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THE SECOND HORIZONTAL CONTROL SURVEY OF THE BOOSTER MONUMENT NETWORK

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Collider Accelerator Department
Brookhaven National Laboratory

U.S. Department of Energy

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THE SECOND HORIZONTAL CONTROL SURVEY OF THE
BOOSTER MONUMENT NETWORK

BOOSTER TECHNICAL NOTE
NO. 219

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February 1, 1993

ALTERNATING GRADIENT SYNCHROTRON DEPARTMENT
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The Second Horizontal Control Survey
Of The
Booster Monument Network

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F.X. Karl, M.A. Goldman

ABSTRACT

A network of survey control monuments, installed in the Booster tunnel, is used as a geodetic reference to define the locations of the Booster machine magnets in the tunnel. The horizontal positions of the monuments were established in the initial control survey, of July 1989, prior to installation of the magnets. In the autumn of 1990 additional radiation shielding was installed between the AGS and Booster machines, increasing floor loading in the area of installation. A second horizontal survey of the Booster ring was made between June and October 1990. The Booster ring magnets were initially installed and aligned using 1990 survey monument coordinates for alignment control.

Results of the 1990 survey are reported here and are compared to those of the 1989 survey. A coherent monument shift pattern is observed, possibly due to shield load induced soil flow. Further survey work is suggested.

INTRODUCTION

Forty-eight precision-machined stainless steel cylindrical bushings are grout-cemented in the floor of the Booster ring tunnel. These cylinders provide precise locating surfaces for mounting of optical survey targets or theodolites and provide basic reference stations for survey and alignment of the Booster.

The locations of these stations were established in a July 1989 horizontal control survey of the Booster ring. Detailed results of that survey are reported in Booster Technical Note No.164 [1].

Subsequent to that survey, additional radiation shielding was introduced between the AGS and Booster tunnels. The project engineer was J. Feldman of BNL Plant Engineering. A shielding upgrade at the Booster/AGS interface was completed in the autumn of 1990. In summer of 1991, shielding upgrade work was done at AGS areas I and J. In summer of 1992 shielding upgrade work was done at Fan Houses B, C, D. Shielding was also added along the Booster extraction region of the Booster to AGS transfer line.

The AGS Booster tunnel is a corrugated metal tube structure, with a poured concrete floor, which joins tangentially to Building 914, a building which housed the previously existing 50 MeV Linac. The Booster to AGS beam transfer line (BTA Line) passes through this building, to connect the two machines.

The 1990 survey indicates monument shifts from the 1989 monument positions in the corrugated tube part of the tunnel. The position

shift vector, for any monument, is larger than the sum of any pair of vectors lying within the 95% error ellipses, respectively, for the 1989 and 1990 control surveys. In the portion of the tunnel in Building 914, the monument position shifts are small or comparable to the sum of the standard errors of the two surveys. The position shift vectors do not appear to vary randomly but, instead, are relatively smoothly varying, in both magnitude and orientation along the length of the Booster. The position shifts are statistically significant, and appear to correlate with shifts which one could expect from subfloor soil motion caused by the additional weight of shield material loading between the AGS and Booster machines. The survey results are presented in this note, together with an error propagation plot showing monument position shift vectors compared with the error ellipses of the 1989 control survey. The Booster magnets were aligned during Booster magnet installation, using control monument coordinates established by the 1990 control survey.

DISCUSSION

The second horizontal control survey of Booster monuments, June through October 1990, was carried out by the BNL AGS Survey Group under supervision of F.X. Karl. The surveyors were: Don Kazmark, Jr. , Robert Marascia, Jr., Ralph McDowell, Sorin Pop, Joseph Roecklein, and John Slavic.

Angles were turned with Wild T-3000 Theodolites, using sets of three to four direct and reverse angle measurements. Distances

were measured with a Hewlett-Packard 5526A Laser Interferometer. Five monument sighting observations were made per set, and three sets of observations were made for each monument pair distance.

The survey data was adjusted using the STAR*NET survey adjustment software [2]. The survey data, updated monument coordinates, and adjustment results are presented in Appendix A of this note.

Monument position shifts between 1989 and 1990 control surveys are tabulated in Appendix B. The monument position shift vectors are shown on an error propagation plot of the 1989 survey results in Figure 1. The two-sigma error ellipse (95% probability ellipse for the 1989 survey) is plotted for each monument, together with a position shift vector, showing the direction and amplitude of the apparent monument displacement. [The 1989 positions of the monuments are shown at the dotted ends of the segments in Fig. 1. The 1990 adjusted positions are at the undotted ends of the segments. Note that the ellipses and segments are drawn to a common scale, which differs from the network scale.]

The monuments A1 and A2 have been assumed to remain fixed in position for both the 1989 and 1990 surveys, and these monuments are taken as fixed reference stations for the survey adjustments. We believe that this assumption can be made, without introducing survey control error leading to physically significant alignment errors of the machine components, for a number of reasons.

The monuments A1 and A2 are grouted into the thick floor slab

of Building 914, a large building, over 20 years of age. The interferometrically measured distance from monument A1 to monument A2 shows no significant change from 1989 to 1990. Both the 95% error ellipses and the apparent position shifts of the monuments F6 through to A6 are small; these monuments lie in or near the slab floor of Building 914. It is not expected that Building 914 would experience significant lateral shift. But neighboring soil under the newly constructed corrugated Booster tunnel pipe could well show a plastic flow displacement locally directed in the general direction of the Booster interior. The observed monument shifts, of up to 3 millimeters, are large compared to survey statistical error. Their generally smooth variation along the tunnel, except near D2 to D4, where a discontinuity in the tunnel floor structure exists, suggests that the observed monument shifts are real, and due to subtunnel earth shift, rather than survey error.

The 1990 survey results summarize the monument location data used for initial magnet alignment control. They suggest that additional survey work be considered, subsequent to the completion of the upgrade shielding installation, in case of further monument shift.

