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CRYOGENIC CONSULTANTS, INC.

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June 23, 1986

Mr. Kelly Dixon
Fermilab
P.O. Box 500
M.S. 310
Batavia, Illinois 60510

Subject: Fermilab Subcontract #94362

Dear Kelly:

In response to your stated concern regarding the temperature vulnerability of the LAC top plate and upper shell, we are submitting CCI Report No. 593-117 entitled "Analysis of LAC Top Plate and Upper Shell Thermal Condition During Operation". This report represent the results of a study of the expected temperature profiles in the upper section of the dewar. Heat leak from ambient will be sufficient to maintain the temperature of the carbon steel components well above the danger level during normal operation. The use of the PVC filler in place of fiber-glass as originally specified does not compromise the thermal integrity of the system.

Should you have any questions or comments regarding the enclosed, please do not hesitate to call.

Very truly yours,

CRYOGENIC CONSULTANTS, INC.

Jerry

Jerry B. Gibbs
Process Engineer

JBG/eaj

cc: P.C. Vander Arend

Encls: CCI Report 593-117

Copies to: W.E. Cooper
W. Baker
R.P. Smith
F. Lobkowicz

CCI Report 593-117

ANALYSIS OF LAC TOP PLATE AND UPPER SHELL THERMAL CONDITION DURING OPERATION

Prepared Under Subcontract No. SC-94362

By

Cryogenic Consultants, Inc.
Allentown, PA

For

Fermilab
Batavia, IL

June 23, 1986

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I. INTRODUCTION

The top plate and the upper shell of the liquid argon cryostat (LAC) are constructed of carbon steel and must be maintained at a temperature above 244°C (-20°F) to prevent structural damage from thermal stress. The heat flux into the upper vapor space of the cryostat must be sufficient to maintain the temperature of the argon gas at the flange level at 244°C and preferably greater. This required heat flux will be provided by heat leak through the top plate and upper shell walls during steady state operation. Additional heat flux, if needed, can be provided by the rim heaters.

II. DISCUSSIONS AND RESULTS

Calculations were performed to determine the heat flux required into the dewar upper argon vapor space to maintain the temperature of the argon vapor at the flange level at two acceptable temperature extremes, namely (1) ambient, or 300°C, and (2) 244°C. Figure 1 is a graphical presentation of the results of these calculations. The heat flux required to sustain a flange-level argon vapor temperature of 300°K is 41.9 watts (143 Btu/hr); the flux required to sustain a temperature of 244°C at the same location is 29.0 watts (99 Btu/hr). These heat flux levels are easily sustained from heat leak via thermal conduction through the dewar top plate and upper shell walls.

For a given temperature level of the argon vapor at the flange level, the heat flux to the surface of the liquid argon (LAr) is governed by the thermal resistances between these two points. These resistances are in series and consist of the upper argon vapor space, the Marley Tower Fill MC-67, and the lower argon vapor space. The heat flux through each of these resistances is a constant and is represented by the following general equation;

$$Q = \frac{kA\Delta T}{x}$$

where
Q = heat flux
k = thermal conductivity of the resistance
ΔT = temperature difference across the resistance
x = thickness of the resistance

