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25" Hydrogen Bubble Chamber Heat Load & Superinsulation Study

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UNIVERSITY OF
CALIFORNIA

Ernest O. Lawrence

*Radiation
Laboratory*

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BERKELEY, CALIFORNIA

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ENGINEERING NOTE

4312-03M26

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. (LN₂ PUMPED.) - 300 WATT.MAX. (LN₂ UNPUMPED) - 200 WATT.FOR OPERATION EASE THE UNPUMPED SYSTEM IS
DESIRED.DYNAMIC HEAT LOAD, (12 pulse per min. est. max.) 37 WATTSTATIC HEAT LOADSCASE 1 DESIGN USING HIGH VACUUM & LN₂ SHIELD
WITH ALL LH₂ STEM CONDUCTION SHUNTED
TO LN₂STATIC LOAD TO LN₂ - $8.3 \frac{\text{LITERS LN}_2}{\text{HR.}} = \underline{364 \text{ WATT}}$ STATIC LOAD TO LH₂ (TOTAL)

STEM CONDUCTION TO CHAMBER 12.0

RADIATION FROM LN₂ SHIELD .82

" " 300°K WINDOWS. 15.0

GAS CONDUCTION (P = 10⁻⁵ MM.) 1.76STEM CONDUCTION TO H₂ FLASK (EST.) 15.0TOTAL $\approx 6 \frac{\text{LITERS LH}_2}{\text{HR.}} \approx \underline{45 \text{ WATT}}$ FOR COMPARISON, HEAT LOAD TO THE PRESENT
15" B.C. IS ESTIMATED BY G. ECKMAN.HEAT LOAD TO LN₂ - 12-15 $\frac{\text{LITERS LN}_2}{\text{HR.}}$ 540-670 WATT

HEAT TO CHAMBER - 25-30 WATT

" TO H₂ FLASK 25-20 "TOTAL $\approx 6 \frac{\text{LITERS LH}_2}{\text{HR.}} \approx \underline{50 \text{ WATT}}$ CASE 2DESIGN USING SUPERINSULATION & NO LN₂ 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 $k = 0.8 \text{ WATT/FT.}^2$
IF 1/2" SI $k \approx 0.08 \text{ "}$

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SUBJECT

25" Hydrogen Bubble Chamber
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STATIC LOAD TO LH₂

STEM CONDUCTION TO CHAMBER - 60 WATT

" " " FLASK 20 "

RADIATION FROM 300°K WINDOWS 15

CONDUCTION THRU "1/4" SI 71

TOTAL 21 LITERS LH₂ = 166 WATT
HR

IF 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 LO₂ STORAGE, OR EVEN LH₂ STORAGE COMPARED TO POWDER. "SI" FOR LHe STORAGE SEEMS ATTRACTIVE.

