Fermilab

TS-SSC 91-182
9/20/91
J. Strait

Estimate of Shell Tension from Coil Stress Data

In a previous note I presented an analysis of the shell gauge data from DSA312 to determine the azimuthal tension in the shell. While this method is direct, bending effects in the shell (due to its not having a perfectly circular shape before welding) introduce a large scatter into the data and result in significant uncertainty in the result. A less direct method is to compare the change in coil stress with shell welding with that resulting from the yoking press load. This method has much less random uncertainty and can be applied to magnets without shell gauges; however, there are uncertainties, particularly with short magnets, in understanding the load per unit length applied to the magnet by the press. Also, it does not allow the tracking of shell stress changes with time, thermal cycling and excitation, which can only be done with shell gauges.

Figure 1 shows the DSA324 coil stress history during the collar keying and shell welding processes. The yoking press is closed to a load somewhat above the expected clamping force of the welded shell, and then the load is reduced to about the expected shell clamping force and the shell is welded. The inner coil stress changes with press load, while the outer coil changes very little. (A qualitative explanation of this behavior is given in an appendix to this note.) With the press held at constant load the shell halves are welded in several passes. The weld shrinkage induces an azimuthal stress in the shell which adds to the clamping force of the press. Finally the press is opened. The inner coil stress is increased by the clamping force of the shell and this clamping force and hence the shell tension can be deduced by finding the press load that yields the same coil stress increase.

Figure 2 is a plot of the DSA324 coil stresses versus press load before shell welding. The final coil stresses after welding and removal from the press are indicated by the dashed horizontal lines. The press load is gotten by assuming that the press beam averages perfectly over the alternating 100 T and 150 T cylinder pairs and that there are no end effects, yielding a slope of 4.17 lbs/in per hydraulic system psi. The hydraulic pressure required to overcome the press springs and bring the tooling into contact with the magnet (300 psi) is subtracted. The final inner coil stress corresponds to a press load of about 11500 lbs/in. Dividing this by twice the shell thickness yields a shell tension of 29 kpsi. That the final stress in the outer coil lies above any stress observed in the press results from the fact that the shell applies the load to the yoke in a different way than does the press.

Figures 3-7 show the same data for short magnets DSA326 and DSA323 (second assembly) and long magnets DCA310-312. Data from both collar packs in each long magnet are shown, but for simplicity only the inner coil data are displayed. In the long press a load of 2 lbs/in per hydraulic system psi is used. In the current mode of operation the upper press beam and tooling are

lowered onto the magnet before the hydaulic system is energized. The weight of the upper platen and tooling, 178 lbs/in[2], is added to the hydraulic system load.

Table I summarized the deduced shell stresses for these 6 magnets. All short magnets have higher stresses than all long magnets. This difference (with the exception of DCA311) may not be significant relative to the uncertainties in comparing data from the long and short presses. The deduced shell tension for DCA312 is considerably lower than that estimated by the shell gauges[1]. The reason for this apperent discrepancy is not understood; however, either value is acceptable. The coil stress increase with shell welding, also given in Table I, appears systematically larger in the long than in the short magnets. This may result from systematic differences in the calibrations of the strain gauges used in the long and short magnets, or from differences in the amount of yoke-collar interference, since the long magnet use Rev. C collars and the short use Rev. A. There is, however, no known difference in the gauges or the calibration method between those used in long and short magnets, and the collared coil diameter data[3,4] do not show the long collared coils to be larger than the short. Therefore this difference is not currently understood. However, the method of estimation of shell stress does not depend on the accuracy of the gauge calibrationor the details of the collar-yoke fit.

DCA311 has an apparent shell tension well below the other magnets. The change in DCA311 inner coil stress is also much lower than in the other magnets. Diameter measurements of the DCA311 cold mass indicate that significant "chevroning" of the yoke laminations has occurred, an effect absent from the other magnets. This would relieve much of the shell stress if it occurred during or after welding. Beginning with DCA312 the yoke packing fraction has been increased[5] from 98% to 99% and 5" epoxy bonded packs have been placed between the standard 135" packs. It is hoped that this will eliminate "chevroning" in all future magnets.

REFERENCES

[1] J. Strait, DCA312 Shell Gauge Data During Welding Operation, TS-SSC 91-179, 9/13/91.
[2] W. Robotham, private communication.
[3] J. Strait, Collar Deflection Measurements of Short 50 mm Magnets, TS-SSC 91-116, 6/10/91.
[4] J. Strait, Collar Diameter Measurements of Long Magnets DCA310-315, TS-SSC 91-178, 9/13/91.
[5] M. Gordon, 50 mm Dipole Revised Yoke Assembly, TS-SSC 91-169, 9/3/91.

Distribution: R. Bossert, J. Carson, S. Delchamps, A. Devred, C. Goodzeit, M. Gordon, N. Hassan, W. Koska, M. Lamm, M. Packer, R. Riecken, H. Trenham, M. Wake

Table I
Shell Azimuthal Stress Estimate
(For long magnets the average of the two gauge packs is given.)

Magnet	Equivalent Press Load (1000 lbs/in)	Shell Stress (kpsi)	Inner Coil Stress Change (kpsi)
DSA324	11.5	29	2.0
DSA326	10.8	28	2.1
DSA323	15	38	2.3
DCA310	10.3	26	2.7
DCA311	3.0	8	0.9
DCA312	10.1	26	3.1

Appendix

Qualitative Explanation of Coil Stress Changes with Shell Welding

When the vertically split yoke is assembled about the collared coil and the shell is welded, the collared coil is compressed from the sides and undergoes a vertically elliptical deflection. (The collars are free to expand in the vertical direction.) Such a deflection of a thick cylinder induces a compressive stress at its inner radius near 90 degrees, near the position of the inner coil pole where the stress is measured. At larger radii the stress at 90 degrees becomes less compressive, becoming extensive towards the outer radius. At some intermediate radius there is no stress change. Also, the stress goes from compressive to extensive along the inner radius from 90 degrees to 0 degrees and from extensive to compresive along the outer radius. At some intermediate angle there is an axis along which there is no stress change. The outer coil is at an intermediate radius and its pole turn is at an intermediate angle, therefore the stress change there should be much smaller than at the inner coil pole. This is the observed pattern in the data discussed above.

With a horizontally split yoke, the behaviors in the vertical and horizontal directions are opposite from the vertically split yoke case. However, collars for a horizontally split yoke are not free to expand horizontally, but contact the yoke after a small amount of deflection. Therefore there is both an elliptical distortion and an overall compression of the coils, which should increase both the inner and outer coil stresses. Thus the inner coil stress tends to decrease due to the horizontally elliptical deflection and increase due to the overall compression, while the outer coil is largely uneffected by the elliptical deflection, but increases due to the compression. This is reflected in the data[A1] for horizontally split yoke magnets in which the outer coil stress increases more than the inner with shell welding.

REFERENCE

[A1] W. Koska, et al., Tests of Fermilab Built 40mm Aperture Full Length SSC Dipole Magnets, submitted to the 12th International Conference on Magnet Technology, Leningrad, USSR, June 24-28, 1991.

