AD/RHIC/RD–43

RHIC PROJECT

Brookhaven National Laboratory

The RHIC Reference Geometry

M. A. Goldman

August 1992

THE RHIC REFERENCE GEOMETRY

M. A. Goldman August 12, 1992

The spatial location and orientation of RHIC is described by a machine reference geometry, defining the geometric configuration of the machine, and by an embedding of this configuration into a geodetic reference network.

The machine's reference geometry, and its embedding into the geodetic framework, are described in the paragraphs which follow.

A. The RHIC Machine Reference Geometry

1. The locations of the six RHIC trajectory crossing points, X02, X04, ..., X12, at the 2, 4, ..., 12 o'clock positions generate the RHIC geometry.

   These six crossing points lie exactly at the vertices of a plane regular hexagon.

2. The plane defined by the six crossing points is called the "RHIC median plane", or "machine plane", M .

   The geometric center of this regular hexagon, also in plane M , is called the "machine center point" or "ring center point", MCP .

3. The common distance, Rx , between the machine center point MCP and each of the trajectory crossing points X02, ..., X12 is to be Rx = 590.581658 meters .

4. Positions of fiducial reference markers, locating component parts of the machine with respect to the RHIC configuration, are described by an orthogonal cartesian reference frame: (U,V,W) .

5. The straight line passing through the three points X06, MCP, X12 is defined to be the V-axis; the ray directed from MCP to X12 is defined to be the "positive V-axis".

   The line normal to the machine plane, at the machine center center point, MCP , is defined to be the W-axis.

   The machine plane, M , is embedded in space so the positive W-axis is directed upward, along the local gravity vertical at MCP.

   That is, the machine plane passes precisely horizontally through the machine center point.

6. The origin of the (U,V,W) frame lies at the machine center point, MCP. The positive V- and W-axes are defined above. The positive U-axis is directed so that the positive U-, V-, W-axes in that order form a right handed orthogonal triad.

Seen from above the median plane: the positive U-axis points from machine center point MCP to 3 o'clock; the positive V-axis points from MCP to 12 o'clock; the positive W-axis points upwards along the local gravity vertical at MCP .

7. The axis of the AGS-to-RHIC beam transfer line, just before entry to the ring-selector switching magnet, lies in the (V,W)-plane, defined by the V- and W-axes.

   [This requirement defines the orientation of the hexagon of trajectory crossing points, spatially. The positive v-axis lies nominally at a 2 degree azimuth to BNL grid North; an azimuth angle 1.999898 degree has been given in: G.F.Dell ISA Tech. Note 398, July 1982; this azimuth agrees with the azimuth derived from the ratio of the Northing and Easting increments from points 3 to 33 of Ammann & Whitney construction drawing C-2, August 15, 1980.]

8. The elevation of the machine center point MCP above mean sea level is determined by the requirement: at the 6 o'clock crossing point, the median plane , M , passes through this point, and is locally at elevation 830.000" above mean sea level at this point. [1" = 2.54 cm].

[Because of curvature of the earth, the points of plane M do not lie at uniform elevation above sea level. The vertical positioning of the machine plane is specified by the direction of the vertical at the machine center point, and the elevation of an appropriately selected point of M in the RHIC tunnel. Below that chosen elevation point, the nominal floor elevation is specified to be 780.00". Reference: page 229, May 1989 RHIC Conceptual Design Report, BNL No. 52195.]

B. Geodetic Embedding Of The Machine Configuration

1. A set of twelve steel monument bushings of CERN type, cemented into the RHIC tunnel floor, beneath the external survey tower penetration pipes, provides a primary network of survey control reference stations to tie the RHIC geometric configuration to the existing BNL grid network, which in turn is tied to the New York State plane coordinate system (S.P.C.), Long Island Zone.

