



Fermilab

TS-SSC 92-022

SSC Collider Dipole Magnet End Force Issues

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Fermilab**

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Outline:

- **End Force Measurement Variations**
- **Fermilab 50 mm Dipole End Design**
- **Construction Variations which might affect end force**
- **Conclusions**

Acknowledgments: Jim Strait
 Steve Delchamps
 Rodger Bossert
 Tricia Heger

15m Dipole Magnet

Performance

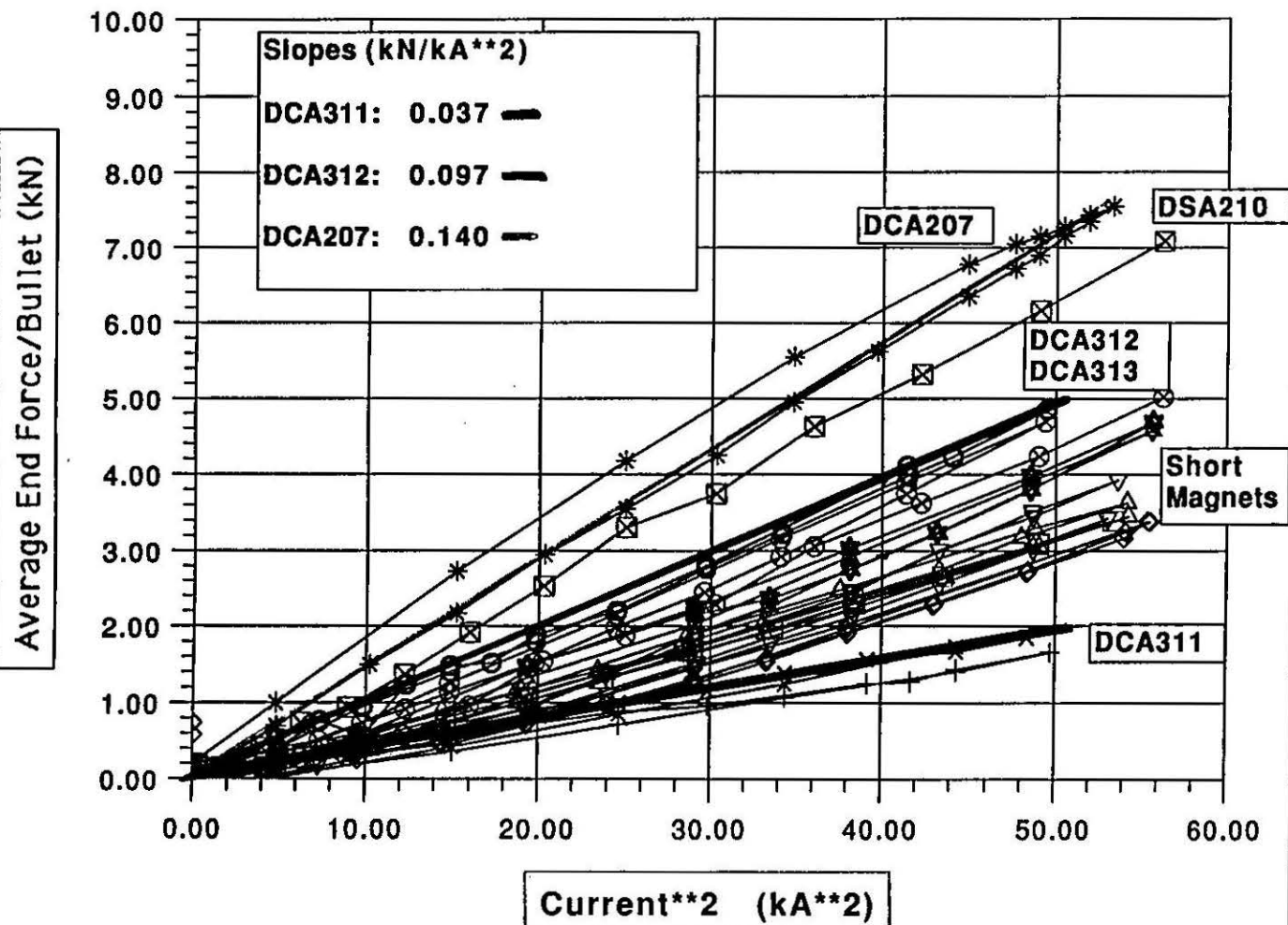
DCA311, 312 + 207 reached operating current without quenching.

DCA313 quenched at ≈ 5 kA, then went to short sample.

All magnets exhibit a strong ramp rate dependence

All magnets had adequate azimuthal pre load to prevent unloading.

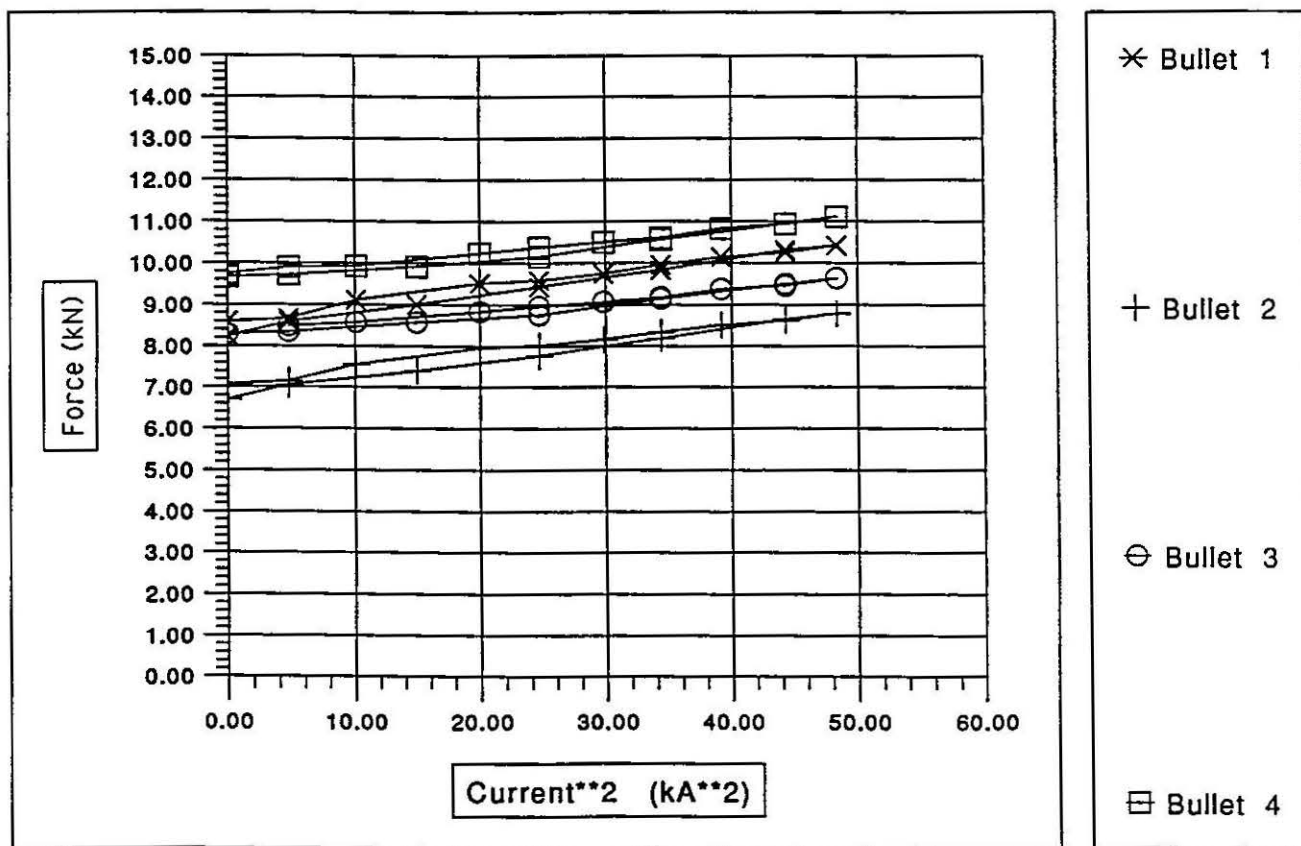
Average End Force vs. I^{**2} (Pre-load Subtracted)



- ⊗ DCA311 TC1
- + DCA311 TC2
- ⊗ DCA312 TC1
- ⊠ DSA324 TC1
- △ DSA324 TC2
- △ DSA324 TC4
- ▽ DSA326 TC1
- ▽ DSA326 TC2
- ◇ DSA101 TC1
- ◇ DSA101 TC2
- ⊠ DSA102 TC1
- ⊠ DSA102 TC2
- ⊗ DCA207
- ⊗ DSA209
- ⊠ DSA210
- ⊗ DCA313 TC1

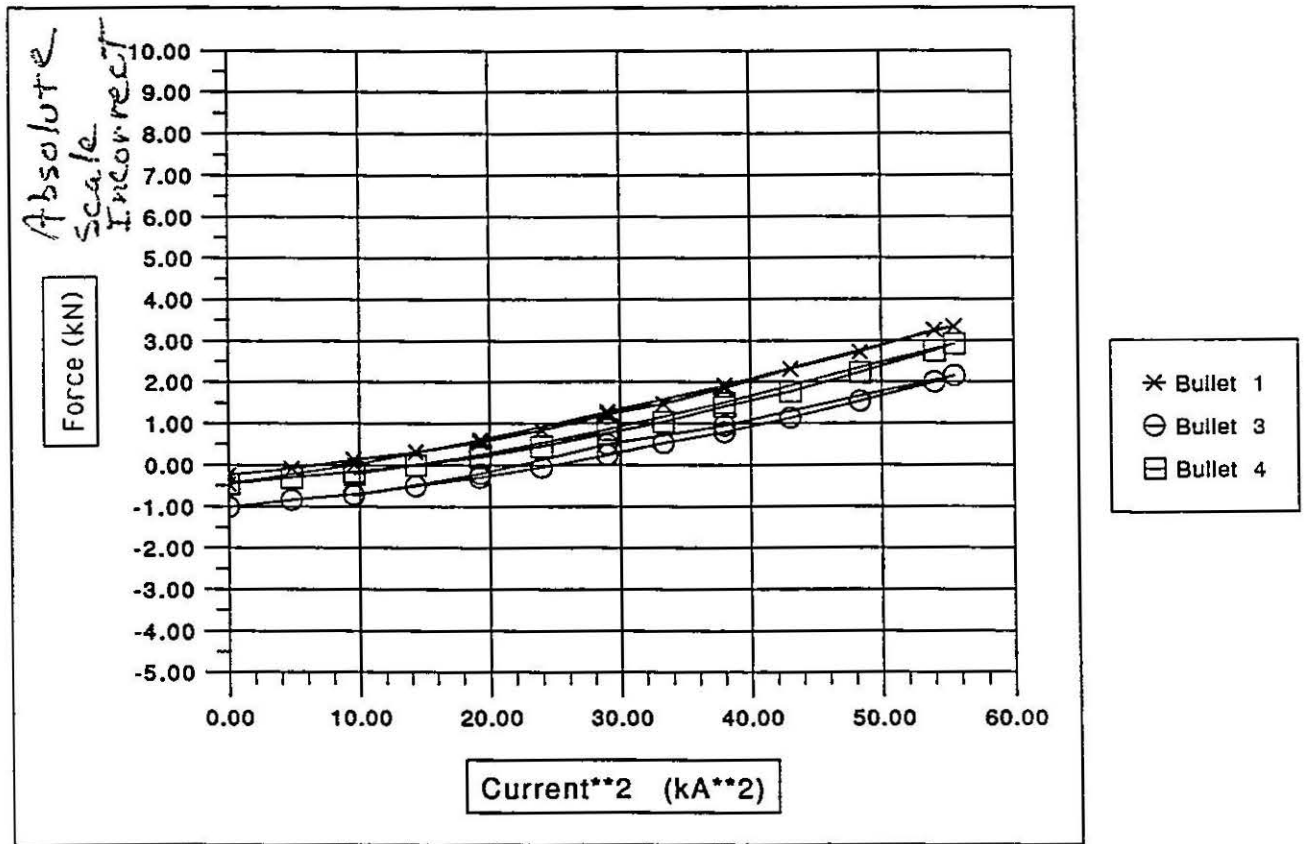
	B	C	D	E	F	G
53	DCA311 TC1					
54	Current	Bullet 1	Bullet 2	Bullet 3	Bullet 4	Ave 311 TC 1
55	0.00	8.58	7.07	9.74	8.44	
56	4.79	8.66	7.14	8.48	9.89	8.54
57	10.12	9.11	7.55	8.57	9.93	8.79
58	19.99	9.51	7.95	8.83	10.24	9.13
59	24.68	9.59	8.01	8.96	10.37	9.23
60	29.85	9.74	8.14	9.06	10.50	9.36
61	34.35	9.96	8.33	9.18	10.61	9.52
62	39.16	10.14	8.50	9.38	10.82	9.71
63	44.29	10.25	8.62	9.45	10.92	9.81
64	48.35	10.43	8.79	9.63	11.10	9.99
65	44.29	10.31	8.64	9.50	10.93	9.84
66	34.35	9.83	8.18	9.13	10.55	9.42
67	24.68	9.43	7.77	8.75	10.16	9.03
68	15.02	9.00	7.39	8.56	9.91	8.72
69	4.79	8.59	7.05	8.34	9.71	8.42
70	0.00	8.22	6.69	8.29	9.66	8.22
71	0.00	0.00	0.00	0.00	0.00	0.00
72	0.00	0.00	0.00	0.00	0.00	0.00
73	0.00	0.00	0.00	0.00	0.00	0.00
74	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00
77	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00