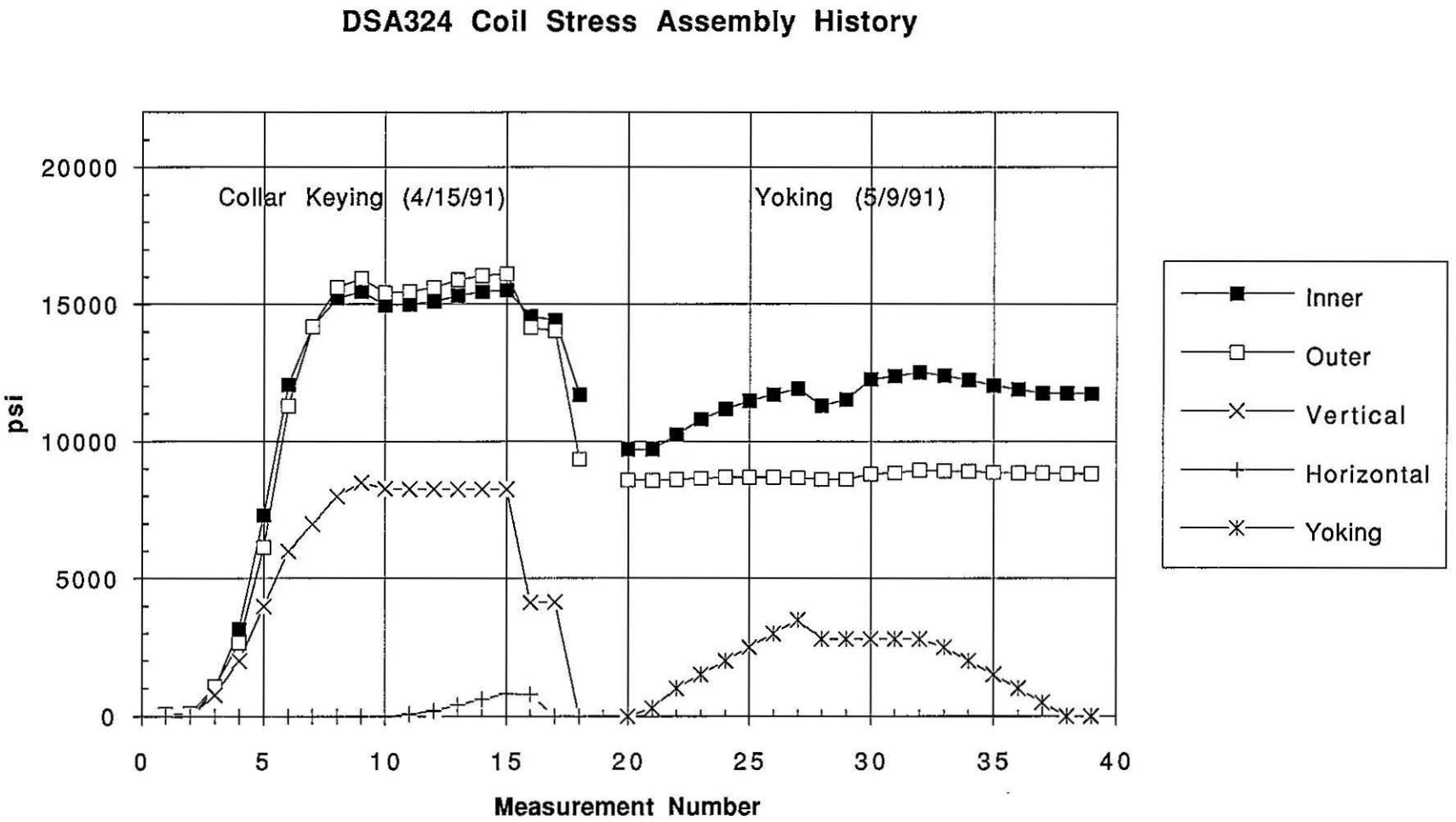

DSA324 Coil Stress Assembly History
Collar Keying (4/15/91)
Yoking (5/9/91)
psi
20000
15000
10000
5000
0
0
5
10
15
20
25
30
35
40
Measurement Number
Inner
Outer
Vertical
Horizontal
Yoking

Figure 1

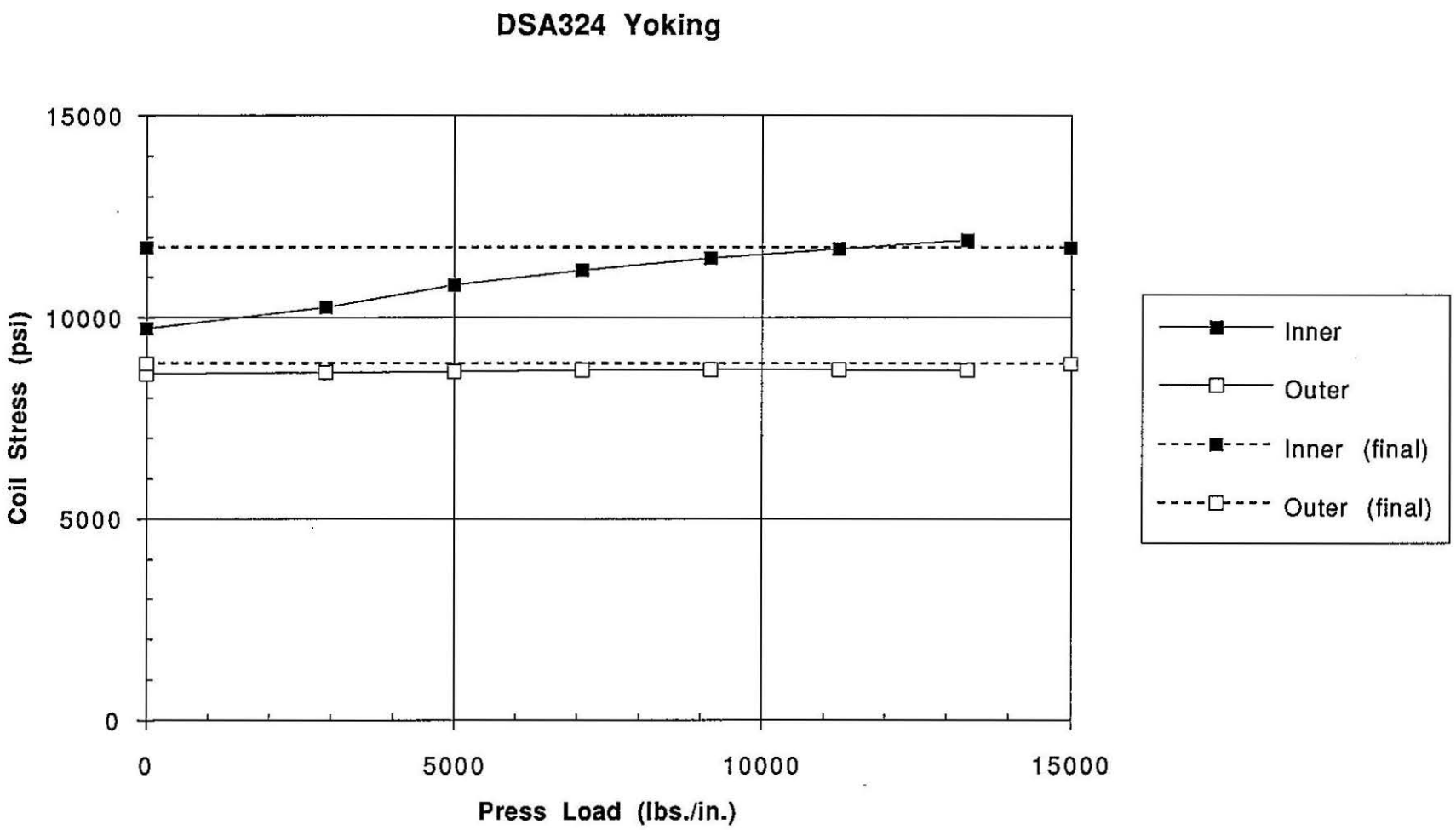

DSA324 Yoking
15000
10000
5000
0
Coil Stress (psi)
0
5000
10000
15000
Press Load (lbs./in.)
Inner
Outer
Inner (final)
Outer (final)

