Proposed magnet alignment changes for AP-1

February 2, 2001
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Beamline Description

AP-1 was built to connect the Antiproton Source with the Main Ring accelerator. The beamline was designed to support modes of operation at both 8 GeV and 120 GeV kinetic energy. During the days of Main Ring operation, 120 GeV beam was extracted through the field region of a Lambertson at F-17 and transported approximately 174 meters to the production target. This "pbar production" mode required a lattice that would focus the proton beam to a small spot size on the target to maximize antiproton yield. The AP-1 line would also be reconfigured to operate at 8 GeV to support antiproton transfers and tuning cycles with protons. The AP-1 line is also connected to the Accumulator via AP-3, so the lattices of these beamlines needed to be compatible.

After the Main Injector was built to replace the Main Ring, a beamline was required to connect it with the Antiproton Source. Designers chose to combine beam transfers of 150 GeV protons to the Tevatron, 120 GeV protons to AP-1, 120 GeV protons to Switchyard and 8 GeV proton tune-up or antiproton transfers via AP-1 into the P1 and P2 lines. The P2 line resides in the Main Ring tunnel enclosure between F-0 and F-17 and utilizes original Main Ring magnets. The lattice was designed to duplicate the Twiss parameters of the old Main Ring at F-17, including the large horizontal beta and dispersion functions. The addition of the P1 and P2 lines add almost an additional 1,000 meters and an extra Lambertson magnet (at F0) to beam transfers to and from the Main Injector versus the Main Ring.

Although Lambertson magnets are still used to extract beam from the Main Injector, the Lambertson at F-17 was no longer required. Unfortunately, the limited aperture C-magnets at F-17 remained, necessitated by the P3 line which is intended to provide beam to Switchyard for future "Meson 120" operation. The C-magnets are one of the limiting horizontal apertures in the AP-1 line due to the combination of small physical aperture and the large horizontal beta and dispersion functions.

Most of the AP-1 magnets were originally used in Switchyard. Apertures of these magnets are adequate for high energy operation, but have apertures that are smaller than magnets traditionally used in other 8 GeV transfer lines. This makes the AP-1 line unusually sensitive to alignment and steering errors. In addition, the lattice constraints imposed by the beamlines attached to AP-1 does not allow much freedom in suppressing the lattice functions at key locations to reduce the beam size.

Changes to AP-1 in the Main Injector era

With the replacement of the Main Ring, the F-17 location no longer needed a Lambertson to provide a field-free aperture for beam to circulate through. The old extraction process required a 42 mm excursion to the right of center (proton direction) in the F-17-1 quadrupole magnet which is no longer necessary. With the P2 line in place, the AP-1 magnets could be shifted to correspond with the horizontal centerline of the F-17 quadrupole. This was only partially carried out however, logistical problems with the magnet hangers for PB1&2 and PBR1&2 led to the adoption of an alternative scheme. The first F-17 Lambertson magnet field region was aligned to the F-17 quadrupole centerline, but the Lambertson was rolled 5.4 degrees to provide a horizontal kick to the right that would displace beam about 25 mm at the entrance to dipole PB1. Figure 1 illustrates the horizontal trajectory change between F-17 and PB1. The four-dipole string PB1&2, PBR1&2 was then located so that beam would pass through PQ1 with the original design trajectory. The new geometry required an increased operating current in the magnet string, which is powered series by a single power supply. The two rolled dipoles, PBR1&2, had their roll angles changed from 45.5 degrees to 39.6 degrees to preserve the vertical pitch required to transport beam through the "sewer pipe" connecting the Tevatron and Pre-Target enclosures.

The two F-17 Lambertson magnets were later replaced with a single B-3 style dipole to improve the physical horizontal aperture. Unfortunately the two C-magnets remain just downstream of F17B3. Their physical horizontal apertures are just as tight as the Lambertson's and the beam size is only a little smaller. From the perspective of improving performance of the Antiproton Source, it would be a significant aperture improvement to replace the C-magnets with another B-3 dipole. This would block beam from entering the P-3 line for Meson 120 operation, however.

Operational experience

AP-1 performance has been lower than expected through the Run II commissioning period for the pbar source. The overall transfer efficiency of reverse protons from the Main Injector to the Accumulator has been about 10-15% lower than in Run I, perhaps half of the beam loss occurring in AP-1. Comparing present conditions to those in Run I, the AP-1 line is less tolerant of steering errors. Measurements of emittances and momentum spread in the Main Injector are comparable with those from the Main Ring in Run I. Calculations of the Twiss parameters at F-17 suggest that the conditions at the P2/AP-1 interface are about the same as from the Main Ring in Run I. Presuming the measurements and calculations are accurate, the most likely source of the performance loss is a combination of magnet misalignment in AP-1 and the new beam trajectory through the P-2/AP-1 interface.

An AP-1 problem that surfaced immediately during the commissioning of P1 and P2 is that the new roll angles of PBR1&2 are not correct. It was not possible to center beam through the F-17 and PQ1 quadrupoles and arrive within 10mm in both planes at PQ2 without a significant contribution from trim magnets. The addition of a new trim, VT101A, just downstream of PBR2 provided enough bend strength with 8 GeV beam to compensate for the lack of down-bend provided by the rolled dipoles. However the VT101A trim isn't strong enough to compensate when running 120 GeV beam. To correct the roll angle, an increase of 1.5 degrees on both PBR1&2 has been calculated based on beam studies with both 8 GeV and 120 GeV beam.

After VT101A was installed, it was possible to center 8 GeV protons through the PQ1-3 quadrupoles. However, PQ4 was found to be several millimeters lower than the line described by the upstream quadrupoles. In addition, it appeared that PQ5A&B were also too low, but by a lesser amount than PQ4. Looking back at position data from Run I shows evidence that this alignment problem existed at that time. The quadrupole alignment problem in conjunction with the lack of down-bend from PBR1&2 results in 120 GeV beam being subjected to strong steering from the quadrupoles. This not only reduces the available aperture of the beamline but prevents the proton beam from exiting AP-1 without a significant position and/or angle error.

