BNL-105163-2014-TECH

Booster Technical Note No. 119;BNL-105163-2014-IR

Coordinates of magnet survey markers and tunnel survey monuments for the AGS Booster

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April 1988

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

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Booster Technical Note

No. 119

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APRIL 26, 1988

ACCELERATOR DEVELOPMENT DEPARTMENT

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COORDINATES OF MAGNET SURVEY MARKERS AND TUNNEL SURVEY MONUMENTS FOR THE AGS BOOSTER

G.F. Dell

Introduction

In the past, the effective (magnetic) lengths of the magnetic elements have been used to generate the coordinates for elements of the AGS Booster; however, this length extends beyond the physical length of these elements. The coordinates reported in this report correspond to the physical lengths of the magnets. Coordinates have been generated for survey markers located on magnets and also for survey monuments located in the tunnel floor. These coordinates are tabulated both in the AGS grid and in the BNL grid. The latter listing is included so direct comparison can be made with the construction drawing of the Booster tunnel -- See Figure 1. The coordinates of the various working points listed on the drawing are tabulated in Table 1.

Method

The "old" coordinates reported previously for the locations of magnets of the AGS Booster were generated from SYNCH runs in which magnets had hard edges and a magnetic length ℓ_m measured along the trajectory of the particle. For a radius of curvature ρ_o, the bending angle is $\theta_m = \ell_m/\rho_o$, and the magnet length is $2*\rho_o*\sin(\theta_m/2)$. This length is greater than the physical length of the Booster dipoles having a magnetic length ℓ_m that includes the fringe fields which extend beyond the ends of the dipoles. The same is true for the quadrupoles.

The present tabulation of coordinates ("new" coordinates) has been generated using the physical length ℓ_p of the dipoles. In this case the angle θ_p subtended by the dipole is: $\theta_p=2*\sin^{-1}(\ell_p/2\rho_o)$. Consider a dipole oriented at an angle θ from the X axis as shown in Figure 2. The coordinates of the survey markers (located on the central orbit at the end of the magnet laminations) have been generated by:

1). using the average value of the "old" coordinates at the entrance and exit of the dipole to find a point $(\overline{x}_m, \overline{y}_m)$ on the bisector of the dipole,

2). determining a correction Δr necessary to locate the point $(\overline{x}_p, \overline{y}_p)$ on the magnet bisector and the midpoint of the line connecting the survey markers, and

3). determining the coordinates (x_p, y_p) of the survey markers (endpoints of the magnet laminations). See Figure 2.

Nomenclature

Elements are assigned names having four or five characters that comprise 4 identifiers. The first identifier "M" is common to all names. The second identifier has one or two characters; D, Q, SF, or SD and denotes dipoles, quadrupoles, horizontally focusing sextupoles, or horizontally defocusing sextupoles, respectively. The next identifier is a letter A to F that indicates the period, and the last identifier is a number 1 to 8 that indicates the half cell in the period.

Survey markers on magnets

Survey markers to be used for survey and alignment purposes will be located on the dipoles and quadrupoles and probably on the sextupoles. These markers consist of precision bushings located in the groove in the magnet laminations along the centerline of the magnets. There is considerable freedom in choosing the position of the bushings along the length of the magnets, however for the present discussion, it is assumed they will be centered over the junction of the magnet laminations and the magnet endplates. This location is convenient in that the fixtures holding the bushings can be pinned to the endplates of the magnets; it is also convenient in that it corresponds to the physical length of the magnet laminations. If this location interferes with electrical or water connections, the bushing locations can be moved with little or no impact to the survey system.

As the yoke of sextupoles is only 3 inches long, placing more than one survey bushing on a sextupole serves little purpose. Hence one bushing placed at the center of the laminations is suggested. The effective and magnetic lengths of the various elements are listed below.

	Magnetic Length(m)		Physical Length(m)	
	arc	chord	arc	chord
Dipole	2.40	2.39696	2.31744	2.31470
Quad	0.50375		0.42228 (16 5/8")[1] 0.45085 (17 3/4")[2]	
Sextupole	0.10		0.075	

Magnetic and physical lengths of magnetic elements for the Booster. 1). Standard length quadrupole, 2.) Quadrupole with extra laminations.

Coordinates of the survey bushings have been generated with the standard geometry program altered to compensate for the shorter magnet lengths. The coordinates of the survey bushings are listed in Table 2 for the AGS grid and in Table 2(a) for the BNL grid.

Survey Monuments

Survey monuments have been arbitrarily placed a distance of 1.1m perpendicularly outwards from the upstream end of each horizontally focusing quadrupole; there are 24 such monuments. These monuments consist of bushings located in the tunnel floor at positions where they will not interfere with the magnet installation. The use of 24 regularly spaced monuments gives uniformity in location and also provides more than the minimum required number for the redundant measurements needed to sort out survey errors and inconsistencies. The choice of monument location is arbitrary and can be changed if there are disadvantages to this choice of location or if there are extra advantages to other locations. There is some indication that placement near defocusing quadrupoles could reduce interference from beam lines for injection and extraction. In some areas such as those

with penetrations to the linac and AGS, more monuments and/or irregularly spaced monuments may be required; their need has not yet been determined. The coordinates of the survey monuments located in the tunnel floor are listed on Table 3 for the AGS grid and in Table 3(a) for the BNL grid..

