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LBL - SSRL BEAM LINE DEVELOPMENT PERMEABILITY MEASUREMENTS OF VANADIUM PERMENDUR

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LBL - SSRL BEAM LINE DEVELOPMENT

PERMEABILITY MEASUREMENTS OF VANADIUM PERMENDUR

Donald H. Nelson and Michael I. Green

Lawrence Berkeley Laboratory
Magnetic Measurements Engineering

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INTRODUCTION--CHRONOLOGICAL DEVELOPMENT

In September 1981, Egon Hoyer requested that Magnetic Measurements Engineering (MME) prepare to make permeability measurements of Vanadium Permendur. The design of (rare earth) focusing, undulator, and wiggler elements in proposed beam lines at SSRL may be facilitated by dependable permeability tables of Vanadium Permendur.

We decided, that it would be cost-effective and appropriate to implement, as Phase II of the MME General Purpose Data Acquisition System (DAS), the capability of permeability measurements. We had the necessary hardware (after borrowing a 30A, bipolar power supply from LLNL).

Preliminary results of our first efforts were delivered to Halbach on October 30, 1981, but we were not able to justify a high level of confidence in those results.

Additional tests, needed to justify this confidence, were delayed first, to meet other commitments for both our time and the DAS, and, second, when a critical element of the permeability equipment was destroyed (A 0.060-inch diameter by 18.0-inch-long Hall-Probe was broken and the MME spare was found to be defective).

On November 11, 1981 we made a status report of this project to Tommy Elioff and requested and were granted additional funds to complete this project. Preliminary results of our second effort were presented to Klaus Halbach and Egon Hoyer on November 30. Based on these results we agreed on the need for additional tests. Hoyer recommended a higher temperature heat treatment for the previously annealed Vanadium Permendur sample. The heat treatment was completed on December 2 and the sample retested on December 4.
We completed the LBL tests outlined in our November 11 memo to within the budget and time frame approved. Joe Cobb (SLAC Magnetic Measurements) agreed to measure the permeability of a sample of heat-treated steel (see Fig. 2a) prepared at LBL and delivered to SLAC on November 25. His tests were done at no expense to LBL because of the mutual benefit of cross checking between two different measurement procedures. A summary of comparative measurements of two samples of the same material is provided in Appendix A. Copies of the SLAC data are preserved in Appendix C. The corresponding LBL data is in data book MT 644.

This report (I) describes the Permeability Implementation of the MME DAS, (II) presents the results of tests of Vanadium Permendur under various conditions, (III) describes validity tests which establish a high degree of confidence in our test results, and (IV) discusses improvements and additional tests that would enhance the MME Permeability Measurement facility.

This work was supported by the U.S. Dept. of Energy under Contract DE-AC03-76SF00098.
I. LBL PERMEABILITY MEASUREMENT SYSTEM

A. TECHNIQUE

Permeameters may be characterized by (1) the geometry of both sample and electromagnet, (2) the method of supplying magnetomotive force "MMF", (3) the method of determining magnetic induction "B" and (4) the method of determining magnetizing intensity "H". In addition, several acceptable magnetization cycles exist.

1. Geometry

The basic design of the permeameter employed for these tests was suggested by Klaus Halbach in 1978 and first implemented by MME in 1979 in conjunction with the Doublet III Project. Because the technique for determining \( H \) is unique among permeameters described in the literature, we recommend naming both this D.C. permeameter and the method of measurement after Halbach.

The Halbach Permeameter

Figure 1 is a schematic diagram of the Halbach permeameter. The sample under test is sandwiched between the pole tips of an electromagnet and the "B-coil" surrounds the center portion of the sample in the usual manner. \( H \) is determined from a measurement of \( B \) on the axis of the cylindrical sample. To permit this measurement, small (0.10 in. D.) holes were drilled on the axis of each sample and through both the pole tips and yoke of the electromagnet.

Any "regular cross-section" sample may be tested (with a redesigned "B-coil") as long as the sample has a 0.10 in. diameter hole on its axis of symmetry. We chose a cylindrical sample for these test because (1) we had suitable B-coils from a previous project and (2) the geometry of the cylinder chosen had been studied analytically and found suitable for the measurement of ferromagnetic samples.\(^1\) The sample geometry is shown in Figure 2b.
FIGURE 1  HALBACH PERMEAMETER MME
DATA ACQUISITION SYSTEM - PHASE II
PERMEABILITY MEASUREMENT SYSTEM
COMPARATIVE MSMTS TEST PLAN

SAMPLE 1 (DOUGHNUT SHAPED) FOR SLAC

SAMPLE 2 (CYLINDRICAL) FOR LBL

MATERIAL: LBL STOCK NO. 9510-10198

HEAT TREATMENT: VACUUM ANNEAL (PRES < 10^-4 Torr)
- 1500°F (815°C) for 1 HR, SLOW COOL @≤300°F/HR (166°C/HR)

FIG 2 SAMPLES FOR COMPARATIVE MEASUREMENTS OF
Ideally, the yoke and especially the pole-tips of the electromagnet should have both a higher saturation induction ($B_s$) and relative permeability ($\mu_r$) than the sample under test. Differences in magnetic-potential between sample and pole tip introduce "self-demagnetization" effects which influence the interpretation of the quantities measured. Additional studies are needed to verify our belief that in the range of interest, i.e., $B \geq 1.8$ Teslas, the differences in magnetic potential are of "second-order" importance for the geometry of our sample and electromagnet.

2. Magnetomotive Force

The power supply used for these tests was chosen because it matched the requirements of our electromagnet; it had the capacity of supplying a magnetizing force of several thousand-Oersteds; it was programmable and bipolar; and most importantly, it was available on loan from Lawrence Livermore National Laboratory (LLNL).

In order to measure permeability at low values of magnetizing intensity, we supplemented the 800 turns of the electromagnet with auxiliary windings around the return yoke. For these measurements, we tested each sample first by energizing the auxiliary windings and then (after demagnetizing) by energizing the 800 turn windings.

The magnetizing windings are depicted in Fig. 1 (note, they do not surround the sample, so magnetizing current is not a reliable parameter for determining magnetic intensity).

3. Magnetic Induction Determinization

In order to measure flux-linkage (rather than only changes in flux-linkage), it is necessary to establish zero. One advantage of the Halbach Permeameter is that the "B-coil" may be removed from the sample and
placed in a mu-metal shield to establish zero. This exercise is performed both as the first and last step of our measurement sequence.

The "B-coil" actually measures changes in flux-linkage over the coil's "effective-area" and in order to determine magnetic induction in the sample, adjustments are necessary to account for flux-linkage in the air both surrounding the sample and within the hole on the axis of the sample.

4. Magnetizing Intensity Determination

Magnetic induction at the center of the axial hole through the sample \( B_{\text{air}} \) provides our determination of magnetizing intensity \( H \) as follows:

\[
H_{\text{air}} = \frac{B_{\text{air}}}{\mu_0} = \frac{B_{\text{air}}}{4\pi \times 10^{-7}} \text{ (Ampere-Turns/Meter)}
\]

\[
H_{\text{sample}} = H_{\text{air}} \text{ because}
\]

a. at any boundary, the tangential component of \( H \) is continuous.\(^2\)

b. for the geometry of these samples, \( H \) may be considered constant over the radial dimensions of the samples at their longitudinal centerline.\(^1\)

5. Magnetization Cycle

The Halbach Permeameter may be employed to measure magnetic properties with any acceptable magnetization sequence. For the present application, i.e., vanadium permendur providing low reluctance flux paths for (rare-earth) permanent magnets, the relationship between \( B \) and \( H \) is of interest only in the first quadrant where \( B \) and \( H \) are in the same direction. For this reason, we collected each set of data on the ascending and descending portions of a unipolar excursion of MMF. Beginning with a "demagnetized" sample, we increased MMF to a peak value and then decreased MMF to zero. On both the ascending and descending portions of this "half-loop", we measured flux linkage (\( \psi \)), Magnetizing Intensity (\( H \)) and the potential drop across a resistor monitoring magnet current. Elapsed time was also recorded for
subsequent drift corrections to the integrator output potential data.

With program modifications, we could use the same hardware to cycle between selected values of either magnet current or $H = B_{\text{air}}/\mu_0$. The number of cycles could either be preselected or feedback dependent, e.g. $\Delta H$ and/or $\Delta \psi$ could be tested for reproducibility. After sufficient cycles are completed, measurements of magnet current, $\Delta H$, and $\Delta \psi$ between the extremes of the final minor hysteresis loop could be saved.
B. HARDWARE, Firmware AND Software

Figure 1 (page 4) is a schematic representation of the measurement system and Table I (page 10) lists specific equipment, including firmware and software.

MEASUREMENT PROCEDURE

1. General

For each sample measured, we carried out the following steps.

<table>
<thead>
<tr>
<th>Step</th>
<th>Program Executed</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DEMAG1</td>
<td>Demagnetize permeameter with a previously measured sample. (The sample to be tested next may have been demagnetized by annealing.)</td>
</tr>
<tr>
<td>2</td>
<td>PERM7</td>
<td>Measure and store magnet current, flux linkage, B_{air} and elapsed time in Quadrant 1 of the hysteresis curve produced by energizing the auxiliary windings (101 measurements on the ascending and 100 measurements on the descending portion of the half cycle). As the last step of PERM7, the data set is identified and stored on the disk DATA1 in DY1:</td>
</tr>
<tr>
<td>3</td>
<td>PROCC1</td>
<td>Process and print data stored on disk.</td>
</tr>
<tr>
<td>4 a</td>
<td>DEMAG1</td>
<td>With power supply connected to 800 turn windings.</td>
</tr>
<tr>
<td>4 b</td>
<td></td>
<td>With power supply connected to auxiliary windings.</td>
</tr>
<tr>
<td>5</td>
<td>PERM7</td>
<td>Repeat 2 except power supply connected to 800 turn windings.</td>
</tr>
<tr>
<td>6</td>
<td>PROCC1</td>
<td>Process and print data stored on disk.</td>
</tr>
</tbody>
</table>
### TABLE I. TEST EQUIPMENT

<table>
<thead>
<tr>
<th>HARDWARE</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samples</td>
<td>Vanadium Permendur Iron LBL Stock No. 9510-10198 (1018 cold finished steel bar)</td>
</tr>
<tr>
<td>Coil</td>
<td>B-162, nA = 0.0411[m^2], n = 100[t]</td>
</tr>
<tr>
<td>Flux Standard</td>
<td>SLFS 40.02, ( \psi_{(SLFS)} = 0.0210 ) [Wb]</td>
</tr>
<tr>
<td>Integrator</td>
<td>LBL MOD 71 Ser. No. 1 R = 19.6 k ( `, ) C = 0.1 ( \mu F ) ( \text{ATT} = 360, \text{BAL} = 497 )</td>
</tr>
<tr>
<td>Hall Probe</td>
<td>F.W. Bell Mod. SAE4-0818, SN 155966 CAL = 1.000</td>
</tr>
<tr>
<td>Gaussmeter</td>
<td>F.W. BELL Model 620, DOE 501586, Polarity = +</td>
</tr>
<tr>
<td>Multiplexer</td>
<td>Hewlett Packard Model 3495A Scanner, DOE 517528</td>
</tr>
<tr>
<td>DVM</td>
<td>Hewlett Packard Model 3455A Digital Voltmeter, DOE 517459</td>
</tr>
<tr>
<td>Magnet</td>
<td>MME Charging magnet - 13 turn, 45 turn, and 800 turn magnetizing windings</td>
</tr>
<tr>
<td>Power Supply</td>
<td>LLNL, LEA 74-4035-01-50 20 VDC at 30A, bipolar Regulator LEA 74-4035-41-50</td>
</tr>
<tr>
<td>PS Controller</td>
<td>KS 3160 CAMAC, DOE 512977</td>
</tr>
<tr>
<td>CAMAC Controller</td>
<td>Std. Eng., CCLSI-II, DOE 512996</td>
</tr>
<tr>
<td>Computer</td>
<td>LSI 11/23</td>
</tr>
<tr>
<td>Clock Calendar</td>
<td>TCU-500, S/N 6446</td>
</tr>
<tr>
<td>Printer</td>
<td>LA 120, DOE 519478</td>
</tr>
<tr>
<td>CRT Terminal</td>
<td>Zenith H19, DOE 518712</td>
</tr>
<tr>
<td>Floppy Disc Sys.</td>
<td>DSD 440, DOE No.519465</td>
</tr>
</tbody>
</table>

**SOFTWARE**

- PERM7
- PROC1
- MPX1
- CMCPS1
- DEMAG1

Programs on Floppy
Disk MME 36
(See Table II)
2. FORTRAN Listings

Appendix B, to be distributed on request, contains FORTRAN source listings of the data acquisition and data processing programs and subroutines. Table II is a directory of the permeability running disk MME36. MME36 contains the necessary files for operating the Halbach Permeameter. Data collected for this project were saved on a disk named DATA1. Table II is part of a printout of the file named DATA.TXT on DATA1. The remainder of that file describes how to reconstruct software for future projects.

