle #1 (N1)

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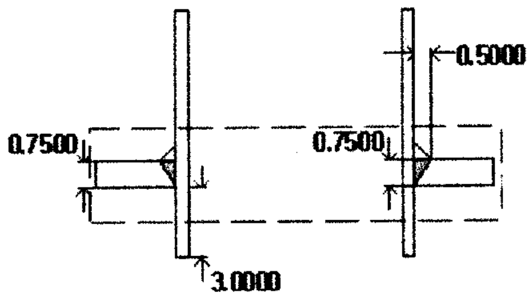


$t_{w(lower)}$ = 0.7500 in
Leg_{41} = 0.5000 in
Leg_{43} = 0.0000 in
h_{new} = 3.0000 in

Note: round inside edges per [illegible]

Located on:	Welded Cover #2
Liquid static head included:	0 psi
Nozzle material specification:	SA-312 TP304 Wld pipe (II-D p. 86, ln. 11)
Nozzle longitudinal joint efficiency:	1.00
Nozzle description:	18" Std Weight
Nozzle orientation:	0°
Local vessel minimum thickness:	0.75 in
Nozzle inside diameter, new:	17.25 in
Nozzle nominal wall thickness:	0.375 in
Nozzle corrosion allowance:	0 in
Projection available outside vessel, Lpr:	5.25 in
Distance to head center, R:	0 in

Reinforcement Calculations for Internal Pressure

Available reinforcement per UG-39 governs the MAWP of this nozzle.

UG-39 Area Calculation Summary (in²) For P = 49.6 psi @ 120 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
4.7809	4.7890	3.4153	0.5635	0.5977	--	0.2125	0.3281	0.3281

Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status

Nozzle to shell fillet (Leg_{41})	0.2500	0.3500	weld size is adequate

Reinforcement Calculations for MAP

Available reinforcement per UG-39 governs the MAP of this nozzle.

UG-39 Area Calculation Summary (in^2) For P = 49.6 psi @ 70 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
4.7809	4.7890	3.4153	0.5635	0.5977	--	0.2125	0.3281	0.3281

Weld Failure Path Analysis Summary
The nozzle is exempt from weld strength calculations per UW-15(b)(1)

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.3500	weld size is adequate

Reinforcement Calculations for External Pressure

UG-39 Area Calculation Summary (in^2) For Pe = 49.12 psi @ 120 °F The opening is adequately reinforced							UG-45 Nozzle Wall Thickness Summary (in) The nozzle passes UG-45	
A required	A available	A_1	A_2	A_3	A_5	A welds	t_{req}	t_{min}
4.7573	4.7582	3.4618	0.4862	0.5977	--	0.2125	0.3281	0.3281

Weld Failure Path Analysis Summary
Weld strength calculations are not required for external pressure

UW-16 Weld Sizing Summary			
Weld description	Required weld throat size (in)	Actual weld throat size (in)	Status
Nozzle to shell fillet (Leg_{41})	0.2500	0.3500	weld size is adequate

Cylinder #1

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Component:	Cylinder
Material specification:	SA-53 E/B Wld pipe (II-D p. 10, ln. 2)
Pipe NPS and Schedule:	20" Sch 20 (Std)

Material is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.00626)

Internal design pressure: P = 3 psi @ 120°F
External design pressure: P_e = 15 psi @ 120°F

Static liquid head:

P_{th}=0.6949 psi(SG=1.0000, H_s=19.2500", Horizontal test head)

Corrosion allowance: Inner C = 0.0000" Outer C = 0.0000"

Design MDMT = -20.00°F
Rated MDMT = -155.00°F

No impact test performed
Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography:		
	Longitudinal joint -	Seamless No RT
	Top circumferential joint -	None UW-11(c) Type 2
	Bottom circumferential joint -	None UW-11(c) Type 2

Estimated weight:	New = 588.8704 lb	corr = 588.8704 lb
Capacity:	New = 113.3919 gal	corr = 113.3919 gal

OD = 20.0000"
Length L_c = 90.0000"
t = 0.3750"

Design thickness, (at 120.00°F) Appendix 1-1

$$t = P*R_o/(S*E + 0.40*P) + \text{Corrosion}$$
$$= 3.00*10.0000/(14600*1.00 + 0.40*3.00) + 0.0000$$
$$= 0.0021"$$

Maximum allowable working pressure, (at 120.00°F) Appendix 1-1

$$P = S*E*t/(R_o - 0.40*t) - P_s$$
$$= 14600*1.00*0.3281 / (10.0000 - 0.40*0.3281) - 0.0000$$
$$= 485.4338 \text{ psi}$$

Maximum allowable pressure, (at 70.00°F) Appendix 1-1

$$P = S*E*t/(R_o - 0.40*t)$$
$$= 14600*1.00*0.3281 / (10.0000 - 0.40*0.3281)$$
$$= 485.4338 \text{ psi}$$

External Pressure, (Corroded & at 120.00°F) UG-28(c)

$L/D_o = 90.0000/20.0000 = 4.5000$
$D_o/t = 20.0000/0.120035 = 166.6180$
From table G: A = 0.000131
From table CS-2: B = 1874.4591 psi

$P_a = 4*B/(3*(D_o/t))$
$= 4*1874.4591/(3*(20.0000/0.120035))$
$= 15.0001$ psi

Design thickness for external pressure P_a = 15.0001 psi

= t + Corrosion = 0.120035 + 0.0000 = 0.1200"

Maximum Allowable External Pressure, (Corroded & at 120.00°F) UG-28(c)

$L/D_o = 90.0000/20.0000 = 4.5000$
$D_o/t = 20.0000/0.3281 = 60.9524$
From table G: A = 0.000556
From table CS-2: B = 8010.0127 psi

$P_a = 4*B/(3*(D_o/t))$
$= 4*8010.0127/(3*(20.0000/0.3281))$
$= 175.2190$ psi

External Pressure + Weight + Wind Loading Check (Bergman, ASME paper 54-A-104)

$P_v = W / (2*\pi*R_m) + M / (\pi*R_m^2)$
$= 1805.43 / (2*\pi*9.8125) + 2447.13 / (\pi*9.8125^2)$
$= 37.3734$ lb/in
$\alpha = P_v / (P_e*D_o)$
$= 37.373432 / (15.0000*20.0000)$
$= 0.1246$
$n = 2$
$m = 1.23 / (L/D_o)^2$
$= 1.23 / (90.000000/20.0000)^2$
$= 0.0607$
Ratio $P_e = (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$
$= (2^2 - 1 + 0.060741 + 0.060741*0.124578) / (2^2 - 1 + 0.060741)$
$= 1.0025$
Ratio $P_e * P_e \leq$ MAEP design cylinder thickness is satisfactory.

External Pressure + Weight + Wind Loading Check at Bottom Seam (Bergman, ASME paper 54-A-104)

$P_v = W / (2*\pi*R_m) + M / (\pi*R_m^2)$
$= 1805.43 / (2*\pi*9.8125) + 0.80 / (\pi*9.8125^2)$
$= 29.2861$ lb/in

$\alpha = P_v / (P_e * D_o)$
$= 29.286104 / (15.0000*20.0000)$
$= 0.0976$

$n = 2$

$m = 1.23 / (L/D_o)^2$
$= 1.23 / (90.000000/20.0000)^2$
$= 0.0607$

Ratio $P_e = (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$
$= (2^2 - 1 + 0.060741 + 0.060741*0.097620) / (2^2 - 1 + 0.060741)$
$= 1.0019$

Ratio $P_e * P_e \leq$ MAEP design cylinder thickness is satisfactory.

External Pressure + Weight + Seismic Loading Check (Bergman, ASME paper 54-A-104)

$P_v = (1 + VAccel)*W / (2*\pi*R_m) + M / (\pi*R_m^2)$
$= 1.6500*1805.43 / (2*\pi*9.8125) + 39666.87 / (\pi*9.8125^2)$
$= 179.4527$ lb/in

$\alpha = P_v / (P_e * D_o)$
$= 179.452713 / (15.0000*20.0000)$
$= 0.5982$

$n = 2$

$m = 1.23 / (L/D_o)^2$
$= 1.23 / (90.000000/20.0000)^2$
$= 0.0607$

Ratio $P_e = (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$
$= (2^2 - 1 + 0.060741 + 0.060741*0.598176) / (2^2 - 1 + 0.060741)$
$= 1.0119$

Ratio $P_e * P_e \leq$ MAEP design cylinder thickness is satisfactory.

External Pressure + Weight + Seismic Loading Check at Bottom Seam(Bergman, ASME paper 54-A-104)

$P_v = (1 + VAccel)*W / (2*\pi*R_m) + M / (\pi*R_m^2)$
$= 1.6500*1805.43 / (2*\pi*9.8125) + 3.34 / (\pi*9.8125^2)$
$= 48.3287$ lb/in

$\alpha = P_v / (P_e * D_o)$
$= 48.328735 / (15.0000*20.0000)$
$= 0.1611$

$n = 2$

$m = 1.23 / (L/D_o)^2$
$= 1.23 / (90.000000/20.0000)^2$
$= 0.0607$

Ratio $P_e = (n^2 - 1 + m + m*\alpha) / (n^2 - 1 + m)$
$= (2^2 - 1 + 0.060741 + 0.060741*0.161096) / (2^2 - 1 + 0.060741)$
$= 1.0032$

Ratio $P_e * P_e \leq$ MAEP design cylinder thickness is satisfactory.

Design thickness = 0.1200"

The governing condition is due to external pressure.

The cylinder thickness of 0.3750" is adequate.

Thickness Required Due to Pressure + External Loads

Condition	Pressure P (psi)	Allowable Stress Before UG-23 Stress Increase (psi)		Temperature (°F)	Corrosion C (in)	Location	Load	Req'd Thk Due to Tension (in)	Req'd Thk Due to Compression (in)
		S_t	S_c						
Operating, Hot & Corroded	3.00	17176.47	16844.48	120.00	0.0000	Top	Wind	0.0003	0.0011
							Seismic	0.0056	0.0082
						Bottom	Wind	0.0007	0.0007
							Seismic	0.0007	0.0017
Operating, Hot & New	3.00	17176.47	16844.48	120.00	0.0000	Top	Wind	0.0003	0.0011
							Seismic	0.0056	0.0082
						Bottom	Wind	0.0007	0.0007
							Seismic	0.0007	0.0017
Hot Shut Down, Corroded	0.00	17176.47	16844.48	120.00	0.0000	Top	Wind	0.0010	0.0018
							Seismic	0.0049	0.0089
						Bottom	Wind	0.0014	0.0014
							Seismic	0.0014	0.0024
Hot Shut Down, New	0.00	17176.47	16844.48	120.00	0.0000	Top	Wind	0.0010	0.0018
							Seismic	0.0049	0.0089
						Bottom	Wind	0.0014	0.0014
							Seismic	0.0014	0.0024
Empty, Corroded	0.00	17176.47	16844.48	0.00	0.0000	Top	Wind	0.0010	0.0018
							Seismic	0.0049	0.0089
						Bottom	Wind	0.0014	0.0014
							Seismic	0.0014	0.0024
Empty, New	0.00	17176.47	16844.48	0.00	0.0000	Top	Wind	0.0010	0.0018
							Seismic	0.0049	0.0089
						Bottom	Wind	0.0014	0.0014
							Seismic	0.0014	0.0024
Vacuum	-15.00	17176.47	16844.48	120.00	0.0000	Top	Wind	0.0046	0.0054
							Seismic	0.0014	0.0124
						Bottom	Wind	0.0050	0.0050
							Seismic	0.0050	0.0060

Hot Shut Down, Corroded, Weight & Eccentric Moments Only	0.00	17176.47	16844.48	120.00	0.0000	Top	Weight	0.0017	0.0017
						Bottom	Weight	0.0017	0.0017

Legs #1

Leg material:		ASME SA36
Leg description:		3x3x1/4 Equal Angle (Leg in)
Number of legs:	N =	4
Overall length:		18.0000 in
Base to girth seam length:		4.0000 in
Bolt circle:		17.6875 in
Anchor bolt size:		0.625 inch series 8 threaded
Anchor bolt material:		
Anchor bolts/leg:		1
Anchor bolt allowable stress:	S_b =	20,000 psi
Anchor bolt corrosion allowance:		0.0000 in
Anchor bolt hole clearance:		0.0620 in
Base plate width:		4.0000 in
Base plate length:		4.0000 in
Base plate thickness:		0.5625 in (0.5316 in required)
Base plate allowable stress:		24,000 psi
Foundation allowable bearing stress:		750 psi
Effective length coefficient:	K =	1.2
Coefficient:	C_m =	0.85
Leg yield stress:	F_y =	36,000 psi
Leg elastic modulus:	E =	29,000,000 psi
Leg to shell fillet weld:		0.1880 in (0.0165 in required)
Legs braced:		No

Note: The support attachment point is assumed to be 1 in up from the cylinder circumferential seam.

Conditions Investigated (Only Governing Condition Reported)

Wind operating corroded
Wind empty corroded
Wind vacuum corroded
Seismic operating corroded
Seismic empty corroded
Seismic vacuum corroded

Loading	Force attack angle °	Leg position °	Axial end load (1) lb_f	Shear resisted lb_f	Axial f_a psi	Bending f_{bx} psi	Bending f_{by} psi	Ratio H_{1-1}	Ratio H_{1-2}
Governing Condition **Seismic operating corroded** **Moment = 3,305.3 lb-ft**	**0**	0	-1,531.0	78.1	-1,063	3,377	0	0.0602	0.0929
		90	746.0	309.1	518	1,292	1,656	0.1349	0.1480
		180	2,729.2	78.1	1,895	5,451	0	0.3032	0.3172
		270	746.0	309.1	518	1,292	1,656	0.1349	0.1480
	45	0	-1,531.0	193.6	-1,063	3,924	733	0.1060	0.1468
		90	-1,531.0	193.6	-1,063	3,924	733	0.1060	0.1468
		180	2,729.2	193.6	1,895	5,998	733	0.3491	0.3711
		270	2,729.2	193.6	1,895	5,998	733	0.3491	0.3711

(1) Axial end load includes consideration of seismic vertical acceleration.

Leg Calculations (AISC manual ninth edition)

Axial end load, P_1 (Based on vessel total bending moment acting at leg attachment elevation)

$P_1 = W_t/N + 48*M_t/(N*D) + V_v/N$
= 1,808.589/ 4 + 48*3,305.294/(4*20) + 1,175.583/ 4
= 2,729.2192 lb

Allowable axial compressive stress, F_a (AISC chapter E)

Local buckling check (AISC 5-99)

b/t = (3/0.25) < (76 / Sqr(36)) so Q_s = 1

Flexural-torsional buckling (AISC 5-317)

Shear center distance w_o = 1.013991
$r_o^2 = w_o^2 + (I_z + I_w)/A$
= 1.013991^2 + (0.5001664 + 1.979786)/1.44
= 2.750366

Torsional constant J = 0.03
Shear modulus G = 11,165.00 kips/in^2

$F_{ej} = G*J / (A*r_o^2)$
= 11,165.00*0.03 / (1.44*2.750366)
= 84.57207

$K*l/r_w$ = 1.2*5/1.172541 = 5.117094

$F_{ew} = \pi^2*E/(Kl/r_w)^2$
= π^2*29,000.00/(5.117094)^2
= 10,930.77

$H = 1 - (w_o^2 / r_o^2)$
= 1 - (1.013991^2 / 2.750366)
= 0.6261672

$F_e = ((F_{ew} + F_{ej})/(2*H))*(1 - Sqr(1 - (4*F_{ew}*F_{ej}*H)/(F_{ew} + F_{ej})^2))$

$= ((10{,}930.77 + 84.57207)/(2*0.6261672))*(1 - Sqr(1 - (4*10{,}930.77*84.57207*0.6261672)/(10{,}930.77 + 84.57207)^2))$
$= 84.32698$

Equivalent slenderness ratio

$Kl/r = \pi*Sqr(E/F_e)$
$= \pi*Sqr(29{,}000.00/84.32698)$
$= 58.25935$

$C_c = Sqr(2*\pi^2*E/(F_y*Q_s))$
$= Sqr(2*\pi^2*29{,}000{,}000/(36{,}000.00*1))$
$= 126.0993$

$K*l/r = 1.2*5/0.5893537 = 10.18064$

$F_a = 1 * (1 - (Kl/r)^2/(2*C_c^2))*F_y / (5/3 + 3*(Kl/r)/(8*C_c)-(Kl/r)^3/(8*C_c^3))$
$= 1 * (1 - (58.25935)^2/(2*126.0993^2))*36{,}000.00 / (5/3 + 3*(58.25935)/(8*126.0993)-(58.25935)^3/(8*126.0993^3))$
$= 17{,}595.71$ psi

Allowable axial compression and bending (AISC chapter H)

Note: r is divided by 1.35 - See AISC 6.1.4, pg. 5-314

$F'_{ex} = 1*12*\pi^2*E/(23*(Kl/r)^2)$
$= 1*12*\pi^2*29{,}000{,}000/(23*(13.74387)^2)$
$= 790{,}556.8$ psi

$F'_{ey} = 1*12*\pi^2*E/(23*(Kl/r)^2)$
$= 1*12*\pi^2*29{,}000{,}000/(23*(6.908077)^2)$
$= 3{,}129{,}225$ psi

$F_b = 1*0.66*F_y$
$= 23{,}760.00$ psi

Compressive axial stress

$f_a = P_1/A$
$= 2{,}729.219/1.44$
$= \underline{1{,}895.291}$ psi

Bending stresses

$f_{bx} = F*Cos(\alpha)*L/(I_x/C_x) + P_1*E_{cc}/(I_x/C_x)$
$= 193.6087*Cos(135)*5/(0.5001664/0.9305325) + 2{,}729.219*0.9305/(0.5001664/0.9305325)$
$= 5{,}998.168$ psi

$f_{by} = F*Sin(\alpha)*L/(I_y/C_y)$
$= 193.6087*Sin(135)*5/(1.979786/2.1213)$
$= \underline{733.4388}$ psi

AISC equation H_{1-1}

$H_{1-1} = f_a/F_a + C_{mx}*f_{bx}/((1 - f_a/F'_{ex})*F_{bx}) + C_{my}*f_{by}/((1 - f_a/F'_{ey})*F_{by})$
$= 1{,}895.291/17{,}595.71 + 0.85*5{,}998.168/((1 - 1{,}895.291/790{,}556.8)*23{,}760.00) + 0.85*733.4388/((1 - 1{,}895.291/3{,}129{,}225)*23{,}760.00)$
$= \underline{0.3490641}$

AISC equation H_{1-2}

$H_{1-2} = f_a/(0.6*1*F_y) + f_{bx}/F_{bx} + f_{by}/F_{by}$

= 1,895.291/(0.6*1*36,000.00) + 5,998.168/23,760.00 + 733.4388/23,760.00
= 0.3710617

4, 3x3x1/4 Equal Angle legs are adequate.

