**CRYOGENIC AND SAFETY CONSIDERATIONS
FOR MOVING THE SOUTH END CAP
CALORIMETER TO THE SIDEWALK**

D-ZERO ENGINEERING NOTE # 3823.115 EN-459

Author: Russ Rucinski, RD/D-Zero Mech.
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Approved:
RD/D-Zero Mechanical Group leader

INTRODUCTION

The south end cap calorimeter (ECS) will need to be moved off of the detector platform to allow for the installation of new central tracking components. This engineering note documents the cryogenic and safety issues associated with the planned move. Because of the difficulty involved in building a temporary vent line out of the building, we plan to vent the ECS condenser flow, 6 scfm N₂ into the assembly hall atmosphere. Information contained herein proves that this is safe even for failure/relief conditions.

CRYOGENIC ISSUES

The ECS was drained of liquid argon on 2/28/96 and is currently kept cold (95 Kelvin) and isolated on the detector platform. We plan on keeping the ECS in this condition through out the multi-year upgrade project. The planned move will involve the following:

- 1.) Swap out of cryogenic control cables with extension cables. (Done)
- 2.) Installation of a bridge between the main beam and the south sidewalk.
- 3.) Isolation and capping of cryogenic services to the ECS.
- 4.) Move of the ECS directly southward approximately 25 feet.
- 5.) Reconnection of some cryogenic services.

The cryogenic and associated services to the calorimeters are listed below:

- 1.) 1 1/2" x 3" LN₂ supply
- 2.) 6" Insulating vacuum header
- 3.) 4" Utility vacuum
- 4.) 1 1/2" x 3" GAr line
- 5.) 4" x 6" Vent line
- 6.) 1 1/2" x 3" LAr drain line
- 7.) Instrument air
- 8.) GN₂ purge line for vent
- 9.) GHe for Cold valve, PV319A
- 10.) LAr Spill trough (already disconnected-all calorimeters empty)
- 11.) Cooling water for diffusion pump (disconnect at any time)

Just before the move, each line will be taken out of service in an orderly manner. The tentative order will be as follows:

- 1.) LAr drain line: Isolated dewar. Pull ECS rotating u-tubes. Cap platform side. P&P platform side. ECS side cap has small P&P valve to clean between cap and PV318A. Remove air supply to PV318A. PV318A will be in a closed position.
- 2.) GHe for Cold valve, PV319A: Cap both sides. PV319A will be in a 50% open position.

- 3.) Utility vacuum: Remove air supply to PV315UV after verifying closed. Pull ECS rotating u-tubes. Cap both sides.
- 4.) GAr line: Pull ECS rotating u-tubes. Cap platform side. P&P platform side. ECS side cap has small P&P valve to clean between cap and PV314A.
- 5.) LN2 supply: Several days ahead of time we will lower the ECS pressure to 18 psia. Isolate liquid nitrogen line between MV491N and PVX01N, PVX02N at the calorimeters. Warm line by doing a few P&P. Pull ECS rotating u-tubes. Cap platform side. P&P platform side but do not bring back on line. Attach VJ flex hose to ECS side in anticipation of connection when moved to sidewalk.
- 6.) Vent line: Pull ECS rotating u-tubes. Cap platform side. Install ECS vent heater/check valve assembly in ECS side.
- 7.) GN2 purge line for vent: Cap both sides of connection to ECS. Establish cooling and steady state operating conditions to the CC and ECN.
- 8.) Insulating vacuum: Pull ECS rotating u-tubes. Cap platform side. Attach additional piping to bring ECS side to sidewalk level for a ready connection of a portable vacuum pump to maintain ECS vacuum. (Note: ECS vacuum ROR=1.9 microns per hour when isolated.)
- 9.) Disconnect instrument air to ECS.

During the move it is anticipated that the ECS pressure will rise 0.1 to 0.3 psi per hour. The average module temperature will rise 0.1 to 0.2 Kelvin per hour. It is expected that the ECS cryogenics will be disconnected for no more than two days.

After the ECS is moved to the sidewalk:

- 1.) Connect instrument air.
- 2.) Turn on ECS vent heater.
- 3.) Purge out the LN2 source and connect it to the ECS supply line. Establish liquid nitrogen flow through the ECS cooling coils and steady state pressure maintenance.

