BNL-104693-2014-TECH

AGS/AD/Tech Note No. 275;BNL-104693-2014-IR

THE 1986 VERTICAL SURVEY OF THE AGS

E. J. Bleser

February 1987

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

Accelerator Division
Alternating Gradient Synchrotron Department
BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York 11973

Accelerator Division
Technical Note

AGS/AD/Tech. Note No. 275

THE 1986 VERTICAL SURVEY OF THE AGS

E. Bleser

February 4, 1987

I. Introduction

A vertical survey of the AGS was carried out in the summer of 1986. Its goals were to determine the elevation of the ring and to develop a new monument system for use in the vertical survey. This note describes the new monument system, evaluates the precision of the survey, and reports on the elevation of the ring.

II. The Vertical Monument System

For the past several years the vertical monument system used in the AGS consisted of targets mounted on the tunnel wall. This system had sufficient stability to be satisfactory for the duration of one survey, but as discussed in Technical Note No. 237, one survey had limited usefulness since the accumulation of errors from magnet to magnet around the ring resulted in a random walk effect which limited the ultimate alignment of the ring. In order to defeat the random walk problem, we sought to develop a monument system of long-term stability, which would then enable us to average over many surveys. Quite fortuitously, we found that such a system had been built into the original AGS. Each pair of magnets are mounted on a girder. The ends of each pair of girders are mounted on pile caps, which are mounted on piles which go fifty feet down into the ground. A brass pin was mounted in the top of each of these pile caps for survey purposes. By using the pins as the vertical survey monuments, we have a system that is not subject to accidental intervention by humans and a system that is as stable against ground motion as any that could be found around the AGS.

III. Survey Procedure

Three survey runs were made. Runs 1 and 2 were identical and consisted of measuring the pin elevations with many overlapping points. Run 3 measured selected pins and the magnet elevations. Since some pins were not available, the data are not very systematic, somewhat complicating the analysis. AGS Studies Report No. 211 presented preliminary results from Run 1.

Taking the elevation of Pin A2 as zero, Table I shows the absolute elevations of the pins in inches for Runs 1 and 2, the average of these runs, and the elevation differences. A linear correction has been made for the closing errors. Figure 1 shows the pin elevations for Runs 1 and 2. The gaps in the plot are for pins that were not accessible. The spread in elevation is over an inch but since this is the monument system, that is of no significance. Figure 2 shows a more interesting plot, the difference in elevation as measured in Run 1 and Run 2. This is certainly due to the random walk effect, since it is most unlikely that the earth moved in the short time between measurements and there were no shielding moves at this time. Note that there is a 0.031 inch swing in going from D16 to F12.

In order to evaluate the survey accuracy we have determined the step in elevation in going form one pin to the next, taken the difference in these steps between Run 1 to Run 2 and plotted a frequency distribution of these differences in Figure 3. The width is about ± 0.006 inches. Since there were 40 instrument stations around the ring we should expect a closing error of:

$$0.006 \sqrt{40} = 0.038 \text{ inches}$$

The measured closing errors of -0.033 and -0.31 inches are very acceptable although in remarkable accidental agreement.

The data in Table I should be used for comparing and summing with future measurements.

IV. The Magnet Elevations

Run 3 measured the elevations of a subset of the pins and the elevations of the magnets relative to these pins. The magnets were measured at the most accessible pad, the downstream one when there was a choice. We take as the absolute elevation of each pin the average of Runs 1, 2, and 3, where we have weighted the first two runs at 1.5 each since they had more redundancy than run 3. Figure 4 shows Runs 1, 2, and 3 relative to the mean value, again displaying he random walk effect. Note the 0.040 inch difference between Run 1 and Run 3. Figure 5 shows the absolute magnet elevations based on this analysis. Table II lists the data.

For comparison, Figure 6 shows the magnet elevations as they were left at the end of the 1985 realignment. Cursory examination suggests there has been a 0.030 inch settlement in B, and probably a realignment error in H, occurring in 1985. More detailed examination and much navel contemplation leads to the conclusion, "maybe yes, maybe no".

V. Conclusion

We have not established the long-term stability of the new monument system, but we hope it will be good. The program will be to simplify, standardize, and streamline the survey of the monument system, accumulating more data now that we have a sound basis to work on. By the 1987 summer shutdown, we could usefully undertake a realignment. This realignment would make the ring flatter than it has been for some time. If there were a polarized run in the fall, it could expect to see an improvement, although we do not ever hope to make the ring as flat as they would like.

Analysis is underway to calculate the orbit based on the survey results and compare it with the measured orbits.

VI. Acknowledgments

We would like to acknowledge the hard work of the Survey Group who collected all the data under the leadership of Frank Karl.

