Fermilab

TM-797
1600.000

DOUBLER LATTICE AND PHASE - AMPLITUDE FUNCTIONS

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The lattice described herein should be close to the final arrangement of quadrupole lengths and locations; sufficiently close that readjustment for measured dipole and quadrupole strengths will be minor and can be accomplished wihout changing the position of the quad centers. The following values and constraints were used in its design:

1) The QUAD STRENGTH was assumed to be 19.666 kG/inch at a current that produced an integrated DIPOLE field of 45.00 kG x 252.0 inches. The actual assumption is k=.00375207/inch where k is the constant in cos kl, (1/k) sin kl ect.
2) The CENTERS of GROUPS of 4 DIPOLES in the Doubler are aligned with the 4-dipole group centers in the Main Ring, to insure proper fit into the tunnel. The 2-dipole groups of the medium straight sections are also aligned, but the magnet groups in the long straight sections need special consideration. Because the doubler dipoles are longer, the lattice of doubler QUADS is shifted downstream with respect to the Main Ring.
3) The SPACE between the effective end of a DIPOLE and the effective end of a QUAD is taken to be 12.00 inches.
4) In the LONG STRAIGHT SECTION, the center of the downstream 4-dipole group is pushed upstream by the increased length of doubler dipoles. To compensate one must upstream the 3-dipole group downstream by 4/3 of this displacement, which fixes the beginning of the upstream quad DOUBLET. The end of this doublet is chosen so the beginning of the clear section is aligned with the beginning of the clear straight section in the Main Ring. The effective quad end is 24 inches before its main-ring counterpart to provide space for the cryogenic

transition and quad vacuum pumping which are permanent features of all doubler straight-section ends.

5) The ANTI-SYMMETRY of the main-ring LATTICE is duplicated, fixing the location of the downstream doublet. The centers of the clear straight sections are not aligned because of the lattice shift (see 2 above) and the clear length in the doubler is longer by twice this shift - which helps injection and extraction.

6) These considerations were incorporated into an iterative design procedure which was used to find a LATTICE which has:

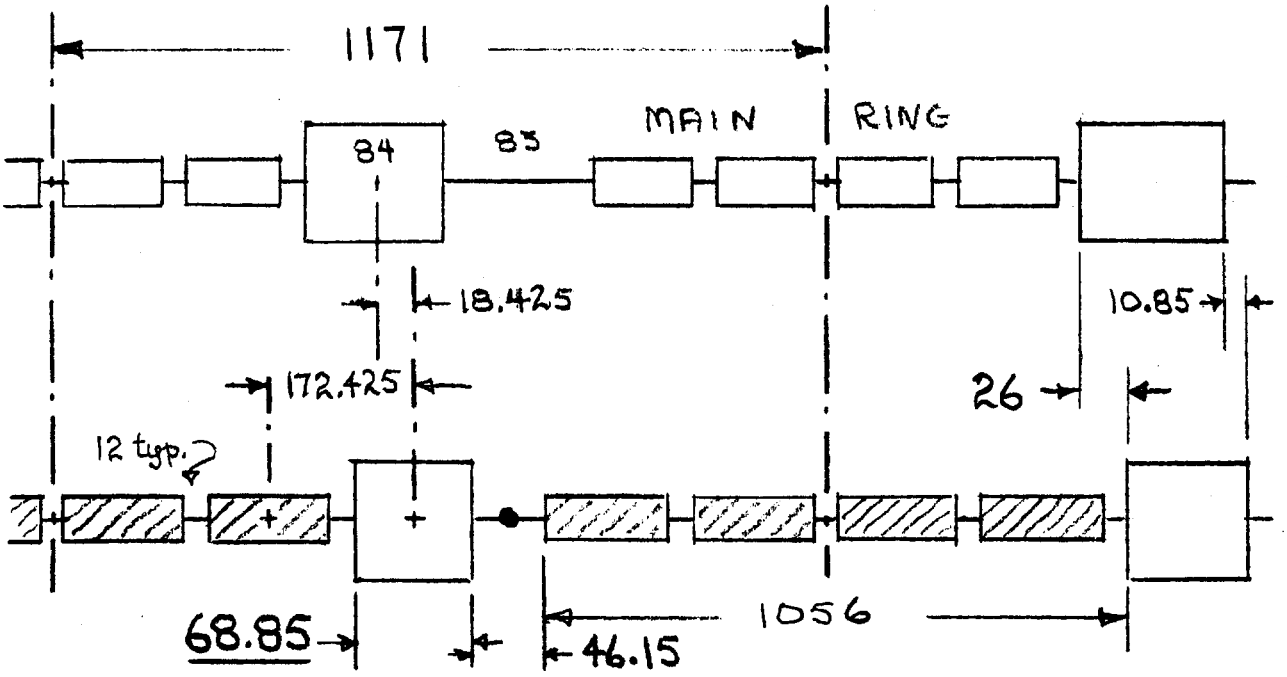
a) a tune of 19.40 m both planes (matched), ignoring the weak dipole end focussing.

