Fermilab

$\bar{p}$ Note #384

RECENT CHANGES TO THE DESIGN OF THE AP-1 BEAM LINE

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4/27/84

Recent Changes to the Design of the AP-1 Beam Line

1. Modifications related to the new extraction channel, including the effects of the rolled Lambertson

The new extraction channel at F17 consists of two 162" Lambertsons and two 118" C-magnets, in place of the original two 204" high-field Lambertsons. The extracted beam at F17 has a residual angle of 0.8 mrad relative to the Main Ring beam; to minimize the required aperture in the first Lambertson, it is rolled by 5.2 degreees, which provides a small horizontal bend to cancel the residual angle. Matching of this new extraction channel to the front end of the AP-1 line required small changes in the magnet positions and operating currents. Table 1 shows the original set of layout coordinates and operating fields; table 2 shows the new set. The separation between PQ1 and PQ2 is reduced by 13", and the drift space between elements in the second set of dipoles (PBR3,PB3,PB4,PB5) is increased by about the same amount. Lateral shifts are generally small, always less than 0.5". The first set of dipoles runs at about 3% higher current, and the last vertical bend at about 4% higher current than before.

2. Effects of vertical dispersion due to the Main Ring overpass on proton targetting and matching of returning pbars.

The modifications to the beam line discussed above do not result in any significant changes to the focussing or dispersive characteristics of the beam line. The inclusion of the vertical dispersion at F17, resulting from the proposed overpass modifications to the Main Ring does, however, produce a significant vertical dispersion both at the pbar production target and at the matching point for the pbar beam from the Accumulator via AP-3. The case discussed below corresponds to the worst case (BO and DO overpasses, WD89+TCB21).

The vertical dispersion at the target is such that it limits the minimum round beam size to sigma$\sim$.27 mm. For larger beam sizes, and in particular for the proposed operating point of sigma $\sim$.4 mm, the increase in vertical dispersion is inconsequential. Table 3 shows the quad settings and values for the beta and eta functions at the target for three different round beam sizes. The overpass also causes a dispersion mismatch for the reverse injected pbars from the Accumulator at F17. However, the resulting phase-space dilution is quite small ($<$0.5%).

Figures 1, and 2 illustrate the monoenergetic beta functions and the dispersion for the revised AP-1 line, including the overpass dispersion. The beam size at the target(sigma) is 0.4 mm. Figure 3 shows the horizontal and vertical half beam sizes for the 120 GeV extracted proton beam (corresponding to 95% limits, with contributions from dp/p=0.2% and emittance=0.2pi mm-mrad, added in quadrature). Figure 4 shows the horizontal and vertical half beam sizes for the 8 Gev injected pbar beam (corresponding to 95% limits, with contributions from dp/p=0.09% and emittance=2pi mm-mrad, added in quadrature).

In summary, there should be no significant deleterious consequences to the focusing or dispersive properties of the AP-1 line, either for proton targeting or for pbar transport to the Main Ring, resulting from either the modified F17 extraction/injection scheme or the Main Ring vertical dispersion associated with the overpass.

3. Trim magnet placement and strength

It is currently planned to have five trim magnets in AP-1. The magnet locations, maximum currents, and bend angles and directions (at 120 GeV) are given in table 4. Three of these (PT3,PT4,PT5) will be 35" long, 200 turn magnets with a 5" by 1.5" aperture. Because of space limitations, PT1 will be only 20" long, with 200 turns and a 4" by 2" aperture. PT2 will be 35" long, with 200 turns and a 4" by 2" aperture. The larger horizontal aperture for this vertical trim is required to accomodate the returning pbar beam. All magnets are powered by 25A bipolar supplies, which can regulate close to zero for the returning pbar beam. The trims PT4 and PT5 serve to allow beam motion at the production target; for the nominal tune of the last four quad sets, these trims will allow±8.8 mm horizontal and±6.9 mm vertical position shifts (at 120 GeV).

4. Apertures and beam sizes for the extracted proton beam and returning pbar beam

The extracted and injected beam sizes illustrated in figures 3 and 4 are tabulated in table 5, together with the beam line apertures. For the extracted 120 GeV proton beam, the tightest clearances are in the extraction channel (the worst case is about 9 mm at the entrance to the first Lambertson). For the antiproton beam, the three tightest clearances are at PQ3 (where betax ~ 550 m), 2 mm (horizontal); at PB2, 5.5 mm (vertical); and at the end of the last Lambertson, 4.6 mm (horizontal). These latter two clearances are probably acceptable, but the 2 mm at PQ3 is

very close. The most satisfactory solution to this problem would be a retune of the AP-1 line (and presumably also the matched AP-3 line) specifically for pbars, with beta reduced to 350 m or less everywhere. In principle, this should be possible, although at the time of this writing it has not been done. Alternatively, one could increase the horizontal size of the vacuum chamber in PQ3 by about .5 inches. This option is currently being pursued.

5. Summary of magnet parameters and operation at higher energies

Table 6 presents a summary of the magnetic fields, currents, voltages and powers for all elements of the AP-1 line, corresponding to operation at 120 GeV. Also shown are the planned power supplies, the maximum operating currents which will be available, and the water flow, temperature rise, and power corresponding to operation at these maximum currents. Table 7 gives the operating parameters for 8 GeV, together with the planned power supply capabilities. Table 8 presents the operating parameters corresponding to 150 GeV; for those magnets whose currents exceed the supply limit, the overage factor is given. The most severe limit to operation above 120 Gev is set by the PQ5A,B supply, which cannot run above 500 A. This current corresponds to 135 GeV, so this is the upper limit of the beam line as presently conceived. To reach 150 GeV, this supply would need to be replaced by one capable of about 700 A and 230 v. Additionally, the ramped Transrex supplies on the first eight EPB dipoles would have to provide peak currents up to 60% above their rms ratings. Since this is probably not possible, additional supplies would be required here also.

