DSA323 Collar Keying Data

TS-SSC 91-36
Steve Delchamps
February 22, 1991

Introduction: DSA323 will be the second* in the Fermilab series of 50 mm aperture 1.5 m model SSC dipole magnets to be cold tested. Two attempts to key the DSA323 collared coil were made, the first on 2/14/91 and the second 2/15/91. The second keying attempt was successful. Both attempts are described in this memo.

Since one of the goals of magnet DSA323 is to try to reproduce the behavior of DSA321 **[1,2]**, no extra kapton pole shims were added to the DSA323 coil insulation during coil package assembly.

Studies of initial 50 mm coil sizing data **[3]** had indicated that most of the coil size variations were from curing tooling features, and would therefore be reproducible. DSA323 was to be built with coils that had similar characteristics to those used in DSA321. Because of irregularities in the coil curing process, this was not possible. Appendix I reviews the coil sizing information for the coils used in DSA323.

There are several other differences between DSA323 and DSA321-322. The strain gage pack in DSA323 was placed two full packs away from the center of the coil so that the strain gage block magnitization **[4]** would not interfere with Lab 2 harmonics measurements. Also, DSA323 has heater strips in all four quadrants. Quadrants 1 and 3 have SSC-2 heaters, while quadrants 2 and 4 have SSC-1 heaters **[5]**.

The press used to key DSA323 was the new 84" short press in IB3, with laminated upper tooling and EDM lower tooling. This meant that the features which index the horizontal flats on the lifting points notches of the collars were present on both the upper and lower tooling, in contrast to DSA322 for which the features were absent on the upper tooling **[6]**.

General Procedure: The general procedure followed in both keying attempts was that specified by Jim Strait for the second keying of experimental collared coil DSA322. Figure 1 shows the arrangement of the collared coil in the press.

1- The collared coil was placed in the tooling so that there was 8" between the north end of the tooling and the first collar pack. (The magnet lead end pointed north.)

2- Cylinders 1, 6 and 7 on both sides of the press were disconnected, so that the conversion factor from pump psi to coil psi should be 2.56.

3- A 5 mil brass shim was placed between the upper tooling and the press platen.

4- Linear potentiometers were installed on both sides of the press to measure the key travel during key insertion.

5- Strain gage readings were taken at 0 pump psi, at line pressure (about 750 psi), at 2000, 4000, 6000, and 8000 pump psi. Tooling gap measurements were taken at five positions on each side of the press at 2000, 4000, 6000, and 8000 pump psi.

*** DSA322 is not to be yoked, but will rather be used for keying experiments in the 84" press. Details of DSA322's first keying can be found in reference [6] of this memo.**

First Keying Attempt (2/14/91):

On the first keying attempt, the press closed at 8000 pump psi. At both ends of the magnet, it was possible to insert a length of keying material by hand on the west side of the collared coil (quadrants 1 and 4.) On the east side (quadrants 2 and 3), it was only possible to insert the key by hand 1/3 to 1/2 way into the slot.

An attempt was begun to insert the keys with horizontal load, but this was abandoned when it was observed that the keys were hitting the edges of the keyway near the magnet ends. This was because the keys had been cut to the exact length of the collared coil, and so were not supported by the pusher bar clips near the ends, and therefore had some sagging.

The strain gage data and press gap data for the first keying attempt are given in Tables 1a and 1b. Figure 2 shows the strain gage data for the first keying attempt.

Second Keying Attempt (2/15/91):

In preparing for this attempt, the collared coil was removed from the tooling. For this reason, it was not known whether the details of press closure and the orientation of the collar laminations would be the same as for the first keying attempt.

The keys were cut long enough so that they would be fully supported by pusher bar clips well beyond the ends of the collared coil. A lubricant, Dow-Corning Gn spray containing molybdinum disulfide, was sprayed on the key lengths before they were mounted in the clips.

At 8000 pump psi, the press was fully closed. As in the first keying attempt, on the west side a piece of key material could be inserted with slight pressure by hand, while on the east side, it could only be inserted 1/3 to 1/2 way in this manner.

Hipots and resistance checks were done with the press at 8000 pump psi. With 500 psi side pump pressure, the keys on the west side appeared to be well seated. The east side looked a little more ambiguous. The side pressure was increased very slightly. The linear pot measurements indicated that the east side was *more* closed than the west side; however, the pots on the east side were close to the limit of their useful range. (See Appendix II for the details of the linear pot data.)

With the horizontal pressure still applied, the vertical pressure was taken to 4000 pump psi, and then to 0 pump psi. The side pressure was then removed.

When the collared coil was removed from the tooling, it was observed that the keys were not perfectly flush with the collar lamination surface. Micrometer measurements showed that in the gage pack region for example, the distance between opposing key surfaces was about 20 mils greater than at the end of the collared coil. Using hammers and metal flats to hammer the keys, we were able to bring all surface-to-surface measurements to within a mil of one-another.

Tables 2a and 2b show the strain gage and press gap data for the second keying attempt. Figure 3 shows the strain gage data plotted for various steps in the procedure.