TABLE I PIN ELEVATIONS for RUNS 1 & 2

PIN	RUN 1	RUN 2	AVG	DIF	PIN	RUN 1	RUN 2	AVG	DIF
A 2	0.000	0.000	0.000	0.000	E 2	0.262	0.255	0.258	-0.007
A 4	-0.208	-0.205	-0.207	0.004	E 4	0.364	0.359	0.361	-0.004
A 6	-0.229	-0.223	-0.226	0.006	E 6	0.416	0.415	0.416	.000
A 8	-0.441	-0.436	-0.438	0.005	E 8	0.390	0.394	0.392	0.003
A10	-0.367	-0.364	-0.366	0.002	E10	0.121	0.119	0.120	-0.002
A12	-0.398	-0.392	-0.395	0.006	E12	0.094	0.104	0.099	0.010
A14	-0.346	-0.349	-0.348	-0.003	E14	0.042	0.050	0.046	0.008
A16	-0.301	-0.296	-0.298	0.005	E16	0.012	0.018	0.015	0.005
A18					E18	-0.184	-0.171	-0.178	0.013
A20					E20				
B 2	0.077	0.077	0.077	.000	F 2	0.073	0.085	0.079	0.012
B 4	-0.098	-0.102	-0.100	-0.003	F 4	0.053	0.064	0.058	0.011
B 6	0.411	0.403	0.407	-0.008	F 6	-0.215	-0.203	-0.209	0.012
B 8	0.262	0.251	0.256	-0.011	F 8	-0.143	-0.131	-0.137	0.012
B10					F10	0.287	0.301	0.294	0.013
B12	-0.007	-0.012	-0.009	-0.005	F12	-0.074	-0.057	-0.066	0.017
B14	-0.112	-0.121	-0.116	-0.009	F14				
B16	-0.024	-0.024	-0.024	.000	F16				
B18	0.109	0.105	0.107	-0.003	F18	0.006	0.017	0.011	0.011
B20	0.029	0.021	0.025	-0.008	F20				
C 2	0.443	0.435	0.439	-0.008	G 2	-0.351	-0.339	-0.345	0.013
C 4	0.336	0.325	0.330	-0.010	G 4				
C 6	0.114	0.099	0.107	-0.014	G 6	-0.338	-0.331	-0.335	0.007
C 8	0.270	0.259	0.265	-0.012	G 8	-0.216	-0.201	-0.208	0.015
C10					G10	-0.123	-0.114	-0.118	0.009
C12	0.352	0.338	0.345	-0.013	G12	-0.016	-0.008	-0.012	0.008
C14	0.291	0.283	0.287	-0.008	G14	-0.200	-0.189	-0.195	0.011
C16	0.295	0.286	0.290	-0.009	G16	-0.328	-0.316	-0.322	0.012
C18					G18	0.060	0.070	0.065	0.010
C20					G20	-0.160	-0.144	-0.152	0.016
D 2	0.107	0.102	0.104	-0.005	H 2	-0.082	-0.066	-0.074	0.016
D 4	0.247	0.241	0.244	-0.006	H 4	0.117	0.129	0.123	0.012
D 6	0.650	0.644	0.647	-0.006	H 6	-0.268	-0.263	-0.266	0.005
D 8	0.328	0.320	0.324	-0.007	H 8	-0.112	-0.102	-0.107	0.011
D10					H10				
D12	0.304	0.295	0.299	-0.009	H12	0.018	0.030	0.024	0.012
D14	0.365	0.361	0.363	-0.003	H14				
D16	0.238	0.224	0.231	-0.014	H16				
D18	0.175	0.168	0.171	-0.006	H18	-0.073	-0.055	-0.064	0.017
D20					H20				

TABLE I PIN ELEVATIONS for RUNS 1 & 2
continued

I 2	0.019	0.030	0.025	0.011
I 4	0.080	0.092	0.086	0.012
I 6	0.215	0.232	0.223	0.017
I 8	0.353	0.364	0.359	0.011
I10	0.337	0.349	0.343	0.012
I12	0.094	0.107	0.100	0.013
I14	0.234	0.247	0.240	0.013
I16	0.308	0.320	0.314	0.013
I18	0.565	0.576	0.570	0.012
I20				
J 2	0.359	0.372	0.365	0.013
J 4	0.300	0.313	0.306	0.013
J 6	0.443	0.457	0.450	0.014
J 8	0.409	0.429	0.419	0.020
J10				
J12	0.210	0.237	0.224	0.027
J14	0.155	0.178	0.166	0.022
J16	0.225	0.240	0.233	0.014
J18	0.220	0.239	0.229	0.019
J20				
K 2	0.351	0.363	0.357	0.011
K 4	0.363	0.380	0.371	0.017
K 6				
K 8	0.324	0.334	0.329	0.011
K10				
K12	0.174	0.175	0.174	0.001
K14	0.052	0.058	0.055	0.006
K16	0.166	0.178	0.172	0.012
K18	0.105	0.110	0.107	0.005
K20	0.205	0.204	0.205	-0.001
L 2	0.099	0.105	0.102	0.006
L 4	-0.109	-0.105	-0.107	0.004
L 6	-0.039	-0.040	-0.040	-0.001
L 8	-0.186	-0.184	-0.185	0.002
L10				
L12	-0.085	-0.085	-0.085	.000
L14	-0.261	-0.255	-0.258	0.007
L16	-0.391	-0.387	-0.389	0.004
L18	-0.275	-0.270	-0.273	0.005
L20	-0.306	-0.302	-0.304	0.003

