Title
LBL - SSRL BEAM LINE DEVELOPMENT PERMEABILITY MEASUREMENTS OF VANADIUM PERMENDUR

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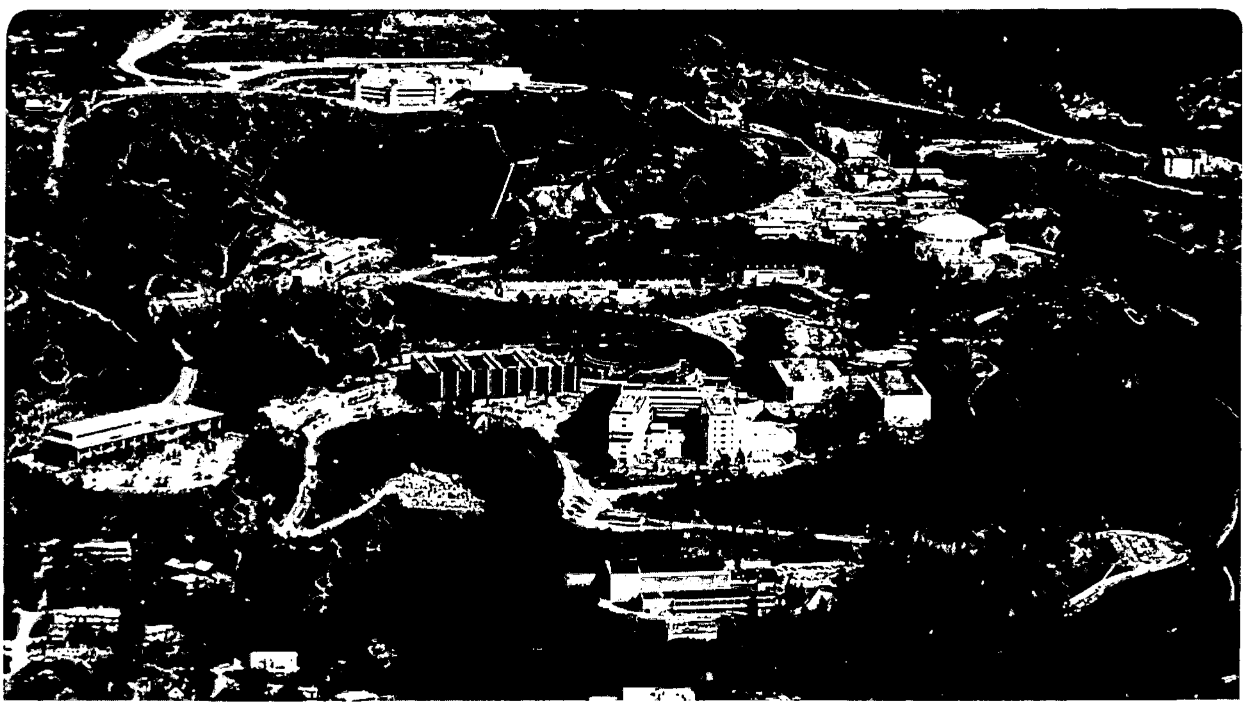

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LBL - SSRL BEAM LINE DEVELOPMENT

PERMEABILITY MEASUREMENTS OF VANADIUM PERMENDUR

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Lawrence Berkeley Laboratory

Magnetic Measurements Engineering

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U.S. Department of Energy under
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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[10] 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.[4]

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.

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ENGINEERING NOTE

Book No. 644

FILE NO. MT 307

SUBJECT PERMEABILIY MEASUREMENTS OF VANADIUM PERMENDUR

NAME M. I. GREEN

DATE 81 DEC 8

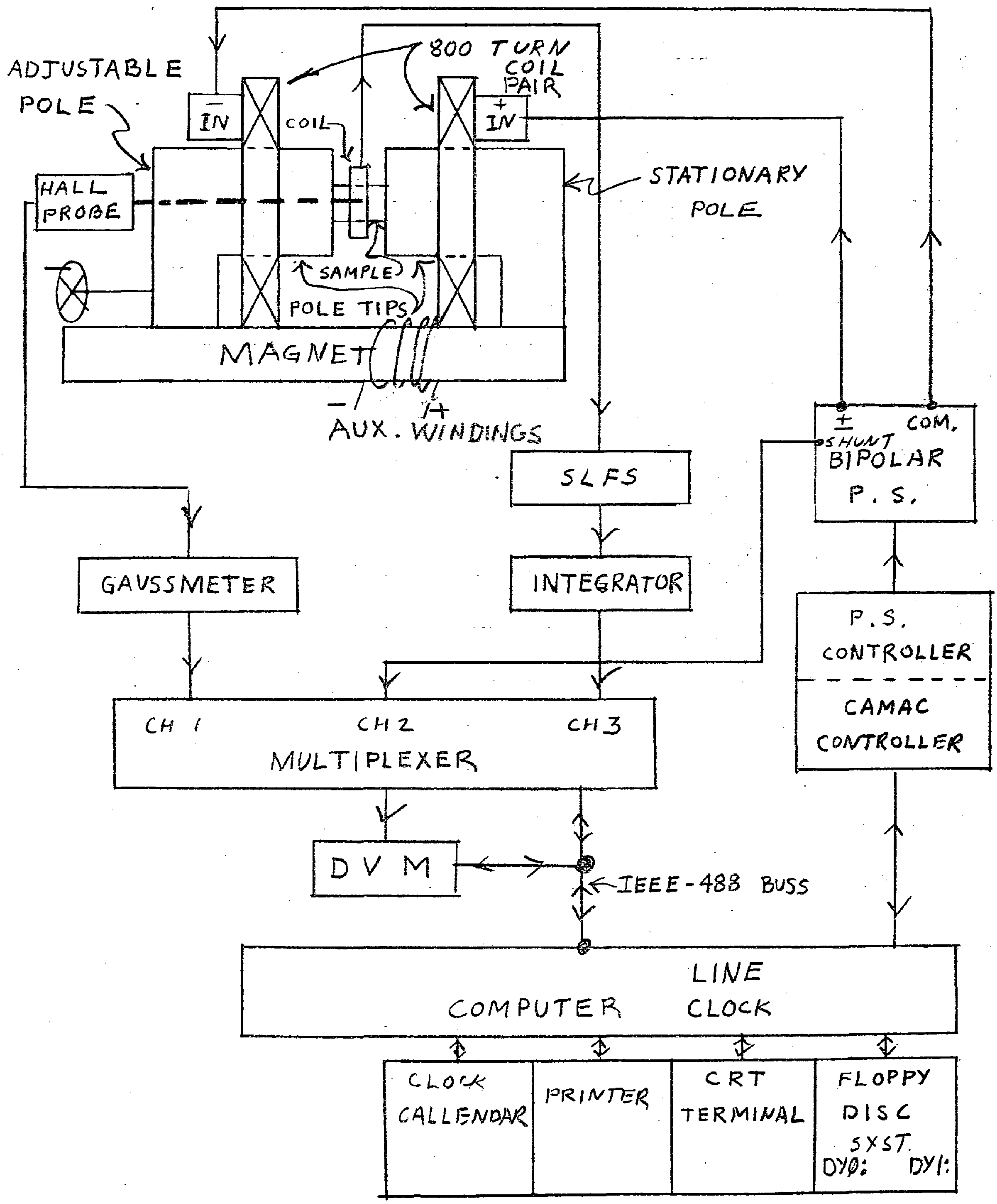
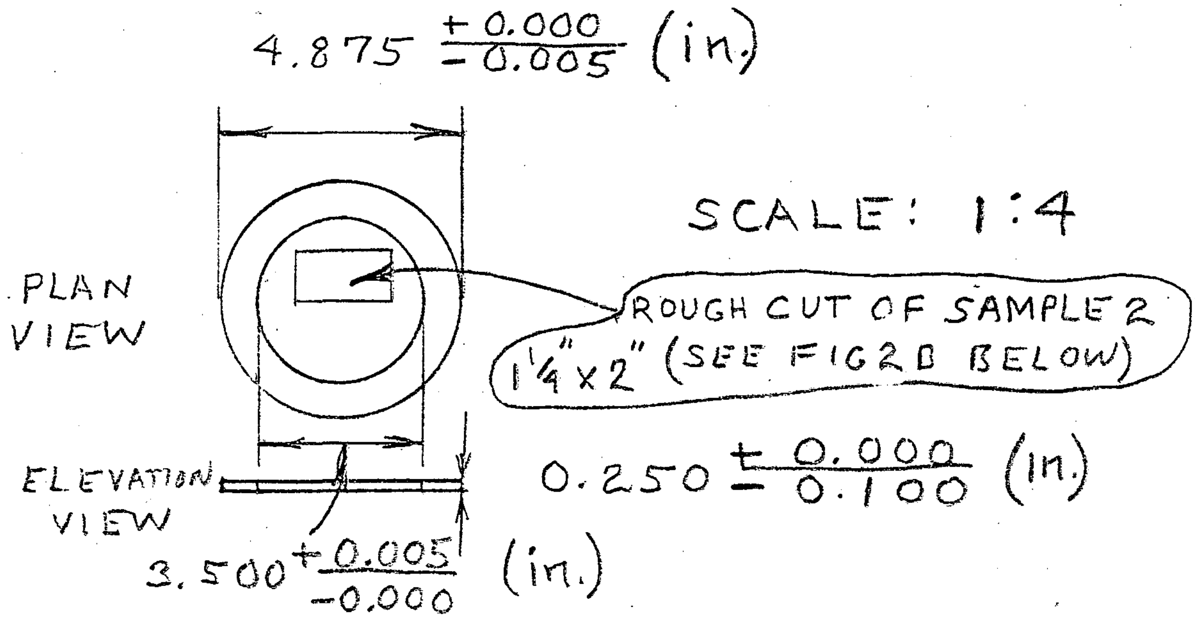


FIGURE 1 HALBACH PERMEAMETER MME DATA ACQUISITION SYSTEM - PHASE II

SUBJECT PERMEABILITY MEASUREMENT SYSTEM COMPARATIVE MSMTS TEST-PLAN

NAME DH Nelson

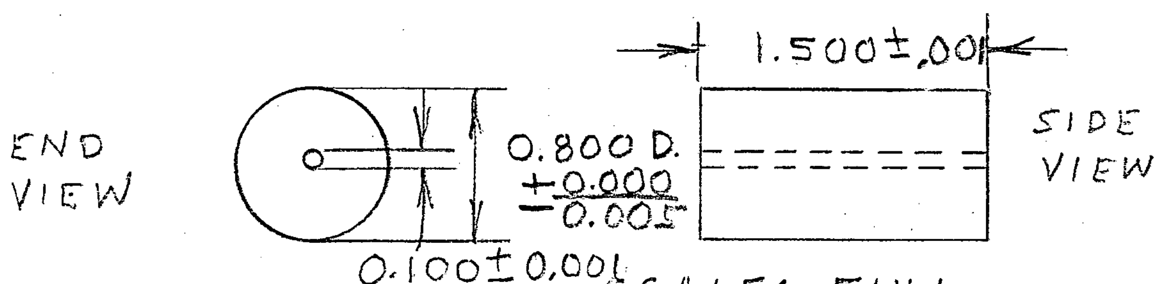
DATE 81 NOV 13



SCALE: 1:4

SAMPLE 1 (DOUGHNUT SHAPED) FOR SLAC SPLIT-COIL-PERMEAMETER

FIG 2a)



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SAMPLE 2 (CYLINDRICAL) FOR LBL MAGNETIC MEASUREMENTS ENGIN. DATA ACQUISITION SYSTEM

FIG 2b)

MATERIAL: LBL STOCK NO. 9510-10198

HEAT TREATMENT: VACUUM ANNEAL (PRES < 10^{-4} TORR)
@ 1500°F (840°C) for 1 Hr.
SLOW COOL @≤300 F°/Hr
(166 C°/Hr)

FIG 2 SAMPLES FOR COMPARATIVE MEASUREMENTS OF μ_r

Ideally, the yoke and especially the pole-tips of the electromagnet should have both a higher saturation induction (B_s) and relative permeability (μ_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_{air}) provides our determination of magnetizing intensity H as follows:

$$H_{air} = B_{air}/\mu_o = B_{air}/4\pi \times 10^{-7} \quad \text{(Ampere-Turns/Meter)}$$

$H_{sample} = H_{air}$ because

a. at any boundary, the tangental 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 (ψ), 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 $H = B_{air}/\mu_0$. The number of cycles could either be preselected or feed back dependent, e.g. ΔH and/or $\Delta\psi$ could be tested for reproducbility. After sufficient cycles are completed, measurements of magnet current, ΔH, 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.

Step	Program Executed	Purpose
1	DEMAG1	Demagnetize permeameter with a previously measured sample. (The sample to be tested next may have been demagnetized by annealing.)
2	PERM7	Measure and store magnet current, flux linkage, B_{air} and elasped 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:
3	PROCC1	Process and print data stored on disk.
4	DEMAG1	
a		With power supply connected to 800 turn windings.
b		With power supply connected to auxiliary windings.
5	PERM7	Repeat 2 except power supply connected to 800 turn windings.
6	PROCC1	Process and print data stored on disk.

TABLE I. TEST EQUIPMENT

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

FIRMWARE

Floppy Discs	MME36 > DYϕ: DATA1 > DY1:

SOFTWARE

PERM7 PROCC1 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 PROCC1. PROCC1 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
bs:                mike i sreen
81 11 30   chansed output format of PROCC1 for more sisnificant disits

updates:           81 dec  9  mis          more documentation text

                   81 nov 30  mis          output format of PROCC1 chansed
                   for more sisnificant disits


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:      MME 36, 'PERMEABILITY RUNNING DISK' is in DY0:.
                   It's directory follows.   This disk is in DY1:.

20-Nov-81
BA    .SYS    7P 01-Mar-80        MPX1  .SAV   27P 26-Oct-81
BINCOM.SAV   10P 01-Mar-80        NL    .SYS    2P 01-Mar-80
CMDP51.SAV   19P 23-Oct-81        PERM7 .SAV   66P 19-Nov-81
CREF  .SAV    6P 01-Mar-80        PERM8 .SAV   67P 19-Nov-81
D     .COM    1P 29-Jan-80        PIP   .SAV   23P 01-Mar-80
DEMAG1.SAV   20P 02-Nov-81        PROCC1.SAV   52P 19-Nov-81
DIR   .SAV   17P 01-Mar-80        RESORC.SAV   15P 01-Mar-80
DUMP  .SAV    8P 01-Mar-80        RT11SJ.SYS   67P 01-Mar-80
DUP   .SAV   41P 01-Mar-80        SETDAT.SAV    2P 08-Feb-81
DY    .SYS    4P 01-Mar-80        SRCCOM.SAV   13P 01-Mar-80
FORMAT.SAV   19P 01-Mar-80        STARTS.COM    1P 23-Feb-81
K52   .SAV   55P 01-Mar-80        SWAP  .SYS   25P 01-Mar-80
LIBR  .SAV   22P 01-Mar-80        TT    .SYS    2P 01-Mar-80
LS    .SYS    2P 01-Mar-80
 27 Files, 593 Blocks
 381 Free blocks
```

TABLE II   Contents of Permeability Running Disk

```
R PERM7
 type sample description (72 characters max):
HEAT TREATED VANADIUM PERMENDUR SAMPLE

PERMEABILITY  PROGRAM   -   THE DATE IS  07-DEC-81    TIME 15:05:32
HEAT TREATED VANADIUM PERMENDUR SAMPLE
 type test description, 72 characters maximum
MAGNET HAS 800 TURNS, SAMPLE NOT DEMAGNETIZED
 type 'Y' if integrator is switched to integrate
Y

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 & sample into magnet
PAUSE --  press return when ready to run


 ENTER MAXDAC :
100


 ENTER HALL PROBE RANGE (GAUSS):
10
     0   -0.0000     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    0.9953       79.     0.1000
    30   -0.0091     0.2014    1.0868       81.     0.1000
    40   -0.0121     0.2950    1.1323       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    1.2295       91.     0.1000
    90   -0.0273     0.7316    1.2488       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    1.2335       99.     0.1000
    70   -0.0212     0.5839    1.2149      101.     0.1000
    60   -0.0182     0.5021    1.1949      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     0.1408    0.2395      128.     0.0100


