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A VERTICAL BUMP AT THE J-10 SCRAPER

E. J. Bleser

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Collider Accelerator Department

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Accelerator Division
Alternating Gradient Synchrotron Department
BROOKHAVEN NATIONAL LABORATORY
Upton, New York 11973

Accelerator Division
Technical Note

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1. SUMMARY

This note describes a possible vertical bump at the J-10 scraper using the new steering dipoles. At injection this bump can be strong enough to scrape off most of the beam.

2. INTRODUCTION

The beam scraper to be installed at J-10 in the summer of 1997 will be essentially fixed in position, and the beam will be moved onto it using local orbit bumps. At present, we have significant injection losses at vertical apertures in the ring, and our goal is to collect those losses on the scraper. This note finds that a local vertical bump using the new low field steering magnet system will scrape the injected beam very nicely. Similar bumps might be designed to scrape the beam at the E-20 dump for the winter 1997 run.

3. THE 3-BUMPS

This note documents two basic three-bump designs: the short three-bump and the long three-bump. The short three-bump uses three dipoles in sequence. The long three-bump uses magnets 1, 3, and 4 in a sequence of four magnets. Table 1 gives the phase advances between various dipoles for "The Standard Injection AGS" (Appendix I). By skipping the second magnet in the sequence, there is always more than a 90 degree phase advance between the first and second magnets of the bump. Therefore at the second magnet of the bump the orbit has already peaked and is decreasing which means that the second magnet of the bump must just steer the orbit back to the axis at the third magnet of the bump. Thus for long three-bumps the first magnet is the strongest magnet and determines the peak amplitude. For short three-bumps this is not always true and the achievable amplitude is less than for the long three-bump. In a superperiod the new steering dipoles will be located in straight sections 2, 8, 12, and 18. Thus for each kind of bump there are four variations. The bumps will be named by the initial magnet position along with the suffix S for short bump or L for long bump. The required dipole strengths are readily calculated from the formula:

$$\frac{\theta_1\sqrt{\beta_1}}{\sin(\Delta\mu_{3,2})} = \frac{\theta_2\sqrt{\beta_2}}{\sin(\Delta\mu_{1,3})} = \frac{\theta_3\sqrt{\beta_3}}{\sin(\Delta\mu_{2,1})}$$

where θ is the bend and $\Delta\mu_{m,n}$ is the phase at m minus the phase at n. Table 2 gives the bends calculated from this formula. At injection the maximum dc current is 12.5 Amperes which gives a bend of 1/3 of a milliradian. Scaling the bends in Table 2 by this value and feeding them into

MAD gives orbits plotted in Figures 1 through 4 and summarized in Table 2. It should be noted that bumps calculated from the formula above have almost no residuals in the MAD calculations.

4. COMBINING BUMPS

In order to maximize the bump amplitude at the J-10 Scraper we combine two long bumps, J02L and J08L. The results are shown in Figure 5. The second peak at J-15 is undesirable and can be reduced by subtracting bump J12L. There is a trade off here. Too much reduction at J-15 produces an undershoot at J-18 which may or may not matter. For discussion purposes we take the vertical bump for scraping at J-10 to be the combination of J02L, J08L, and J12L summarized in Table 3 and plotted in Figure 5. This bump is probably the most compact bump of significant amplitude that we can readily achieve. Table 4 records all the various bump orbits at the exits of the AGS main magnets for a peak bend of 1/3 milliradians.

Acknowledgments

This work was made possible solely through the efforts of those who have developed and maintained the MAD Program.

TABLE 1

PHASE ADVANCES BETWEEN VERTICAL DIPOLES IN STANDARD INJECTION AGS

DIPOLE	PHASE ADVANCE FROM DIPOLE DVCJ02 DEGREES	PHASE ADVANCE BETWEEN DIPOLES DEGREES
DVCJ02	0	
DVCJ08	84.24	84.24
DVCJ12	133.56	49.32
DVCJ18	213.12	79.56
DVCK02	266.76	53.64
DVCK08	351.00	84.24
DVCK12	400.32	49.32
DVCK18	479.88	79.56

TABLE 2

GENERIC VERTICAL THREE-BUMPS

BUMP	MAGNETS	BETAY m	MUY 2PI	BEND mr
J02L	DVCJ02	15.190	0.073	1.000
	DVCJ12	18.458	0.444	0.504
	DVCJ18	14.697	0.665	0.749
J08L	DVCJ08	13.817	0.307	1.000
	DVCJ18	14.697	0.665	0.053
	DVCK02	15.190	0.814	0.922
J12L	DVCJ12	18.458	0.444	1.000
	DVCK02	15.190	0.814	0.674
	DVCK08	13.817	1.048	0.847
J18L	DVCJ18	14.697	0.665	1.000
	DVCK08	13.817	1.048	0.170
	DVCK12	18.458	1.185	0.789
J02S	DVCJ02	15.190	0.073	1.000
	DVCJ08	13.817	0.307	-1.002
	DVCJ12	18.458	0.444	1.190
J08S	DVCJ08	13.817	0.307	1.000
	DVCJ12	18.458	0.444	-0.685
	DVCJ18	14.697	0.665	0.748
J12S	DVCJ12	18.458	0.444	1.000
	DVCJ18	14.697	0.665	-1.014
	DVCK02	15.190	0.814	1.346
J18S	DVCJ18	14.697	0.665	1.000
	DVCK02	15.190	0.814	-0.663
	DVCK08	13.817	1.048	0.835

BUMP	PEAK POSITION EXIT of MAGNET	PEAK* AMPLITUDE mm
J02L	J7CD	5.26
	J11BD	5.29
J08L	J11BD	4.17
	J15AD	6.25
	J19BD	3.89
J12L	J16AD	4.32
	J19BD	6.45
	K3CD	4.77
J18L	K3CD	5.24
	K7CD	4.53
J02S	J7CD	4.42
J08S	J11BD	4.18
	J15AD	3.41
J12S	J16AD	3.20
	J19BD	4.22
J18S	K3CD	4.68

* For max bend =1/3 mr

TABLE 3

THE J-10 VERTICAL BUMP

MAGNETS	J02L	J08L	J12L	J02L+ J08L	J02L+J08L - J12L
	mr	mr	mr	mr	mr
DVCJ02	1.000			1.000	1.000
DVCJ08		1.000		1.000	1.000
DVCJ12	0.504		1.000	0.504	-0.496
DVCJ18	0.749	0.053		0.802	0.802
DVCK02		0.922	0.674	0.922	0.248
DVCK08			0.847		-0.847

