Fermilab

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From: Jim Strait

Subject: Collar keying of DSA324

In this note I summarize the collar keying procedure used for DSA324. The inner coils were molded with the mold components (key inserts, sizing bars, mold stop bars, etc.) at their nominal sizes and no additional molding shims were used. The outer coils were molded with the original key inserts which define a mold cavity 5 mils larger in azimuthal extent than the design coil size. (These are the same mold conditions as for DSA320-323.) Five mils of non-adhesive Kapton was placed between the inner coil pole turn and the pole cap and one layer of outer coil ground wrap had its pole surface removed (a "-5" mil pole shim) as shown in Figure 1. This is the same configuration as used for the 3rd and 4th assemblies of DSA322[1].

Based on the keying of DSA322[1] and DSA325[2] with laminated tooling it was estimated that to set the keys in with no force would require over-closing the tooling (using a shim between the upper tooling and the upper press platen) by 8-10 mils. DSA324 was keyed using an "almost square key" method in which a 6 mil press shim was used.

Feeler gauge measurements indicated that the press was fully closed at 7000 pump psi. To verify full closure, the vertical hydraulic pressure was increased to 8500 psi. Following pre-keying electrical tests the side cylinders were energized to 65 psi (65 lbs./in.), then to 200 psi, and then in 200 psi increments to 800 psi. Full insertion was deduced when the linear potentiometer on the side bars showed less than 5 mils of motion from one step to the next. The linear potentiometer data[3], shown in Figure 2, indicate that at zero force the keys were on the average about 30 mils out and that full insertion occurred at about 500 lbs./in. The vertical load was then reduced to 4000 pump psi, the side load was reduced to zero, and the vertical load was reduced to zero. Visual inspection of the collared coil confirmed the full insertion of the keys.

The strain gauge data are displayed in Table I and Figure 3. The peak coil stresses, averaged over the four quadrants, were 15.5 kpsi and 16.1 kpsi in the inner and outer coils respectively. The final collared coil prestresses are 11.7 kpsi and 9.4 kpsi and the "spring-back" losses (peak minus final stress) were 3.9 kpsi and 6.8 kpsi. The Figure 4 shows the coil stress versus vertical hydraulic pressure before key insertion. Shown also is the expected slope[4] of 2.56 coil psi per pump psi if the press load is fully balanced by the coil and the pole and mid-plane stresses are equal. Two strain gauge readings were taken at full load separated by the roughly one hour that it took to do the pre-keying electrical measurements. During this time the vertical hydraulic pressure and the coil stress both decreased slightly. Both the points are plotted in Figure 4

showing that most of the coil stress decrease results from stress relaxation rather than from the small decrease in press load. Figure 5 shows the slope $d\sigma(\text{coil})/dP(\text{press})$ versus press pressure. As with DSA325 about 20% of the press load is transferred to the coil even after the press is nominally closed at 7000 pump psi.

Figure 6 shows the coil stress as a function of side bar load during keying and Figure 7 shows the derivative $d\sigma(\text{coil})/dP(\text{horizontal})$. Figure 8 is a plot of the rate of key motion with side load change $dx/dP(\text{horizontal})$ for this magnet and the previous two magnets collared. In the progression DSA322, DSA325, DSA324 the amount of tooling over-closure goes from -6 mils to 0 to +6 mils and therefore the coil load that is generated by inserting the keys becomes progressively smaller. As the load on the keys decreases from one magnet to the next the rate of key insertion at a given side load increases, as one would expect.

With no vertical shim on DSA325[2] the keys were on the average 74 mils away from full insertion a minimal side load of 65 lbs./in. With a 6 mil press shim on DSA324 the keys were on the average 32 mils out. The difference of 42 mils is somewhat less than the 60 mils expected from the additional 6 mils of tooling closure and the 10:1 wedge angle of the tapered keys. Extrapolating from these two measurements suggests that an 11 mils shim would be required for full key insertion with minimal force.

References

[1] J. Strait, Second Collaring of DSA322, TS-SSC 91-049, 3/15/91 and
J. Strait, Development of Collar Keying Procedures, TS-SSC 91-060, 4/4/91.

[2] J. Strait, Collar keying of DSA325, TS-SSC 91-062, 4/9/91.

[3] R.E. Sims, private communication.

[4] J. Strait, DSA322 Assembly Experiment Plan, TS-SSC 91-048, Version 7, 3/22/91.

