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SUBJECT

"FIXING" of a 6" LANL Rare Earth Quadrupole Magnet
By The Halbach Technique

NAME

Michael I. Green

DATE

January 7, 1982

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INTRODUCTION

Los Alamos National Laboratory requested that the Magnetic Measurements Engineering (MME) Group of the Lawrence Berkeley Laboratory (LBL) evaluate the error harmonics of a segmented Rare Earth Cobalt (REC) quadrupole magnet, and reduce undesired harmonics by using the theory developed by Klaus Halbach.^{1, 2}

The LBL MME Data Acquisition System (DAS) was programmed to compute the shims required to "zero" the amplitudes of the third, fourth, fifth, and the real part of the sixth harmonic for a LANL REC quadrupole magnet.

After only two iterations, each of these error harmonics of the quadrupole magnet was reduced more than a factor of ten, to below 0.1% of the fundamental amplitude. Note that the imaginary part of the sixth harmonic remained about 1% of fundamental throughout the measurements. The fundamental decreased ~2% in comparison to the unshimmed quadrupole.

THEORY

The details of the theory implemented in this report are described in LBL report no. LBL-13221² (to be published in NIM) which in turn is based on Halbach's 1980 NIM paper.¹

Briefly, reference 2 contains a first order perturbation theory that establishes the (first order) relationships between perturbations of the poles of a segmented REC multipole magnet and the harmonics that are produced by these perturbations. In this study, we use only the coefficients that relate the generation of the real and imaginary parts of certain harmonics to radial movements of poles.

Eight radially adjustable poles are used to "Zero" the real and imaginary parts of the third, fourth, and fifth harmonics, and the real part of the sixth harmonic. Modification of the imaginary part of the sixth harmonic is not possible.² For that reason, the one remaining free parameter is used to minimize the sum of the squares

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of the radial displacements. A very slight reduction in the magnitude of the second harmonic occurs as initially all poles are at their minimum radial position and all adjustments must be made radially outward.

The matrices used to compute shims and the effect of shims were supplied by K. Halbach.³

QUADRUPOLE DESCRIPTION

The quadrupole is identified as 6" LANL Rare Earth Quadrupole S/N R2, Shipping Memo No. SM87945, Shipping Request No. 80718 C.

Figure 1 is a sketch of the REC quadrupole. Each of the eight magnetic poles can be adjusted radially by insertion of shims. The minimum radial position for each block is 3.5 cm. Each block can be moved radially outward approximately 2 mm.

HARDWARE AND SOFTWARE

LBL engineering note MT 303⁴ generally describes the hardware and software used. Exceptions are the use of the new LBL MME voltage to frequency converter designed by W. Hearn^{5,6} and the coding indicated in Appendix A (which will be supplied upon request).

PRELIMINARY TESTS

Harmonic analysis measurements of the first LANL REC quadrupole were found to be inconsistent. Lack of adequate reproducibility was attributed to loose mechanical tolerances in the assembly that controlled the location of the REC blocks.

The second quadrupole (delivered on November 30, 1981), the subject of this report, was manufactured to much closer tolerances. To determine whether consistent results could be obtained after shimming poles and also, to test algorithms used in the coding, thirty-three data measurements were made, seventeen runs with no shims separated by sixteen runs where each pole was twice shimmed by 21 mils. Based on the measurements of the quadrupole with no shims, we conclude that for any error term,

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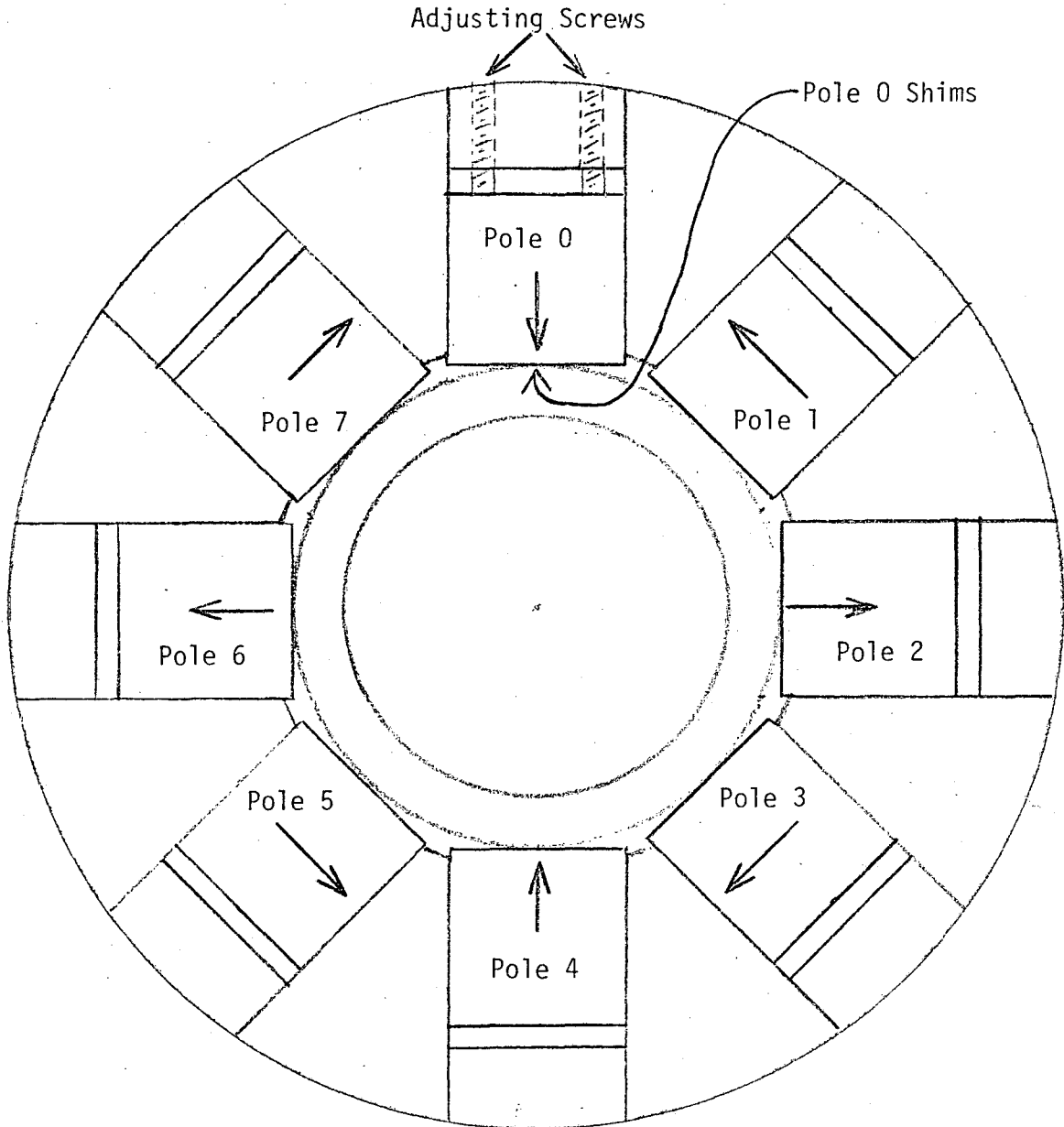


FIGURE 1 Sketch of Quadrupole
Arrow Indicates Magnetization Direction

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the standard deviation is less than 0.05% of the fundamental term for the harmonics up to $n = 10$.

RESULTS

The results of this program are quite dramatic and are summarized in Table I. The amplitudes of the third, fourth, fifth, and real part of the sixth harmonic were reduced more than a factor of ten, to below 0.1% of the fundamental amplitude.

Table II tabulates the shims used for the data sets. Actual copies of the computer output are in Appendixes B, C and D which will be supplied upon request only.

Data sets 1230A1, 1230B1, and 1230C1 are representative of the unshimmed quadrupole. Data sets 1230B1 and 1230C1 were obtained after shimming and then unshimming two of the poles.

Data sets 1231A2, 3, 4, and 5 are the results of the first iteration and data sets 1231B1, 2, 3, and 4 are the results of the second iteration.

ACKNOWLEDGEMENTS

My thanks go to Klaus Halbach for his aid in developing the algorithms used and to Don Nelson for test plan suggestions and editing of this note.

REFERENCES

1. K. Halbach, Nucl. Instr. and Meth., 169, 1, 1980.
2. K. Halbach, LBL Report No. LBL-13221, 1981.
3. K. Halbach, Personal Communications.
4. M.I. Green and D.H. Nelson, LBL Internal Report No. MT 303, 1981.
5. W.E. Hearn, M.I. Green, D.H. Nelson and D.J. Rondeau, IEEE Trans. Nucl. Sci., NS 29, 1, 1982.
6. W.E. Hearn, LBL Internal Report No. MT 305, 1981.

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Data Set	B3/B2 (%)	B4/B2 (%)	B5/B2 (%)	B6/B2 (%)	Re B6/B2 (%)	Description
1230A1	1.035	0.831	0.394	1.954	1.622	No Shims
B1	1.029	0.836	0.390	1.957	1.625	No Shims
C1	1.032	0.838	0.370	1.958	1.620	No Shims
Average	1.032	0.835	0.385	1.956	1.622	No Shims
1231A2	0.042	0.032	0.165	0.999	0.046	Shim Schedule 1
3	0.045	0.023	0.173	0.989	0.032	Shim Schedule 1
4	0.045	0.030	0.164	0.999	0.030	Shim Schedule 1
5	0.044	0.034	0.176	1.005	0.032	Shim Schedule 1
Average	0.044	0.030	0.170	0.998	0.035	Shim Schedule 1
1231B1	0.093	0.048	0.026	0.957	0.035	Shim Schedule 2
2	0.092	0.049	0.024	0.966	0.027	Shim Schedule 2
3	0.091	0.053	0.024	0.973	0.039	Shim Schedule 2
4	0.092	0.048	0.020	0.969	0.036	Shim Schedule 2
Average	0.092	0.050	0.024	0.966	0.034	Shim Schedule 2

TABLE I Tabulation of Measured Error Harmonic Ratios
Evaluated at $r = 3.5$ cm

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Shims Calculated or Used (Mils)

Data Set	Pole 0	Pole 1	Pole 2	Pole 3	Pole 4	Pole 5	Pole 6	Pole 7	Remarks
1230A1	6.3	26.4	11.4	30.7	1.1	1.7	0.0	24.1	Calculated
B1	6.3	26.2	11.1	30.4	0.7	1.6	0.0	24.2	Calculated
C1	6.7	26.0	11.2	30.6	0.6	1.8	0.0	24.1	Calculated
	6	26	11	30	0	1	0	24	Schedule 1
	Used on Data Sets 1 2 3 1 A 2, 3, 4, 5								
1231A2	1.8	1.9	0.0	3.5	1.2	1.2	2.0	0.1	Additional Calculated
3	1.9	1.9	0.2	3.6	1.2	1.2	2.2	0.0	Additional Calculated
4	1.7	1.9	0.1	3.4	1.2	1.0	2.0	0.0	Additional Calculated
5	2.0	2.0	0.1	3.6	1.2	1.1	2.1	0.0	Additional Calculated
	8	28	11	33	1	2	2	24	Schedule 2
	Used on Data Sets 1 2 3 1 B 1, 2, 3, 4								
B1	0.2	0.9	0.9	1.9	2.2	1.2	0.0	0.7	Calculated
2	0.2	0.7	0.8	1.8	2.1	1.1	0.0	0.6	Calculated
3	0.3	0.9	0.8	2.0	2.2	1.2	0.0	0.7	Calculated
4	0.2	0.8	0.8	2.0	2.0	1.1	0.0	0.6	

TABLE II Shim Schedules

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Appendix A

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APPENDIX A

Source Listings of New Coding

SAVE2 Subroutine that saves on disk test parameters and harmonic analysis of permanent magnet Samarium cobalt quadrupoles (incorporated into primary program QDANAL)

QDADJ1 Main program for calculating shims

QDADJ2 Main program for calculating harmonics generated as a result of shimming

RTRV2 Subroutine to retrieve data saved by SAVE2

MTRTST Program to make consistency check of matrices supplied by K. Halbach

SUBROUTINE SAVE2 (DATE, TIME, ATT, REFRAD, VFRNGE, COMM1, COMM2,
1 BL1, PH1, AM2, BL2, PH2, PHN2, BN2, PHN2)

created by: m i green

file name: SAVE2.FOR

modification history:

01b 81 dec 18 mis working

01a 81 dec 18 mis written

PURPOSE:

Save on disk constant parameters, test parameters, and harmonic
analysis of permanent magnet Samarium Cobalt quadrupole.

hardware required: DSD 440 Floppy Disk System

software required: RT-11 operating system

subroutines needed: none

input parameters:

DATE	date of measurement run
TIME	time of measurement
ATT	single coil attenuation ratio used
REFRAD	quadrupole reference radius
VFRNGE	full scale range of V/f converter for 1 Mhz out
COMM1	quad & search coil description
COMM2	test description
BL1	dipole strength (N = 1), unbucked coils
PH1	dipole phase, unbucked coils
AM2	quadrupole fourier amplitude
BL2	quadrupole strength, (N = 2), unbucked coils
PH2	quadrupole phase, unbucked coils
BN2(38)	B(N)/B2 in parts/1000
PHN2(38)	phase of N'th harmonic w/r/t 2nd harmonic

BYTE DATE(10), TIME(8), COMM1(72), COMM2(72), FNAME(12)
DIMENSION BN2(38), PHN2(38)

TYPE 100

100 FORMAT(/, 1X, 'type file name for saving data "MMIDXX.DAT" ', \$)

110 ACCEPT 120, (FNAME(I), I = 1, 10) !read name from terminal

120 FORMAT(10A1)

FNAME(11) = 0 !I/O problem otherwise

check if file already exists

OPEN (UNIT = 1, NAME = FNAME, FORM = 'UNFORMATTED', TYPE =
1 'OLD', ERR = 130)

CLOSE (UNIT = 1)

TYPE *, 'file name already exists, try another'

GO TO 110

```
C open file, write data, close file
```

```
C
```

```
130 OPEN (UNIT = 1, NAME = FNAME, FORM = 'UNFORMATTED')  
WRITE (1) FNAME, DATE, TIME, COMM1, COMM2  
WRITE (1) ATT, REFRAD, VFRNGE, NHARM  
WRITE (1) BL1, PH1, AM2, BL2, PH2, BN2, PHN2  
WRITE (1) (BN2(I), I = 3, NHARM), (PHN2(I), I = 3, NHARM)  
CLOSE (UNIT = 1)
```

```
C
```

```
PRINT 140, ( FNAME( I ), I = 1, 10)  
140 FORMAT ('0 Harmonic Analysis saved in disk file: ', 10A1)  
RETURN  
END
```

PROGRAM QDADJ1

created by: m. i. green

file name: QDADJ1.FOR

modification history:

03a 81 dec 31 mis set min of VCORR instead of max
 02a 81 dec 28 mis added matrix retrieval, and shim calculations
 01b 81 dec 22 mis working
 01a 81 dec 21 mis written (data retrieval, 45 degree rotation,
 separation into real and imaginary parts, and
 printing alphanumeric, constants and analysis)

purpose:

Adjustment of permanent magnet quadrupoles to reduce error
 harmonics, test Klaus Halbach's algorithms and matrices.

subroutines required:

RTRV2(FNAME, DATE, TIME, ATT, REFRAD, VFRNGE, COMM1, COMM2,
 BL1, PH1, AM2, BL2, PH2, NHARM, BN2, PHN2)
 GNPRD(A,B,R,N,M,L) DEC SCIENTIFIC SUBROUTINE PACKAGE

parameter definitions:

output parameters:

FNAME file name of data
 DATE date of measurement run
 TIME time of measurement
 ATT single coil attenuation ratio used
 REFRAD quadrupole reference radius
 VFRNGE full scale range of V/f converter for 1 Mhz out
 COMM1 quad & search coil description
 COMM2 test description
 BL1 dipole strength (N = 1), unbucked coils
 PH1 dipole phase, unbucked coils
 AM2 quadrupole fourier amplitude
 BL2 quadrupole strength, (N = 2), unbucked coils
 PH2 quadrupole phase, unbucked coils
 NHARM highest harmonic saved
 BN2(38) B(N)/B2 in parts/1000
 PHN2(38) phase of N'th harmonic w/r/t 2nd harmonic
 PHROT(38) 45 degree rotated phase angles
 RLBN2(38) real part of rotated B(N)/B(2)
 IMBN2(38) imaginary part of rotated B(N)/B(2)
 FIDENT(72) file identification for P-matrix
 VHAR(7) harmonic vector as defined by K. Halbach
 PMTRX(8,7) P-matrix for generating correction vector
 VCORR(8) correction vector

BYTE DATE(10), TIME(8), COMM1(72), COMM2(72), FNAME(12)

BYTE FIDENT(72)

DIMENSION BN2(38), PHN2(38), PHROT(38), RLBN2(38), VHAR(7)

DIMENSION PMTRX(8, 7), VCORR(8)

REAL IMBN2(38)

```
PI = ATAN2 (0.0, -1.0)
```

```
C-----
C call retrieve subroutine
```

```
CALL RTRV2 (FNAME, DATE, TIME, ATT, REFRAD, VFRNGE,
1 COMM1, COMM2, BL1, PH1, AM2, BL2, PH2, NHARM, BR2, PHN2)
```

```
C-----
FNAME(11) = 0 !I/O problem otherwise
PRINT 130, (FNAME(I), I = 1, 10), DATE, TIME, COMM1, COMM2
130 FORMAT (/, ' file ', 10A1, ', date:', 10A1, ', time:', 8A1,
1, ' has been retrieved. ', 2(/1X, 72A1))
PRINT 140, ATT, VFRNGE, REFRAD
140 FORMAT ( ' The single coil attenuation is ', F6.1, ', the V/f
1 range is ', F7.3, ' volts.', / ' The reference radius is
2 ', f8.6, ' meters.' )
PRINT 150, BL2, PH2
150 FORMAT (/, ' B'L(eff) = ', F6.4, ' AT ', F5.1, ' degrees.' )
```

```
C-----
C 45 phase rotation and separation to real & imaginary parts
```

```
C-----
PRINT 200
200 FORMAT ( ' N B(N)/B(2) ANGLE ROTATED B(N)/B(2)*1000'
1 / ' * 1000 DEG ANGLE REAL IMAGINARY' )
DO 210 N = 3, NHARM
PHROT(N) = PHN2(N) + FLOAT(N) * 45. + 90.
RLBN2(N) = BN2(N) * COS( PHROT(N) * PI / 180. )
IMBN2(N) = BN2(N) * SIN( PHROT(N) * PI / 180. )
PRINT 250, N, BN2(N), PHN2(N), PHROT(N), RLBN2(N), IMBN2(N)
210 CONTINUE
250 FORMAT ( I3, 3X, F6.2, 3X, F6.1, 7X, F6.1, 2( 3X, F6.2) )
```

```
C-----
C---set up harmonic vector
```

```
C-----
DO 310 I = 1, 4
VHAR( 2*I - 1) = 0.001 * RLBN2( I + 2)
IF ( I .EQ. 4 ) GO TO 310
VHAR( 2*I ) = 0.001 * IMBN2( I + 2)
310 CONTINUE
```

```
C-----
C---set P matrix
```

```
C-----
OPEN (UNIT = 1, NAME = 'PMTRX1.DAT', TYPE = 'OLD', READONLY)
READ (1, 320) FIDENT
320 FORMAT( 72A1)
READ (1, 330) ( (PMTRX( I, J), J = 1, 7), I = 1, 8 )
330 FORMAT ( 7(F9.7, 1X) )
CLOSE (UNIT = 1)
TYPE 340, FIDENT
PRINT 340, FIDENT
340 FORMAT ('0'/'0'/'0The P-matrix identification is: ' / 1X, 72A1)
```

```
C-----
C matrix multiplication P-MATRIX * VHAR, note that resultant is
C actually the negative of the correction vector.
```

```
C-----
CALL GMPRD(PMTRX, VHAR, V CORR, 8, 7, 1)
```

```
C-----
C---determine maximum negative correction (delta r)/r.
```

```
C-----
VCRMIN = 1000.
DO 390 I = 1, 8
```



```
VCRMIN = AMIN1 VCRMIN, VCORR(I) )
```

```
390 CONTINUE
```

```
C-----
```

```
C---generate shims needed in mils (39370 mils/meter) and print
```

```
C-----
```

```
PRINT 400
```

```
400 FORMAT ( '0'/'0The 'block' identification and needed shims are:')
```

```
PRINT 410
```

```
410 FORMAT ( '0BLOCK DELTA R(I)' / ' (NO.) (MILS)')
```

```
DO 430 I = 1, 8
```

```
VCORR(I) = ( VCORR(I) - VCRMIN ) * REFRAD * 39370.
```

```
J = I - 1
```

```
PRINT 420, J, VCORR(I)
```

```
420 FORMAT ( 1X, I4, 5X, F10.1)
```

```
430 CONTINUE
```

```
C-----
```

```
CALL EXIT
```

```
END
```

PROGRAM QDADJ2

created by: m. i. sreen

file name: QDADJ2.FOR

modification history:

04a 81 dec 31 mis subtract DVHAR instead of add
 03a 81 dec 28 mis copied QDADJ1.FOR to QDADJ2.FOR
 02a 81 dec 28 mis added matrix retrieval, and shim calculations
 01b 81 dec 22 mis workings
 01a 81 dec 21 mis written (data retrieve, 45 degree rotation,
 separation into real and imaginary parts, and
 printing alphanumeric, constants and analysis

purpose:

Calculate new error harmonics after adjustment of blocks of
 permanent magnet quadrupoles, test Klaus Halbach's algorithms.

subroutines required:

RTRV2(FNAME, DATE, TIME, ATT, REFRAD, VFRNGE, COMM1, COMM2,
 BL1, PH1, AM2, BL2, PH2, NHARM, BN2, PHN2)
 GMFRD(A,B,R,N,M,L) DEC SCIENTIFIC SUBROUTINE PACKAGE

parameter definitions:

output parameters:

FNAME file name of data
 DATE date of measurement run
 TIME time of measurement
 ATT single coil attenuation ratio used
 REFRAD quadrupole reference radius
 VFRNGE full scale range of V/f converter for 1 Mhz out
 COMM1 quad & search coil description
 COMM2 test description
 BL1 dipole strength (N = 1), unbucked coils
 PH1 dipole phase, unbucked coils
 AM2 quadrupole fourier amplitude
 BL2 quadrupole strength, (N = 2), unbucked coils
 PH2 quadrupole phase, unbucked coils
 NHARM highest harmonic saved
 BN2(38) B(N)/B2 in parts/1000
 PHN2(38) phase of N'th harmonic w/r/t 2nd harmonic
 PHROT(38) 45 degree rotated phase angles
 RLBN2(38) real part of rotated B(N)/B(2)
 IMBN2(38) imaginary part of rotated B(N)/B(2)
 FIDENT(72) file identification for F-matrix
 MVHAR(7) measured harmonic vector as defined by K. Halbach
 DVHAR(7) delta harmonic vector generated
 RVHAR(7) resultant harmonic vector
 NMTRX(8,7) N-matrix for generating delta harmonic vector
 VCORR(8) correction vector

BYTE DATE(10), TIME(8), COMM1(72), COMM2(72), FNAME(12)

BYTE FIDENT(72)

DIMENSION BN2(38), PHN2(38), PHROT(38), RLBN2(38), RVHAR(7)

```

DIMENSION UCORR(8), DVHAR(7)
REAL IMBN2(38), MVHAR(7), NMTRX(7, 8)

```

```

C
C      FI = ATAN2 (0.0, -1.0)
C-----
C      call retrieve subroutine
C-----

```

```

CALL RTRV2( FNAME, DATE, TIME, ATT, REFRAD, VFRNGE,
1 COMM1, COMM2, BL1, PH1, AM2, BL2, PH2, NHARM, BN2, PHN2)
C-----

```

```

FNAME(11) = 0 !I/O problem otherwise

```

```

PRINT 130, (FNAME(I), I = 1, 10), DATE, TIME, COMM1, COMM2

```

```

130  FORMAT (/, ' file ', 10A1, ', date: ', 10A1, ', time: ', 8A1,
1, ' has been retrieved. ', 2(/1X, 72A1) )

```

```

PRINT 140, ATT, VFRNGE, REFRAD

```

```

140  FORMAT ( ' The single coil attenuation is ', F6.1, ', the V/f
1 range is ', F7.3, ' volts. ', / ' The reference radius is
2 ', f8.6, ' meters.' )

```

```

PRINT 150, BL2, PH2

```

```

150  FORMAT (/, ' B'L(eff) = ', F6.4, ' AT ', F5.1, ' degrees.' )
C-----

```

```

C      45 phase rotation and separation to real & imaginary parts
C-----

```

```

PRINT 200

```

```

200  FORMAT ( ' N B(N)/B(2) ANGLE ROTATED B(N)/B(2)*1000'
1 / ' * 1000 DEG ANGLE REAL IMAGINARY' )

```

```

DO 210 N = 3, NHARM

```

```

PHROT(N) = PHN2(N) + FLOAT(N) * 45. + 90

```

```

RLBN2(N) = BN2(N) * COS( PHROT(N) * PI / 180. )

```

```

IMBN2(N) = BN2(N) * SIN( PHROT(N) * PI / 180. )

```

```

PRINT 250, N, BN2(N), PHN2(N), PHROT(N), RLBN2(N), IMBN2(N)

```

```

210  CONTINUE

```

```

250  FORMAT ( I3, 3X, F6.2, 3X, F6.1, 7X, F6.1, 2( 3X, F6.2) )
C-----

```

```

C---set up harmonic vector
C-----

```

```

DO 310 I = 1, 4

```

```

VHAR( 2*I - 1) = 0.001 * RLBN2( I + 2)

```

```

IF ( I .EQ. 4 ) GO TO 310

```

```

VHAR( 2*I ) = 0.001 * IMBN2( I + 2)

```

```

310  CONTINUE
C-----

```

```

C---set N matrix
C-----

```

```

OPEN (UNIT = 1, NAME = 'NMTRX1.DAT', TYPE = 'OLD', READONLY)

```

```

READ (1, 320) FIDENT

```

```

320  FORMAT( 72A1)

```

```

READ (1, 330) ( (NMTRX( I, J), J = 1, 8), I = 1, 7 )

```

```

330  FORMAT ( 8(F9.7) )

```

```

CLOSE (UNIT = 1)

```

```

TYPE 340, FIDENT

```

```

PRINT 340, FIDENT

```

```

340  FORMAT ('0' / '0The N-matrix identification is: ' / 1X, 72A1)
C-----

```

```

C      Accept and print shim information
C-----

```

```

PRINT 360

```

```

360  FORMAT ( '0The block identification and added shims are:')

```

```

PRINT 370

```

```

370  FORMAT ( '0BLOCK DELTA R(I)' / ' (NO.) (MILS)')

```

```

C-----
      DO 410 I = 1, 8
      J = I - 1
      TYPE 400, J
400    FORMAT ( ' Type shim adjustment (mils) for block ', I1, ' : ', $ )
      ACCEPT *, VCORR(I)
      PRINT 420, J, VCORR(I)
C-----
C          convert to (delta r) / r and change to parts/thousand
C-----
      VCORR(I) = VCORR(I) * 0.0254 / 0.035
410    CONTINUE
420    FORMAT (1X, I4, 5X, F10.1)
C-----
C    matrix multiplication N-MATRIX * VCDRR
C-----
      CALL GMPRD(NMTRX, VCDRR, DVHAR, 7, 8, 1)
C-----
C          generate MVHAR, measured harmonic vector
C-----
      DO 490 I = 1, 4
      MVHAR(2*I - 1) = RLEN2(I + 2)
      IF ( I .EQ. 4 ) GO TO 490
      MVHAR( 2*I ) = IMEN2(I + 2)
490    CONTINUE
C-----
C          calculate resultant harmonic vector
C-----
      DO 550 I = 1, 7
      RVHAR( I ) = MVHAR( I ) - DVHAR( I )
550    CONTINUE
C-----
C          print harmonic vectors
C-----
      PRINT 600
600    FORMAT (/ 14X, ' MEASURED          DELTA RESULTANT' /
      1          14X, '          *1000          *1000          *1000' )
      DO 690 I = 1, 7
      IF ( I .EQ. 1 .OR. I .EQ. 3 .OR. I .EQ. 5 .OR. I .EQ. 7 )
      1 PRINT 660, ( I + 5 ) / 2
660    FORMAT( ' RE B(', I1, ')/B(2) ', $ )
      IF ( I .EQ. 2 .OR. I .EQ. 4 .OR. I .EQ. 6 )
      1 PRINT 670, ( I + 4 ) / 2
670    FORMAT( ' IM B(', I1, ')/B(2) ', $ )
      PRINT 680, MVHAR(I), DVHAR(I), RVHAR(I)
680    FORMAT( '+', 3( 4X, F6.2) )
690    CONTINUE
      CALL EXIT
      END

```

SUBROUTINE RTRV2(FNAME, DATE, TIME, ATT, REFRAD, VFRNGE,
1 COMM1, COMM2, BL1, PH1, AM2, BL2, PH2, NHARM, BN2, PHN2)

created by: m i sreen

file name: RTRV2.FOR

modification history:

01c 81 dec 22 mis I/O cleanup
01b 81 dec 21 mis workins
01a 81 dec 21 mis copied from SAVE2.FOR MHE 37

PURPOSE:

Retrieve from disk constant parameters, test parameters, and
harmonic analysis of permanent magnet Samarium Cobalt quadrupole.

hardware required: DSD 440 Floppy Disk System

software required: RT-11 operating system

subroutines needed: none

output parameters:

FNAME file name of data
DATE date of measurement run
TIME time of measurement
ATT single coil attenuation ratio used
REFRAD quadrupole reference radius
VFRNGE full scale range of V/f converter for 1 Mhz out
COMM1 quad & search coil description
COMM2 test description
BL1 dipole strength (N = 1), unbucked coils
PH1 dipole phase, unbucked coils
AM2 quadrupole fourier amplitude
BL2 quadrupole strength, (N = 2), unbucked coils
PH2 quadrupole phase, unbucked coils
BN2(38) B(N)/B2 in parts/1000
PHN2(38) phase of N'th harmonic w/r/t 2nd harmonic

BYTE DATE(10), TIME(8), COMM1(72), COMM2(72), FNAME(12)
DIMENSION BN2(38), PHN2(38)

TYPE 100

100 FORMAT(/, ' type file name for retrieving data 'MMDDXX.DAT' ', \$)
110 ACCEPT 120, (FNAME(I), I = 1, 10) !read name from terminal
120 FORMAT(10A1)
FNAME(11) = 0 !!I/O problem otherwise

open file, read data, close file

OPEN (UNIT = 1, NAME = FNAME, FORM = 'UNFORMATTED', TYPE = 'OLD'
1, READONLY)
READ (1) FNAME, DATE, TIME, COMM1, COMM2

```
C-----  
C  matrix multiplication  N-MATRIX * P-MATRIX  
C-----  
C          CALL GMPRD(NMTRX, PMTRX, RMTRX, 7, 8, 7)  
C-----  
C          print resultant matrix  
C-----  
C          PRINT *, '  
C          PRINT *, 'the resultant matrix of N * P is '  
C          PRINT 600, ( (RMTRX( I, J), J = 1, 7), I = 1, 7 )  
600  FORMAT ( 7(1X, F9.6) )  
C          CALL EXIT  
C          END
```

SUBJECT

"FIXING" of a 6" LANL Rare Earth Quadrupole Magnet
By The Halbach Technique

NAME

Michael I. Green

DATE

January 7, 1982

APPENDIX B

Selected Computer Output From
Primary Quadrupole Analysis Program QDANAL
(December 22, 1981 Update)

Date	Time	Data Set
December 30, 1981	13:34:15	1230A1
December 30, 1981	14:16:33	1230B1
December 30, 1981	14:53:00	1230C1
December 31, 1981	13:08:54	1231A2
December 31, 1981	14:05:20	1231A3
December 31, 1981	14:07:37	1231A4
December 31, 1981	14:09:50	1231A5
December 31, 1981	14:37:47	1231B1
December 31, 1981	14:40:41	1231B2
December 31, 1981	14:45:40	1231B3
December 31, 1981	14:48:08	1231B4

THE DATE IS 30-DEC-81 TIME 13:34:15

LANL 6' Se-Co QUADRUPOLE, S/N R2, 2' search coil
 TIGHTENED ALL ADJUSTING SCREWS, NO SHIMS
 THE QUADRUPOLE REFERENCE RADIUS IS 0.0350000 METERS.
 THE V/F IS ON THE 0.001 VOLT RANGE.