Anchor bolts - Seismic operating corroded condition governs

Tensile loading per leg (1 bolt per leg)

R = 48*M/(N*BC) - W/N
= 48*3,563.326/(4*17.6875) - 1,848.118/4
= 1,955.492 lb_f

Required area per bolt

A_b = R/(S_b*n)
= 1,955.492/(20,000.00*1)
= 0.0978 in^2

Area of a 0.625 inch series 8 threaded bolt (corroded) = 0.202 in^2

0.625 inch series 8 threaded bolts are satisfactory.

Check the leg to vessel fillet weld, Bednar 10.3, Seismic operating corroded governs

Note: continuous welding is assumed for all support leg fillet welds.

The following leg attachment weld analysis assumes the fillet weld is present on three sides (leg top closure plate is used).

Z_w = (2*b*d + d^2)/3
= (2*4.2426*13 + 13^2)/3
= 93.10253

J_w = (b + 2*d)^3/12 - d^2*(b + d)^2/(b + 2*d)
= (4.2426 + 2*13)^3/12 - 13^2*(4.2426 + 13)^2/(4.2426 + 2*13)
= 643.6319

E = d^2/(b + 2*d)
= 13^2/(4.2426 + 2*13)
= 5.588144

Governing weld load f_x = Cos(45)*193.6087 = 136.902 lb_f
Governing weld load f_y = Sin(45)*193.6087 = 136.902 lb_f

f_1 = P_1/L_{weld}
= 2,729.219/30.2426
= 90.2442 lb_f/in (V_L direct shear)

f_2= f_y*L_{leg}*0.5*b/J_w
= 136.902*5*0.5*4.2426/643.6319
= 2.256027 lb_f/in (V_L torsion shear)

f_3 = f_y/L_{weld}
= 136.902/30.2426
= 4.526794 lb_f/in (V_c direct shear)

f_4 = f_y*L_{leg}*E/J_w
= 136.902*5*5.588144/643.6319
= 5.943057 lb_f/in (V_c torsion shear)

$f_5 = f_x*L_{leg}/Z_w$
= 136.902*5/93.10253
= 7.352217 lb_f/in (M_L bending)

$f_6 = f_x/L_{weld}$
= 136.902/30.2426
= 4.526793 lb_f/in (Direct outward radial shear)

$f = Sqr((f_1 + f_2)^2 + (f_3 + f_4)^2 + (f_5 + f_6)^2)$
= $Sqr((90.2442 + 2.256027)^2 + (4.526794 + 5.943057)^2 + (7.352217 + 4.526793)^2)$
= 93.84573 lb_f/in (Resultant shear load)

Required leg to vessel fillet weld leg size (welded both sides + top)

$t_w = f / (0.707*0.55*S_a)$
= 93.84573 / (0.707*0.55*14,600.00)
= <u>0.0165</u> in

The 0.1880 in leg to vessel attachment fillet weld size is adequate.

Base plate thickness check, AISC 3-106

$f_p = P/(B*N)$
= 3,179.871/(4*4)
= 198.7419 psi

Required base plate thickness is the largest of the following: (<u>0.5316</u> in)

$t_b = Sqr(0.5*P/S_b)$
= Sqr(0.5*3,179.871/24,000.00)
= 0.2574 in

$t_b = 0.5*(N - d)*Sqr(3*f_p/S_b)$
= 0.5*(4 - 3)*Sqr(3*198.7419/24,000.00)
= 0.0788 in

$t_b = Sqr(3*P_t*0.5*Abs(OD - BC)/S_b)$
= Sqr(3*1,955.492*0.5*Abs(20 - 17.6875)/24,000.00)
= 0.5316 in

The base plate thickness is adequate.

Check the leg to vessel attachment stresses, WRC-107 (Seismic vacuum corroded governs)

Applied Loads

Radial load:	P_r =	-136.90 lb_f
Circumferential moment:	M_c =	0.00 lb_f-in
Circumferential shear:	V_c =	0.00 lb_f
Longitudinal moment:	M_L =	2,109.13 lb_f-in
Longitudinal shear:	V_L =	-1,531.03 lb_f
Torsion moment:	M_t =	0.00 lb_f-in
Internal pressure:	P =	-15.000 psi
Mean shell radius:	R_m =	9.8125 in
Local shell thickness:	t =	0.3750 in
Shell yield stress:	S_y =	34,160.00 psi

Maximum stresses due to the applied loads at the leg edge (includes pressure)

R_m/t = 26.1667

C_1 = 2.1213, C_2 = 8.4852 in

Note: Actual lug C_1/C_2 < 1/4, C_1/C_2 = 1/4 used as this is the minimum ratio covered by WRC 107.

Local circumferential pressure stress = $P*R_i/t$ = -385 psi

Local longitudinal pressure stress = $P*R_i/2t$ = -192 psi

Maximum combined stress (P_L+P_b+Q) = -738.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-43,800.00 psi

The maximum combined stress (P_L+P_b+Q) is within allowable limits.

Maximum local primary membrane stress (P_L) = -397.00 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-21,900.00 psi

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the leg edge per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	0.9279	0.6399	0	0	0	0	35	35	35	35
4C*	2.0535	0.5188	76	76	76	76	0	0	0	0
1C	0.0610	0.3805	0	0	0	0	356	-356	356	-356
2C-1	0.0156	0.3805	91	-91	91	-91	0	0	0	0
3A*	1.0600	0.3432	0	0	0	0	0	0	0	0
1A	0.0675	0.4419	0	0	0	0	0	0	0	0
3B*	1.2473	0.5448	-88	-88	88	88	0	0	0	0
1B-1	0.0110	0.4833	-209	209	209	-209	0	0	0	0
Pressure stress*			-385	-385	-385	-385	-385	-385	-385	-385
Total circumferential stress			-515	-279	79	-521	6	-706	6	-706
Primary membrane circumferential stress*			-397	-397	-221	-221	-350	-350	-350	-350
3C*	0.9279	0.5188	35	35	35	35	0	0	0	0
4C*	2.0535	0.6399	0	0	0	0	76	76	76	76
1C-1	0.0231	0.5405	135	-135	135	-135	0	0	0	0
2C	0.0300	0.5405	0	0	0	0	175	-175	175	-175
4A*	2.4947	0.3432	0	0	0	0	0	0	0	0
2A	0.0293	0.6074	0	0	0	0	0	0	0	0
4B*	0.6854	0.5448	-87	-87	87	87	0	0	0	0
2B-1	0.0207	0.6668	-285	285	285	-285	0	0	0	0
Pressure stress*			-192	-192	-192	-192	-192	-192	-192	-192
Total longitudinal stress			-394	-94	350	-490	59	-291	59	-291
Primary membrane longitudinal stress*			-244	-244	-70	-70	-116	-116	-116	-116
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	120	120	-120	-120
Total Shear stress			0	0	0	0	120	120	-120	-120
Combined stress (P_L+P_b+Q)			-515	-279	350	-521	246	-738	246	-738

Note: * denotes primary stress.

Welded Cover #1

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Component: Welded Cover
Material specification: SA-36 (II-D p. 6, ln. 18)
Head is impact test exempt to -155 °F per UCS-66(b)(3) (coincident ratio = 0.05658).

Internal design pressure: P = 3.0000 psi @ 120.00°F
External design pressure: P_e = 15.0000 psi @ 120.00°F

Static liquid head:

P_{th}=0.3474 psi(SG=1.0000, H_s=9.6250", Horizontal test head)

Corrosion allowance: Inner C = 0.0000" Outer C = 0.0000"

Design MDMT = -20.00°F
Rated MDMT = -155.00°F

No impact test performed
Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography: Category A joints - Seamless No RT

Estimated weight: New = 51.5 lb corr = 51.5 lb

Head outside diameter = 20.0000"
Cover thickness = 0.6250"

Factor C from Fig. UG-34, sketch (h)

Factor C = 0.33

Design thickness, (at 120.00 °F) UG-34 (c)(2)

t = d*Sqr(C*P/(S*E)) + Corrosion
= 19.25*Sqr(0.33*3/(16,600.00*1)) + 0
= 0.1487 in

Maximum allowable working pressure, (at 120.00 °F)

P = (S*E/C)*$(t/d)^2$ - P_s
= (16,600.00*1/0.33)*$(0.625/19.25)^2$ - 0
= 53.026 psi

Maximum allowable pressure, (At 70.00 °F)

P = (S*E/C)*$(t/d)^2$
= (16,600.00*1/0.33)*$(0.625/19.25)^2$
= 53.026 psi

Design thickness for external pressure, (at 120.00 °F) UG-34(c)(2)

t = d*Sqr(C*P_e/(S*E)) + Corrosion
= 19.25*Sqr(0.33*15/(16,600.00*1)) + 0
= 0.3324 in

Maximum allowable external pressure, (At 120.00 °F)

$P = (S*E/C)*(t/d)^2$
$= (16{,}600.00*1/0.33)*(0.625/19.25)^2$
$= 53.026$ psi

Clip #1

Geometry

Height(radial):	5.0000"
Width (circumferential):	0.5000"
Length	5.0000"
Fillet Weld Size:	0.2500"
Location Angle:	0.00°

Applied Loads

Radial load:	P_r =	0.00 lb_f
Circumferential moment:	M_c =	0.00 lb_f-in
Circumferential shear:	V_c =	0.00 lb_f
Longitudinal moment:	M_L =	19,452.00 lb_f-in
Longitudinal shear:	V_L =	0.00 lb_f
Torsion moment:	M_t =	0.00 lb_f-in
Internal pressure:	P =	3.000 psi
Mean shell radius:	R_m =	9.8125 in
Shell yield stress:	S_y =	34,160.00 psi

Maximum stresses due to the applied loads at the lug edge (includes pressure)

R_m/t =26.1667

C_1 = 0.5000, C_2 = 2.0000 in

Note: Actual lug $C_1/C_2 < 1/4$, $C_1/C_2 = 1/4$ used as this is the minimum ratio covered by WRC 107.

Local circumferential pressure stress = $P*R_i/t$ = 77 psi

Local longitudinal pressure stress = $P*R_i/2t$ = 38 psi

Maximum combined stress (P_L+P_b+Q) = 43,794.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-43,800.00 psi

The maximum combined stress (P_L+P_b+Q) is within allowable limits.

Maximum local primary membrane stress (P_L) = 7,563.00 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-21,900.00 psi

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the lug edge per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	3.4639	0.1508	0	0	0	0	0	0	0	0
4C*	4.5298	0.1223	0	0	0	0	0	0	0	0
1C	0.1593	0.0897	0	0	0	0	0	0	0	0
2C-1	0.1198	0.0897	0	0	0	0	0	0	0	0
3A*	0.5349	0.0809	0	0	0	0	0	0	0	0
1A	0.0998	0.1042	0	0	0	0	0	0	0	0
3B*	2.7129	0.1284	-7,486	-7,486	7,486	7,486	0	0	0	0
1B-1	0.0488	0.1139	-36,231	36,231	36,231	-36,231	0	0	0	0
Pressure stress*			77	77	77	77	77	77	77	77
Total circumferential stress			-43,640	28,822	43,794	-28,668	77	77	77	77
Primary membrane circumferential stress*			-7,409	-7,409	7,563	7,563	77	77	77	77
3C*	3.9322	0.1223	0	0	0	0	0	0	0	0
4C*	4.2883	0.1508	0	0	0	0	0	0	0	0
1C-1	0.1291	0.1274	0	0	0	0	0	0	0	0
2C	0.0879	0.1274	0	0	0	0	0	0	0	0
4A*	0.6886	0.0809	0	0	0	0	0	0	0	0
2A	0.0523	0.1432	0	0	0	0	0	0	0	0
4B*	0.7914	0.1284	-3,910	-3,910	3,910	3,910	0	0	0	0
2B-1	0.0632	0.1572	-34,011	34,011	34,011	-34,011	0	0	0	0
Pressure stress*			38	38	38	38	38	38	38	38
Total longitudinal stress			-37,883	30,139	37,959	-30,063	38	38	38	38
Primary membrane longitudinal stress*			-3,872	-3,872	3,948	3,948	38	38	38	38
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	0	0	0	0
Total Shear stress			0	0	0	0	0	0	0	0
Combined stress (P_L+P_b+Q)			-43,640	30,139	43,794	-30,063	77	77	77	77

Note: * denotes primary stress.

Clip #2

Geometry

Height(radial):	5.0000"
Width (circumferential):	0.5000"
Length	5.0000"
Fillet Weld Size:	0.2500"
Location Angle:	120.00°

Applied Loads

Radial load:	P_r =	0.00 lb_f
Circumferential moment:	M_c =	10,356.00 lb_f-in
Circumferential shear:	V_c =	0.00 lb_f
Longitudinal moment:	M_L =	0.00 lb_f-in
Longitudinal shear:	V_L =	0.00 lb_f
Torsion moment:	M_t =	0.00 lb_f-in
Internal pressure:	P =	3.000 psi
Mean shell radius:	R_m =	9.8125 in
Shell yield stress:	S_y =	34,160.00 psi

Maximum stresses due to the applied loads at the lug edge (includes pressure)

R_m/t =26.1667

C_1 = 0.5000, C_2 = 2.0000 in

Note: Actual lug $C_1/C_2 < 1/4$, $C_1/C_2 = 1/4$ used as this is the minimum ratio covered by WRC 107.

Local circumferential pressure stress = $P*R_i/t$ = 77 psi

Local longitudinal pressure stress = $P*R_i/2t$ = 38 psi

Maximum combined stress (P_L+P_b+Q) = 43,750.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-43,800.00 psi

The maximum combined stress (P_L+P_b+Q) is within allowable limits.

Maximum local primary membrane stress (P_L) = 1,211.00 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-21,900.00 psi

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the lug edge per WRC Bulletin 107										
Figure	**value**	**β**	**A_u**	**A_l**	**B_u**	**B_l**	**C_u**	**C_l**	**D_u**	**D_l**
3C*	3.4639	0.1508	0	0	0	0	0	0	0	0
4C*	4.5298	0.1223	0	0	0	0	0	0	0	0
1C	0.1593	0.0897	0	0	0	0	0	0	0	0
2C-1	0.1198	0.0897	0	0	0	0	0	0	0	0
3A*	0.5349	0.0809	0	0	0	0	-527	-527	527	527
1A	0.0998	0.1042	0	0	0	0	-43,146	43,146	43,146	-43,146
3B*	2.7129	0.1284	0	0	0	0	0	0	0	0
1B-1	0.0488	0.1139	0	0	0	0	0	0	0	0
Pressure stress*			77	77	77	77	77	77	77	77
Total circumferential stress			77	77	77	77	-43,596	42,696	43,750	-42,542
Primary membrane circumferential stress*			77	77	77	77	-450	-450	604	604
3C*	3.9322	0.1223	0	0	0	0	0	0	0	0
4C*	4.2883	0.1508	0	0	0	0	0	0	0	0
1C-1	0.1291	0.1274	0	0	0	0	0	0	0	0
2C	0.0879	0.1274	0	0	0	0	0	0	0	0
4A*	0.6886	0.0809	0	0	0	0	-1,173	-1,173	1,173	1,173
2A	0.0523	0.1432	0	0	0	0	-16,451	16,451	16,451	-16,451
4B*	0.7914	0.1284	0	0	0	0	0	0	0	0
2B-1	0.0632	0.1572	0	0	0	0	0	0	0	0
Pressure stress*			38	38	38	38	38	38	38	38
Total longitudinal stress			38	38	38	38	-17,586	15,316	17,662	-15,240
Primary membrane longitudinal stress*			38	38	38	38	-1,135	-1,135	1,211	1,211
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	0	0	0	0
Total Shear stress			0	0	0	0	0	0	0	0
Combined stress (P_L+P_b+Q)			77	77	77	77	-43,596	42,696	43,750	-42,542

Note: * denotes primary stress.

Clip #3

Geometry

Height(radial):	5.0000"
Width (circumferential):	0.5000"
Length	5.0000"
Fillet Weld Size:	0.2500"
Location Angle:	240.00°

Applied Loads

Radial load:	P_r =	5,670.00 lb_f
Circumferential moment:	M_c =	0.00 lb_f-in
Circumferential shear:	V_c =	0.00 lb_f
Longitudinal moment:	M_L =	0.00 lb_f-in
Longitudinal shear:	V_L =	0.00 lb_f
Torsion moment:	M_t =	0.00 lb_f-in
Internal pressure:	P =	3.000 psi
Mean shell radius:	R_m =	9.8125 in
Shell yield stress:	S_y =	34,160.00 psi

Maximum stresses due to the applied loads at the lug edge (includes pressure)

R_m/t =26.1667

C_1 = 0.5000, C_2 = 2.0000 in

Note: Actual lug C_1/C_2 < 1/4, C_1/C_2 = 1/4 used as this is the minimum ratio covered by WRC 107.