Survey results

A complete optical survey of AP-1 was undertaken during February and March 2000. Figures 2 and 3 show deviations between the survey data and the original design location for the horizontal and vertical planes respectively. There are two adjustments to the data. First, the horizontal desired positions between F-17 and PB1 reflect the new desired positions defined by the P1/P2 beamline designer. The second adjustment is that vertically, the elevation of the downstream end of AP-1 line was built differently than the original design. Desired positions downstream of PBV2 reflect the modified elevation which is 1.38 inches lower than the original design.

The horizontal survey (figure 2) shows mostly small deviations from design through AP-1. The most significant offsets from desired positions occur in the PQ6A&B and PQ7A&B quadrupoles. Not shown in the figure are survey errors on Beam Position Monitors and SEM grids. There are several devices that deviate .25 inches or more from the desired positions. In comparing the F-17 to PB1 section of AP-1 that has new desired positions, there appears to be an offset to the right (proton direction) in the PB1,2 and PBR1,2 magnets. In figure 4, old and new survey data are compared to what is expected based on magnet transfer function data. Offsets from the present locations in order to follow this new ideal trajectory are shown in figure 5.

Examining the vertical survey results illustrated in Figure 3, the entire beamline is significantly below the original desired positions, perhaps due to settling. The quadrupoles approximately line up between vertical bend centers, which allows the line to work as well as it does. It would be far easier to create a new design trajectory that approximates the existing pattern than to force the magnets back to the original design. In figure 3 I have illustrated the new design trajectory with a green line. The largest deviations from the new desired trajectory is bend magnets PB2,3&4 and quadrupoles PQ4, PQ5A&B.

Proposed magnet moves

In summary, I am proposing several changes in existing desired position in AP-1 for both planes. In addition, I would like to increase the roll angle of PBR1&2 to provide the proper trajectory through the sewer pipe. Table 1 contains the survey data from last year, the new desired positions and the difference between the two. Position differences that are highlighted are those that are far enough out of tolerance to warrant moving the magnets. In most cases, tolerances were set to .020" for quadrupoles and .040" for dipoles and diagnostics. In some cases (but not quadrupoles), magnets with large apertures were given a wider tolerance and will not be moved. Since PBR1&2 are being moved in both planes and will have a change in roll angle, calculation of the new offsets requires several steps. I have attached worksheets that describe how I arrived at the new survey offsets.

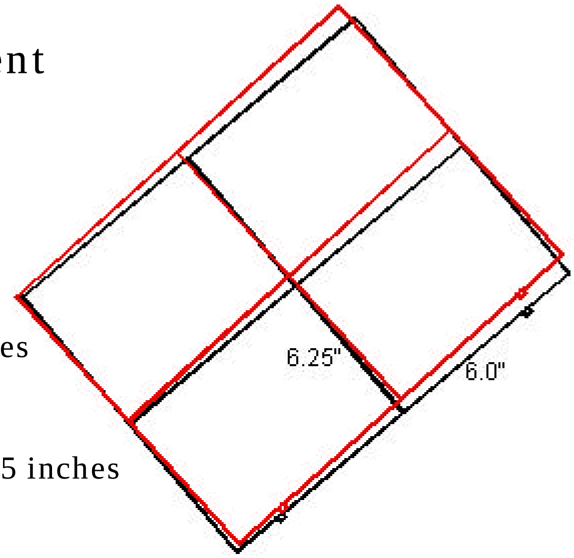
Moving all of the AP-1 magnets in one step would not be prudent, any flaws in concept or calculations would be hard to identify. I would suggest making the magnet moves in four itterations, each followed by a period of beam studies at both 8 GeV and 120 GeV to confirm improved aperture and reduced quadrupole steering. The first set of changes would involve the two F-17 C-magnets. The interface between the magnets needs to be lowered about an inch due to an alignment error during the reinstallation of the magnets. Although the C-magnets have a large vertical physical aperture, beam passes through the lower part of these magnets. In addition, there is some question about whether or not the correct offset was used when the magnets were surveyed in horizontally. The horizontal alignment needs to be checked and the magnets resurveyed if necessary. This is a relatively "safe" set of moves and can take place before beam start-up in the month of February. The roll angle changes to PBR1&2 causes the magnets to shift in both planes, so I would combine horizontal and vertical moves on the Tevatron side of the sewer pipe into one set of moves. After beam studies I would follow with a second step, consisting of the rest of the moves in the vertical plane only. Finally the last set of moves would be the remaining horizontal adjustments. The last step involves only modest changes, the second and third steps have the highest likelihood of problems. If a set of moves does not provide the desired improvements, a new plan will need to be formulated based on the beam data.

Long term improvements

If the AP-1 line is to be used for transfers of large emittance antiprotons, either to the Main Injector or the Recycler, the aperture will not be adequate to transfer the beam without beam loss. To improve the acceptance of the AP-1 line, larger aperture magnets would be needed to replace those that have restricted apertures. The EPB style dipoles from Switchyard, PB1-5 and PBR1-3, have an aperture of only about 35 mm. A suitable replacement magnet should have an aperture of at least 50mm, preferably more. The F-17 C-magnets and AP-1 trim magnets have apertures similar to the EPB's. These magnets would also have to be replaced with larger aperture alternatives. The entire Accumulator to Main Injector transfer process needs to be reexamined. A new dedicated beamline has been proposed for antiproton transfers from the Accumulator on several occasions. It would be beneficial to devise a new scheme that would allow beam transferred to and from pbar to avoid the F0 Lambertson and associated rapid elevation changes in P1 and P2 as well as conflicts with the P3 line.