2. Seven of these primary control station locations were well characterized geodetically in the June 7, 1982 final adjustment (616591) of the 1980-82 NGS Isabelle survey activity. Geodetic latitude, geodetic longitude, and elevation were determined; their BNL grid system coordinates were calculated, as well as their New York State S.P.C. coordinates readjusted to 65 foot elevation. [Stations 12RQ 7 OUT , 2LQ 7 OUT , 2RQ 7 OUT , 4LQ 7 OUT , 4RQ 7 OUT , 5IQ F OUT , 8LQ 7 OUT].

3. An additional primary control station, an NGS permanent benchmark embedded in cement at the base center of the central Bilby survey tower, was also well characterized geodetically in that survey. [Station 13 16281 CENTER POINT ISA].

4. By level and horizontal surveys external to the RHIC tunnel, and subsequent tower-to-tunnel transfer surveys, the primary RHIC tunnel control monument net will be tied to the New York State and BNL horizontal plane grids, and to the national NGS (vertical) level net, by performing a free least-squares adjustment of the primary net, and then locating the adjusted configuration's position (by a rotation and a translation) to minimize the sum of the absolute values of coordinate deviations from the 1982 adjusted coordinates of the eight station points geodetically determined in the 1980-82 survey.

5. The BNL survey network grid North is nominally oriented at 14deg 59min 11.5sec azimuth to geodetic North. During the 1980-82 Isabelle survey activity by NGS, the orientation of BNL grid North was determined by a line from the station point "10 DEGREE POINT 3FT OFF 1979" to a temporary construction station point "6 ISA 1979". The rotation angle of this line, between the BNL grid North and the New York S.P.C. grid North, was determined to be: 14deg 59min 26.45 sec , by the June 7, 1982 final adjustment of the NGS Isabelle survey.

6. The BNL grid coordinates, (E) and (N) , are related to New York State Plane Coordinates - Long Island Zone, (X) and (Y) , in Lambert conical conformal projection and readjusted to 65 foot elevation, by equations:

$$E = Eo + [(X-Xo)*\cos a + (Y-Yo)* \sin a]/S \quad ,$$

$$N = No - [(X-Xo)*\cos a - (Y-Yo)* \sin a]/S \quad ,$$

with

Eo	=	99 120.567	feet ,
No	=	102 962.896	feet ,
Xo	=	2 309 921.896	feet ,
Yo	=	239 035.269	feet ,
a	=	345 deg 00 min 35.55 sec	,
S	=	0.999991959	.

Values of the geodetic latitude and longitude of points can be obtained from their S.P.C. coordinates by using the "Plane Coordinate Projection Tables, New York", US Department of Commerce, Special Publication No. 323, US Government Printing Office, 1954.

7. The BNL grid coordinates of the RHIC machine center point are specified to be:

North	105 920.3314	international standard feet,
East	99 180.5694	international standard feet.

[These coordinates agree with the coordinates of the center point of the Isabelle machine, point 33 of Ammann & Whitney construction drawing C-2, August 15, 1980. Foot coordinates appearing in this drawing are international standard feet.]