3. Data Acquisition Dialog

The data acquisition procedure was programmed into the program PERM7. A dialog between the computer and the operator through the CRT terminal ensures that all the necessary data is collected. To facilitate describing this process, we executed PERM7 with the output normally directed to the CRT terminal directed to the printer. The dialog for that dummy run is represented as Table III.

4. Data Processing (Algorithms)

Processing of the data collected and stored on the data disk is accomplished by executing PROCCI. PROCCI calls subroutines which retrieve data, provide needed constants, adjust integrator output data for drift, process data, and print the results.

To convert measured flux linkage to magnetic induction in the sample an algorithm employing Equation 1 (page 14) is used.
file: DATA.TXT
created: 81 nov 20
by: mike l sreen
81 11 30 changed output format of PROCC1 for more significant digits
updates: 81 dec 9 mis more documentation text
81 nov 30 mis output format of PROCC1 changed for more significant digits

diskette no.: DATA 1
property of: LBL MAGNETIC MEASURMENTS ENGINEERING GROUP

purpose: To document the data acquired on this disk, and the software and hardware used to obtain the data.

running disk: MME 36, 'PERMEABILITY RUNNING DISK' is in DYC.
It's directory follows. This disk is in DFI:

20-Nov-81
BA .SYS 7F 01-Mar-80 HPX1 .SAV 27F 26-Oct-81
BINCOM.SAV 16F 01-Mar-80 NL .SYS 2F 01-Mar-80
CMCPS1.SAV 19F 23-Oct-81 PERH7 .SAV 66F 19-Nov-81
CREF .SAV 6F 01-Mar-80 PERH8 .SAV 67F 19-Nov-81
D .COM 1F 29-Jan-80 PIP .SAV 23F 01-Mar-80
DEMA1.SAV 20F 02-Nov-81 PROCC1.SAV 52F 19-Nov-81
DIR .SAV 17F 01-Mar-80 RESORC.SAV 15F 01-Mar-80
DUMP .SAV 6F 01-Mar-80 RT11.SYS 67F 01-Mar-80
DUP .SAV 41F 01-Mar-80 SETDAT.SAV 2F 08-Feb-81
DY .SYS 4F 01-Mar-80 SPCGSM.SAV 13F 01-Mar-80
FORMAT.SAV 16F 01-Mar-80 START5.COM 1F 23-Feb-81
K52 .SAV 55F 01-Mar-80 SWAP .SYS 25F 01-Mar-80
LIBR .SAV 22F 01-Mar-80 TT .SYS 2F 01-Mar-80
LS .SYS 2F 01-Mar-80
27 Files, 593 Blocks
381 Free blocks

TABLE II Contents of Permeability Running Disk
HEAT TREATED VANADIUM PERPENDUR SAMPLE

PERMEABILITY PROGRAM - THE DATE IS 07-DEC-81  TIME 15:05:32
HEAT TREATED VANADIUM PERPENDUR SAMPLE

Type test description: 72 characters maximum
HYPER TREATMENT SAMPLE NOT DEMAGNETIZED
Type 'Y' if integrator is switched to integrate

PAUSE --- press return when search coil is in mu-metal shield
zero integrator by pressing "RESET TO ZERO BUTTON"
PAUSE --- press return when integrator is zeroed
put search coil around sample and insert into shield
PAUSE --- press return when done

put search coil in sample into magnet
PAUSE --- press return when ready to run

ENTER MAXDAC:
100

ENTER HALL PROBE RANGE (GAUSS):
10
0  -0.0060  0.8340  -0.0002  46.  0.0010
HALL OUT < 1 VOLT, SWITCH RANGE AND ENTER NEW FULL SCALE RANGE (GAUSS):
100
10  -0.0030  0.4089  0.7156  63.  0.0100
HALL OUT < 1 VOLT, SWITCH RANGE AND ENTER NEW FULL SCALE RANGE (GAUSS):
1000
20  -0.0061  0.1131  0.9453  79.  0.1000
30  -0.0091  0.2014  1.0868  81.  0.1000
40  -0.0121  0.2950  1.1233  83.  0.1000
50  -0.0152  0.3862  1.1631  85.  0.1000
60  -0.0182  0.4745  1.1877  87.  0.1000
70  -0.0212  0.5609  1.2094  89.  0.1000
80  -0.0243  0.6466  1.2292  91.  0.1000
90  -0.0273  0.7316  1.2486  93.  0.1000
100  -0.0303  0.8161  1.2674  95.  0.1000
90  -0.0273  0.7417  1.2510  97.  0.1000
80  -0.0243  0.6637  1.2235  99.  0.1000
70  -0.0212  0.5879  1.1949  101.  0.1000
60  -0.0182  0.5021  1.1649  103.  0.1000
50  -0.0152  0.4178  1.1725  105.  0.1000
40  -0.0121  0.3298  1.1454  107.  0.1000
30  -0.0091  0.2383  1.1083  109.  0.1000
20  -0.0061  0.1452  1.0421  111.  0.1000
HALL OUT < 0.1 VOLT, SWITCH RANGE AND ENTER NEW FULL SCALE RANGE (GAUSS):
100
10  -0.0030  0.5926  0.8591  126.  0.0100
0  -0.0000  0.1406  0.2395  128.  0.0100

0  100
\[ \text{take sample and search coil out of magnet} \]
put search coil around sample and insert into shield
PAUSE --- press return when done

put just search coil into mu-metal shield
PAUSE --- press return when search coil is in mu-metal shield

enter any final comments
DEMONSTRATION FOR REPORT
Type 'Y' if you want to save data
Y
Type file name for saving data XXXXX.DAT
1207A2
Type 'Y' if you want to run same sample again
N

TABLE III Data Acquisition Dialog
\[ B = \frac{\psi_{\text{obs}} - \psi_{\text{air}}}{nA_{\text{sample}}} = \frac{\psi_{\text{obs}} - nB_{\text{air}} A_{\text{air}}}{n\pi(r_o^2 - r_i^2)} \]

\[ = \frac{\psi_{\text{obs}} - nB_{\text{air}}}{n\pi(r_o^2 - r_i^2)} \left[ \frac{\pi r_i^2 + \frac{nA}{n \text{ coil}} - \pi r_o^2}{n\pi(r_o^2 - r_i^2)} \right] \]

Equation (1)

B = magnetic induction [Teslas]

\[ \psi_{\text{obs}} = \frac{\psi_{\text{SLFS}}}{E_{\text{SLFS}}} E_{\text{coil}} \] [Wb]

\[ \psi_{\text{SLFS}} = \text{Flux linkage produced by flux standard SLFS 40} = 0.0210 \] [Wb]

\[ E_{\text{SLFS}} = \text{Integrator output potential due to } \psi_{\text{SLFS}} \] [V]

\[ E_{\text{coil}} = \text{Integrator output potential due to flux linkage in coil} \] [V]

\[ \psi_{\text{air}} = \text{Flux linkage of coil not linking sample} \] [Wb]

\[ nA = nA_{B-162} = \text{turns area product of coil B-162} = 0.0411 \] [m²]

\[ n = n_{B-162} = \text{no. of turns of coil B-162} = 100 \] [t]

\[ r_o = \text{outer radius of sample} = 0.01016 \] [m]

\[ r_i = \text{inner radius of sample} = 0.00127 \] [m]

\[ B_{\text{air}} = \text{Magnetic induction in center of axial hole through sample} \] [T]
II. RESULTS

In Figure 3 we have plotted intrinsic induction vs magnetizing intensity for five tests made at LBL. For reference we included a curve for Vanadium Permendur from a General Electric drawing.\(^3\)

Table IV contains the processed data for a single data set (MME Data Set No. 1204A3.DAT). Similar tabulations are saved in an LBL data book\(^4\) for different test conditions. The data are also stored on a floppy disk for reproduction and/or additional processing. Table V lists data sets that may be of interest.
FIGURE 3
DC MAGNETIZATION CURVES
FOR
VANADIUM PERMEDUR
(See Legend for Conditions)

Intrinsic Induction, 
$B = \mu H$ (Teslas)

MAGNETIZING INTENSITY $\mu H$ (Teslas $= 10^4$ Gausses)

<table>
<thead>
<tr>
<th>LINE NO./SYMBOL</th>
<th>SOURCE</th>
<th>HEAT TREATMENT</th>
<th>DATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ---------------</td>
<td>ENG4 NOTE 11410</td>
<td>ANNEALED (1120 °C 4 HOURS)</td>
<td>1968</td>
</tr>
<tr>
<td>2 ---------------</td>
<td>ENG4 NOTE 11410</td>
<td>AS RECEIVED</td>
<td>1968</td>
</tr>
<tr>
<td>3 ---------------</td>
<td>GE MAGNETIZATION PLOT 1</td>
<td>(NO SPECIFIED)</td>
<td>1955</td>
</tr>
<tr>
<td>4 - X - X - X</td>
<td>MPE DATA SET 1124A2</td>
<td>(YOGG)</td>
<td>November 24, 1960</td>
</tr>
<tr>
<td>5 - O - O - O</td>
<td>MPE DATA SET 1125A1</td>
<td>ANNEALED (640 °C 4 HOURS)</td>
<td>November 25, 1961</td>
</tr>
<tr>
<td>6 - --- - - -</td>
<td>MPE DATA SET 1126A3</td>
<td>ANNEALED (1120 °C 4 HOURS)</td>
<td>December 4, 1961</td>
</tr>
<tr>
<td>I</td>
<td>BSMLP (I)</td>
<td>RPERNH (I)</td>
<td>BAIR (I)</td>
</tr>
<tr>
<td>---</td>
<td>-----------</td>
<td>-----------</td>
<td>---------</td>
</tr>
<tr>
<td></td>
<td>(UNIT)</td>
<td>(TESLA)</td>
<td>(UNIT)</td>
</tr>
<tr>
<td>1</td>
<td>0.3862</td>
<td>2553.860</td>
<td>0.000151</td>
</tr>
<tr>
<td>2</td>
<td>1.8754</td>
<td>662.766</td>
<td>0.002830</td>
</tr>
<tr>
<td>3</td>
<td>2.1476</td>
<td>249.740</td>
<td>0.006000</td>
</tr>
<tr>
<td>4</td>
<td>2.2225</td>
<td>126.016</td>
<td>0.017437</td>
</tr>
<tr>
<td>5</td>
<td>2.2520</td>
<td>84.404</td>
<td>0.026681</td>
</tr>
<tr>
<td>6</td>
<td>2.2701</td>
<td>63.231</td>
<td>0.025901</td>
</tr>
<tr>
<td>7</td>
<td>2.2836</td>
<td>50.074</td>
<td>0.044880</td>
</tr>
<tr>
<td>8</td>
<td>2.2994</td>
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**TABLE IV** MME DATA SET 1204A3 DAT

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TABLE IV  MME DATA SET 1204A3 DAT
### TABLE V. DATA SET IDENTIFICATION

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III. VALIDITY MEASUREMENTS

A. GENERAL

The validity of the results of permeability tests depends on the accuracy of various measurements and the interpretation of the measured data. The American Society for Testing and Materials, in its discussion of DC permeameters presents the following disclaimer:

"Permeameters in general are comparative only, cannot handle all magnetizing forces in their test specimens, and should not be considered capable of always determining the absolute value of the basic magnetic properties of the test specimen. Their absolute accuracy is unknown...."\(^5\)

Elsewhere, they estimate precision in measuring magnetic induction as \(\pm 1\) percent and the precision in measuring \(H\) from 1 percent to 8 percent, depending on the permeameter and range.\(^6\)

We believe that the limitation on the Halbach permeameter (in fact, the limitation of modern permeameters in general) is no longer the precision of measurement but the interpretation of the measured quantities and the effect of other independent variables such as detailed magnetic history (including rate of change), temperature, mechanical stress, etc.

Since there apparently is no acceptable standard for the absolute accuracy of the magnetic properties of a test specimen\(^5\), we are limited to considering the resolution and accuracy of our test equipment and to relying on mathematical models to relate the measured quantities to magnetic properties. We will consider the test equipment that affects the accuracy of magnetic intensity and magnetic induction and discuss the assumptions in specifying magnetic properties.
B. DETERMINATION OF MAGNETIC INTENSITY, $H_{sample}$

The determination of magnetic intensity in the sample, $H_{sample}$, depends on (1) the accuracy of measurement of magnetic induction in the axial hole through the sample, $B_{air}$, (2) the proper application of boundary conditions at the interface between the sample and air, and (3) the uniformity of magnetic intensity over the sample cross section.