     0    100
 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 XXXXXX.DAT
1207A2
 type 'Y' if you want to run same sample again
N
```

TABLE III Data Acquisition Dialog

$$B = \frac{\psi_{obs} - \psi_{air}}{nA_{sample}} = \frac{\psi_{obs} - nB_{air}A_{air}}{n\pi(r_o^{-2} - r_i^2)}$$

$$= \frac{\psi_{obs} - nB_{air}\left[\pi r_i^2 + \frac{nA}{n}_{coil} - \pi r_o^2\right]}{n\pi(r_o^2 - r_i^2)} \qquad \text{Equation (1)}$$

B = magnetic induction [Teslas]

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

ψ_{SLFS} = Flux linkage produced by flux standard SLFS 40 = 0.0210 [Wb]

E_{SLFS} = Integrator output potential due to ψ_{SLFS} [V]

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

ψ_{air} = Flux linkage of coil not linking sample [Wb]

$nA = nA_{B-162}$ = turns area product of coil B-162 = 0.0411 [m^2]

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

r_o = outer radius of sample = 0.01016 [m]

r_i = inner radius of sample = 0.00127 [m]

B_{air} = 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.

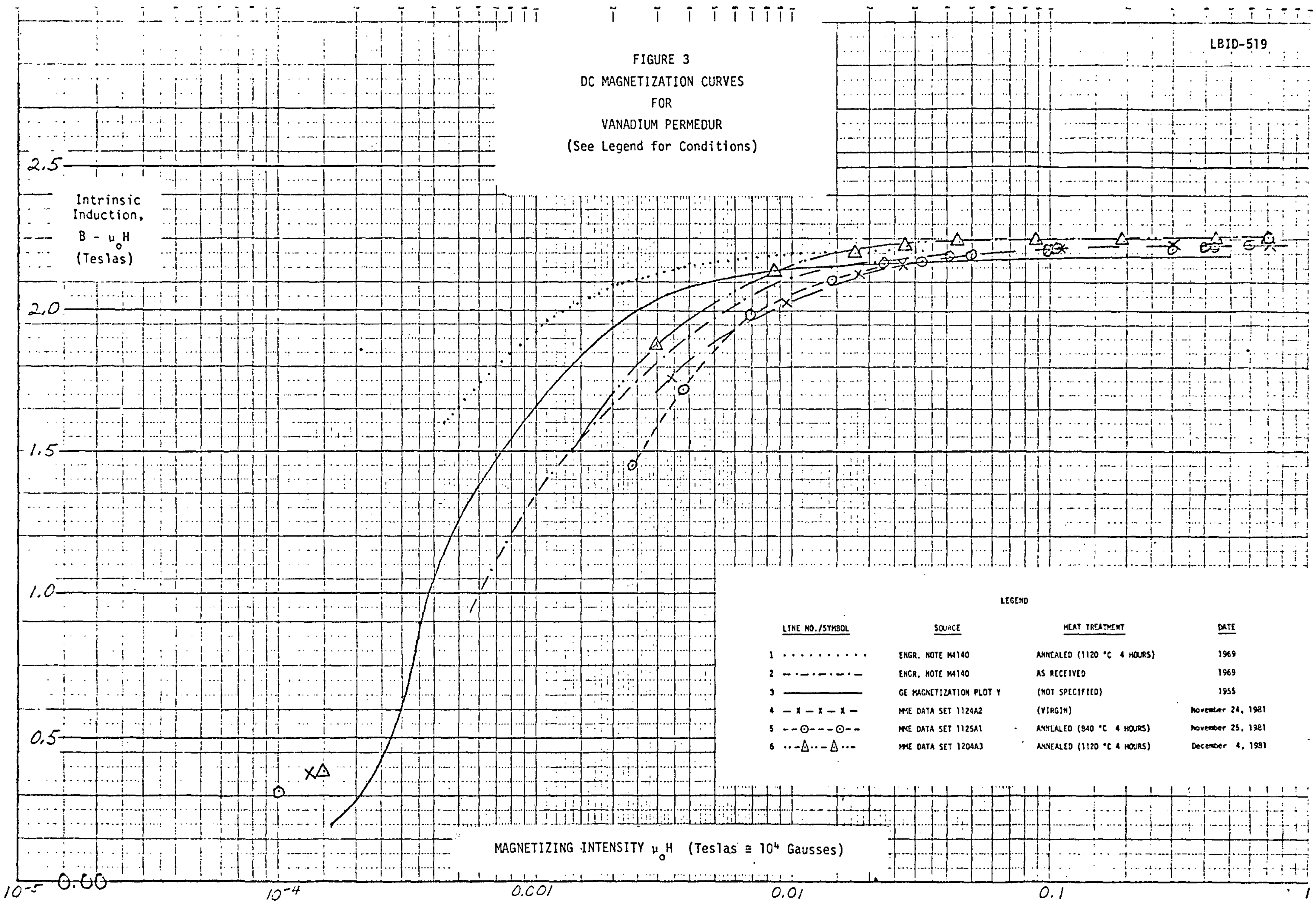
FIGURE 3
DC MAGNETIZATION CURVES
FOR
VANADIUM PERMEDUR
(See Legend for Conditions)
Intrinsic Induction, B - μ_oH (Teslas)
2.5
2.0
1.5
1.0
0.5
0.00
MAGNETIZING INTENSITY μ_oH (Teslas ≡ 10^4 Gausses)
10^{-5}
10^{-4}
0.001
0.01
0.1
1
LEGEND
LINE NO./SYMBOL
SOURCE
HEAT TREATMENT
DATE
1 . . . . ENGR. NOTE M4140 ANNEALED (1120 °C 4 HOURS) 1969
2 — · — · — · — ENGR. NOTE M4140 AS RECEIVED 1969
3 ———— GE MAGNETIZATION PLOT Y (NOT SPECIFIED) 1955
4 — X — X — X — MME DATA SET 1124A2 (VIRGIN) November 24, 1981
5 - - ⊙ - - - ⊙ - - MME DATA SET 1125A1 ANNEALED (840 °C 4 HOURS) November 25, 1981
6 · · - Δ · · - Δ · · · MME DATA SET 1204A3 ANNEALED (1120 °C 4 HOURS) December 4, 1981

I	BSMPL(I)	RPERM(I)	BAIR(I)	BINTR
(UNIT)	(TESLA)	(UNIT)	(TESLA)	(TESLA)
1	0.3862	2553.860	0.000151	0.3860
2	1.8754	662.768	0.002830	1.8725
3	2.1476	249.740	0.008600	2.1390
4	2.2225	126.016	0.017637	2.2049
5	2.2520	84.404	0.026681	2.2253
6	2.2701	63.231	0.035901	2.2342
7	2.2836	50.874	0.044888	2.2387
8	2.2954	42.728	0.053720	2.2416
9	2.3061	36.919	0.062463	2.2436
10	2.3161	32.545	0.071167	2.2450
11	2.3258	29.152	0.079782	2.2460
12	2.3353	26.418	0.088400	2.2469
13	2.3446	24.173	0.096995	2.2476
14	2.3527	21.349	0.110201	2.2425
15	2.3615	19.930	0.118489	2.2430
16	2.3705	18.658	0.127053	2.2435
17	2.3794	17.555	0.135537	2.2439
18	2.3883	16.579	0.144059	2.2443
19	2.3971	15.706	0.152630	2.2445
20	2.4060	14.935	0.161100	2.2449
21	2.4147	14.244	0.169520	2.2452
22	2.4234	13.612	0.178030	2.2454
23	2.4320	13.042	0.186480	2.2456
24	2.4407	12.525	0.194870	2.2458
25	2.4493	12.047	0.203320	2.2460
26	2.4579	11.609	0.211720	2.2462
27	2.4665	11.206	0.220110	2.2464
28	2.4751	10.833	0.228470	2.2466
29	2.4836	10.486	0.236840	2.2468
30	2.4921	10.165	0.245150	2.2469
31	2.5005	9.864	0.253500	2.2470
32	2.5090	9.584	0.261780	2.2472
33	2.5174	9.321	0.270070	2.2473
34	2.5257	9.074	0.278340	2.2474
35	2.5341	8.843	0.286560	2.2475
36	2.5424	8.623	0.294830	2.2476
37	2.5507	8.420	0.302950	2.2478
38	2.5590	8.225	0.311110	2.2479
39	2.5672	8.040	0.319320	2.2479
40	2.5754	7.867	0.327390	2.2480
41	2.5835	7.702	0.335440	2.2481
42	2.5917	7.544	0.343560	2.2481
43	2.5998	7.395	0.351540	2.2482
44	2.6079	7.253	0.359550	2.2483
45	2.6159	7.119	0.367470	2.2485
46	2.6239	6.989	0.375450	2.2485
47	2.6319	6.867	0.383280	2.2486
48	2.6398	6.749	0.391140	2.2487
49	2.6477	6.636	0.398980	2.2487
50	2.6556	6.530	0.406700	2.2489
51	2.6633	6.425	0.414510	2.2488
52	2.6711	6.327	0.422180	2.2489
53	2.6788	6.232	0.429840	2.2490
54	2.6865	6.142	0.437430	2.2491
55	2.6941	6.055	0.444930	2.2492

TABLE IV MME DATA SET 1204A3 DAT
(Page 1/4)

I (UNIT)	BSMPL(I) (TESLA)	RPERM(I) (UNIT)	BAIR(I) (TESLA)	BINTR (TESLA)
56	2.7017	5.972	0.452400	2.2493
57	2.7092	5.892	0.459800	2.2494
58	2.7166	5.816	0.467130	2.2495
59	2.7240	5.742	0.474420	2.2495
60	2.7312	5.671	0.481600	2.2496
61	2.7385	5.603	0.488750	2.2498
62	2.7457	5.537	0.495920	2.2498
63	2.7528	5.474	0.502850	2.2500
64	2.7598	5.412	0.509920	2.2499
65	2.7668	5.355	0.516680	2.2501
66	2.7737	5.298	0.523500	2.2502
67	2.7805	5.244	0.530180	2.2503
68	2.7872	5.192	0.536880	2.2504
69	2.7939	5.142	0.543320	2.2506
70	2.8005	5.093	0.549860	2.2506
71	2.8069	5.046	0.556230	2.2507
72	2.8133	5.001	0.562570	2.2507
73	2.8196	4.958	0.568670	2.2509
74	2.8258	4.916	0.574860	2.2509
75	2.8319	4.875	0.580870	2.2511
76	2.8380	4.836	0.586810	2.2512
77	2.8439	4.799	0.592550	2.2514
78	2.8498	4.762	0.598450	2.2514
79	2.8556	4.727	0.604080	2.2515
80	2.8613	4.693	0.609660	2.2516
81	2.8668	4.661	0.615060	2.2518
82	2.8724	4.630	0.620380	2.2520
83	2.8778	4.598	0.625820	2.2519
84	2.8831	4.570	0.630880	2.2523
85	2.8884	4.542	0.635980	2.2524
86	2.8935	4.514	0.641000	2.2525
87	2.8984	4.487	0.645960	2.2525
88	2.9034	4.461	0.650790	2.2526
89	2.9083	4.436	0.655630	2.2526
90	2.9131	4.411	0.660340	2.2527
91	2.9178	4.388	0.664910	2.2529
92	2.9225	4.366	0.669360	2.2531
93	2.9270	4.344	0.673840	2.2531
94	2.9314	4.323	0.678050	2.2534
95	2.9358	4.302	0.682440	2.2534
96	2.9402	4.282	0.686680	2.2535
97	2.9444	4.263	0.690700	2.2537
98	2.9486	4.244	0.694760	2.2538
99	2.9527	4.225	0.698870	2.2539
100	2.9568	4.207	0.702810	2.2540
101	2.9608	4.190	0.706710	2.2541
102	2.9575	4.204	0.703440	2.2541
103	2.9540	4.220	0.699980	2.2540
104	2.9505	4.235	0.696650	2.2538
105	2.9468	4.251	0.693210	2.2536
106	2.9433	4.268	0.689580	2.2537
107	2.9395	4.285	0.685930	2.2536
108	2.9357	4.302	0.682360	2.2534
109	2.9319	4.321	0.678520	2.2534
110	2.9279	4.340	0.674660	2.2533
111	2.9239	4.359	0.670740	2.2532
112	2.9198	4.379	0.666790	2.2530
113	2.9156	4.399	0.662720	2.2529
114	2.9113	4.420	0.658620	2.2527
115	2.9069	4.442	0.654360	2.2526

TABLE IV MME DATA SET 1204A3 DAT
(Page 2/4)

I	BSMPL(I)	RPERM(I)	BAIR(I)	BINTR
<UNIT>	<TESLA>	<UNIT>	<TESLA>	<TESLA>
116	2.9025	4.466	0.649920	2.2526
117	2.8979	4.489	0.645610	2.2523
118	2.8933	4.514	0.640940	2.2524
119	2.8885	4.539	0.636310	2.2522
120	2.8836	4.565	0.631670	2.2519
121	2.8786	4.592	0.626820	2.2518
122	2.8736	4.621	0.621870	2.2517
123	2.8684	4.650	0.616810	2.2516
124	2.8631	4.681	0.611650	2.2515
125	2.8578	4.714	0.606270	2.2515
126	2.8522	4.746	0.601000	2.2512
127	2.8467	4.780	0.595500	2.2512
128	2.8410	4.817	0.589820	2.2512
129	2.8351	4.853	0.584190	2.2510
130	2.8292	4.891	0.578420	2.2508
131	2.8233	4.932	0.572440	2.2508
132	2.8171	4.974	0.566420	2.2507
133	2.8109	5.017	0.560290	2.2506
134	2.8046	5.061	0.554130	2.2504
135	2.7981	5.108	0.547830	2.2503
136	2.7915	5.156	0.541410	2.2501
137	2.7849	5.208	0.534770	2.2502
138	2.7781	5.259	0.528230	2.2499
139	2.7713	5.314	0.521480	2.2498
140	2.7643	5.371	0.514640	2.2497
141	2.7573	5.431	0.507720	2.2495
142	2.7502	5.494	0.500570	2.2496
143	2.7429	5.557	0.493550	2.2493
144	2.7357	5.626	0.486260	2.2494
145	2.7282	5.695	0.479020	2.2492
146	2.7208	5.768	0.471670	2.2491
147	2.7132	5.845	0.464200	2.2490
148	2.7056	5.925	0.456650	2.2490
149	2.6979	6.009	0.448980	2.2489
150	2.6902	6.096	0.441330	2.2489
151	2.6823	6.186	0.433610	2.2487
152	2.6744	6.280	0.425860	2.2486
153	2.6665	6.378	0.418060	2.2484
154	2.6586	6.481	0.410210	2.2484
155	2.6505	6.590	0.402230	2.2483
156	2.6425	6.703	0.394230	2.2482
157	2.6343	6.820	0.386250	2.2481
158	2.6262	6.945	0.378130	2.2481
159	2.6180	7.074	0.370070	2.2479
160	2.6099	7.212	0.361900	2.2480
161	2.6016	7.353	0.353800	2.2478
162	2.5932	7.504	0.345560	2.2477
163	2.5850	7.662	0.337360	2.2476
164	2.5766	7.828	0.329140	2.2475
165	2.5682	8.006	0.320780	2.2474
166	2.5598	8.190	0.312570	2.2473
167	2.5514	8.387	0.304200	2.2472
168	2.5429	8.597	0.295810	2.2471
169	2.5344	8.817	0.287450	2.2469
170	2.5259	9.050	0.279120	2.2468
171	2.5174	9.302	0.270620	2.2468
172	2.5088	9.567	0.262230	2.2466
173	2.5002	9.854	0.253740	2.2465
174	2.4915	10.159	0.245250	2.2463
175	2.4829	10.485	0.236800	2.2461

TABLE IV MME DATA SET 1204A3 DAT
(Page 3/4)

I	BSMPL(I)	RPERM(I)	BAIR(I)	BINTR
(UNIT)	(TESLA)	(UNIT)	(TESLA)	(TESLA)
176	2.4741	10.840	0.228230	2.2459
177	2.4654	11.223	0.219680	2.2457
178	2.4567	11.639	0.211080	2.2456
179	2.4479	12.086	0.202540	2.2454
180	2.4391	12.576	0.193940	2.2451
181	2.4303	13.115	0.185300	2.2450
182	2.4214	13.702	0.176720	2.2447
183	2.4125	14.357	0.168040	2.2445
184	2.4035	15.080	0.159380	2.2441
185	2.3945	15.885	0.150740	2.2438
186	2.3855	16.791	0.142071	2.2435
187	2.3764	17.816	0.133382	2.2430
188	2.3673	18.992	0.124651	2.2427
189	2.3582	20.331	0.115990	2.2422
190	2.3489	21.899	0.107258	2.2416
191	2.3404	24.989	0.093655	2.2467
192	2.3312	27.327	0.085309	2.2459
193	2.3215	30.342	0.076510	2.2450
194	2.3114	34.154	0.067677	2.2438
195	2.3010	39.120	0.058818	2.2421
196	2.2897	45.932	0.049850	2.2399
197	2.2770	55.906	0.040729	2.2363
198	2.2616	71.902	0.031454	2.2301
199	2.2387	102.242	0.021896	2.2168
200	2.1913	174.352	0.012568	2.1788
201	2.0234	466.621	0.004336	2.0191

DISK FILE : 1204A3.DAT
VANADIUM PERMENDUR, REHEATTREATED TO 1120 CELSIUS, 4 HR. SOAK
800 T, MAXDAC = 1000. STEEL POLES AFTER DEMAG 800 T ONLY MAXDAC = 1024.
RUN LOOKS O.K.
04-DEC-81 18:34:00
SEARCH COIL: B-162 INTEGRATOR: MOD71#01 FLUX STANDARD: SLFS 40
GAUSSMETER: BELL 620, S/N: 501586. HALL PROBE: SAE40618, S/N: 120011.
MAXDAC = 1000 201 DATA SETS 5 PARAMETERS LONG

TABLE IV MME DATA SET 1204A3 DAT
(Page 4/4)

TABLE V. DATA SET IDENTIFICATION

Data Set	Description	No. Magnetizing Windings
1124A1.DAT	Vanadium Permendur-- Virgin	13
1124A2.DAT	" " " "	800
1124B1.DAT	Vanadium Permendur-- Annealed 815°C--1 hour	13
1124B2.DAT	" " " "	800
1125A1.DAT	" " " " (repeat)	800
1124C1.DAT	Carbon Steel-- Annealed 840°C--1 hour	13
1124C2.DAT	" " " "	800
1124A1.DAT	" " " "	45
1204.DAT	Vanadium Permendur-- Annealed 1120°C--4 hours	45
1204A2.DAT	" " " " (repeat)	45
1204A3.DAT	" " " "	800
1204B1.DAT	" " " " (with heat treated Vanadium Permendur Pole Tips)	800

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 ± 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."[7] If improved accuracy in the measurement of B_{air} is warranted, a simple field calibration procedure could improve the accuracy of B_{air} to $\pm$ 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.[2] 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[1] 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 ψ_{total}, A_{sample}, nA_{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 (ψ) with an absolute accuracy of ± 0.1 percent (ψ). 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 C^o) and long time periods (years).[8]

2. We are capable of determining the cross-sectional area of the sample (A_{sample}) to better than ± 0.1 percent (A_{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_{air} to ± 0.2 percent (B_{air}).

D. INTERPRETING THE MEASUREMENTS

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

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

$$\approx \frac{\psi_{total} - nB_{air}A_{air}}{nA_{sample}} = \frac{\psi_{total} - nB_{air}\left(\frac{nA_{coil}}{n} - A_{sample}\right)}{nA_{sample}}$$

The first two terms are related to B_{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_{air} is approximate. Equation 1 could be refined by including the integrated effect of variations in B_{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:

Task	Job Classification	Man Hrs.
preparation and set up	9132	8
sample preparation	9147	2
heat treatment	9147	0-4
tests including demagnetizing	9132	4/sample
report	9132	4-24

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 thouroughly. (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

1. Halbach, Kaviani, Nelson, "Accurate Permeability at Low Magnetic Field for Doublet III Project," LBL Report MT-276, March 1, 1979.

2. Ramo, S., Whinnery, J. R., and VanDuzer, T., Fields and Waves in Communications Electronics, John Wiley and Sons, Inc., 1965, Libr. of Congress Catalog No. 65-19477, Section 2.35, Page 129.

3. Kettner, A. E., "DC Magnetization Curves for Various Magnetic Materials," General Engineering Laboratory, General Electric Company, Schenectady, N.Y., October 6, 1955 (LBL Mech. Engr. Drawing No. MMS-55-0730).

4. Nelson, D. H., Green, M. I., LBL Magnetic Measurements Engineering Data Book MT 644, "Permeability of Vanadium Permendur (SSRL Beam Line Development)," 1981.

5. American Society for Testing and Materials (A.S.T.M.), Annual Book of Standards, Part 44, Designation A341-69, Reapproved 1974 (Page 36, A7.3.3.3).

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

7. F. W. Bell Catalog, "Third Generation Gaussmeter Probes," Document No. 60700, March 1980.

8. Nelson, D. H. and Green, M. I., LBL Magnetic Measurements Engineering Data Book No. 553, "Square Loop Flux Standard (SLFS) Calibrations," 1974-1978.

9. ASTM Annual Book of Standards Part 44, Designation A34-70, Reapproved 1976, (page 2).

10. Nelson, D.H., Green, M.I., LBL memorandum to Tom Elioff et. al.; Subject: Permeability Measurements; Nov. 11, 1981.

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Note: Appendices B and C to be distributed on request only.

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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 indentical material (Cold Rolled 1018 Carbon Steel LBL stock no. 9510 - 10198 Vacuum Annealed at $1500^{o}F$ ($840^{o}C$) for 1 hour then cooled at 300 F^{o}/Hr (166 C^{o}/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.

Organization	Test No.	Range of Magnetic Intensity [Oe] Min	Max	Date
LBL	1124C1.DAT	0.69	36.8	11/24/81
LBL	1124C2.DAT	0.37	7056.	11/24/81
LBL	1130A1.DAT	0.35	298.9	11/30/81
SLAC	1	1.54	83.2	1/14/82
"	2	1.45	84.7	1/14/82
"	3	0.18	9.1	1/14/82
"	4	1.54	86.1	1/14/82

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 $\mu_r = B/\mu_o H$ 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 815 °C
(For Reference 6 Points Plotted for 1020 Hot Rolled Steel Annealed at 1500 °F)

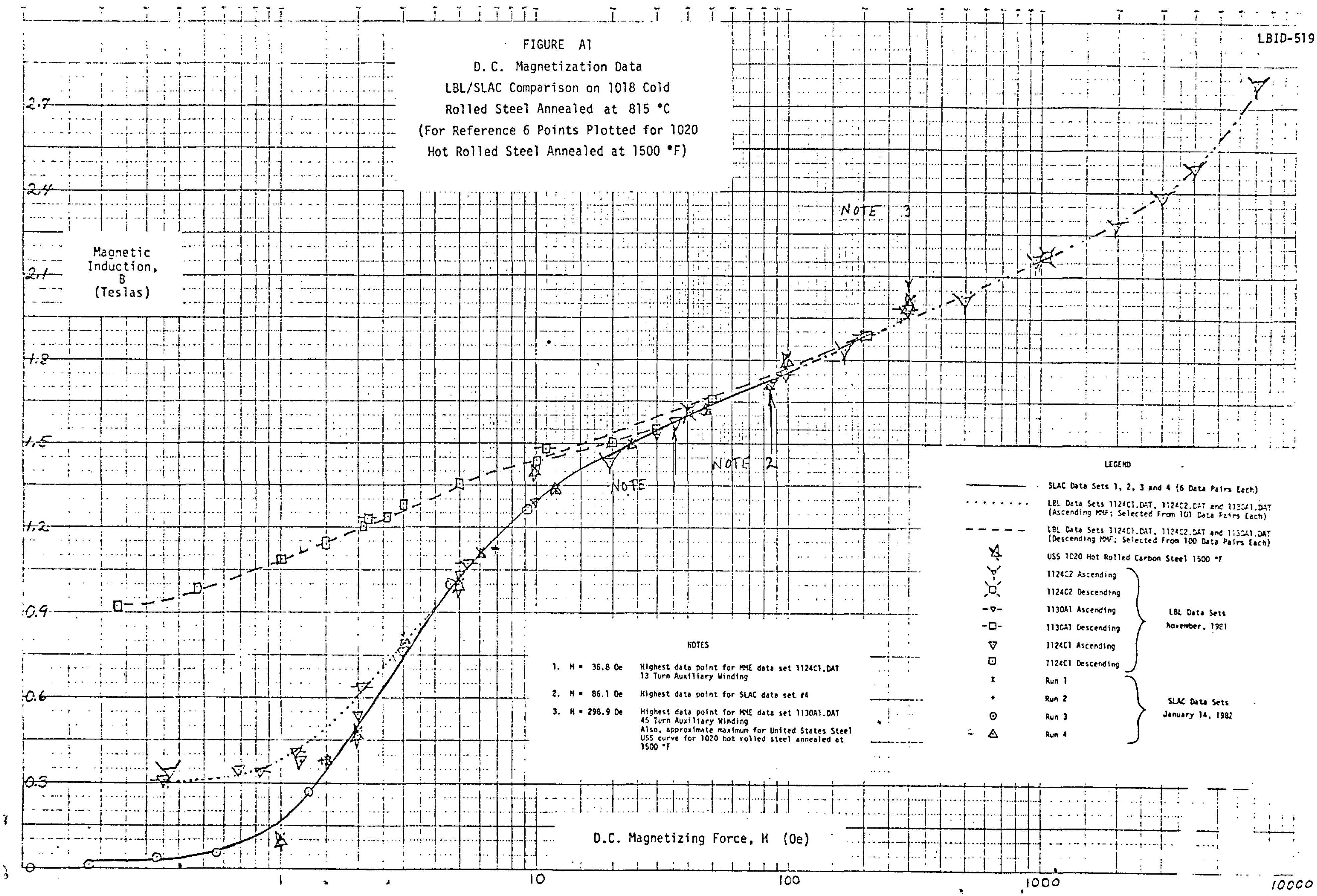
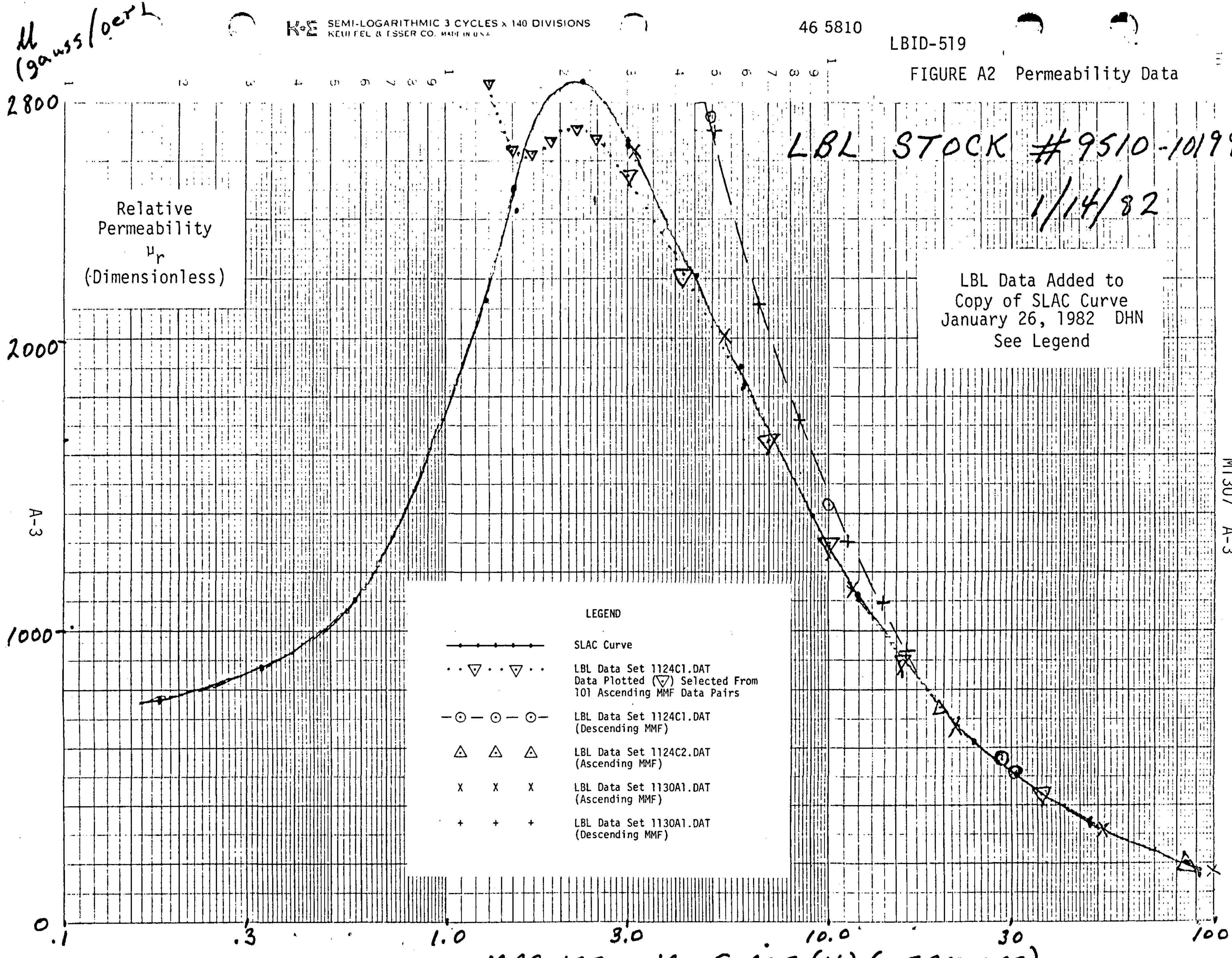


FIGURE A2 Permeability Data



1. In the range 5.0 $\leq$ H $\leq$ 86 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 completly 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 permeamenter, magnetic induction is determined from a measurement of a change of flux-linkage when magnetic intensity is chaged 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.

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.

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AUTHOR Donald H. Nelson, Michael I. Green — DEPARTMENT Electronics Engineering	LOCATION B25A-124	DATE February 4, 1982	

LBL - SSRL BEAM LINE DEVELOPMENT

PERMEABILITY MEASUREMENTS OF VANADIUM PERMENDUR

APPENDIX B

SOURCE LISTINGS, LBL PERMEABILITY CODES

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Magnetic Measurements Engineering

APPENDIX B

Source Listings, LBL Permeability Codes

Table of Contents MT 307 Appendix B