After the keys had been hammered in, measurements were made of the collar diameters at several azimuthal positions. These measurements are attached as Appendix III.

Discussion: For the second keying attempt, the springback losses were 4.47 kpsi and 8.67 kpsi for the inner and outer coils respectively. For DSA322, the losses were 4.4 and 8.6 kpsi **[6]**.

The average inner and outer coil pole stresses were 6.86 and 11.30 kpsi when the coil was removed from the press. After hammering in the keys (~20 mils in some locations), the stresses were 6.90 and 11.47 kpsi for the inner and outer coils, respectively. For DSA322, the final stresses were 5.8 and 4.7 kpsi for the inner and outer coils [6].

It is not clear in retrospect that the lubrication of the keys helped in any way.

Figure 4 shows the average coil stress (inners + outers) plotted against the vertical press pump pressure. Both keying attempts are shown, and the second pass on DSA322 is shown for comparison. (The DSA322 numbers are taken from reference [6].) Also shown is the line with the expected slope for the press arrangement used for DSA323.

Notes

[1] TS-SSC 91-029, S. Gourlay, "Summary of DSA321 Quench Performance," February 12, 1991.

[2] TS-SSC 91-031, T. Jaffery, "DSA321 Harmonics at Lab 2," February 4, 1991.

[3] TS-SSC 91-023, M. Wake, Memo concerning 50 mm coils, January 31, 1991.

[4] TS-SSC 91-024, M. Wake, "Magnetization Effect of Pressure Gage Block," January 31, 1991.

[5] Chris Haddock, private communication. Both varieties of SSC heater use the same copper-plated 1 mil 304 stainless steel conductor, with 24" unplated heating pads. The difference between the SSC1 and SSC2 heaters is the insulation; SSC1 is just adhesive-backed kapton on both sides, while SSC2 has glass-impregnated polyimide with adhesive-backed kapton on the outside.

[6] TS-SSC 91-030, J. Strait, "First Collaring of DSA322," February 12, 1991.

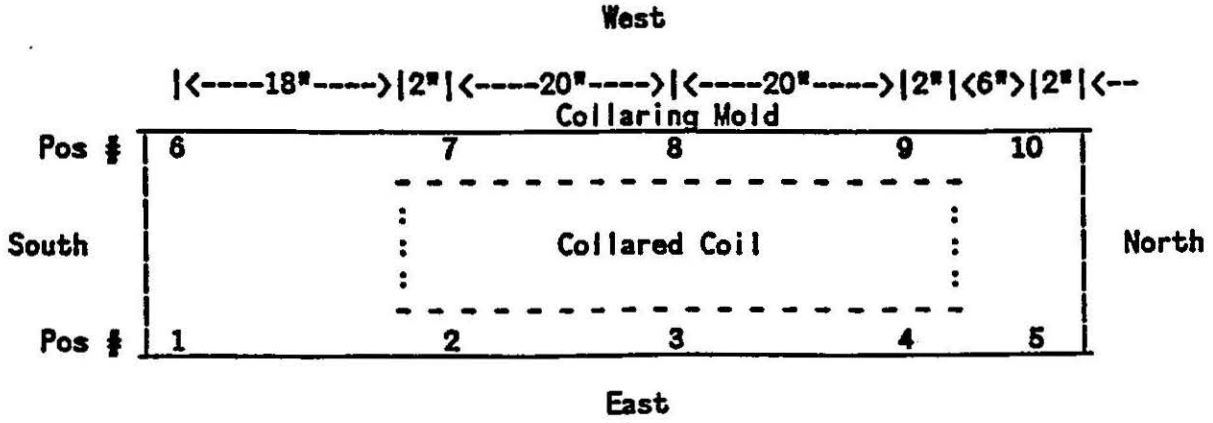

West
|<----18"---->|2"|<----20"---->|<----20"---->|2"|<6">|2"|<--
Collaring Mold
Pos #
6
7
8
9
10
South
Collared Coil
North
Pos #
1
2
3
4
5
East

Figure 1.

