BNL-105208-2014-TECH

Booster Technical Note No. 164;BNL-105208-2014-IR

DESIGN and FIRST CONTROL SURVEY of the BOOSTER MONUMENT NETWORK AND MODIFIED SURVEY MARKER COORDINATES FOR THE BOOSTER RING MAGNETS

M. A. Goldman

May 1990

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

DESIGN & FIRST CONTROL SURVEY of the BOOSTER MONUMENT NETWORK AND MODIFIED SURVEY MARKER COORDINATES for the BOOSTER RING MAGNETS

BOOSTER TECHNICAL NOTE
NO. 164

M. A. GOLDMAN, F. X. KARL and R. E. THERN

MAY 16, 1990

ALTERNATING GRADIENT SYNCHROTRON DEPARTMENT
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973

THE DESIGN AND FIRST CONTROL SURVEY OF THE BOOSTER MONUMENT NETWORK, AND MODIFIED SURVEY MARKER COORDINATES FOR THE BOOSTER RING MAGNETS

March 20, 1990

M.A. Goldman, F.X. Karl, R.E. Thern

ABSTRACT

A network of survey control monuments has been installed in the Booster tunnel. This network will be used as a geodetic reference to define the locations of the magnets to be placed in the tunnel. The monument locations are specified by means of control surveys.

In this note we describe the design of the control monument net, and discuss the choice of surveying procedure which is used to define the monument locations, and the accuracy to be expected for this procedure, as determined by network survey modelling experiments.

We also provide a revised and expanded list of the Booster magnet survey marker points, giving reference marker point coordinates for magnet installation.

Finally, we present survey data and a least squares adjustment for the July 1989 first control survey of the Booster tunnel monuments. The survey standard errors lie within the standard errors estimated for the survey of an ideal monument network by an appropriate modelling experiment.

1. Introduction

Forty-eight stainless steel precision-machined bushings have been grout-cemented into the floor of the Booster tunnel. These hollow bored cylinders provide precise locating surfaces for the mounting of optical survey targets or theodolites. They are the survey monuments which will be used to guide the installation of Booster ring magnets into the Booster tunnel. Their positions with respect to the AGS geodetic grid, are measured both before and after placement of magnets into the tunnel, by control surveys.

Proper magnet placement requires an accurate knowledge of the monument locations, with respect to the AGS machine and to one another. In turn, the precision and accuracy in determining monument locations depends upon the accuracy of the instruments used to survey the collection of monuments and upon the choice of the control monument network to be surveyed. [Here, by the term "control monument network" we mean a geometric figure composed of a set of vertices (with a vertex lying on each monument's bore axis), a subset of the line segments linking these vertices, and a subset of the set of angles formed by pairs of these link segments; it is assumed that these are the link distances and link angles which will be measured during a control survey of the Booster tunnel.] To investigate the accuracy to be expected from different network surveys, we have carried out survey modelling experiments. These modelling calculations lead to a preferred network, that is a preferred method of carrying out control surveys of the monument locations.

Ring magnet placement into the Booster tunnel also requires a list of survey marker point coordinates. The survey marker points of a magnet are geometric points, having locations which are rigidly fixed, with respect to the magnet structure. Cartesian position coordinates are supplied for each marker point, to thereby define the position of the magnet in the Booster tunnel. To date, the tabulated list of Booster ring magnet survey marker points is given by Table 2 of G.F. Dell, Booster Technical Note No. 119, April 26, 1988 [1]. Table 3 of that document lists proposed coordinates for a set of 24 control monuments to be located 1.1 meter outward of the upstream survey marker points of the focusing quadrupole magnets. A number of changes have been made in the quadrupole magnet design, the Booster lattice, and the desired control monument network since the appearance of that document. In section 2 of the present note we indicate these changes, and supply updated listings of magnet survey marker point coordinates in Table 1 and Table 5.

The first control survey of the installed Booster ring monuments was completed in July 1989. Survey data and least squares adjusted monument coordinates are given in Table 4 of this note, together with least squares adjusted lengths and angles of the control monument network. The survey is discussed in section 4.

2. Changes In Quadrupole Design, Booster Lattice, and Monument Network Configuration.

The updated coordinates of the quadrupole survey marker points, listed in Table 1 of this note, are modified values of the coordinates given in Table 2 of Booster Technical Note No. 119, April 26, 1988 [1]. The horizontal marker point coordinates are, by definition, the horizontal coordinates of the points of intersection of the magnetic axis of the quadrupole with the quadrupole lamination end face planes, when the quadrupole magnet has been placed at its assigned location in the Booster ring (as determined by the Booster lattice design).

In principle, physical survey target bushings are mounted onto each quadrupole magnet, so their centers lie precisely above these marker points, when the magnet has been levelled. (In actual construction, the bushing centers may have some offset, which can be measured and compensated for during alignment of the quadrupole module assembly). Optical surveyor's targets are placed into these bushings during magnet installation in the Booster ring. The ring monuments are used as survey reference stations to set the quadrupoles in place so that the survey marker points are brought to their assigned locations.

The quadrupole survey marker coordinates given in this report differ from those listed in [1], because the manufactured lengths have been changed to 17.250", for the vertical-focus quadrupoles, and to 16.750" for the horizontal-focus quadrupoles, instead of the common 16.625" length assumed in [1]. The center of gravity and direction defined by each pair of survey marker points is, however, the same as in [1].

Since appearance of the report [1], the following changes have been made in the magnet survey markers and proposed tunnel monument network:

(1) Quadrupole survey marker point coordinates have been modified, as described above, because of changes in quadrupole lengths.

(2) Additional sextupole magnets have been included in the Booster lattice. Survey marker point coordinates for these extra sextupoles have been calculated. Forty-eight sextupole magnets are to be placed into the ring.

(3) In order to provide redundancy in the tunnel control survey, forty-eight control monuments have been cemented into the tunnel floor, instead of the twenty-four monuments proposed in [1]. The design and geometry of the installed monument network is discussed in section 3 of this note.

(4) The Booster ring dipole magnet survey marker point coordinates listed in [1] were calculated under the assumption that the dipole magnet field has a sharp cutoff at each magnet end face. When one takes into account the finite gradient of the end field, a small shift of the dipole survey marker point coordinates should be introduced, so as to introduce a small parallel lateral shift inwards of the line of marker points of each dipole magnet. The unshifted dipole magnet survey marker point coordinates (the same as in [1]) are listed as part of Table I. The

shifted marker point coordinates are given in Table 5.

(5) The names used to designate the survey marker points and control monuments have been changed from the names used in [1], in order to conform to the nomenclature convention introduced in Booster Technical Note No. 142, June 5, 1989 [2]. In the new convention, survey marker points of magnets mounted on the same support girder, that is, in the same cell module, have a common section designation.

3. Design Of The Control Monument Network.

The following general guidelines were followed in the design of the control monument network for the Booster ring:

(1) The monuments must fit into the Booster tunnel and not interfere with accelerator structures. Free lines of sight are to be available between successive monuments and alternate monuments. Physical access space must exist for the surveyors to make their measurments.

(2) Distances between successive monuments should be between ten and thirty feet. This allows convenient use of a helium-neon laser interferometer to measure distance between monuments without excessive displacement and wander of the laser beam due to refraction caused by gradients in tunnel air temperature.

(3) The angles linking successive pairs of monuments should not be too close to a straight angle.

(4) The time and labor required to survey the installed monument network should be economical, while the network structure should be "stiff" enough to hold standard measurement errors to allowable levels.

(5) The standard error propagation of the survey procedure, from half-cell to half-cell, should not exceed 0.006 inches.

It was found that guidelines (1) - (4) could be satisfied if a monument was placed 1.1 meters outboard from the upstream marker point of each quadrupole magnet, on a line perpendicular to the line segment joining the two marker points of that magnet, and passing through the upstream marker point.

Smaller outboard distances were less desirable, since they could lead to blockage of optical lines of sight by ring magnets; larger outboard distances provided insufficient access space for the surveyors.

This monument geometry, with a monument 1.1 meters outboard of each quadrupole's upstream survey marker point, was selected as a base geometry for investigations of candidate control survey networks. We will call this the "monument reference geometry", and refer to monuments located at these positions as "ideal survey control monuments". The forty-eight (North, East) cartesian coordinate pairs given in 5.

Table 1, for monuments BRI.MON.A1 through BRI.MON.F8 are the AGS grid coordinates of the ideal survey control monuments. They are the vertices of a convex plane 48-gon having 6-fold rotational symmetry.

To define the control monument network, that is the set of angles and link segments used to survey the selected monument reference geometry, one can choose from among the following survey variables:

(1) Distances between successive vertices, V(i) and V(i+1), of the monument polygon.

(2) Distances between alternate vertices, V(i) and V(i+2), of the monument polygon.

(3) Interior angles between successive legs of the monument polygon. These are the clockwise angles from vertex V(i+1) to vertex V(i-1), measured by an observer stationed at vertex V(i). Equivalently, one can measure their complements, the angles of deviation between successive polygon legs.

(4) Backsight angles, from V(i-2) to V(i-1) measured by an observer stationed at V(i).

(5) Frontsight angles, from V(i+1) to V(i+2), measured by an observer stationed at V(i).

(6) Normal offset distances, of vertex V(i) from the line of sight joining vertices V(i-1) and V(i+1).

The above set of 288 survey variables allows great redundancy in choice of a control monument survey. But a survey employing this full set of variables would be a survey having unnecessarily many measurements, collecting excessive data, requiring too much survey time, and excessive labor for data reduction.

The following questions then present themselves:

What is a strong and efficient survey network; that is, strong with respect to the accuracy of the monument coordinates extracted from the survey measurements, and efficient with regard to the time and labor needed for survey data taking and data reduction? How does one reduce the data; what data base is to be provided?

To answer the second question, we note that a suitable least squares survey adjustment program, STAR*NET, is available commercially [3]. This program provides simultaneous adjustment of 2- and 3-dimensional survey data. It can analyze up to 300 2-dimensional observations from up to 110 stations, and up to 250 3-dimensional observations from up to 75 stations. This capability is sufficient for the analysis of Booster control monument surveys. The program inputs are the measured control monument network angles and distances, root mean square deviations of these survey variables, and a tabulation of approximate station coordinates (including any available geodetic reference station coordinates). The program output consists of a file of adjusted monument coordinates, a list of adjusted survey angles and distances and their residuals, and a statistical analysis of the adjustment. A program option is included which allows the user to plot the error ellipses of the adusted monument locations.

The STAR*NET program was used to analyze possible control monument networks. The following survey schemes were examined:

(A) Trilateration Network - The distances between successive monuments, and the distances between alternate monuments are measured. No angles are measured. This survey procedure imposes 95 conditional equations on 92 unknowns. There are 3 degrees of freedom, that is redundancy conditions, in the network.

(B) Simple Traverse Network - Distances between successive monuments and angles of deviation of successive legs of the convex 48-sided monument polygon are measured. This network also has 92 unknowns, 95 conditional equations, and 3 degrees of freedom.

(C) Simple Traverse, Plus Distances Between Alternate Monuments - This network has 92 unknowns, 143 conditional equations, and 51 degrees of freedom.

(D) Simple Traverse Together With Backsight And Frontsight Angles - This network has 92 unknowns, 191 conditional equations, and 99 degrees of freedom.

(E) Simple Traverse Together With Trilateration And Back-sight And Frontsight Angles - This is a strong, maximal network. There are 92 unknowns, 239 conditional equations, and 147 degrees of freedom.

To investigate the proposed survey networks (A) through (E), a least squares adjustment of each network was made, by using the STAR*NET program. To accomplish this, we first computed the angles and distances for the monument polygon, from the ideal control monument North and East coordinates listed in Table 1. (A commercial software program was used: SURVEYOR I, Carlson Software, Maysville, Kentucky 41056). The results are listed in Table 2. We then entered the angle and distance information for each network into the STAR*NET program, together with assumed theodolite standard errors and assumed distance measurement standard errors. We assumed 2 seconds of arc and 1 milli-inch distance as our a-priori root-mean-square statistical estimators for the accuracy of the theodolite angle measurements and laser interferometer distance measurements, respectively.