Monuments for vertical surveys

The availability of monuments near the level of the survey plane would ease vertical surveys. Such secondary monuments will be affixed to the outer wall of the Booster tunnel. The locations will be chosen to avoid interference with conduits and with water mains for the sprinkler system. Their mounting will require ease of use without interference with other operations such as magnet transport. These monuments can be installed after most installation work is complete when their optimum location will become more obvious.

2.10.3 Alignment algorithm

The alignment algorithm used to smooth the location of the magnets will be selected on the basis of simulation results. "Realistic" survey files will be generated from the suggested magnet survey points and tunnel survey monuments. Errors, both systematic and random, will be assigned to computer generated measurements of position and magnet offsets, and the data with and without errors will be analyzed to smooth the magnet positions and establish how well the smoothing algorithms work. From this simulation, an acceptable smoothing algorithm will be selected.

Summary

The coordinates tabluated in Tables 2, 2(a), 3, and 3(a) depend upon the positions assigned to the survey markers on the magnets and the survey monuments in the tunnel floor. They will become obsolete if changes are made in the locations of markers or monuments (such as the probable increase in length of quadrupole laminations from 16 5/8" to 17 3/4"). Still, the coordinates are useful; the tabulation in the BNL grid makes possible easy consistency checks between the coordinates of Table 1 for the tunnel construction and the locations, specified by the accelerator physicists, of the magnets within the tunnel.

The listing also represents a realistic set of survey markers and survey monuments that can be used to generate survey files for analysis and correction studies.