	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 Facto	R0 (Ohms)	FNAL A0	FNAL A1	FNAL A2	FNAL A3
5				A039	Active	Inner	1	2.03	349.799	-158.399	4.139875	0.003577	-7.3E-07
6				A040	Active	Inner	2	2.03	349.923	56.76847	3.886679	0.004337	-8.8E-07
7				C026	Comp.	Inner	1&2	2.03	349.900				
8				A037	Active	Inner	3	2.03	350.158	-60.8908	3.572337	0.004468	-9.2E-07
9				A038	Active	Inner	4	2.03	349.929	119.5315	4.174774	0.003354	-5.4E-07
10				C025	Comp.	Inner	3&4	2.03	349.714				
11				A033	Active	Outer	1	2.03	349.754	-13.7798	3.350154	0.004299	-8E-07
12				A034	Active	Outer	2	2.03	349.852	63.45121	4.951642	0.003168	-5.7E-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	-125.511	3.675807	0.004407	-9E-07
16				A036	Active	Outer	4	2.03	349.704	1.900681	4.418026	0.003616	-6.4E-07
17				C022	Comp.	Outer	3	2.03	350.139				
18				C023	Comp.	Outer	4	2.03	350.001				
19													
20													
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(8	0	0	-16	66	25			
24			2	4/15/91	Collaring(8	0	0	-78	85	3			
25			3	4/15/91	Collaring(8	770	0	986	1070	1028	1.38	1.28	1.33
26			4	4/15/91	Collaring(8	2000	0	3147	2659	2903	1.76	1.29	1.52
27			5	4/15/91	Collaring(8	4000	0	7307	6133	6720	2.08	1.74	1.91
28			6	4/15/91	Collaring(8	6000	0	12057	11280	11668	2.37	2.57	2.47
29			7	4/15/91	Collaring(8	7000	0	14189	14187	14188	2.13	2.91	2.52
30			8	4/15/91	Collaring(8	8000	0	15228	15633	15430	1.04	1.45	1.24
31			9	4/15/91	Collaring(8	8500	0	15451	15945	15698	0.45	0.62	0.54
32			10	4/15/91	Collaring(8	8278	0	14974	15419	15197		d(Stress)/dPh	
33			11	4/15/91	Collaring(8	8276	70	14997	15459	15228	0.33	0.57	0.45
34			12	4/15/91	Collaring(8	8274	200	15115	15618	15366	0.91	1.22	1.06
35			13	4/15/91	Collaring(8	8270	403	15328	15893	15611	1.05	1.36	1.20
36			14	4/15/91	Collaring(8	8269	601	15468	16064	15766	0.71	0.86	0.79
37			15	4/15/91	Collaring(8	8269	800	15522	16116	15819	0.27	0.26	0.27
38			16	4/15/91	Collaring(8	4127	786	14565	14145	14355			
39			17	4/15/91	Collaring(8	4139	0	14435	14027	14231			
40			18	4/15/91	Collaring(8	0	0	11698	9354	10526			

Table I

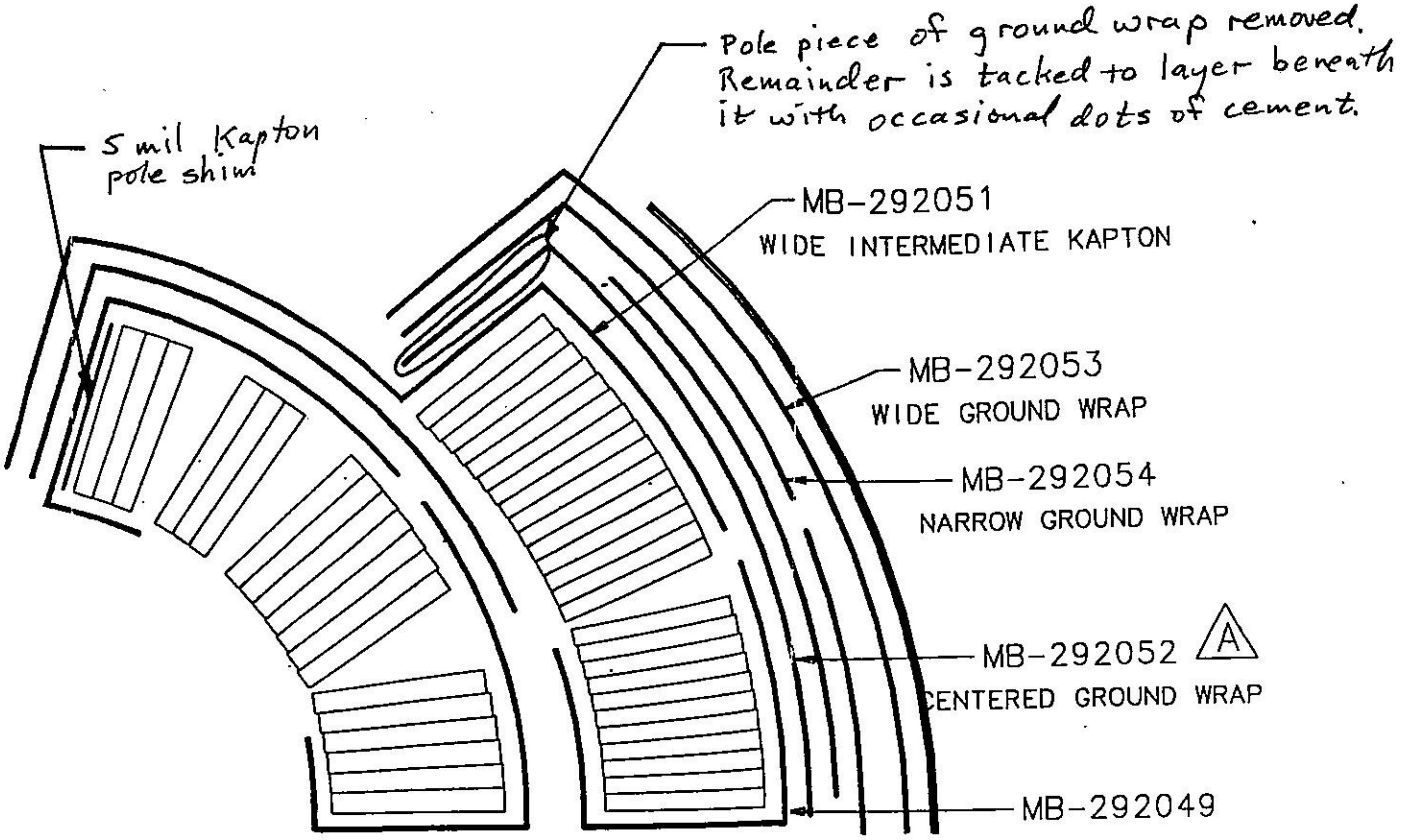
Pole piece of ground wrap removed. Remainder is tacked to layer beneath it with occasional dots of cement.
5 mil Kapton pole shim
MB-292051
WIDE INTERMEDIATE KAPTON
MB-292053
WIDE GROUND WRAP
MB-292054
NARROW GROUND WRAP
MB-292052
A
CENTERED GROUND WRAP
MB-292049