-----UNBUCKED COIL-----

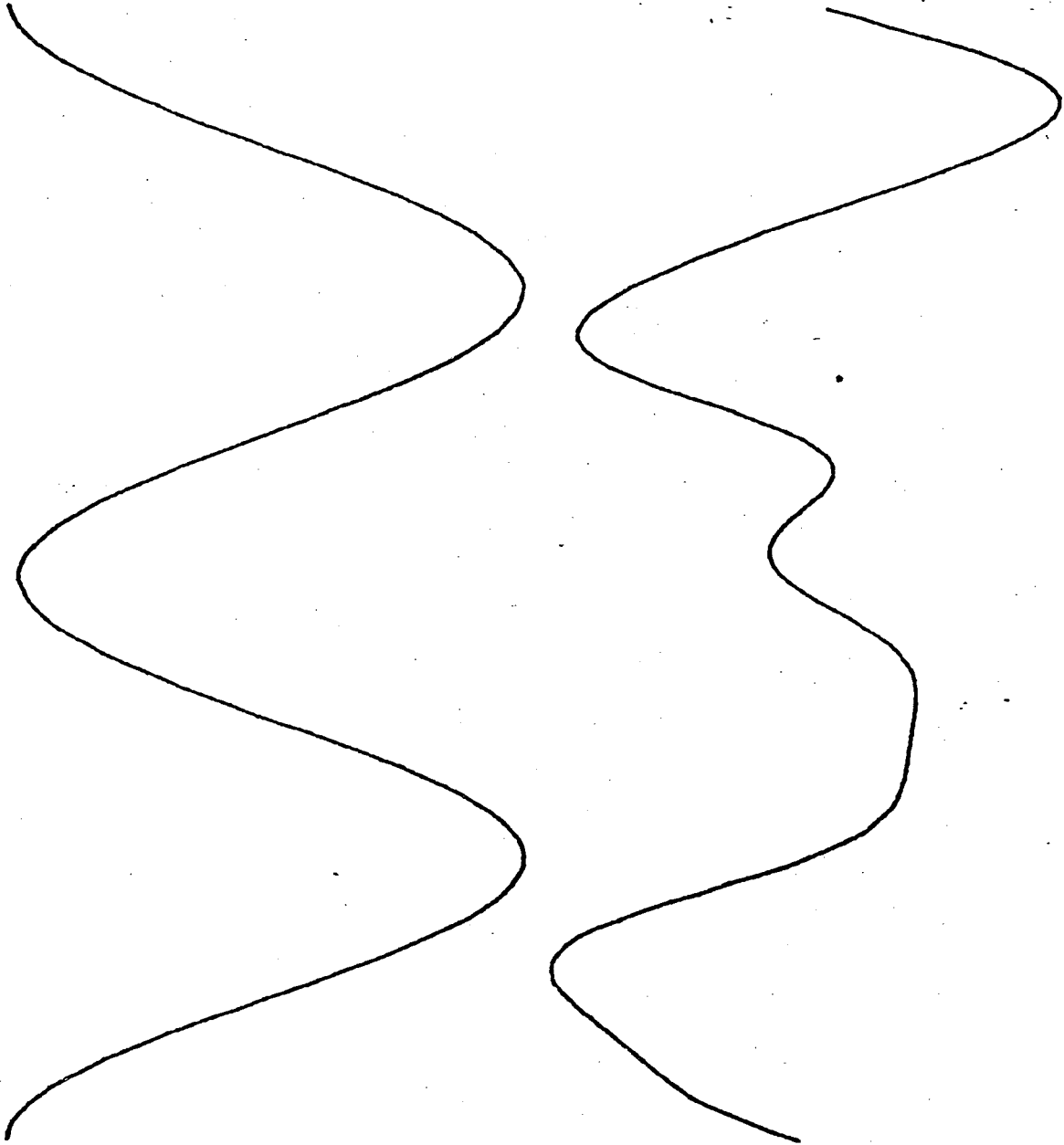
120840. COUNTS DRIFT OVER 129 POINTS WITH 944. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 105400.5 COUNTS
 DIPOLE STRENGTH = 0.000069, PHASE ANGLE = -11.77
 B(L(EFF)) = 0.1609 TESLA, WITH PHASE ANGLE 1.07

-----BUCKED COILS-----

670191. COUNTS DRIFT OVER 129 POINTS WITH 5236. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 146942.6 COUNTS

N	S(N) (COUNTS)	B(N)/B(2) (*1000)	ANGLE (DEG)
3	52019.	10.35	-106.7
4	19619.	8.31	8.4
5	6209.	3.94	99.9
6	16558.	19.54	-33.9
7	2111.	4.29	55.5
8	991.	3.61	-111.8
9	137.	0.87	125.4
10	220.	2.46	30.7
11	81.	1.57	-69.0
12	60.	2.02	153.1
13	86.	5.02	-142.1
14	77.	7.65	146.6
15	72.	12.29	-125.7
16	35.	10.15	-163.4
17	25.	12.16	-186.9
18	39.	32.50	-169.5

Harmonic Analysis saved in disk file: 1230A1.DAT



THE DATE IS 30-DEC-81 TIME 14:16:33

LANL 6' Sa-Ce QUADRUPOLE. 5/4 P2, 2' search coil

NO SHIMS

THE QUADRUPOLE REFERENCE RADIUS IS 0.0350000 METERS.

THE V/F IS ON THE 0.001 VOLT RANGE.

-----UNBUCKED COIL-----

-16188. COUNTS DRIFT OVER 129 POINTS WITH -126. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 106236.5 COUNTS

DIPOLE STRENGTH = 0.000107, PHASE ANGLE = -21.76

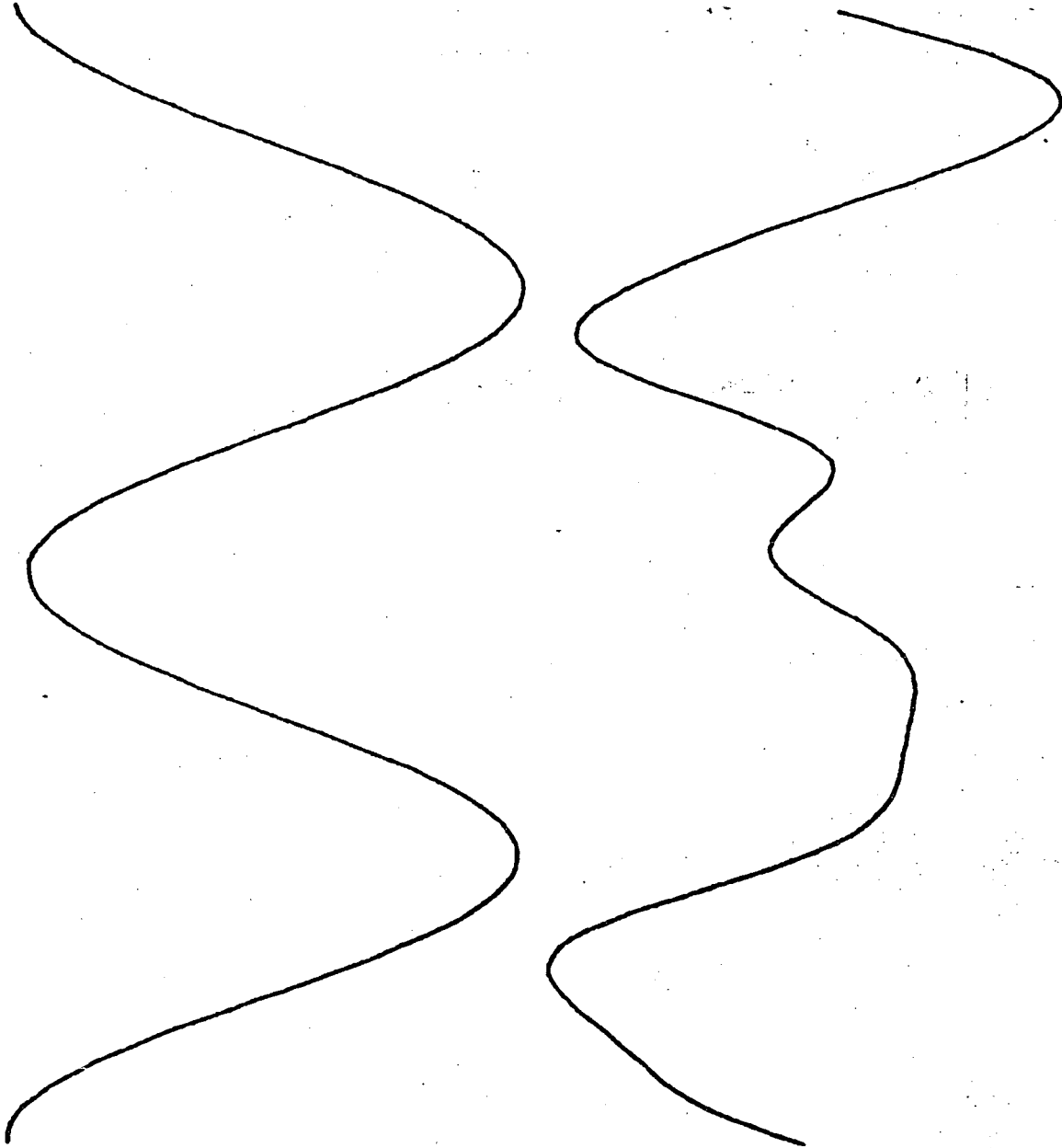
B(L(EFF)) = 0.1609 TESLA, WITH PHASE ANGLE -0.16

-----BUCKED COILS-----

551382. COUNTS DRIFT OVER 129 POINTS WITH 4308. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 147864.6 COUNTS

N	S(N) (COUNTS)	B(N)/B(2) (*1000)	ANGLE (DEG)
3	51711.	10.29	-105.5
4	19729.	8.36	8.7
5	6138.	3.90	100.3
6	16577.	19.57	-33.8
7	2036.	4.14	56.2
8	1012.	3.68	-114.6
9	103.	0.66	61.4
10	181.	2.03	32.8
11	45.	0.87	20.2
12	92.	3.11	167.2
13	103.	6.02	-90.5
14	34.	3.38	148.5
15	58.	9.90	-101.7
16	9.	2.73	2.5
17	29.	14.05	102.2
18	30.	25.00	-138.5

Harmonic Analysis saved in disk file: 1230B1.DAT



THE DATE IS 30-DEC-81 TIME 11:53:00

LANL 6' Sa-Co QUADRUPOLE, S/W R2, 2' search coil
 NO SHIMS
 THE QUADRUPOLE REFERENCE RADIUS IS 0.0350000 METERS.
 THE V/F IS ON THE 0.001 VOLT RANGE.

-----UNBUCKED COIL-----

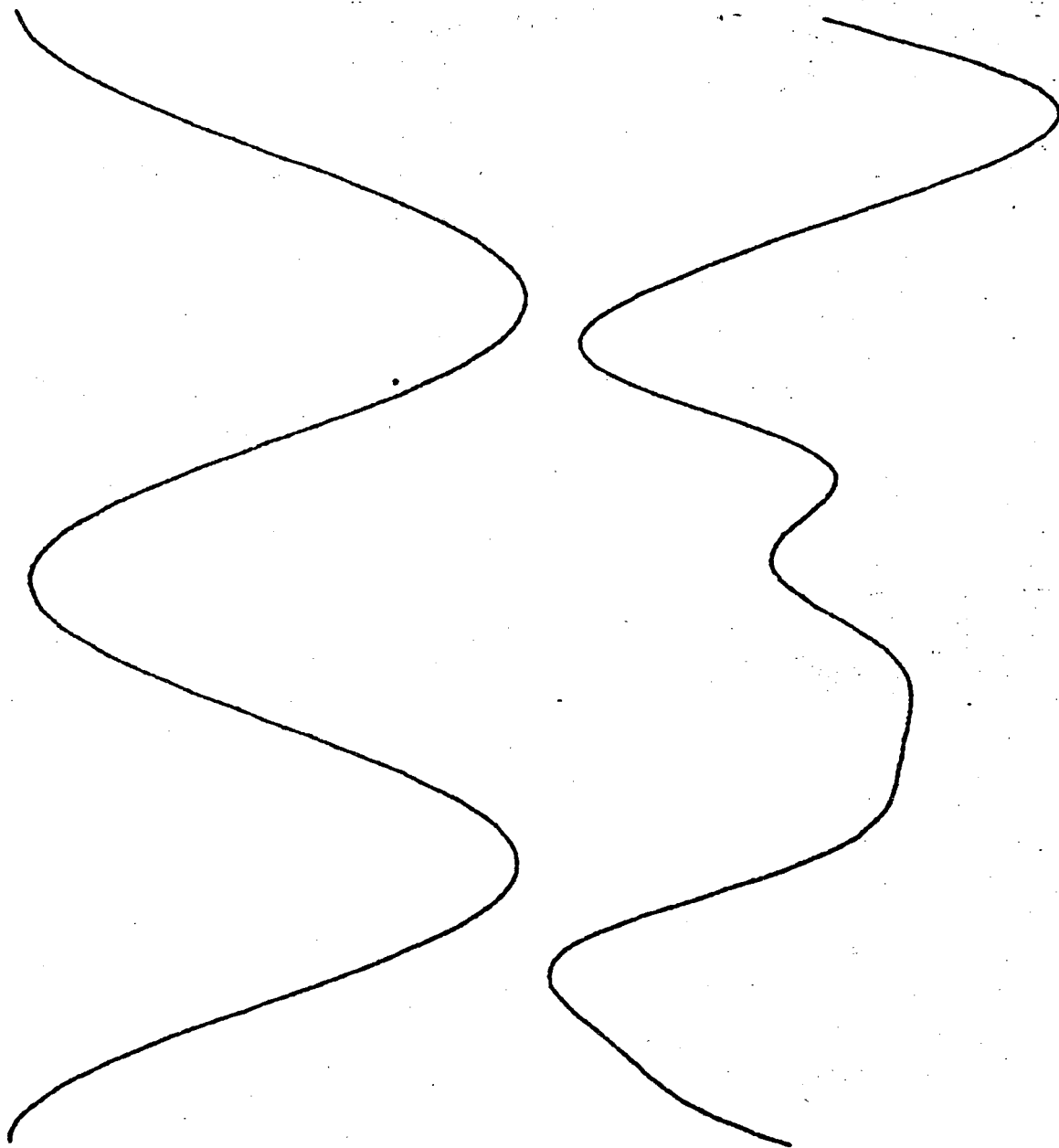
-55160. COUNTS DRIFT OVER 129 POINTS WITH -431. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 106299.5 COUNTS
 DIPOLE STRENGTH = 0.000106, PHASE ANGLE = -26.66
 B/L(EFF) = 0.1608 TESLA, WITH PHASE ANGLE 1.30