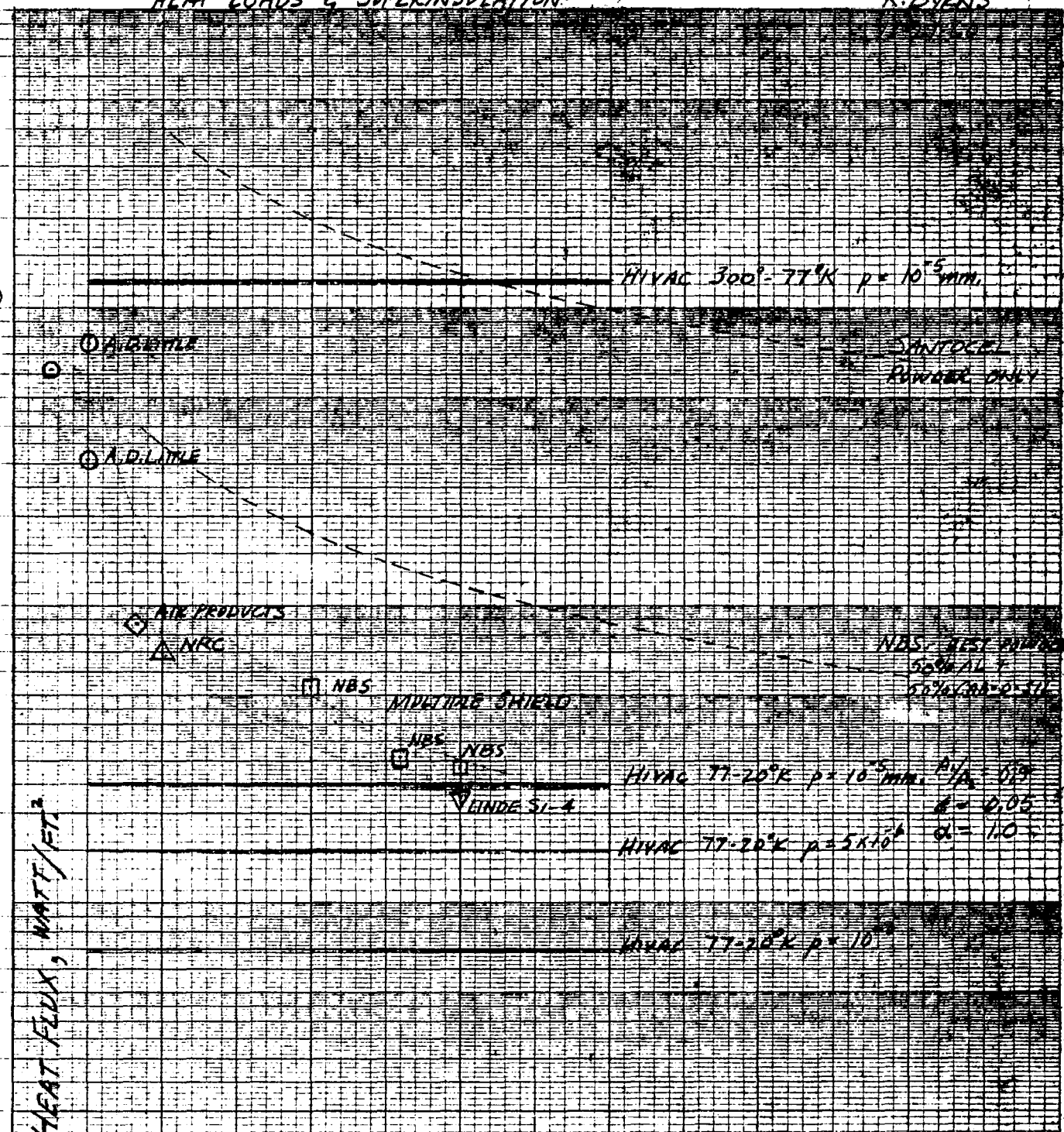
"SI" REQUIRES PUMPDOWNS OF 2-3 DAYS FOR COMPLETE EVACUATION. OUTGASSING ABOVE 100°C IS ALSO NECESSARY, REQUIRING HEATERS. ALL RESIDUAL GAS & WATER VAPOR MUST BE REMOVED BEFORE COOLDOWN, AS FROZEN IMPURITIES WILL BRIDGE & DESTROY THE INSULATION, BY PROVIDING CONDUCTION PATHS.

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

USE OF "SI" COULD ELIMINATE THE LN₂ 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.

KE SEMI-LOGARITHMIC 359-91G
 KEUFFEL & ESSER CO. MADE IN U.S.A.
 5 CYCLES X 70 DIVISIONS

10
 1.0
 0.1
 0.01
 HEAT FLUX, WATT/FT.²



INSULATION THICKNESS, INCHES

0.5 1.0 1.5 2.0

INSULATION COMPARISON

HiVAC & SINTERED POWDER DATA FROM CRYOGENIC DATA BOOK VOLUME 3-3001
 MULTIPLE SHIELD & NBS POWDER FROM "ADVANCES IN CRYOGENICS" VOL. 5
 1959 CIV. ENG. CONF. BERKELEY.

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DYNAMIC HEAT LOAD.

$$\text{CHAMBER DIA.} = 25" \quad A = \pi/4 D^2 = 492 \text{ in.}^2$$

$$\text{STROKE LENGTH, } S = 0.10"$$

PRESS. RANGE 6 ATM TO 3 ATM., LINEAR WITH TIME,
MEAN PRESS. = 4.5 ATM = 67 PSIA.

$$\text{FORCE} = PA = 67 \text{ #/in.}^2 (492 \text{ in.}^2) = 33,000 \text{ #}$$

$$\text{WORK} = FS = 33000 (0.10) = \underline{3300 \text{ #-in.}}$$

ABOVE WORK IS WORK OF EXP. OR RECOMP. FOR IDEAL
REVERSIBLE PROCESS ALL EXP. WORK EQUALS RECOMP. WORK.

FOR THIS CASE, ASSUME EFFICIENCY, $\eta = 50\%$

$$\text{WORK} = 0.50 (3300) = \underline{1650 \text{ #-in.}}, \quad 12 \text{ pulse/min.} = 1 \text{ pulse/5 SEC.}$$

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

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

STEM CONDUCTION HEAT LOADS.

