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THE 1988 VERTICAL SURVEY OF THE AGS

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Accelerator Division Technical Note
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I. Introduction

In 1985 we surveyed and realigned vertically the AGS main magnets and we developed an understanding of the limitations of our then used techniques.[1] In 1986 we surveyed the AGS again and started to develop some improved procedures.[2] In 1987 with a fully developed set of new procedures, we carried out a complete vertical survey and realignment.[3] This year, 1988, we surveyed the vertical monuments using the same procedures first applied in 1987, and we are thus able to present in this paper for the first time a careful evaluation of the vertical motion of the AGS.

II. The Vertical Monument System

As described in reference 3 the vertical monument system was standardized in 1987. It consists of a set of stainless steel pins mounted in the pile caps which are on top of the 50-foot pilings used to support the AGS magnets. We have standardized on a set of 40 pins spaced every 6 magnets around the ring, starting at SS A-02. In some instances new pins were installed in 1987 so there is not one-to-one comparison with earlier work. The pin elevations were measured using the standard procedures, but with considerable care, taking about one day to complete an orbit.

Three complete orbits were run. Five pieces of data were adjusted. In run 1 two errors of plus and minus 0.500 inches were assumed, and the three measurements from F-10 to F-16 were reshot using longer rods. The results were averaged to give the pin elevations listed in Table 1 and plotted in Figure 1. (We have followed Reference 3 and defined the elevation of Pin A-02 as 0.616 inches.) As is customary the closing errors were corrected for by distributing them linearly around the ring. Table 2 summarizes the results of a statistical analysis of the data.

The distribution of the errors in measuring the change in height from one pin to the next was analyzed from the 120 measurements that were made, and has a standard deviation of 0.00176 inches. In 1987 we found the result to be 0.00177 inches.

Based on the survey accuracy, the closing errors should be distributed around zero with a standard deviation of 0.011 inches, which is the square root of 40 times the standard deviation per step. The results are very good, except for the one mysterious fact that the closing errors average to -0.026 inches when we would expect them to average to 0.000±0.011. This result appears to be significant and suggests a systematic -0.0005 inch error per pin measurement. This error can be ignored on an individual basis and is corrected for on an overall basis, but the procedures are designed to eliminate such a bias; we have at present no idea where it comes from. However we note that in 1987 we seemed to have a systematic +0.0005 inch error per pin. Either we are having a bit of bad luck with statistics or we have a bias in the instrument, which might be taken care of by making alternating clockwise and counterclockwise circuits around the ring.

To emphasize the necessarily statistical nature of the vertical survey, we plot in Figures 2 through 4 the deviation of each run from the average value of all 3 runs, displaying, as we have in previous papers, the random walk effect. In the L sector the deviations are rather large, and, as will be seen below, this is due to shielding moves that were being made in conjunction with the booster construction.

III. Is the AGS Moving?

The elevation of the vertical monuments around the ring is found by defining the elevation for the first (n=0) pin and then adding in sequence the steps in elevation from pin to pin. The accuracy with which we know the elevation of the nth pin is given by the square root of n times the standard deviation per pin. Since we close the ring and tie the first point to the last, we actually do much better than this, and the proper value for the standard deviation of the absolute value of the nth pin, $\sigma(n)$, is given by:

$$\frac{1}{\sigma^2(n)} = \frac{1}{n * \sigma^2} + \frac{1}{(40-n)\sigma^2}$$

where σ is the standard deviation per pin elevation. Figure 5 shows two envelops plotted from this formula. The outer one is an envelope one standard deviation wide for single measurements around the ring. It is to be compared with Figures 2 through 4 and seems reasonable. The inner envelop is plotted for an average of 3 runs and purports to show the absolute accuracy with which we know the elevations of the vertical monuments, 0.003 in the worst case.