PBR1 Realignment

January 4, 2001



Horizontal

Move towards wall (left in proton direction)
Upstream +0.240 inches, Downstream +0.160 inches

Vertical

Raise Upstream +0.170 inches, Downstream +0.175 inches

Make roll angle 41.0°

Centroid, Winter 2000

Horizontal (from Murphy line)
Upstream 27.241 inches, Downstream 29.828 inches
Vertical (inches above 720 foot elevation)
Upstream 89.456 inches, Downstream 92.952 inches

New Desired centroid

Horizontal (from Murphy line)
Upstream 27.481 inches, Downstream 29.988 inches
Vertical (inches above 720 foot elevation)
Upstream 89.626 inches, Downstream 93.127 inches

Adjustment for roll angle to calculate survey offsets

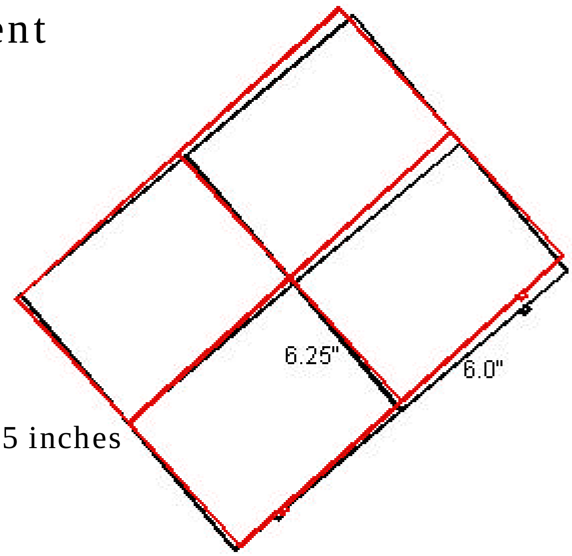
Sin 41° (6.25") = 4.100"	Horizontal	BL = centroid + (4.528" - 4.100")
Cos 41° (6.0") = 4.528"		BR = centroid - (4.528" + 4.100")
Cos 41° (6.25") = 4.717"	Vertical	BL = centroid - (4.717" - 3.936")
Sin 41° (6.0") = 3.936"		BR = centroid - (4.717" + 3.936")

Survey points

	Horizontal		Vertical	
Upstream	BR	18.853"	BR	88.845"
	BL	27.909"	BL	80.973"
Downstream	BR	21.360"	BR	92.346"
	BL	30.416"	BL	84.474"

PBR2 Realignment

January 4, 2001



Horizontal

Move towards wall (left in proton direction)
Upstream +0.330 inches, Downstream no move

Vertical

Raise Upstream +0.140 inches, Downstream +0.095 inches

Make roll angle 41.0°

Centroid, Winter 2000

Horizontal (from Murphy line)
Upstream 30.162 inches, Downstream 33.644 inches
Vertical (inches above 720 foot elevation)
Upstream 93.334 inches, Downstream 95.964 inches

New Desired centroid

Horizontal (from Murphy line)
Upstream 30.492 inches, Downstream 33.644 inches
Vertical (inches above 720 foot elevation)
Upstream 93.474 inches, Downstream 96.059 inches

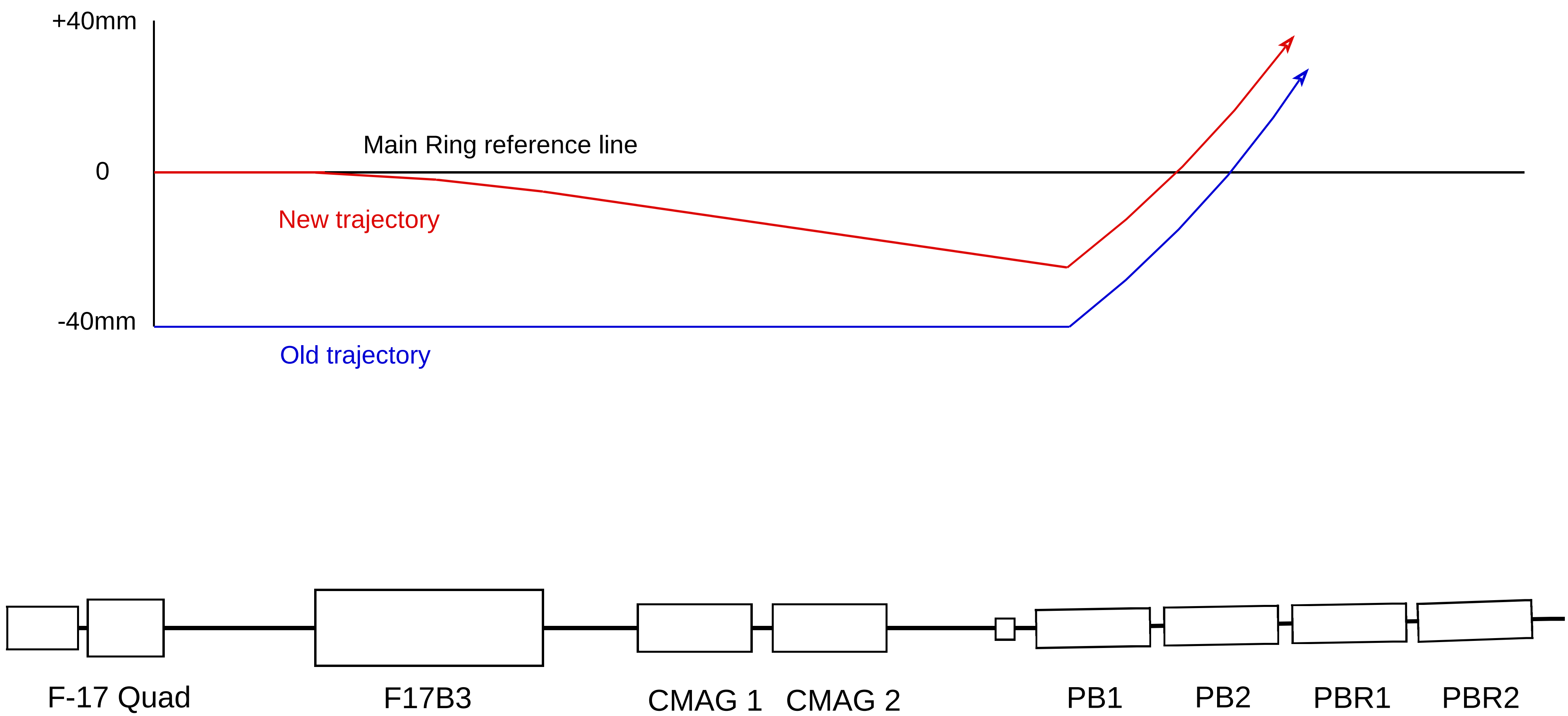
Adjustment for roll angle to calculate survey offsets