References:

1. M.A. Goldman, F.X. Karl and R.E Thern, Design And First Control Survey of the Booster Monument Network, Booster Technical Note No. 164, May 16, 1990; AGS Department, Brookhaven National Laboratory, Upton New York 11973.
2. STAR*NET (Least Squares Survey Adjustment Program). Starplus Software, Inc. , Oakland California 94610.

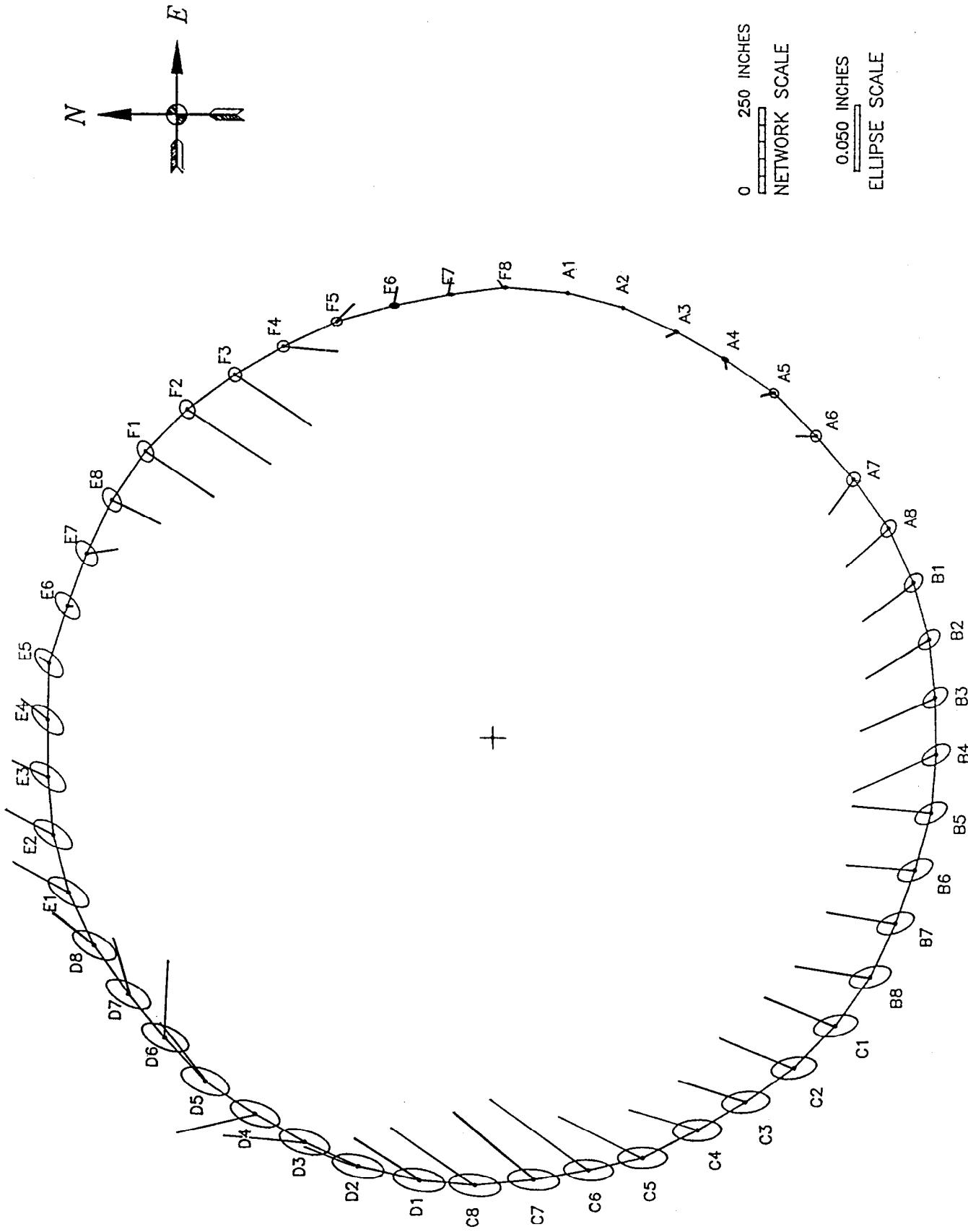


Figure 1. Booster Monument Displacement July 1989 To October 1990.

Appendix A
THE 1990 BOOSTER HORIZONTAL CONTROL SURVEY

STAR*NET Adjustment Program
Copyright 1991 STARPLUS SOFTWARE, INC.
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Serial Number 10204

STAR*NET V4.065
Run Date : Wed Dec 09 04:29:41 1992

Summary of Files Used

Input data file	:	C:\STAR\BOOSTER2.DAT
Output listing (this file)	:	C:\STAR\BOOSTER2.LST
Coordinates	:	C:\STAR\BOOSTER2.PTS
Project parameters	:	C:\STAR\BOOSTER2.PRJ
Error log	:	C:\STAR\BOOSTER2.ERR
Plot File	:	C:\STAR\BOOSTER2.SPL

Adjustment Options

STAR*NET Run Mode	:	Adjust with Error Propagation
Type of Adjustment	:	2D
Input Order for Coordinates	:	N,E
Coordinate System	:	AGS [Inch]
Project Scale Factor	:	1.00000000
Input Lineal Units	:	Inches
Input Order for Angle Stations	:	At-From-To
Maximum Number of Iterations	:	8
Convergence Limit Test Value	:	0.000100

Listing Options

Print Copy of Input Data File	:	No
Print Summary of All Input Observations	:	Yes
Print Coordinate Changes Each Iteration	:	No
Print Horiz Traverse Closure Summaries	:	No

Default Instrument Settings

Default Standard Error for Distances	:	0.0003 [Inches]
Default Standard Error for Angles	:	0.5000 [Arc-Seconds]
Default Standard Error for Directions	:	0.5000 [Arc-Seconds]
Default Standard Error for Az/Bearings	:	4.000
Centering Error for Instrument	:	0.0000
Centering Error for Target	:	0.0000
EDM Parts Per Million	:	0.0000