1. The axial probe used for measuring $B_{air}$ is reported to have a linearity of "2% to 10 kG." If improved accuracy in the measurement of $B_{air}$ is warranted, a simple field calibration procedure could improve the accuracy of $B_{air}$ to ± 0.2 percent of the full scale range. (The difficulty of an accurate calibration increases on the lower ranges.)

2. The principle that the tangential component of magnetic intensity across any boundary is continuous is well established. The aspect ratio of the sample, the symmetry of the magnetic circuit, and the size of the axial hole through the sample, influence the application of that principle to the equality $H_{sample} = H_{air}$. A previous study of these factors suggests that the error due to the practical application of this principle is less than 2 percent (at 300 Oe).

3. The same conclusion was reached on the field distribution over the sample cross-section, i.e., less than 2 percent variation.

C. DETERMINATION OF MAGNETIC INDUCTION, $B_{sample}$

The determination of $B_{sample}$ depends on the measured quantities $\Psi_{total}$, $A_{sample}$, $n_{coil}$ and $n_{coil}$, and $B_{air}$. Also important in the determination of $B_{sample}$ are the assumptions made in deriving $B_{sample}$ from the measured quantities.
1. We believe we are capable of measuring flux linkage ($\psi$) with an absolute accuracy of ± 0.1 percent ($\psi$). Using our electronic integrator as a transfer device we compare a measured flux-linkage with flux-linkage generated by a flux-standard whose absolute accuracy is ± 0.05 percent on the range used over wide ranges of ambient temperature ($10^0C$) and long time periods (years).\(^8\)

2. We are capable of determining the cross-sectional area of the sample ($A_{\text{sample}}$) to better than ± 0.1 percent ($A_{\text{sample}}$) using length-weight-density calculations described by ASTM.\(^9\)

3. We are capable of determining the absolute turns-area product of the "B-coil" ($nA$) to ± 0.1 percent ($nA$). The number of turns ($n = 100$) were carefully counted during fabrication of the B-coil and verified by tests conducted during this project.\(^4\)

4. As described above, we are capable of measuring $B_{\text{air}}$ to ± 0.2 percent ($B_{\text{air}}$).

D. INTERPRETING THE MEASUREMENTS.

The influence of the accuracy of the measured quantities on the accuracy of determining $B_{\text{sample}}$ may be discussed with reference to Eq. 1 repeated here for convenience:

$$B_{\text{sample}} = \frac{\psi_{\text{sample}}}{nA_{\text{sample}}} = \frac{\psi_{\text{total}} - \psi_{\text{air}}}{nA_{\text{sample}}}$$

$$\approx \frac{\psi_{\text{total}} - nB_{\text{air}}A_{\text{air}}}{nA_{\text{sample}}} = \frac{\psi_{\text{total}} - nB_{\text{air}}\left(\frac{nA_{\text{coil}}}{n} - A_{\text{sample}}\right)}{nA_{\text{sample}}}$$
The first two terms are related to $B_{\text{sample}}$ by equal signs. No assumptions are made at this point (except that the average magnetic induction in the center portion of the sample is a meaningful magnetic property). The approximately-equal-symbol separating the next term suggests that $B_{\text{air}}$ is approximate. Equation 1 could be refined by including the integrated effect of variations in $B_{\text{air}}$ with radius (both in the hole on the axis of the sample and external to the sample).

E. Comparison with SLAC Split Coil Permeameter

The most convincing validity tests were the comparative measurements made by SLAC and LBL on samples of cold rolled 1018 carbon steel fabricated from the same piece of steel and heat treated together in the same oven. The SLAC split coil permeameter calibration has been traced to NBS. The results of the comparative test are summarized in Appendix A.
IV. DISCUSSION

A. General

We believe our decision to automate the Halbach permeameter as Phase II of the MME DAS was prudent. LBL now has a facility to test the magnetic properties of a wide range of materials, and MME has an "expanded" General Purpose Data Acquisition System. To simply duplicate the tests made on samples fabricated as shown in figure 2b, we estimate the following effort:

<table>
<thead>
<tr>
<th>Task</th>
<th>Job Classification</th>
<th>Man Hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>preparation and set up</td>
<td>9132</td>
<td>8</td>
</tr>
<tr>
<td>sample preparation</td>
<td>9147</td>
<td>2</td>
</tr>
<tr>
<td>heat treatment</td>
<td>9147</td>
<td>0-4</td>
</tr>
<tr>
<td>tests including demagnetizing</td>
<td>9132</td>
<td>4/sample</td>
</tr>
<tr>
<td>report</td>
<td>9132</td>
<td>4-24</td>
</tr>
</tbody>
</table>

However, we believe that in the interest of advancing MME capabilities, we should request additional support. Hopefully, prospective customers would have a special interest in one or more of the generally useful improvements listed below.

B. Hardware Modifications

1. Magnet

The Magnet used for these tests and previous measurements of this type was fabricated at LBL ~30 years ago for magnetizing small permanent magnets. Although it was satisfactory for these tests, the Halbach permeameter would benefit from a redesigned magnet. It may be cost effective to modify a different magnet or design and build a magnet specifically for testing magnetic properties.
B. Hardware Modifications (continued)

2. Power Supply
   a. For the existing magnet
      (1) We should attempt to acquire permanently the bipolar, 30 A
          power supply now on loan from LLNL.
      (2) The (lower end of the) dynamic range of magnetomotive force
          could be improved
          (i) by providing a "controllable" parallel path for current
              from the LLNL supply
          (ii) by adding another bipolar supply to auxiliary windings
               and modifying the coding as required
          (iii) by acquiring a more flexible power supply
   b. For a different magnet
      If the decision is made to use a different magnet for subsequent
      tests, the question of a suitable power supply must be addressed.

C. Range of Application Studies
   1. The Halbach permeameter is worthy of additional test to determine its
      capability of measuring paramagnetic and diamagnetic materials.
   2. Ultimately, comparisons with the National Bureau of Standards for
      various material types will be required to certify the Halbach permeameter and
      LBL Magnetic Measurements Engineering test procedures.

D. Magnetization/Demagnetization Procedures
   1. The improved capability for determining the state of magnetization of
      the sample (and the electromagnet's magnetic circuit) is fundamental to
      establishing suitable magnetizing cycles. More studies are needed in this
      area.
D. Magnetization/Demagnetization Procedures (continued)

2. Comparison of Different Magnetization Cycles

Comparison of results as a function of magnetization cycle and magnetizing intensity should be made for various material types. Cycles of interest are described below.

(a) First Quadrant Only

Starting with a demagnetized sample, measure magnetic properties as MMF is increased to a maximum and then as MMF is decreased to zero. (This is the procedure we followed.)

(b) Bipolar Measurements of B and H at One Value of ±MMF After Demagnetization

For any value of MMF, first demagnetize, then cycle once from zero to +MMF and back to zero, then to -MMF and back to zero. Measurements are made at 5 points on the cycle, three at MMF = 0, one at +MMF, and one at -MMF. In this sequence, (the technique used by SLAC's Magnetic Measurements Group) the data corresponding to +MMF and -MMF is reduced to determine permeability.

(c) Repetitive Cycling with Gradual Increase in MMF Magnitude

Starting with a demagnetized sample, repetitively cycle between + and -MMF values while recording data at selected values of B and H. The average of the absolute value of consecutive end point data is used to determine permeability, and consecutive measurements of H(B = 0) determine coercive force.

3. The dependence of the measurements on the rate of change of MMF and "delay-times" should be studied more thoroughly. (There is evidence that time constants are much longer for low values of H).
E. Sample Geometry

1. Although the cylindrical geometry of the sample used for these tests was studied analytically in 1978, we only have conclusions from those tests. The investigator (M. Kaviani) is no longer at LBL and his studies are not in our files. More comprehensive studies over a range of magnetizing intensities and for a variety of materials (for samples and poletips) would serve to increase our confidence in the approximations required.

2. In addition to analytic studies, additional tests would serve to increase our confidence and identify limitations of the Halbach permeameter. These test include:
   
   a. determination of variation in magnetic intensity on the axis of the sample, i.e., \( H(r = 0, z) \)
   
   b. determination of variation in magnetic intensity outside the sample, i.e., \( H(r, z) r > R_0 \)
   
   c. determination of the variation of flux-linkage as the "B-coil" is moved axially, i.e. \( \Psi(z) \)

F. Effect of environmental parameters

1. temperature
2. mechanical stress
3. pole tip material

G. Software modifications

1. coding required to accomplish any of the above
2. clean-up and generalization of existing coding
3. Graphics -- Real time plots of raw data would:
   a. aid in immediate verification of test data
   b. aid in analyzing results
   c. facilitate writing of reports
REFERENCES


6. Same as Ref. 5 (Page 31, Table 4).


DISTRIBUTION

R. Avery
D. Clark
T. Elioff
K. Halbach
E. Hartwig/L. Wagner/W. Deuser
W. Hartsough
W. Hassenzahl
E. Hoyer
S. Loken
R. Main
J. Peterson
L. Schroeder
J. Staples
C. Taylor
H. Winick (SSRL)
Magnetic Measurements Engineering (4)

Note: Appendices B and C to be distributed on request only.
LBL - SSRL BEAM LINE DEVELOPMENT
PERMEABILITY MEASUREMENTS OF VANADIUM PERMENDUR

APPENDIX A

SUMMARY OF COMPARATIVE MEASUREMENTS
OF PERMEABILITY BY SLAC AND LBL

Donald H. Nelson and Michael I. Green
Lawrence Berkeley Laboratory
Magnetic Measurements Engineering
APPENDIX A

Comparison of SLAC and LBL Measurements of 1018 Carbon Steel

The purpose of this appendix is to compare permeability measurements of two samples of identical material (Cold Rolled 1018 Carbon Steel LBL stock no. 9510 - 10198 Vacuum Annealed at 1500°F (840°C) for 1 hour then cooled at 300°F/Hr (166°C/Hr).

Table A1 summarizes the tests made at LBL and at SLAC. Appendix C contains copies of the data sheets provided by SLAC. MME Book No. 644 contains the LBL data sheets.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Test No.</th>
<th>Min</th>
<th>Max</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>LBL</td>
<td>1124C1.DAT</td>
<td>0.69</td>
<td>36.8</td>
<td>11/24/81</td>
</tr>
<tr>
<td>LBL</td>
<td>1124C2.DAT</td>
<td>0.37</td>
<td>7056</td>
<td>11/24/81</td>
</tr>
<tr>
<td>LBL</td>
<td>1130A1.DAT</td>
<td>0.35</td>
<td>298.9</td>
<td>11/30/81</td>
</tr>
<tr>
<td>SLAC</td>
<td>1</td>
<td>1.54</td>
<td>83.2</td>
<td>1/14/82</td>
</tr>
<tr>
<td>&quot;</td>
<td>2</td>
<td>1.45</td>
<td>84.7</td>
<td>1/14/82</td>
</tr>
<tr>
<td>&quot;</td>
<td>3</td>
<td>0.18</td>
<td>9.1</td>
<td>1/14/82</td>
</tr>
<tr>
<td>&quot;</td>
<td>4</td>
<td>1.54</td>
<td>86.1</td>
<td>1/14/82</td>
</tr>
</tbody>
</table>

Table A1 Summary of Comparative Tests

Figures A1 and A2 summarize the test results. Figure A1 shows magnetic induction, B, as a function of Magnetic Intensity, H; while Figure A2 presents $\mu_r = B/\mu_0 H$ as a function of H for the same data.

We have reached the following conclusions:
FIGURE A1
D.C. Magnetization Data
LBL/SLAC Comparison on 1018 Cold Rolled Steel Annealed at 816 °C
(For Reference 6 Points Plotted for 1020 Hot Rolled Steel Annealed at 1500 °F)

Magnetic Induction, B (Teslas)

D.C. Magnetizing Force, H (Oe)

NOTES
1. H = 35.8 Oe Highest data point for NBE data set 113435.DAT
   13 Turn Auxiliary Winding
2. H = 86.3 Oe Highest data point for SLAC data set #4
3. H = 298.9 Oe Highest data point for NBE data set 113541.DAT
   45 Turn Auxiliary Winding
   Also, approximate maximum for United States Steel 1020 cold for 1020 hot-rolled steel annealed at 1500 °F
1. In the range $5.0 \leq H \leq 86 \text{ Oe.}$ the agreement between SLAC Data and LBL ascending MMF Data is better than 2% (above 10 Oe. the curves are indistinguishable).

2. The LBL descending MMF data is indistinguishable from LBL ascending MMF data for magnetizing intensities above 200 Oe. (even for the data set descending from 7056 Oe.). Below 200 Oe., the sample and/or the LBL magnet retain permanent magnetism as shown by the dashed curves in both figures.