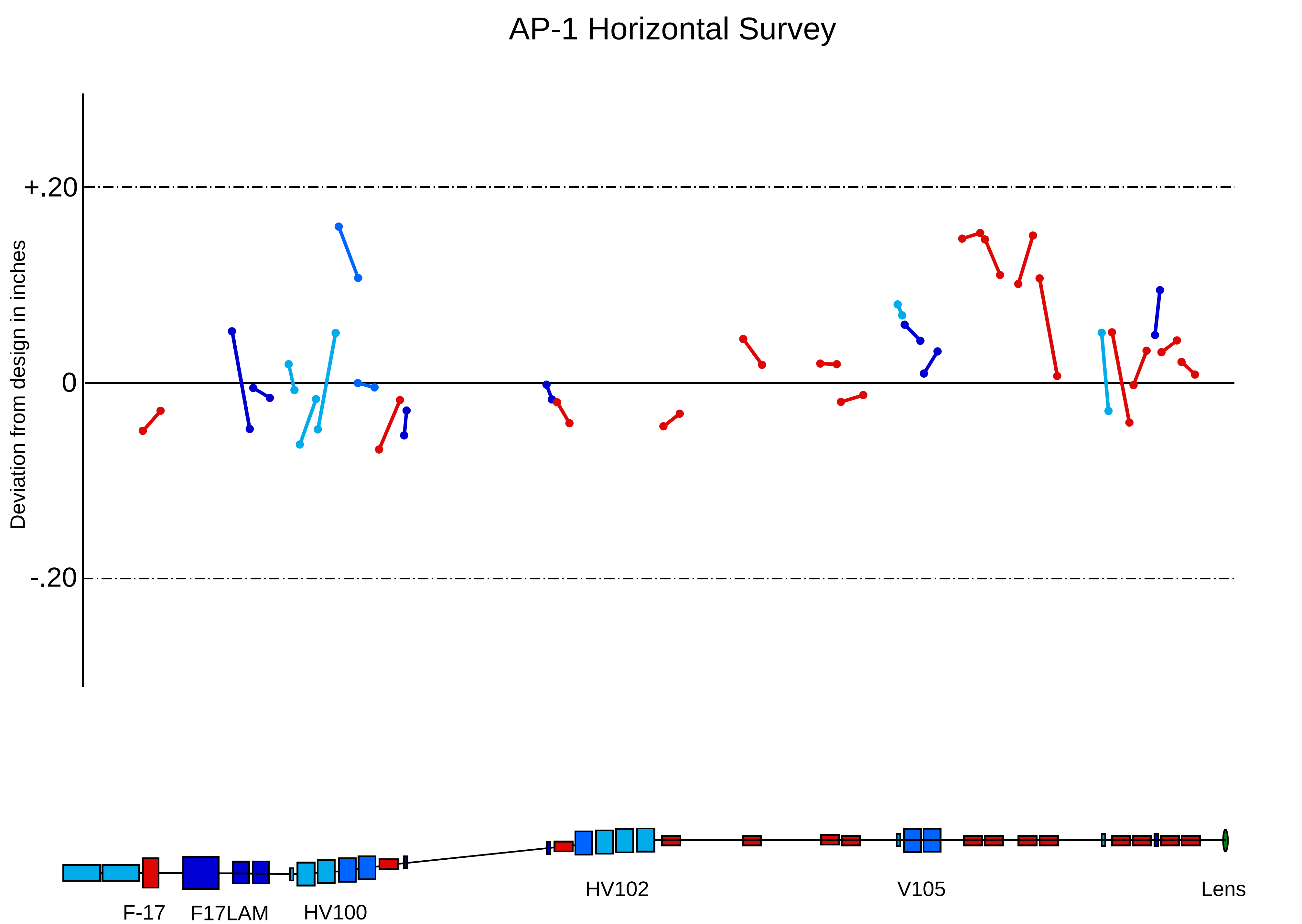
Sin 41° (6.25") = 4.100" Horizontal BL = centroid + (4.528" - 4.100")
Cos 41° (6.0") = 4.528" BR = centroid - (4.528" + 4.100")

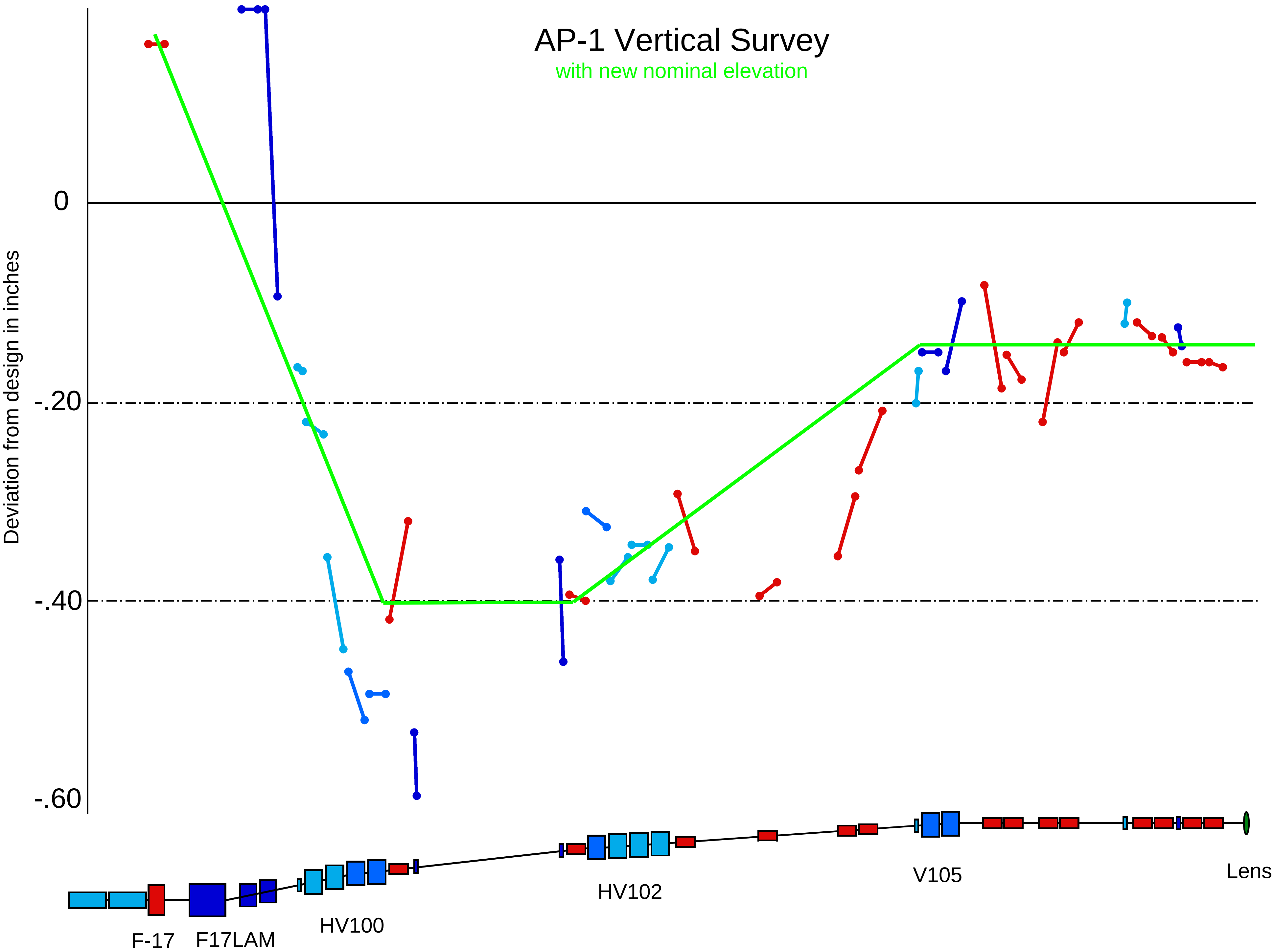
Cos 41° (6.25") = 4.717" Vertical BL = centroid - (4.717" + 3.936")
Sin 41° (6.0") = 3.936" BR = centroid - (4.717" - 3.936")

