DØ SOLENOID UPGRADE PROJECT

**Chimney LN2 radiation shield
attachment area calculation**

D-ZERO ENGINEERING NOTE # 3823.111-EN-342

May 26, 1993

Russ Rucinski

A short calculation was done to check the attachment method of the radiation shield to its LN2 cooling tubes. The case considered was only for the obround chimney section. The proposed attachment method was to use 1/8" plug welds spaced every 5" along the length of the shield. The calculations were done conservatively for 6" spacing between plug welds. The criteria used was that the LN2 shield warmest temperature be less than 2 K above the temperature of the LN2 fluid.

Using a very conservative heat transfer model, the calculations predict that the warmest temperature on the radiation shield will be < 1.4 K warmer than the LN2 fluid temperature.

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SUBJECT

CHIMNEY LN₂ HEAT LOAD / SHIELD

NAME

RUSS RUCINSKI

DATE

4/23/93

REVISION DATE

HEAT LOADS TO THE LN₂ SHIELD WERE CALCULATED BY ANDY STEFANIK IN 2/25/93 CALCS, PGS. 1-3.

THEY ARE CONSERVATIVE, REASONABLE & ATTACHED TO THESE CALCS. AS AN APPENDIX.

- SUMMARY OF HEAT LOADS [PER AMS 2/25/93]
TO LN₂ SHIELD 300K-78K

RADIATION: 100 W

G-10 SUPPORTS: 7.4 W

LINE STOP: 0.2 W

TOTAL 107.6 W $\approx \frac{107.6 \text{ W}}{45 \text{ ft}} = 2.4 \text{ W/ft}$

→ CALCULATE REQ'D CROSSSECTIONAL AREA OF ATTACHMENT FOR SHIELD TO LN₂ PIPE.

ASSUME ATTACHMENT EVERY 6" ALONG LENGTH.

THERE WILL BE 4 LN₂ TUBES THEREFORE EACH ATTACHMENT POINT WILL NEED TO CONDUCT:

$$Q_{\text{ONE ATTACH. PT.}} = 2.4 \text{ W/ft} \times 0.5 \text{ ft} \times \frac{1}{4} = 0.3 \text{ W}$$

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SUBJECT

CHIMNEY LN₂ RADIATION SHIELD

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THERMAL MODEL I WANT TO LIMIT $T_{SHIELD} - T_{LN_2} < 2 K$

IN AN EFFORT TO SOLVE THIS PROBLEM WITHOUT GOING TO TIME CONSUMING ENDS, I WILL SIMPLIFY THE MODEL TO A ONE DIMENSIONAL PARTS AS:

TRY
 $r = 1/16"$

$$R_{SHIELD} = \frac{\ln(r_2/r_1)}{2\pi LK} = \frac{\ln\left(\frac{2.54 \text{ in}}{0.0625 \text{ in}}\right)}{2\pi \left(\frac{1}{32} \text{ in}\right) (2.3 \frac{\text{W}}{\text{cm}\cdot\text{K}}) 2.54 \text{ cm}} \frac{1 \text{ in}}{1 \text{ in}}$$

$$= 3.23 \text{ K/W}$$

$$\pi r_2^2 = (6 \text{ in}) (3.375 \text{ in})$$

$$r_2 = 2.54 \text{ in.}$$

$\left\{ \begin{array}{l} \text{THERMAL} \\ \text{CONDUCTIVITY, K} \\ \text{TAKEN FOR} \\ \text{6063-T5 AT 80K} \end{array} \right\}$

$$R_{WELD} = \frac{L}{KA} = \frac{(\frac{1}{32} \text{ in.})}{(2.3 \frac{\text{W}}{\text{cm}\cdot\text{K}}) \pi (.0625 \text{ in})^2 \frac{1 \text{ in}}{2.54 \text{ cm}}} = 0.44 \text{ K/W}$$

$$R_{TUBE WALL} = \frac{L}{KA} = \frac{(.065 \text{ in})}{(2.3 \frac{\text{W}}{\text{cm}\cdot\text{K}}) \pi (.0625 \text{ in})^2 \frac{1 \text{ in}}{2.54 \text{ cm}}} = 0.92 \text{ K/W}$$

$$\Sigma R = 3.23 + 0.44 + .92 = 4.59 \text{ K/W}$$

$\left\{ \begin{array}{l} \text{CONSERVATIVELY} \\ \text{ASSUMING ONLY} \\ \text{TRANSFER THRU} \\ \text{PROJECTION OF} \\ \text{WELD.} \end{array} \right\}$

$$\Delta T = q \cdot R_{TOTAL} = (0.3 \text{ W}) (4.59 \text{ K/W}) = \underline{1.4 \text{ K}}$$

$T_{SHIELD} - T_{LN_2} \leq 1.4 \text{ K}$ FOR $1/8"$ PLUG WELD
ON $6"$ SPACING
FOR OBOUNDO
SECTION

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SUBJECT

SUPPLY LINE

NAME

A.M.S.

DATE

Feb 25, 1993

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1. SIZE: $\frac{1}{2}$ " OD TUBE $\times$ 0.065" wall
(CDF size: 12mm OD $\times$ 2mm wall $\approx$ 0.5" OD $\times$ 0.0787" wall)
Warm id = $0.5" - 2(0.065) = 0.37"$
2. LENGTH: (BASED ON R. RUCINSKI CHIMNEY CALCS DATED 1/8/93.)
 $12" + 69" + 138" + 69" + 38" + 38" + 38" + 12" + 12" + 36" + 36" + 9" + 9" + 24" = 540" = 45'$
3. RESISTANCE COEFFICIENT FOR MINOR LOSSES: (BASED ON R. RUCINSKI CHIMNEY CALCS DATED 1/8/93.)