TABLE II. MAGNET ELEVATIONS

Inches

A 1	0.000	C 1	-0.017	E 1	0.013
A 2	-0.003	C 2	-0.017	E 2	0.003
A 3	0.006	C 3	-0.018	E 3	0.004
A 4	0.008	C 4	-0.027	E 4	0.005
A 5	0.009	C 5	-0.011	E 5	0.012
A 6	0.001	C 6	-0.012	E 6	0.008
A 7	0.001	C 7	-0.005	E 7	0.005
A 8	-0.006	C 8	-0.010	E 8	.000
A 9	-0.006	C 9	-0.009	E 9	-0.001
A10	-0.007	C10	-0.012	E10	-0.004
A11	-0.013	C11	-0.012	E11	-0.003
A12	-0.014	C12	-0.025	E12	-0.002
A13	-0.012	C13*	-0.025	E13	0.001
A14	-0.013	C14	-0.021	E14	-0.006
A15	-0.004	C15	-0.020	E15	-0.007
A16	-0.009	C16	-0.024	E16	-0.010
A17	-0.017	C17	-0.010	E17	-0.015
A18	-0.018	C18	-0.002	E18	-0.012
A19	-0.019	C19	-0.003	E19	-0.010
A20	-0.023	C20	-0.004	E20	-0.011
B 1	-0.029	D 1	-0.007	F 1	-0.002
B 2	-0.024	D 2	0.001	F 2	-0.003
B 3	-0.022	D 3	-0.009	F 3	-0.003
B 4	-0.015	D 4	0.001	F 4	.000
B 5	-0.018	D 5	-0.002	F 5	-0.001
B 6	-0.021	D 6	-0.002	F 6	-0.006
B 7	-0.029	D 7	0.014	F 7	-0.008
B 8	-0.037	D 8	0.009	F 8	-0.008
B 9	-0.037	D 9	0.009	F 9	-0.004
B10	-0.030	D10	0.012	F10	0.008
B11	-0.029	D11	-0.004	F11	0.003
B12	-0.029	D12	0.001	F12	.000
B13	-0.027	D13	0.005	F13	-0.001
B14	-0.031	D14	0.018	F14	-0.001
B15	-0.034	D15	0.020	F15	0.010
B16	-0.038	D16	0.018	F16	0.003
B17	-0.012	D17	0.020	F17	.000
B18	-0.042	D18	0.025	F18	.000
B19	-0.034	D19	0.007	F19	0.005
B20	-0.028	D20	0.011	F20	0.001

TABLE II. MAGNET ELEVATIONS, continued

Inches

G 1	0.010	I 1	0.006	K 1	-0.003
G 2	0.010	I 2	0.003	K 2	-0.002
G 3	0.008	I 3	0.001	K 3	0.001
G 4	0.016	I 4	0.004	K 4	0.001
G 5	0.010	I 5	0.004	K 5	0.009
G 6	0.003	I 6	0.021	K 6	0.007
G 7	0.007	I 7	0.016	K 7	0.011
G 8	0.021	I 8	0.009	K 8	0.012
G 9	0.011	I 9	0.017	K 9	0.008
G10	0.008	I10	0.015	K10	-0.002
G11	0.009	I11	.000	K11	-0.009
G12	0.011	I12	0.008	K12	-0.016
G13	0.005	I13	0.014	K13	-0.015
G14	0.013	I14	0.017	K14	-0.010
G15	0.007	I15	0.027	K15	-0.003
G16	-0.003	I16	0.005	K16	.000
G17	0.002	I17	-0.005	K17	.000
G18	0.018	I18	-0.013	K18	-0.006
G19	-0.012	I19	-0.007	K19	-0.008
G20	-0.007	I20	.000	K20	-0.009
H 1	-0.013	J 1	0.005	L 1	-0.012
H 2	-0.016	J 2	0.007	L 2	-0.013
H 3	-0.029	J 3	0.018	L 3	-0.010
H 4	-0.024	J 4	0.012	L 4	-0.018
H 5	-0.031	J 5	0.008	L 5	-0.016
H 6	-0.020	J 6	-0.002	L 6	-0.010
H 7	-0.018	J 7	0.007	L 7	-0.012
H 8	-0.018	J 8	-0.002	L 8	-0.002
H 9	-0.018	J 9	-0.004	L 9	-0.003
H10	-0.024	J10	0.003	L10	-0.010
H11	-0.029	J11	-0.008	L11	-0.022
H12	-0.023	J12	-0.003	L12	-0.016
H13	-0.023	J13	-0.011	L13	-0.018
H14	-0.023	J14	-0.019	L14	-0.015
H15	-0.013	J15	0.001	L15	-0.017
H16	0.004	J16	0.004	L16	-0.021
H17	0.001	J17	0.011	L17	-0.014
H18	0.011	J18	0.010	L18	-0.018
H19	0.010	J19	0.004	L19	-0.015
H20	0.011	J20	0.007	L20	-0.014

