UCRL UCID-1345

UNIVERSITY OF CALIFORNIA

Ernest O. Lawrence Radiation Laboratory

BERKELEY, CALIFORNIA

DISCLAIMER

LAWRENCE RADIATION LABORATORY - UNIVERSITY OF CALIFORNIA ENGINEERING NOTE		FILE NO 4312-03M26	PAGE 1
SUBJECT 25" HYDROGEN BUBBLE CHAMBER HEAT LOAD & SUPERINSULATION STUDY		NAME R. BYRNS	
		DATE 12-27-60	

SUMMARY.

AVAILABLE REFRIGERATION

WITH PRESENT 15" B.C. REFRIGERATOR AT 25°K.

MAX. (LN_2 PUMPED.) – 300 WATT.

MAX. (LN_2 UNPUMPED) – 200 WATT

FOR OPERATION EASE THE UNPUMPED SYSTEM IS DESIRED.

DYNAMIC HEAT LOAD, (12 pulse per min. est. max.) 37 WATT

STATIC HEAT LOADS

CASE 1 DESIGN USING HIGH VACUUM & $L.N_2$ SHIELD WITH ALL LH_2 STEM CONDUCTION SHUNTED TO LN_2

STATIC LOAD TO LN_2 – 8.3 $\frac{\text{LITERS } LN_2}{\text{HR.}}$ = 364 WATT

STATIC LOAD TO LH_2 (TOTAL)

STEM CONDUCTION TO CHAMBER	12.0
RADIATION FROM LN_2 SHIELD	.82
" " 300°K WINDOWS.	15.0
GAS CONDUCTION ($p = 10^{-5}$ mm.)	1.76
STEM CONDUCTION TO H_2 FLASK (EST.)	15.0

TOTAL ≃ 6 $\frac{\text{LITERS } LH_2}{\text{HR}}$ ≃ 45 WATT

FOR COMPARISON, HEAT LOAD TO THE PRESENT 15" B.C. IS ESTIMATED BY G. ECKMAN,

HEAT LOAD TO LN_2 – 12–15 $\frac{\text{LITERS } LN_2}{\text{HR}}$

540–670 WATT

HEAT TO CHAMBER – 25–30 WATT

" TO H_2 FLASK 25–20 "

TOTAL ≃ 6 $\frac{\text{LITERS } LH_2}{\text{HR}}$ ≃ 50 WATT

CASE 2 DESIGN USING SUPERINSULATION & NO LN_2 SHIELD OR CONDUCTION SHUNTS. HEAT LOAD TO CHAMBER COULD BE ZERO OR NEGATIVE. INSIDE WALL OF SUPERINSULATION MUST APPROACH 30–70°K. THEREFORE CONDUCTION HEAT LOAD FROM 300°K TO INNER WALL MUST BE MINIMIZED.

USE 1/4" OF SI $k = 0.8$ watt/ft.²

IF 1/2" SI $k \simeq 0.08$ "

STATIC LOAD TO LH_2

STEM CONDUCTION TO CHAMBER	= 60 watt
" " " FLASK	20 "
RADIATION FROM 300°K WINDOWS	15
CONDUCTION THRU 1/4" SI	71
TOTAL = 21 $\frac{\text{LITERS } LH_2}{HR}$	= 166 WATT

IF $\frac{1}{2}$" SI USED:
CONDUCTION THRU SI ≃ 7 — 102 Watt

HEAT TRANSFER FIGURES MAY BE IN ERROR BY ~50% GENERAL, NOT EXACT GEOMETRIES, HAVE BEEN USED. HEAT TRANSFER VARIES AS VACUUM PRESSURE, EMISSIVITIES, ETC. SUPERINSULATION EXPERIMENTAL & MEASURED DATA IS SCATTERED, PARTICULARLY IN THE 1/8" – 1/2" THICK RANGE.

SUPERINSULATION. APPLICATION & MATERIAL COSTS ARE HIGH, 20-40 TIMES GREATER THAN POWDER. "AIR PRODUCTS" FEELS "SI" IS NOT ECONOMICALLY FEASIBLE FOR LO_2 STORAGE, OR EVEN LH_2 STORAGE COMPARED TO POWDER. "SI" FOR L.He STORAGE SEEMS ATTRACTIVE.