DCA311 End Force vs I**2



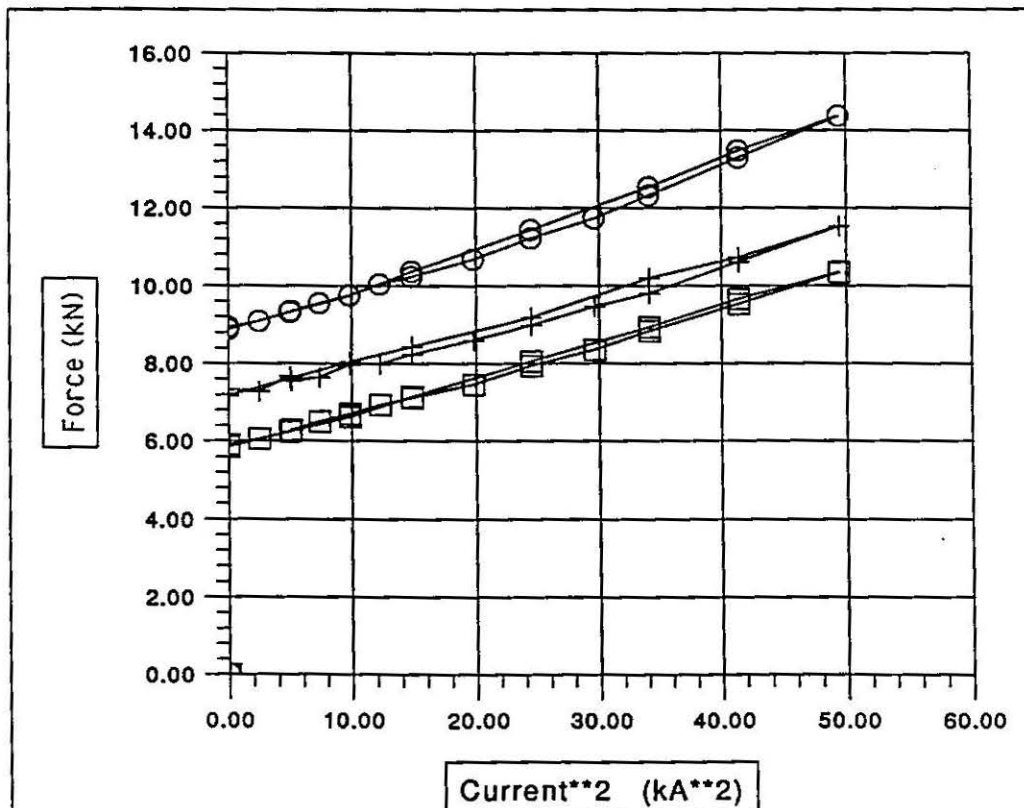
	BD	BE	BF	BG	BH	BI
53	0.		Bullet 1	Bullet 3	Bullet 4	
54	DSA101 TC1	Bullet 1	Bullet 3	Bullet 3	Bullet 4	Average
55	0.00	-0.25	4529.21	-1.02	-0.47	-0.58
56	4.82	-0.09	4529.66	-0.85	-0.31	-0.42
57	9.55	0.13	4529.21	-0.71	-0.17	-0.25
58	14.33	0.31	4529.66	-0.52	-0.01	-0.07
59	19.29	0.54	4530.10	-0.30	0.19	0.14
60	23.92	0.83	4530.10	-0.06	0.45	0.40
61	29.00	1.20	4530.99	0.24	0.76	0.73
62	33.31	1.46	4530.99	0.53	1.03	1.01
63	38.00	1.85	4530.55	0.78	1.40	1.34
64	43.05	2.29	4530.99	1.13	1.76	1.73
65	48.40	2.72	4530.55	1.53	2.23	2.16
66	54.07	3.26	4531.44	1.99	2.75	2.67
67	55.51	3.34	4531.44	2.14	2.92	2.80
68	38.00	1.91	4530.55	0.94	1.49	1.45
69	29.02	1.27	4530.10	0.49	0.85	0.87
70	19.31	0.60	4529.66	-0.21	0.24	0.21
71	9.56	0.00	4529.66	-0.74	-0.23	-0.33
72	0.00	-0.46	4529.21	-1.15	-0.57	-0.73
73	0.00	-0.33	4528.77	-1.07	-0.47	-0.63
74	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00
77	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00

DSA101 End Force vs I**2



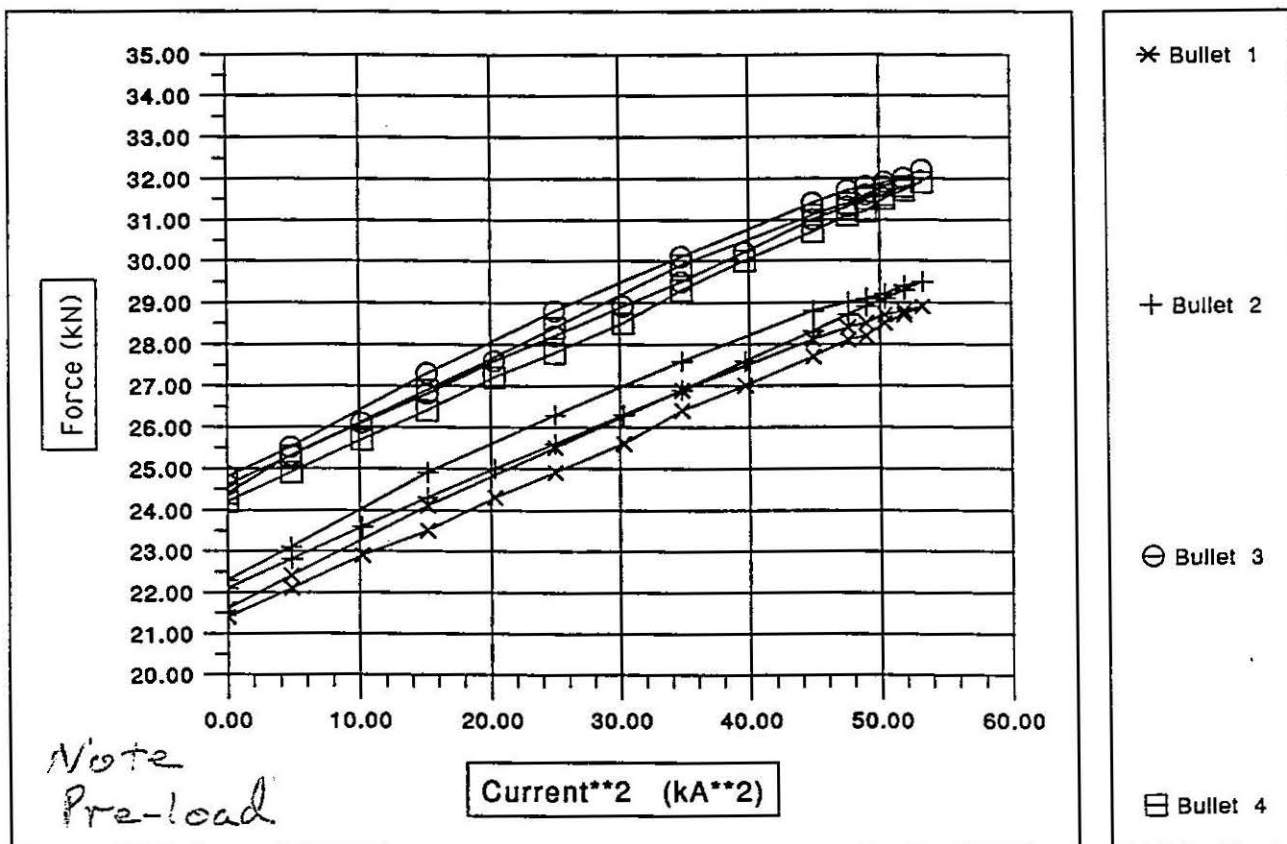
	CH	CI	CJ	CK	CL	CM
53						0.00
54	DCA313 TC1	Bullet 1	Bullet 2	Bullet 3	Bullet 4	Average
55	0.00	4486.49	7.33	8.92	5.91	7.39
56	2.47	4486.49	7.27	9.07	6.06	7.47
57	4.91	4486.49	7.67	9.32	6.25	7.75
58	5.02	4486.49	7.54	9.33	6.29	7.72
59	7.36	4486.49	7.63	9.54	6.50	7.89
60	9.83	4486.94	7.97	9.74	6.69	8.13
61	12.30	4486.49	7.98	10.02	6.93	8.31
62	14.85	4486.49	8.23	10.23	7.11	8.52
63	19.79	4486.94	8.60	10.67	7.46	8.91
64	24.46	4486.94	8.97	11.22	7.94	9.38
65	29.62	4486.94	9.45	11.73	8.34	9.84
66	34.09	4486.94	9.80	12.32	8.82	10.31
67	41.39	4487.38	10.61	13.29	9.52	11.14
68	49.42	4487.38	11.52	14.37	10.35	12.08
69	41.39	4486.94	10.72	13.48	9.66	11.28
70	34.09	4486.94	10.20	12.54	8.92	10.55
71	24.46	4486.94	9.17	11.42	8.06	9.55
72	14.85	4486.49	8.42	10.36	7.14	8.64
73	9.82	4486.49	8.04	9.73	6.61	8.13
74	4.91	4486.49	7.61	9.30	6.24	7.72
75	0.00	4486.49	7.17	8.86	5.84	7.29
76	0.00	0.00	0.00	0.00	0.00	0.00
77	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00

DCA313 End Force vs I**2



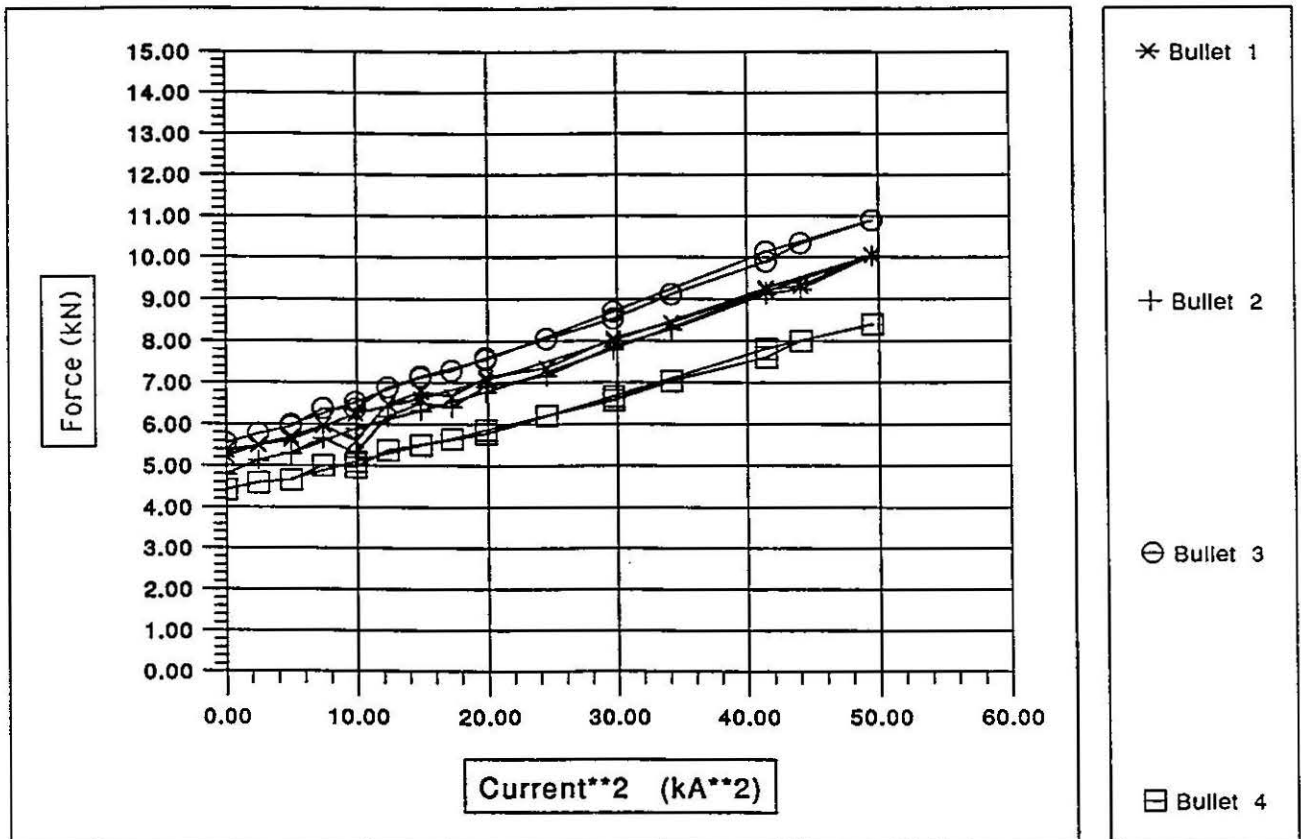
	CB	CC	CD	CE	CF	CG
53	0.					
54	DCA207	Bullet 1	Bullet 2	Bullet 3	Bullet 4	Average
55	0.00	21.40	22.10	24.60	24.20	23.08
56	4.84	22.10	22.80	25.30	24.90	23.78
57	10.20	22.90	23.60	26.10	25.70	24.58
58	15.20	23.50	24.30	26.80	26.40	25.25
59	20.30	24.30	25.00	27.60	27.20	26.03
60	25.00	24.90	25.60	28.20	27.80	26.63
61	30.30	25.60	26.30	28.90	28.50	27.33
62	34.80	26.40	26.90	29.50	29.30	28.03
63	39.70	27.00	27.60	30.20	30.00	28.70
64	44.90	27.70	28.30	31.00	30.70	29.43
65	47.60	28.10	28.70	31.30	31.10	29.80
66	49.00	28.20	28.90	31.60	31.20	29.98
67	50.40	28.50	29.10	31.80	31.50	30.23
68	51.90	28.70	29.30	32.00	31.70	30.43
69	53.30	28.90	29.50	32.20	31.90	30.63
70	51.90	28.80	29.40	32.00	31.80	30.50
71	50.40	28.70	29.20	31.90	31.60	30.35
72	49.00	28.50	29.10	31.80	31.50	30.23
73	47.60	28.40	29.00	31.70	31.40	30.13
74	44.90	28.10	28.80	31.40	31.10	29.85
75	34.80	26.90	27.60	30.10	29.90	28.63
76	25.00	25.50	26.30	28.80	28.40	27.25
77	15.20	24.10	24.90	27.30	26.90	25.80
78	4.80	22.40	23.10	25.50	25.30	24.08
79	0.00	21.60	22.30	24.80	24.40	23.28
80	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00