Figure 2

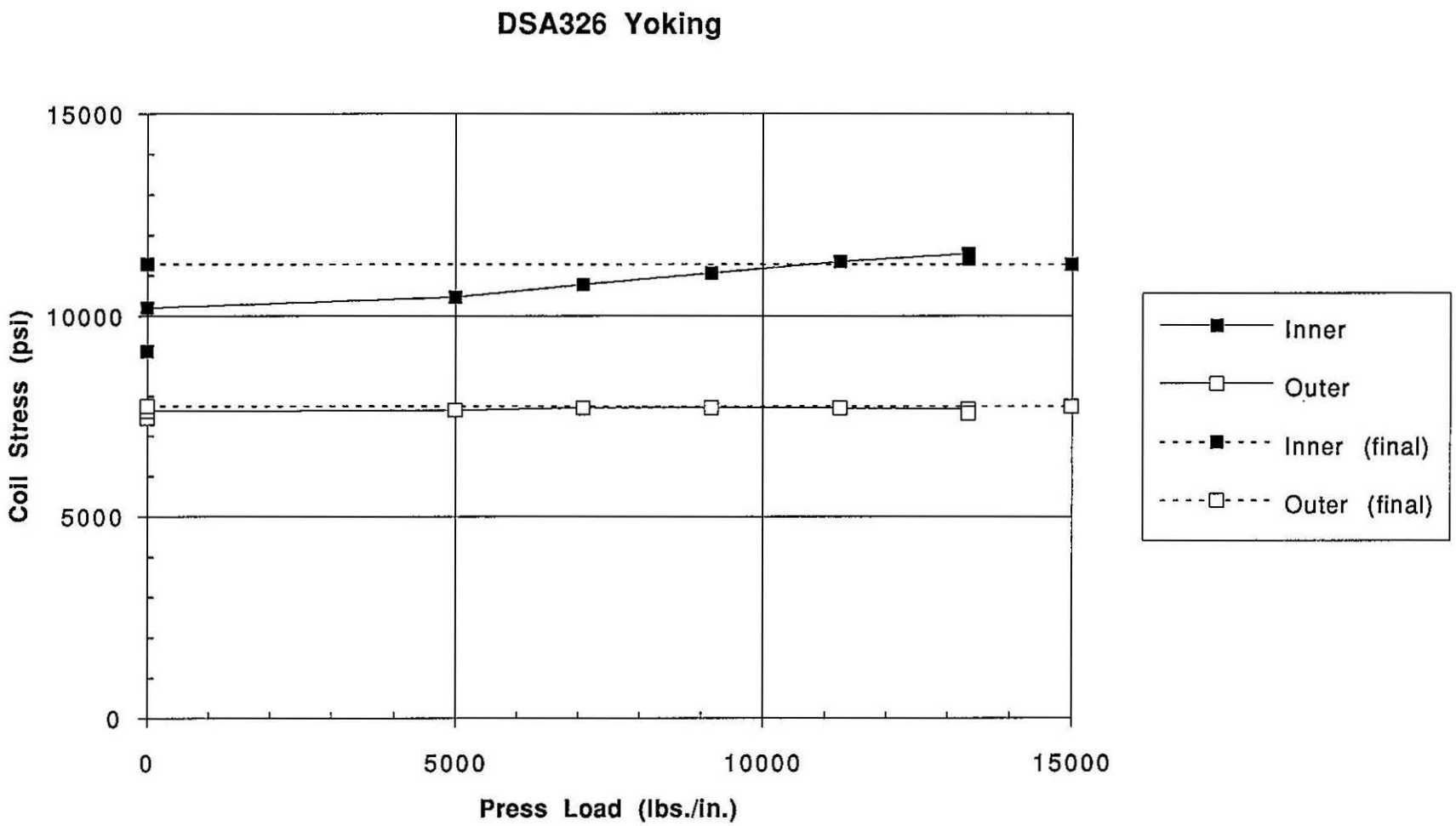

DSA326 Yoking
15000
10000
5000
0
Coil Stress (psi)
0
5000
10000
15000
Press Load (lbs./in.)
Inner
Outer
Inner (final)
Outer (final)

Figure 3

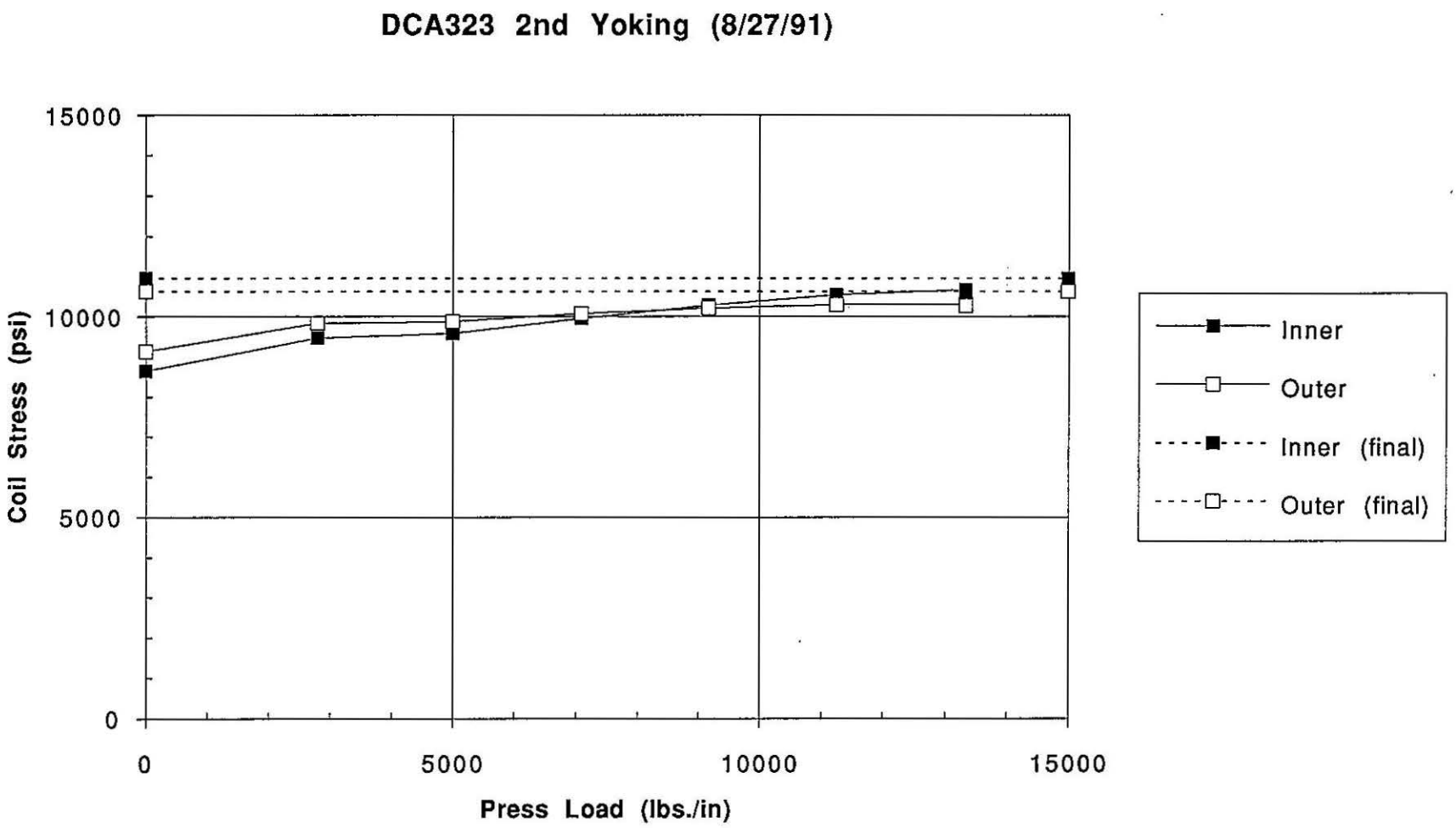

DCA323 2nd Yoking (8/27/91)
15000
10000
5000
0
Coil Stress (psi)
0
5000
10000
15000
Press Load (lbs./in)
Inner
Outer
Inner (final)
Outer (final)

