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ANALYSIS OF LAr CALORIMETER EMERGENCY VENTING SYSTEMS

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I. INTRODUCTION

The liquid argon (LAr) dewar located in the MW Experimental Hall at Fermi will contain approximately 210,000 lbs. of LAr when the detector is in place. This LAr is saturated at a pressure slightly above atmospheric pressure. The dewar is well insulated with a composite consisting of an inner fiberglass layer and five distinct layers of polyurethane spray foam, each 1-1/2" thick and separated by fiberglass cloth. The insulation is covered with a 30 mil butyl rubber coating sprayed with a 1/8" fire proofing and staycoat top coat. LAr vaporized as a result of normal heatleak to the dewar is routinely recondensed using the LN_2 refrigerated coils provided. The vessel is protected against overpressurization by two distinct and separate pressure relief systems:

(1) An Anderson-Greenwood pilot-operated relief valve Model #93T0608FA, set at 7.0 psig. The valve has a 6" suction and 8" discharge port, and is vented via an 8" IPS Sch 5 line from the building.

(2) A 6" rupture disc, BS&B#6-FA-6 w/type DSV Aluminum disc set at 12.5 psig, vented via a 6" IPS Sch 5 line from the building.

The purpose of this study was to evaluate the ability of these safety relief systems to protect the dewar under loss of insulation and/or fire conditions. Specifically, the tasks were:

(1) Calculate the relief capacity required to meet ASME and CGA S-1.3 (Reference 1) fire condition requirements.

(2) Calculate the relief capacity available with the existing relief devices, including a consideration of the relief system piping.

(3) Recommend location and procedure for venting argon so that the oxygen partial pressure does not drop below 135mm Hg (17.8%O_2) at any location routinely accessible to personnel.

(4) If the present relief devices are inadequate or marginal, recommend changes to correct the situation.

II. SUMMARY

The heatleak to the LAr dewar and the resultant argon vapor generation rate were calculated assuming a total loss of vessel insulation for outside heat transfer coefficients (h_o) of 2.0, 10.0 and 100 Btu/hr.ft^2.°F. Inside LAr boiling coefficients (h_i) were estimated using the data presented for LN_2 by Brentair and Smith (Reference 4). The results are presented in Table I for ambient temperatures of 80°F and 1200°F (fire condition).

The requirements for sizing the pressure relief system for an uninsulated liquified compressed gas container subject to 1200°F (ie, fire condition) are given in Section 5.3.6 of CGA S-1.3-1980 (Reference 1). The formula for uninsulated containers yields a relief system flow capacity requirement of 14,930 cubic feet per minute of "free air", which is defined in Section 2.10 as "air or gas measured at a pressure of 14.7 psia and a temperature of 60°F". This translates to a vapor generation rate of 94,530 lbs/hr of argon.

The combined capacity of the relief valve system and the rupture disc system as a function of (1) argon discharge temperature from the vent and (2) dewar pressure is shown graphically on Figure 1 and in tabular form in Table II. The results as calculated were based on the vent systems as currently recommended, with the exception that the discharge pipe from the rupture disc to the location for ambient discharge has been increased from 6" IPS Sch 5 to 8" IPS Sch 5. With the exception of the scenario which assumes an outside heat transfer coefficient of 100 Btu/hr.ft^2.°F and greater, the relief system as recommended with the increased rupture disc discharge pipe is adequate to vent a totally uninsulated LAr dewar. The probability of achieving an environment wherein the resistance to heat flow between the ambient and the bare vessel wall is low (ie, h_o 100 Btu/hr.ft^2.°F) will need

TABLE I

HEATLEAK TO UNINSULATED LAr DEWAR

	80°F AMBIENT TEMPERATURE			1200°F AMBIENT TEMPERATURE			
LAr Dewar Pressure, psig	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Outside Heat Transfer Coefficient, h_o, Btu/hr.ft^2.°F	2.0	10.0	100.0	2.0	10.0	100.0	1000.0
Heat Flux, MM Btu/hr	0.71	3.27	20.11	2.62	9.62	28.08	31.70
LAr Vaporization Rate, M lbs/hr	10.3	47.3	293.2	38.0	140.2	409.5	468.0

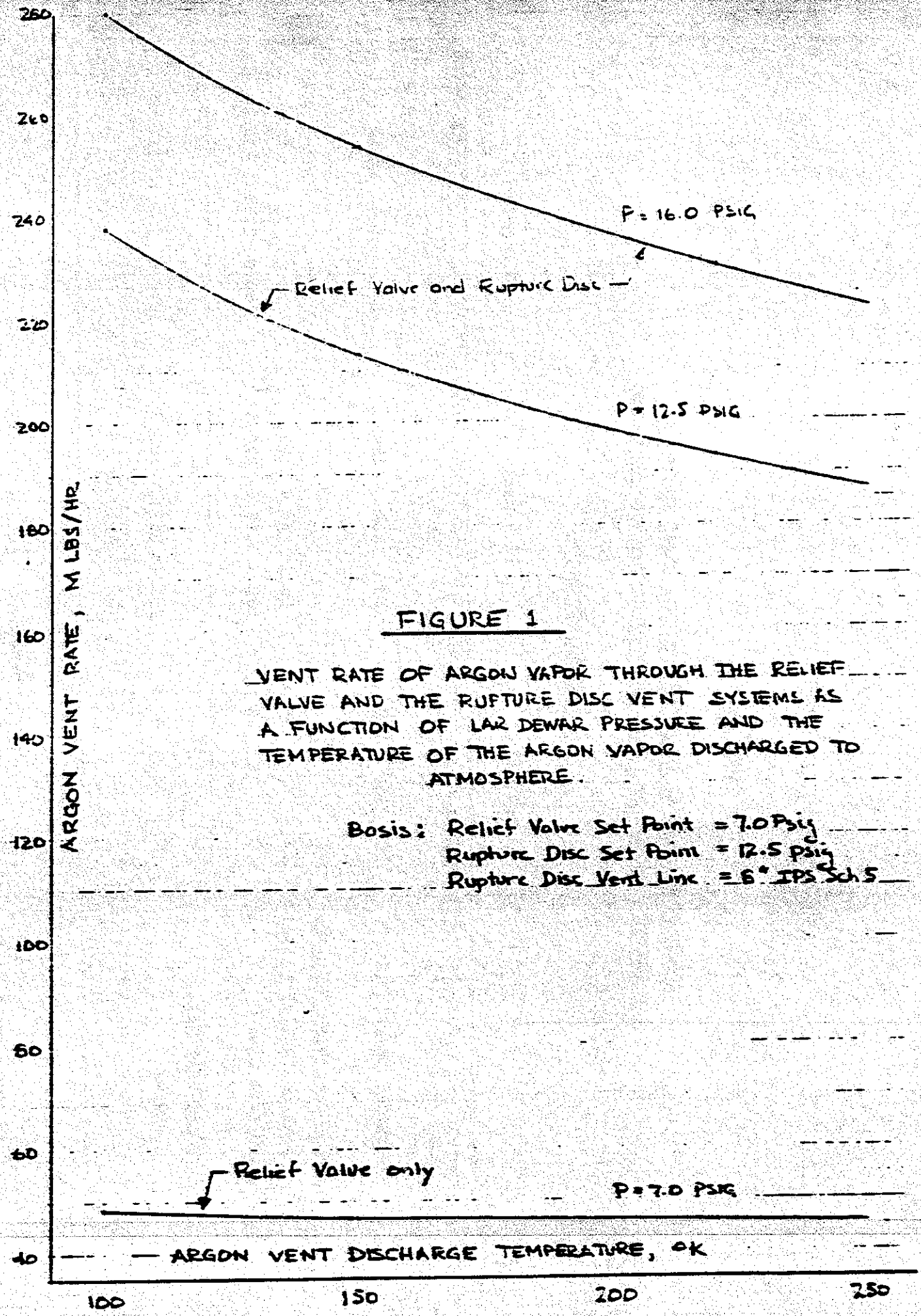


FIGURE 1

VENT RATE OF ARGON VAPOR THROUGH THE RELIEF VALVE AND THE RUPTURE DISC VENT SYSTEMS AS A FUNCTION OF LAR DEWAR PRESSURE AND THE TEMPERATURE OF THE ARGON VAPOR DISCHARGED TO ATMOSPHERE.