"SI" REQUIRES PUMPDOWNS OF 2-3 DAYS FOR COMPLETE EVACUATION. OUTGASSING ABOVE 100°C IS ALSO NECESSARY, REQUIRING HEATERS. ALL RESIDUAL GAS & WATER VAPOR MUST BE REMOVED BEFORE COOLDOWN, AS FROZEN IMPURITIES WILL BRIDGE & DESTROY THE INSULATION, BY PROVIDING CONDUCTION PATHS.

"SI" REQUIRES 2-3 DAYS, DEPENDANT ON BULK TO REACH THERMAL EQUILIBRIUM, AS THE SHIELDS COOL BY RADIATION.

USE OF "SI" COULD ELIMINATE THE LN_2 SHIELD AND ALSO PROVIDE MORE INHERENT SAFETY, WERE IT IN AN INDEPENDANT VACUUM JACKET. THIS MIGHT BE AT THE COST OF MAGNET FIELD & CHAMBER O.D.

25" HYDROGEN BUBBLE CHAMBER — EN 4312-03 M-6 — PAGE 3

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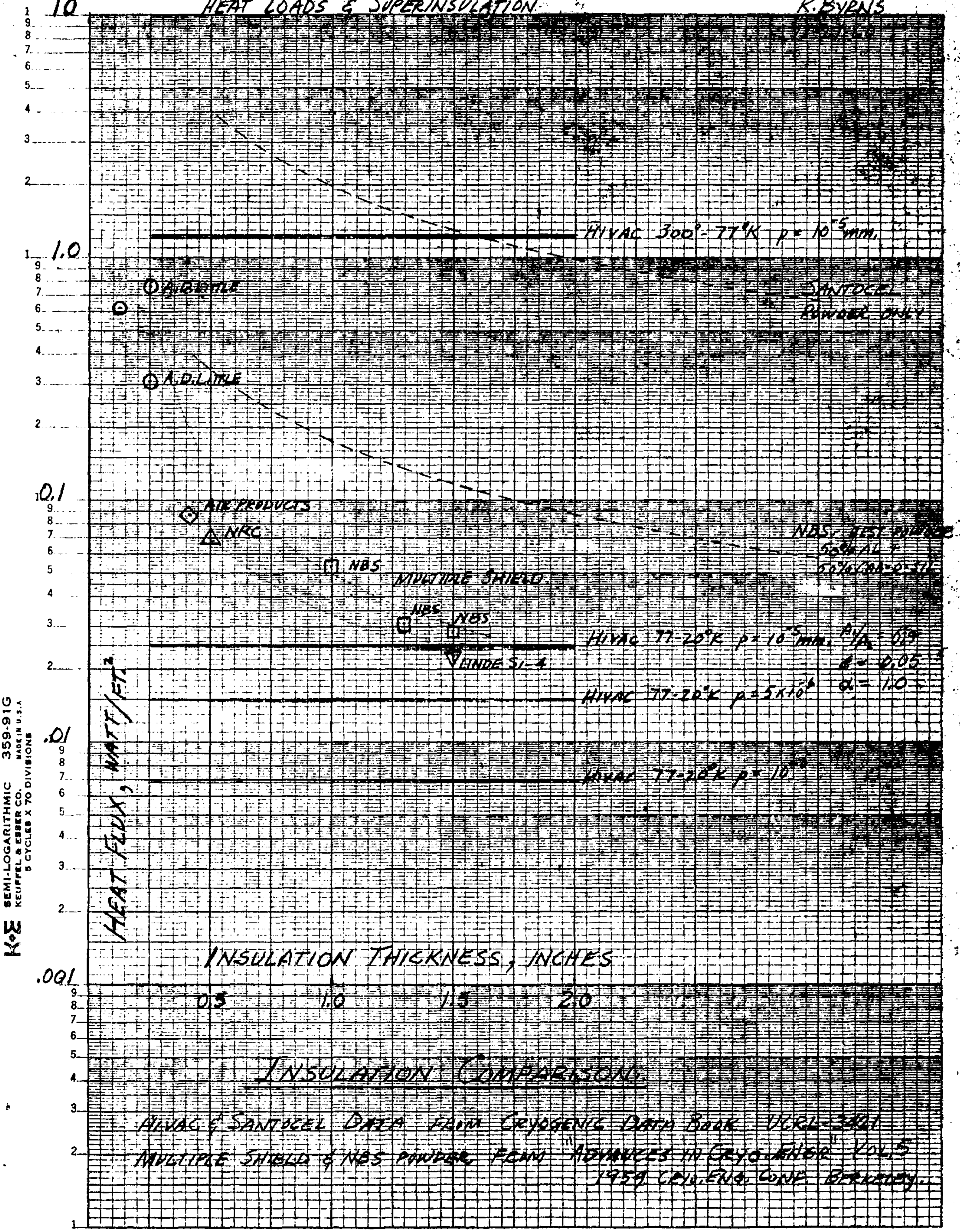
HEAT LOADS & SUPERINSULATION — R. BYRNS