```
file:               DATA.TXT
created:            81 nov 20
by:                 mike i green
81 11 30   changed output format of PROCC1 for more significant digits

updates:            81 dec  9  mig          more documentation text

                    81 nov 30  mig          output format of PROCC1 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:       MME 36, 'PERMEABILITY RUNNING DISK' is in DY0:.
                    It's directory follows.   This disk is in DY1:.

20-Nov-81
DA    .SYS     7P 01-Mar-80        MPX1  .SAV     27P 26-Oct-81
BINCOM.SAV    10P 01-Mar-80        NL    .SYS      2P 01-Mar-80
CMCP81.SAV    19P 23-Oct-81        PERM7 .SAV     66P 19-Nov-81
CREF  .SAV     6P 01-Mar-80        PERM8 .SAV     67P 19-Nov-81
D     .COM     1P 29-Jan-80        PIP   .SAV     23P 01-Mar-80
DEMAG1.SAV    20P 02-Nov-81        PROCC1.SAV     52P 19-Nov-81
DIR   .SAV    17P 01-Mar-80        RESORC.SAV     13P 01-Mar-80
DUMP  .SAV     5P 01-Mar-80        RT11SJ.SYS     67P 01-Mar-80
DUP   .SAV    41P 01-Mar-80        SETDAT.SAV      2P 08-Feb-81
DY    .SYS     4P 01-Mar-80        SRCCOM.SAV     13P 01-Mar-80
FORMAT.SAV    19P 01-Mar-80        STARTS.COM      1P 23-Feb-81
K52   .SAV    55P 01-Mar-80        SWAP  .SYS     25P 01-Mar-80
LIBR  .SAV    22P 01-Mar-80        TT    .SYS      2P 01-Mar-80
LS    .SYS     2P 01-Mar-80
 27 Files, 593 Blocks
 381 Free blocks

The disk MME 36 can be generated from two master backup disks,
MG 30 which has just operating system type files, plus the
neccessary *.SAV files from MG 29.

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


updates:
 09-Dec-81
CALMU1.FOR     6   04-Nov-81          PERM7 .SAV     66   19-Nov-81
CALMU1.LST    11   15-Nov-81          PERM8 .BAK     16   17-Nov-81
CALMU1.OBJ     9   15-Nov-81          PERM8 .FOR     16   19-Nov-81
CMCP81.FOR     2   24-Sep-81          PERM8 .LST     27   19-Nov-81
CMCP81.LST     3   23-Oct-81          PERM8 .MAP     13   19-Nov-81
CMCP81.OBJ     7   23-Oct-81          PERM8 .OBJ     28   19-Nov-81
CMCP81.SAV    19   23-Oct-81          PERM8 .SAV     67   19-Nov-81
COILP1.FOR     1   15-Nov-81          PREINT.FOR      5   15-Nov-81
COILP1.LST     4   15-Nov-81          PREINT.LST      8   15-Nov-81
COILP1.OBJ     5   15-Nov-81          PREINT.OBJ      9   15-Nov-81
DELAY1.FOR     1   15-Nov-81          PREPR1.FOR      3   13-Nov-81
DELAY1.LST     3   15-Nov-81          PREPR1.LST      4   04-Nov-81
DELAY1.OBJ     3   15-Nov-81          PREPR1.OBJ      6   04-Nov-81
```

```
DEMAG1.FOR     4  15-Oct-81      PRNT01.FOR     4  30-Nov-81
DEMAG1.LST     7  23-Oct-81      PRNT01.LST     9  30-Nov-81
DEMAG1.OBJ     9  23-Oct-81      PRNT01.OBJ     6  30-Nov-81
DEMAG1.SAV    20  02-Nov-81      PROCC1.FOR     7  19-Nov-81
DEVTBL.TXT     1  23-Oct-81      PROCC1.LST    13  19-Nov-81
DRFTC2.FOR     3  06-Nov-81      PROCC1.OBJ    16  19-Nov-81
DRFTC2.LST     6  15-Nov-81      PROCC1.SAV    52  30-Nov-81
DRFTC2.OBJ     6  13-Nov-81      PSTINT.FOR     4  01-Nov-81
HALLP1.FOR     2  15-Nov-81      PSTINT.LST     8  01-Nov-81
HALLP1.LST     4  15-Nov-81      PSTINT.OBJ     9  01-Nov-81
HALLP1.OBJ     5  15-Nov-81      PTOUT1.FOR     5  16-Nov-81
INGRP1.FOR     1  15-Nov-81      PTOUT1.LST    10  16-Nov-81
INGRP1.LST     4  15-Nov-81      PTOUT1.OBJ     8  16-Nov-81
INGRP1.OBJ     5  15-Nov-81      SAVE3 .FOR     5  19-Nov-81
INIT  .FOR     4  19-Nov-81      SAVE3 .LST    10  19-Nov-81
INIT  .LST     8  19-Nov-81      SAVE3 .OBJ    11  19-Nov-81
INIT  .OBJ     8  19-Nov-81      SLFSP1.FOR     1  15-Nov-81
L     .BAK     1  19-Nov-81      SLFSP1.LST     4  15-Nov-81
L     .COM     1  19-Nov-81      SLFSP1.OBJ     5  15-Nov-81
MPX1  .FOR     4  26-Oct-81      SMPLP1.FOR     2  15-Nov-81
MPX1  .LST     6  26-Oct-81      SMPLP1.LST     3  13-Nov-81
MPX1  .OBJ    11  26-Oct-81      SMPLP1.OBJ     5  13-Nov-81
MPX1  .SAV    27  26-Oct-81      VOMIT3.FOR     4  19-Nov-81
P     .COM     1  02-Apr-81      VOMIT3.LST     9  19-Nov-81
PERM7 .FOR    14  19-Nov-81      VOMIT3.OBJ    10  19-Nov-81
PERM7 .LST    25  19-Nov-81      1119A1.DAT     3  19-Nov-81
PERM7 .MAP    15  19-Nov-81      1119A2.DAT     3  19-Nov-81
PERM7 .OBJ    26  19-Nov-81
 81 Files, 801 Blocks
 173 Free blocks
```

The above were compiled and linked using a copy of the master backup disk MG 28 plus the file CMCLIB.OBJ from MG 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 11/23)
        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 DELAY 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 gaussmeter zero offset.
6. Formatting output 'constants' so that they are identified.

(PS Don, the above took 6 minutes. 81 dec 9 sid)

```
      PROGRAM DEMAG1
C
C     created by mike i green
C
C     file name:  DEMAG1.FOR
C
C     modification history
C
C     01c  81 oct 13  mig  reduce cycle time by commenting out a
C                          delay caused by CALL TIME
C     01b  81 OCT  9  mig  working
C     01a  81 oct 09  mig  copied from CMCPS3
C
C
C     purpose:
C
C         demagnitization of samples in electromagnet by cycling power
C         supply to plus and minus maximum current and then decreasing
C         maximums
C
C         cycle LLNL 30 amp bipolar powersuply plus and minus 30 amps by
C         cycling the KINETIC SYSTEMS 3160 POWER SUPPLY CONTROLLER from
C         zero to 1024 then to -1024, then back to zero.  we then decrease
C         maximum DAC count by 1 until we get to maximum of 0.
C
C
C     hardware required:
C
C     CAMAC controller - STANDARD ENGINEERING CORP. MODEL CC-LSI-11
C     KS 3130 POWER SUPPLY CONTROLLER
C     LLNL BIPOLAR 30 AMP, 20 VOLT PS, DWG LEA 74-4035
C
C
C     software required:
C
C     RT-11 operating system
C     STD. ENG. CORP., "PDP-11/CAMAC SUPPORT LIBRARY"
C
C
         IMPLICIT INTEGER(A-Z)
         BYTE TIME1(8)
         LOGICAL*1 ENABLE, DISABL
         DATA ENABLE, DISABL /.TRUE.,.FALSE./
         DATA CRATE, SLOT, SBADDR /1, 15, 0/
         CADDR = CDREG( ,, CRATE, 0, 0)   !declare crate address
         CALL CCCZ(CADDR)                 !initialize crate "dataway Z cycle"
         CALL CCCI(CADDR, DISABL)         !clear dataway inhibit
C
         ADDR = CDREG( ,, CRATE, SLOT, SBADDR )
         IDAC = 0
         INC  = 1
         TYPE *, ' ENTER MAXDAC: '
         ACCEPT *, MAXDAC
100      CONTINUE
         CALL CSSA (16, ADDR, IDAC)
C        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
900   CONTINUE
      CALL CSSA (16, ADDR, 0)
      CALL EXIT
      END
```

```
      PROGRAM PERM7
C
C   created by mike i green
C
C   file name:  PERM7.FOR
C
C   modification history
C
C   06f  81 nov 13       mig  byte dimensions all even
C   06e  81 nov 13       mig  added variable delay
C   06d  81 nov 04       mig  corrections from hall probe stuff
C   06c  81 nov 04       dhn  dimension adc,bair,bsmpl,& rperm (250)
C   06b  81 nov  1       mig  inserting PREINT & PSTINT sbr's
C   06a  81 oct 30       mig  inserting subroutines
C   05a  81 oct 26       mig  copied from PERM5; use 3455A DVM
C   04a  81 oct 15       mig  copied from PERM4 & only pos cycle
C   03a  81 Oct 13       mig  added delay sbr and print for dac<100
C   02a  81 oct 13       mig  copied from PERM2 & added init SBR
C   01a  81 oct 08       mig  copied from PERM1.FOR
C
C
C   purpose:
C
C       cycle LLNL 30 amp bipolar powersuply plus 'amps' by
C       cycling the KINETIC SYSTEMS 3160 POWER SUPPLY CONTROLLER from
C       zero to MAXDAC then back to zero.
C
C       input constant data from subroutines and save on disk
C
C       read power suply current output, hall probe output, and
C       integrator output by means of multiplexed DVM.
C
C
C
C
C   hardware required:
C
C   CAMAC controller - STANDARD ENGINEERING CORP. MODEL CC-LSI-11
C   KS 3130 POWER SUPPLY CONTROLLER
C   LLNL BIPOLAR 30 AMP, 20 VOLT PS, DWG LEA 74-4035
C       HP-3495A SCANNER
C       HP-3455A DVM
C       F. W. BELL MODEL 811 GAUSSMETER
C       INTEGRATOR AND SLFB 43
C
C
C   software required:
C
C   RT-11 opperating system
C   STD. ENG. CORP., "PDP-11/CAMAC SUPPORT LIBRARY"
C       GPIB.OBJ            81 Oct 23
C       DEVTP1.TXT          81 oct 23
C       DELAY1.OBJ          81 nov
C       INIT.OBJ            subroutine -- accepts comments, date, time
C                           types and prints them and table headings
C       COILPR              in file COILP1
C       DRFTCR              in file DRFTC1
C       HALLPR              in file HALLP1
C       INGRPR              in file INGRP1
C       PREINT              in file PREINT
```

```
C       PREPAR              in file PREPR1
C       PSTINT              in file PSTINT
C       SLFSPR              in file SLFSP1
C       SMPLPR              in file SMPLP1
C       SAVE                in file SAVE1
C       RESTOR              in file RSTR1
C
C-----------------------------------------------------------------------------
C
C
C
C-----------------------------------------------------------------------------
C
        INTEGER CRATE, SLOT, SBADDR, CADDR, CDREG, CCCZ, CCCI, ADDR
        INTEGER CSSA
        DIMENSION RWDATA(250, 5), EDC(250), BAIR(250), BSMPL(250),
     1  RPERM(250)
        BYTE TIME1(8), V(16), COMM2(72), COMM3(72)
        BYTE COILNM(10), GMRMOD(10), PRBMOD(10), INTMOD(10), SLFMOD(10)
        BYTE SPLDES(72), ANSWER(2), ENABLE(2), DISABL(2), DATE1(10)
        DATA ENABLE(1), DISABL(1) /.TRUE.,.FALSE./
        DATA CRATE, SLOT, SBADDR /1, 13, 0/
        CADDR = CDREG( ,, CRATE, 0, 0)  !declare crate address
        CALL CCCZ(CADDR)                !initialize crate "dataway Z cycle"
        CALL CCCI(CADDR, DISABL(1))     !clear dataway inhibit
C
        ADDR = CDREG( ,, CRATE, SLOT, SBADDR )
C
C
C     put all GPIB devices into remote mode
C
        J = ISUP(4, 0)
C
C
C     program DVM
C
        I = ISUP(0, 3, 'F1R7T1M3A1H0', 0)
C
C
C     call preparization subroutine
C       coil parameters
C       sample parameters
C       hall probe parameter
C       integrator parameters
C       slfs parameters
C
        CALL PREPAR(COILNM, ACOIL, TCOIL, SPLDES, SPLOD, SPLID, SPLNTH,
     1 GMRMOD, GMRNUM, PRBMOD, PRBNUM, PRBCON, GMZERO, GMCAL, INTMOD,
     2 RINT, CINT, ATNINT, SLFMOD, SLFLUX, ESLFS)
C
C
C
C
C     call initialization subroutine
C       type and print date and time, comments, table headings
C
30      CALL INIT(COMM2, DATE1, TIME1, COILNM, ACOIL, TCOIL, SPLDES,
     1 SPLOD, SPLID, SPLNTH, GMRMOD, GMRNUM, PRBMOD, PRBNUM, PRBCON,
     2 GMZERO, GMCAL, INTMOD, RINT, CINT, ATNINT, SLFMOD, SLFLUX,
     3 ESLFS)
```