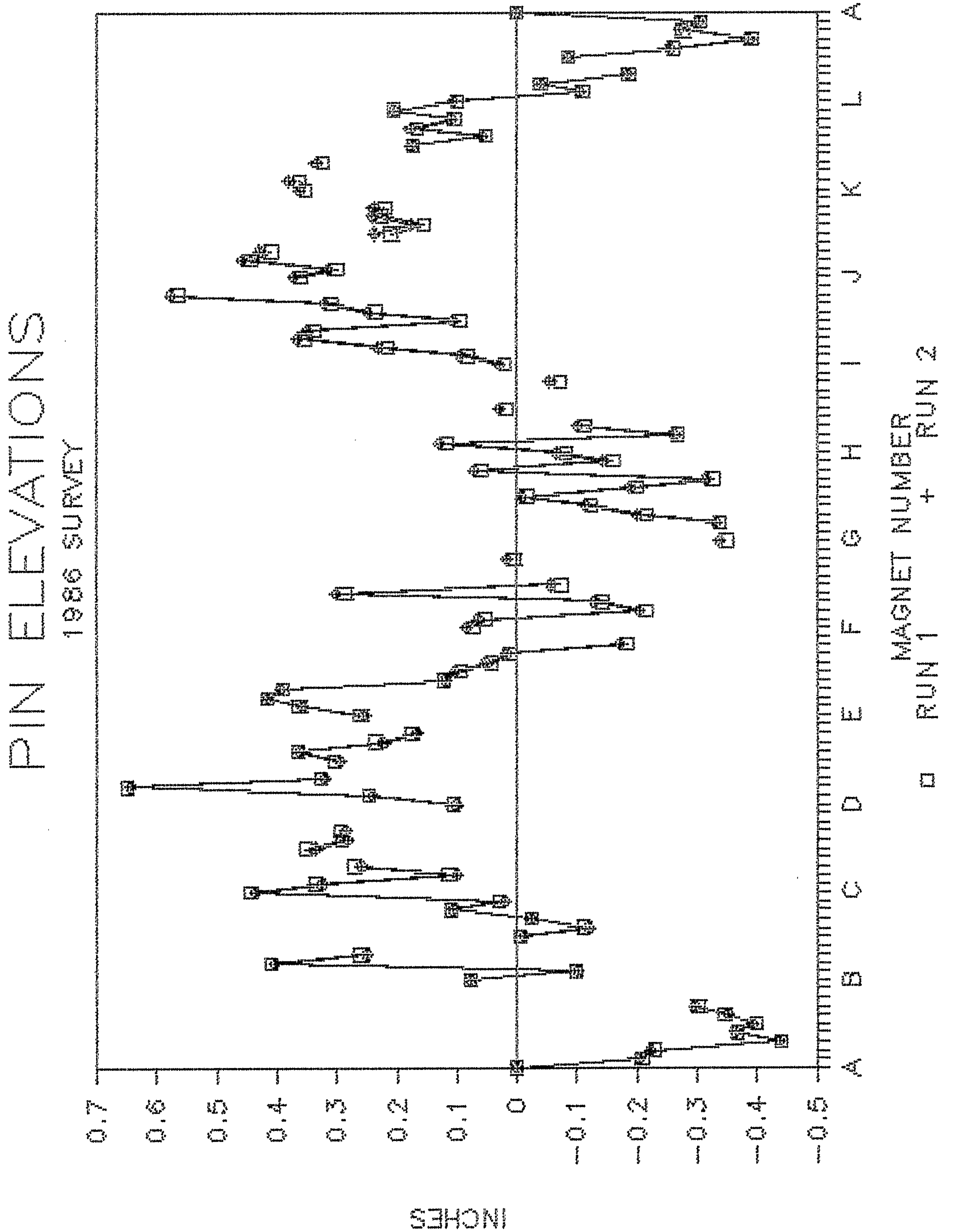
PIN ELEVATIONS
1986 SURVEY
INCHES
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
A
B
C
D
E
F
G
H
I
J
K
L
A
MAGNET NUMBER
□ RUN 1
+ RUN 2

Figure 1.

