DEVELOPMENT OF COLLAR KEYING PROCEDURES

J. STRAIT, FERMILAB

MSIM 5/14/91

OBJECTIVES

1) OPTIMIZE PROCEDURES TO MINIMIZE PEAK COIL STRESS IN COLLARING PRESS:
   a) "PRIMARY" METHOD: SET THE KEYS IN ("SQUARE KEY" METHOD).
   b) "BACKUP" METHOD: DRIVE THE KEYS IN ("TAPERED KEY" METHOD).

2) DETERMINE COIL SIZE + POLE SHIM COMBINATION THAT GIVES PRESTRESS IN THE TARGET WINDOW: 10 (8) ± 2 KPSI IN THE INNER (OUTER) COIL.

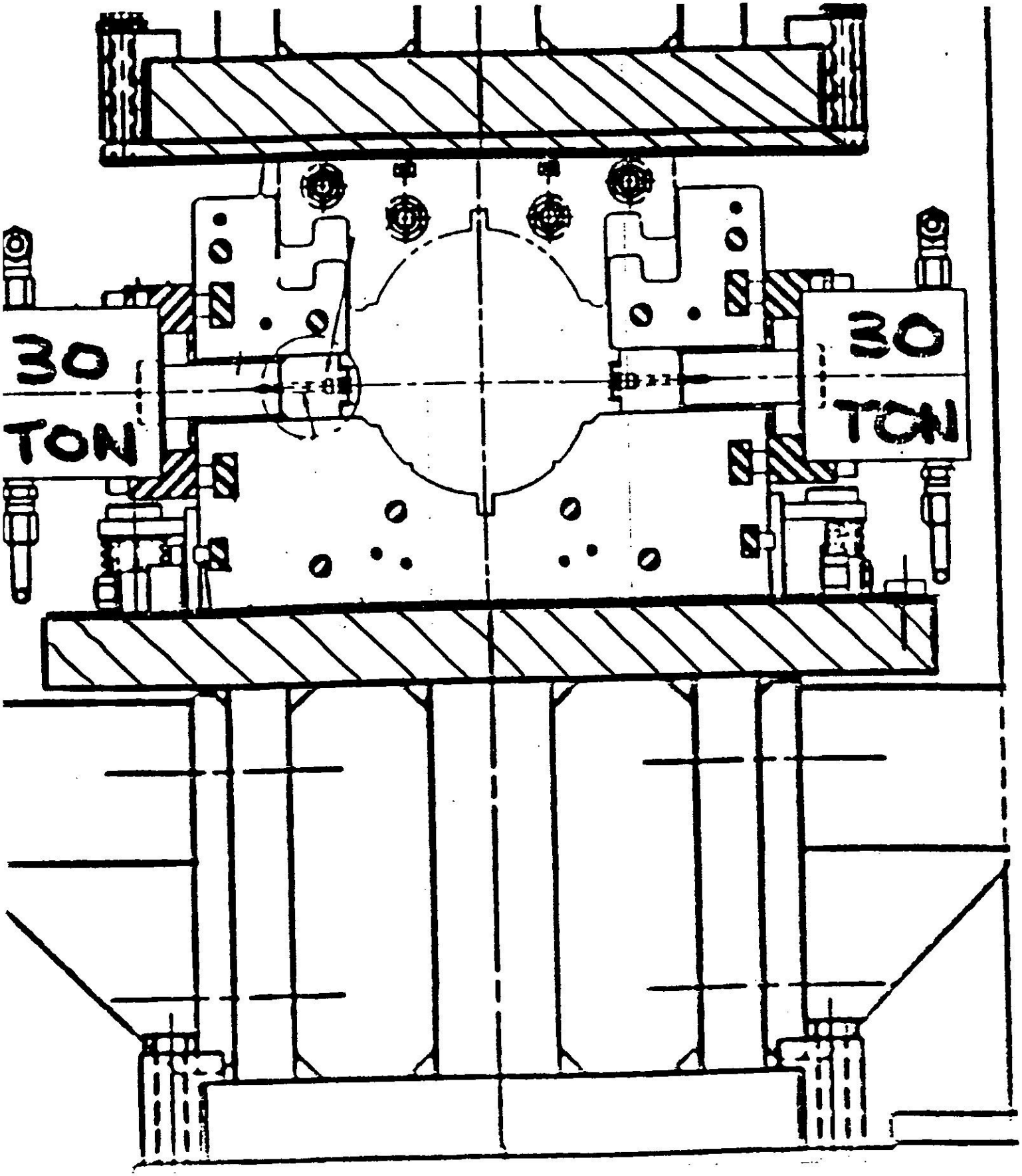
3) OPTIMIZING FIELD QUALITY IS NOT A PRIMARY OBJECTIVE BUT HARMONICS ARE MEASURED ON EACH ASSEMBLY

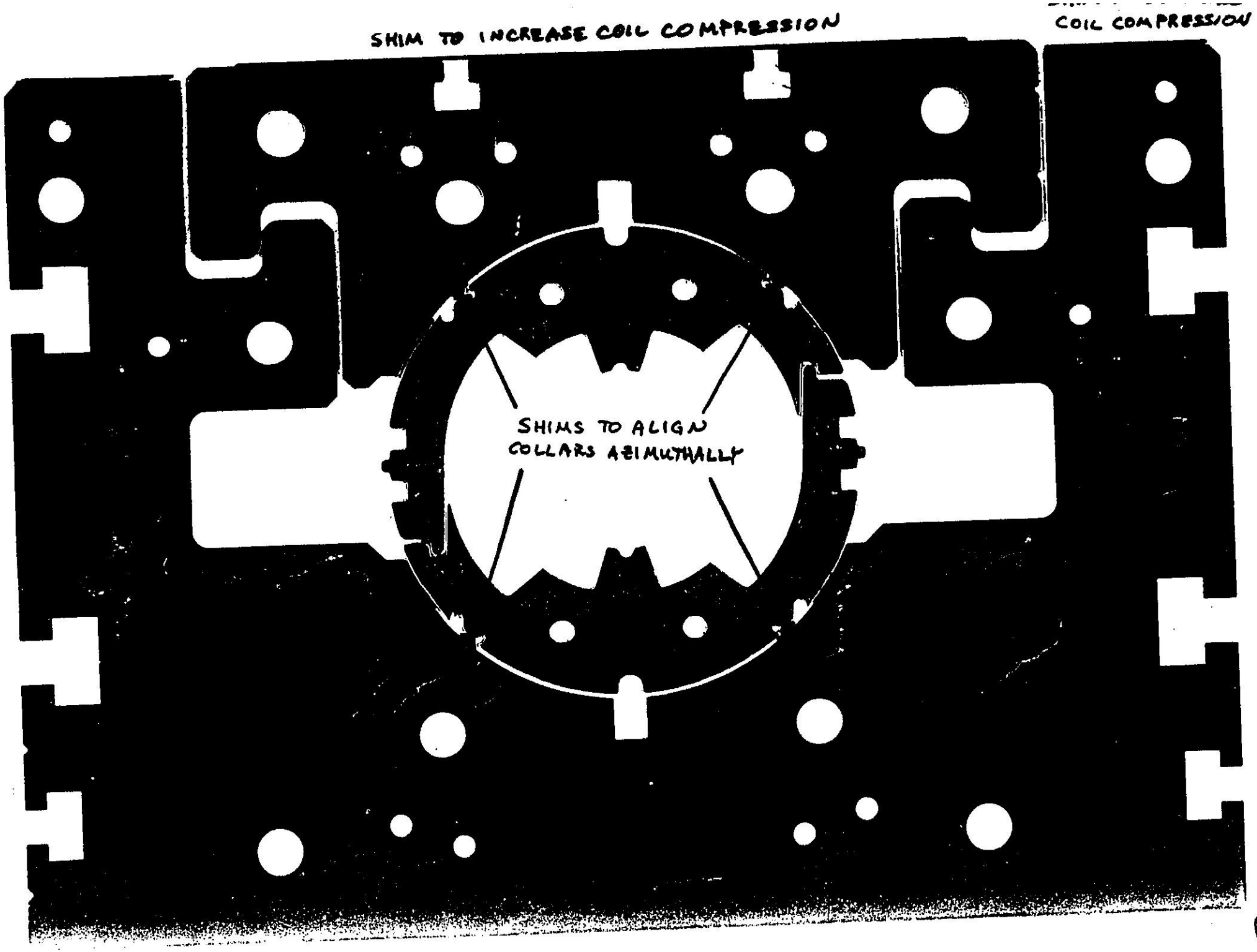
TOOLING IS DESIGNED TO OPERATE IN A "CLOSED CAVITY" CONDITION – COLLARS ARE CLOSED TO A FIXED DIMENSION AND THE KEYS ARE INSERTED.