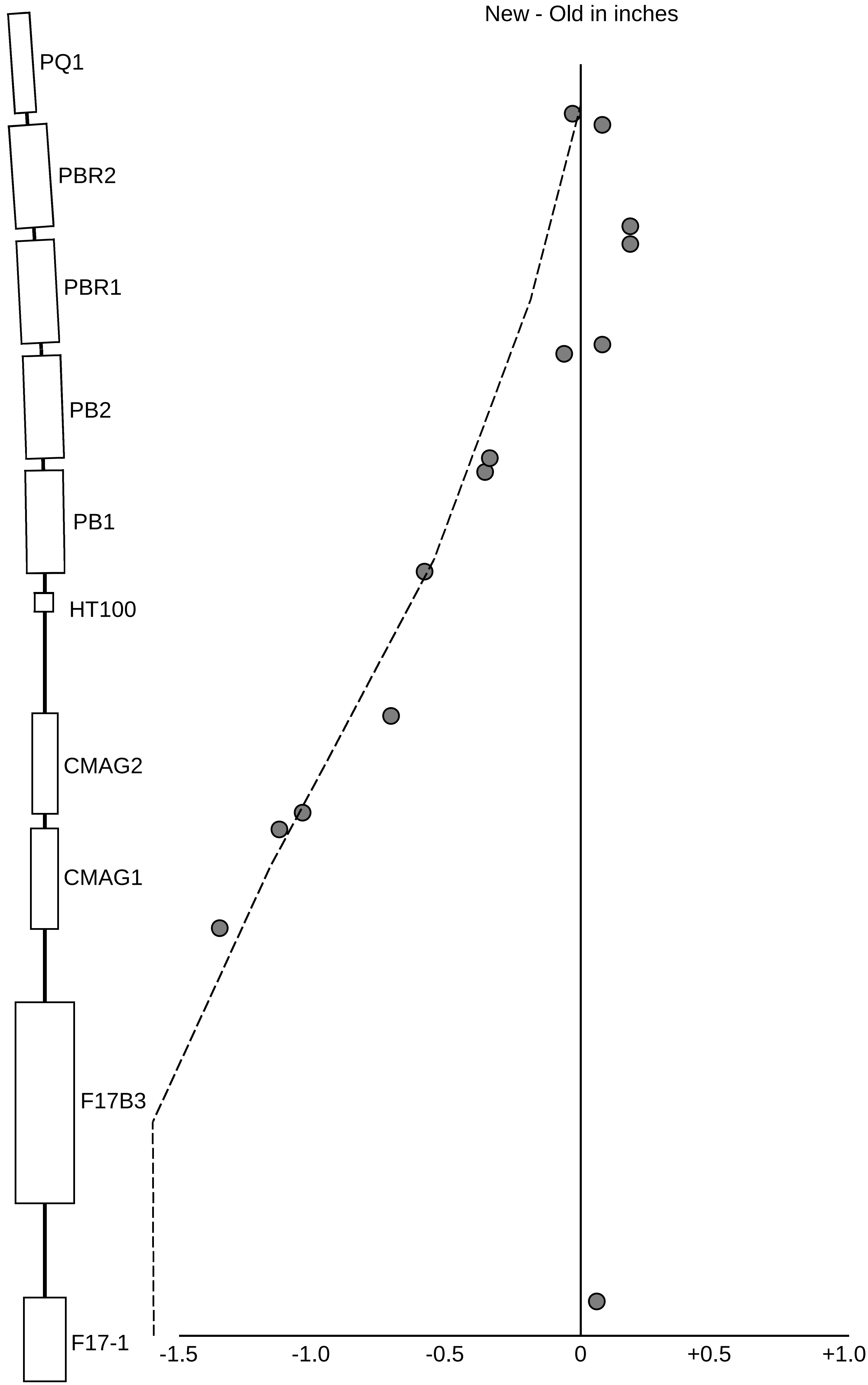
Survey points

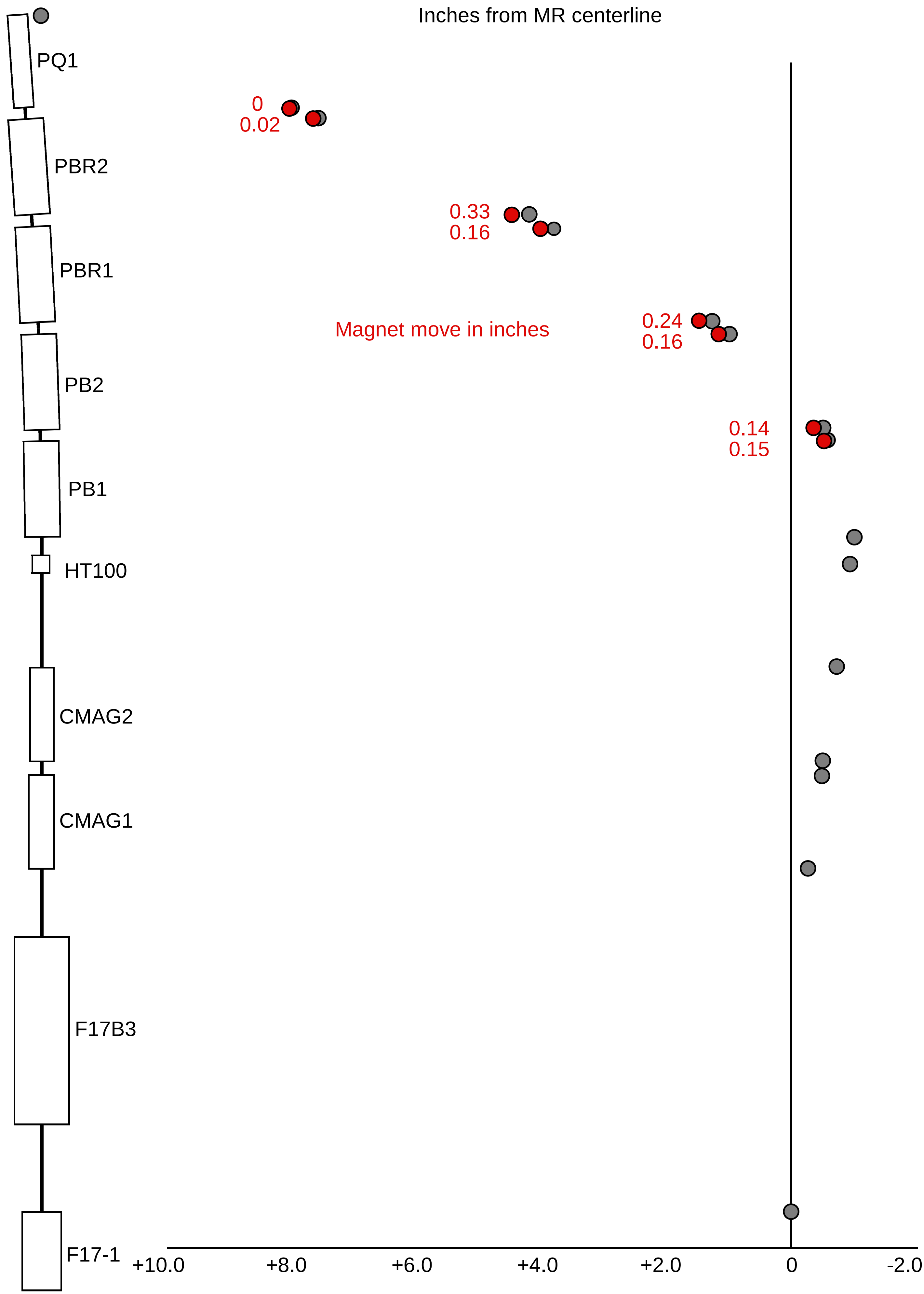
	Horizontal	Vertical
Upstream	BR 21.864"	BR 92.693"
	BL 30.920"	BL 84.821"
Downstream	BR 25.016"	BR 95.278"
	BL 34.072"	BL 87.406"


+40mm
0
-40mm
Main Ring reference line
New trajectory
Old trajectory
F-17 Quad
F17B3
CMAG 1
CMAG 2
PB1
PB2
PBR1
PBR2


AP-1 Horizontal Survey
Deviation from design in inches
+.20
0
-.20
F-17
F17LAM
HV100
HV102
V105
Lens


AP-1 Vertical Survey
with new nominal elevation
Deviation from design in inches
0
-.20
-.40
-.60
F-17
F17LAM
HV100
HV102
V105
Lens


New - Old in inches
PQ1
PBR2
PBR1
PB2
PB1
HT100
CMAG2
CMAG1
F17B3
F17-1
-1.5
-1.0
-0.5
0
+0.5
+1.0



Inches from MR centerline
PQ1
PBR2
PBR1
PB2
PB1
HT100
CMAG2
CMAG1
F17B3
F17-1
0
0.02
0.33
0.16
0.24
0.16
0.14
0.15
Magnet move in inches
+10.0
+8.0
+6.0
+4.0
+2.0
0
-2.0

AP-1 vertical alignment, Tevatron enclosure

Tolerances: Quadrupoles .020", Dipoles .040", Diagnostics .040"
Winter survey completed February 15 2000, reference book 78-8 pages 58-67
Positive change means to move device up

Location	Magnet	Distance to	Survey Point (in)		Winter '00 Survey (Inches above 720')		New desired positions (Inches above 720')		Change		Comments
	Length (in)	Center (ft)	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	
MRF17											
a,c					66.154	66.151	66.150	66.150	-0.004	-0.001	
b,d					66.156	66.158	66.150	66.150	-0.006	-0.008	
F17B3	240	9.87									