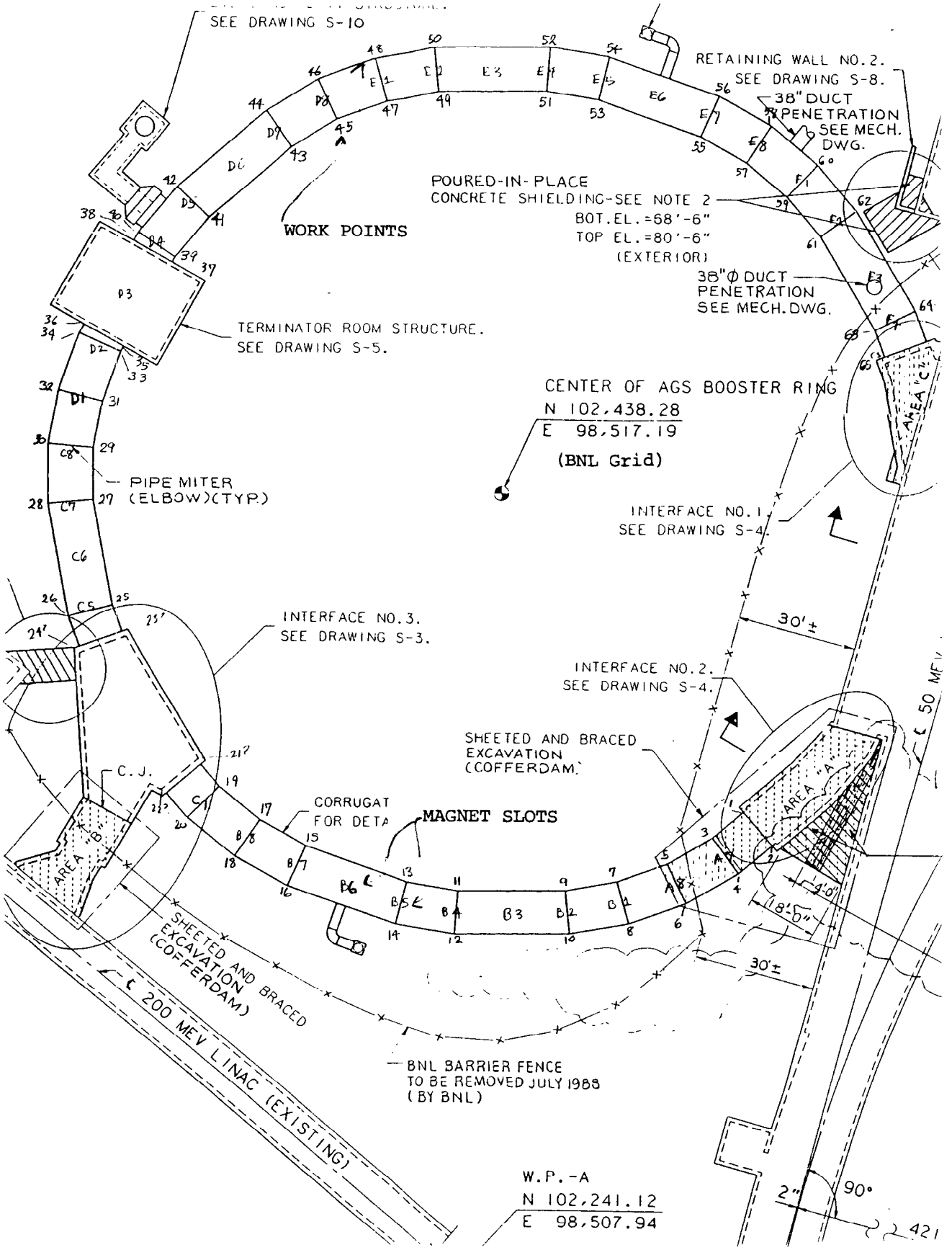
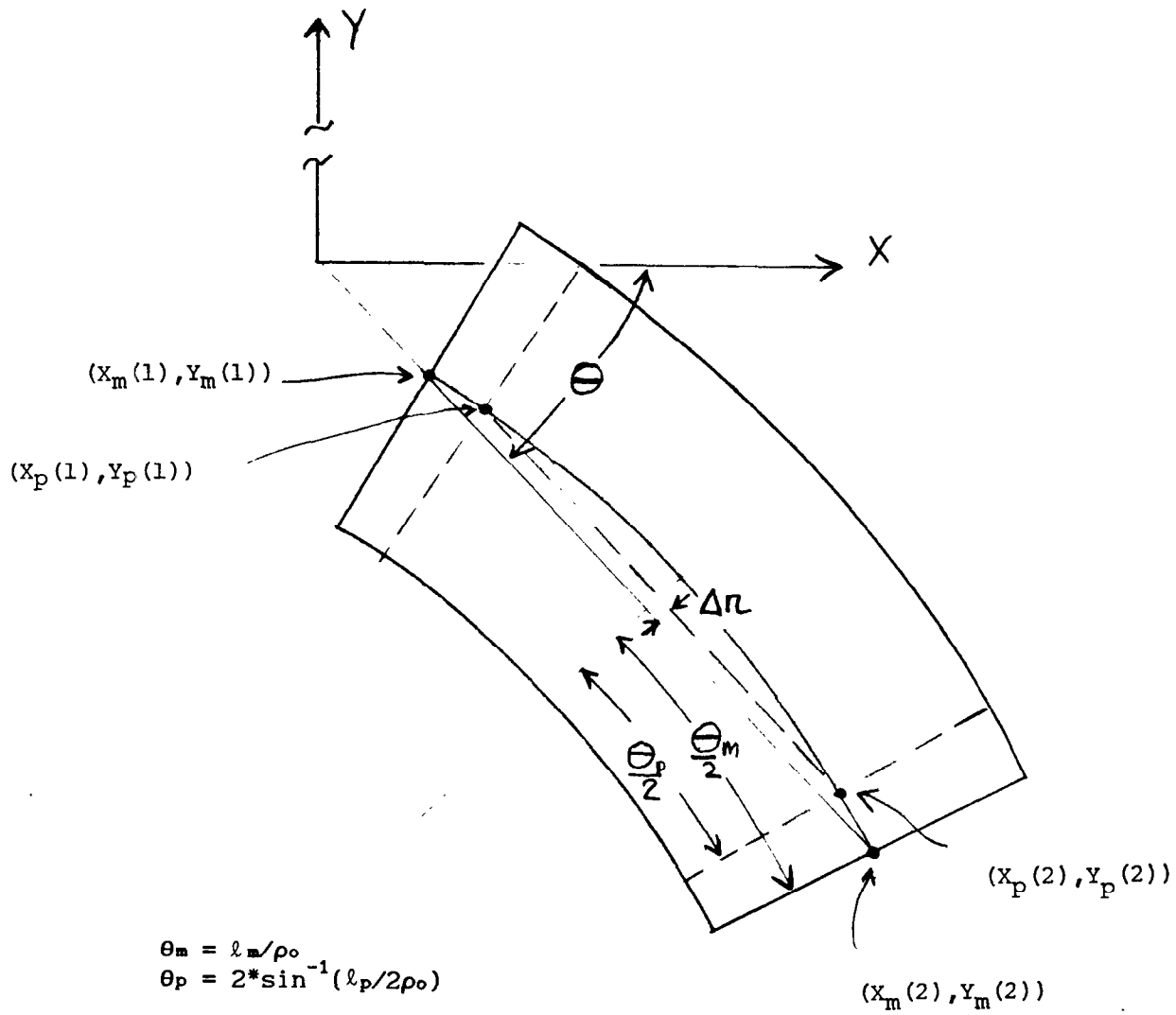


Figure 1. Reduction of Booster drawing S-2 (General Plan, 10/7/87) with Work Points from drawing S-6 added. Also indicated are the magnets slots: B1, B2, etc. Dipoles are centered on lines between odd and even numbered work points, viz. (11,12), (13,14), ... Long sections such as B3 and B6 indicate locations where dipoles are missing.