```
C
C
C     zero integrator and set intitial sample condition
C
         CALL PREINT(TO, VINTO, TRAMP, VINTS)
C
C
C     enter maximum DAC value going to power supply
C                2047 = +2.5 volts
C               -2048 = -2.5 volts
C
         TYPE *,  ' ENTER MAXDAC :'
         ACCEPT *, MAXDAC
         IDAC = 0
C        TYPE *, ' ENTER DAC INCREMENT :'
C        ACCEPT *, INC
         INC = 1
         I = 0
C
C
         TYPE *, ' ENTER HALL PROBE RANGE (GAUSS):'
         ACCEPT *, X5
C
C
C     the main loop starts
C
         CALL OSSA (16, ADDR, IDAC)          !write DAC value to PS
200      CONTINUE
C
C     delay before reading voltages
C
         CALL DELAY(500)
C
         I = I + 1                           !counter for data set #
C
C     read power supply current, ( 0.1 volts / 10 AMPS ? )
C
         J = IBUP(0, 1, '01', 0)             !scanner to ch 1
         J = IBUP(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
         DECODE(13, 100, V) X1
         RWDATA(I, 1) = X1
C
C     read Hall probe voltage ( 1.0 volts / 10 KGauss )
C
         J = IBUP(0, 1, '02', 0)             !scanner to ch 2
         J = IBUP(3, 1)                      !trigger scanner
         J = IBUP(0, 3, 'F1R7T1', 0)         !program DVM
250      J = IBUP(3, 3)                      !trigger DVM
         J = IBUP(1, 3, V, 16)               !read DVM
         DECODE(13, 100, V) X2
         IF (X2 .GT. 1.0) TYPE *,' HALL OUT > 1 VOLT, SWITCH RANGE AND
     1 ENTER NEW FULL SCALE RANGE (GAUSS):'
         IF (X2 .GT. 1.0) ACCEPT *, X5
         IF (X2 .GT. 1.0) GOTO 250
         IF (X2 .LT. 0.1) TYPE *,' HALL OUT < 0.1 VOLT, SWITCH RANGE AND
     1 ENTER NEW FULL SCALE RANGE (GAUSS):'
         IF (X2 .LT. 0.1) ACCEPT *, X5
```

```
      IF (X2 .LT. 0.1) GOTO 250
      RWDATA(I, 2) = X2
      RWDATA(I, 5) = X5 * .0001
C
C   read integrator voltage
C
      J = IBUP(0, 1, '03', 0)          !scanner to ch 3
      J = IBUP(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
      DECODE(13, 100, V) X3
      RWDATA(I, 3) = X3
C
C   get elapsed time
C
      RWDATA( I, 4) = SECNDS(T0)
C
C
C
100   FORMAT(E14.6)
      TYPE 1000, IDAC, (RWDATA(I, K), K = 1, 5)
      PRINT 1000, IDAC, (RWDATA(I, K), K = 1, 5)
1000  FORMAT(1X, I6, 3F10.4, F10.0, F10.4)
C
C   terminate program
C
      IF (( IDAC .EQ. 0 ) .AND. ( INC .EQ. -1 )) GO TO 900
C
C   do loop to increment DAC by 10
C
      DO 210 K = 1, 10
      IDAC = IDAC + INC
      CALL C56A(16, ADDR, IDAC)
      CALL DELAY(5)
210   CONTINUE
      IF ( IDAC .EQ. MAXDAC ) INC = -INC
      IF ( IDAC .EQ. -MAXDAC ) INC = -INC
C
C   read voltages
C
      GO TO 200
900   CONTINUE
C
C
      TYPE *, IDAC, MAXDAC
C
C
C   get final sample condition and integrator voltage & corresponding
C   times.   get any final comments
C
      CALL PSTINT(T0, TSAMPF, VINTGF, TEND, VEND, COMM3)
C
C
C     IF (MAXDAC .GT. 100) GO TO 310
C     M = 1 + 2 * MAXDAC/10
C     DO 300 K = 1, M
C     PRINT 1010, RWDATA(K, 1), RWDATA(K, 2), RWDATA(K, 3)
C300  CONTINUE
C     GO TO 2000
```

```
C310    DO 320 K = 1, I, 10
C       PRINT 1010, RWDATA(K, 1), RWDATA(K, 2), RWDATA(K, 3)
C320    CONTINUE
C
C
C
C1010   FORMAT(1X, 3F10.4)
C
C
C   we now start the disk save procedure
C
        TYPE *, ' type "Y" if you want to save data'
        ACCEPT 1100, ANSWER(1)
1100    FORMAT(1A1)
        IF(ANSWER(1) .EQ. 'Y') CALL SAVE(COMM2, DATE1, TIME1, COILNM,
        1 ACOIL, TCOIL, SPLDES, SPLOD, SPLID, SPLNTH, GMRMOD, GMRNUM,
        2 PRBMOD, PRBNUM, PRBCON, GMZERO, GMCAL, INTMOD, RINT, CINT,
        3 ATNINT, SLFMOD, SLFLUX, ESLFS, VINTO, TSAMP, VINTS, MAXDAC,
        4 I, 5, RWDATA, TSAMPF, VINTSF, TEND, VEND, COMM3)
C
C
        TYPE *, ' 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 PERM8
C
C     created by mike i green
C
C     file name:  PERM8.FOR
C
C     modification history
C
C     07b  81 nov 19       mig  documentation & minor debugs
C     07a  81 nov 17       mig  copied from PERM7, DELAY test
C     06f  81 nov 13       mig  byte dimensions all even
C     06e  81 nov 13       mig  added variable delay
C     06d  81 nov 04       mig  corrections from hall probe stuff
C     06c  81 nov 04       dhn  dimension adc,bair,bsmpl,& rperm (250)
C     06b  81 nov  1       mig  inserting PREINT & PSTINT sbr's
C     06a  81 oct 30       mig  inserting subroutines
C     05a  81 oct 26       mig  copied from PERM5, use 3455A DVM
C     04a  81 oct 15       mig  copied from PERM4 & only pos cycle
C     03a  81 Oct 13       mig  added delay sbr and print for dac<100
C     02a  81 oct 13       mig  copied from PERM2 & added init SBR
C     01a  81 oct 08       mig  copied from PERM1.FOR
C
C
C     purpose:
C
C          cycle LLNL 30 amp bipolar powersuply plus "omrs" by
C          cycling the KINETIC SYSTEMS 3160 POWER SUPPLY CONTROLLER from
C          zero to MAXDAC then back to zero.
C
C          input constant data from subroutines and save on disk
C
C          read power suply current output, hall probe output, and
C          integrator output by means of multiplexed DVM.
C
C          variable delay and double readings at each dac output
C
C
C
C     hardware required:
C
C     CAMAC controller - STANDARD ENGINEERING CORP. MODEL CC-LSI-11
C     KS 3130 POWER SUPPLY CONTROLLER
C     LLNL BIPOLAR 30 AMP, 20 VOLT PS, DWG LEH 74-4035
C          HP-3495A SCANNER
C          HP-3455A DVM
C          F. W. BELL MODEL 811 GAUSSMETER
C          INTEGRATOR AND SLFI 43
C
C
C     software required:
C
C     RT-11 operating system
C     STD. ENG. CORP., "PDP-11/CAMAC SUPPORT LIBRARY"
C          SFIB.OBJ             81 Oct 23
C          DEVTBI.TXT           81 oct 23
C          DELAY1.OBJ           81 oct 23
C          INIT.OBJ             subroutine -- accepts comments, date, time
C                               types and prints them and table headings
C          COILPR               in file COILP1
C          DAFTOR               in file DAFTO1
```

```
C       HALLPR          in file HALLP1
C       INGRPR          in file INGRP1
C       PREINT          in file PREINT
C       PREPAR          in file PREPR1
C       PSTINT          in file PSTINT
C       SLFSPR          in file SLFSP1
C       SMPLPR          in file SMPLP1
C       SAVE            in file SAVE1
C       RESTOR          in file RSTR1
C
C------------------------------------------------------------------------
C
C
C
C------------------------------------------------------------------------
C
        INTEGER CRATE, SLOT, SBADDR, CADDR, CDREG, CCCZ, CCCI, ADDR
        INTEGER CSSA
        DIMENSION RWDATA(250, 5), EDC(250), BAIR(250), BSMPL(250),
     1  RPERM(250)
        BYTE TIME1(8), V(16), COMM2(72), COMM3(72)
        BYTE COILNM(10), GMRMOD(10), PRBMOD(10), INTMOD(10), SLFMOD(10)
        BYTE SPLDES(72), ANSWER(2), ENABLE(2), DISABL(2), DATE1(10)
        DATA ENABLE(1), DISABL(1) /.TRUE.,.FALSE./
        DATA CRATE, SLOT, SBADDR /1, 15, 0/
        CADDR = CDREG( ,, CRATE, 0, 0)  !declare crate address
        CALL CCCZ(CADDR)                 !initialize crate "dataway Z cycle"
        CALL CCCI(CADDR, DISABL(1))      !clear dataway inhibit
C
        ADDR = CDREG( ,, CRATE, SLOT, SBADDR )
C
C
C   put all GPIB devices into remote mode
C
        J = IBUP(4, 0)
C
C
C   program DVM
C
        J = IBUP(0, 3, 'F1R7T1M3A1H0', 0)
C
C
C   call prepreparization subroutine
C       coil parameters
C       sample parameters
C       hall probe parameter
C       integrator parameters
C       slfs parameters
C
        CALL PREPAR(COILNM, ACOIL, TCOIL, SPLDES, SPLOG, SPLID, SPLNTH,
        1 GMRMOD, GMRNUM, PRBMOD, PRBNUM, PRBCON, GMZERO, GMCAL, INTMOD,
        2 RINT, CINT, ATNINT, SLFMOD, SLFLUX, ERLFS)
C
C
C
C
C   call initialization subroutine
C       type and print date and time, comments, table headings
C
50      CALL INIT(COMM2, DATE1, TIME1, COILNM, ACOIL, TCOIL, SPLDES,
```

```
     1 PFLOD, PFLID, PPLNTH, GMRMOD, GMRNUM, PRBMOD, PRBNUM, PRPCON,
     2 GMZERO, GMCAL, INTMOD, RINT, CINT, ATNINT, SLFMOD, SLFLUX,
     3 SSLFB)
C
C
C    zero integrator and set intitial sample condition
C
      CALL PREINT(TO, VINTO, TSAMP, VINTS)
C
C
C    enter maximum DAC value going to power supply
C              2047 = +2.5 volts
C             -2048 = -2.5 volts
C
      TYPE *,  ' ENTER MAXDAC :'
      ACCEPT *, MAXDAC
      IDAC = 0
C-------------------------------------------------------------------------
C    the following is used to test if we have sufficient delay before
C    reading voltages.
C
      TYPE *, ' ENTER number of delay loops : '
      ACCEPT *, NDELAY
C-------------------------------------------------------------------------
C
      INC = 1
      I = 0
C
C
      TYPE *, ' ENTER HALL PROBE RANGE (GAUSS):'
      ACCEPT *, X5
C
C
C    the main loop starts
C
      CALL CESA (16, ADDR, IDAC)          write DAC value to PS
300   CONTINUE
C
C    the following DO LOOP is to test if we have suffient delay before
C    reading voltages.
C
      DO 400 NDLY = 1, 2
C
C    delay before reading voltages
C
      CALL DELAY( NDELAY / NDLY )
400   CONTINUE
      I = I + 1                    !counter for data set number
C
C    read power supply current, ( 0.1 volts / 10 AMPS ? )
C
      J = IBUF(0, 1, 'C1', 0)            !scanner to ch 1
      J = IBUF(3, 1)                     !trigger scanner
      J = IBUF(0, 2, 'F1R7T1', 0)        !program DVM
      J = IBUF(3, 2)                     !trigger DVM
      J = IBUF(1, 2, V, 16)              !read DVM
      DECODE(15, 100, V) X1
      DUDATA(I, 1) = X1
C
C    read Hall probe voltage ( 1.0 volts / 10 KGauss )
```

```
C
      J = IBUF(0, 1, '02', 0)                !scanner ch on 2
      J = IBUF(3, 1)                         !trigger scanner
      J = IBUF(0, 7, 'FIRST1', 0)            !program DVM
250   J = IBUF(3, 3)                         !trigger DVM
      J = IBUF(1, 3, V, 16)                  !read DVM
      DECODE(13, 101, V) X2
      IF (X2 .GT. 1.0) TYPE *,' HALL OUT > 1 VOLT, SWITCH RANGE AND
     1 ENTER NEW FULL SCALE RANGE (GAUSS)'
      IF (X2 .GT. 1.0) ACCEPT *, X5
      IF (X2 .GT. 1.0) GOTO 250
      IF (X2 .LT. 0.1) TYPE *,' HALL OUT < 0.1 VOLT, SWITCH RANGE AND
     1 ENTER NEW FULL SCALE RANGE (GAUSS)'
      IF (X2 .LT. 0.1) ACCEPT *, X5
      IF (X2 .LT. 0.1) GOTO 250
      RWDATA(I, 2) = X2
      RWDATA(I, 5) = X5 * .0001
C
C     read integrator voltage
C
      J = IBUF(0, 1, '03', 0)                !scanner ch on 3
      J = IBUF(3, 1)                         !trigger scanner
      J = IBUF(0, 7, 'FIRST1', 0)            !program DVM
      J = IBUF(3, 3)                         !trigger DVM
      J = IBUF(1, 3, V, 16)                  !read DVM
      DECODE(13, 100, V) X3
      RWDATA(I, 3) = X3
C
C     get elapsed time
C
      RWDATA(I, 4) = SECNDS(T0)
C
C
C
C
101   FORMAT(E13.6)
      TYPE 1000, IDAC, (RWDATA(I, N), N = 1, 5)
      PRINT 1000, IDAC, (RWDATA(I, N), N = 1, 5)
1000  FORMAT(1X, I6, 3F10.3, F10.5, F10.4)
C
C     print % of integrator voltage reached on first pass
C
      IF ( IOUT .EQ. 1 ) GOTO 260
      II = I - 1
      PRCNT = 100. * RWDATA(II, 3) / RWDATA(I, 3)
      IF ( IOUT .EQ. 2 ) PRINT *, PRCNT
      IF ( IOUT .EQ. 2 ) TYPE *, PRCNT
C
260   CONTINUE                              !for second delay
C
C     terminate program
C
      IF ( IDAC .EQ. 0 .AND. INC .EQ. -1 ) GO TO 400
C
C     do loop to increment DAC by 10
C
      DO 210 L = 1, 10
      IDAC = IDAC + INC
      CALL IEEE(1, 'DDA', IDAC)
      CALL DELAY(T)
210   CONTINUE
```

```
      IF ( IDAC .EQ. MAXDAC ) INC = -INC
      IF ( IDAC .EQ. -MAXDAC   INC = -INC
C
C  read voltages
C
      GO TO 200
900   CONTINUE
C
C
      TYPE *, IDAC, MAXDAC, NDELAY
      PRINT *, IDAC, MAXDAC, NDELAY
C
C
C   get final sample condition and integrator voltage & corresponding
C   times.   get any final comments
C
      CALL PETINT(T0, TSAMPF, VINTSF, TEND, VEND, COMM3)
C
C
C     IF (MAXDAC .GT. 100) GO TO 310
C     M = 1 + 2 * MAXDAC/10
C     DO 300 K = 1, M
C     PRINT 1010, RWDATA(K, 1), RWDATA(K, 2), RWDATA(K, 3)
C300  CONTINUE
C     GO TO 2000
C310  DO 320 K = 1, I, 10
C     PRINT 1010, RWDATA(K, 1), RWDATA(K, 2), RWDATA(K, 3)
C320  CONTINUE
C
C
C
C1010  FORMAT(1X, 3F10.4)
C
C
C   we now start the disk save procedure
C
      TYPE *, ' type "Y" if you want to save data'
      ACCEPT 1100, ANSWER(1)
1100  FORMAT(1A1)
      IF(ANSWER(1) .EQ. 'Y') CALL SAVE(COMM2, DATE1, TIME1, COILNM,
     1 ACOIL, TCOIL, SPLDES, SPLOD, SPLID, SPLNTH, GMRMOD, GMRNUM,
     2 PRBMOD, PRBNUM, PRBCON, GAZERO, GMCAL, INTMOD, RINT, CINT,
     3 ATRINT, SLFMOD, SLFLUX, ESLFS, VINTO, TSAMP, VINTS, MAXDAC,
     4 I, 3, RWDATA, TSAMPF, VINTSF, TEND, VEND, COMM3)
C
C
      TYPE *, ' type "Y" if you want to run same sample again'
      ACCEPT 1100, ANSWER(1)
      IF(ANSWER(1) .EQ. 'Y') GOTO 50
      CALL EXIT
      END
```

```
C       FILE:    PREPR1.FOR
C       DATE:    '81 OCT 29
C       REVISED:         81 nov  4  mis  some misc corrections
C       PURPOSE:         To call subroutines that will provide the necessary
C                        constants for processing permeability data.
C
      SUBROUTINE PREPAR(COILNM,ACOIL,TCOIL,SPLDES,SPLOD,SPLID,SPLNTH,
     1 GMRMOD, GMRNUM ,PRBMOD,PRBNUM ,PRBCON,GMZERO,GMCAL,
     2 INTMOD,RINT,CINT,ATNINT, SLFMOD,SLFLUX,ESLFS)
C
C
C       COILNM,SPLDES,GMRMOD,PRBMOD,INTMOD,SLFMOD ARE ALPANUMERIC
C
      CALL COILPR(COILNM,ACOIL,TCOIL)
      CALL SMPLPR(SPLDES,SPLOD,SPLID,SPLNTH)
      CALL HALLPR(GMRMOD, GMRNUM, PRBMOD, PRBNUM,PRBCON,GMZERO,GMCAL)
      CALL INGRPR(INTMOD,RINT,CINT,ATNINT)
      CALL SLFSPR(SLFMOD,SLFLUX,ESLFS)
C
      RETURN
      END
```

```
C
C
C       FILE:    COILP1.FOR
C       DATE:    '81 OCT 29 DHN
C   81 nov 13  mis  removed len par
C       REVISED:  81 nov 12  mis  SCOPY len & pad
C       PURPOSE:        To provide coil parameters required by PERMn to
C                       process permeability data.
C
        SUBROUTINE COILPR( COILNM, ACOIL, TCOIL)
C
C       FOR NOW FORTRAN STATEMENTS WILL SUPPLY REQUIRED DATA.
C
        BYTE COILNM(10)
        ACOIL = 0.04113                 !coil turns area
        TCOIL = 100.                    !coil turns
        CALL SCOPY('B-162    ', COILNM)  !coil identification
        RETURN
        END
```

```
C
C
C         FILE      SMPLP1.FOR
C         DATE:     '81 OCT 29 DHN
C         REVISED:    81 nov 12    mis    sample description accept from term.
C         PURPOSE:            To define sample parameters needed by PERMn to
C                             process permeability data.
C
      SUBROUTINE SMPLPR( SPLDES, SPLOD, SPLID, SPLNTH )
C
C         For now define all constants with  data statements.
C
         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
```

```
C
C
C         FILE:    HALLP1.FOR
C         DATE:    '81 OCT 29 DHN
C         REVISED:   81 nov 12  mis   SCOPY lrn
C         PURPOSE:          To define Gaussmeter parameters required by PERMn to
C                           process permeability data.
C
      SUBROUTINE HALLPR(GMRMOD,GMRnum,PRBMOD,PRBnum,PRBCON,GMZERO,gmcal)
C
C         For now statements will supply the required data.
C
          BYTE GMRMOD(10), PRBMOD(10)
          GMRnum = 501586.                              !gaussmeter s/n
          PRBCON = 1.                                   !probe constant
          PRBnum = 120011.                              !probe s/n
          GMZERO = 0.0                                  !(in shield) zero
          GMCAL = 1.                                    !internal calibration
C gmrnge removed
          CALL SCOPY('BELL 620', GMRMOD)  !gaussmeter model
          CALL SCOPY('SAE40618', PRBMOD)  !probe model
      RETURN
      END
```

```
C
C
C       FILE:    INGRP1.FOR
C       DATE:    '81 OCT 29 DHN
C       REVISED:  81 nov 12 mis     SCOPY len
C       PURPOSE:          To provide integrator parameters required by PERMn to
C                         process permeability data.
C
      SUBROUTINE INGRPR(INTMOD, RINT,CINT, ATNINT)
C
C       FOR NOW DATA STATEMENTS WILL SUPPLY THE REQUIRED DATA.
C
        BYTE INTMOD(10)
        rint = 19600.
        cint = 0.000001
        atnint = .9360
        CALL SCOPY('MOD71#01', INTMOD)
      RETURN
      END
```

```
C
C
C      FILE:    SLFSP1.FOR
C      DATE:    '81 OCT 29 DHN
C      REVISED:    81 nov 12    mis    SCOPY len & pad
C      PURPOSE:          To provide SLFS constants required by PERMn to
C                        process permeability data.
C
      SUBROUTINE SLFSPR( SLFMOD, SLFLUX, ESLFS )
C
C      For now data statements will supply the required data.
C
        BYTE SLFMOD(10)
        SLFLUX = .02101                               !SLFS flux-linkage
        ESLFS = 1.007                                 !SLFS output
        CALL SCOPY('SLFS 43 ', SLFMOD)  !SLFS identification
      RETURN
      END
```

```
      [illegible]
      [illegible]
      [illegible]
      [illegible]

C    created by mike f. green

C    file name:  INIT.FOR

C    modification history:

C    [illegible]
C    [illegible]                   all [illegible] direction
C    [illegible]
C    [illegible]                   [illegible] corrections from hall probe stuff
C    [illegible]                   external input [illegible] PREPAR
C    [illegible]
C    [illegible]
C    [illegible]                   [illegible]

C    purpose:

C         [illegible] file of experiment
C         [illegible] associated with the search coil,
C         [illegible] hall probe, 1 [illegible] and [illegible]
C         [illegible]


C    hardware required: none


C    software required: [illegible]

C         INIT - [illegible] author


C----COMMENT is a comment describing the particular test being run.