DCA207 End Force vs I**2



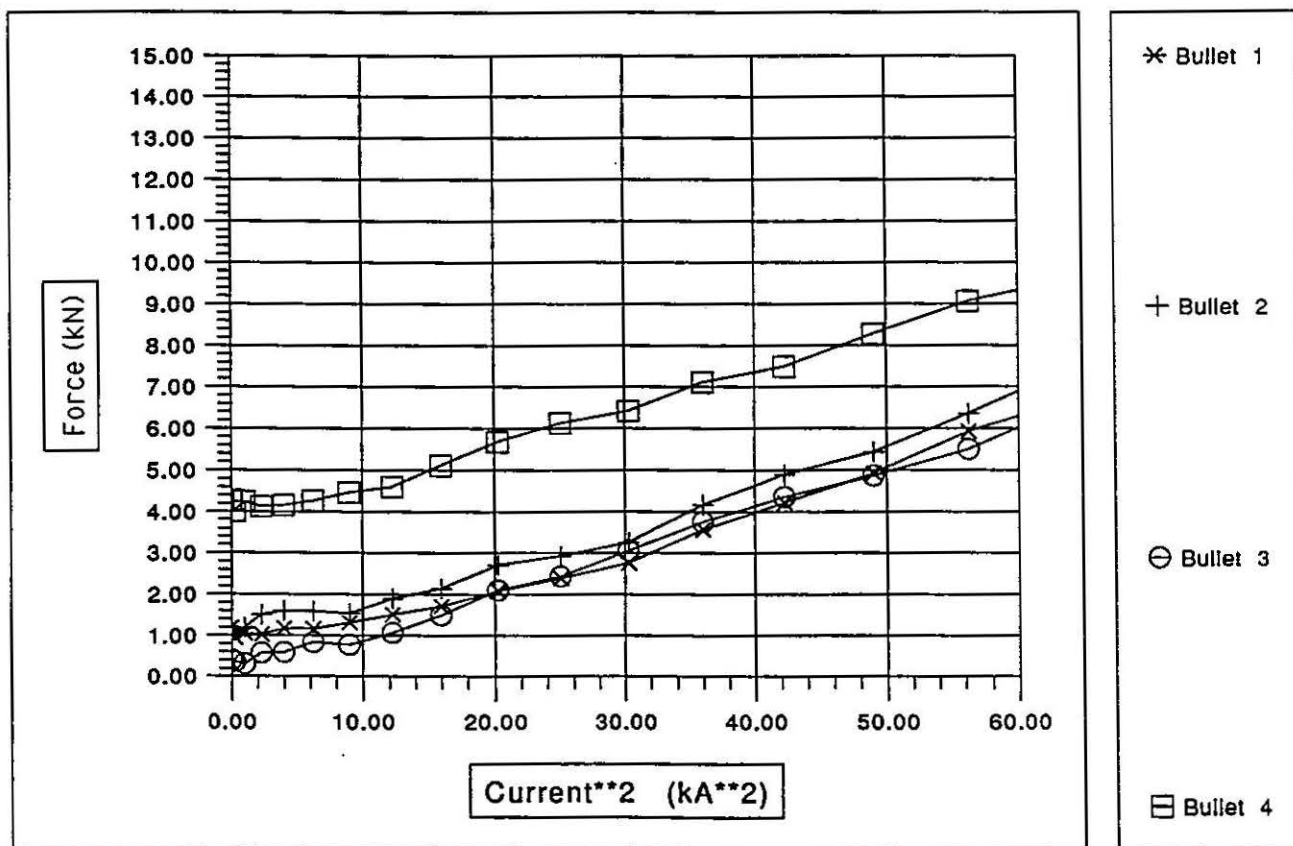
	N	O	P	Q	R	S
53	0.					
54	OCA312 TC1	Bullet 1	Bullet 2	Bullet 3	Bullet 4	Average 312 TC1
55	0.00	5.21	4.78	5.54	4.41	4.99
56	2.49	5.49	5.12	5.78	4.58	5.24
57	4.94	5.69	5.31	5.94	4.65	5.40
58	7.40	5.97	5.66	6.37	5.01	5.75
59	9.87	5.59	5.30	6.37	4.95	5.55
60	12.35	6.48	6.18	6.88	5.38	6.23
61	14.91	6.77	6.50	7.11	5.50	6.47
62	17.30	6.67	6.42	7.29	5.65	6.51
63	19.86	7.13	6.92	7.59	5.86	6.87
64	24.53	7.35	7.17	8.04	6.21	7.19
65	29.70	8.05	7.85	8.52	6.57	7.75
66	34.18	8.42	8.27	9.11	7.04	8.21
67	41.50	9.22	9.12	9.90	7.62	8.96
68	44.11	9.31	9.23	10.33	8.00	9.22
69	49.52	10.05	10.03	10.89	8.40	9.84
70	41.49	9.27	9.17	10.13	7.81	9.10
71	29.70	8.00	7.79	8.69	6.67	7.79
72	19.86	7.06	6.78	7.55	5.78	6.79
73	14.91	6.62	6.32	7.14	5.50	6.40
74	9.87	6.25	5.90	6.53	5.09	5.94
75	4.94	5.62	5.28	5.98	4.65	5.38
76	0.00	5.36	4.92	5.55	4.42	5.06
77	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00

DCA312 End Force vs I**2



	CN	CO	CP	CO	CR	CS
53	DSA209	Bullet 1	Bullet 2	Bullet 3	Bullet 4	Average
54						
55	0.00	1.18	1.17	0.39	4.28	1.95
56	0.25	0.93	1.11	0.35	3.99	1.82
57	1.00	1.05	1.18	0.30	4.24	1.91
58	2.25	1.02	1.50	0.57	4.12	2.06
59	4.00	1.17	1.60	0.57	4.15	2.11
60	6.25	1.15	1.59	0.82	4.25	2.22
61	9.01	1.31	1.54	0.76	4.45	2.25
62	12.26	1.51	1.90	1.06	4.60	2.52
63	16.01	1.71	2.14	1.49	5.10	2.91
64	20.27	2.08	2.72	2.09	5.67	3.49
65	25.02	2.38	2.93	2.44	6.13	3.83
66	30.27	2.76	3.25	3.06	6.42	4.24
67	36.03	3.56	4.17	3.74	7.11	5.01
68	42.28	4.21	4.89	4.35	7.49	5.57
69	49.04	4.92	5.42	4.86	8.28	6.19
70	56.30	5.93	6.36	5.50	9.06	6.97
71	64.05	6.68	7.47	6.57	9.60	7.88
72	65.66	7.00	7.55	6.66	10.05	8.09
73	67.29	7.15	7.93	6.86	9.81	8.20
74	68.95	7.27	7.94	6.93	9.85	8.24
75	70.61	7.51	8.16	7.07	10.26	8.50
76	72.30	7.83	8.24	7.26	10.51	8.67
77	74.02	7.81	8.76	7.45	10.47	8.89
78	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00
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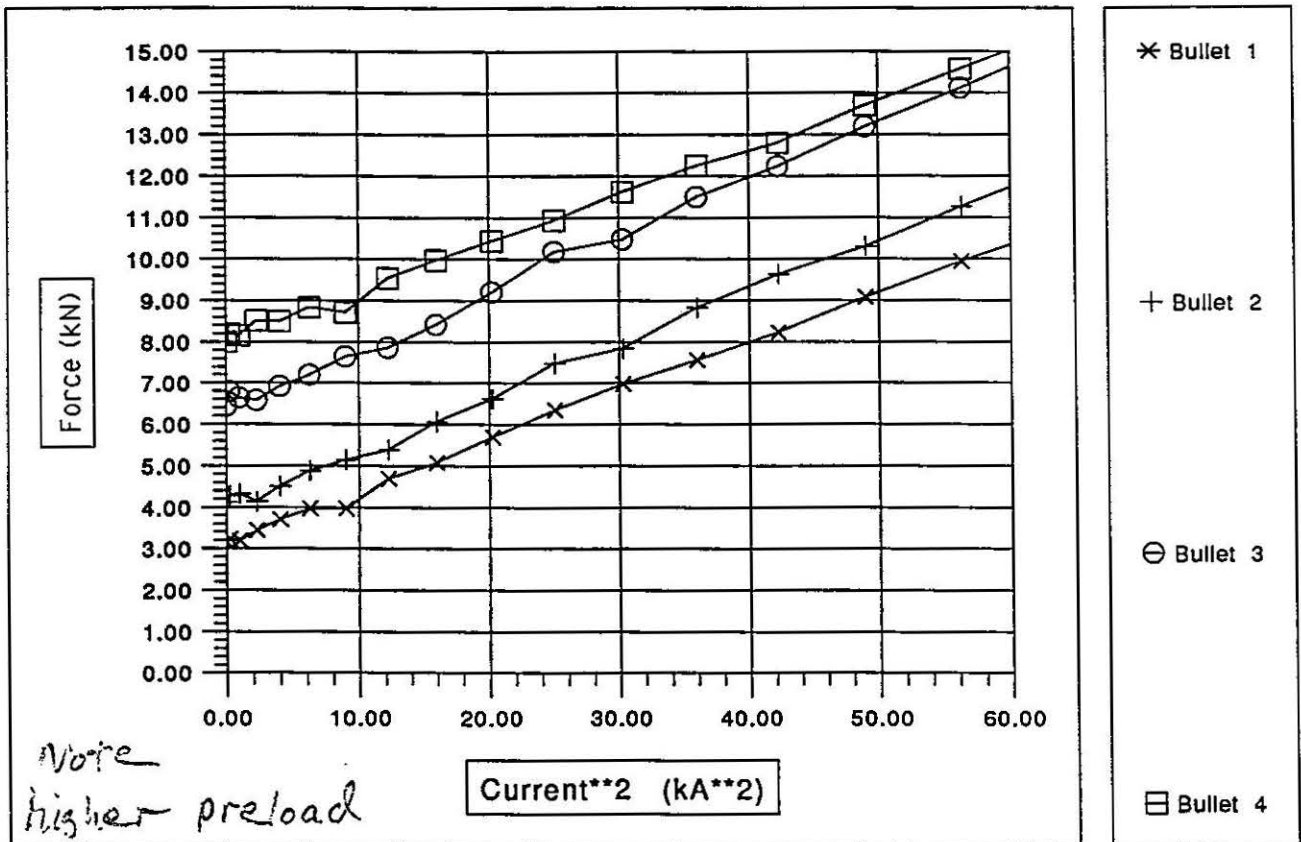
DSA209 End Force vs I**2