SAFETY ISSUES

The main safety issue that needs to be addressed is the **ODH consideration** of venting the nitrogen exhaust gas into the building. ODH calculations are included as an appendix. Three cases are considered. The first case is for the normal steady state operation of the ECS. The second case is a failure case where the control valve fails open and a maximum liquid nitrogen flowrate is dumped into the building. (This second case also happens to be equivalent to the maximum flow required for a pressure vessel main relief blowing due to a condenser rupture.) The third case is a failure case where the vacuum jacketed flex hose supplying the ECS with liquid nitrogen is severed. The calculations show that the ODH classification of the building stays class 0.

Additional control features that were not taken into account make the analysis conservative. These features are:

1. A flow switch that will automatically shut off flow at the liquid nitrogen dewar in an overflow condition.
2. A liquid sensor in the ECS vent that will automatically shut off flow at the ECS condenser inlet valves if liquid is sensed.
3. ODH heads in the assembly hall remain active.
4. Building ventilation, natural and forced, was neglected. Only the cryogenic system exhaust fan which is monitored and tested daily was used.

Table 1. Summary of ODH analysis

CASE	I	II	III
Time to get O ₂ = 18%	Never	269 minutes	216 minutes
Fatality factor @ t=infinity	0.0	3.13 E-5	1.93 E-4
Probability factor $\phi = P_i * F_i$	1.0	1.0 E-8	3.0 E-6
	0.0	3.1 E-13	5.8 E-10

The current assembly hall ODH analysis presented in D-Zero engineering note 3740.510-EN-258 has a summed total $\phi = 5.96 \text{ E-9}$. Adding the individual ϕ 's of the above cases does not change the conclusion that $\phi < 1.0 \text{ E-7}$ which is the criteria for a class 0 ODH classification.

An additional item that needs to be addressed is the **warm up heater** that is going to be installed in the 4 x 6 rotating bayonet. A design sketch, pertinent calculations and circuit diagram are attached as appendix B. The 2 kW circulation heater and associated controls are existing equipment purchased for the D-Zero test beam. It was for a similar cryogenic application. The warm up heater will be set to bring the nitrogen exhaust gas up to room temperature by applying approximately 800 watts of heat. If the heater fails with no power, some frosting will occur locally without any safety risk. If the heater fails at full power, an over temperature cut-out switch will shut off it's power.

The heater can be considered to be a check valve in the vent pipe. It will rest in the female bayonet making a gas seal at the top by it's own weight (8 lbs). The normal flow path will be through the 3/4" pipe size heater and then exhausted out a standard Fermilab cryogenic check valve (Drg. 1650-MB-258040). The pressure drop at steady state flow is less than 0.01 psi. If the flow rate was increased significantly, (such as for a relieving case) the heater/check valve assembly will lift. At 0.4 psid (> eight times the normal flow rate), the plate making the gas seal would lift. At that point an

additional flow path between the 3 1/4" dia. heater sheath and the 4 1/4" inside diameter pipe would be created. The heater may pop up and down during a relieving case. For a maximum flow relieving case, the heater/check valve assembly would either pop out of the bayonet port entirely or lift such that the pressure drop across the 3 1/4" x 4 1/4" annular path equals 1.0 psi. This pressure reacting on the 3 1/4" diameter bottom of the heater will balance the 8 lbs. weight of the heater.

In the ECS pressure vessel engineering note (D0 EN-329), it was calculated that the pressure drop through the normal vent line from the cryo corner to the vent pipe outside would be 2.13 psi at maximum flow capacity conditions. Since the maximum back pressure of 1.0 psi that the warm up heater could create is less, it does not decrease the relief valve capacity calculations in the engineering note.

CLOSING REMARKS

The details regarding the cryogenic and safety aspects of the ECS move have been thought out and planned. The cryogenic operation of the ECS calorimeter will be limited to maintaining its pressure by keeping it cold and isolated while it is in its temporary position off the platform. The 4 gph liquid nitrogen flow required for this operation is easily absorbed into the D-Zero assembly building atmosphere without any safety concerns. Emergency or failure scenarios have been addressed on a conservative basis and also pose little threat. Other safety features built into the system such as the liquid nitrogen excess flow switch, vent line liquid sensor, and monitored ODH heads provide additional assurance that an unexpected hazard would be identified and contained.

