

Lawrence Berkeley National Laboratory

LBL Publications

Title

Bump Magnets BH1

Permalink

<https://escholarship.org/uc/item/0p510963>

Author

Caylor, R

Publication Date

1978-03-01

Copyright Information

This work is made available under the terms of a Creative Commons Attribution License, available at <https://creativecommons.org/licenses/by/4.0/>

LBID- 053 e. 1

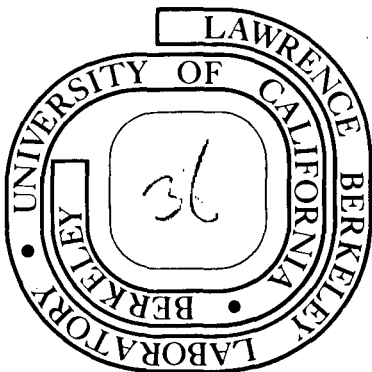
RECEIVED
LAWRENCE
BERKELEY LABORATORY

JUN 29 1979

LIBRARY AND
DOCUMENTS SECTION

For Reference

Not to be taken from this room



LBID - 053 e. 1

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

ENGINEERING NOTE

CODE

SERIAL

PAGE

PE0103

M5148A

1 of 11

AUTHOR

DEPARTMENT

LOCATION

DATE

R. Caylor

M.E.

Berkeley

March 20, 1978

PROGRAM - PROJECT - JOB

PEP

INJECTION

TITLE

BUMP MAGNETS BH1

'A' Rev. 5/29/79 R. Reimers, first three pages revised and retyped \triangle

The required magnet parameters and design calculations for the #1 Bump magnets are summarized below. The detailed design calculations are given in the appendix of this report. The magnets will be physically located at positions 8B274BH1 and 10A274BH1 in the PEP ring in accordance with the 11/78 printout and show on PEP drawing SA-204-235-22.

1. REQUIRED MAGNET PARAMETERS

A. Bend angle	θ	3 milliradians max.
B. Beam stiffness	B_p	667.2 kilogauss meters
C. Beam Energy	E	20 GeV
D. BL product	$\int Bd l$	2 kilogauss meters
E. Field Uniformity	$\Delta B/B$	$\leq \pm 0.3\%$ for $ \Delta x \leq 70$ mm from \mathcal{E}
F. Effective length	L_{eff}	2 meters
G. Entrance and exit pole angle	-	Normal to beam
H. Excitation	-	DC
I. Power supply required	-	53 amps, includes 5% above 20GeV level
J. Gap	g	105 mm

2. DESIGN CALCULATION2.1 Magnetic Design

Dipole field	997 Gauss
Pole width	300 mm
Effective length	2,006 mm
Est. Efficiency	98%
Magnet ampere turns	8,495
Est. yoke field = 200/38 x 1000	5,263 gauss
Stored energy	402 joules
Iron length along beam \mathcal{E}	1901 mm

ENGINEERING NOTE

PE0103

M5148A

2 OF 11

AUTHOR

R. Caylor

DEPARTMENT

M.E.

LOCATION

Berkeley

DATE

March 20, 1979

2.2 Engineering Design @ 20 GeV**2.2.1 Coil**

Conductor: 5.82 mm x 5.82 mm copper, solid
(.229" x .229")

Conductor Cross Sectional Area: 31.8 mm²

Average turn length: 4.73 meters

Number of turns per magnet: 168

Conductor length per magnet 795 meters

Coil resistance per mag. @ 20°C: .430 ohm

Coil resistance per mag. @ 82°C: .536 ohm

Conductor Weight per magnet: 506 lbs

Coils/magnet 2 each

2.2.2 Magnet Current, Power, and Time Constant

Current @ 20 GeV 50.7 Amps

Voltage @ 81.8°C (per magnet) 27.2 Volts

Power (Peak) @ 81.8°C 137 Watts

Current density @ 20 GeV 1.59 Amps/mm²

Inductance .313 henrys

Time constant @ 20°C .73 Seconds

2.2.3 Magnet Cooling (Air-cooled)

Max. Iron Temp. 78°C

Max. Coil Temp. 82°C

2.2.4 Core

Material AISI 1010 Steel

Core Weight 2880 lbs

Total Magnet Weight 3400 lbs

3. DOCUMENTATION

	<u>PO/JO</u>	<u>Drawing</u>	<u>Specification</u>
Steel	3797002	-	-
Conductor	3791702	-	-
Core	036582,036397	204-235-01	LBL M584
Coil	6206802	204-235-07	LBL M580
Assy	036629	204-235-21	LBL M582

