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TO: E706 Safety Panel

FROM: K.Dixon

SUBJECT: **Engineering Note E706EN011**

Attached is the revised engineering note regarding the "ODH Classification of the MW Detector Hall Without Power". This note supercedes the note bearing the same number dated October 8, 1986. Please review this and bring any comments that you might have to the next meeting.

KD:ls

E706 CRYOSYSTEM DESIGN NOTE

E706EN011

TITLE: **ODH Classification of the MW Detector Hall Without Power**

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DATE: 24 November 86

OBJECTIVE:

This note determines the ODH Classification of the MW detector Hall when total power is lost to the building. Normally, the building will have an ODH classification of zero; however, this classification will start to increase once the monitoring and warning systems become disabled during a power outage.

ASSUMPTIONS:

- If we neglect the gas piping from outdoors to PV-306, then the LAC vessel is the only source of inert gas to be considered in MW during a power outage.
- **Pressure in the LAC is a maximum, 7 psig.**
- Zero building ventilation.
- Complete mixing of gas within the building.
- Gas flow from the gas phase flanges is at room temperature.

- The oxygen concentration of the building, prior to the power outage, is 20.9%.
- The failure mode assessments are the median values taken from 5064TA-1 of the *Fermilab Safety Manual.*
- The failure assessment of the paddle connections located in the rabbit hutch junction boxes will be 1000 times the probability of leaks through flanges, or $3 \times 10^{-3} hr^{-1}$. Although this number is somewhat arbitrary, it will not significantly affect the conclusions in this report pertaining to the MW building as a whole.
- The leakage path heights across <u>all</u> flanged connections is 0.001 in.
- Since the product $P_i F_i$ for gas valves and line ruptures is much smaller than that for liquid, it will be neglected.

CALCULATIONS AND DISCUSSION

We will use the following equations given in 5064 of the *Fermilab Safety Manual*:

$$\begin{aligned} \phi &= \sum_{i=1}^{n} (P_i F_i) \\ F_i &= Antilog_{10}(6.5 - PO_2/10) \ , \end{aligned}$$

where P_i is the probability of the ith event (hr^{-1}), F_i is the fatality factor of the ith event, PO_2 is the partial pressure of oxygen (mmHg), and ϕ is the oxygen deficiency hazard index (hr^{-1}). The ODH class is a function of ϕ.

Since zero building ventilation is assumed, even a small leak will eventually lead to a F_i of 1 as time approaches infinity. Therefore, the oxygen deficiency hazard can easily be calculated, if F_i is assumed to be equal to unity for all cases. After

searching the assessment medians from 5064TA-1, it appears that the assumed probability for the paddle connectors is much higher than the tabulated values pertaining to the failure modes associated with the LAC. By estimating that there are 1.2×10^3 paddle connections at the LAC and its associated piping, then the oxygen deficiency hazard is estimated to be:

$$\begin{aligned} \phi &= (1.2 \times 10^3)(3 \times 10^{-3} hr^{-1})(1) \\ &= 3.6 hr^{-1} . \end{aligned}$$

From Table 2 of Appendix I, the above number implies an ODH Class 4 area.

Since $F_i = f(PO_2)$, and $PO_2 = f(t)$, we can find the time which will lapse before an ODH condition is reached ($\phi > 10^{-7} hr^{-1}$) in the building. If the initial oxygen partial pressure is 159 mmHg, and the volume of the building is $5.0 \times 10^5 ft^3$, then the partial pressure of oxygen of the ith event, PO_{2_i}, can be given by:

$$\begin{aligned} PO_{2_i} &= \frac{(5 \times 10^5 ft^3 - \dot{V}_i t)159}{5 \times 10^5 ft^3} \\ &= 159 - 3.2 \times 10^{-4} \dot{V}_i t , \end{aligned}$$

where $\dot{V}_i$ is the leakage rate in SCFM, and t is the time that has elapsed after a power outage (min.).

Substituting the above equation into the one given in Appendix I for F_i yields:

$$\begin{aligned} F_i &= 1 \quad \text{when } \dot{V}_i t \gtrsim 2.9 \times 10^5 ft^3 \\ F_i &= 10^{(3.2 \times 10^{-5} \dot{V}_i t - 9.4)} \quad \text{when } \dot{V}_i t < 2.9 \times 10^5 . \end{aligned}$$

The fatality factors for items 1 and 2 listed in Table 1 of this note can be derived from the CCI report No. 593-110, "ODH Analysis for a Liquid Spill from the University of Rochester LAC Cryostat." Items 3-9 are the other predominant

potential leak sources located at the LAC vessel. The leakage rate from each of these items has to be evaluated individually in order to find the fatality factor.

According to the aforementioned CCI report, an ODH condition due to the complete rupture of the 3 in. nominal diameter liquid fill line, will occur after 160 s (0.044 hrs.). A simplified approach is to make $F_i = 0$ initially, and then assign unity to F_i after 0.044 hrs.