For each network, the program output supplied a set of least-squares-adjusted ideal monument coordinates together with error ellipse parameters for each monument position. The sizes of the resulting error ellipses, for different networks, give a measure of the strengths of the network surveying procedures. If no blunders are entered into the program entry data then the adjusted angles and distances are just the same as those entered, because the entry angles and distances belong to a precisely defined geometric figure.

The relative strengths of the model survey procedures (A) through (E) are indicated by the dimensions of the 95% confidence region error ellipses [4] for these procedures. The results are shown in Table 3, for the case when monuments A1 and A2 are taken as fixed reference stations, and the error ellipses are compared for monument D1, half way around the ring, the case of largest propagated error.

Networks (A), (B) and (C) are not as strong as (D). Network (E) is only slightly stronger than (D), but requires significantly greater time and labor for its survey. As indicated by the size of the error ellipses generated by the adjustment program, network (D) is strong enough to be used as the control monument network for the Booster tunnel.

The procedure (D), a simple traverse together with measurement of backsight and front-sight angles, was chosen to be the method of survey of the control monuments installed in the Booster tunnel. It is strong enough to provide the accuracy required of the actual physical survey of the installed ring monuments, but does not require excessive time or labor for its implementation.

4. The July 1989 Control Survey Of The Monuments Installed In The Booster Tunnel.

The forty-eight stainless steel control monument bushings were cemented into the Booster tunnel floor at positions close to the ideal control monument positions. At some few locations,the physical monuments were displaced by a few inches, to avoid floor exit drains.

At the time of survey, earthwork fill construction above the Booster tunnel was not yet complete. It is expected that the adjusted monument coordinates obtained in this survey will be used to initially position the dipole-quadrupole-sextupole half-cell and quadrupole-sextupole quarter-cell magnet module units in the tunnel. Deformation of the monument network is expected due to soil settlement and due to floor slab loading by the twelve-ton half-cells. It is expected that additional control surveys will be made to investigate such deformations and to allow final positioning of the ring magnets prior to Booster machine commisioning. By comparing the results of later surveys to those of the July 1989 survey one should be able to determine the extent of tunnel floor movements.

The method of survey, initial survey data, and adjusted survey results are given in Table 4. The final adjusted monument coordinates are listed in the columns labelled "Updated Coordinates". The adjusted angles between monument polygon legs, and distances between monuments are given, together with their residuals (adjusted values minus entry values of the survey variables) in the section "Residuals in Observations After Adjustment".

In computing the survey adjustments, the observational variance of four theodolite sightings of each measured angle was compounded in quadrature with the angular variance due to a measured 0.001 inch centering offset in the theodolite's tribrach stand. This results in an average standard angle error slightly above 2 seconds of arc. A uniform standard error of 0.001 inch in the interferometer distance measurements compounded with the tribrach offset was used for the distance standard error.

The angle residuals from the adjustments were typically near 2 seconds, and no outliers were seen. The distance residuals were all less than 0.001 inch.

To examine the effect of the distance variances upon the coordinate adjustments, the survey adjustment was subsequently recomputed under the assumptions of no tribrach centering error and an interferometer distance measurement variance of 0.0003 inch. All adjusted coordinates were the same, to 0.001 inch, as the previously computed adjusted coordinates. Nearly all of them remained unchanged.

5. Summary Of Results.

(1) A revised list of Booster survey marker point coordinates is given in Table 1. The quadrupole marker coordinates have been updated to accomodate changes in quadrupole magnet lengths. The dipole marker coordinates in Table 1 are the same as in [1].

A modified list of dipole marker coordinates which incorporates calculated modifications of the dipole magnet positions to compensate for the effects of dipole magnet end fringing fields is given in Table 5, and discussed in the Addendum accompanying that table. It is expected that the dipole magnets will be positioned on their half-cells, with respect to the quadrupole magnets, to include these positional corrections. If this is done, in fact, then the dipole magnet survey marker point coordinates used during half-cell installation should be those of Table 5.

(2) A monument reference geometry, configured to consist of 48 monuments, with a

monument located 1.1 meters normally outboard from the upstream survey marker point of each of the 48 ring quadrupole magnets, was selected as the desired model for the ring monument layout.

Distances and angles for this ideal geometry were computed, and are listed in Table 2. Model surveys were then performed to determine if a suitably strong and economical survey could be made using a Wild T-2 theodolite and Hewlett-Packard 5526A laser interferometer as survey instruments. It was found that the survey network consisting of a simple traverse, together with frontsight and backsight angle measurements, should have error propagation below the 0.006 inch rms limit allowed from half-cell to half-cell.

(3) With knowledge of these results, the AGS Survey Group installed 48 monuments in the Booster tunnel, in a configuration close to the ideal reference geometry defined above. In a few cases, monuments were offset slightly to avoid floor drains.

The installed monument network was surveyed in July 1989. At that time, earth fill operations outside the Booster tunnel had not yet been completed, and the magnet half-cells had not been installed in the tunnel.

The strength of the installed network turned out to be near to that of the modelled network (D). The standard errors of the July 1989 control survey lie within the standard errors estimated for the model survey of (D).

Table 4 gives the adjusted monument coordinates for the July 1989 control survey, together with the measured survey data, adjusted network angles and distances, residuals, and error ellipse parameters.

Error propagation, as reflected by the 95% confidence ellipses is shown in Figure 1.

(4) The adjusted monument coordinates derived from the July 1989 control survey in Table 4, together with the magnet survey marker point coordinates in Tables 1 and 5, should give sufficient survey information to allow initial positioning of the magnet cells in the Booster tunnel. It is recommended that final positioning of the magnets, before Booster commisioning, be done after one or more additional monument control surveys, to insure that any monument control network deformation caused by initial tunnel floor settling and floor loading by the magnet cells is corrected before final magnet alignment. A comparison of adjusted survey data for the July 1989 survey and subsequent adjusted survey data will indicate the extent of such network deformation.

References

[1] G.F. Dell, Coordinates Of Magnet Survey Markers And Tunnel Survey Monuments For The AGS Booster, BNL AD Booster Technical Note No. 119, April 26, 1988.

[2] E.H. Auerbach, A Revised Convention For Naming Sections In The Booster and Naming Booster Elements. BNL AD Booster Technical Note No. 142, June 5, 1989.

[3] STAR*NET (Least Squares Survey Adjustment Program). STAR*NET Associates, Oakland, California 94620.

[4] M.A.R. Cooper, Control Surveys In Civil Engineering. Nichols Publishing Company, New York, 1987, pp 123-146 and 261-277.

Table 1. COORDINATES OF IDEAL SURVEY CONTROL MONUMENTS

AND

MAGNET SURVEY MARKERS

Ideal Control Monument Coordinates And Ideal Quadrupole Survey Marker Coordinates Are Calculated Assuming That Vertical-Focus-Quadrupole Length = 17.250 [Inches], Horizontal-Focus-Quadrupole Length = 16.750 [Inches] And Survey Monuments Are Located 1.1 Meters Normally Outward From The Upstream Survey Point Of The Nearest Quadrupole. Ideal Dipole Survey Point Coordinates Are Given According To Table 2 Of BNL Booster Technical Note No. 119.

Names Describing Monuments And Survey Markers Follow The Revised Convention Of BNL Booster Technical Note No. 142.

Coordinates Are In [Inches] On The AGS Grid

	North	East
MONUMENT: BRI.MON.A1	15242.2366	2447.3662
Survey Points		
SRVPT.SA1	15262.1428	2406.7348
SRVPT.QA1.US	15249.2115	2404.6245
SRVPT.QA1.DS	15232.1867	2401.8463
SRVPT.DA1.US	15217.6525	2399.4773
SRVPT.DA1.DS	15129.3300	2377.0159
MONUMENT: BRI.MON.A2	15074.8874	2403.8581
Survey Points		
SRVPT.SA2	15101.7830	2367.3832
SRVPT.QA2.US	15089.1784	2362.9770
SRVPT.QA2.DS	15073.3667	2357.4496
SRVPT.DA2.US	15059.2288	2352.5102
SRVPT.DA2.DS	14976.1485	2315.0531

	North	East
MONUMENT: BRI.MON.A3	14918.0899	2332.1558
Survey Points		
SRVPT.SA3	14950.6926	2300.7832
SRVPT.QA3.US	14939.2628	2294.3774
SRVPT.QA3.DS	14924.2150	2285.9438
MONUMENT: BRI.MON.A4	14773.4980	2251.1193
Survey Points		
SRVPT.SA4	14806.3189	2219.8689
SRVPT.QA4.US	14794.6709	2213.3409
SRVPT.QA4.DS	14780.0593	2205.1517
SRVPT.DA4.US	14766.9939	2197.8325
SRVPT.DA4.DS	14691.6801	2146.5176
MONUMENT: BRI.MON.A5	14631.5338	2153.2788
Survey Points		
SURVPT.SA5	14669.0889	2128.0442
SRVPT.QA5.US	14658.9451	2119.7508
SRVPT.QA5.DS	14645.5904	2108.8324
SRVPT.DA5.US	14634.1880	2099.5138
SRVPT.DA5.DS	14568.9291	2035.9004
MONUMENT: BRI.MON.A6	14508.3594	2031.9252
Survey Points		
SRVPT.SA6	14549.8890	2013.7847
SRVPT.QA6.US	14541.1764	2003.6666
SRVPT.QA6.DS	14530.2467	1990.9738

	North	East
MONUMENT: BRI.MON.A7	14400.5297	1906.7012
Survey Points		
SRVPT.SA7	14441.8963	1888.3714
SRVPT.QA7.US	14433.3468	1878.4427
SRVPT.QA7.DS	14422.0909	1865.3711
SRVPT.DA7.US	14412.4799	1854.214
SRVPT.DA7.DS	14359.2587	1780.235
MONUMENT: BRI.MON.A8	14300.2994	1765.8022
Survey Points		
SRVPT.SA8	14344.3483	1755.1490
SRVPT.QA8.US	14337.5250	1743.6716
SRVPT.QA8.DS	14328.9655	1729.2738
SRVPT.DA8.US	14321.3101	1716.4024
SRVPT.DA8.DS	14281.7438	1634.3055
MONUMENT: BRI.MON.B1	14226.2750	1610.0877
Survey Points		
SRVPT.SB1	14271.4161	1607.0114
SRVPT.QB1.US	14266.7779	1594.7574
SRVPT.QB1.DS	14260.6716	1578.6243
SRVPT.DB1.US	14255.4561	1564.8529
SRVPT.DB1.DS	14230.7470	1477.1327
MONUMENT: BRI.MON.B2	14180.2796	1443.4050
Survey Points		
SRVPT.SB2	14225.3157	1448.4599
SRVPT.QB2.US	14222.8293	1435.3409
SRVPT.QB2.DS	14219.7104	1418.8839
SRVPT.DB2.US	14216.9190	1404.1704
SRVPT.DB2.DS	14207.8176	1313.4922

	North	East
MONUMENT: BRI.MON.B3	14163.9769	1271.7632
Survey Points		
SRVPT.SB3	14207.4478	1284.3118
SRVPT.QB3.US	14207.2805	1271.2104
SRVPT.QB3.DS	14207.0603	1253.9618
MONUMENT: BRI.MON.B4	14161.8606	1106.0250
Survey Points		
SRVPT.SB4	14205.3347	1118.8233
SRVPT.QB4.US	14205.1642	1105.4719
SRVPT.QB4.DS	14204.9503	1088.7233
SRVPT.DB4.US	14204.7563	1073.7487
SRVPT.DB4.DS	14211.5394	982.8676
MONUMENT: BRI.MON.B5	14175.6109	934.1601
Survey Points		
SRVPT.SB5	14216.2423	954.0663
SRVPT.QB5.US	14218.3526	941.1350
SRVPT.QB5.DS	14221.1308	924.1102
SRVPT.DB5.US	14223.4999	909.5760
SRVPT.DB5.DS	14245.9612	821.2535
MONUMENT: BRI.MON.B6	14219.1191	766.8109
Survey Points		
SRVPT.SB6	14255.5940	793.7065
SRVPT.QB6.US	14260.0002	781.1019
SRVPT.QB6.DS	14265.5276	765.2902