Summary of All Unadjusted Input Observations

Number of Stations with Coordinates = 48

Fixed Stations	N	E	
A1	15242.158	2447.155	[AGS Inches]
A2	15075.199	2403.250	
 Free Stations	 N	 E	
A3	14918.920	2332.566	[AGS Inches]
A4	14773.566	2250.945	
A5	14632.120	2152.974	
A6	14508.669	2030.619	
A7	14400.693	1906.303	
A8	14300.237	1765.762	
B1	14226.102	1609.451	
B2	14180.864	1442.563	
B3	14164.184	1271.498	
B4	14162.059	1105.667	
B5	14175.948	933.455	
B6	14219.207	766.023	
B7	14274.679	610.279	
B8	14346.151	453.088	
C1	14444.535	311.201	
C2	14565.569	188.247	
C3	14706.108	88.031	
C4	14848.855	3.621	
C5	15009.796	-77.590	
C6	15170.852	-116.228	
C7	15333.304	-146.904	
C8	15504.652	-163.836	
D1	15667.150	-148.156	
D2	15844.701	-105.752	
D3	16001.043	-34.251	
D4	16146.226	47.049	
D5	16293.074	140.430	
D6	16410.828	266.064	
D7	16518.389	391.121	
D8	16618.580	532.217	
E1	16693.347	687.931	
E2	16738.648	855.306	
E3	16754.850	1026.427	
E4	16756.326	1192.677	
E5	16752.690	1361.951	
E6	16699.602	1531.619	
E7	16645.201	1687.255	
E8	16573.176	1844.657	
F1	16475.251	1986.594	
F2	16353.624	2108.988	
F3	16213.443	2209.519	
F4	16071.806	2293.342	
F5	15916.304	2367.608	
F6	15749.166	2413.997	
F7	15586.174	2444.801	
F8	15424.673	2464.612	

Number of Angle Observations = 144

At	From	To	Obs Angle [Deg-Min-Sec]	StdErr [Sec]
A1	F7	A2	195-07-38.18	3.64
A1	F7	A3	199-54-45.51	0.93
A1	F7	F8	5-51-17.31	2.26
A2	F8	A1	4-46-29.68	0.58
A2	F8	A3	194-22-41.93	2.44
A2	F8	A4	196-49-54.45	0.85
A3	A1	A2	4-49-03.40	2.04
A3	A1	A4	189-47-34.10	2.76
A3	A1	A5	192-31-57.25	3.21
A4	A2	A3	2-31-24.78	0.81
A4	A2	A5	187-54-58.28	2.25
A4	A2	A6	192-57-37.77	1.86
A5	A3	A4	2-39-15.68	3.53
A5	A3	A7	194-46-22.05	1.50
A6	A4	A5	4-59-30.78	4.00
A6	A4	A7	189-16-38.30	4.59
A6	A4	A8	192-03-02.18	3.28
A7	A5	A6	2-12-04.73	0.80
A7	A5	A8	187-37-05.25	2.13
A7	A5	B1	192-42-42.10	1.34
A8	A6	A7	2-38-37.92	2.11
A8	A6	B1	192-49-27.48	1.63
A8	A6	B2	197-55-38.78	1.45
B1	A7	A8	5-05-11.00	1.08
B1	A7	B2	195-17-43.47	5.04
B1	A7	B3	200-04-41.42	5.02
B2	A8	B1	5-06-22.29	3.08
B2	A8	B3	194-41-58.00	1.06
B2	A8	B4	197-04-29.86	1.44
B3	B1	B2	4-48-42.60	1.50
B3	B1	B4	189-38-52.51	2.03
B3	B1	B5	192-22-28.26	1.11
B4	B2	B3	2-27-43.09	1.16
B4	B2	B5	187-48-11.00	0.88
B4	B2	B6	192-44-30.20	3.16
B5	B3	B4	2-36-58.93	3.28
B5	B3	B6	192-29-16.18	4.74
B5	B3	B7	194-59-24.73	4.65
B6	B4	B5	4-56-00.48	1.82
B6	B4	B7	190-03-14.78	4.91
B6	B4	B8	192-31-48.23	3.08
B7	B5	B6	2-37-04.11	1.67
B7	B5	B8	187-27-49.79	2.14
B7	B5	C1	192-36-25.33	2.08
B8	B6	B7	2-22-12.48	2.40
B8	B6	C1	192-39-26.08	6.17
B8	B6	C2	197-33-36.10	6.99
C1	B7	B8	5-08-37.21	2.11
C1	B7	C2	194-57-07.66	5.89
C1	B7	C3	199-55-53.01	2.62