Figure 6 shows the three individual runs minus the average value of the five runs that were taken in 1987. Figure 7 shows the 1988 average minus the 1987 average. There are three areas we might comment on. In L sector shielding was removed in June and July for the booster penetration, and the monuments rose by 0.050 inches at the time of the first run. During August the shielding was replaced and by the end of the month the monuments had settled back by 0.020 to 0.050 inches. We shall continue to watch this area.

There is a very tentative suggestion that the region of G-20 is sinking. This is near the junction of the target building and the tunnel and is perhaps a region of instability. The most striking effect is in B sector which seems to low by 0.040 inches. This looks to be a very believable effect. Historically the 1985 survey found B sector to be high 0.030 inches. The magnets were lowered appropriately and resurveyed. In 1986 they were found to be low by 0.030 inches but were not repositioned. In 1987 B sector was low by 0.035 inches and was repositioned. Now in 1988 we find that the monuments have settled by 0.030 inches since 1987.

Sectors D through K look reasonably flat and stable. They are about 0.005 inches below where they were last year but we can explain that by saying our normalizing point, A2 has risen by 0.005 inches. Then the scatter of points in D thru K seems to be well within that which would be allowed by the curves of Figure 5.

IV. <u>Conclusions</u>

Our first conclusion is that B sector is certainly unstable and has recently been settling by 0.030 inches per year, perhaps having risen at earlier times.

A second conclusion is that most of the rest of the machine, D through K, is reasonably stable.

A third conclusion is that construction work can rapidly shift the machine by 0.050 inches, which is no surprise.

A fourth conclusion is that our system of vertical monuments gives us a reliable and effective means of tracking the long term vertical motion of the AGS.

V. References

1. E. Bleser, K. Brown, R. Thern. AGS Tech. Note No. 237, January 23, 1986.

2. E. Bleser. AGS/AD/Tech. Note No. 275, February 4, 1987.

3. E. Bleser, E. Auerbach, S. Tanaka, R. Thern. AGS/AD/Tech. Note No. 283, August 12, 1987.

TABLE 1

VERTICAL MONUMENT ELEVATIONS

Average of 3 Runs, 8/1-8/29/88
A2 set to 0.616 inches

MONUMENT	ELEVATION
A- 2	0.616 INCHES
A- 8	0.155
A-14	0.235
A-20	0.516
B- 6	0.982
B-12	0.569
B-18	0.685
C- 4	0.905
C-10	0.511
C-16	0.873
D- 2	0.694
D- 8	0.921
D-14	0.970
D-20	0.819
E- 6	1.029
E-12	0.714
E-18	0.428
F- 4	0.672
F-10	0.909
F-16	0.135
G- 2	0.276
G- 8	0.413
G-14	0.419
G-20	0.448
H- 6	0.504
H-12	0.640
H-18	0.539
I- 4	0.693
I-10	0.955
I-16	0.930
J- 2	0.988
J- 8	1.035
J-14	0.786
J-20	0.927
K- 6	1.007
K-12	0.799
K-18	0.721
L- 4	0.536
L-10	0.645
L-16	0.264
A- 2	0.616