-----BUCKED COILS-----

524612. COUNTS DRIFT OVER 129 POINTS WITH 4099. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 147654.8 COUNTS

N	S(N) (COUNTS)	B(N)/B(2) (*1000)	ANGLE (DEG)
3	51794.	10.32	-105.4
4	19761.	8.38	8.4
5	5823.	3.70	103.1
6	16579.	19.58	-34.2
7	2028.	4.13	55.5
8	974.	3.55	-113.6
9	146.	0.93	88.1
10	105.	1.18	85.1
11	80.	1.56	-21.4
12	70.	2.35	164.4
13	119.	6.95	-104.5
14	44.	4.44	135.3
15	58.	9.89	-78.5
16	10.	2.89	-110.6
17	50.	24.58	-196.4
18	31.	26.14	-94.9

Harmonic Analysis saved in disk file: 1230D1.DAT



THE DATE IS 31-DEC-81 TIME 13:02:54
 LANE 6' Sg-Cc QUADRUPOLE, 57M RZ, 2' SEARCH COIL
 POLES SHIM, 046, 1426K, 2411, 3430, 440, 541, 640, 7424
 THE QUADRUPOLE REFERENCE RADIUS IS 0.0350000 METERS.
 THE V/F IS ON THE 0.001 VOLT RANGE.

-----UNBUCKED COIL-----

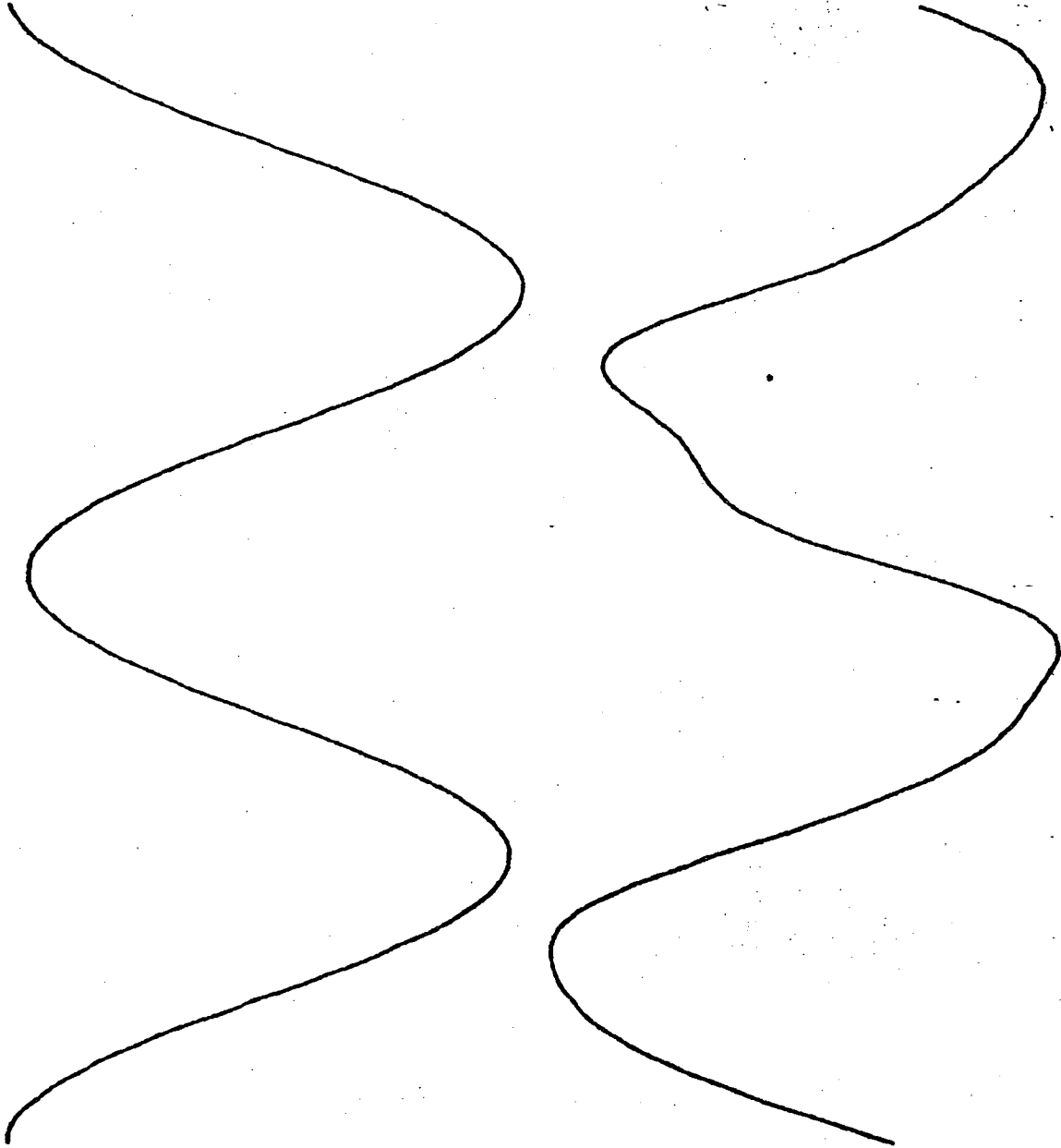
-193703. COUNTS DRIFT OVER 129 POINTS WITH -1513. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 105648.0 COUNTS
 DIPOLE STRENGTH = 0.000127, PHASE ANGLE = -35.96
 B'L(EFF) = 0.1580 TESLA, WITH PHASE ANGLE 0.23

-----BUCKED COILS-----

388027. COUNTS DRIFT OVER 129 POINTS WITH 3031. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 102029.3 COUNTS

N	S(N) (COUNTS)	B(N)/B(2) (*1000)	ANGLE (DEG)
3	2091.	0.42	170.6
4	741.	0.32	-60.4
5	2557.	1.65	161.6
6	8313.	9.99	-87.3
7	3140.	6.50	67.9
8	1298.	4.81	-149.3
9	92.	0.60	-18.0
10	641.	7.31	-8.0
11	306.	6.07	-98.1
12	56.	1.94	-15.8
13	60.	3.54	-48.0
14	76.	7.74	-3.2
15	32.	5.59	-70.3
16	42.	12.56	-88.0
17	42.	21.19	-93.9
18	25.	20.88	144.9

Harmonic Analysis saved in disk file: 1231A2.DAT



THE DATE IS 31-DEC-81 TIME 14:05:20
LANL 6' Sa-Co QUADRUPOLE, S/N R2, 2' search coil
REPEAT 13:08:54
THE QUADRUPOLE REFERENCE RADIUS IS 0.0350000 METERS.
THE V/F IS ON THE 0.001 VOLT RANGE.

-----UNBUCKED COIL-----

-180057. COUNTS DRIFT OVER 129 POINTS WITH -1407. DRIFT PER POINT
MAXIMUM AMPLITUDE IS 105773.0 COUNTS
DIPOLE STRENGTH = 0.000132, PHASE ANGLE = -36.66

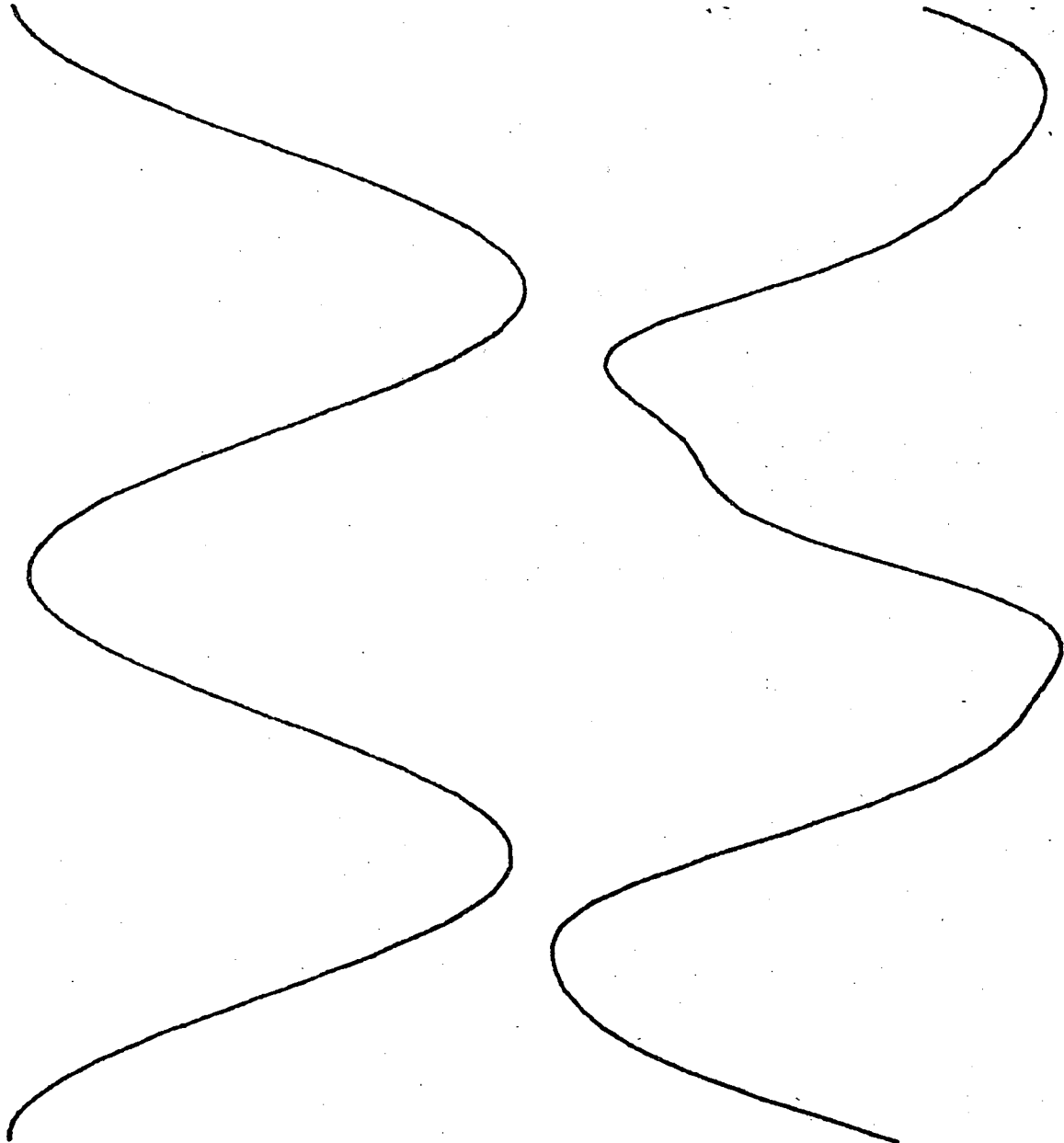
B'L(EFF) = 0.1585 TESLA, WITH PHASE ANGLE 0.27

-----BUCKED COILS-----

401016. COUNTS DRIFT OVER 129 POINTS WITH 3133. DRIFT PER POINT
MAXIMUM AMPLITUDE IS 102457.4 COUNTS

N	S(N) (COUNTS)	B(N)/B(2) (*1000)	ANGLE (DEG)
3	2219.	0.45	173.1
4	537.	0.23	-52.9
5	2683.	1.73	163.2
6	8254.	9.89	-88.1
7	3193.	6.59	67.1
8	1334.	4.93	-148.6
9	99.	0.64	23.0
10	723.	8.22	-8.1
11	220.	4.35	-84.1
12	61.	2.09	8.8
13	46.	2.71	-25.4
14	119.	12.10	-3.8
15	21.	3.69	-57.2
16	22.	6.40	-83.1
17	26.	12.78	-94.6
18	34.	29.01	-177.8

Harmonic Analysis saved in disk file: 1231A3.DAT



THE DATE IS 31-DEC-81 TIME 14:07:37

LANE 6' Se-05 QUADRUPOLE, S/N R2, 2' search coil

2ND REPEAT OF 13:08:54

THE QUADRUPOLE REFERENCE RADIUS IS 0.0350000 METERS.

THE V/F IS ON THE 0.001 VOLT RANGE.