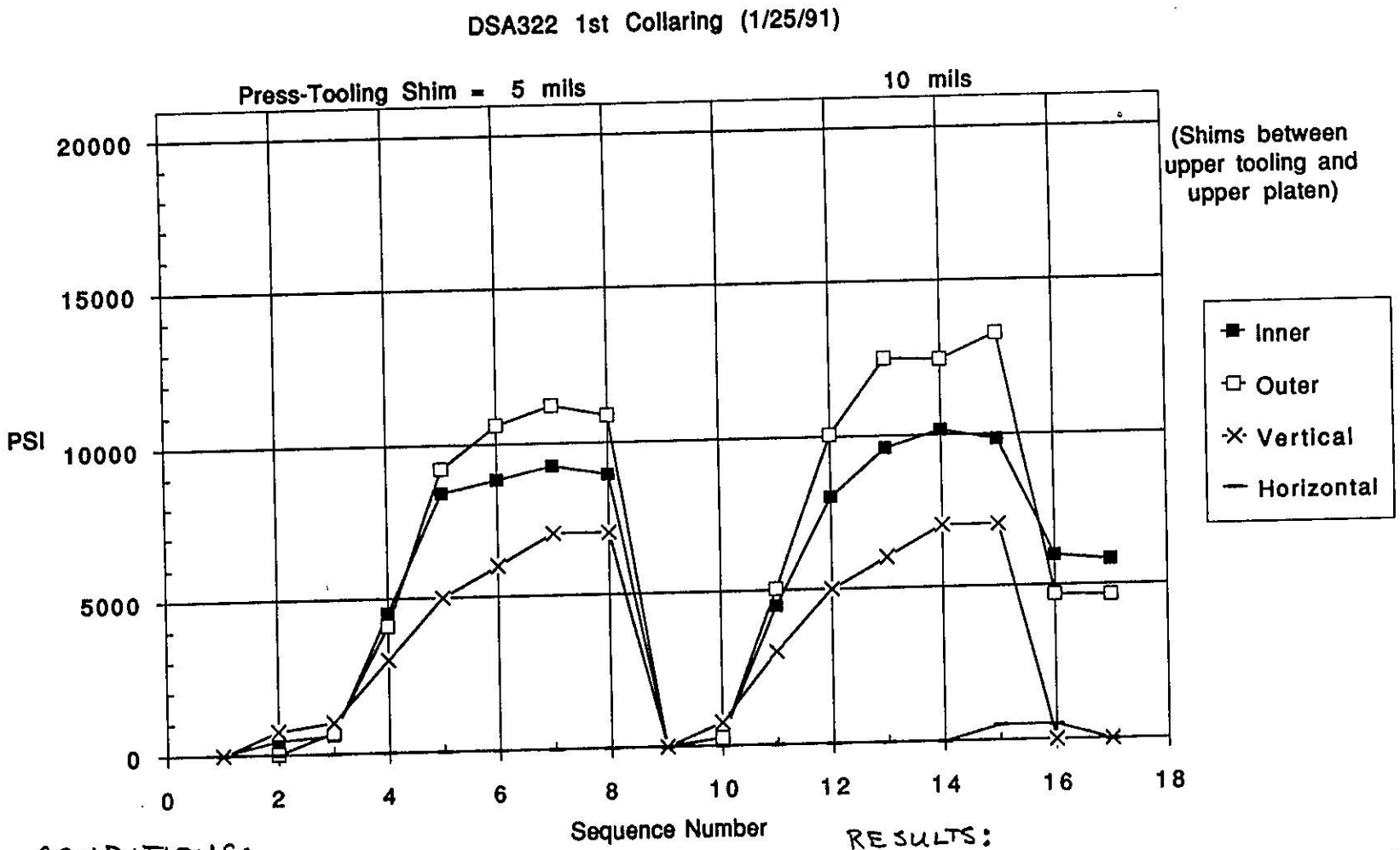
OPTIMIZE

1) VERTICAL PRESS STOP TO
   a) SET KEY INTO COLLARS WITH MINIMAL OVERCOMPRESSION ("SQUARE KEY" METHOD). OR
   b) DRIVE KEYS INTO COLLARS WITH MINIMAL SIDE FORCE ("TAPERED KEY" METHOD).

2) AZIMUTHAL ALIGNMENT OF UPPER RELATIVE TO LOWER COLLARS TO ACHIEVE THE SAME OBJECTIVES.