      [illegible] EPLUSB(72), COMMENT([illegible]), TIMEB([illegible]), [illegible]
      [illegible] PRBPOS(10), [illegible]
      CALL [illegible]
      CALL DATE(DATE1,[illegible])
      CALL TIME(TIME1)
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]
      [illegible]              CALL INTEGRATOR [illegible]
```

```
      1 RANGE')
      PRINT 140
140   FORMAT(' (COUNTS) (VOLTS)   (VOLTS)   (VOLTS)  (SECONDS)   (
     1TESLA)')
      RETURN
      END
```

```
      SUBROUTINE PREINT(TO, VINTO, TSAMP, VINTS)
C
C     created by mike i green
C
C     file name: PREINT.FOR
C
C     modification history:
C
C     01d  81 nov 13  mig  null for ANSWER(2)
C     01c  81 nov 13  mig  all bytes even
C     01b  81 nov  1  mig  working
C     01a  81 nov  1  mig  written
C
C     purpose:
C
C          zero integrator, obtain zero time for drift calculation,
C          determine initial sample condition, and instructions to
C          operator to accomplish same.
C
C     hardware required:
C
C          HP-3495A scanner
C          HP-3455A DVM
C          LBL MODEL 71 INTEGRATOR (6ZV1763)
C          LBL SQUARE LOOP FLUX STANDARD (SLFS)
C          SEARCH COIL
C
C
C     software required:
C
C          RT-11 operating system
C          GPIB.OBJ          81 oct 23 DEVTBL
C
C
C     parameter definitions:
C
C          TO:     time (seconds) that integrator is zeroed
C          VINTO:  integrator voltage at TO, with search coil in shield
C          TSAMP:  time (seconds) that sample with search coil around it
C                  is put in mu metal shield
C          VINTS:  integraator voltage at TSAMP
C
C
          BYTE V(16), ANSWER(2)
C
C
200       TYPE *, ' type "Y" if integrator is switched to integrate'
          ACCEPT 1010, ANSWER(2)
1010      FORMAT(1A1)
          IF (ANSWER(2) .NE. 'Y') GOTO 200
C
C
          PAUSE ' press return when search coil is in mu-metal shield'
          TYPE *, ' zero integrator by pressing 'RESET TO ZERO BUTTON''
          PAUSE ' press return when integrator is zeroed'
C
C     read integrator voltage and time zero
C
          J = IBUP(0, 1, '03', 0)             !scanner to channel 3
          J = IBUP(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 = SECNDS(0.0)                     !start timing
      DECODE(13, 100, V) VINTO
100   FORMAT(E14.6)
C
C
      TYPE *, ' put search coil around sample and insert into shield'
      PAUSE ' press return when done'
C
C   read sample integrator voltage and time
C
      J = IBUP(0, 1, '03', 0)              !scanner to channel 3
      J = IBUP(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
      TSAMP = SECNDS(TO)                   !get sample time
      DECODE(13, 100, V) VINTS
C
C
      TYPE *, ' put search coil & sample into magnet'
      PAUSE ' press return when ready to run'
C
C
      RETURN
      END
```

```
      SUBROUTINE DELAY(N)
C
C     created by mike i. green
C
C     file name:          DELAY1.FOR
C
C     modification history:
C
C     02a   81 nov 13   mig   incorporated 'N' for variable delay time
C     01a   81 oct 23   mig   written and working
C
C
C     purpose:
C
C     this SBR is designed just to put  a time delay into another
C     program
C
C
C     hardware required:  none
C
C     software required:  RT-11 operating system
C
C
      DO 100 I = 1, N
      CALL TIME
100   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PSTINT(T0, TSAMP, VINTS, TEND, VEND, COMM3)
C
C     created by mike i green
C
C     file name:  PSTINT.FOR
C
C     modification history:
C
C     01b  81 nov  1  mig  working
C     01a  81 nov  1  mig  written
C
C     purpose:
C
C          determine final sample condition, integrator drift voltage
C          and instructions to operator to accomplish same.
C          input final comments
C
C     hardware required:
C
C          HP-3495A scanner
C          HP-3455A DVM
C          LBL MODEL 71 INTEGRATOR (6ZV1763)
C          LBL SQUARE LOOP FLUX STANDARD (SLFS)
C          SEARCH COIL
C
C
C     software required:
C
C          RT-11 operating system
C          GPIB.OBJ          81 oct 23 DEVTBL
C
C
C     parameter definitions:
C
C          T0:     input from main program, time integrator zeroed
C          TSAMP:  time (seconds) that sample with search coil around it
C                  is put in mu metal shield
C          VINTS:  integrator voltage at TSAMP
C          TEND:   time when just search coil is in mu-metal shield
C          VEND:   integrator voltage at TEND
C          COMM3:  final comments
C
C
      BYTE V(16), COMM3(72)
C
C
      TYPE *, ' take sample and search coil out of magnet'
      TYPE *, ' put search coil around sample and insert into shield'
      PAUSE ' press return when done'
C
C     read sample integrator voltage and time
C
      J = IBUP(0, 1, '03', 0)          !scanner to channel 3
      J = IBUP(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
      TSAMP = SECNDS(T0)               !get sample time
      DECODE(13, 100, V) VINTS
C
```

```
C
      TYPE *, ' put just search coil into mu-metal shield'
      PAUSE ' press return when search coil is in mu-metal shield'
C
C   read integrator voltage and final time
C
      J = IBUP(0, 1, '03', 0)            !scanner to channel 3
      J = IBUP(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
      TEND = SECNDS(TO)                  !get end time
      DECODE(13, 100, V) VEND
100   FORMAT(E14.6)
C
C
      TYPE *, ' enter any final comments'
      ACCEPT 110, COMM3
110   FORMAT(72A1)
C
C
      RETURN
      END
```

```
      SUBROUTINE SAVE(COMM2, DATE1, TIME1, COILNM, ACOIL, TCOIL,
     1 SPLDES, SPLOD, SPLID, SPLNTH, GMRMOD, GMRNUM, PRBMOD,
     2 PRBNUM, PRBCON, GMZERO, GMCAL, INTMOD, RINT, CINT, ATNINT,
     3 SLFMOD, SLFLUX, ESLFS, VINTO, TSAMP, VINTS, MAXDAC,
     4 I1, X1, ARRAY, TSAMPF, VINTSF, TEND, VEND, COMM3)
C
C     created by mike j. green
C
C     file name:  SAVE3.FOR
C
C     modification history
C
C     05c  81 nov 19        mjg     add code to prevent overwriting datafile
C     05b  81 NOV 19        MJG     FNAME(12), ACCEPT (1=>10), (11)=0
C     05a  81 nov 16        mjg     output FNAME, reordered  DATE1, TIME1
C     04c  81 nov 13        mjg     all bytes even dimension
C     04a  81 nov 12        mjg     unformated sequential save
C     03b  81 nov 04        mjg     misc hall probe corrections
C     03a  81 nov 03        mjg     input alphanumerics & output everything
C                                   copied from SAVE1.FOR
C     02a  81 oct 31        mjg     input constant parameters
C     01b  81 OCT 30        mjg     working
C     01a  81 oct 30        mjg     written
C
C
C     purpose:
C
C          save on disk data from PERM7
C
C
C     hardware required:
C
C          none
C
C
C     software required:
C
C          RT-11 operating system
C
C
      DIMENSION ARRAY(250, 5)
      BYTE FNAME(12), COMM2(72), SPLDES(72), TIME1(8), DATE1(10)
      BYTE COMM3(72)
      BYTE COILNM(10), GMRMOD(10), PRBMOD(10), INTMOD(10), SLFMOD(10)
      TYPE *, 'type file name for saving data XXXXXX.DAT '
90    ACCEPT 100, (FNAME(I), I = 1, 10)          !reads fname from terminal
100   FORMAT(10A1)
      FNAME(11) = 0
      OPEN (UNIT = 1, NAME = FNAME, FORM = 'UNFORMATTED', TYPE = 'OLD',
     1 ERR = 110)
      CLOSE (UNIT = 1)
      TYPE *, 'file name already exists, try another'
      GO TO 90
110   OPEN (UNIT = 1, NAME = FNAME, FORM = 'UNFORMATTED')
      WRITE (1) FNAME, DATE1, TIME1, SPLDES, COMM2, COMM3
      WRITE (1) COILNM, GMRMOD, PRBMOD, INTMOD, SLFMOD
      WRITE(1) MAXDAC, I1, X1
      WRITE(1) ACOIL, TCOIL, SPLOD, SPLID, SPLNTH, PRBCON,
     1 GMZERO, GMCAL, RINT, CINT, ATNINT, SLFLUX, ESLFS, VINTO,
     2 TSAMP, VINTS, TSAMPF, VINTSF, TEND, VEND, GMRNUM, PRBNUM
```

```
        WRITE (1) ((ARRAY(I, K), K = 1, 5), I = 1, I1)
        CLOSE(UNIT = 1)                   !closes disk file
        RETURN
        END
EXIT
```

```
      PROGRAM PROCD1
C
C     created by mike l. green and don h. nelson
C
C     file name:   PROCD1.FOR
C
C     modification history:
C
C          02b   81 nov 19   mlg   FNAME from 10 to 12 bytes
C          02a   81 nov 16   mlg   FNAME added to print & VOMIT call
C          01d   81 nov 13   mlg   all bytes even dimension
C          01c   81 nov 06   mlg   cleaning up
C          01b   81 nov 05   mlg   working
C          01a   81 nov 05   mlg   copied from VMTST2.FOR
C
C     purpose:
C
C          process permeability data saved by PERM7
C          print processed data
C
C
C     hardware required:
C
C          none
C
C
C     software required:
C
C          RT-11 operating system
C          subroutines        VOMIT    in file VOMIT2.FOR
C                             PUTPUT           PTOUT1.FOR
C                             DRFTCR           DRFTC2.FOR
C                             CALCMU           CALMU1.FOR
C                             PRNTOT           PRNTO1.FOR
C
C-----------------------------------------------------------------------
C
C     note:         need to link with bottom of stack raised above 1000
C
C-----------------------------------------------------------------------
C
C
      DIMENSION ARRAY(250, 5), RAIR(250), RSMPL(250), RPERM(250)
      BYTE COMM2(72), SPLDES(72), TIME1(8), DATE1(10), COMM3(72)
      BYTE COILNM(10), GMRMOD(10), PRBMOD(10), INTMOD(10), SLFMOD(10)
      BYTE ANSWER(2), FNAME(12)
C
D     pause $, ' call disk file retrieve subroutine'
C
      CALL VOMIT ( FNAME, COMM2, DATE1, TIME1, COILNM, ACOIL, TCOIL,
     1 SPLDES, SPLOD, SPLID, SPLNTH, GMRMOD, GMRNUM, PRBMOD,
     2 PRBNUM, PRBCON, GMZERO, GMCAL, INTMOD, RINT, CINT, ATNINT,
     3 SLFMOD, SLFLUX, ESLFS, VINTO, TSAMP, VINTS, MAXDAC,
     4 I1, K1, ARRAY, TSAMPF, VINTSF, TEND, VEND, COMM3)
C
C     type and print comments, etc
C
      TYPE 190, (FNAME(I), I = 1, 10)
      TYPE 210, SPLDES, COMM2, COMM3, DATE1, TIME1
      TYPE 220, COILNM, INTMOD, SLFMOD
```

```
      TYPE 225, GMRMOD, GMRNUM, PRBMOD, PRBNUM
      TYPE 230, MAXDAC, I1, K1
      PRINT 190, (FNAME(I), I = 1, 10)
      PRINT 210, SPLDES, COMM2, COMM3, DATE1, TIME1
      PRINT 220, COILNM, INTMOD, SLFMOD
      PRINT 225, GMRMOD, GMRNUM, PRBMOD, PRBNUM
      PRINT 230, MAXDAC, I1, K1
C
C   print initialization parameters
C

      PRINT 240, ACOIL, TCOIL, SPLOD, SPLID, SPLNTH, PRBCON,
      1 GMZERO, GMCAL, RINT, CINT, ATNINT, SLFLUX, ESLFS, VINTO,
      2 TSAMP, VINTS, TSAMPF, VINTSF, TEND, VEND, GMRNUM, PRBNUM
C
C
C
      TYPE *, ' type 'Y' if you want raw data array printed'
C
C
      ACCEPT 200, ANSWER(2)
200   FORMAT( 1A1 )
      IF (ANSWER(2) .EQ. 'Y') PRINT 250, ((ARRAY(I, K),
      1 K = 1, 5), I = 1, I1)
C
C   call subroutine that processes data
C
D     TYPE *, ' we now call putout'
      CALL PUTOUT(COMM2, DATE1, TIME1, COILNM, ACOIL, TCOIL,
      1 SPLDES, SPLOD, SPLID, SPLNTH, GMRMOD, GMRNUM, PRBMOD,
      2 PRBNUM, PRBCON, GMZERO, GMCAL, INTMOD, RINT, CINT, ATNINT,
      3 SLFMOD, SLFLUX, ESLFS, VINTO, TSAMP, VINTS, MAXDAC,
      4 I1, K1, ARRAY, TSAMPF, VINTSF, TEND, VEND, COMM3,
      5 BAIR, BSMPL, RPERM)
C
C
C
190   FORMAT (1X, 'DISK FILE : ', 10A1)
210   FORMAT( 3(1X, 72A1/), 1X, 10A1, 1X, 8A1)
220   FORMAT( ' SEARCH COIL: ', 10A1, 5X, 'INTEGRATOR: ', 10A1,
      1 5X, 'FLUX STANDARD: ', 10A1)
225   FORMAT( ' GAUSSMETER: ', 10A1, ', S/N: ', F7.0, 5X,
      1 'HALL PROBE: ', 10A1, ', S/N: ', F7.0)
230   FORMAT( ' MAXDAC = 'I4, 15X, I4,' DATA SETS ', 15X, I3,
      1 ' PARAMETERS LONG')
240   FORMAT (5 (1X, E13.6 ) )
250   FORMAT( 1X, 3F10.4, F10.0, F10.4)
C
C
      CALL EXIT
      END
```

```
      SUBROUTINE VOMIT (DNAME, COMM2, DATE1, TIME1, COILNM, ACOIL,
     1 TCOIL, SPLDES, SPLOD, SPLID, SPLNTH, GMRMOD, GMRNUM, PRBMOD,
     2 PRBNUM, PRBCON, GMZERO, GMCAL, INTMOD, RINT, CINT, ATNINT,
     3 SLFMOD, SLFLUX, ESLFS, VINTO, TSAMP, VINTS, MAXDAC,
     4 I1, K1, ARRAY, TSAMPF, VINTSF, TEND, VEND, COMM3)
C
C    created by mike i. green
C
C    file name:  VOMIT3.FOR
C
C    modification history
C
C    04a  81 nov 19       mis     DNAME added to input
C    03b  81 nov 13       mis     all bytes even dimension
C    03a  81 nov 11       mis     copied from VOMIT2, made unformatted
C    02a  81 nov 04       mis     several fixes
C    01a  81 nov 03       mis     copied from SAVE2.FOR
C
C
C    purpose:
C
C         retrieve from disk data saved from PERM7 by SAVE2
C
C
C    hardware required:
C
C         none
C
C
C    software required:
C
C         RT-11 operating system
C
C
      DIMENSION ARRAY(250, 5)
      BYTE FNAME(12), COMM2(72), SPLDES(72), TIME1(8), DATE1(10)
      BYTE COMM3(72), DNAME(12)
      BYTE COILNM(10), GMRMOD(10), PRBMOD(10), INTMOD(10), SLFMOD(10)
      TYPE %, 'type file name for retrieving data XXXXXX.DAT '
      ACCEPT 100, (FNAME(I), I=1,10)            !reads fname from terminal
100   FORMAT(10A1)
      FNAME(11) = 0               !null byte terminates string
C
C    access file
C
      OPEN (UNIT = 1, TYPE = 'OLD', READONLY, NAME = FNAME, FORM =
     1 'UNFORMATTED')
C
C
      READ (1) DNAME, DATE1, TIME1, SPLDES, COMM2, COMM3
      READ (1) COILNM, GMRMOD, PRBMOD, INTMOD, SLFMOD
      READ (1) MAXDAC, I1, K1
      READ (1) ACOIL, TCOIL, SPLOD, SPLID, SPLNTH, PRBCON,
     1 GMZERO, GMCAL, RINT, CINT, ATNINT, SLFLUX, ESLFS, VINTO,
     2 TSAMP, VINTS, TSAMPF, VINTSF, TEND, VEND, GMRNUM, PRBNUM
      READ (1) ((ARRAY(I, K), K = 1, 5), I = 1, I1)
C
C    close file
C
      CLOSE(UNIT = 1)                        !closes disk file
```

```
TYPE *, ' FILE HAS BEEN READ & CLOSED'
RETURN
END
```

```
      SUBROUTINE PUTOUT(COMM2, DATE1, TIME1, COILNM, ACOIL, TCOIL,
     1 SPLDES, SPLOD, SPLID, SPLNTH, GMRMOD, GMRNUM, PRBMOD,
     2 PRBNUM, PRBCON, GMZERO, GMCAL, INTMOD, RINT, CINT, ATNINT,
     3 SLFMOD, SLFLUX, ESLFS, VINTO, TSAMP, VINTS, MAXDAC,
     4 I1, K1, ARRAY, TSAMPF, VINTSF, TEND, VEND, COMM3,
     5 BAIR, BSMPL, RPERM)
C
C     created by don nelson
C
C     file name: PTOUT1.FOR
C
C     modification history:
C
C          02b  81 nov 13  mjs  all bytes even dimension
C          02a  81 nov 06  mjs  cleaning up
C          01c  81 nov 05  mjs  working
C          01b  81 nov 05  mjs & dhn  misc additions & corrections
C          01a  81 NOV 3 copied save1.for to ptout1.for to facilitate coding
C
C
C     purpose:
C
C          to process data collected by PERM7 and print parameters of
C          interest.
C
C
C     hardware required:
C
C          none
C
C
C     software required:
C
C          RT-11 operating system
C
C          called by        program PROCC1  in file PROCC1.FOR
C
C          subroutines needed:
C                           CALCMU  in file CALMU1.for
C                           DRFTCR          DRFTC2.FOR
C                           PRNTOT          PRNTO1.FOR
C
C
C     note:        arrays must be dimensioned 250 in calling programs
C
C
      DIMENSION ARRAY(250, 5), EDC(250), BAIR(1), BSMPL(1), RPERM(1)
C
C
      BYTE COMM2(72), SPLDES(72), TIME1(8), DATE1(10), COMM3(72)
      BYTE COILNM(10), GMRMOD(10), PRBMOD(10), INTMOD(10), SLFMOD(10)
C
D     PRINT *, ' ARRAY FROM PUTOUT'
D     PRINT 1010, ((ARRAY(I, K), K = 1, 5), I = 1, I1)
1010  FORMAT( 1X, 3F10.4, F10.0, F10.4)
C
      TYPE *, ' we now call drift correct subroutine'
C
      CALL DRFTCR(TEND,VINTO, VEND, I1, ARRAY, EDC)
C
```