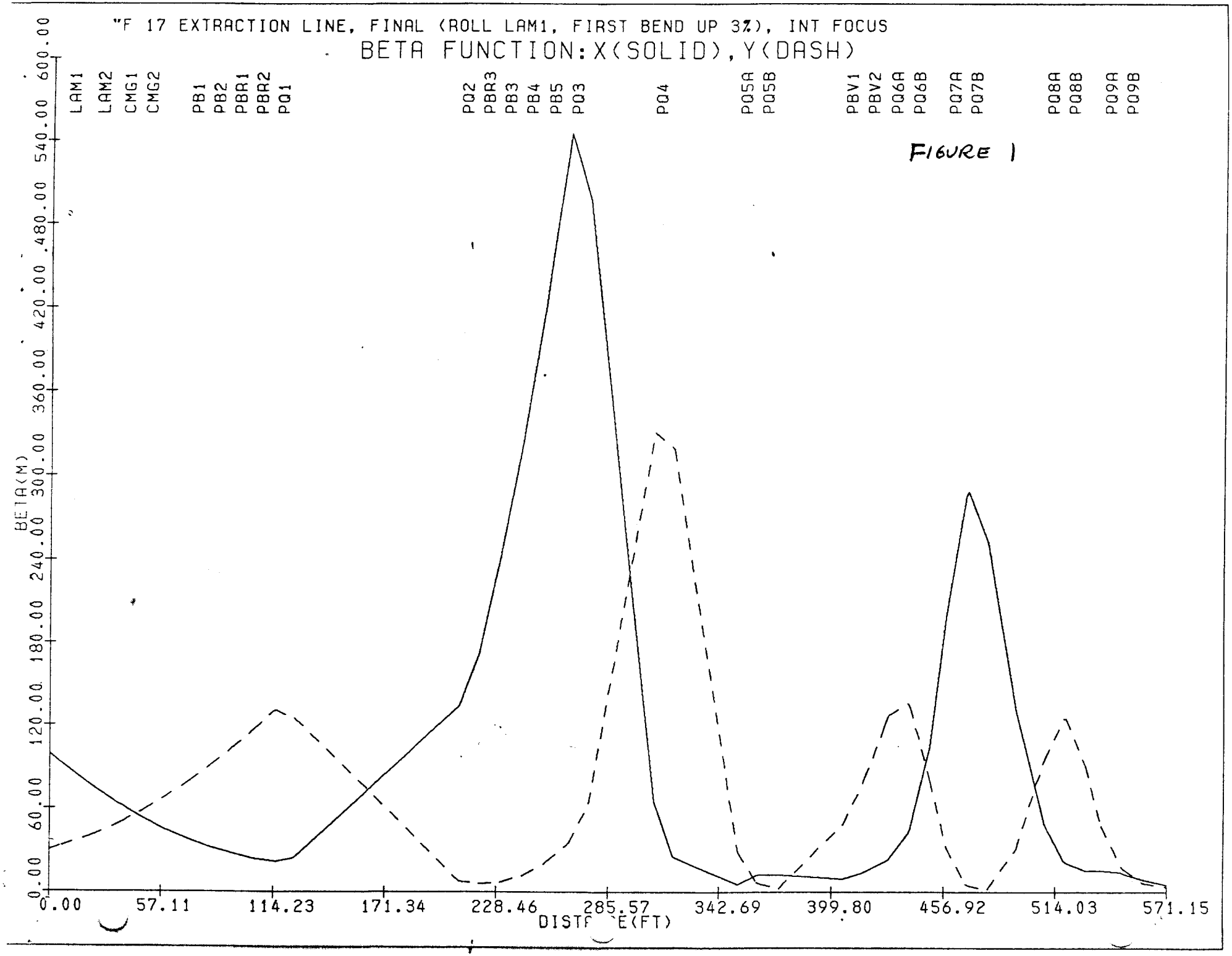
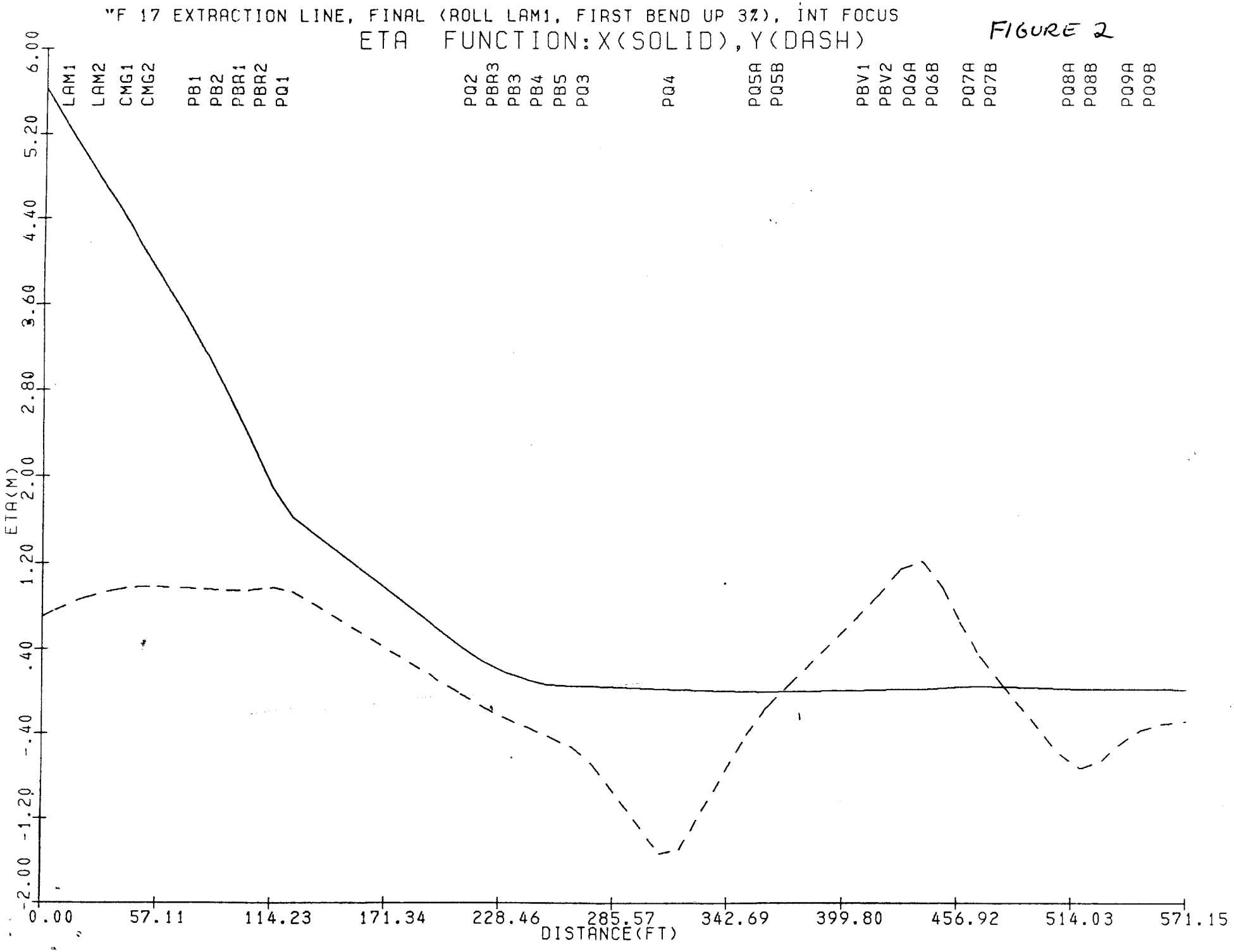
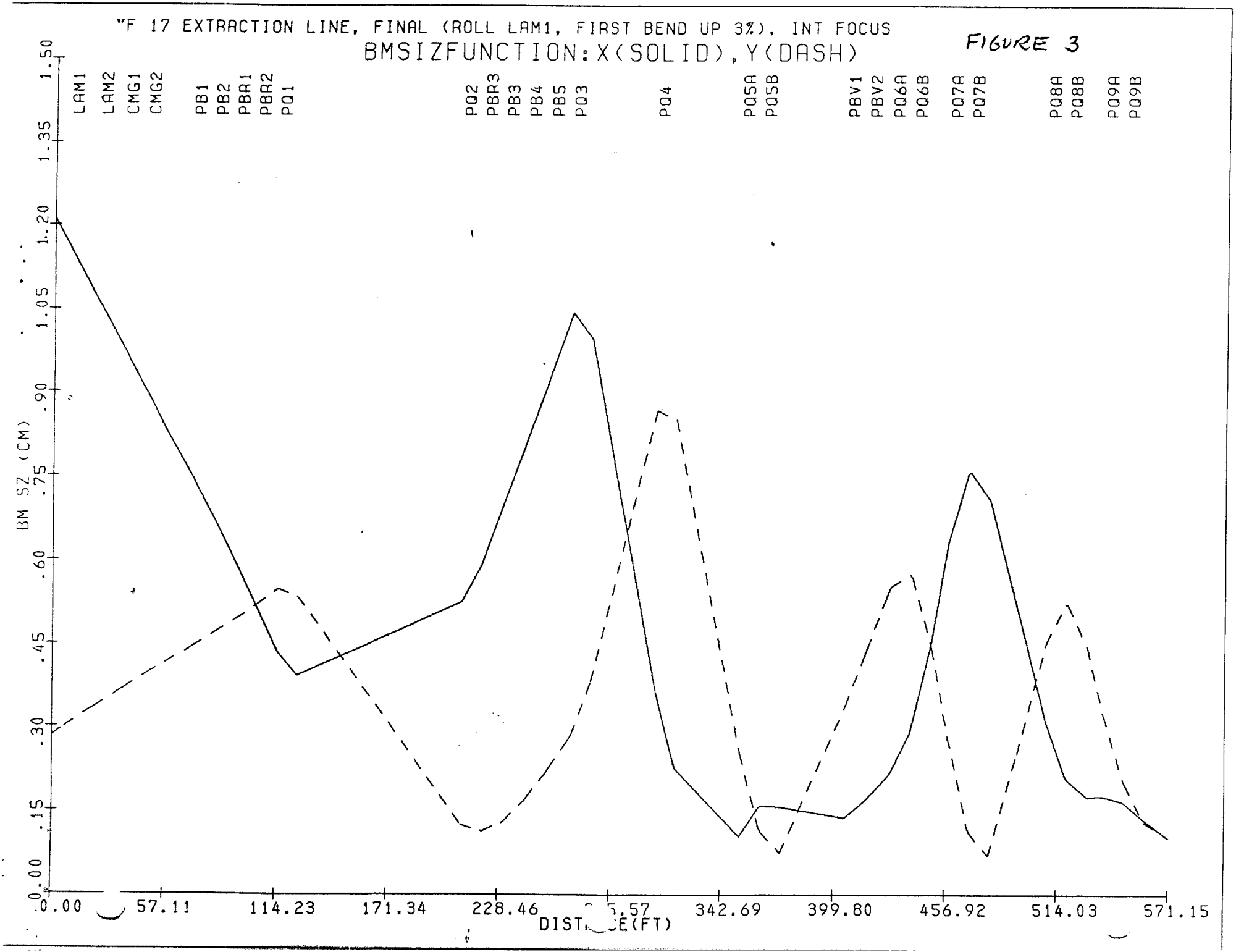

