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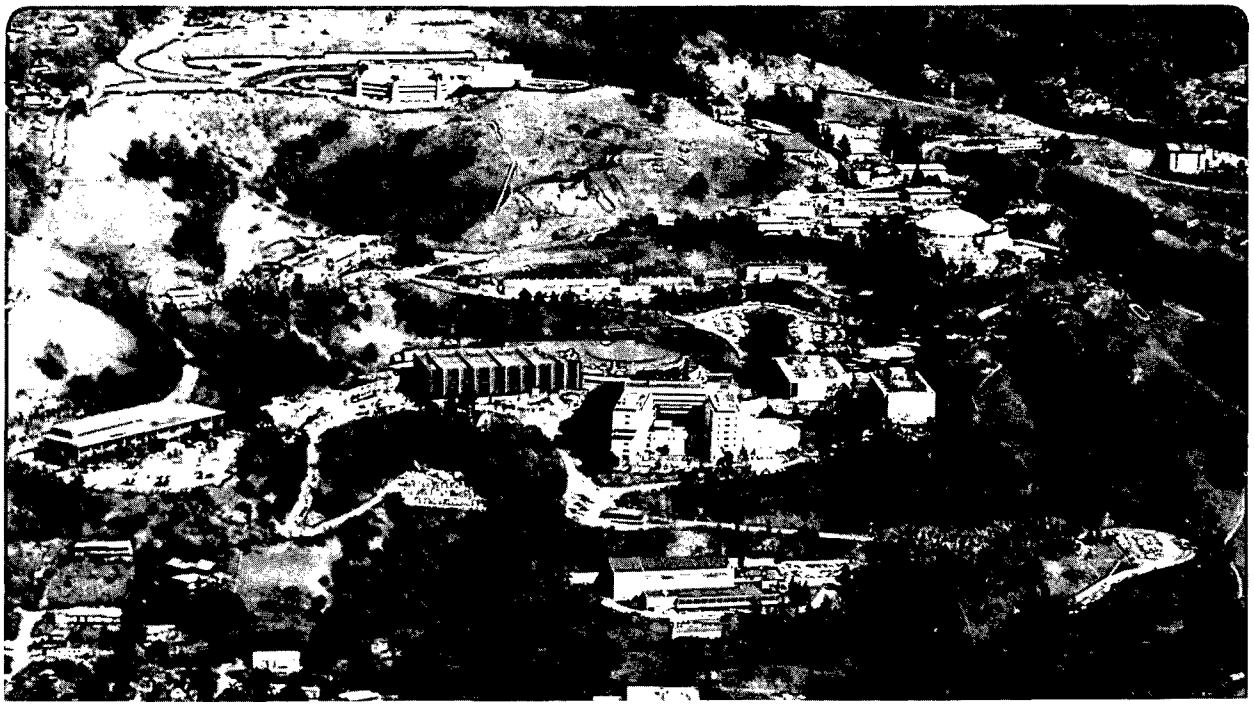

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LAWRENCE BERKELEY LABORATORY - UNIVERSITY OF CALIFORNIA

ENGINEERING NOTE

CODE	SERIAL	PAGE
D32250	M5566	1 OF 7

AUTHOR	DEPARTMENT	LOCATION	DATE
Robert DeWitt	Mechanical Department	B29C	July 17, 1980

PROGRAM — PROJECT — JOB

Doublet III Project--Neutral Beam Injection System

DEFLECTING MAGNET

TITLE

Hall Probe Fabrication

SUMMARY

The Doublet III (DIII) Neutral Beam Injection System (NBIS) utilizes a two gap magnet to separate the ionized particles from the neutral ions. The field must be closely regulated to assure control of the twin 4 mega-Watt beams. The method chosen for measuring the field is using either of 2 Hall probe devices switched in a feedback loop.

The Hall probe was designed to meet certain parameters:

1. Operate at temperatures up to 100°C.
2. Operate in non-radioactive environment.
3. Maintain calibration within 1% accuracy.
4. Have resolution of 0.2%.
5. Have back-up system for failure of non-accessible parts.
6. Readily adapt to computer servo-system.

These parameters led to the choice of a BHT-910 Hall element from F. W. Bell Inc. The matching readout and switching devices also came from Bell.

The final probe sub-assemblies were sent to General Atomic (GA) after test. Final assembly was to be done in San Diego by GA personnel.