$\theta_m = \ell_m/\rho_o$

$\theta_p = 2*\sin^{-1}(\ell_p/2\rho_o)$

STEP

1. $\overline{X_m}=0.5(x_m(1)+x_m(2))$
   $\overline{y_m}=0.5(y_m(1)+y_m(2))$

2. $\Delta r=\rho_o(\cos(\theta_p/2)-\cos(\theta_m/2))$
   $\Delta x= \Delta r*\cos(\theta+\pi/2)$
   $\Delta y= \Delta r*\sin(\theta+\pi/2)$
   $\overline{x_p} = \overline{x_m} + \Delta x$
   $\overline{y_p} = \overline{y_m} + \Delta y$

3. $x_p(1) = \overline{x_p} - 0.5*\ell_p*\cos(\theta)$
   $y_p(1) = \overline{y_p} - 0.5*\ell_p*\sin(\theta)$
   $x_p(2) = \overline{x_p} + 0.5*\ell_p*\cos(\theta)$
   $y_p(2) = \overline{y_p} + 0.5*\ell_p*\sin(\theta)$

Figure 2. Explanation of the geometry used to convert from coordinates determined from the magnetic length to coordinates based on the physical length of elements. Δr = 3.54 mm.

WP	N(ft)	E(ft)	WP	N(ft)	E(ft)
1	102359.10	98579.33	36	102481.13	98413.33
2	102350.76	98586.51	37	102494.95	98433.68
3	102351.74	98570.79	38	102500.33	98424.08
4	102342.77	98577.24	39	102497.09	98434.88
5	102345.03	98559.50	40	102503.31	98425.76
6	102335.08	98564.30	41	102507.26	98443.19
7	102340.38	98547.23	42	102514.97	98435.29
8	102329.75	98550.22	43	102524.82	98463.59
9	102337.94	98534.33	44	102533.79	98457.14
10	102326.95	98535.43	45	102531.53	98474.88
11	102337.59	98507.41	46	102541.48	98470.08
12	102326.58	98506.59	47	102536.18	98487.15
13	102339.71	98494.45	48	102546.81	98484.16
14	102329.01	98491.73	49	102538.62	98500.05
15	102348.59	98469.04	50	102549.61	98498.95
16	102338.52	98464.50	51	102538.97	98526.97
17	102355.01	98457.59	52	102549.98	98527.79
18	102345.88	98451.37	53	102536.85	98539.93
19	102363.32	98447.42	54	102547.55	98542.65
20	102355.41	98439.72	55	102527.97	98565.34
21	102369.78	98441.86	56	102538.04	98569.88
22	102362.60	98433.53	57	102521.55	98576.79
23	102400.71	98423.47	58	102530.68	98583.01
24	102396.82	98413.18	59	102513.24	98586.96
25	102408.68	98420.45	60	102521.15	98594.66
26	102405.69	98409.83	61	102503.29	98595.52
27	102435.13	98415.44	62	102509.74	98604.49
28	102434.03	98404.46	63	102480.15	98609.28
29	102448.26	98415.27	64	102484.95	98619.23
30	102449.08	98404.26	65	102472.18	98612.30
31	102461.22	98417.39	66	102476.08	98622.58
32	102463.94	98406.69	67	102511.48	98432.44
33	102473.61	98421.72	68	102504.13	98426.42
34	102478.15	98411.66	69	102542.80	98556.26
35	102475.76	98422.92	70	102333.77	98478.12

Table 1. Coordinates of Work Points (WP'S) obtained from drawing S-6 for Building B-942 (Corrugated steel pipe construction plan, 10/7/87).