Local circumferential pressure stress = $P*R_i/t$ = 77 psi

Local longitudinal pressure stress = $P*R_i/2t$ = 38 psi

Maximum combined stress (P_L+P_b+Q) = -43,798.00 psi
Allowable combined stress (P_L+P_b+Q) = +-3*S = +-43,800.00 psi

The maximum combined stress (P_L+P_b+Q) is within allowable limits.

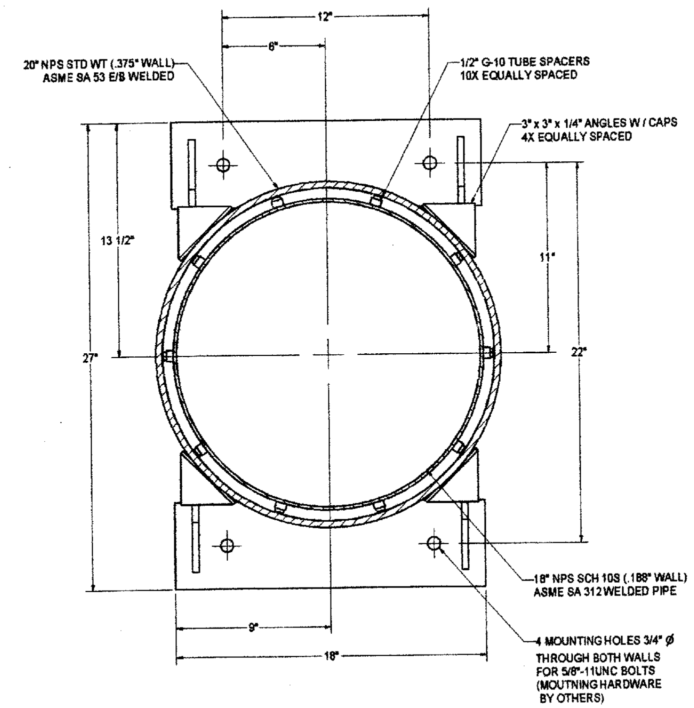
Maximum local primary membrane stress (P_L) = -6,903.00 psi
Allowable local primary membrane (P_L) = +-1.5*S = +-21,900.00 psi

The maximum local primary membrane stress (P_L) is within allowable limits.

Stresses at the lug edge per WRC Bulletin 107										
Figure	value	β	A_u	A_l	B_u	B_l	C_u	C_l	D_u	D_l
3C*	3.4639	0.1508	0	0	0	0	-5,337	-5,337	-5,337	-5,337
4C*	4.5298	0.1223	-6,980	-6,980	-6,980	-6,980	0	0	0	0
1C	0.1593	0.0897	0	0	0	0	-38,538	38,538	-38,538	38,538
2C-1	0.1198	0.0897	-28,982	28,982	-28,982	28,982	0	0	0	0
3A*	0.5349	0.0809	0	0	0	0	0	0	0	0
1A	0.0998	0.1042	0	0	0	0	0	0	0	0
3B*	2.7129	0.1284	0	0	0	0	0	0	0	0
1B-1	0.0488	0.1139	0	0	0	0	0	0	0	0
Pressure stress*			77	77	77	77	77	77	77	77
Total circumferential stress			-35,885	22,079	-35,885	22,079	-43,798	33,278	-43,798	33,278
Primary membrane circumferential stress*			-6,903	-6,903	-6,903	-6,903	-5,260	-5,260	-5,260	-5,260
3C*	3.9322	0.1223	-6,059	-6,059	-6,059	-6,059	0	0	0	0
4C*	4.2883	0.1508	0	0	0	0	-6,608	-6,608	-6,608	-6,608
1C-1	0.1291	0.1274	-31,232	31,232	-31,232	31,232	0	0	0	0
2C	0.0879	0.1274	0	0	0	0	-21,265	21,265	-21,265	21,265
4A*	0.6886	0.0809	0	0	0	0	0	0	0	0
2A	0.0523	0.1432	0	0	0	0	0	0	0	0
4B*	0.7914	0.1284	0	0	0	0	0	0	0	0
2B-1	0.0632	0.1572	0	0	0	0	0	0	0	0
Pressure stress*			38	38	38	38	38	38	38	38
Total longitudinal stress			-37,253	25,211	-37,253	25,211	-27,835	14,695	-27,835	14,695
Primary membrane longitudinal stress*			-6,021	-6,021	-6,021	-6,021	-6,570	-6,570	-6,570	-6,570
Shear from M_t			0	0	0	0	0	0	0	0
Circ shear from V_c			0	0	0	0	0	0	0	0
Long shear from V_L			0	0	0	0	0	0	0	0
Total Shear stress			0	0	0	0	0	0	0	0
Combined stress (P_L+P_b+Q)			-37,253	25,211	-37,253	25,211	-43,798	33,278	-43,798	33,278

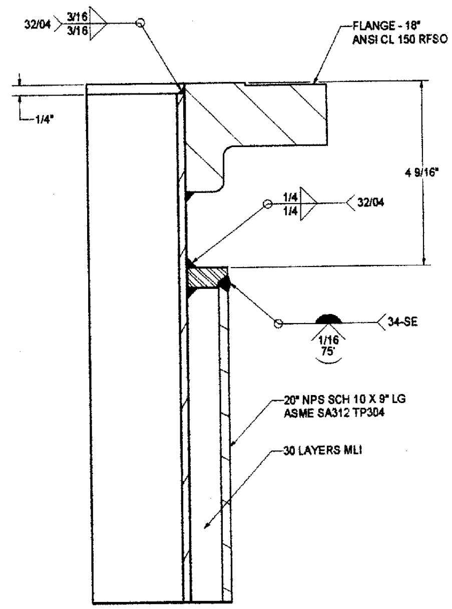
Note: * denotes primary stress.


NB 19
CERTIFIED BY
PHPK TECHNOLOGIES
COLUMBUS, OHIO 43204
U
W
150 PSI AT 120 °F
MAX. ALLOWABLE WORKING PRESSURE
-14.7 PSI AT 120 °F
MAX. ALLOWABLE EXTERNAL WORKING PRESSURE
-320 °F AT 150 PSI
MIN. DESIGN METAL TEMPERATURE
PHPK SERIAL NO. 5819
YEAR BUILT 2007
DUPLICATE



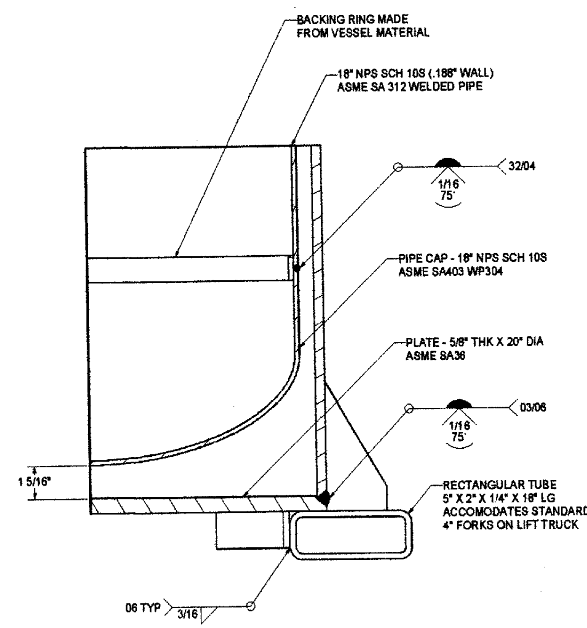
SECTION B-B

FOOT PRINT
FROM SHEET 1



DETAIL C

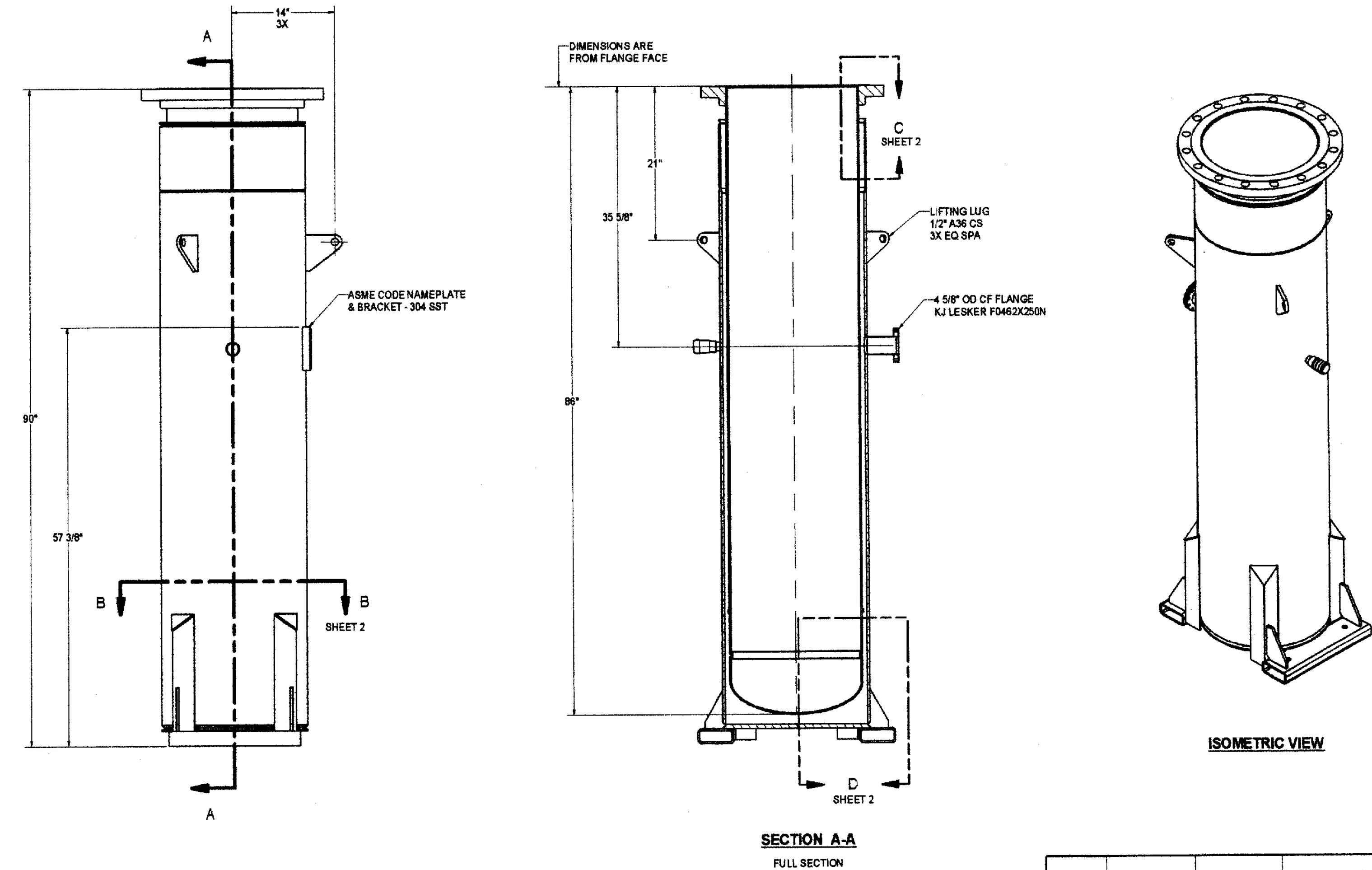
FROM SHEET 1



DETAIL D

FROM SHEET 1

SIZE	DRAWING NUMBER	CHG
B	07-1963-0500	A
SCALE		SHEET 2 OF 2



REVISIONS

REV	DATE	DWN	CHKD	ENG'R	EDR	DESCRIPTION
A	07-30-07	SW	KAK	SW		1) REDUCED OVERALL HEIGHT TO 90" BY SHORTENING LEGS 2) ADDED MOUNTING HOLES TO FORK TRUCK STAVES

INFORMATION SHOWN ON THIS DRAWING IS PROPRIETARY AND THE SOLE PROPERTY OF PHPK AND IS NOT TO BE DISCLOSED OR TRANSMITTED TO UNAUTHORIZED PARTIES.

WEIGHT	COST CENTER	CONTRACT NO	PART NUMBER	NO REQD	NEXT ASSEMBLY

DRAWN BY	Steve Wilming 7/27/2007	TOLERANCES	
CHECKED	SW 7/29/2007	FRACTION	± 1/8
ENGINEER	SW 7/29/2007	2 PL .XX	± .01
		3 PL .XXX	± .005
REVIEWED	KAK 7/29/2007	ANGULAR	± 1/2'
RELEASE DATE	07-27-07	EDR NO	

DIMENSIONS ARE IN INCHES AND PROVIDED PRIOR TO SURFACE TREATMENTS, UNLESS NOTED

PHPK TECHNOLOGIES

2111 BUILDERS PLACE COLUMBUS, OH 43204 614-486-4750 WWW.PHPK.COM

FNAL DES PRESSURE VESSEL
GENERAL ARRANGEMENT

SIZE	DRAWING NUMBER	CHG
B	07-1963-0500	A

SCALE: | SHEET 1 OF 2

PHPK

PHPK Technologies
2111 Builders Place
Columbus, Ohio 43204

Pressure Test Report

Work Order: 1963
Drawing No.: 1963-6501
Customer: FERMI National Accelerator
Description: Inner vessel Assembly
Project Engineer: SW
Tested By: Randy Basham
PHPK Specification: 01-QA-0017
Disposition By: Randy Basham

Hydrostatic ☐
Pneumatic ☒
Test Pressure: 182.00 psi
Time: See Below
Test medium: Air ☐ N_2 ☒ H_2 ☐ Other ☐
Gage S/N (#1): C-20
Cal Due: 2-17-08
Gage S/N (#2):
Cal Due:

RESULTS

TIME	Pressure
2:03 PM - 2:07 PM	45.00
2:19 - 2:23 PM	90.00
2:23 - 2:27 PM	135.00
2:27 - 2:32	182.00
	Reduce to 165.00 psi and Bubble test.
	Start - 2:32 PM
	Finish - 2:43 PM
	No Reportable Indications

Final Disposition

☒ ACCEPT
☐ REJECT

Performed By	Date	Witnessed By
Randy Basham LII	9/13/07	TAB 9/13/07

PHPK Technologies

2111 Builders Place

Columbus, Ohio 43204

COMPRESS Pressure Vessel Design Calculations

Item:	DES Pressure Vessel
Customer:	Fermi National Accelerator laboratory
Diameter/Thk	18" Sch 10S Pipe (.188 Wall)
Design Pressure	165 psig
Revision Date	July 26, 2007

Table Of Contents

Nozzle Schedule

Nozzle mark	Service	Size	Materials								
			Nozzle	Impact	Norm	Fine Grain	Pad	Impact	Norm	Fine Grain	Flange

Nozzle Summary

Nozzle mark	OD (in)	t_n (in)	Req t_n (in)	A_1?	A_2?	Shell			Reinforcement Pad		Corr (in)	A_a/A_r (%)
						Nom t (in)	Design t (in)	User t (in)	Width (in)	t_{pad} (in)		

t_n: Nozzle thickness

Req t_n: Nozzle thickness required per UG-45/UG-16

Nom t: Vessel wall thickness

Design t: Required vessel wall thickness due to pressure + corrosion allowance per UG-37

User t: Local vessel wall thickness (near opening)

A_a: Area available per UG-37, governing condition

A_r: Area required per UG-37, governing condition

Corr: Corrosion allowance on nozzle wall

Pressure Summary

Pressure Summary for Chamber bounded by Ellipsoidal Head #1 and Top of vessel

Identifier	P Design (psi)	T Design (°F)	MAWP (psi)	MAP (psi)	MAEP (psi)	T_e external (°F)	MDMT (°F)	MDMT Exemption	Total Corrosion Allowance (in)	Impact Test
Cylinder #1	165.0	120.0	263.45	266.06	34.75	120.0	-320.0	Note 1	0.000	No
Straight Flange on Ellipsoidal Head #1	165.0	120.0	355.44	358.10	47.94	120.0	-320.0	Note 1	0.000	No
Ellipsoidal Head #1	165.0	120.0	250.85	253.64	73.96	120.0	-320.0	Note 2	0.000	No
Flange #1	165.0	120.0	266.00	275.00	N/A	120.0	-55.0	Note 3, 4	0.000	No

Chamber design MDMT is -320.00°F
Chamber rated MDMT is -55.00°F @ 250.85 psi
Chamber MAWP was used in the MDMT determination

Chamber MAWP hot & corroded is 250.85 psi @ 120.0°F

Chamber MAP cold & new is 253.64 psi @ 70.0°F

Chamber MAEP is 34.75 psi @ 120.0°F
Vacuum rings did not govern the external pressure rating.

Notes for MDMT Rating:

Note #	Exemption	Details
1.	Rated MDMT per UHA-51(d)(1)(a) = -320 °F	
2.	Straight Flange governs MDMT	
3.	Per UHA-51(d)(1)(a)	
4.	Flange rated MDMT = -320 °F	Bolts rated MDMT per Fig UCS-66 note (e) = -55 °F

Design notes are available on the Settings Summary page.

Revision History

No.	Date	Operator	Notes
0	6/28/2007	Steve Willming	New vessel created ASME Division 1 [Build 6252]

Settings Summary

COMPRESS Build 6252

Units: U.S. Customary

Datum Line Location: 0.00" from bottom seam

Design

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Design or Rating:	Get Thickness from Pressure
Minimum thickness:	1/16" per UG-16(b)
Design for cold shut down only:	No
Design for lethal service (full radiography required):	No
Design nozzles for:	Design P, find nozzle MAWP and MAP
Corrosion weight loss:	100% of theoretical loss
UG-23 Stress Increase:	1.20
Skirt/legs stress increase:	1.0
Minimum nozzle projection:	1.5000"
Juncture calculations for $\alpha > 30$ only:	Yes
Preheat P-No 1 Materials > 1.25" and <= 1.50" thick:	No

Butt welds are tapered per Figure UCS-66.3(a).