-----UNBUCKET COIL-----

-49578. COUNTS DRIFT OVER 129 POINTS WITH -387. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 105227.3 COUNTS
 DIPOLE STRENGTH = 0.000114, PHASE ANGLE = -40.68

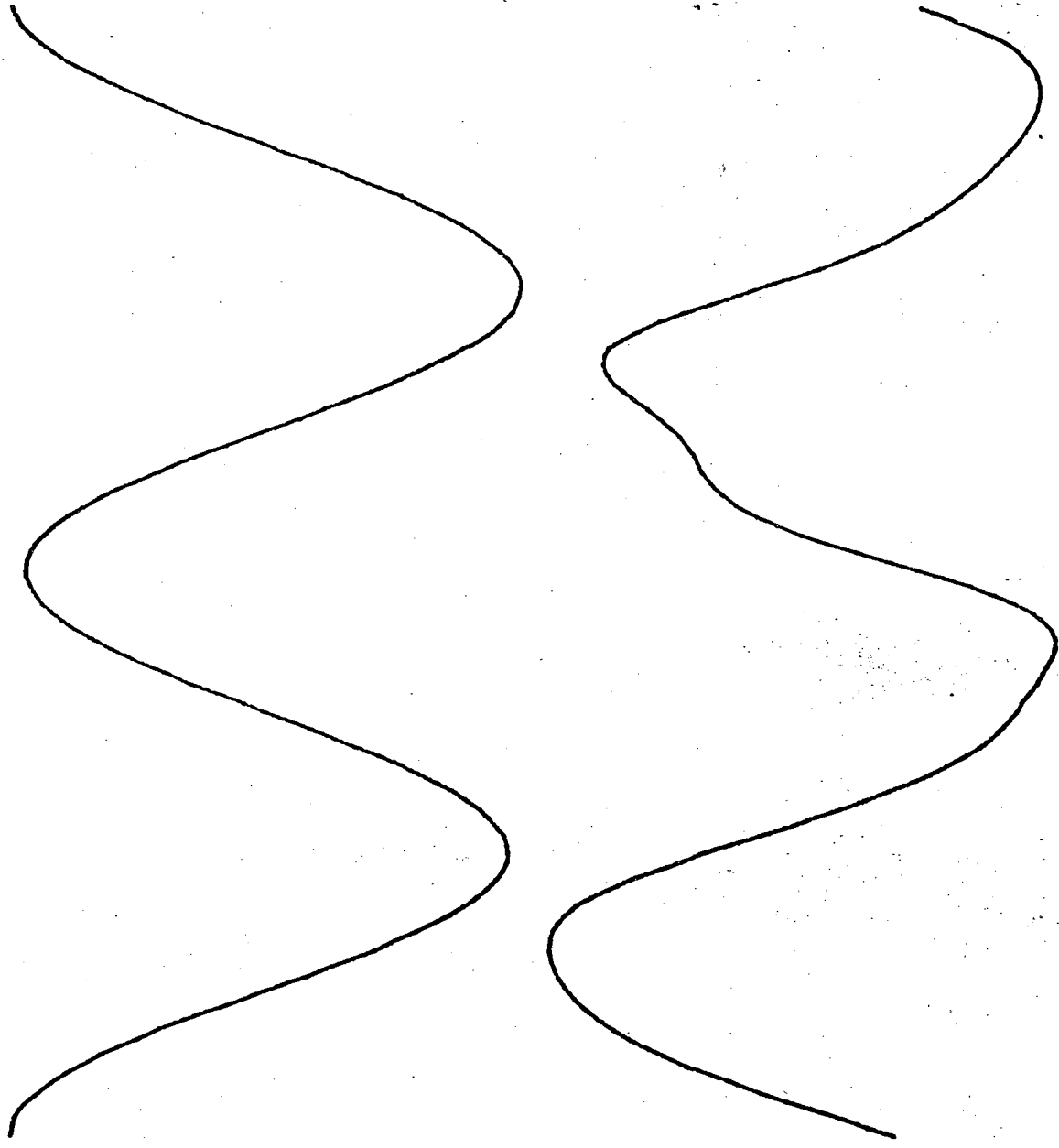
B'L(EFF) = 0.1583 TESLA, WITH PHASE ANGLE 0.31

-----BUCKET COILS-----

504286. COUNTS DRIFT OVER 129 POINTS WITH 3940. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 102479.9 COUNTS

N	S(N) (COUNTS)	B(N)/B(2) (*1000)	ANGLE (DEG)
3	2218.	0.45	177.1
4	701.	0.30	-56.9
5	2541.	1.64	159.8
6	8325.	9.99	-88.3
7	3175.	6.56	67.1
8	1280.	4.74	-149.7
9	72.	0.47	-6.1
10	694.	7.90	-10.1
11	307.	6.08	-97.3
12	89.	3.07	-6.4
13	77.	4.54	-37.7
14	99.	10.08	5.6
15	51.	8.88	-99.4
16	25.	7.32	-125.9
17	15.	7.67	-128.9
18	46.	38.74	-163.7

Harmonic Analysis saved in disk file: 1231A4.DAT



THE DATE IS 31-DEC-81 TIME 14:09:50
 LANE 6 Sa-Co QUADRUPOLE, S/N 82, 2' search coil
 3RD REPEAT OF 13:08:54
 THE QUADRUPOLE REFERENCE RADIUS IS 0.0350000 METERS.
 THE V/F IS ON THE 0.001 VOLT RANGE.

-----UNBUCKETED COIL-----

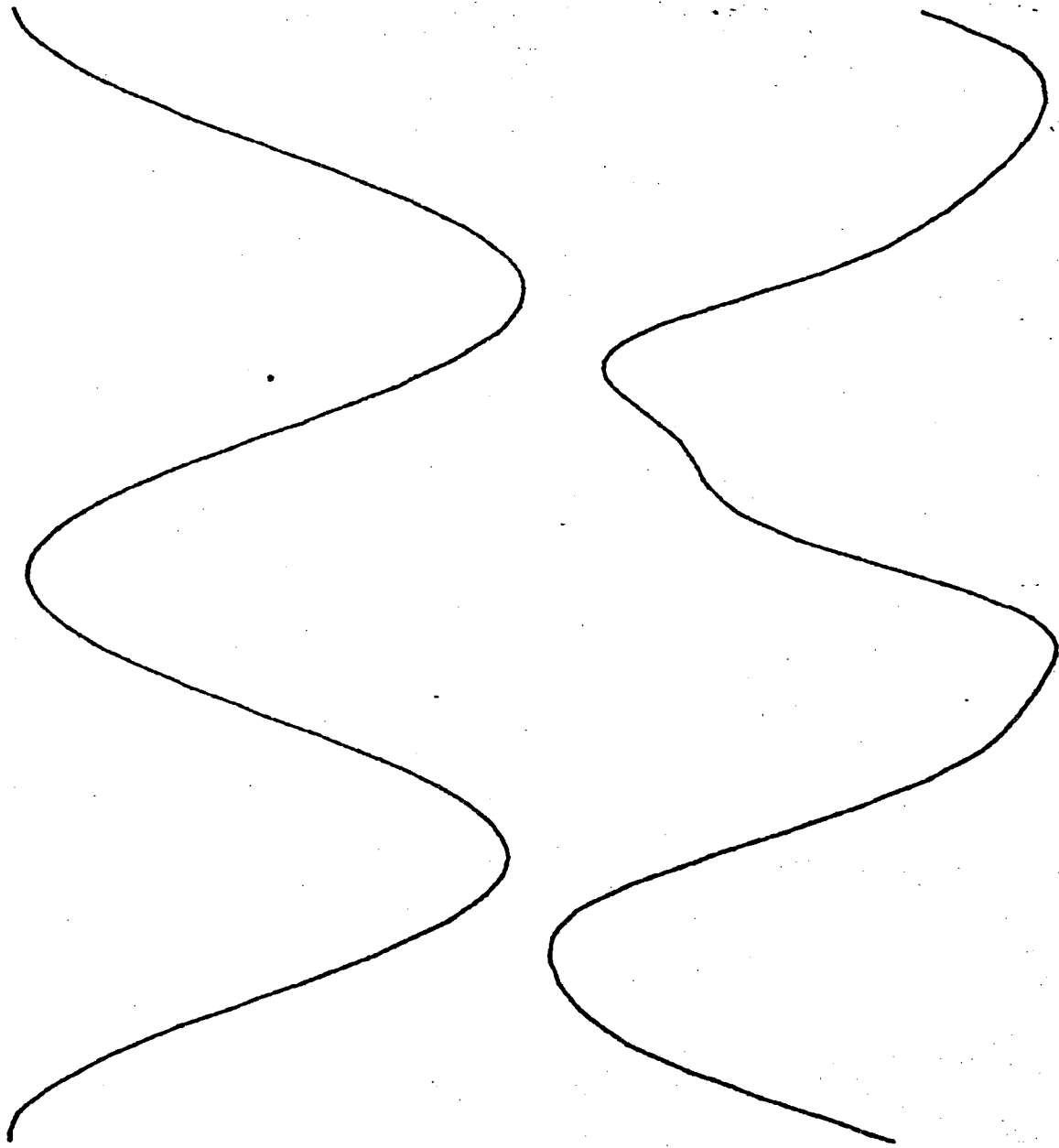
39442. COUNTS DRIFT OVER 129 POINTS WITH 308. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 105205.8 COUNTS
 DIPOLE STRENGTH = 0.000123, PHASE ANGLE = -42.73
 B'L(EFF) = 0.1579 TESLA, WITH PHASE ANGLE 0.29

-----BUCKETED COILS-----

582346. COUNTS DRIFT OVER 129 POINTS WITH 4550. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 101880.3 COUNTS

N	S(N) (COUNTS)	B(N)/B(2) (*1000)	ANGLE (DEG)
3	2177.	0.44	179.1
4	796.	0.34	-64.0
5	2727.	1.76	161.9
6	8354.	10.05	-88.2
7	3216.	6.66	66.3
8	1321.	4.90	-149.8
9	139.	0.90	39.9
10	651.	7.43	-10.8
11	247.	4.90	-83.2
12	65.	2.24	28.2
13	60.	3.55	0.3
14	51.	5.23	-8.8
15	85.	14.85	-94.3
16	39.	11.64	-107.1
17	30.	15.14	167.0
18	45.	37.78	-168.5

Harmonic Analysis saved in disk file: 1231A5.DAT



THE DATE IS 31-DEC-81 TIME 14:37:47

LANL 6' Se-Co QUADRUPOLE, S/N R2, 2' search coil
 POLE SHIM, 0<8, 1<28, 2<11, 3<33, 4<1, 5<2, 6<2, 7<24
 THE QUADRUPOLE REFERENCE RADIUS IS 0.0350000 METERS.
 THE V/F IS ON THE 0.001 VOLT RANGE.

-----UNBUCKED COIL-----

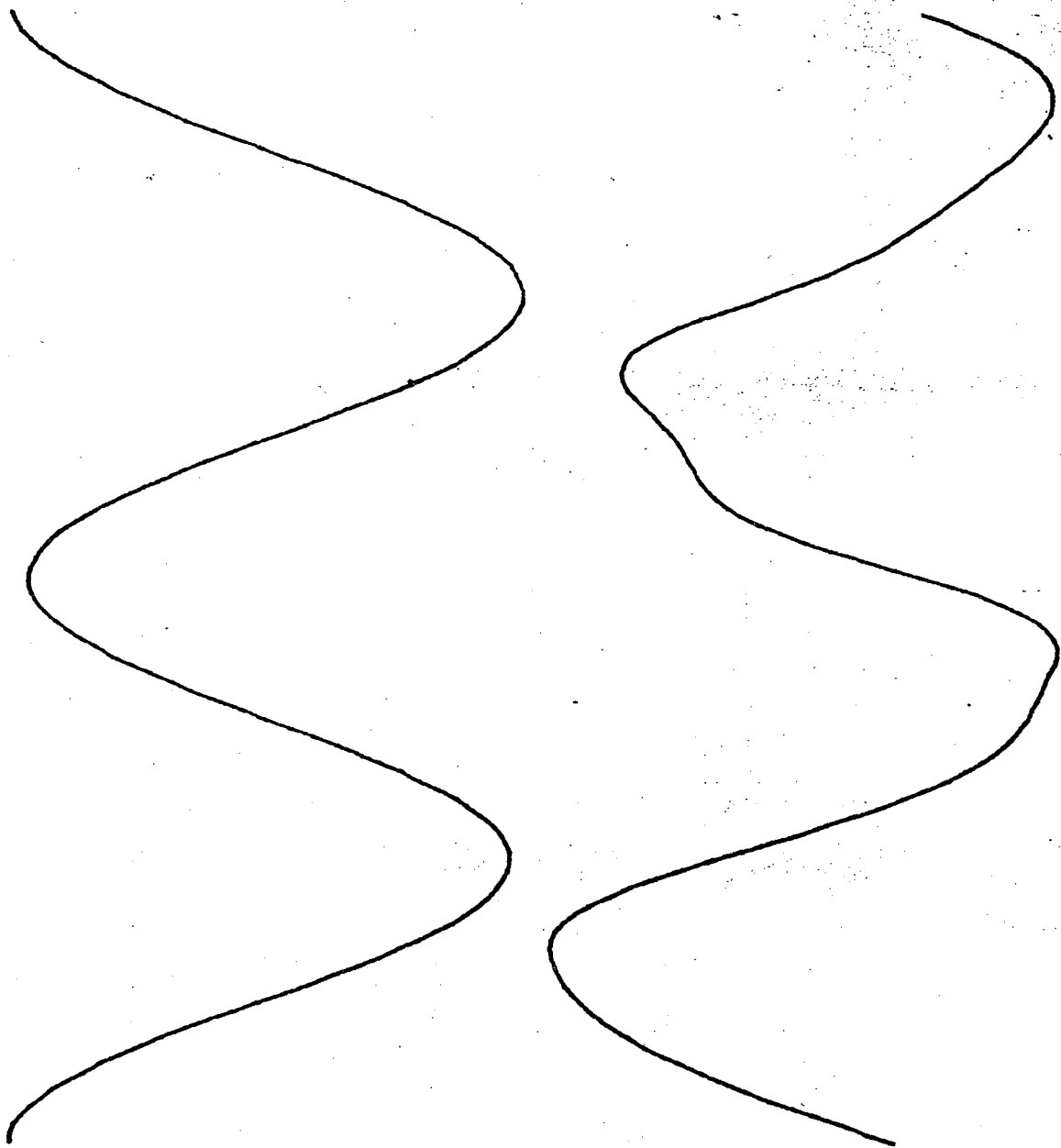
-193355. COUNTS DRIFT OVER 129 POINTS WITH -1511. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 105274.9 COUNTS
 DIPOLE STRENGTH = 0.000125, PHASE ANGLE = -33.60
 B'L(EFF) = 0.1578 TESLA, WITH PHASE ANGLE 0.51

-----BUCKED COILS-----

385914. COUNTS DRIFT OVER 129 POINTS WITH 3015. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 101372.2 COUNTS

N	S(N) (COUNTS)	B(N)/B(2) (*1000)	ANGLE (DEG)
3	4601.	0.93	163.6
4	1100.	0.48	-71.4
5	406.	0.26	30.2
6	7951.	9.57	-87.9
7	3486.	7.23	58.5
8	1258.	4.67	-153.2
9	100.	0.65	57.8
10	780.	8.91	-16.9
11	245.	4.86	-97.5
12	76.	2.62	13.4
13	43.	2.55	-175.3
14	73.	7.42	2.9
15	66.	11.40	-112.5
16	38.	11.17	-71.5
17	59.	29.50	-119.6
18	60.	51.25	-177.0

Harmonic Analysis saved in disk file: 1231B1.DAT



LBID-520

THE DATE IS 31-DEC-81 TIME 14:40:41

LANL 6' 9a-Co QUADRUPOLE, S/N R2, 2' search coil

1ST REPEAT OF 14:37:47

THE QUADRUPOLE REFERENCE RADIUS IS 0.0350000 METERS.

THE V/F IS ON THE 0.001 VOLT RANGE.