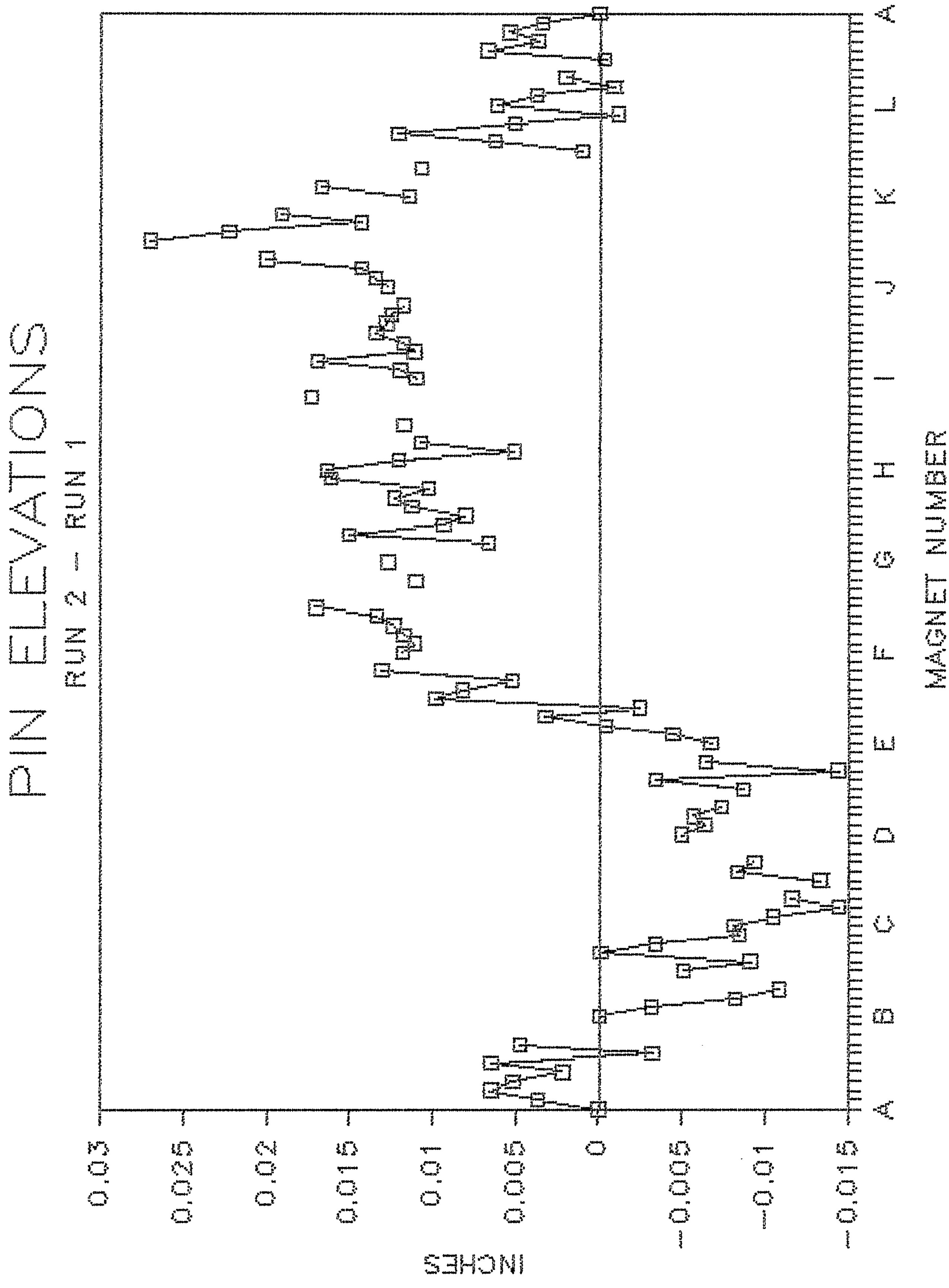
PIN ELEVATIONS
RUN 2 - RUN 1
INCHES
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
MAGNET NUMBER
A
B
C
D
E
F
G
H
I
J
K
L
A

Figure 2.