b) a good match to the Main Ring for direct beam transfer. The different focussing necessitates a mis-match, but only an 8% increase in emittance.

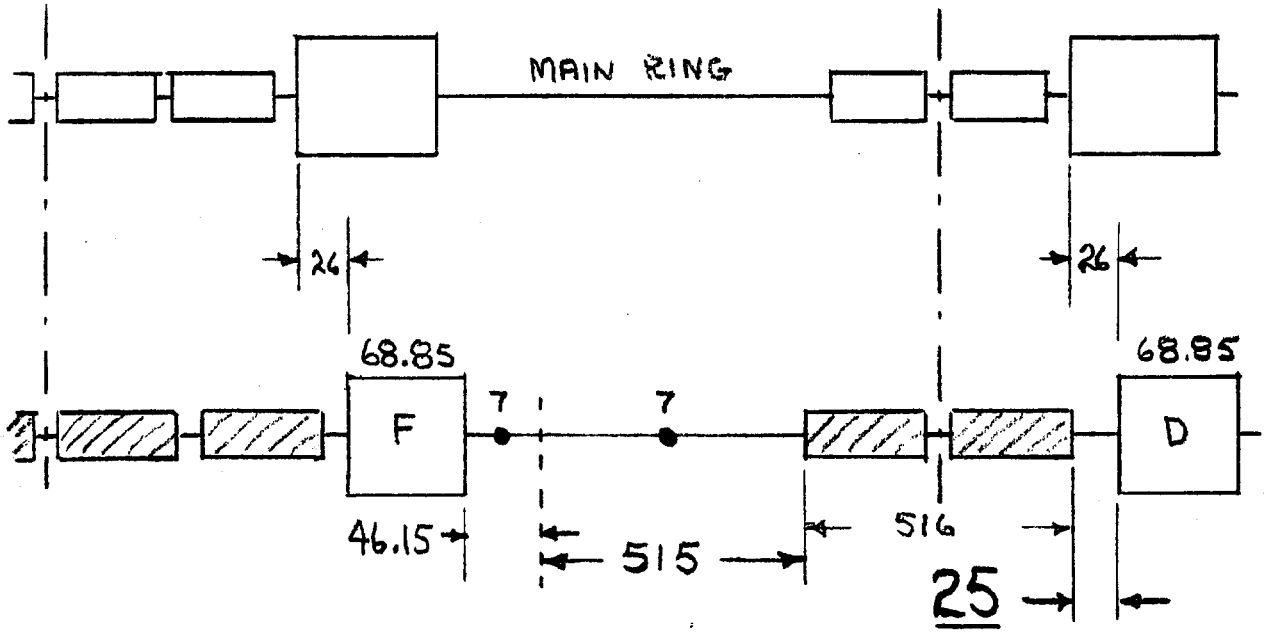
c) quadrupole lengths which can be expressed to .01 with minimal round-off. The tables are calculated with rounded values and show a trifling variation of β in the standard cells.

7) The important lengths are: a standard QUAD EFFECTIVE LENGTH of 68.85 inches, and a DIPOLE to QUAD center-to-center spacing of 172.425 inches. For special quads this spacing is changed by one-half of the length difference.

DOUBLER STANDARD HALF-CELL.