"F 17 EXTRACTION LINE, FINAL (ROLL LAM1, FIRST BEND UP 3%), INT FOCUS
BETA FUNCTION:X(SOLID),Y(DASH)
LAM1
LAM2
CMG1
CMG2
PB1
PB2
PBR1
PBR2
PQ1
PQ2
PBR3
PB3
PB4
PB5
PQ3
PQ4
PQ5A
PQ5B
PBV1
PBV2
PQ6A
PQ6B
PQ7A
PQ7B
PQ8A
PQ8B
PQ9A
PQ9B
BETA(M)
0.00
60.00
120.00
180.00
240.00
300.00
360.00
420.00
480.00
540.00
600.00
0.00
57.11
114.23
171.34
228.46
285.57
342.69
399.80
456.92
514.03
571.15
DISTANCE(FT)

FIGURE 1


"F 17 EXTRACTION LINE, FINAL (ROLL LAM1, FIRST BEND UP 3%), INT FOCUS
ETA FUNCTION:X(SOLID),Y(DASH)
FIGURE 2
LAM1
LAM2
CMG1
CMG2
PB1
PB2
PBR1
PBR2
PQ1
PQ2
PBR3
PB3
PB4
PB5
PQ3
PQ4
PQ5A
PQ5B
PBV1
PBV2
PQ6A
PQ6B
PQ7A
PQ7B
PQ8A
PQ8B
PQ9A
PQ9B
ETA(M)
6.00
5.20
4.40
3.60
2.80
2.00
1.20
.40
-.40
-1.20
-2.00
0.00
57.11
114.23
171.34
228.46
285.57
342.69
399.80
456.92
514.03
571.15
DISTANCE(FT)


"F 17 EXTRACTION LINE, FINAL (ROLL LAM1, FIRST BEND UP 3%), INT FOCUS
BMSIZFUNCTION:X(SOLID),Y(DASH)
FIGURE 3
LAM1
LAM2
CMG1
CMG2
PB1
PB2
PBR1
PBR2
PQ1
PQ2
PBR3
PB3
PB4
PB5
PQ3
PQ4
PQ5A
PQ5B
PBV1
PBV2
PQ6A
PQ6B
PQ7A
PQ7B
PQ8A
PQ8B
PQ9A
PQ9B
BM SZ (CM)
0.00
.15
.30
.45
.60
.75
.90
1.05
1.20
1.35
1.50
0.00
57.11
114.23
171.34
228.46
342.69
399.80
456.92
514.03
571.15
DIST E(FT)