C2	B8	C1	4-54-22.24	2.25
C2	B8	C3	194-51-40.74	3.23
C2	B8	C4	197-15-39.30	4.04
C3	C1	C2	4-58-37.68	4.55
C3	C1	C4	189-52-21.87	4.08
C3	C1	C5	191-51-56.82	6.80
C4	C2	C3	2-29-50.40	0.89
C4	C2	C5	186-19-21.72	6.38
C4	C2	C6	192-41-05.30	6.55
C5	C3	C4	1-49-59.95	2.29
C5	C3	C6	195-07-13.10	0.71
C5	C3	C7	196-30-50.88	3.96
C6	C4	C5	6-55-37.28	2.23
C6	C4	C7	189-42-48.83	2.27
C6	C4	C8	192-17-23.08	1.91
C7	C5	C6	1-23-42.50	3.38
C7	C5	D1	191-52-13.27	4.49
C8	C6	C7	2-28-20.68	0.23
C8	C6	D1	193-37-28.18	2.36
C8	C6	D2	197-48-23.37	3.57
D1	C7	C8	5-43-31.73	3.14
D1	C7	D2	193-38-42.63	1.17
D1	C7	D3	199-02-56.60	0.21
D2	C8	D1	3-44-18.15	1.43
D2	C8	D3	194-52-48.50	5.52
D2	C8	D4	197-10-42.52	5.62
D3	D1	D2	5-44-15.13	0.87
D3	D1	D4	190-24-36.03	5.48
D3	D1	D5	192-03-41.23	5.12
D4	D2	D3	2-22-27.30	0.07
D4	D2	D5	185-36-10.43	4.84
D4	D2	D6	192-45-39.60	3.18
D5	D3	D4	1-34-41.02	2.97
D5	D3	D6	195-58-15.70	2.62
D5	D3	D7	197-09-34.93	2.06
D6	D4	D5	7-14-05.47	2.24
D6	D4	D7	189-39-48.52	2.41
D6	D4	D8	192-23-14.22	2.66
D7	D5	D6	1-14-23.35	1.39
D7	D5	D8	186-33-36.15	1.47
D7	D5	E1	191-25-21.27	0.66
D8	D6	D7	2-35-43.40	1.51
D8	D6	E1	192-19-46.48	5.34
D8	D6	E2	197-35-34.17	2.75
E2	D8	E1	5-14-36.33	2.70
E2	D8	E3	194-58-51.59	3.35
E2	D8	E4	197-23-23.28	3.43
E4	E2	E3	2-29-24.58	0.60
E4	E2	E5	184-13-57.36	0.73
E4	E2	E6	192-30-08.95	0.44
E5	E3	E4	0-51-48.73	0.52
E5	E3	E6	197-00-17.58	2.26
E5	E3	E7	197-54-59.43	2.65
E6	E4	E5	7-52-19.35	3.30

E6	E4	E7	189-45-57.40	0.79
E6	E4	E8	192-29-33.78	2.01
E7	E5	E6	0-58-58.75	2.45
E7	E5	E8	186-18-19.43	2.89
E7	E5	F1	191-18-14.02	4.33
E8	E6	E7	2-35-49.85	0.85
E8	E6	F1	192-36-30.25	3.65
E8	E6	F2	197-42-58.42	2.23
F1	E7	E8	5-00-53.28	2.84
F1	E7	F2	195-13-39.95	4.97
F1	E7	F3	199-59-30.02	4.88
F2	E8	F1	5-06-13.48	0.52
F2	E8	F3	194-38-00.83	2.01
F2	E8	F4	197-05-54.53	1.40
F3	F1	F2	4-45-59.27	2.83
F3	F1	F4	189-49-45.67	9.00
F3	F1	F5	192-25-07.38	5.32
F4	F2	F3	2-35-00.60	4.00
F4	F2	F5	187-40-38.40	6.95
F4	F2	F6	192-42-24.08	4.85
F5	F3	F4	2-29-19.23	2.01
F5	F3	F6	192-30-44.37	2.49
F5	F3	F7	194-51-53.08	3.15
F6	F4	F5	4-59-47.02	1.03
F6	F4	F7	189-48-23.42	5.99
F6	F4	F8	191-38-06.75	4.42
F7	F5	A1	192-45-10.85	5.80
F7	F5	F6	2-27-31.97	0.12
F7	F5	F8	186-09-04.78	3.72
F8	F6	A1	194-19-16.30	0.26
F8	F6	A2	198-49-01.10	0.60
F8	F6	F7	1-51-52.70	0.96
C7	C5	C8	186-26-33.48	3.18
E1	D7	D8	4-52-15.57	0.83
E1	D7	E2	195-22-40.32	1.98
E1	D7	E3	200-13-31.90	1.64
E3	E1	E2	4-53-24.82	1.40
E3	E1	E4	189-47-20.77	2.35
E3	E1	E5	190-40-06.90	0.72
A5	A3	A6	192-41-14.92	0.45

Number of Distance Observations = 48
 Distance Units Are [Inches]

From	To	Obs Dist	StdErr
A1	A2	172.6348	0.006
A2	A3	171.5294	0.001
A3	A4	166.7118	0.002
A4	A5	172.0467	0.001
A5	A6	173.8096	0.000
A6	A7	164.6707	0.001

A7	A8	172.7390	0.003
A8	B1	172.9901	0.000
B1	B2	172.8927	0.002
B2	B3	171.8495	0.002
B3	B4	165.8364	0.001
B4	B5	172.7172	0.001
B5	B6	172.9069	0.000
B6	B7	165.3022	0.001
B7	B8	172.6559	0.001
B8	C1	172.6262	0.000
C1	C2	172.5065	0.000
C2	C3	172.5888	0.001
C3	C4	165.8172	0.001
C4	C5	180.2536	0.001
C5	C6	165.6147	0.000
C6	C7	165.2921	0.000
C7	C8	172.1704	0.001
C8	D1	163.2279	0.001
D1	D2	182.5240	0.001
D2	D3	171.9231	0.001
D3	D4	166.3838	0.001
D4	D5	174.0312	0.001
D5	D6	172.1827	0.000
D6	D7	164.9522	0.001
D7	D8	173.0535	0.000
D8	E1	172.7466	0.001
E1	E2	173.4068	0.001
E2	E3	171.8947	0.000
E3	E4	166.2803	0.001
E4	E5	169.3207	0.001
E5	E6	177.8016	0.001
E6	E7	164.8996	0.001
E7	E8	173.1083	0.001
E8	F1	172.4606	0.002
F1	F2	172.5756	0.002
F2	F3	172.5229	0.000
F3	F4	164.6027	0.000
F4	F5	172.3286	0.001
F5	F6	173.4635	0.000
F6	F7	165.8913	0.000
F7	F8	162.7209	0.001
F8	A1	183.3637	0.001

Network Solution

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Solution Has Converged in 4 Iterations

