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# THE SECOND HORIZONTAL CONTROL SURVEY OF THE BOOSTER MONUMENT NETWORK

F. X. Karl

February 1993

Collider Accelerator Department

**Brookhaven National Laboratory**

**U.S. Department of Energy**

USDOE Office of Science (SC)

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# THE SECOND HORIZONTAL CONTROL SURVEY OF THE BOOSTER MONUMENT NETWORK

BOOSTER TECHNICAL NOTE
NO. 219

F. X. KARL and M.A. GOLDMAN

February 1, 1993

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

January 7, 1993

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 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.

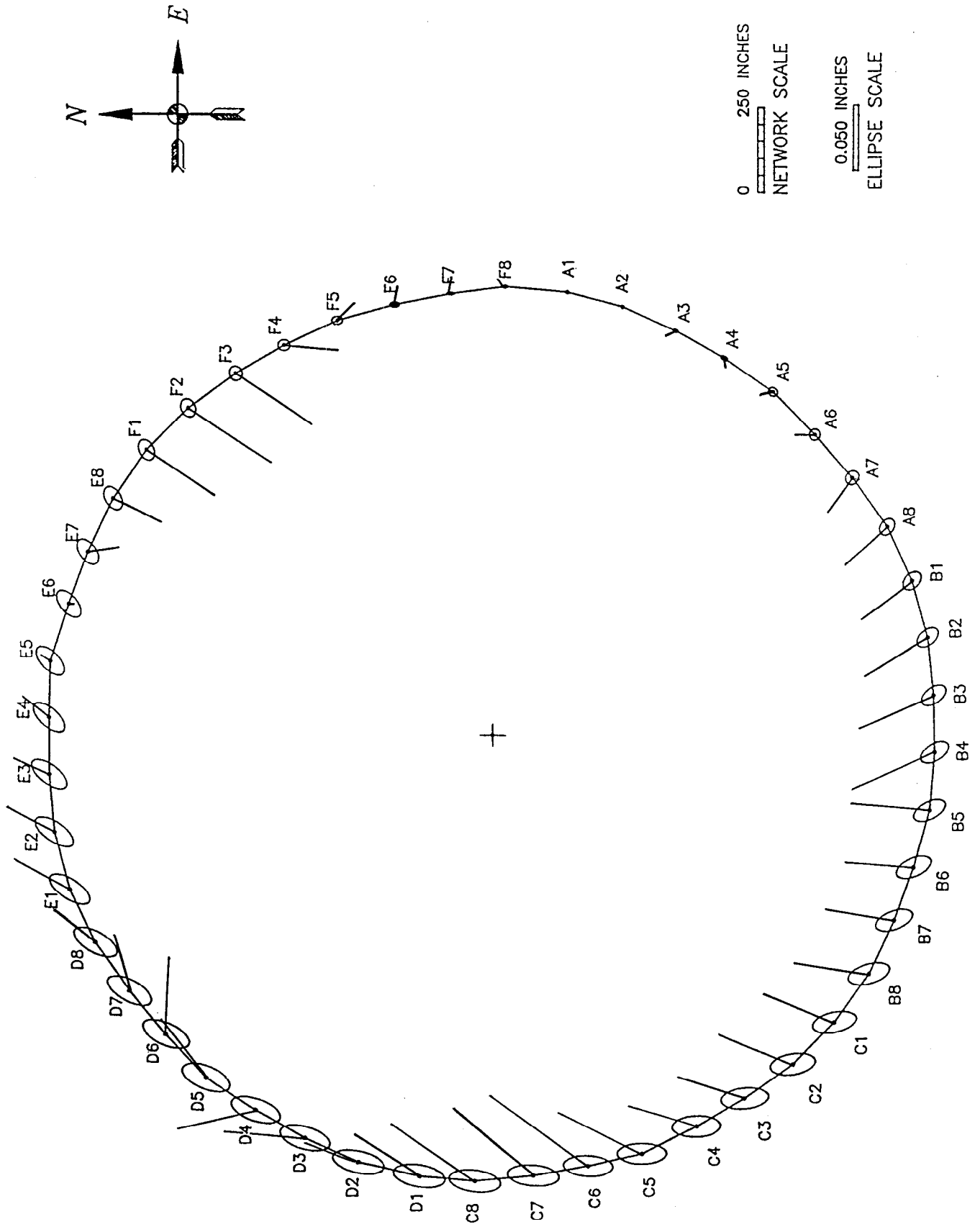


Figure 1. Booster Monument Displacement July 1989 To October 1990.

Appendix A

THE 1990 BOOSTER HORIZONTAL CONTROL SURVEY

STAR*NET Adjustment Program

Licensed for Use by Brookhaven National Laboratory, AGS Department
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

Solution Has Converged in 4 Iterations

## Final Results

### Updated Coordinates

| Station | N | E | |
|---|---|---|---|
| A1 | 15242.158 | 2447.155 | [AGS Inches] |
| 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

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

## Station Coordinate Standard Deviations

| Station | N | E | |
|---|---|---|---|
| A1 | 0.000 | 0.000 | [Inches] |
| 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 |