-----UNBUCKED COIL-----

-100085. COUNTS DRIFT OVER 129 POINTS WITH -782. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 105095.6 COUNTS
 DIPOLE STRENGTH = 0.000119, PHASE ANGLE = -30.38

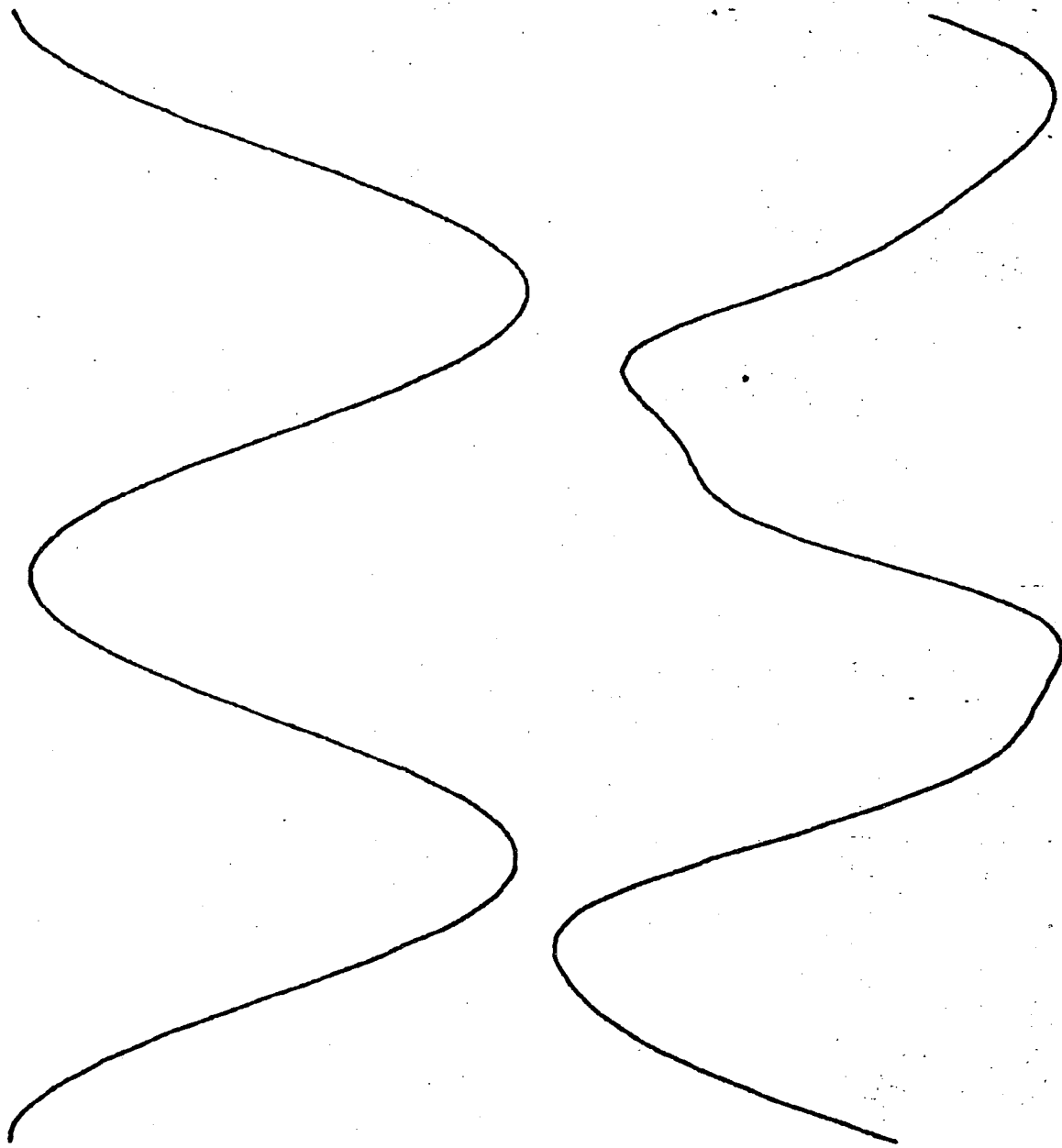
B'L(EFF) = 0.1579 TESLA, WITH PHASE ANGLE 0.45

-----BUCKED COILS-----

466928. COUNTS DRIFT OVER 129 POINTS WITH 3648. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 101136.4 COUNTS

N	S(N) (COUNTS)	B(N)/B(2) (*1000)	ANGLE (DEG)
3	4513.	0.92	160.9
4	1138.	0.49	-68.4
5	365.	0.24	29.6
6	8030.	9.66	-88.4
7	3519.	7.29	59.4
8	1297.	4.81	-151.8
9	71.	0.46	-7.4
10	756.	8.63	-13.8
11	290.	5.75	-92.5
12	27.	0.91	-23.8
13	75.	4.43	-57.7
14	98.	9.96	3.6
15	65.	11.34	-141.8
16	24.	7.02	-52.2
17	45.	22.35	-146.5
18	36.	30.57	-133.7

Harmonic Analysis saved in disk file: 123152.DAT



THE DATE IS 31-DEC-81 TIME 14:35:40
 LANL 6" Sa-Co QUADRUPOLE, S/N R2, 2" search coil
 2ND REPEAT OF 14:37:47
 THE QUADRUPOLE REFERENCE RADIUS IS 0.0350000 METERS.
 THE V/F IS ON THE 0.001 VOLT RANGE.

-----UNBUCKED COIL-----

5699. COUNTS DRIFT OVER 129 POINTS WITH 45. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 104611.1 COUNTS
 DIPOLE STRENGTH = 0.000112, PHASE ANGLE = -37.89

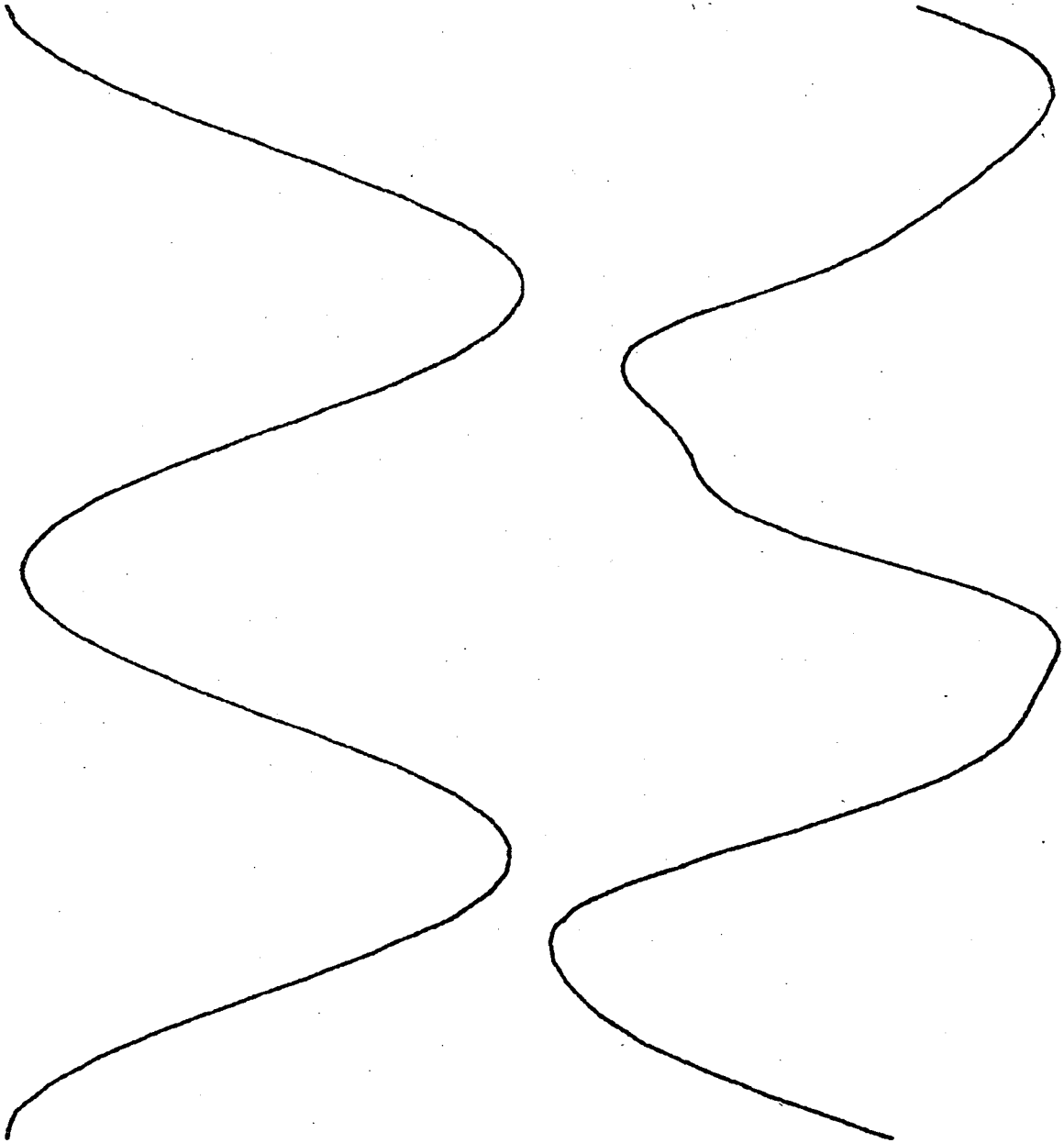
B'L(EFF) = 0.1574 TESLA, WITH PHASE ANGLE 0.47

-----BUCKED COILS-----

555059. COUNTS DRIFT OVER 129 POINTS WITH 4336. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 101630.8 COUNTS

N	S(N) (COUNTS)	B(N)/B(2) (*1000)	ANGLE (DEG)
3	4479.	0.91	163.5
4	1234.	0.53	-67.3
5	370.	0.24	38.0
6	8064.	9.73	-87.7
7	3628.	7.54	59.0
8	1303.	4.85	-150.1
9	122.	0.80	36.6
10	788.	9.02	-8.7
11	259.	5.16	-78.2
12	65.	2.26	39.4
13	48.	2.85	-80.9
14	105.	10.77	-2.0
15	43.	7.48	-85.7
16	49.	-14.60	-77.5
17	35.	17.44	-174.0
18	25.	20.84	-157.5

Harmonic Analysis saved in disk file: 1231R3.DAT



THE DATE IS 31-DEC-81 TIME 14:49:08
 LANL 6' Se-Co QUADRUPOLE, S/N R2, 2' search coil
 3'RD REPEAT OF 13:37:47
 THE QUADRUPOLE REFERENCE RADIUS IS 0.0350000 METERS.
 THE V/F IS ON THE 0.001 VOLT RANGE.

-----UNBUCKED COIL-----

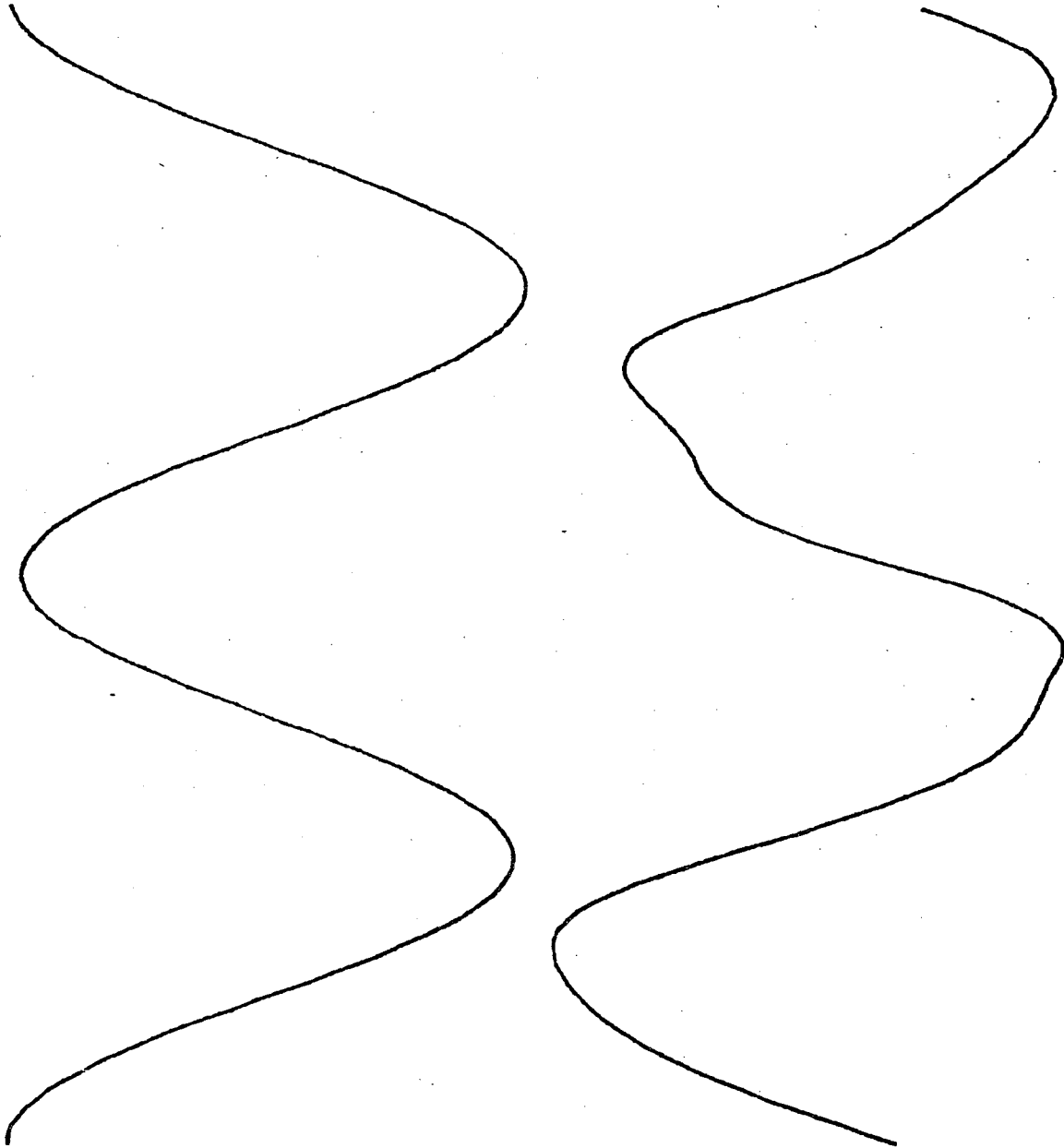
64919. COUNTS DRIFT OVER 129 POINTS WITH 507. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 104472.1 COUNTS
 DIPOLE STRENGTH = 0.000101, PHASE ANGLE = -40.45
 B'L(EFF) = 0.1577 TESLA, WITH PHASE ANGLE 0.50

-----BUCKED COILS-----

606597. COUNTS DRIFT OVER 129 POINTS WITH 4739. DRIFT PER POINT
 MAXIMUM AMPLITUDE IS 102291.1 COUNTS

N	S(N) (COUNTS)	B(N)/B(2) (*1000)	ANGLE (DEG)
3	4552.	0.92	163.2
4	1106.	0.48	-68.2
5	304.	0.20	44.7
6	8043.	9.69	-87.9
7	3547.	7.36	59.3
8	1285.	4.77	-149.5
9	161.	1.05	42.6
10	795.	9.08	-16.3
11	209.	4.16	-86.3
12	78.	2.70	30.2
13	49.	2.92	-37.5
14	60.	6.07	1.1
15	27.	4.64	-116.0
16	34.	10.06	-105.2
17	9.	4.73	-35.1
18	27.	22.62	-117.5

Harmonic Analysis saved in disk file: 1231B4.DAT



ENGINEERING NOTE

Appendix C

FILE NO.
MT 308PAGE
C1 of C12

SUBJECT

"FIXING" of a 6" LANL Rare Earth Quadrupole Magnet
By The Halbach Technique

NAME

Michael I. Green

DATE

January 7, 1982

APPENDIX C

Computer Output From Quadrupole Adjusting Program QDADJ1
... (December 31, 1981 Update)

Data Set

1230A1	No Shims
1230B1	No Shims
1230C1	No Shims
1231A2	Schedule 1 Shims
1231A3	Schedule 1 Shims
1231A4	Schedule 1 Shims
1231A5	Schedule 1 Shims
1231B1	Schedule 2 Shims
1231B2	Schedule 2 Shims
1231B3	Schedule 2 Shims
1231B4	Schedule 2 Shims

file 1230A1.DAT, date: 30-DEC-81, time: 13:34:15 has been retrieved.
 LANL 6' Sa-Co QUADRUPOLE, S/N R2, 2' search coil
 TIGHTENED ALL ADJUSTING SCREWS, NO SHIMS
 The single coil attenuation is 101.6, the V/f range is 0.001 volts.
 The reference radius is 0.035000 meters.

B'L(eff) = 0.1609 AT 1.1 degrees.