3. For magnetizing intensities below 5 Oe, values of magnetic induction reported by LBL are consistently higher than corresponding measurements by SLAC. There are two effects that could explain these differences (qualitatively at least). More studies are required to determine the relative contribution of each effect to the measured value.

   a] The first effect is due to the failure of the LBL procedure to completely demagnetize the magnet used for the tests (the sample was demagnetized by annealing).

   b] The second effect is due to the magnetic history differences inherent in the two methods of measurements. For the SLAC split-coil permeameter, magnetic induction is determined from a measurement of a change of flux-linkage when magnetic intensity is changed from $+H$ to $-H$. In the Halbach permeameter, magnetic induction is determined from a measurement of a change in flux-linkage from $H = 0$ to $+H$. 

A-4
Because of the non-linear effect of magnetic history on the final state of magnetization $B(+H) - B(-H) < 2 (B(+H) - B(0))$

Although we suspect that the LBL demagnetization procedure is the main contribution to the higher magnetic induction measured by LBL, the second effect will influence the basic shape of the permeability curve at low magnetizing intensities and should be studied in more detail.
LBL - SSRL BEAM LINE DEVELOPMENT

PERMEABILITY MEASUREMENTS OF VANADIUM PERMENDUR

APPENDIX B

SOURCE LISTINGS, LBL PERMEABILITY CODES

Donald H. Nelson and Michael I. Green

Lawrence Berkeley Laboratory

Magnetic Measurements Engineering
APPENDIX B

Source Listings, LBL Permeability Codes

I. Software Documentation File

   File: DATA.TXT on Disk: DATA 1

II. Program DEMAG1

III. Data Acquisition Coding

   A. Program PERM7
   B. Program PERMB
   C. Subroutine PREPAR
      1. Sub. COILPR
      2. SMPLPR
      3. HALLPR
      4. INGRPR
      5. SLFSPR
   D. Subroutine INIT
   E. " PREINT
   F. " DELAY
   G. " PSTINT
   H. " SAVE

IV. Program PROCCI

   A. Subroutine VOMIT
   B. " PUTOUT
      1. Sub. DRFFCR
      2. Sub. CALCMU
      3. Sub. PRNTOT

V. Program CMCPSI

VI. Program MPX1

VII. GPIB device table
file: DATA.TXT
created: 31 Nov 78
by: Mike I. Green
At 1130 changed output format of PROG1 for more significant digits
updated: 31 Dec 79 more documentation text
At 1 Nov 30 output format of PROG1 changed for more significant digits

diskette no.: DATA 1
property of: LBL MAGNETIC MEASUREMENTS ENGINEERING GROUP

purpose: To document the data acquired on this disk, and the software and hardware used to obtain the data.

running disk: NME 16; "PERMEABILITY RUNNING DISK" is in 5Y1.

It's directory follows. This disk is in 5Y1.

20-Nov-81
BA .SYS 7P 01-Mar-80 PFXT .SAV 7P 26-Oct-81
BINCDS.SAV 16P 01-Mar-80 KL .SYS 2P 01-Mar-80
CDP1 .SAV 19P 23-Oct-81 PERM7 .SAV 6P 15-Nov-81
CREF .SAV 6P 01-Mar-80 PERM6 .SAV 6P 15-Nov-81
D .COM 1F 29-Jan-80 PIP .SAV 2P 01-Mar-80
DEMRG1 .SAV 26P 02-Nov-80 PROC1 .SAV 5P 19-Nov-81
DIR .SAV 17P 01-Mar-80 REPORT .SAV 15P 01-Mar-80
BUFP .SAV 8P 01-Mar-80 RT11SG.SYS 6P 01-Mar-80
DUP .SAV 41P 01-Mar-80 SSET .SAV 5P 08-Feb-81
DT .SYS 4P 01-Mar-80 SDCMP .SAV 15P 01-Mar-80
FORMAT .SAV 19P 01-Mar-80 STARTS .COM 1F 23-Feb-81
K52 .SAV 55P 01-Mar-80 SWAP .SYS 25P 01-Mar-80
LIBA .SAV 15P 01-Mar-80 TT .SYS 2P 01-Mar-80
LS .SYS 3P 01-Mar-80

27 Files, 273 Blocks
381 Free Blocks

The disk NME 16 can be generated from two master backup disks, N3 30 which has just operating system type files, plus the necessary .SAV files from N3 29.

The following is a directory of the master backup disk N3 29.

updated: 09-DEC-81
CALHUI.FOR 6 08-Nov-81 PERM7 .SAV 6 19-Nov-81
CALHUI.LST 21 15-Nov-81 PERM6 .BAK 16 17-Nov-81
CALHUI.SYS 3 15-Nov-81 PERMB .FOR 1 19-Nov-81
CHCPS1.FOR 12 24-Sep-81 PERMB .LST 27 19-Nov-81
CHCPS1.LST 1 23-Oct-81 PERMB .PAP 27 19-Nov-81
CHCPS1.SYS 7 23-Oct-81 PERMB .CRJ 27 19-Nov-81
CMCP51.SAV 19 27-Oct-81 PERM5 .SAV 6 17-Nov-81
COILP.FOR 1 15-Nov-81 PREINT .FOR 5 15-Nov-81
COILP.LST 4 15-Nov-81 PREINT .LST 6 15-Nov-81
COILP.CPJ 5 15-Nov-81 PREINT .CRJ 7 15-Nov-81
DELAY1.FOR 4 15-Nov-81 PREPR1 .FOR 4 15-Nov-81
DELAY1.LST 3 15-Nov-81 PREPR1 .LST 4 15-Nov-81
DELAY1.SYS 3 15-Nov-81 PREPR1 .SYS 4 15-Nov-81
The above were compiled and linked using a copy of the master backup disk H6 25 plus the file CMCLIB.OBJ from H6 14.

To reach this stage of development, several other permeability disks were used:

- MME 28 PERMEABILITY #1, (LSI 11/2)
- MME 29 PERMEABILITY #2, (LSI 11/12)
- MME 31 PERMEABILITY #3, (LSI 11/23)
- MME 32 PERMEABILITY #4, (LSI 11/23)
- MME 33 operating system disk used to generate all LSI 11/23 programs from start to December 81
- MME 35 PERMEABILITY RELAY TEST (LSI 11/23)

Most of the above programs and subroutines could be improved. Some of the improvements would include:

1. Deleting COMMENTED OUT lines.
2. Deleting DEBUG lines.
3. Incorporating processing in the main program.
4. Accepting some input from terminal that is now frozen into subroutines.
5. Compensation for gage meter zero offset.
6. Formatting output "constants" so that they are identified.

(PS Don, the above took 5 minutes. Bilder 7 aid)
PROGRAM DEMAG1
created by mike i green
File name: DEMAG1.FOR
Modification history:
01a 31 oct 13 mis reduce cycle time by commenting out a
delay caused by CALL TIME
01b 31 oct 9 mis workings
01a 31 oct 09 mis copied from CHCP3

Purpose:

demagnetization of sampler in electromagnet by cycling power
supply to plus and minus maximum current and then decreasing
maximums

cycle LLNL 30 amp bipolar power supply plus and minus 30 amps by
cycling the KINETIC SYSTEMS 3160 POWER SUPPLY CONTROLLER from
zero to 1024 then to -1024, then back to zero, we then decrease
maximum DAC count by 1 until we get to maximum of 0.

Hardware required:

CANAC controller - STANDARD ENGINEERING CORP. MODEL CC-LSI-11
KS 3150 POWER SUPPLY CONTROLLER
LLNL BIPOLAR 20 AMP, 20 VOLT PS, WM LEA 74-4035

Software required:

RT-11 operating system
STD. ENG. CORP., "PDP-11/CANAC SUPPORT LIBRARY"

IMPLICIT INTEGER(A-Z)
BYTE TIME(8)
LOGICAL ENABLE, DISAB
DATA ENABLE, DISAB /.TRUE., .FALSE./
DATA CRATE, SLOT, SBADDR /1, 15, 0/
CADDR = CRREG(1, CRATE, 0, 0) 'declare crate address
CALL CCSZ(CADDR) 'initialize crate "dataway I cycle"
CALL CCSI(CADDR, DISAB) 'clear dataway inhibit
ADDY = CRREG(1, CRATE, SLOT, SBADDR)
IDAC = 0
INC = 1
TYPE *, ' ENTER MAXDAC:'
ACCEPT &, MAXDAC
100 CONTINUE
CALL CSSA(16, ADDY, IDAC)
CALL TIME(TIME1)
IF ( IDAC .EQ. MAXDAC) INC = -1
IF ( IDAC .EQ. -MAXDAC) INC = 1
IDAC = IDAC + INC
IF (( IDAC .EQ. 0) .AND. ( INC .EQ. 1 )) MAXDAC = MAXDAC -1
IF (( IDAC .EQ. 0 ) .AND. ( INC .EQ. 1 )) TYPE *, MAXDAC
IF (MAXDAC .EQ. 0 ) GO TO 900
GO TO 100
CONTINUE
CALL CSSA (16, ADDR, 0)
CALL EXIT
END
PROGRAM PERM7

created by mike i green

file name: PERM7.FOR

modification history:

06f 51 nov 13 mis byte dimensions all even
06c 51 nov 13 mis added variable delay
04g 51 nov 04 mis corrections from hall probe stuff
04c 51 nov 04 dhn dimension edc; bair; bamp; & ream (250)
04b 51 nov 1 mis inserting PREINT & PSTINT shr's
06a 51 oct 30 mis inserting subroutines
05a 51 oct 26 mis copied from PERM5; use 3455A DVM
04a 51 oct 15 mis copied from PERM4 & only 10s cycle
03a 51 Oct 13 mis added delay shr and print for deck100
02a 51 Oct 13 mis copied from PERM2 & added init SBR
01a 51 oct 08 mis copied from PERM1.FOR

purpose:

cycle LNL 30 sar bipolar powersupply plus "amps" by
cycling the KINETIC SYSTEMS 3160 POWER SUPPLY CONTROLLER from
zero to MAXDAC then back to zero.

input constant data from subroutines and save on disk

read power supply current output, hall probe output, and
integrator output by means of multiplexed DVM.

hardware required:

CANAC controller - STANDARD ENGINEERING CORP. MODEL CC-LSI-11
KE 3130 POWER SUPPLY CONTROLLER
LLNL BIPOLAR 30 AMP, 20 VOLT FS, DWO LEA 74-4035
HP-3495A SCANNER
HP-3455A DVM
F. W. KELL MODEL 811 GAUSSMETER
INTEGRATOR AND SELFS 43

software required:

RT-11 operating system
STA. ENG. CORP., 'PDP-11/CANAC SUPPORT LIBRARY'
SPLIB-08J 81 Oct 23
DEUTAL.TXT 81 Oct 23
DELAY-OBJ 81 nov
INIT-0BJ subroutine -- accept comments, data, time
types and prints them and table headings
COILCTR in file COILPL1
DRFCTR in file DRFTCI
HALLPR in file HALLP1
INGRPR in file INGRP1
PREINT in file PREINT
C PREPAR in file PREPR1
C PSTINT in file PSTINT
C SLFSR in file SLFSPR
C SHLP in file SHLP1
C SAVE in file SAVE1
C RSTOR in file RSTOR

INTEGER CRATE, SLOT, SBADDR, CADIR, CCZ, CCC, ABIR
INTEGER CSSA
DIMENSION RDATA(250, 5), ENC(250), AIR(250), SHPL(250),
1 RPERM(250)
BYTE TIME1(16), OMME(16), OMME2(16), OMME3(16)
BYTE COILHA(10), GTREH(10), FPREH(10), INTREH(10), SLPREH(10)
BYTE SPLDGES(10), ANSWER(2), ENABLE(2), DISABLE(2), DATE1(10)
DATA ENABLE(1), DISABLE(1) /'TRUE', 'FALSE'/
DATA CRATE, SLOT, SBADDR /1, 13, 0/
CADI R = CRAREG( , CRATE, 0, 0) /! declare crate address
CALL CCZ(CADIR) /! initialize crate 'dataway Z cycle'!
CALL CC(L)(CADIR, DISABLE(1)) /! clear dataway inhibit

AIDBR = CRAREG( , CRATE, 0, 0)

put all GPIB devices into remote mode
READ 0

C program UVH
READ 0

CALL preparation subroutine
Coi parameters
sample parameters
H1 probe parameter
interator parameters

call preparation subroutine
CALL PREPAR(COILHA, ACOIL, TCOIL, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, SPLDG, 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zero integrator and set initial sample condition

CALL FINT(V0, UIWTO, TSAMP, VINTS)

enter maximum DAC value going to power supply
2047 = ?2.5 volts
-2048 = ?2.5 volts

TYPE '?, 'ENTER MAXDAC !'
ACCEPT ?R MAXDAC
IDAC = 0

TYPE '?, 'ENTER DAC INCREMENT !'
ACCEPT ?R INC
I = ?