Hydro/Pneumatic Test

Shop Hydrotest Pressure:	1.3 times vessel MAWP
Test liquid specific gravity:	1.00
Maximum stress during test:	90% of yield

Required Marking - UG-116

UG-116 (e) Radiography:	None
UG-116 (f) Postweld heat treatment:	None

Code Interpretations

Use Code Case 2547:	No
Apply interpretation VIII-1-83-66:	Yes
Apply interpretation VIII-1-86-175:	Yes
Apply interpretation VIII-1-83-115:	Yes
Apply interpretation VIII-1-01-37:	Yes
Disallow UG-20(f) exemptions:	No

UG-22 Loadings

UG-22 (a) Internal or External Design Pressure :	Yes
UG-22 (b) Weight of the vessel and normal contents under operating or test conditions:	No

UG-22 (c) Superimposed static reactions from weight of attached equipment (external loads):	No
UG-22 (d)(2) Vessel supports such as lugs, rings, skirts, saddles and legs:	No
UG-22 (f) Wind reactions:	No
UG-22 (f) Seismic reactions:	No

Note: UG-22 (b),(c) and (f) loads only considered when supports are present.

Thickness Summary

Component Identifier	Material	Diameter (in)	Length (in)	Nominal t (in)	Design t (in)	Joint E	Load
Cylinder #1	SA-312 TP304 Wld pipe	18.00 OD	90.00	0.1880	0.1175	0.8500	External
Straight Flange on Ellipsoidal Head #1	SA-240 304	18.00 OD	2.00	0.1880	0.1175	0.8500	External
Ellipsoidal Head #1	SA-240 304	18.00 OD	4.57	0.1325*	0.0881	0.8500	Internal

Nominal t: Vessel wall nominal thickness

Design t: Required vessel thickness due to governing loading + corrosion

Joint E: Longitudinal seam joint efficiency

* Head minimum thickness after forming

Load

internal: Circumferential stress due to internal pressure governs

external: External pressure governs

Wind: Combined longitudinal stress of pressure + weight + wind governs

Seismic: Combined longitudinal stress of pressure + weight + seismic governs

Weight Summary

Component	Weight (lb) Contributed by Vessel Elements						
	Metal New*	Metal Corroded*	Insulation & Supports	Lining	Piping + Liquid	Operating Liquid	Test Liquid
Cylinder #1	274.57	274.57	0.00	0.00	0.00	634.02	0.00
Ellipsoidal Head #1	20.29	20.29	0.00	0.00	0.00	35.18	0.00
TOTAL:	**294.86**	**294.86**	**0.00**	**0.00**	**0.00**	**669.20**	**0.00**

* Shells with attached nozzles have weight reduced by material cut out for opening.

Component	Weight (lb) Contributed by Attachments								
	Body Flanges		Nozzles & Flanges		Packed Beds	Ladders & Platforms	Trays & Supports	Rings & Clips	Vertical Loads
	New	Corroded	New	Corroded					
Cylinder #1	130.00	130.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ellipsoidal Head #1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL:	**130.00**	**130.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Vessel operating weight, Corroded: 1,094 lb
Vessel operating weight, New: 1,094 lb
Vessel empty weight, Corroded: 425 lb
Vessel empty weight, New: 425 lb
Vessel test weight, New: 425 lb

Vessel center of gravity location - from datum - lift condition

Vessel Lift Weight, New: 425 lb
Center of Gravity: 56.08"

Vessel Capacity

Vessel Capacity** (New): 100 US gal
Vessel Capacity** (Corroded): 100 US gal
**The vessel capacity does not include volume of nozzle, piping or other attachments.

Hydrostatic Test

Shop test pressure determination for Chamber bounded by Ellipsoidal Head #1 and Top of vessel based on MAWP per UG-99(b)

Shop hydrostatic test gauge pressure is 326.103 psi at 70.00 °F (the chamber MAWP = 250.848 psi)

The shop test is performed with the vessel in the horizontal position.

Identifier	Local test pressure psi	Test liquid static head psi	UG-99 stress ratio	UG-99 pressure factor	Stress during test psi	Allowable test stress psi	Stress excessive?
Cylinder #1 (1)	326.103	0.000	1.0000	1.30	17,631	27,000	No
Flange #1	326.103	0.000	N/A	1.30	NI	NI	NI
Straight Flange on Ellipsoidal Head #1	326.103	0.000	1.0000	1.30	15,448	27,000	No
Ellipsoidal Head #1	326.103	0.000	1.0000	1.30	19,642	27,000	No

Notes:
(1) Cylinder #1 limits the UG-99 stress ratio.
(2) NI indicates that test stress was not investigated.
(3) The zero degree angular position is assumed to be up, and the test liquid height is assumed to the top-most flange.

The field test condition has not been investigated for the Chamber bounded by Ellipsoidal Head #1 and Top of vessel.

Vacuum Summary

Component	Line of Support	Elevation above Datum (in)	Length Le (in)
-	Flange #1	90.19	N/A
-	Flange #1	90.19	N/A
Cylinder #1 Top	-	90.00	93.67
Cylinder #1 Bottom	-	0.00	93.67
Straight Flange on Ellipsoidal Head #1 Top	-	0.00	93.67
Straight Flange on Ellipsoidal Head #1 Bottom	-	-2.00	93.67
-	1/3 depth of Ellipsoidal Head #1	-3.48	N/A
Ellipsoidal Head #1	-	-6.57	N/A

Note
For main components, the listed value of 'Le' is the largest unsupported length for the component.

Cylinder #1

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Component:	Cylinder
Material specification:	SA-312 TP304 Wld pipe (II-D p. 86, ln. 11)
Pipe NPS and Schedule:	18" Sch 10S
Rated MDMT per UHA-51(d)(1)(a) = -320 °F	

Internal design pressure: P = 165 psi @ 120°F
External design pressure: P_e = 15 psi @ 120°F

Static liquid head:

P_s =2.6044 psi(SG=0.8000, H_s=90.1880" Operating head)
P_{th}=0.0000 psi(SG=0.0000, H_s=17.9020", Horizontal test head)

Corrosion allowance: Inner C = 0.0000" Outer C = 0.0000"

Design MDMT = -320.00°F
Rated MDMT = -320.00°F

No impact test performed
Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography:		
	Longitudinal joint -	Seamless No RT
	Top circumferential joint -	N/A
	Bottom circumferential joint -	None UW-11(c) Type 2

Estimated weight: New = 274.5746 lb corr = 274.5746 lb
Capacity: New = 95.0450 gal corr = 95.0450 gal

OD = 18.0000"
Length L_c = 90.0000"
t = 0.1880"

Design thickness, (at 120.00°F) Appendix 1-1

$$t = P*R_o/(S*E + 0.40*P) + Corrosion$$
$$= 167.60*9.0000/(17000*0.85 + 0.40*167.60) + 0.0000$$
$$= 0.1040"$$

Maximum allowable working pressure, (at 120.00°F) Appendix 1-1

$$P = S*E*t/(R_o - 0.40*t) - P_s$$
$$= 17000*0.85*0.1645 / (9.0000 - 0.40*0.1645) - 2.6044$$
$$= 263.4547 \text{ psi}$$

Maximum allowable pressure, (at 70.00°F) Appendix 1-1

$$P = S*E*t/(R_o - 0.40*t)$$
$$= 17000*0.85*0.1645 / (9.0000 - 0.40*0.1645)$$
$$= 266.0591 \text{ psi}$$

External Pressure, (Corroded & at 120.00°F) UG-28(c)

L/D_o = 93.6659/18.0000 = 5.2037
D_o/t = 18.0000/0.117530 = 153.1526
From table G: A = 0.000123
From table HA-1: B = 1722.9647 psi

$P_a = 4*B/(3*(D_o/t))$
= 4*1722.9647/(3*(18.0000/0.117530))
= 15.0000 psi

Design thickness for external pressure P_a = 15.0000 psi

= t + Corrosion = 0.117530 + 0.0000 = 0.1175"

Maximum Allowable External Pressure, (Corroded & at 120.00°F) UG-28(c)

L/D_o = 93.6659/18.0000 = 5.2037
D_o/t = 18.0000/0.1645 = 109.4225
From table G: A = 0.000204
From table HA-1: B = 2851.7754 psi

$P_a = 4*B/(3*(D_o/t))$
= 4*2851.7754/(3*(18.0000/0.1645))
= 34.7494 psi

Flange #1

Flange description:	18 inch Class 150 SO A182 F304
Bolt Material:	SA-193 B7 Bolt <= 2 1/2
Flange rated MDMT:	-55°F
(Per UHA-51(d)(1)(a))	
(Flange rated MDMT = -320 °F	
Bolts rated MDMT per Fig UCS-66 note (e) = -55 °F)	
Liquid static head on flange:	0 psi
ASME B16.5 flange rating MAWP:	266 psi @ 120°F
ASME B16.5 flange rating MAP:	275 psi @ 70°F
ASME B16.5 flange hydro test:	425 psi @ 70°F

Straight Flange on Ellipsoidal Head #1

ASME Section VIII Division 1, 2004 Edition, A06 Addenda

Component: Straight Flange
Material specification: SA-240 304 (II-D p. 82, ln. 38)
Rated MDMT per UHA-51(d)(1)(a) = -320 °F

Internal design pressure: P = 165 psi @ 120°F
External design pressure: P_e = 15 psi @ 120°F

Static liquid head:

P_s =2.6622 psi(SG=0.8000, H_s=92.1880" Operating head)
P_{th}=0.0000 psi(SG=0.0000, H_s=17.9020", Horizontal test head)

Corrosion allowance: Inner C = 0.0000" Outer C = 0.0000"

Design MDMT = -320.00°F
Rated MDMT = -320.00°F

No impact test performed
Material is not normalized
Material is not produced to Fine Grain Practice
PWHT is not performed

Radiography:	Longitudinal joint -	Seamless No RT
	Circumferential joint -	None UW-11(c) Type 2

Estimated weight: New = 6.1017 lb corr = 6.1017 lb
Capacity: New = 2.1121 gal corr = 2.1121 gal

OD = 18.0000"
Length L_c = 2.0000"
t = 0.1880"

Design thickness, (at 120.00°F) Appendix 1-1

t = $P*R_o/(S*E + 0.40*P)$ + Corrosion
= 167.66*9.0000/(20000*0.85 + 0.40*167.66) + 0.0000
= 0.0885"

Maximum allowable working pressure, (at 120.00°F) Appendix 1-1

P = $S*E*t/(R_o - 0.40*t) - P_s$
= 20000*0.85*0.1880 / (9.0000 - 0.40*0.1880) - 2.6622
= 355.4411 psi

Maximum allowable pressure, (at 70.00°F) Appendix 1-1

P = $S*E*t/(R_o - 0.40*t)$
= 20000*0.85*0.1880 / (9.0000 - 0.40*0.1880)
= 358.1033 psi

External Pressure, (Corroded & at 120.00°F) UG-28(c)

$L/D_o = 93.6659/18.0000 = 5.2037$
$D_o/t = 18.0000/0.117530 = 153.1526$
From table G: A = 0.000123
From table HA-1: B = 1722.9647 psi

$P_a = 4*B/(3*(D_o/t))$
$= 4*1722.9647/(3*(18.0000/0.117530))$
$= 15.0000$ psi

Design thickness for external pressure P_a = 15.0000 psi

= t + Corrosion = 0.117530 + 0.0000 = 0.1175"

Maximum Allowable External Pressure, (Corroded & at 120.00°F) UG-28(c)

$L/D_o = 93.6659/18.0000 = 5.2037$
$D_o/t = 18.0000/0.1880 = 95.7447$
From table G: A = 0.000247
From table HA-1: B = 3442.8372 psi

$P_a = 4*B/(3*(D_o/t))$
$= 4*3442.8372/(3*(18.0000/0.1880))$
$= 47.9447$ psi

% Forming Strain - UHA-44(a)(2)(a)

$= (50 * t / R_f) * (1 - R_f / R_o)$
$= (50 * 0.1880 / 8.9060) * (1 - 8.9060 / \infty)$
= 1.0555 %

Ellipsoidal Head #1

ASME Section VIII, Division 1, 2004 Edition, A06 Addenda

Component:	Ellipsoidal Head
Material Specification:	SA-240 304 (II-D p.82, ln. 38)
Straight Flange governs MDMT	

Internal design pressure: P = 165 psi @ 120 °F
External design pressure: P_e = 15 psi @ 120 °F

Static liquid head:

P_s= 2.7902 psi (SG=0.8, H_s=96.6218" Operating head)

Corrosion allowance:	Inner C = 0"	Outer C = 0"

Design MDMT = -320°F	No impact test performed
Rated MDMT = -320°F	Material is not normalized
	Material is not produced to fine grain practice
	PWHT is not performed
	Do not Optimize MDMT / Find MAWP

Radiography:	Category A joints -	Seamless No RT
	Head to shell seam -	None UW-11(c) Type 2

Estimated weight*:	new = 20.3 lb	corr = 20.3 lb
Capacity*:	new = 5.3 US gal	corr = 5.3 US gal

* includes straight flange

Outer diameter	=	18"
Minimum head thickness	=	0.1325"
Head ratio D/2h	=	2 (new)
Head ratio D/2h	=	2 (corroded)
Straight flange length L_{sf}	=	2"
Nominal straight flange thickness t_{sf}	=	0.188"

Insulation thk*:	0"	density: 0 lb/ft^3	weight: 0 lb
Insulation support ring spacing:	0"	individual weight: 0 lb	total weight: 0 lb
Lining/ref thk*:	0"	density: 0 lb/ft^3	weight: 0 lb

* includes straight flange if applicable

Results Summary

The governing condition is internal pressure.

Minimum thickness per UG-16	=	0.0625" + 0" = 0.0625"
Design thickness due to internal pressure (t)	=	0.0881"
Design thickness due to external pressure (t_e)	=	0.0469"
Maximum allowable working pressure (MAWP)	=	250.8483 psi
Maximum allowable pressure (MAP)	=	253.6385 psi
Maximum allowable external pressure (MAEP)	=	73.9572 psi

K (Corroded)

$$K = (1/6)*[2 + (D / (2*h))^2]$$
$$= (1/6)*[2 + (17.735 / (2*4.4338))^2]$$
$$= 1$$

K (New)

$K = (1/6)*[2 + (D / (2*h))^2]$
$= (1/6)*[2 + (17.735 / (2*4.4338))^2]$
$= 1$

Design thickness for internal pressure, (Corroded at 120 °F) Appendix 1-4(c)

$t = P*D_o*K / (2*S*E + 2*P*(K - 0.1)) + Corrosion$
$= 167.7902*18*1 / (2*20000*0.85 + 2*167.7902*(1 - 0.1)) + 0$
$= 0.088"$

The head internal pressure design thickness is 0.0881".

Maximum allowable working pressure, (Corroded at 120 °F) Appendix 1-4(c)

$P = 2*S*E*t / (K*D_o - 2*t*(K - 0.1)) - P_s$
$= 2*20000*0.85*0.1325 / (1*18 - 2*0.1325*(1 - 0.1)) - 2.7902$
$= 250.8483$ psi

The maximum allowable working pressure (MAWP) is 250.8483 psi.

Maximum allowable pressure, (New at 70 °F) Appendix 1-4(c)

$P = 2*S*E*t / (K*D_o - 2*t*(K - 0.1)) - P_s$
$= 2*20000*0.85*0.1325 / (1*18 - 2*0.1325*(1 - 0.1)) - 0$
$= 253.6385$ psi

The maximum allowable pressure (MAP) is 253.6385 psi.

Design thickness for external pressure, (Corroded at 120 °F) UG-33(d)

Equivalent outside spherical radius (R_o)

$R_o = K_o*D_o$
$= 0.8869 * 18$
$= 15.965$ in

$A = 0.125 / (R_o/t)$
$= 0.125 / (15.965/0.046817)$
$= 0.000367$

From Table HA-1: B=5,115.1064 psi

$P_a = B/(R_o/t)$
$= 5115.106/(15.965/0.046817)$
$= 15$ psi

$t = 0.0468" + Corrosion = 0.0468" + 0" = 0.0468"$

Check the external pressure per UG-33(a)(1) Appendix 1-4(c)

$t = 1.67*P_e*D_o*K / (2*S*E + 2*1.67*P_e*(K - 0.1)) + Corrosion$
$= 1.67*15*18*1 / (2*20000*1 + 2*1.67*15*(1 - 0.1)) + 0$
$= 0.0113"$

The head external pressure design thickness (t_e) is 0.046817".

Maximum Allowable External Pressure, (Corroded at 120 °F) UG-33(d)

Equivalent outside spherical radius (R_o)

R_o = K_o*D_o
= 0.8869 * 18
= 15.965 in

A = 0.125 / (R_o/t)
= 0.125 / (15.965/0.1325)
= 0.001037

From Table HA-1: B=8,911.1270 psi

P_a = B/(R_o/t)
= 8911.127/(15.965/0.1325)
= 73.9572 psi

Check the Maximum External Pressure, UG-33(a)(1) Appendix 1-4(c)

P = 2*S*E*t / ((K*D_o - 2*t*(K - 0.1))*1.67) - P_{s2}
= 2*20000*1*0.1325 / ((1*18 - 2*0.1325*(1 - 0.1))*1.67) - 0
= 178.6816 psi

The maximum allowable external pressure (MAEP) is 73.9572 psi.