TABLE 2. STATISTICAL ANALYSIS

FOR ONE RUN

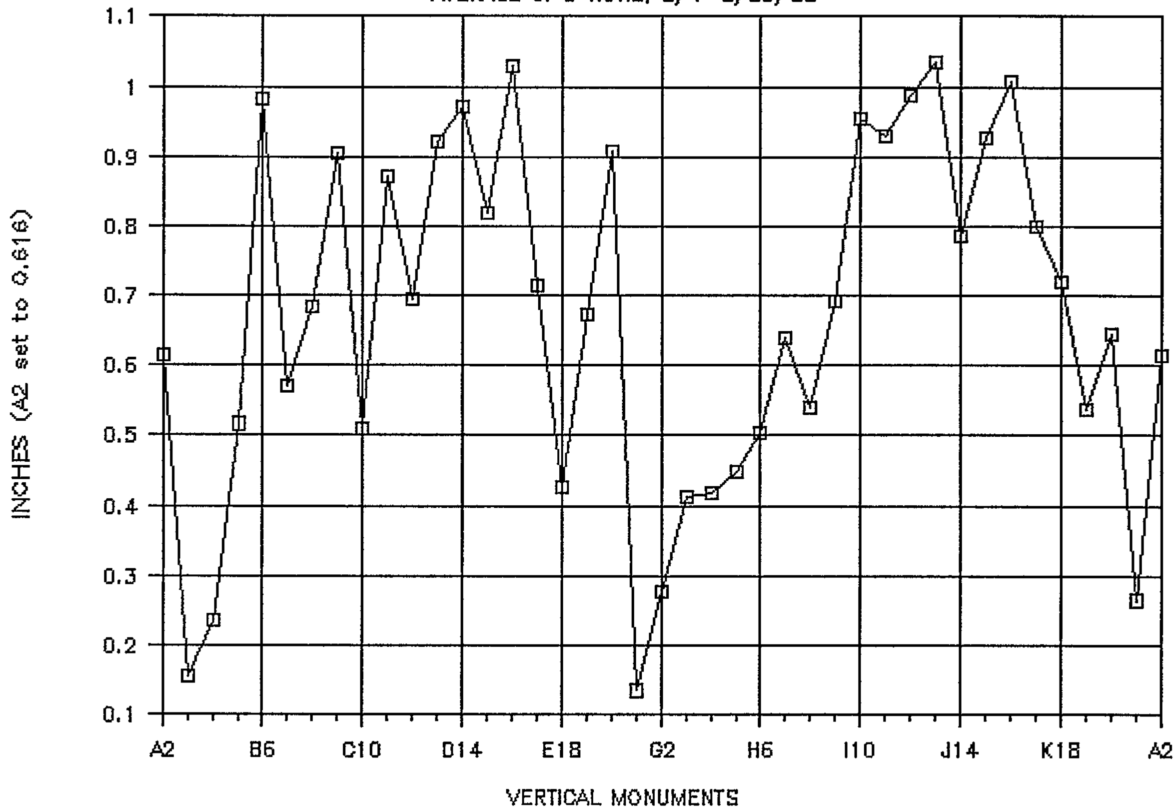
STANDARD DEVIATION		
	PER PIN ELEVATION	1.76 *0.001 in
	PER SIGHT	1.24 *0.001 in
PREDICTED CLOSING ERRORS		
	MEAN	0 *0.001 in
	STANDARD DEVIATION	11 *0.001 in
MEASURED CLOSING ERRORS		
	RUN 1	-15 *0.001 in
	RUN 2	-15 *0.001 in
	RUN 3	-49 *0.001 in
	MEAN	-26 *0.001 in
	STANDARD DEVIATION	16 *0.001 in