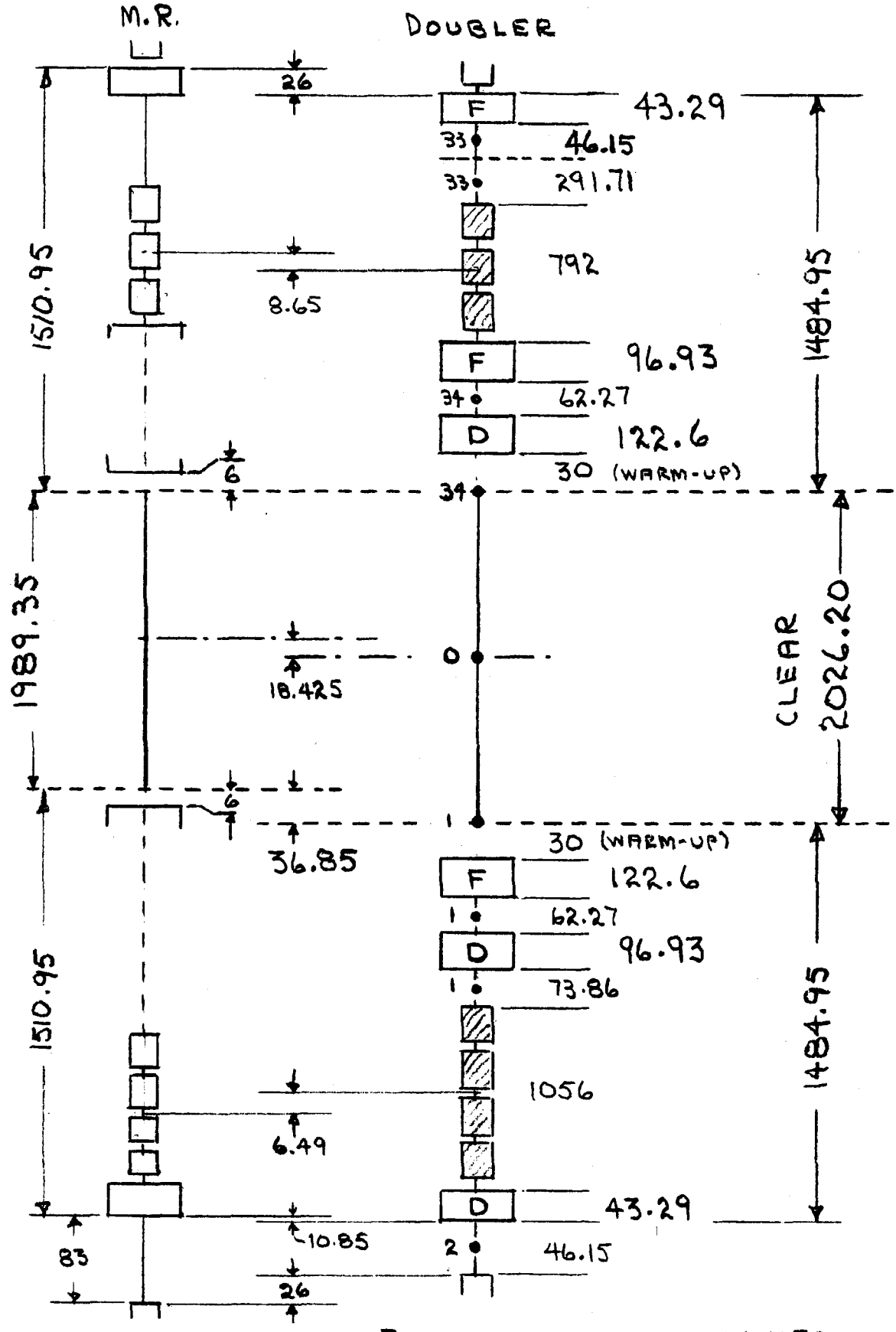


MEDIUM STRAIGHT SECTION



EFFECTIVE LENGTHS - INCHES

LONG STRAIGHT SECTION



EFFECTIVE LENGTHS - INCHES.

Phase Amplitide Function Tables

Quadrupoles and their nearby elements are designated by STATION NUMBERS, which in this listing run from 0 (straight section center) to 35 (next st. section center). Odd numbers are F quads, except for 1 and 34 which are used for the two FD doublets. In the quad center table (II), stations 1 and 34 are repeated, designating the two quads of each doublet. In the space center table (I), which normally gives values for the center of the ministraight, repeated station numbers 7 (medium straight) and 33 refer to the center of additional space (missing magnets), and 1 and 34 to positions around the doublets, as indicated on the diagrams.

Table III lists η for the center of every dipole, and β for dipoles in standard cells and in locations following 1,7 and 33. Otherwise, the tables list ϕ - in degrees module 360, β, α, η, and η'. For persons whose space is metric the tables are repeated with conversion before round-off.