DYNAMIC HEAT LOAD.

CHAMBER DIA. = 25" $A = \pi/4\, D^2 = 492\ in^2$

STROKE LENGTH, S = 0.10"

PRESS. RANGE 6 ATM TO 3 ATM., LINEAR WITH TIME,

MEAN PRESS. = 4.5 ATM = 67 PSIA.

FORCE = PA = 67 #/in² (492 in²) = 33,000 #

WORK = FS = 33000 (0.10) = 3300 #-in.

ABOVE WORK IS WORK OF EXP. OR RECOMP. FOR IDEAL REVERSIBLE PROCESS ALL EXP. WORK EQUALS RECOMP. WORK. FOR THIS CASE, ASSUME EFFICIENCY, $\eta = 50\%$

WORK = 0.50 (3300) = 1650 #-in., 12 pulse/min. = 1 pulse/5 SEC.

$$POWER = 1650 \frac{\#\text{-}in}{pulse} \frac{1\ pulse}{5\ SEC} \frac{FT.}{12\ in.} = 27.5 \frac{FT.LB.}{SEC.}$$

$$POWER = 27.5 \frac{FT.LB}{SEC} \left(1.356 \times 10^{-3} \frac{KW\ SEC}{FT\ LB.}\right) = 37.3\ WATTS$$

STEM CONDUCTION HEAT LOADS.

FOR CHAMBER SUPPORT, USE 3/16" stnls. stl. SHIELD & SUSPENSION, 30" DIA. $A = \pi D t = \pi 30 (3/16) = 17.7\ in^2 \left(2.54 \frac{cm}{in}\right)^2 = 114.4\ cm^2$

FOR EXPANSION DRIVE USE 3-2" DIA RODS.

$$A = n \pi/4\, D^2 = (3) \pi/4 (4) = 9.42\ in^2 = 60.8\ cm^2$$

$$\Sigma A = 175.2\ cm^2$$

USE LENGTH = 31.5 in. = 80 cm.

USE EN3140-01 M241. (FOR. stnls. stl. 30-300°K.)

$$\frac{QL}{A} = \int_{30}^{300} k\,dt = 31.6 - 0.5 = 31.1$$

$$Q = 31.1 \frac{\Sigma A}{L} = 31.1 \frac{175}{80} = 60\ WATTS \quad 30\text{-}300°K.$$

IF CONDUCTION SHUNTED TO LN_2 AT 77°K.

AT L = 12" 77°-300°K L = 20" 20°-77°K

$$Q = \frac{A}{L} \int_{77}^{300} k\,dt = \frac{175}{12(2.54)} (31.5 - 4) = \frac{175}{30.4} (27.5) = 158\ WATTS \quad 77\text{-}300°K.$$

$$Q = \frac{A}{L} \int_{20}^{77} k\,dt = \frac{175}{20(2.54)} (4.0 - 0.5) = 12\ WATTS \quad 30\text{-}77°K.$$