PEAK ORBIT AMPLITUDES

for 1/3 mr maximum bend

AT THE EXIT OF MAGNET

BUMP	J7CD	J11CD	J15BE	K3CD	
J02L+J08L	5.27	9.45	9.670	0.000	mm
J02L+J08L-J12L	5.25	9.46	5.500	-4.790	mm

TABLE 4

SUMMARY of VERTICAL BUMP ORBITS

		J02L	J02S	J08L	J08S	J12L	J12S	J18L	J18S	J02L+ J08L	J02L+ J08L- J12L
EXIT of	S	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
MAGNET	meters	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
J1BF	607.31	-0.01	-0.01							0.00	-0.01
J2BF	609.93	-0.01	-0.01							0.01	-0.01
J3CD	612.93	0.84	0.71							0.86	0.85
J4CD	616.84	1.69	1.42							1.71	1.70
J5AF	619.84	2.22	1.86							2.23	2.22
J6AF	623.75	3.86	3.25							3.88	3.87
J7CD	626.74	5.26	4.42	0.01	0.00					5.27	5.27
J8CD	630.66	4.97	4.17	0.01	0.00					4.98	4.97
J9BF	633.27	4.08	2.74	0.81	0.81					4.89	4.89
J10BF	635.89	4.25	1.95	1.92	1.93					6.17	6.17
D10	638.94	5.19	1.40	3.50	3.51					7.43	7.43
J11BD	640.94	5.29	0.92	4.17	4.18	-0.01	-0.01			9.45	9.46
J12BD	643.56	4.25	0.11	4.11	4.12	-0.01	-0.01			8.36	8.37
J13CF	646.56	3.18	0.01	3.81	3.16	0.95	0.70			6.98	6.03
J14CF	650.47	3.17	0.00	5.03	3.16	2.75	2.03			8.20	5.45
J15AD	653.46	3.42	0.00	6.25	3.41	4.16	3.08			9.67	5.50
J16AD	657.38	2.38	0.00	5.33	2.38	4.32	3.20			7.71	3.39
J17CF	660.37	1.15	-0.01	3.82	1.16	3.90	2.89	0.00	0.01	4.97	1.07
J18CF	664.28	0.06	-0.01	3.61	0.07	5.19	3.84	0.00	0.01	3.67	-1.52
J19BD	666.90	-0.02	-0.02	3.89	0.00	6.45	4.22	0.75	0.76	3.87	-2.59
J20BD	669.52	-0.02	-0.02	3.20	0.00	6.11	3.47	1.40	1.41	3.18	-2.93
K1BFM	674.57			0.95	0.00	3.92	1.03	2.49	2.50	0.93	-2.99
K2BFM	677.19			0.09	0.00	4.00	0.10	3.80	3.80	0.07	-3.93
K3CD	680.18			0.01	-0.01	4.77	0.01	5.24	4.68	-0.02	-4.79
K4CD	684.09			0.01	0.00	3.77	0.02	4.82	3.70	-0.01	-3.78
K5AF	687.09					2.37	0.01	3.79	2.32	0.00	-2.37
K6AF	691.00					1.52	0.02	4.04	1.48	0.01	-1.52
K7CD	694.00					1.08	0.02	4.53	1.04	0.01	-1.07
K8CD	697.91					0.09	0.02	3.36	0.07	0.02	-0.07
K9BF	700.53							2.16	-0.01	0.02	0.01
K10BF	703.14							1.53	-0.01	0.02	0.02
D10	706.19							1.10	-0.01		
K11BD	708.20							0.72	-0.01		
K12BD	710.81							0.08	-0.01		
K13CF	713.81							0.00	0.00		