30
TON
30
TON


SHIM TO INCREASE COIL COMPRESSION
COIL COMPRESSION
SHIMS TO ALIGN
COLLARS AZIMUTHALLY

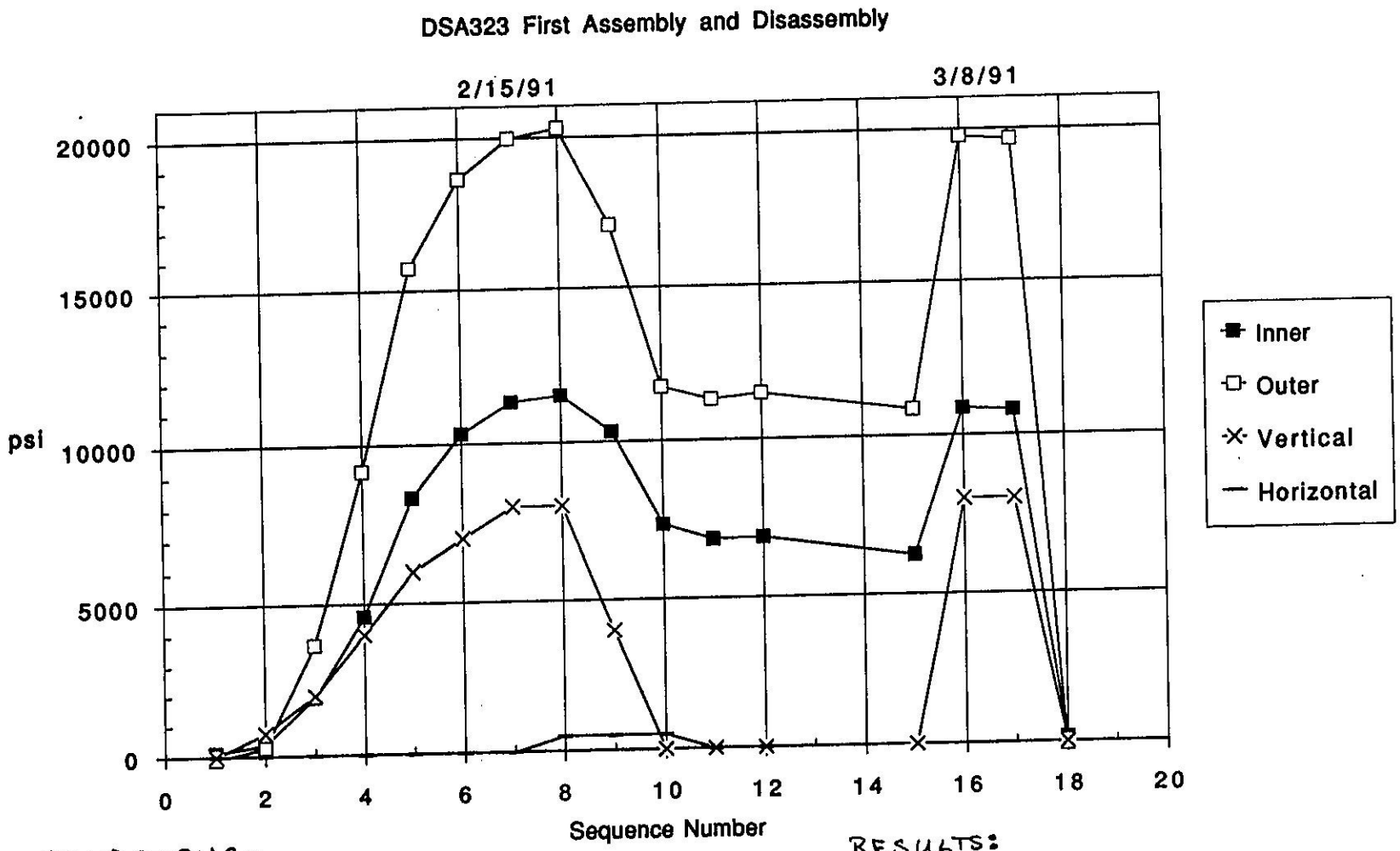


CONDITIONS:

1) NO POLE SHIMS
2) EDMed TOOLING
   UPPER - NO AZIMUTHAL ALIGNMENT FEATURES

RESULTS:

1) SIGNIFICANT AZIMUTHAL MIS-ALIGNMENT ~ 12-15 mil LEFT-RIGHT COLLAR CLOSURE DIFFERENCE
2) SIGNIFICANT OVERCOMPRESSION REQUIRED TO OVERCOME EFFECT OF (1)

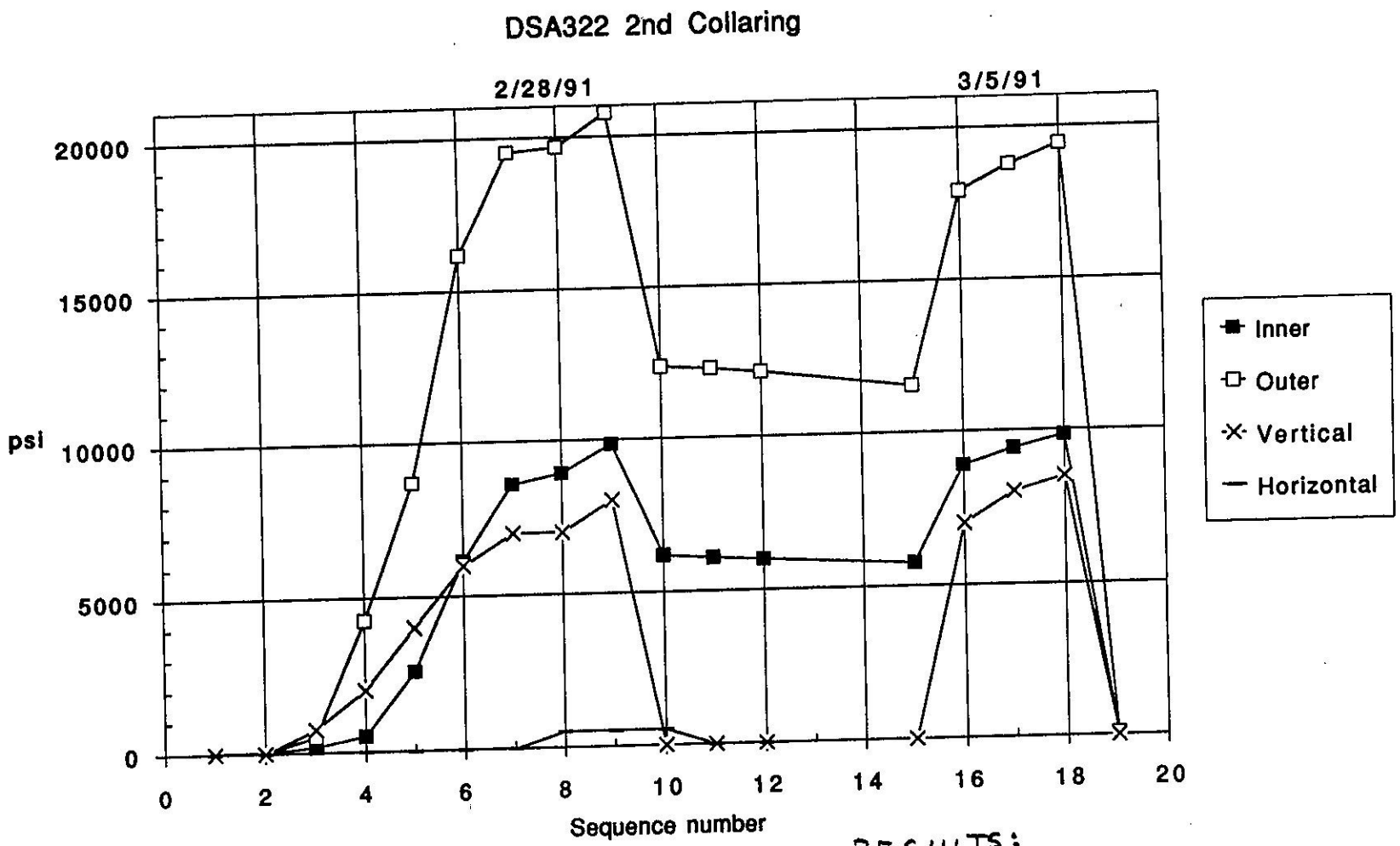


CONDITIONS:

1) NO POLE SHIMS
2) LAMINATED UPPER TOOLING HAS ALIGNMENT FEATURES
3) 5 mil PRESS STOP SHIM

RESULTS:

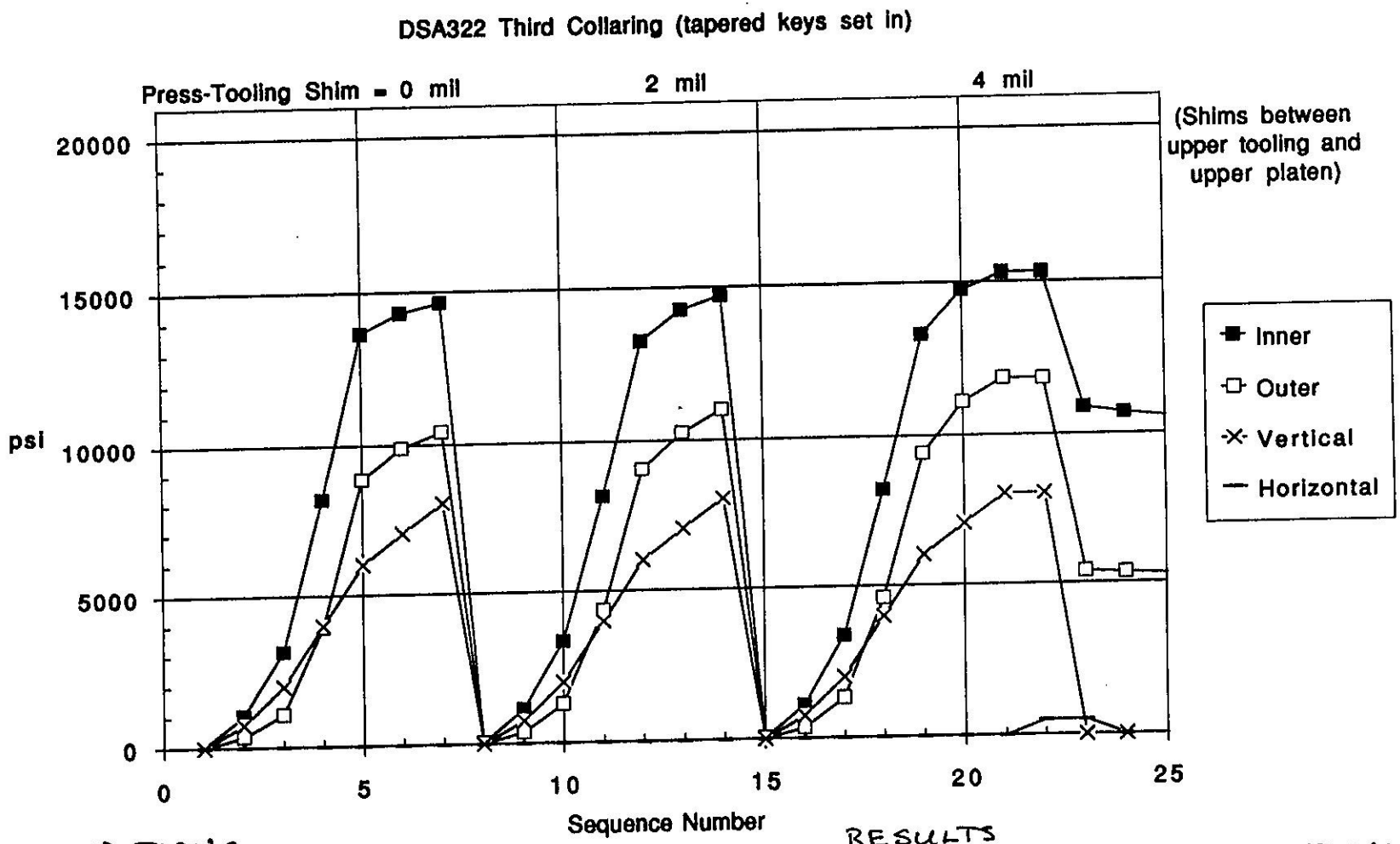
1) SIGNIFICANT AZIM. MIS-ALIGNMENT ~10-12 mil LEFT-RIGHT DIFFERENCE
2) KEYS NOT FULLY INSERTED (~10 mils) AT 500 LBS./IN.



CONDITIONS:
1) NO POLE SHIMS
2) 5 MIL "AZIMUTHAL" SHIMS, 4 QUADRANTS
3) 5 MIL PRESS STOP SHIM

RESULTS:
1) NO AZIMUTHAL MIS-ALIGNMENT
2) KEYS FULLY INSERTED AT 500 LBS./IN.

(E)



CONDITIONS

1) +5 (−5) MIL INNER (OUTER) POLE SHIM
2) 5 MIL "AZIMUTHAL" SHIMS
3) INCREASE PRESS STOP SHIM UNTIL KEYS CAN BE PLACED BY HAND

RESULTS

1) 4 MIL PRESS STOP SHIM OPTIMAL FOR "SQUARE KEY" METHOD
2) INNER COIL "SPRING-BACK" = 4.5 KPSI
3) NO MID-PLANE INSULATION DAMAGE @ 15 KPSI
4) CHOSEN POLE SHIMS GIVE "CORRECT" INNER PRESTRESS, TOO LOW OUTER PRESTR.