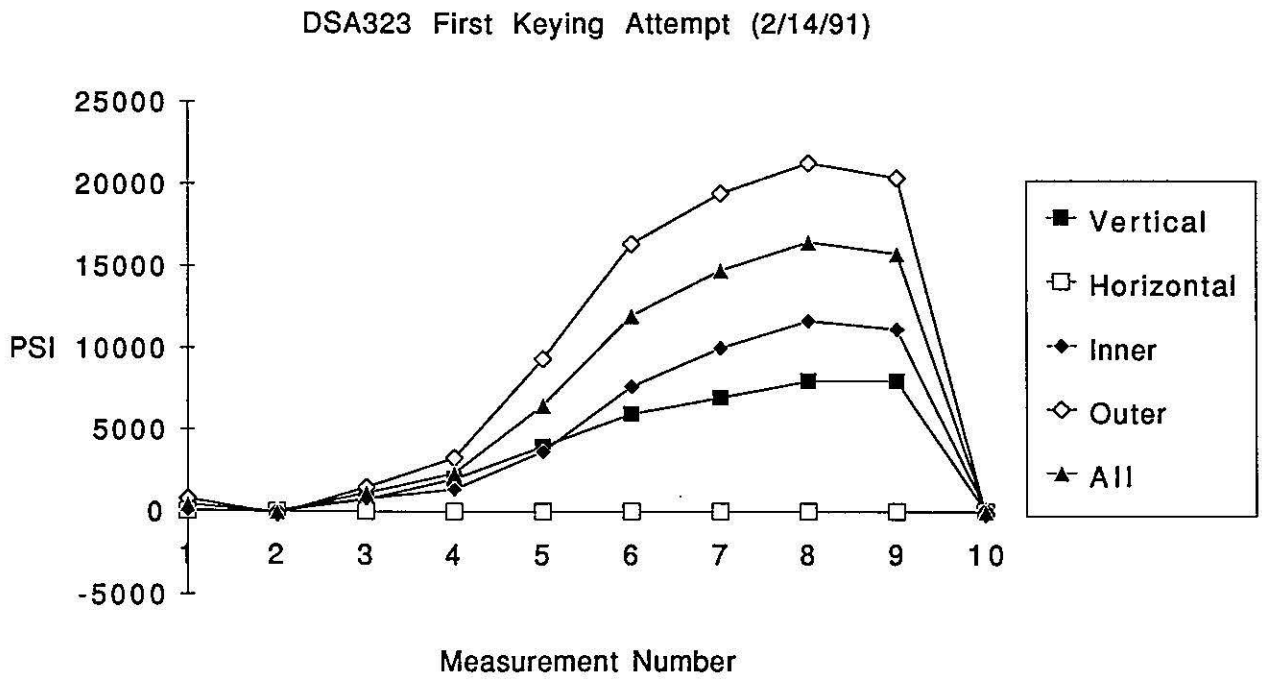

DSA323 First Keying Attempt (2/14/91)
25000
20000
15000
10000
5000
0
-5000
PSI
1
2
3
4
5
6
7
8
9
10
Measurement Number
Vertical
Horizontal
Inner
Outer
All

Figure 2.

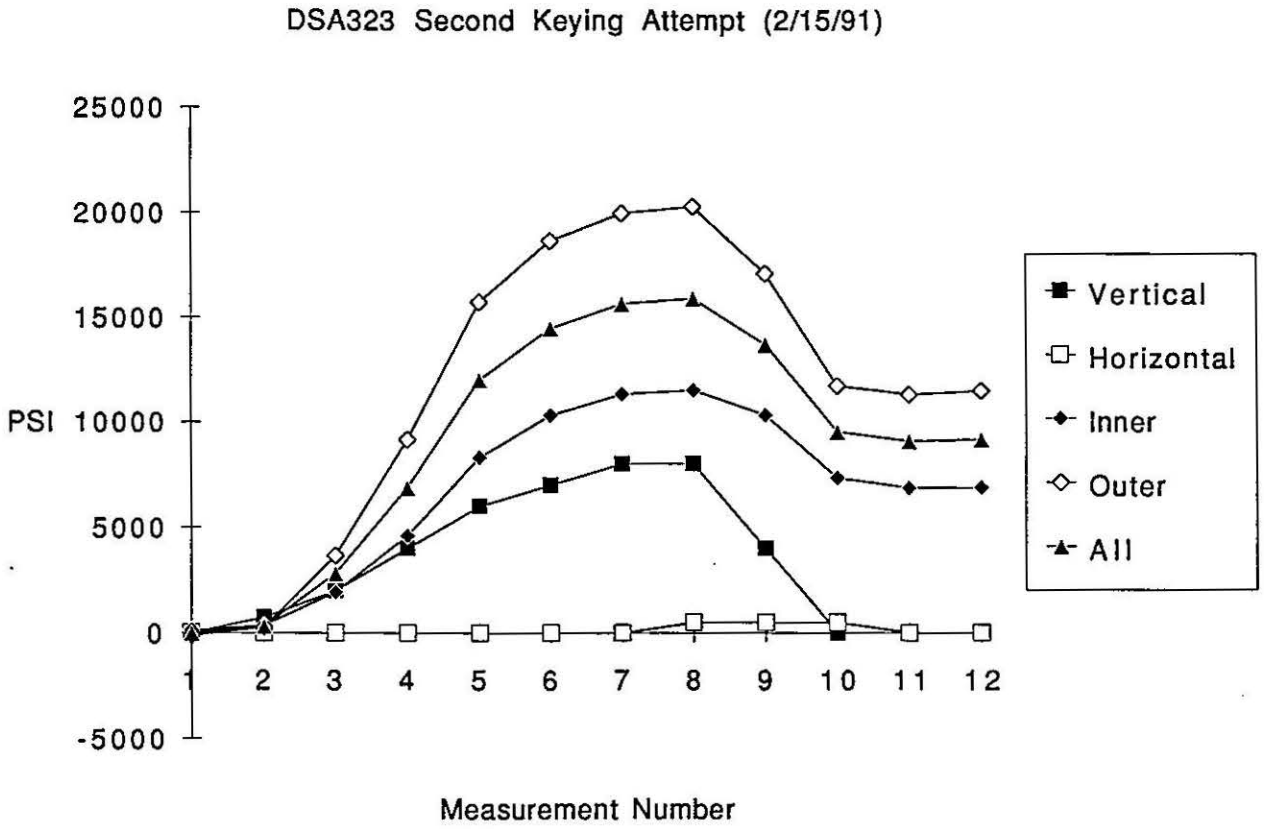

DSA323 Second Keying Attempt (2/15/91)
25000
20000
15000
10000
5000
0
-5000
PSI
1
2
3
4
5
6
7
8
9
10
11
12
Measurement Number
Vertical
Horizontal
Inner
Outer
All

Figure 3.