Table 2. COORDINATES OF MAGNET SURVEY POINTS IN THE AGS GRID

		SURVEY Pt #1		SURVEY Pt #2	
INDEX	NAME	N(in)	E(in)	N(in)	E(in)
1	MDA1	15217.6525	2399.4773	15129.3300	2377.0159
2	MSFA1	15101.7830	2367.3832		
3	MQA1	15089.1196	2362.9564	15073.4257	2357.4702
4	MDA2	15059.2288	2352.5102	14976.1485	2315.0531
5	MSDA2	14950.6926	2300.7832		
6	MQA2	14938.9904	2294.2247	14924.4876	2286.0966
7	MQA3	14794.6166	2213.3104	14780.1138	2205.1823
8	MDA4	14766.9939	2197.8325	14691.6801	2146.5176
9	MSDA4	14669.0889	2128.0442		
10	MQA4	14658.7034	2119.5532	14645.8323	2109.0302
11	MDA5	14634.1880	2099.5138	14568.9291	2035.9004
12	MQA5	14541.1357	2003.6193	14530.2875	1991.0212
13	MQA6	14433.1430	1878.2061	14422.2948	1865.6079
14	MDA7	14412.4799	1854.2140	14359.2587	1780.2350
15	MSFA7	14344.3483	1755.1490		
16	MQA7	14337.4931	1743.6180	14328.9974	1729.3275
17	MDA8	14321.3101	1716.4024	14281.7438	1634.3055
18	MQA8	14266.6674	1594.4653	14260.7822	1578.9166
19	MDB1	14255.4561	1564.8529	14230.7470	1477.1327
20	MSFB1	14225.3157	1448.4599		
21	MQB1	14222.8177	1435.2797	14219.7220	1418.9453
22	MDB2	14216.9190	1404.1704	14207.8176	1313.4922
23	MSDB2	14207.4478	1284.3118		
24	MQB2	14207.2765	1270.8981	14207.0643	1254.2743
25	MQB3	14205.1634	1105.4097	14204.9511	1088.7858
26	MDB4	14204.7563	1073.7487	14211.5394	982.8676
27	MSDB4	14216.2423	954.0663		
28	MQB4	14218.4029	940.8267	14221.0805	924.4186
29	MDB5	14223.4999	909.5760	14245.9612	821.2535
30	MQB5	14260.0208	781.0431	14265.5070	765.3492
31	MQB6	14314.6355	624.8121	14320.1217	609.1182
32	MDB7	14325.0816	594.9213	14362.5388	511.8409
33	MSFB7	14376.8087	486.3851		
34	MQB7	14383.3672	474.6829	14391.4953	460.1801
35	MDB8	14398.8452	447.0601	14450.1600	371.7463
36	MQB8	14477.1244	338.7696	14487.6474	325.8986

Table 2. COORDINATES OF MAGNET SURVEY POINTS IN THE AGS GRID

		SURVEY Pt #1		SURVEY Pt #2	
INDEX	NAME	N(in)	E(in)	N(in)	E(in)
37	MDC1	14497.1638	314.2542	14560.7772	248.9953
38	MSFC1	14582.8929	229.9553		
39	MQC1	14593.0583	221.2019	14605.6565	210.3537
40	MDC2	14617.0504	200.5388	14691.0294	147.3177
41	MSDC2	14716.1154	132.4072		
42	MQC2	14727.6463	125.5521	14741.9369	117.0563
43	MQC3	14869.9070	40.9778	14884.1975	32.4821
44	MDC4	14897.1227	24.7948	14979.2195	-14.7715
45	MSDC4	15006.5136	-25.0993		
46	MQC4	15019.0598	-29.8479	15034.6085	-35.7331
47	MDC5	15048.6721	-41.0592	15136.3923	-65.7684
48	MQC5	15178.2453	-73.6976	15194.5797	-76.7933
49	MQC6	15340.8527	-104.5154	15357.1871	-107.6111
50	MDC7	15371.9620	-110.4141	15462.6403	-119.5155
51	MSFC7	15491.8206	-119.8853		
52	MQC7	15505.2343	-120.0566	15521.8581	-120.2688
53	MDC8	15536.8953	-120.4636	15627.7764	-113.6806
54	MQC8	15669.8173	-106.8171	15686.2254	-104.1394
55	MDD1	15701.0679	-101.7201	15789.3905	-79.2588
56	MSFD1	15816.9375	-69.6260		
57	MQD1	15829.6008	-65.1992	15845.2947	-59.7130
58	MDD2	15859.4916	-54.7531	15942.5720	-17.2959
59	MSDD2	15968.0278	-3.0260		
60	MQD2	15979.7300	3.5325	15994.2328	11.6606
61	MQD3	16124.1038	84.4467	16138.6066	92.5748
62	MDD4	16151.7266	99.9247	16227.0404	151.2395
63	MSDD4	16249.6315	169.7130		
64	MQD4	16260.0171	178.2039	16272.8882	188.7269
65	MDD5	16284.5325	198.2434	16349.7914	261.8567
66	MQD5	16377.5848	294.1378	16388.4330	306.7360
67	MQD6	16485.5775	419.5511	16496.4257	432.1492
68	MDD7	16506.2406	443.5431	16559.4617	517.5221
69	MSDF7	16574.3722	542.6082		
70	MQD7	16581.2273	554.1391	16589.7231	568.4296
71	MDD8	16597.4104	581.3548	16636.9766	663.4516
72	MQD8	16652.0531	703.2919	16657.9383	718.8406