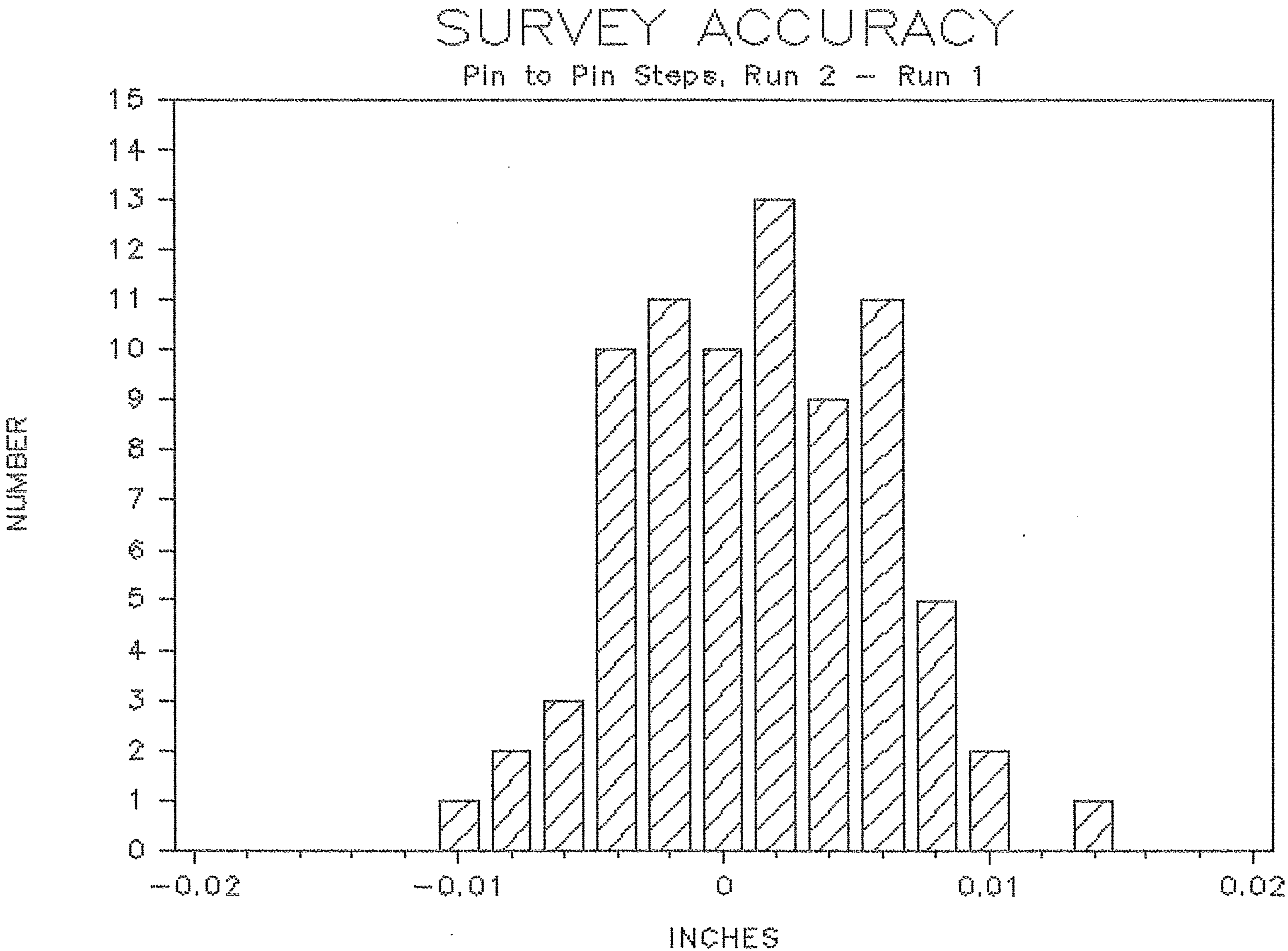
SURVEY ACCURACY
Pin to Pin Steps, Run 2 — Run 1
NUMBER
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
−0.02
−0.01
0
0.01
0.02
INCHES

Figure 3.

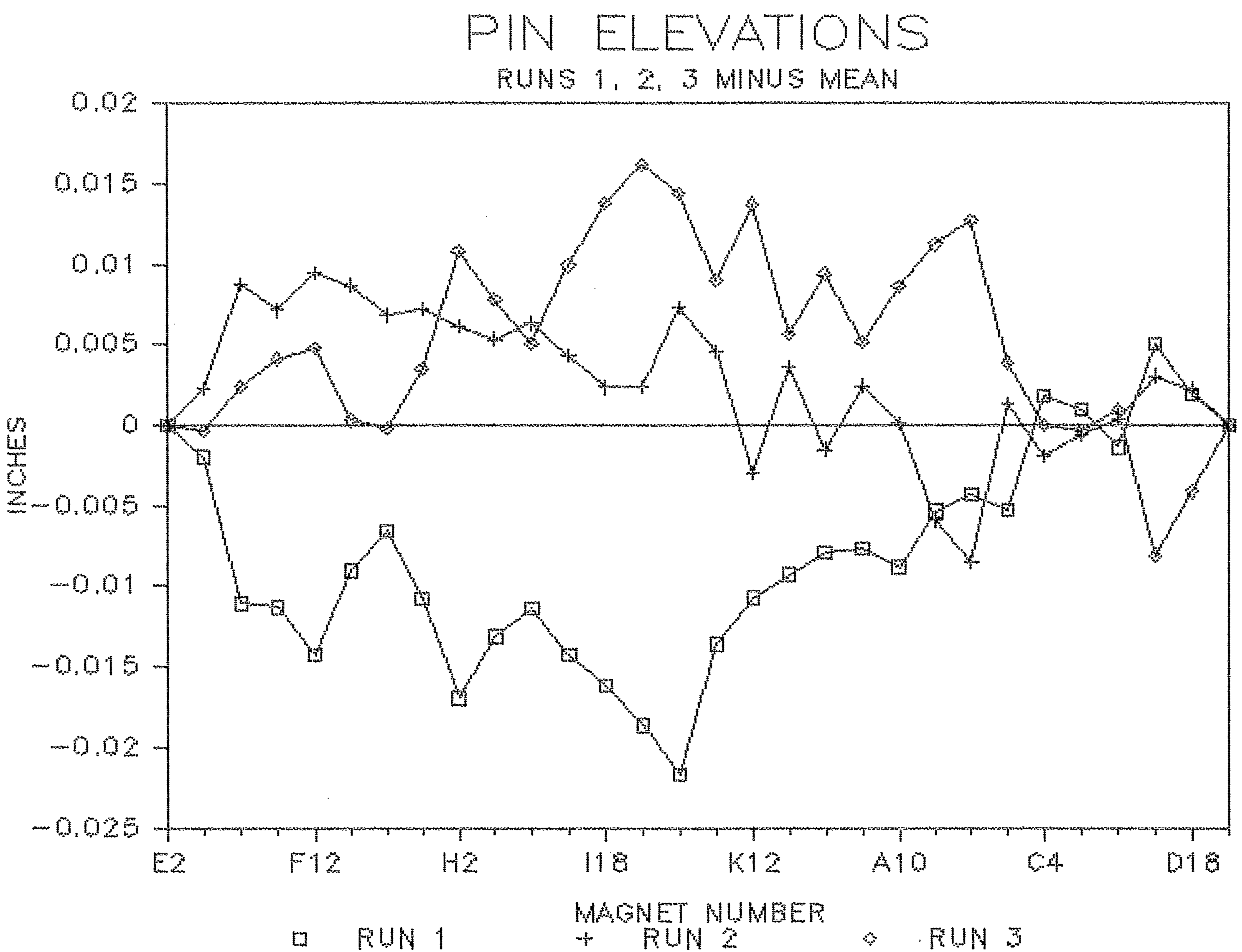
PIN ELEVATIONS
RUNS 1, 2, 3 MINUS MEAN
INCHES
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.025
E2
F12
H2
I18
K12
A10
C4
D18
MAGNET NUMBER
RUN 1
RUN 2
RUN 3