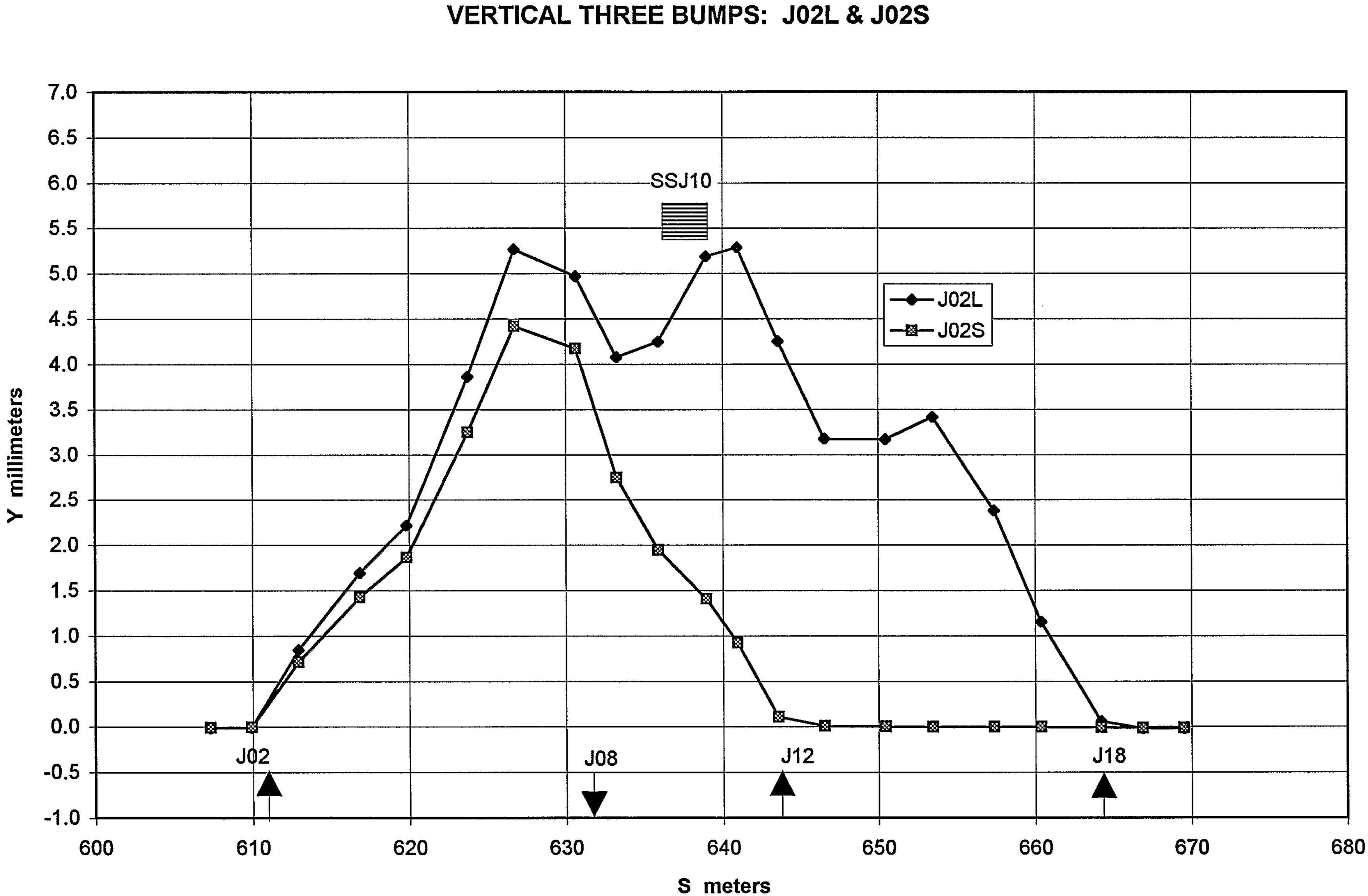

VERTICAL THREE BUMPS: J02L & J02S
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
Y millimeters
SSJ10
J02L
J02S
J02
J08
J12
J18
600
610
620
630
640
650
660
670
680
S meters

Figure 1

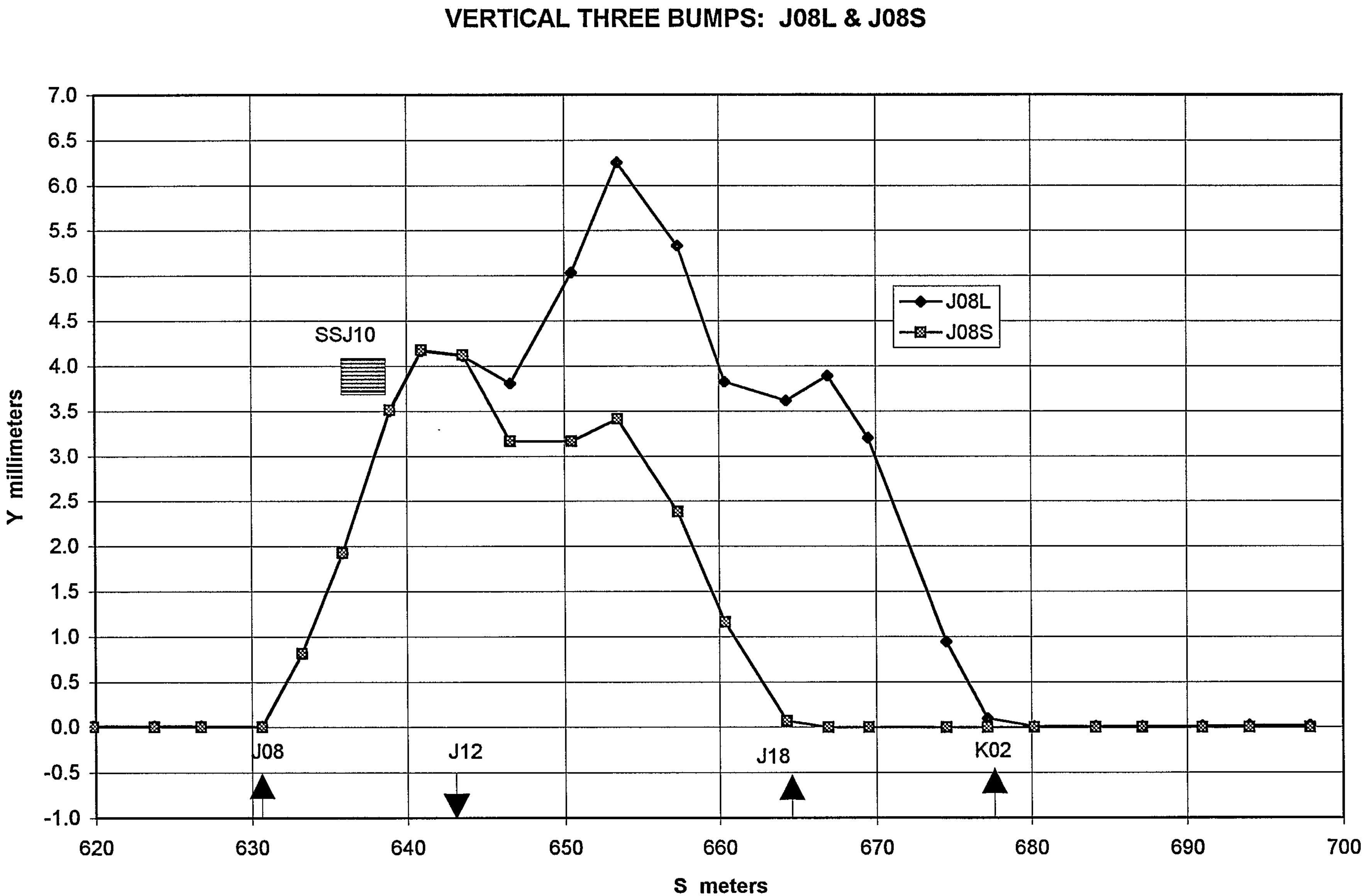

VERTICAL THREE BUMPS: J08L & J08S
Y millimeters
S meters
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
620
630
640
650
660
670
680
690
700
J08L
J08S
SSJ10
J08
J12
J18
K02