ENGINEERING NOTE

PE0103

M5148A

3 of 11

AUTHOR

DEPARTMENT

LOCATION

DATE

R. Caylor

M.E.

Berkeley

March 20, 1979

4. SCHEDULE

Assembly will begin on June 7, 1979 with LBL (Main, Nelson) measurement and installation at PEP immediately following. SLAC beam tubes will be fitted there by the vacuum group.

5. COSTS

Projected direct costs (excluding design, inspection, measurement, and shipment to SLAC);

	Unit	Unit Cost	Qty	Matl. Cost	Labor Cost	Total \$	PO/JO	Date
Conductor, solid, copper	lb	1.40	1100	1540	-	1540	3791702	77
Coil fabrication	ea	630	4	-	2520	4926 (a)	6026802	79
Core steel (Incl. grind 2 surf)	lb	.32	5840	1871	-	1871	3797002	77
Core fabrication	ea		2	-	2000	2000	036582	79
Misc. hardware	-	-	-	-	800	800	036506	78
Assembly	ea		2	-	2000	2000	036629	79

TOTAL FABRICATION

13,137

\$/LB = 13,137/6800 = \$1.93/lb

(a) Includes \$2,406 prorated tooling charge

ENGINEERING NOTE

CODE
PE0103

SERIAL
M5148

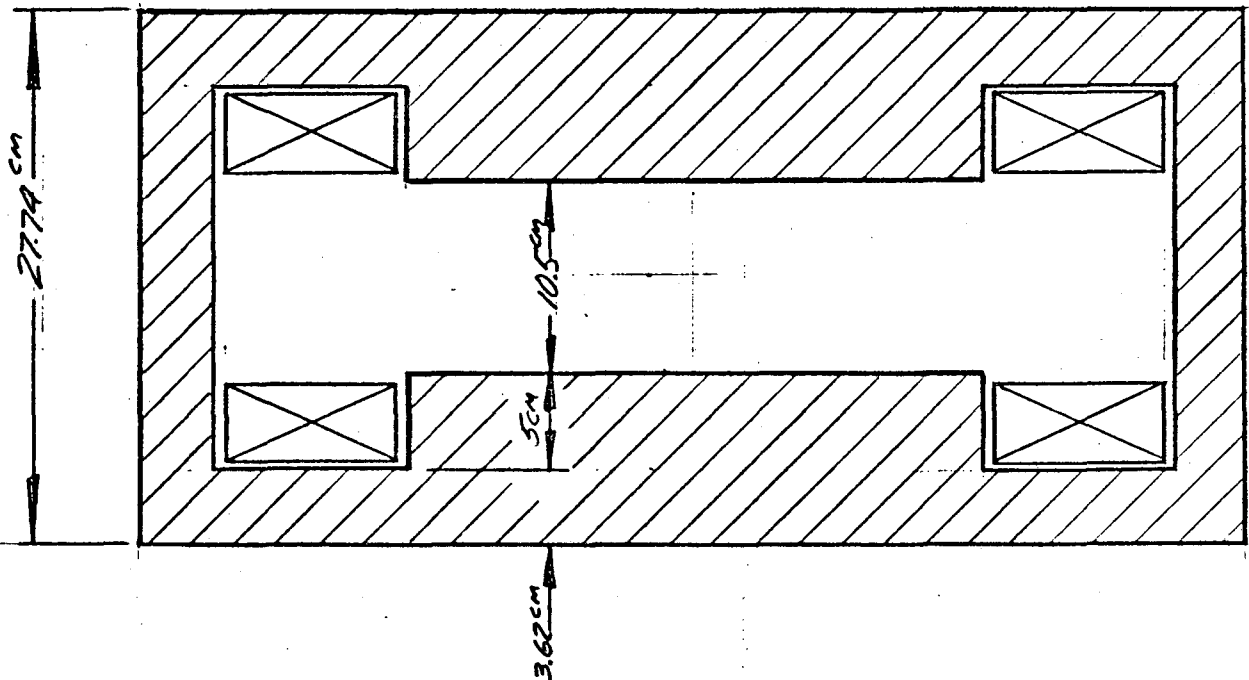
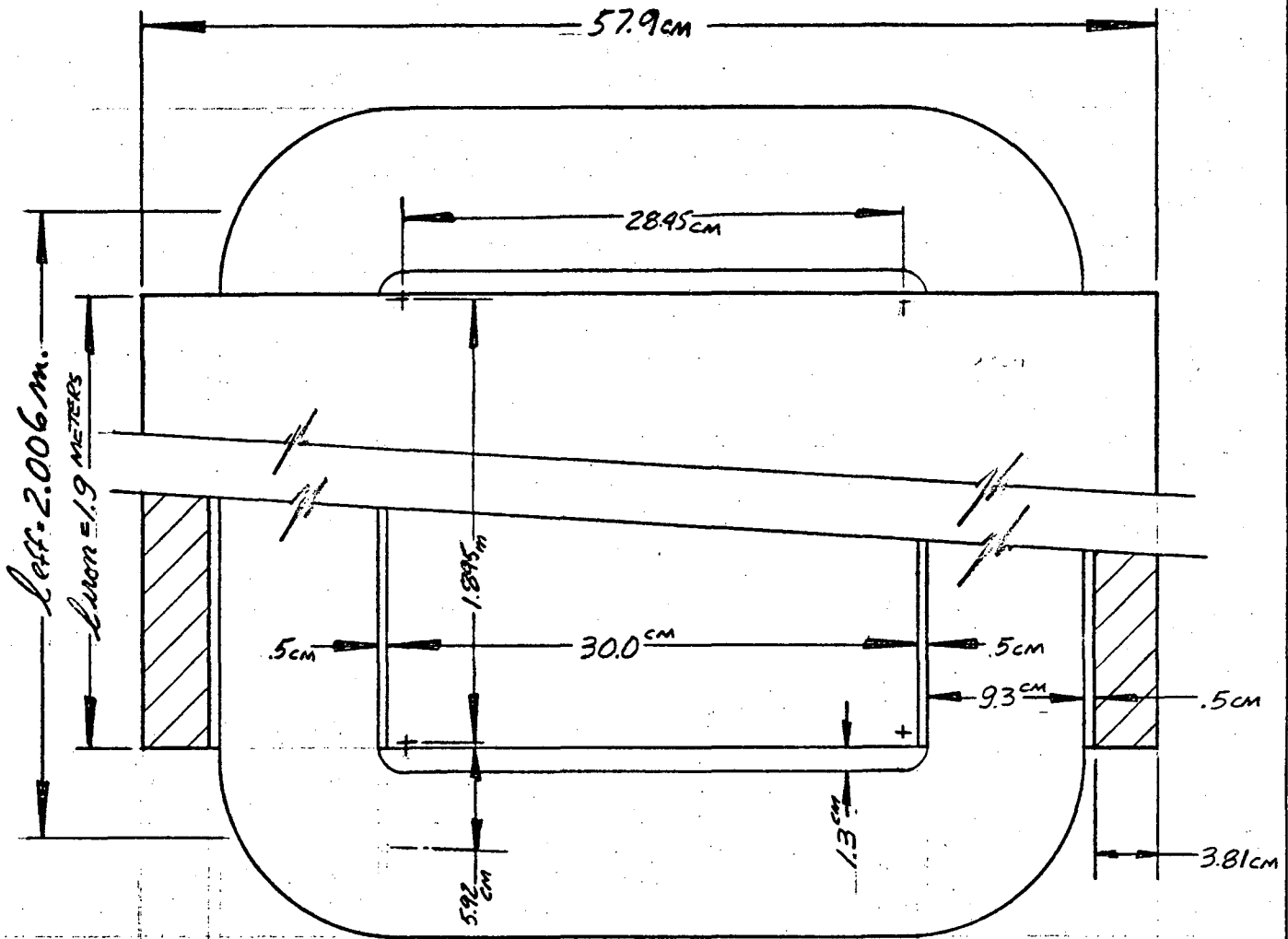
PAGE
4 OF 11