```
C
D         PRINT *, ' EDC'
D         PRINT 1000, (EDC(I), I = 1, I1)
1000      FORMAT( 3(1X, F10.5))
C
          TYPE *, ' we now call permeability calculation subroutine'
C
          CALL CALCMU( SPLOD, SPLID, ACOIL, TCOIL, SLFLUX, ESLFS, I1,
     1    ARRAY, EDC, BAIR, BSMPL, RPERM)
C
          TYPE *, ' we now call print subroutine'
C
          CALL PRNTOT (DATE1, TIME1, COILNM, ACOIL, TCOIL,
     1    SPLDES, SPLOD, SPLID, SPLNTH, GMRMOD, GMRNUM, PRBMOD,
     2    PRBNUM, PRBCON, GMZERO, GMCAL, INTMOD, RINT, CINT, ATNINT,
     3    SLFMOD, SLFLUX, ESLFS, VINTO, TSAMP, VINTS, MAXDAC,
     4    I1, K1, ARRAY, TSAMPF, VINTSF, TEND, VEND, COMM3,
          5 BAIR, BSMPL, RPERM)
C
C
          RETURN
          END
```

```
      SUBROUTINE DR[illegible](TZ2, Z1, Z2, N, ARRAY, EDC)
C
C   created by don h, nelson
C
C   file name:  DRFTC2.FOR
C
C   modification history:
C
C         02a  81 nov 06  mjs   cleaning up
C         01d  81 nov 05  mjs   working
C         01c  81 nov 05  mjs   changed dimension statement for explicit 250
C         01b  81 n[illegible]v 05  mjs   changed DATA(I, J) to ARRAY(I, J)
C         01a  81 nov [illegible]  mjs   copied from file DRFTC1.FOR
C
C
C   parameter definitions:
C
C         TZ2       time of last integrator zero [illegible] (seconds)
C         Z1        first integrator zero reading in [illegible] (volts)
C         Z2        final   "        "       "       "      "
C                   no of data points
C         ARRAY(I, [illegible])      integrator output potential (volts)
C         ARRAY(I, 4)      elapse[illegible] time since zeroing integrator (seconds)
C         EDC(I)           drift [illegible]rrected output array (volts)
C
C
C
      DIMENSION ARRA[illegible] [illegible]50, 5), EDC(250)
C
C  compute drift rat[illegible]
C
      DRFTRT = [illegible].0
      IF( T[illegible] .EQ. 0 ) GO TO 10
      DRFT[illegible] = (Z2 - Z1) / TZ2
10    CON[illegible]
C
C
D     PR[illegible]T 1000, TZ2, Z1, Z2, N
D100[illegible]  FORMAT(' TZ2=',F10.0, 'Z1=',F10.6, 'Z2=',F10.6, 'N=',I5)
C
D     PRINT *, ' I            EDC(I)       ARRAY(I, 3)       ARRAY(1,4)'
C
C  adjust for linear (in time) drift
C
      DO 100 I = 1,N
      EDC(I) = ARRAY(I,3) - DRFTRT * ARR[illegible]I,4)
D     PRINT 1010, I, EDC(I), ARRAY(I, [illegible] ARRAY(I, 4)
D1010 FORMAT(I8, F10.4, F10.4, F10.[illegible]
100   CONTINUE
C
C
      RETURN
      END
```

```
      SUBROUTINE CALCMU(SMPL..., SMPLID, ACOIL, TCOIL, SLFLUX, ESLFS,
     1 N, DATA, EFLUX, BAIR, BSMPL, RPERM )
C
C     created by don h. ..lson
C
C     file name:  CALMU..FOR
C
C     modificatio  istory:
C
C          02a  81 .ov 06  mjs  cleaning up
C          0.   81 nov 05  mjs  working
C          . .  81 nov 05  mjs  explicitly stated dimensions
C          01a  81 oct 31  dhn  written
C
C
C     purpose:
          to compute BAIR(I), BSMPL(I), and RPERM(I) from three arrays,
C         EHALL(I), GMRNGE(I), and EFLUX(I)
C
C
C     hardware required:  none
C
C
C     software required:
C         no subroutines needed ---- called by sbr PUTOUT
C
C
C
C
C
C
C         INPUT PARAMETERS:
C                   SMPLOD  the Out.. Diameter of a cylindrical sample with a
C                           .mall hole on its axis {meters}.
C                   SMPLID  .he diameter of the hole {meters}.
C                   ACOIL   The turns area product of the coil that measures
C                           flux-linkage. {turns * meters * meters}
C                   TCOIL   The no. of turns of the coil. {turns = dimension-
C                                                             less = "1" }
C                   SLFLUX  The flux produced by the flux-standard (SLFS).
C                           {Wb}
C                   ESLFS   The output potential of the integrator due to
C                           SLFLUX. {V}
C                   N       The no. of input (and output) "sets".
C                   DATA(I, 5)       The Ga.ssmeter range. {Teslas full scale
C                                                           = T / V }
C                   DATA(I, 2)       The Gaussmeter output potential {V}
C                   EFLUX(I)         The integrator output potential due to
C                                    flux linkage of coil. {V}
C
C         INTERMEDI..E PARAMETERS:
C                   .T      ATAN2(0.0,-1.0) {1}
C                   ASMPL   The area of the sample. {meters * meters}
C                   AAIR    The area associated with the flux measured by the
C                           coil but not in the sample i.e. the area of "air".
C                           {meters * meters}
C                   FLXPRE  SLFLUX / ESLFS {Wb / V}
C                   FLUX    The total flux measured by the coil i.e.
C                           flux-linkage / (no. of turns) {Wb}.
C
```

```
C       OUTPUT PARAMETERS:
C               BAIR(I) The magnetic induction in the air as measured by
C                       the Hall-probe at the center of the sample. {T}
C               BSMPL(I) The magnetic induction in the sample as com-
C                        puted.
C               RPERM(I) The relative permeability of the sample,
C                        = BSMPL(I) / BAIR(I) = BSMPL / (MUO*H).
C
        DIMENSION DATA (250, 5), EFLUX(250), BAIR(250), BSMPL(250)
        DIMENSION RPERM(250)
C
C
        PI = ATAN2(0.0, -1.0)
C
C   calculate area of sample
C
        ASMPL = 0.25 * PI * ( SMPLOD ** 2 - SMPLID ** 2 )
C
        AAIR = ACOIL / TCOIL - ASMPL
        IF (ESLFS .EQ. 0.0) PAUSE ' ESLFS = 0.0'
        IF ( TCOIL .EQ. 0.0 ) PAUSE ' TCOIL = 0.0'
        FLXPRE = SLFLUX / ESLFS / TCOIL
        IF ( ASMPL .EQ. 0.0) PAUSE ' SAMPLE AREA = 0.0'
D       TYPE *, ' we now begin calculation loop'
C
C
D       TYPE *, N
        IF ( N .GT. 250) PAUSE ' N greater than 250'
        DO 200 I = 1, N
D       TYPE *, T
        BAIR(I) = DATA(I, 5) * DATA(T, 2)
        FLUX = ( FLXPRE * EFLUX(I) )
        BSMPL(I) = ( FLUX - BAIR(I) * AAIR) / ASMPL
        RPERM(I) = 9999.
D       TYPE *, I, BSMPL(I), BAIR(I), RPERM(I), EFLUX(I)
        IF( BAIR(I) .EQ. 0.0) GO TO 200
        RPERM(I) = BSMPL(I) / BAIR(I)
  200   CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE PRNTOT (DATE1, TIME1, COILNM, ACOIL, TCOIL,
     1 SPLDES, SPLOD, SPLID, SPLNTH, GMRMOD, GMRNUM, PRBMOD,
     2 PRBNUM, PRBCON, GMZERO, GMCAL, INTMOD, RINT, CINT, ATNINT,
     3 SLFMOD, SLFLUX, ESLFS, VINTO, TSAMP, VINTS, MAXDAC,
     4 I1, K1, ARRAY, TSAMPF, VINTSF, TEND, VEND, COMM3,
     5 BAIR, BSMPL, RPERM)
C
C   created by don nelson
C
C   file name: PRNT01.FOR
C
C   modification history:
C
C       03a  81 nov 30  mis  output format changed for more digits
C       02b  81 nov 13  mis  all bytes even dimensioned
C       02a  81 nov 06  mis  cleaning up
C       01e  81 nov 05  mis  working
C       01d  81 nov 05  mis   made dimensions explicit, added DEBUG stmt
C       01c  81 nov 05  mis & dhn  misc corrections and additions
C       01b  81 nov 04  dhn  copied from PTOUT1.FOR to facilitate coding.
C       01a  81 nov 03  dhn copied SAVE1.FOR to PTOUT1.FOR
C
C
C   purpose:
C
C       to print parameters of interest.
C
C
C   hardware required:
C
C       none
C
C
C   software required:
C
C       RT-11 operating system
C
C
      DIMENSION ARRAY(250, 3), BAIR(250), BSMPL(250), RPERM(250)
C
C   in main program the 4 new arrays must be dimensioned (250).
C
      BYTE COMM2(72), SPLDES(72), TIME1(8), DATE1(10), COMM3(72)
      BYTE COILNM(10), GMRMOD(10), PRBMOD(10), INTMOD(10), SLFMOD(10)
C
D     PAUSE ' print sbr just before print 500'
C
      PRINT 500
500   FORMAT(1H1, 2X, 1HI, 11H    BSMPL(I),10H  RPERM(I), 13X,
     1 7HBAIR(I), 5X, 5HBINTR// 4X, 6H(UNIT), 10H    (TESLA), 4X,
     2 6H(UNIT), 13X, 7H(TESLA), 10H    (TESLA) // )
C
C
D     PAUSE ' PRINT SBR just after format 500'
C
      N = I1
      DO 501, I = 1, N
      BINTR = BSMPL(I) - BAIR(I)
C
D     TYPE *, I
```

```
C
      PRINT 502, I, BSMPL(I), RPERM(I), BAIR(I), BINTR
  502 FORMAT ( I10, F10.4, F10.3, 10X, F10.6, F10.4)
  501 CONTINUE
D
D     PAUSE 'print sbr just before return'
C
C
      RETURN
      END
```

```
      PROGRAM CMCPS1
C
C   created by mike i green
C
C   file name:  CMCPS1.FOR
C
C   modification history
C
C   01c    4 aug 81  mig  comments added, order changed
C   01b   81 sep 24  mig  working
C   01a   81 sep 23  mig  written
C
C
C   purpose:
C
C   exercise KINETIC SYSTEMS 3160 POWER SUPPLY CONTROLLER
C
C
C   hardware required:
C
C   CAMAC controller - STANDARD ENGINEERING CORP. MODEL CC-LSI-11
C   KS 3130 POWER SUPPLY CONTROLLER
C
C
C   software required:
C
C   RT-11 operating system
C   STD. ENG. CORP., "PDP-11/CAMAC SUPPORT LIBRARY"
C
C
      IMPLICIT INTEGER(A-Z)
      LOGICAL*1 ENABLE, DISABL
      DATA ENABLE, DISABL /.TRUE.,.FALSE./
      DATA CRATE, SLOT, SBADDR /1, 15, 0/
      CADDR = CDREG( ,, CRATE, 0, 0)  !declare crate address
      CALL CCCZ(CADDR)                !initialize crate "dataway Z cycle"
      CALL CCCI(CADDR, DISABL)        !clear dataway inhibit
C
      ADDR = CDREG( ,, CRATE, SLOT, SBADDR )
100   TYPE *, ' enter dataword :'
      ACCEPT *, W1
      CALL CSSA (16, ADDR, W1)
      GO TO 100
      CALL EXIT
      END
```

```
      PROGRAM MPX1
C
C   created by mike i green
C
C   file name:  MPX1.FOR
C
C   modification history
C
C   01a  81 oct 26        mig  written
C
C
C   purpose:
C
C        set HP-3495A Scanner channel
C
C
C   hardware required:
C
C        HP-3495A SCANNER
C
C
C   software required:
C
C   RT-11 opperating system
C        GPIB.OBJ          81 Oct 23
C        DEVTB1.TXT        81 oct 23
C
      IMPLICIT INTEGER(A-Z)
C
C
C   put all GPIB devices into remote mode
C
      J = IBUP(4, 0)
C
C
      TYPE *, 'ENTER CHANNEL DESIRED :'
      ACCEPT *, CH
      GOTO(101, 102, 103, 104, 105, 106, 107, 108, 109, 110), CH

C
101   J = IBUP(0, 1, '01', 0)          !scanner to ch 1
      J = IBUP(3, 1)                   !trigger scanner
      GOTO 900
C
102   J = IBUP(0, 1, '02', 0)          !scanner to ch 2
      J = IBUP(3, 1)                   !trigger scanner
      GOTO 900
C
103   J = IBUP(0, 1, '03', 0)          !scanner to ch 3
      J = IBUP(3, 1)                   !trigger scanner
      GOTO 900
C
104   J = IBUP(0, 1, '04', 0)          !scanner to ch 1
      J = IBUP(3, 1)                   !trigger scanner
      GOTO 900
C
105   J = IBUP(0, 1, '05', 0)          !scanner to ch 1
      J = IBUP(3, 1)                   !trigger scanner
      GOTO 900
C
```

```
106     J = IBUP(0, 1, '06', 0)             !scanner to ch 1
        J = IBUP(3, 1)                      !trigger scanner
        GOTO 900
C
107     J = IBUP(0, 1, '07', 0)             !scanner to ch 1
        J = IBUP(3, 1)                      !trigger scanner
        GOTO 900
C
108     J = IBUP(0, 1, '08', 0)             !scanner to ch 1
        J = IBUP(3, 1)                      !trigger scanner
        GOTO 900
C
109     J = IBUP(0, 1, '09', 0)             !scanner to ch 1
        J = IBUP(3, 1)                      !trigger scanner
        GOTO 900
C
110     J = IBUP(0, 1, '10', 0)             !scanner to ch 1
        J = IBUP(3, 1)                      !trigger scanner
        GOTO 900
C
900     CALL EXIT
        END
```

```
        TALK    LISTEN  SECOND  READ    EOD     WRITE   DEVICE NAME     SLOT
.BYTE   79.,    47.,    -1.,    -1.,    -1.,    -1.     ;GPIB11V-1       0
.BYTE   -1.,    42.,    -1.,    -1.,    -1.,    1.      ;HP-3495A-MPX    1
.BYTE   87.,    55.,    -1.,    1.,     10.,    1.      ;HP-3437A-DVM    2
.BYTE   86.,    54.,    -1.,    1.,     10.,    1.      ;HP-3455A-DVM    3
.BYTE   80.,    48.,    -1.,    1.,     10.,    3.      ;HAR-ANAL-SYS    4
```

LAWRENCE BERKELEY LABORATORY - UNIVERSITY OF CALIFORNIA ENGINEERING NOTE	CODE Book No. 644	SERIAL MT 307	PAGE 1 OF 15
AUTHOR Donald H. Nelson, Michael I. Green — DEPARTMENT Electronics Engineering	LOCATION B25A-124	DATE February 4, 1982	

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

CODE	SERIAL	PAGE
Appendix C	MT 307	2 OF 15

AUTHOR	DEPARTMENT	LOCATION	DATE
D.H. Nelson	Electronics Engineering	B25A-124	

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 C1 Magnetization Data

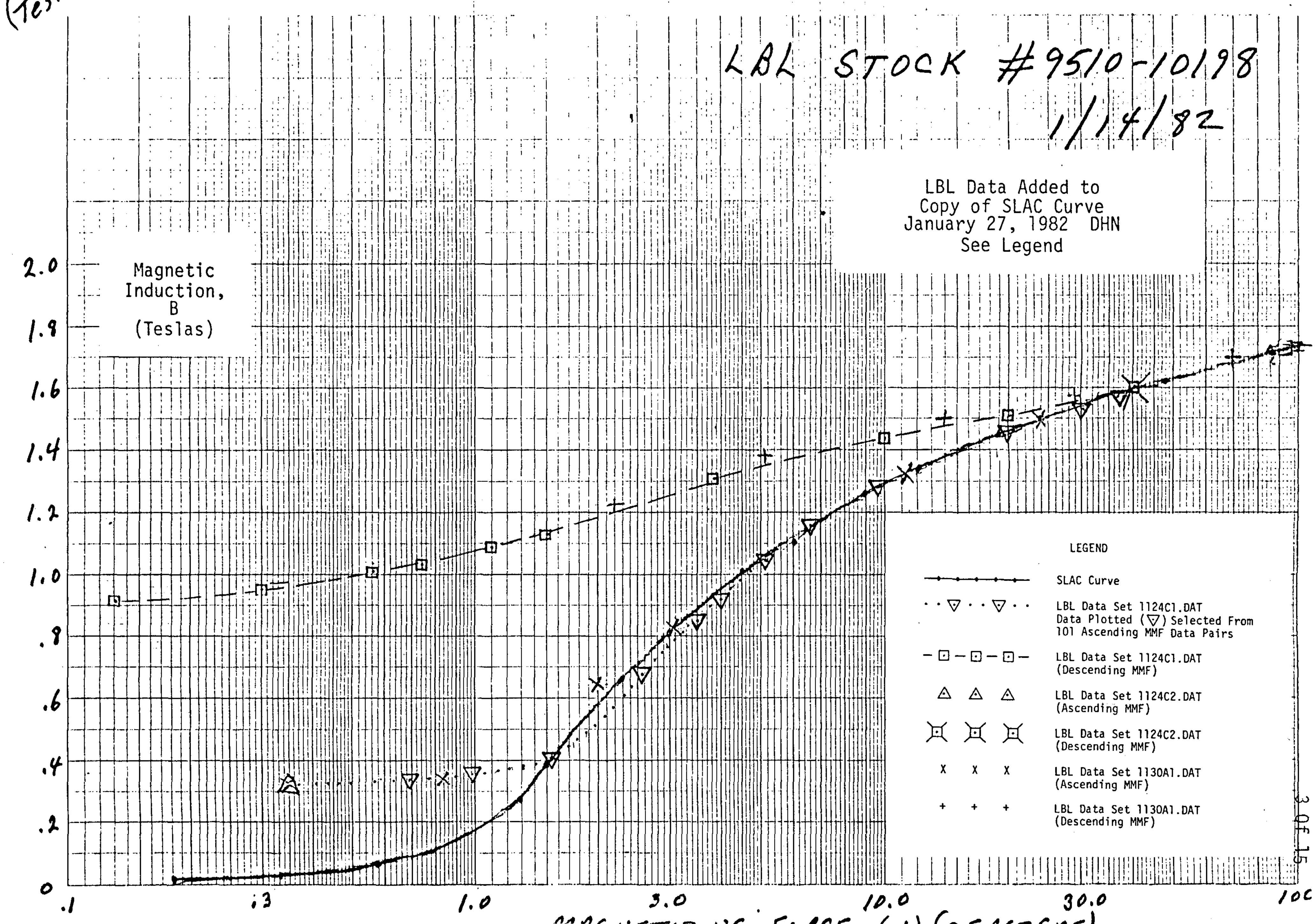
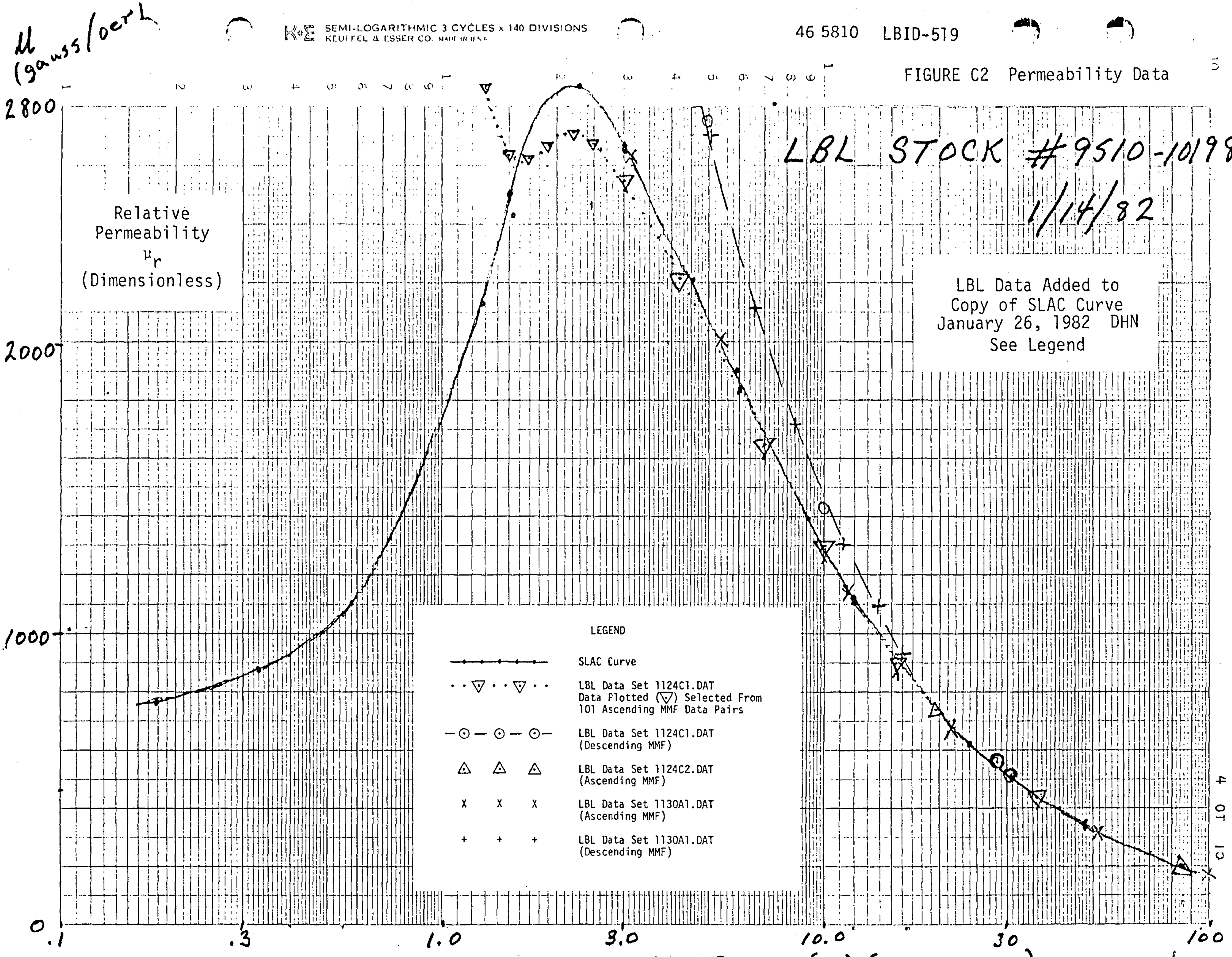


FIGURE C2 Permeability Data