FOR AVERAGE OF THREE RUNS

STANDARD DEVIATION		
	PER PIN ELEVATION	1.01 *0.001 in

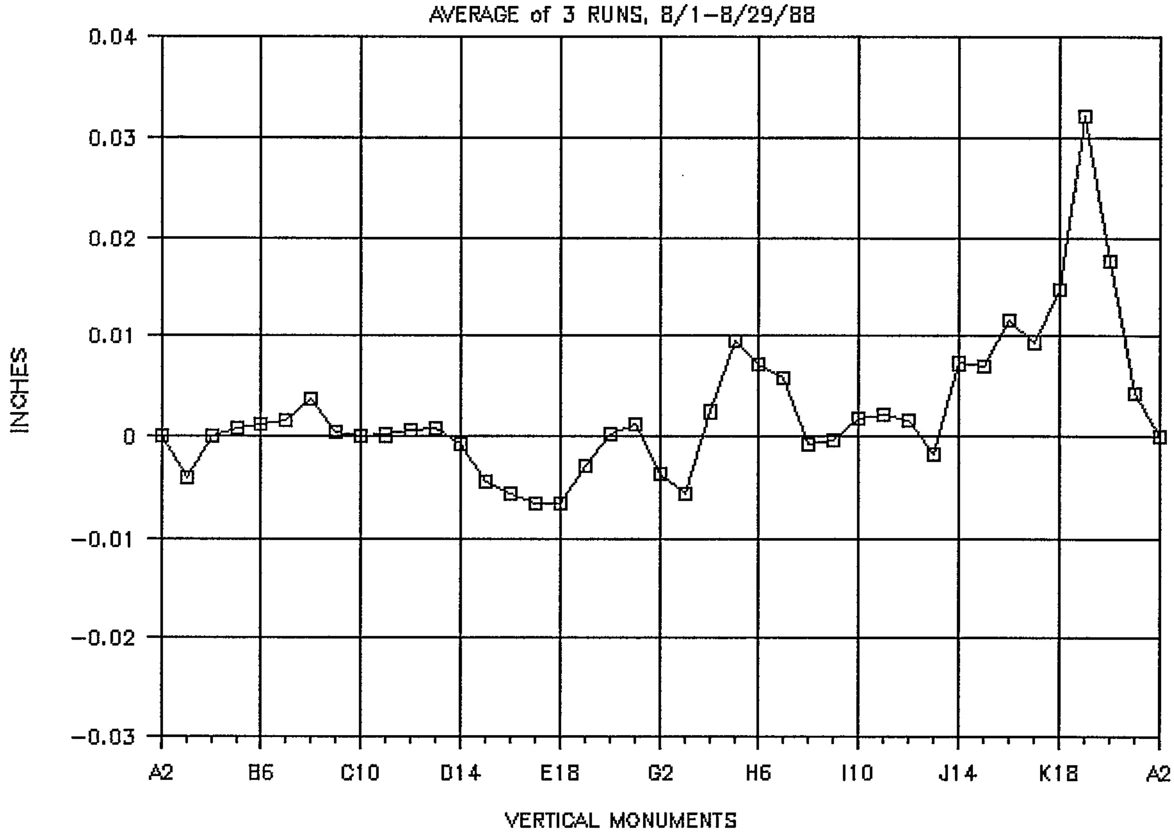
VERTICAL MONUMENT ELEVATIONS GRAPH 1

AVERAGE of 3 RUNS, 8/1-8/29/88