Figure 2

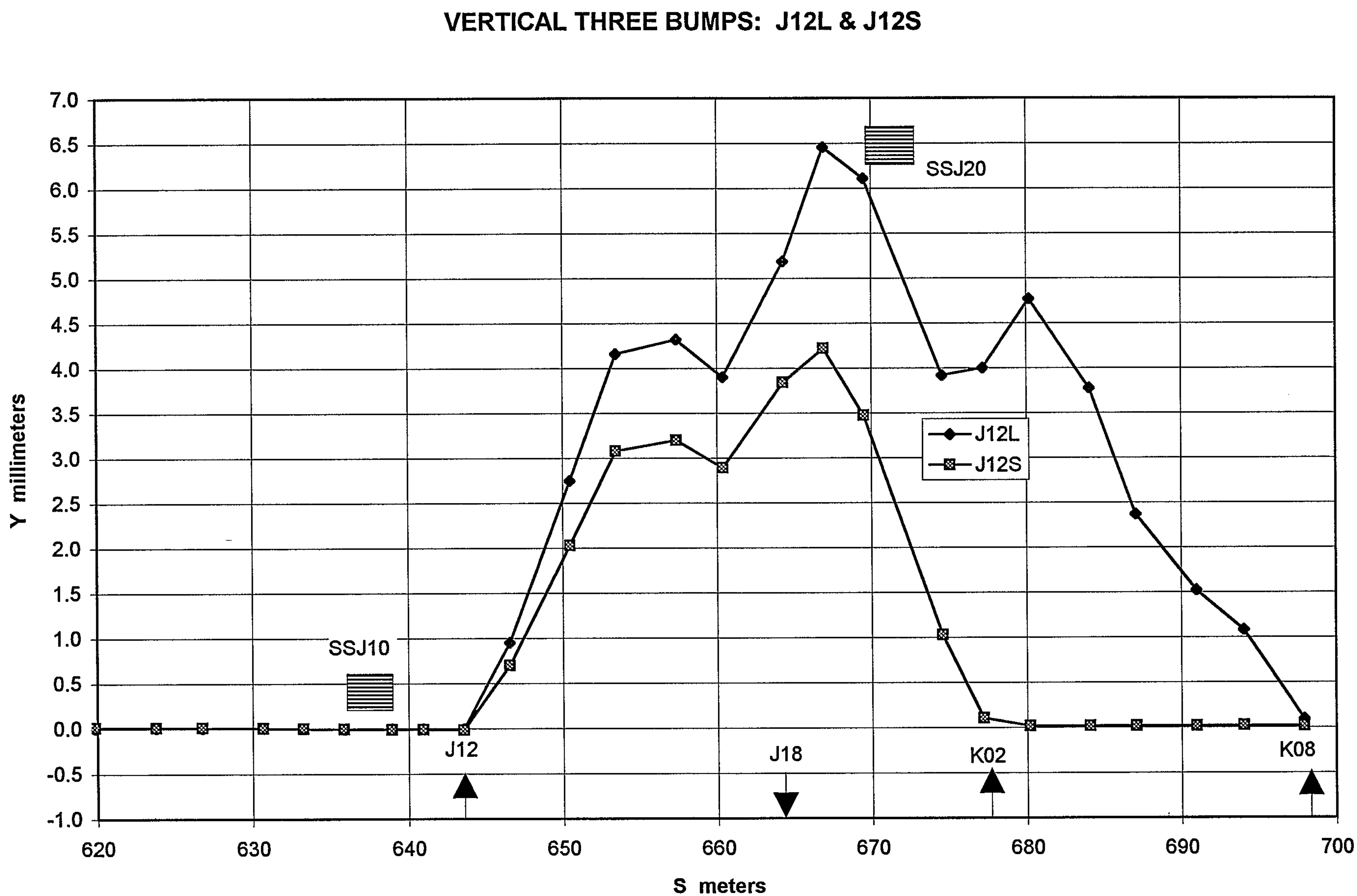

VERTICAL THREE BUMPS: J12L & J12S
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
Y millimeters
SSJ20
SSJ10
J12L
J12S
J12
J18
K02
K08
620
630
640
650
660
670
680
690
700
S meters