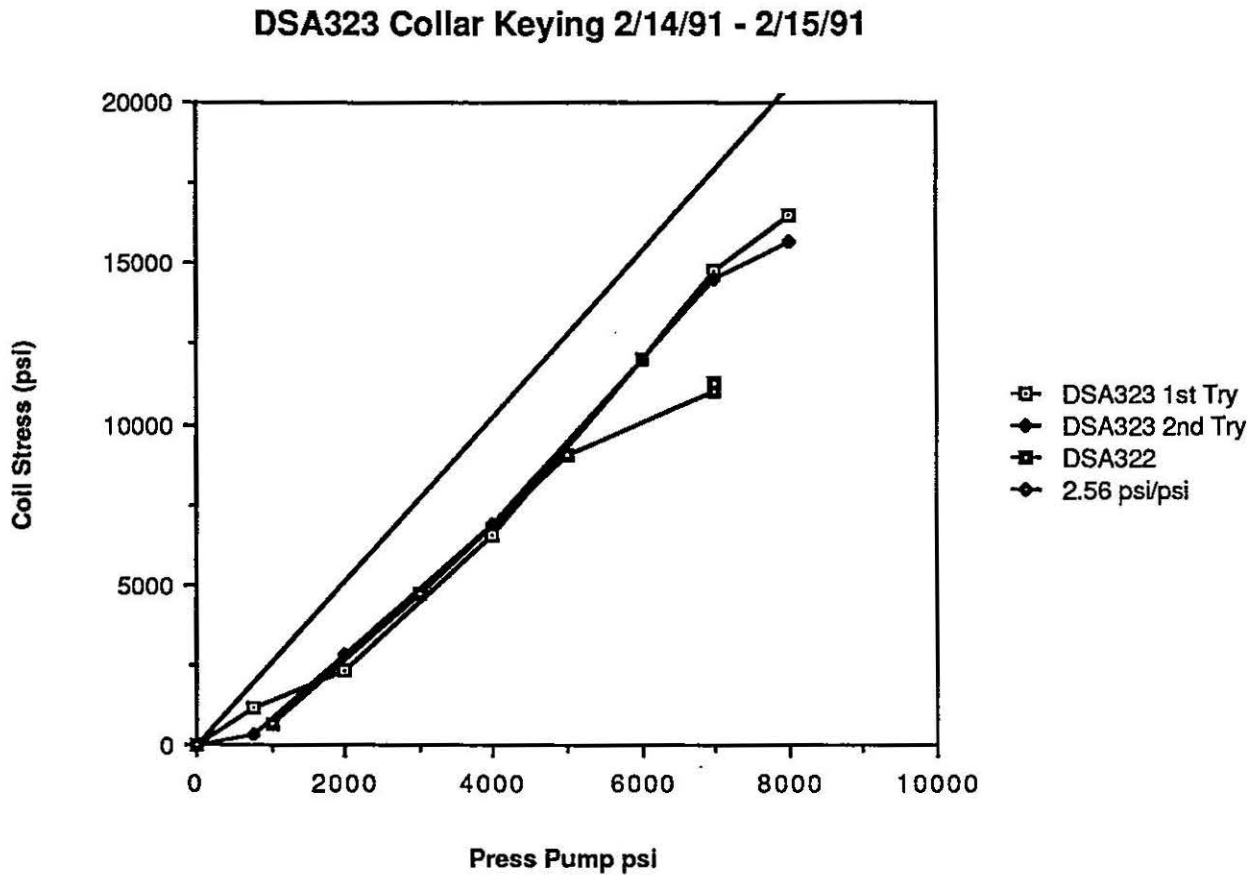

DSA323 Collar Keying 2/14/91 - 2/15/91
Coil Stress (psi)
20000
15000
10000
5000
0
0
2000
4000
6000
8000
10000
Press Pump psi
DSA323 1st Try
DSA323 2nd Try
DSA322
2.56 psi/psi

Figure 4.