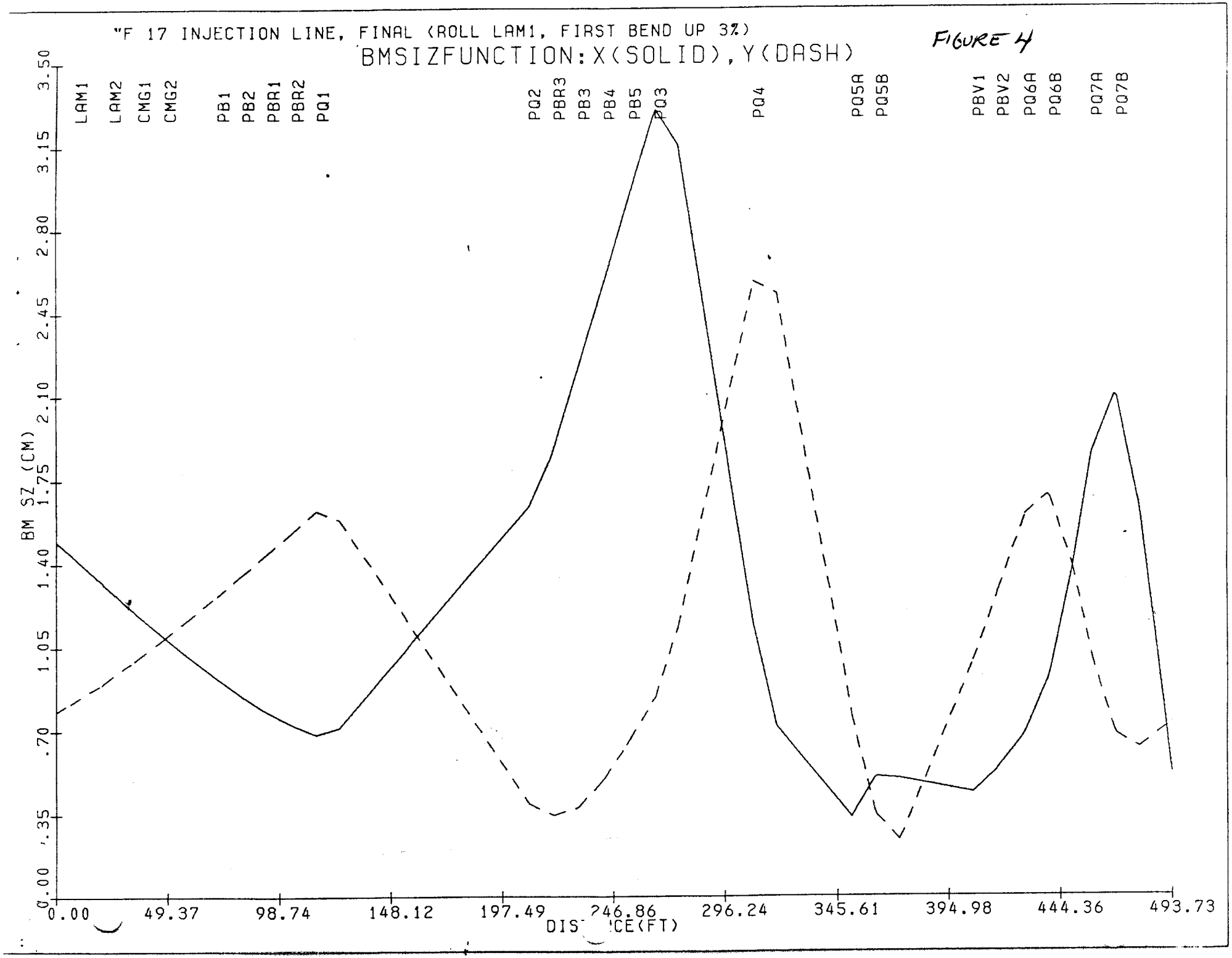

"F 17 INJECTION LINE, FINAL (ROLL LAM1, FIRST BEND UP 3%)
BMSIZFUNCTION:X(SOLID),Y(DASH)
FIGURE 4
LAM1
LAM2
CMG1
CMG2
PB1
PB2
PBR1
PBR2
PQ1
PQ2
PBR3
PB3
PB4
PB5
PQ3
PQ4
PQ5A
PQ5B
PBV1
PBV2
PQ6A
PQ6B
PQ7A
PQ7B
BM SZ (CM)
0.00
.35
.70
1.05
1.40
1.75
2.10
2.45
2.80
3.15
3.50
0.00
49.37
98.74
148.12
197.49
246.86
296.24
345.61
394.98
444.36
493.73
DIS CE(FT)

TABLE 1 (OBSOLETE)

COORDINATES GIVEN AT END OF ELEMENT (TOWARD TARGET)
MAIN RING STATION A0 AT X=0.0, Y=0.0

NAME	LENGTH (IN)	FIELD (KG KG/M)	X (FT)	Y (FT)	Z (FT)
MAIN RING			1010.537	-2446.096	725.500
P-LAMBERTSON 1	204.00	12.53	991.330	-2428.573	725.637
P-LAMBERTSON 2	204.00	12.53	977.667	-2416.105	726.071
PB1	120.00	12.71	950.622	-2391.496	717.249
PB2	120.00	12.71	942.397	-2384.199	727.603
PBR1	120.00	12.71	934.111	-2376.970	727.623
PBR2	120.00	12.71	925.774	-2369.797	728.168
PQ1	120.00	-65.87	917.411	-2362.653	728.372
PQ2	120.00	-48.50	844.863	-2300.699	730.146
PBR3	120.00	12.71	836.521	-2293.530	730.316
PB3	120.00	12.71	828.236	-2286.293	730.446
PB4	120.00	12.71	820.022	-2278.975	730.576
PB5	120.00	12.71	811.878	-2271.581	730.706
PQ3	120.00	120.93	803.773	-2264.144	730.836
PQ4	120.00	-159.61	771.845	-2234.847	731.348
PQ5A	120.00	183.05	739.917	-2205.551	731.860
PQ5B	120.00	183.05	731.813	-2198.113	731.990
PBV1	120.00	7.82	700.398	-2169.289	732.465
PBV2	120.00	7.82	692.239	-2161.852	732.500
PQ6A	120.00	-114.28	683.451	-2153.738	732.500
PQ6B	120.00	-114.28	675.345	-2146.300	732.500
PQ7A	120.00	102.73	661.836	-2133.905	732.500
PQ7B	120.00	102.73	653.731	-2126.467	732.500
PQ8A	120.00	-123.78	624.871	-2099.986	732.500
PQ8B	120.00	-123.78	616.765	-2092.549	732.500
PQ9A	120.00	92.66	603.257	-2080.153	732.500
PQ9B	120.00	92.66	595.151	-2072.716	732.500
TARGET			585.940	-2064.263	732.500

** END OF LISTING **

TABLE 2 (NEW COORDINATES)