Basis: Relief Valve Set Point = 7.0 Psig
Rupture Disc Set Point = 12.5 psig
Rupture Disc Vent Line = 6" IPS Sch 5

TABLE II

ARGON VENT RATES AS A FUNCTION OF LAr DEWAR PRESSURE AND THE TEMPERATURE OF ARGON VAPOR DISCHARGED TO ATMOSPHERE

	LAr DEWAR PRESSURE								
	7.0 psig			12.5 psig			16.0 psig		
Discharge Temperature, °K	100	150	220	100	150	220	100	150	220
Argon Vent Rate, Mlbs/hr									
Pressure Relief Valve	48.5	46.9	45.9	68.3	67.2	64.7	79.6	78.1	76.8
Rupture Disc [1]	0	0	0	169.6	146.0	128.5	199.8	175.0	153.1
Total Vent Rate, M lbs/hr	48.5	46.9	45.9	237.9	213.2	193.2	279.4	253.1	229.9

1. 8" IPS Sch 5 Vent Line downstream of the rupture disc

to be assessed, and based on the results of that assessment, a decision rendered as to whether or not additional relief capacity is required.

A qualitative analysis of the argon vent gas disposal problem was performed, and a proposed solution offered. The proposed solution will not guarantee the absence of an ODH area, but will localize one should it occur as well as delay the occurrence for a finite time following the initiation of the vent. If the concept is acceptable, a quantitative evaluation can be performed.

III. DISCUSSION

The following assumptions were used in this study:

(1) Wetted surface area of the LAr dewar = $960.7 ft^2$

(2) Total surface area of the LAr dewar = $1054.2 ft^2$

(3) Pressure drop relationships:

(a) Sudden Contraction: $$P_c = \frac{0.5\ \rho V^2}{2\ g_c}$$

(b) Sudden Enlargement: $$P_e = \frac{\rho V^2}{2 g_c}$$

(c) Frictional: $$P = \frac{f\ (G/3600)^2 (L)}{193\ \rho\ d}$$

where: $$f = \frac{0.046}{(N_{Re})^{0.2}}$$

(4) Maximum allowable working pressure (MAWP) for the LAr dewar is 16.0 psig.

(5) Heat transfer rates to the LAr dewar were calculated neglecting any frost layer.

(6) Boiling coefficients for liquid nitrogen were used for the liquid argon (Reference 4).

(7) Argon at saturated conditions was assumed for vent calculations for dewar pressures of 7.0 psig, 12.5 psig and 16.0 psig.

(8) The equivalent length of vent piping from the relief device to discharge to ambient was assumed constant at 150 feet.

A. LAr VAPORIZATION RATES

The calculations reported in this section were performed to determine the various vapor loads produced by differing heatleak conditions. Under normal operating conditions, the insulation blanket is in place and the heatleak is at a minimum. The argon vapor thus generated is recondensed by the LN_2 coils located in the dewar vapor space. The conditions of concern occur when the insulation blanket is damaged resulting in a sudden increase in the heatleak which in turn produces large quantities of cold argon vapor which must be vented from the dewar to prevent overpressurization.

The design standards for pressure relief devices for compressed gas storage containers are contained in CGA S1.3, Part 3, (Reference 1) and the Handbook of Compressed Gases (Reference 2), pages 105-112. There are two basic design conditions to be considered: (1) uninsulated containers and (2) insulated containers. The former is a consideration when a 100% insulation failure is postulated. Also to be considered is the occurrence of a fire condition which would produce a 1200°F ambient environment.

1.) Liquefied Compressed Gases in Uninsulated Containers

1a) This condition approximates a 100% insulation failure. Although the probability of this occurring is essentially zero, it is of interest to evaluate this condition as an "absolute worst condition". The formula for calculating the required flow capacity of the relief device(s) is given in Section 5.3, Page 7, Reference 1.

$\rho_{sat}^{7psig} = 0.515\ lbm/ft^3$

$$Q_a = G_u A^{0.82}$$

where Q_a = flow capacity in cubic feet per minute of "free air" ("free air" is air measured at 60°F and 14.7 psia)

A = total outside surface area of the container in square feet

G_u = gas factor for uninsulated containers

$$= \frac{633,000}{LC}\left(\frac{ZT}{M}\right)^{0.5}$$

where

L = heat of vaporization, Btu/lb = 68.22

C = constant related to C_p/C_v = 1.73

Z = compressibility factor

T = absolute temperature of the gas, °R = 164°R

M = molecular weight

The relief valve recommended for installation on this dewar is an Anderson-Greenwood Model #93T0608FA having a 6" suction and an 8" discharge. The recommended set pressure is 7.0 psig. At this set pressure, and assuming the gas to be saturated at this pressure, the calculated value of Q_a = 14,930 cfm of free air, which is equivalent to a LAr vaporization rate of 94,530 lbs/hr. / 133,000 The value of the surface area of the vessel used was 1054 ft², 961 ft² of wetted surface area and 93 ft² of unwetted surface area between the liquid level and the bottom of the PVC filler. Any surface area above the filler has a negligible contribution to the heatleak.

1b.) Of interest is to calculate the vapor generation rates achievable based on heat transfer coefficients controlling. Assuming that the vessel is uninsulated, and the ambient temperature is 80°F, the impedance to heat flow is controlled by the outside gas film coefficient, h_o and the inside boiling coefficient h_i. The resistance of the steel is negligible and the assumption is made that there is no frost layer.

As a first assumption, assume h_o = 2.0 Btu/hr.ft^2.°R. The boiling coefficients used were those for nitrogen given in Reference 4 . Using an iterative process, the maximum heat flux attainable to the argon is 704,950 Btu/hr which is equivalent to a vapor generation rate of 10,279 lbs/hr. If the outside gas film heat transfer coefficient were 10.0 instead of 2.0, the heat flux increases to 3.27x10^6 Btu/hr, or a vapor generation rate of 47,690 lbs/hr, which is about 50% of that calculated in 1a.) as required. These results are presented in Table I.

With time, a frost layer will form on the exterior of the vessel, acting as an insulator and reducing the heat flux to the LAr. Based on these calculations, it appears that the vapor sizing rate of Q_a = 94,530 lbs/hr for an uninsulated vessel is conservative.

1c.) The worst condition and one which has an extremely small probability of occurring is an uninsulated vessel exposed to a fire condition which produces a 1200°F ambient environment. If the resistance to heat transfer between the ambient and the vessel wall is negligible, ie h_o = 1000 Btu/hr.ft^2.°F, a heat flux of 3.17x10^7 Btu/hr to the LAr would result in a vaporization rate 468,000 lbs/hr of LAr. Similar calculations were performed for values of h_o equal to 2, 10 and 100 Btu/hr.ft^2.°F. The results are shown in Table I.

The vapor generation rates calculated above are all based on either the "wetted" surface area when the vessel is fully charged with LAr, or the so-called total outside surface area, the latter being the sum of the wetted surface area plus the surface area of the vessel wall between the top of the liquid level and the bottom of the PVC filler. However, the bulk of the heat transferred to the liquid is through the wetted surface area. The resistance to heat flow at the non-wetted surfaces is high because of a stagnant gas film present. As LAr is vaporized, the wetted surface area decreases resulting in a decrease in the rate of heatleak, and a subsequent decrease in the vapor generation rate. The worst condition for pressure relief is then at the initiation of the event, when heat flux to the LAr is a maximum.