Figure 3

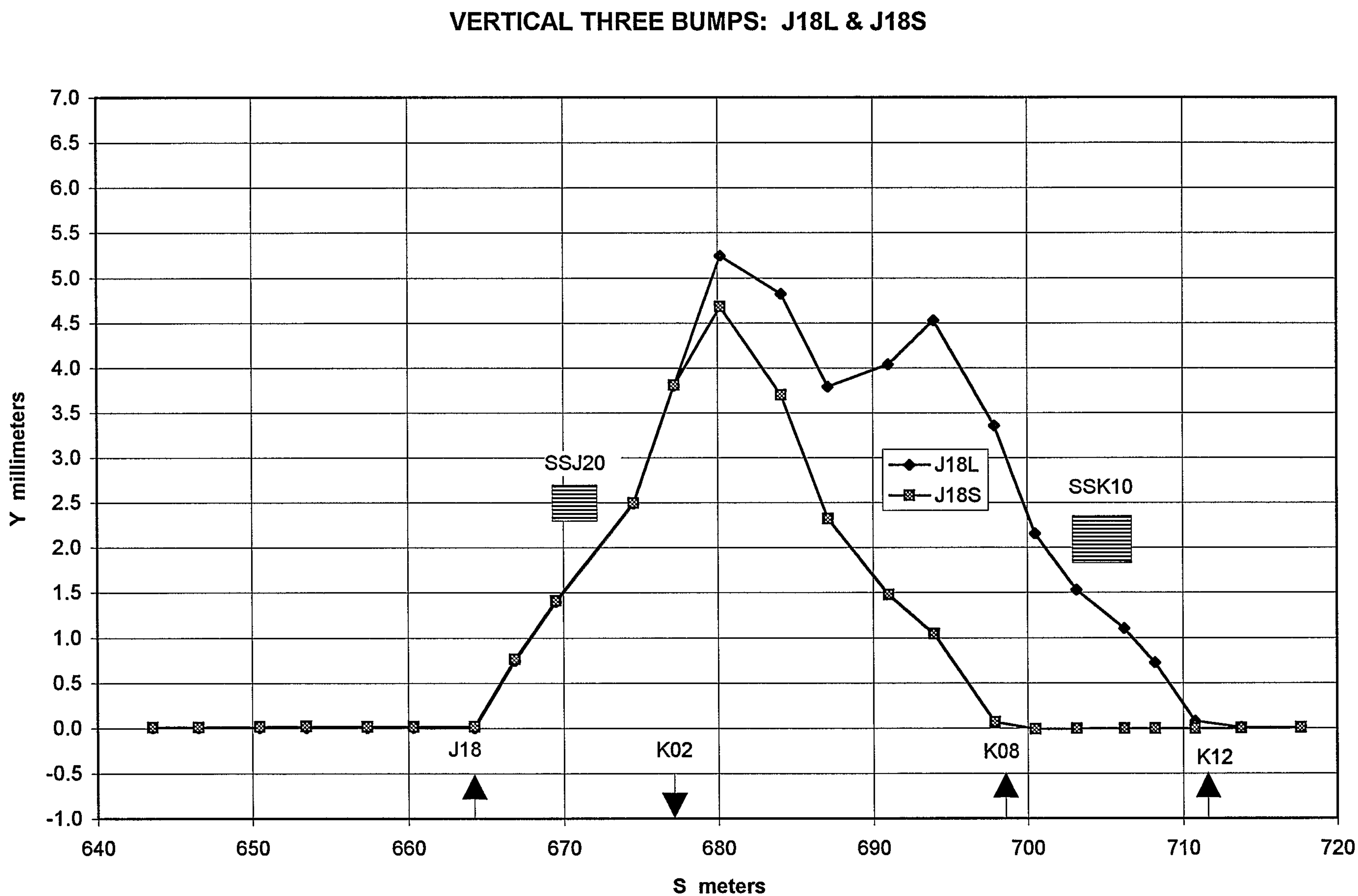
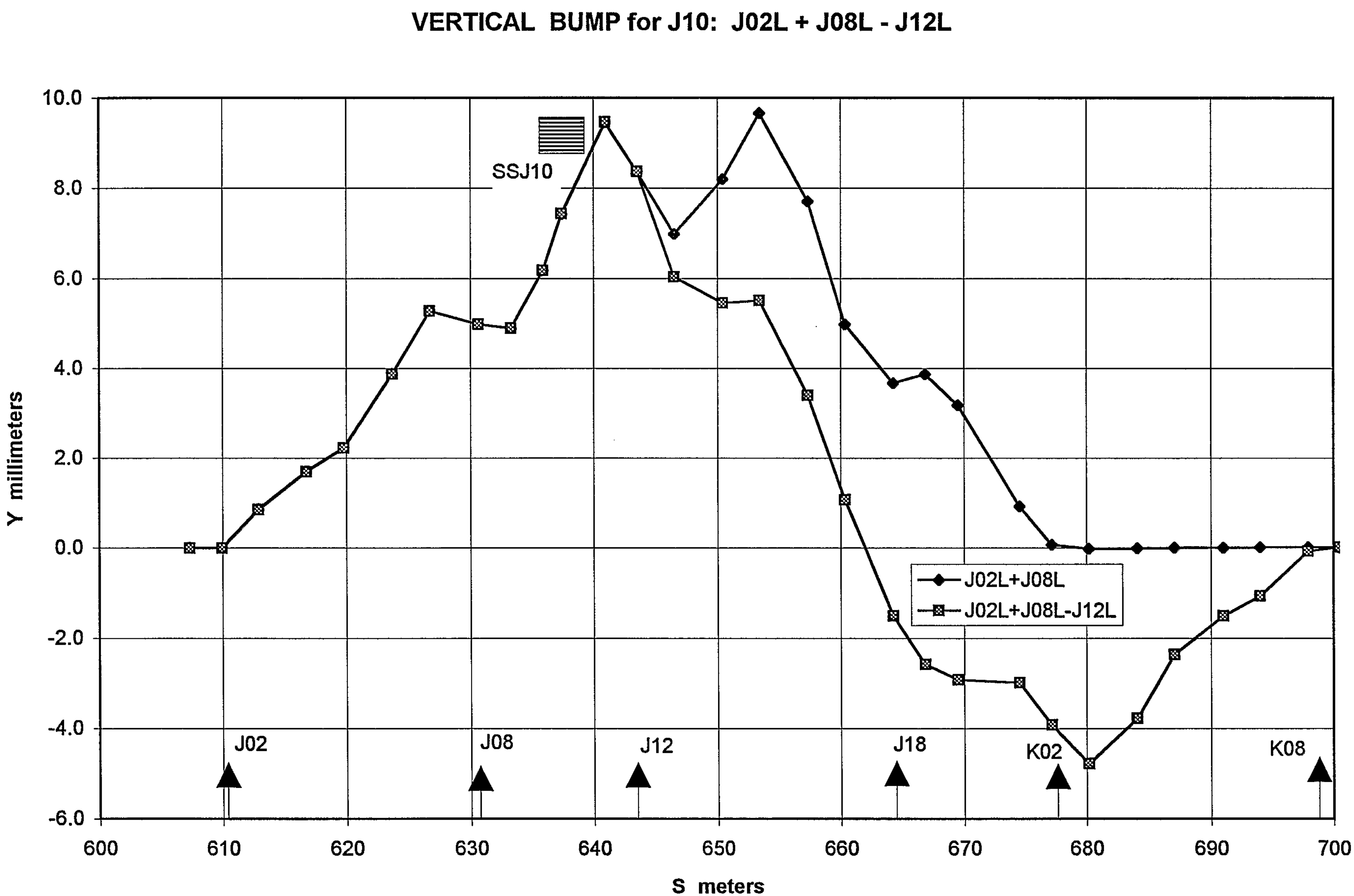

VERTICAL THREE BUMPS: J18L & J18S
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
Y millimeters
640
650
660
670
680
690
700
710
720
S meters
SSJ20
SSK10
J18L
J18S
J18
K02
K08
K12

Figure 4



VERTICAL BUMP for J10: J02L + J08L - J12L
Y millimeters
S meters
SSJ10
J02
J08
J12
J18
K02
K08
J02L+J08L
J02L+J08L-J12L
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
600
610
620
630
640
650
660
670
680
690
700

Figure 5

Appendix I

The Standard Injection AGS

We define the standard injection AGS as having a momentum of 2.25 GeV/c and currents in both tune quad strings of 50 Amperes. This produces a lumpy AGS as tabulated in Table A1 and shown in Figures A1, A2, and A3. On the figures the arrows indicate the exit points of the main magnets. The results given are for Superperiod J, but the other superperiods are identical. The absolute value of the tune of the AGS has not been carefully cross calibrated against the MAD calculation and the present results may not agree exactly with reality, but they are in general very good.