Both DSA209 & DSA210 unloaded
azimuthally

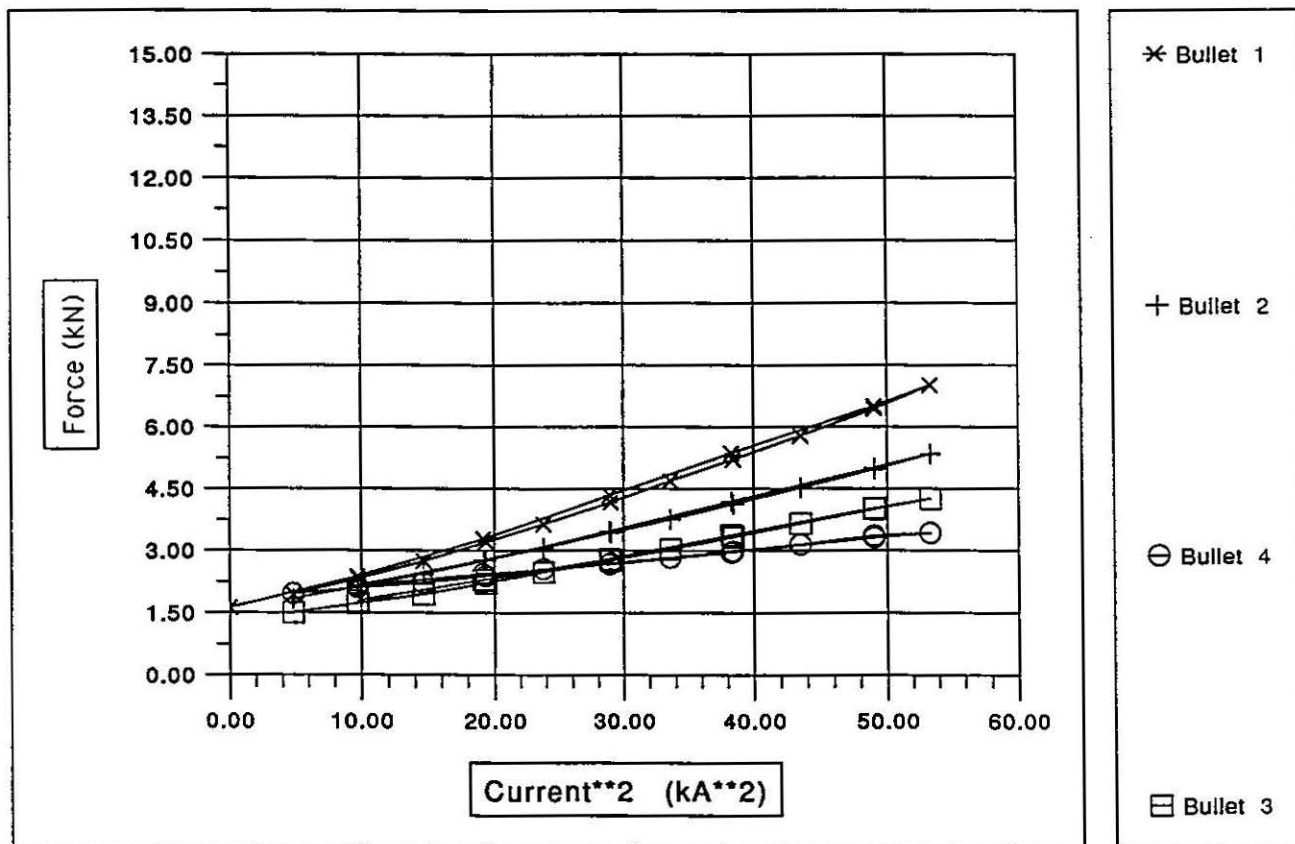
	CT	CU	CV	CW	CX	CY
53						
54	DSA210	Bullet 1	Bullet 2	Bullet 3	Bullet 4	Average
55	0.00	3.14	4.12	6.43	8.00	6.22
56	0.25	3.23	4.26	6.79	8.19	6.41
57	1.00	3.19	4.31	6.63	8.15	6.37
58	2.25	3.44	4.14	6.58	8.51	6.41
59	4.00	3.70	4.51	6.92	8.50	6.64
60	6.25	3.96	4.88	7.20	8.82	6.97
61	9.01	3.97	5.14	7.64	8.71	7.16
62	12.26	4.69	5.39	7.85	9.54	7.59
63	16.01	5.07	6.06	8.41	9.97	8.15
64	20.27	5.70	6.62	9.19	10.44	8.75
65	25.02	6.34	7.49	10.17	10.94	9.53
66	30.27	6.97	7.84	10.47	11.61	9.97
67	36.03	7.57	8.82	11.50	12.24	10.85
68	42.28	8.23	9.63	12.23	12.80	11.55
69	49.04	9.08	10.30	13.19	13.70	12.40
70	56.29	9.94	11.26	14.11	14.58	13.32
71	64.05	10.78	12.22	15.19	15.50	14.30
72	65.66	10.79	12.65	15.62	15.45	14.57
73	67.29	11.01	12.87	15.82	15.70	14.80
74	68.95	11.14	13.16	16.10	15.76	15.01
75	70.62	11.40	13.37	16.53	16.27	15.39
76	72.31	11.81	13.44	16.46	16.62	15.51
77	74.02	11.83	13.87	16.76	16.69	15.77
78	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00

DSA210 End Force vs I**2



	T	U	V	W	X	Y
53	0.					
54	DSA324 TC1	Bullet 1	Bullet 2	Bullet 4	Bullet 3	Average
55	4.84	1.93	1.83	1.96	1.50	1.81
56	9.73	2.31	2.12	2.09	1.72	2.06
57	14.66	2.74	2.43	2.23	1.94	2.33
58	19.37	3.21	2.77	2.38	2.22	2.65
59	23.76	3.64	3.07	2.55	2.48	2.94
60	28.99	4.17	3.43	2.69	2.76	3.26
61	33.62	4.68	3.76	2.83	3.04	3.58
62	38.45	5.19	4.13	2.98	3.32	3.91
63	43.51	5.77	4.51	3.14	3.65	4.27
64	49.03	6.44	4.97	3.36	4.01	4.70
65	53.35	7.00	5.34	3.43	4.26	5.00
66	49.03	6.50	5.00	3.31	4.03	4.71
67	38.32	5.35	4.19	2.96	3.37	3.97
68	28.91	4.33	3.47	2.67	2.80	3.32
69	19.17	3.28	2.78	2.43	2.30	2.70
70	9.69	2.38	2.16	2.13	1.78	2.11
71	0.00	1.61	1.63	1.87	1.34	1.61
72	0.00	0.00	0.00	0.00	0.00	0.00
73	0.00	0.00	0.00	0.00	0.00	0.00
74	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00
77	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00