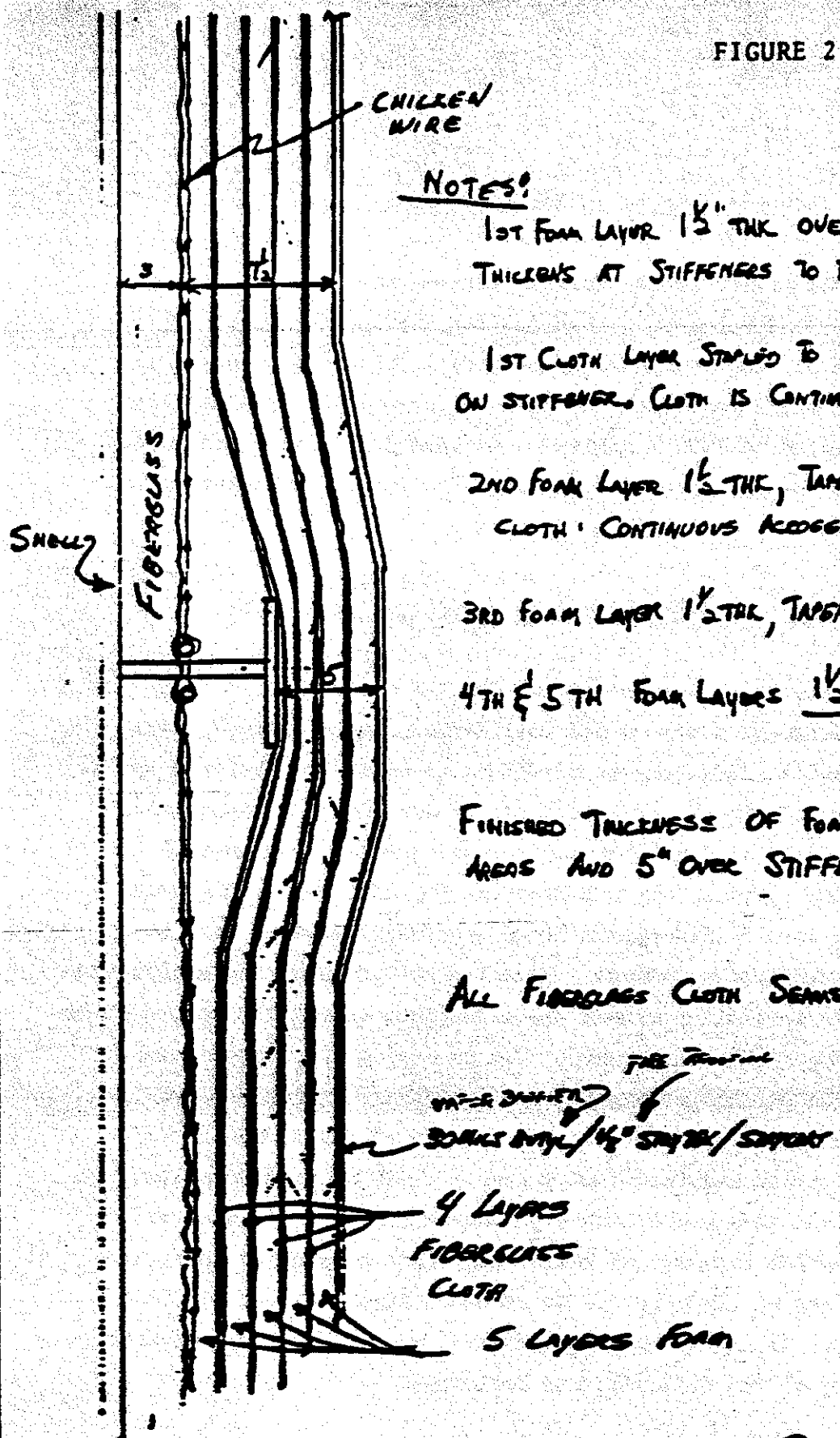
2.) Liquefied Compressed Gases in Insulated Containers

The pressure relief device design criteria for insulated vessels is defined in Section 5.3.5 and Section 5.3.6 of CGA S1.3 (Reference 1). The procedure in Section 5.3.5 is for those situations where the insulation remains completely in place even when subjected to 1200°F ambient. Section 5.3.6 defines the procedure for insulated containers where the insulation deteriorates when subjected to a 1200°F environment.

2a.) Section 5.3.5 - Insulation is Unaffected at 1200°F.

The insulation specifications for the dewar used in this analysis are shown on CBI Dwg. 851553 Sheets 1 and 2, dated October 4, 1985, copies of which are shown as Figures 2 and 3. The insulation barrier consists of six distinct layers all covered by a 30 mil butyl rubber covering sprayed with a 1/8" Staytex fireproofing and Staycoat top coat. The innermost layer is a 3" fiberglass board insulation covered with stainsteel chicken wire mesh. Visual observation during application of the insulation showed the fiberglass around the bottom to be batting rather than board. The remaining five layers are applied successively and consist of 1-1/2" thick 2-3 PCF polyurethane spray foam. Four layers of Style 1659 fiberglass cloth reinforcement separate the polyurethane coats. Aluminum rods are attached perpendicular to the vessel wall to provide support and stiffening. The insulation layer is modified at these points as shown on Figures 2 and 3. The effect, if any, of these stiffeners upon the thermal conductivity of the inslation was neglected.

FIGURE 2



NOTES:

1ST FOAM LAYER 1½" THK OVER FIBERGLASS, AND THICKENS AT STIFFENERS TO BE FLUSH WITH FLANGE

1ST CLOTH LAYER STAPLED TO FOAM AND LAYS DIRECTLY ON STIFFENER. CLOTH IS CONTINUOUS ACROSS STIFFENER

2ND FOAM LAYER 1½ THK, TAPERS TO 1" OVER STIFF. CLOTH: CONTINUOUS ACROSS STIFF., ALL LAYERS

3RD FOAM LAYER 1½ THK, TAPERS TO 1" OVER STIFF

4TH & 5TH FOAM LAYERS 1½" THICK OVER ALL

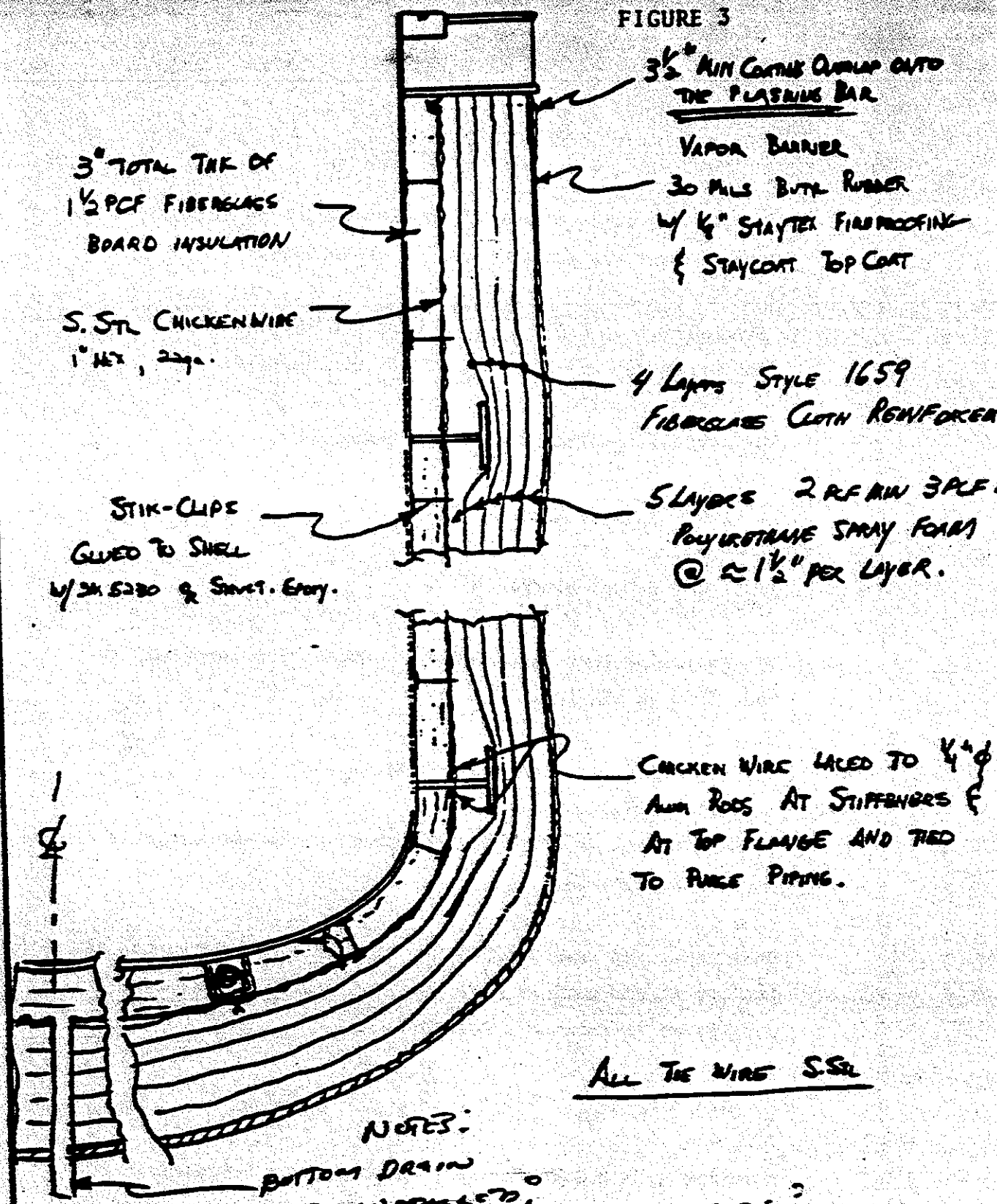
FINISHED THICKNESS OF FOAM IS 7½" IN OPEN AREAS AND 5" OVER STIFFENER.

ALL FIBERGLASS CLOTH SEAMS OVERLAPPED 4" MIN.

TYPICAL DETAIL AT STIFF.

SUBJECT	OFFICE		REVISION		REFERENCE NO.
LIQUID ARGON DEWAR INSUL. DETAILS	CBI OB ENG				851553
	MADE BY MPD	CHKD BY	MADE BY	CHKD BY	SHT. 1 OF __
	DATE	DATE	DATE	DATE	

FIGURE 3



SUBJECT	OFFICE	REVISION		REFERENCE NO.
LIQUID ARGON DEWAR INSULATION DETAILS	CB CB ENG			851553
	MADE BY / CHKD BY	MADE BY	CHKD BY	SHT 2 OF —
	DATE 4/20/85	DATE	DATE	DATE

The thermal conductivity of the insulating material as specified by the manufacturer is as follows:

Fiberglass, 1.5 PCF $k_F = 0.18$ Btu.in/hr.ft^2.°F
Polyurethane, 2-3 PCF $k_u = 0.14$ Btu.in/hr.ft^2.°F

The overall coefficient for the insulation,

$$1/U = X_F/k_F + X_u/k_u = 70.2$$

$$U = 0.0142 \text{ Btu/hr.ft}^2.°R$$

The following four resistances represent the impedance to heat flow to the LAr:

(1) Ambient air to insulation, h_o
(2) Insulation, U
(3) Vessel wall (negligible relative to the other 3)
(4) Boiling LAr, h_i

Therefore, the heat flux to the LAr can be approximated as follows if the surface area for heat transfer for each resistance is assumed a constant.

=?

$$q/A = h_i\ (T_{wi} - T_i) + U\ (T_{in,o} - T_{wi}) + h_o\ (T_o - T_{in,o})$$

Assuming $h_o = 2.0$ Btu/hr.ft^2.°F, an ambient temperature of 80°F, and using the heat flux data for boiling liquid nitrogen (Reference 4), the heat flux through the insulation to the LAr is calculated to be:

$$q_{80°F} = 5{,}130 \text{ lbs/hr}$$

This is equivalent to a saturated vapor generation rate at 21.7 psia of 75 lbs/hr.

If the ambient temperature rises to 1200°F, the heat flux increases to

$$q_{1200°F} = 20{,}410 \text{ Btu/hr}$$

equivalent to a vaporization rate = 298 lbs/hr.

Having established vaporization rates for the insulated dewar based on the thermal impedances to heat flow, the required flow capacity for the relief devices is now determined. This is done using the formula specified in Section 5.3.5.

$$Q_a = G_i U A^{0.82}$$

Where U = total thermal conductance of the insulating material when sat'd with gaseous lading or air at atmospheric pressure, But/hr.ft^2.°F

G_i = gas factor for insulated container

$$= \frac{73.4 \times (1200-t)}{LC} \left(\frac{ZT}{M}\right)^{0.5}$$

where t = temperature of the flowing gas, °F

The thermal conductance of air at 14.7 psia is

	100°F	500°F
k_u, Btu/hr.ft.°F	0.0157	0.0250

The total insulation thickness is 10.5 in = 0.875ft

Therefore the value of U for the insulation when saturated with air is,

	100°F	500°F
U, Btu/hr.ft^2.°F	0.0179	0.0285

which of course is greater than the value for U = 0.0142 Btu/hr.ft^2.°F as calculated earlier based on the manufacturers literature.

Solving for G_i = 8.60, and substituting in the equation for Q_a yields the following values at the two gas temperatures

	100°F
Q_a, cfm of "free air"	46.4
$\dot{m}$, sat'd argon vapor, lbs/hr	295

These rates agree well with the 298 lbs/hr as calculated earlier in this section using the conventional heat transfer correlations.

2b.) <u>Section 5.3.6 - Insulation Deterioration when Subjected to 1200°F</u>

There are two alternates, namely Sections 5.3.6.1 and 5.3.6.2 (Reference 1) applicable to this situation. Section 5.3.6.1 assumes the vessel to be totally uninsulated and the minimum relief flowrate calculation to be based on that assumption. Section 1a.) of this report addresses this situation. The results are as follows:

Q_a = 14,929 cfm of "free air" or
$\dot{m}$ = 94,530 lbs/hr of argon vapor

Section 5.3.6.2 stipulates that the U value for the insulation shall be determined assuming the insulation to be saturated with gaseous lading or air at atmospheric pressure. This situation was described in part in Section 2a.) of this report. Assuming the insulation to be saturated with air, the thermal conductivity becomes essentially that of air at 14.7 psia and the average temperature. For an ambient temperature of 1200°F, assume an average insulation temperature of 500°F. The overall coefficient for the insulation is,

$$U = 0.0285 \text{ Btu/hr.ft}^2.°F$$

The controlling resistance for heatleak to the LAr will still be the insulation. The heat flux is then,

$$q = 40{,}850 \text{ Btu/hr}$$

Which will generate,

$$\dot{m} = 596 \text{ lbs/hr}$$

of cold argon vapor. Obviously, the relief valve must be sized for total loss of insulation, or adequate to vent 94,530 lbs/hr.

B. PRESSURE RELIEF SYSTEMS

The present design for the LAr dewar provides for two separate and independent pressure relief systems. The first is an Anderson-Greenwood Model #93T0608FA pilot operated relief valve set at 7.0 psig, and the second is a 6" BS&B Model #6-FA-6 rupture disc set at 12.5 psig. The dewar maximum allowable working pressure (MAWP) is 16.0 psig internal pressure. The vent lines from the relief devices are separate and run in parallel through the East wall of the MW Experimental Hall and to the roof of the building for dispersal.