Figure 4.

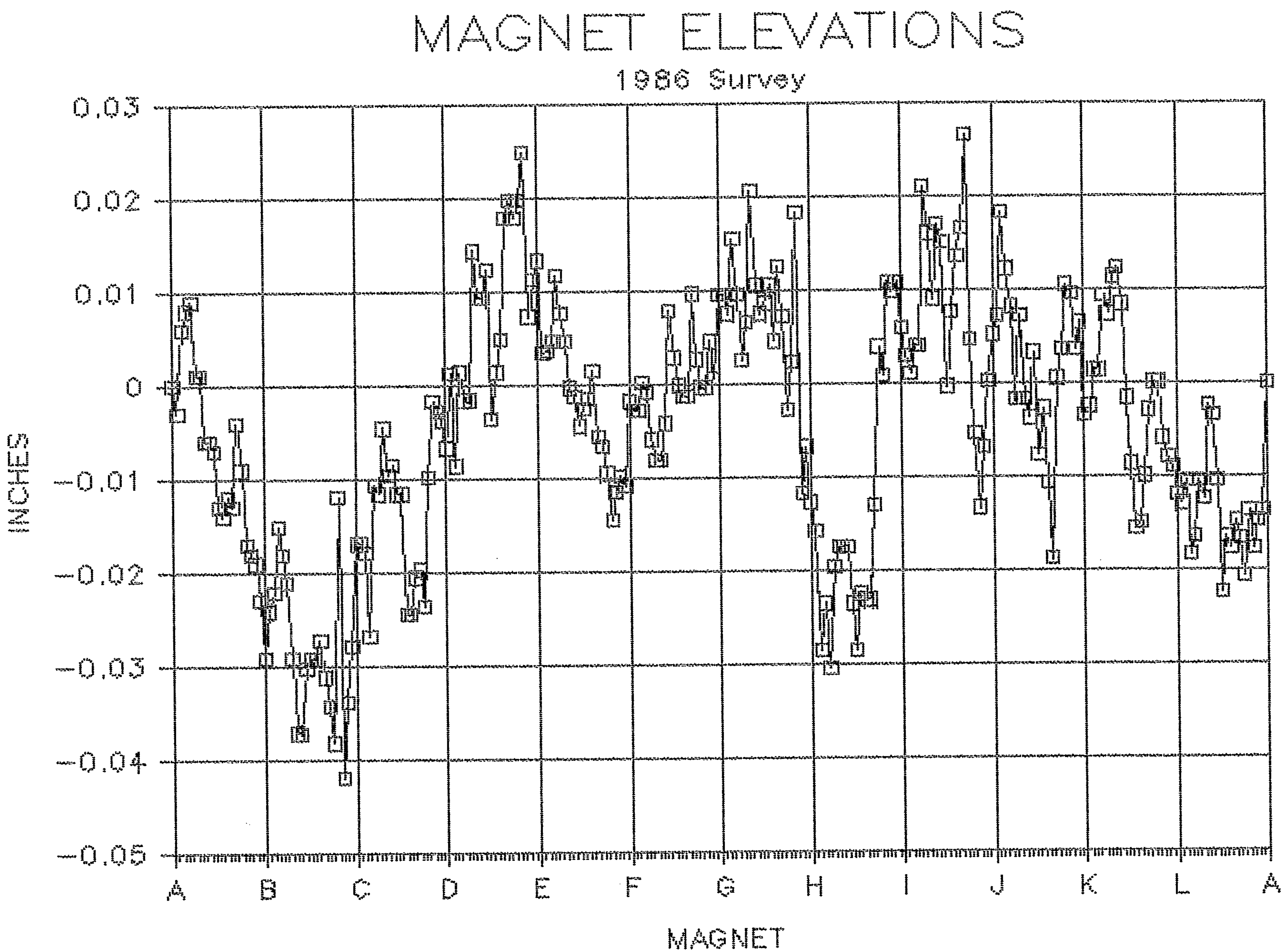
MAGNET ELEVATIONS
1986 Survey
INCHES
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
−0.04
−0.05
A
B
C
D
E
F
G
H
I
J
K
L
A
MAGNET