	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		A024	Active	Inner	1	2.03	349.793	85.6	3.0E+00	5.27E-03	0.00000
6		A025	Active	Inner	2	2.03	349.952	54.2	3.5E+00	6.55E-03	0.00000
7		C018	Comp.	Inner	1&2	2.03	349.895				
8		A027	Active	Inner	3	2.03	349.696	28.1	3.9E+00	4.26E-03	0.00000
9		A026	Active	Inner	4	2.03	349.497	0.4	3.1E+00	4.56E-03	0.00000
10		C019	Comp.	Inner	3&4	2.03	349.968				
11		A028	Active	Outer	1	2.03	350.189	-87.7	4.0E+00	4.03E-03	0.00000
12		A029	Active	Outer	2	2.03	349.735	-17.6	4.7E+00	3.88E-03	0.00000
13		C011	Comp.	Outer	1	2.03	349.797				
14		C015	Comp.	Outer	2	2.03	349.946				
15		A030	Active	Outer	3	2.03	349.896	-115.2	4.4E+00	3.97E-03	0.00000
16		A032	Active	Outer	4	2.03	350.005	-10.5	3.6E+00	4.20E-03	0.00000
17		C016	Comp.	Outer	3	2.03	349.894				
18		C017	Comp.	Outer	4	2.03	349.987				
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	2/7/91	0	0	0	98	800	449			
24	2	2/14/91	0	0	0	101	-99	1			
25	3	2/14/91	0	750	0	784	1495	1140	0.91	2.13	1.52
26	4	2/14/91	0	2000	0	1368	3307	2338	0.47	1.45	0.96
27	5	2/14/91	0	4000	0	3685	9375	6530	1.16	3.03	2.10
28	6	2/14/91	0	6000	0	7663	16375	12019	1.99	3.50	2.74
29	7	2/14/91	0	7000	0	10056	19473	14764	2.39	3.10	2.75
30	8	2/14/91	0	8000	0	11665	21302	16483	1.61	1.83	1.72
31	9	2/14/91	0	8000	0	11191	20410	15801			
32	10	2/14/91	0	0	0	130	-86	22	1.38	2.56	1.97

Table 1a. First Keying Attempt

Press Gaps:

Pos 1	XXXXXXX XXXXXXX	>.015	>.015	0	0	0	
Pos 2	XXXXXXX XXXXXXX	>.015	>.015	.002	0	0	
Pos 3	XXXXXXX XXXXXXX	>.015	>.015	.007	.002	0	
Pos 4	XXXXXXX XXXXXXX	>.015	>.015	.006	.001	0	
Pos 5	XXXXXXX XXXXXXX	>.015	>.015	.004	0	0	
Pos 6	XXXXXXX XXXXXXX	>.015	.009	0	0	0	
Pos 7	XXXXXXX XXXXXXX	>.015	>.015	.007	0	0	
Pos 8	XXXXXXX XXXXXXX	>.015	>.015	.011	.004	0	
Pos 9	XXXXXXX XXXXXXX	>.015	>.015	.012	.003	0	
Pos 10	XXXXXXX XXXXXXX	>.015	>.015	.009	0	0	

Table 16. Press Gap Data from First Attempt

	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		A024	Active	Inner	1	2.03	349.793	85.6	3.0E+00	5.27E-03	0.00000
6		A025	Active	Inner	2	2.03	349.952	54.2	3.5E+00	6.55E-03	0.00000
7		C018	Comp.	Inner	1&2	2.03	349.895				
8		A027	Active	Inner	3	2.03	349.696	28.1	3.9E+00	4.26E-03	0.00000
9		A026	Active	Inner	4	2.03	349.497	0.4	3.1E+00	4.56E-03	0.00000
10		C019	Comp.	Inner	3&4	2.03	349.968				
11		A028	Active	Outer	1	2.03	350.189	-87.7	4.0E+00	4.03E-03	0.00000
12		A029	Active	Outer	2	2.03	349.735	-17.6	4.7E+00	3.88E-03	0.00000
13		C011	Comp.	Outer	1	2.03	349.797				
14		C015	Comp.	Outer	2	2.03	349.946				
15		A030	Active	Outer	3	2.03	349.896	-115.2	4.4E+00	3.97E-03	0.00000
16		A032	Active	Outer	4	2.03	350.005	-10.5	3.6E+00	4.20E-03	0.00000
17		C016	Comp.	Outer	3	2.03	349.894				
18		C017	Comp.	Outer	4	2.03	349.987				
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	2/15/91	0	0	0	125	-101	12			
24	2	2/15/91	0	750	0	383	272	328			
25	3	2/15/91	0	2000	0	1928	3669	2798	1.24	2.72	1.98
26	4	2/15/91	0	4000	0	4600	9168	6884	1.34	2.75	2.04
27	5	2/15/91	0	6000	0	8324	15749	12037	1.86	3.29	2.58
28	6	2/15/91	0	7000	0	10316	18666	14491	1.99	2.92	2.45
29	7	2/15/91	0	8000	0	11330	19973	15651	1.01	1.31	1.16
30	8	2/15/91	0	8000	500	11507	20275	15891			
31	9	2/15/91	0	4000	500	10328	17092	13710	0.29	0.80	0.55
32	10	2/15/91	0	0	500	7343	11735	9539	0.75	1.34	1.04
33	11	2/15/91	0	0	0	6856	11299	9078			
34	12	2/15/91	0	0	0	6895	11474	9185			