1.) Pressure Relief Valve System

The pressure relief valve vent system with pipe sizes and approximate pipe lengths is shown in Figure 4. The maximum vent rate through this relief system for a given set of dewar conditions is a function of the valve characteristics and the pressure losses in the vent piping.

Calculations were made to determine the vent rate at the pressure relief valve setting of 7.0 psig, the rupture disc setting of 12.5 psig, and the vessel MAWP of 16.0 psig. The gas was assumed to pass the relief device at saturated conditions for those pressures. However, at the instant of pressure relief, ie 7.0 psig, the valve and the downstream vent piping are warm and consequently the gas will at least initially warm as it passes throug these lines. An estimate of the initial discharge temperature of the argon gas assuming 150 feet of 8" IPS Sch 5 pipe initially at 80°F and gaseous argon at -296°F flowing through it at a rate of 50,000 lbs/hr was made using the following relationship:

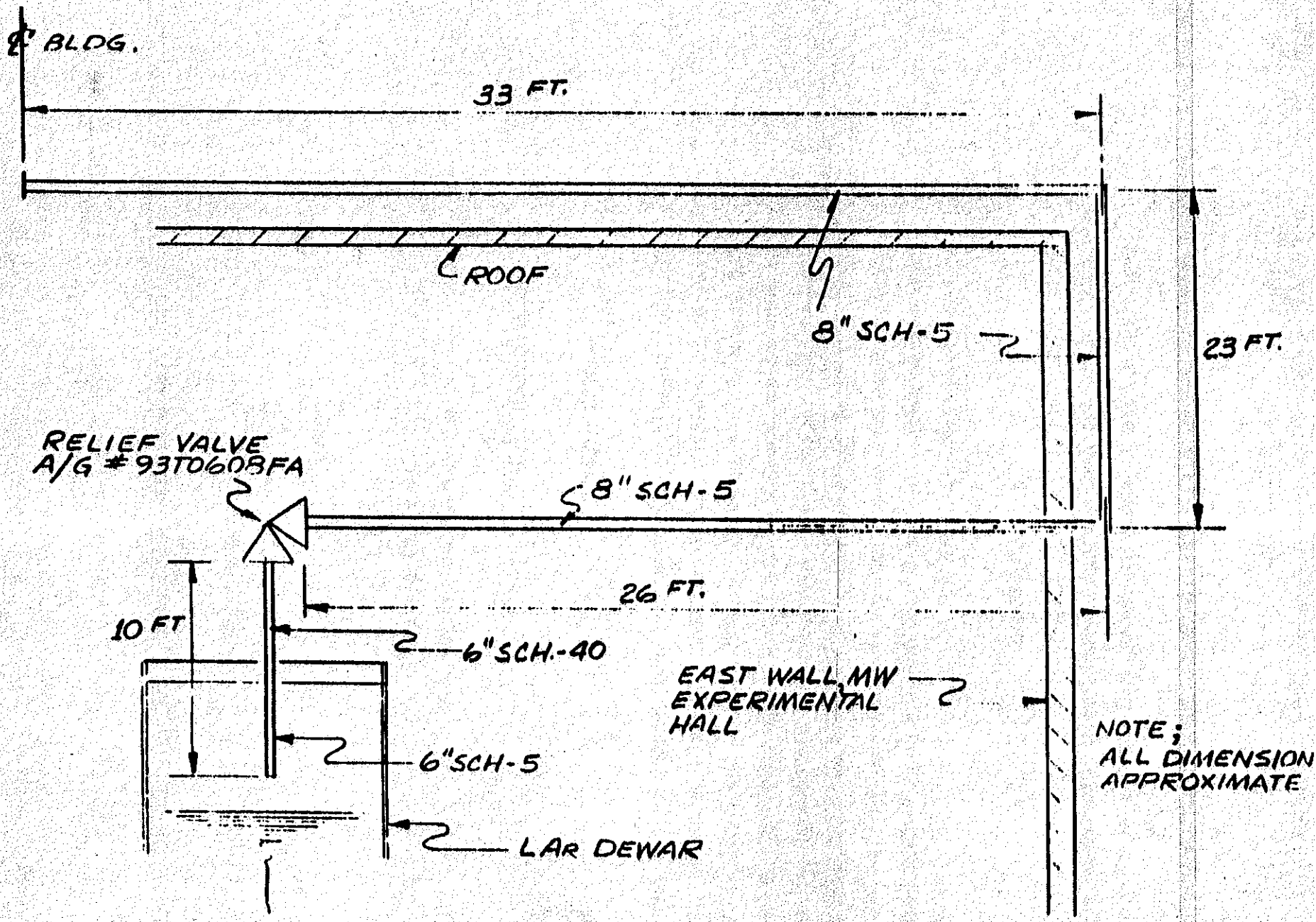


FIGURE - 4

VENT PIPING FOR PRESSURE RELIEF VALVE SYSTEM

$$\ln k = \frac{h\,A}{C_p \dot{m}}$$

where $k = (T_{wall} - T_{in})/(T_{wall} - T_{out})$

T_{wall} = 80°F = 540°R
T_{in} = -296°F = 164°R
T_{out} = ?
h = 50 Btu/hr.ft².°F
A = 330.1 ft²
C_p = 0.127 Btu/lb.°F
$\dot{m}$ = 50,000 lbs/hr

$\ln k = 2.60$

T_{out} = 52°F = 512°R

The heat transfer coefficient from the ambient to the pipe wall will be controlling during venting. This may be of the order of 2.0 Btu/hr.ft².°F at most. In addition, an ice layer will begin to form on the outside of the pipe further reducing the heat flux from ambient to the pipe. Consequently, the thermal energy needed to raise the temperature of the vent gas will have to be supplied from that stored energy initially in the pipe wall at time equals zero. For the 8" IPS Sch 5 pipe, 150 foot long, the stored energy between 164°R and 540°R is,

$$q = 47{,}950 \text{ Btu}$$

which, if it all were available, would warm 1020 lbs of cold argon gas to 540°K, which represents 1.2 minutes of flow at

50,000 lbs/hr. However, all this thermal energy is not available to raise the gas temperature to 540°R, nor will the exit gas temperature likely reach the 512°R calculated above. Therefore, for this study the assumption was made that the initial exit gas temperature will reach 400°R and that shortly thereafter the exit temperature will drop to 180°R and continue at that level throughout the vent.