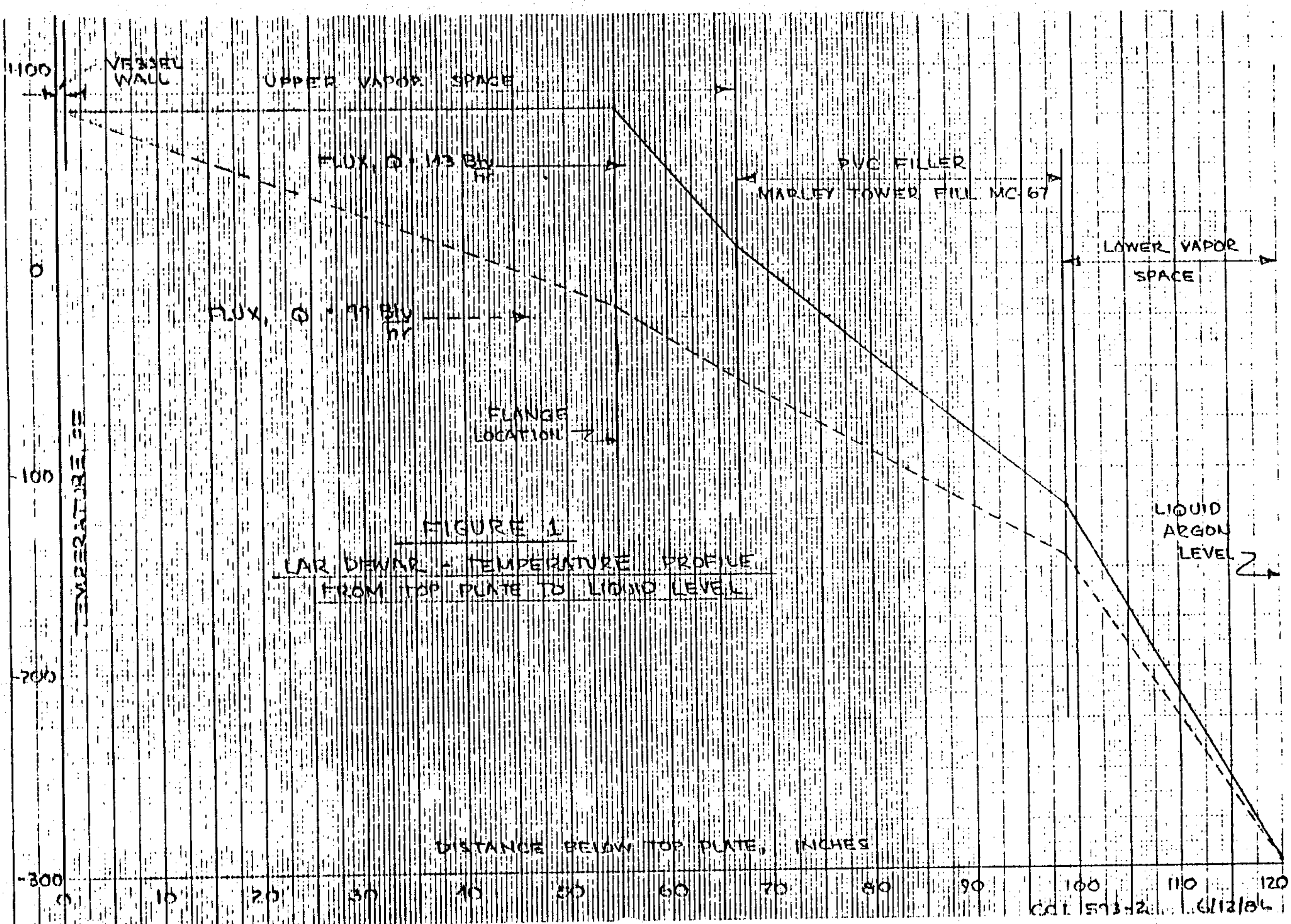

FIGURE 1
LAR DEWAR - TEMPERATURE PROFILE FROM TOP PLATE TO LIQUID LEVEL

A trial-and-error solution yields the temperature profiles shown in Figure 1 from which the heat flux can be calculated. Average values for the thermal conductivity for each resistance were assumed which accounts for the linear temperature gradients across the resistances. In reality, the temperature profiles across each resistance are curved (converse) reflecting the fact that the thermal conductivity decreases with temperature. A more rigorous analysis using incremental temperature differences would produce such a result.

Having determined the heat fluxes required to sustain the desired dewar wall temperature at the flange location, an estimate of the temperature driving forces across the stagnant gas layers on the inside and outside of the metal walls required to produce a heat leak equal to this heat flux can be made. Heat transfer coefficients for the top plate and upper shell gas resistances were assumed to be 0.2 Btu/hr.ft^2.°K and 1.0 Btu/hr.ft^2.°K respectfully. The surface areas for the top plate and upper shell are 230 ft^2 and 246 ft^2 respectively. Using these parameters and the required heat fluxes, temperature differentials of 0.98°F and 0.68°F on either side of the metal would be required to sustain a heat leak from ambient to the argon gas of 41.9 watts (143 Btu/hr) and 29.0 watts (99.0 Btu/hr) respectively. Temperature differentials of these magnitudes will easily be sustained during normal operation assuring that the upper shell and top plate will remain near room temperature.

The other concern is heat leak from the flange to the liquid argon via conduction through the wall of the dewar lower shell. This heat flux will be approximately 350 watts (assuming the flange is at 300°K) and will be provided by heat leak, and if necessary the rim heaters. The rim heaters have adequate capacity (1300 watts) to also provide backup protection for the upper shell and top plate during an operational upset