	North	East
MONUMENT: BRI.MON.B7	14273.6513	610.8159
Survey Points		
SRVPT.SB7	14310.2087	637.4754
SRVPT.QB7.US	14314.5324	625.1069
SRVPT.QB7.DS	14320.2248	608.8232
SRVPT.DB7.US	14325.0816	594.9213
SRVPT.DB7.DS	14362.5388	511.8409
MONUMENT: BRI.MON.B8	14345.5583	453.5643
Survey Points		
SRVPT.SB8	14376.8087	486.3851
SRVPT.QB8.US	14383.3367	474.7372
SRVPT.QB8.DS	14391.5259	460.1256
SRVPT.DB8.US	14398.8452	447.0601
SRVPT.DB8.DS	14450.1600	371.7463
MONUMENT: BRI.MON.C1	14443.3989	311.5999
Survey Points		
SRVPT.SC1	14468.6335	349.1552
SRVPT.QC1.US	14476.9267	339.0114
SRVPT.QC1.DS	**14487.8452**	325.6567
SRVPT.DC1.US	14497.1638	314.2542
SRVPT.DC1.DS	14560.7772	248.9953
MONUMENT: BRI.MON.C2	14564.7526	188.4254
Survey Points		
SRVPT.SC2	14582.8929	229.9553
SRVPT.QC2.US	14593.0111	221.2425
SRVPT.QC2.DS	14605.7039	210.3129
SRVPT.DC2.US	14617.0504	200.5388
SRVPT.DC2.DS	14691.0294	147.3177

	North	East
MONUMENT: BRI.MON.C3	14705.2472	88.4861
Survey Points		
SRVPT.SC3	14716.1154	132.4072
SRVPT.QC3.US	14727.3779	125.7117
SRVPT.QC3.DS	14742.2055	116.8966
MONUMENT: BRI.MON.C4	14847.7228	3.7841
Survey Points		
SRVPT.SC4	14858.3761	47.8330
SRVPT.QC4.US	14869.8534	41.0097
SRVPT.QC4.DS	14884.2512	32.4502
SRVPT.DC4.US	14897.1227	24.7948
SRVPT.DC4.DS	14979.2195	-14.7715
MONUMENT: BRI.MON.C5	15003.4374	-70.2403
Survey Points		
SRVPT.SC5	15006.5136	-25.0993
SRVPT.QC5.US	15018.7677	-29.7374
SRVPT.QC5.DS	15034.9008	-35.8437
SRVPT.DC5.US	15048.6721	-41.0592
SRVPT.DC5.DS	15136.3923	-65.7684
MONUMENT: BRI.MON.C6	15170.1200	-116.2357
Survey Points		
SRVPT.SC6	15165.0652	-71.1997
SRVPT.QC6.US	15178.1841	-73.6860
SRVPT.QC6.DS	15194.6411	-76.8049

	North	East
MONUMENT: BRI.MON.C7	15332.4818	-147.0069
Survey Points		
SRVPT.SC7	15327.6726	-102.0174
SRVPT.QC7.US	15340.5458	-104.4572
SRVPT.QC7.DS	15357.4941	-107.6693
SRVPT.DC7.US	15371.9620	-110.4141
SRVPT.DC7.DS	15462.6403	-119.5155
MONUMENT: BRI.MON.C8	15504.6192	-163.3594
Survey Points		
SRVPT.SC8	15491.8206	-119.8853
SRVPT.QC8.US	15505.1720	-120.0558
SRVPT.QC8.DS	15521.9206	-120.2696
SRVPT.DC8.US	15536.8953	-120.4636
SRVPT.DC8.DS	15627.7764	-113.6806
MONUMENT: BRI.MON.D1	15676.4842	-149.6091
Survey Points		
SRVPT.SD1	15656.5776	-108.9777
SRVPT.QD1.US	15669.5090	-106.8674
SRVPT.QD1.DS	15686.5338	-104.0891
SRVPT.DD1.US	15701.0679	-101.7201
SRVPT.DD1.DS	15789.3905	-79.2588
MONUMENT: BRI.MON.D2	15843.833	-106.1009
Survey Points		
SRVPT.SD2	15816.9375	-69.6260
SRVPT.QD2.US	15829.5420	-65.2198
SRVPT.QD2.DS	15845.3537	-59.6924
SRVPT.DD2.US	15859.4916	-54.7531
SRVPT.DD2.DS	15942.572	-17.2959

	North	East
MONUMENT: BRI.MON.D3	16000.6305	-34.3986
Survey Points		
SRVPT.SD3	15968.0278	-3.0260
SRVPT.QD3.US	15979.4576	3.3798
SRVPT.QD3.DS	15994.5054	11.8134
MONUMENT: BRI.MON.D4	16145.2224	46.6378
Survey Points		
SRVPT.SD4	16112.4016	77.8882
SRVPT.QD4.US	16124.0495	84.4162
SRVPT.QD4.DS	16138.6611	92.6054
SRVPT.DD4.US	16151.7266	99.9247
SRVPT.DD4.DS	16227.0404	151.2395
MONUMENT: BRI.MON.D5	16287.1867	144.4783
Survey Points		
SRVPT.SD5	16249.6315	169.7130
SRVPT.QD5.US	16259.7754	178.0063
SRVPT.QD5.DS	16273.1301	188.9247
SRVPT.DD5.US	16284.5325	198.2434
SRVPT.DD5.DS	16349.7914	261.8567
MONUMENT: BRI.MON.D6	16410.3613	265.8321
Survey Points		
SRVPT.SD6	16368.8315	283.9725
SRVPT.QD6.US	16377.5442	294.0906
SRVPT.QD6.DS	16388.4738	306.7834

	North	East
MONUMENT: BRI.MON.D7	16518.1907	391.0558
Survey Points		
SRVPT.SD7	16476.8241	409.3857
SRVPT.QD7.US	16485.3737	419.3144
SRVPT.QD7.DS	16496.6296	432.3860
SRVPT.DD7.US	16506.2406	443.5431
SRVPT.DD7.DS	16559.4617	517.5221
MONUMENT: BRI.MON.D8	16618.4209	531.9548
Survey Points		
SRVPT.SD8	16574.3722	542.6082
SRVPT.QD8.US	16581.1955	554.0855
SRVPT.QD8.DS	16589.7550	568.4833
SRVPT.DD8.US	16597.4104	581.3548
SRVPT.DD8.DS	16636.9766	663.4516
MONUMENT: BRI.MON.E1	16692.4455	687.6695
Survey Points		
SRVPT.SE1	16647.3044	690.7457
SRVPT.QE1.US	16651.9426	702.9998
SRVPT.QE1.DS	16658.0489	719.1329
SRVPT.DE1.US	16663.2643	732.9042
SRVPT.DE1.DS	16687.9735	820.6245
MONUMENT: BRI.MON.E2	16738.4408	854.3520
Survey Points		
SRVPT.SE2	16693.4048	849.2973
SRVPT.QE2.US	16695.8911	862.4163
SRVPT.QE2.DS	16699.0101	878.8733
SRVPT.DE2.US	16701.8015	893.5867
SRVPT.DE2.DS	16710.9029	984.2650

	North	East
MONUMENT: BRI.MON.E3	16754.7435	1025.9937
Survey Points		
SRVPT.SE3	16711.2727	1013.4453
SRVPT.QE3.US	16711.4399	1026.5467
SRVPT.QE3.DS	16711.6602	1043.7953
MONUMENT: BRI.MON.E4	16756.8599	1191.7324
Survey Points		
SRVPT.SE4	16713.3858	1178.9338
SRVPT.QE4.US	16713.5563	1192.2852
SRVPT.QE4.DS	16713.7701	1209.0338
SRVPT.DE4.US	16713.9641	1224.0085
SRVPT.DE4.DS	16707.1811	1314.8896
MONUMENT: BRI.MON.E5	16743.1096	1363.5974
Survey Points		
SRVPT.SE5	16702.4782	1343.6908
SRVPT.QE5.US	16700.3679	1356.6222
SRVPT.QE5.DS	16697.5896	1373.647
SRVPT.DE5.US	16695.2206	1388.1811
SRVPT.DE5.DS	16672.7593	1476.5036
MONUMENT: BRI.MON.E6	16699.6014	1530.9462
Survey Points		
SRVPT.SE6	16663.1265	1504.0507
SRVPT.QE6.US	16658.7203	1516.6552
SRVPT.QE6.DS	16653.1929	1532.4669

	North	East
MONUMENT: BRI.MON.E7	16645.0692	1686.9412
Survey Points		
SRVPT.SE7	16608.5118	1660.2817
SRVPT.QE7.US	16604.1881	1672.6502
SRVPT.QE7.DS	16598.4957	1688.9339
SRVPT.DE7.US	16593.6388	1702.8359
SRVPT.DE7.DS	16556.1817	1785.9162
MONUMENT: BRI.MON.E8	16573.1622	1844.1929
Survey Points		
SRVPT.SE8	16541.9118	1811.3720
SRVPT.QE8.US	16535.3838	1823.0200
SRVPT.QE8.DS	16527.1946	1837.6316
SRVPT.DE8.US	16519.8753	1850.6970
SRVPT.DE8.DS	16468.5605	1926.0108
MONUMENT: BRI.MON.F1	16475.3217	1986.1571
Survey Points		
SRVPT.SF1	16450.0870	1948.6020
SRVPT.QF1.US	16441.7937	1958.7458
SRVPT.QF1.DS	16430.8753	1972.1005
SRVPT.DF1.US	16421.5566	1983.5029
SRVPT.DF1.DS	16357.9433	2048.7618
MONUMENT: BRI.MON.F2	16353.9679	2109.3317
Survey Points		
SRVPT.SF2	16335.8275	2067.8019
SRVPT.QF2.US	16325.7094	2076.5146
SRVPT.QF2.DS	16313.0166	2087.4442
SRVPT.DF2.US	16301.6701	2097.2184
SRVPT.DF2.DS	16227.6911	2150.4395

	North	East
MONUMENT: BRI.MON.F3	16213.4732	2209.2710
Survey Points		
SRVPT.SF3	16202.6051	2165.3499
SRVPT.QF3.US	16191.3426	2172.0455
SRVPT.QF3.DS	16176.5150	2180.8605
MONUMENT: BRI.MON.F4	16070.9977	2293.9730
Survey Points		
SRVPT.SF4	16060.3440	2249.9244
SRVPT.QF4.US	16048.8670	2256.7475
SRVPT.QF4.DS	16034.4692	2265.3070
SRVPT.DF4.US	16021.5978	2272.9624
SRVPT.DF4.DS	15939.5009	2312.5286
MONUMENT: BRI.MON.F5	15915.2831	2367.9975
Survey Points		
SRVPT.SF5	15912.2069	2322.8564
SRVPT.QF5.US	15899.9528	2327.4946
SRVPT.QF5.DS	15883.8197	2333.6009
SRVPT.DF5.US	15870.0483	2338.8163
SRVPT.DF5.DS	15782.3281	2363.5255
MONUMENT: BRI.MON.F6	15748.6006	2413.9927
Survey Points		
SRVPT.SF6	15753.6553	2368.9568
SRVPT.QF6.US	15740.5363	2371.4431
SRVPT.QF6.DS	15724.0793	2374.5621

	North	East
MONUMENT: BRI.MON.F7	15586.2388	2444.7640
Survey Points		
SRVPT.SF7	15591.0479	2399.7746
SRVPT.QF7.US	15578.1746	2402.2143
SRVPT.QF7.DS	15561.2263	2405.4265
SRVPT.DF7.US	15546.7584	2408.1713
SRVPT.DF7.DS	15456.0802	2417.2726
MONUMENT: BRI.MON.F8	15414.1015	2461.1165
Survey Points		
SRVPT.SF8	15426.8998	2417.6424
SRVPT.QF8.US	15413.5484	2417.8129
SRVPT.QF8.DS	15396.7998	2418.0268
SRVPT.DF8.US	15381.8252	2418.2208
SRVPT.DF8.DS	15290.9441	2411.4378

Table 2. SURVEY INPUT VARIABLES FOR IDEAL MONUMENT SURVEY MODELS USING STAR☆NET ADJUSTMENT PROGRAM

Ideal Monument Coordinates of A1 and A2 are fixed; coordinates of the other monuments have variance determined by the assumed root-mean-square accuracy of the angle and distance measuring instruments.