SUBJECT

VENTING N₂ EXHAUST INSIDE DAB
ODH CONSIDERATIONS

NAME

RUSS RUCINSKI

DATE

9-25-96

REVISION DATE

- MAXIMUM POSSIBLE FLOW RATE:
I WILL CALCULATE THE MAXIMUM POSSIBLE
FLOWRATE BASED ON PHYSICAL PIPING
AND 100% OPEN VALVES.

TO CONVERTING K'S OF DIFFERENT PIPE SIZES, $K_1 = K_2 \left(\frac{d_1}{d_2} \right)^4$ [EQN. 2-5]
K'S WILL BE FIGURED ON THE BASIS OF 1 1/2" SCH. 10 PIPE, $d = 1.682$ in.

$$\Sigma K = (K_{Cv 34}) \cdot 2 + K_{PIPE 1} + K_{PIPE 2} + K_{Cv 5.9} + \left[\frac{K_{.8} \cdot K_{1.25}}{K_{.8} + K_{1.25}} \right] + K_{Cv 14}$$

$$K_{Cv 34} = \frac{891 (1.682)^4}{34^2} = 6.17$$

$$K_{PIPE 1} = \frac{(0.023)(100 \text{ FT})}{\frac{1.682}{12} \text{ FT}} = 16.4$$

$$K_{PIPE 2} = \frac{(0.0275)(300)}{\frac{.622}{12}} = 159.2 \text{ BASED ON } \frac{1}{2} \text{\" PIPE}$$

$$K_{PIPE 2} = 159.2 \left(\frac{1.682}{.622} \right)^4 = 8513$$

NOTE: $f = .023 \pm .0275$
FOR 1 1/2" & 1/2" PIPE RESP.
FROM CALCS IN EN 435
APPENDIX D, PG. 1 & 2

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$$K_{cv} = 204.9 \quad K_{cv} = 11,143 \quad K_{cv} = 4564 \quad K_{cv} = 36.4$$

$$\Sigma K = (6.17)^2 + 16.4 + 8513 + 204.9 + \left[\frac{(11,143)(4564)}{15,707} \right] + 36.4$$

$$\Sigma K = 12,021$$

$$\rho = 0.8066 \frac{g}{cc} (62.427869 \frac{lbm}{ft^3} \frac{g}{cc}) = 50.353 \frac{lbm}{ft^3} \left\{ \begin{array}{l} \text{SAT. LIQUID} \\ P = 1.5 \text{ ATM} \end{array} \right\}$$

SUBSTITUTING INTO EQN. 3-16;

$$W = \sqrt{\frac{(35 \text{ psi})(50.353 \frac{lb}{ft^3})(1.682 \text{ in.})^4}{(2.8 \times 10^{-7})(12,021)}} = 2047 \frac{lbm}{hr}$$

$$= 2047 \frac{lbm}{hr} \times \frac{1 ft^3}{50.353 lb} \times \frac{7.48052 \text{ gal}}{ft^3} = \underline{304 \text{ gal/hr}}$$

- NORMAL ECS FLOWRATE : WITH THE CALORIMETERS COLD AND EMPTY, IT HAS BEEN MEASURED THAT TOTAL LN₂ CONSUMPTION IS 25 gal/hr.

12 gal/hr IS ESTIMATED TO BE USED FOR THE LAR STORAGE DEWAR.

$$\therefore \text{ECS FLOWRATE} \approx \frac{13 \text{ gal/hr}}{3} = \underline{4.33 \text{ gal/hr}}$$

- MAX. FLOW IF FLEX HOSE IS BROKEN

$$\Sigma K = (6.17)^2 + 16.4 + 8513 + 204.9 = 8747$$

$$W = 2047 \frac{lbm}{hr} \times \sqrt{\frac{12,021}{8747}} = 2400 \frac{lbm}{hr} = 357 \text{ gal/hr}$$

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- I WILL CALCULATE THE ASSEMBLY HALL VOLUME.

$$V = (225)(24)(75) + (70)(75)(37)$$

$$= 599,250 \text{ Ft}^3$$

• ODH CALCULATION

REF. ES&H CHAPTER 5064TA

$$\phi = \sum P_i F_i$$

3 CASES NEED TO BE ADDRESSED:

CASE I: NORMAL OPERATION

CASE II: MAX. LN₂ FLOW INTO DAB THRU PIPING SYSTEM

CASE III: FLEX HOSE BROKEN

COMMON INFORMATION:

$$V = 599,250 \text{ Ft}^3$$

$Q = 1500 \text{ scfm}$ MINIMUM EXHAUST VENTILATION RATE
ASSURED BY CRYO EXHAUST FANS

$R = \text{SPILL RATE IN SCFM}$

NOTE: BUILDING AIR HANDLING SYSTEM NOMINALLY
PROVIDES 4440 SCFM FRESH AIR MAKE-UP.