Final Results

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Updated Coordinates

Station	N	E	[AGS Inches]
A1	15242.158	2447.155	
A2	15075.199	2403.250	
A3	14918.913	2332.561	
A4	14773.548	2250.941	
A5	14632.113	2152.981	
A6	14508.655	2030.637	
A7	14400.680	1906.307	
A8	14300.232	1765.776	
B1	14226.097	1609.477	
B2	14180.863	1442.606	
B3	14164.174	1271.568	
B4	14162.045	1105.746	
B5	14175.915	933.586	
B6	14219.143	766.170	
B7	14274.591	610.445	
B8	14346.039	453.266	
C1	14444.391	311.397	
C2	14565.390	188.443	
C3	14705.891	88.212	
C4	14848.607	3.787	
C5	15009.527	-77.429	
C6	15170.571	-116.072	
C7	15332.986	-146.774	
C8	15504.318	-163.745	
D1	15666.796	-148.113	
D2	15844.339	-105.765	
D3	16000.711	-34.313	
D4	16145.910	46.933	
D5	16292.753	140.335	
D6	16410.506	265.958	
D7	16518.113	390.977	
D8	16618.359	532.039	
E1	16693.180	687.741	
E2	16738.525	855.114	

E3	16754.765	1026.240
E4	16756.279	1192.513
E5	16752.672	1361.795
E6	16699.612	1531.495
E7	16645.229	1687.169
E8	16573.221	1844.590
F1	16475.309	1986.561
F2	16353.699	2109.008
F3	16213.538	2209.601
F4	16071.881	2293.432
F5	15916.370	2367.683
F6	15749.213	2414.033
F7	15586.199	2444.797
F8	15424.689	2464.611

Statistical Summary

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Number of Observations = 192
Number of Unknowns = 92
Degrees of Freedom = 100

Data Type	Count	Weighted Residuals	Error Factor
Distances	48	0.24	0.10
Angles	144	116.88	1.25
Directions	0	0.00	0.00
Az/Bearings	0	0.00	0.00
Stations	48	0.00	0.00
Total	240	117.11	1.08

Adjustment passes the Chi Square test at 5% level

Adjusted Observations and Residuals

Adjusted Angle Observations

At	From	To	Adj Angle	Residual	StdErr	StdRes
A1	F7	A2	195-07-34.05	-0-00-04.13	3.64	1.1
A1	F7	A3	199-54-45.17	-0-00-00.34	0.93	0.4
A1	F7	F8	5-51-19.44	0-00-02.13	2.26	0.9
A2	F8	A1	4-46-31.28	0-00-01.60	0.58	2.8
A2	F8	A3	194-22-44.89	0-00-02.96	2.44	1.2
A2	F8	A4	196-49-54.32	-0-00-00.13	0.85	0.2
A3	A1	A2	4-49-02.49	-0-00-00.91	2.04	0.4
A3	A1	A4	189-47-36.66	0-00-02.56	2.76	0.9
A3	A1	A5	192-31-58.44	0-00-01.19	3.21	0.4
A4	A2	A3	2-31-24.74	-0-00-00.04	0.81	0.0
A4	A2	A5	187-55-02.28	0-00-04.00	2.25	1.8
A4	A2	A6	192-57-34.20	-0-00-03.57	1.86	1.9
A5	A3	A4	2-39-15.76	0-00-00.08	3.53	0.0
A5	A3	A7	194-46-22.55	0-00-00.50	1.50	0.3
A6	A4	A5	4-59-27.34	-0-00-03.44	4.00	0.9
A6	A4	A7	189-16-39.23	0-00-00.93	4.59	0.2
A6	A4	A8	192-03-02.73	0-00-00.55	3.28	0.2
A7	A5	A6	2-12-04.37	-0-00-00.36	0.80	0.5
A7	A5	A8	187-37-04.71	-0-00-00.54	2.13	0.3
A7	A5	B1	192-42-43.17	0-00-01.07	1.34	0.8
A8	A6	A7	2-38-36.84	-0-00-01.08	2.11	0.5
A8	A6	B1	192-49-27.11	-0-00-00.37	1.63	0.2
A8	A6	B2	197-55-38.07	-0-00-00.71	1.45	0.5
B1	A7	A8	5-05-11.80	0-00-00.80	1.08	0.7
B1	A7	B2	195-17-44.05	0-00-00.58	5.04	0.1
B1	A7	B3	200-04-40.16	-0-00-01.26	5.02	0.3
B2	A8	B1	5-06-21.29	-0-00-01.00	3.08	0.3
B2	A8	B3	194-41-58.30	0-00-00.30	1.06	0.3
B2	A8	B4	197-04-31.01	0-00-01.15	1.44	0.8
B3	B1	B2	4-48-40.90	-0-00-01.70	1.50	1.1
B3	B1	B4	189-38-56.62	0-00-04.11	2.03	2.0
B3	B1	B5	192-22-26.45	-0-00-01.81	1.11	1.6
B4	B2	B3	2-27-43.01	-0-00-00.08	1.16	0.1
B4	B2	B5	187-48-11.57	0-00-00.57	0.88	0.6
B4	B2	B6	192-44-31.26	0-00-01.06	3.16	0.3
B5	B3	B4	2-36-58.74	-0-00-00.19	3.28	0.1
B5	B3	B6	192-29-18.56	0-00-02.38	4.74	0.5
B5	B3	B7	194-59-28.49	0-00-03.76	4.65	0.8
B6	B4	B5	4-56-00.13	-0-00-00.35	1.82	0.2
B6	B4	B7	190-03-14.78	-0-00-00.00	4.91	0.0
B6	B4	B8	192-31-47.65	-0-00-00.58	3.08	0.2
B7	B5	B6	2-37-04.71	0-00-00.60	1.67	0.4
B7	B5	B8	187-27-50.62	0-00-00.83	2.14	0.4
B7	B5	C1	192-36-25.83	0-00-00.50	2.08	0.2
B8	B6	B7	2-22-13.04	0-00-00.56	2.40	0.2
B8	B6	C1	192-39-26.64	0-00-00.56	6.17	0.1
B8	B6	C2	197-33-36.28	0-00-00.18	6.99	0.0