TABLE A1

THE STANDARD INJECTION AGS

MAD INPUT: P = 2.25 GeV/c, I_{QX} = 50 AMPS, I_{QY} = 50 AMPS

MAD OUTPUT: Q_X = 8.83903, Q_Y = 8.892302

			HORIZONTAL					VERTICAL		
POS.	ELEMENT	DIST	BETAX	ALFAX	MUX	DX	DPX	BETAY	ALFAY	MUY
NO.	NAME	m	m		[2PI]	m		m		[2PI]
630	D10	605.307	18.463	-1.483	6.629	1.971	0.111	10.983	0.947	6.669
631	J1BF	607.313	20.948	0.326	6.645	2.019	-0.063	9.692	-0.263	6.701
632	D2S	607.923	20.570	0.294	6.650	1.981	-0.063	10.054	-0.330	6.711
633	J2BF	609.929	15.974	1.845	6.667	1.692	-0.221	14.117	-1.825	6.739
634	DPUE	610.216	14.938	1.766	6.670	1.629	-0.221	15.190	-1.913	6.742
635	PUE_J02	610.216	14.938	1.766	6.670	1.629	-0.221	15.190	-1.913	6.742
636	**DVCJ02**	**610.216**	**14.938**	**1.766**	**6.670**	**1.629**	**-0.221**	**15.190**	**-1.913**	**6.742**
637	D2TX	610.539	13.828	1.677	6.673	1.558	-0.221	16.456	-2.012	6.745
638	J3CD	612.927	10.180	-0.011	6.707	1.261	-0.033	21.805	-0.017	6.765
639	DSQ	613.298	10.202	-0.047	6.713	1.249	-0.033	21.824	-0.034	6.767
640	QHFV	613.688	10.301	-0.206	6.719	1.239	-0.019	21.757	0.204	6.770
641	QPOL	614.079	10.477	-0.245	6.725	1.232	-0.019	21.605	0.185	6.773
642	DSQ	614.450	10.673	-0.283	6.731	1.225	-0.019	21.475	0.167	6.776
643	J4CD	616.838	16.163	-2.226	6.761	1.386	0.157	15.627	2.051	6.796
644	DPUE	617.125	17.471	-2.331	6.764	1.431	0.157	14.477	1.955	6.799
645	PUE_J04	617.125	17.471	-2.331	6.764	1.431	0.157	14.477	1.955	6.799
646	D2LX	617.447	19.013	-2.450	6.767	1.482	0.157	13.251	1.848	6.802
647	J5AF	619.835	25.769	-0.113	6.783	1.671	-0.002	8.806	0.182	6.840
648	D2H	620.597	25.965	-0.143	6.788	1.669	-0.002	8.596	0.093	6.854
649	D2H	621.359	26.205	-0.173	6.792	1.668	-0.002	8.523	0.004	6.868
650	J6AF	623.746	20.466	2.350	6.808	1.469	-0.160	11.820	-1.509	6.908
651	D2L	624.356	17.720	2.156	6.813	1.372	-0.160	13.763	-1.678	6.915
652	J7CD	626.744	12.790	0.096	6.840	1.200	0.013	18.328	-0.053	6.938
653	DSS	627.178	12.721	0.062	6.845	1.206	0.013	18.384	-0.077	6.942
654	SXV	627.833	12.673	0.010	6.853	1.215	0.013	18.508	-0.112	6.948
655	DSS	628.267	12.679	-0.024	6.859	1.220	0.013	18.616	-0.136	6.951
656	J8CD	630.655	17.161	-2.024	6.886	1.461	0.193	14.722	1.613	6.973
657	DPUE	630.942	18.347	-2.109	6.888	1.516	0.193	13.817	1.543	6.977
658	PUE_J08	630.942	18.347	-2.109	6.888	1.516	0.193	13.817	1.543	6.977
659	**DVCJ08**	**630.942**	**18.347**	**-2.109**	**6.888**	**1.516**	**0.193**	**13.817**	**1.543**	**6.977**
660	D2TX	631.264	19.739	-2.205	6.891	1.578	0.193	12.847	1.464	6.980
661	J9BF	633.271	24.990	-0.240	6.905	1.824	0.048	9.898	0.100	7.010
662	D2S	633.881	25.298	-0.265	6.909	1.854	0.048	9.814	0.038	7.020
663	J10BF	635.887	21.763	1.911	6.922	1.793	-0.108	12.118	-1.260	7.050
664	D10	637.411	16.435	1.585	6.935	1.628	-0.108	16.452	-1.585	7.067
665	D10	638.935	12.100	1.260	6.952	1.463	-0.108	21.778	-1.910	7.080
666	J11BD	640.941	9.798	-0.039	6.983	1.408	0.052	25.298	0.272	7.093
667	D2S	641.551	9.883	-0.101	6.992	1.440	0.052	24.982	0.246	7.097
668	J12BD	643.558	12.838	-1.466	7.022	1.715	0.226	19.703	2.211	7.111
669	DPUE	643.845	13.700	-1.537	7.025	1.780	0.226	18.458	2.125	7.114
670	PUE_J12	643.845	13.700	-1.537	7.025	1.780	0.226	18.458	2.125	7.114
671	**DVCJ12**	**643.845**	**13.700**	**-1.537**	**7.025**	**1.780**	**0.226**	**18.458**	**2.125**	**7.114**
672	D2TX	644.167	14.717	-1.616	7.029	1.854	0.226	17.119	2.029	7.116
673	J13CF	646.555	18.632	0.130	7.051	2.151	0.017	12.600	0.035	7.144

			HORIZONTAL					VERTICAL		
POS.	ELEMENT	DIST	BETAX	ALFAX	MUX	DX	DPX	BETAY	ALFAY	MUY
NO.	NAME	m	m		[2PI]	m		m		[2PI]
674	DSS	646.989	18.529	0.107	7.055	2.158	0.017	12.585	0.000	7.149
675	SXH	647.644	18.413	0.071	7.060	2.169	0.017	12.619	-0.052	7.157
676	DSS	648.079	18.362	0.047	7.064	2.176	0.017	12.679	-0.086	7.163
677	J14CF	650.466	13.814	1.678	7.087	1.951	-0.200	17.516	-2.123	7.190
678	DPUE	650.753	12.874	1.599	7.090	1.894	-0.200	18.761	-2.213	7.192
679	PUE_J14	650.753	12.874	1.599	7.090	1.894	-0.200	18.761	-2.213	7.192
680	D2LX	651.076	11.872	1.509	7.094	1.829	-0.200	20.221	-2.315	7.195
681	J15AD	653.463	8.589	-0.009	7.134	1.622	0.023	25.849	0.180	7.211
682	D2H	654.225	8.670	-0.098	7.148	1.639	0.023	25.598	0.150	7.216
683	D2H	654.987	8.888	-0.187	7.162	1.656	0.023	25.393	0.119	7.220
684	J16AD	657.375	13.382	-1.866	7.199	1.982	0.257	18.702	2.418	7.237
685	D2L	657.984	15.781	-2.071	7.206	2.139	0.257	15.890	2.195	7.243
686	J17CF	660.372	21.684	-0.169	7.225	2.466	0.011	10.470	0.280	7.274
687	DSQ	660.743	21.815	-0.186	7.228	2.470	0.011	10.276	0.242	7.279
688	QHFH	661.134	21.868	0.052	7.231	2.469	-0.018	10.150	0.083	7.285
689	QHFS	661.525	21.835	0.034	7.234	2.462	-0.018	10.100	0.044	7.292
690	DSQ	661.896	21.816	0.017	7.236	2.455	-0.018	10.081	0.007	7.297
691	J18CF	664.283	16.470	2.011	7.256	2.114	-0.261	13.717	-1.668	7.331
692	DPUE	664.570	15.341	1.923	7.258	2.039	-0.261	14.697	-1.747	7.335
693	PUE_J18	664.570	15.341	1.923	7.258	2.039	-0.261	14.697	-1.747	7.335
694	**DVCJ18**	**664.570**	**15.341**	**1.923**	**7.258**	**2.039**	**-0.261**	**14.697**	**-1.747**	**7.335**
695	D2TX	664.893	14.132	1.825	7.262	1.955	-0.261	15.853	-1.836	7.338
696	J19BD	666.899	10.076	0.327	7.290	1.631	-0.067	20.436	-0.296	7.355
697	D2S	667.509	9.719	0.260	7.300	1.590	-0.067	20.816	-0.329	7.360
698	J20BD	669.515	11.031	-0.955	7.332	1.634	0.111	18.357	1.473	7.376
699	D10	671.039	14.344	-1.219	7.351	1.802	0.111	14.269	1.210	7.391
700	D10	672.563	18.463	-1.483	7.366	1.971	0.111	10.983	0.947	7.410