Figure 4

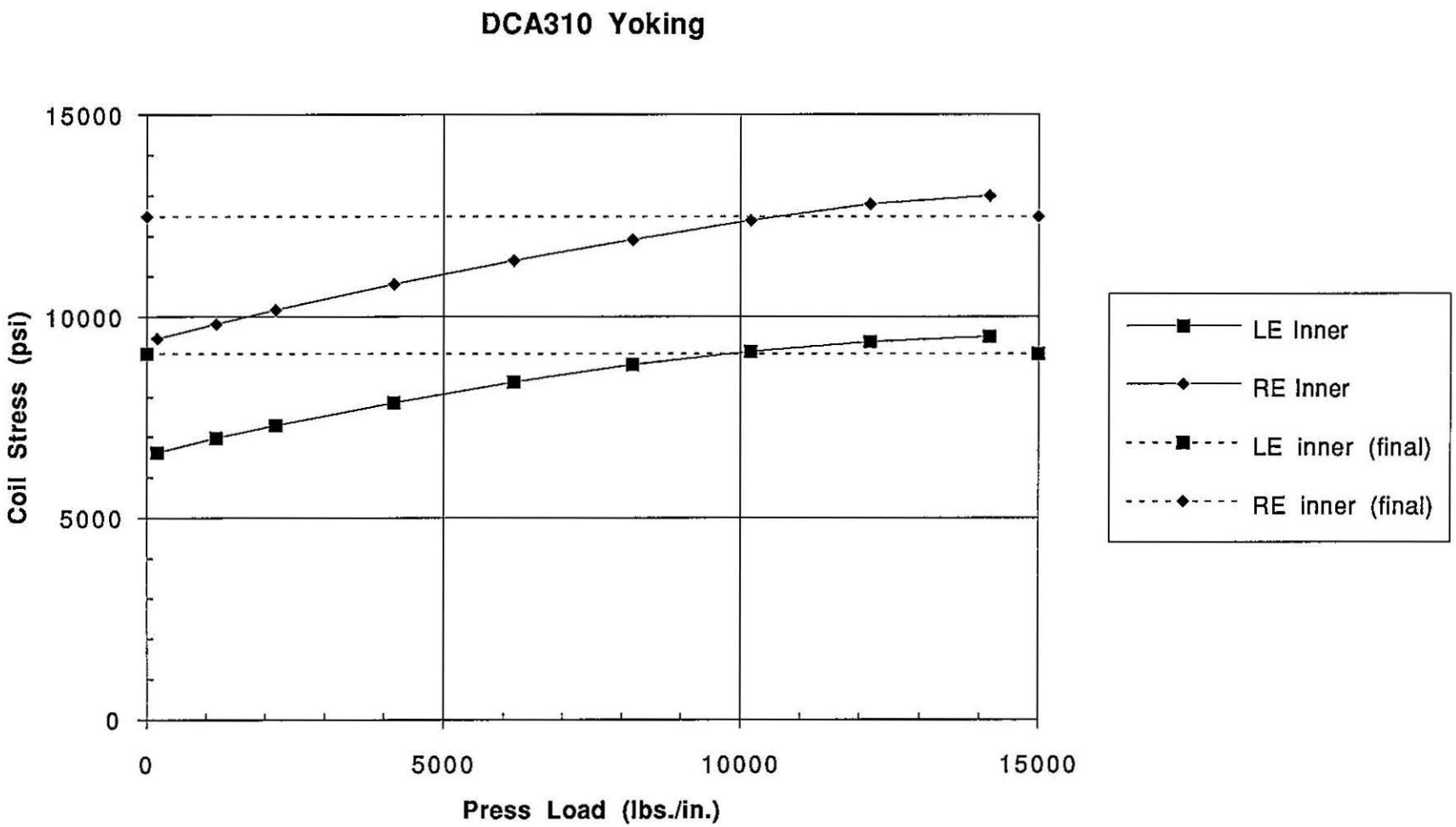

DCA310 Yoking
15000
10000
5000
0
Coil Stress (psi)
0
5000
10000
15000
Press Load (lbs./in.)
LE Inner
RE Inner
LE inner (final)
RE inner (final)

Figure 5

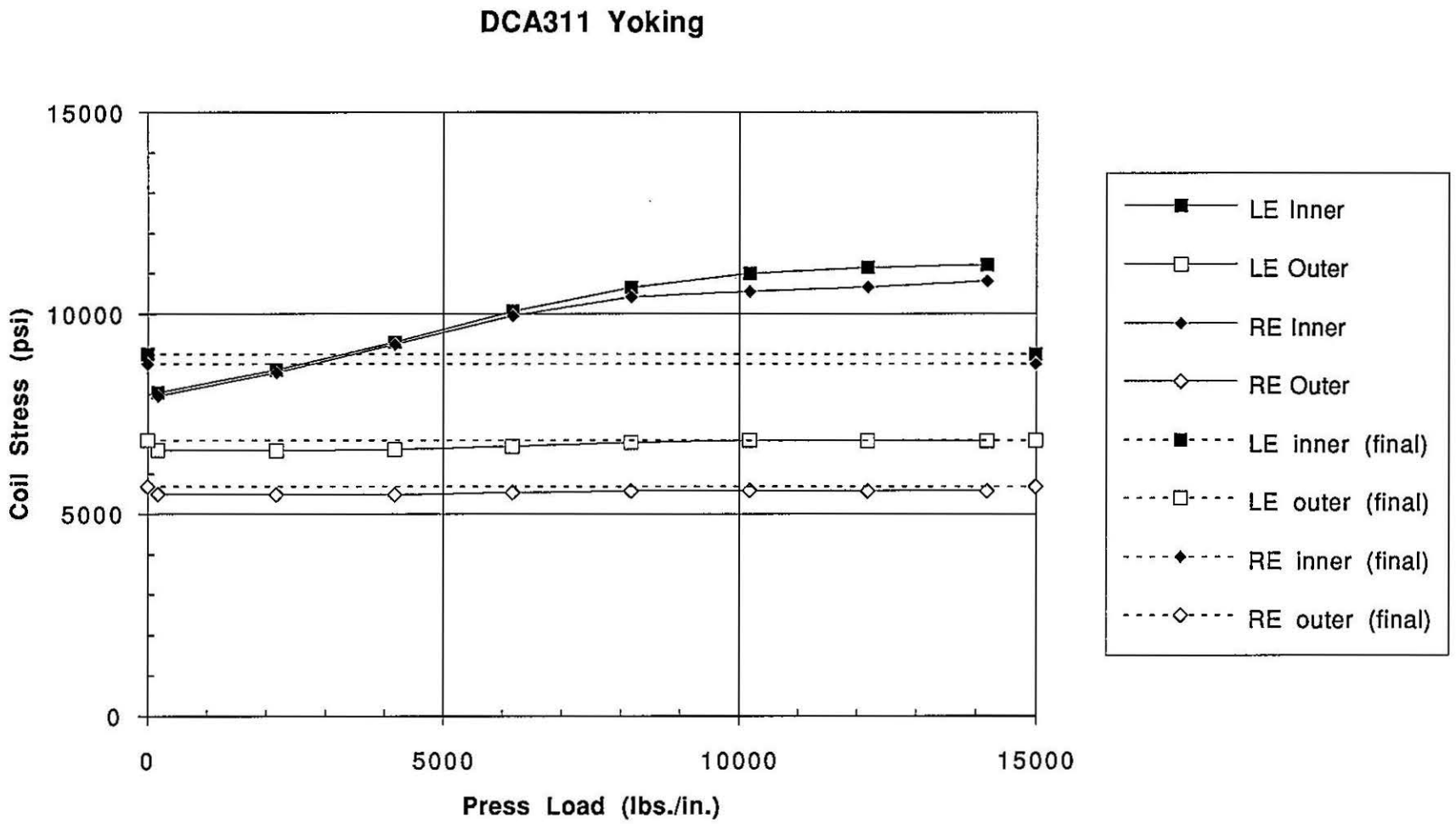

DCA311 Yoking
15000
10000
5000
0
Coil Stress (psi)
0
5000
10000
15000
Press Load (lbs./in.)
LE Inner
LE Outer
RE Inner
RE Outer
LE inner (final)
LE outer (final)
RE inner (final)
RE outer (final)