Table 2a. Second Keying Attempt

Press Gaps:			MILS					
Pos 1	XXXXXXX XXXXXXX	XXXXXXX XXXXXXX	>15	004	0	0	0	
Pos 2	XXXXXXX XXXXXXX	XXXXXXX XXXXXXX	" "	> 15	.006	0	0	
Pos 3	XXXXXXX XXXXXXX	XXXXXXX XXXXXXX	" "	> 15	.006	.0015	0	
Pos 4	XXXXXXX XXXXXXX	XXXXXXX XXXXXXX	" "	> 15	.006	.0015	0	
Pos 5	XXXXXXX XXXXXXX	XXXXXXX XXXXXXX	" "	> 15	.003	0	0	
Pos 6	XXXXXXX XXXXXXX	XXXXXXX XXXXXXX	>15	0	0	0	0	
Pos 7	XXXXXXX XXXXXXX	XXXXXXX XXXXXXX	>15	.016	.001	0	0	
Pos 8	XXXXXXX XXXXXXX	XXXXXXX XXXXXXX	>15	.013	.003	0	0	
Pos 9	XXXXXXX XXXXXXX	XXXXXXX XXXXXXX	>15	.013	.003	0	0	
Pos 10	XXXXXXX XXXXXXX	XXXXXXX XXXXXXX	>15	.011	0	0	0	

E.C. & D.M.
2-15-91

Table 2b. Press Gap Data from Second Attempt

Appendix I: Coil Size Measurements for DSA323

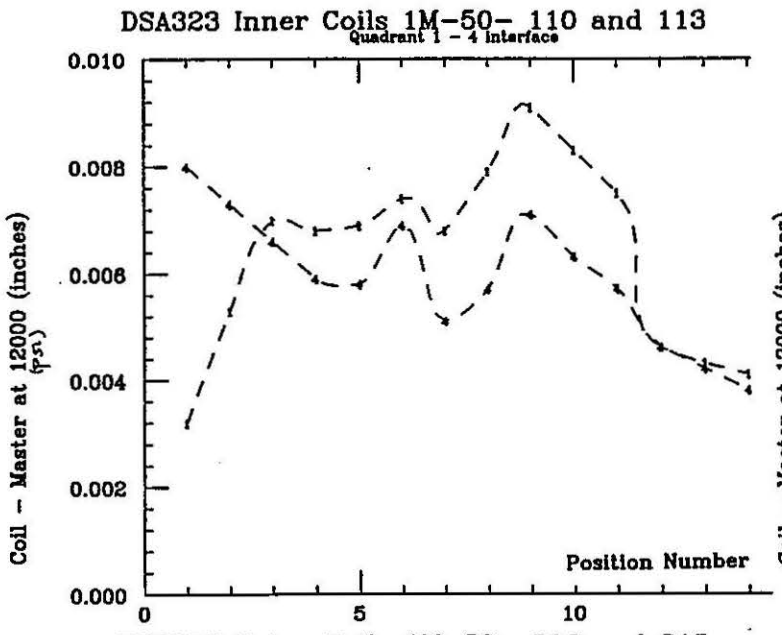
The coils used in DSA323 are:

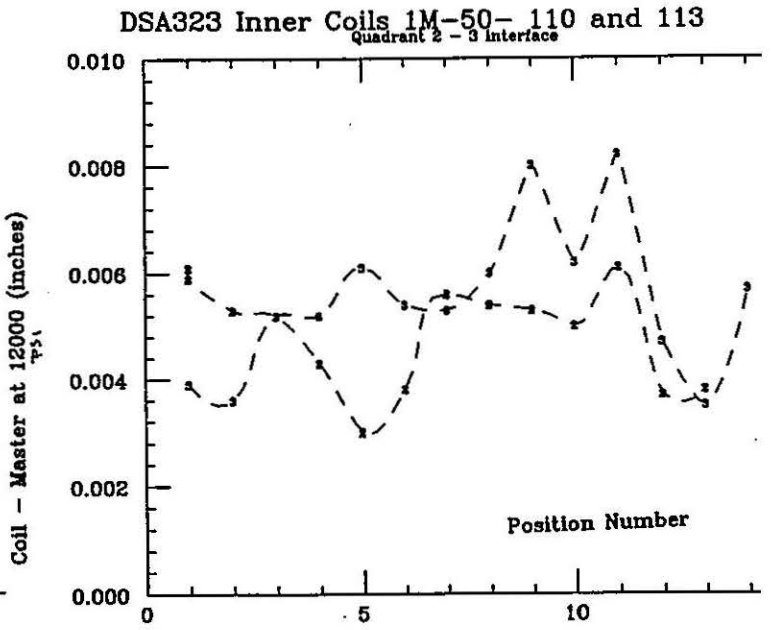
upper inner: 1M-50-110
lower inner: 1M-50-113
upper outer: 1M-50-216
lower outer: 1M-50-215