TYPE '?, 'ENTER HALL PROBE RANGE (GAUSS) !'
ACCEPT ?R X5

the main loop starts

CALL CSEA (16, ADVR, IDAC)  \write DAC value to RS
CONTINUE

delay before reading voltages

CALL DELAY(500)

J = I ++ 1  \counter for data set #

read power supply current, (0.1 volts / 10 AMPS ? )

J = IBUP(0, 1, 'C1', 0)  \scanner to ch 1
J = IBUP(3, 1)  \trigger scanner
J = IBUP(0, 3, 'F1771', 0)  \program DVM
J = IBUP(3, 3)  \trigger DVM
J = IBUP(1, 3, V, 16)  \read DVM
RECODE(13, 160, V) X1
RDATA(1, 1) = X1

read hall probe voltage, (1.0 volts / 10 kGauss )

J = IBUP(0, 1, 'C2', 0)  \scanner to ch 2
J = IBUP(3, 1)  \trigger scanner
J = IBUP(0, 3, 'F1771', 0)  \program DVM
J = IBUP(3, 3)  \trigger DVM
J = IBUP(1, 3, V, 16)  \read DVM
RECODE(13, 160, V) X2
IF (X2 .LT. 1.0) TYPE '?, 'HALL OUT > 1 VOLT, SWITCH RANGE AND
\ENTER NEW FULL SCALE RANGE (GAUSS) !'
IF (X2 .GT. 1.0) ACCEPT ?R X5
IF (X2 .LT. 1.0) ACCEPT ?R X5
IF (X2 .LT. 0.1) TYPE '?, 'HALL OUT < 0.1 VOLT, SWITCH RANGE AND
\ENTER NEW FULL SCALE RANGE (GAUSS) !'
IF (X2 .LT. 0.1) ACCEPT ?R X5
IF (X2 .LT. 0.1) GOTO 250
RWDATA(I, 2) = X2
RWDATA(I, 5) = X5 * .0001

C read integrator voltages
J = IBUP(0, 1; '03', 0) ! scanner to ch 3
J = IBUP(3, 1) ! trisrer scanner
J = IBUP(0, 3; 'F1R7T1', 0) ! program DVM
J = IBUP(3, 3) ! trisrer DVM
J = IBUP(1, 3; V, 16) ! read DVM
DECODE(13, 100, 9) X3
RWDATA(I, 3) = X3

C set elapsed time
RWDATA(I, 4) = SECONDS(T0)

C FORMAT(El4,6)
TYPE 1000, IDAC, (RWDATA(I, K); K = 1, 3)
PRINT 1000, IDAC, (RWDATA(I, K); K = 1, 5)

1000 FORMAT(I4, I6, SF10.4, F10.0, F10.4)

C terminate program
IF ((IDAC .EQ. 6) .AND. (INC .EQ. -1)) GO TO 900

C do loop to increment DAC by 10
DO 210 K = 1, 10
IDAC = IDAC + INC
CALL ESA(16; ANDR, IDAC)
CALL DELAY(5)
210 CONTINUE
IF (IDAC .EQ. MAXDAC) INC = -INC
IF (IDAC .EQ. -MAXDAC) INC = -INC

C read voltages
GO TO 200

900 CONTINUE

C TYPE *: IDAC, MAXDAC

C set final sample condition and integrator voltages & corresponding times, set any final comments
CALL PSTINT(T0; TSAMPF; UTINTER; TEND; VERD; COMH3)

C IF (MAXDAC .GT. 100) GO TO 310
M = 1 + 2 * MAXDAC/10
GO 300 K = 1, M
C PRINT 1010: RWDATA(K, 1), RWDATA(K, 2), RWDATA(K, 3)
300 CONTINUE
C GO TO 2000
DO 320 K = 1, I, 10
C PRINT 1010, RWDATA(K, 1), RWDATA(K, 2), RWDATA(K, 3)
C320 CONTINUE
C
C1010 FORMAT(1X, 3F10.4)
C
C we now start the disk save procedure

TYPE K, ' type 'Y' if you want to save data'
ACCEPT 1100, ANSWER(1)
1100 FORMAT(1A1)
IF(ANSWER(1) .EQ. 'Y') CALL SAVE(COHMA, DATE1, TIME1, COILMA,
1 ACOIL, TC0IL, SPLDES, SPLID, SPLTH, GMKMOD, GMKNUM,
2 PRMOD, PRNUM, PRCON, GMZERO, GMDAN, INTMOD, RIINT, CIINT,
3 ATINT, SLFHO, SLFLUX, ESLFS, VIINT, TSAMP, VINTS, MAXDAC,
4 1, 5, RWDATA, TSAMPP, VINTSF, TEND, VEND, COHMA)
C
C TYPE K, ' type 'Y' if you want to run same sample again'
ACCEPT 1100, ANSWER(1)
IF(ANSWER(1) .EQ. 'Y') GOTO 50
CALL EXIT
END
PROGRAM PERMS

created by mike i aren

file name: PERMS.FOR

modification history:

076 81 nov 19  mis documentation & misc obuass
076 81 nov 17  mis copied from FERM7, DELAY test
067 81 nov 13  mis byte dimensions all even
066 81 nov 13  mis added variable delay
066 81 nov 04  mis corrections from hall probe stuff
066 81 nov 04  dhm dimension edcorairibsmi51a term (250)
066 81 nov 04  dhm inserting PRINT & PENVNT subr's
066 81 oct 30  mis inserting subroutines
058 81 oct 26  mis copied from PERMS1 cse 3453A DVM
044 81 oct 26  mis copied from PERMS1 only pos cycle
028 81 oct 13  mis added delay cbr and print for doc100
028 81 oct 13  mis copied from PERMS1 added init SUB
028 81 oct 03  mis copied from PERMS1.FOR

Purpose:

cycle LNL 36 amp bipolar powersuply plus 'com' by
cycling the KINETIC SYSTEMS 3160 POWER SUPPLY CONTROLLER from
zero to 0.5VAC then back to zero.

input constant data from subroutines and save on disk
read powers supply current output, hall probe output, and
integrator output by means of multiplexed DVM.
variable delay and double readings at each doc output

Hardware required:

CAMAC controller - STANDARD ENGINEERING CORP. MODEL CC-LEI-11
KL 3130 POWER SUPPLY CONTROLLER
LNL BIPOLAR 36 AMP, 20 VOLT FS, 500 LBA 74-4033
HP-3453A SCANNER
HP-3453A DVM
P. S. KELLY MODEL 511 GAUGEMETER
INTEGRATOR AND MLFT 43

Software required:

AT-11 operating system
37J. ENG. CORP., "PDP-11/CAMAC SUPPORT LIBRARY"
PRJ-06J 81 oct 23
DEBTR1.TXT 81 oct 23
DELAY.LIB 81 oct 23
INIT.06J subroutine -- accepts comments, date, time
hubes and prints them and table readings
C.CUTLPF in file CUTLPF1
DRF.06J in file DRAFT01
integer crate, slot, sbaddr, cadbr, coreg, cclz, ccli, addr
integer cssa

dimension rdata(250, 5), eoc(250), pair(250), empl(250),
1 rperh(250)

byte time(3), y(16), comm(72), comm3(72)
byte coilhm(10), gmrm(10), prbh(10), intmod(10), slfhod(10)
byte splies(72), answer(2), enable(2), disable(2), date1(10)
data enable(2), date1(10) /true, false/
data crate, slot, sbaddr /1, 15, 0/
cadbr = coreg(1, crate, slot, sbaddr) ! declare crate address
call cclz(cadbr) ! initialize crate "detawaw2; cycle"
call ccli(cadbr, disable(1)) ! clear detawaw inhibit

put all sp12 devices into remote mode

j = ibup(4, 0)

program dbm

j = ibup(0, 3, 'f1r7t1m3a140', 0)
call preparation subroutine.
call parameters.
sample parameters.
hall probe parameter.
integtrator parameters.
elfs parameters.

call initialization subroutine.
type and print data and time, comments, table headings.
50 call init(cmm2, date1, time1, coilhm, acol, tcoil, splies,
zero integrator and set initial sample condition

CALL PREINT(T0, VINT, TSAMP, VINTS)

enter maximum DAC value arising to power supply

\[
\begin{align*}
2V47 & = +2.5 \text{ volts} \\
-2V46 & = -2.5 \text{ volts}
\end{align*}
\]

TYPE k, ' ENTER DAC \('' ?'
ACCEPT \(k\), DAC

\[
\text{DAC} = 0
\]

the following is used to test if we have sufficient delay before
reading voltages.

TYPE k, ' ENTER number of delay loops \('' ?'
ACCEPT \(k\), NDELAY

\[
\text{NDelay} = 1
\]

\[
\text{i} = 0
\]

TYPE k, ' ENTER Hall probe range (usually)
ACCEPT \(k\), kH

the main loop starts.

CALL DAOA \((kH)\), DAC) \(\text{write}\) \(kH\) \text{val to DS}

CONTINUE

the following 50 TIMES is to test if we have sufficient delay before
reading voltages.

\[
50 \text{ i} = 0, 1
\]

delay before reading voltages

CALL DELAY \((\text{NDelay})\), KDLY

CONTINUE

\[
i = i + 1
\]

\(\text{counter for core coil number}\)

read power supply current \((\text{0.1 volts/10 Amps}) \text{?}\)

\[
\text{I} = \text{IBOO}(kH, 0, 0)
\]

\(\text{scane}\)r \(\text{on}\)\(\text{1}\)

\[
\text{I} = \text{IBOO}(kH, 1, 0)
\]

\(\text{trigs}\)er \(\text{scane}\)r

\[
\text{I} = \text{IBOO}(kH, 2, 0)
\]

\(\text{program SUM}\)

\[
\text{I} = \text{IBOO}(kH, 3, 0)
\]

\(\text{trigs}\)er \(\text{SUM}\)

\[
\text{I} = \text{IBOO}(kH, 4, 0)
\]

\(\text{read SUM}\)

\[
\text{IBOPE0}, \text{I} = 0 \text{, I}
\]

\(\text{read Hall probe voltage } (1.0 \text{ volts/100 \text{ counts}})\)
read integrator voltage

read

set elapsed time

print W of integration voltage recorded on first pass

print time for second pass

write output

write output on tape

end program
IF ( IDAC .EQ. MAXDAC ) INC = -INC
IF ( IDAC .EQ. -MAXDAC ) INC = -INC

C read voltages

GO TO 300

900 CONTINUE

C

TYPE *, IDAC, MAXDAC, NDELAY
PRINT *, IDAC, MAXDAC, NDELAY

C set final sample condition and integrator voltages & corresponding times. set any final comments

CALL PSETMT(T0, TSAMPS, VINTS, TEND, VEND, CMNM3)

C

IF ( MAXDAC .GT. 100 ) GO TO 310
H = 1 / 2 * MAXDAC/10
DO 300 K = 1, H
PRINT 1010, RWDATA(K, 1), RWDATA(K, 2), RWDATA(K, 3)
300 CONTINUE

C GO TO 2000

C

C310 DO 320 N = 1, I, 10
C320 PRINT 1010, RWDATA(K, 1), RWDATA(K, 2), RWDATA(K, 3)
C320 CONTINUE

C

C1010 FORMAT(1X, 3F10.4)
C

C we now start the disk save procedure
C

TYPE A/ type 'Y' if you want to save data
ACCEPT 1100, ANSWER(1)

1100 FORMAT(1A1)
IF ( ANSWER(1) .EQ. 'Y') CALL SAVE(CMNM2, DATE1, TIME1, CMNM3, 1 AC0IL, TC0IL, SPLINES, SPL00, SPL10, SPLTH, CMNM0, CMNM0; A PRMO1, PR01M; PRE01, PRE01M0, GZERO3, GA03, INTMOD, PINT, CINT, 3 ATINT, SL IPO; SLFUX, ESL0S, VINTG, TSAMPS, VINTS, MAXDAC, A 1, 3, RWDATA, TSAMPS, VINTS, TEND, VEND, CMNM3)

C

TYPE A, type 'Y' if you want to run same sample again
ACCEPT 1100, ANSWER(1)
IF ( ANSWER(1) .EQ. 'Y') GOTO 30
CALL EXIT
END
FILE: PREPR1.FOR
DATE: '81 OCT 29
REVISION: 81 nov 4 mis some misc corrections
PURPOSE: To call subroutines that will provide the necessary
constants for processing permeability data.

SUBROUTINE PREPAR(COILNM,ACOIL,TCOIL,SPLDES,SPLOD,SPLID,SPLNTH,)
1 GMRMD, GMRNUM, PRBMOD, PRBNUM, PRBCON, GMZERO, GMCAL,
2 INTMOD, RINT, CINT, ATNNINT, SLFMD, SLFUX, ESLF)

COILNM, SPLDES, GMRMD, PRBMOD, INTMOD, SLFMD ARE ALPHANUMERIC

CALL COILPR(COILNM,ACOIL,TCOIL)
CALL SMPLPR(SPLDES, SPLOD, SPLID, SPLNTH)
CALL HALLPR(GMRMD, GMRNUM, PRBMOD, PRBNUM, PRBCON, GMZERO, GMCAL)
CALL INGRPR(INTMOD, RINT, CINT, ATNNINT)
CALL SLFSPR(SLFMD, SLFUX, ESLF)

RETURN
END
FILE: COILP1.FOR
DATE: '81 OCT 29 DHM

REVISIRED: '81 nov. 12 mis SCOPY len & pad
PURPOSE: To provide coil parameters required by PERMn to
process permeability data.