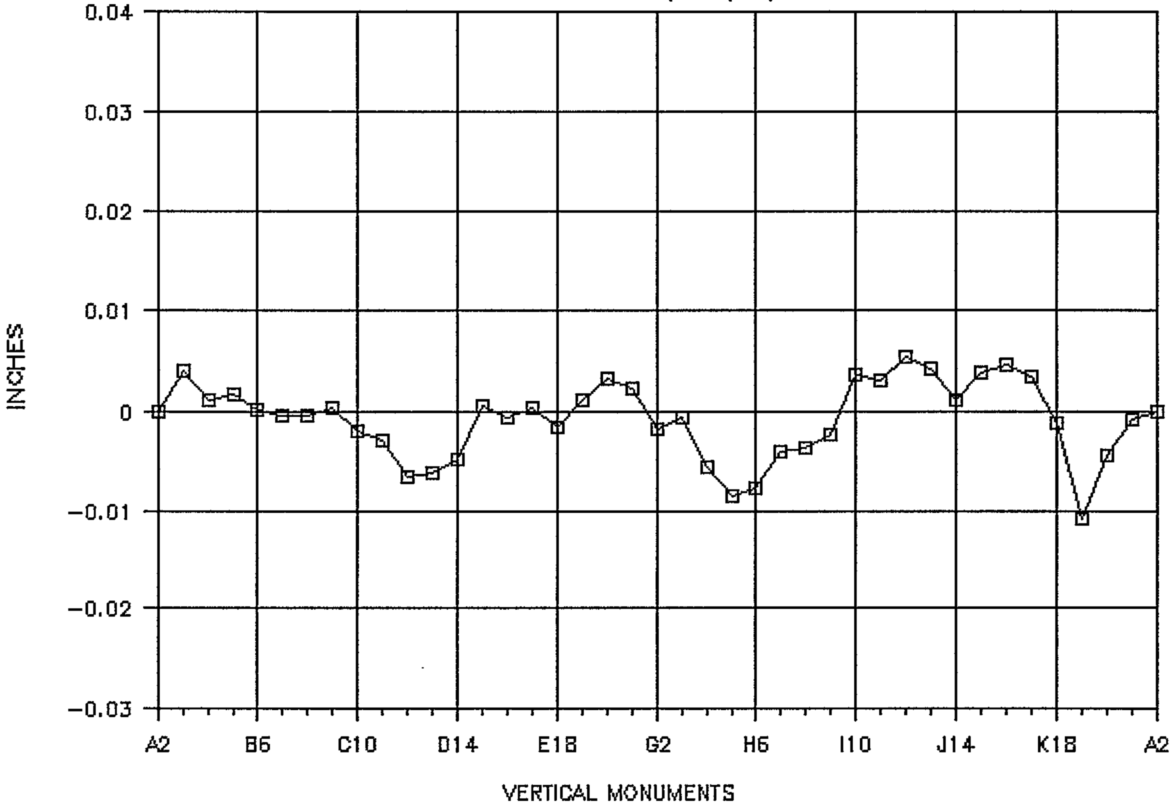
RUN 1 MINUS the AVERAGE GRAPH 2

AVERAGE of 3 RUNS, 8/1-8/29/88



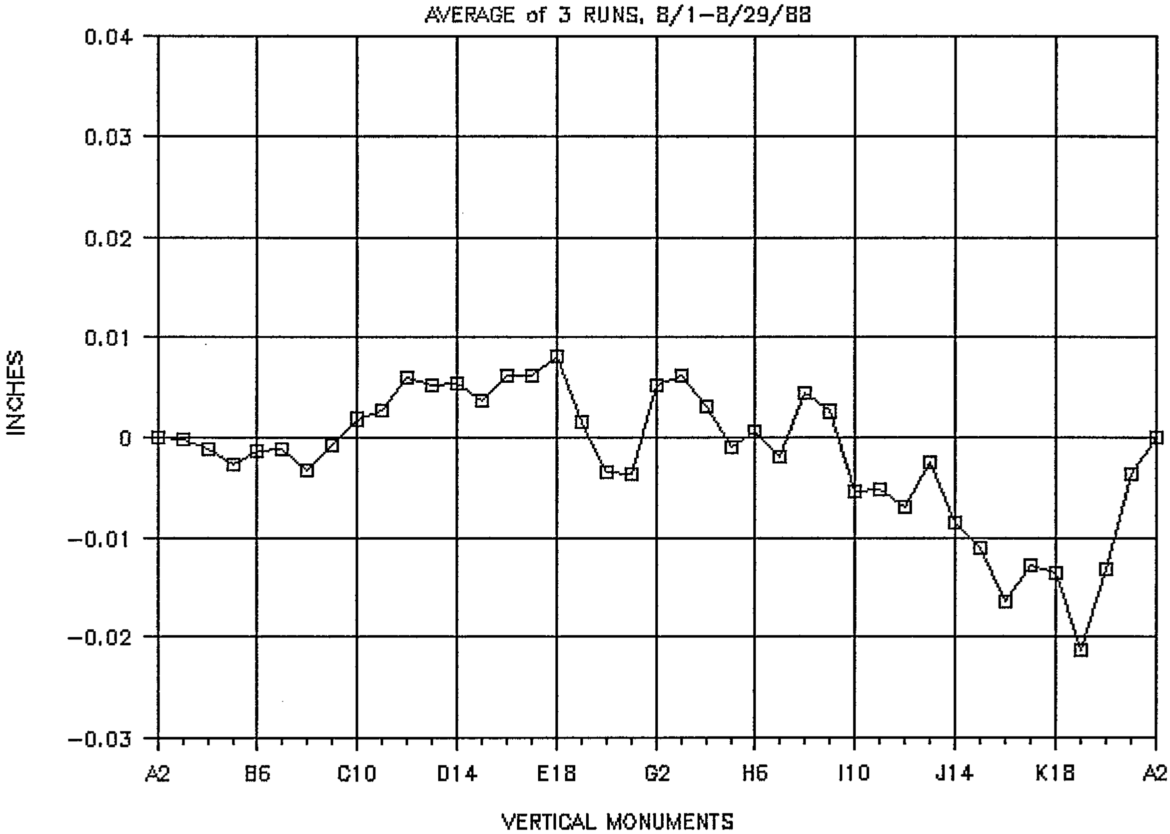
RUN 2 MINUS the AVERAGE GRAPH 3