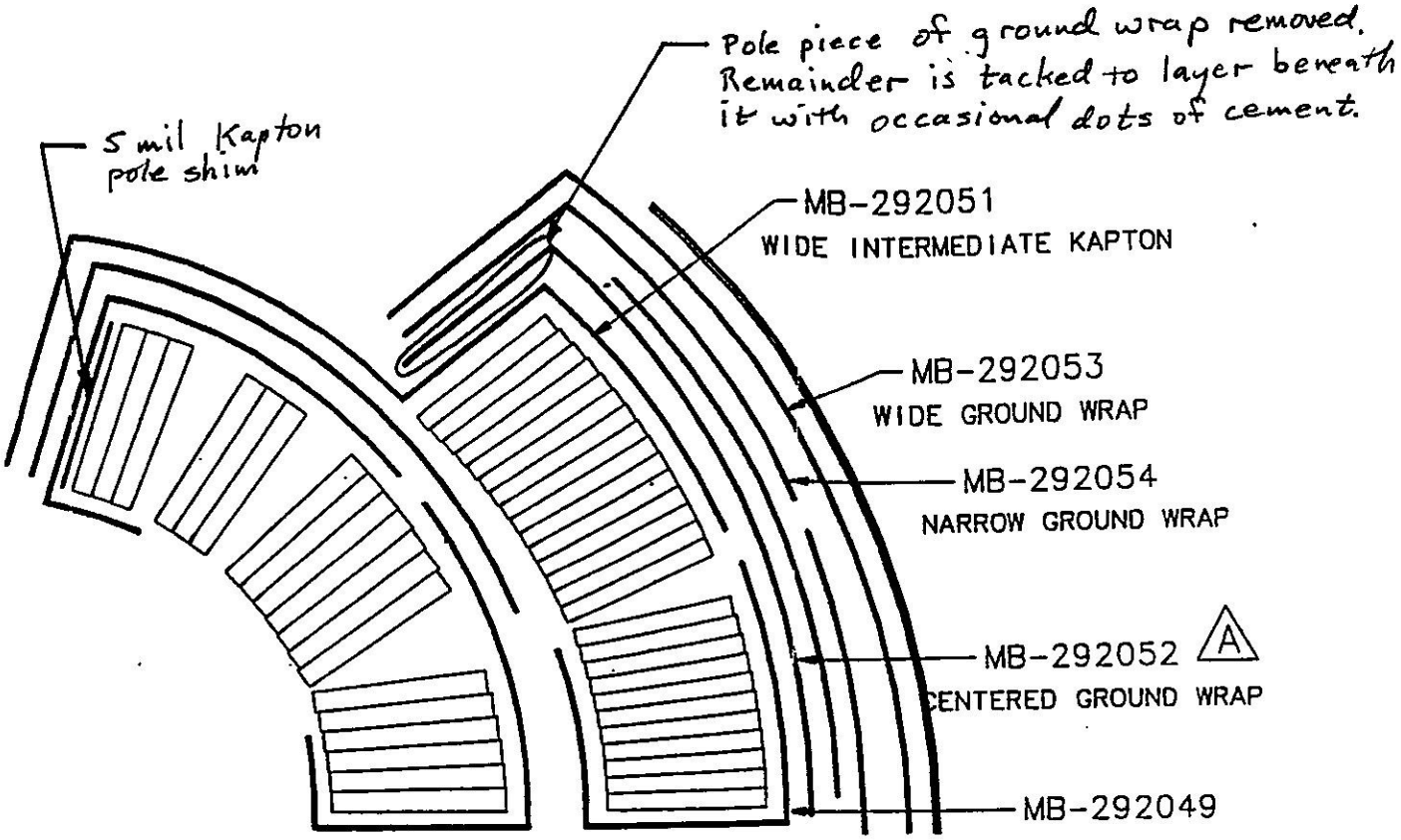
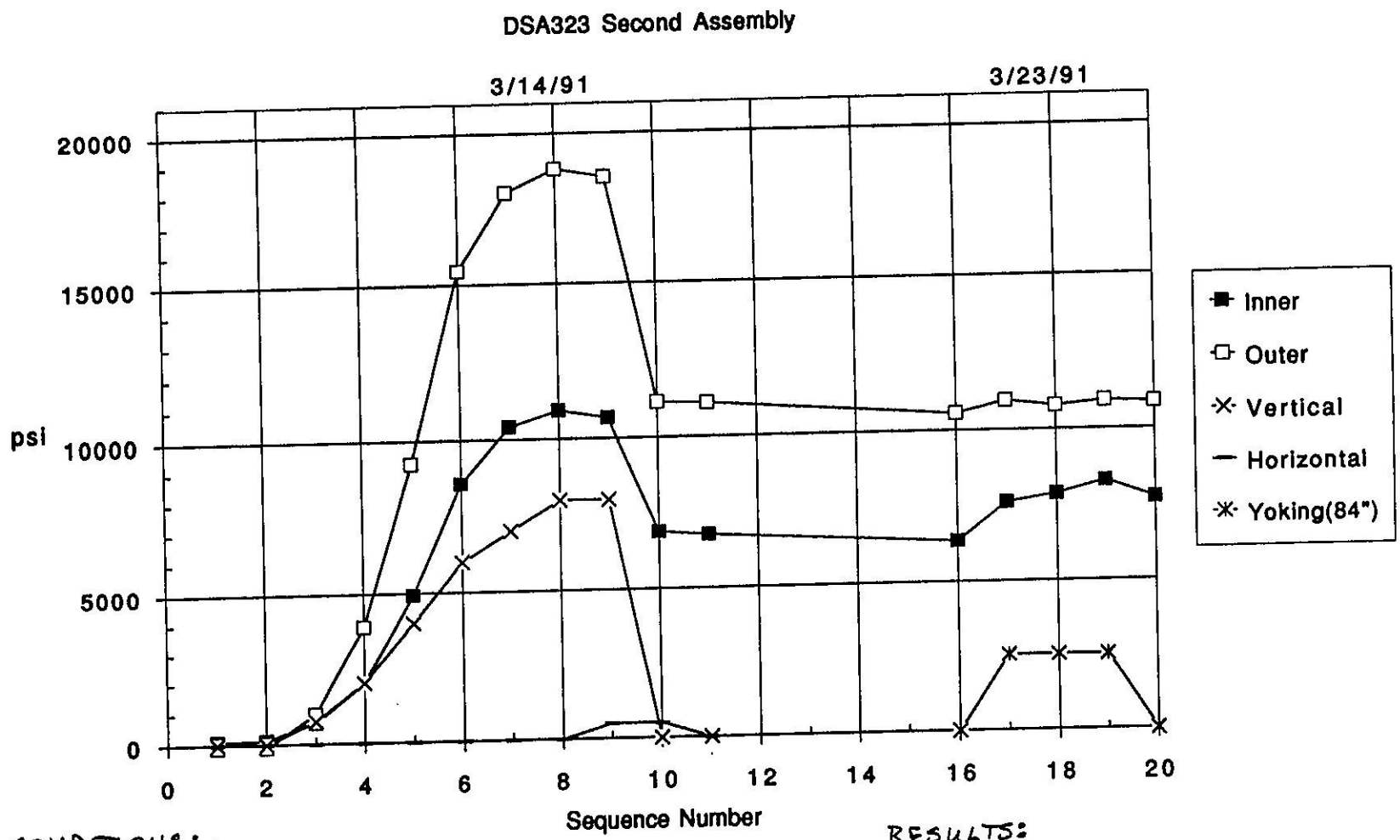

Pole piece of ground wrap removed. Remainder is tacked to layer beneath it with occasional dots of cement.
5 mil Kapton pole shim
MB-292051
WIDE INTERMEDIATE KAPTON
MB-292053
WIDE GROUND WRAP
MB-292054
NARROW GROUND WRAP
MB-292052
A
CENTERED GROUND WRAP
MB-292049

Figure 1

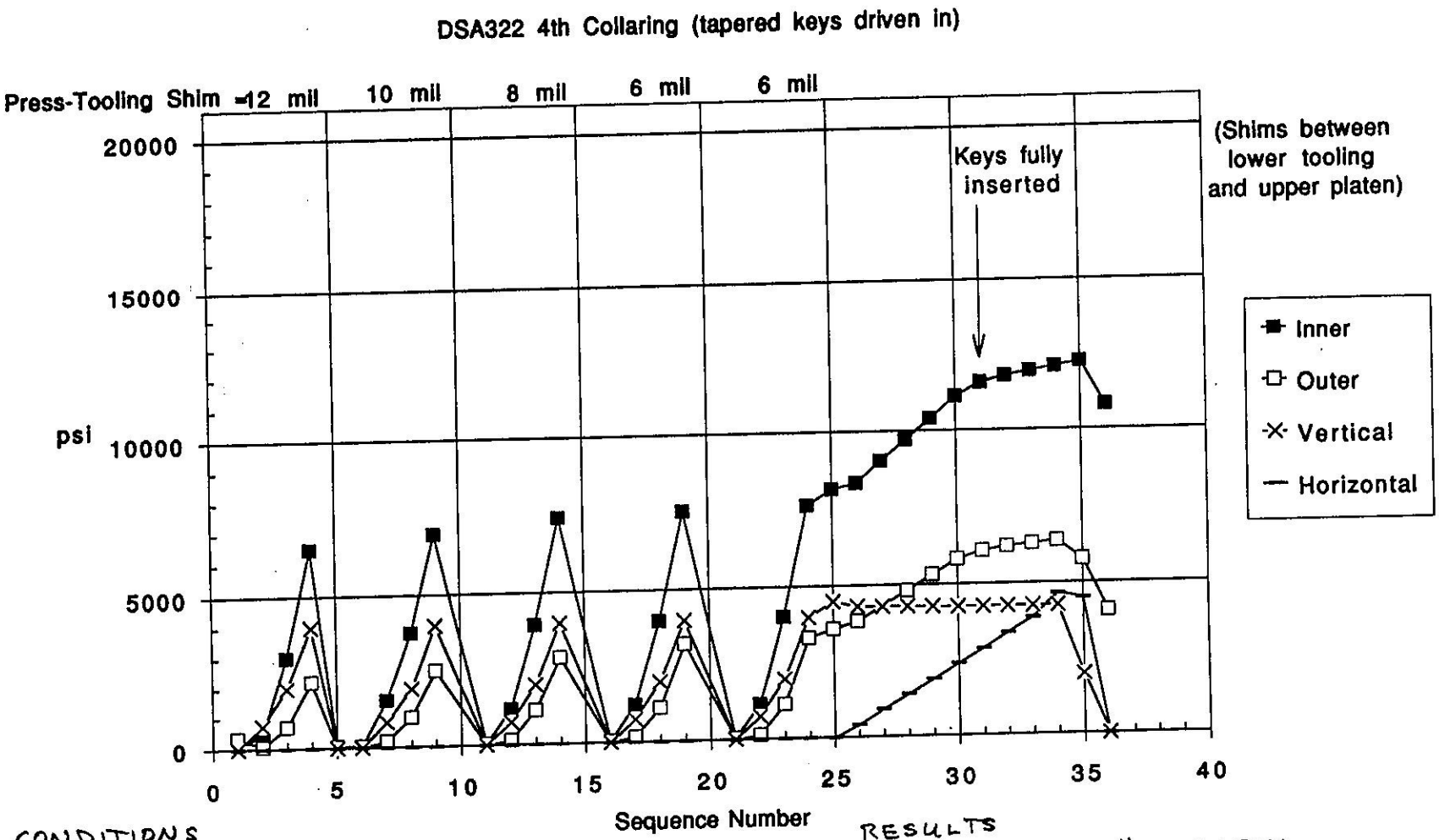


CONDITIONS:

1) NO POLE SHIMS
2) TOOLING SETUP THE SAME AS 3RD DSA322 ASSEMBLY

RESULTS:

1) SUCCESSFUL APPLICATION OF "SQUARE KEY" ASSEMBLY METHOD
2) ≈1 KPSI LOWER PEAK STRESS THAN PREVIOUS ASSEMBLY



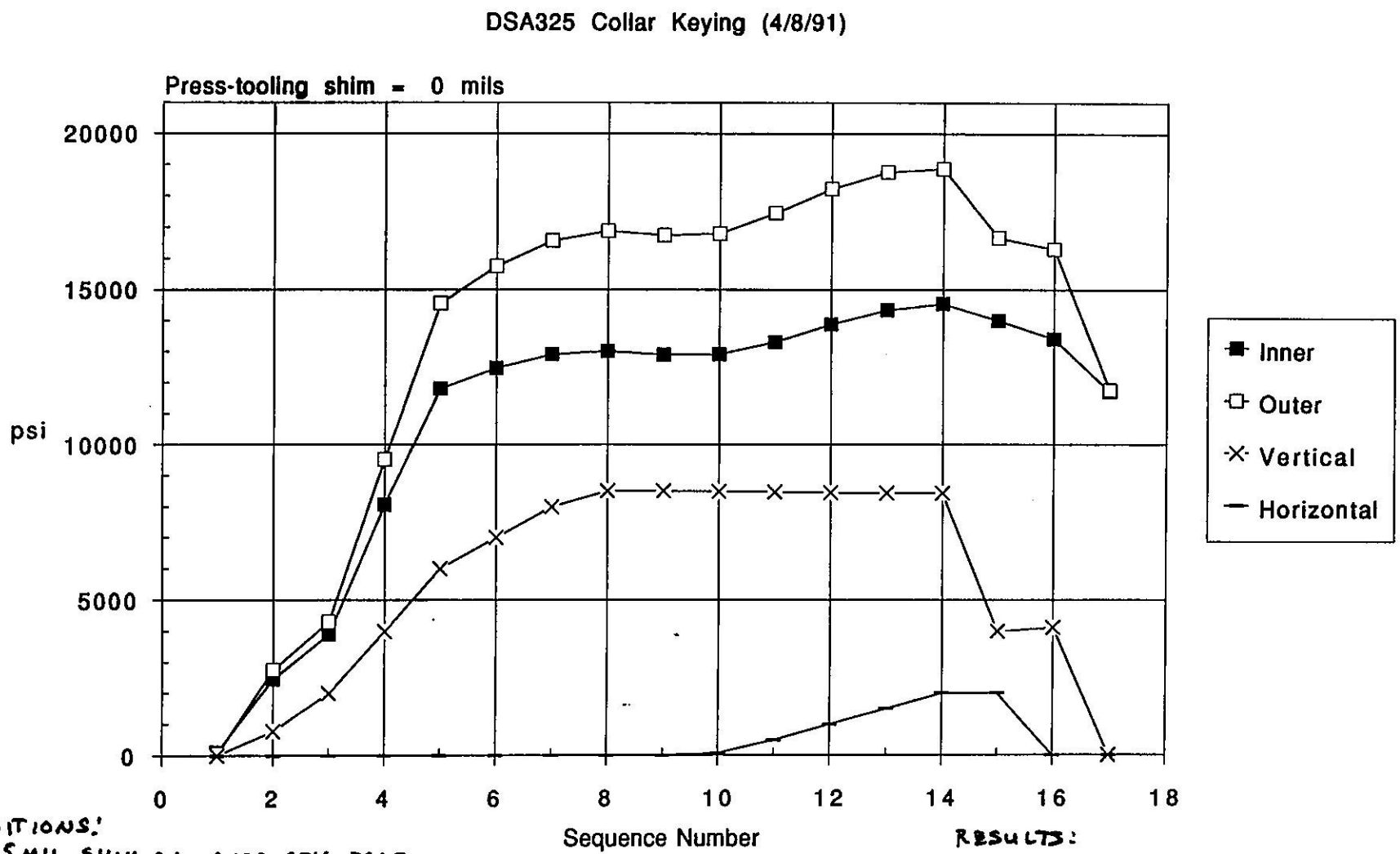
CONDITIONS

1) +5(-5) MIL INNER (OUTER) POLE SHIM
2) LAMINATED LOWER TOOLING
3) 5 MIL "AZIMUTHAL" SHIMS
4) PRESS STOP SHIMS ADJUSTED UNTIL KEYS CAN BE INSERTED 50 MILS

RESULTS

1) "SPRING BACK" ≈ 1 KPSI
2) TAPERED KEYS DID "MORE WORK" THAN NECESSARY
3) EVALUATION RELATIVE TO SQUARE KEY ASSEMBLY IS IN PROGRESS.