Top									NC	NC	
Bottom									NC	NC	
CMAG1	118.4	31.43	5.5	112.9	81.157	83.362	80.024	82.360	-1.133	-1.002	CMAG1/2 interface move may be limited by P3
CMAG2	118.4	43.11	5.5	112.9	84.126	86.250	83.120	86.240	-1.006	-0.010	line beampipe. If so, lower as far as possible.
BPM100					78.163	78.787	78.460	78.940	0.297	0.153	
HT100	20	59.25	0	20							
Bottom right					79.837	80.480	79.830	80.480	-0.007	0.000	
Bottom left					79.819	80.484	79.830	80.480	0.011	-0.004	
PB1	120	66.47	1	119							
Bottom right					81.006	84.813	81.030	84.820	0.024	0.007	
Bottom left					81.021	84.818	81.030	84.820	0.009	0.002	
PB2	120	77.46	1	119							
Bottom right					85.246	89.058	85.350	89.200	0.104	0.142	
Bottom left					85.248	89.048	85.350	89.200	0.102	0.152	
PBR1	120	88.48	1	119							
Bottom right					88.468	91.824	88.845	92.346	0.377	0.522	
Bottom left					80.815	84.323	80.973	84.474	0.158	0.151	
PBR2	120	99.47	1	119							
Bottom right					92.251	94.940	92.693	95.278	0.442	0.338	
Bottom left					84.700	87.326	84.821	87.406	0.121	0.080	
PQ1	120	110.52	1	119							
Bottom right					96.313	98.658	96.340	98.580	0.027	-0.078	
Bottom left					96.333	98.664	96.340	98.580	0.007	-0.084	
BPM101					98.790	99.043	98.790	99.040	0.000	-0.003	
SEM100					99.240	99.495	99.140	99.400	-0.100	-0.095	
VT101A	20	120.70	0	20							
Bottom right					99.792	100.230	99.920	100.425	0.128	0.195	
Bottom left					99.793	100.223	99.920	100.425	0.127	0.202	