AUTHOR
R. Caylor

DEPARTMENT
M.E.

LOCATION
Berkeley

DATE
March 20, 1978



ENGINEERING NOTE

PE0103

M5148

5 of 11

AUTHOR

R. Caylor

DEPARTMENT

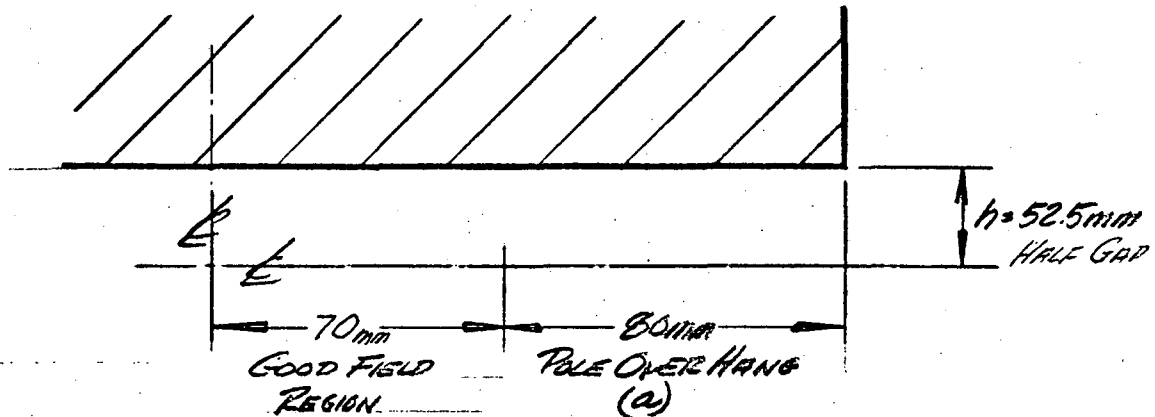
M.E.

LOCATION

Berkeley

DATE

March 20, 1978

APPENDIX2. DESIGN CALCULATIONS2.1 MAGNETIC DESIGN

ALLOWABLE $\frac{\Delta B}{B} \leq .003$ @ $\pm 70 \text{ mm}$ from ϵ (from physicist)

FOR NON OPTIMIZED POLE:

$$k = \frac{a}{h} = .75 - .36 \ln \left(100 \times \frac{\Delta B}{B} \right)$$

$$= .75 - .36 \ln (100 \times .003)$$

$$= \underline{1.183}$$

$$\frac{a}{h}$$

$$a = h k = 52.5 \times 1.183 = 62.13 \text{ mm}$$

MAKE OVERHANG 80 mm

POLE WIDTH

$$w_p = 2(70 + 80) = \underline{300 \text{ mm}}$$

w_p

ENGINEERING NOTE

PE0103

M5148

6 OF 11

AUTHOR

DEPARTMENT

LOCATION

DATE

R. Caylor

M.E.