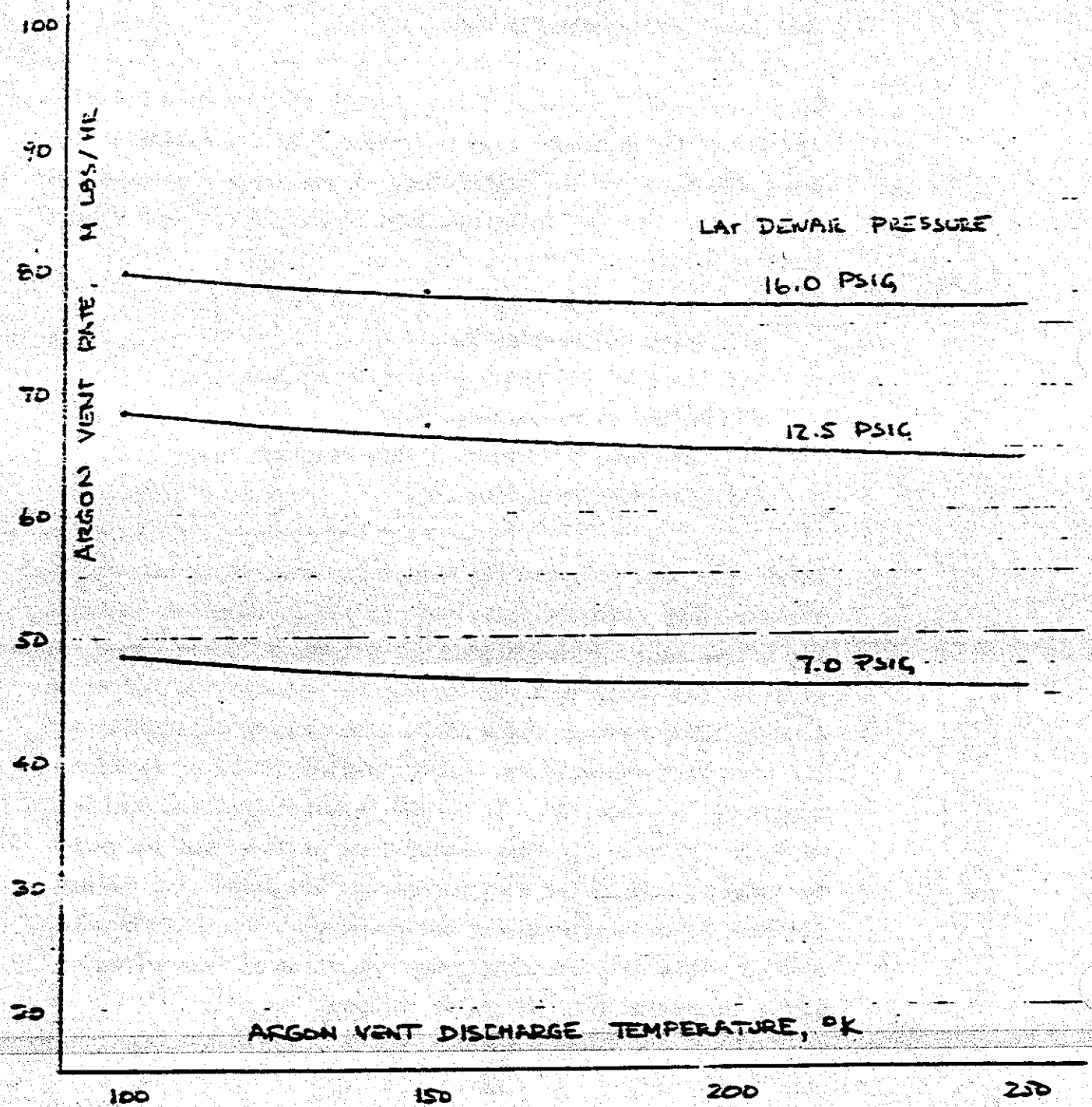
The calculated argon vent rates through the pressure relief valve system are shown graphically in Figure 5 as a function of LAr dewar pressure and the temperature of the argon discharged to atmosphere. The following pressure losses in the vent system were included:

(1) Inlet contraction loss
(2) Inlet 6" IPS Sch 5 pipe friction loss
(3) Relief valve pressure loss
(4) Discharge 8" IPS Sch 5 pipe friction loss
(5) Discharge expansion loss

Items (1), (2), (4), and (5) were calculated using conventional pressure drop correlations listed in the Assumptions Section. The relief valve pressure loss was determined using correlations given in the Anderson-Greenwood Series 90 Safety-Relief Valve Catalog 1900, revised March 1982. The results were verified via telephone conversation with Mr Harlan Oehlke of Anderson-Greenwood, Houston, TX. It should be noted that the Series 93T valve is suitable for this application provided the set point for this 6" x 8" valve does not exceed 8.0 psig. The teflon diaphram is not suitable for set pressures above this level. However, this will not affect the operation of this valve at higher pressures once the valve is open.

FIGURE 5

VENT RATE OF ARGON VAPOR THROUGH RELIEF VALVE VENT SYSTEM AS A FUNCTION OF LAR DEWAR PRESSURE AND THE TEMPERATURE OF THE ARGON VAPOR DISCHARGED TO ATMOSPHERE



2.) Rupture Disc System

The rupture disc relief system with existing pipe sizes and approximate pipe lengths is shown in Figure 6. The maximum vent rate through this relief system for a given set of dewar conditions is a function of the rupture disc set pressure and the vent piping pressure losses.

The present design specifies a 6" IPS Sch 10 suction line to the rupture disc, a rupture disc set pressure of 12.5 psig, and a 6" IPS Sch 5 discharge vent line. The mass flow vent rate of argon vapor from the dewar through the rupture disc system as a function of LAr dewar pressure and the temperature of the argon vapor discharged to atmosphere is shown graphically on Figure 7. Vent rates for a 6" and an 8" vent line downstream of the rupture disc are shown. The vent rates were calculated assuming the pressure heads available were dissipated through the following resistances:

(1) Inlet contraction loss
(2) Vent pipe frictional loss
(3) Discharge expansion loss

A total equivalent length for the vent pipe frictional loss of 150 feet was assumed. The conventional pressure drop correlations presented in the Assumptions Section were used.

The installation of an 8" vent line rather than the 6" line now specified downstream of the rupture disc is recommended. The significantly greater vent rates achievable through the 8" vent line as compared to the 6" vent line warrant installation of the 8" line.