FOR CHAMBER SUPPORT, USE 3/16" STAINL. ST. SHIELD & SUSPENSION,
30" DIA. $A = \pi D L = \pi 30 (3/16) = 17.7 \text{ in.}^2 \left(2.54 \frac{\text{CM}}{\text{IN.}} \right)^2 = 114.4 \text{ cm.}^2$
FOR EXPANSION DRIVE USE 3-2" DIA RODS.

$$A = n \pi/4 D^2 = (3) \pi/4 (4) = 9.42 \text{ in.}^2 = \underline{60.8 \text{ cm.}^2}$$

$$\Sigma A = 175.2 \text{ cm.}^2$$

USE LENGTH = 31.5 in. = 80 cm.

USE EN3140-01 M241. (FOR STAINL. ST. 30-300°K.)

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

$$Q = 31.1 \frac{\Sigma A}{L} = 31.1 \frac{175}{80} = \underline{60 \text{ WATTS}}$$

30-300°K.

IF CONDUCTION SHUNTED TO LN₂ AT 77°K.

AT $L = 12" \quad 77^\circ - 300^\circ \text{K}$

$L = 20" \quad 20^\circ - 77^\circ \text{K}$

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

77-300°K.

$$Q = \frac{A}{L} \int_{20}^{77} k dt = \frac{175}{20(2.54)} (4.0 - 0.5) = \underline{12 \text{ WATTS}}$$

30-77°K.

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25" HYDROGEN BUBBLE CHAMBER
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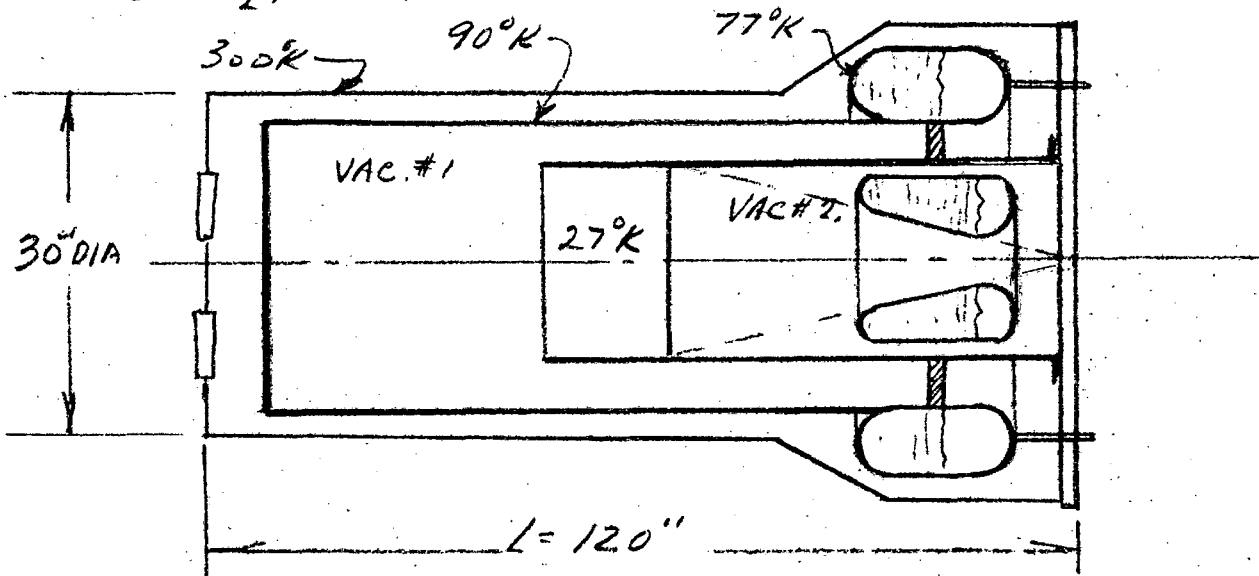
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DATE

12-29-60

CASE 1 HIGH VACUUM WITH LN₂ SHIELD & STEM CONDUCTION SHUNTED TO LN₂.



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

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

HEAT LEAK TO LN₂ SHIELD. FROM 300°K. SEE EN4311-14 M11

$$Q = A \epsilon (T_1^4 - T_0^4) = 12,700 \text{ in}^2 (0.037 \times 10^{-8} \frac{\text{WATT}}{\text{in}^2 \cdot \text{K}^4}) (0.5 (81 \times 10^8))$$

$$Q = 190.5 \text{ WATTS.}$$

EST. COND. TO N₂ STEMS. ≈ 15 WATTS.