Berkeley

March 20, 1978

$$\begin{aligned} \text{CHECK } \frac{\Delta B}{B} &: 100 \frac{\Delta B}{B} = \exp(-2.77(x-.75)) \\ &= \exp(-2.77\left(\frac{80}{52.5} - .75\right)) \\ &= .117 \\ \frac{\Delta B}{B} &= \frac{.117}{100} = \underline{1.17 \times 10^{-3} \text{ OK}} \end{aligned}$$

$$B = \underline{997 \text{ GAUSS}}$$

MAGNET EFFICIENCY = 98% EST
EFF WILL BE MEASURED & GIVEN IN
REISSUED NOTE

MAGNET AMPERE TURNS:

$$NI = \frac{2.02 B_0}{\mu} = \frac{2.02 \times 997 \times 10.5 \text{ cm} \times .3937 \frac{1}{\text{cm}}}{.98}$$

$$= \underline{8.495 \text{ AMP TURNS}}$$

STORED ENERGY

$$U_s = \frac{1}{2\mu_0} \int B^2 dV$$

$$= \frac{10^7 \times \mu_0^{-1}}{2 \times 4\pi} 2m \left[(.105m \times .3m) + (.093m \times .205m) \right]$$

$$= \underline{402.4 \text{ JOULES}}$$

2.2 ENGINEERING DESIGN

2.2.1 COIL

AVERAGE COIL LENGTH

$$L_{avg} = 2 \times 1.895m + 2 \times .2845m + 2\pi \times .0592m$$

$$= \underline{4.731 \text{ METERS}}$$

ENGINEERING NOTE

PE0104

M5148

7 OF 11

AUTHOR

R. Caylor

DEPARTMENT

M.E.

LOCATION

Berkeley

DATE

March 20, 1978

NUMBER OF TURNS

$$N = 84 \text{ TURNS/COIL} \\ = 168 \text{ TURNS/MAGNET}$$

NCONDUCTOR LENGTH/MAGNET

$$L = N \lambda_{\text{coil}} = 168 \times 4.73 \text{ METERS} \\ = 794.8 \text{ METERS}$$

LRESISTANCE

$$R_{20^\circ\text{C}} = 8.521 \times 10^{-9} \Omega/\text{LB}$$

$$R_{20^\circ\text{C}} = 8.521 \times 10^{-9} \Omega/\text{LB} \times 794.8 \text{ m} \times \frac{59.37 \text{ IN/M}}{12 \text{ IN/FT}} \\ \times \frac{194 \text{ LB/FT}}{1000} = \underline{.4310 \Omega/\text{MAG}}$$

R_{20°C}WEIGHT COPPER

$$W_{\text{Cu}} = 84 \text{ TURNS/COIL} \times 4.73 \text{ METERS/TURN} \times \frac{59.37 \text{ IN/M}}{12 \text{ IN/FT}} \\ \times \frac{194 \text{ LB/FT}}{1000} = 253 \text{ LBS/COIL} \\ = \underline{506 \text{ LBS/MAG}}$$

W_{Cu}2.2.2 MAGNET CURRENT, POWER, AND TIME CONSTANTCURRENT

$$I = \frac{NI}{N} = \frac{8495 \text{ AT}}{168 \text{ TURNS}} = \underline{50.6 \text{ AMPS}}$$

IVOLTAGE

$$E = IR = 50.71 \text{ AMP} \times .431 \text{ OHMS} = \underline{21.86 \text{ VOLTS}} \\ @ 20^\circ\text{C}$$

E

ENGINEERING NOTE

PE0103

M5148

8 OF 11

AUTHOR

R. Caylor

DEPARTMENT

M.E.

LOCATION

Berkeley

DATE

March 20, 1978

POWER

$$P = I^2 R = 50.71_{\text{AMPS}}^2 \times .4310_{\text{OHMS}}$$

$$= \underline{1108 \text{ WATTS @ } 20^\circ\text{C}}$$

PCURRENT DENSITY

$$A_{\text{CROSS}} = 31.8 \text{ MM}^2$$

$$I_A = \frac{50.71_{\text{AMPS}}}{31.8 \text{ MM}^2} = \underline{1.59 \text{ AMPS/MM}^2} \quad @ 20^\circ\text{C}$$

I_AINDUCTANCE

$$L_M = \frac{2U_s}{I^2} = \frac{2 \times 402.4_{\text{Joules}}}{50.71_{\text{AMPS}}^2}$$

$$= \underline{.313 \text{ HENREYS}}$$

L_MMAGNET TIME CONSTANT

$$t = \frac{L_M}{R} = \frac{.313_{\text{HENREYS}}}{.4310_{\text{OHMS}}}$$

$$= \underline{.73 \text{ SECONDS}}$$

t

ENGINEERING NOTE

PE0103

M5148

9 of 11

AUTHOR

R. Caylor

DEPARTMENT

M.E.