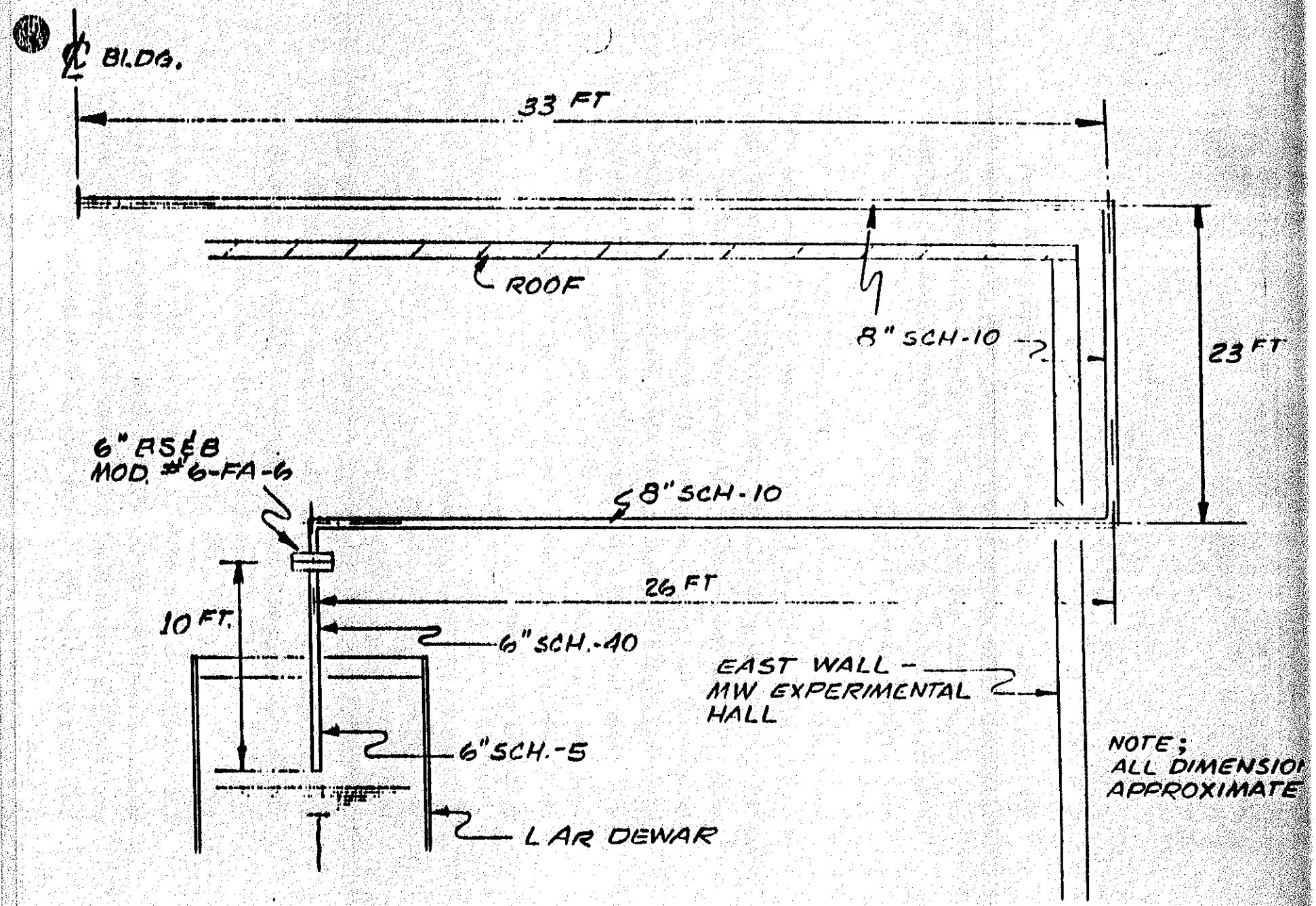


FIGURE - 6

VENT PIPING FOR RUPTURE DISC RELIEF SYSTEM

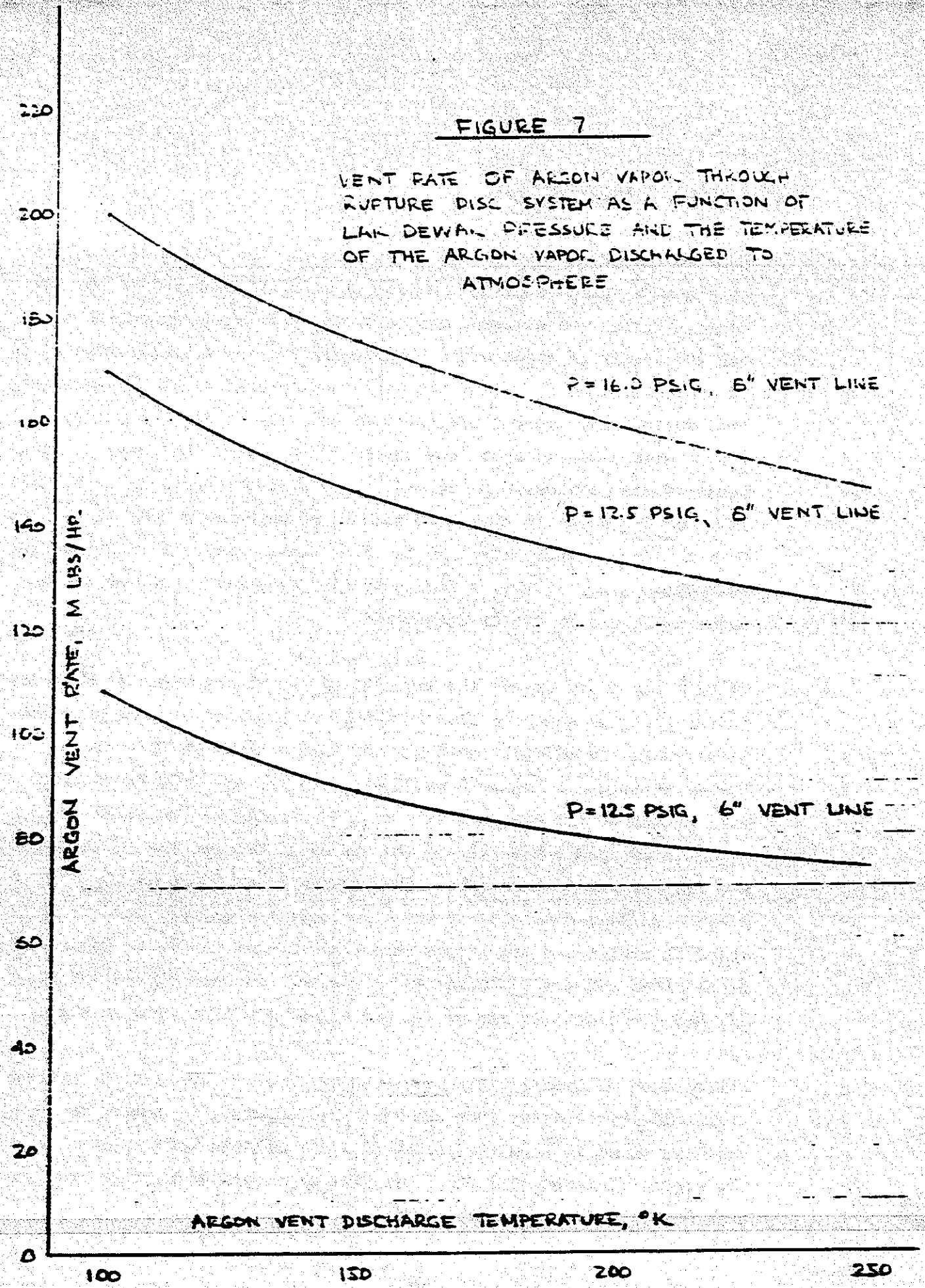


FIGURE 7
VENT RATE OF ARGON VAPOR THROUGH RUPTURE DISC SYSTEM AS A FUNCTION OF LAK DEWAR PRESSURE AND THE TEMPERATURE OF THE ARGON VAPOR DISCHARGED TO ATMOSPHERE
P = 16.0 PSIG, 6" VENT LINE
P = 12.5 PSIG, 6" VENT LINE
P = 12.5 PSIG, 6" VENT LINE
ARGON VENT RATE, M LBS/HR.
ARGON VENT DISCHARGE TEMPERATURE, °K
0
20
40
60
80
100
120
140
160
180
200
220
100
150
200
250

C. DISPERSAL OF ARGON VENT GAS

Because the argon vent gas is an asphyxiant, the possibility exists that an ODH would be created during an emergency venting of the LAr dewar. During the extreme, and unlikely, case where in excess of 468,000 lbs/hr of argon would be released, it is virtually impossible to assure that an ODH condition would not be created in the immediate area surrounding the building without actually piping the gas to a remote area some distance from the building. The likelihood of occurrence of this extreme case is very small however, and a decision will have to be made if the probability of occurrence of this event warrant its consideration. If so, then remote disposal will have to be implemented. If not, a less expensive alternate, such as the one shown in Figure 8, can be considered.

To vent the argon gas in the vicinity of the MW Experimental Hall requires that the argon be dispersed over as great an area as possible to expedite its dilution with air and thus prevent an ODH. The scheme proposed in Figure 8 would disperse the gas over the surface area of the MW Experimental Hall roof by running two parallel spargers along the N-S axis of the building, one for the relief valve and one for the rupture disc. The sparger holes would be sized to provide uniform discharge of the argon over the sparger length; ie the holes at either end are larger than those nearer the "T". Holes would be oriented between 9 o'clock and 3 o'clock (perhaps 3 rows, at 10, 12, and 2 o'clock) to direct the gas upward and thus promote mixing.

During most of the venting, the argon gas leaving the sparger will be cold, and much heavier than the air. By directing it upward initially, there is a larger volume of air available for mixing with the argon. Even at 70°F and 1 ata, the argon gas is heavier than the air, 0.107 lbs/ft vs 0.075 lbs/ft .