3 APRIL 84. DE JOHNSON

120 GEV PROTONS KINETIC

FINAL 4/3/84

X, Y, Z SITE COORDINATES
COORDINATES GIVEN AT EACH END OF ELEMENT
MAIN RING STATION A0 AT X=0.0, Y=0.0

NAME	EFF. LENGTH (IN)	FIELD (KG-KG/M)	X (FT)	Y (FT)	Z (FT)
MAIN RING					
drift	76.70		1010.529	-2446.090	725.500
P-LAMBERTSON 1	162.00	8.68	1005.807	-2441.782	725.500
drift	15.00		995.839	-2432.679	725.559
P-LAMBERTSON 2	162.00	8.68	994.916	-2431.835	725.571
drift	18.00		984.952	-2422.729	725.749
P-CMAG 1	118.40	10.31	983.844	-2421.717	725.776
drift	21.00		976.563	-2415.063	725.988
P-CMAG 2	118.40	10.31	975.272	-2413.883	726.033
drift	162.00		967.991	-2407.229	726.321
PB1	120.00	13.11	958.031	-2398.127	726.767
drift	12.00		950.620	-2391.421	727.097
PB2	120.00	13.11	949.876	-2390.754	727.131
drift	12.00		942.399	-2384.122	727.461
PBR1	120.00	13.11	941.648	-2383.463	727.494
drift	12.00		934.114	-2376.893	727.789
PBR2	120.00	13.11	933.358	-2376.239	727.816
drift	12.00		925.778	-2369.722	728.041
PQ1	120.00	-65.87	925.017	-2369.073	728.060
drift	1012.20		917.413	-2362.581	728.250
PQ2	120.00	-48.50	853.271	-2307.825	729.856
drift	12.00		845.667	-2301.333	730.046
PBR3	120.00	12.72	844.906	-2300.684	730.065
drift	12.00		837.324	-2294.166	730.221
PB3	120.00	12.72	836.568	-2293.512	730.234
drift	16.17		829.039	-2286.932	730.356
PB4	120.00	12.72	828.028	-2286.040	730.372
drift	16.17		820.563	-2279.389	730.495
PB5	120.00	12.72	819.561	-2278.487	730.512
drift	16.17		812.160	-2271.764	730.634
PQ3	120.00	120.93	811.167	-2270.853	730.651
drift	400.00		803.798	-2264.094	730.773
PQ4	120.00	-159.61	779.235	-2241.563	731.182
drift	400.00		771.866	-2234.804	731.305
PQ5A	120.00	183.05	747.304	-2212.274	731.714
drift	12.00		739.935	-2205.515	731.836
PQ5B	120.00	183.05	739.198	-2204.839	731.848
drift	391.63		731.829	-2198.080	731.971
PBV1	120.00	8.12	707.780	-2176.022	732.371
drift	12.00		700.411	-2169.262	732.463
PBV2	120.00	8.12	699.674	-2168.586	732.470
drift	24.00		692.304	-2161.827	732.500
PQ6A	120.00	-114.28	690.831	-2160.475	732.500
drift	12.00		683.462	-2153.715	
PQ6B	120.00	-114.28	682.725	-2153.039	
drift	100.00		675.355	-2146.280	
PQ7A	120.00	102.73	669.214	-2140.647	
			661.845	-2133.887	

TABLE 2 (cont.)

NAME	EFF.	LENGTH (IN)	FIELD (KG-KG/M)	X (FT)	Y (FT)	Z (FT)
drift		12.00		661.108	-2133.211	
PQ7B		120.00	102.73	653.738	-2126.451	
drift		350.00		632.244	-2106.736	
PQ8A		120.00	-123.78	624.875	-2099.976	
drift		12.00		624.138	-2099.300	
PQ8B		120.00	-123.78	616.769	-2092.541	
drift		100.00		610.628	-2086.908	
PQ9A		120.00	92.66	603.258	-2080.148	
drift		12.00		602.521	-2079.472	
PQ9B		120.00	92.66	595.152	-2072.713	
drift		150.00		585.940	-2064.263	
TARGET				585.940	-2064.263	732.500

** END OF LISTING **

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ENGINEERING NOTE

SECTION	PROJECT	SERIAL-CATEGORY	PAGE

SUBJECT

NAME

DATE

REVISION DATE

TABLE 3 SETTINGS FOR FOCUSSING QUADS TO ACHIEVE VARIOUS BEAM SIZES AT THE PRODUCTION TARGET

PQ6 (kg/m)	PQ7 (kg/m)	PQ8 (kg/m)	PQ9 (kg/m)	σ_x (mm)	σ_y (mm)	β_x (m)	β_y (m)	η_x (m)	η_y (m)
-102	97	-98	114	.91	.87	25.1	17.8	.02	-.49
-114	103	-124	82	.42	.42	5.3	3.6	.005	-.29
-132	103	-121	120	.27	.28	2.2	1.6	.004	-.19

TABLE 4 TRIM MAGNET PLACEMENTS, CURRENTS AND BEND ANGLES

MAGNET	LOCATION	CURRENT (A)	BEND ANGLE (μrad)	BEND PLANE
PT1	IMM. UPSTREAM OF PB1	±25	±150	HORIZONTAL
PT2	IMM. UPSTREAM OF PQ2	±25	±280	VERTICAL
PT3	IMM. UPSTREAM OF PBV1	±25	±375	HORIZONTAL
PT4	IMM. UPSTREAM OF PQ8A	±25	±375	HORIZONTAL
PT5	IMM. UPSTREAM OF PQ9A	±25	±375	VERTICAL

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ENGINEERING NOTE

SECTION	PROJECT	SERIAL-CATEGORY	PAGE

SUBJECT: HALF-BEAM SIZES AT UPSTREAM ENDS OF API ELEMENTS (IN CM) (TABLE 5)

NAME:

DATE:

REVISION DATE:

ELEMENT	S (ft)	HORIZONTAL APERTURE	HORIZONTAL BM (120)	HORIZONTAL BM (8)	VERTICAL APERTURE	VERTICAL BM (120)	VERTICAL BM (8)
PLAM1	6.4	1.87	1.17	1.44	—	.30	.82
PLAM2	21.1	1.87	1.07	1.31	—	.33	.90
PCM1	36.1	2.0	.97	1.19	—	.37	1.00
PCM2	47.7	2.0	.90	1.09	—	.39	1.09
PT1	69.5	4.76	.76	.93	2.2	.43	1.25
PB1	71.1	6.4	.75	.92	1.9	.44	1.26
PB2	82.1	6.4	.67	.85	1.9	.47	1.35
PBR1	93.1	2.7	.60	.78	2.7	.49	1.44
PBR2	104.1	2.7	.51	.73	2.7	.52	1.53
PQ1	115.1	3.5	.43	.69	3.5	.55	1.62
PT2	206.5	2.7	.51	1.62	5.1	.14	.41
PQ2	209.4	3.5	.52	1.64	3.5	.13	.39
PBR3	220.5	2.7	.60	1.89	2.7	.11	.35
PB3	231.5	6.4	.71	2.23	1.9	.13	.38
PB4	242.8	6.4	.82	2.59	1.9	.17	.50
PB5	254.2	6.4	.93	2.95	1.9	.23	.66
PQ3	265.5	3.5	1.04	3.30	3.5	.29	.84
PQ4	308.9	3.5	.36	1.14	3.5	.87	2.58
PQ5A	352.2	3.5	.11	.33	3.5	.25	.76
PQ5B	363.2	3.5	.16	.50	3.5	.11	.34
PT3	402.9	6.4	.14	.44	1.9	.33	.95
PBV1	405.8	1.9	.14	.43	6.4	.34	.98
PBV2	416.8	1.9	.17	.54	6.4	.44	1.28
PQ6A	428.8	3.5	.22		3.5	.55	
PQ6B	439.8	3.5	.30		3.5	.57	
PQ7A	458.2	3.5	.63		3.5	.28	
PQ7B	469.2	3.5	.76		3.5	.11	
PT4	505.3	6.4	.33	—	1.9	.42	—
PQ8A	508.3	3.5	.31	—	3.5	.45	—
PQ8B	519.3	3.5	.21	—	3.5	.52	—
PT5	534.7	1.9	.18	—	6.4	.33	—
PQ9A	537.6	3.5	.18	—	3.5	.32	—
PQ9B	548.6	3.5	.16	—	3.5	.20	—

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ENGINEERING NOTE

SECTION	PROJECT	SERIAL-CATEGORY	PAGE

SUBJECT: API MAGNET SETTINGS (120 GeV)

NAME:

DATE: REVISION DATE:

TABLE 6

MAGNET(S)	NOM FIELD (kg; kg/in)	NOM I_{peak} (A)	NOM I_{RMS} (A)	R (mΩ)	L (mh)	NOM V_{PK} (volts)	NOM V_{RMS} (volts)	NOM V_{tot} (volts)	NOM POWER (KW)	MAX I_{RMS} (A)	MAX I_{Peak} (A)	MAX Volts	Supply Type	MAX PK CURRENT (AMP)	MAX VOLTS (V)	WATER FLOW (GPM)	MAX ΔT(°C)	[illegible] (KW)
LAM 1,2 +CM 1,2	8.68, 10.31	2866	1654	23.6	9.6	67.6	27.5	95.1	64.6	2500	3400	200	T	3400	113	15.4	22.3	90.9
PB1, 2; R1 R2	13.11	1340	774	64	120	85.7	160.8	247	38.3	1250	1700	400	T	1700	313	18.3	12.4	61.5
PQ1	-65.7	135	135	160	60	22	—	22	2.9	200	200	70	C	200	32	5.7	4.3	6.4
PQ2	-48.4	99	99	160	60	16	—	16	1.6	200	200	70	C	200	32	5.7	4.3	6.4
PBR3; PB3,4,5	12.72	1300	750	64	120	83.2	156	239	36.0	1250	1700	400	T	1700	313	18.8	12.4	61.5
PQ3	120.9	248	248	160	60	40	—	40	9.8	500	500	100	D	500	81	11.4	13.5	40.5
PQ4	-159.5	340	340	160	60	54	—	54	18.9	500	500	100	D	500	81	11.4	13.5	40.5
PQ5A,B	+183.1	400	400	320	60	128	—	128	51.2	500	500	200	2D	500	162	11.4	27	81
PQN1, 2	8.12	790	790	32	60	25.3	—	25	20	1200	1200	100	P	1200	38	9.4	18.4	45.6
PQ6A,B	-131.9	278	278	320	60	89	—	89	24.7	500	500	100	D	314	100	11.4	10.4	31.4
PQ7A,B	103.1	217	217	320	60	69	—	69	15.0	500	500	100	D	314	100	11.4	10.4	31.4
PQ8A,B	-120.8	255	255	320	60	82	—	82	20.9	500	500	100	D	314	100	11.4	10.4	31.4
PQ9A,B	131.9	278	278	320	60	89	—	89	24.7	500	500	100	D	314	100	11.4	10.4	31.4
TOTAL									329							153.2		560

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TABLE 7

MAGNET(S)	NOM FIELD (kg-kg/in)	NOM I_{peak} (A)	NOM I_{RMS} (A)	R (mΩ)	L (mH)	NOM V_{PK} (volts)	NOM V_{RMP} (volts)	NOM V_{tot} (volts)	NOM Power (KW)	MAX I_{RMS} (A)	MAX I_{PEAK} (A)	MAX Volts	Supply Type	MAX Current (AMP)	MAX VOLTS (V)	WATER FLOW (GPM)	MAX ΔT(°C)
LAM 1,2 +CM 1,2	.6383, .7582	211	211	23.6		5		5	1.06								
PB1, 2; R1 R2	.9635	93.4	93.4	64		6		6	.56	100							
PQ1	−4.84	9.92	9.9	160		1.6		1.6	.016	30							
PQ2	−3.57	7.31	7.3	160		1.2		1.2	.009	30							
PBR3; PB3,4,5	.9351	90.7	90.7	64		5.8		5.8	.53	100							
PQ3	8.89	18.2	18.2	160		2.9		2.9	.053	30							
PQ4	−11.73	24.0	24.0	160		3.8		3.8	.092	30							
PQ5A,B	13.46	27.6	27.6	320		8.8		8.8	.244	30							
PQN1, 2	23.5	57.9	57.9	32		1.9		1.9	.107	100							
PQ6A,B	−7.23	14.82	14.82	320		4.7		4.7	70	30							
PQ7A,B	10.87	22.2	22.2	320		7.1		7.1	158	30							
PQ8A,B	—																
PQ9A,B	—																

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[illegible] GeV
[illegible]
Everything [illegible]