Figure 1

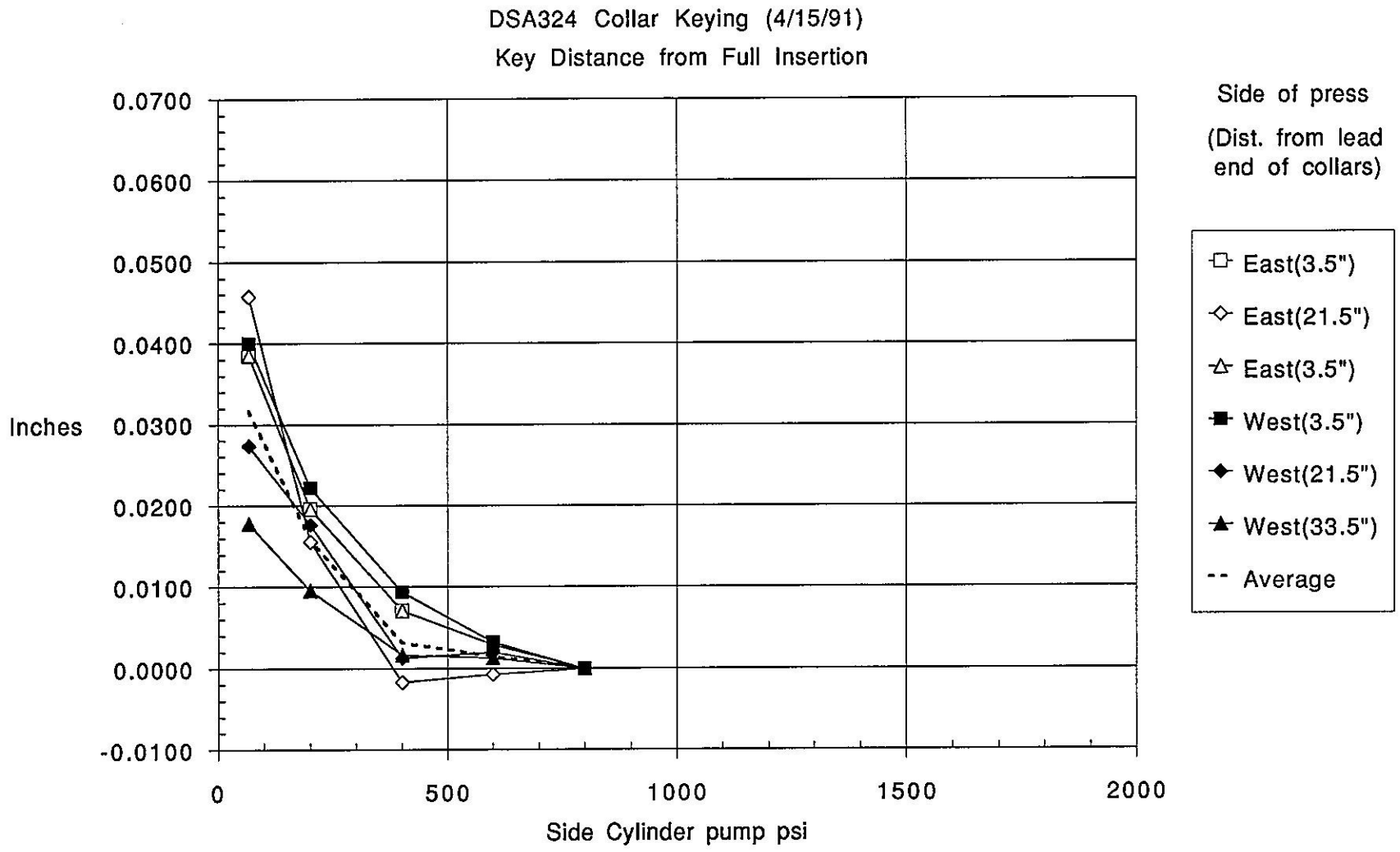
DSA324 Collar Keying (4/15/91)
Key Distance from Full Insertion
Inches
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
-0.0100
0
500
1000
1500
2000
Side Cylinder pump psi
Side of press
(Dist. from lead end of collars)
East(3.5")
East(21.5")
East(3.5")
West(3.5")
West(21.5")
West(33.5")
Average