In the data list below the symbol A⟨I⟩ refers to the ideal position of Booster ring monument **BRI.MON.A⟨I⟩**.

	North	East
C A1	15242.2366	2447.3662
C A2	15074.8874	2403.8581
C A3	14918.0899	2332.1588
C A4	14773.4980	2251.1193
C A5	14631.5338	2153.2788
C A6	14508.3594	2031.9252
C A7	14400.5297	1906.7012
C A8	14300.2994	1765.8022
C B1	14226.2750	1610.0877
C B2	14180.2796	1443.4050
C B3	14163.9769	1271.7632
C B4	14161.8606	1106.0250
C B5	14175.6109	0934.1601
C B6	14219.1191	0766.8109
C B7	14273.6513	0610.8159
C B8	14345.5583	0453.5643
C C1	14443.3989	0311.5999
C C2	14564.7526	0188.4254
C C3	14705.2472	0088.4861

	North	East
C C4	14847.7228	0003.7841
C C5	15003.4374	-0070.2403
C C6	15170.1200	-0116.2357
C C7	15332.4818	-0147.0069
C C8	15504.6192	-0163.3594
C D1	15676.4842	-0149.6091
C D2	15843.8330	-0106.1009
C D3	16000.6305	-0034.3986
C D4	16145.2224	0046.6378
C D5	16287.1867	0144.4783
C D6	16410.3613	0265.8321
C D7	16518.1907	0391.0558
C D8	16618.4209	0531.9548
C E1	16692.4455	0687.6695
C E2	16738.4408	0854.3520
C E3	16754.7435	1025.9937
C E4	16756.8599	1191.7324
C E5	16743.1096	1363.5974
C E6	16699.6014	1530.9462
C E7	16645.0692	1686.9412
C E8	16573.1622	1844.1929
C F1	16475.3217	1986.1571
C F2	16353.9679	2109.3317
C F3	16213.4732	2209.2710
C F4	16070.9977	2293.9730
C F5	15915.2831	2367.9975
C F6	15748.6006	2413.9927
C F7	15586.2388	2444.7640
C F8	15414.1015	2461.1165

Computed distances [inches] between successive monuments.
(Computations using Surveyor 1 program).

Monuments	Distance (inches)
D A2-A3	172.414
D A3-A4	165.752
D A4-A5	172.414
D A5-A6	172.912
D A6-A7	165.252
D A7-A8	172.912
D A8-B1	172.414
D B1-B2	172.912
D B2-B3	172.414
D B3-B4	165.752
D B4-B5	172.414
D B5-B6	172.912
D B6-B7	165.252
D B7-B8	172.912
D B8-C1	172.414
D C1-C2	172.912
D C2-C3	172.414
D C3-C4	165.752
D C4-C5	172.414
D C5-C6	172.912
D C6-C7	165.252
D C7-C8	172.912
D C8-D1	172.414

Monuments	Distance (inches)
D D1-D2	172.912
D D2-D3	172.414
D D3-D4	165.752
D D4-D5	172.414
D D5-D6	172.912
D D6-D7	165.252
D D7-D8	172.912
D D8-E1	172.414
D E1-E2	172.912
D E2-E3	172.414
D E3-E4	165.752
D E4-E5	172.414
D E5-E6	172.912
D E6-E7	165.252
D E7-E8	172.912
D E8-F1	172.414
D F1-F2	172.912
D F2-F3	172.414
D F3-F4	165.752
D F4-F5	172.414
D F5-F6	172.912
D F6-F7	165.252
D F7-F8	172.912
D F8-A1	172.414

Computed distances to alternate monuments.

Monuments	Distance (inches)
D F8-A2	344.013
D A2-A4	337.883
D A4-A6	344.012
D A6-A8	337.802
D A8-B2	344.013
D B2-B4	337.882
D B4-B6	344.013
D B6-B8	337.802
D B8-C2	344.013
D C2-C4	337.882
D C4-C6	344.013
D C6-C8	337.802
D C8-D2	344.012
D D2-D4	337.883
D D4-D6	344.013
D D6-D8	337.802
D D8-E2	344.013
D E2-E4	337.883
D E4-E6	344.012
D E6-E8	337.802
D E8-F2	344.013
D F2-F4	337.882
D F4-F6	344.013
D F6-F8	337.802

Monuments	Distance (inches)
D A1-A3	344.012
D A3-A5	337.804
D A5-A7	337.881
D A7-B1	344.012
D B1-B3	344.012
D B3-B5	337.803
D B5-B7	337.881
D B7-C1	344.012
D C1-C3	344.012
D C3-C5	337.804
D C5-C7	337.881
D C7-D1	344.012
D D1-D3	344.012
D D3-D5	337.804
D D5-D7	337.881
D D7-E1	344.012
D E1-E3	344.012
D E3-E5	337.804
D E5-E7	337.881
D E7-F1	344.012
D F1-F3	344.012
D F3-F5	337.804
D F5-F7	337.881
D F7-A1	344.012

Computed monument link angles

From-At-To	Angle
A A3-A2-A1	169° 59′ 56.8″
A A4-A3-A2	175° 18′ 20.9″
A A5-A4-A3	174° 41′ 39.0″
A A6-A5-A4	170° 0′ 3.3″
A A7-A6-A5	175° 18′ 17.7″
A A8-A7-A6	174° 41′ 42.2″
A B1-A8-A7	169° 59′ 56.8″
A B2-B1-A8	170° 0′ 3.2″
A B3-B2-B1	169° 59′ 56.8″
A B4-B3-B2	175° 18′ 21.0″
A B5-B4-B3	174° 41′ 39.0″
A B6-B5-B4	170° 0′ 3.2″
A B7-B6-B5	175° 18′ 17.8″
A B8-B7-B6	174° 41′ 42.3″
A C1-B8-B7	169° 59′ 56.7″
A C2-C1-B8	170° 0′ 3.3″
A C3-C2-C1	169° 59′ 56.7″
A C4-C3-C2	175° 18′ 21.0″
A C5-C4-C3	174° 41′ 39.0″
A C6-C5-C4	170° 0′ 3.3″
A C7-C6-C5	175° 18′ 17.7″
A C8-C7-C6	174° 41′ 42.3″
A D1-C8-C7	169° 59′ 56.7″
A D2-D1-C8	170° 0′ 3.1″

From-At-To	Angle
A D3-D2-D1	169° 59′ 57.0″
A D4-D3-D2	175° 18′ 21.0″
A D5-D4-D3	174° 41′ 39.0″
A D6-D5-D4	170° 0′ 3.2″
A D7-D6-D5	175° 18′ 17.7″
A D8-D7-D6	174° 41′ 42.2″
A E1-D8-D7	169° 59′ 56.9″
A E2-E1-D8	170° 0′ 3.1″
A E3-E2-E1	169° 59′ 56.8″
A E4-E3-E2	175° 18′ 21.2″
A E5-E4-E3	174° 41′ 38.8″
A E6-E5-E4	170° 0′ 3.1″
A E7-E6-E5	175° 18′ 17.9″
A E8-E7-E6	174° 41′ 42.3″
A F1-E8-E7	169° 59′ 56.7″
A F2-F1-E8	170° 0′ 3.3″
A F3-F2-F1	169° 59′ 56.7″
A F4-F3-F2	175° 18′ 21.1″
A F5-F4-F3	174° 41′ 39.0″
A F6-F5-F4	170° 0′ 3.0″
A F7-F6-F5	175° 18′ 18.0″
A F8-F7-F6	174° 41′ 42.2″
A A1-F8-F7	169° 59′ 56.7″
A A2-A1-F8	170° 0′ 3.3″

Table 3. IDEAL CONTROL MONUMENT SURVEY 95% CONFIDENCE ERROR ELLIPSES AT MONUMENT D1

Monuments BRI.MON.A1 and BRI.MON.A2 are assumed to be fixed references, located at points A1 and A2 respectively, whose coordinates are listed in Table 2.

The standard error of the distance measurements is assumed to be 0.001 inch; the standard error of the angle measurements is assumed to be 2 seconds of arc.

Type Of Survey	Semimajor Axis Of Error Ellipse	Semiminor Axis Of Error Ellipse	Angle Of Major Axis To [East]
	a (inches)	b (inches)	(Deg/Min/Sec)
A. Trilateration	2.067	0.728	81/49/7.2
B. Simple Traverse	0.0897	0.0336	77/57/13.2
C. Simple Traverse Plus Distances Between Alternate Monuments	0.0889	0.0330	77/56/14.9
D. Simple Traverse Plus Frontsight And Backsight Angles	0.0735	0.0276	77/57/52.4
E. Simple Traverse Plus Frontsight And Backsight Angles And Distances Between Alternate Monuments	0.0727	0.0270	77/56/24.6

Table 4. THE JULY 1989 SURVEY OF THE BOOSTER RING

CONTROL MONUMENT NETWORK

This table gives a summary of the unadjusted observational data, and the results of a least-squares adjustment of the data for the initial control survey of the monument positions in the Booster ring, made in July 1989.

At the time of survey, earth fill construction work lateral to the Booster tunnel was complete, but earth fill construction above the tunnel was incomplete. Magnet support stands and magnet cell assembly modules were not yet in the tunnel.

Angle measurements were made using a Wild Heerbrugg T-2 theodolite. Distance measurements were made using a Hewlett-Packard 5526A laser interferometer, with beam retro-reflector on a rail-mounted travelling microscope, to observe CERN-type monuments grouted vertically into the floor of the Booster tunnel.

The Booster control monument network was joined to the AGS control network at monuments A1 and A2. These two monuments have been chosen as the zero variance reference base for survey error propagation computations [3].

The surveyors were: Francis X. Karl, Donald L. Kazmark Jr., Joseph C. Roecklein, and John S. Sullivan.

Survey monument station coordinates are in inches, referred to the AGS coordinate net, with coordinates along North and East directions.

The column labelled "vtvw" in the tables of angle and distance residuals of the adjusted survey, lists a number which is the square of the residual multiplied by the weight of the observation. A large value of this quantity may indicate a blunder in the observation; the adjustment program is configured to flag excessive vtvw values with the indicator "**" .