% Forming strain - UHA-44(a)(2)(a)

= (75*t / R_f)*(1 - R_f / R_o)
= (75*0.188 / 3.109)*(1 - 3.109 / ∞)
= 4.5353%

Liquid Level bounded by Ellipsoidal Head #1

Location from datum	90.1880"
Operating Liquid Specific Gravity	0.8000
Test liquid specific gravity	0.0000

FORM U-1A MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS

(Alternative Form for Single Chamber, Completely Shop or Field Fabricated Vessels Only)

As Required by the Provisions of the ASME Code Rules, Section VIII, Division 1

1. Manufactured and certified by **PHPK Technologies, 2111 Builders Place, Columbus, Ohio, 43204, USA**
(Name and address of manufacturer)

2. Manufactured for **Fermi National Accelerator Laboratory, P.O. box 500, Batavia, Illinois, 60510, USA**
(Name and address of purchaser)

3. Location of Installation **NOT KNOWN**
(Name and address)

4. Type **VERTICAL** (Horiz. or Vert. tank) **5819** (Mfr's serial No.) **N/A** (CRN) **07-1963-6501** (Drawing No.) **19** (Nat'l. Bd. No.) **2007** (Year built)

5. The chemical and physical properties of all parts meet the requirements of material specifications of the ASME BOILER AND PRESSURE VESSEL CODE. The design, construction, and workmanship conform to ASME Rules, Section VIII, Division 1 **2004** (year) to **2006** Addenda (Date)
N/A Code Case Nos. **N/A** Special Service per UG-120(d)

6. Shell: **SA312 TYPE 304/304L WELDED** Matl. (Spec. No., Grade) **.250** Nom. Thk. **0** Corr. Allow. **1' 6" (OD)** Diam. I.D. **6' 6"** Length (overall)

7. Seams: **MILL WELDED PIPE** Long. (Welded, Dbl., Sngl., Lap, Butt) **NONE** R.T.(Spot or Full) **85** Eff.(%) **N/A** H.T. Temp **N/A** Time (hr) **TYPE 2** Girth. (Welded, Dbl., Sngl., Lap, Butt) **NONE** R.T (Spot or Full) **85** Eff(%) **1** No. of Courses

8. Heads: (a) Mat'l: **SA403, TYPE 304/304L** (Spec. No., Grade) (b) Mat'l (Spec. No., Grade)

	Location (Top, Bottom, Ends)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a)	BOTTOM	.1325	0	N/A	N/A	2:1	N/A	N/A	N/A	CONCAVE

If removable, bolts used (describe other fastenings) **N/A**
(Mat'l., Spec. No., Gr., Size, No.)

9. MAWP **150 psi** (internal) **-14.7 psi** (external) at max. temp. **120 °F** (internal) **120 °F** (external)

Min. design metal temp. **-320 °F** at **150 psi** Hydro, pneu., or comb. test pressure **PNEUMATIC at 182 psi**

10. Nozzles, inspection and safety valve openings:

Purpose (Inlet, Outlet, Drain)	No.	Diam. or Size	Type	Mat'l.	Nom. Thk.	Reinforcement Mat'l.	How Attached	Location

11. Supports: Skirt **N/A** (Yes or no) Lugs **N/A** (No.) Legs **4** (No.) Other **N/A** (Describe) Attached **WELDED TO SHELL** (Where and how)

12. Remarks: Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors, have been furnished for the following items of the report:

N/A
(Name of part, item number, Mfgr's name and identifying stamp)

78" SHELL SECTION WITH SA403 LOWER HEAD AND SA182 SO FLANGE WITHOUT COVER.
Safety valve provided in system.
Impact exempt per UHA 51(g).
Designed for Noncorrosive service.

CERTIFICATE OF SHOP/FIELD COMPLIANCE

We certify that the statements made in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME Code for Pressure Vessels, Section VIII, Division 1. "U" Certificate of Authorization No. **35253** expires **08/17/2008**

Date **10/01/2007** Co. name **PHPK Technologies** (Manufacturer) Signed [signature] (Representative)

CERTIFICATE OF SHOP/FIELD INSPECTION

Vessel constructed by PHPK Technologies at 2111 Builders Place, Columbus, Ohio, 43204, USA I, the undersigned, holding a valid commission issued by The National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province OH and employed by HSB CT of Hartford, CT have inspected the component described in this Manufacturer's Data Report on September 13, 2007 and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME Code, Section VIII, Division 1. By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date 10/19/2007 Signed [signature] (Authorized Inspector) Commissions 13166A, OH665 (Nat'l Board (incl. endorsements), State, Prov. and No.)

PRESSURE VESSEL ENGINEERING NOTE
PER CHAPTER 5031

Prepared by: Herman Cease
Preparation date: Aug 14, 2008

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

This vessel conforms to Fermilab ES&H Manual Chapter 5031

Vessel Title DES Pressure Vessel, 200L PHPK Technologies

Vessel Number 5819

Vessel Drawing Number PHPK Technologies, 07-1963-0500 REV A

Maximum Allowable Working Pressures (MAWP):
Internal Pressure 150 PSIG
External Pressure -14.7 PSIG

Working Temperature Range -320^{o}F to 120 ^{o}F

Contents Liquid Nitrogen

Designer/Manufacturer PHPK Technologies
Columbus Ohio

Test Pressure (if tested at Fermi) Acceptance Date: ________

_______PSIG, Hydraulic __________ Pneumatic __________

Accepted as conforming to standard by

____

of Division/Section______________ Date:_______

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

Reviewed by:_______________________________________ Date: ________________

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

_______________________________________Date:________________

_______________________________________Date: ________________

ES&H Director Concurrence

Amendment No.:	Reviewed by:	Date:

Lab Property Number(s):
Lab Location Code:_______________(obtain from safety officer)
Purpose of Vessel(s): Closed Loop LN2 cooling, DES Camera Vessel

Vessel Capacity/Size: 380Liters Diameter: 20 inch Length: 90 inch
Normal Operating Pressure (OP) 100 PSIG
MAWP-OP = 50 PSIG

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

Drawing #	Location of Original
07-1963-0500 REV A SHEET 1 (Vessel)	Fermilab BEG
07-1963-0500 REV A SHEET 2 (Vessel)	Fermilab BEG
4900.120-MD-436428 (Flange)	Fermilab BEG
4900.120-ME-436366 (Flange Weldment)	Fermilab BEG

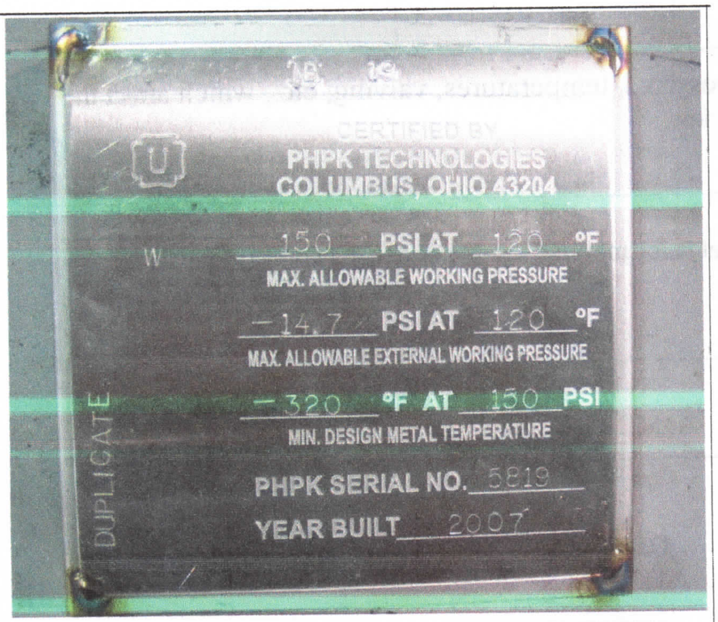
2. Design Verification

Is this vessel designed and built to meet the Code or "In-House Built" requirements?
Yes__X__ No_____.

If "No" state the standard that was used _____________.
Demonstrate that design calculations of that standard have been made and that other requirements of that standard have been satisfied.
Skip to part 3 "system venting verification."

Does the vessel(s) have a U stamp? Yes__X__ No_____. If "Yes", complete section 2A; if "No", complete section 2B.

A. Staple photo of U stamp plate below.
Copy "U" label details to the side



Copy data here:
Certified by

PHPK Technologies

Columbus Ohio, 43204

150 PSI at 120 F

Max Allowable Working Pressure

-14.7 PSI at 120 F

Max Allowable External Working Pressure

-320 F at 150 PSI Min Design Metal Temp

PHPK Serial No 5819

Year Built 2007

```
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)
```

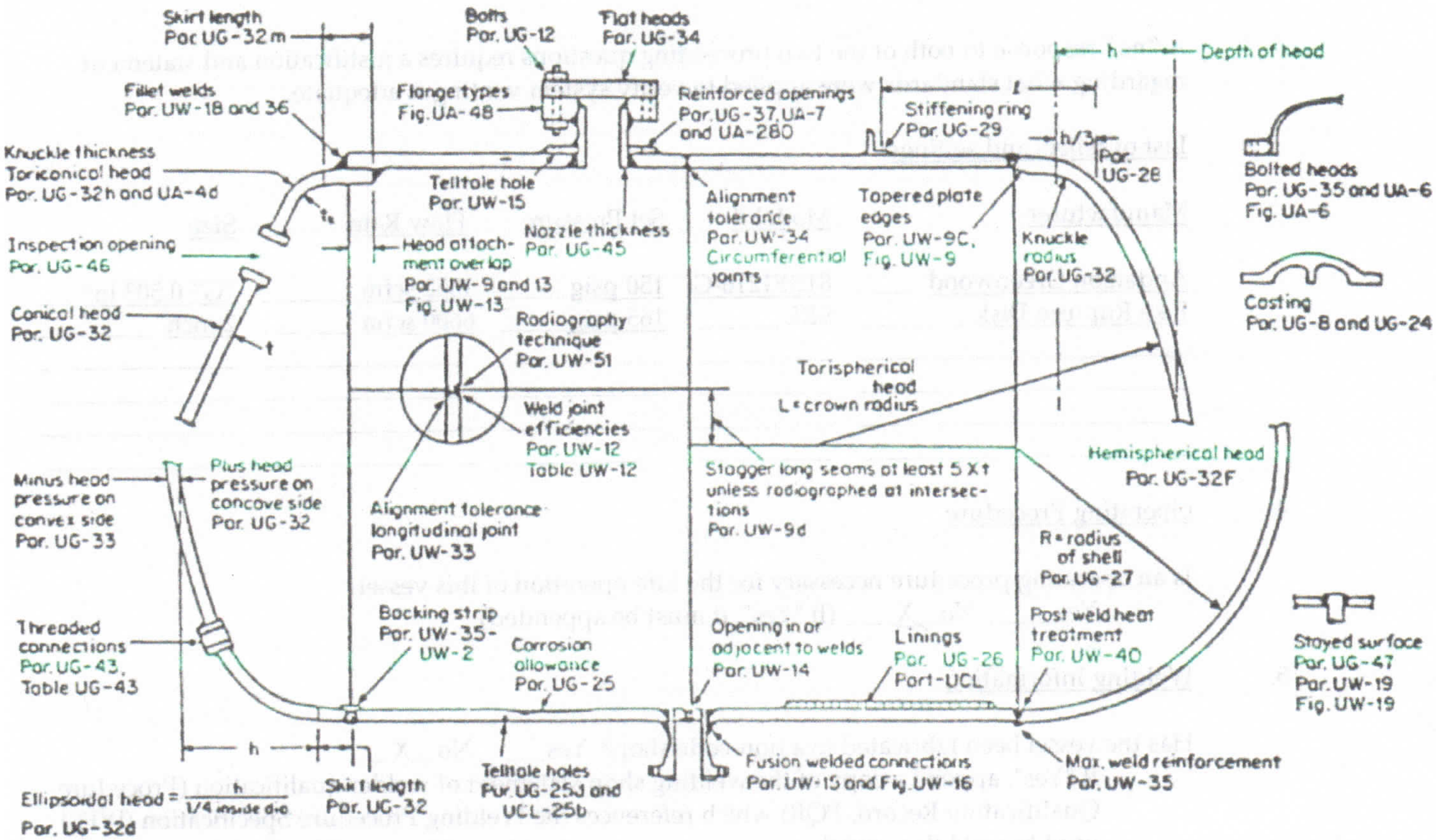


Figure 1. ASME Code: Applicable Sections

2B.

<u>Summary of ASME Code</u>

Item	Reference ASME Code Section	CALCULATION RESULT (Required thickness or stress level vs. actual thickness calculated stress level)		
18 inch Flange	UG-34, UG-39, 2-5	1.23" req t	vs.	1.56" actual t
			vs	
			vs	
			vs	

3. System Venting Verification Provide the vent system schematic.

Does the venting system follow the Code UG-125 through UG-137?
Yes__X_ No___

Does the venting system also follow the Compressed Gas Association Standards S-1.1 and S-1.3?
Yes __X__ No_____

A "no" response to both of the two proceeding questions requires a justification and statement regarding what standards were applied to verify system venting is adequate.

List of reliefs and settings:

Manufacturer	Model #	Set Pressure	Flow Rate	Size
Anderson Greenwood	81BF1216-G	150 psig	1352 scfm	"G" 0.503 in^2
Fike Rupture Disk	SRL	165 psig	6600 scfm	2 inch

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. Existing, Used and Unmanned Area Vessels

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

If "Yes", follow the requirements for an Extended Engineering Note for Existing, Used and Unmanned Area Vessels.

7. Exceptional Vessels

Is this vessel or any part thereof in the above category?
Yes_____ No___X__

If "Yes", follow the requirements for an Extended Engineering Note for Exceptional Vessels.

Introduction:

SV-6213 and SV-6214

Safety relief valve

Title: Calculating Size of Safety Valve for the DES Camera Cooling System

Author: Birce Onal, Revised 8/14/08 H. Cease

Date: February 28, 2007

1. OBJECT
   To calculate the size of a safety valve and orifice for the pipes of the DES cryo-cooling system.
2. REFERENCE
   "Pressure Relief Device Standards; Part 3: Stationary Storage Containers for Compressed Gases." Compressed Gas Association, Inc. AGCD- Anderson Greenwood. 1993.
3. INPUT DATA
   1) Running system of vaporized liquid nitrogen.
   2) Input pressure is .76 MPa (100 psig), pressure running back is .871 MPa.
   3) Diameter of vessel is 20 in.
   4) Height of vessel is 90 in.
4. CALCULATIONS
   Finding required capacity using CGA section 5.3.2, pressure relief device flow capacity under emergency conditions including fire.

$$Q_a = F \times G_u \times A^{.82}$$

Where,
Qa = flow capacity of the relief device
F= 1 , correction factor
Gu = 69, Cryogenic Liquid Nitrogen at 200 psi, Gas factor from Table 1 for un-insulated container.
A = vessel square area

$$A = 2\pi(10in)^2 + 2\pi(10in) \times (90in)$$

$$A = 6280in^2 = 43.6ft^2$$

$$Q_A = (69.0) \times (43.6ft^2)^{.82} = 1525\frac{ft^3}{\min}$$

Per CGA 1.3-1995, no correction terms for the temperature or pressure drop in the vent line is needed if the vent line is less than 2 feet.
The vent line inlet length is 1 foot, and the vent line is also 1 foot in length.

5. CONCLUSION

The required capacity of the safety valve is 1525 scfm at 121% of the MAWP of 150 psig or 181 psig. The fill lines on the vessel are ¾ inch tube with a 0.652 inch inner diameter ($0.33 in^2$). To satisfy the overfill condition and the flow capacity a relief valve with an orifice diameter larger than $0.33 in^2$ is selected.

A valve such as Anderson Greenwood #81-BF-1216-G is suitable
Body size 81 for gas service
Brass body
1 ½ Female NPT inlet
2 inch FNPT outlet
Orifice size $0.5 in^2$
Set Pressure 150 psig, relief capacity = 1352 scfm
Capacity at 121% MAWP (181 psig) = 1600 scfm

The second relief selected is a 2 inch FIKE rupture disk, 165 psig set pressure and is sized to meet the fire conditions. The flow rate for this relief is calculated using Appendix 11 of the ASME Section VIII division 1.