Figure 2

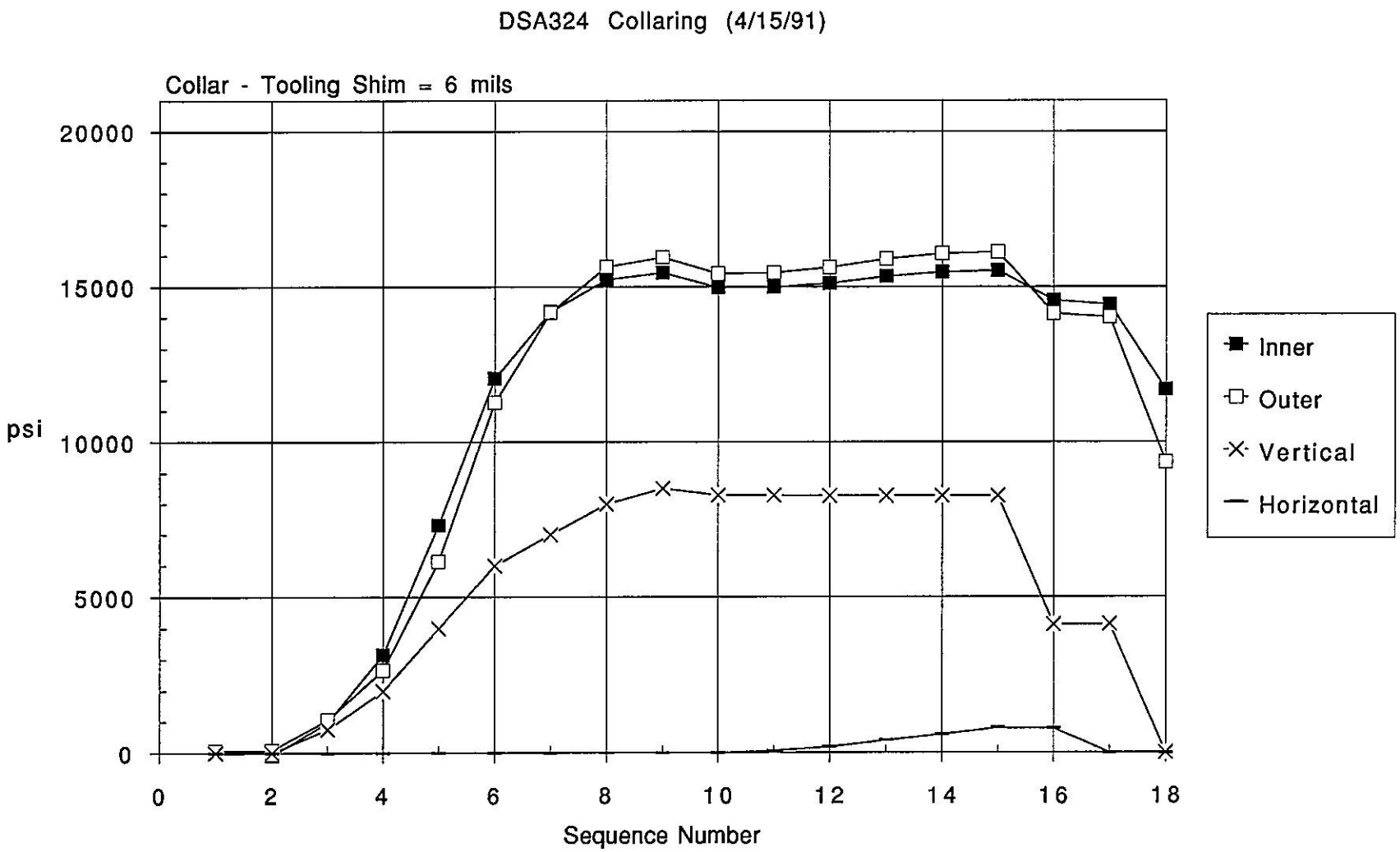
DSA324 Collaring (4/15/91)
Collar - Tooling Shim = 6 mils
psi
20000
15000
10000
5000
0
0
2
4
6
8
10
12
14
16
18
Sequence Number
Inner
Outer
Vertical
Horizontal