STAR☆NET Adjustment Program

Version 2.34 March 1989

Run Date: Thursday, July 27, 10:49:57 1989

Summary of Files Used

Input data file	: C:\STAR\FXDATA\BOOSTER.DAT
Output listing (this file)	: C:\STAR\FXDATA\BOOSTER.lst
Coordinates	: C:\STAR\FXDATA\BOOSTER.pts
Project parameters	: C:\STAR\FXDATA\BOOSTER.prj
Error log	: C:\STAR\FXDATA\BOOSTER.err

Summary of Options Used

Type of Adjustment	: 2D
Input Order for Coordinates	: N,E
Input Order for Angle Stations	: At-From-To
Input Units	: Inches
Print Input Data File	: No
Print Summary of All Input Observations	: Yes
Print Adjustment Summary Each Iteration	: No
Correct Zeniths for Curvature & Refraction	: No
Perform Error Propagation	: Yes
Maximum Number of Iterations	: 8
Convergence Limit for Sigma	: 0.000100
Default Standard Deviation for Coordinates	: 10000000.0000
Default Standard Deviation for Angles	: 4.0000
Default Standard Deviation for Distances	: 0.0010
Default Standard Deviation for Zeniths	: 20.0000
Default Standard Deviation for Azimuths	: 4.0000
Tribrach Centering Error	: 0.0010
EDM Parts Per Million	: 0.0000

Summary of All Unadjusted Input Observations

Number of Stations With Coordinates = 48

Station	*N*	*E*	*S*	*SE*
A1	15242.158	2447.155	1.0×10^{-7}	1.0×10^{-7}
A2	15075.199	2403.250	1.0×10^{-7}	1.0×10^{-7}
A3	14918.920	2332.566	$1.0 \times 10^{+7}$	$1.0 \times 10^{+7}$
A4	14773.566	2250.945	$1.0 \times 10^{+7}$	$1.0 \times 10^{+7}$
A5	14632.120	2152.974	$1.0 \times 10^{+7}$	$1.0 \times 10^{+7}$
A6	14508.669	2030.619	$1.0 \times 10^{+7}$	$1.0 \times 10^{+7}$
A7	14400.693	1906.303	Ditto	Ditto
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		

Station	*N*	*E*	*S*	*SE*
D1	15667.150	-148.156	$1.0 \times 10^{+7}$	$1.0 \times 10^{+7}$
D2	15844.701	-105.752	Ditto	Ditto
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*	*Angle*	*Std Dev*
A1	F7	A2	+195° 07′ 41.50″	0.500
A1	F7	A3	+199° 54′ 49.17″	1.530
A1	F7	F8	+5° 51′ 21.57″	2.680
A2	F8	A1	+4° 46′ 33.13″	1.380
A2	F8	A3	+194° 22′ 41.25″	1.550
A2	F8	A4	+196° 49′ 52.38″	1.650
A3	A1	A2	+4° 48′ 57.75″	2.060
A3	A1	A4	+189° 47′ 42.33″	0.290
A3	A1	A5	+192° 31′ 56.63″	2.560
A4	A2	A3	+2° 31′ 24.13″	1.800
A4	A2	A5	+187° 55′ 1.13″	2.840
A4	A2	A6	+192° 57′ 32.00″	4.760
A5	A3	A4	+2° 39′ 15.50″	2.680
A5	A3	A7	+194° 46′ 8.37″	0.950
A6	A4	A5	+4° 59′ 30.00″	2.380
A6	A4	A7	+189° 16′ 19.75″	11.15
A6	A4	A8	+192° 02′ 51.00″	6.870
A7	A5	A6	+2° 11′ 53.13″	2.020
A7	A5	A8	+187° 37′ 3.50″	1.410
A7	A5	B1	+192° 42′ 48.13″	1.800
A8	A6	A7	+2° 38′ 44.63″	1.490
A8	A6	B1	+192° 49′ 40.25″	1.940
A8	A6	B2	+197° 55′ 46.38″	1.650
B1	A7	A8	+5° 05′ 15.00″	1.870
B1	A7	B2	+195° 17′ 40.12″	2.500
B1	A7	B3	+200° 04′ 42.63″	2.530
B2	A8	B1	+5° 06′ 15.25″	3.230
B2	A8	B3	+194° 42′ 3.63″	1.650
B2	A8	B4	+197° 04′ 31.38″	3.520
B3	B1	B2	+4° 48′ 46.00″	3.340
B3	B1	B4	+189° 38′ 51.50″	3.630
B3	B1	B5	+192° 22′ 30.00″	1.780
B4	B2	B3	+2° 27′ 38.37″	3.640
B4	B2	B5	+187° 48′ 18.63″	1.310
B4	B2	B6	+192° 44′ 41.50″	1.470
B5	B3	B4	+2° 37′ 5.87″	1.440
B5	B3	B6	+192° 29′ 35.12″	2.660
B5	B3	B7	+194° 59′ 36.37″	2.390
B6	B4	B5	+4° 56′ 4.87″	1.110
B6	B4	B7	+190° 03′ 8.63″	2.750
B6	B4	B8	+192° 31′ 41.38″	3.010
B7	B5	B6	+2° 36′ 56.75″	3.400
B7	B5	B8	+187° 27′ 40.50″	1.960
B7	B5	C1	+192° 36′ 16.63″	1.030
B8	B6	B7	+2° 22′ 10.87″	1.930
B8	B6	C1	+192° 39′ 22.25″	1.040
B8	B6	C2	+197° 33′ 29.50″	3.290
C1	B7	B8	+5° 08′ 35.12″	2.720
C1	B7	C2	+194° 57′ 14.50″	3.240
C1	B7	C3	+199° 56′ 2.00″	1.960
C2	B8	C1	+4° 54′ 25.88″	2.930
C2	B8	C3	+194° 51′ 57.37″	1.550
C2	B8	C4	+197° 15′ 48.38″	4.110
C3	C1	C2	+4° 58′ 38.50″	3.700
C3	C1	C4	+189° 52′ 17.38″	4.170
C3	C1	C5	+191° 51′ 41.13″	2.320
C4	C2	C3	+2° 29′ 42.75″	3.570
C4	C2	C5	+186° 18′ 59.63″	3.970
C4	C2	C6	+192° 40′ 34.50″	1.630
C5	C3	C4	+1° 49′ 51.88″	3.950
C5	C3	C6	+195° 06′ 54.50″	3.940
C5	C3	C7	+196° 30′ 41.25″	3.120
C6	C4	C5	+6° 55′ 30.50″	0.870
C6	C4	C7	+189° 43′ 19.67″	1.040
C6	C4	C8	+192° 17′ 56.67″	1.150
C7	C5	C6	+1° 24′ 0.67″	2.020
C7	C5	D1	+191° 52′ 38.67″	0.760
C8	C6	C7	+2° 28′ 23.25″	2.220
C8	C6	D1	+193° 37′ 39.87″	2.500
C8	C6	D2	+197° 48′ 29.50″	4.740
D1	C7	C8	+5° 43′ 33.12″	2.140
D1	C7	D2	+193° 38′ 45.25″	2.020
D1	C7	D3	+199° 03′ 0.63″	3.040
D2	C8	D1	+3° 44′ 19.12″	2.210
D2	C8	D3	+194° 52′ 57.50″	1.080
D2	C8	D4	+197° 10′ 46.75″	3.520
D3	D1	D2	+5° 44′ 22.00″	1.220
D3	D1	D4	+190° 24′ 37.50″	2.420
D3	D1	D5	+192° 02′ 52.12″	1.650
D4	D2	D3	+2° 22′ 22.38″	2.500

At	*From*	*To*	*Angle*	*Std Dev*	*At*	*From*	*To*	*Angle*	*Std Dev*
D4	D2	D5	+185° 34′ 36.00″	2.380	F1	E7	E8	+5° 00′ 54.50″	2.420
D4	D2	D6	+192° 44′ 22.38″	3.540	F1	E7	F2	+195° 13′ 55.00″	4.140
D5	D3	D4	+1° 33′ 57.75″	1.260	F1	E7	F3	+199° 59′ 49.37″	2.020
D5	D3	D6	+195° 58′ 3.00″	2.680	F2	E8	F1	+5° 06′ 19.67″	2.255
D5	D3	D7	+197° 09′ 54.62″	4.210	F2	E8	F3	+194° 38′ 25.00″	5.210
D6	D4	D5	+7° 14′ 19.12″	4.090	F2	E8	F4	+197° 06′ 39.00″	4.880
D6	D4	D7	+189° 41′ 6.50″	2.740	F3	F1	F2	+4° 46′ 9.13″	1.650
D6	D4	D8	+192° 24′ 34.25″	4.630	F3	F1	F4	+189° 49′ 50.50″	2.000
D7	D5	D6	+1° 15′ 3.88″	2.020	F3	F1	F5	+192° 26′ 0.83″	1.160
D7	D5	D8	+186° 34′ 15.50″	1.780	F4	F2	F3	+2° 35′ 26.37″	2.250
D7	D5	E1	+191° 25′ 52.50″	1.780	F4	F2	F5	+187° 40′ 44.13″	1.650
D8	D6	D7	+2° 35′ 44.87″	3.350	F4	F2	F6	+192° 42′ 12.87″	3.470
D8	D6	E1	+192° 19′ 30.62″	4.660	F5	F3	F4	+2° 29′ 12.25″	1.660
D8	D6	E2	+197° 35′ 13.62″	3.640	F5	F3	F6	+192° 30′ 11.50″	3.140
E2	D8	E1	+5° 14′ 27.50″	2.480	F5	F3	F7	+194° 51′ 14.37″	2.430
E2	D8	E3	+194° 58′ 34.13″	2.560	F6	F4	F5	+4° 59′ 31.25″	2.630
E2	D8	E4	+197° 23′ 9.62″	4.210	F6	F4	F7	+189° 48′ 4.75″	2.470
E4	E2	E3	+2° 29′ 27.25″	1.940	F6	F4	F8	+191° 37′ 46.50″	2.080
E4	E2	E5	+184° 13′ 47.17″	1.155	F7	F5	A1	+192° 45′ 3.50″	2.080
E4	E2	E6	+192° 30′ 2.88″	2.390	F7	F5	F6	+2° 27′ 29.00″	2.120
E5	E3	E4	+0° 51′ 45.88″	2.290	F7	F5	F8	+186° 08′ 58.38″	2.810
E5	E3	E6	+197° 00′ 22.12″	2.560	F8	F6	A1	+194° 19′ 17.33″	1.143
E5	E3	E7	+197° 54′ 58.88″	1.930	F8	F6	A2	+198° 49′ 1.00″	3.000
E6	E4	E5	+7° 52′ 25.62″	1.110	F8	F6	F7	+1° 51′ 52.38″	4.250
E6	E4	E7	+189° 45′ 56.37″	2.780	C7	C5	C8	+186° 26′ 58.00″	1.730
E6	E4	E8	+192° 29′ 26.50″	1.870	E1	D7	D8	+4° 52′ 11.60″	2.363
E7	E5	E6	+0° 58′ 53.87″	3.520	E1	D7	E2	+195° 22′ 14.50″	2.784
E7	E5	E8	+186° 18′ 8.25″	2.100	E1	D7	E3	+200° 13′ 3.33″	2.466
E7	E5	F1	+191° 18′ 0.50″	3.340	E3	E1	E2	+4° 53′ 23.13″	3.902
E8	E6	E7	+2° 35′ 42.63″	3.500	E3	E1	E4	+189° 47′ 21.00″	3.968
E8	E6	F1	+192° 36′ 33.38″	1.700	E3	E1	E5	+190° 40′ 3.33″	7.320
E8	E6	F2	+197° 43′ 0.87″	0.750	A5	A3	A6	+192° 41′ 13.00″	0.913

Number of Distance Observations = 48

At	*To*	*Distance*	*Std Dev*	*At*	*To*	*Distance*	*Std Dev*
A1	A2	172.6354	0.001732	D1	D2	182.5348	0.001732
A2	A3	171.5334	0.001732	D2	D3	171.9125	0.001732
A3	A4	166.7048	0.001732	D3	D4	166.3936	0.001732
A4	A5	172.0554	0.001732	D4	D5	174.0225	0.001732
A5	A6	173.8161	0.001732	D5	D6	172.1955	0.001732
A6	A7	164.6560	0.001732	D6	D7	164.9555	0.001732
A7	A8	172.7436	0.001732	D7	D8	173.0577	0.001732
A8	B1	172.9898	0.001732	D8	E1	172.7448	0.001732
B1	B2	172.8961	0.001732	E1	E2	173.4113	0.001732
B2	B3	171.8593	0.001732	E2	E3	171.9040	0.001732
B3	B4	165.8272	0.001732	E3	E4	166.2744	0.001732
B4	B5	172.7508	0.001732	E4	E5	169.3318	0.001732
B5	B6	172.9090	0.001732	E5	E6	177.8019	0.001732
B6	B7	165.3070	0.001732	E6	E7	164.8907	0.001732
B7	B8	172.6537	0.001732	E7	E8	173.1204	0.001732
B8	C1	172.6372	0.001732	E8	F1	172.4629	0.001732
C1	C2	172.5081	0.001732	F1	F2	172.5724	0.001732
C2	C3	172.5892	0.001732	F2	F3	172.5248	0.001732
C3	C4	165.8166	0.001732	F3	F4	164.6021	0.001732
C4	C5	180.2481	0.001732	F4	F5	172.3457	0.001732
C5	C6	165.6092	0.001732	F5	F6	173.4751	0.001732
C6	C7	165.3072	0.001732	F6	F7	165.8925	0.001732
C7	C8	172.1678	0.001732	F7	F8	162.7263	0.001732
C8	D1	163.2421	0.001732	F8	A1	183.3600	0.001732