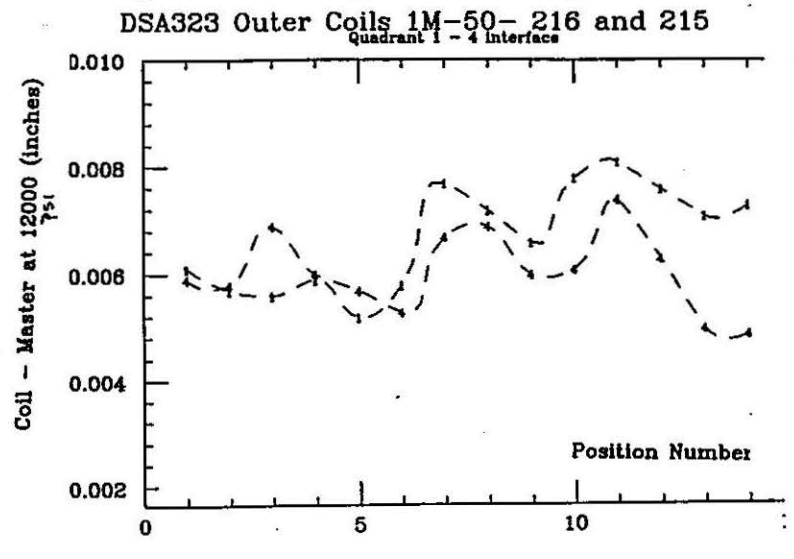
Some of the overall coil properties are given in the following table.

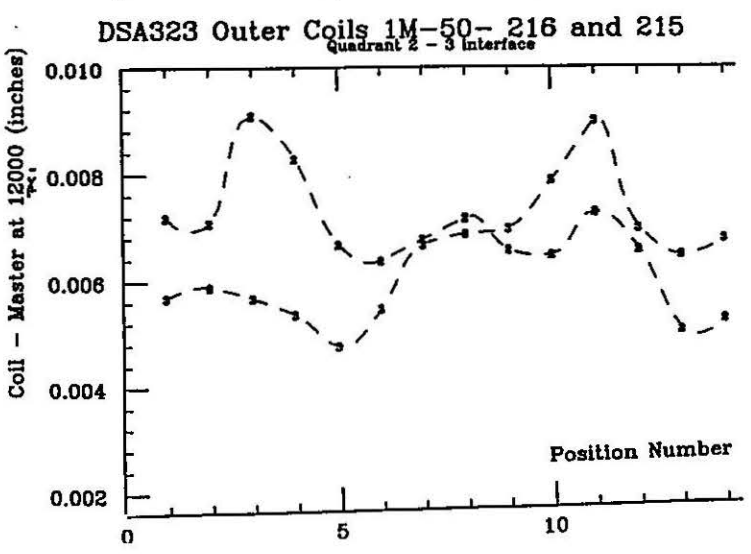
coil number	avg. size quad 1/3	avg. size quad 2/4	avg. size whole coil	size range
110	.0064	.0049	.0056	.0061
113	.0055	.0059	.0057	.0047
215	.0065	.0061	.0063	.0042
216	.0067	.0069	.0068	.0040

The coil size profiles are shown in the figures below. There are several positions at which coil pairs are badly matched, and in general there are differences between upper and lowerc coils at a given position of 2 - 3 mils.



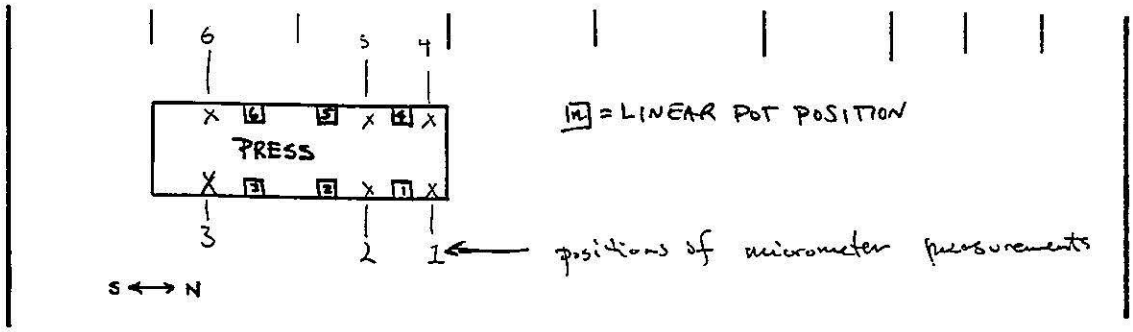






Appendix II: Linear Potentiometer Measurements of Key Closure for DSA323

The figure below shows the positions on the 84" press at which linear pots were installed.



The following table contains the linear pot and micromenter data during the second keying attempt of DSA323.

The second and third columns show the resistance in ohms measured before and after collaring (these should be the same), and at 500 pump psi side pressure. Note that the nominal resistance of each pot is 0 to 1000 Ohms, so that at positions 3, 2, 1, and 6 the high reading is either uncomfortably close to the limit or maxed out.

The absolute and fractional changes in resistance are given in the fourth and fifth columns. The inferred change in position (in inches) is given in the sixth column, using a conversion factor that had been determined earlier. The nominal value for a completely keyed magnet is .585".

The final three columns contain micrometer data from the positions shown in the figure above. Because the press columns get in the way, it is not possible to take micrometer readings at the linear pot positions. Simple subtraction of the data from the sixth and ninth columns, admittedly not an optimal procedure, gives deviations that range from +20 mils to -14 mils for the pots that are not operating outside their nominal resistance range.