Figure 3

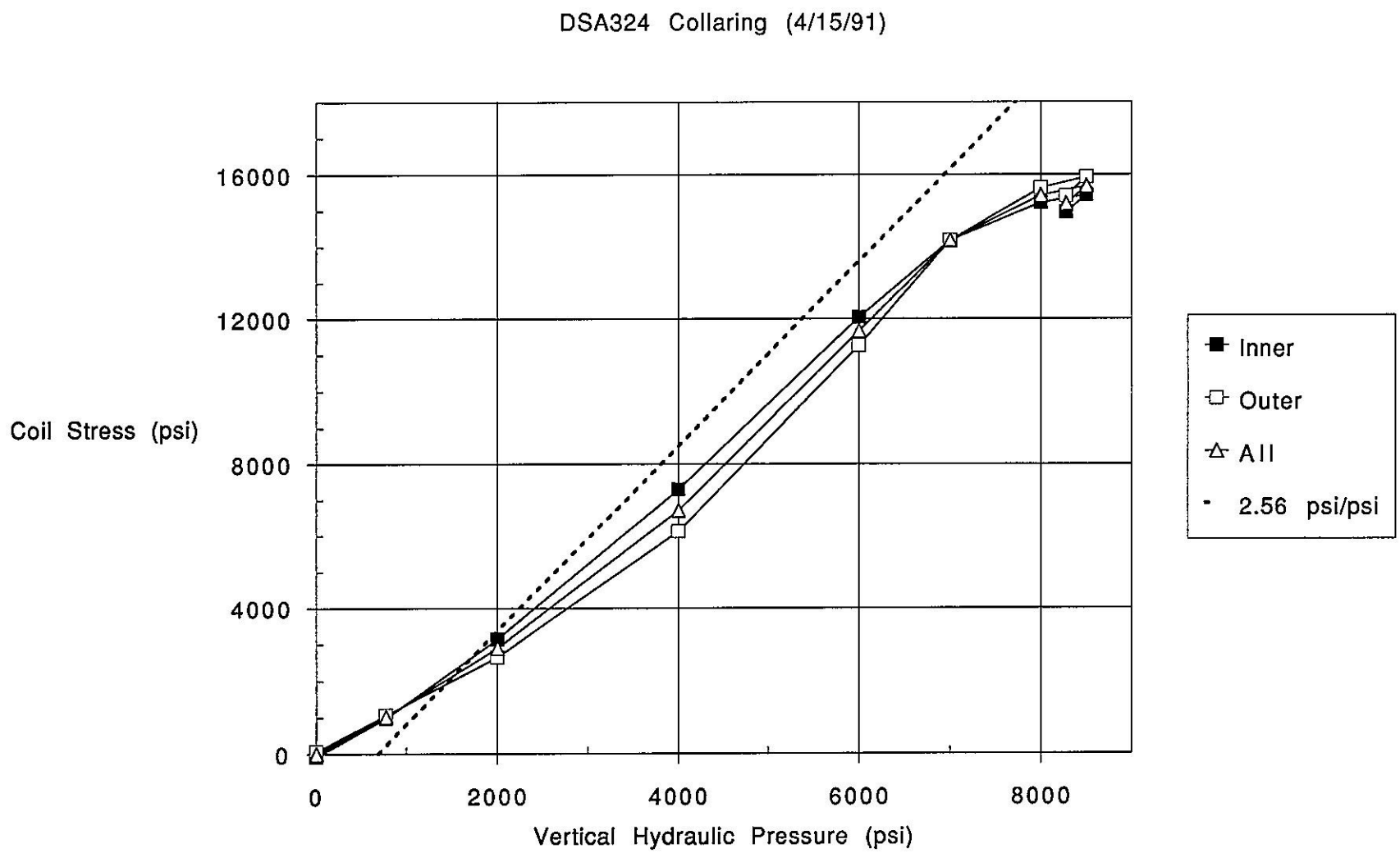
DSA324 Collaring (4/15/91)
Coil Stress (psi)
16000
12000
8000
4000
0
0
2000
4000
6000
8000
Vertical Hydraulic Pressure (psi)
Inner
Outer
All
2.56 psi/psi