It is anticipated that this different format will eliminate much of the arithmetic attendant on use of SYNCH tables, which give values for element ends rather than centers.

Horizontal Functions at Space Centers. Ia.

STN.	φ DEG.	β INCHES	α	h INCHES	h' m-rod.
0	0	2672	-0.65	80.6	22
1	16.9	4534	-1.189	103.3	22
1	19.4	3591	5.789	91.1	-153
1	22.7	2536	1.137	75.3	-43
2	66.1	1178	-0.611	46.3	17
3	97.9	3770	1.843	82.2	-31
4	133.8	1178	-0.612	70.3	67
5	165.5	3771	1.844	160	-57
6	201.3	1178	-0.611	119.9	88
7	233.1	3770	1.843	230.1	-106
7	238	2827	1.516	200.3	-106
8	268.9	1178	-0.612	118.6	25
9	300.7	3770	1.843	159.1	-101
10	336.5	1178	-0.612	65.3	-4
11	8.3	3771	1.844	76.8	-48
12	44.1	1178	-0.611	43.7	26
13	75.9	3770	1.843	89.8	-29
14	111.7	1178	-0.612	80.5	78
15	143.5	3771	1.844	182	-68
16	179.3	1178	-0.612	130.1	87
17	211.1	3770	1.844	239.3	-116
18	246.9	1178	-0.611	131.2	43
19	278.7	3770	1.843	190.8	-114
20	314.5	1178	-0.612	82.4	-1
21	346.3	3771	1.844	96.5	-64
22	22.1	1178	-0.611	44.1	11
23	53.9	3770	1.843	73.1	-28
24	89.7	1178	-0.612	63.7	63
25	121.5	3770	1.843	149.6	-51
26	157.3	1178	-0.612	117	91
27	189.1	3771	1.844	231.3	-104
28	224.9	1178	-0.611	137.9	61
29	256.7	3770	1.843	217	-122
30	292.5	1178	-0.612	100.7	9
31	324.3	3771	1.844	124.5	-82
32	0.1	1178	-0.612	51.3	0
33	31.5	3894	0.48	69.4	-9
33	34	3741	0.426	67.8	-9
34	52.2	2544.	3.888	62.9	-77
34	57.3	1902	-0.11	57.9	22
35	84	2672	-0.65	80.6	22

Vertical Functions at Space Centers

STN.	φ DEG.	β INCHES	α
0	0	2672	0.65
1	26.7	1902	0.11
1	31.8	2544	-3.888
1	35	3230	-0.142
2	53.8	3770	1.843
3	89.7	1178	-0.612
4	121.4	3771	1.844
5	157.3	1178	-0.611
6	189	3770	1.843
7	224.9	1178	-0.612
7	236.6	1613	-0.939
8	256.6	3771	1.844
9	292.4	1178	-0.612
10	324.2	3770	1.844
11	0	1178	-0.611
12	31.8	3770	1.843
13	67.6	1178	-0.612
14	99.4	3771	1.844
15	135.2	1178	-0.611
16	167	3770	1.843
17	202.8	1178	-0.612
18	234.6	3770	1.843
19	270.4	1178	-0.612
20	302.2	3771	1.844
21	338	1178	-0.611
22	9.8	3770	1.843
23	45.6	1178	-0.612
24	77.4	3771	1.844
25	113.2	1178	-0.612
26	145	3770	1.844
27	180.8	1178	-0.611
28	212.6	3770	1.843
29	248.4	1178	-0.612
30	280.2	3771	1.844
31	316	1178	-0.611
32	347.8	3770	1.843
33	22.3	1139	-0.17
33	30.6	1222	-0.323
34	64.6	3591	-5.789
34	67.1	4534	1.189
35	84	2672	0.65

HORIZONTAL FUNCTIONS AT QUAD CENTERS II A.