Table 2. COORDINATES OF MAGNET SURVEY POINTS IN THE AGS GRID

		SURVEY Pt #1		SURVEY Pt #2	
INDEX	NAME	N(in)	E(in)	N(in)	E(in)
73	MDE1	16663.2643	732.9042	16687.9735	820.6245
74	MSFE1	16693.4048	849.2973		
75	MQE1	16695.9027	862.4774	16698.9985	878.8119
76	MDE2	16701.8015	893.5867	16710.9029	984.2650
77	MSDE2	16711.2727	1013.4453		
78	MQE2	16711.4439	1026.8590	16711.6562	1043.4828
79	MQE3	16713.5571	1192.3475	16713.7693	1208.9713
80	MDE4	16713.9641	1224.0085	16707.1811	1314.8896
81	MSDE4	16702.4782	1343.6908		
82	MQE4	16700.3176	1356.9304	16697.6399	1373.3386
83	MDE5	16695.2206	1388.1811	16672.7593	1476.5036
84	MQE5	16658.6997	1516.7140	16653.2135	1532.4079
85	MQE6	16604.0850	1672.9450	16598.5988	1688.6389
86	MDE7	16593.6388	1702.8359	16556.1817	1785.9162
87	MSFE7	16541.9118	1811.3720		
88	MQE7	16535.3533	1823.0743	16527.2252	1837.5771
89	MDE8	16519.8753	1850.6970	16468.5605	1926.0108
90	MQE8	16441.5961	1958.9875	16431.0731	1971.8586
91	MDF1	16421.5566	1983.5029	16357.9433	2048.7618
92	MSFF1	16335.8275	2067.8019		
93	MQF1	16325.6622	2076.5552	16313.0640	2087.4034
94	MDF2	16301.6701	2097.2184	16227.6911	2150.4395
95	MSDF2	16202.6051	2165.3499		
96	MQF2	16191.0741	2172.2051	16176.7836	2180.7008
97	MQF3	16048.8135	2256.7793	16034.5229	2265.2751
98	MDF4	16021.5978	2272.9624	15939.5009	2312.5286
99	MSDF4	15912.2069	2322.8564		
100	MQF4	15899.6607	2327.6051	15884.1120	2333.4903
101	MDF5	15870.0483	2338.8163	15782.3281	2363.5255
102	MQF5	15740.4751	2371.4547	15724.1407	2374.5505
103	MQF6	15577.8677	2402.2725	15561.5333	2405.3683
104	MDF7	15546.7584	2408.1713	15456.0802	2417.2726
105	MSFF7	15426.8998	2417.6424		
106	MQF7	15413.4862	2417.8137	15396.8623	2418.0260
107	MDF8	15381.8252	2418.2208	15290.9441	2411.4378
108	MQF8	15248.9032	2404.5742	15232.4951	2401.8966

Table 2(a). COORDINATES OF MAGNET SURVEY POINTS IN THE BNL GRID

		SURVEY Pt #1		SURVEY Pt #2	
INDEX	NAME	N(ft)	E(ft)	N(ft)	E(ft)
1	MDA1	102418.1377	98621.4064	102410.7775	98619.5347
2	MSFA1	102408.4819	98618.7319		
3	MQA1	102407.4266	98618.3630	102406.1188	98617.9058
4	MDA2	102404.9357	98617.4925	102398.0124	98614.3711
5	MSDA2	102395.8911	98613.1819		
6	MQA2	102394.9159	98612.6354	102393.7073	98611.9580
7	MQA3	102382.8847	98605.8925	102381.6762	98605.2152
8	MDA4	102380.5828	98604.6027	102374.3067	98600.3265
9	MSDA4	102372.4241	98598.7870		
10	MQA4	102371.5586	98598.0794	102370.4860	98597.2025
11	MDA5	102369.5157	98596.4095	102364.0774	98591.1084
12	MQA5	102361.7613	98588.4183	102360.8573	98587.3684
13	MQA6	102352.7619	98577.9672	102351.8579	98576.9173
14	MDA7	102351.0400	98575.9678	102346.6049	98569.8029
15	MSFA7	102345.3624	98567.7124		
16	MQA7	102344.7911	98566.7515	102344.0831	98565.5606
17	MDA8	102343.4425	98564.4835	102340.1453	98557.6421
18	MQA8	102338.8889	98554.3221	102338.3985	98553.0264
19	MDB1	102337.9547	98551.8544	102335.8956	98544.5444
20	MSFB1	102335.4430	98542.1550		
21	MQB1	102335.2348	98541.0566	102334.9768	98539.6954
22	MDB2	102334.7432	98538.4642	102333.9848	98530.9077
23	MSDB2	102333.9540	98528.4760		
24	MQB2	102333.9397	98527.3582	102333.9220	98525.9729
25	MQB3	102333.7636	98513.5675	102333.7459	98512.1822
26	MDB4	102333.7297	98510.9291	102334.2949	98503.3556
27	MSDB4	102334.6869	98500.9555		
28	MQB4	102334.8669	98499.8522	102335.0900	98498.4849
29	MDB5	102335.2917	98497.2480	102337.1634	98489.8878
30	MQB5	102338.3351	98486.5369	102338.7922	98485.2291
31	MQB6	102342.8863	98473.5177	102343.3435	98472.2099
32	MDB7	102343.7568	98471.0268	102346.8782	98464.1034
33	MSFB7	102348.0674	98461.9821		
34	MQB7	102348.6139	98461.0069	102349.2913	98459.7983
35	MDB8	102349.9038	98458.7050	102354.1800	98452.4289
36	MQB8	102356.4270	98449.6808	102357.3039	98448.6082