Figure 4

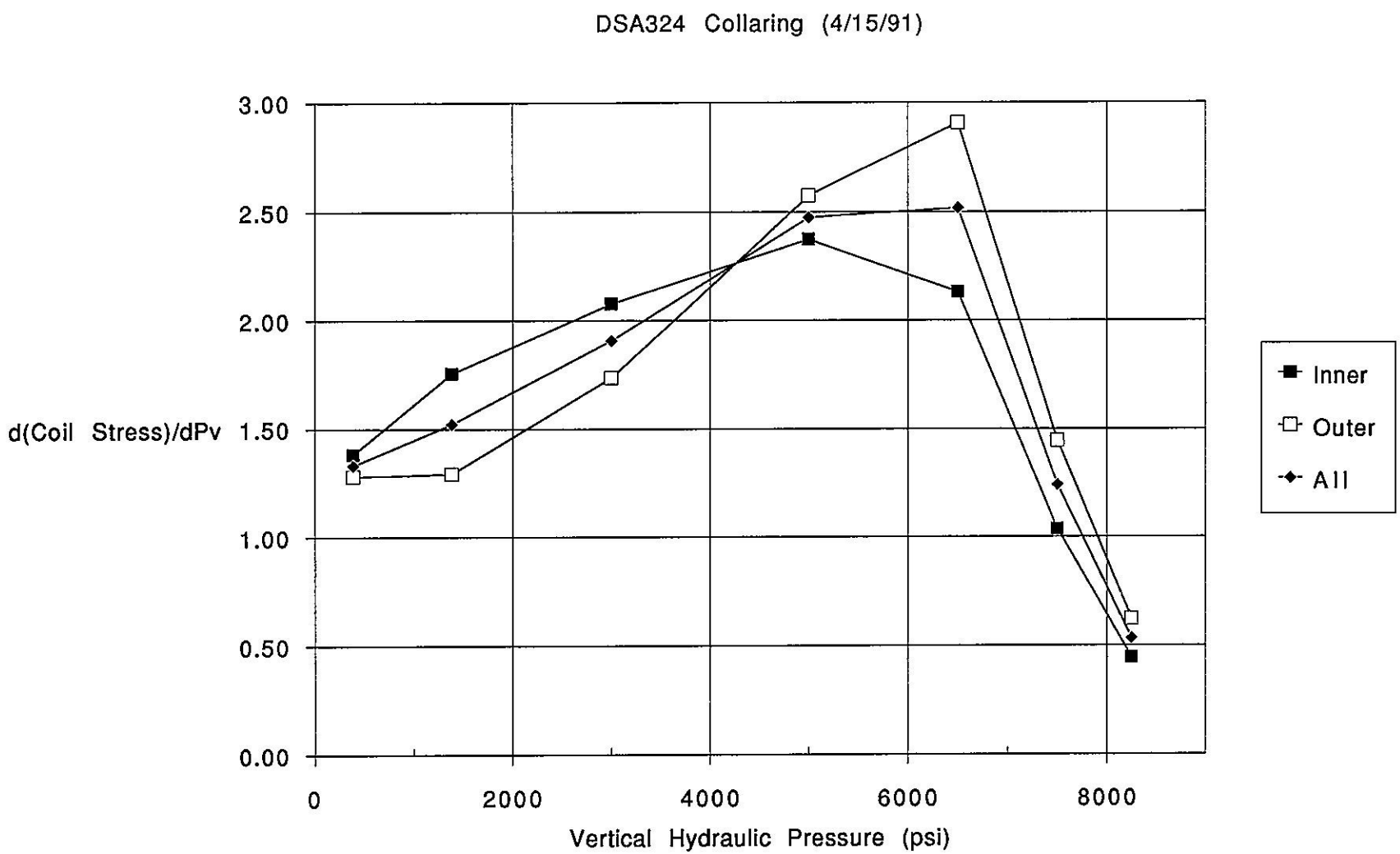
DSA324 Collaring (4/15/91)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
d(Coil Stress)/dPv
0
2000
4000
6000
8000
Vertical Hydraulic Pressure (psi)
Inner
Outer
All

Figure 5

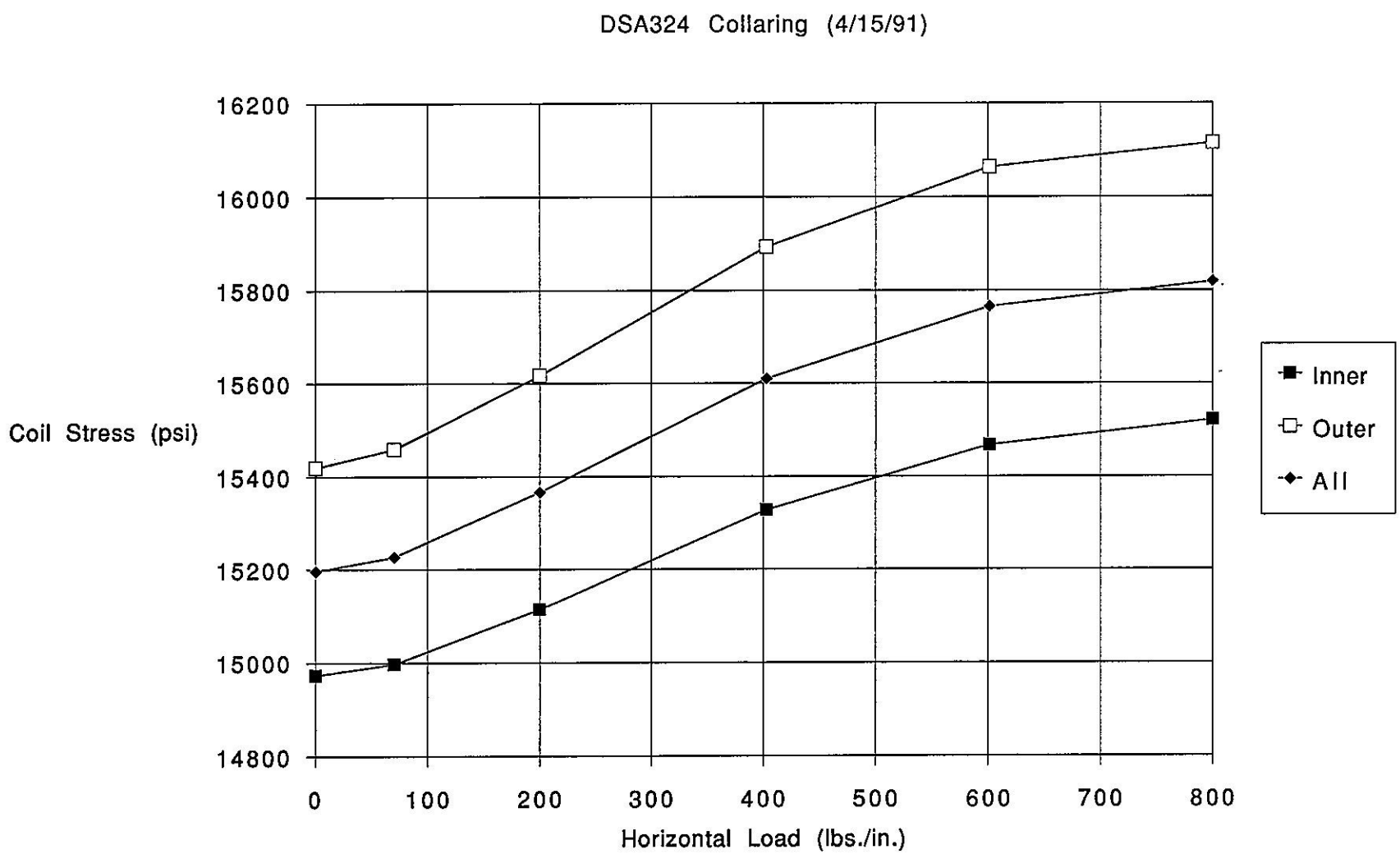
DSA324 Collaring (4/15/91)
Coil Stress (psi)
16200
16000
15800
15600
15400
15200
15000
14800
0
100
200
300
400
500
600
700
800
Horizontal Load (lbs./in.)
Inner
Outer
All