TABLE 8

MAGNET(S)	NOM FIELD (kg; kg/in)	NOM I_{peak} (A)	NOM I_{RMS} (A)	R (mΩ)	L (mh)	NOM V_{pk} (volts)	NOM V_{ramp} (volts)	NOM V_{tot} (volts)	NOM POWER (KW)	MAX I_{RMS} (A)	MAX I_{peak} (A)	MAX Volts	Supply Type	MAX CURRENT (AMP)	MAX VOLTS (V)	WATER FLOW (GPM)	MAX ΔT(°C)
LAM 1,2 +CM 1,2	10.83, 12.87	3577	2065	23.6	9.6	84.4	34.3	118.7	100.6	EXCEEDS	I_{pk} by 1.052						
PB1,2; R1,R2	16.36	2010	1160	64	120	128.6	241.2	369.8	86.1	EXCEEDS	I_{pk} by 1.182						
PQ1	-81.9	172	172	160	60	27.5	–	27.5	4.7	OK							
PQ2	-60.4	127	127	160	60	20.3	–	20.3	2.6	OK							
PBR3; PB3,4,5	15.87	1860	1073	64	120	119	223	342	73.7	EXCEEDS	I_{pk} by 1.094						
PQ3	150.8	322	322	160	60	51.5	–	51.5	16.6	OK							
PQ4	-198.8	465	465	160	60	74.4	–	74.4	34.6	OK							
PQ5A,B	230.3	680	680	320	60	218	–	218	142.0	EXCEEDS	I_{pk} by 1.36						
PBV1,2	10.13	982	982	32	60	31.4	–	31.4	30.8	OK							
PQ6A,B	-131.9	278	278	320	60	89	–	89	24.7	SAME	AS 120						
PQ7A,B	103.1	217	217	320	60	69	–	69	15.0	SAME	" "						
PQ8A,B	-120.9	255	255	320	60	82	–	82	20.9	"	" "						
PQ9A,B	131.9	278	278	320	60	89	–	89	24.7	"	" "						
									583								

extra 254 kW!

Recent Changes to the Design of the AP-1 Beam Line

1. Modifications related to the new extraction channel, including the effects of the rolled Lambertson

The new extraction channel at F17 consists of two 162" Lambertsons and two 118" C-magnets, in place of the original two 204" high-field Lambertsons. The extracted beam at F17 has a residual angle of 0.8 mrad relative to the Main Ring beam; to minimize the required aperture in the first Lambertson, it is rolled by 5.2 degreees, which provides a small horizontal bend to cancel the residual angle. Matching of this new extraction channel to the front end of the AP-1 line required small changes in the magnet positions and operating currents. Table 1 shows the original set of layout coordinates and operating fields; table 2 shows the new set. The separation between PQ1 and PQ2 is reduced by 13", and the drift space between elements in the second set of dipoles (PBR3,PB3,PB4,PB5) is increased by about the same amount. Lateral shifts are generally small, always less than 0.5". The first set of dipoles runs at about 3% higher current, and the last vertical bend at about 4% higher current than before.

2. Effects of vertical dispersion due to the Main Ring overpass on proton targetting and matching of returning pbars.

The modifications to the beam line discussed above do not result in any significant changes to the focussing or dispersive characteristics of the beam line. The inclusion of the vertical dispersion at F17, resulting from the proposed overpass modifications to the Main Ring does, however, produce a significant vertical dispersion both at the pbar production target and at the matching point for the pbar beam from the Accumulator via AP-3. The case discussed below corresponds to the worst case (BO and DO overpasses, WD89+TCB21).

The vertical dispersion at the target is such that it limits the minimum round beam size to sigma$\sim$27 mm. For larger beam sizes, and in particular for the proposed operating point of sigma $\sim$4 mm, the increase in vertical dispersion is inconsequential. Table 3 shows the quad settings and values for the beta and eta functions at the target for three different round beam sizes. The overpass also causes a dispersion mismatch for the reverse injected pbars from the Accumulator at F17. However, the resulting phase-space dilution is quite small ($<$0.5%).

Figures 1, and 2 illustrate the monoenergetic beta functions and the dispersion for the revised AP-1 line, including the overpass dispersion. The beam size at the target(sigma) is 0.4 mm. Figure 3 shows the horizontal and vertical half beam sizes for the 120 GeV extracted proton beam (corresponding to 95% limits, with contributions from dp/p=0.2% and emittance=0.2pi mm-mrad, added in quadrature). Figure 4 shows the horizontal and vertical half beam sizes for the 8 Gev injected pbar beam (corresponding to 95% limits, with contributions from dp/p=0.09% and emittance=2pi mm-mrad, added in quadrature).

In summary, there should be no significant deleterious consequences to the focusing or dispersive properties of the AP-1 line, either for proton targeting or for pbar transport to the Main Ring, resulting from either the modified F17 extraction/injection scheme or the Main Ring vertical dispersion associated with the overpass.

3. Trim magnet placement and strength

It is currently planned to have five trim magnets in AP-1. The magnet locations, maximum currents, and bend angles and directions (at 120 GeV) are given in table 4. Three of these (PT3,PT4,PT5) will be 35" long, 200 turn magnets with a 5" by 1.5" aperture. Because of space limitations, PT1 will be only 20" long, with 200 turns and a 4" by 2" aperture. PT2 will be 35" long, with 200 turns and a 4" by 2" aperture. The larger horizontal aperture for this vertical trim is required to accomodate the returning pbar beam. All magnets are powered by 25A bipolar supplies, which can regulate close to zero for the returning pbar beam. The trims PT4 and PT5 serve to allow beam motion at the production target; for the nominal tune of the last four quad sets, these trims will allow ±8.8 mm horizontal and ±6.9 mm vertical position shifts (at 120 GeV).

4. Apertures and beam sizes for the extracted proton beam and returning pbar beam

The extracted and injected beam sizes illustrated in figures 3 and 4 are tabulated in table 5, together with the beam line apertures. For the extracted 120 GeV proton beam, the tightest clearances are in the extraction channel (the worst case is about 9 mm at the entrance to the first Lambertson). For the antiproton beam, the three tightest clearances are at PQ3 (where betax ~ 550 m), 2 mm (horizontal); at PB2, 5.5 mm (vertical); and at the end of the last Lambertson, 4.6 mm (horizontal). These latter two clearances are probably acceptable, but the 2 mm at PQ3 is

very close. The most satisfactory solution to this problem would be a retune of the AP-1 line (and presumably also the matched AP-3 line) specifically for pbars, with beta reduced to 350 m or less everywhere. In principle, this should be possible, although at the time of this writing it has not been done. Alternatively, one could increase the horizontal size of the vacuum chamber in PQ3 by about .5 inches. This option is currently being pursued.

5. Summary of magnet parameters and operation at higher energies

Table 6 presents a summary of the magnetic fields, currents, voltages and powers for all elements of the AP-1 line, corresponding to operation at 120 GeV. Also shown are the planned power supplies, the maximum operating currents which will be available, and the water flow, temperature rise, and power corresponding to operation at these maximum currents. Table 7 gives the operating parameters for 8 GeV, together with the planned power supply capabilities. Table 8 presents the operating parameters corresponding to 150 GeV; for those magnets whose currents exceed the supply limit, the overage factor is given. The most severe limit to operation above 120 Gev is set by the PQ5A,B supply, which cannot run above 500 A. This current corresponds to 135 GeV, so this is the upper limit of the beam line as presently conceived. To reach 150 GeV, this supply would need to be replaced by one capable of about 700 A and 230 v. Additionally, the ramped Transrex supplies on the first eight EPB dipoles would have to provide peak currents up to 60% above their rms ratings. Since this is probably not possible, additional supplies would be required here also.