AP-1 horizontal alignment, Tevatron enclosure

Tolerances: Quadrupoles .020", Dipoles .040", Diagnostics .040"
Winter survey completed February 15 2000, reference book 78-8 pages 58-67
Positive change means to move device towards wall (left in proton beam direction), NC means no change

					Inches from Murphy Line						
Location	Magnet	Distance to	Survey Point (in)		Winter '00 Survey		New desired positions		Change		Comments
	Length (in)	Center (ft)	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	
MRF17					26.578	26.530			NC	NC	
F17B3	240	9.87									
Top									NC	NC	
Bottom									NC	NC	
CMAG1	118.4	31.43	5.5	112.9							
Top					25.840	25.781	25.916	25.669	0.076	-0.112	
Bottom					26.031	25.806	26.058	25.811	0.027	0.005	
CMAG2	118.4	43.11	5.5	112.9							
Top					25.641	25.399	25.625	25.374	-0.016	-0.025	
Bottom					25.759	25.527	25.767	25.517	0.008	-0.010	
BPM100					24.920	25.032	25.325	25.287	0.405	0.255	
HT100	20	59.25	0	20							
Top					25.191	25.175	25.208	25.164	0.017	-0.011	
Bottom					25.175	25.168	25.208	25.164	0.033	-0.004	
PB1	120	66.47	1	119	25.202	25.479	25.128	25.620	-0.074	0.141	
PB2	120	77.46	1	119	25.600	27.000	25.750	27.160	0.150	0.160	
PBR1	120	88.48	1	119							
Bottom right					18.623	21.205	18.853	21.360	0.230	0.155	
Bottom left					27.775	30.321	27.909	30.416	0.134	0.095	
PBR2	120	99.47	1	119							
Bottom right					21.554	25.038	21.864	25.016	0.310	-0.022	
Bottom left					30.795	34.289	30.920	34.072	0.125	-0.217	
PQ1	120	110.52	1	119	33.672	37.544	33.650	37.550	-0.022	0.006	
BPM101					38.410	38.830	38.127	38.543	-0.283	-0.287	
SEM100					39.132	39.494	38.843	39.225	-0.289	-0.269	
VT101A	20	120.70	0	20							
Top					39.848	40.469	39.774	40.439	-0.074	-0.030	
Bottom					39.832	40.473	39.774	40.439	-0.058	-0.034	

AP-1 vertical alignment, Pre-Target/Pre-Vault enclosures

Tolerances: Quadrupoles .020", Dipoles .040", Diagnostics .040"
Spring survey completed March 16, 2000, reference book 78-8 pages 71-89
Positive change means to move device up

Location	Magnet	Distance to	Survey Point (in)		Spring '00 Survey		New desired positions		Change		Comments
					Inches above 720'						
	Length (in)	Center (ft)	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	
VT101	35	196.03	0	35	116.695	117.250	116.640	117.312	-0.055	0.062	
SEM101					117.677	117.655	117.612	117.612	-0.065	-0.043	
PQ2	120	204.94	15	115							
Right					118.165	120.065	118.200	120.036	0.035	-0.029	
Left					118.174	120.056	118.200	120.036	0.026	-0.020	
PBR3	120	215.94									Elevations are to tooling ball with no offsets
Right					125.652	127.370	125.572	127.320	-0.080	-0.050	
Left					126.876	128.528	126.796	128.478	-0.080	-0.050	
PB3	120	226.93	12	108							
Right					122.571	123.761	122.580	123.768	0.009	0.007	
Left					122.581	123.767	122.580	123.768	-0.001	0.001	
PB4	120	238.39	12	108							
Right					124.275	125.447	124.260	125.448	-0.015	0.001	
Left					124.265	125.453	124.260	125.448	-0.005	-0.005	
PB5	120	249.64	12	108							
Right					125.919	127.119	125.976	127.128	0.057	0.009	
Left					125.926	127.124	125.976	127.128	0.050	0.004	
PQ3	120	260.98	15	105							
Right					127.689	128.749	127.668	128.772	-0.021	0.023	
Left					127.700	128.758	127.668	128.772	-0.032	0.014	
BPM103					129.231	129.396	129.036	129.168	-0.195	-0.228	
SEM103					129.514	129.515	129.300	129.300	-0.214	-0.215	
PQ4	120	304.22	18	102							
Right					134.024	135.056	134.124	135.180	0.100	0.124	
Left					134.013	135.061	134.124	135.180	0.111	0.119	
BPM104					135.319	135.457	135.480	135.612	0.161	0.155	
PQ5A	120	347.69	6	114							
Right					140.287	141.656	140.424	141.768	0.137	0.112	
Left					140.281	141.668	140.424	141.768	0.143	0.100	
PQ5B	120	358.84	6	114							
Right					141.983	143.367	142.056	143.400	0.073	0.033	
Left					141.981	143.366	142.056	143.400	0.075	0.034	
BPM105					143.663	143.794	143.556	143.676	-0.107	-0.118	
SEM105					143.876	143.890	143.808	143.808	-0.068	-0.082	
HT105	35	385.5	3	29							
Right					146.478	146.799	146.508	146.832	0.030	0.033	
Left					146.461	146.802	146.508	146.832	0.047	0.030	
PBV1	120	393.04	12	108							
Right					147.177	148.066	147.072	148.176	-0.105	0.110	