REF. DØ EN-258 ASS'Y HALL PLATFORM ODH ANALYSIS.

$C_r = \text{OXYGEN CONCENTRATION DURING RELEASE}$

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CASE I $R = 4.33 \frac{\text{gal}}{\text{hr}} \times \frac{1 \text{ hr}}{60 \text{ min.}} \times 86.4 \frac{\text{STD. FT}^3}{1 \text{ GAL. LN}_2} = 6.2 \text{ scfm N}_2$

FROM SOG4TA THE APPROPRIATE EQUATION IS CASE B, EQ'N 1

$$C_r(t) = 0.21 \left\{ 1 - \frac{R}{Q} \left[1 - e^{-\frac{Qt}{V}} \right] \right\} \quad \begin{array}{l} \text{DURING RELEASE} \\ \text{VENT FANS EXHAUSTING OUT} \\ Q > R \end{array}$$

I WILL CALCULATE WHAT THE CONCENTRATION WILL BE
DURING THIS RELEASE AFTER 2 YEARS.

$$t = 2 \text{ yrs} \times \frac{365 \text{ DAYS}}{\text{yr}} \times \frac{24 \text{ HRS}}{\text{DAY}} \times \frac{60 \text{ MIN}}{1 \text{ HR}} = 1,051,200 \text{ MINUTES}$$

$$C_r(t) = 0.21 \left\{ 1 - \frac{6.2}{1500} \left[1 - e^{-\frac{1500 (1,051,200)}{600,000}} \right] \right\}$$

$$= .21 \{ 1 - .004133 \} = .209 > 18\% \{ F_i = 0 \}$$

SINCE THE OXYGEN CONCENTRATION BARELY CHANGES
AND IS GREATER THAN 18% THERE IS NO
CONCERN.CASE II

$$R = 304 \frac{\text{gal}}{\text{hr}} \times \frac{1 \text{ hr}}{60 \text{ min.}} \times 86.4 \frac{\text{FT}^3}{1 \text{ GAL LN}_2} = 437.8 \text{ scfm N}_2$$

IF THIS HAPPENED AND WENT UN-NOTICED THEN AT $t = \infty$

$$C_r(\infty) = .21 \left\{ 1 - \frac{R}{Q} \right\} = .21 \left\{ 1 - \frac{437.8}{1500} \right\} = .1487$$

PARTIAL PRESSURE OF OXYGEN;

$$P_{O_2} = .1487 (740 \text{ mm Hg}) = 110 \text{ mm Hg}$$

FATALITY FACTOR;

$$F = 10^{(6.5 - \frac{P_{O_2}}{10})} = 3.13 \times 10^{-5}$$

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 P_i EXPECTED RATE OF FAILURE (HR^{-1})FROM TABLE 2 IN FESHM, FAILURE OF AN AUTOMATICALLY
OPERATED VALVE TO REMAIN OPEN IS

$$P_i = 1 \times 10^{-8} \text{ HR}^{-1}$$

IE. PV302N OR PV301N REMAIN
OPEN.ASSUME PV310N WILL STAY OPEN
TO MAINTAIN CONDENSOR PRESSURE

$$\phi_{\text{THIS CASE}} = P_i F_i = (1 \times 10^{-8} \text{ HR}^{-1})(3.13 \times 10^{-5}) = 3 \times 10^{-13}$$

FOLDING THIS INTO THE EXISTING OVERALL ODH ANALYSIS
FOR THE ASSEMBLY HALL IN DØ EN-258

$$\begin{aligned} \Sigma \phi_{\text{TOTAL ASSY HALL NOW}} &= \Sigma \phi_{\text{EN-258 ANALYSIS}} + \phi_{\text{THIS CASE}} \\ &= 5.96 \times 10^{-9} + 3 \times 10^{-13} = 5.96 \times 10^{-9} \end{aligned}$$

ODH CLASSIFICATION DOES NOT CHANGE

$$\phi < 10^{-7} \quad \text{ODH CLASS O.}$$

FOR THIS CASE, HOW LONG BEFORE $C_r(t) = .18$?