N	B(N)/B(2) * 1000	ANGLE DEG	ROTATED ANGLE	B(N)/B(2)*1000	
				REAL	IMAGINARY
3	10.35	-106.7	118.3	-4.90	9.12
4	8.31	8.4	278.4	1.22	-8.22
5	3.94	99.9	414.9	2.27	3.23
6	19.54	-33.9	326.1	16.22	-10.89
7	4.29	55.5	460.5	-0.78	4.22
8	3.61	-111.8	338.2	3.35	-1.34
9	0.87	125.4	620.4	-0.15	-0.86
10	2.46	30.7	570.7	-2.11	-1.26
11	1.57	-69.0	516.0	-1.44	0.64
12	2.02	153.1	783.1	0.91	1.81
13	5.02	-142.1	532.9	-4.98	0.62
14	7.65	146.6	866.6	-6.39	4.21
15	12.29	-125.7	639.3	1.99	-12.13
16	10.15	-163.4	646.6	2.90	-9.72
17	12.16	-186.9	668.1	7.51	-9.57
18	32.50	-169.5	730.5	31.95	5.93

The F-matrix identification is:
 PMTRX1.DAT 81-dec-29

The 'block' identification and needed shims are:

BLOCK (NO.)	DELTA R(I) (MILS)
0	6.3
1	26.4
2	11.4
3	30.7
4	1.1
5	1.7
6	0.0
7	24.1

file 1230B1.DAT, date: 30-DEC-81, time: 14:16:33 has been retrieved.

LANL 6" Sa-Co QUADRUPOLE, S/N R2, 2" search coil

NO SHIMS

The single coil attenuation is 101.6, the V/f range is 0.001 volts.

The reference radius is 0.035000 meters.

R'L(eff) = 0.1609 AT -0.2 degrees.

N	B(N)/B(2) * 1000	ANGLE DEG	ROTATED ANGLE	B(N)/B(2)*1000	
				REAL	IMAGINARY
3	10.29	-105.5	119.5	-5.08	8.95
4	8.36	8.7	278.7	1.26	-8.26
5	3.90	100.3	415.3	2.22	3.21
6	19.57	-33.8	326.2	16.25	-10.90
7	4.14	56.2	461.2	-0.81	4.06
8	3.68	-114.6	335.4	3.35	-1.53
9	0.66	61.4	556.4	-0.63	-0.18
10	2.03	32.8	572.8	-1.70	-1.10
11	0.87	20.2	605.2	-0.36	-0.79
12	3.11	167.2	797.2	0.69	3.04
13	6.02	-90.5	584.5	-4.29	-4.21
14	3.38	148.5	868.5	-2.88	1.76
15	9.90	-101.7	663.3	5.44	-8.27
16	2.73	2.5	812.5	-0.12	2.72
17	14.05	102.2	957.2	-7.62	-11.81
18	25.00	-138.5	761.5	18.72	16.57

The F-matrix identification is:
PMTRX1.DAT 81-dec-29

The 'block' identification and needed shims are:

BLOCK (NO.)	DELTA R(I) (MILS)
0	6.3
1	26.2
2	11.1
3	30.4
4	0.7
5	1.6
6	0.0
7	24.2

file 1230C1.DAT, date: 30-DEC-81, time: 14:53:00 has been retrieved.
 LANL 6' Sa-Co QUADRUPOLE, S/N R2, 2' search coil
 NO SHIMS
 The single coil attenuation is 101.6, the V/f range is 0.001 volts.
 The reference radius is 0.035000 meters.

B'L(eff) = 0.1608 AT 1.3 degrees.

N	B(N)/B(2) * 1000	ANGLE DEG	ROTATED ANGLF	B(N)/B(2)*1000	
				REAL	IMAGINARY
3	10.32	-105.4	119.6	-5.10	8.97
4	8.38	8.4	278.4	1.22	-8.29
5	3.70	103.1	418.1	1.96	3.14
6	19.58	-34.2	325.8	16.20	-11.00
7	4.13	55.5	460.5	-0.75	4.06
8	3.55	-113.6	336.4	3.25	-1.42
9	0.93	88.1	583.1	-0.68	-0.64
10	1.18	85.1	625.1	-0.10	-1.18
11	1.56	-21.4	563.6	-1.43	-0.62
12	2.35	164.4	794.4	0.63	2.26
13	6.95	-104.5	570.5	-5.99	-3.53
14	4.44	135.3	855.3	-3.15	3.12
15	9.89	-78.5	686.5	8.24	-5.46
16	2.89	-110.8	699.2	2.70	-1.02
17	24.58	-196.4	658.6	11.78	-21.57
18	26.14	-94.9	805.1	2.25	26.04

The P-matrix identification is:
 PMTRX1.DAT 81-dec-29

The 'block' identification and needed shims are:

BLOCK (NO.)	DELTA R(I) (MILS)
0	6.7
1	26.0
2	11.2
3	30.6
4	0.6
5	1.8
6	0.0
7	24.1

file 1231A2.DAT, date: 31-DEC-81, time: 13:08:54 has been retrieved.
 LANL 6' Sa-Co QUADRUPOLE, S/N R2, 2' search coil
 POLE<SHIM, 0<6, 1<26<, 2<11, 3<30, 4<0, 5<1, 6<0, 7<24
 The single coil attenuation is 101.6, the V/f range is 0.001 volts.
 The reference radius is 0.035000 meters.

B'L(eff) = 0.1580 AT 0.2 degrees.

N	B(N)/B(2) * 1000	ANGLE DEG	ROTATED ANGLE	B(N)/B(2)*1000	
				REAL	IMAGINARY
3	0.42	170.6	395.6	0.34	0.25
4	0.32	-60.4	209.6	-0.28	-0.16
5	1.65	161.6	476.6	-0.74	1.48
6	9.99	-87.3	272.7	0.46	-9.98
7	6.50	67.9	472.9	-2.53	5.99
8	4.81	-149.3	300.7	2.45	-4.14
9	0.60	-18.0	477.0	-0.27	0.53
10	7.31	-8.0	532.0	-7.24	1.02
11	6.07	-98.1	486.9	-3.64	4.85
12	1.94	-15.8	614.2	-0.53	-1.87
13	3.54	-48.0	627.0	-0.19	-3.54
14	7.74	-3.2	716.8	7.73	-0.44
15	5.59	-70.3	694.7	5.06	-2.39
16	12.56	-88.0	722.0	12.55	0.44
17	21.19	-93.9	761.1	15.97	13.92
18	20.88	144.9	1044.9	17.08	-12.01

The F-matrix identification is:
 PMTRX1.DAT 81-dec-29

The 'block' identification and needed shims are:

BLOCK (NO.)	DELTA R(I) (MILS)
0	1.9
1	1.9
2	0.0
3	3.5
4	1.2
5	1.2
6	2.0
7	0.1

File 1231A3.DAT, date: 31-DEC-81, time: 14:05:20 has been retrieved.
 LANL 6" Sa-Co QUADRUPOLE, S/N R2, 2" search coil
 REPEAT 13:08:54
 The single coil attenuation is 101.6, the V/f range is 0.001 volts.
 The reference radius is 0.035000 meters.

$B^2 L(\text{eff}) = 0.1585 \text{ AT } 0.3 \text{ degrees.}$

N	B(N)/B(2)	ANGLE	ROTATED	B(N)/B(2)*1000	
	* 1000	DEG	ANGLE	REAL	IMAGINARY
3	0.45	173.1	398.1	0.35	0.28
4	0.23	-52.9	217.1	-0.18	-0.14
5	1.73	163.2	478.2	-0.82	1.53
6	9.89	-88.1	271.9	0.32	-9.89
7	6.59	67.1	472.1	-2.48	6.11
8	4.93	-148.6	301.4	2.57	-4.21
9	0.64	23.0	518.0	-0.59	0.24
10	8.22	-8.1	531.9	-8.14	1.16
11	4.35	-84.1	500.9	-3.38	2.74
12	2.09	8.8	638.8	0.32	-2.07
13	2.71	-25.4	649.6	0.91	-2.55
14	12.10	-3.8	716.2	12.07	-0.81
15	3.69	-57.2	707.8	3.61	-0.78
16	6.40	-83.1	726.9	6.36	0.77
17	12.78	-94.6	760.4	9.73	8.27
18	29.01	-177.8	722.2	28.99	1.12

The F-matrix identification is:
 PMTRX1.DAT 81-dec-29

The 'block' identification and needed shims are:

BLOCK (NO.)	DELTA R(I) (MILS)
0	1.9
1	1.9
2	0.2
3	3.6
4	1.2
5	1.2
6	2.2
7	0.0

file 123144.DAT, date: 31-DEC-81, time: 14:07:37 has been retrieved.
 LANL 6' ~~S~~-Co QUADRUPOLE, S/N R2, 2' search coil
 2ND REPEAT OF 13:08:54
 The single coil attenuation is 101.6, the V/f range is 0.001 volts.
 The reference radius is 0.035000 meters.

B'L(eff) = 0.1583 AT 0.3 degrees.

N	B(N)/B(2) * 1000	ANGLE DEG	ROTATED ANGLE	B(N)/B(2)*1000	
				REAL	IMAGINARY
3	0.45	177.1	402.1	0.33	0.30
4	0.30	-56.9	213.1	-0.25	-0.16
5	1.64	159.8	474.8	-0.69	1.49
6	9.99	-88.3	271.7	0.30	-9.98
7	6.56	67.1	472.1	-2.47	6.08
8	4.74	-149.7	300.3	2.39	-4.09
9	0.47	-6.1	488.9	-0.29	0.37
10	7.90	-10.1	529.9	-7.78	1.39
11	6.08	-97.3	487.7	-3.71	4.81
12	3.07	-6.4	623.6	-0.34	-3.05
13	4.54	-37.7	637.3	0.58	-4.50
14	10.08	5.6	725.6	10.04	0.98
15	8.88	-99.4	665.6	5.18	-7.22
16	7.32	-125.9	684.1	5.93	-4.29
17	7.67	-128.9	726.1	7.63	0.81
18	38.74	-163.7	736.3	37.18	10.86

The P-matrix identification is:
 PMTRX1.DAT 81-dec-29

The "block" identification and needed shims are:

BLOCK (NO.)	DELTA R(I) (MILS)
0	1.7
1	1.9
2	0.1
3	3.4
4	1.2
5	1.0
6	2.0
7	0.0

file 1231A5.DAT, date: 31-DEC-81, time: 14:09:50 has been retrieved.
 LANL 6' Sa-Co QUADRUPOLE, S/N R2, 2' search coil
 3RD REPEAT OF 13:08:54
 The single coil attenuation is 101.6, the V/f range is 0.001 volts.
 The reference radius is 0.035000 meters.

B'L(eff) = 0.1579 AT 0.3 degrees.

N	B(N)/B(2)		ANGLE DEG	ROTATED ANGLE	B(N)/B(2)*1000	
	* 1000				REAL	IMAGINARY
3	0.44		179.1	404.1	0.32	0.31
4	0.34		-64.0	206.0	-0.31	-0.15
5	1.76		161.9	476.9	-0.80	1.57
6	10.05		-88.2	271.8	0.32	-10.04
7	6.66		66.3	471.3	-2.42	6.21
8	4.90		-149.8	300.2	2.46	-4.24
9	0.90		39.9	534.9	-0.90	0.08
10	7.43		-10.8	529.2	-7.30	1.39
11	4.90		-83.2	501.8	-3.85	3.03
12	2.24		28.2	658.2	1.06	-1.98
13	3.55		0.3	675.3	2.53	-2.50
14	5.23		-8.8	711.2	5.17	-0.80
15	14.85		-94.3	670.7	9.68	-11.26
16	11.64		-107.1	702.9	11.13	-3.43
17	15.14		167.0	1022.0	8.02	-12.84
18	37.78		-168.5	731.5	37.02	7.55

The P-matrix identification is:
 PMTRX1.DAT 81-dec-29

The 'block' identification and needed shims are:

BLOCK (NO.)	DELTA R(I) (MILS)
0	2.0
1	2.0
2	0.1
3	3.6
4	1.2
5	1.1
6	2.1
7	0.0

file 1231B1.DAT, date: 31-DEC-81, time: 14:37:47 has been retrieved.
 LANL 6' Sa-Co QUADRUPOLE, S/N R2, 2' search coil
 POLE<SHIM, 0<8, 1<28, 2<11, 3<33, 4<1, 5<2, 6<2, 7<24
 The single coil attenuation is 101.6, the V/f range is 0.001 volts.
 The reference radius is 0.035000 meters.

B'L(eff) = 0:1578 AT 0.5 degrees.

N	B(N)/B(2) * 1000	ANGLE DEG	ROTATED ANGLE	B(N)/B(2)*1000	
				REAL	IMAGINARY
3	0.93	163.6	388.6	0.82	0.45
4	0.48	-71.4	198.6	-0.45	-0.15
5	0.26	30.2	345.2	0.25	-0.07
6	9.57	-87.9	272.1	0.35	-9.56
7	7.23	58.5	463.5	-1.69	7.03
8	4.67	-153.2	296.8	2.11	-4.17
9	0.65	57.8	552.8	-0.63	-0.14
10	8.91	-16.9	523.1	-8.53	2.59
11	4.86	-97.5	487.5	-2.96	3.86
12	2.62	13.4	643.4	0.61	-2.55
13	2.55	-175.3	499.7	-1.95	1.65
14	7.42	2.9	722.9	7.41	0.38
15	11.40	-112.5	652.5	4.36	-10.53
16	11.17	-71.5	738.5	10.60	3.54
17	29.50	-119.6	735.4	28.45	7.82
18	51.25	-177.0	723.0	51.18	2.68

The F-matrix identification is:
 FMTRX1.DAT 81-dec-29

The 'block' identification and needed shims are:

BLOCK (NO.)	DELTA R(I) (MILS)
0	0.2
1	0.9
2	0.9
3	1.9
4	2.2
5	1.2
6	0.0
7	0.7

file 1231B2.DAT, date: 31-DEC-81, time: 14:40:41 has been retrieved.
 LANL 6' Sa-Co QUADRUPOLE, S/N R2, 2' search coil
 1'ST REPEAT OF 14:37:47
 The single coil attenuation is 101.6, the V/f range is 0.001 volts.
 The reference radius is 0.035000 meters.

B/L(eff) = 0.1579 AT 0.5 degrees.

N	B(N)/B(2)	ANGLE	ROTATED	B(N)/B(2)*1000	
	* 1000	DEG	ANGLE	REAL	IMAGINARY
3	0.92	160.9	385.9	0.82	0.40
4	0.49	-68.4	201.6	-0.46	-0.18
5	0.24	29.6	344.6	0.23	-0.06
6	9.66	-88.4	271.6	0.27	-9.66
7	7.29	59.4	464.4	-1.81	7.07
8	4.81	-151.8	298.2	2.27	-4.24
9	0.46	-7.4	487.6	-0.28	0.37
10	8.63	-13.8	526.2	-8.38	2.05
11	5.75	-92.5	492.5	-3.89	4.24
12	0.91	-23.8	606.2	-0.37	-0.83
13	4.43	-57.7	617.3	-0.97	-4.32
14	9.96	3.6	723.6	9.94	0.62
15	11.34	-141.8	623.2	-1.34	-11.26
16	7.02	-52.2	757.8	5.55	4.30
17	22.35	-146.5	708.5	21.91	-4.45
18	30.57	-133.7	766.3	21.10	22.12

The P-matrix identification is:
 FMTRX1.DAT 81-dec-29

The 'block' identification and needed shims are:

BLOCK (NO.)	DELTA R(I) (MILS)
0	0.2
1	0.7
2	0.8
3	1.8
4	2.1
5	1.1
6	0.0
7	0.6

LBID-520

file 1231B3.DAT, date: 31-DEC-81, time: 14:45:40 has been retrieved.