LOCATION

Berkeley

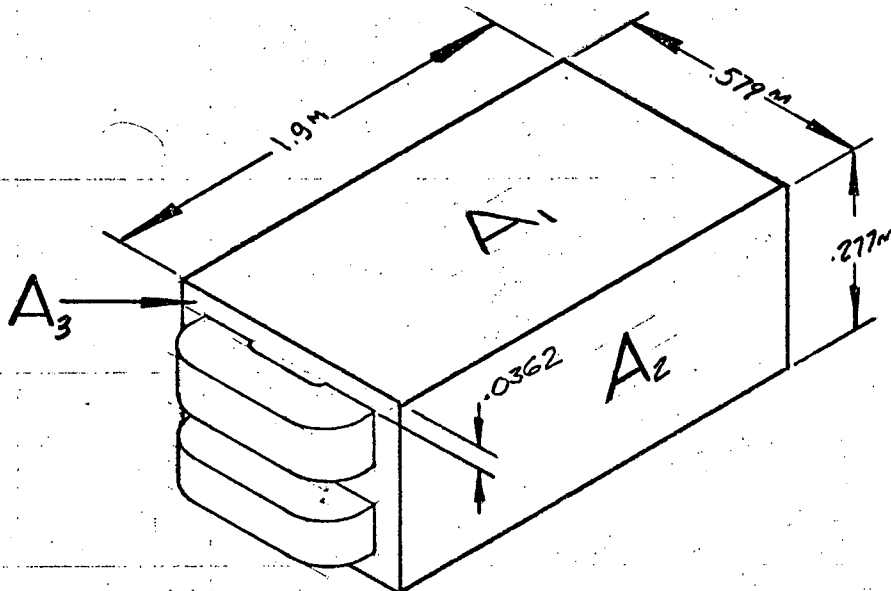
DATE

March 20, 1978

2.2.3 MAGNET COOLINGMAXIMUM COIL TEMP.ASSUME $T_{COIL} = 80^{\circ}C$

$$\text{RESISTANCE}_{80^{\circ}C} = R_{20} \left(\frac{234 + T_{80}}{234 + 20} \right) = .43 \left(\frac{314}{254} \right) = \underline{533 \Omega} \quad R_{80^{\circ}C}$$

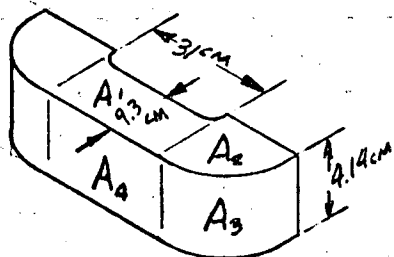
$$\text{POWER}_{80^{\circ}C} = I^2 R = 50.71^2 \times 533 = \underline{1371 \text{ WATTS}} \quad P_{80^{\circ}C}$$



IRON SURFACE AREA (A_I): $A_I = 2A_1 + 2A_2 + 4A_3$

$$= 2(1.9 \times 579) + 2(1.9 \times 277) + 4(579 \times 0.362) = 3336 \text{ m}^2$$

$$= \underline{5172 \text{ in}^2} \quad A_I$$

COIL SURFACE AREA (A_C)

$$A_C = 4A_1 + 8A_2 + 8A_3 + 4A_4$$

$$= 4(31 \times 9.3) + 8 \left(\frac{\pi \times 9.3^2}{4} \right) + 8 \left(\frac{2\pi \times 9.3 \times 4.14}{4} \right) + 4(31 \times 4.14)$$

$$= \underline{2693.8 \text{ cm}^2}$$

$$= \underline{417.54 \text{ in}^2} \quad A_C$$

ENGINEERING NOTE

PE0103

M5148

10 of 11

AUTHOR

R. Caylor

DEPARTMENT

M.E.