$$C_r(t) = .18 = .21 \left\{ 1 - \frac{437.8}{1500} \left[1 - e^{-\frac{1500 t}{600,000}} \right] \right\}$$

$$t = 269 \text{ MINUTES} = 4.5 \text{ HOURS.}$$

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9-26-96

REVISION DATE

CASE III FLEX HOSE BREAK

$$R = 357 \frac{\text{gal}}{\text{hr}} \times \frac{86.4}{60} = 514 \text{ SCFM N}_2$$

HOW LONG WOULD THIS HAVE TO GO UN-NOTICED FOR IT TO BE
A CONCERN? SOLVE FOR $C_r(t) = .18$

$$C_r(t) = .18 = .21 \left\{ 1 - \frac{514}{1500} \left[1 - e^{\frac{-1500t}{600000}} \right] \right\}$$

$$t = 216 \text{ MINUTES} = 3.6 \text{ HOURS.}$$

$$C_r(t=\infty) = .21 \left\{ 1 - \frac{R}{Q} \right\} = .21 \left\{ 1 - \frac{514}{1500} \right\} = .138$$

$$P_{O_2} = .138 (740 \text{ mm Hg}) = 102 \text{ mm Hg}$$

$$\text{FATALITY FACTOR; } F = 10^{(6.5 - \frac{102}{10})} = 1.93 \times 10^{-4}$$

P_i , EXPECTED RATE OF FAILURE (HR⁻¹)

TABLE 1 5064TA, CRYOGENIC FLUID LINE LEAK OR
RUPTURE $3 \times 10^{-6} \text{ HR}^{-1}$

$$\phi_{\text{THIS CASE}} = P_i F_i = (3 \times 10^{-6} \text{ HR}^{-1}) (1.93 \times 10^{-4}) = 5.8 \times 10^{-10}$$

FOLDING THIS INTO THE EXISTING ASS'Y HALL ODH ANALYSIS

$$\begin{aligned} \sum \phi_{\text{TOTAL ASS'Y HALL NOW}} &= \sum \phi_{\text{EN-258 ANALYSIS}} + \phi_{\text{THIS CASE}} \\ &= 5.96 \times 10^{-9} + 5.8 \times 10^{-10} = 6.5 \times 10^{-9} \end{aligned}$$

$\phi < 10^{-7}$ ODH CLASS 0
CLASSIFICATION DOES NOT CHANGE.

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OTHER ODH RELATED FACTORS:

A FLOW VENTURI, FM558N AND A DIFFERENTIAL PRESSURE SWITCH DPS 560N WILL SENSE ANY ABNORMAL EXCESSIVE LN₂ FLOW AND WILL TRIGGER THE PLC COMPUTER TO CLOSE OFF THE SOURCE AT PV513N.

A LIQUID NITROGEN SENSOR IN THE ECS CONDENSOR EXHAUST PIPE, TS332N WILL AUTOMATICALLY CLOSE THE CONDENSOR INLET VALVES PV301N & PV302N IF LIQUID IS SENSED. THIS ENSURES THAT ONLY VAPOR PHASE NITROGEN WILL MAKE IT OUT THE VENT.

ODH HEADS LOCATED ON THE PLATFORM AND IN THE CRYOCORNER (AND OTHERS) WILL REMAIN ACTIVE EVEN THOUGH NOT REQUIRED FOR ODH REASONS.

THE VENTILATION RATE USED IN THE ANALYSIS IS CONSERVATIVE @ 1500 SCFM. THE BUILDING VENTILATION RATE IS NOMINALLY 4440 SCFM.
{ REF. ASS'Y HALL ODH ANALYSIS DØEN298 }

FIGURE 1. SKETCH OF ECS VENT HEATER.