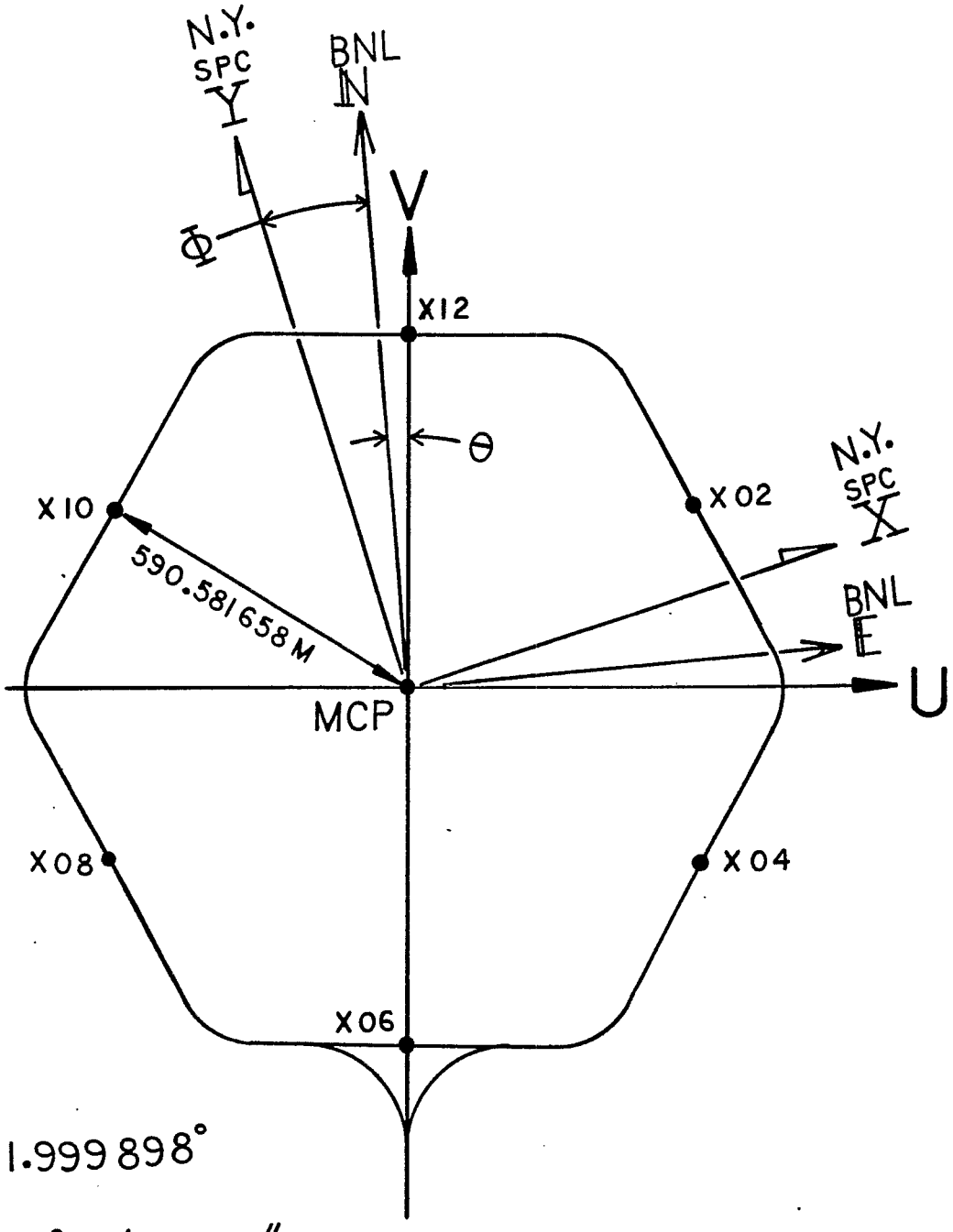
C. Embedding Of Lattice Point Coordinates Into The RHIC Reference Geometry

1. The RHIC lattice is a set of points in an (abstract) Euclidean plane, the lattice plane, L. Each lattice point represents the location of an ideal marker point, used in specification of the installation of a physical component into the RHIC machine.

   Lattice points are located in L, by giving their coordinates with respect to a rectangular Cartesian coordinate system, with origin at the lattice center point, and one axis specified by a ray from the 6-o'clock intersection point to the 12-o'clock intersection point; those lattice points are well-defined in L and are colinear.

2. To embed lattice plane L into the RHIC reference geometry, the lattice point coordinates are transformed, in common, by a rigid body rotation about the lattice center point followed by a translation so that the lattice center point will have the BNL (meter) coordinates of the machine center point (MCP), and the lattice points corresponding to the 6 and 12-o'clock intersection points have the BNL (meter) coordinates of points X06 and X12, respectively, given in the present document.