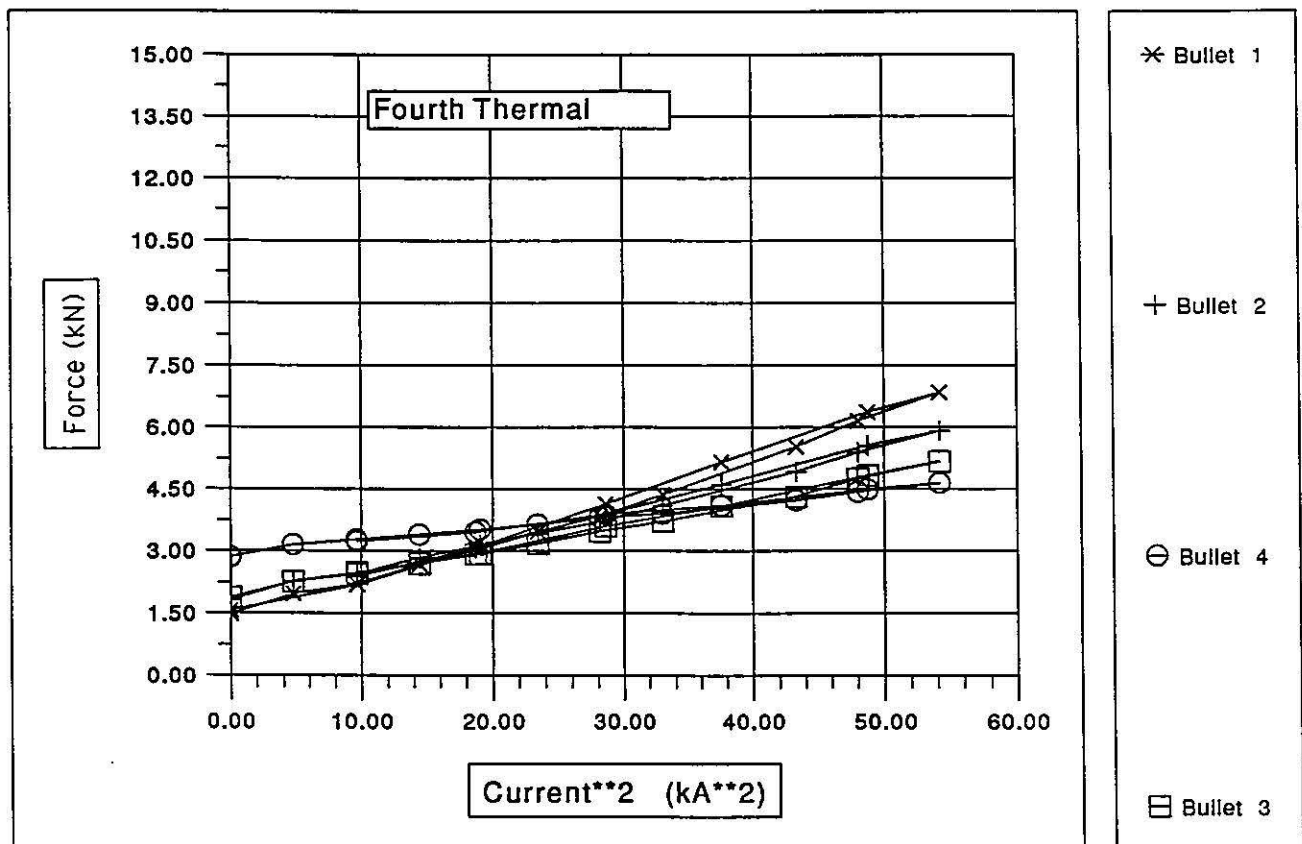
DSA324 End Force vs I**2

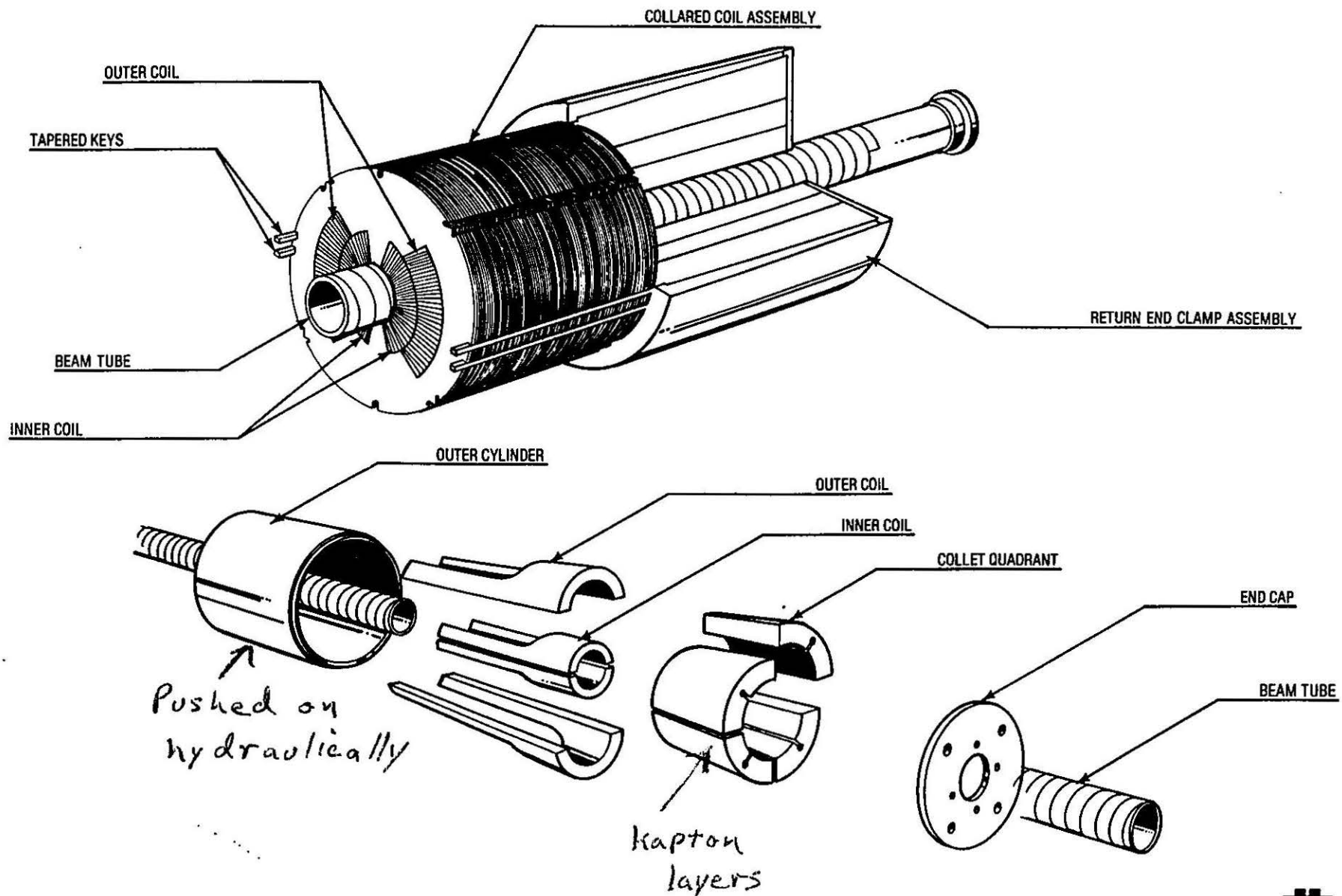


Note variation in individual Bullets

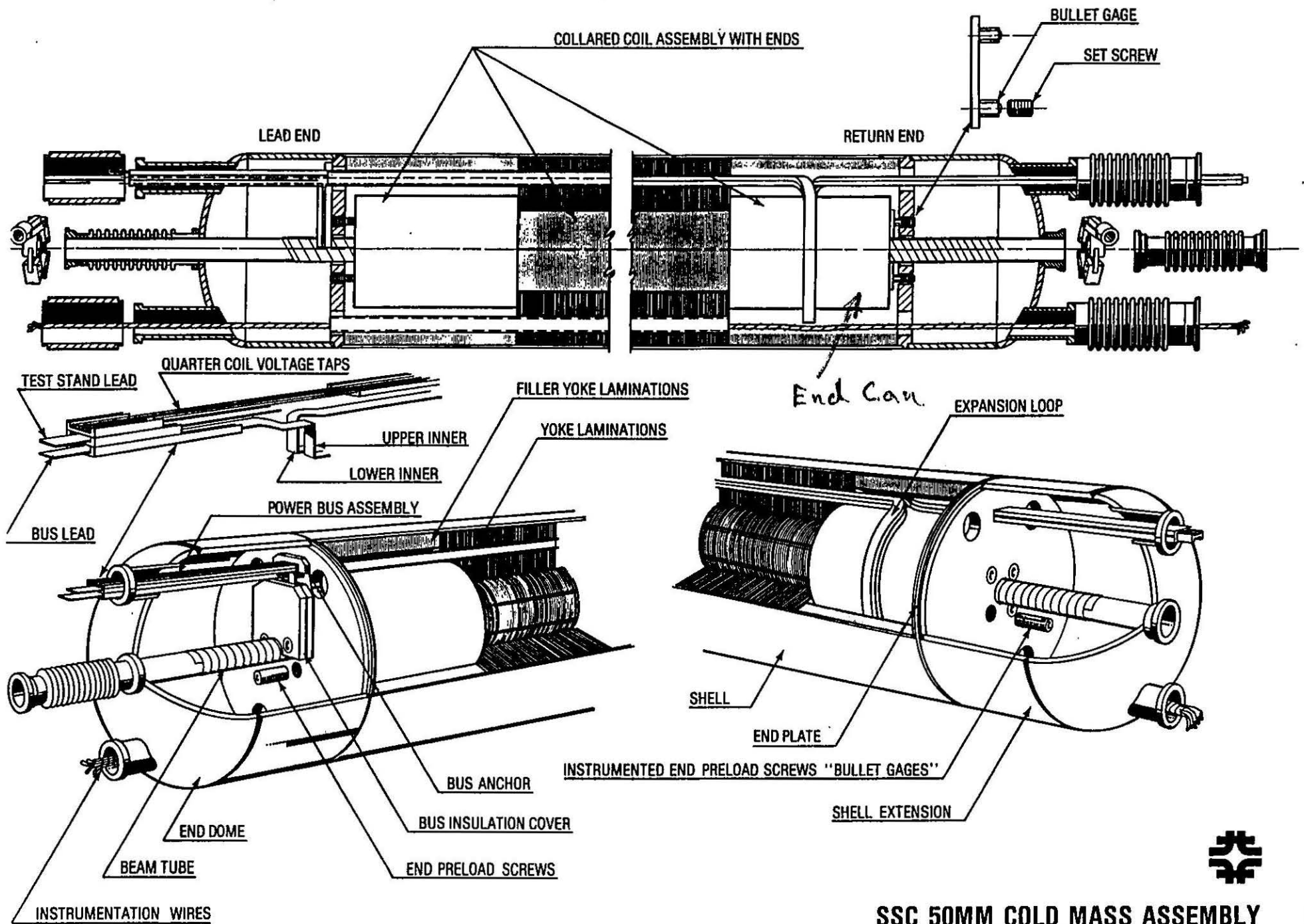
	AL	AM	AN	AO	AP	AQ
53	0.00					
54	DSA324 TC4	Bullet 1	Bullet 2	Bullet 4	Bullet 3	Average
55	0.00	1.48	1.82	2.84	1.88	2.00
56	4.78	1.97	2.28	3.15	2.26	2.42
57	9.62	2.19	2.44	3.26	2.48	2.59
58	14.46	2.69	2.83	3.39	2.70	2.90
59	19.05	3.06	3.14	3.52	2.93	3.16
60	23.44	3.45	3.43	3.64	3.18	3.42
61	28.16	3.85	3.69	3.81	3.47	3.70
62	33.04	4.37	4.10	3.91	3.71	4.02
63	43.34	5.52	4.92	4.23	4.32	4.75
64	48.03	6.14	5.39	4.42	4.75	5.18
65	54.19	6.84	5.90	4.64	5.17	5.64
66	48.77	6.36	5.55	4.48	4.83	5.30
67	37.58	5.15	4.61	4.11	4.08	4.49
68	28.59	4.14	3.88	3.88	3.59	3.87
69	18.72	3.07	3.06	3.46	2.93	3.13
70	9.68	2.19	2.38	3.22	2.46	2.56
71	0.00	1.57	1.90		1.97	1.81
72	0.00	0.00	0.00	0.00	0.00	0.00
73	0.00	0.00	0.00	0.00	0.00	0.00
74	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00
77	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00

DSA324 End Force vs I**2





SSC 50MM COLLARED COIL RETURN END ASSEMBLY
FERMI NATIONAL ACCELERATOR LABORATORY



SSC 50MM COLD MASS ASSEMBLY
 FERMI NATIONAL ACCELERATOR LABORATORY

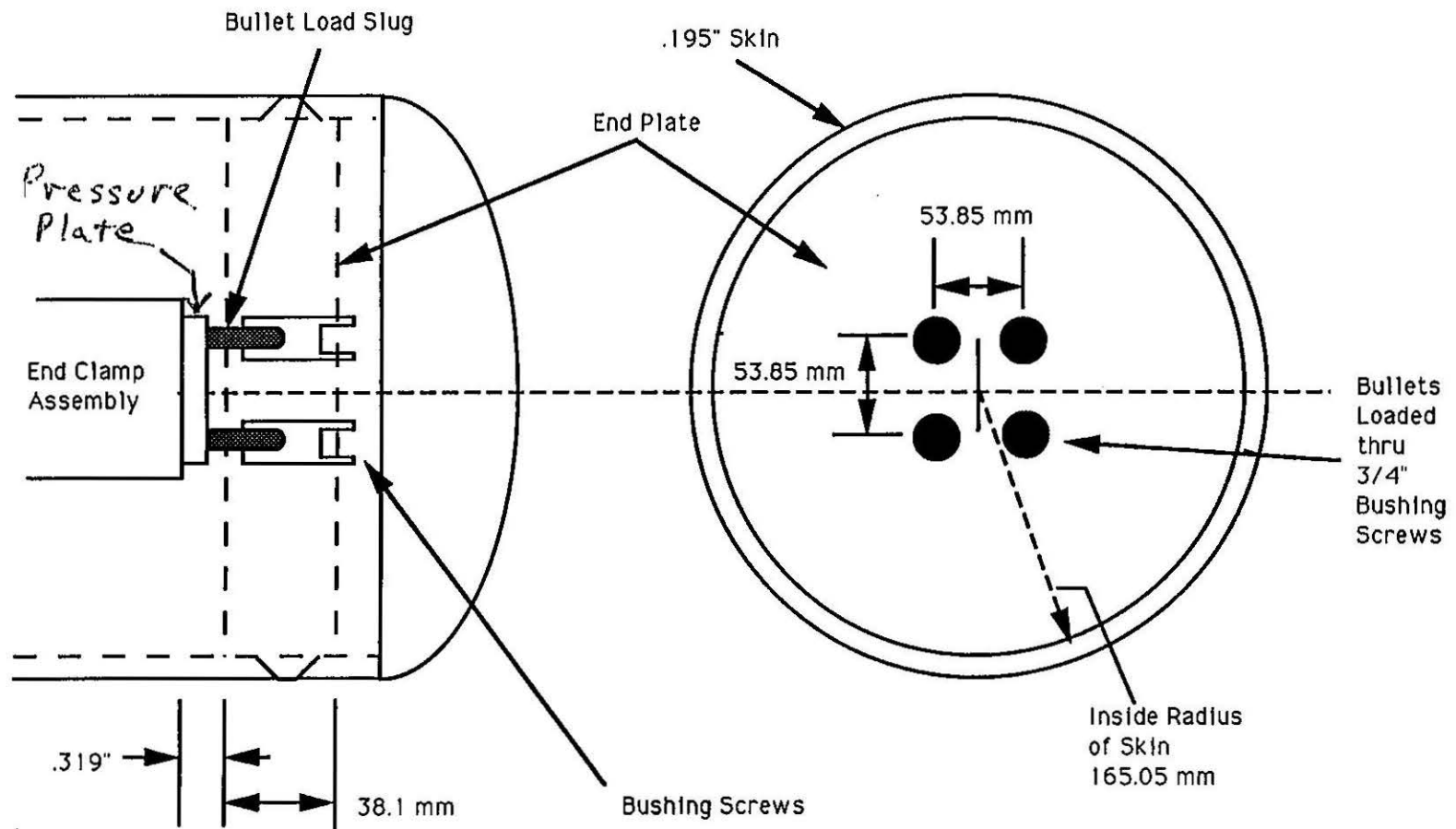
Bullet Gage Assembly Sketch

50 mm SSC Collider Dipole

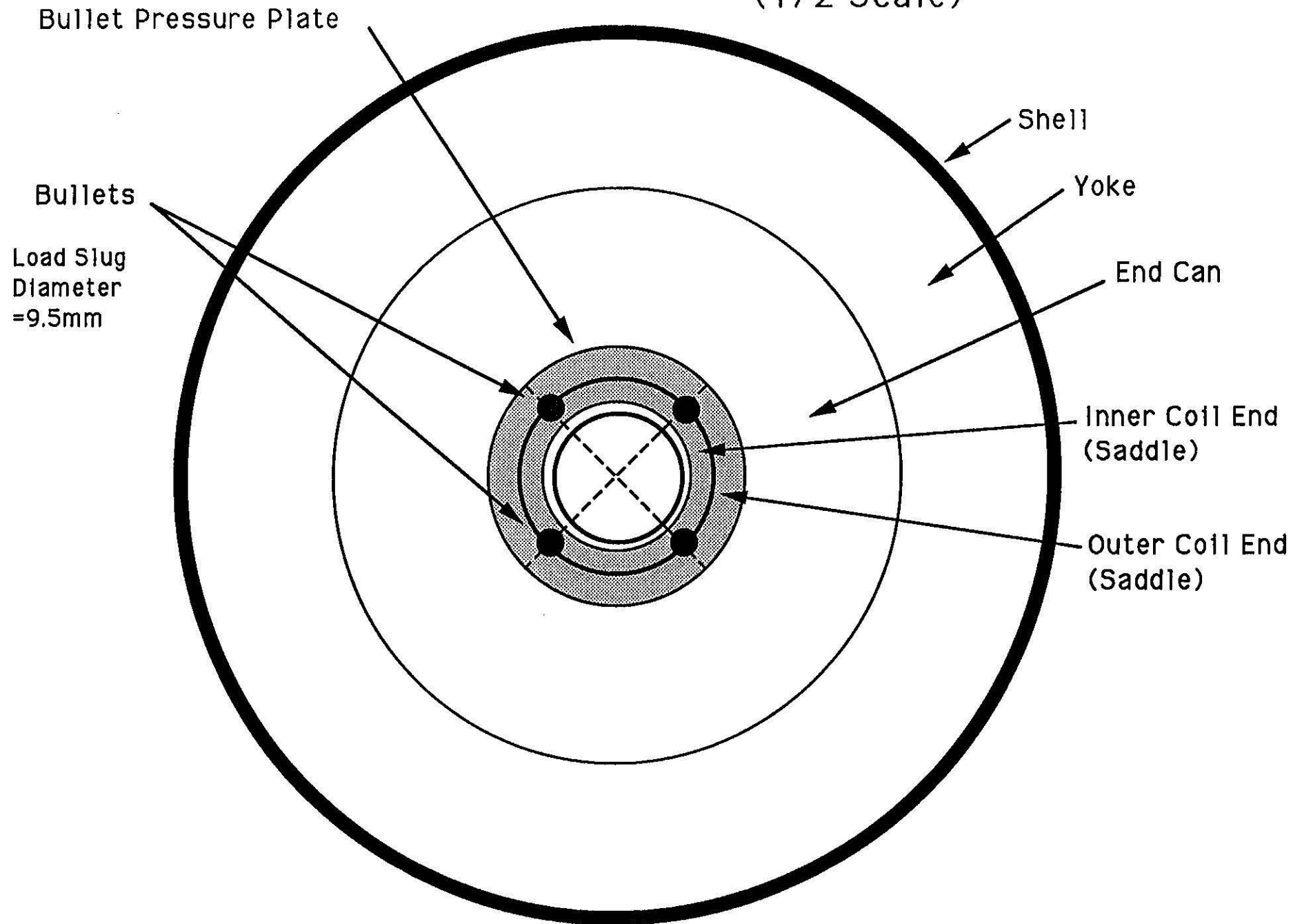
Not to Scale

Modified 1/16/91

Wayne Koska
11-19-90



Bullet Load Slug Location Relative to Coil Ends (1/2 Scale)