Table 2(a). COORDINATES OF MAGNET SURVEY POINTS IN THE BNL GRID

		SURVEY Pt #1		SURVEY Pt #2	
INDEX	NAME	N(ft)	E(ft)	N(ft)	E(ft)
37	MDC1	102358.0970	98447.6379	102363.3981	98442.1996
38	MSFC1	102365.2411	98440.6129		
39	MQC1	102366.0882	98439.8835	102367.1380	98438.9795
40	MDC2	102368.0875	98438.1616	102374.2524	98433.7265
41	MSDC2	102376.3429	98432.4839		
42	MQC2	102377.3039	98431.9127	102378.4947	98431.2047
43	MQC3	102389.1589	98424.8648	102390.3498	98424.1568
44	MDC4	102391.4269	98423.5162	102398.2683	98420.2190
45	MSDC4	102400.5428	98419.3584		
46	MQC4	102401.5883	98418.9627	102402.8840	98418.4722
47	MDC5	102404.0560	98418.0284	102411.3660	98415.9693
48	MQC5	102414.8538	98415.3085	102416.2150	98415.0506
49	MQC6	102428.4044	98412.7404	102429.7656	98412.4824
50	MDC7	102430.9968	98412.2488	102438.5534	98411.4904
51	MSFC7	102440.9851	98411.4596		
52	MQC7	102442.1029	98411.4453	102443.4882	98411.4276
53	MDC8	102444.7413	98411.4114	102452.3147	98411.9766
54	MQC8	102455.8181	98412.5486	102457.1855	98412.7717
55	MDD1	102458.4223	98412.9733	102465.7825	98414.8451
56	MSFD1	102468.0781	98415.6478		
57	MQD1	102469.1334	98416.0167	102470.4412	98416.4739
58	MDD2	102471.6243	98416.8872	102478.5477	98420.0087
59	MSDD2	102480.6690	98421.1978		
60	MQD2	102481.6442	98421.7444	102482.8527	98422.4217
61	MQD3	102493.6753	98428.4872	102494.8839	98429.1646
62	MDD4	102495.9772	98429.7771	102502.2534	98434.0533
63	MSDD4	102504.1360	98435.5927		
64	MQD4	102505.0014	98436.3003	102506.0740	98437.1772
65	MDD5	102507.0444	98437.9703	102512.4826	98443.2714
66	MQD5	102514.7987	98445.9615	102515.7028	98447.0113
67	MQD6	102523.7981	98456.4126	102524.7021	98457.4624
68	MDD7	102525.5201	98458.4119	102529.9551	98464.5768
69	MSDF7	102531.1977	98466.6673		
70	MQD7	102531.7689	98467.6283	102532.4769	98468.8191
71	MDD8	102533.1175	98469.8962	102536.4147	98476.7376
72	MQD8	102537.6711	98480.0577	102538.1615	98481.3534

Table 2(a). COORDINATES OF MAGNET SURVEY POINTS IN THE BNL GRID

		SURVEY Pt #1		SURVEY Pt #2	
INDEX	NAME	N(ft)	E(ft)	N(ft)	E(ft)
73	MDE1	102538.6054	98482.5254	102540.6645	98489.8354
74	MSFE1	102541.1171	98492.2248		
75	MQE1	102541.3252	98493.3231	102541.5832	98494.6843
76	MDE2	102541.8168	98495.9156	102542.5752	98503.4721
77	MSDE2	102542.6061	98505.9038		
78	MQE2	102542.6203	98507.0216	102542.6380	98508.4069
79	MQE3	102542.7964	98520.8123	102542.8141	98522.1976
80	MDE4	102542.8303	98523.4507	102542.2651	98531.0241
81	MSDE4	102541.8732	98533.4242		
82	MQE4	102541.6931	98534.5275	102541.4700	98535.8949
83	MDE5	102541.2684	98537.1318	102539.3966	98544.4920
84	MQE5	102538.2250	98547.8428	102537.7678	98549.1507
85	MQE6	102533.6737	98560.8621	102533.2166	98562.1699
86	MDE7	102532.8032	98563.3530	102529.6818	98570.2764
87	MSFE7	102528.4926	98572.3977		
88	MQE7	102527.9461	98573.3729	102527.2688	98574.5814
89	MDE8	102526.6563	98575.6748	102522.3800	98581.9509
90	MQE8	102520.1330	98584.6990	102519.2561	98585.7715
91	MDF1	102518.4631	98586.7419	102513.1619	98592.1802
92	MSFF1	102511.3190	98593.7668		
93	MQF1	102510.4718	98594.4963	102509.4220	98595.4003
94	MDF2	102508.4725	98596.2182	102502.3076	98600.6533
95	MSDF2	102500.2171	98601.8958		
96	MQF2	102499.2562	98602.4671	102498.0653	98603.1751
97	MQF3	102487.4011	98609.5149	102486.2102	98610.2229
98	MDF4	102485.1331	98610.8635	102478.2917	98614.1607
99	MSDF4	102476.0172	98615.0214		
100	MQF4	102474.9717	98615.4171	102473.6760	98615.9075
101	MDF5	102472.5040	98616.3514	102465.1940	98618.4105
102	MQF5	102461.7063	98619.0712	102460.3451	98619.3292
103	MQF6	102448.1556	98621.6394	102446.7944	98621.8974
104	MDF7	102445.5632	98622.1309	102438.0067	98622.8894
105	MSFF7	102435.5750	98622.9202		
106	MQF7	102434.4572	98622.9345	102433.0719	98622.9522
107	MDF8	102431.8188	98622.9684	102424.2453	98622.4031
108	MQF8	102420.7419	98621.8312	102419.3746	98621.6080