Figure 6

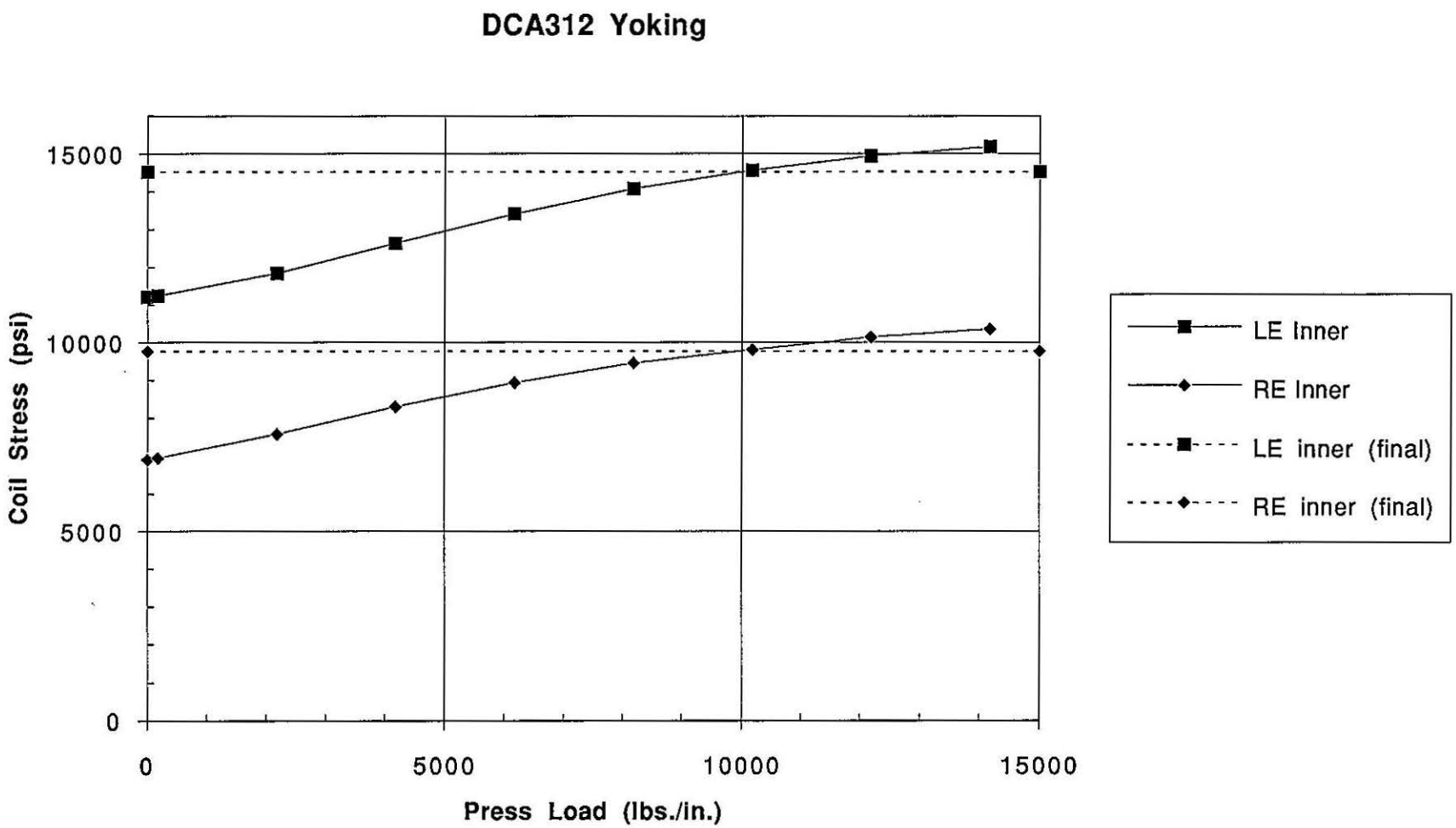
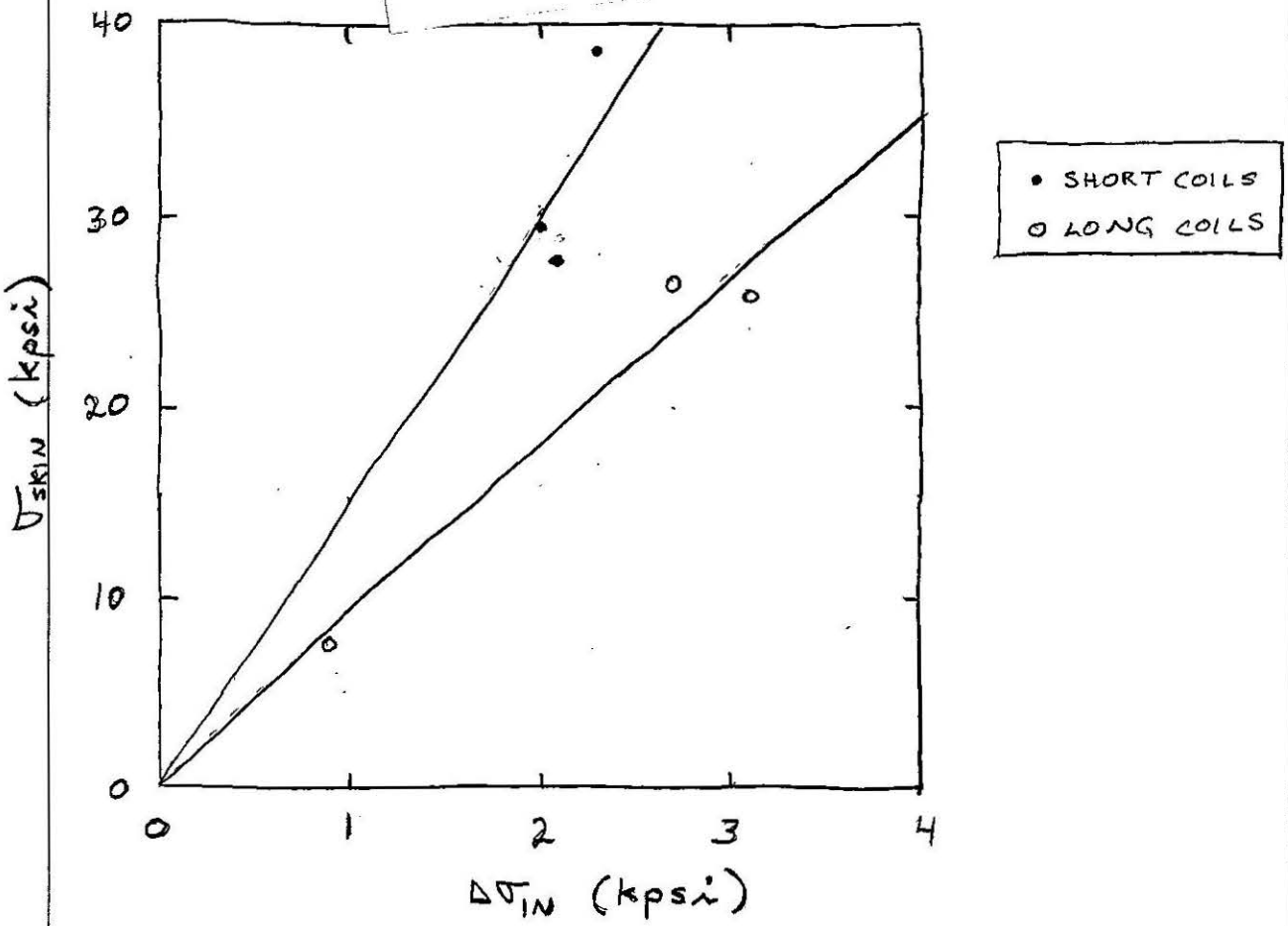

DCA312 Yoking
15000
10000
5000
0
Coil Stress (psi)
0
5000
10000
15000
Press Load (lbs./in.)
LE Inner
RE Inner
LE inner (final)
RE inner (final)