Tarig Jaffery
TS-SSC 91-175

DSA324 QUENCH HISTORY Model Magnet

Poor quench behavior
on removal of
end pre-load also
observed on BNL
magnets

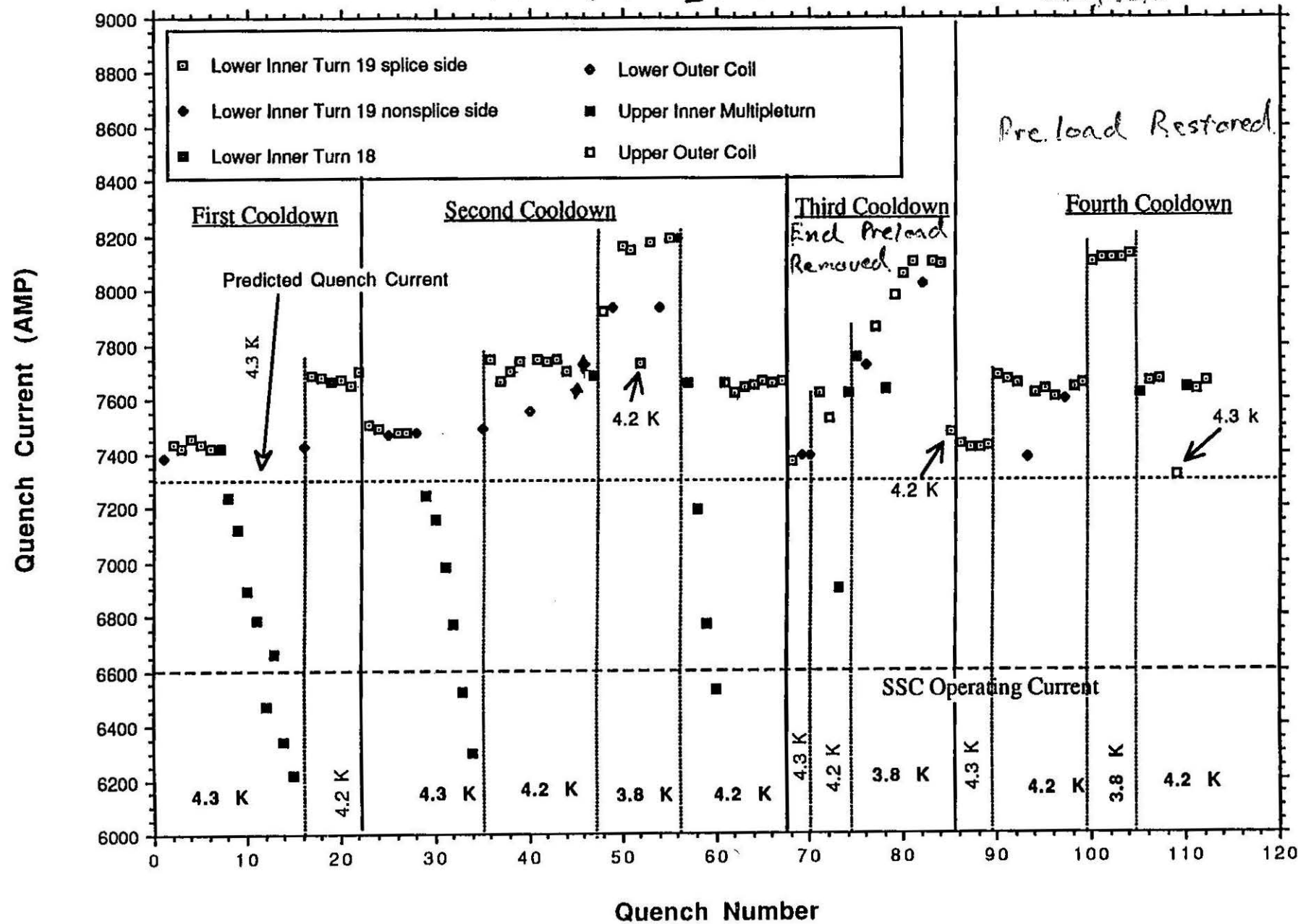
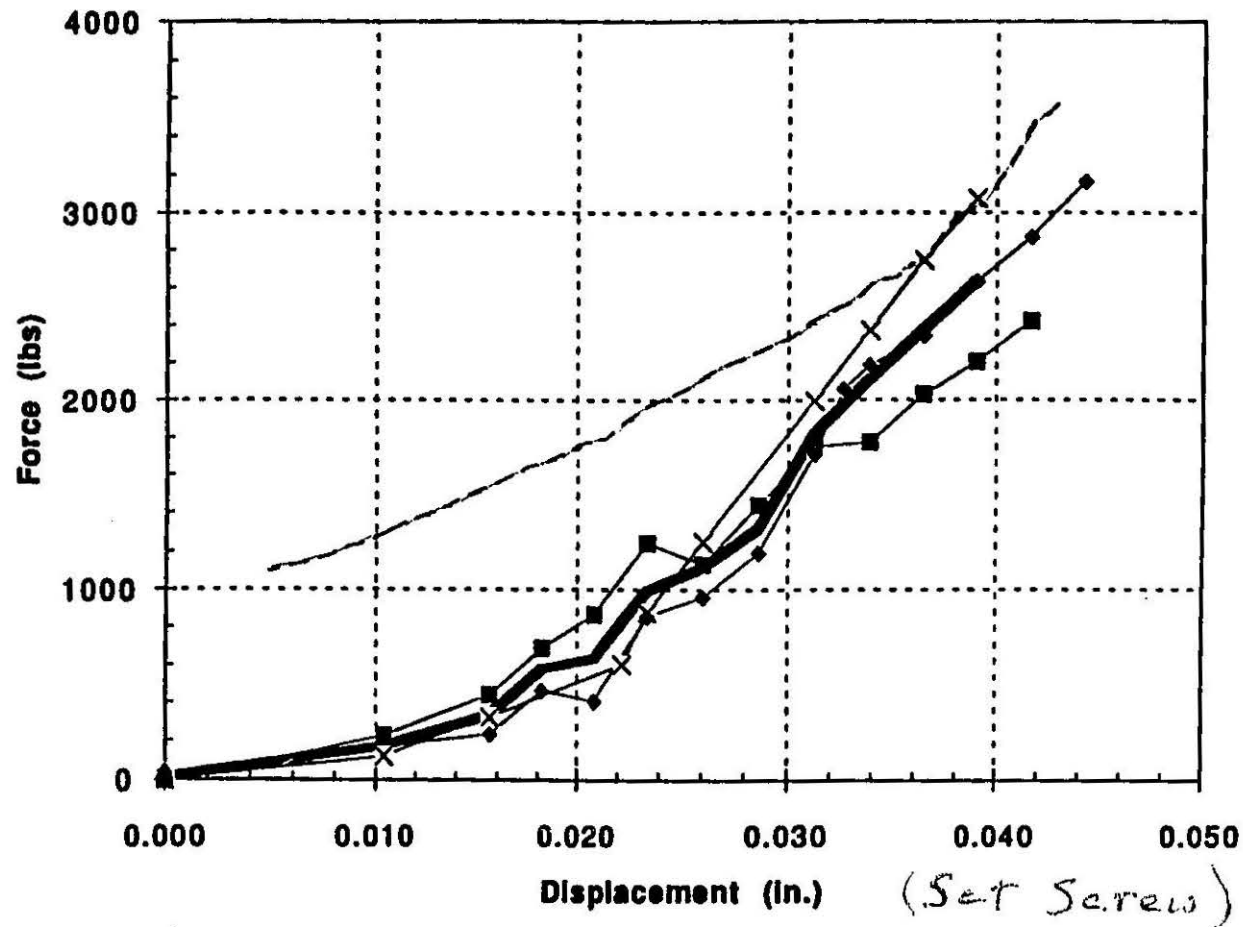


Figure 1

Long Magnet End Force vs. Displacement



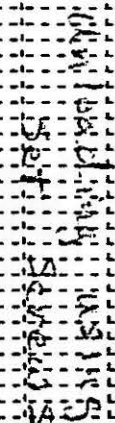
After Extension
Tube welded
on.

Figure 5

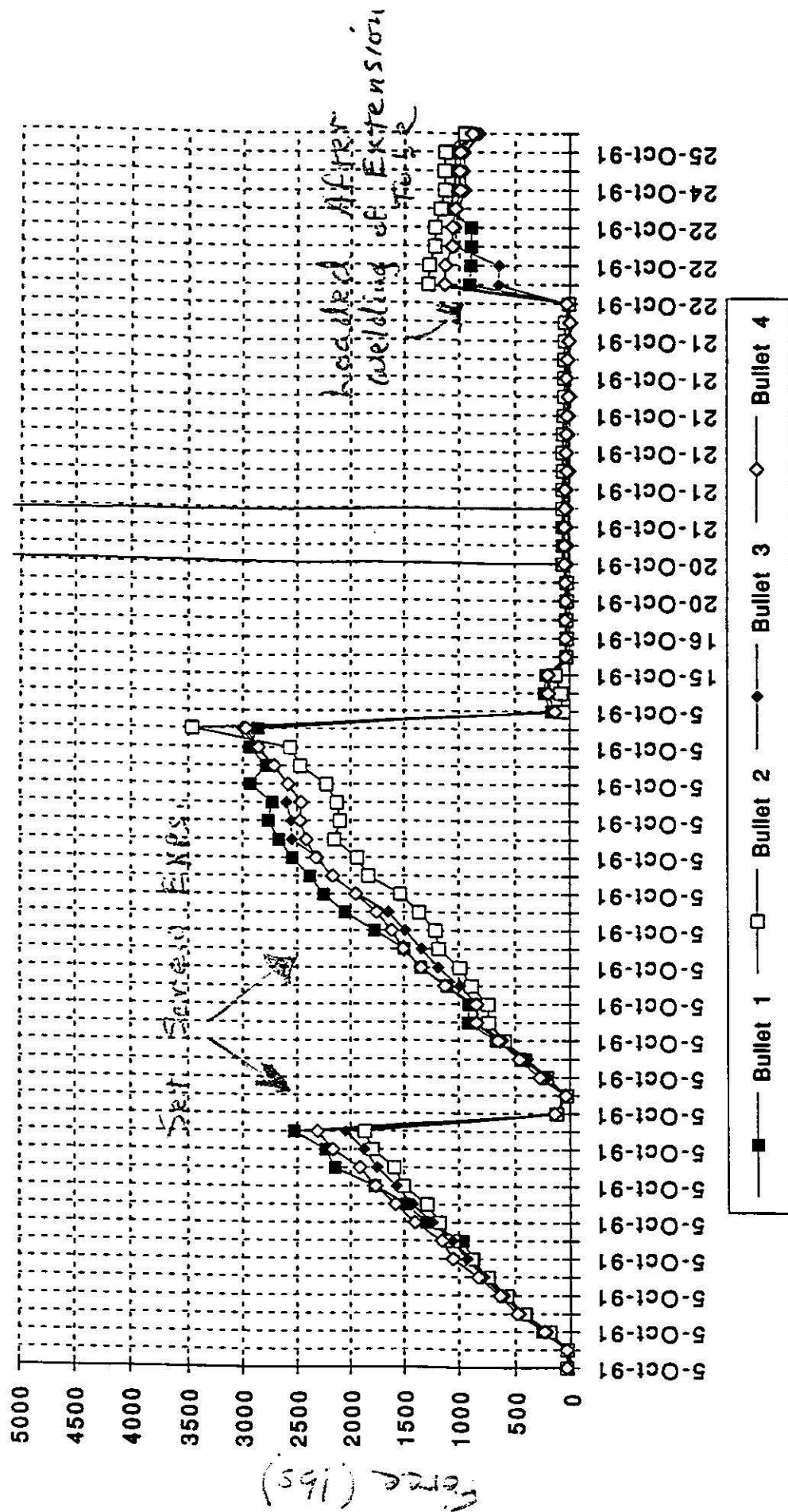
TS-SSC 91-198

I. Strait

End Force (lbs)