COND. FROM H₂ SHIELD = 158 WATT

$$\text{TOTAL HEAT LOAD TO N}_2 = 8.3 \frac{\text{LITRES}}{\text{HR}} = 364 \text{ WATT}$$

HEAT LOAD TO 25°K REFRIG.

ASSUME ALL RADIATION FROM LN SHIELD ADSORBED BY LH₂.

$$\epsilon = 0.05 \quad T_1 = 25^\circ\text{K} \quad T_2 = 77^\circ\text{K}$$

$$Q = 12700 (0.037 \times 10^{-8}) (0.05) (0.35 \times 10^8) = 0.82 \text{ WATT.}$$

GAS CONDUCTION. p. 97 Cryo. Data. Book.

ASSUME PRESS = 10⁻⁵ mm., H₂ GAS RESIDUAL.

$$Q/A = 0.2 \frac{\text{WATT}}{\text{FT}} \quad Q = 88 (0.2) = 1.76 \text{ WATT}$$

HEAT LEAK FROM 300°K WINDOWS - ASSUME 5 3" DIA. WINDOWS.

WORST CASE - FROM EN4311-14 M11

$$Q = 15 \text{ WATT}$$

MORE ACCURATE - EN7911-30 M35

$$Q = 0.297 (0.12) 35 \text{ in}^2 = 1.25 \text{ WATT.}$$

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SUPERINSULATION REFER "ADVANCES OF CRYO. ENGR" VOL. 5 pages. 181-221A.D. LITTLE page 186. $p = 10^{-6}$ mm. - $\frac{1}{4}$ " THICK, 10-13 SHIELDS, AL FOIL, DEXTER PAPER OR FGAA $T = 300 - 77^{\circ}K.$

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

$$t = \frac{1}{4}" \quad k = .0012 \quad \frac{Q}{A} = 0.309 "$$

$$t = \frac{1}{8}" \quad k = .0012 \quad \frac{Q}{A} = 0.618 "$$

NBS-CEL. p. 193.

.008" dexter paper, .0023" Al foil, 55 SHIELDS/IN, 300-20°K

$$t = 1.3" \quad \frac{Q}{A} = k \frac{dt}{dx} = 0.39 \times 10^{-6} \frac{\text{watt}}{\text{cm}^{\circ}K} \frac{280^{\circ}K}{1.3 \text{ in.}} \frac{2.54 \text{ cm}}{\text{in.}} \frac{144 \text{ in}^2}{\text{ft.}^2} = 0.0307 \frac{\text{w}}{\text{ft.}^2}$$

$$t = 1.5" \quad \frac{Q}{A} = \frac{0.42}{0.39} \frac{13}{15} \cdot 0.0307 = 0.0286$$

$$t = 1.0" \quad \frac{Q}{A} = \frac{0.60}{0.39} \frac{1.3}{1.0} (0.0307) = 0.0615.$$

NRC. p. 203.

300-77°K.

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

LINDE p. 210

"51-4"

 $t(\text{est.}) = 1.5$

60°F - -323°F

$$t(\text{est.}) = 1.5" \quad \frac{Q}{A} = k \frac{dt}{dx} = .025 \times 10^{-3} \frac{\text{BTU}}{\text{hr. ft.}^2 \text{ } ^{\circ}F} \frac{383^{\circ}F}{1.5 \text{ in.}} \cdot 0.293 \frac{\text{watt hr}}{\text{BTU}} \frac{12 \text{ in}}{\text{ft.}} = .0225 \frac{\text{watt}}{\text{ft.}^2}$$

AIR PRODUCTS p. 219

300° - 77°K.

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

HIVAC WITH LN₂ SHIELD.

77° - 20°K.

Refer "CRYO. DATA BOOK" UCRL 3421

GAS CONDUCTION
(p. 97.) $p = 10^{-5}$ mm $\frac{Q}{A} = 0.02 \frac{\text{watt}}{\text{ft.}^2}$ TOTAL $\frac{Q}{A} = 0.025$ $p = 5 \times 10^{-6}$ mm

= 0.01

= 0.015

 $p = 1 \times 10^{-6}$ mm

= 0.002

= 0.007

RADIATION
(p. 94) $\epsilon = 0.05$ $\frac{A}{A_2} = 0.9$ $\frac{Q}{A} = 0.005$ HIVAC WITHOUT LN₂ 300-77°K.RADIATION $\frac{Q}{A} = 1.2 \frac{\text{w}}{\text{ft.}^2}$ COND $\frac{Q}{A} = 0.05 \frac{\text{w}}{\text{ft.}^2}$

" = 1.25