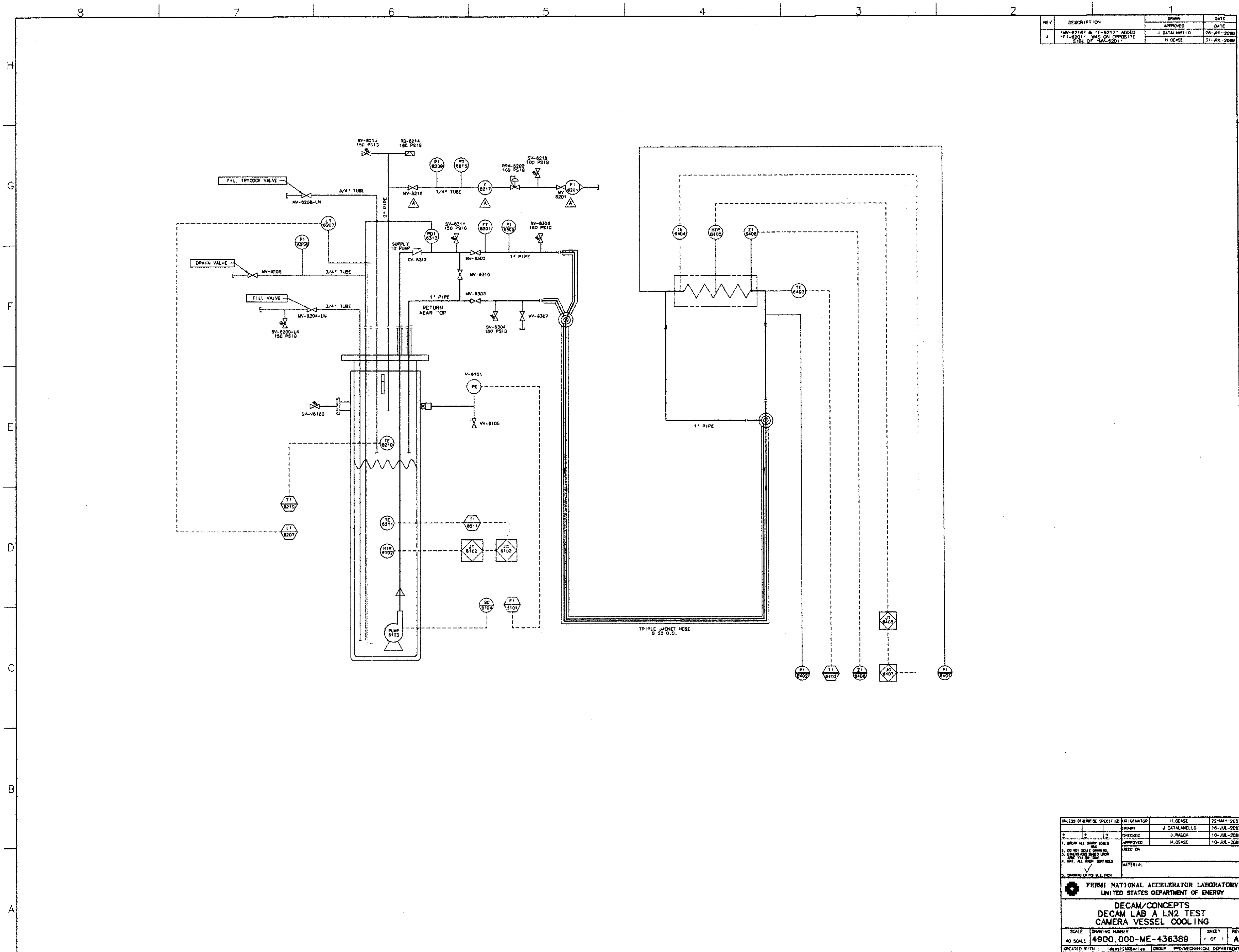
$$Wa = CKAP\sqrt{\frac{M}{T}}$$

Where:
Wa = Flow rate lbs/hr
C = 356 gas constant
K = 0.62 Coef. ff discharge for the rupture disk
A = 2 inch nominal diameter = 3.36 $inch^2$ flow area from FIKE
P = 157 psig + 14.7 psi = 171.7 psia as tested by FIKE, not to exceed 165 psig.
M = 28.97 molecular weight air
T = 520 Rankine

Wa = 30,000 lbs air per hr = 500 lbs/min
Using 0.075 lbs/ ft^3 density of dry air at standard conditions
Flow rate = 6600 scfm air

6. Inspection and Testing

Per FESHM 5031, The Vessel will be inspected prior to any operational start and on an annual basis.
The Vessel and Flange Assembly will be tested prior to operational use using FESHM 5034. Attached documents are the Testing Procedure and Testing Permit. Results are documented on the testing permit form.



Created: 09:57:18 on 31-07-08 (D-M-Y) By: catalan State: 3-RELEASED

Silicon Detector Facility
ODH Analysis

Dan Olis 6/1/2004

LAB A Control Room Addendum
Herman Cease 4/8/05

LAB A Control Room LN2 Auto Fill System Addendum
LAB A Silicon Storage Room
Herman Cease 1/30/06

Manual Fill LN2 Cube in Lab C South Cleanroom Addendum
Herman Cease 3/14/07

LN2 Test Lab A, Closed loop system
Herman Cease 3/10/08

SUMMARY

A component of the Silicon Detector Facility's utility infrastructure is a gaseous nitrogen header. Nitrogen is used primarily to purge enclosures to eliminate ambient moisture and, in some cases, the presence of oxygen. The Silicon Detector Facility (SiDet) includes Labs A, B, C, D, A-B Bridge, C-D Cross-connect, and adjoining hallways. This analysis is inclusive of all lab spaces within the facility that have any part of the nitrogen header running through them or that are fed by nitrogen piping drops. Separate calculations are included for each portion of the facility that can be isolated by closed doors. This analysis shows that all regions within SiDet are class 0 ODH environments.

Note: This document supercedes the ODH analysis done for the Lab A/B Bridge. The analysis for that single volume has been revised and incorporated into this facility-wide document.

INTRODUCTION

Gaseous nitrogen is primarily used in the Silicon Detector Facility for purging enclosures of sensitive items. Although the plumbing system is extensive, the total nominal flow rate into the facility less than 5 SCFM. Compared to facilities holding cryogenic piping, the nitrogen supply at SiDet is very low risk. The supply is a 5000-gallon liquid nitrogen dewar located outdoors at the north end of Lab D. It has an operating pressure of 34 PSIG and relief valves set to 45 PSIG. A gaseous nitrogen header is fed from the dewar through two Pennwalt CVI vaporizers and the header pressure is nominally the same as the dewar's. The header is piped throughout the facility, interconnecting piping in Lab A, Lab B, Lab C, Lab D, Lab A-B Bridge, and the C-D Cross Connect into a single system. Smaller lines drop from the header as take off points where nitrogen is used. A restricting orifice outdoors in the main feed puts an upper limit on the total possible flow into the facility at 25 SCFM. Additionally, orifices in the individual branches inside the facility limit downstream spills to 2-4 SCFM.

Spreadsheets are attached which show the ODH analysis for each isolated space within the facility that is currently using nitrogen purge or that has the header running through it. The analysis is done as described in Fermilab ES&H chapter 5064, Oxygen Deficiency Hazards. This document shows that all regions within SiDet are class 0 ODH environments.

Si-DET PIPING AND PURGE USAGE OVERVIEW

The piping schematic of the header and dewar is drawing 9214.000-ME-435001. It is attached. The nitrogen header (indoors) is plumbed entirely with type-K copper tube with sweated joints. At points of delivery, flexible poly lines are most frequently used to make the connection to purge enclosures. In addition to serving as a continual purge supply, the nitrogen gas is used in some work areas to periodically spray contaminants from delicate work pieces.

It is facility policy that all purge enclosures use a rotometer style flow meter to set and monitor usage. A summary of all purge usage at the time of this writing of this document is shown in the table below.

SiDet Lab Space	Current Usage [SCFM]	Usage assumed in analysis [SCFM]
Lab A	0.50	3.0
Lab B	0.27	1.5
A-B Bridge	0.01	0.8
Lab C	0.39	2.0
Lab D	0.50	3.4
C-D Cross Connection	0.20	1.1
Total	**1.9**	**11.8**

The left column shows how low the facility's nitrogen consumption is. The right column of the table shows the assumed purge rates used in these analyses. The table illustrates a fairly conservative overestimate of the nitrogen consumption is used. This allows the facility to add to or move a significant number of purge volumes around the system without requiring a revision to this document.

A restricting orifice in the supply line connecting the dewar to the facility limits the maximum flow of nitrogen into the facility to 25 SCFM. This orifice is outdoors. The calculation assumes a catastrophic failure of the downstream piping and uses the dewar's relief valve pressure, not the current operating pressure, as the differential pressure across the orifice. Within the facility, the presence of flow limiting orifices in each drop places a strict upper limit on the nitrogen that can be delivered to a room (typically 2 SCFM). The piping component totals, number of purge enclosures, and ventilation and spill rates are presented for each separate enclosed room within the facility in the following sections.

A time-delayed shutoff valve is installed in the gas supply just at the inlet to the system. The valve is a normally closed solenoid, held open by an uninterruptible power supply (UPS). The valve is EV-3101 on the piping schematic. During short power outages, nitrogen flow to the facility is maintained. During longer outages, the continued flow of nitrogen into some clean rooms could present an oxygen deficiency hazard since forced ventilation is lost. Purge rates are low, so the time to an ODH risk is typically 24 hours or greater. A relay with a timer is set to shutoff gas flow after a 12-hour loss of commercial power. This system is wired for fail-safe operation. The bypass valve shown in the schematic is to be opened only during maintenance and safety tests. It is locked out and labeled with a yellow caution tag. The lock's key is on file with the facility's secretary. This safety system is tested once a year. A copy of the test log is included in the appendix. The tests are the responsibility of the facility's systems technician.

This document assumes that each port on the gas line in an area has a purge volume attached to it. The quantity of purge enclosures listed is an upper limit estimate as to how many could be attached in a given area. Since purges are 'intentional leaks' they are assigned a probability of 1.0 in the calculations. The leak rate assigned to the purge volumes is 0.1 SCFM (6 SCFH), a conservative estimate.

As stated previously, purge volumes are connected to the system through a Dwyer style flow meter with integrated flow control valve. These flow meters are counted as 'valves' in the analyses. In the spreadsheet calculations, the total number of valves in an area includes all the valves that are part of the hard copper piping plus additional flow meter control 'valves' attached to ports in the piping to make use of the nitrogen utility.

Some technicians make use of spray nozzles to periodically blow dust from work pieces. This too represents an intentional 'leak' but the time averaged usage is too small to consider. The spray nozzles are commercial products and can also be accounted as 'valves' in the analyses. There is not a separate line item in the calculations for the spray nozzles since it is assumed that a spray nozzle would be used at a port in place of a purge enclosure (with integrated flow control valve). This is a conservative approach since these spray nozzles do not have a continual purge rate associated with them.

VENITILATION AND ODH ANALYSES FOR EACH LAB AREA

A description of the ventilation system and ODH analysis of each room volume at SiDet is presented in the sections below. To simplify counting of joints in the piping system, the number is estimated by conservatively assuming one joint for every five feet of pipe length. A 5 SCFM spill rate is assumed in leaky joints in the main header. Spill rates in leaky joints in the branches of the system are smaller and assigned the maximum flow rate allowed by the orifice controlling that branch. The leak rate for catastrophic failure of a pipe or valve is assumed equal to the maximum spill rate calculated for the controlling restricting orifice. For pipes and valves in the main run of the header, 25 SCFM is used per the discussion in the introduction. This calculation is in the appendix. In side branches of the system, leak rates are assumed equal to the maximum flow rate of the restricting orifice in that branch. These rates are described in subsequent sections. The probability of failure of the piping components is taken from the NEC tables included in FESHM 5064. The probability of the 'leak rates' of the purge boxes is assigned to 1.0 since they are continually present.

Ventilation rates in the analyses for the building shells (*not* the internal clean rooms) are generated by assuming each building's natural leakiness, or infiltration, provides adequate fresh air for its occupants and the operations taking place within it. The estimated infiltration rate is a conservative estimate based on 1 building volume change per day. The 1989 American Society of Heating and Refrigeration Fundamentals Handbook shows this to be a conservative estimate. The *Infiltration* section in Chapter 23 indicates that office buildings constructed in mid-1980's have infiltration rates of 0.1 to 0.6 air exchanges per hour. This is equivalent to 2.4 to 14.4 air exchanges per day. The 1 volume change per day assumed in this analysis is conservative for SiDet buildings.

Ventilation rates for clean rooms and smaller workspaces are measured rates and described in more detail in the sections below.

Appended to the ODH Analysis spreadsheets are additional documents: calculations, an explanation of the spreadsheet columns, sheets showing the equations used in the spreadsheets, and a copy of the failure rate tables taken from FESHM 5064.

Lab A, (Clean room walls removed 3/10/08 H. Cease)

Lab A houses office space around the perimeter of the second floor and technician workspace on the first floor. The class 5000 and 1000 clean rooms have been removed.

The estimated infiltration rate for the building is 45 CFM and is simply a conservative estimate based on 1 building volume change per day. The calculation is shown here:

$$65000FT^3 x \frac{1day}{24hrs} x \frac{1hr}{60\,\text{min.}} = 45\frac{FT^3}{\text{min.}}$$

There are many spaces within SiDet that have enclosures within larger rooms (e.g. clean rooms within a larger building shell). In these cases, the piping within these smaller rooms is included in the ODH analysis of the larger room volume because a leak within the clean room may eventually find its way into the larger volume. That is to say, the smaller room is considered a part of the larger space it occupies. A separate analysis is then done for the smaller interior spaces (individual clean rooms) to prove that there is not a concentrated risk as a result of the clean room enclosure.

The main nitrogen header in this space is 1" type-K copper. There is currently one purge enclosure in the technician area drawing 0.01 SCFM of nitrogen. The analysis assumes three may exist at some point in the future, each drawing 0.1 SCFM. Furthermore it this analysis, it is assumed that any nitrogen spill in the clean rooms finds its way into the larger tech area. Therefore, the attached spreadsheet calculation includes the piping components found in both the technician area and in the clean rooms. Those components are summarized below and in the spreadsheets in the appendix.

The calculation shows that Lab A is an ODH class 0 environment.

Lab A Class 5000 Clean Room Area (Clean Room walls removed 3/10/08 H. Cease)

The class 5000 clean room occupies the center of the building and the volume extends up into the bubble-shaped roof. The space is more accurately described as a semi-clean room because it is not sealed very well to the inside of Lab A or to the outdoors through the roof. The large presence of bugs and an occasional bird attest to its leakiness.

The room volume is filtered by large HEPA filters, fed by a McQuay Model LYP108C 14-9/16" airfoil powered by a 10 HP motor. The measured makeup rate is 100 CFM. It draws from the Lab A shell. Like all clean rooms, a mechanical failure of the air-handling unit would be quickly recognized and addressed.

The class 1000 clean room is a smaller volume contained inside the class 5000 clean room so the piping components in both areas are included here. The attached analysis summarizes the current piping sizes and lengths and the number of valves inside the clean rooms. The piping feed to the clean room is a single ½" drop from the header. A restricting orifice, located in the larger Lab A volume, limits the maximum flow of nitrogen to 3.8 SCFM. The orifice calculation is included in the appendix.

There are currently six enclosures in the class 5000 room and four in the class 1000 room receiving nitrogen purge. The current consumptions are 0.32 and 0.25 SCFM of nitrogen respectively. To be conservative, a purge rate of 1.7 SCFM is used in the ODH analysis. This is calculated by assuming a purge enclosure is added to each of the existing (10) ports in the class 5000 room and the (7) ports in the class 1000 room. It's assumed each draws 0.1 SCFM of nitrogen.

The analysis shows that the class 5000 clean room has an ODH class 0 rating. The first calculation shows the normal ventilation condition. The second calculation includes the probability of failure of the ventilation system. The probability assigned to the mechanical failure of the air-handling unit was taken from Table 2 in FESHM 5064 for the failure of an electrical motor ($1x10^{-5}$events/hr). A column is added to the table to multiply the probability of the leak times the probability of a ventilation failure due to motor failure. The 5 SCFM fresh air makeup rate used in this calculation is quite reasonable considering the leakiness of the volume previously described.

Ventilation loss as a result of a power outage occurs more frequently at Fermilab. Power outages typically last a few hours at most. Table 1 in FESHM 5064 provides a 1-hour duration for unplanned outages. It would take more than 98 hours of a 1.7 SCFM purge and zero makeup air to lower the oxygen concentration in the clean room to 18%. This calculation is included in the appendix. The 12-hour time-delay shutoff in the facility's main nitrogen feed line eliminates any ODH concern for long-term outages.

<u>Lab A , (Lab A LN2 Test, Closed Loop System Addendum 3/10/08 H. Cease)</u>

A closed loop LN2 system is installed in the Lab A Class 5000 clean room area. The area is no longer being using as a clean room. The closed loop LN2 system installation will be used to cool a heat exchanger inside the Multi-CCD test vessel (MCCDTV). The MCCDTV operations will be moved from the Lab A control room to under the dome at Lab A. A single triple jacketed hose with supply, return and vacuum jacket, runs from the supply outdoors to the MCCDTV heat exchanger in Lab A. The hose is run through support guides to ensure that twisting of the hose in operations does not occur. The LN2 reservoir, pump, and circulation station will be outdoors Lab A very near the existing 500 L dewar used to supply the Lab A control room LN2 autofill system. Operating valves and safety relief valves are all located outdoors to mitigate the ODH. The closed loop cooling system operating pressure is 100 psig.

The calculation shows that Lab A with the Closed Loop LN2 System is an ODH class 0 environment.

Lab A Class 1000 Clean Room (Clean room walls removed, 3/10/08 H. Cease)

The class 1000 clean room sits between the class 5000 clean room and an exterior wall. The ventilation system for the room is shown in the following sketch. A Train Company ventilation unit cools the space but draws no makeup air. The supply side of the unit discharges into the drop ceiling, in a volume called a plenum. There are (18) fan-powered HEPA units installed in the drop ceiling. Each unit includes a filter and its own fan. These ceiling units draw air from the plenum space within the drop ceiling and discharge into the room below. Each ceiling unit moves approximately 616 CFM of air for a total delivery to the room of 18 x 616 = 11,090 CFM of air. The plenum pressure is negative to the room volume, running at approximately -0.08" WC. An intake attached to the plenum draws makeup air from the larger class 5000 clean room. The makeup rate is 100 CFM.

The attached analysis summarizes the current piping sizes and lengths and the size and number of valves inside the clean room. The piping is fed from the larger class 5000 clean room through a single ½" line. The same size restricting orifice that controls flow to the class 5000 clean room limits the maximum flow of nitrogen to 3.8 SCFM.

There are currently four enclosures receiving nitrogen purge. The current consumption is 0.25 SCFM. To be conservative, a purge rate of 0.7 SCFM is used in the ODH analysis.

The analysis shows that the class 1000 clean room has an ODH class 0 rating. The first calculation shows the normal ventilation condition. The second calculation includes the probability of a single point failure of the ventilation system. The class 1000 clean room has a very robust ventilation system since it is assembled from (18) parallel fans on the HEPA units. With a failure of a single unit, seventeen are still operational and the ventilation makeup is essentially unchanged.