STN.	ψ DEG.	β INCHES	α	η INCHES	η' in-rad
(0	0	2672	-0.65	80.6	22)
1	18.1	4511	2.725	102.6	-67
1	20.8	2827	3.121	80.3	-96
2	63.9	1133	-0.215	45.6	3
3	97.1	3920	0	83.3	10
4	130.9	1130	0	67	34
5	164.7	3921	0	161.9	21
6	198.5	1130	0	115.8	31
7	232.3	3920	0	234.2	7
8	266.1	1130	0	118.1	-32
9	299.9	3921	0	163.5	-22
10	333.7	1130	0	66.1	-36
11	7.5	3921	0	78.9	-10
12	41.3	1130	0	42.6	6
13	75.1	3920	0	90.7	15
14	108.9	1130	0	76.7	40
15	142.7	3921	0	184.4	22
16	176.4	1130	0	126.2	26
17	210.2	3921	0	243.9	2
18	244	1130	0	129.8	-20
19	277.8	3920	0	195.7	-19
20	311.6	1130	0	83.1	-41
21	345.4	3921	0	99.3	-16
22	19.2	1130	0	43.8	-10
23	53	3920	0	74.1	8
24	86.8	1130	0	60.6	33
25	120.6	3921	0	151.3	23
26	154.4	1130	0	112.7	36
27	188.2	3921	0	235.3	10
28	222	1130	0	135.6	-5
29	255.8	3920	0	222.2	-14
30	289.6	1130	0	101	-40
31	323.4	3921	0	128.2	-21
32	357.2	1130	0	51.7	-25
33	30.8	3912	-0.701	69.6	12
34	50.6	3103	2.255	68	-32
34	54.6	1988	1.623	57.3	-27
(35	84	2672	-0.65	80.6	22)

VERTICAL FUNCTIONS AT QUAD. CENTERS.

STN.	φ DEG.	β INCHES	α
[0	0	2672	0.65]
1	29.4	1988	-1.623
1	33.4	3103	-2.255
2	53.2	3912	0.701
3	86.8	1130	0
4	120.6	3921	0
5	154.4	1130	0
6	188.2	3920	0
7	222	1130	0
8	255.8	3921	0
9	289.6	1130	0
10	323.4	3921	0
11	357.2	1130	0
12	31	3920	0
13	64.8	1130	0
14	98.6	3921	0
15	132.4	1130	0
16	166.2	3920	0
17	200	1130	0
18	233.8	3921	0
19	267.6	1130	0
20	301.3	3921	0
21	335.1	1130	0
22	8.9	3920	0
23	42.7	1130	0
24	76.5	3921	0
25	110.3	1130	0
26	144.1	3921	0
27	177.9	1130	0
28	211.7	3920	0
29	245.5	1130	0
30	279.3	3921	0
31	313.1	1130	0
32	346.9	3920	0
33	20.1	1133	0.215
34	63.2	2827	-3.121
34	65.9	4511	-2.725
[35	84	2672	0.65]

Functions at Dipole Centers III A.

η - inches.

STN.									STN.
1	69	59	52	47	49	56	65	76	3
3	78	72	68	66	81	100	122	146	5
5	152	139	128	119	133	159	186	216	7
7			160	134	124	133	144	158	9
9	147	122	99	79	66	67	70	76	11
11	70	60	51	45	47	56	67	80	13
13	84	79	75	74	91	113	138	165	15
15	170	155	142	131	143	168	196	226	17
17	223	194	168	144	139	153	169	187	19
19	176	148	122	98	84	86	90	96	21
21	88	73	60	50	46	51	57	67	23
23	68	63	59	58	72	91	111	134	25
25	140	129	120	114	130	156	185	215	27
27	216	191	168	147	148	166	187	210	29
29	201	171	143	117	104	109	115	124	31
31	114	94	77	61	52	54	58	65	33
33		65	64	66					0

$\frac{\beta_H}{\beta_V}$ - inches

F									F
	3247	2446	1809	1334	1386	1882	2541	3362	
	1386	1882	2541	3362	3247	2446	1809	1334	
1	2190	1731	1397	1190	1386	1882	2541	3362	3
	3284	3408	3576	3788	3247	2446	1809	1334	
7			1836	1353	1386	1882	2541	3362	9
			2504	3318	3247	2446	1809	1334	
33		3533	3375	3261					0
		1464	1827	2316					