MATERIEL

The determining factor in selecting a Hall device was the operating temperature. Most devices have a maximum operating temperature of 70°C. Only one device had a 100°C. value, the F. W. Bell BHT-910. A transverse element was chosen, rather than an axial version, for simplicity and ease of use. (See Fig. 5.)

Next, the temperature measurement device needed to be selected. Since the unit would operate in a vacuum, conduction seemed the proper transfer method. A large glass-bead thermistor was chosen for two reasons. First, it was the right size. The BHT-910 element is .043" high, and the large glass-bead thermistor is also .043" high. (See Fig. 2, 3, and 4, and Table 2.)

Second, thermistors have a large change in resistance per degree centigrade. Resistance is a readily measurable quantity, and compares favorably to other devices. For example, thermocouples have voltage as the measurable quantity, but have a very small change in voltage per degree of temperature change. The thermistor chosen, a GA42J1 from Fenwall, has a maximum operating temperature of 300°C, well above the design point.

The heater coil was the next item to be designed. The coil was bifilar wound with teflon insulated wire. The wire chosen was chromel thermocouple wire. It is non-magnetic and has a resistivity 46 times that of copper. However, it does not change the resistivity much with variations in temperature; it changes less than $.1R_{cu}$. The heater was wound to about 15^{Ω}, and then potted in epoxy to make it a solid structure and keep the wire from unraveling. The epoxy was Emerson & Cumming "Eccobond 45 LV Black".

Some additional parts were made also. These special parts included a special cable, a printed circuit board, and a two piece mounting box. The cable was made from #24 AWG copper wire insulated with glass sleeve. The matching plug was attached to one end and the PC board to the other. The outer sleeve of tinned copper braid and PC board also served as the strain relief. The loose wires were compressed and held by twisted rings of the bare copper wire.

The PC board was etched to have straight traces. Then it was cut, and doubled on top of itself and glued in place. The traces were heavy enough to avoid overheating, and the PC material provided good insulation to the box.

The box was cut from aluminum plate and machined for both right and left hand installation. The extra holes allowed rapid pump down to vacuum. The main reason for combining them is to reduce the spare parts count.

FABRICATION AND ASSEMBLY

The first step was to solder longer, heavier wires onto the thermistor leads. The original wires are only .004" in diameter and tend to be brittle. The extension wire used, #24 AWG SF copper, was then epoxied into place. All leads are twisted in pairs to minimize noise and integrated EMI effects (see Fig. 3).

The coil was wound, checked for resistance, and potted. After the coil was complete, the Hall element assembly was slipped into the coil for fit. Then the assembly was wired to the PC board. The coil was wrapped in Superinsulation (King-Seely Thermos Co.) for thermal isolation and the PC board was epoxied to the box.

The cable was then attached to the PC board and the terminals tested for proper continuity. A separate ground wire was then screwed to the box to assure a good ground to the system. Then the cable connector and box lid were attached, and the system was ready for test.

CALIBRATION

The continuity of each pair of wires was tested first, and all corrections and alterations made. The thermistors and heater were calibrated next. The aluminum box was mounted between large aluminum blocks to act as a massive thermal damper. The oven was regulated to ≃ .1°C, but not accurate. The set temperature was 100°C, but the actual operating temperature was only 93°C. A precision thermometer was used for a precise readout.

The resistance test meter used had a minimum current of 1mA, so the thermistor would self-heat during test. Therefore, the test measurements had to be short compared to the thermal time constant of the probe. The self-heat from 1mA is about 1mW, so the temperature change is only a couple of degrees C. The heat is transferred to the Hall device via conduction, and the time-temperature curve is similar to Figure 1 below.

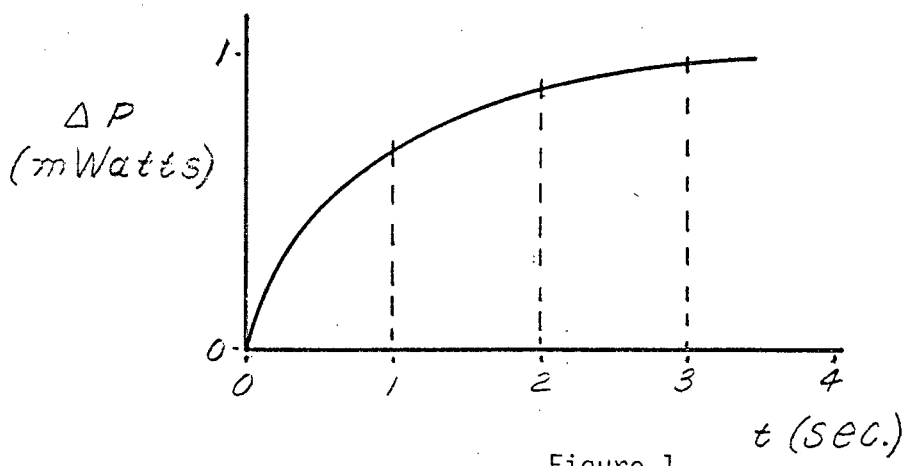


Figure 1.