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ENGINEERING NOTE

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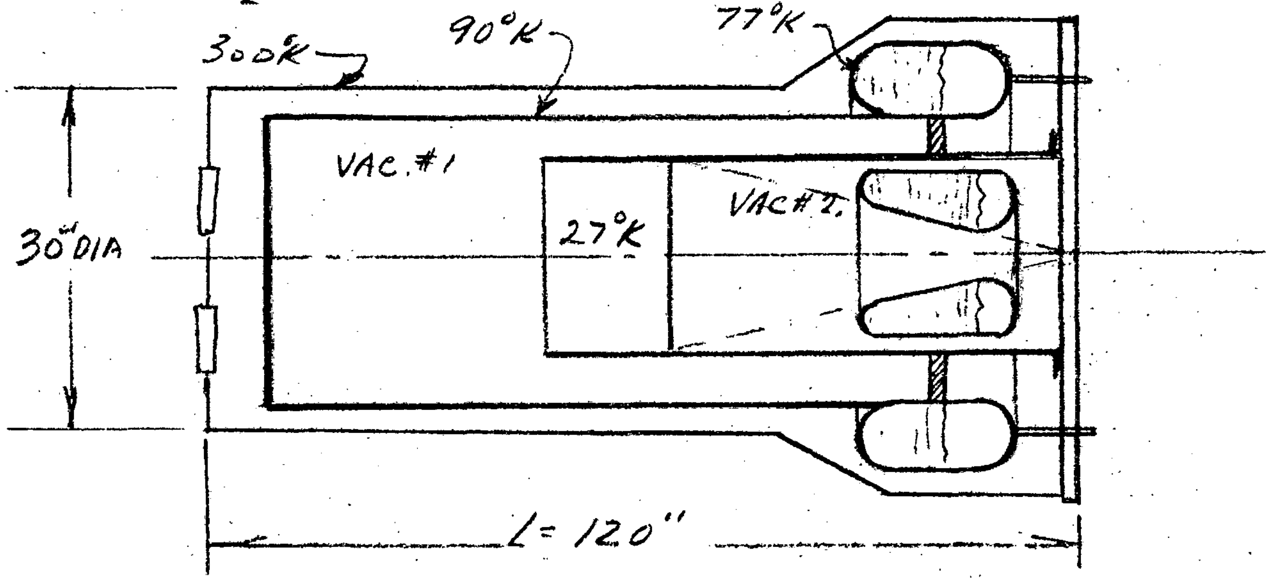
SUBJECT 25" HYDROGEN BUBBLE CHAMBER HEAT LOAD & SUPERINSULATION STUDY	NAME R. BYRNS	DATE 12-29-60	

CASE I HIGH VACUUM WITH LN_2 SHIELD & STEM CONDUCTION SHUNTED TO LN_2.



SHELL AREA - APPROX. $A = 2\frac{\pi}{4}D^2 + \pi DL = \pi D(D/2 + L)$

$A = \pi 30(15 + 120) = \underline{12,700\ in^2} = \underline{88\ FT^2}$

HEAT LEAK TO LN_2 SHIELD. FROM 300°K. SEE EN4311-14 M11

$Q = A\sigma\epsilon(T_1^4 - T_0^4) = 12,700\ in^2 \left(.0037 \times 10^{-8} \frac{watt}{in^2\ °K^4}\right).05(81 \times 10^8)$

$\underline{Q = 190.5\ watts.}$

EST. COND. TO N_2 STEMS. ≃ 15 Watts.
COND. FROM H_2 SHIELD = 158 watt

TOTAL HEAT LOAD TO N_2 = 8.3 $\frac{LITRES}{HR}$ = $\underline{364\ watt}$

HEAT LOAD TO 25°K REFRIG.

ASSUME ALL RADIATION FROM LN SHIELD ABSORBED BY LH_2.
$\varepsilon = .05$ $T_1 = 25°K$ $T_2 = 77°K$.

$Q = 12700(.0037 \times 10^{-8})(.05)(0.35 \times 10^8) = \underline{0.82\ watt.}$

GAS CONDUCTION. p.97 Cryo. Data. Book.
assume press = 10^{-5} mm., H_2 GAS RESIDUAL.