FERMILAB **ENGINEERING NOTE** | SECTION 755/SSC mag Anal | PROJECT | SERIAL-CATEGORY | PAGE 1

SUBJECT: Small Collaring Press 3852/LinPot Measurements — Mag # DSA 323 — IBB Bld.

NAME: K Bri— 9574/S. Paulek

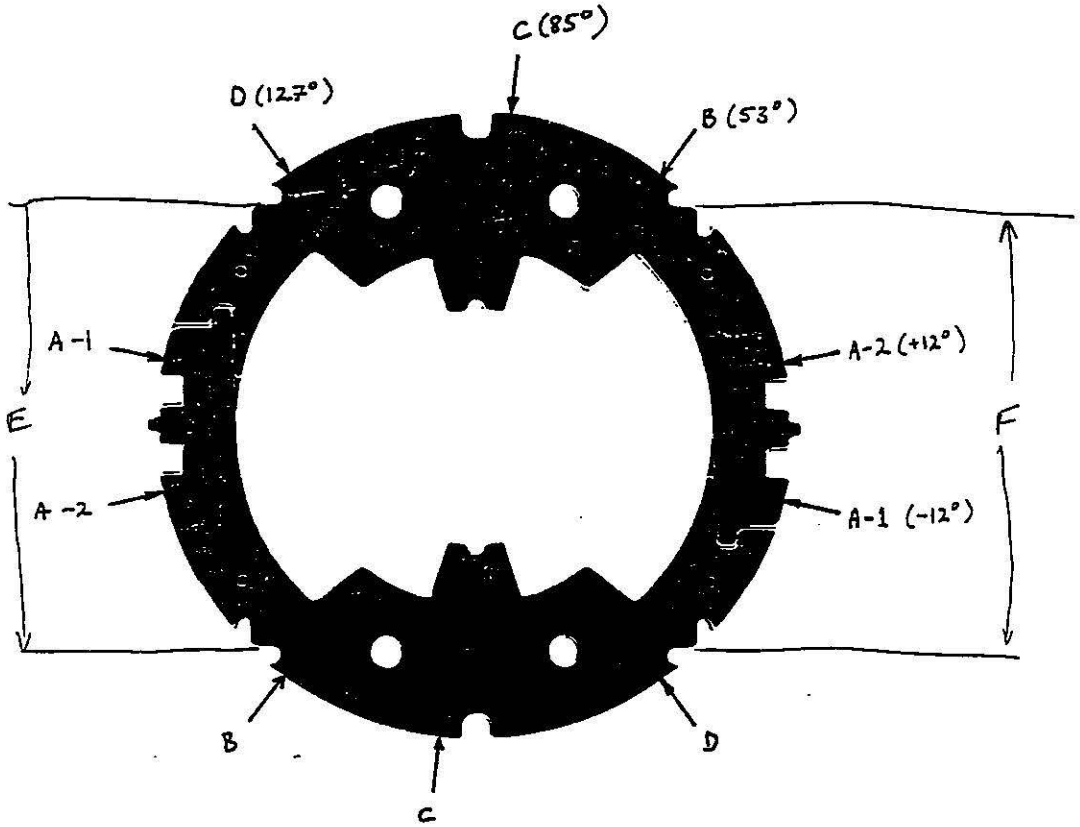
DATE: 3/4/91 | REVISION DATE:

Sensor #/Ch #	Before (After) Collaring	@ 500psi	ΔR	ΔDISK/ΔR (mm/Ω)	ΔD	MCasured TRAVEL @500psi	MCasured TRAVEL No Press	.585
3 / 0	456.55 (459.57)	893.31	436.76	.00134	.5853	4.199"	3.634"	.565
2 / 1	599.40 (600.98)	1096.66	497.22	.00132	.6564	4.193"	3.623	.570
1 / 2	568.64 (569.24)	1015.73	447.79	.00129	.5777	4.212	3.628	.584
6 / 3	387.08 (386.53)	837.11	450.03	.00124	.5580	4.201	3.629	.572
5 / 4	310.39 (311.15)	725.50	415.11	.00136	.5645	4.175	3.624	.551
4 / 5	285.27 (287.93)	727.70	442.43	.00127	.5619	4.204	3.630	.574

Appendix III. Diameter Measurements of Collared Coil (Keyed)

The figure shows the azimuthal positions at which the collars were measured with micrometer after keying. The table above the figure gives the mean and rms values over the length of the collared coil. (Each azimuthal position was measured at 14 positions along the collared coil.) Also given are the values measured for an undeflected collar pack (keyed, braced with pieces of wood.) The full data set is available in the DSA323 traveller.

position	mean (inches)	rms (inches)	undeflected
A-1	5.348	.001	5.352
A-2	5.348	.000	5.351
B	5.314	.001	5.310
C	5.310	.000	5.304
D	5.313	.000	5.309
E	3.755	.002	not measured
F	3.754	.000	not measured



Collared Coil Viewed From the Lead End