It would take more than 36 hours of a 0.7 SCFM purge and zero makeup air to lower the oxygen concentration in the clean room to 18%. This calculation is included in the appendix. The 12-hour time-delay shutoff in the facility's main nitrogen feed line eliminates any ODH concern for long-term outages.

Lab A Control Room Addendum H. Cease 4/8/05

Attached to the Lab A area is an enclosed room known as the Lab A Control Room. Utilities to the room include building nitrogen gas. A restricting orifice (0.052" diam.) in the nitrogen gas line feeding the room limits the maximum flow to 1.8 SCFM. The total room volume is approximately 5500 FT^3. The room is partitioned for a gowning area reducing the room volume to approximately 3800 FT^3. Infiltration to the room is assumed to be one volume exchange per day –or about 2.6 cfm makeup air. At no time does the nitrogen gas purge rate exceed the natural infiltration rate of fresh air.

Three fan powered HEPA units in the ceiling circulate air throughout the room. A baffle is used to take air from the LAB A general area and mix it with the Control Room air at a rate greater than 20 FT^3/min. The Control Room has a positive pressure with respect to the surrounding Lab A area. If a single fan fails, the mixing of air with Lab A remains about the same. The fuse panel for the fans are locked out and labeled with a yellow caution tag. The lock's key is on file with the facility's secretary

LN2 will be used in the control room. The total room volume is approximately 5500 FT^3. The room is partitioned for a gowning area reducing the room volume to approximately 3800 FT^3. A 21 liter LN2 spill is allowed and maintains an ODH Class 0; the Oxygen partial pressure does not dip below 18%. Using a fresh air makeup of 20 FT^3/min, approximately 25 minutes are needed to return the partial pressure of oxygen to 21.9%. Signs are posted to limit the amount of liquid nitrogen in the room to 21 liters. A Job Hazard Analysis is written to ensure workers understand proper personal protection when handling liquid nitrogen, the limitation on the amount of liquid nitrogen that can be stored in the control room, and no additional liquid nitrogen to be brought into the room during a power failure.

Lab A Control Room with LN2 Auto Fill System Addendum H. Cease 11/29/05

An automatic LN2 fill system is replacing the need to hand fill small dewars inside the Control Room. The automatic fill system has a 1000 liter dewar outside the building, a single plumbing line enters the building and runs through the Lab A space, then into the Lab A control room. The supply line of the 1000 liter dewar has a solenoid valve such that in the event of a power failure, LN2 supply is stopped from entering the building. The ODH in Lab A remains Class 0 since the probability of a plumbing line failure is low independent of flow rate. Oxygen monitors on the wall in the Lab A Control Room are used in a fail safe mode where in the event of a power failure or a drop in the partial pressure of Oxygen, the LN2 supply solenoid valve is closed. The Oxygen monitor power is tied to the powered ventilation in the room. If power fails to the ventilation, the Oxygen monitor power also fails, closing the LN2 supply solenoid. The LN2 PID system is included as drawing # 4900.121-MD-436109. The ODH in the Lab A Control Room is Class 0 since in the event of a failure, the LN2 supply is shut off.

The total room volume is approximately 5500 FT^3. The room is partitioned for a gowning area reducing the room volume to approximately 3800 FT^3. A 21 liter LN2 spill is allowed and maintains an ODH Class 0; the Oxygen partial pressure does not dip below 18%. Using a fresh air makeup of 20 FT^3/min, approximately 25 minutes are needed to return the partial pressure of oxygen to 21.9%. Signs are posted to limit the amount of liquid nitrogen in the room to 21 liters. Although carrying in hand flasks with LN2 is no longer needed, the amount of LN2 stored in internal dewars remains limited to 21 liters.

A Job Hazard Analysis is revised to ensure workers understand proper personal protection when handling liquid nitrogen, the limitation on the amount of liquid nitrogen that can be stored in the control room, no additional liquid nitrogen to be brought into the room during a power failure, and to leave the room in the event the Oxygen monitor is tripped.

Lab A Silicon Storage Room, Addendum H. Cease 1/30/2006

Attached to the Lab A area is an enclosed room known as the Lab A Silicon Storage Room. Utilities to the room include building nitrogen gas. A restricting orifice (0.052" diam.) in the nitrogen gas line feeding the room limits the maximum flow to 1.8 SCFM. The total room volume is approximately 2250 FT^3. Infiltration to the room is assumed to be one volume exchange per day –or about 1.6 cfm makeup air.

A ventilation fan with a minimum flow rate of 20 scfm is used pull air through the room. The air comes from the general Lab A volume. If a power outage occurs, the supply to the room N2 line is shut off using a solenoid valve. The Silicon Storage Room has a negative pressure with respect to the surrounding Lab A area. At all times the ODH class for the Silicon Storage Room is Class 0.

Lab B Shop and Basement

Lab B houses a small machine shop and technician work area. It also held the old Bubble Chamber and for that reason is the only building at SiDet with a basement. The shop area and basement around the bubble chamber are considered a single building volume since they are interconnected through large openings.

Lab B has corrugated steel walls and a large rollup door to the outside. The infiltration rate into the building due to the leaky nature of the structure is estimated to be 35 CFM based on one building volume change per day.

Lab B is the terminal branch of the nitrogen header. The pipe lengths, number of valves, purge enclosures, and potential spill rates are summarized in the appended analysis.

Freezers in the basement are purged with nitrogen to reduce the accumulation of ice inside them. Currently, 0.03 SCFM of purge gas is used. The analysis conservatively assumes 0.3 SCFM or purge may eventually be drawn in the shop. A restricting orifice in the line feeding this drop limits the maximum flow to 1.8 SCFM. The calculation shows that the Lab B shop is an ODH class 0 environment.

Lab B Lotema Room

Three smaller rooms are attached to the larger Lab B shop. They are each analyzed separately. The construction of these rooms is the same as the rest of Lab B. The estimated infiltration rate into the Lotema Room due to the leaky construction is 33 CFM.

The Lotema Room is usually used to setup tests and experiments. There are currently no purge volumes in the room but nitrogen is sometimes used as a purge when running cold tests to prevent the formation of condensation on test pieces. A half-inch nitrogen header runs the perimeter of the room. A restricting orifice in the line limits the maximum flow into the room to 1.8 SCFM. For this analysis, it is assumed that a second valve is attached to each of the five drops and each is drawing 0.1 SCFM of nitrogen gas.

The attached analysis shows that the Lotema room is a class 0 ODH environment.

Lab B Mycom and Norwalk Rooms

These rooms are fairly small (6300 ft^3 for Mycom and 5000 ft^3 for Norwalk) so the estimated infiltrated rates do not provide enough confidence that natural infiltration is an adequate source of fresh air. Forced ventilation of 550 CFM is provided to each room with fans (Comair-Rotron brand, Caravel model). The switches on the fans are locked out and labeled with a yellow caution tag. The lock's key is on file with the facility's secretary. The facility's systems technician verifies operation regularly. A copy of the verification log is included in the appendix.

The Mycom room is currently used as an assembly area. There are currently two volumes in the room drawing 0.03 SCFM of nitrogen. A half-inch nitrogen header runs the room's perimeter and includes three drops. A restricting orifice in the line limits the maximum flow into the room to 1.8 SCFM. For this analysis, it is assumed that a second valve is attached to each of the three drops and each is drawing 0.1 SCFM of nitrogen gas.

The attached analysis shows that the Mycom room is a class 0 ODH environment for both 'normal ventilation' and 'ventilation failure' cases. A 1 CFM of infiltration was assumed for the ventilation failure analysis. It is equivalent to a room air change every 4.3 days. A calculation in the appendix shows that a leak of 0.3 SCFM of nitrogen gas into the room will result in an oxygen level of 18% after 54 hours. This calculation is included in the appendix. The 12-hour time-delay shutoff in the facility's main nitrogen feed line eliminates any ODH concern for outages of 12 hours or more.

The Norwalk room is currently used as an assembly area. Currently there are no users attached to the nitrogen lines in the room. A restricting orifice limits the maximum flow into the room to 1.8 SCFM. For this analysis, it is assumed that a second valve is attached to each of the three drops and each is drawing 0.1 SCFM of nitrogen gas.

The attached analysis shows that the Norwalk room is a class 0 ODH environment for both 'normal ventilation' and 'ventilation failure' cases. A 1 CFM of infiltration was assumed for the ventilation failure analysis. It is equivalent to a room air change every 3.5 days. A calculation in the appendix shows that a leak of 0.3 SCFM of nitrogen gas into the room will result in an oxygen level of 18% after 43 hours. This calculation is included in the appendix. The 12-hour time-delay shutoff in the facility's main nitrogen feed line eliminates any ODH concern for outages of 12 hours or more.

A-B Bridge

The A-B Bridge is a steel shell industrial building on a concrete pad. It houses both offices and lab space. The building is ventilated by AC-1, a Trane model YCH330 unit rated to deliver 11,000 CFM. The minimum fresh air intake on the unit is 646 CFM but is delivered only when the thermostat calls for operation. Like other industrial buildings, fresh air is maintained by infiltration leakage. This number is estimated as 64 CFM.

The attached analysis summarizes the current piping sizes and lengths and the size and number of valves inside the A-B Bridge. There are three possible modes of nitrogen delivery to the bridge considered: full rupture of the piping or valves, leakage from a joint failure on the piping, and intentional purging of nitrogen gas into dry boxes. For conservativeness, it is assumed that one purge box is used at each of the eight nitrogen drops. There is currently only one enclosure in the bridge that is fed a nitrogen purge. The total current purge consumption is 0.01 SCFM of nitrogen. To be conservative, a purge rate of 0.8 SCFM is used in the ODH analysis. This is calculated by assuming a purge enclosure is added to each of the existing (8) drops from the nitrogen header and each draws 0.1 SCFM. Since purging is intentional and continual, the probability of this mode of delivery assigned in the spreadsheet is 1.

The probabilities assigned to a pipe rupture, valve rupture, and leaky joint (weld) are taken from Table 2 in FESHM chapter 5064. The spill rate out of a leaking joint in the header is conservatively assigned 5 SCFM. The spill rate from a ruptured valve or pipe is 25 SCFM, the maximum flow that can be delivered to the system. Orifices in each drop limit the maximum flow rate to 0.9 SCFM. This calculation is in the appendix.

The attached analysis shows that the Lab A-B Bridge is a class 0 ODH environment.

Lab C

Lab C is an industrial building shell constructed on a concrete pad with corrugated steel walls and an asphalt roof. The building is heated and cooled by a unit that runs only when called for by a thermostat. The building's natural leakiness, or infiltration, provides adequate fresh air for its occupants and the operations taking place within it. The estimated infiltration rate for the building is 69 CFM. The building volume is 100,000 FT^3.

The gaseous nitrogen supply header enters from the C-D Cross Connection and exits towards Lab A. There is additional piping inside the Lab C clean room, which resides in the volume of the Lab C shell. The nitrogen is fed to the clean room through a single ½-inch line dropped through the ceiling. Since the clean room is contained within the larger shell, any nitrogen leak in the clean room eventually finds its way into the larger high bay volume. The attached Lab C analysis summarizes the piping found in the high bay and the clean rooms. The pipe lengths and valve count are included. A spill rate of 25 SCFM for catastrophic failure of components is used for piping in the high bay. The flow-limiting orifice in the feed to SiDet sets this limit. The spill rate from components inside the clean room is controlled by a flow-limiting orifice in the ½-inch pipe feeding the clean room. The maximum spill is 3.8 SCFM.

The calculation shows that the Lab C high bay is an ODH class 0 environment. Since the ventilation of the building is supplied by natural infiltration, no analysis is required for the case of a 'ventilation failure'.

Lab C Clean Rooms

A glass wall separates the clean rooms into 'north' and 'south'. The two sides are connected with a walk-through door and a large rollup door (normally closed). The ventilation system is described in FESS drawing number 8-2-125. The two sides have identical ventilation systems. Each includes two parallel cooling units that feed a larger ventilation blower with associated HEPA filtration. The cooling units each have a 5 HP direct-drive blower. They supply the suction side of an airfoil scroll unit driven by a 10 HP motor. The makeup rate on each cooling unit specified on the drawing is 500 CFM, or 1000 CFM of fresh air to each clean room. Measurements indicate the makeup rate is currently 1240 CFM to the north and 1232 to the south. The analysis uses 1000 CFM per the design specification. Ventilation makeup is drawn from the Lab C shell.

The attached analysis summarizes the current piping sizes and lengths and the size and number of valves inside the clean room. Since the piping, ventilation, and sizes of the two halves are very similar a single analysis is valid for both sides. The piping system is fed by a single ½" drop from the header through the clean room roof. A restricting orifice in the drop, located above the clean room roof, limits the maximum nitrogen flow to 3.8 SCFM. The orifice calculation is included in the appendix.

There is currently one enclosure in the north side and seven in the south that are receiving nitrogen purge. The current consumptions are 0.14 and 0.25 SCFM of nitrogen respectively. To be conservative, a purge rate of 1.0 SCFM per side is used in the ODH analysis. This is calculated by assuming a purge enclosure is added to each of the existing (10) ports on the nitrogen header and each draws 0.1 SCFM of nitrogen. The valve total in the tables also shows that a valve is assumed to be included on each purge enclosure.

The analysis shows that Lab C clean rooms have ODH class 0 rating. The analysis in the appendix is for the normal ventilation condition. The second condition to consider includes the probability of failure of the ventilation system. This is discussed in the following paragraph.

From the perspective of controlling oxygen deficiency hazards, the ventilation system is very robust. The system for each half of the clean room includes three fans. Although a mechanical failure of the main HEPA blower would reduce the nominal makeup, the smaller 5 HP units will very easily draw the minimum makeup required to control the hazard. As stated above, each half of the clean room normally is fed 1200 CFM of makeup air. When considering the probability of mechanical failure of the primary blower, it is calculated that only 2 CFM of makeup air is needed to control the oxygen deficiency hazard. The parallel Liebert blowers feeding the larger unit will continue to push 450 CFM of makeup air through the system when the main unit is inoperable. This was determined by a test. Therefore the hazard is controlled in the event of a mechanical failure of the main blower. The probability of failure of two of the three blowers is $P_{event} = P^n$, where P = 1e-5 motor failures/hr and n = 2 motors. Therefore the probability of a complete loss of ventilation on either half of the clean room from mechanical failure is 1e-10/hr and further calculation is not required.

Because each clean room has its own separate ventilation system, there is an additional level of ventilation redundancy. Each clean room is pressurized to 0.04"WC. A total failure of one unit, and subsequent depressurization of the clean space, would cause leakage of air from the other half of the clean room (whose ventilation system is still operational) around the cracks in the window seals and around the walk-through and rollup doors separating the two sides. A 1.4 in^2 leak area between the north and south clean rooms provides 5 CFM of air into the depressurized room.

During a power outage, it would take more than 50 hours of a 1.0 SCFM purge and zero makeup air to lower the oxygen concentration in the either half of the clean room to 18%. This calculation is included in the appendix. The 12-hour time-delay shutoff in the facility's main nitrogen feed line eliminates any ODH concern for outages of 12 hours or more.

Lab C South Clean Room Addendum H. Cease 3/14/07

A test cube for CCD measurements is being operated in the lab C south clean room. The LN2 dewar used to cool the CCD has a 5 liter capacity. Since the dewar is filled by hand using a 5 liter flask, an additional 5 liters may be located in a nearby flask in the same room. The ODH for the room is calculated. The volume of the clean room is 18,000 FT^3. Ventilation makeup is drawn from the Lab C shell at a rate of 1000 CFM. To drop the oxygen partial pressure below 18% from a one time spill, at least 99 liters of liquid nitrogen would have to be spilled. At no time will this amount of liquid nitrogen be available in the clean room. The LN2 consumption rate of the test cube is estimated at 0.3 L/hr. This is equivalent to 0.1 CFM of N2 gas being generated in the room. The ODH is class 0 in the lab C South clean room.

Five liter flasks are used to transport the liquid nitrogen from the main outside reservoir to the lab C south clean room. The transportation path includes two vestibules, one at the entrance to the building, and the other is the clean room gowning area. A limit for the maximum spilled amount of LN2 is calculated for each area.

The Oxygen partial pressure in the vestibule at the entrance of the building during a 6 liter spill drops from 21.9% to 15%. The Fatality Factor for a 15% oxygen concentration is 2.4e-4. When the Fatality Factor is multiplied by the risk factor, 0.002, for a human error spilling the flask while in the vestibule the ODH fatality risk factor drops below 10^{-7}, deeming the area ODH class 0.

The Oxygen partial pressure in the lab C south gowning area during a 10 liter spill drops from 21.9 % to 18%. The gowning area vestibule remains at Class 0.

A Job Hazard Analysis is used to ensure workers understand proper personal protection when handling liquid nitrogen.

C-D Cross Connect

The C-D Cross Connect holds both office and testing space. It is constructed in the same style as other industrial buildings in the complex. The building temperature is controlled by an HVAC unit that runs only when the thermostat calls for heating or cooling. The estimated infiltration rate for the building is 53 CFM, based on one air exchange per day for the building's 75,600 FT^3 volume.

The gaseous nitrogen supply header enters from Lab D and exits to Lab C. Nitrogen gas is available in the testing area for purge volumes. The attached analysis summarizes the piping found in the C-D cross connect. The pipe lengths and valve count are included. A spill rate of 25 SCFM for catastrophic failure of components is used for the overhead piping while the flow-limiting orifice in the drops controls the maximum spill in the testing area to 1.8 SCFM.

There are currently eight enclosures in the cross-connect receiving nitrogen purge. The current consumption is 0.2 SCFM. To be conservative, a purge rate of 1.1 SCFM is used in the ODH analysis. This is calculated by assuming a purge enclosure is added to each of the existing (11) ports on the nitrogen header and each draws 0.1 SCFM of nitrogen.