Factory calibration of thermistors uses a constant current supply of 0.5μA and a 1000 MΩ impedance 6 digit DVM with .2V full scale. No self-heating problems arise under these types of controls. The thermistors should be re-calibrated in vacuum at GA using similar equipment.

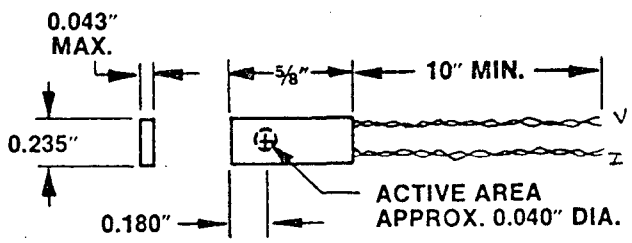
The Hall device was then calibrated. The probe was inserted in a constant field magnet at 1000 Gauss using an NMR field controlled supply. The calibrating resistors were adjusted to set the end points for each probe. Precision resistors were sent to GA in labeled envelopes for installation on the special connectors to complete the final assembly.

ELECTRICAL SPECIFICATIONS

	BHT
Nominal control current, I_{cn}	100mA
Maximum continuous control current, I_{cmos} (in 25C static air)	300mA
Magnetic sensitivity, γB, I = 100ma	0.8mV/KG≈30%
Typical load required for proper linearity	50 to 500Ω
Linearity error (I_c= 100ma)-30 to +30kG	≈0.1%
Operating temperature range	-40 to +100°C
Mean temperature coefficient of Hall voltage, β_T	≈50 ppm/°C(max)
Mean temperature coefficient of resistive residual voltage, D_T	≈0.07μV/°C(max.)
Mean temperature coefficient of resistance, α_T	≈0.15%/°C(max.)
Resistive residual voltage, Vm, (I_c=100mA)	50μV (max.)
Input resistance in zero field, R_{in} (including leads)	∿1.0Ω
Output resistance in zero field, R_{out} (including leads)	∿1.0Ω

NOTE: Unless otherwise stated, all specificiations apply nominal control current with T=25°C.

MECHANICAL SPECIFICATIONS



Note: Cross indicates tail of magnetic field vector.

TRANSVERSE HALL GENERATORS BHT-900, 910 & 921

Table 1.

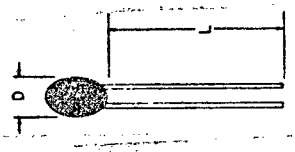


Figure 2.

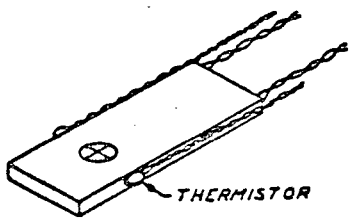


Figure 3.

	°F	°C
145.2	−76	−60
68.88	−58	−50
34.28	−40	−40
17.92	−22	−30
9.792	− 4	−20
5.560	14	−10
3.274	32	0
1.992	50	10
1.250	68	20
1.000	77	25
.8053	86	30
.5316	104	40
.3595	122	50
.2482	140	60
.1747	158	70
.1252	176	80
.09126	194	90
.06754	212	100
.05076	230	110
.03867	248	120
.03399	257	125
.02988	266	130
.02327	284	140
.01843	302	150
.01470	320	160
.009700	356	180
.006600	392	200
.004700	428	220
.003500	464	240
.002600	500	260
.002100	536	280
.001700	572	300

Table 2.

FENWAL

Bead Thermistor (Glass Coated)

R_0@ 25°C	15K Ohms
Tol.	±15%
Lead Dia.	.004"
Lead Matl.	Pt-Ir
'D' Dim.	.043"
'L' Dim.	3/8"
Dpat.Const.	.4mW
Time Const.	4 sec.
Code	GA42J1
Beta in °K	3894±90
Ratio Ro@0/50°C	9.1±5%
Ratio Test Limits 0/50° C	8.65-9.56
Ratio Ro@25/125°C	29.42
Temp. Coefficient @25°C	-4.4%/°C

Table 3.