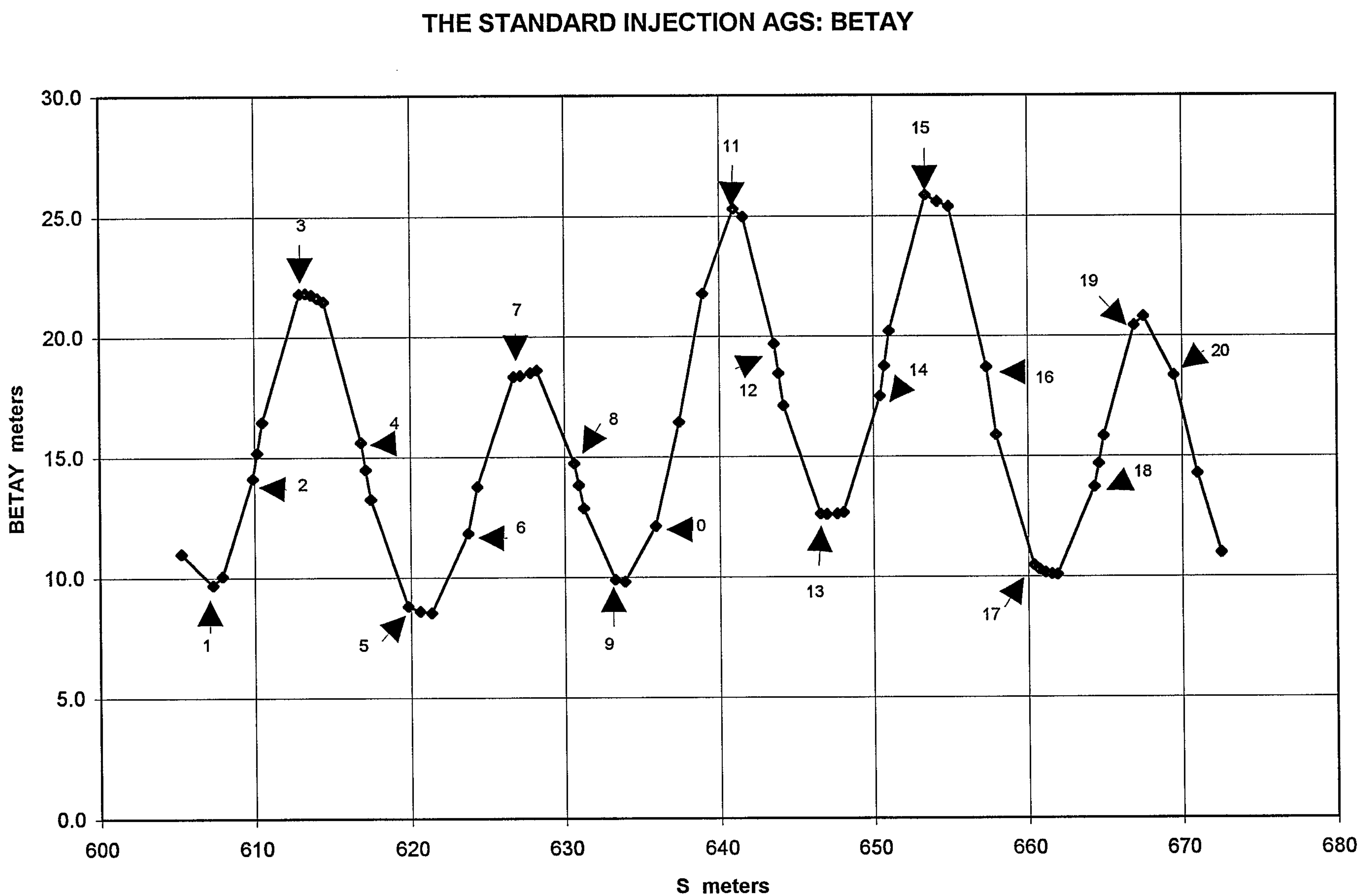

THE STANDARD INJECTION AGS: BETAY
BETAY meters
S meters
30.0
25.0
20.0
15.0
10.0
5.0
0.0
600
610
620
630
640
650
660
670
680
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Figure A1