C1	B7	B8	5-08-38.40	0-00-01.19	2.11	0.6
C1	B7	C2	194-57-09.96	0-00-02.30	5.89	0.4
C1	B7	C3	199-55-54.65	0-00-01.64	2.62	0.6
C2	B8	C1	4-54-21.92	-0-00-00.32	2.25	0.1
C2	B8	C3	194-51-42.72	0-00-01.98	3.23	0.6
C2	B8	C4	197-15-40.43	0-00-01.13	4.04	0.3
C3	C1	C2	4-58-36.12	-0-00-01.56	4.55	0.3
C3	C1	C4	189-52-24.50	0-00-02.63	4.08	0.6
C3	C1	C5	191-51-59.74	0-00-02.92	6.80	0.4
C4	C2	C3	2-29-50.68	0-00-00.28	0.89	0.3
C4	C2	C5	186-19-26.29	0-00-04.57	6.38	0.7
C4	C2	C6	192-41-06.05	0-00-00.75	6.55	0.1
C5	C3	C4	1-50-00.37	0-00-00.42	2.29	0.2
C5	C3	C6	195-07-13.56	0-00-00.46	0.71	0.6
C5	C3	C7	196-30-47.79	-0-00-03.09	3.96	0.8
C6	C4	C5	6-55-33.42	-0-00-03.86	2.23	1.7
C6	C4	C7	189-42-51.66	0-00-02.83	2.27	1.2
C6	C4	C8	192-17-22.99	-0-00-00.09	1.91	0.0
C7	C5	C6	1-23-44.01	0-00-01.51	3.38	0.4
C7	C5	D1	191-52-13.98	0-00-00.71	4.49	0.2
C8	C6	C7	2-28-20.70	0-00-00.02	0.23	0.1
C8	C6	D1	193-37-30.44	0-00-02.26	2.36	1.0
C8	C6	D2	197-48-23.16	-0-00-00.21	3.57	0.1
D1	C7	C8	5-43-31.80	0-00-00.07	3.14	0.0
D1	C7	D2	193-38-43.51	0-00-00.88	1.17	0.8
D1	C7	D3	199-02-56.60	-0-00-00.00	0.21	0.0
D2	C8	D1	3-44-18.99	0-00-00.84	1.43	0.6
D2	C8	D3	194-52-48.54	0-00-00.04	5.52	0.0
D2	C8	D4	197-10-40.31	-0-00-02.21	5.62	0.4
D3	D1	D2	5-44-16.47	0-00-01.34	0.87	1.5
D3	D1	D4	190-24-35.54	-0-00-00.49	5.48	0.1
D3	D1	D5	192-03-39.84	-0-00-01.39	5.12	0.3
D4	D2	D3	2-22-27.31	0-00-00.01	0.07	0.1
D4	D2	D5	185-36-14.62	0-00-04.19	4.84	0.9
D4	D2	D6	192-45-43.02	0-00-03.42	3.18	1.1
D5	D3	D4	1-34-43.02	0-00-02.00	2.97	0.7
D5	D3	D6	195-58-17.93	0-00-02.23	2.62	0.9
D5	D3	D7	197-09-35.58	0-00-00.65	2.06	0.3
D6	D4	D5	7-14-06.51	0-00-01.04	2.24	0.5
D6	D4	D7	189-39-49.35	0-00-00.83	2.41	0.3
D6	D4	D8	192-23-14.65	0-00-00.43	2.66	0.2
D7	D5	D6	1-14-25.19	0-00-01.84	1.39	1.3
D7	D5	D8	186-33-36.43	0-00-00.28	1.47	0.2
D7	D5	E1	191-25-21.30	0-00-00.03	0.66	0.0
D8	D6	D7	2-35-45.95	0-00-02.55	1.51	1.7
D8	D6	E1	192-19-46.85	0-00-00.37	5.34	0.1
D8	D6	E2	197-35-35.61	0-00-01.44	2.75	0.5
E2	D8	E1	5-14-36.41	0-00-00.08	2.70	0.0
E2	D8	E3	194-58-53.63	0-00-02.04	3.35	0.6
E2	D8	E4	197-23-25.21	0-00-01.93	3.43	0.6
E4	E2	E3	2-29-24.56	-0-00-00.02	0.60	0.0
E4	E2	E5	184-13-58.24	0-00-00.88	0.73	1.2