```
*RUN

*****    PERMEAMETER PROGRAM    *****

X-SECTIONAL AREA OF SAMPLE IN M↑2 = 1.1198E-04
RANGE: 12 OR 120 OERSTEDS? 120

H(OERSTEDS) =  8.7716  * I(AMPERES)
B(TESLA) = 99.2241  * IVDT(VOLT-SECONDS)

TITLE FOR PLOT ? LBL STOCK #9510-10198 1/14/82    RUN #1

***** DEGAUSSING *****
   1.50 OERSTEDS
***** DEGAUSSING *****
   3.00 OERSTEDS
***** DEGAUSSING *****
   6.00 OERSTEDS
***** DEGAUSSING *****
  12.00 OERSTEDS
***** DEGAUSSING *****
  24.00 OERSTEDS
***** DEGAUSSING *****
  48.00 OERSTEDS
***** DEGAUSSING *****
  96.00 OERSTEDS

***** SUMMARY VALUES *****
```

1/2-CYCLE	H(OERSTEDS)	B(TESLA)	B/H(GAUSS/OER)
1	1.5087	.3258	2159.3100
2	-1.5613	-.4232	2710.2400
AVERAGES:	1.5350	.3745	2434.7800
3	3.0174	.6831	2263.9000
4	-3.0701	-.9391	3059.0200
AVERAGES:	3.0437	.8111	2661.4600
5	6.0612	.9847	1624.5700
6	-6.0875	-1.2536	2059.3100
AVERAGES:	6.0743	1.1191	1841.9400
7	12.1259	1.2012	990.6200
8	-12.1171	-1.4843	1224.9500
AVERAGES:	12.1215	1.3428	1107.7900
9	24.2346	1.3504	557.2160
10	-24.1294	-1.6496	683.6390
AVERAGES:	24.1820	1.5000	620.4280
11	48.3062	1.4692	304.1440
12	-48.0079	-1.7787	370.5030
AVERAGES:	48.1571	1.6240	337.3240
13	82.4866	1.5420	186.9370
14	-83.8637	-1.7865	213.0240
AVERAGES:	83.1752	1.6642	199.9800

```
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 OF AXES: X = -6   Y = -4
X-SCALE (OER/IN) = 2X-OFFSET (OER) = -12
Y-SCALE (TESLA/IN) = .5Y-OFFSET (TESLA) = -2    RUN #1A
TITLE FOR PLOT ? LBL STOCK #9510-10198 1/14/82
LABEL FOR PLOT (YES/NO) ? Y

ANOTHER PLOT (YES/NO) ? N
ENTER 1 TO RERUN, 2 TO RESTART, 3 TO END ? 3
```

TABLE CI Run #1 Data

```
#RUN

*****     PERMEAMETER PROGRAM     *****

X-SECTIONAL AREA OF SAMPLE IN M^2 = 1.1197E-04
RANGE: 12 OR 120 OERSTEDS? 120

H(OERSTEDS) =  8.7716  * I(AMPERES)
B(TESLA) =  99.2329  * IVDT(VOLT-SECONDS)

TITLE FOR PLOT ? LEL STOCK # 9510-10198 1/14/82 RUN #2

***** DEGAUSSING *****
   1.50 OERSTEDS
***** DEGAUSSING *****
   3.00 OERSTEDS
***** DEGAUSSING *****
   6.00 OERSTEDS
***** DEGAUSSING *****
  12.00 OERSTEDS
***** DEGAUSSING *****
  24.00 OERSTEDS
***** DEGAUSSING *****
  48.00 OERSTEDS
***** DEGAUSSING *****
  96.00 OERSTEDS

***** SUMMARY VALUES *****
```

1/2-CYCLE	H(OERSTEDS)	B(TESLA)	B/H(GAUSS/OER)
1	1.4999	.3358	2238.9500
2	-1.4035	-.4297	3062.0800
AVERAGES:	1.4517	.3828	2650.5200
3	3.0087	.7097	2358.9000
4	-3.0876	-.9172	2970.5700
AVERAGES:	3.0481	.8135	2664.7300
5	5.8682	1.0069	1715.9300
6	-5.9208	-1.2351	2085.9600
AVERAGES:	5.8945	1.1210	1900.9400
7	11.9417	1.2218	1023.1100
8	-11.9505	-1.4688	1229.1100
AVERAGES:	11.9461	1.3453	1126.1100
9	24.2259	1.3700	565.4960
10	-24.1382	-1.6341	676.9970
AVERAGES:	24.1820	1.5021	621.2470
11	48.2887	1.4762	305.7000
12	-48.0167	-1.7762	369.9110
AVERAGES:	48.1527	1.6262	337.8050
13	84.2585	1.5553	184.5880
14	-85.1707	-1.8866	221.5110
AVERAGES:	84.7146	1.7210	203.0500

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

ANOTHER PLOT (YES/NO) ? Y
ENTER PLOT PARAMETERS (YES/NO) ? Y
PLOT SIZE (INCHES): X = 12  Y = 8
ORIGI[illegible]
X-SCALE (OER/IN) = 2   X-OFFSET (OER) = -12
Y-SCALE (TESLA/IN) = .5   Y-OFFSET (TESLA) = -2
TITLE FOR PLOT ? LEL STOCK #9510-10198 RUN #2A
LABEL FOR PLOT (YES/NO) ? Y

ANOTHER PLOT (YES/NO) ? N
```

TABLE CII Run #2 Data

```
ENTER 1 TO RERUN, 2 TO RESTART, 3 TO END ? 2

*****     PERMEAMETER PROGRAM     *****

X-SECTIONAL AREA OF SAMPLE IN M^2 = 1.1197E-04
RANGE: 12 OR 120 OERSTEDS? 12

H(OERSTEDS) =  8.7716  * I(AMPERES)
B(TESLA) =  99.2329  * IVDT(VOLT-SECONDS)

TITLE FOR PLOT ? LBL STOCK # 9510-10198 RUN 3

***** DEGAUSSING *****
   0.15 OERSTEDS
***** DEGAUSSING *****
   0.30 OERSTEDS
***** DEGAUSSING *****
   0.60 OERSTEDS
***** DEGAUSSING *****
   1.20 OERSTEDS
***** DEGAUSSING *****
   2.40 OERSTEDS
***** DEGAUSSING *****
   4.80 OERSTEDS
***** DEGAUSSING *****
   9.60 OERSTEDS

***** SUMMARY VALUES *****
```

1/2-CYCLE	H(OERSTEDS)	B(TESLA)	B/H(GAUSS/OER)
1	.1403	.0100	714.1320
2	-.2193	-.0185	841.6860
AVERAGES:	.1798	.0142	777.9090
3	.2895	.0224	774.7680
4	-.3684	-.0372	1010.0900
AVERAGES:	.3289	.0298	892.4280
5	.5351	.0539	1007.0400
6	-.6228	-.0747	1199.8100
AVERAGES:	.5789	.0643	1103.4300
7	1.2456	.2410	1935.0400
8	-1.3245	-.3084	2328.7200
AVERAGES:	1.2850	.2747	2131.8800
9	2.2543	.5603	2485.3800
10	-2.3332	-.7608	3260.7600
AVERAGES:	2.2938	.6605	2873.0700
11	4.5349	.8962	1976.1200
12	-4.5875	-1.1242	2450.5000
AVERAGES:	4.5612	1.0102	2213.3100
13	9.0822	1.1413	1256.6900
14	-9.1085	-1.3900	1526.1100
AVERAGES:	9.0953	1.2657	1391.4000

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

ANOTHER PLOT (YES/NO) ? N
ENTER 1 TO RERUN, 2 TO RESTART, 3 TO END ? 3

[illegible]
*LIST 1230
1230 GOSUB 1030
*1230 GOSUB 1010
```

TABLE CIII Run #3 Data

```
*RUN

*****     PERMEAMETER PROGRAM     *****

X-SECTIONAL AREA OF SAMPLE IN M↑2 = 1.1197E-04
RANGE: 12 OR 120 OERSTEDS? 120

H(OERSTEDS) =  8.7716   * I(AMPERES)
B(TESLA) =   99.2329   * IVDT(VOLT-SECONDS)

TITLE FOR PLOT ? LBL STOCK #9510-10198 1/14/82 RUN #4

***** DEGAUSSING *****
   1.50 OERSTEDS
***** DEGAUSSING *****
   3.00 OERSTEDS
***** DEGAUSSING *****
   6.00 OERSTEDS
***** DEGAUSSING *****
  12.00 OERSTEDS
***** DEGAUSSING *****
  24.00 OERSTEDS
***** DEGAUSSING *****
  48.00 OERSTEDS
***** DEGAUSSING *****
  96.00 OERSTEDS

***** SUMMARY VALUES *****
```

1/2-CYCLE	H(OERSTEDS)	B(TESLA)	B/H(GAUSS/OER)
1	1.4999	.3359	2239.6100
2	-1.5789	-.4388	2779.0400
AVERAGES:	1.5394	.3874	2509.3300
3	3.0174	.7048	2335.9200
4	-3.0876	-.9210	2982.7800
AVERAGES:	3.0525	.8129	2659.3500
5	6.0524	1.0061	1662.3900
6	-6.0963	-1.2324	2021.5400
AVERAGES:	6.0743	1.1193	1841.9600
7	12.1171	1.2162	1003.7100
8	-12.1171	-1.4670	1210.6500
AVERAGES:	12.1171	1.3416	1107.1800
9	24.2259	1.3614	561.9730
10	-24.1469	-1.6367	677.8200
AVERAGES:	24.1864	1.4991	619.8960
11	48.4553	1.4665	302.6410
12	-48.1834	-1.7765	368.6930
AVERAGES:	48.3194	1.6215	335.6670
13	85.8812	1.5779	183.7350
14	-86.3197	-1.8633	215.8560
AVERAGES:	86.1005	1.7206	199.7950

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

ANOTHER PLOT (YES/NO) ? Y
ENTER PLOT PARAMETERS (YES/NO) ? Y
PLOT SIZE (INCHES): X = 12  Y = 8
[illegible] = [illegible]  Y = -4
X-SCALE (OER/IN) = 2   X-OFFSET (OER) = -12
Y-SCALE (TESLA/IN) = .5   Y-OFFSET (TESLA) = -2
TITLE FOR PLOT ? LBL STOCK #9510-10198 1/14/82 RUN #4A
LABEL FOR PLOT (YES/NO) ? Y

ANOTHER PLOT (YES/NO) ? N
ENTER 1 TO RERUN, 2 TO RESTART, 3 TO END ? 3
```