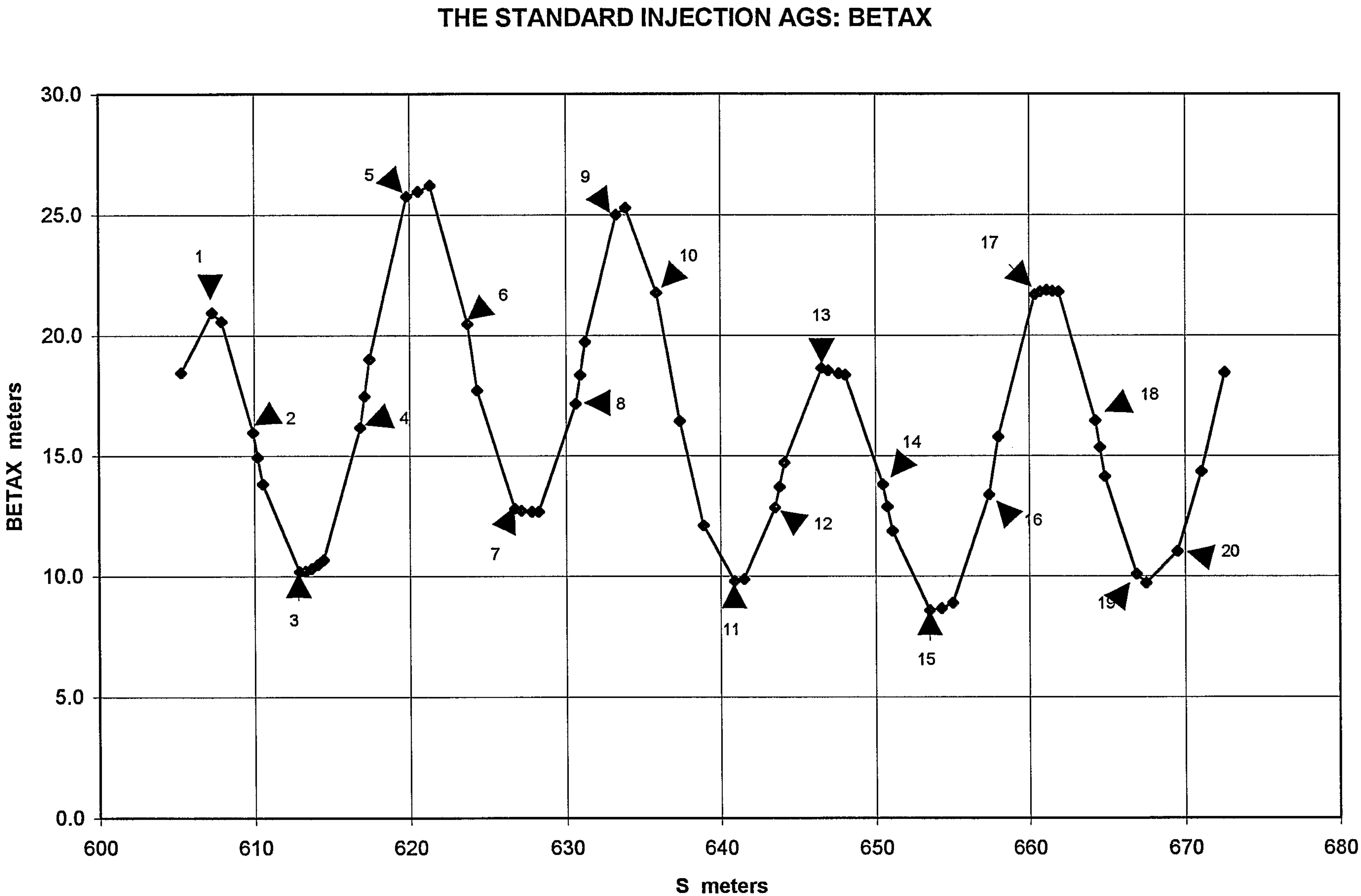

THE STANDARD INJECTION AGS: BETAX
BETAX meters
S meters
30.0
25.0
20.0
15.0
10.0
5.0
0.0
600
610
620
630
640
650
660
670
680
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Figure A2

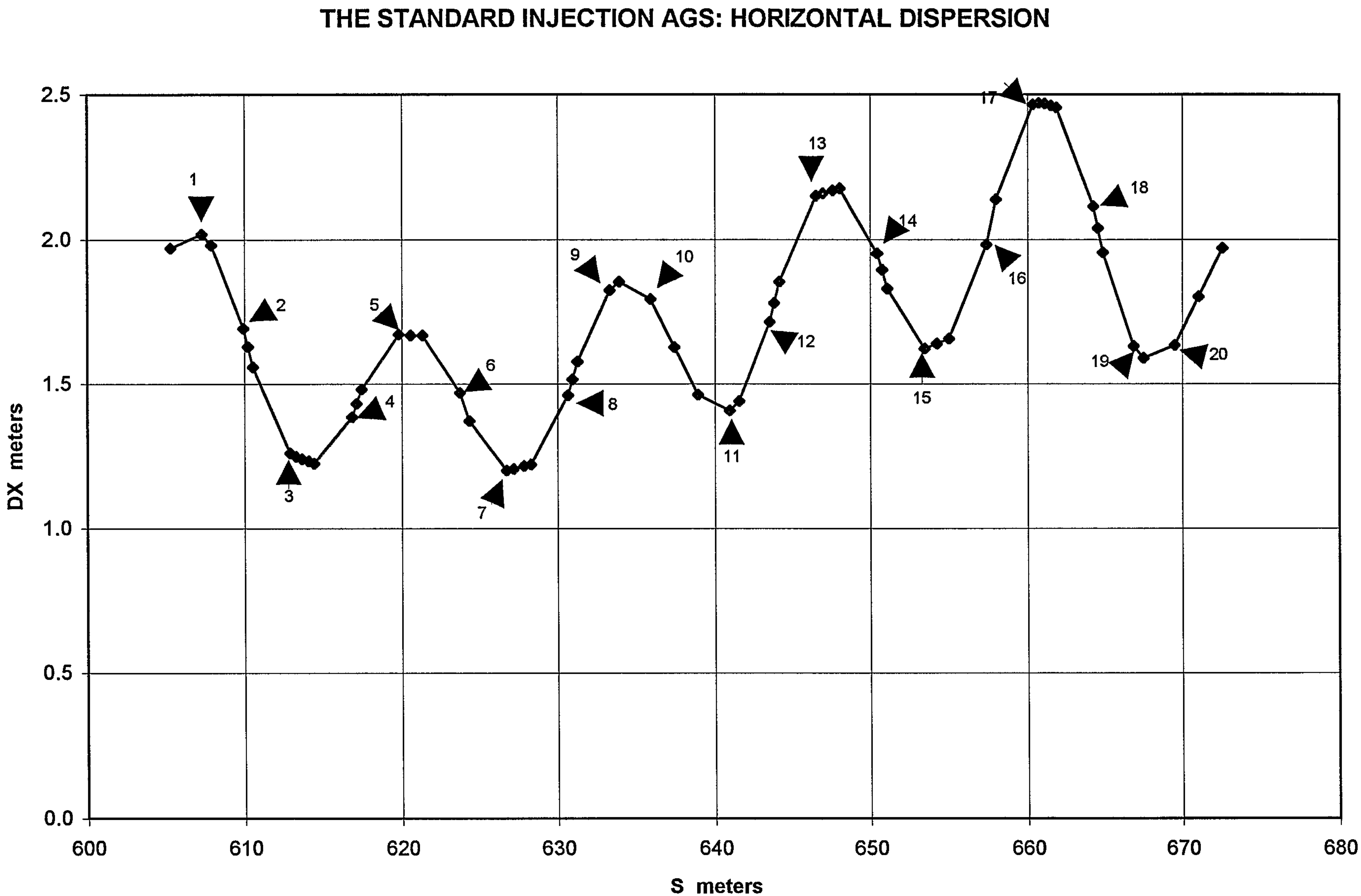

THE STANDARD INJECTION AGS: HORIZONTAL DISPERSION
DX meters
S meters
2.5
2.0
1.5
1.0
0.5
0.0
600
610
620
630
640
650
660
670
680
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Figure A3