Left					147.173	148.057	147.072	148.176	-0.101	0.119
PBV2	120	403.87	12	108						
Right					148.281	148.619	148.260	148.615	-0.021	-0.004
Left					148.269	148.615	148.260	148.615	-0.009	0.000
Wallmon					148.731	148.711	148.620	148.620	-0.111	-0.091
TOR105					148.689	148.678	148.620	148.620	-0.069	-0.058
PQ6A	120	424.46	15	105						
Right					148.658	148.540	148.620	148.620	-0.038	0.080
Left					148.677	148.589	148.620	148.620	-0.057	0.031
PQ6B	120	435.29	17	103						
Right					148.603	148.589	148.620	148.620	0.017	0.031
Left					148.614	148.593	148.620	148.620	0.006	0.027
SEM106					148.622	148.590	148.620	148.620	-0.002	0.030
BPM106					148.618	148.607	148.620	148.620	0.002	0.013
PQ7A	120	453.66	18	112						
Right					148.603	148.599	148.620	148.620	0.017	0.021
Left					148.590	148.634	148.620	148.620	0.030	-0.014
PQ7B	120	464.82	16	101						
Right					148.619	148.638	148.620	148.620	0.001	-0.018
Left					148.612	148.640	148.620	148.620	0.008	-0.020
EB6	63.9	471.78	0	63.9						
Right					148.651	148.656	148.620	148.620	-0.031	-0.036
Left					148.663	148.673	148.620	148.620	-0.043	-0.053
BPM107					148.618	148.607	148.620	148.620	0.002	0.013
HT107	35	496.39	3	32						
Right					148.644	148.667	148.620	148.620	-0.024	-0.047
Left					148.642	148.662	148.620	148.620	-0.022	-0.042
PQ8A	120	503.86	15	110						
Right					148.641	148.632	148.620	148.620	-0.021	-0.012
Left					148.652	148.637	148.620	148.620	-0.032	-0.017
PQ8B	120	515.01	16	112						
Right					148.613	148.633	148.620	148.620	0.007	-0.013
Left					148.647	148.599	148.620	148.620	-0.027	0.021
VT108	35	523.62	1	31						
Right					148.638	148.626	148.620	148.620	-0.018	-0.006
Left					148.647	148.621	148.620	148.620	-0.027	-0.001
BPM108					148.650	148.663	148.620	148.620	-0.030	-0.043
PQ9A	120	532.4	20	111						
Right					148.606	148.606	148.620	148.620	0.014	0.014
Left					148.601	148.603	148.620	148.620	0.019	0.017
PQ9B	120	543.56	18	112						
Right					148.605	148.590	148.620	148.620	0.015	0.030
Left					148.610	148.602	148.620	148.620	0.010	0.018

AP-1 horizontal alignment, Pre-Target/Pre-Vault enclosures

Tolerances: Quadrupoles .020", Dipoles .040", Diagnostics .040"
Spring survey completed March 16, 2000, reference book 78-8 pages 71-89
Positive change means to move device farther from reference line

					Inches from reference line						
Location	Magnet	Distance to	Survey Point (in)		Spring '00 Survey		New desired positions		Change		Comments
	Length (in)	Center (ft)	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream	
VT101	35	196.03	0	35							
Top					20.001	20.018	20.000	20.000	-0.001	-0.018	
Bottom					20.006	20.015	20.000	20.000	-0.006	-0.015	
SEM101					20.085	20.021	20.000	20.000	-0.085	-0.021	
PQ2	120	204.94	14	115	20.019	20.043	20.000	20.000	-0.019	-0.043	
PBR3	120	215.94			20.077	20.300	20.000	20.280	-0.077	-0.020	
PB3	120	226.93	12	108	20.628	21.717	20.390	21.530	-0.238	-0.187	
PB4	120	238.39	12	108	22.245	20.887	22.135	20.568	-0.110	-0.319	
PB5	120	249.64	12	108	20.480	20.068	20.448	20.000	-0.032	-0.068	
PQ3	120	260.98	15	105	20.046	20.027	20.000	20.000	-0.046	-0.027	
BPM103					19.945	19.903	20.000	20.000	0.055	0.097	
SEM103					19.959	19.918	20.000	20.000	0.041	0.082	
PQ4	120	304.22	18	102	19.963	19.983	20.000	20.000	0.037	0.017	
BPM104					19.979	19.918	20.000	20.000	0.021	0.082	
PQ5A	120	347.69	6	114	19.985	19.983	20.000	20.000	0.015	0.017	
PQ5B	120	358.84	6	114	20.021	20.015	20.000	20.000	-0.021	-0.015	
BPM105					19.937	19.865	20.000	20.000	0.063	0.135	
SEM105					20.031	19.851	20.000	20.000	-0.031	0.149	
HT105	35	385.5	3	29	19.920	19.933	20.000	20.000	0.080	0.067	
PBV1	120	393.04	12	108	19.940	19.957	20.000	20.000	0.060	0.043	
PBV2	120	403.87	12	108	19.990	19.968	20.000	20.000	0.010	0.032	
Wallmon					20.082	20.084	20.000	20.000	-0.082	-0.084	
TOR105					20.066	19.972	20.000	20.000	-0.066	0.028	
PQ6A	120	424.46	15	105	19.864	19.849	20.000	20.000	0.136	0.151	
PQ6B	120	435.29	17	103	19.864	19.889	20.000	20.000	0.136	0.111	
SEM106					19.184	19.209	20.000	20.000	0.816	0.791	
BPM106					19.784	19.943	20.000	20.000	0.216	0.057	
PQ7A	120	453.66	18	112	19.905	19.853	20.000	20.000	0.095	0.147	
PQ7B	120	464.82	16	101	19.892	19.995	20.000	20.000	0.108	0.005	
EB6	63.9	471.78	0	63.9	18.592	21.096	19.700	21.200	1.108	0.104	
BPM107					20.275	20.191	20.000	20.000	-0.275	-0.191	
HT107	35	496.39	3	32	19.952	20.028	20.000	20.000	0.048	-0.028	
PQ8A	120	503.86	15	110	19.953	20.039	20.000	20.000	0.047	-0.039	
PQ8B	120	515.01	16	112	20.004	19.966	20.000	20.000	-0.004	0.034	
VT108	35	523.62	1	31	19.965	19.913	20.000	20.000	0.035	0.087	
BPM108					19.907	19.884	20.000	20.000	0.093	0.116	
PQ9A	120	532.4	20	111	19.971	19.959	20.000	20.000	0.029	0.041	
PQ9B	120	543.56	18	112	19.983	19.990	20.000	20.000	0.017	0.010	