Network Solution

Number of condition equations = 192
Number of unknowns = 92
Degrees of freedom in network = 100

Solution has converged in 4 iterations

Final Results

Updated Coordinates

Station	*N*	*E*	*Station*	*N*	*E*
A1	15242.158	2447.155	C7	15332.925	-146.827
F7	15586.201	2444.785	C8	15504.255	-163.790
A2	15075.199	2403.250	D1	15666.746	-148.145
A3	14918.907	2332.564	D2	15844.296	-105.782
F8	15424.686	2464.607	D3	16000.650	-34.316
A4	14773.549	2250.946	D4	16145.850	46.948
A5	14632.105	2152.983	D5	16292.719	140.292
A6	14508.641	2030.637	D6	16410.508	265.899
A7	14400.660	1906.332	D7	16518.102	390.934
A8	14300.200	1765.804	D8	16618.330	532.013
B1	14226.060	1609.507	E1	16693.139	687.720
B2	14180.815	1442.636	E2	16738.489	855.096
B3	14164.122	1271.589	E3	16754.738	1026.230
B4	14161.983	1105.776	E4	16756.259	1192.498
B5	14175.856	933.583	E5	16752.667	1361.792
B6	14219.092	766.167	E6	16699.616	1531.495
B7	14274.540	610.437	E7	16645.250	1687.165
B8	14345.983	453.259	E8	16573.259	1844.607
C1	14444.336	311.377	F1	16475.363	1986.593
C2	14565.335	188.421	F2	16353.765	2109.048
C3	14705.841	88.197	F3	16213.598	2209.637
C4	14848.556	3.772	F4	16071.923	2293.434
C5	15009.462	-77.460	F5	15916.384	2367.669
C6	15170.494	-116.124	F6	15749.216	2414.019

Statistical Summary

Sum of Weighted Residuals (Distances)	= 0.45311
Sum of Weighted Residuals (Angles)	= 86.605
Sum of Weighted Residuals (Azimuths)	= 0.00000
Sum of Weighted Residuals (Coords)	= 5.4421×10^{-9}
Sum of Weighted Residuals (Total)	= 87.059
Change from Previous Iteration	= 3.8864×10^{-9}
Standard Error of Unit Weight	= 0.93305

Adjustment passes the Chi Squared test at 5% level

Residuals in Observations After Adjustment

Residuals in Angles

At	*From*	*To*	*Residual*	*Adj Angle*	*vtwv*
A1	F7	A2	-0° 00′ 0.10″	+195° 07′ 41.40″	0.04
A1	F7	A3	+0° 00′ 0.35″	+199° 54′ 49.52″	0.05
A1	F7	F8	+0° 00′ 0.67″	+5° 51′ 22.24″	0.06
A2	F8	A1	+0° 00′ 0.33″	+4° 46′ 33.46″	0.06
A2	F8	A3	-0° 00′ 0.60″	+194° 22′ 40.65″	0.15
A2	F8	A4	+0° 00′ 1.83″	+196° 49′ 54.21″	1.23
A3	A1	A2	+0° 00′ 1.33″	+4° 48′ 59.08″	0.42
A3	A1	A4	-0° 00′ 0.13″	+189° 47′ 42.20″	0.21
A3	A1	A5	+0° 00′ 4.32″	+192° 32′ 0.95″	2.85
A4	A2	A3	+0° 00′ 5.43″	+2° 31′ 29.56″	9.11
A4	A2	A5	-0° 00′ 0.86″	+187° 55′ 0.27″	0.09
A4	A2	A6	+0° 00′ 1.04″	+192° 57′ 33.04″	0.05
A5	A3	A4	-0° 00′ 3.55″	+2° 39′ 11.95″	1.75
A5	A3	A7	+0° 00′ 0.27″	+194° 46′ 8.64″	0.08
A6	A4	A5	-0° 00′ 1.57″	+4° 59′ 28.43″	0.44
A6	A4	A7	-0° 00′ 3.16″	+189° 16′ 16.59″	0.08
A6	A4	A8	-0° 00′ 4.04″	+192° 02′ 46.96″	0.35
A7	A5	A6	-0° 00′ 0.45″	+2° 11′ 52.68″	0.05
A7	A5	A8	+0° 00′ 1.84″	+187° 37′ 5.34″	1.70
A7	A5	B1	-0° 00′ 0.63″	+192° 42′ 47.50″	0.12
A8	A6	A7	-0° 00′ 2.33″	+2° 38′ 42.30″	2.45
A8	A6	B1	+0° 00′ 0.19″	+192° 49′ 40.44″	0.01
A8	A6	B2	+0° 00′ 1.10″	+197° 55′ 47.48″	0.44
B1	A7	A8	+0° 00′ 0.98″	+5° 05′ 15.98″	0.27
B1	A7	B2	-0° 00′ 0.09″	+195° 17′ 40.03″	0.00
B1	A7	B3	-0° 00′ 0.63″	+200° 04′ 41.99″	0.06
B2	A8	B1	+0° 00′ 1.77″	+5° 06′ 17.02″	0.30
B2	A8	B3	+0° 00′ 1.47″	+194° 42′ 5.10″	0.79
B2	A8	B4	+0° 00′ 1.08″	+197° 04′ 32.45″	0.09
B3	B1	B2	+0° 00′ 0.12″	+4° 48′ 46.12″	0.00
B3	B1	B4	+0° 00′ 0.42″	+189° 38′ 51.92″	0.01
B3	B1	B5	-0° 00′ 0.43″	+192° 22′ 29.57″	0.06
B4	B2	B3	+0° 00′ 0.07″	+2° 27′ 38.45″	0.00
B4	B2	B5	+0° 00′ 1.39″	+187° 48′ 20.01″	1.12
B4	B2	B6	+0° 00′ 0.93″	+192° 44′ 42.43″	0.40
B5	B3	B4	-0° 00′ 1.96″	+2° 37′ 3.91″	1.85
B5	B3	B6	-0° 00′ 2.71″	+192° 29′ 32.41″	1.04

At	*From*	*To*	*Residual*	*Adj Angle*	*vtwv*
B5	B3	B7	+0° 00′ 1.07″	+194° 59′ 37.45″	0.20
B6	B4	B5	+0° 00′ 1.21″	+4° 56′ 6.08″	1.18
B6	B4	B7	+0° 00′ 1.92″	+190° 03′ 10.55″	0.49
B6	B4	B8	+0° 00′ 0.23″	+192° 31′ 41.60″	0.01
B7	B5	B6	+0° 00′ 2.69″	+2° 36′ 59.44″	0.62
B7	B5	B8	+0° 00′ 1.65″	+187° 27′ 42.15″	0.71
B7	B5	C1	-0° 00′ 0.06″	+192° 36′ 16.57″	0.00
B8	B6	B7	+0° 00′ 0.78″	+2° 22′ 11.66″	0.16
B8	B6	C1	-0° 00′ 0.01″	+192° 39′ 22.24″	0.00
B8	B6	C2	+0° 00′ 4.96″	+197° 33′ 34.46″	2.27
C1	B7	B8	+0° 00′ 1.04″	+5° 08′ 36.17″	0.15
C1	B7	C2	-0° 00′ 0.63″	+194° 57′ 13.87″	0.04
C1	B7	C3	+0° 00′ 2.08″	+199° 56′ 4.08″	1.13
C2	B8	C1	-0° 00′ 0.39″	+4° 54′ 25.49″	0.02
C2	B8	C3	+0° 00′ 0.09″	+194° 51′ 57.46″	0.00
C2	B8	C4	+0° 00′ 1.60″	+197° 15′ 49.97″	0.15
C3	C1	C2	+0° 00′ 3.26″	+4° 58′ 41.76″	0.78
C3	C1	C4	+0° 00′ 2.20″	+189° 52′ 19.58″	0.28
C3	C1	C5	+0° 00′ 1.95″	+191° 51′ 43.07″	0.70
C4	C2	C3	+0° 00′ 2.56″	+2° 29′ 45.31″	0.51
C4	C2	C5	-0° 00′ 1.08″	+186° 18′ 58.55″	0.07
C4	C2	C6	+0° 00′ 0.88″	+192° 40′ 35.38″	0.29
C5	C3	C4	-0° 00′ 2.13″	+1° 49′ 49.74″	0.29
C5	C3	C6	+0° 00′ 2.40″	+195° 06′ 56.90″	0.37
C5	C3	C7	+0° 00′ 6.34″	+196° 30′ 47.59″	4.13
C6	C4	C5	-0° 00′ 0.17″	+6° 55′ 30.33″	0.04
C6	C4	C7	+0° 00′ 1.23″	+189° 43′ 20.90″	1.40
C6	C4	C8	-0° 00′ 1.70″	+192° 17′ 54.97″	2.18
C7	C5	C6	-0° 00′ 0.78″	+1° 23′ 59.88″	0.15
C7	C5	D1	+0° 00′ 0.73″	+191° 52′ 39.40″	0.93
C8	C6	C7	+0° 00′ 1.01″	+2° 28′ 24.26″	0.21
C8	C6	D1	-0° 00′ 1.23″	+193° 37′ 38.64″	0.24
C8	C6	D2	+0° 00′ 2.31″	+197° 48′ 31.81″	0.24
D1	C7	C8	+0° 00′ 0.07″	+5° 43′ 33.20″	0.00
D1	C7	D2	+0° 00′ 0.84″	+193° 38′ 46.09″	0.17
D1	C7	D3	+0° 00′ 1.51″	+199° 03′ 2.13″	0.25
D2	C8	D1	+0° 00′ 0.60″	+3° 44′ 19.72″	0.07
D2	C8	D3	+0° 00′ 0.41″	+194° 52′ 57.91″	0.15
D2	C8	D4	+0° 00′ 1.24″	+197° 10′ 47.99″	0.12
D3	D1	D2	+0° 00′ 0.15″	+5° 44′ 22.15″	0.01
D3	D1	D4	-0° 00′ 0.75″	+190° 24′ 36.76″	0.09
D3	D1	D5	+0° 00′ 0.76″	+192° 02′ 52.88″	0.21