$Q/A = 0.2 \frac{watt}{ft^2}$ $Q = 88(0.2)$ $= \underline{1.76\ watt}$

HEAT LEAK FROM 300°K WINDOWS - ASSUME 5 3" DIA. WINDOWS.
WORST CASE - FROM EN4311-14 M11 $Q = \underline{15\ WATT}$
MORE ACCURATE - EN7911-30M35
$Q = 0.297(0.12)35\ in^2 = 1.25\ watt.$

SUBJECT: 25" HYDROGEN BUBBLE CHAMBER HEAT LOAD & SUPERINSULATION STUDY

NAME: R. BYRNS
DATE: 12-27-60.

SUPERINSULATION REFER "ADVANCES OF CRYO. ENG'R" VOL. 5 pages. 181-221

A.D. LITTLE page 186.

$p = 10^{-6}$ mm. - 1/4" THICK, 10-13 SHIELDS, AL FOIL, DEXTER PAPER OR FGAA
T = 300-77°K.

$t = 1/4"$ $\quad Q/A = k\frac{dt}{dy} = .0030 \frac{BTU\ in.}{hr.\ ft^2\ °K.} \frac{220°K.}{1/4\ in.} 0.293 \frac{watt\ hr.}{BTU} = 0.768 \frac{watt}{ft^2}$

$t = 1/4"$ $\quad k = .0012$ $\quad Q/A = 0.309$ "

$t = 1/8"$ $\quad k = .0012$ $\quad Q/A = 0.618$ "

NBS-CEL. p. 193.

.008" Dexter paper, .00023" Al foil, 55 SHIELDS/IN, 300-20°K

$t = 1.3"$ $\quad \frac{Q}{A} = K\frac{dt}{dx} = 0.39\times10^{-6} \frac{watt}{Cm\ °K} \frac{280°K}{1.3\ in.} \frac{2.54\ cm}{in.} \frac{144\ in^2}{ft^2} = 0.0307 \frac{W}{ft^2}$

$t = 1.5"$ $\quad \frac{Q}{A} = \frac{0.42}{0.39} \frac{13}{15} .0307 = 0.0286$

$t = 1.0"$ $\quad Q/A = \frac{0.60}{0.39} \frac{1.3}{1.0} (.0307) = 0.0615.$

NRC. p. 203. 300-77°K.

$t = 1/2"$ $\quad \frac{Q}{A} = 75 \frac{\mu\cdot watt}{Cm^2} \left[2.54 \frac{cm}{in} 12 \frac{in.}{ft.}\right]^2 = .0696 \frac{watt}{ft^2}$

LINDE p. 210 "SI-4" t(est.) = 1.5 60°F - -323°F

$t(est.) = 1.5"$ $\quad \frac{Q}{A} = k\frac{dt}{dx} = .025\times10^{-3} \frac{BTU}{hr.\ ft\ °F} \frac{383°F}{1.5\ in.} .293 \frac{watt\ hr}{BTU} \frac{12\ in}{ft.} = .0225 \frac{watt}{ft^2}$

AIR PRODUCTS p. 219 300°-77°K.

$t = 0.415"$ $\quad \frac{Q}{A} = 0.30 \frac{BTU}{hr\ ft^2} (.293) \frac{watt\ hr.}{BTU} = .0878 \frac{Watt}{ft^2}$

HIVAC WITH LN_2 SHIELD. 77°-20°K. Refer "Cryo. Data Book" UCRL 3421

GAS CONDUCTION (p. 97.)
- $p = 10^{-5}$ mm $\quad Q/A = 0.02\ watt/ft^2$ $\quad$ TOTAL $Q/A = 0.025$
- $p = 5\times10^{-6}$ mm $\quad = 0.01$ $\quad = 0.015$
- $p = 1\times10^{-6}$ mm $\quad = 0.002$ $\quad = 0.007$

RADIATION (p. 94) $\quad \epsilon = .05$ $\quad A_1/A_2 = 0.9$ $\quad Q/A = 0.005$

HIVAC WITHOUT LN_2 300-77°K.
RADIATION $Q/A = 1.2\ W/ft^2$ $\quad$ COND $Q/A = 0.05\ W/ft^2$ $\quad$ " $= 1.25$