PARTS LIST: 1) CHROMALOX CIRCULATION HEATER
GCH15-C20E2, 2 KW

HEATER IN VENT PIPE

$$\bullet \text{ MAX. BACKPRESSURE} = \frac{5 \text{ LBS}^{\text{HTR}} + 3 \text{ LBS}^{\text{WIRE + LID}}}{\pi \frac{(3.25 \text{ in})^2}{4}} = \underline{0.96 \text{ psi}}$$

$\therefore @ 1 \text{ psi } \Delta P \text{ HEATER WILL LIFT.}$

$\bullet \text{ EXPECTED } \Delta P \text{ UP } 3/4" \text{ PIPE... ASSUME ROOM TEMP. } N_2$

$$Re = 6.31 \frac{W}{d\mu} = 6.31 \frac{(29.2 \frac{\text{lbs}}{\text{hr}})}{(.324 \text{ in})(1.78 \times 10^{-6} \text{ poises}) \frac{100 \text{ cp}}{1 \text{ poise}}}$$

$$Re = 12,562 \Rightarrow f = .027$$

$$\Delta P = 3.36 \times 10^{-6} \frac{f L W^2}{\rho d^5} = 3.36 \times 10^{-6} \frac{(.027) \left(\frac{26}{12} \text{ ft}\right) \left(29.2 \frac{\text{lbs}}{\text{hr}}\right)^2}{(.07245 \frac{\text{lbm}}{\text{ft}^3}) (.324 \text{ in})^5}$$

$$\Delta P = .006 \text{ psi} \leftarrow \text{NEGLIGIBLE.}$$

$\bullet \text{ IF SEC RELIEF VALVE BLOWS:}$

$$S.P. = 13 \text{ psi} = 28 \text{ psia.}$$

$$\text{SEC DESIGN} = 30 \text{ psid}$$

REFERENCE DØ EN-329 ECS PRESSURE VESSEL

NOTE: CRYOCORNER TO OUTSIDE PRESSURE

$$\text{DROP} = 2.13 \text{ psi LINE 165 Pg. 114}$$

$\bullet \text{ SINCE PRESSURE REQ'D TO LIFT HEATER ASS'Y OUT IS LESS THAN PRESSURE DROP CRYOCORNER TO OUTSIDE: (DURING RELIEVING COND.) ECS IS STILL SAFE, IN FACT BACKPRESSURE IS LESS OF A CONSIDERATION.}$

$$\% \text{ OVERPRESSURE DUE TO "CHECK VALVE" HTR} = \frac{15.96 + 14.7}{15 + 14.7} (100) - 100 = \underline{3.2\%}$$

INITIAL LIFT BACKPRESSURE ;

$$\Delta P = \frac{8 \text{ LBS}}{\pi \frac{(5.34 \text{ in})^2}{4}} = 0.36 \text{ psi}$$

THEN FLOW PATHS:

IF $P_1 > 1 \text{ psi}$
HEATER WILL LIFT UP
ADDITIONAL AMOUNTS.

• CALCULATE WHAT ΔP UP $3/4"$ PIPE @
MAX RELIEVING FLOW RATE; IS IT $> 0.4 \text{ psi}$?

$Q = 443 \text{ SCFM AIR}$ - CONDENSOR COIL RUPTURE.

FROM EN329 ECS PRESSURE VESSEL
ENGINEERING NOTE RELIEF CALC. SUMMARY.

A NOTE: THIS MATCHES 438 SCFM N_2 THAT
WAS CALCULATED IN CASE II OF THE OPH
ANALYSIS FOR A FAILURE OF ALL THE
VALVES IN THE LN₂ SUPPLY LINE
BEING WIDE OPEN.

TO BOUND IT, ASSUME WARM GAS.

$$Re = 22,700 \frac{q}{d \mu} \quad q = 438 \frac{\text{ft}^3}{\text{MIN}} \times \frac{1 \text{ MIN}}{60 \text{ S}} = 7.3 \frac{\text{ft}^3}{\text{S}}$$

$$\rho = .07245 \frac{\text{lb}}{\text{ft}^3}$$

$$d = .824 \quad \mu = 178 \times 10^{-4} \text{ cp.}$$

EQU. 3-3
CRANE TECH.
PAPER 410.

$$Re = 22700 \frac{(7.3)(.07245)}{.824 (178 \times 10^{-4})} = 8.185 \times 10^5$$

$$\frac{\epsilon}{d} = .002 \quad f = .0235$$

$$\Delta P = 3.36 \times 10^{-6} \frac{(.0235) \left(\frac{26}{12} \text{ ft} \right) (2047 \text{ lb/hr})^2}{(.07245) (.824 \text{ in})^5} = 26 \text{ psi}$$