SUBROUTINE COILPR (COILNM, ACOIL, TCOIL)

FOR NOW FORTRAN STATEMENTS WILL SUPPLY REQUIRED DATA.

BYTE COILNM(10)
ACOIL = 0.04113  !coil turns area
TCOIL = 100.  !coil turns
CALL SCOPY('/B-162 ', COILNM) !coil identification
RETURN
END
FILE SMPLF1.FOR
DATE: '81 OCT 29 DHM
REVISED: 81 nov 12 mis sample description accept from term.
PURPOSE: To define sample parameters needed by PERMn to
process permeability data.

SUBROUTINE SMPLF1( SPLDES, SPLOD, SPLID, SPLNTH )

For now define all constants with data statements.

BYTE SPLDES(72)
splod = 0.02032
splid = 0.00254
splnth = 0.04445
TYPE * Type sample description (72 characters max)!
ACCEPT 100, SPLDES
100 FORMAT(72A1)
RETURN
END
SUBROUTINE HALLPR(GMRMOD,GMNum,PRBMOD,PRBnum,PRBCON,GMZERO,sncal)

For now statements will supply the required data.

BYTE GMRMOD(10), PRBMOD(10)
GMNum = 501586.     !Gaussmeter s/n
PRBCON = 1.          !Probe constant
PRBnum = 120011.     !Probe s/n
GMZERO = 0.0         !(in shield) zero
GHCAL = 1.           !Internal calibration

CALL SCOPY('BELL 620', GMRMOD) !Gaussmeter model
CALL SCOPY('SNA40618', PRBMOD)  !Probe model
RETURN
END
SUBROUTINE INGRPR(INTMOD, RINT, CINT, ATNINT)

FOR NOW DATA STATEMENTS WILL SUPPLY THE REQUIRED DATA.

BYTE INTMOD(10)
rint = 19600,
cint = 0.000001
atnint = .9360
CALL SCOPI(’MOD71*01’, INTMOD)
RETURN
END
FILE: SLFSPL.FOR
DATE: '81 OCT 29 DHN
REVISED: 31 nov 12 mid SCOPY len & pad
PURPOSE: To provide SLFS constants required by PERMn to process permeability data.

SUBROUTINE SLFSPR( SLFMOD, SLFLUX, ESLFS )

For now data statements will supply the required data.

BYTE SLFMOD(10)
SLFLUX = .02101 ! SLFS flux-linkase
ESLFS = 1.007 ! SLFS output
CALL SCOPY('SLFS 43 ', SLFMOD) ! SLFS identification
RETURN
END

B-21
uncover the object in order

3. High volume.

4. Consideration for:

5. The wall and the side

6. The vent and the

7. More connections for the half pipe side

8. Internal linking to prevent air

9. To be aware of

10. To consider the

...
1 RANGE
PRINT 140
140 FORMAT(' (COUNTS) (VOLTS) (VOLTS) (VOLTS) (SECONDS)
1 TESLA)')
RETURN
END
SUBROUTINE PREINT(T0, VINTO, TSAMP, VINTS)

file name: PREINT.FOR

modification history:
01a 81 nov 13 mis null for ANSWER(2)
01b 81 nov 13 mis all bytes even
01b 81 nov 1 mis working
01m 81 nov 1 mis written

purpose:
0 integrator; obtain zero time for drift calculation;
0 determine initial sample condition; and instructions to
0 operator to accomplish same.

hardware required:
HP-3455A scanner
HP-3455A DVM
LSL MODEL 71 INTEGRATOR (6ZV1763)
LSL SQUARE LOOP FLUX STANDARD (SLFS)
SEARCH COIL

software required:
RT-11 operating system
GRIB.OBJ 81 oct 23 DEUTER

parameter definitions:
T0: time (seconds) that integrator is zeroed
VINTO: integrator voltage at T0, with search coil in shield
TSAMP: time (seconds) that sample with search coil around it
0 put in my metal shield
VINTS: integrator voltage at TSAMP

BYTE U(16), ANSWER(2)

200 TYPE *, ' type "Y" if integrator is switched to integrate'
ACCEPT 1010, ANSWER(2)
1010 FORMAT(A1)
0 IF (ANSWER(2), 'Y') GOTO 200

PAUSE 'press return when search coil is in my metal shield'
TYPE *, ' zero integrator by pressing "RESET TO ZERO BUTTON"
PAUSE 'press return when integrator in zeroed'

read integrator voltage and time zero
j = IEUP(0, 1, '03', 0) !scanner to channel 3
j = IRUP(3, 1) !trigger scanner
J = IBUP(0, 3; 'F1R7T1', 0) !program DVM
J = IBUP(3, 3) !trigger DVM
J = IBUP(1, 3; V, 16) !read DVM
TO = SECONDS(0.0) !start timer
DECODE(13, 100, V) VINTO
FORMAT(E14.6) -

100

C

TYPE A, 'put search coil around sample and insert into shield'
PAUSE 'press return when done'

C

read sample integrator voltage and time

C

j = IBUP(0, i; '03', 0) !scanner to channel 3
j = IBUP(3, i) !trigger scanner
J = IBUP(0, 3; 'F1R7T1', 0) !program DVM
J = IBUP(3, 3) !trigger DVM
J = IBUP(1, 3; V, 16) !read DVM
TSAMP = SECONDS(TO) !set sample time
DECODE(13, 100, V) VINTS

C

TYPE B, 'put search coil & sample into magnet'
PAUSE 'press return when ready to run'

C

RETURN
END
SUBROUTINE DELAY(N)

created by mike i. green

file name: DELAY1.FOR

modification history:
02s 81 nov 13 mis incorporated "N" for variable delay time
01s 81 oct 23 mis written and working

purpose:
this SBR is designed just to put a time delay into another program

hardware required: none

software required: RT-11 operating system

50 100 I = 1, N
CALL TIME
100 CONTINUE
RETURN
END
SUBROUTINE PSTINT(T0, TSAMP, VINTE: TEND, VEND, COMM3)

created by mike i sreen
file: PSTINT.FOR

modification history:
01b 81 nov 1 mis working
01a 81 nov 1 mis written

purpose:
determine final sample condition, integrator drift voltage
and instructions to operator to accomplish same.
input final comments

hardware required:
HP-3455A scanner
HP-3455A DVM
LBL MODEL 171 INTEGRATOR (62V1761)
LBL SQUARE LOOP FLUX STANDARD (SLFS)
SEARCH COIL

software required:
RT-1: operating system
GPIB.COM 31 oct 23 DEVTL

parameter definitions:
T0: input from main program, time integrator scoped
TSAMP: time (seconds) that sample with search coil around it
is put in mu-metal shield
VINTE: integrator voltage at TSAMP
TEND: time when just search coil is in mu-metal shield
VEND: integrator voltage at TEND
COMM3: final comments

BYTE V(16), COMM3(72)

TYPE #, 'take sample and search coil out of magnet'
TYPE #, 'put search coil around sample and insert into shield'
PAUSE 'press return when done'

read sample integrator voltage and time

j = IBUP(0, 1, '03', 0) !scanner to channel 3
J = IBUP(3, 1) !trigger scanner
J = IBUP(0, 3, 'F17T1', 0) !program DVM
J = IBUP(3, 3) !trigger DVM
J = IBUP(1, 3, V, 16) !read DVM
TSAMP = SECONDS(T0)
DEC0DE(13, 100, V) VINTE

B-27
TYPE *, 'Put just search coil into mu-metal shield'
PAUSE 'Press return when search coil is in mu-metal shield'

C read integrator voltage and final time
J = IBUP(0; 1, '03'; 0) ! scanner to channel 3
J = IBUP(3, 1) ! trigger scanner
J = IBUP(0, 3, 'F1R7Tl', 0) ! program DUM
J = IBUP(3, 3) ! trigger DUM
J = IBUP(1, 3, V, 16) ! read DUM
TEND = SECNS(T0) ! set end time
DECODE(13, 100, V) VEND

FORMAT(E14.6)

C TYPE *, 'Enter any final comments'
ACCEPT 110, COMM3
110 FORMAT(72A1)

C RETURN
END
SUBROUTINE SAVE0COMI ; DATEI; TIMEI; COLUNH; AODIL; TOOL;
1 SPLDES; SPLGD; SPLID; SPLNTH; GRMNUM; PRBMOD,
2 PRENUM; PRECON; GHZERO; GNCAI; INTMOD; RINT; CINT; ATINT;
3 SLMONH; SLMUX; ESLFS; VINTO; TSAMP; VINTS; MAXDNC,
4 IT; XI; ARRAY; TSAMPP; VINTSF; TEND; VEND; COMHI)

created by mike i. green

file name: SAVEI.FOR

modification history

05a 31 nov 17 mis add code to prevent overwriting datafile
05a 31 nov 17 mis NAME(12); ACCEPT (1=10); (11)=0
05a 31 nov 17 mis output NAME; reordered DATE1; TIME1
04c 31 nov 13 mis all buts even dimension
04a 31 nov 12 mis unformatted sequential save
03b 31 nov 04 mis misc. file name corrections
02a 31 nov 03 mis input or incorrect output everywhere
02a 31 oct 31 mis input constant parameters
01b 31 OCT 30 mis working
01a 31 oct 30 mis written

purpose:

save on disk data from FERM7

hardware required:

none

software required:

FT-11 operating system

DIMENSION ARRAY(250, 2)
BYTE NAME(12); COMM(72); SPLDES(72); TIME1(8); DATE1(10)
BYTE COMM(72)
BYTE COILNH(10); GRMNUM(10); PRBMOD(10); INTMOD(10); SLMONH(10)
TYPE #, 'type file name for saving data XXXXXX.LAT'
90 ACCEPT 10); (NAME(I); I = 1, 10) reads name from terminal
100 FORMAT(10A1)
NAME(I) = 0
OPEN (UNIT = 1, NAME = NAME, FORM = 'UNFORMATTED', TYPE = 'OLD',
1 ERR = 110)
CLOSE (UNIT = 1)
TYPE #, 'file name already exists, try another'
60 TO 70
110 OPEN (UNIT = 1, NAME = NAME, FORM = 'UNFORMATTED')
WRITE (1) NAME; DATE1; TIME1; SPLDES; COMM2; COMM3
WRITE (1) COILNH; GRMNUM; PRBMOD; INTMOD; SLMONH
WRITE (1) MAXDNC; IT; XI
WRITE (1) AODIL; TOOL; SPLGD; SPLID; SPLNTH; PRECON,
1 GHZERO; GNCAI; RINT; CINT; ATINT; SLMUX; ESLFS; VINTO;
2 TSAMP; VINTS; TSAMPP; VINTSF; TEND; VEND; GRMNUM; PRBNUM

LBID-519 30 of 46
WRITE (1) (((ARRAY(I, K), K = 1, 5), I = 1, II)
CLOSE(UNIT = 1)             ! closes disk file
RETURN
END
PROGRAM PROCCL

file name: FROGCL.FOR

modification history:

02b 81 nov 19 mis FNAME from 10 to 12 bytes
02a 81 nov 19 mis FNAME added to print & VOMIT call
01d 81 nov 13 mis all bytes even dimension
01c 81 nov 06 mis cleaning up
01b 81 nov 05 mis working
01a 81 nov 05 mis copied from VMTST2.FOR

purpose:

Process permeability data saved by REM7
Print processed data

hardware required:

none

software required:

RT-11 operating system
subroutines
   VOMIT in file VOMIT2.FOR
   PUTPUT PRPTUT1.FOR
   DRFTCR DRFTC2.FOR
   CALCMU CALCMUL.FOR
   PRNTOT PRNTO1.FOR

note: need to link with bottom of stack raised above 1000

DIMENSION ARRAY(250, 5), BAIR(250), RSHPL(250), RPERM(250)
BYTE COMM2(72), SPLDES(72), TIME1(5), DATE1(10), COMM3(72)
BYTE COILM(10), BMROM(10), PRROM(10), INTROM(10), SLFOM(10)
DATE ANSWER(2), FNAME(12)

pause *' call disk file retrieve subroutine'