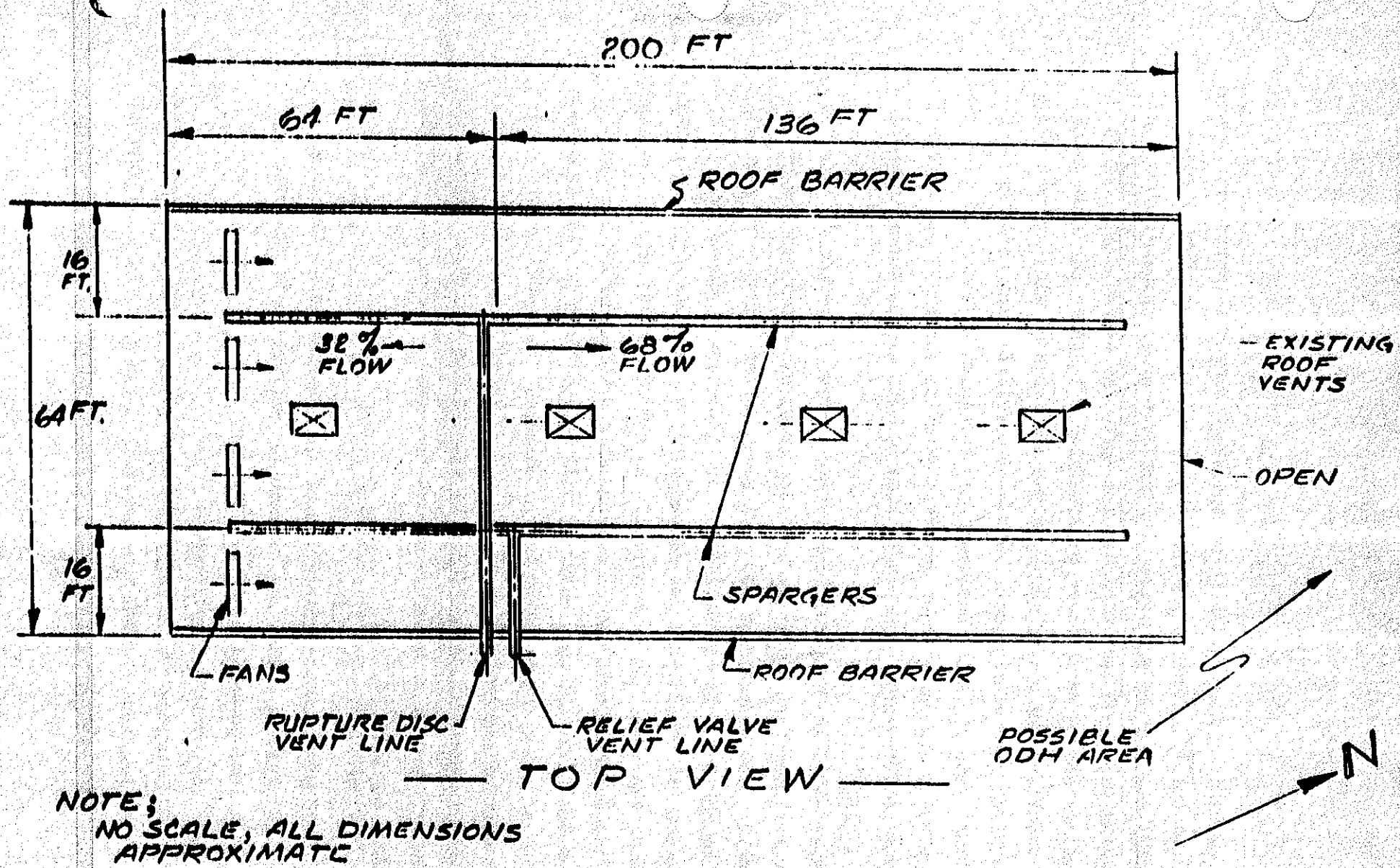


FIGURE - 8

PROPOSED ROOF TOP DISPERSAL OF ARGON VENT GAS

To prevent cold argon gas from "spilling" over the longitudinal sides of the building, and to prevent the prevailing winds from blowing incompletely mixed argon gas over the East side, barriers should be erected along the East edge and the West edge of the roof. These barriers should be at least 6-8 ft. high. In addition, some means of promoting the mixing of argon and air, such as fans mounted along the South edge of the roof, should be provided. The existing roof exhaust fans should be automatically turned on at the start of a vent to prevent the dense argon gas from entering the building through these roof louvers. This would also promote mixing and dispersal.

Having provided the above, those areas on the longitudinal sides of the building most likely to be occupied by personnel will be protected. The disposal of the vent gases, after mixing with air, will be to the North of the building where there are no doors, air intake louvers, or facilities, and consequently a low probability of personnel in the area. It is impossible to guarantee that an ODH area north of the building will not be created at some time during the vent. However, if an ODH does occur it will be localized to this area, and will not occur until some time has elapsed. This will provide time for warning and evacuation of the area. Regardless of what disposal method is provided, it will not be possible to guarantee that an ODH area will not occur sometime during the event. Therefore, a disposal method should:

(1) Minimize the likelihood of the creation of an ODH area,
(2) Provide a time lag between the initiation of the vent and the possibility of the creation of an ODH area to permit evacuation of personnel,
(3) Localize and minimize the area where an ODH could occur, and
(4) Localize the ODH area so that it can easily and quickly be eliminated.

IV. RECOMMENDATIONS AND CONCLUSIONS

1. The argon vapor vent line downstream of the rupture disc should be increased in size from a 6" line to an 8" line. With this modification, the pressure relief system capacity will exceed that required by CGA S1.3, fire condition (Reference 1).

2. The combined capacity of the relief valve and rupture disc vent systems at 12.0 psig and above exceeds the argon vapor flow capacity of 94,530 lbs/hr as determined by CGA S1.3 fire condition requirements. The pressure relief valve capacity alone is less than the CGA S1.3 fire condition requirement. The pressure will rise in the dewar until the rupture disc set point of 12.5 psig, after which the relieving capacity of both systems will exceed the CGA S1.3 requirement.

3. Loss of insulation calculations were performed for a range of values of outside gas to metal heat transfer coefficients (h_o), and ambient temperatures of 80°F and 1200°F. At values of h_o of 100 Btu/hr.ft^2.°F and above, the resulting vapor generation rate exceeds the relief capacity of the combined relief system. However gas phase heat transfer coefficients of this magnitude are not probable even with forced convection, and therefore this is not a realistic scenario.

4. An argon vapor dispersal system whereby the vapor is dispersed over the surface area of the roof of the MW Experimental Hall is proposed. The erection of barriers along the longitudinal sides of the roof and the addition of dispersal fans are suggested to (1) promote the mixing of argon and air and (2) to localize the possibility of an ODH to the north end of the building. In this manner

it should not be necessary to make any modifications to the existing building venting system as there are at present no air intake louvers on this end of the building.

5. The Anderson-Greenwood pressure relief valve is pilot operated. The pilot pickup should be located in the vapor space above the LAr rather than in the inlet line to the valve to insure that true dewar pressure is sensed.

References

1) Pressure Relief Device Standards, CGA S1.3, Part 3, Compressed Gas Storage Containers, 4th Edition, 1980 The Compressed Gas Association, Inc., New York, N.Y. 10110

2) Handbook of Compressed Gases, 2nd Edition, Compressed Gas Association, Inc., New York, N.Y. 10110

3) Thermodynamic Properties of Argon from the Triple Point to 300°K at Pressures to 1000 Atmospheres, NSRDS-NBS 27, National Standard Reference Data Series-National Bureau of Standards 27, March 1969

4) Nucleate and Film Pool Boiling Design Correlations for O_2, N_2, H_2, and He, E.G. Brentair and R.V. Smith, International Advances in Cryogenic Engineering, Volume 10, 1964, Pgs. 325-341

5) Approximate Theory for Film Boiling on Vertical Surfaces, Y.V. Hsu and J.W. Westwater, Chemical Engineering Progress Symposium Series, No. 30, Volume 56, 1960, Pgs. 15-24