The calculation shows that the C-D cross connect is an ODH class 0 environment. Since the ventilation of the building is supplied by natural infiltration, no analysis is required for the case of a 'ventilation failure'.

Lab D

Lab D is an industrial building shell constructed on a concrete pad with corrugated steel walls and an asphalt roof. The building is heated and cooled by AHU-1. The unit runs only when heating and cooling are required. The building's natural infiltration provides adequate fresh air for its occupants and the operations taking place within it. The estimated infiltration rate for the building is 72 CFM, assuming one volume change per day. The building volume is 103,800 FT^3.

The gaseous nitrogen supply line enters the Silicon Facility through the northeast corner of Lab D. Additionally, there is piping inside the Lab D clean room and Bonding Area, which reside inside the shell of Lab D. Since the clean room and bonding area are contained within the larger shell, any nitrogen leaked in theses spaces will eventually find its way into the larger high bay volume. The attached analysis summarizes the piping found in the high bay, clean room, and bonding area. The pipe lengths and valve count are included. A spill rate of 25 SCFM for catastrophic failure of components is used for piping in the high bay. The orifice outside the building that controls the total flow to the facility sets this limit. The spill rate from components inside the clean room and bonding area is controlled by flow limiting orifices in the individual pipe drops to these spaces. This number is 1.8 SCFM.

The calculation shows that the Lab D high bay is an ODH class 0 environment. Since the ventilation of the building is supplied by natural infiltration, no analysis is required for the case of a 'ventilation failure'.

Lab D Clean Room

The Lab D clean room resides inside the Lab D high bay. The clean room has a separate air-handling unit (ACU-2) on the roof of Lab D. It draws fresh air from outdoors. The makeup on the unit is 1100 CFM. The unit runs continuously.

The attached analysis summarizes the current piping sizes and lengths and the size and number of valves inside the clean room. The system is fed by four ½" drops from the above header in the Lab D high bay. A restricting orifice in each drop limits the maximum flow to 1.8 SCFM in each line. The orifices are located in the drops above the clean room roof. Therefore a catastrophic failure of any piping component results in a maximum spill of 1.8 SCFM. The orifice calculation is included in the appendix.

There are currently eleven enclosures in the clean room that are fed a nitrogen purge. The total current consumption is 0.5 SCFM of nitrogen. To be conservative, a purge rate of 2.4 SCFM is used in the ODH analysis. This is calculated by assuming a purge enclosure is added to each of the existing (24) ports on the nitrogen header and each draws 0.1 SCFM of nitrogen.

The attached analysis shows that with a ventilation rate of 1100 CFM provided by the air-handling unit, the risk of death by asphyxiation from the nitrogen system is very low and the space has an ODH class 0 rating.

In the event that forced ventilation to the clean room is lost due to a mechanical failure of the air handling unit, the second table shows that the simultaneous probability of a leak event and the mechanical breakdown of the AHU is so unlikely that the clean room remains an ODH class 0 environment. For this case, a minimum infiltration rate of 5 CFM of fresh air is assumed due to leakage from the attached annex called the Bonding Area. The Bonding Area has its own ventilation system and is connected to the Lab D clean room by a walkthrough door and a large rollup door. Both doors are usually closed but present enough of a leak path around cracks to easily provide the 5 CFM used in the analysis. Additional sources of leakage include stack effects to the outdoors through the clean room's ventilation system as well as normal opening and closing of doors.

The probability assigned to the mechanical failure of the air-handling unit was taken from Table 2 in FESHM 5064 for the failure of an electrical motor ($1x10^{-5}$events/hr). A column is added to the table to multiply the probability of the leak times the probability of a ventilation failure due to motor failure.

Ventilation loss as a result of a power outage is a more frequent event at Fermilab. Power outages typically last a few hours at most. Table 1 in FESHM 5064 provides a 1-hour duration for unplanned outages. It takes 30 hours of a 2.4 SCFM purge to lower the oxygen concentration in the clean room to 18%. This calculation is included in the appendix. The 12-hour time-delay shutoff in the facility's main nitrogen feed line eliminates any ODH concern for outages of 12 hours or more.

Lab D Bonding Area

The Bonding Area is adjacent to the clean room. It is a semi-clean space heated and cooled by a small air-handling unit in the hallway. The AHU delivers approximately 1400 CFM to the suction side of three HEPA units installed in the ceiling. A makeup rate of 25 CFM is drawn from the high bay.

The nitrogen header does not run through this area but some nitrogen is fed to the room through plastic lines to feed dry boxes and as a utility at some of the bonding stations. An orifice in the copper line that feeds this space limits the maximum spill rate to 1.8 SCFM. The purge volumes currently consume 0.2 SCFM but 1.0 SCFM is used in the analysis. The analysis assumes one valve for each of the six bonding stations and one on each of ten possible dry boxes.

From an ODH standpoint, the ventilation system is robust since it includes the main blower on the AHU as well as individual fans on the three ceiling-mounted HEPA units. Forced ventilation will still exist with a single failure on the main blower or one of the HEPA units. Furthermore, the adjacent Lab D clean room normally operates at 0.01"WC of positive pressure. This provides a constant rate of leakage into the bonding area through the large rollup door, walkthrough door, and pass through window. A small 5 CFM of makeup air is assumed in the analysis for the case of a mechanical breakdown of one of the HEPA units or the main blower.

For both normal operation of the ventilation system and a possible single mechanical failure in the system, the attached analyses show the space has an ODH class 0. In the event of a power outage, it would take 23 hours of a 1.0 SCFM purge to lower the oxygen concentration in the clean room to 18%. This calculation is included in the appendix. The 12-hour time-delay shutoff in the facility's main nitrogen feed line eliminates any ODH concern for outages of 12 hours or more.

3-10-08 H. Cease (add LN2 test Lab A, Remove Lab A Class 5K and 1K clean rooms)
2-19-07 H. Cease
9-6-06 H. Cease

LAB A SHELL
VENTILATION BY INFILTRATION

Intake E	TC, min. V/E	
45 SCFM	1440	
Volume V	Elevation	Pressure
65,000 ft^3	756 ft	740 mmHg

ITEM	TYPE	N	P[events/hr] FAIL RATE	GROUP FAIL RATE	L [SCFM] leak rate	fO2(=) FRACT O2	F Fatal. Factor	Ø Fatal. Rate	ODH Class	
High Bay										
N2 Gas Lines										
Pipes<3" (1.5,1,0.5")	sections	11	1.0E-09	1.10E-08	25	13.51%	3.12E-04	3.43E-12	0	
valves (ball)	rupture	6	1.0E-08	6.00E-08	25	13.51%	3.12E-04	1.87E-11	0	
welded/brazed joints	leak	44	3.0E-09	1.32E-07	5	18.91%	3.18E-08	4.20E-15	0	
purge volumes (3 @0.1 CFM per)		1	1.0E+00	1.00E+00	0.3	20.86%	1.14E-09	1.14E-09	0	
LN2 Lines										
relief valves	leak	0	4.0E-07	0.00E+00	1000	0.91%	1.00E+00	0.00E+00	0	
valves (solenoid)	rupture	0	1.0E-08	0.00E+00	1000	0.91%	1.00E+00	0.00E+00	0	Add 3-10-08 Lab A LN2 test
welded/brazed joints	leak	25	3.0E-09	7.50E-08	1000	0.91%	1.00E+00	7.50E-08	0	Add 3-10-08 Lab A LN2 test
Pipes<3" (1.5,1,0.5")	sections	3	1.0E-09	3.00E-09	1000	0.91%	1.00E+00	3.00E-09	0	Add 3-10-08 Lab A LN2 test
Old Class 5k&1k Clean Room area										
N2 Gas Lines										
Pipes < 3" (1/2" Line)	sections	15	1.0E-09	1.50E-08	3.8	19.37%	1.44E-08	2.17E-16	0	
valves (ball&rotometers	rupture	44	1.0E-08	4.40E-07	3.8	19.36%	1.47E-08	6.49E-15	0	
welded/brazed joints	leak	60	3.0E-09	1.80E-07	3.8	19.37%	1.44E-08	2.60E-15	0	
purge volumes (24 @0.1 CFM per)		1	1.0E+00	1.00E+00	2.4	19.94%	5.46E-09	5.46E-09	0	
Control Room										
N2 Gas Lines										
Pipes<3" (1.5,1)	sections	2	1.0E-09	2.00E-09	1.8	20.19%	3.54E-09	7.08E-18	0	
valves (ball)	rupture	10	1.0E-08	1.00E-07	1.8	20.19%	3.54E-09	3.54E-16	0	
welded/brazed joints	leak	82	3.0E-09	2.46E-07	1.8	20.19%	3.54E-09	8.70E-16	0	
purge volumes (7 @0.1 CFM per)		1	1.0E+00	1.00E+00	0.7	20.68%	1.55E-09	1.55E-09	0	
LN2 Lines										
Failure Rate, event/hr										
####### for O2 monitor										
Pipes < 3" (1/2" Line)	sections	2	1.0E-09	8.00E-14	1000.0	0.91%	1.00E+00	8.00E-14	0	
valves (solenoid)	rupture	7	1.0E-08	2.80E-12	1000.0	0.91%	1.00E+00	2.80E-12	0	
welded/brazed/	leak	80	3.0E-09	9.60E-12	1000.0	0.91%	1.00E+00	9.60E-12	0	
relief valves	leak	6	4.0E-07	9.60E-11	1000.0	0.91%	1.00E+00	9.60E-11	0	
Boil-off Vent (3 @.035 CFM per)		1	1.0E+00	1.00E+00	0.1	20.95%	9.74E-10	9.74E-10	0	
Silicon Storage Room										
N2 Gas Lines										
Pipes < 3" (1/2" Line)	sections	4	1.0E-09	4.00E-09	1.8	20.19%	3.54E-09	1.42E-17	0	
valves (ball&rotometers	rupture	19	1.0E-08	1.90E-07	1.8	20.19%	3.54E-09	6.72E-16	0	
welded/brazed joints	leak	75	3.0E-09	2.25E-07	1.8	20.19%	3.54E-09	7.96E-16	0	
purge volumes (8 @0.1 CFM per)		1	1.0E+00	1.00E+00	0.8	20.63%	1.67E-09	1.67E-09	0	
TOTAL								8.89E-08	0	

LAB A CONTROL ROOM
NORMAL VENTILATION OPERATION -GN2 PURGE and LN2 AUTOFILL SYSTEM

Intake E	TC, min. V/E	
22.6 SCFM	168	
Volume V	Elevation	Pressure
3,800 ft^3	756 ft	740 mmHg

ITEM	TYPE	N	P[events/hr] FAIL RATE	GROUP FAIL RATE	L [SCFM] leak rate	fO2(=) FRACT O2	F Fatal. Factor	Ø Fatal. Rate	ODH Class	
Gas Lines										
Pipes < 3" (1/2" Line)	sections	2	1.0E-09	2.00E-09	3.8	17.98%	1.55E-07	3.10E-16	0	
valves (solenoid)	rupture	10	1.0E-08	1.00E-07	3.8	17.98%	1.55E-07	1.55E-14	0	
welded/brazed/	leak	82	3.0E-09	2.46E-07	3.8	17.98%	1.55E-07	3.81E-14	0	
relief valves	leak	0	4.0E-07	0.00E+00	3.8	17.98%	1.55E-07	0.00E+00	0	
purge volumes (7 @.1 CFM per)		1	1.0E+00	1.00E+00	0.7	20.37%	2.63E-09	2.63E-09	0	
LN2 Lines										
Failure Rate, event/hr										
####### for O2 monitor										
Pipes < 3" (1/2" Line)	sections	4	1.0E-09	1.60E-13	1000.0	0.46%	1.00E+00	1.60E-13	0	
valves (solenoid)	rupture	9	1.0E-08	3.60E-12	1000.0	0.46%	1.00E+00	3.60E-12	0	9-6-06 added 2 transfer lines for the Multi-CCD Vessel
welded/brazed/	leak	80	3.0E-09	9.60E-12	1000.0	0.46%	1.00E+00	9.60E-12	0	9-6-06 added 2 Valves for the Multi-CCD Vessel
relief valves	leak	6	4.0E-07	9.60E-11	1000.0	0.46%	1.00E+00	9.60E-11	0	
Boil-off Vent (3 @.035 CFM per)		1	1.0E+00	1.00E+00	0.1	20.90%	1.06E-09	1.06E-09	0	
TOTAL								3.80E-09	0	

LAB A CONTROL ROOM
VENTILATION FAILURE -GN2 PURGE and LN2 AUTOFILL SYSTEM

Intake E	TC, min. V/E	
2.6 SCFM	1462	
Volume V	Elevation	Pressure
3,800 ft^3	756 ft	740 mmHg

ITEM	TYPE	N	P[events/hr] FAIL RATE	GROUP FAIL RATE	GROUP FAIL *VENT FAIL	L [SCFM] leak rate	fO2(=) FRACT O2	F Fatal. Factor	Ø Fatal. Rate	ODH Class
Gas Lines										
Pipes < 3" (1/2" Line)	sections	2	1.0E-09	2.00E-09	2.00E-14	3.8	8.53%	1.00E+00	2.00E-14	0
valves (1/2" ball)	rupture	6	1.0E-08	6.00E-08	6.00E-13	3.8	8.53%	1.00E+00	6.00E-13	0
welded/brazed/	leak	82	3.0E-09	2.46E-07	2.46E-12	3.8	8.53%	1.00E+00	2.46E-12	0
purge volumes (@.1 CFM per)		12	1.0E+00	1.20E+01	1.20E-04	1.2	14.37%	7.28E-05	8.74E-09	0
LN2 Lines										
Failure Rate, event/hr										
####### for O2 monitor										
Pipes < 3" (1/2" Line)	sections	2	1.0E-09	8.00E-14	8.00E-19	1000.0	0.05%	1.00E+00	8.00E-19	0
valves (1/2" ball)	rupture	7	1.0E-08	2.80E-12	2.80E-17	1000.0	0.05%	1.00E+00	2.80E-17	0
welded/brazed/	leak	80	3.0E-09	9.60E-12	9.60E-17	1000.0	0.05%	1.00E+00	9.60E-17	0
relief valves	leak	6	4.0E-07	9.60E-11	9.60E-16	1000.0	0.05%	1.00E+00	9.60E-16	0
Boil-off Vent (3 @.035 CFM per)		1	1.0E+00	4.00E-05	4.00E-10	0.1	20.18%	3.60E-09	1.44E-18	
TOTAL									8.74E-09	0

LAB A SILICON STORAGE ROOM
NORMAL VENTILATION OPERATION

Intake E	TC, min. V/E	
20 SCFM	113	
Volume V	Elevation	Pressure
2,257 ft^3	756 ft	740 mmHg

ITEM	TYPE	N	P[events/hr] FAIL RATE	GROUP FAIL RATE	L [SCFM] leak rate	fO2(=) FRACT O2	F Fatal. Factor	Ø Fatal. Rate	ODH Class
Pipes < 3" (1/2" Line)	sections	2	1.0E-09	2.00E-09	1.8	19.27%	1.72E-08	3.45E-17	0
valves (ball&rotometers	rupture	17	1.0E-08	1.70E-07	1.8	19.27%	1.72E-08	2.93E-15	0
welded/brazed joints	leak	75	3.0E-09	2.25E-07	1.8	19.27%	1.72E-08	3.88E-15	0
purge volumes (8 @0.1 CFM per)		1	1.0E+00	1.00E+00	0.8	20.19%	3.55E-09	3.55E-09	0
TOTAL								3.55E-09	0

LAB A SILICON STORAGE ROOM
VENTILATION FAILURE FROM MECH BREAKDOWN

Intake E	TC, min. V/E	
1.6 SCFM	1440	
Volume V	Elevation	Pressure
2,257 ft^3	756 ft	740 mmHg

ITEM	TYPE	N	P[events/hr] FAIL RATE	GROUP FAIL RATE	GROUP FAIL *VENT FAIL	L [SCFM] leak rate	fO2(=) FRACT O2	F Fatal. Factor	Ø Fatal. Rate	ODH Class
Pipes < 3" (1/2" Line)	sections	2	1.0E-09	2.00E-09	2.00E-14	1.8	9.78%	1.83E-01	3.66E-15	0
valves (1/2" ball)	rupture	17	1.0E-08	1.70E-07	1.70E-12	1.8	9.78%	1.83E-01	3.11E-13	0
welded/brazed joints	leak	75	3.0E-09	2.25E-07	2.25E-12	1.8	9.78%	1.83E-01	4.12E-13	0
purge volumes (8 @0.1 CFM per)		1	1.0E+00	1.00E+00	1.00E-05	0.8	13.90%	1.61E-04	1.61E-09	0
TOTAL									1.61E-09	0

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Welder Qualification Test Record

Welder's Name Leonard Harbacek Ident No. 122261 Date 03/19/99

Welding Process GTAW Type Manual

Test in Accordance With WPS # ES-155003 Root Open

Material Specification SA 53-B To Material Specification SA 53-B

P-No 1 To P-No 1 Thickness .280" Diam 6"

Filler Metal Specification SFA A5.18 Classification ER-70S-2 F-No 6

Thickness Deposited .280

Backing Argon Gas Shielding Argon

Position 6-G Progression Upward

Electrical Characteristics: Current DC Polarity Straight

Thickness Qualified .560" Max Diameter Qualified 2-7/8" O.D. and over

GUIDED BEND TEST RESULTS

Specimen No	Type	Figure	Results
1	Face	QW-462.3a	Acceptable
2	Face	QW-462.3a	Acceptable
3	Root	QW-462.3a	Acceptable
4	Root	QW-462.3a	Acceptable

Test Conducted By IFR Engineering Test No. 008-09-01 Date 3/19/99

We certify that the statements in this record are correct and that the test welds were prepared, welded and tested in accordance with the requirements of Section IX of the ASME Code.

By: [signature]

Date: 4/22/99