E4	E2	E6	192-30-08.82	-0-00-00.13	0.44	0.3
E5	E3	E4	0-51-48.42	-0-00-00.31	0.52	0.6
E5	E3	E6	197-00-20.30	0-00-02.72	2.26	1.2
E5	E3	E7	197-55-00.27	0-00-00.84	2.65	0.3
E6	E4	E5	7-52-21.29	0-00-01.94	3.30	0.6
E6	E4	E7	189-45-57.88	0-00-00.48	0.79	0.6
E6	E4	E8	192-29-33.73	-0-00-00.05	2.01	0.0
E7	E5	E6	0-58-56.62	-0-00-02.13	2.45	0.9
E7	E5	E8	186-18-22.53	0-00-03.10	2.89	1.1
E7	E5	F1	191-18-10.90	-0-00-03.12	4.33	0.7
E8	E6	E7	2-35-50.06	0-00-00.21	0.85	0.2
E8	E6	F1	192-36-34.54	0-00-04.29	3.65	1.2
E8	E6	F2	197-43-00.48	0-00-02.06	2.23	0.9
F1	E7	E8	5-00-56.12	0-00-02.84	2.84	1.0
F1	E7	F2	195-13-35.66	-0-00-04.29	4.97	0.9
F1	E7	F3	199-59-26.12	-0-00-03.90	4.88	0.8
F2	E8	F1	5-06-13.61	0-00-00.13	0.52	0.2
F2	E8	F3	194-37-59.80	-0-00-01.03	2.01	0.5
F2	E8	F4	197-05-57.02	0-00-02.49	1.40	1.8
F3	F1	F2	4-45-55.73	-0-00-03.54	2.83	1.3
F3	F1	F4	189-48-57.61	-0-00-48.06	9.00	5.3*
F3	F1	F5	192-25-16.03	0-00-08.65	5.32	1.6
F4	F2	F3	2-35-04.65	0-00-04.05	4.00	1.0
F4	F2	F5	187-40-40.78	0-00-02.38	6.95	0.3
F4	F2	F6	192-42-25.66	0-00-01.58	4.85	0.3
F5	F3	F4	2-29-17.70	-0-00-01.53	2.01	0.8
F5	F3	F6	192-30-48.71	0-00-04.34	2.49	1.7
F5	F3	F7	194-51-54.05	0-00-00.97	3.15	0.3
F6	F4	F5	4-59-46.13	-0-00-00.89	1.03	0.9
F6	F4	F7	189-48-23.44	0-00-00.02	5.99	0.0
F6	F4	F8	191-38-07.45	0-00-00.70	4.42	0.2
F7	F5	A1	192-45-13.10	0-00-02.25	5.80	0.4
F7	F5	F6	2-27-31.97	0-00-00.00	0.12	0.0
F7	F5	F8	186-09-08.31	0-00-03.53	3.72	0.9
F8	F6	A1	194-19-16.56	0-00-00.26	0.26	1.0
F8	F6	A2	198-48-59.89	-0-00-01.21	0.60	2.0
F8	F6	F7	1-51-52.33	-0-00-00.37	0.96	0.4
C7	C5	C8	186-26-36.05	0-00-02.57	3.18	0.8
E1	D7	D8	4-52-16.04	0-00-00.47	0.83	0.6
E1	D7	E2	195-22-41.21	0-00-00.89	1.98	0.4
E1	D7	E3	200-13-32.87	0-00-00.97	1.64	0.6
E3	E1	E2	4-53-25.55	0-00-00.73	1.40	0.5
E3	E1	E4	189-47-21.69	0-00-00.92	2.35	0.4
E3	E1	E5	190-40-06.95	0-00-00.05	0.72	0.1
A5	A3	A6	192-41-15.03	0-00-00.11	0.45	0.2

Adjusted Distance Observations [Inches]

At	To	Adj Dist	Residual	StdErr	StdRes
A1	A2	172.6355	0.0007	0.006	0.1
A2	A3	171.5294	0.0000	0.001	0.0
A3	A4	166.7119	0.0001	0.002	0.1
A4	A5	172.0467	0.0000	0.001	0.0
A5	A6	173.8096	0.0000	0.000	0.0
A6	A7	164.6708	0.0001	0.001	0.1
A7	A8	172.7392	0.0002	0.003	0.1
A8	B1	172.9901	0.0000	0.000	0.0
B1	B2	172.8931	0.0004	0.002	0.3
B2	B3	171.8495	-0.0000	0.002	0.0
B3	B4	165.8364	0.0000	0.001	0.0
B4	B5	172.7172	0.0000	0.001	0.1
B5	B6	172.9069	0.0000	0.000	0.0
B6	B7	165.3022	0.0000	0.001	0.0
B7	B8	172.6559	0.0000	0.001	0.0
B8	C1	172.6262	0.0000	0.000	0.0
C1	C2	172.5065	0.0000	0.000	0.0
C2	C3	172.5888	-0.0000	0.001	0.0
C3	C4	165.8172	-0.0000	0.001	0.0
C4	C5	180.2536	0.0000	0.001	0.0
C5	C6	165.6147	-0.0000	0.000	0.0
C6	C7	165.2921	-0.0000	0.000	0.0
C7	C8	172.1704	-0.0000	0.001	0.0
C8	D1	163.2279	-0.0000	0.001	0.0
D1	D2	182.5239	-0.0001	0.001	0.1
D2	D3	171.9231	0.0000	0.001	0.0
D3	D4	166.3838	-0.0000	0.001	0.0
D4	D5	174.0312	-0.0000	0.001	0.0
D5	D6	172.1827	-0.0000	0.000	0.0
D6	D7	164.9521	-0.0001	0.001	0.1
D7	D8	173.0535	-0.0000	0.000	0.0
D8	E1	172.7466	-0.0000	0.001	0.0
E1	E2	173.4068	-0.0000	0.001	0.0
E2	E3	171.8947	-0.0000	0.000	0.0
E3	E4	166.2803	-0.0000	0.001	0.0
E4	E5	169.3205	-0.0002	0.001	0.2
E5	E6	177.8016	0.0000	0.001	0.1
E6	E7	164.8996	-0.0000	0.001	0.0
E7	E8	173.1083	-0.0000	0.001	0.0
E8	F1	172.4604	-0.0002	0.002	0.1
F1	F2	172.5758	0.0002	0.002	0.1
F2	F3	172.5229	-0.0000	0.000	0.0
F3	F4	164.6027	-0.0000	0.000	0.0
F4	F5	172.3286	0.0000	0.001	0.0
F5	F6	173.4635	-0.0000	0.000	0.0
F6	F7	165.8913	0.0000	0.000	0.0
F7	F8	162.7209	0.0000	0.001	0.0
F8	A1	183.3636	-0.0001	0.001	0.2

Error Propagation

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Station Coordinate Standard Deviations