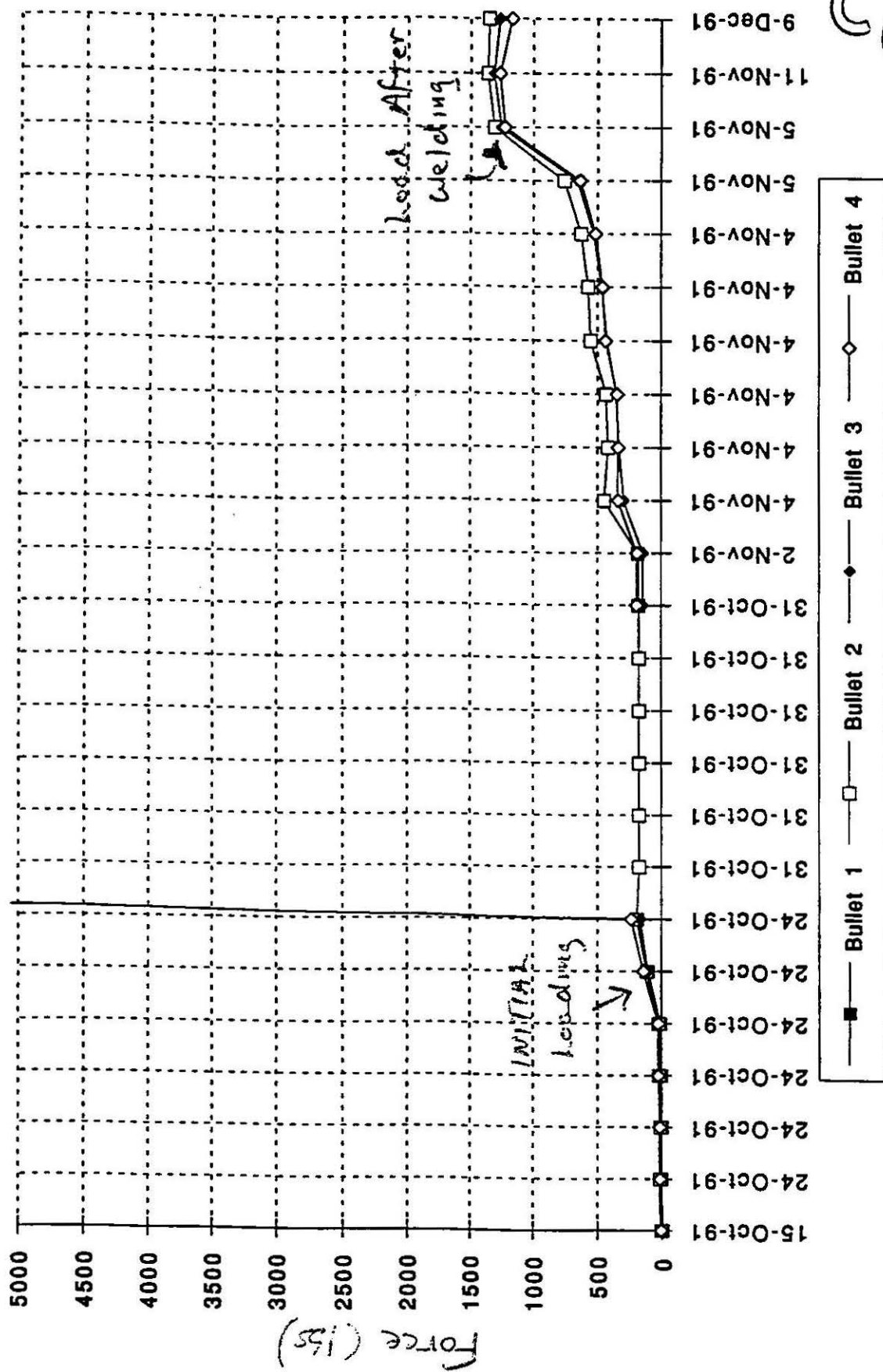


DCA 312 End Force Plot



T. Skweres 11/18/91

DCA 313 End Force Plot



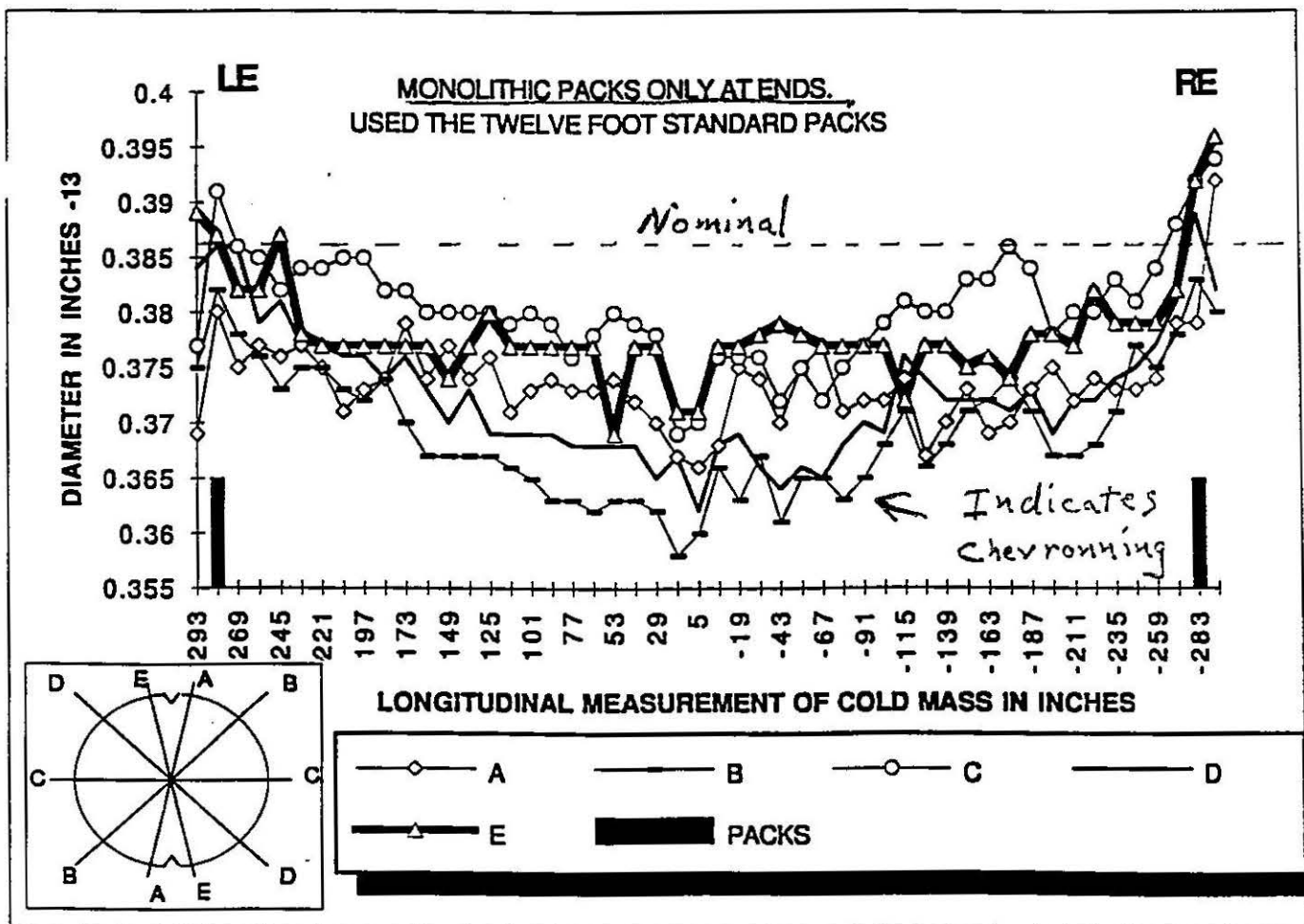
Packing Factor
98%

DIAMETRAL DATA DCA 311

RC ARNOLD

11/11/91

	A	B	C	D	E
IDEAL SIZE	OFFSET	OFFSET	OFFSET	OFFSET	OFFSET
13.386 INCHES	0.0124	0.0168	0.0055	0.0133	0.0076
POSITION FROM	AVERAGE	AVERAGE	AVERAGE	AVERAGE	AVERAGE
THE COLD MASS	13.3736	13.3692	13.3805	13.3727	13.3784
CENTERLINE	STD DEVIATION	STD DEVIATION	STD DEVIATION	STD DEVIATION	STD DEVIATION
IN INCHES	0.00414	0.00593	0.00507	0.00606	0.00485
-199	13.375	13.367	13.378	13.369	13.378
-211	13.372	13.367	13.38	13.372	13.377
-223	13.374	13.368	13.38	13.372	13.382
-235	13.373	13.371	13.383	13.374	13.379
-247	13.373	13.377	13.381	13.375	13.379
-259	13.374	13.375	13.384	13.377	13.379
-271	13.379	13.378	13.388	13.381	13.382
-283	13.379	13.383	13.392	13.389	13.392
-295	13.392	13.38	13.394	13.382	13.396