AVERAGE of 3 RUNS, 8/1-8/29/88



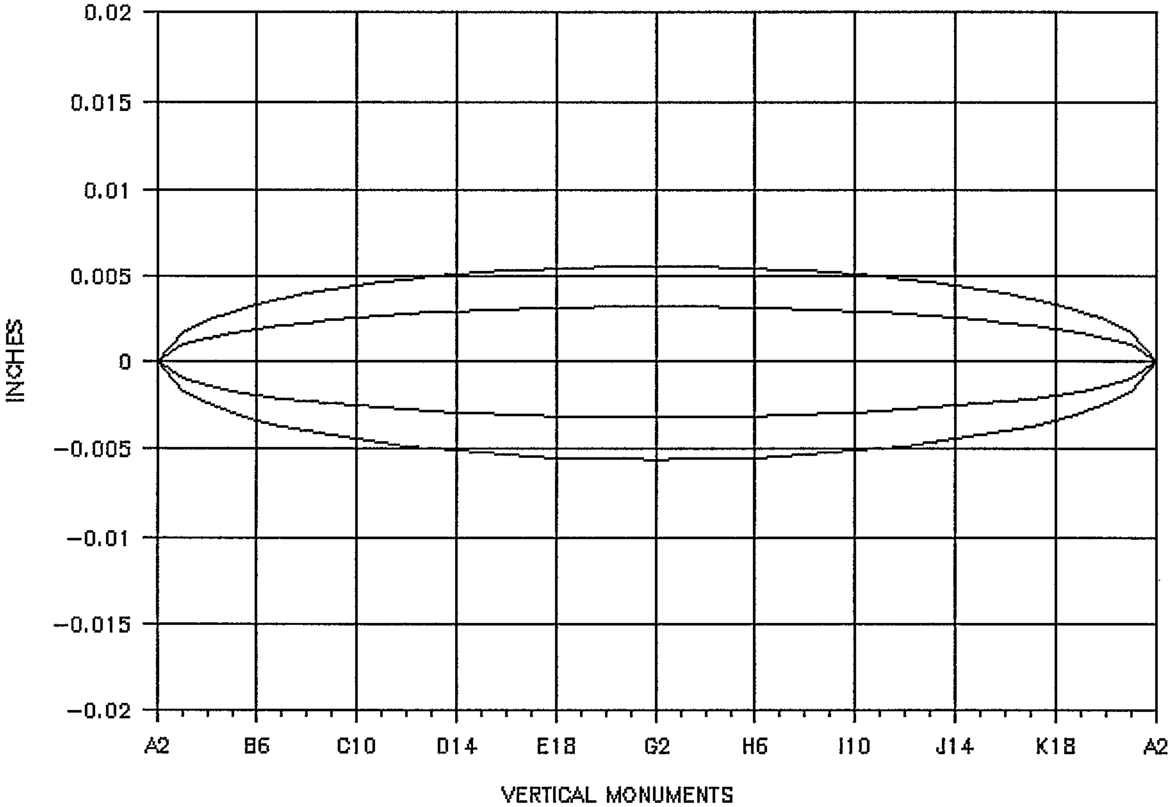
RUN 3 MINUS the AVERAGE GRAPH 4

AVERAGE of 3 RUNS, 8/1-8/29/88



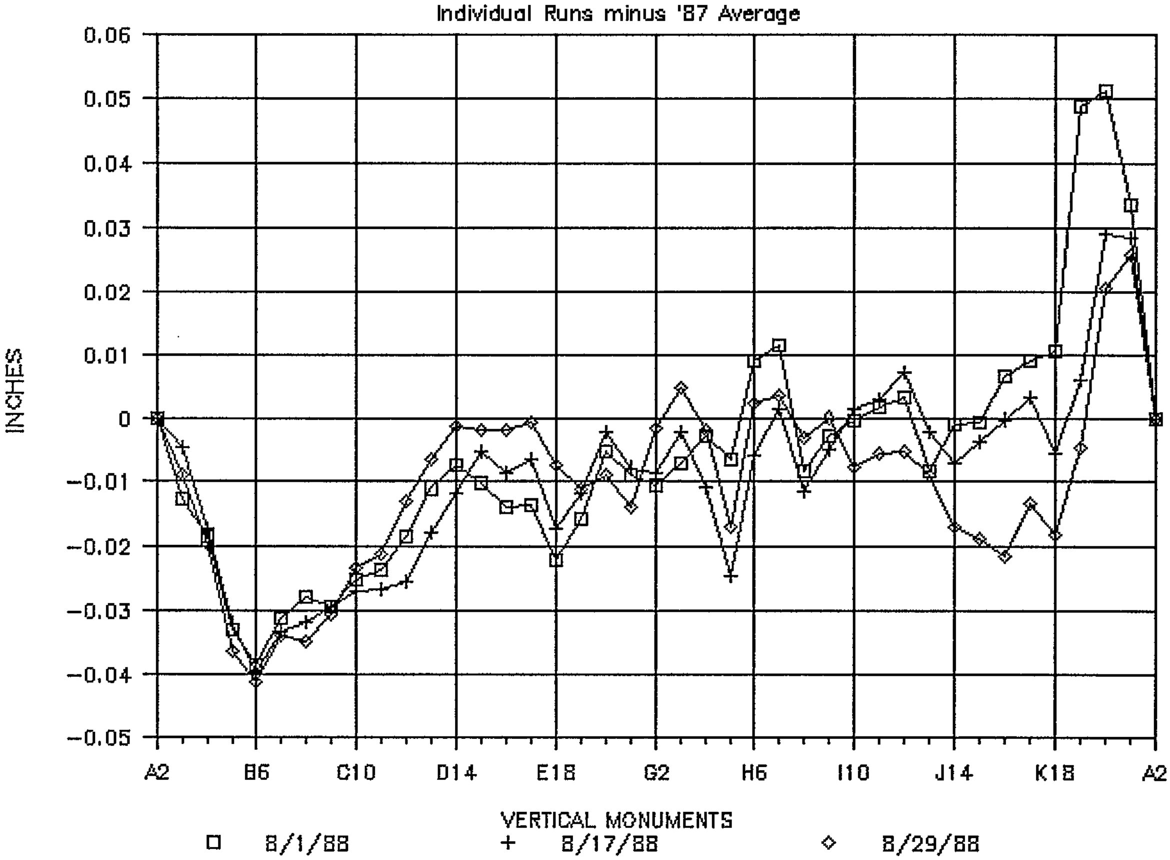
ENVELOPE for RANDOM WALKS GRAPH 5

One Standard Deviation for 1 and 3 Runs



1988 MINUS 1987 ELEVATIONS GRAPH 6

Individual Runs minus '87 Average



1988 MINUS 1987 ELEVATIONS GRAPH 7