Figure 5.

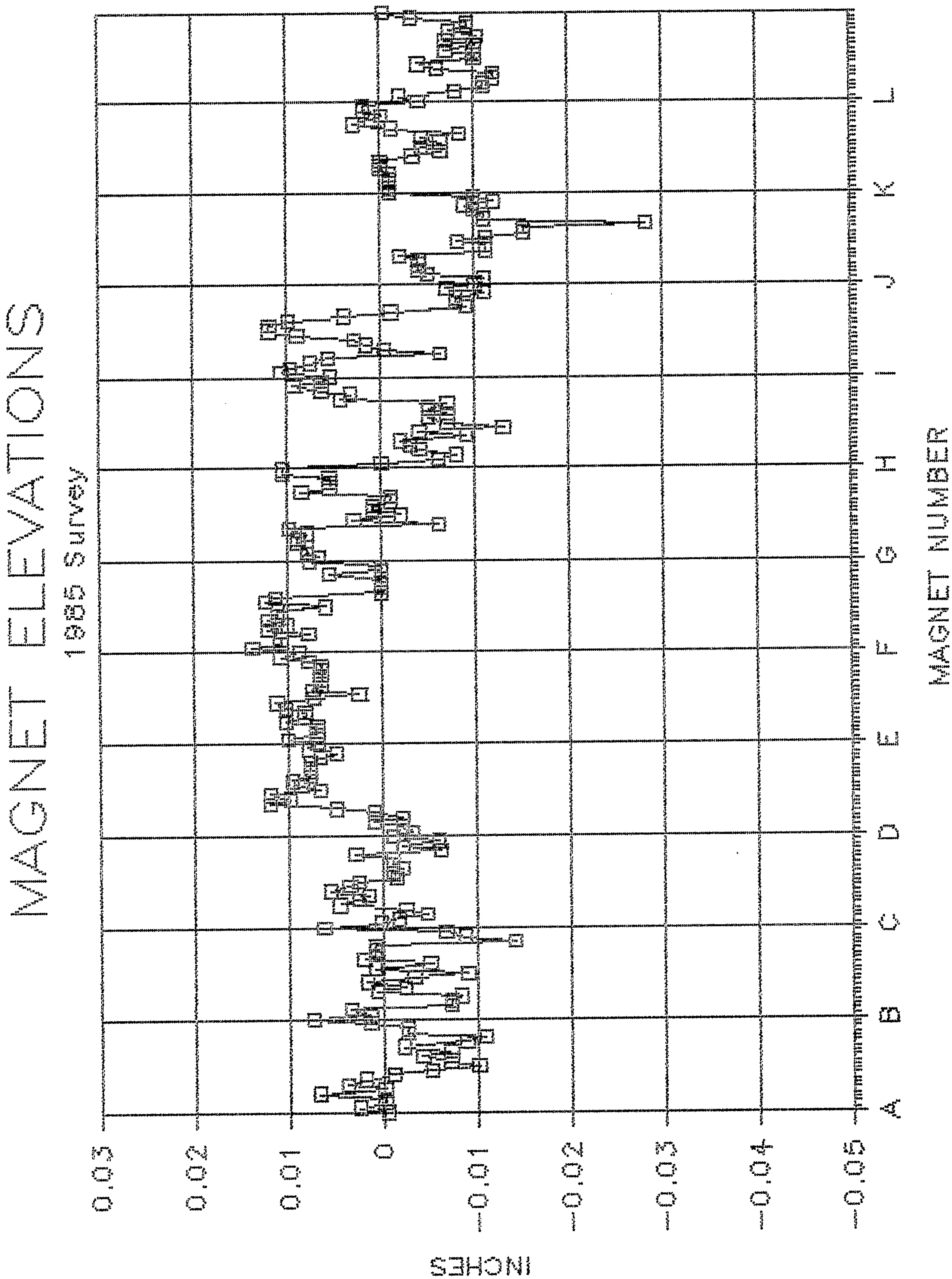
MAGNET ELEVATIONS
1985 Survey
INCHES
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
A
B
C
D
E
F
G
H
I
J
K
L
MAGNET NUMBER

Figure 6.