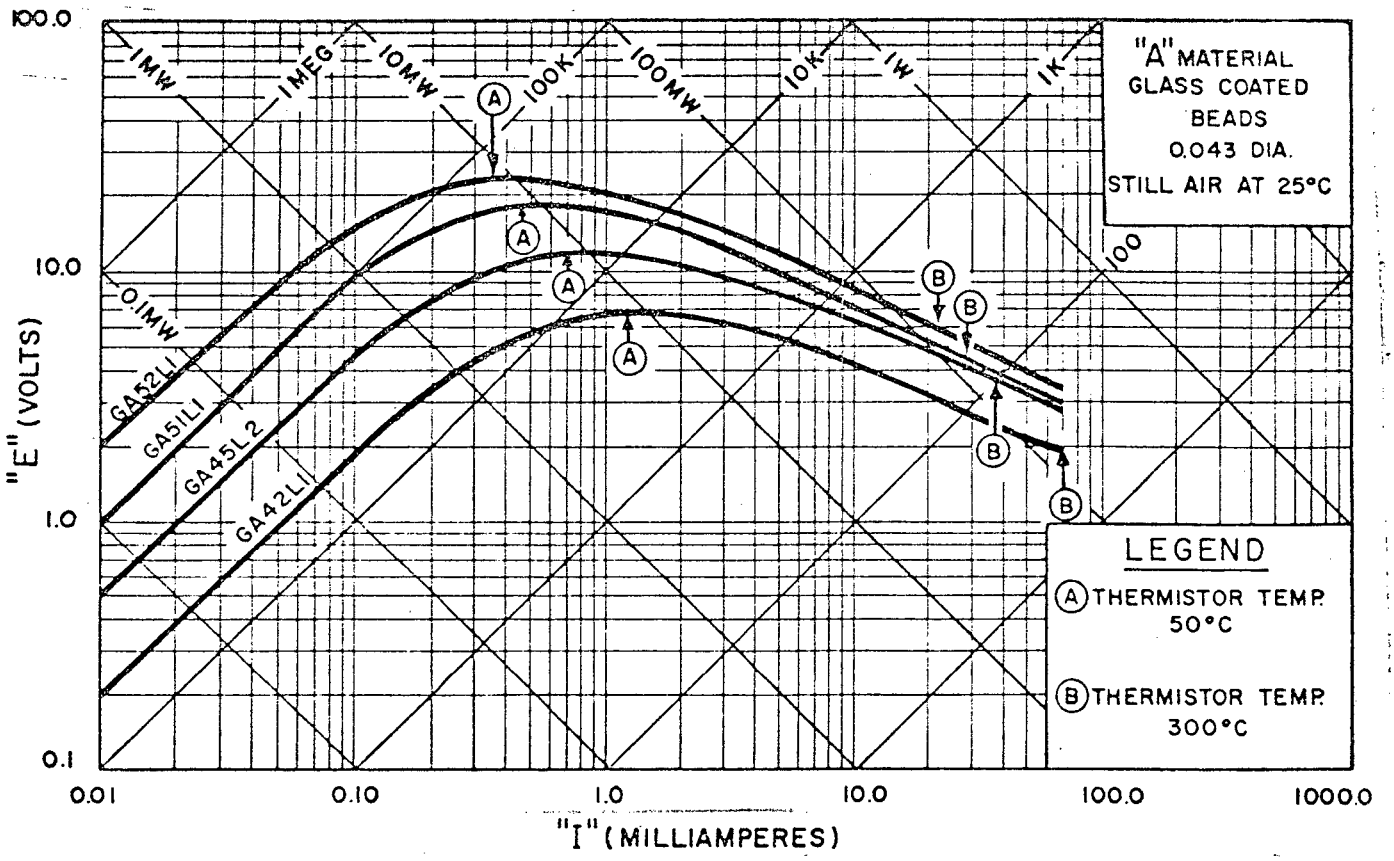


Figure 4.

HALL PROBE LINEARITY DEVIATION PLOT — F. W. BELL, INC., COLUMBUS, OHIO — DRAWING UA 2014

SUBASSEMBLY NO. _____ LINEARIZING RESISTOR = 60 Ω DATE: 8/1/78 INITIALS E.A.M.