3. Lattice coordinates will be provided in meters, and reported to 6 decimal places, of which 5 places will be considered to be of physical significance. The sixth place will be carried to reduce roundoff noise error during coordinate geometry computations.



$\theta = 1.999898^\circ$

$\Phi = 14^\circ 59' 26.45''$

FIGURE 1. THE RHIC REFERENCE GEOMETRY

Appendix 1.

LOCATION OF THE RHIC MACHINE CENTER POINT (MCP)

BNL Northing (international standard feet): 105 920.3314

BNL Easting (international standard feet): 99 180.5694

These numbers are listed coordinates on Ammann & Whitney construction drawing C-2 , August 15, 1980.

[In metric units these become

BNL Northing (meter): 32284.517011

BNL Easting (meter): 30230.237553]

Geodetic Reference Datum: NAD27

Geodetic Reference Spheroid: Clarke 1866

This point is identified as "33 ISA RING CENTER" in the August 15, 1980 Ammann & Whitney drawing C-2 . The ideal RHIC center point (MCP) is to be the same as the point ISA RING CENTER. The foot units on drawing C-2 are international standard feet. The generation of this point's coordinates is of unspecified origin. (The point is 832.1630062 meter horizontal distance from tunnel reference point 3 in drawing C-2).

Appendix 2.

COMPUTED BNL COORDINATES

OF RHIC CROSSING POINTS

$$E = E(MCP) + R * \cos(A - \theta)$$

$$N = N(MCP) + R * \sin(A - \theta)$$

R	=	590.581658	Meter
θ	=	1.999898	Degree
E(MCP)	=	30 230.237553	Meter
N(MCP)	=	32 284.517011	Meter

POINT	BNL Easting (Meter)	BNL Northing (Meter)	A = Angle To Machine's U Axis (Degree)
X02	30 751.689713	32 561.779233	030
X04	30 731.079761	31 971.557305	330
X06	30 209.627601	31 694.295082	270
X08	29 708.785393	32 007.254788	210
X10	29 729.395345	32 597.476717	150
X12	30 250.847505	32 874.738939	090

Appendix 3.

THE AGS MACHINE LOCATION

The center of the AGS local plane coordinate system has BNL grid coordinates:

101,150.00 international standard feet (BNL grid) North of grid origin,

98,421.45 international standard feet (BNL grid) East of grid origin.

These coordinate values are computed from the BNL coordinate information provided on pages 2-44, 2-45 of the Booster Design Manual. They are in agreement with values of of BNL/AGS point coordinates presented in Injection Line Geometry file ARHIC 13 , Sept.12, 1988.

In the summer of 1992 the AGS machine (beam) height was set to an elevation of 899.950 inches above mean sea level (899.95" x .0254 meter/inch = 22.858730 meter).

References:

1. Booster Design Manual, Revision 1; January 12, 1989, pp 2-44, 2-45.

2. E. Bleser, AGS Department Memorandum, Thursday, October 24, 1991, Minutes Of BTA Survey Meeting.

Appendix 4.

1982 ADJUSTED SURVEY LOCATION Of The CENTER TOWER MONUMENT

The 1982 adjusted position is obtained from the NGS June 7, 1982 final adjustment 616591, using the 8/76 version of the TRAV10 codes; Monday 11:51, page 1, list of adjusted positions. The center tower monument location is reported for the survey station: 13 16281 CENTER POINT ISA at

(Geodetic) Latitude 40 deg 53 min 2.24156 sec
(Geodetic) Longitude 72 deg 52 min 34.35778 sec
Height 19.187 meter
Geoidal height 0.0 meter .

These give:

Decimal Degree Latitude = 40.8839559 deg
Decimal Degree Longitude = 72.8762104 deg
Height = 62.949475 international standard feet.

Appendix 5.