CALL VOMIT (FNAME, COMM2, DATE1, TIME1, COILM, ACOL, TCOIL, 1 SPLDES, SPLID, SPLLTH, BMROM, BMNUM, PRROM,
2 PRNUM, PRCON, ONZERD, ONCAL, INTROM, RINT, CTINT, ATINT,
3 SLFOM, SSLFLUX, ESSLFS, VINTO, TSAMP, VINST, MAXDAC,
4 II, XI, ARRAY, TASAMP, VIINST, TEND, VEND, COMM3)

type and print comments; etc

TYPE 190, (FNAME(I); I = 1, 10)
TYPE 210, SPLDES, COMM2, COMM3, DATE1, TIME1
TYPE 220, COILM, INTROM, SLFOM
PRINT 190, (FRAME(I), I = 1, 10)
PRINT 210, SPLDES, COMM2, COMM3, DATE1, TIME1
PRINT 220, COILNM, INTMOD, SLFMOI
PRINT 225, GMRMOD, GMNUM, PRBMOD, PRBNUM
PRINT 230, MAXDAC, I1, K1

C print initialization parameters

PRINT 240, ACOIL, TCOIL, SPLYD, SPLID, SPLNTH, PRBCON,
1 GMRZERO, GMCAL, RINT, CINT, ATNINT, SLFLUX, ESLFS, VINTO,
2 TSAMP, VINTS, TSAMPF, VINTSF, TEND, VEND, GMNUM, PRBNUM

C C C

TYPE *, ' type 'Y' if you want raw data array printed'

ACCEPT 290, ANSWER(2)

200 FORMAT (1A1)
IF (ANSWER(2) .EQ. 'Y') PRINT 250, ((ARRAY(I, K),
1 K = 1, 3), I = 1, II)

C call subroutine that processes data

C TYPE *, ' we now call rutout'

CALL PUTOUT(COMM2, DATE1, TIME1, COILNM, ACOIL, TCOIL,
1 SPLDES, SPLOD, SPLID, SPLNTH, GMRMOD, GMNUM, PRBMOD,
2 PRBNUM, PRBCON, GMRZERO, GMCAL, INTMOD, RINT, CINT, ATNINT,
3 SLFMOI, SLFLUX, ESLFS, VINTO, TSAMP, VINTS, MAXDAC,
4 II, K1, ARRAY, TSAMPF, VINTSF, TEND, VEND, COMM3,
5 BAIR, BMPL, RFERN)

190 FORMAT (1X, '!DISK FILE !', 10A1)
210 FORMAT (3(1X, 72A1/), 1X, 10A1, 1X, 8A1)
220 FORMAT (1A1, '!SEARCH COIL!', 10A1, 5X, '!INTEGRATOR!', 10A1,
1 5X, '!FLUX STANDARD!', 10A1)
225 FORMAT ('GAUSSMETER!', 10A1, ': 10A1, ', 5X, '!S/N:', 'F7.0, 5X,
1 'HALL PROBE!', 10A1, ': 10A1, ', 5X, '!S/N:', 'F7.0')
230 FORMAT ('MAXDAC = 'IA1, 15X, IA1', DATA SETS ', 5X, IA1,
1 'PARAMETERS LONG')
240 FORMAT (3 (1X, E13.6))
250 FORMAT (1X, 3F10.4, F10.0, F10.4)

CALL EXIT
END
SUBROUTINE VOMIT (DHAME, COMM2, DATE1, TIME1, COILNM, AGOIL,
1 TCOIL, SPLDES, SPLOD, SPLID, SPLTHM, GMRMD, GMRNUM, PRBMD,
2 PRNUM, PRECON, GMZERO, GMCAL, INTMD, RINT, CINT, ATNINT,
3 SLFMOD, SLFLUX, ESLFS, VINT0, TSAMP, VINTSF, MAXDAC,
4 II, K1, ARRAY, TSAMPF, VINTSF, TENO, VEND, COMM3)

created by mike i. green

file name: VOMIT3,FOR

modification history:
04a 81 Nov 19 mis DHAME added to input
03b 81 Nov 13 mis all bytes even dimension
03a 81 Nov 11 mis copied from VOMIT2, mode unformatted
02a 81 Nov 04 mis several fixes
01a 81 Nov 03 mis copied from SAVE2,FOR

purpose:
retrieve from disk data saved from PERM7 by SAVE2

hardware required:
none

software required:

AT-11 operating system

DIMENSION ARRAY(250, 5)
BYTE FNAME(12), COMM2(72), SPLDES(72), TIME1(8), DATE1(10)
BYTE COMM3(72), DHAME(12)
BYTE COILNM(10), GMRMD(10), PRBMD(10), INTMD(10), SLFMOD(10)
TYPE *, 'type file name for retrieving data XXXXX.DAT'
ACCEPT 100, (FNAME(I), I=1,10) ; reads file name from terminal
100 FORMAT(1OA1)
FNAME(11) = 0 ; null byte terminates strings

access file

OPEN (UNIT = 1, TYPE = 'OLD', READONLY, NAME = FNAME, FORM =
1 'UNFORMATTED')

READ (1) DHAME, DATE1, TIME1, SPLDES, COMM2, COMM3
READ (1) COILNM, GMRMD, PRBMD, INTMD, SLFMOD
READ (1) MAXDAC, II, K1
READ (1) TCOIL, TCOIL, SPLOD, SPLID, SPLTHM, PRECON,
1 GMZERO, GMCAL, RINT, CINT, ATNINT, SLFLUX, ESLFS, VINT0,
2 TSAMP, VINTSF, TSAMPF, VINTSF, TENO, VEND, GMRNUM, PRBNUM
READ (1) ((ARRAY(I, K), K = 1, 5), I = 1, II)

close file

CLOSE(UNIT = 1) ; closes disk file
TYPE *, ' FILE HAS BEEN READ & CLOSED'
RETURN
END
SUBROUTINE PUTOUT(COMH2, DATE1, TIME1, COILNH, ACOIL, TC Oil, COIL, 
1 SPLDES, SPLCD, SPLID, SPLNTH, GMRMOD, GMRMNUM, PRBMOD, 
2 PRNUM, PRECON, GMZERO, GACAL, INTMOD, RINT, CINT, ATNINT,
3 SLFMOD, SLFLUX, ESLFS, VINTO, TSAMP, VINTS, MAXDAC, 
4 IL, KI, ARRAY, TSAMPF, VINTSF, TEND, VEND, COMM3, 
5 BAIR, BSMLP, RPERM)

created by don nelson

file name: PTOUT1,FOR

modification history:

02b 81 nov 13 mis all butes even dimension
02a 81 nov 06 mis cleaning up
01c 81 nov 05 mis working
01b 81 nov 03 mis & dhn misc additions & corrections
01a '81 Nov 3 copied savel.for to ptout1.for to facilitate coding

purpose:

to process data collected by PERM7 and print parameters of
interest.

hardware required:

none

software required:

RT-11 operating system

called by program PROCC1 in file PROCC1,FOR

subroutines needed:

CALCHU in file CALMU1,FOR

PRINT DRFTCR DRFTC2,FOR

PRINT10 PRINT101,FOR

note: arrays must be dimensioned 250 in calling programs

DIMENSION ARRAY(250, 5), EDC(250), BAIR(1), BSMLP(1), RPERM(1)

BYTE COHM2(72), SPLDES(72), TIME1(8), DATE1(10), COMM3(72)
BYTE COILNH(10), GMRMOD(10), PRBMOD(10), INTMOD(10), SLFMOD(10)

PRINT 10 ' ARRAY FROM PUTOUT' 
PRINT 1010, (ARRAY(I, K), K = 1, 5), I = 1, II)
1010 FORMAT (1X, 5F10.4, F10.0, F10.4)

TYPE ": we now call drift correct subroutine'

CALL DRFTCR(TEND, VINTO, VEND, II, ARRAY, EDC).
PRINT *, ' EDC'
PRINT 1000, (EDC(I), I = 1, II)
1000 FORMAT (5(1X, F10.5))

TYPE *, ' we now call permeability calculation subroutine'

CALL CALCHU( SPLID, SPLID, ACOIL, TCOIL, SLFLUX, ESLFS; I1,
1 ARRAY, EDC, BAIR, BSMPL, RPERM)

TYPE *, ' we now call print subroutine'

CALL FRNTO2 (DATE1, TIME1, COILNM, ACOIL, TCOIL,
1 SPLIDES, SPLID, SPLID, SPLNTH, GMRMOD, GMRNUM, PRBMOD,
2 PRBNUM, PRSCON, GHZERO, GHCAL, INTMOD, RINT, CINT, ATHINT,
3 SLFMOD, SLFLUX, ESLFS, VINT0, TAMP, VINTS, MAXDAC,
4 I1, K1, ARRAY, TAMPF, VINTSF, TEND, VEND, COHAM3,
5 BAIR, BSMPL, RPERM)

RETURN
END
SUBROUTINE DRFTC2(TZ2, Z1, Z2, N); ARRAY; EDC

created by don h. nelson

file name: DRFTC2.FOR

modification history:

02a 81 nov 06 mis cleanins up
01d 81 nov 05 mis workins
01c 81 nov 05 mis changed dimension statement for explicit 250
01b 81 nov 05 mis changed DATA(I, J) to ARRAY(I, J)
01a 81 nov 02 mis copied from file DRFTC1.FOR

parameter definitions:

TZ2 time of last integrator zero reading (seconds)
Z1 first integrator zero reading in shield (volts)
Z2 final " 
H no of data points
ARRAY(I: 4) integrator output potential (volts)
ARRAY(I: 4) elapsed time since zeroing integrator (seconds)
EDC(I) drift corrected output array (volts)

DIMENSION ARRAY(150, 5); EDC(250)

compute drift rate.

DRFTRT = 0.0
IF (TZ2 .LE. 50, 0) GO TO 10
DRFTRT = (Z2 - Z1) / TZ2
10 CONTINUE

PRINT *, 'I EDC(I) ARRAY(I, 3) ARRAY(I, 4)'

adjust for linear (in time) drift

DO 100 I = 1, N
EDC(I) = ARRAY(I, 3) - DRFTRT * ARRAY(I, 4)
100 PRINT 1010; I, EDC(I), ARRAY(I, 2), ARRAY(I, 4)
1010 FORMAT (1, 5, F10.4, F10.4, F10.4)
CONTINUE

RETURN

END
SUBROUTINE CALMUL(WMPL, WMPLD, ACOIL, TCOIL, SLFLUX, ESLFS,
N, DATA, EFLUX, BAIR, BSML, RPERM)

created by don h. colson

file name: CALMUL.FOR

modification history:
02a 81 nov 06 mis cleaning up
01 81 nov 05 mis working
... 81 nov 05 mis explicitly stated dimensions
01a 81 oct 31 don written

purpose:
to compute BAIR(I), BSML(I), and RPERM(I) from three arrays,
EHALL(I), OMRNGE(I), and EFLUX(I)

hardware required: none

software required:
no subroutines needed ---- called in sbr PUTOUT

INPUT PARAMETERS:
WMPLD  the outer Diameter of a cylindrical sample with a
small hole on its axis (meters).
WMPLD  the diameter of the hole (meters).
ACOIL  the turns area product of the coil that measures
flux-linkage. (turns * meters * meters)
TCOIL  the no. of turns of the coil. (turns = dimension-
less = 'i'
SLFLUX  the flux produced by the flux-standard (SLFS),
(Wb)
ESLFS  the output potential of the integrator due to
SLFLUX. (V)
N      the no. of input (and output) 'sets'.
DATA(I, 5)  the parameter range. (Teslas full scale
= T / V)
DATA(I, 2)  the gaussmeter output potential (V)
EFLUX(I)  the integrator output potential due to
flux linkage of coil. (V)

INTERMEDIATE PARAMETERS:
I     ATAN2(0.6,-1.0) (I)
WSML  the area of the sample. (meters * meters)
MAIR  the area associated with the flux measured by the
coil but not in the sample i.e. the area of 'air',
(meters * meters)
FLUXREF  SLFLUX / ESLFS (Wb / V)
FLUX  the total flux measured by the coil i.e.
flux-linkage / (no. of turns) (Wb).
OUTPUT PARAMETERS:

BPAIR(I) The magnetic induction in the air as measured by
the hall-probe at the center of the sample, (I).
BSMPL(I) The magnetic induction in the sample as com-
puted.
PRERM(I) The relative permeability of the sample.

= BSMPL(I) / BPAIR(I) = BSMPL / (MU0*M),

DIMENSION DATA (250, 5), EFLUX(250), BPAIR(250), BSMPL(250)

DIMENSION PRERM(250)

PI = ATAN2(0.0, -1.0)

calculate area of sample

ASMPL = 0.25 * PI * ( SMPL0D ** 2 - SMPL1D ** 2 )

BPAIR = TCOIL / TCOIL - ASMPL

IF ( ESLFS .EQ. 0.0 ) PAUSE ' ESLFS = 0.0'

IF ( TCOIL .EQ. 0.0 ) PAUSE ' TCOIL = 0.0'

FLXPRE = ESLFS / EFLUX / TCOIL

IF ( ASMPL .EQ. 0.0 ) PAUSE ' SAMPLE AREA = 0.0'

TYPE *, ' we now begin calculation loop'

TYPE *, N

IF ( N .GT. 250 ) PAUSE ' N greater than 250'

DO 200 I = 1, N

BPAIR(I) = (-74.I, 5) * DATA(I, 2)

FLUX = ( FLXPRE * EFLUX(I) )

BSMPL(I) = ( FLUX - BPAIR(I) * AAIR ) / ASMPL

PRERM(I) = 9999.