Figure 7

Attach to file copy. Do not distribute



	A	B	C	D	E	F	G	H	I	J	K	L	M
1				CORRECTED AVERAGING FORMULAS 11-20-90									
2													
3											BNL C3	BNL C2	BNL C1
4				GAGE NO.	TYPE	COIL	Quadrant	Gage Factor	R0 (Ohms)	FNAL A0	FNAL A1	FNAL A2	FNAL A3
5				A039	Active	Inner	1	2.03	349.799	-158.3985	4.139875	0.0035771	-7.25E-07
6				A040	Active	Inner	2	2.03	349.923	56.76847	3.886679	0.0043368	-8.78E-07
7				C026	Comp.	Inner	1&2	2.03	349.900				
8				A037	Active	Inner	3	2.03	350.158	-60.89078	3.572337	0.0044684	-9.24E-07
9				A038	Active	Inner	4	2.03	349.929	119.5315	4.174774	0.0033537	-5.38E-07
10				C025	Comp.	Inner	3&4	2.03	349.714				
11				A033	Active	Outer	1	2.03	349.754	-13.77975	3.350154	0.0042988	-7.99E-07
12				A034	Active	Outer	2	2.03	349.852	63.45121	4.951642	0.003168	-5.66E-07
13				C020	Comp.	Outer	1	2.03	350.028				
14				C021	Comp.	Outer	2	2.03	350.063				
15				A035	Active	Outer	3	2.03	349.599	-125.5109	3.675807	0.0044072	-8.99E-07
16				A036	Active	Outer	4	2.03	349.704	1.900681	4.418026	0.0036161	-6.43E-07
17				C022	Comp.	Outer	3	2.03	350.139				
18				C023	Comp.	Outer	4	2.03	350.001				
19													V
20													Hor
21						Hydraulic Pressure		Average Coil Stress			d(Stress)/dPv		
22			Seq #	Date	Press	Vertical	Horizontal	Inner	Outer	All	Inner	Outer	All
23			1	4/11/91	Collaring(84	0	0	-16	66	25			
24			2	4/15/91	Collaring(84	0	0	-78	85	3			
25			3	4/15/91	Collaring(84	770	0	986	1070	1028	1.38	1.28	1.33
26			4	4/15/91	Collaring(84	2000	0	3147	2659	2903	1.76	1.29	1.52
27			5	4/15/91	Collaring(84	4000	0	7307	6133	6720	2.08	1.74	1.91
28			6	4/15/91	Collaring(84	6000	0	12057	11280	11668	2.37	2.57	2.47
29			7	4/15/91	Collaring(84	7000	0	14189	14187	14188	2.13	2.91	2.52
30			8	4/15/91	Collaring(84	8000	0	15228	15633	15430	1.04	1.45	1.24
31			9	4/15/91	Collaring(84	8500	0	15451	15945	15698	0.45	0.62	0.54
32			10	4/15/91	Collaring(84	8278	0	14974	15419	15197		d(Stress)/dPh	
33			11	4/15/91	Collaring(84	8276	70	14997	15459	15228	0.33	0.57	0.45
34			12	4/15/91	Collaring(84	8274	200	15115	15618	15366	0.91	1.22	1.06
35			13	4/15/91	Collaring(84	8270	403	15328	15893	15611	1.05	1.36	1.20
36			14	4/15/91	Collaring(84	8269	601	15468	16064	15766	0.71	0.86	0.79
37			15	4/15/91	Collaring(84	8269	800	15522	16116	15819	0.27	0.26	0.27
38			16	4/15/91	Collaring(84	4127	786	14565	14145	14355			
39			17	4/15/91	Collaring(84	4139	0	14435	14027	14231		MPa/(kN/mm)	
40			18	4/15/91	Collaring(84	0	0	11698	9354	10526		d(Stress)/dPv	
41						Yoking	lbs./in						
42			20	5/9/91	Yoking	0	0	9726	8592	9159	Inner	Outer	Average
43			21	5/9/91	Yoking	300	0	9723	8586	9155	-0.1	-0.2	-0.1
44			22	5/9/91	Yoking	1000	2917	10252	8628	9440	7.1	0.6	3.9
45			23	5/9/91	Yoking	1500	5000	10811	8657	9734	10.6	0.5	5.6
46			24	5/9/91	Yoking	2000	7083	11180	8692	9936	7.0	0.7	3.8
47			25	5/9/91	Yoking	2500	9167	11477	8703	10090	5.6	0.2	2.9
48			26	5/9/91	Yoking	3000	11250	11706	8699	10202	4.3	-0.1	2.1
49			27	5/9/91	Yoking	3500	13333	11925	8681	10303	4.1	-0.3	1.9
50			28	5/9/91	Yoking	2800	10417	11308	8614	9961	8.3	0.9	4.6
51			29	5/9/91	Yoking	2800	10417	11518	8625	10071	lbs./in.	Inner (final)	Outer (final)
52			30	5/9/91	Yoking	2800	10417	12257	8818	10537	0	11737	8843
53			31	5/9/91	Yoking	2800	10417	12380	8872	10626	15000	11737	8843
54			32	5/9/91	Yoking	2800	10417	12522	8956	10739			
55			33	5/9/91	Yoking	2500	9167	12406	8944	10675			
56			34	5/9/91	Yoking	2000	7083	12249	8912	10581			
57			35	5/9/91	Yoking	1500	5000	12050	8875	10463			
58			36	5/9/91	Yoking	1000	2917	11906	8860	10383			2.56 psi/psi
59			37	5/9/91	Yoking	500	833	11768	8854	10311		100	-1500
60			38	5/9/91	Yoking	0	0	11763	8837	10300		8100	18980
61			39	5/9/91	Yoking	0	0	11737	8843	10290			

	N	O	P	Q	R	S	T	U
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15		pump psi to contact magnet		=		300		
16					(collaring)	(yoking)		
17			MPa / psi	=	0.0069046			
18		(N/mm) / (lbs./in.)		=	0.1754			
19	ertical press load (lbs./in) / pump psi			=	5.909	4.167		
20	izontal press load (lbs./in) / pump psi			=	1.000			
21	<Pv>		SI units:		N/mm	N/mm	MPa	Mpa
22		10*F(horizontal)			F(vertical)	F(yoking)	Inner Coil	Outer Coil
23			-10000	C	0	-10000	-0.1	0.5
24			-10000	C	0	-10000	-0.5	0.6
25	385		-10000	C	798	-10000	6.8	7.4
26	1385		-10000	C	2073	-10000	21.7	18.4
27	3000		-10000	C	4145	-10000	50.5	42.3
28	5000		-10000	C	6218	-10000	83.2	77.9
29	6500		-10000	C	7254	-10000	98.0	98.0
30	7500		-10000	C	8290	-10000	105.1	107.9
31	8250		-10000	C	8809	-10000	106.7	110.1
32			0	C	8579	-10000	103.4	106.5
33	35		123	C	8577	-10000	103.5	106.7
34	135		351	C	8574	-10000	104.4	107.8
35	301.5		707	C	8570	-10000	105.8	109.7
36	502		1054	C	8569	-10000	106.8	110.9
37	700.5		1403	C	8569	-10000	107.2	111.3
38			1378	C	4277	-10000	100.6	97.7
39	N/mm		0	C	4289	-10000	99.7	96.9
40	<Fv>		0	C	0	-10000	80.8	64.6
41								
42			-10000	y	-10000	0	67.2	59.3
43	110		-10000	Y	-10000	219	67.1	59.3
44	475		-10000	Y	-10000	731	70.8	59.6
45	913		-10000	Y	-10000	1096	74.6	59.8
46	1279		-10000	Y	-10000	1461	77.2	60.0
47	1644		-10000	Y	-10000	1827	79.2	60.1
48	2010		-10000	Y	-10000	2192	80.8	60.1
49	2375		-10000	Y	-10000	2558	82.3	59.9
50	2302		-10000	Y	-10000	2046	78.1	59.5
51			-10000	Y	-10000	2046	79.5	59.6
52			-10000	Y	-10000	2046	84.6	60.9
53			-10000	Y	-10000	2046	85.5	61.3
54			-10000	Y	-10000	2046	86.5	61.8
55			-10000	Y	-10000	1827	85.7	61.8
56			-10000	Y	-10000	1461	84.6	61.5
57			-10000	Y	-10000	1096	83.2	61.3
58			-10000	Y	-10000	731	82.2	61.2
59			-10000	Y	-10000	365	81.3	61.1
60			-10000	Y	-10000	0	81.2	61.0
61			-10000	Y	-10000	0	81.0	61.1

			Hydraulic Pressure		Average Coil Stress			Hydraulic Pressure		d(Stress)/dPv			
Seq. No.	Date	Time	Vertical	Horizontal	Inner	Outer	Average	Vertical	Horizontal	Inner	Outer	Average	
1	07/03/91	08:08:2	0	0	-132	-89	-111						
2	07/03/91	09:38:2	800	0	892	659	775	400	0	1.28	0.94	1.11	Verti
3	07/03/91	09:40:0	2000	0	3325	1896	2610	1400	0	2.03	1.03	1.53	Horizon
4	07/03/91	09:41:3	4000	0	8269	5762	7015	3000	0	2.47	1.93	2.20	
5	07/03/91	09:48:0	6000	0	13953	12074	13014	5000	0	2.84	3.16	3.00	
6	07/03/91	09:52:1	7000	0	16050	15070	15560	6500	0	2.10	3.00	2.55	
7	07/03/91	09:56:4	8000	0	16753	16270	16512	7500	0	0.70	1.20	0.95	
8	07/03/91	10:02:0	8500	0	16821	16564	16693	8250	0	0.14	0.59	0.36	
9	07/03/91	10:29:3	8325	65	16453	16429	16441	8413	33	-5.66	-2.08	-3.87	d(Stress)/dP
10	07/03/91	10:31:3	8325	200	16515	16515	16515	8325	133	0.46	0.63	0.54	
11	07/03/91	10:32:2	8320	400	16565	16582	16574	8323	300	0.25	0.34	0.29	
12	07/03/91	10:35:1	8320	600	16598	16628	16613	8320	500	0.16	0.23	0.19	
13	07/03/91	10:36:5	8320	700	16610	16652	16631	8320	650	0.12	0.25	0.18	
14	07/03/91	10:37:5	8320	800	16630	16669	16650	8320	750	0.20	0.17	0.18	
15	07/03/91	10:40:5	8320	900	16636	16685	16660	8320	850	0.06	0.15	0.11	
16	07/03/91	10:47:2	4000	900	15087	13882	14484	6160	900				
17	07/03/91	10:51:4	4000	0	14799	13597	14198	4000	450				
18	07/03/91	10:52:4	0	0	11210	8594	9902	2000	0				
19	07/03/91	11:05:4	0	0	11064	8385	9724	0	0				
20	07/03/91	11:06:0	0	0	11063	8383	9723	0	0				
21	07/03/91	11:06:4	0	0	11061	8382	9721	0	0				
22	07/03/91	11:07:0	0	0	11061	8377	9719	0	0				
23	07/03/91	11:07:3	0	0	11058	8377	9718	0	0				
24	07/03/91	11:07:5	0	0	11057	8375	9716	0	0				
25	07/03/91	11:08:2	0	0	11059	8374	9716	0	0				
26	07/03/91	11:08:4	0	0	11051	8373	9712	0	0				
27	07/03/91	11:09:0	0	0	11054	8371	9712	0	0				
28	07/03/91	11:09:2	0	0	11050	8370	9710	0	0				
29	07/03/91	11:09:4	0	0	11051	8370	9711	0	0				
30	07/03/91	11:10:1	0	0	11048	8369	9709	0	0				