Similarly, a rupture to the manual valve on that line, MV-3001, will result in an ODH condition after a time period given by:

$$\frac{t_1}{t_2} \cong \left(\frac{d_2}{d_1}\right)^{2.5} ,$$

where t_2 = 0.044 hrs., d_2 =3.26in., and D_1 is the valve stem diameter, 1.375 in. Solving for t_1 gives a value of 0.38 hrs. Therefore F_i will change from zero to unity when 3 hrs. and 20 min. has elapsed.

The leakage rates are given for the rabbit hutch paddle connections, feedthrough plates, and the dewar mating flange in CCI report No. 593-120, "ODH Analysis of the MW Faraday Cage." At a LAC pressure of 7 psig and a leak path height of 0.001 in., the rates are 0.099 cfm per paddle connection, 0.17 cfm per feedthrough plate bolt hole path, and 0.091 cfm per mating flange bolt hole path.

Since there are approximately 10 wires per paddle connection and some 500 miscellaneous wires that are routed through the LAC top, then an estimated 50 paddle connections can be added to the 1120 connections in the rabbit hutches. Due to the lack of data, we will consider each of these 1170 connections to be flanges when assigning values of P_i.

Each of the 30 rabbit hutches has 2 feedthrough plates with 20 bolt hole paths. Therefore, there is a total of 60 feedthrough plates with a potential leakage of 3.4 cfm argon per plate.

With 108 flowpaths, if we again use the same assumptions given in the CCI report, the mating flange could yield a flow of 10 cfm.

Similar to the feedthrough plates, there are two access plates per rabbit hutch, which brings the total to 60. The velocity of flow through the bolt hole paths of the access plates will be 190 ft/s, the same value that was found in CCI report No. 593-120. The leak rate will vary according to the flow area, which is approximately 0.00135 in^2, given a leak path height of 0.001 in. Since there are 34 leak paths per access plate, then the total flow rate per plate will be:

$$\begin{aligned} \dot{V}_i &= \frac{(190)(0.00135)(60)(34)}{144} \\ &= 3.6cfm\ . \end{aligned}$$

By correcting the velocity due to the difference in path length between the CCI report and the 8 in. flanges connecting the rabbit hutches to the LAC vessel, the potential leakage per flange is given by:

$$\begin{aligned} \dot{V}_i &= \frac{190(\frac{0.75}{0.95})(0.00461)(60)(8)}{144} \\ &= 2.3cfm\ . \end{aligned}$$

Using an average length path of 0.84 in. and a width of 4.4 in. for a total of 240 bolt hole paths, we can similarly find the potential leakage per flange of the remaining 27 gas phase flanges:

$$\begin{aligned} \dot{V}_i &= \frac{(190)(\frac{0.75}{0.84})(0.0044)(\frac{240}{27})(60)}{144} \\ &= 2.8cfm\ . \end{aligned}$$

By using Darcy's Law of Permeability (as used in the CCI report), we can find the leakage past the beam window. Once again the leakage height is assumed to be

.001 in. and the leakage length is 0.068 ft. The width, assuming a rectangular cross section, is 2.5 in. The equivalent diameter, D, is based on the height and width and is $1.67 \times 10^{-4} ft$. ϵ is the material porosity, and is equal to 1.0. At saturated conditions, the viscosity, μ, is 0.610 $lb_f/ft.hr$. Lastly, the differential pressure, Δp, is 11 psig, which includes the hydrostatic head.

$$\begin{aligned} V &= \frac{\Delta p g_c \epsilon^3 D^2}{9.645 \times 10^{-6} \mu L} \\ &= \frac{(11)(32.2)(1)^3(1.67 \times 10^{-4})^2}{(9.645 \times 10^{-6})(0.610)(0.068)} \\ &= 24.7 ft/s \ . \end{aligned}$$

Given that there are six bolt hole paths, the leakage rate is then:

$$\begin{aligned} \dot{V}_i^l &= \frac{(24.7)(0.001)(2.5)(60)(6)}{144} \\ &= 0.154 cfm \text{ saturated liquid} \ . \end{aligned}$$

Assuming that this liquid flow will flash to warm gas, then the rate becomes:

$$\dot{V}_i = 0.154 \left(\frac{\rho_{liq}^{sat}}{\rho_{520^\circ R}^{1atm}} \right) = 0.154 \left(\frac{87.56}{0.1014} \right) = 133 cfm.$$

After substituting the potential flow rates into the equation for the fatality factor, which was previously derived, we obtain the equations for fatality as a function of time as listed in Table 1 of this note. The total sum of the products of the fatality factors and probabilities of each single event (line rupture, flange leakage, etc.) will give us the oxygen deficiency hazard index for a particular time, t.