TABLE 1 (OBSOLETE)

COORDINATES GIVEN AT END OF ELEMENT (TOWARD TARGET)
MAIN RING STATION A0 AT X=0.0, Y=0.0

NAME	LENGTH (IN)	FIELD (KG KG/M)	X (FT)	Y (FT)	Z (FT)
MAIN RING			1010.537	-2446.096	725.500
P-LAMBERTSON 1	204.00	12.53	991.330	-2428.573	725.637
P-LAMBERTSON 2	204.00	12.53	977.667	-2416.105	726.071
PB1	120.00	12.71	950.622	-2391.496	717.249
PB2	120.00	12.71	942.397	-2384.199	727.603
PBR1	120.00	12.71	934.111	-2376.970	727.623
PBR2	120.00	12.71	925.774	-2369.797	728.168
PQ1	120.00	-65.87	917.411	-2362.653	728.372
PQ2	120.00	-48.50	844.863	-2300.699	730.146
PBR3	120.00	12.71	836.521	-2293.530	730.316
PB3	120.00	12.71	828.236	-2286.293	730.446
PB4	120.00	12.71	820.022	-2278.975	730.576
PB5	120.00	12.71	811.878	-2271.581	730.706
PQ3	120.00	120.93	803.773	-2264.144	730.836
PQ4	120.00	-159.61	771.845	-2234.847	731.348
PQ5A	120.00	183.05	739.917	-2205.551	731.860
PQ5B	120.00	183.05	731.813	-2198.113	731.990
PBV1	120.00	7.82	700.398	-2169.289	732.465
PBV2	120.00	7.82	692.239	-2161.852	732.500
PQ6A	120.00	-114.28	683.451	-2153.738	732.500
PQ6B	120.00	-114.28	675.345	-2146.300	732.500
PQ7A	120.00	102.73	661.836	-2133.905	732.500
PQ7B	120.00	102.73	653.731	-2126.467	732.500
PQ8A	120.00	-123.78	624.871	-2099.986	732.500
PQ8B	120.00	-123.78	616.765	-2092.549	732.500
PQ9A	120.00	92.66	603.257	-2080.153	732.500
PQ9B	120.00	92.66	595.151	-2072.716	732.500
TARGET			585.940	-2064.263	732.500

** END OF LISTING **

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TABLE 3 SETTINGS FOR FOCUSSING QUADS TO ACHIEVE VARIOUS BEAM SIZES AT THE PRODUCTION TARGET

PQ6 (kg/m)	PQ7 (kg/m)	PQ8 (kg/m)	PQ9 (kg/m)	σ_x (mm)	σ_y (mm)	β_x (m)	β_y (m)	η_x (m)	η_y (m)
-10.2	9.7	-9.8	1.14	.91	.87	25.1	17.8	.02	-.49
-11.4	10.3	-12.4	8.2	.42	.42	5.3	3.6	.005	-.29
-13.2	10.3	-12.1	12.0	.27	.28	2.2	1.6	.004	-.19

TABLE 4 TRIM MAGNET PLACEMENTS, CURRENTS AND BEND ANGLES

MAGNET	LOCATION	CURRENT (A)	BEND ANGLE (μrad)	BEND PLANE
PT1	IMM. UPSTREAM OF PB1	±25	±150	HORIZONTAL
PT2	IMM. UPSTREAM OF PQ2	±25	±280	VERTICAL
PT3	IMM. UPSTREAM OF PBV1	±25	±375	HORIZONTAL
PT4	IMM. UPSTREAM OF PQ8A	±25	±375	HORIZONTAL
PT5	IMM. UPSTREAM OF PQ9A	±25	±375	VERTICAL

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ELEMENT	S (ft)	HORIZONTAL APERTURE	HORIZONTAL BM (120)	HORIZONTAL BM (8)	VERTICAL APERTURE	VERTICAL BM (120)	VERTICAL BM (8)
PLAM1	6.4	1.87	1.17	1.44	—	.30	.82
PLAM2	21.1	1.87	1.07	1.31	—	.33	.90
PCM1	36.1	2.0	.97	1.19	—	.37	1.00
PCM2	47.7	2.0	.90	1.09	—	.39	1.09
PT1	69.5	4.76	.76	.93	2.2	.43	1.25
PB1	71.1	6.4	.75	.92	1.9	.44	1.26
PB2	82.1	6.4	.67	.85	1.9	.47	1.35
PBR1	93.1	2.7	.60	.78	2.7	.49	1.44
PBR2	104.1	2.7	.51	.73	2.7	.52	1.53
PQ1	115.1	3.5	.43	.69	3.5	.55	1.62
PT2	206.5	2.7	.51	1.62	5.1	.14	.41
PQ2	209.4	3.5	.52	1.64	3.5	.13	.39
PBR3	220.5	2.7	.60	1.89	2.7	.11	.35
PB3	231.5	6.4	.71	2.23	1.9	.13	.38
PB4	242.8	6.4	.82	2.59	1.9	.17	.50
PB5	254.2	6.4	.93	2.95	1.9	.23	.66
PQ3	265.5	3.5	1.04	3.30	3.5	.29	.84
PQ4	308.9	3.5	.36	1.14	3.5	.87	2.58
PQ5A	352.2	3.5	.11	.33	3.5	.25	.76
PQ5B	363.2	3.5	.16	.50	3.5	.11	.34
PT3	402.9	6.4	.14	.44	1.9	.33	.95
PBV1	405.8	1.9	.14	.43	6.4	.34	.98
PBV2	416.8	1.9	.17	.54	6.4	.44	1.28
PQ6A	428.8	3.5	.22		3.5	.55	
PQ6B	439.8	3.5	.30		3.5	.57	
PQ7A	458.2	3.5	.63		3.5	.28	
PQ7B	469.2	3.5	.76		3.5	.11	
PT4	505.3	6.4	.33	—	1.9	.42	—
PQ8A	508.3	3.5	.31	—	3.5	.45	—
PQ8B	519.3	3.5	.21	—	3.5	.52	—
PT5	534.7	1.9	.18	—	6.4	.33	—
PQ9A	537.6	3.5	.18	—	3.5	.32	—
PQ9B	548.6	3.5	.16	—	3.5	.20	—