			Yoking	lbs./in.									Yoking
32	08/08/91	11:45:4	0	0	9182	7473	8327						
33	08/12/91	08:41:1	0	0	9112	7447	8280						
34	08/12/91	09:11:4	0	0	10210	7634	8922						
35	08/12/91	09:16:2	1500	5000	10468	7657	9062	750	2500	0.17	0.02	0.09	
36	08/12/91	09:18:4	2000	7083	10781	7705	9243	1750	6042	0.63	0.10	0.36	
37	08/12/91	09:20:3	2500	9167	11077	7712	9394	2250	8125	0.59	0.01	0.30	
38	08/12/91	09:23:1	3000	11250	11358	7714	9536	2750	10208	0.56	0.00	0.28	
39	08/12/91	09:26:5	3500	13333	11550	7681	9615	3250	12292	0.38	-0.07	0.16	
40	08/12/91	09:41:5	3500	13333	11417	7573	9495	3500	13333				
41	08/12/91	09:45:3	2800	10417	10971	7588	9279	3150	11875				
42	08/12/91	13:17:5	2800	10417	11276	7442	9359	2800	10417				
43	08/12/91	14:08:4	2800	10417	11825	7563	9694	2800	10417				
44	08/12/91	16:35:1	2800	10417	11961	7574	9767	2800	10417				
45	08/12/91	17:16:0	2800	10417	12063	7620	9841	2800	10417				
46	08/12/91	17:17:1	2500	9167	11990	7631	9810	2650	9792				
47	08/12/91	17:17:4	2000	7083	11778	7664	9721	2250	8125				
48	08/12/91	17:18:1	1500	5000	11615	7692	9653	1750	6042				
49	08/12/91	17:18:4	1000	2917	11442	7721	9581	1250	3958				
50	08/12/91	17:19:1	500	833	11329	7739	9534	750	1875				
51	08/12/91	17:19:4	0	0	11284	7747	9515	250	417				
					Inner (final)	Outer (final)							
				0	11284	7747							
				15000	11284	7747							

				(collaring)	(yoking)
		MPa / psi	=	0.006905	
		(N/mm) / (lbs./in.)	=	0.1754	
cal press load (lbs./in) / pump psi			=	5.909	4.167
tal press load (lbs./in) / pump psi			=	1.000	
		pump psi to contact magnet	=		300
h					

			Hydraulic Pressure		Average Coil Stress			Hydraulic Pressure		d(Stress)/dPv			
Seq. No.	Date	Time	Yoking	lbs./in	Inner	Outer	Average	Yoking	lbs./in	Inner	Outer	Average	
1	08/27/91	09:46:0	0	0	8638	9136	8887						
2	08/27/91	09:55:5	970	2792	9470	9835	9653	485	1396	0.86	0.72	0.79	Verti
3	08/27/91	09:58:3	1500	5000	9583	9872	9728	1235	3896	0.21	0.07	0.14	Horizon
4	08/27/91	09:59:2	2000	7083	9965	10079	10022	1750	6042	0.76	0.41	0.59	
5	08/27/91	10:00:0	2500	9167	10283	10221	10252	2250	8125	0.64	0.29	0.46	
6	08/27/91	10:00:3	3000	11250	10536	10302	10419	2750	10208	0.51	0.16	0.33	
7	08/27/91	10:06:3	3500	13333	10668	10301	10485	3250	12292	0.27	0.00	0.13	
8	08/27/91	10:27:3	3500	13333	10609	10265	10437	3500	13333				
9	08/27/91	10:29:3	2800	10417	10293	10209	10251	3150	11875				
10	08/27/91	13:07:0	2800	10417	10570	10287	10429	2800	10417				
11	08/27/91	13:11:1	2800	10417	10585	10291	10438	2800	10417				
12	08/27/91	13:55:4	2800	10417	11061	10512	10786	2800	10417				
13	08/27/91	14:32:0	2800	10417	11191	10610	10901	2800	10417				
14	08/27/91	15:13:0	2800	10417	11306	10694	11000	2800	10417				
15	08/27/91	15:14:5	2500	9167	11262	10682	10972	2650	9792				
16	08/27/91	15:15:3	2000	7083	11153	10657	10905	2250	8125				
17	08/27/91	15:16:0	1500	5000	11069	10640	10855	1750	6042				
18	08/27/91	15:16:3	1000	2917	10993	10628	10811	1250	3958				
19	08/27/91	15:17:0	500	833	10954	10619	10786	750	1875				
20	08/27/91	15:18:2	0	0	10942	10618	10780	250	417				

					Average Stress								
Seq Number	Date	Time	Yoking	Horizontal	LE Inner	LE Outer	RE Inner	RE Outer		Press Load (lb./in.)			
1	07/18/91	09:45:4	0	0	6945	10300	1308	584	Yoking	0			
2	07/18/91	09:46:0	0	0	6942	10296	1308	584		0			
3	07/22/91	08:30:1	0	0	6907	10286	9963	11016		0			
4	07/22/91	08:30:4	0	0	6906	10286	9960	11014		0			
5	07/24/91	16:25:2	5587	0	9057	9845	12476	10576		11174			
6	07/24/91	16:25:5	5587	0	9057	9843	12479	10578		11174			
7	07/25/91	14:17:1	0	0	6623	10528	9463	11168		0			
8	07/25/91	15:28:3	0	0	6617	10528	9451	11166		178			
9	07/25/91	15:36:1	500	0	6976	10420	9829	11096		1178			
10	07/25/91	15:37:5	1000	0	7292	10333	10177	11034		2178			
11	07/25/91	15:39:3	2000	0	7858	10211	10811	10934		4178			
12	07/25/91	15:40:4	3000	0	8367	10120	11394	10856		6178			
13	07/25/91	15:41:4	4000	0	8807	10054	11909	10809		8178			
14	07/25/91	15:42:5	5000	0	9137	10000	12388	10780		10178			
15	07/25/91	15:44:0	6000	0	9382	9971	12789	10763		12178			
16	07/25/91	15:45:1	7000	0	9516	9963	13002	10747		14178			
17	07/25/91	15:46:2	6000	0	9347	9975	12813	10729		12178			
18	07/26/91	07:56:3	6000	0	9076	9776	12505	10432		12178			
19	07/27/91	07:15:3	6000	0	9372	9760	12797	10419		12178			
20	07/27/91	07:16:1	6000	0	9373	9758	12793	10414		12178			
21	07/29/91	09:46:1	5500	0	9322	9785	12718	10432		11178			
22	07/29/91	16:31:3	5500	0	9372	9827	12802	10478		11178			
23	07/29/91	16:33:1	4000	0	9237	9885	12641	10525		8178			
24	07/29/91	16:35:1	2000	0	9052	9990	12393	10617		4178			
25	07/29/91	16:37:4	0	0	9100	10144	12510	10809		178			
26	07/30/91	09:32:0	0	0	9082	10220	12480	10900		0			
					LE inner (fir	LE outer (fir	RE inner (fir	RE outer (final)					
			0		9082	10220	12480	10900					
			15000		9082	10220	12480	10900					