Values for time versus the oxygen deficiency hazard index and its corresponding ODH class are given in Table 2. It is shown that an ODH condition will not exist until the 31st hour after a power outage has been reached, given the assumptions listed in this note. An ODH Class 2 will not occur until 46 days has lapsed. The

probability of a power outage for this length of time is quite small; therefore, it is unlikely that a Class 2 condition will ever be reached. The same argument obviously applies to a Class 3 and Class 4 conditions.

If a similar approach is used to find the relationship between ϕ and time for the Faraday Room, it can be shown that an ODH situation develops very quickly in the Faraday Room after a power outage. An ODH Class 4 situation will arise after a little more than a day has elapsed (see Table 3).

While computing values for ϕ for the MW Detector Hall, it was discovered that the beam window failure was the only leakage source of importance when determining the time for an ODH Class 1. If we provide enough ventilation to reduce the fatality rate of this failure to zero, then we can keep the building "ODH free" for at least a month without power provided no transferring of argon takes place. This ventilation rate required can be obtained from the following oxygen and volumetric balance of the building:

$$\begin{aligned} PO_{2_f} V_{MW} &= PO_{2_i} V_{MW} + PO_{2_i} \dot{V}_{in} t - PO_{2_f} \dot{V}_e t \\ \dot{V}_e &= \dot{V}_{leak} + \dot{V}_{in} \, . \end{aligned}$$

Solving for $\dot{V}_{in}$, which is the required ventilation rate:

$$\dot{V}_{in} = 5.625 \dot{V}_{leak} - 5 \times 10^5 t^{-1} \, ,$$

where $PO_{2_f} = 135 mmHg$, $PO_{2_i} = 159 mmHg$, V_{MW}, the building volume, is $5 \times 10^5 ft^3$, $\dot{V}_{leak}$ is the potential leakage rate, t is time in minutes.

If we let $\dot{V}_{leak}$ be the potential leakage through the beam window flange, and let $t = 4.5 \times 10^4$min. or a month period, then the required minimum ventilation rate is 737 cfm. This rate can be easily achieved if we made provisions to install a portable generator to activate the 6,000 scfm blower in the pit. This generator

could be installed within a few hours, which is more than ample time before any probable ODH situation could arise.

CONCLUSIONS

It appears that the total loss of power to the MW Detector Hall will not result in an ODH condition where immediate emergency actions are needed. Furthermore, an ODH situation could be altogether avoided if provisions can be made to install a portable generator to the pit blower within a few hours of a power outage.

However, during a power outage an ODH potential quickly exists in the Faraday Room, and will also exist in the MW Detector Hall if liquid argon is being transferred. Therefore, without power and with argon in the LAC, no personnel will be allowed to enter the Faraday Room without the proper equipment, ODH training, medical approval, and Fire Department supervision. Similarly, these restrictions hold true for the rest of the building, when argon is being transferred under the same circumstances. This mandate will be incorporated into the Emergency Procedures section of the Operating Procedures.

Table 1:

Item	Leakage Source	N	$P_i(hr^-1)$	$V_i(cfm)$	F_i
1	fill/dump line rupture	1	1×10^{-9}	-	0 until 0.044 hrs., 1 afterward
2	fill/dump valve leak or rupture	1	1×10^{-8}	-	0 until 0.38 hrs., 1 afterward
3	rabbit hutch & misc. paddle connections	1170	3×10^{-3}	0.099	$10^{(1.9\times10^{-4}t^*-9.4)}$,
4	r.h. feedthrough plate flanges	60	3×10^{-6}	3.4	$10^{(6.5\times10^{-3}t-9.4)}$,
5	LAC dewar mating flange	1	"	10	$10^{(0.019t-9.4)}$, 1 after 20 days
6	rabbit hutch access plates	60	"	3.6	$10^{(6.9\times10^{-3}t-9.4)}$,
7	r.h. to LAC flanges	30	"	2.3	$10^{(4.4\times10^{-3}t-9.4)}$,
8	misc. gas phase flanges	27	"	2.8	$10^{(5.4\times10^{-3}t-9.4)}$,
9	beam window flange	1	"	133	$10^{0.26t-9.4)}$, 1 after 36 hrs.

*t is in hrs.

Table 2: MW Detector Hall

$t(hrs)$	$\phi(hr^{-1})$	$ODH\ Class$
4	1.1×10^{-8}	0
8	1.1×10^{-8}	0
31	1.0×10^{-7}	1
1100	1.0×10^{-5}	2
3.1×10^{4}	1.0×10^{-3}	3
4.1×10^{4}	1.0×10^{-1}	4

Table 3: Faraday Room

t	$\phi(hr^{-1})$	$ODHClass$
$16min.$	1.0×10^{-7}	1
$45min.$	1.0×10^{-5}	2
$19hrs.$	1.0×10^{-3}	3
$27hrs.$	1.0×10^{-1}	4

REVIEWED BY:

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Name	**Date**	**Project Manager**	**Date**