Station	N	E	[Inches]
A1	0.000	0.000	
A2	0.000	0.000	
A3	0.001	0.001	
A4	0.002	0.002	
A5	0.002	0.002	
A6	0.003	0.003	
A7	0.003	0.004	
A8	0.004	0.005	
B1	0.005	0.005	
B2	0.006	0.006	
B3	0.007	0.006	
B4	0.008	0.006	
B5	0.010	0.006	
B6	0.011	0.006	
B7	0.012	0.006	
B8	0.013	0.006	
C1	0.013	0.006	
C2	0.014	0.006	
C3	0.015	0.006	
C4	0.015	0.006	
C5	0.015	0.006	
C6	0.015	0.006	
C7	0.015	0.006	
C8	0.015	0.006	
D1	0.015	0.006	
D2	0.015	0.006	
D3	0.015	0.006	
D4	0.015	0.007	
D5	0.014	0.007	
D6	0.014	0.007	
D7	0.013	0.007	
D8	0.012	0.008	
E1	0.012	0.008	
E2	0.011	0.008	
E3	0.010	0.008	
E4	0.009	0.008	
E5	0.008	0.008	
E6	0.007	0.008	
E7	0.006	0.007	
E8	0.005	0.007	
F1	0.004	0.006	
F2	0.002	0.005	
F3	0.002	0.004	
F4	0.001	0.003	
F5	0.001	0.002	
F6	0.001	0.002	
F7	0.001	0.001	
F8	0.001	0.001	

Station Coordinate Error Ellipses
Confidence Region = 95%

Station	Semi-Major Axis [Inch]	Semi-Minor Axis [Inch]	Azimuth of Major Axis [Deg-Min]
A1	0.000	0.000	0-00
A2	0.000	0.000	0-00
A3	0.002	0.001	113-33
A4	0.005	0.003	28-39
A5	0.006	0.005	125-49
A6	0.008	0.005	128-58
A7	0.010	0.006	130-19
A8	0.013	0.009	126-28
B1	0.016	0.009	134-29
B2	0.018	0.009	138-51
B3	0.021	0.010	143-44
B4	0.023	0.011	149-17
B5	0.026	0.011	154-28
B6	0.028	0.011	158-34
B7	0.030	0.011	162-19
B8	0.032	0.012	166-38
C1	0.033	0.012	170-07
C2	0.035	0.013	173-58
C3	0.036	0.014	177-07
C4	0.036	0.015	0-10
C5	0.037	0.014	1-16
C6	0.037	0.014	3-37
C7	0.038	0.014	5-19
C8	0.038	0.014	7-13
D1	0.038	0.013	8-52
D2	0.038	0.013	10-43
D3	0.038	0.014	12-40
D4	0.037	0.014	14-26
D5	0.037	0.013	17-46
D6	0.036	0.012	21-02
D7	0.035	0.012	24-22
D8	0.034	0.011	27-41
E1	0.033	0.011	30-52
E2	0.031	0.010	34-30
E3	0.029	0.009	38-46
E4	0.027	0.009	42-45
E5	0.026	0.008	46-34
E6	0.023	0.007	50-23
E7	0.022	0.007	54-08
E8	0.019	0.007	58-43
F1	0.016	0.005	63-07
F2	0.013	0.003	66-58
F3	0.011	0.003	71-05
F4	0.009	0.003	75-30
F5	0.006	0.002	81-42
F6	0.004	0.002	86-09
F7	0.003	0.002	88-46
F8	0.002	0.001	96-39

Appendix B.

Control Monument Position Shifts July 1989 To October 1990

The N and E coordinate axis directions are those of AGS North and East respectively.

$$\Delta N = N(1990) - N(1989)$$

$$\Delta E = E(1990) - E(1989)$$

Angle = Arctan ($\Delta N / \Delta E$) = Position Shift Vector Angle
To AGS East Direction

Monument	Delta N [Inches]	Delta E [Inches]	Shift Amplitude [Inches]	Angle [Degrees]
A1	0.000	0.000	0.000	0.000
A2	0.000	0.000	0.000	0.000
A3	0.006	-0.003	0.007	116.565
A4	-0.001	-0.005	0.005	191.310
A5	0.008	-0.002	0.008	104.036
A6	0.014	0.000	0.014	90.000
A7	0.020	-0.025	0.032	141.340
A8	0.032	-0.028	0.043	131.186
B1	0.037	-0.030	0.048	129.035
B2	0.048	-0.030	0.057	122.005
B3	0.052	-0.021	0.056	111.991
B4	0.062	-0.030	0.069	115.821
B5	0.059	0.003	0.059	87.089
B6	0.051	0.003	0.051	86.634

B7	0.051	0.008	0.052	81.085
B8	0.056	0.007	0.056	82.875
C1	0.055	0.020	0.059	70.017
C2	0.055	0.022	0.059	68.199
C3	0.050	0.015	0.052	73.301
C4	0.051	0.015	0.053	73.610
C5	0.065	0.031	0.072	64.502
C6	0.077	0.052	0.093	55.968
C7	0.061	0.053	0.081	49.014
C8	0.063	0.045	0.077	54.468
D1	0.050	0.032	0.059	57.381
D2	0.043	0.017	0.046	68.429
D3	0.061	0.003	0.061	87.184
D4	0.060	-0.015	0.062	104.036
D5	0.034	0.043	0.055	38.333
D6	-0.002	0.059	0.059	-1.941
D7	0.011	0.043	0.044	14.349
D8	0.029	0.026	0.039	48.122
E1	0.041	0.021	0.046	62.879
E2	0.036	0.018	0.040	63.435
E3	0.027	0.010	0.029	69.677
E4	0.020	0.015	0.025	53.130
E5	0.005	0.003	0.006	59.036
E6	-0.004	0.000	0.004	-90.000
E7	-0.021	0.004	0.021	-79.216
E8	-0.038	-0.017	0.042	245.898

F1	-0.054	-0.032	0.063	239.349
F2	-0.066	-0.040	0.077	238.782
F3	-0.060	-0.036	0.070	239.036
F4	-0.042	-0.002	0.042	267.274
F5	-0.014	0.014	0.020	-45.000
F6	-0.003	0.014	0.014	-12.095
F7	-0.002	0.012	0.012	-9.462
F8	0.003	0.004	0.005	36.870