RELATED SURVEYS

During construction, of the tunnel structures which will house the RHIC rings, from 1979 to 1982, extensive geodetic survey work was done by the National Geodetic Survey organization of the U.S. Department of Commerce. This work was performed under supervision of Charles J. Fronczek, Geodesist, with the on-site collaboration of Captain L.S. Baker (Retired), and the BNL/AGS Survey Group, under supervision of Frank Atkinson.

Construction survey control towers, tunnel survey control towers, and tunnel line-of-sight pipe penetrations were fabricated. South end tunnel control monumentation, big bend tunnel monumentation and penetrations, and seven of the twelve primary tunnel survey control monuments lying beneath tunnel penetrations were installed. Monument station information is given in [1].

A near-centrally located geodetic survey tower was constructed in the wooded area inside the ring road, to provide radial survey lines of sight from center to periphery of the tunnel. A permanent N.G.S. monument station was cemented into place beneath this survey tower.

A geodetic survey reduction and adjustment was performed, at the N.G.S. on June 7, 1982 using N.G.S.' TRAV-10 codes [2]. Copies of the adjustment printout are available at the BNL/AGS Survey Group.

The reduction was made using metric distance measurements and angle degree units. The reduction used an elliptical model earth employing the 1927 North American Datum and the 1886 Clarke ellipsoid. A geoidal height of 0.0 meter was assumed [3].

In that survey, the monument station at the central tower (13 16281 CENTER POINT ISA) was found to lie at:

Geodetic Latitude	40 deg	53 min	2.24156 sec ,
Geodetic Longitude	72 deg	52 min	34.35778 sec ,
Elevation	19.187 meter ,		

and was reported to have BNL plane grid coordinates:

[E] = 99,180.692 Feet

[N] = 105,920.760 Feet .

BNL Plane Grid horizontal coordinates were reported for seven tunnel monuments lying below penetrations through the earth berm. These monuments, reported as: 12RQ 7 OUT, 2LQ 7 OUT, 2RQ 7 OUT, 4LQ 7 OUT, 4RQ 7OUT, 5IQ F OUT, 8LQ 7 OUT, and located respecively at the 1 , 2 , 3 , 4 , 5 , 6 , and 8-o'clock sections, will be used as seven of the twelve primary RHIC monuments.

By a 1979 survey between two station points "10 DEGREE POINT 3 FT. OFF 1979" and "6 ISA 1979" , the angle between the BNL grid North and the New York State Plane Coordinate System's grid North [4] was determined to be 14 deg 59 min 26.45 sec.

Both BNL grid coordinates [feet] and New York State plane coordinates, raised to 65 foot elevation, were reported for these ten points.

A summary of information relating to the 1982 N.G.S. survey and to effects of the earth's curvature on magnet placement is given in G.F. Dell, ISABELLE Project Technical Note No. 388 [5].

References

1. Drawing C-2, August 15, 1990. Injection / Ejection Structures, Accelerator Geometry. Job No. ISA -12-1-467000-15. Ammann & Whitney, Consulting Engineers, Two World Trade Center, New York, N.Y. .

2. C.R. Schwarz, TRAV10 Horizontal Network Adjustment Program, NOAA Technical Memorandum NOS NGS-12, NOAA National Geodetic Survey, Rockville Md. , April 1978.

3. C. Fronczek [Private communication, 03-15-92]. Relating to the 1980-82 Isabelle survey activity: when the NAD27 datum is used, the geoid surface at the RHIC ring should be within +/- 1 meter of the reference Clarke 1866 ellipsoid.

4. Plane Coordinate Projection Tables, New York, U.S. Department of Commerce, Coast and Geodetic Survey, 1954, U.S. Government Printing Office, Washington DC.

5. G.F. Dell, Note On ISA Lattice Coordinates (1-in-1), ISABELLE Project Technical Note No. 388, Brookhaven National Laboratory, Upton, N.Y., July, 1982.