NOW CALC. ΔP IF GAS IS AT SAT. TEMP,
(MORE REALISTIC)

$$Re = 6.31 \frac{W}{d\mu}$$

$$W = 2047 \frac{\text{lb}}{\text{hr}}$$

$$d = .824$$

$$\mu = .0056 \text{ cp @ SAT. PRESS. \& TEMP.}$$

$$Re = 6.31 \frac{(2047)}{(.824)(.0056)} = 2.8 \times 10^6$$

$$F = .0235$$

$$\Delta P = 3.36 \times 10^{-6} \frac{(.0235) \left(\frac{26}{12}\right) (2047 \frac{\text{lb}}{\text{hr}})^2}{(.2756 \frac{\text{lb}}{\text{ft}^3}) (.824 \text{ in})^5}$$

$$\Delta P = 6.85 \text{ psi}$$

HEATER WOULD LIFT.

REV	DESCRIPTION	DRAWN	DATE
		APPROVED	DATE

1	CHROMALOX SS-AR HIGH LIMIT TEMPERATURE CUTOUT SWITCH MODEL NUMBER: 3283-21000	1
2	CHROMALOX TEMPERATURE CONTROLLER MODEL NUMBER: 3910-11104	1
3	HEATER	1
4	OMEGA MAGNETIC CONTACTOR MODEL MC1-2-30-120	1
5	STANDARD 20 AMP WALL SWITCH	1

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY

UNLESS OTHERWISE SPECIFIED			ORIGINATOR	D. MARKLEY	9/20/96
FRACTION	DECIMAL	ANGLES	DRAWN	M. ZACZEK	9/20/96
$\pm 1/16$	$\pm .015$	$\pm 1^\circ$	CHECKED		
1. BREAK ALL SHARP EDGES 1/8" MAX.			APPROVED		
2. DO NOT SCALE DRAWING.			USED ON		
3. DIMENSIONS BASED UPON ANSI Y14.5M-1982					
4. MAX. ALL MACH. SURFACES 125			MATERIAL		

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

CIRCUIT DIAGRAM OF HEATER AND CONTROLS

SCALE	DRAWING NUMBER	SHEET	REV
		1 OF 1	

CREATED WITH :	MS2.1	GROUP:	DOMS
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specifications

Customer Specifications Circulation Heater

PE305-1

Date: MARCH 1, 1989 Prepared By: RUSSELL RUCINSKIRepresentative Co.: TOURTELOT CO. INC. Customer Name: FERMILABSales Engineer: TROY A. COURTNEY Location: TOURTELOT CO. INC.Qty. of Heaters: Per Order Per Year Order/Inquiry No. 1. Medium Being Heated NITROGEN From -300 °F To +140 °FSp. Ht. Viscosity @ °F Minimum Flow Rate -0-Maximum Flow Rate 30 lb/hr OR 6.7 SCFMMax. Pressure: Operating 50 PSIG Design 22 PSIGMax. Temperature: Operating 140 °F Design 140 °FMIN. " : OPERATING -300 °F DESIGN 130 °F2. Heater Construction — Catalog Description GCHIS-C20E2Nominal Vessel Size — 3", 5", 8", 14", 18", 24", Other 150

lb. Construction (150, 300, 400, etc.)*

STAINLESS STEEL

Materials of Construction (C.S., S.S.)*

INCOLOY

Element Material (Copper, Steel, S.S. Incoloy)*

3/4" - 14

Inlet & Outlet (Inch, NPT or Flanged)

MOISTURE
TIGHT

Terminal Cover (STD, ER, LT)

VERTICAL

Mounting Position (Vertical or Horizontal)

* STD

Insulation Jacket (STD, Weatherproof, None)

~~Section of Code (I, IV, VIII)~~~~Circulation (Baffled or Unbaffled)~~

3. Electrical Data

kW 2.0 Voltage 120 Phase 1 No. of Circuits 1Watt Density* 50 W/IN² Overheat Protection SET 50 INSULATION JACKET
WILL BE < 160°F IF POSSIBLE

4. Temperature Control Requirements

Chromalox Model No. TC-3910-11104ASRange 0 - 999 °F Nema Type STD (ER, LT, STD)5. Power Control Requirements N/AA. CSCR Model No. B. Step Controller, ISSC ISSU C. Contactor 6. Other Regulatory or Code Requirements * 7. Remarks (Other Requirements) NO INSULATION, 150 PSI MAWP

* Design parameters may be specified, but factory will advise if design calculations suggest better choice.