IF ( BPAIR(I) .EQ. 0.0 ) GO TO 200

PRERM(I) = BSMPL(I) / BPAIR(I)

200 CONTINUE

RETURN
END
SUBROUTINE PRTOT (DATE1, TIME1, COILNM, ACOIL, TOTOL, 
SPLODES, SPLOD, SPLID, SPLNTH, GMHMOD, GMHNUM, PRBMOD, 
PRBNUM, PRBCON, OZERO, OMECAL, INTMOD, RINT, CIINT, ATIINT, 
SLFMOD, SLFLUK, ESLFS, VINT0, TSAHP, VINTS, MAXDAC, 
11, XI, ARRAY, TSAMPS, VINTSF, TEND, VEND, CMHM3, 
5 BAIR, BMFL, PFRM)

created by don nelson

file name: PRTOT1.FOR

modification history:
03a 81 nov 39 mis output format changed for more digits
02b 81 nov 13 mis all bytes even dimensioned
02a 81 nov 08 mis cleaning up
01c 81 nov 05 mis working
01d 81 nov 05 mis mode dimensions explicit; added Debug stat
01a 81 nov 05 mis 3 dhn misc corrections and additions
01b 81 nov 04 dhn copied from PTOUT1.FOR to facilitate coding.
01a 81 nov 03 dhn copied SAVE1.FOR to PTOUT1.FOR

purpose:

to print parameters of interest.

hardware required:
none

software required:
AT-11 operating system

DIMENSION ARRAY(230, 5), BAIR(250), BMPL(250), PFRM(230)

In main program the 4 new arrays must be dimensioned (250).

BYTE COMM(72), SPLODES(72), TIME1(3), DATE1(10), CMHM3(72)
BYTE COILNM(10), GMHMOD(10), PRBMOD(10), INTMOD(10), SLFMOD(10)
FAUSE 'print ctrl just before print 500'
PRINT 500
FORMAT(11H1, 8X, 11H, 11H BMPL(I), 10H RPFRM(I), 13X, 
12HBAIR(I), 5X, 6HINT1// 4X, 6HUNIT1, 10H TESLA, 4X, 
2 6HUNIT1, 13X, 2H TESLA, 10H TESLA, // )

'CAUSE 'PRINT SBR just after format 500'

N = 11
DO 501, I = 1, N
BAIR = BMPL(I) - BAIR(I)
501 TYPE #, I

B-40
C
PRINT 502, I, TPML(I), RP1M(I), BaIr(I), DINR
502 FORMAT ( I10, F10.4, F10.3, 10X, F10.6, F10.4)
501 CONTINUE
PAUSE 'Print sbr just before return'

RETURN
END
PROGRAM CMPS1

CREATED BY: MIKE I. GREEN

FILENAME: CMPS1.FOR

MODIFICATION HISTORY

01c 4aug 81 misc comments added, order changed
01b 21 sep 24 misc workings
01a 21 sep 23 misc written

PURPOSE:

TO EXERCISE KINETIC SYSTEMS 3160 POWER SUPPLY CONTROLLER

HARDWARE REQUIRED:

CAMAC CONTROLLER - STANDARD ENGINEERING CORP., MODEL CC-LSJ-11
KS 3130 POWER SUPPLY CONTROLLER

SOFTWARE REQUIRED:

RT-11 OPERATING SYSTEM
STL. ENG. CORP., "PDP-11/CAMAC SUPPORT LIBRARY"

INTEGRAL INTEGER(A-Z)
LOGICAL K ENABLE, DISABLE
DATA ENABLE, DISABLE / TRUE, FALSE /
DATA CRATE, SLOT, SBADDR / 1, 15, 0 /
ADDR = CRDEM(CRAT, CRATE, 0, 0)  ! DECLARE CRATE ADDRESS
CALL CCCZ(CRDEM)  ! INITIALIZE CRATE "DATAWAY Z CYCLE"
CALL CCCI(CRDEM, DISABLE)  ! CLEAR DATAWAY INHIBIT

100 TYPE W, "ENTER DATAWAY "
ACCEPT W, W1
CALL CGSA (16, ADDR, W1)
GO TO 100
CALL EXIT
END
PROGRAM MPX1

created by mike i green

file name: MPX1.FOR

modification history

01s 81 oct 26 misc written

purpose:

set HP-3495A Scanner channel

hardware required:

HP-3495A SCANNER

software required:

RT-11 operating system

SPIE.CAD 81 oct 23

DEUTBI.TXT 81 oct 23

IMPLICIT INTEGER(A-Z)

put all GPIB devices into remote mode

J = IBUF(4, 0)

TYPE J, 'ENTER CHANNEL DESIRED :'

ACCEPT *, CH

GOTO(101, 102, 103, 104, 105, 106, 107, 108, 109, 110), CH

101 J = IBUF(0, 1; '01', 0)  ! scanner to ch 1
     J = IBUF(3, 1)  ! trigger scanner
     GOTO 900

102 J = IBUF(0, 1; '02', 0)  ! scanner to ch 2
     J = IBUF(3, 1)  ! trigger scanner
     GOTO 900

103 J = IBUF(0, 1; '03', 0)  ! scanner to ch 3
     J = IBUF(3, 1)  ! trigger scanner
     GOTO 900

104 J = IBUF(0, 1; '04', 0)  ! scanner to ch 4
     J = IBUF(3, 1)  ! trigger scanner
     GOTO 900

105 J = IBUF(0, 1; '05', 0)  ! scanner to ch 5
     J = IBUF(3, 1)  ! trigger scanner
     GOTO 900
106  J = IBUP(0, 1, '06', 0)
    J = IBUP(3, 1)
    GOTO 900
   !scanner to ch 1
   !trigger scanner

107  J = IBUP(0, 1, '07', 0)
    J = IBUP(3, 1)
    GOTO 900
   !scanner to ch 1
   !trigger scanner

108  J = IBUP(0, 1, '08', 0)
    J = IBUP(3, 1)
    GOTO 900
   !scanner to ch 1
   !trigger scanner

109  J = IBUP(0, 1, '09', 0)
    J = IBUP(3, 1)
    GOTO 900
   !scanner to ch 1
   !trigger scanner

110  J = IBUP(0, 1, '10', 0)
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   !scanner to ch 1
   !trigger scanner

900  CALL EXIT
    END
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LBL - SSRL BEAM LINE DEVELOPMENT
PERMEABILITY MEASUREMENTS OF VANADIUM PERMENDUR

APPENDIX C

DATA SHEETS PROVIDED BY SLAC

Donald H. Nelson and Michael I. Green
Lawrence Berkeley Laboratory
Magnetic Measurements Engineering
The following data sheets were sent to LBL Magnetic Measurements Engineering by SLAC's Magnetic Measurement Group. They represent measurements made on January 14, 1982 of a 1018 cold rolled steel sample, LBL stock no. 9510-10198, vacuum annealed at 1500 °F (840 °C) for one hour then cooled at 300 °F/hour (166 °C/hour).

Similar LBL data is saved in LBL engineering data book MME 644, section labeled "Heat Treated G1018 Carbon Steel", and a summary of both data sets is provided in appendix A of this report.

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Figure C3 Run #1 Magnetization Plot
Figure C4 Run #1A Magnetization Plot
Figure C5 Run #2 Magnetization Plot
Figure C6 Run #2A Magnetization Plot
Figure C7 Run #3 Magnetization Plot
Figure C8 Run #4 Magnetization Plot
Figure C9 Run #4A Magnetization Plot
Figure C1: Magnetization Data

LBL Stock #9510-10198
1/14/82

LBL Data Added to
Copy of SLAC Curve
January 27, 1982 DHN
See Legend

Legend

- SLAC Curve
- LBL Data Set 1124C1.DAT
  Data Plotted (>) Selected From
  101 Ascending MMF Data Pairs
- LBL Data Set 1124C1.DAT
  (Descending MMF)
- LBL Data Set 1124C2.DAT
  (Ascending MMF)
- LBL Data Set 1124C2.DAT
  (Descending MMF)
- LBL Data Set 1130A1.DAT
  (Ascending MMF)
- LBL Data Set 1130A1.DAT
  (Descending MMF)

Magnetic Induction, B
(Teslas)
Relative Permeability $\mu_r$ (Dimensionless)

FIGURE C2 Permeability Data

LBL Stock #9510-10198

1/14/82

LBL Data Added to
Copy of SLAC Curve
January 26, 1982 DHN
See Legend
### Run #1 Data

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**Label for Plot (Yes/No)? Y**

**Another Plot (Yes/No)? Y**

### Run #1A

**Enter Plot Parameters (Yes/No)? Y**

**Plot Size (Inches): X = 12 Y = 8**

**Title for Plot? LIL. Stock #9510-18198 1/14/82**

**Label for Plot (Yes/No)? Y**

**Another Plot (Yes/No)? N**

**Enter 1 to rerun, 2 to restart, 3 to end? 2**

---

**Table CI**

Run #1 Data
***** PERMEAMETER PROGRAM *****

X-SECTIONAL AREA OF SAMPLE IN M^2 = 1.1197E-04.
RANGE: 12 OR 100 OERSTEDS? 100

H(OERSTEDS) = 8.7716 * I(AMPERES)
B(TESLA) = 99.2929 * IVDT(VOLT-SECONDS)

TITLE FOR PLOT ? LEL STOCK #9510-18198 1/14/82 RUN #2

***** DEGAUSSING *****
1-50 OERSTEDS
***** DEGAUSSING *****
3-80 OERSTEDS
***** DEGAUSSING *****
6-80 OERSTEDS
***** DEGAUSSING *****
12-80 OERSTEDS
***** DEGAUSSING *****
24-80 OERSTEDS
***** DEGAUSSING *****
48-80 OERSTEDS
***** DEGAUSSING *****
96-80 OERSTEDS

***** SUMMARY VALUES *****

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LABEL FOR PLOT (YES/NO) ? Y
ANOTHER PLOT (YES/NO) ? Y
ENTER PLOT PARAMETERS (YES/NO) ? Y
PLOT SIZE (INCHES): X = 12 Y = 8
ORIGIN: CT/IN: .
X-SCALE (DER/IN) = 2 X-OFFSET (OER) = -12
Y-SCALE (TESLA/IN) = 5 Y-OFFSET (TESLA) = -2
TITLE FOR PLOT ? LEL STOCK #9510-18198 RUN #2A
LABEL FOR PLOT (YES/NO) ? Y
ANOTHER PLOT (YES/NO) ? N

TABLE CII Run #2 Data
### PERMEAMETER PROGRAM

X-SECTIONAL AREA OF SAMPLE IN $\text{M}^2 = 1.11972 \times 10^{-4}$

**Range:** 12 or 120 Oersteds

**H (Oersteds) =** 0.7716 * I (Amperes)

**B (Tesla) =** 99.0298 * I V (Volt-Seconds)

**Title for Plot:** 7-LIL Stock # 9518-16198 Run 3

#### Degaussing

- 0.15 Oersteds
- 0.30 Oersteds
- 0.60 Oersteds
- 1.20 Oersteds
- 2.40 Oersteds
- 4.80 Oersteds
- 9.60 Oersteds

#### Summary Values

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**Label for Plot:** (YES/NO) ? Y

Another Plot (YES/NO) ? N

**Enter 1 to Rerun, 2 to Restart, 3 to End**?
### PERIMETER PROGRAM

X-SECTIONAL AREA OF SAMPLE IN M² = 1.1197E-04
RANGE: 0.1 OR 0.0266

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**TITLE FOR PLOT?** YES/NO

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### DEGAUSSING

- **1.50 OERSTEDS**
- **3.00 OERSTEDS**
- **6.00 OERSTEDS**
- **9.00 OERSTEDS**
- **24.00 OERSTEDS**
- **48.00 OERSTEDS**
- **96.00 OERSTEDS**

**DEGAUSSING RANGES, 12 OR 120 OERSTEDS?**

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**LABEL FOR PLOT (YES/NO)? Y**

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**REMOTE PLOT?** YES/NO

---

**ENTER PLOT PARAMETERS (YES/NO)? Y**

**PLOT SIZE (INCHES):** X = 10 Y = 8

**TITLE FOR PLOT?** YES/NO

---

**ENTER PLOT PARAMETERS (YES/NO)? N**

**END**
FIGURE C5
Run #2 Magnetization Plot
This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

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