Horizontal Functions at Space Centers IB

STN.	φ DEG.	β M.	α	η M.	η' m-rad.
0	0	67.86	-0.65	2.05	22
1	16.9	115.17	-1.189	2.62	22
1	19.4	91.22	5.789	2.31	-153
1	22.7	64.43	1.137	1.91	-43
2	66.1	29.91	-0.611	1.17	17
3	97.9	95.76	1.843	2.09	-31
4	133.8	29.92	-0.612	1.79	67
5	165.5	95.78	1.844	4.06	-57
6	201.3	29.92	-0.611	3.04	88
7	233.1	95.76	1.843	5.84	-106
7	238	71.82	1.516	5.09	-106
8	268.9	29.91	-0.612	3.01	25
9	300.7	95.76	1.843	4.04	-101
10	336.5	29.92	-0.612	1.66	-4
11	8.3	95.78	1.844	1.95	-48
12	44.1	29.91	-0.611	1.11	26
13	75.9	95.75	1.843	2.28	-29
14	111.7	29.91	-0.612	2.04	78
15	143.5	95.77	1.844	4.62	-68
16	179.3	29.92	-0.612	3.31	87
17	211.1	95.77	1.844	6.08	-116
18	246.9	29.91	-0.611	3.33	43
19	278.7	95.76	1.843	4.85	-114
20	314.5	29.92	-0.612	2.09	-1
21	346.3	95.78	1.844	2.45	-64
22	22.1	29.92	-0.611	1.12	11
23	53.9	95.76	1.843	1.86	-28
24	89.7	29.91	-0.612	1.62	63
25	121.5	95.76	1.843	3.8	-51
26	157.3	29.92	-0.612	2.97	91
27	189.1	95.78	1.844	5.87	-104
28	224.9	29.91	-0.611	3.5	61
29	256.7	95.75	1.843	5.51	-122
30	292.5	29.91	-0.612	2.56	9
31	324.3	95.77	1.844	3.16	-82
32	0.1	29.92	-0.612	1.3	0
33	31.5	98.91	0.48	1.76	-9
33	34	95.03	0.426	1.72	-9
34	52.2	64.61	3.888	1.6	-77
34	57.3	48.3	-0.11	1.47	22
35	84	67.86	-0.65	2.05	22

Vertical Functions at Space Centers.

STN.	φ DEG.	β M.	α
0	0	67.86	0.65
1	26.7	48.3	0.11
1	31.8	64.61	-3.888
1	35	82.03	-0.142
2	53.8	95.77	1.843
3	89.7	29.92	-0.612
4	121.4	95.77	1.844
5	157.3	29.91	-0.611
6	189	95.75	1.843
7	224.9	29.92	-0.612
7	236.6	40.97	-0.939
8	256.6	95.78	1.844
9	292.4	29.92	-0.612
10	324.2	95.76	1.844
11	0	29.91	-0.611
12	31.8	95.76	1.843
13	67.6	29.92	-0.612
14	99.4	95.78	1.844
15	135.2	29.92	-0.611
16	167	95.76	1.843
17	202.8	29.91	-0.612
18	234.6	95.77	1.843
19	270.4	29.92	-0.612
20	302.2	95.77	1.844
21	338	29.91	-0.611
22	9.8	95.75	1.843
23	45.6	29.92	-0.612
24	77.4	95.78	1.844
25	113.2	29.92	-0.612
26	145	95.76	1.844
27	180.8	29.91	-0.611
28	212.6	95.76	1.843
29	248.4	29.92	-0.612
30	280.2	95.78	1.844
31	316	29.92	-0.611
32	347.8	95.76	1.843
33	22.3	28.92	-0.17
33	30.6	31.04	-0.323
34	64.6	91.22	-5.789
34	67.1	115.17	1.189
35	84	67.86	0.65

HORIZONTAL FUNCTIONS AT QUAD CENTERS II B.

STN.	φ DEG.	β M.	α	η M.	η' m-rad
(0	0	67.86	-0.65	2.05	22)
1	18.1	114.58	2.725	2.61	-67
1	20.8	71.81	3.121	2.04	-96
2	63.9	28.77	-0.215	1.16	3
3	97.1	99.58	0	2.12	10
4	130.9	28.71	0	1.7	34
5	164.7	99.6	0	4.11	21
6	198.5	28.71	0	2.94	31
7	232.3	99.58	0	5.95	7
8	266.1	28.7	0	3	-32
9	299.9	99.58	0	4.15	-22
10	333.7	28.71	0	1.68	-36
11	7.5	99.6	0	2	-10
12	41.3	28.71	0	1.08	6
13	75.1	99.57	0	2.3	15
14	108.9	28.7	0	1.95	40
15	142.7	99.59	0	4.68	22
16	176.4	28.71	0	3.2	26
17	210.2	99.59	0	6.2	2
18	244	28.7	0	3.3	-20
19	277.8	99.58	0	4.97	-19
20	311.6	28.71	0	2.11	-41
21	345.4	99.6	0	2.52	-16
22	19.2	28.71	0	1.11	-10
23	53	99.58	0	1.88	8
24	86.8	28.7	0	1.54	33
25	120.6	99.58	0	3.84	23
26	154.4	28.71	0	2.86	36
27	188.2	99.6	0	5.98	10
28	222	28.71	0	3.44	-5
29	255.8	99.57	0	5.64	-14
30	289.6	28.7	0	2.57	-40
31	323.4	99.59	0	3.26	-21
32	357.2	28.71	0	1.31	-25
33	30.8	99.36	-0.701	1.77	12
34	50.6	78.81	2.255	1.73	-32
34	54.6	50.49	1.623	1.46	-27
(35	84	67.86	-0.65	2.05	22)