TABLE IV Run #4 Data

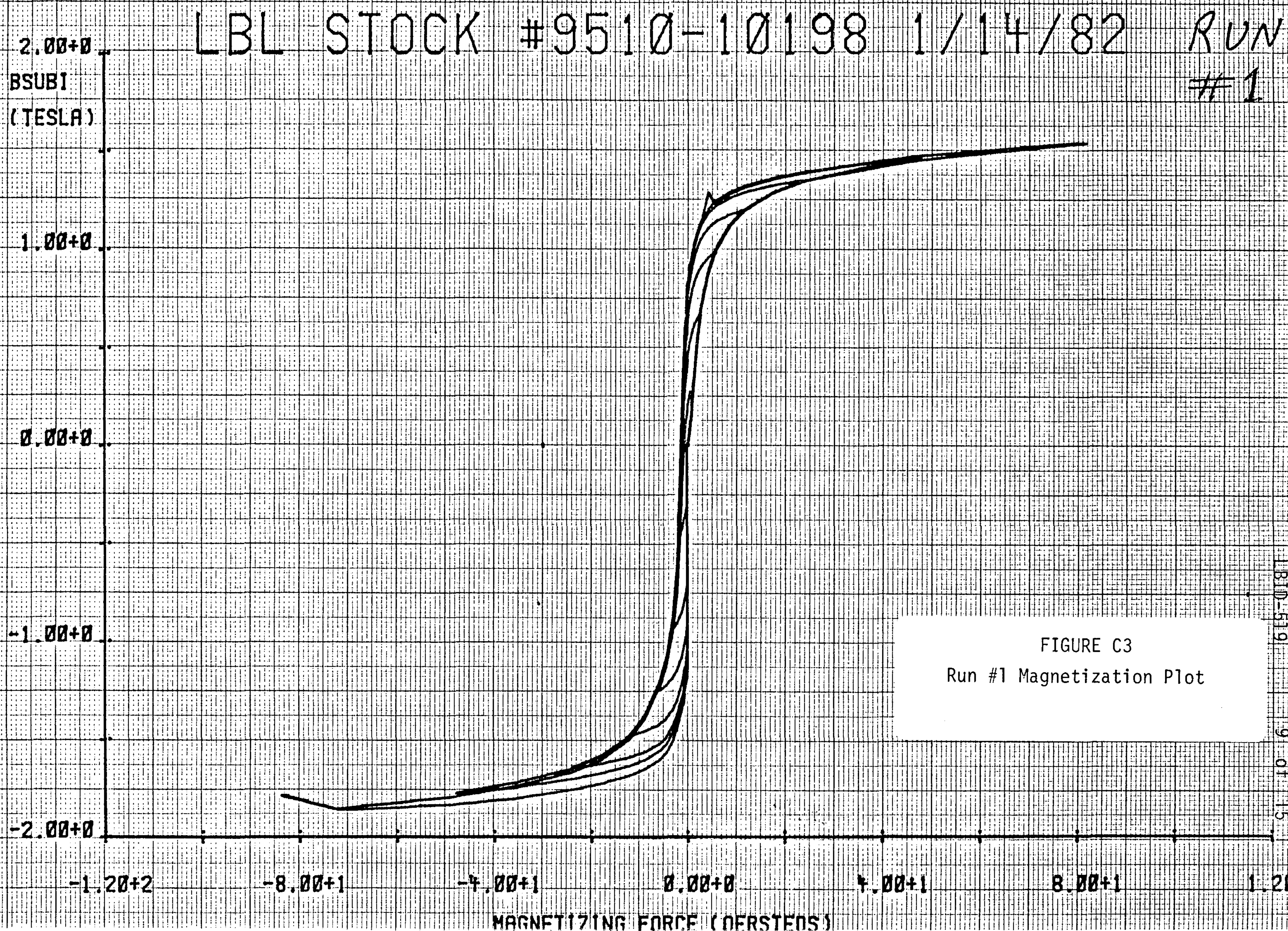


FIGURE C3
Run #1 Magnetization Plot

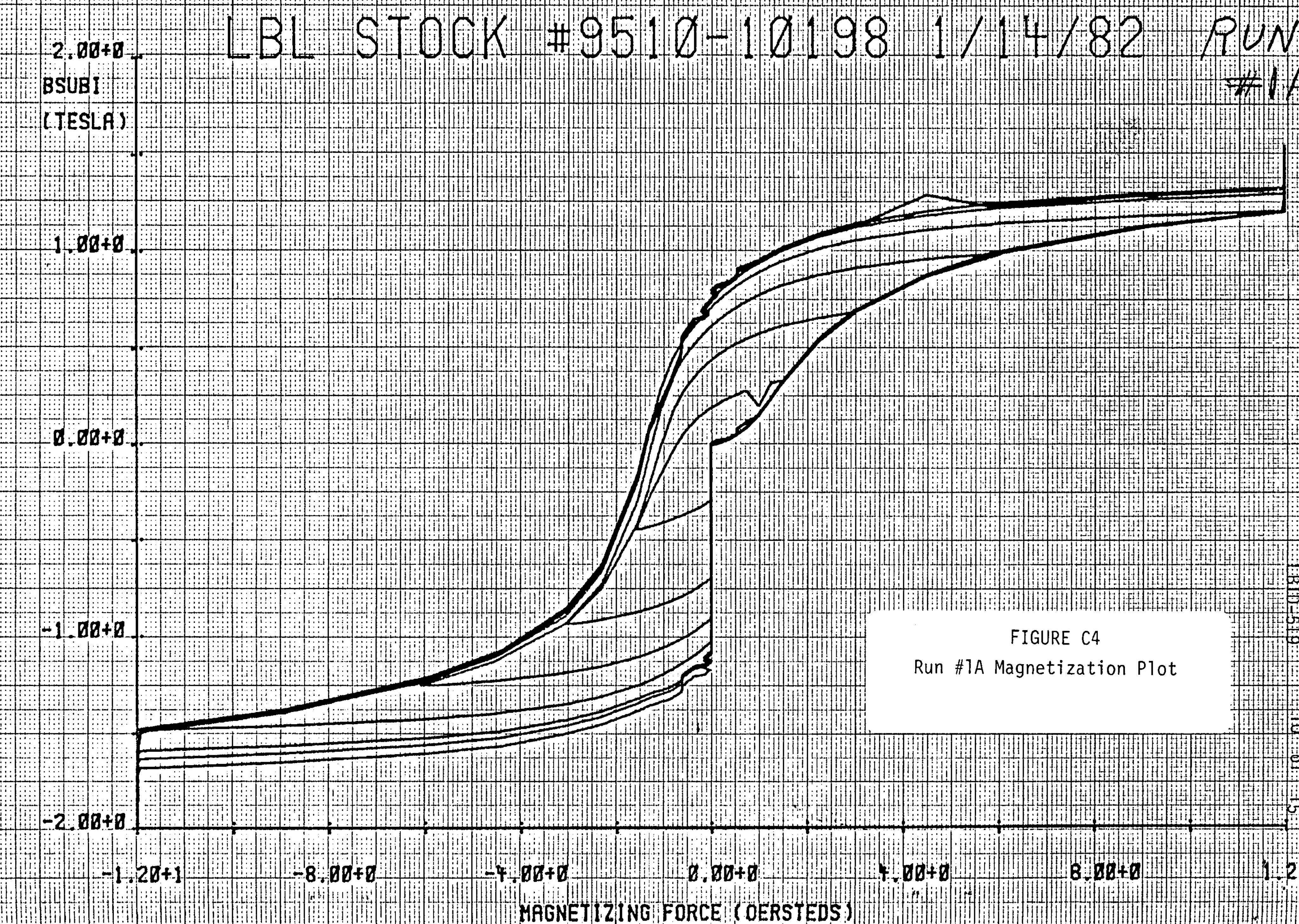


FIGURE C4
Run #1A Magnetization Plot

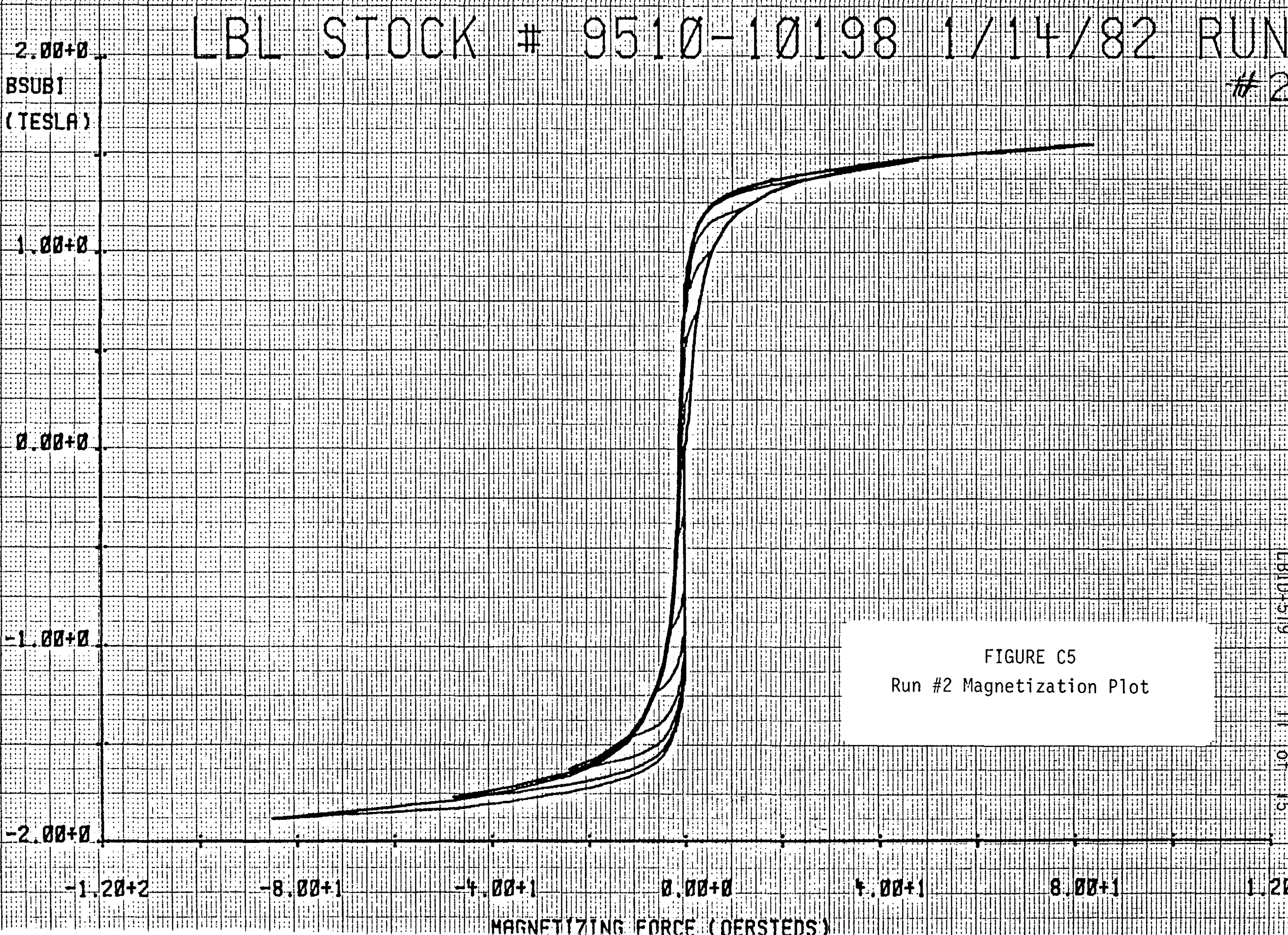


FIGURE C5
Run #2 Magnetization Plot

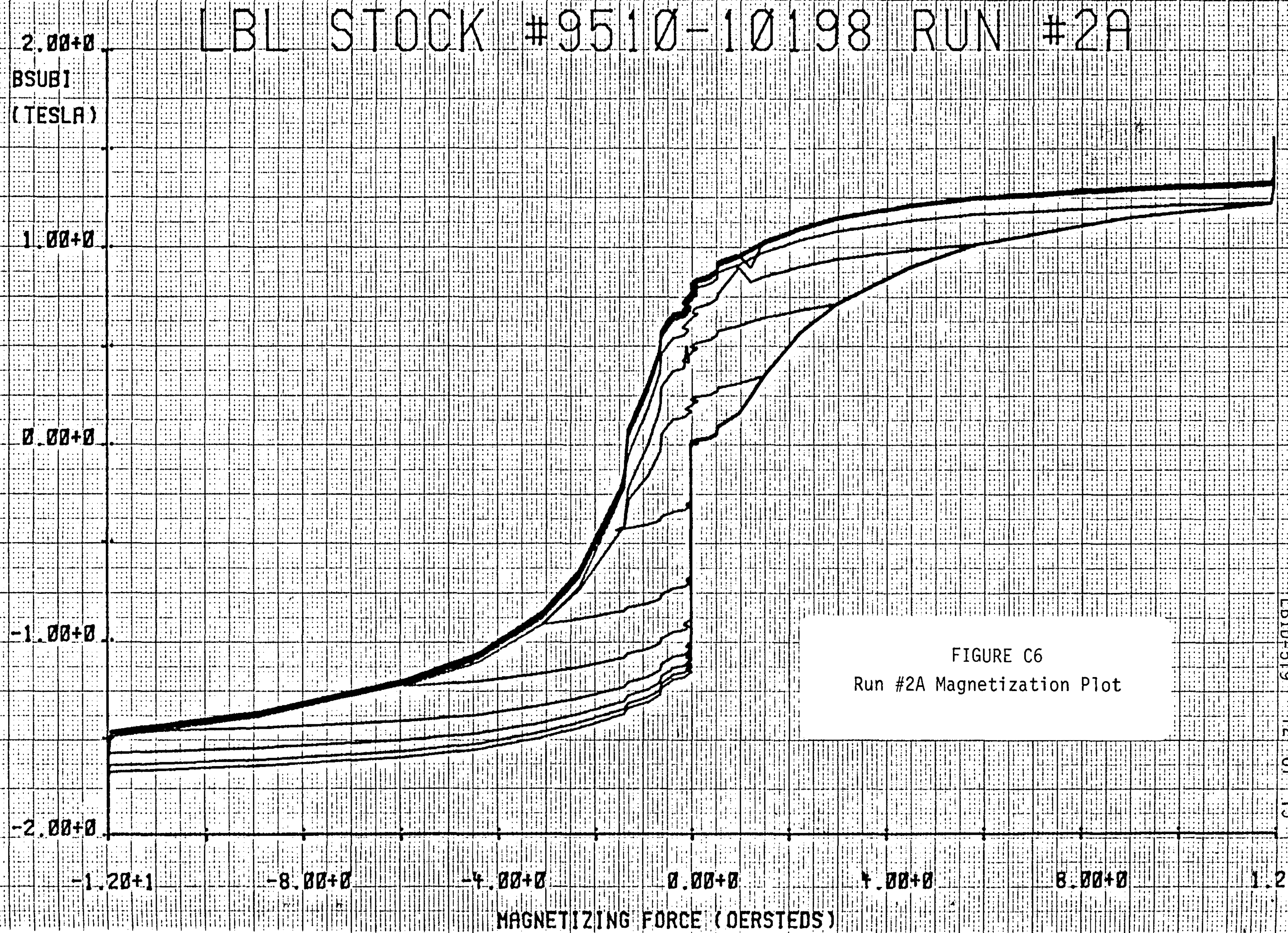


FIGURE C6
Run #2A Magnetization Plot

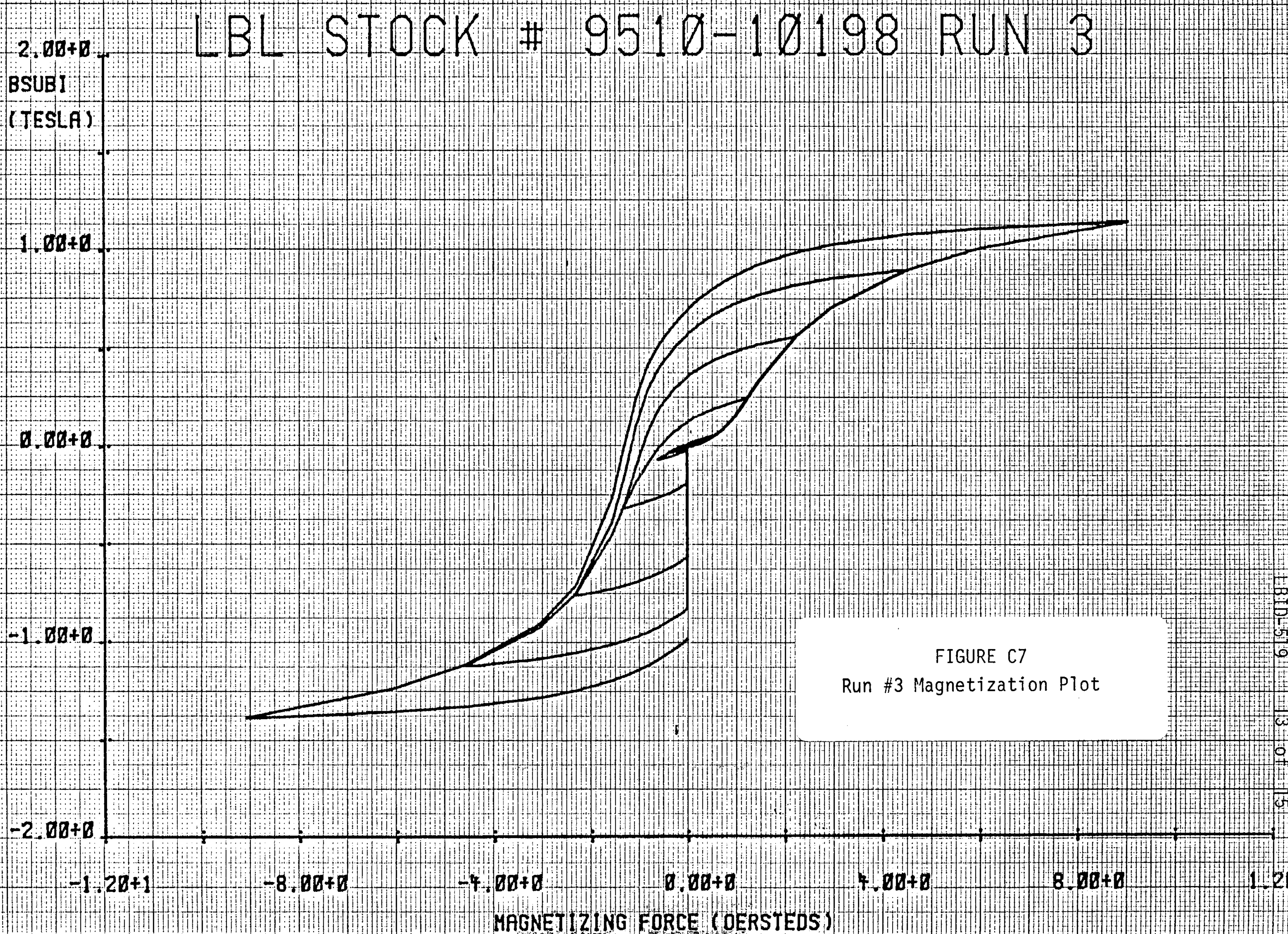


FIGURE C7
Run #3 Magnetization Plot

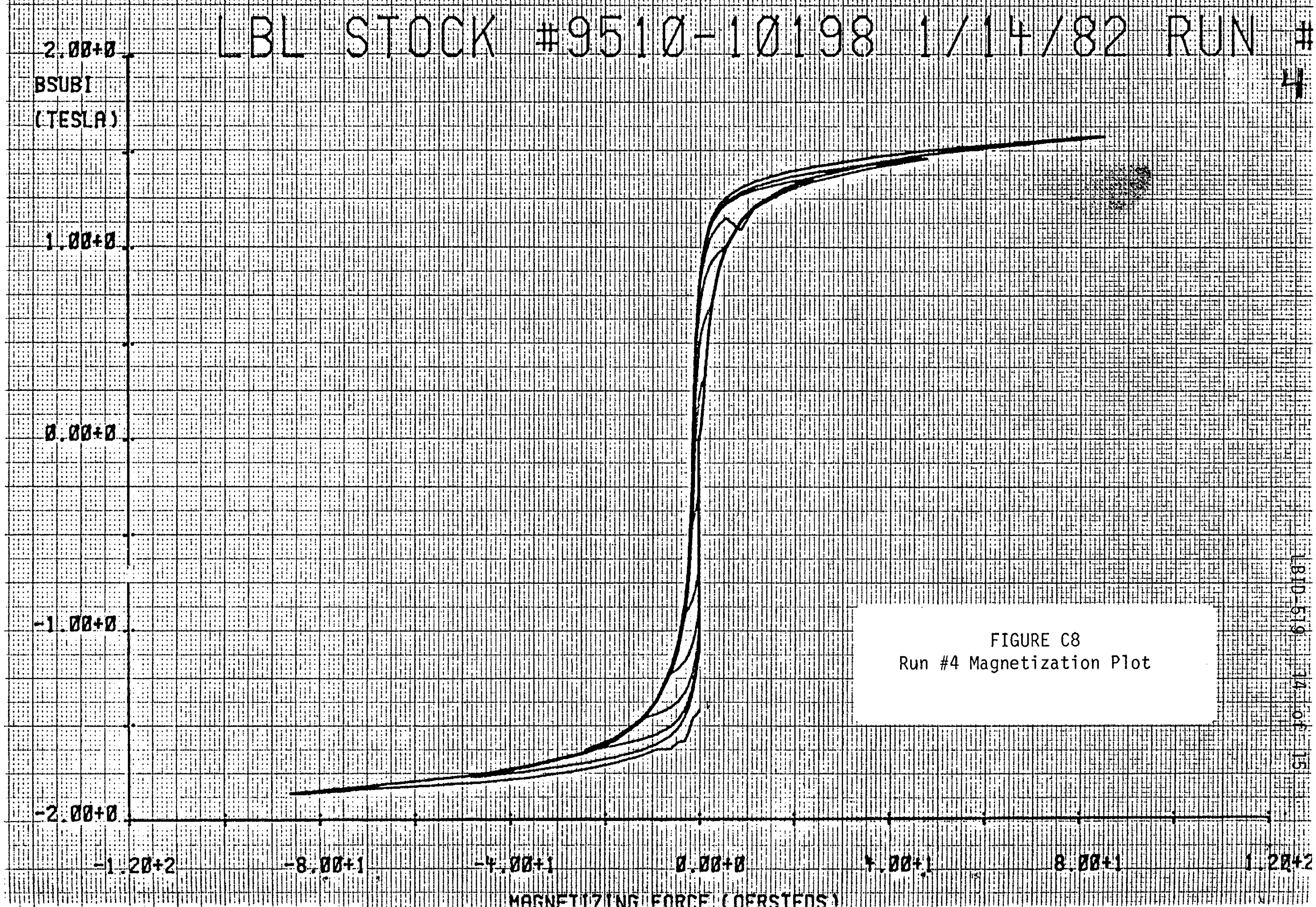


FIGURE C8
Run #4 Magnetization Plot

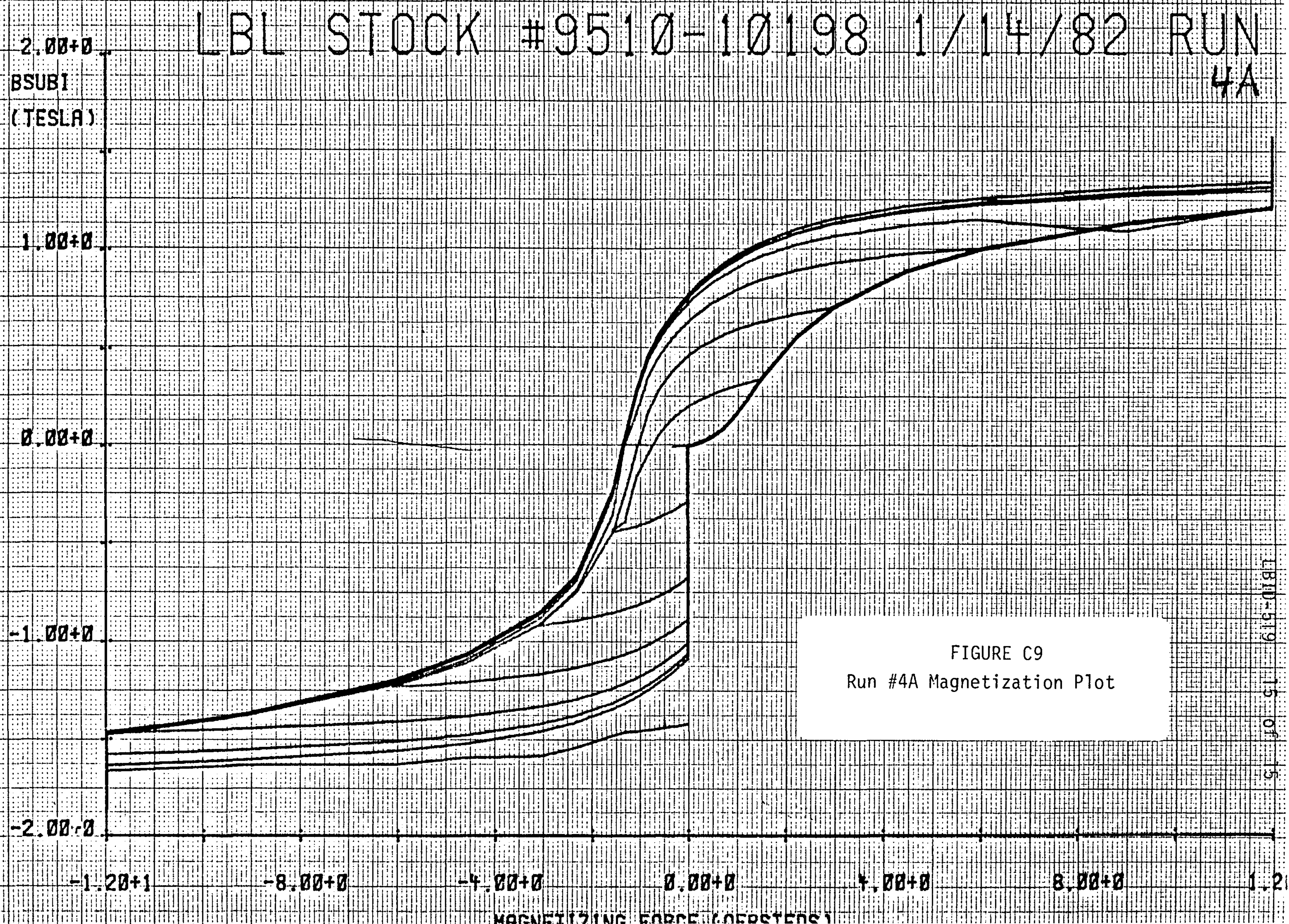


FIGURE C9
Run #4A Magnetization Plot

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