Figure 6

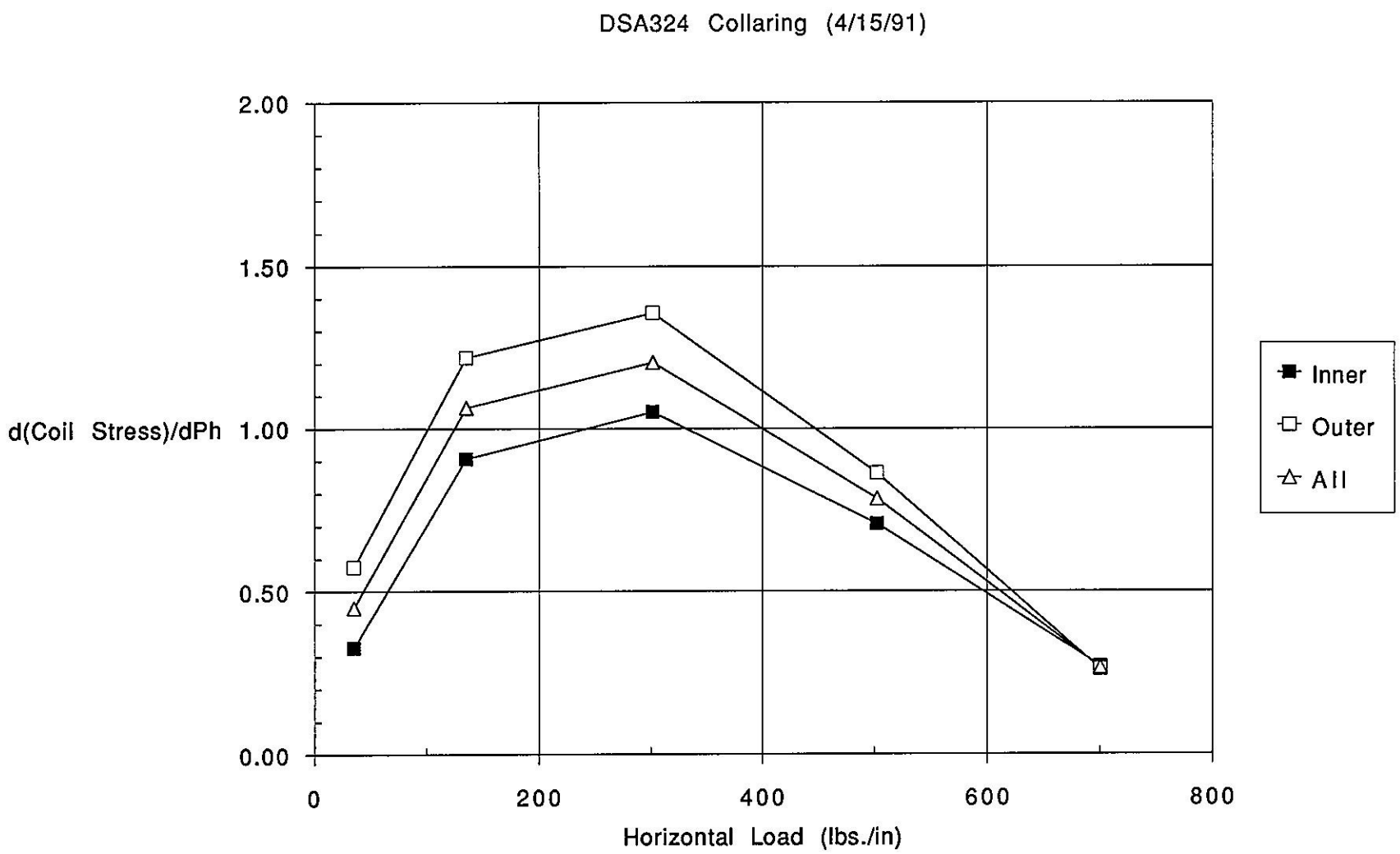
DSA324 Collaring (4/15/91)
2.00
1.50
1.00
0.50
0.00
d(Coil Stress)/dPh
0
200
400
600
800
Horizontal Load (lbs./in)
Inner
Outer
All