Table 3. SURVEY MONUMENTS 1.1m OUTWARD FROM UPSTREAM END OF THE QF's

		BOOSTER FRAME		AGS GRID	
NUM	QUAD	X(m)	Y(m)	N(in)	E(in)
1	MQA1	31.32855	-10.35657	15051.621	2382.288
2	MQA3	27.35469	-17.90774	14754.331	2225.836
3	MQA5	21.65937	-24.39327	14498.995	2001.611
4	MQA7	14.87025	-29.54067	14296.342	1734.323
5	MQB1	6.69520	-32.30964	14187.327	1412.470
6	MQB3	-1.83124	-32.64376	14174.173	1076.784
7	MQB5	-10.29552	-30.95423	14240.690	743.544
8	MQB7	-18.14787	-27.64838	14370.841	434.397
9	MQC1	-24.63339	-21.95306	14595.066	179.061
10	MQC3	-29.18597	-14.73601	14879.202	-0.174
11	MQC5	-31.95494	-6.56096	15201.055	-109.188
12	MQC7	-33.01815	1.89230	15533.860	-151.047
13	MQD1	-31.32863	10.35659	15867.100	-84.530
14	MQD3	-27.35476	17.90776	16164.390	71.921
15	MQD5	-21.65945	24.39328	16419.725	296.146
16	MQD7	-14.87032	29.54068	16622.379	563.434
17	MQE1	-6.69527	32.30965	16731.393	885.287
18	MQE3	1.83117	32.64377	16744.548	1220.973
19	MQE5	10.29545	30.95424	16678.031	1554.213
20	MQE7	18.14780	27.64839	16547.879	1863.360
21	MQF1	24.63332	21.95307	16323.654	2118.696
22	MQF3	29.18589	14.73602	16039.518	2297.931
23	MQF5	31.95486	6.56097	15717.666	2406.945
24	MQF7	33.01808	-1.89229	15384.861	2448.804

Table 3(a). SURVEY MONUMENTS 1.1m OUTWARD FROM UPSTREAM END OF THE QF's

		BOOSTER FRAME		BNL GRID	
NUM	QUAD	X(m)	Y(m)	N(ft)	E(ft)
1	MQA1	31.32855	-10.35657	102404.302	98619.974
2	MQA3	27.35469	-17.90774	102379.528	98606.936
3	MQA5	21.65937	-24.39327	102358.250	98588.251
4	MQA7	14.87025	-29.54067	102341.362	98565.977
5	MQB1	6.69520	-32.30964	102332.277	98539.156
6	MQB3	-1.83124	-32.64376	102331.181	98511.182
7	MQB5	-10.29552	-30.95423	102336.724	98483.412
8	MQB7	-18.14787	-27.64838	102347.570	98457.650
9	MQC1	-24.63339	-21.95306	102366.256	98436.372
10	MQC3	-29.18597	-14.73601	102389.934	98421.436
11	MQC5	-31.95494	-6.56096	102416.755	98412.351
12	MQC7	-33.01815	1.89230	102444.488	98408.863
13	MQD1	-31.32863	10.35659	102472.258	98414.406
14	MQD3	-27.35476	17.90776	102497.032	98427.443
15	MQD5	-21.65945	24.39328	102518.310	98446.129
16	MQD7	-14.87032	29.54068	102535.198	98468.403
17	MQE1	-6.69527	32.30965	102544.283	98495.224
18	MQE3	1.83117	32.64377	102545.379	98523.198
19	MQE5	10.29545	30.95424	102539.836	98550.968
20	MQE7	18.14780	27.64839	102528.990	98576.730
21	MQF1	24.63332	21.95307	102510.305	98598.008
22	MQF3	29.18589	14.73602	102486.627	98612.944
23	MQF5	31.95486	6.56097	102459.805	98622.029
24	MQF7	33.01808	-1.89229	102432.072	98625.517