At	From	To	Residual	Adj Angle	vtwv
D4	D2	D3	+0° 00′ 2.15″	+2° 22′ 24.53″	0.74
D4	D2	D5	+0° 00′ 2.25″	+185° 34′ 38.25″	0.89
D4	D2	D6	+0° 00′ 1.18″	+192° 44′ 23.56″	0.11
D5	D3	D4	-0° 00′ 0.16″	+1° 33′ 57.59″	0.02
D5	D3	D6	+0° 00′ 0.17″	+195° 58′ 3.17″	0.00
D5	D3	D7	-0° 00′ 0.34″	+197° 09′ 54.29″	0.01
D6	D4	D5	+0° 00′ 1.14″	+7° 14′ 20.27″	0.08
D6	D4	D7	+0° 00′ 5.26″	+189° 41′ 11.76″	3.68
D6	D4	D8	+0° 00′ 4.58″	+192° 24′ 38.83″	0.98
D7	D5	D6	-0° 00′ 3.50″	+1° 15′ 0.37″	3.00
D7	D5	D8	-0° 00′ 0.46″	+186° 34′ 15.04″	0.07
D7	D5	E1	+0° 00′ 0.67″	+191° 25′ 53.17″	0.14
D8	D6	D7	+0° 00′ 2.72″	+2° 35′ 47.60″	0.66
D8	D6	E1	+0° 00′ 5.01″	+192° 19′ 35.63″	1.15
D8	D6	E2	+0° 00′ 1.38″	+197° 35′ 15.01″	0.14
E2	D8	E1	-0° 00′ 1.13″	+5° 14′ 26.37″	0.21
E2	D8	E3	+0° 00′ 2.17″	+194° 58′ 36.30″	0.72
E2	D8	E4	-0° 00′ 0.19″	+197° 23′ 9.43″	0.00
E4	E2	E3	-0° 00′ 0.29″	+2° 29′ 26.96″	0.02
E4	E2	E5	+0° 00′ 1.06″	+184° 13′ 48.23″	0.84
E4	E2	E6	-0° 00′ 0.89″	+192° 30′ 1.98″	0.14
E5	E3	E4	-0° 00′ 3.76″	+0° 51′ 42.12″	2.69
E5	E3	E6	-0° 00′ 0.15″	+197° 00′ 21.97″	0.00
E5	E3	E7	-0° 00′ 0.04″	+197° 54′ 58.84″	0.00
E6	E4	E5	+0° 00′ 0.47″	+7° 52′ 26.10″	0.18
E6	E4	E7	+0° 00′ 0.07″	+189° 45′ 56.44″	0.00
E6	E4	E8	+0° 00′ 0.90″	+192° 29′ 27.40″	0.23
E7	E5	E6	-0° 00′ 0.40″	+0° 58′ 53.48″	0.01
E7	E5	E8	+0° 00′ 0.43″	+186° 18′ 8.68″	0.04
E7	E5	F1	-0° 00′ 2.68″	+191° 17′ 57.82″	0.64
E8	E6	E7	+0° 00′ 1.62″	+2° 35′ 44.24″	0.21
E8	E6	F1	-0° 00′ 2.12″	+192° 36′ 31.26″	1.55
E8	E6	F2	+0° 00′ 0.52″	+197° 43′ 1.39″	0.47
F1	E7	E8	+0° 00′ 3.37″	+5° 00′ 57.87″	1.94
F1	E7	F2	-0° 00′ 8.55″	+195° 13′ 46.45″	4.27
F1	E7	F3	+0° 00′ 0.12″	+199° 59′ 49.50″	0.00
F2	E8	F1	-0° 00′ 1.23″	+5° 06′ 18.44″	0.30
F2	E8	F3	+0° 00′ 4.31″	+194° 38′ 29.31″	0.69
F2	E8	F4	+0° 00′ 7.13″	+197° 06′ 46.13″	2.14
F3	F1	F2	-0° 00′ 1.31″	+4° 46′ 7.82″	0.63
F3	F1	F4	-0° 00′ 0.54″	+189° 49′ 49.96″	0.07
F3	F1	F5	-0° 00′ 0.22″	+192° 26′ 0.62″	0.03

At	*From*	*To*	*Residual*	*Adj Angle*	*vtwv*
F4	F2	F3	-0° 00′ 1.06″	+2° 35′ 25.32″	0.22
F4	F2	F5	+0° 00′ 1.21″	+187° 40′ 45.34″	0.54
F4	F2	F6	+0° 00′ 2.58″	+192° 42′ 15.45″	0.55
F5	F3	F4	-0° 00′ 2.89″	+2° 29′ 9.36″	3.03
F5	F3	F6	+0° 00′ 0.03″	+192° 30′ 11.53″	0.00
F5	F3	F7	+0° 00′ 0.17″	+194° 51′ 14.54″	0.00
F6	F4	F5	+0° 00′ 0.81″	+4° 59′ 32.06″	0.09
F6	F4	F7	+0° 00′ 0.38″	+189° 48′ 5.13″	0.02
F6	F4	F8	-0° 00′ 1.23″	+191° 37′ 45.27″	0.35
F7	F5	A1	+0° 00′ 1.55″	+192° 45′ 5.05″	0.56
F7	F5	F6	+0° 00′ 1.06″	+2° 27′ 30.06″	0.25
F7	F5	F8	+0° 00′ 0.04″	+186° 08′ 58.42″	0.00
F8	F6	A1	-0° 00′ 0.25″	+194° 19′ 17.09″	0.05
F8	F6	A2	+0° 00′ 1.79″	+198° 49′ 2.79″	0.36
F8	F6	F7	-0° 00′ 4.16″	+1° 51′ 48.22″	0.96
C7	C5	C8	+0° 00′ 0.21″	+186° 26′ 58.21″	0.02
E1	D7	D8	-0° 00′ 1.69″	+4° 52′ 9.91″	0.51
E1	D7	E2	+0° 00′ 1.15″	+195° 22′ 15.65″	0.17
E1	D7	E3	+0° 00′ 0.60″	+200° 13′ 3.93″	0.06
E3	E1	E2	-0° 00′ 1.47″	+4° 53′ 21.65″	0.14
E3	E1	E4	+0° 00′ 0.74″	+189° 47′ 21.74″	0.03
E3	E1	E5	-0° 00′ 2.43″	+190° 40′ 0.90″	0.11
A5	A3	A6	+0° 00′ 0.15″	+192° 41′ 13.15″	0.03

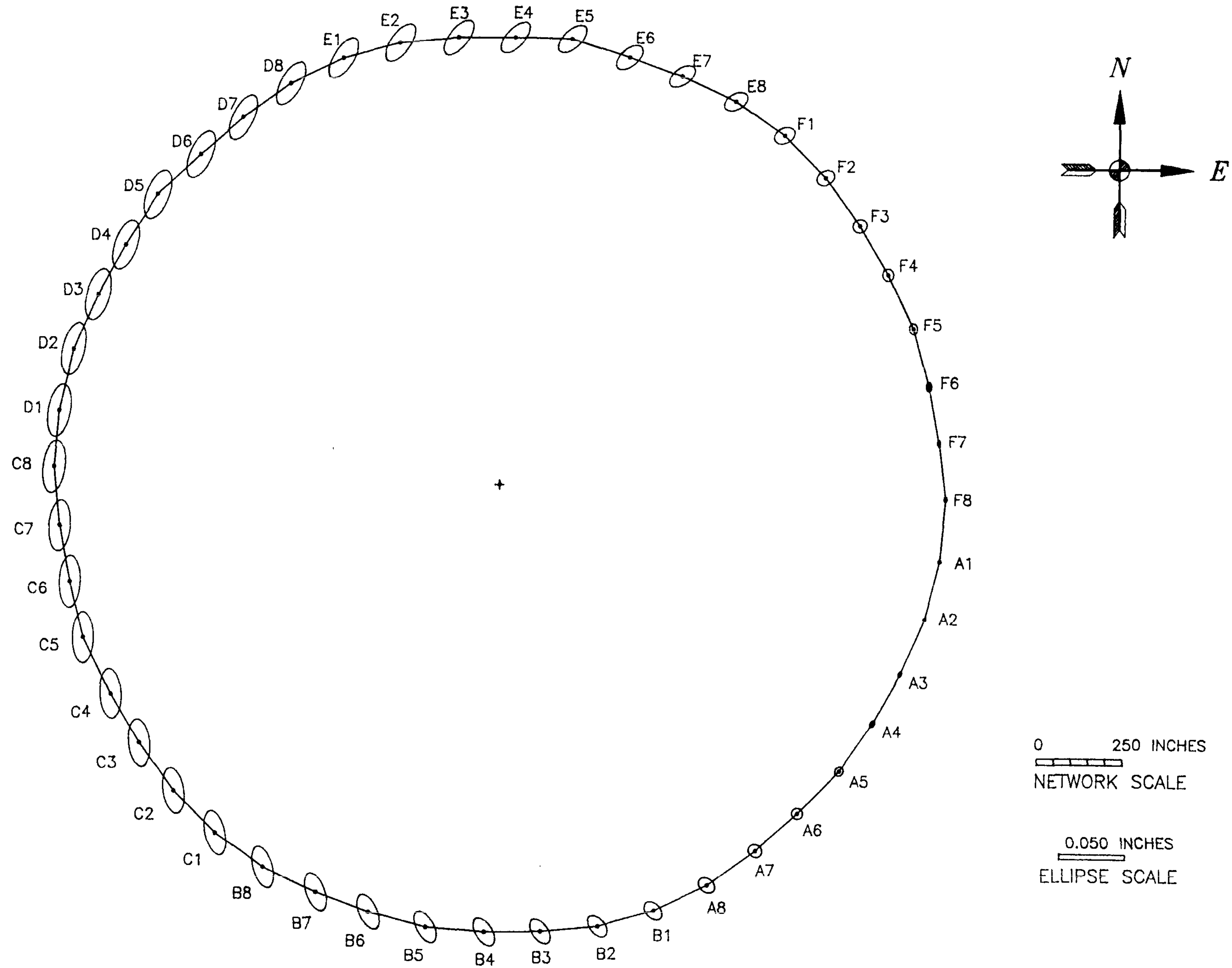
Residuals in Distances

At	*To*	*Residual*	*Adj Dist*	*vtwv*	*At*	*To*	*Residual*	*Adj Dist*	*vtwv*
A1	A2	0.0001	172.6355	0.00	D1	D2	-0.0001	182.5347	0.00
A2	A3	-0.0001	171.5333	0.00	D2	D3	-0.0001	171.9123	0.01
A3	A4	0.0002	166.7050	0.02	D3	D4	-0.0000	166.3935	0.00
A4	A5	0.0001	172.0554	0.00	D4	D5	-0.0003	174.0222	0.03
A5	A6	-0.0000	173.8161	0.00	D5	D6	0.0002	172.1957	0.01
A6	A7	0.0001	164.6560	0.00	D6	D7	-0.0001	164.9554	0.00
A7	A8	-0.0001	172.7435	0.00	D7	D8	0.0001	173.0577	0.00
A8	B1	-0.0000	172.9898	0.00	D8	E1	-0.0000	172.7448	0.00
B1	B2	0.0000	172.8961	0.00	E1	E2	0.0001	173.4114	0.00
B2	B3	-0.0002	171.8591	0.01	E2	E3	-0.0000	171.9040	0.00
B3	B4	0.0001	165.8273	0.00	E3	E4	0.0001	166.2746	0.01
B4	B5	-0.0003	172.7505	0.03	E4	E5	-0.0001	169.3316	0.01
B5	B6	-0.0000	172.9089	0.00	E5	E6	0.0003	177.8022	0.04
B6	B7	-0.0001	165.3068	0.01	E6	E7	0.0001	164.8908	0.00
B7	B8	-0.0002	172.6535	0.01	E7	E8	0.0001	173.1205	0.00
B8	C1	0.0000	172.6372	0.00	E8	F1	0.0003	172.4632	0.03
C1	C2	-0.0002	172.5078	0.02	F1	F2	0.0002	172.5726	0.01
C2	C3	-0.0002	172.5890	0.01	F2	F3	0.0000	172.5248	0.00
C3	C4	-0.0002	165.8164	0.01	F3	F4	0.0002	164.6023	0.02
C4	C5	-0.0000	180.2481	0.00	F4	F5	0.0001	172.3459	0.01
C5	C6	-0.0003	165.6089	0.04	F5	F6	0.0001	173.4751	0.00
C6	C7	-0.0002	165.3069	0.02	F6	F7	0.0002	165.8927	0.01
C7	C8	0.0001	172.1679	0.00	F7	F8	0.0003	162.7266	0.02
C8	D1	-0.0004	163.2417	0.04	F8	A1	-0.0000	183.3599	0.00

Error Propagation

Station Coordinate Standard Deviations

Station	*N*	*E*	*Station*	*N*	*E*
A1	0.000000	0.000000	C7	0.015969	0.006811
F7	0.002422	0.000793	C8	0.016075	0.007217
A2	0.000000	0.000000	D1	0.016041	0.007519
A3	0.001618	0.001154	D2	0.015885	0.007745
F8	0.001717	0.000777	D3	0.015622	0.008096
A4	0.002242	0.001754	D4	0.015315	0.008378
A5	0.002852	0.002746	D5	0.014966	0.008726
A6	0.003445	0.003600	D6	0.014398	0.008872
A7	0.004007	0.004344	D7	0.013809	0.009025
A8	0.004714	0.005100	D8	0.013216	0.009221
B1	0.005579	0.005745	E1	0.012416	0.009358
B2	0.006493	0.006230	E2	0.011650	0.009392
B3	0.007499	0.006558	E3	0.010702	0.009305
B4	0.008453	0.006798	E4	0.009520	0.009151
B5	0.009585	0.006962	E5	0.008525	0.008933
B6	0.010665	0.006992	E6	0.007515	0.008461
B7	0.011548	0.006990	E7	0.006612	0.007929
B8	0.012557	0.006944	E8	0.005733	0.007264
C1	0.013501	0.006867	F1	0.005120	0.006509
C2	0.014189	0.006770	F2	0.004655	0.005608
C3	0.014798	0.006723	F3	0.004150	0.004494
C4	0.015193	0.006666	F4	0.003765	0.003513
C5	0.015603	0.006613	F5	0.003392	0.002561
C6	0.015801	0.006626	F6	0.002949	0.001730