					Average Stress								
Seq Number	Date	Time	Vertical	Horizontal	LE Inner	LE Outer	RE Inner	RE Outer					
1	06/18/91	13:38:2	0	0	-74	-105	-170	-207	COLLARING				
2	06/18/91	13:45:4	350	0	230	655	148	289					
3	06/18/91	13:48:5	2500	0	4960	3349	5370	2207					
4	06/18/91	13:51:5	4500	0	9842	6586	10362	6078					
5	06/18/91	13:54:3	6500	0	13152	10678	13664	10428					
6	06/18/91	13:56:3	7500	0	13271	11113	13904	11026					
7	06/18/91	13:59:2	8500	0	13431	11529	14075	11462					
8	06/18/91	14:19:1	8500	0	13106	11397	13686	11284					
9	06/18/91	14:23:5	8500	75	13156	11453	13719	11351					
10	06/18/91	14:35:0	8500	150	13187	11536	13697	11409					
11	06/18/91	14:41:3	8500	500	13628	12063	14075	11912					
12	06/18/91	14:50:2	8500	1000	13862	12362	14319	12271					
13	06/18/91	14:54:5	8500	1500	13963	12465	14365	12331					
14	06/18/91	15:01:5	8500	2000	14020	12537	14400	12389					
15	06/18/91	15:06:2	4000	2000	13593	11266	13928	10997					
16	06/18/91	15:08:5	0	0	10473	7373	10869	6324					
17	06/18/91	15:10:2	0	0	10382	7299	10740	6234					
18	06/18/91	15:13:5	0	0	10341	7252	10714	6170					

			Yoking							Press Load (lb./in.)			
20	08/05/91	08:17:0	0	0	8312	6400	8258	5325	Yoking	0			
21	08/05/91	08:21:2	0	0	8315	6401	8254	5324		0			
22	08/06/91	11:11:4	0	0	8308	6395	8244	5316		178			
23	08/09/91	09:35:0	0	0	8358	6381	8298	5306		178			
24	08/09/91	09:53:3	1000	0	8952	6370	8993	5297		2178			
25	08/09/91	09:57:3	2000	0	9585	6432	9641	5353		4178			
26	08/09/91	09:58:5	3000	0	10166	6577	10209	5457		6178			
27	08/09/91	10:02:0	4000	0	10627	6678	10675	5529		8178			
28	08/09/91	10:03:5	5000	0	11283	6862	10951	5630		10178			
29	08/09/91	10:40:1	0	0	7993	6519	7900	5430		178			
30	08/09/91	12:58:3	0	0	8036	6596	7950	5494		178			
31	08/09/91	13:09:3	1000	0	8605	6587	8537	5480		2178			
32	08/09/91	13:10:3	2000	0	9299	6609	9243	5491		4178			
33	08/09/91	13:11:5	3000	0	10062	6691	9961	5536		6178			
34	08/09/91	13:13:0	4000	0	10647	6787	10414	5581		8178			
35	08/09/91	13:13:5	5000	0	11000	6840	10554	5593		10178			
36	08/09/91	13:17:0	6000	0	11148	6827	10660	5576		12178			
37	08/09/91	13:20:0	7000	0	11215	6824	10808	5583		14178			
38	08/09/91	13:21:0	6000	0	10973	6845	10587	5598		12178			
39	08/10/91	10:48:4	5700	0	10906	6768	10686	5613		11578			
40	08/12/91	11:13:4	5700	0	10821	6728	10530	5581		11578			
41	08/13/91	15:22:0	5500	0	10729	6711	10521	5562		11178			
42	08/14/91	12:58:4	5600	0	10564	6698	10397	5548		11378			
43	08/14/91	13:00:5	4000	0	10146	6751	9970	5592		8178			
44	08/14/91	13:03:0	2000	0	9513	6770	9283	5608		4178			
45	08/14/91	13:05:2	0	0	8944	6727	8731	5590		178			
46	08/14/91	14:18:2	0	0	8995	6843	8748	5683		178			
					LE inner (fir	LE outer (fir	RE inner (fi	RE outer (final)					
			0		8995	6843	8748	5683					
			15000		8995	6843	8748	5683					

Seq Number	Date	Time	Vertical	Horizontal	LE Inner	LE Outer	RE Inner	RE Outer
1	06/27/91	10:48:4	0	0	178	6	26	85
2	06/27/91	11:13:0	350	0	1242	-418	80	414
3	06/27/91	11:16:5	2500	0	9017	539	4140	2692
4	06/27/91	11:21:3	2500	0	9195	585	4248	2793
5	06/27/91	11:23:4	3500	0	12084	1726	6610	4227
6	06/27/91	11:31:5	4500	0	14775	3585	9174	6265
7	06/27/91	11:51:0	5500	0	16848	6010	11136	8382
8	06/27/91	12:00:4	6000	0	17247	6674	11422	8803
9	06/27/91	12:54:0	6000	75	17034	6767	11330	8982
10	06/27/91	12:56:2	6000	150	17109	6856	11422	9065
11	06/27/91	12:59:1	6000	500	17540	7419	11942	9574
12	06/27/91	13:02:0	6000	1000	17998	8064	12595	10234
13	06/27/91	13:04:3	6000	1500	18187	8300	12798	10401
14	06/27/91	13:09:4	6000	2000	18255	8382	12867	10464
15	06/27/91	13:17:3	4000	2000	18005	7810	12658	10014
16	06/27/91	13:20:3	0	0	14761	3970	10104	6983
17	06/27/91	13:31:1	0	0	14534	3864	9941	6795
			Yoking	lbs./in				
19	08/22/91	15:00:2	0	0	11860	3750	7194	6671
20	08/23/91	14:30:2	0	0	11867	3756	7205	6679
21	08/26/91	08:52:1	0	178	11860	3780	7179	
22	08/26/91	08:54:3	0	178	11858	3780	7178	
23	08/26/91	08:59:1	1000	2178	12542	3785	7861	
24	08/26/91	09:00:3	2000	4178	13410	4047	8620	
25	08/26/91	09:01:5	3000	6178	14060	4312	9168	
26	08/26/91	09:03:1	4000	8178	14521	4604	9602	
27	08/26/91	09:04:1	5000	10178	14980	4935	10002	
28	08/26/91	09:05:4	6000	12178	15418	5320	10169	
29	08/26/91	09:07:0	7000	14178	15274	5353	9954	
30	08/26/91	09:08:1	6000	12178	15009	5321	9741	
31	08/26/91	11:10:3	0	178	11313	4710	6925	6783
32	08/26/91	11:13:0	1000	2178	12142	4720	7753	6695
33	08/26/91	11:14:2	2000	4178	12966	4798	8456	6695
34	08/26/91	11:15:4	3000	6178	13758	4938	9036	6749
35	08/26/91	11:17:3	4000	8178	14274	5046	9301	6766
36	08/26/91	11:18:4	5000	10178	14564	5132	9496	6788
37	08/26/91	11:19:5	6000	12178	14720	5183	9616	6803
38	08/26/91	11:21:1	7000	14178	14743	5155	9693	6875
39	08/26/91	13:02:4	0	0	11362	4780	6968	6835

Yoking Press (lbs/in)/psi
2

Yoking Press lbs/in at Phyd = 0
178

			Yoking	lbs./in									
41	08/30/91	14:53:2	0	0	11209	4813	6890	6833					
42	08/31/91	10:31:2	0	0	10627	4793	6903	6815					
43	09/03/91	11:01:2	0	0	11162	4813	6849	6837					
44	09/04/91	08:54:3	0	0	11227	4789	6909	6824					
45	09/04/91	08:55:1	0	0	11220	4790	6913	6825					
46	09/04/91	09:33:0	0	178	11241	4768	6954	6822					
47	09/04/91	09:36:5	1000	2178	11842	4766	7590	6764					
48	09/04/91	09:38:1	2000	4178	12628	4805	8316	6761					
49	09/04/91	09:40:1	3000	6178	13412	4914	8950	6831					
50	09/04/91	09:41:3	4000	8178	14083	5048	9470	6881					
51	09/04/91	10:57:1	5000	10178	14568	5092	9813	6761					
52	09/04/91	10:58:5	6000	12178	14951	5247	10143	6806					
53	09/04/91	11:00:5	7000	14178	15188	5415	10363	6826					
54	09/04/91	11:03:2	6000	12178	14898	5385	10137	6811					
55	09/06/91	07:29:5	5800	11778	14940	5524	10299	6724					
56	09/06/91	12:45:5	5800	11778	15134	5589	10530	6799					
57	09/09/91	14:58:3	5076	10330	14843	5583	10230	6812					
58	09/09/91	15:01:5	4000	8178	14689	5570	10066	6829					
59	09/09/91	15:04:0	2000	4178	14420	5554	9759	6875					
60	09/09/91	15:05:0	0	178	14483	5538	9726	6961					
61	09/09/91	17:00:4	0	0	14524	5376	9770	7045					
					LE inner (final)		RE inner (final)						
				0	14524	5376	9770	7045					
				15000	14524	5376	9770	7045					