VERTICAL FUNCTIONS AT QUAD. CENTERS.

STN.	φ DEG.	β M.	α
[0	0	67.86	0.65]
1	29.4	50.49	-1.623
1	33.4	78.81	-2.255
2	53.2	99.36	0.701
3	86.8	28.71	0
4	120.6	99.59	0
5	154.4	28.7	0
6	188.2	99.57	0
7	222	28.71	0
8	255.8	99.6	0
9	289.6	28.71	0
10	323.4	99.58	0
11	357.2	28.7	0
12	31	99.58	0
13	64.8	28.71	0
14	98.6	99.6	0
15	132.4	28.71	0
16	166.2	99.58	0
17	200	28.7	0
18	233.8	99.59	0
19	267.6	28.71	0
20	301.3	99.59	0
21	335.1	28.7	0
22	8.9	99.57	0
23	42.7	28.71	0
24	76.5	99.6	0
25	110.3	28.71	0
26	144.1	99.58	0
27	177.9	28.7	0
28	211.7	99.58	0
29	245.5	28.71	0
30	279.3	99.6	0
31	313.1	28.71	0
32	346.9	99.58	0
33	20.1	28.77	0.215
34	63.2	71.81	-3.121
34	65.9	114.58	-2.725
[35	84	67.86	0.65]

Functions at Dipole Centers III B

η - meters

STN.									STN.
1	1.74	1.51	1.33	1.2	1.25	1.42	1.64	1.92	3
3	1.98	1.83	1.73	1.69	2.05	2.55	3.11	3.72	5
5	3.85	3.53	3.25	3.03	3.38	4.03	4.73	5.48	7
7			4.06	3.4	3.15	3.38	3.66	4	9
9	3.72	3.1	2.52	2	1.68	1.7	1.79	1.92	11
11	1.79	1.52	1.3	1.14	1.2	1.42	1.7	2.03	13
13	2.13	1.99	1.91	1.89	2.31	2.88	3.51	4.19	15
15	4.32	3.93	3.6	3.32	3.63	4.28	4.98	5.73	17
17	5.65	4.94	4.27	3.66	3.53	3.88	4.28	4.74	19
19	4.48	3.76	3.1	2.49	2.13	2.18	2.29	2.45	21
21	2.25	1.86	1.53	1.26	1.17	1.29	1.46	1.69	23
23	1.73	1.59	1.51	1.49	1.83	2.3	2.82	3.4	25
25	3.56	3.28	3.06	2.89	3.3	3.97	4.69	5.47	27
27	5.48	4.84	4.26	3.74	3.76	4.23	4.75	5.33	29
29	5.11	4.34	3.63	2.98	2.64	2.76	2.93	3.16	31
31	2.91	2.4	1.95	1.55	1.32	1.37	1.48	1.64	33
33		1.65	1.63	1.68					0

$\frac{\beta_H}{\beta_v}$ - meters.

F	82.5	62.1	45.9	33.9	35.2	47.8	64.5	85.4	F
	35.2	47.8	64.5	85.4	82.5	62.1	45.9	33.9	
1	55.6	44.0	35.5	30.2	35.2	47.8	64.5	85.4	3
	83.4	86.6	90.8	96.2	82.5	62.1	45.9	33.9	
7			46.6	34.4	35.2	47.8	64.5	85.4	9
			63.6	84.3	82.5	62.1	45.9	33.9	
33		89.7	85.7	82.8					0
		37.2	46.4	58.8					