LOCATION

Berkeley

DATE

March 20, 1978

POWER DENSITY

$$Q = \frac{P}{A_I + A_C} = \frac{1371 \text{ WATTS}}{33360_{\text{cm}^2} + 2694_{\text{cm}^2}}$$

$$= \underline{.0390 \text{ WATTS}/\text{cm}^2}$$

$$= \underline{.245 \text{ WATTS}/\text{IN}^2}$$

QFROM GRAPH ENG-NOTE M5077 Pg 7, $\alpha = .6$

$$T_{\text{IRON}} = \underline{78 \text{ }^\circ\text{C}}$$

T_{FE}

$$P = h A_{\text{CON}} (T_{\text{COIL}} - T_{\text{IRON}})$$

WHERE $h = .0542 \text{ WATTS}/\text{cm}^2\text{-}^\circ\text{C}$
 FOR .010" MYLAR + .005" INSULGREASE
 AND $A_{\text{CON}} = \text{AREA OF COIL IN CONTACT w/IRON}$ (EN M5077)

h

CONTACT w/IRON

$$A_{\text{CON}} = A (9.3_{\text{cm}} \times 190_{\text{cm}}) = \underline{7068 \text{ cm}^2}$$

A_{CON}

$$T_{\text{COIL}} = T_{\text{IRON}} + \frac{P_0}{h A_{\text{CON}}} = 78.2 + \frac{1371_{\text{W}}}{.0542 \times 7068_{\text{cm}^2}}$$

$$= \underline{82 \text{ }^\circ\text{C}}$$

T_{coil} (82°)RECALCULATE T_{COIL} NOW 82 °CRESISTANCE

$$R_{81.75} = R_{20} \left(\frac{234 + T_{\text{COIL}}}{234 + 20} \right)$$

$$= .431 \left(\frac{316}{254} \right)$$

$$= \underline{.536 \text{ OHMS}}$$

R_{82 °C}

ENGINEERING NOTE

PE0103

M5148

11 OF 11

AUTHOR

DEPARTMENT

LOCATION

DATE

R. Caylor

M.E.

Berkeley

March 20, 1978

POWER

$$P = I^2 R = 50.71_{\text{AMP}}^2 \times .536_{\text{OHMS}}$$

$$= \underline{1378 \text{ WATTS}}$$

P
81.75°C

$$D = \frac{P}{A_s + A_c} = \frac{1378}{33360 + 2694}$$

$$= \underline{.0382 \text{ WATTS/CM}^2}$$

Q
81.75°C

$$= \underline{.247 \text{ WATTS/IN}^2}$$

FROM GRAPH ENM5077 PG 7, c. 6

$$T_{\text{IRON}} = \underline{78.^\circ \text{C}}$$

T_{IRON}

$$T_{\text{COIL}} = T_{\text{IRON}} + \frac{P_{82}}{h A_{\text{CON}}}$$

$$= 78. + \frac{1378}{.05485 \times 7068_{\text{CM}^2}} = \underline{82.^\circ \text{C}}$$

T_{coil}2.2.4 CORE

$$\underline{\text{WEIGHT}} \quad W_{\text{STL}} = .0173 \frac{\text{LBS}}{\text{CM}^3} \times 190_{\text{CM}} \times 0$$

$$\text{(INNER \& OUTER LEG)} \quad 20.5 \times (2 \times 3.81)$$

$$\text{PLUS TOP \& BOTTOM YOKE} \quad 57.9 (2 \times 3.62)$$

$$\text{PLUS POLE TIP} \quad 30 (2 \times 5)$$

$$\underline{= 2,880 \text{ LBS}}$$

W_{STL}TOTAL MAGNET WEIGHT

$$W_T = W_{\text{CU}} + W_{\text{STL}}$$

$$= 506 + 2880 \underline{= 3400 \text{ LBS}}$$

W_T

LEGAL NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