Figure 7

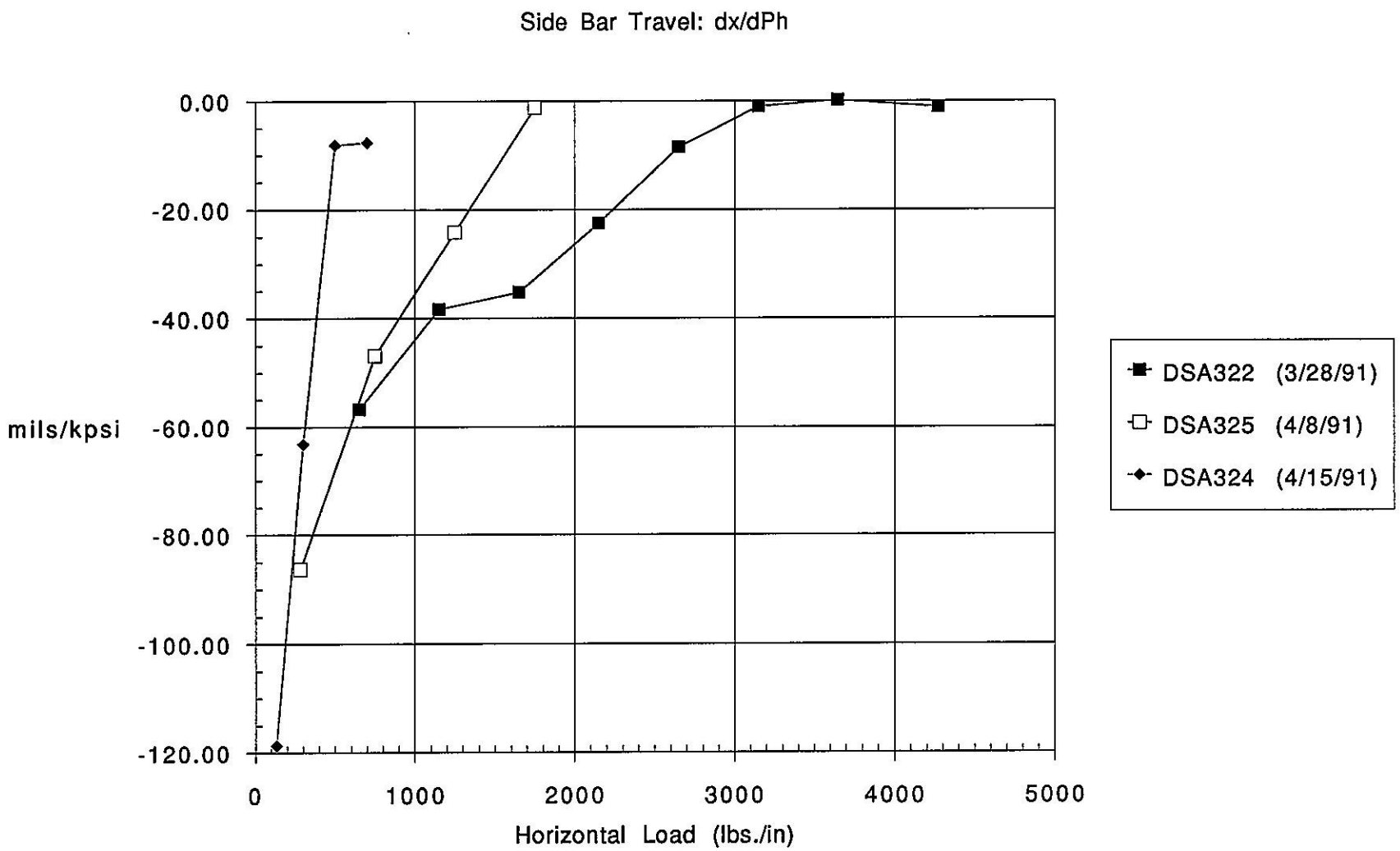
Side Bar Travel: dx/dPh
0.00
-20.00
-40.00
-60.00
-80.00
-100.00
-120.00
mils/kpsi
0
1000
2000
3000
4000
5000
Horizontal Load (lbs./in)
DSA322 (3/28/91)
DSA325 (4/8/91)
DSA324 (4/15/91)

Figure 8