No. OF 90° SHORT RADIUS ELBOWS $\approx$ 10

$$K_{\text{pipe}} = 10(20 \text{ ft}) = 10(20)(0.027) = 5.4$$

$$K_{\text{tube}} = 5.4 \left(\frac{0.37}{0.622} \right)^4 = 0.7$$

No. OF TEE BRANCHES = 2

$$K_{\text{pipes}} = 2(60 \text{ ft}) = 2(60)(0.027) = 3.24$$

$$K_{\text{tube}} = 3.24 \left(\frac{0.37}{0.622} \right)^4 = 0.4$$

$$\Sigma K = 0.7 + 0.4 = 1.1$$

4. CHIMNEY HEAT LEAK

• SHIELD -

ASSUME A CIRCULAR SHIELD FOR THE ENTIRE LENGTH.

O.D. = 6.625" (FROM R. RUCINSKI)

$$\text{SURFACE AREA} = \pi (6.625/12)' \times 45' \approx 80 \text{ ft}^2$$

THE SHIELD IS WRAPPED WITH ALUMINUM TAPE. THE VACUUM JACKET IS STAINLESS STEEL PIPE.

$$Q/A_1 = F_{1-2} \sigma (T_1^4 - T_2^4)$$

1 $\equiv$ SMALLER SURFACE AT 78 K2 $\equiv$ LARGER SURFACE AT 300 K

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$$f_{1-2} = \frac{1}{\frac{1-\epsilon_1}{\epsilon_1} + 1 + \frac{A_1(1-\epsilon_2)}{A_2\epsilon_2}} \quad \text{FOR CONCENTRIC CYLINDERS}$$

$$\epsilon_1 = 0.03$$

$$\epsilon_2 = 0.85 \text{ - weathered}$$

$$A = \pi d l$$

$$\frac{A_1}{A_2} = \frac{\pi d_1 l}{\pi d_2 l} = \frac{d_1}{d_2} = \frac{6.625''}{8.329''} = 0.8$$

8" SCH 10S

$$f_{1-2} = \frac{1}{\frac{1-0.03}{0.03} + 1 + 0.8(1-0.85)} = 0.03$$

$$Q/A_1 = 0.03 \left(5.67 \times 10^{-8} \frac{\text{W}}{\text{m}^2 \text{K}^4} \right) (300^4 - 78^4)$$

$$= 13.7 \text{ W/m}^2 = 1.274 \text{ W/ft}^2$$

$$Q = 1.274 \text{ W/ft}^2 \times 80 \text{ ft}^2 = 102, \text{ SAY } 100 \text{ W}$$

• SUPPORTS

THERE ARE 6 G-10 SUPPORTS.

ASSUME 4-1/2" x 1/8" WALL G-10 RODS FOR EACH SUPPORT.

$$Q = \frac{A}{l} \int k(T) dT$$

ASSUME 2 OF THE 4 RODS MAKE GOOD THERMAL CONTACT.

$$A_{\text{supt}} = \frac{\pi}{4} (0.5^2 - 0.25^2) \times 2 = 0.295 \text{ in}^2 = 1.9 \text{ cm}^2$$

$$l = (8.329'' - 6.625'')/2 = 0.852 \text{ in} = 2.164 \text{ cm}$$

$$\int_{78}^{300} k(T) dT = 1.4 \text{ W/cm}$$

$$Q_{\text{supt}} = \frac{1.9 \text{ cm}^2}{2.164 \text{ cm}} \times 1.4 \frac{\text{W}}{\text{cm}} = 1.23 \text{ W}$$

$$Q \text{ FOR 6 SUPPORTS} = 1.23 (6) = 7.4 \text{ W}$$

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SUBJECT

NAME
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PIPE STOP

ASSUME 2 - 1/4" ϕ SS RODS, FEET LONG

$$Q = \frac{A}{L} \int k(T) dT$$

$$A = 2 \left[\pi \frac{(0.25")^2}{4} \right] = 0.1 \text{ in}^2 = 0.63 \text{ cm}^2$$

$$L = 3 \text{ ft} = 91.44 \text{ cm}$$

$$\int_{78}^{300} k(T) dT = 27.43 \text{ W/cm}$$

$$Q = \frac{0.63 \text{ cm}^2}{91.44 \text{ cm}} \times 27.43 \frac{\text{W}}{\text{cm}} = 0.2 \text{ W}$$

TOTAL HEAT LOAD = $100 + 7.4 + 0.2 = 107.6 \text{ W}$

UNIFORM HEAT LOAD/FOOT OF PIPE = $\frac{107.6 \text{ W}}{45 \text{ ft}} = 2.4 \text{ W/ft}$

CHECK THE 2.4 W/ft NUMBER:

IN THE CVI CATALOG, THE HEAT LEAK FOR AN MLI, 6"X8" LN₂ LINE = 1.657 Btu/hr-ft = 0.49 W/ft.

ASSUME THE HEAT FLUX TO A MLI INSULATED SHIELD IS ~ 2 W/m² FOR THIS APPLICATION.

$$\text{THE SHIELD HEAT LEAK IS} = \frac{2 \text{ W/m}^2}{13 \text{ W/m}^2} \times 96.6 \text{ W} = 15 \text{ W}$$

$$\begin{aligned} \text{THE UNIFORM HEAT LOAD/FOOT OF PIPE} &= \frac{15 + 7.4 + 0.2}{45} = \frac{22.6}{45} \\ &= 0.5 \text{ W/ft} \end{aligned}$$

THE 0.5 W/ft RESULT COMPARES WELL WITH THE CVI PUBLISHED, ESTIMATED DATA.

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