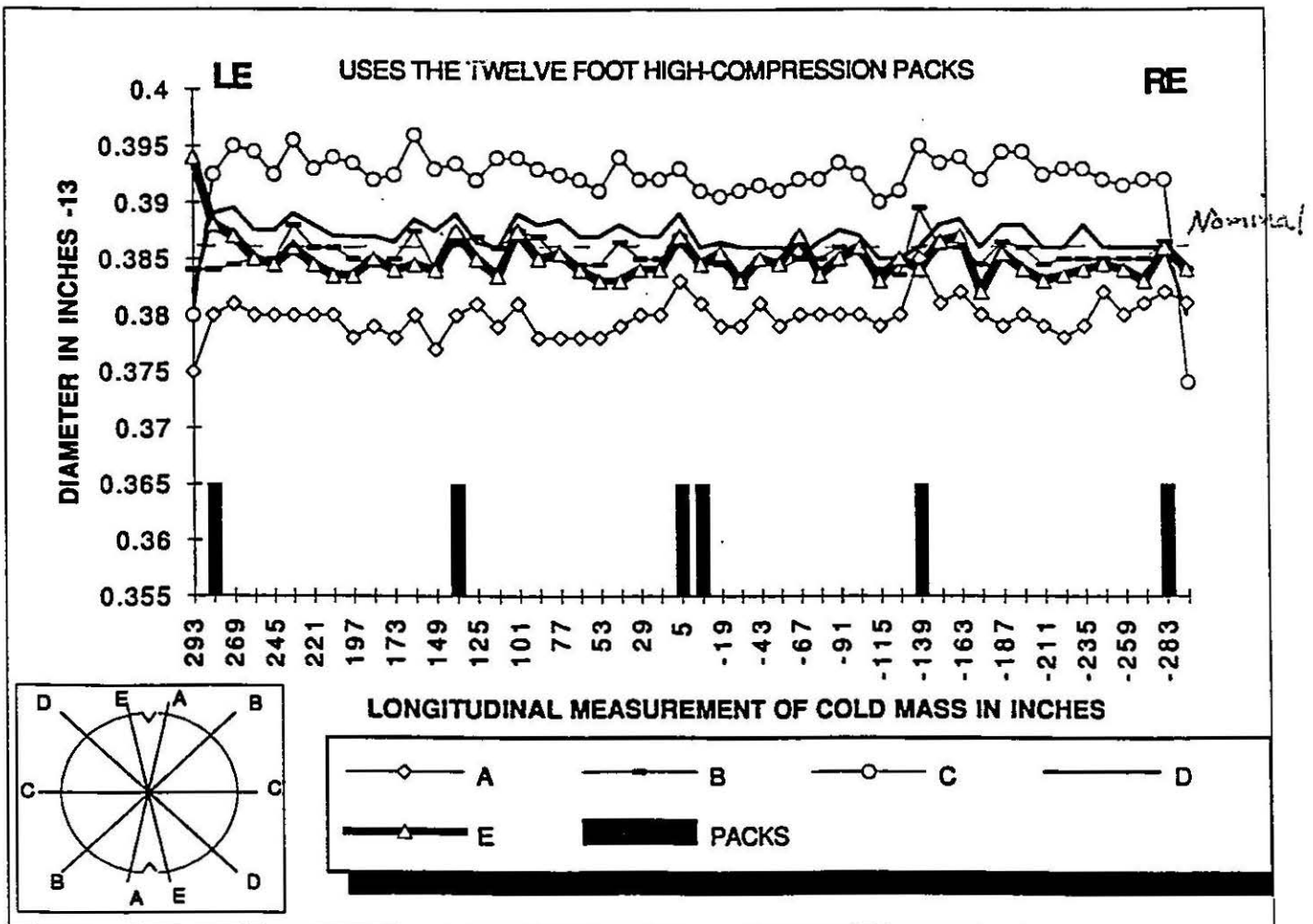


Packing Factor
99%

DIAMETRAL DATA DCA 312

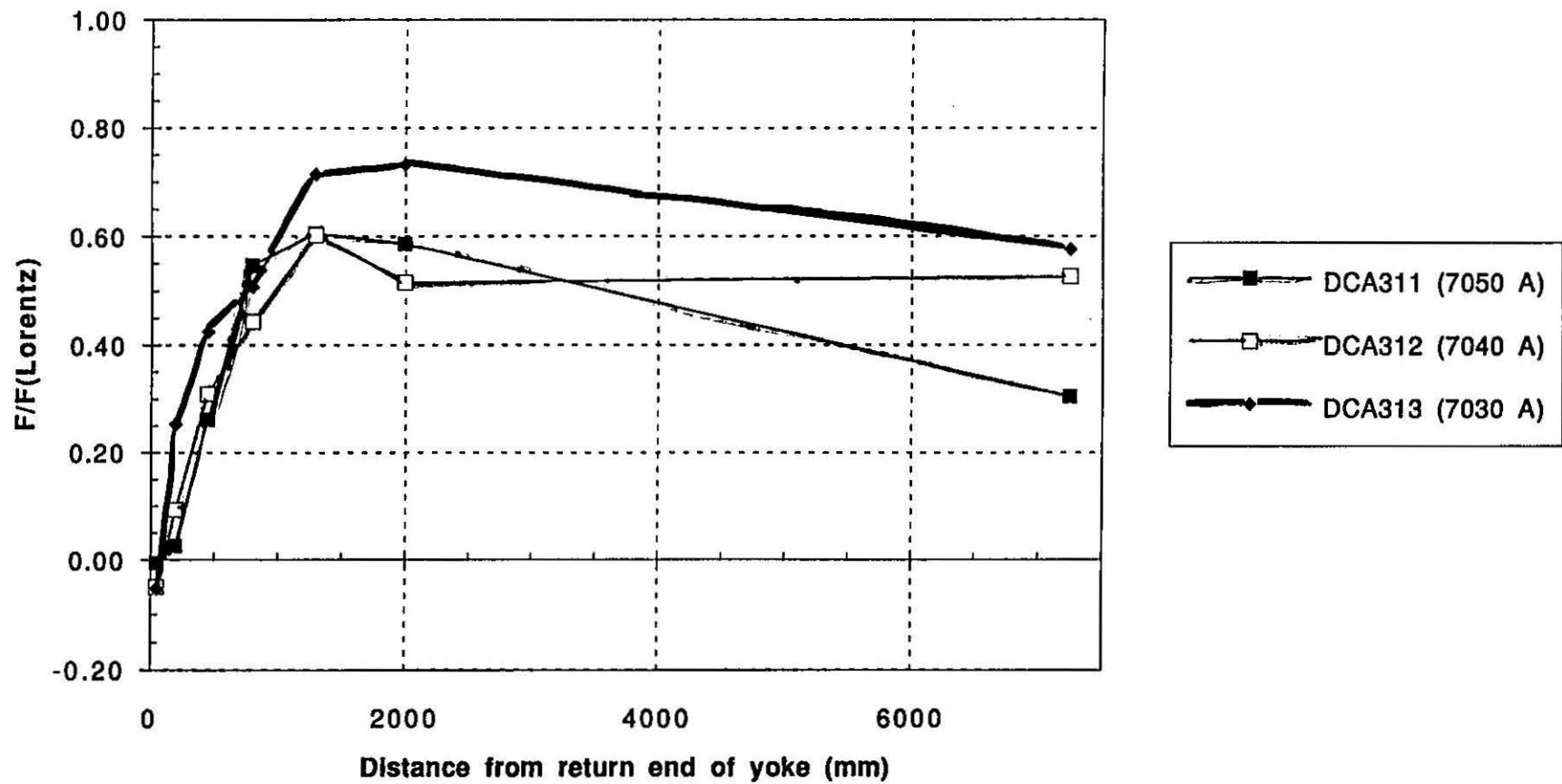
RC ARNOLD 11/11/91

	A	B	C	D	E
IDEAL SIZE	OFFSET	OFFSET	OFFSET	OFFSET	OFFSET
13.386 INCHES	0.0062	0.0006	-0.0061	-0.0009	0.0011
POSITION FROM	AVERAGE	AVERAGE	AVERAGE	AVERAGE	AVERAGE
THE COLD MASS	13.3798	13.3854	13.3921	13.3869	13.3849
CENTERLINE	STD DEVIATION	STD DEVIATION	STD DEVIATION	STD DEVIATION	STD DEVIATION
IN INCHES	0.00159	0.00126	0.00344	0.00169	0.00192
-199	13.38	13.386	13.3945	13.388	13.384
-211	13.379	13.3845	13.3925	13.386	13.383
-223	13.378	13.385	13.393	13.386	13.3835
-235	13.379	13.385	13.393	13.388	13.384
-247	13.382	13.385	13.392	13.386	13.3845
-259	13.38	13.385	13.3915	13.386	13.384
-271	13.381	13.385	13.392	13.386	13.383
-283	13.382	13.3865	13.392	13.386	13.386
-295	13.381	13.384	13.374	13.38	13.384



J. Strait

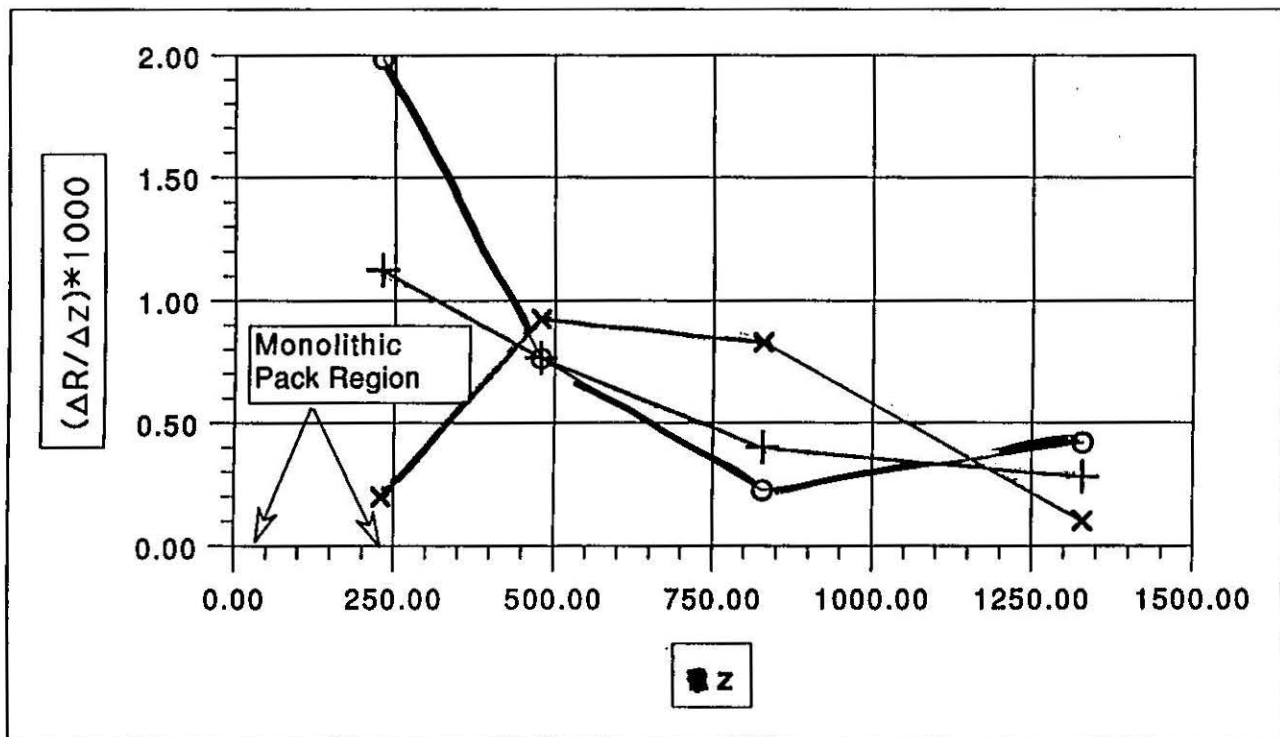
Long 50 mm Dipole Shell Axial Force Change with Excitation



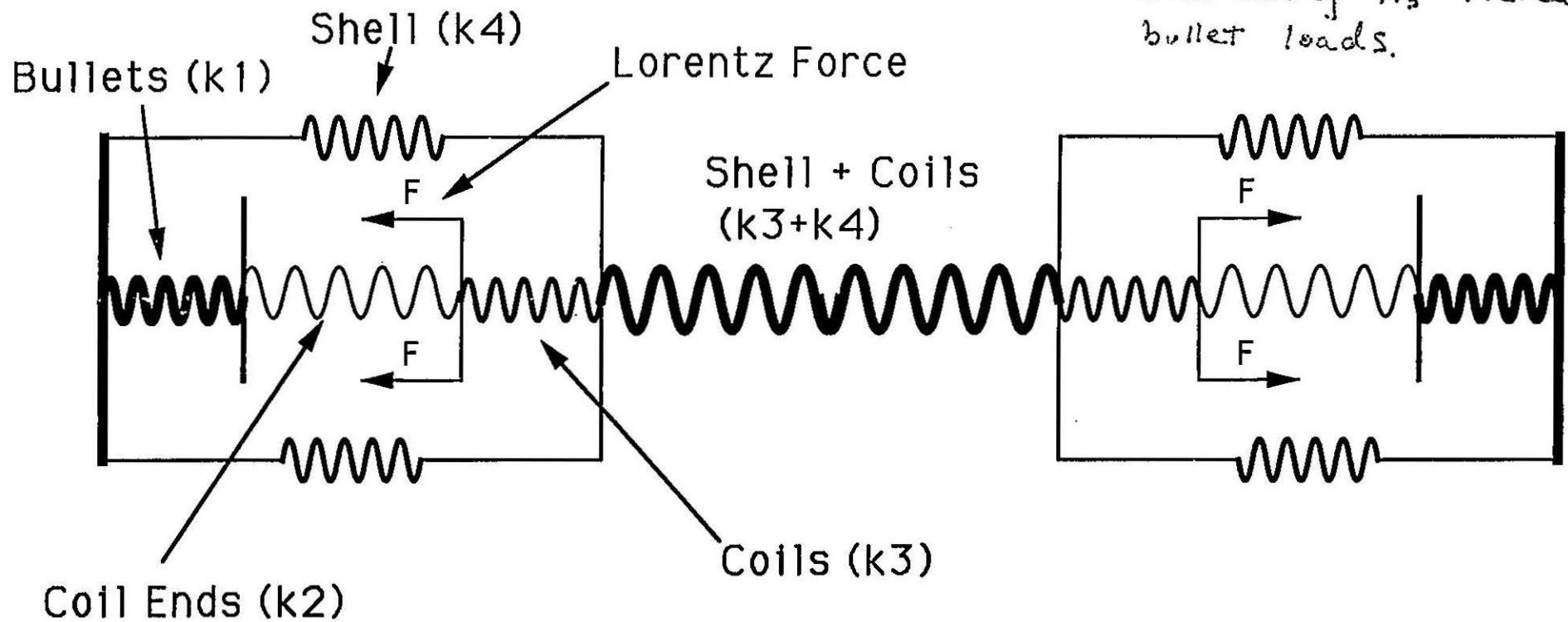
	O	P	Q	R	S	T	U
1	Position from Beginning	DCA311	DCA312	DCA313			
2	of Yoke (mm)	$(\Delta R/\Delta z) * 100$	$(\Delta R/\Delta z) * 1000$	$(\Delta R/\Delta z) * 1000$			
3	78.99						
4	230.12	0.20	1.12	1.99			
5	479.04	0.92	0.76	0.76			
6	829.06	0.83	0.40	0.23			
7	1328.93	0.10	0.28	0.42			
8	2028.44	-0.01	-0.14	0.01			
9							
10							

Shell Axial Force Gradient

Preliminary



Factor of 4 change
in k_2 produces observed
change in bullet loads.
Decreasing k_3 increases
bullet loads.



Very Simple Spring Model of Coil End Axial Mechanics

Conclusions:

1) Variations in average forces measured by bullet gauges in Fermilab long magnets may be due to differences in bullet loading and/or the chevronning of yoke packs in DCA311.

2) Variations in measured average forces between Fermilab long magnets and Brookhaven long magnets may be due to differences in end pre-loading and/or shell clamping of vertical versus horizontal yokes

3) Variations in bullet measurements of Fermilab short magnets may be due to uneven axial support.