JULY 1989 BOOSTER CONTROL MONUMENT SURVEY
MONUMENT COORDINATE ERROR ELLIPSES
95% CONFIDENCE REGION

Station Coordinate Error Ellipses
Confidence Region = 95%

Station	*a*	*b*	*Theta*	*Station*	*a*	*b*	*Theta*
A1	0.000000	0.000000	0° 00′ 0.00	C7	0.039185	0.016411	85° 19′ 14.29″
F7	0.005927	0.001941	90° 27′ 14.34″	C8	0.039628	0.016995	82° 17′ 22.19″
A2	0.000000	0.000000	0° 00′ 0.00	D1	0.039790	0.017203	79° 31′ 8.89
A3	0.004217	0.002421	65° 05′ 37.72″	D2	0.039751	0.017031	76° 36′ 39.15″
F8	0.004206	0.001890	86° 48′ 36.35″	D3	0.039460	0.017224	73° 59′ 37.15″
A4	0.005955	0.003613	60° 41′ 38.39″	D4	0.039101	0.017200	71° 28′ 39.21″
A5	0.007281	0.006390	53° 27′ 8.34	D5	0.038692	0.017319	68° 50′ 33.46″
A6	0.008910	0.008322	155° 05′ 18.36″	D6	0.037873	0.016678	65° 52′ 31.15″
A7	0.011126	0.009237	147° 59′ 48.15″	D7	0.037062	0.015999	62° 54′ 37.68″
A8	0.013695	0.010061	142° 37′ 5.31	D8	0.036169	0.015711	60° 11′ 19.04″
B1	0.016355	0.010795	137° 08′ 36.89″	E1	0.034890	0.015172	56° 54′ 46.48″
B2	0.018832	0.011410	132° 26′ 37.95″	E2	0.033477	0.014838	54° 12′ 31.28″
B3	0.021226	0.011986	127° 31′ 13.91″	E3	0.031555	0.014440	51° 08′ 12.20″
B4	0.023403	0.012526	123° 37′ 29.54″	E4	0.029233	0.013767	46° 46′ 38.63″
B5	0.025855	0.013108	119° 13′ 18.69″	E5	0.027100	0.013364	42° 47′ 52.24″
B6	0.028050	0.013675	114° 49′ 31.28″	E6	0.024535	0.012839	39° 01′ 42.67″
B7	0.029871	0.014097	111° 34′ 42.23″	E7	0.022041	0.012344	34° 56′ 43.69″
B8	0.031913	0.014643	107° 41′ 36.78″	E8	0.019321	0.011808	29° 41′ 17.96″
C1	0.033781	0.015254	103° 31′ 26.35″	F1	0.016831	0.011287	25° 49′ 23.91″
C2	0.035154	0.015626	100° 03′ 22.54″	F2	0.014249	0.010725	24° 09′ 25.62″
C3	0.036384	0.016065	96° 13′ 38.60″	F3	0.011158	0.009978	22° 14′ 58.69″
C4	0.037239	0.016170	93° 39′ 53.61″	F4	0.009215	0.008595	92° 52′ 13.62″
C5	0.038184	0.016175	90° 44′ 9.31	F5	0.008320	0.006242	95° 58′ 15.40″
C6	0.038682	0.016171	88° 05′ 43.97″	F6	0.007229	0.004212	94° 04′ 43.10″

ADDENDUM

Calculated Modifications Of Booster Dipole Magnet Position And Survey Marker Coordinates Due To The Effects Of Magnet End Fringe Fields

The positions of the dipole survey marker coordinates tabulated in Booster Technical Note No. 119 [1], and also appearing in Table 1 of this report, were computed under the assumption that the fringe magnetic field of the dipole magnets acts as a hard edged, that is sharp cutoff, field one half magnet gap width in extension. A detailed analysis of bending magnet fringing field effects, by H.A.Enge [5],indicates that the effective length of the fringe field is longer than the value assumed, and the dipole bending magnet position should be offset laterally, parallel to its nominal position, to compensate for the finite fall gradient of the fringe field at each end of the magnet.

The magnet offsets were calculated [6] using Enge's analysis. The calculation shows that the dipoles should be moved by 0.007 inches laterally inwards.

The appended Table 5 tabulates dipole survey marker coordinates which have been laterally offset by that amount from the coordinates listed in Table 1 of this report.

Additional References

[5] H.A. Enge, Effect of Extended Fringing Fields On Ion-Focusing Properties Of Deflecting Magnets, *Rev. Sci. Instr.* **35**, 278 (1964).

[6] M.A. Goldman , Booster Dipole Magnet Half-Cell Alignment Including Magnet Fringe Field Effects. BNL AD *Booster Technical Note* (To Appear, 1990).

Table 5. MODIFIED DIPOLE MAGNET SURVEY MARKER

COORDINATES

Modified Ideal Dipole Survey Marker Coordinates Are Calculated Assuming That The Line Joining The Two Dipole Survey Marker Points On Each Dipole Magnet Is Moved Inboard By 0.007 Inch Parallel To Itself, To Compensate For The Gradual Falloff Of The Magnet Fringe Field, Compared To The Marker Point Positions Of Table 1.

Names Describing The Survey Markers Follow The Revised Convention Of BNL Booster Technical Note No. 142.

Coordinates Are In [Inches] On The AGS Grid

	North	East
MONUMENT: BRI.MON.A1		
Survey Points		
SRVPT.DA1.US	15217.6542	2399.4705
SRVPT.DA1.DS	15129.3317	2377.0095
MONUMENT: BRI.MON.A2		
Survey Points		
SRVPT.DA2.US	15059.2317	2352.5038
SRVPT.DA2.DS	14976.1514	2315.0467

	North	East
MONUMENT: BRI.MON.A4		
Survey Points		
SRVPT.DA4.US	14766.9978	2197.8267
SRVPT.DA4.DS	14691.6840	2146.51180
MONUMENT: BRI.MON.A5		
Survey Points		
SRVPT.DA5.US	14634.1931	2099.5090
SRVPT.DA5.DS	14568.9340	2035.8950
MONUMENT: BRI.MON.A7		
Survey Points		
SRVPT.DA7.US	14412.4856	1854.2099
SRVPT.DA7.DS	14359.2644	1780.2309
MONUMENT: BRI.MON.A8		
Survey Points		
SRVPT.DA8.US	14321.3164	1716.3994
SRVPT.DA8.DS	14281.7501	1634.3025
MONUMENT: BRI.MON.B1		
Survey Points		
SRVPT.DB1.US	14255.4628	1564.8510
SRVPT.DB1.DS	14230.7537	1477.1308

	North	East
MONUMENT: BRI.MON.B2		
Survey Points		
SRVPT.DB2.US	14216.9260	1404.1697
SRVPT.DB2.DS	14207.8246	1313.4915
MONUMENT: BRI.MON.B4		
Survey Points		
SRVPT.DB4.US	14204.7633	1073.7492
SRVPT.DB4.DS	14211.5464	982.8681
MONUMENT: BRI.MON.B5		
Survey Points		
SRVPT.DB5.US	14223.5069	909.5777
SRVPT.DB5.DS	14245.9680	821.2552
MONUMENT: BRI.MON.B7		
Survey Points		
SRVPT.DB7.US	14325.0880	594.9242
SRVPT.DB7.DS	14362.5452	511.84380
MONUMENT: BRI.MON.B8		
Survey Points		
SRVPT.DB8.US	14398.8510	447.0640
SRVPT.DB8.DS	14450.1658	371.7502

	North	East
MONUMENT: BRI.MON.C1		
Survey Points		
SRVPT.DC1.US	14497.1688	314.2591
SRVPT.DC1.DS	14560.7822	249.0002
MONUMENT: BRI.MON.C2		
Survey Points		
SRVPT.DC2.US	14617.0545	200.5445
SRVPT.DC2.DS	14691.0335	147.3234
MONUMENT: BRI.MON.C4		
Survey Points		
SRVPT.DC4.US	14897.1257	24.8011
SRVPT.DC4.DS	14979.2225	-14.7652
MONUMENT: BRI.MON.C5		
Survey Points		
SRVPT.DC5.US	15048.6740	-41.0525
SRVPT.DC5.DS	15136.3942	-65.7617
MONUMENT: BRI.MON.C7		
Survey Points		
SRVPT.DC7.US	15371.9627	-110.4071
SRVPT.DC7.DS	15462.6410	-119.5085

	North	East
MONUMENT: BRI.MON.C8		
Survey Points		
SRVPT.DC8.US	15536.8952	-120.4566
SRVPT.DC8.DS	15627.7759	-113.6736
MONUMENT: BRI.MON.D1		
Survey Points		
SRVPT.DD1.US	15701.0662	-101.7133
SRVPT.DD1.DS	15789.3888	-79.25200
MONUMENT: BRI.MON.D2		
Survey Points		
SRVPT.DD2.US	15859.4887	-54.7467
SRVPT.DD2.DS	15942.5691	-17.2895
MONUMENT: BRI.MON.D4		
Survey Points		
SRVPT.DD4.US	16151.7227	99.9305
SRVPT.DD4.DS	16227.0365	151.2453
MONUMENT: BRI.MON.D5		
Survey Points		
SRVPT.DD5.US	16284.5276	198.2484
SRVPT.DD5.DS	16349.7865	261.8617

	North	East
MONUMENT: BRI.MON.D7		
Survey Points		
SRVPT.DD7.US	16506.2349	443.5472
SRVPT.DD7.DS	16559.4560	517.5262
MONUMENT: BRI.MON.D8		
Survey Points		
SRVPT.DD8.US	16597.4041	581.3579
SRVPT.DD8.DS	16636.9703	663.4546
MONUMENT: BRI.MON.E1		
Survey Points		
SRVPT.DE1.US	16663.2576	732.9061
SRVPT.DE1.DS	16687.9668	820.6264
MONUMENT: BRI.MON.E2		
Survey Points		
SRVPT.DE2.US	16701.7945	893.5873
SRVPT.DE2.DS	16710.8959	984.2657
MONUMENT: BRI.MON.E4		
Survey Points		
SRVPT.DE4.US	16713.9571	1224.0080
SRVPT.DE4.DS	16707.1741	1314.88910

	North	East
MONUMENT: BRI.MON.E5		
Survey Points		
SRVPT.DE5.US	16695.2138	1388.1794
SRVPT.DE5.DS	16672.7524	1476.5019
MONUMENT: BRI.MON.E7		
Survey Points		
SRVPT.DE7.US	16593.6324	1702.8330
SRVPT.DE7.DS	16556.1753	1785.9133
MONUMENT: BRI.MON.E8		
Survey Points		
SRVPT.DE8.US	16519.8695	1850.6931
SRVPT.DE8.DS	16468.5547	1926.0069
MONUMENT: BRI.MON.F1		
Survey Points		
SRVPT.DF1.US	16421.5516	1983.4980
SRVPT.DF1.DS	16357.9382	2048.7569
MONUMENT: BRI.MON.F2		
Survey Points		
SRVPT.DF2.US	16301.6660	2097.2127
SRVPT.DF2.DS	16227.6870	2150.4338

	North	East
MONUMENT: BRI.MON.F4		
Survey Points		
SRVPT.DF4.US	16021.5948	2272.9561
SRVPT.DF4.DS	15939.4979	2312.5223
MONUMENT: BRI.MON.F5		
Survey Points		
SRVPT.DF5.US	15870.0464	2338.8096
SRVPT.DF5.DS	15782.3262	2363.5187
MONUMENT: BRI.MON.F7		
Survey Points		
SRVPT.DF7.US	15546.7577	2408.1643
SRVPT.DF7.DS	15456.0795	2417.26560
MONUMENT: BRI.MON.F8		
Survey Points		
SRVPT.DF8.US	15381.8257	2418.2138
SRVPT.DF8.DS	15290.9446	2411.4308