HALL ELEMENT TYPE BHT-910 INPUT RESISTANCE, R_{in} = .82 Ω SENSITIVITY CONSTANT, γ_B = 0.702m/kG

HALL ELEMENT SERIAL NO. 2445 OUTPUT RESISTANCE, R_{out} = .73 Ω CONTROL CURRENT, I_c = 100 mA

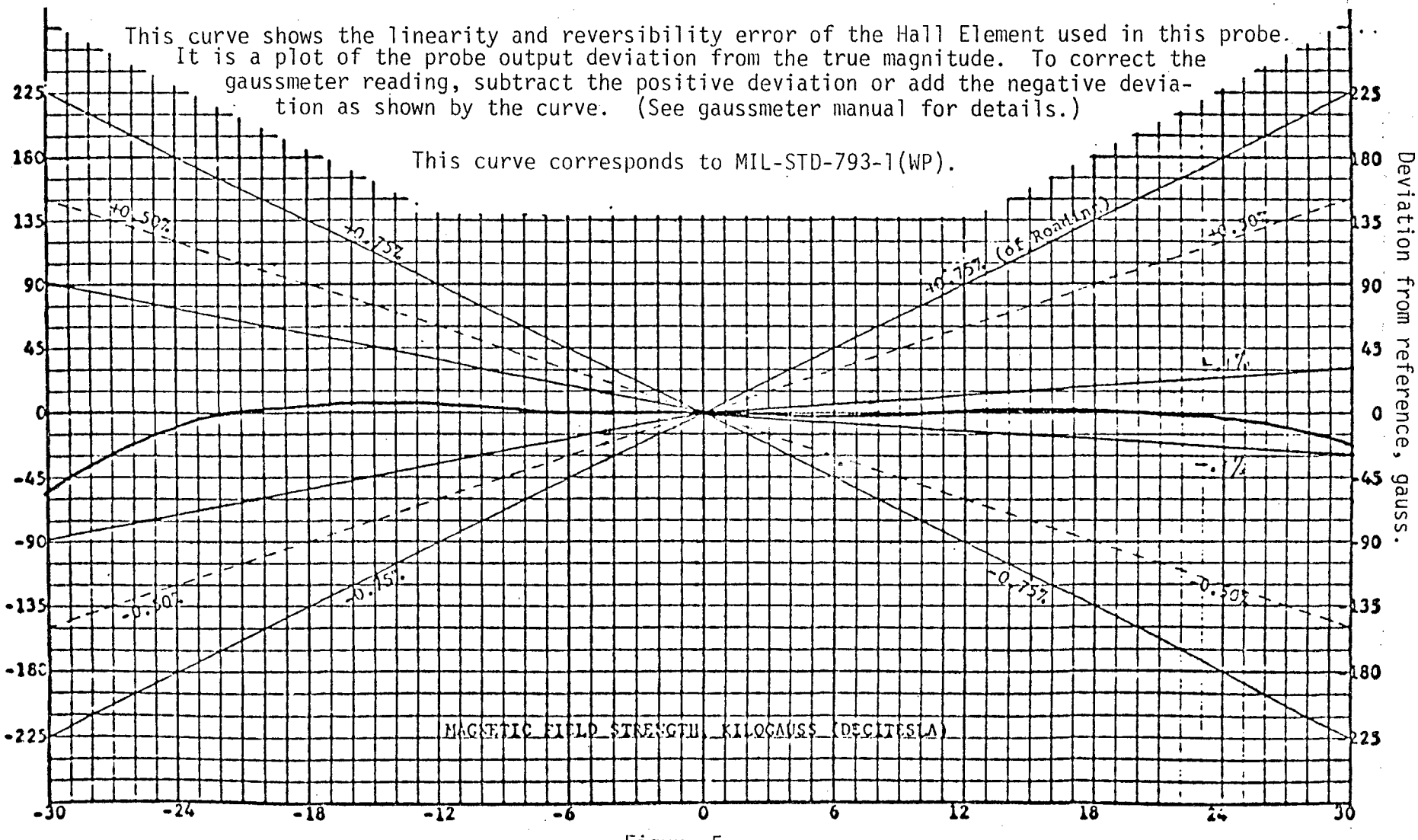


Figure 5.

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	LOCATION B29C	DATE July 17, 1980	PAGE 7 OF 7

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