LANL 6" Sa-Co QUADRUPOLE, S/N R2, 2" search coil

2ND REPEAT OF 14:37:47

The single coil attenuation is 101.6, the V/f range is 0.001 volts.

The reference radius is 0.035000 meters.

$B'L(\text{eff}) = 0.1574 \text{ AT}$ 0.5 degrees.

N	B(N)/B(2)		ROTATED ANGLE	B(N)/B(2)*1000	
	* 1000	ANGLE DEG		REAL	IMAGINARY
3	0.91	163.5	388.5	0.80	0.44
4	0.53	-67.3	202.7	-0.49	-0.21
5	0.24	38.0	353.0	0.24	-0.03
6	9.73	-87.7	272.3	0.39	-9.72
7	7.54	59.0	464.0	-1.82	7.32
8	4.85	-150.1	299.9	2.42	-4.20
9	0.80	36.6	531.6	-0.79	0.12
10	9.02	-8.7	531.3	-8.92	1.36
11	5.16	-78.2	506.8	-4.32	2.83
12	2.26	39.4	669.4	1.43	-1.75
13	2.85	-80.9	594.1	-1.67	-2.31
14	10.77	-2.0	718.0	10.76	-0.38
15	7.48	-85.7	679.3	5.66	-4.88
16	14.60	-77.5	732.5	14.26	3.15
17	17.44	-174.0	681.0	13.56	-10.97
18	20.84	-157.5	742.5	19.26	7.97

The F-matrix identification is:

PMTRX1.DAT 81-dec-29

The 'block' identification and needed shims are:

BLOCK (NO.)	DELTA R(I) (MILS)
0	0.3
1	0.9
2	0.8
3	2.0
4	2.2
5	1.2
6	0.0
7	0.7

file 1231B4.DAT, date: 31-DEC-81, time: 14:48:08 has been retrieved.
 LANL 6" Se-Co QUADRUPOLE, S/N R2, 2" search coil
 3'RD REPEAT OF 13:37:47
 The single coil attenuation is 101.6, the V/f range is 0.001 volts.
 The reference radius is 0.035000 meters.

R'L(eff) = 0:1577 AT 0.5 deereps.

N	B(N)/B(2) * 1000	ANGLE DEG	ROTATED ANGLE	B(N)/B(2)*1000 REAL	IMAGINARY
3	0.92	163.2	388.2	0.81	0.44
4	0.48	-68.2	201.8	-0.44	-0.18
5	0.20	44.7	359.7	0.20	-0.00
6	9.69	-87.9	272.1	0.36	-9.68
7	7.36	59.3	464.3	-1.82	7.13
8	4.77	-149.5	300.5	2.43	-4.11
9	1.05	42.6	537.6	-1.05	0.04
10	9.08	-16.3	523.7	-8.72	2.56
11	4.16	-86.3	498.7	-3.13	2.74
12	2.70	30.2	660.2	1.36	-2.33
13	2.92	-37.5	637.5	0.38	-2.89
14	6.07	1.1	721.1	6.07	0.11
15	4.64	-116.0	649.0	1.51	-4.39
16	10.06	-105.2	704.8	9.71	-2.64
17	4.73	-35.1	819.9	-0.81	4.66
18	22.62	-117.5	782.5	10.44	20.06

The P-matrix indentification is:
 PMTRX1.DAT 81-dec-29

The "block" identification and needed shims are:

BLOCK (NO.)	DELTA R(I) (MILS)
0	0.2
1	0.8
2	0.8
3	2.0
4	2.0
5	1.1
6	0.0
7	0.6

ENGINEERING NOTE

Appendix D

FILE NO.
MT 308PAGE
D1 of D6

SUBJECT "FIXING" of a 6" LANL Rare Earth Quadrupole Magnet
By The Halbach Technique

NAME
Michael I. GreenDATE
January 7, 1982

APPENDIX D

Computer Output From
Error Harmonic Generation Program QDADJ2
(December 31, 1981 Update)

Data Set

1230A1	Self Consistency Check of QDADJ1 on Data
1231A2	Shim Schedule 2
1231A3	Shim Schedule 2
1231A4	Shim Schedule 2
1231A5	Shim Schedule 2

file 1230A1.DAT, date: 30-DEC-81, time: 13:34:15 has been retrieved.
 LANL 6" Sa-Co QUADRUPOLE, S/N R2, 2" search coil
 TIGHTENED ALL ADJUSTING SCREWS, NO SHIMS
 The single coil attenuation is 101.6, the V/f range is 0.001 volts.
 The reference radius is 0.035000 meters.

B'L(eff) = 0.1609 AT 1.1 degrees.

N	B(N)/B(2) * 1000	ANGLE DEG	ROTATED ANGLE	R(N)/R(2)*1000	
				REAL	IMAGINARY
3	10.35	-106.7	118.3	-4.90	9.12
4	8.31	8.4	278.4	1.22	-8.22
5	3.94	99.9	414.9	2.27	3.23
6	19.54	-33.9	326.1	16.22	-10.89
7	4.29	55.5	460.5	-0.78	4.22
8	3.61	-111.8	338.2	3.35	-1.34
9	0.87	125.4	620.4	-0.15	-0.86
10	2.46	30.7	570.7	-2.11	-1.26
11	1.57	-69.0	516.0	-1.44	0.64
12	2.02	153.1	783.1	0.91	1.81
13	5.02	-142.1	532.9	-4.98	0.62
14	7.65	146.6	866.6	-6.39	4.21
15	12.29	-125.7	639.3	1.99	-12.13
16	10.15	-163.4	646.6	2.90	-9.72
17	12.16	-186.9	668.1	7.51	-9.57
18	32.50	-169.5	730.5	31.95	5.93

The N-matrix identification is:
 NMTRX1,DAT 81-dec-29

The block identification and added shims are:

BLOCK (NO.)	DELTA R(I) (MILS)
0	6.3
1	26.4
2	11.4
3	30.7
4	1.1
5	1.7
6	0.0
7	24.1

	MEASURED *1000	DELTA *1000	RESULTANT *1000
RE B(3)/B(2)	-4.90	-4.90	-0.00
IM B(3)/B(2)	9.12	9.13	-0.01
RE B(4)/B(2)	1.22	1.23	-0.02
IM B(4)/B(2)	-8.22	-8.22	0.00
RE B(5)/B(2)	2.27	2.28	-0.01
IM B(5)/B(2)	3.23	3.22	0.01
RE B(6)/B(2)	16.22	16.22	0.00

file 1231A2.DAT, date: 31-DEC-81, time: 13:08:54 has been retrieved.
 LANL 6' Sa-Co QUADRUPOLE, S/N R2, 2' search coil
 POLE<SHIM, 0<6, 1<26<, 2<11, 3<30, 4<0, 5<1, 6<0, 7<24
 The single coil attenuation is 101.6, the V/f range is 0.001 volts.
 The reference radius is 0.035000 meters.

B'L(eff) = 0.1580 AT 0.2 degrees.

N	B(N)/B(2) * 1000	ANGLE DEG	ROTATED ANGLE	B(N)/B(2)*1000 REAL	IMAGINARY
3	0.42	170.6	395.6	0.34	0.25
4	0.32	-60.4	209.6	-0.28	-0.16
5	1.65	161.6	476.6	-0.74	1.48
6	9.99	-87.3	272.7	0.46	-9.98
7	6.50	67.9	472.9	-2.53	5.99
8	4.81	-149.3	300.7	2.45	-4.14
9	0.60	-18.0	477.0	-0.27	0.53
10	7.31	-8.0	532.0	-7.24	1.02
11	6.07	-98.1	486.9	-3.64	4.85
12	1.94	-15.8	614.2	-0.53	-1.87
13	3.54	-48.0	627.0	-0.19	-3.54
14	7.74	-3.2	716.8	7.73	-0.44
15	5.59	-70.3	694.7	5.06	-2.39
16	12.56	-88.0	722.0	12.55	0.44
17	21.19	-93.9	761.1	15.97	13.92
18	20.88	144.9	1044.9	17.08	-12.01

The N-matrix identification is:
 NMTRX1.DAT 81-dec-29

The block identification and added shims are:

BLOCK (NO.)	DELTA R(I) (MILS)
0	2.0
1	2.0
2	0.0
3	3.0
4	1.0
5	1.0
6	2.0
7	0.0

	MEASURED *1000	DELTA *1000	RESULTANT *1000
RE B(3)/B(2)	0.34	0.11	0.23
IM B(3)/B(2)	0.25	0.23	0.02
RE B(4)/B(2)	-0.28	-0.31	0.03
IM B(4)/B(2)	-0.16	0.00	-0.16
RE B(5)/B(2)	-0.74	-0.72	-0.02
IM B(5)/B(2)	1.48	1.45	0.03
RE B(6)/B(2)	0.46	0.25	0.21

file 1231A3.DAT, date: 31-DEC-81, time: 14:05:20 has been retrieved.
 LANL 6' Sa-Co QUADRUPOLE, S/N.R2, 2' search coil
 REPEAT 13:08:54
 The single coil attenuation is 101.6, the V/f range is 0.001 volts.
 The reference radius is 0.035000 meters.

- B/L(eff) = 0.1585 AT 0.3 degrees.

N	B(N)/B(2)		ANGLE DEG	ROTATED ANGLE	B(N)/B(2)*1000	
	* 1000				REAL	IMAGINARY
3	0.45		173.1	398.1	0.35	0.28
4	0.23		-52.9	217.1	-0.18	-0.14
5	1.73		163.2	478.2	-0.82	1.53
6	9.89		-88.1	271.9	0.32	-9.89
7	6.59		67.1	472.1	-2.48	6.11
8	4.93		-148.6	301.4	2.57	-4.21
9	0.64		23.0	518.0	-0.59	0.24
10	8.22		-8.1	531.9	-8.14	1.16
11	4.35		-84.1	500.9	-3.38	2.74
12	2.09		8.8	638.8	0.32	-2.07
13	2.71		-25.4	649.6	0.91	-2.55
14	12.10		-3.8	716.2	12.07	-0.81
15	3.69		-57.2	707.8	3.61	-0.78
16	6.40		-83.1	726.9	6.36	0.77
17	12.78		-94.6	760.4	9.73	8.27
18	29.01		-177.8	722.2	28.99	1.12

The N-matrix identification is:
 NMTRX1.DAT 81-dec-29

The block identification and added shims are:

BLOCK (NO.)	DELTA R(I) (MILS)
0	2.0
1	2.0
2	0.0
3	3.0
4	1.0
5	1.0
6	2.0
7	0.0

	MEASURED *1000	DELTA *1000	RESULTANT *1000
RE B(3)/B(2)	0.35	0.11	0.24
IM B(3)/B(2)	0.28	0.23	0.05
RE B(4)/B(2)	-0.18	-0.31	0.12
IM B(4)/B(2)	-0.14	0.00	-0.14
RE B(5)/B(2)	-0.82	-0.72	-0.09
IM B(5)/B(2)	1.53	1.45	0.08
RE B(6)/B(2)	0.32	0.25	0.07

file 1231A4.DAT, date: 31-DEC-81, time: 14:07:37 has been retrieved.
 LANL 6' Sa-Co QUADRUPOLE, S/N R2, 2' search coil
 2ND REPEAT OF 13:08:54
 The single coil attenuation is 101.6, the V/f range is 0.001 volts.
 The reference radius is 0.035000 meters.

- B'L(eff) = 0.1583 AT 0.3 degrees.

N	B(N)/B(2) * 1000	ANGLE DEG	ROTATED ANGLE	B(N)/B(2)*1000	
				REAL	IMAGINARY
3	0.45	177.1	402.1	0.33	0.30
4	0.30	-56.9	213.1	-0.25	-0.16
5	1.64	159.8	474.8	-0.69	1.49
6	9.99	-88.3	271.7	0.30	-9.98
7	6.56	67.1	472.1	-2.47	6.08
8	4.74	-149.7	300.3	2.39	-4.09
9	0.47	-6.1	488.9	-0.29	0.37
10	7.90	-10.1	529.9	-7.78	1.39
11	6.08	-97.3	487.7	-3.71	4.81
12	3.07	-6.4	623.6	-0.34	-3.05
13	4.54	-37.7	637.3	0.58	-4.50
14	10.08	5.6	725.6	10.04	0.98
15	8.88	-99.4	665.6	5.18	-7.22
16	7.32	-125.9	684.1	5.93	-4.29
17	7.67	-128.9	726.1	7.63	0.81
18	38.74	-163.7	736.3	37.18	10.86

The N-matrix identification is:
 NMTRX1.DAT 81-dec-29

The block identification and added shims are:

BLOCK (NO.)	DELTA R(I) (MILS)
0	2.0
1	2.0
2	0.0
3	3.0
4	1.0
5	1.0
6	2.0
7	0.0

	MEASURED *1000	DELTA *1000	RESULTANT *1000
RE B(3)/B(2)	0.33	0.11	0.22
IM B(3)/B(2)	0.30	0.23	0.08
RE B(4)/B(2)	-0.25	-0.31	0.06
IM B(4)/B(2)	-0.16	0.00	-0.16
RE B(5)/B(2)	-0.69	-0.72	0.03
IM B(5)/B(2)	1.49	1.45	0.04
RE B(6)/B(2)	0.30	0.25	0.05

file 1231A5.DAT, date: 31-DEC-81, time: 14:09:50 has been retrieved.
LANL 6" Sa-Co QUADRUPOLE, S/N R2, 2" search coil
3RD REPEAT OF 13:08:54
The single coil attenuation is 101.6, the V/f range is 0.001 volts.
The reference radius is 0.035000 meters.

B/L(eff) = 0.1579 AT 0.3 degrees.

N	B(N)/B(2) * 1000	ANGLE DEG	ROTATED ANGLE	B(N)/B(2)*1000	
				REAL	IMAGINARY
3	0.44	179.1	404.1	0.32	0.31
4	0.34	-64.0	206.0	-0.31	-0.15
5	1.76	161.9	476.9	-0.80	1.57
6	10.05	-88.2	271.8	0.32	-10.04
7	6.66	66.3	471.3	-2.42	6.21
8	4.90	-149.8	300.2	2.46	-4.24
9	0.90	39.9	534.9	-0.90	0.08
10	7.43	-10.8	529.2	-7.30	1.39
11	4.90	-83.2	501.8	-3.85	3.03
12	2.24	28.2	658.2	1.06	-1.98
13	3.55	0.3	675.3	2.53	-2.50
14	5.23	-8.8	711.2	5.17	-0.80
15	14.85	-94.3	670.7	9.68	-11.26
16	11.64	-107.1	702.9	11.13	-3.43
17	15.14	167.0	1022.0	8.02	-12.84
18	37.78	-168.5	731.5	37.02	7.55

The N-matrix identification is:
NMTRX1.DAT 81-dec-29

The block identification and added shims are:

BLOCK (NO.)	DELTA R(I) (MILS)
0	2.0
1	2.0
2	0.0
3	3.0
4	1.0
5	1.0
6	2.0
7	0.0

	MEASURED *1000	DELTA *1000	RESULTANT *1000
RE B(3)/B(2)	0.32	0.11	0.20
IM B(3)/B(2)	0.31	0.23	0.08
RE B(4)/B(2)	-0.31	-0.31	-0.00
IM B(4)/B(2)	-0.15	0.00	-0.15
RE B(5)/B(2)	-0.80	-0.72	-0.08
IM B(5)/B(2)	1.57	1.45	0.13
RE B(6)/B(2)	0.32	0.25	0.07

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