"MIXED" KEY INSERTION

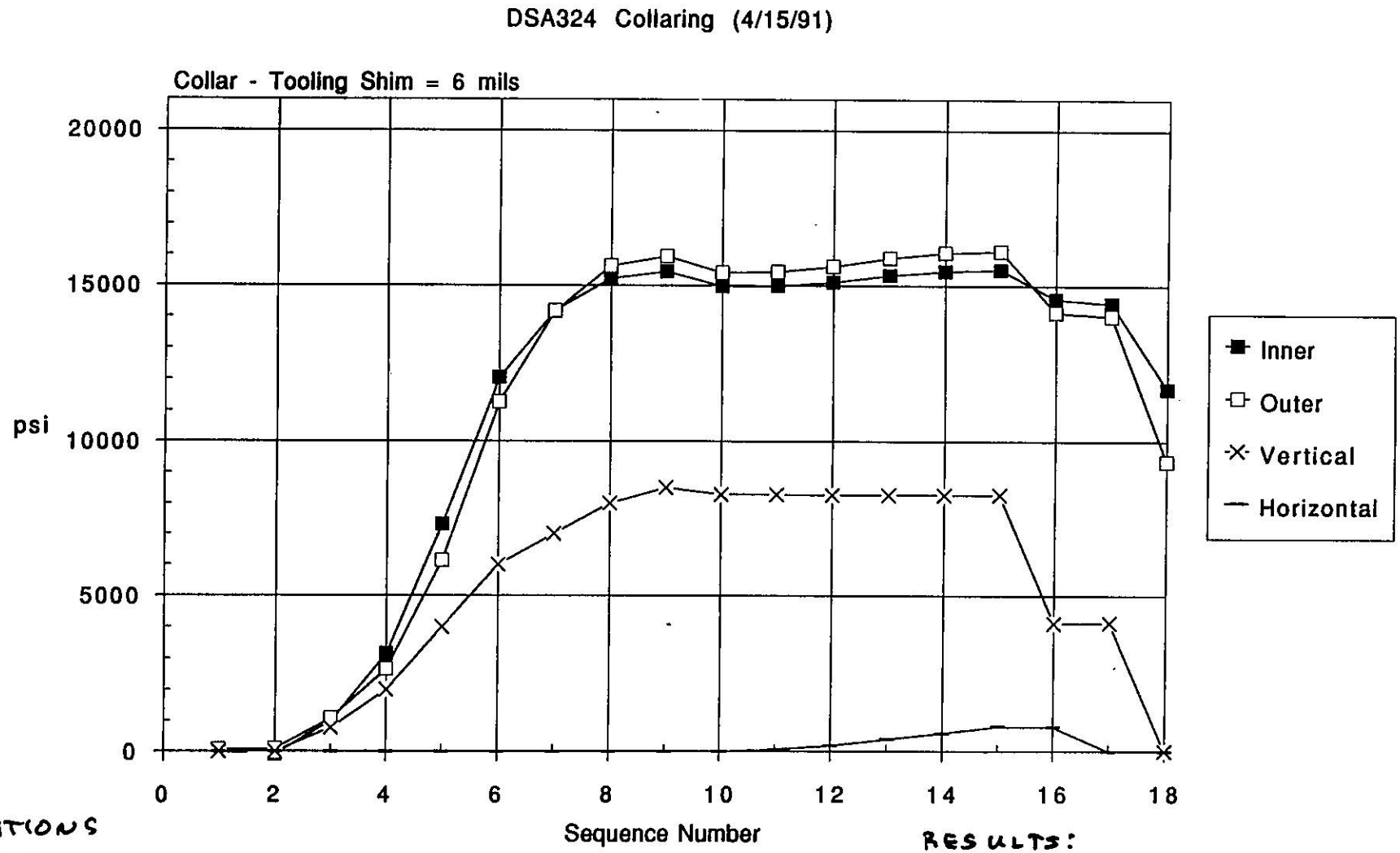


CONDITIONS:
1) +5 MIL SHIM ON INNER COIL POLE
2) OUTER COIL MOLDED IN CAVITY 5 MILS SMALLER THAN PREVIOUS COILS; NO POLE SHIM.
3) 5 MIL "AZIMUTHAL" FORMING SHIMS
4) NO PRESS STOP SHIM
5) KEYS LUBRICATED

Figure 3

RESULTS:
1) "SPRING BACK" = 3 KPSI (INNER)
2) 1500 LBS/IN REQ'D FOR KEY INSERTION.

"SQUARE KEY" INSERTION



CONDITIONS

1) +5(-5) MIL POLE SHIM INNER (OUTER) COIL
2) 5 MIL "AZIMUTHAL" TOOLING SHIMS
3) PRESS STOP SHIM = 6 MILS
4) KEYS LUBRICATED

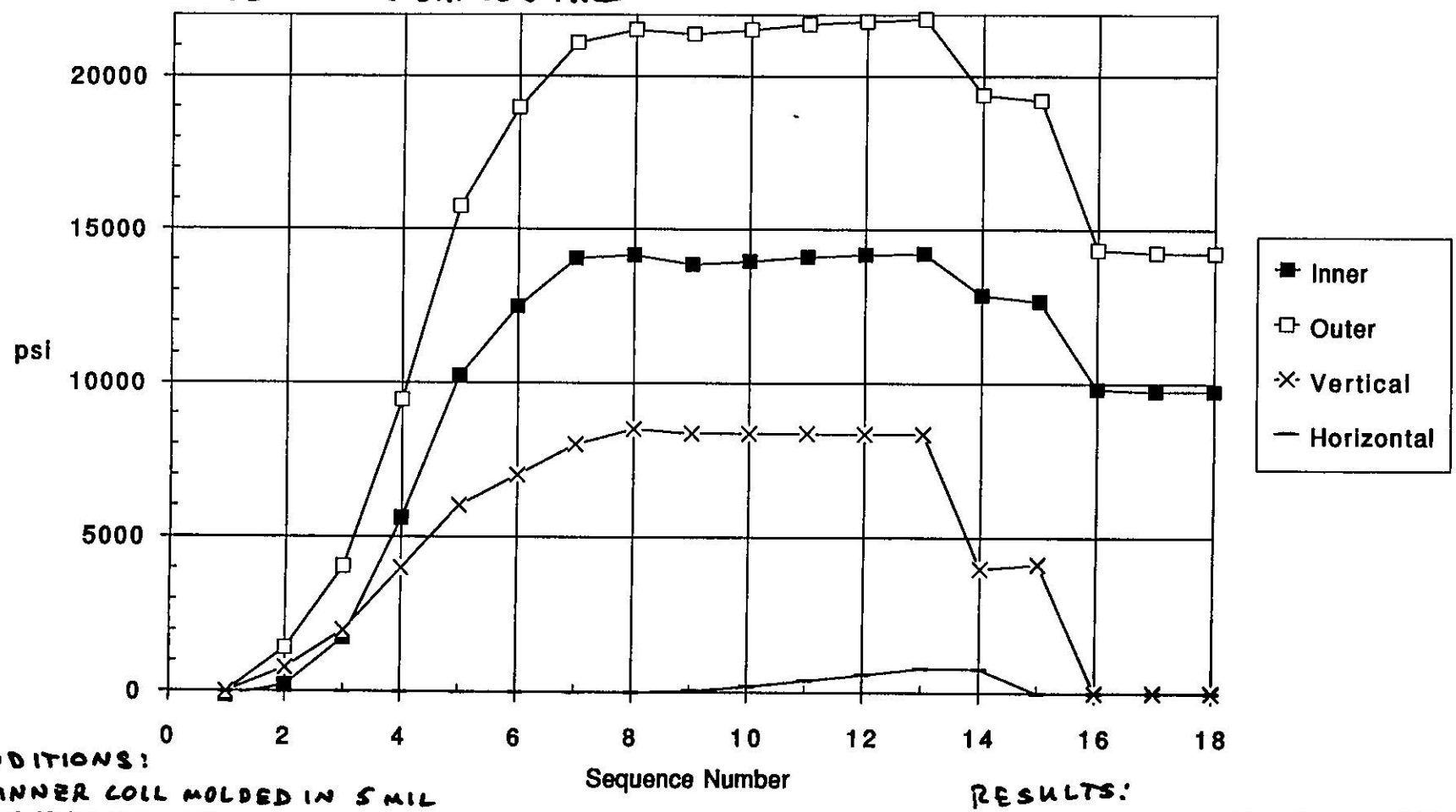
Figure 3

RESULTS:

1) "SPRING BACK" LOSS = 4 KPSI
2) 600 LBS/IN REQ'D FOR KEY INSERTION

DSA327 Collaring 5/7/91

PRESS-TOOLING SHIM = 8 MILS



CONDITIONS:

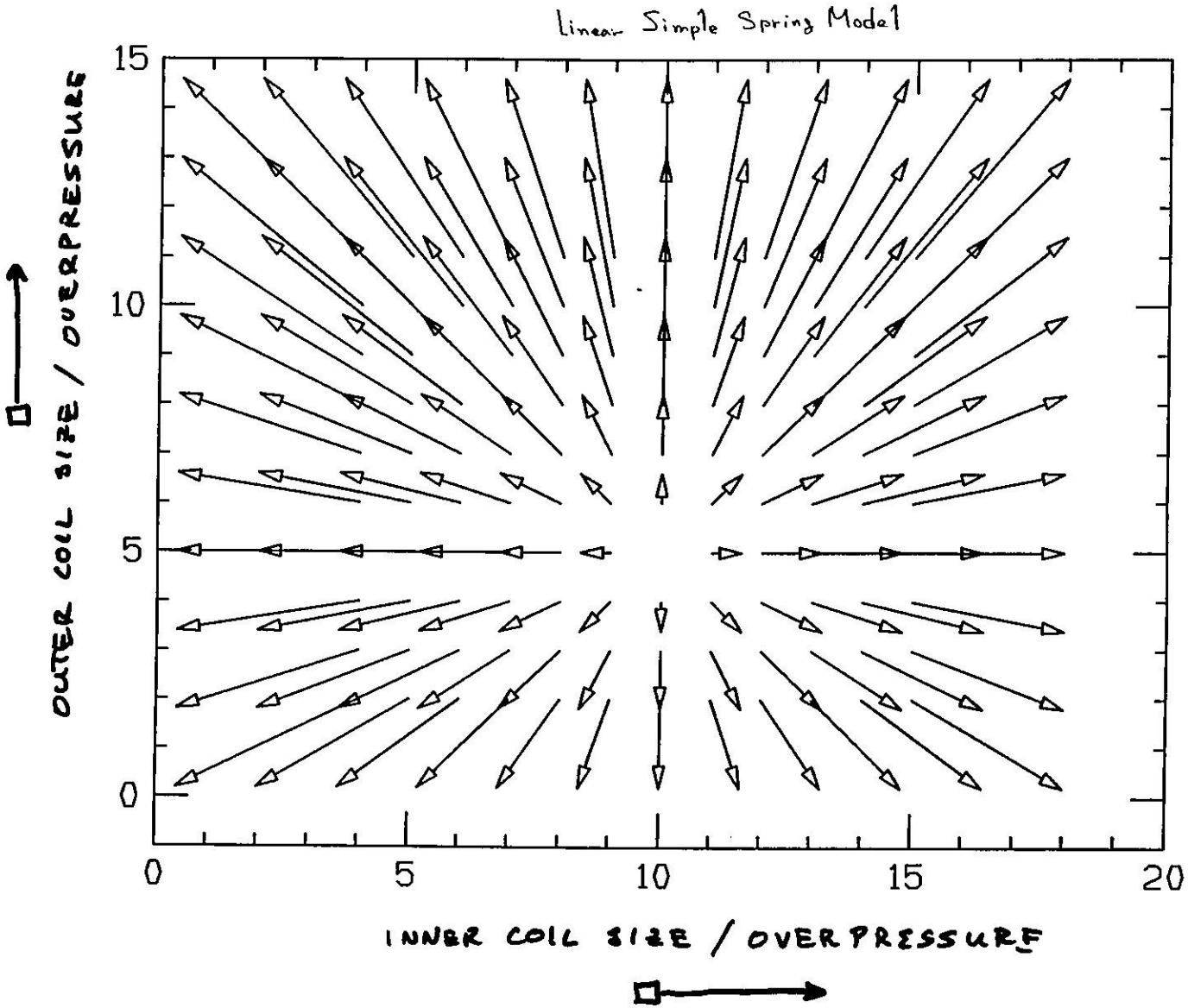
1) INNER COIL MOLDED IN 5 MIL OVERSIZE CAVITY
2) OUTER COIL MOLDED IN 3 MIL UNDERSIZE CAVITY
3) 8 MIL PRESS STOP SHIM
4) KEYS LUBRICATED

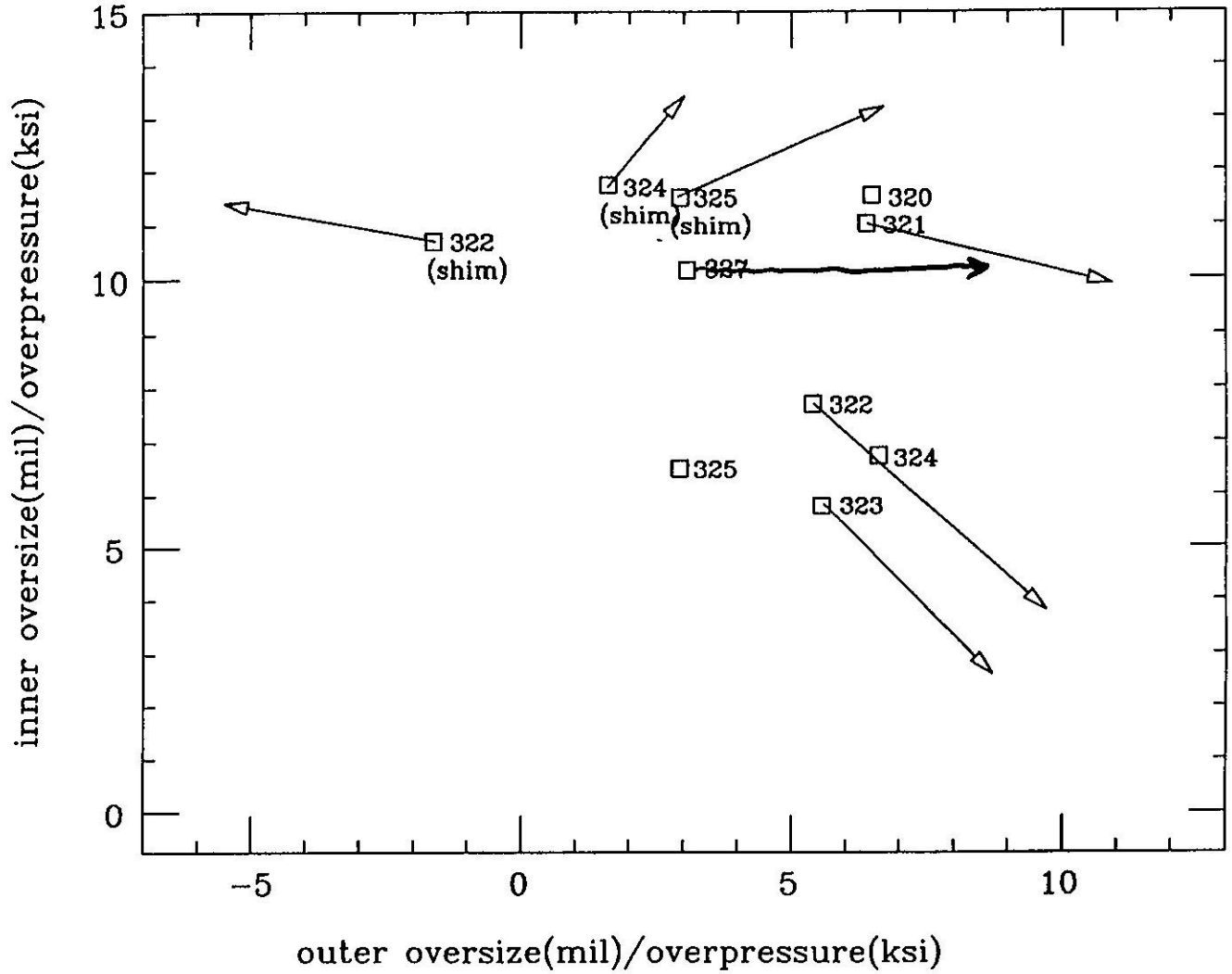
RESULTS:

1) 4.5 KPSI INNER "SPRING BACK"
2) <400 LBS/IN FOR KEY INSERTION
3) OUTER COIL IS STILL TOO LARGE

COIL SIZE/PRESTRESS ANALYSIS
(MASAYOSHI WAKE)

FIG.2




15
10
5
0
-5
0
5
10
inner oversize(mil)/overpressure(ksi)
outer oversize(mil)/overpressure(ksi)
322
(shim)
324
(shim)
325
(shim)
320
321
327
322
324
325
323

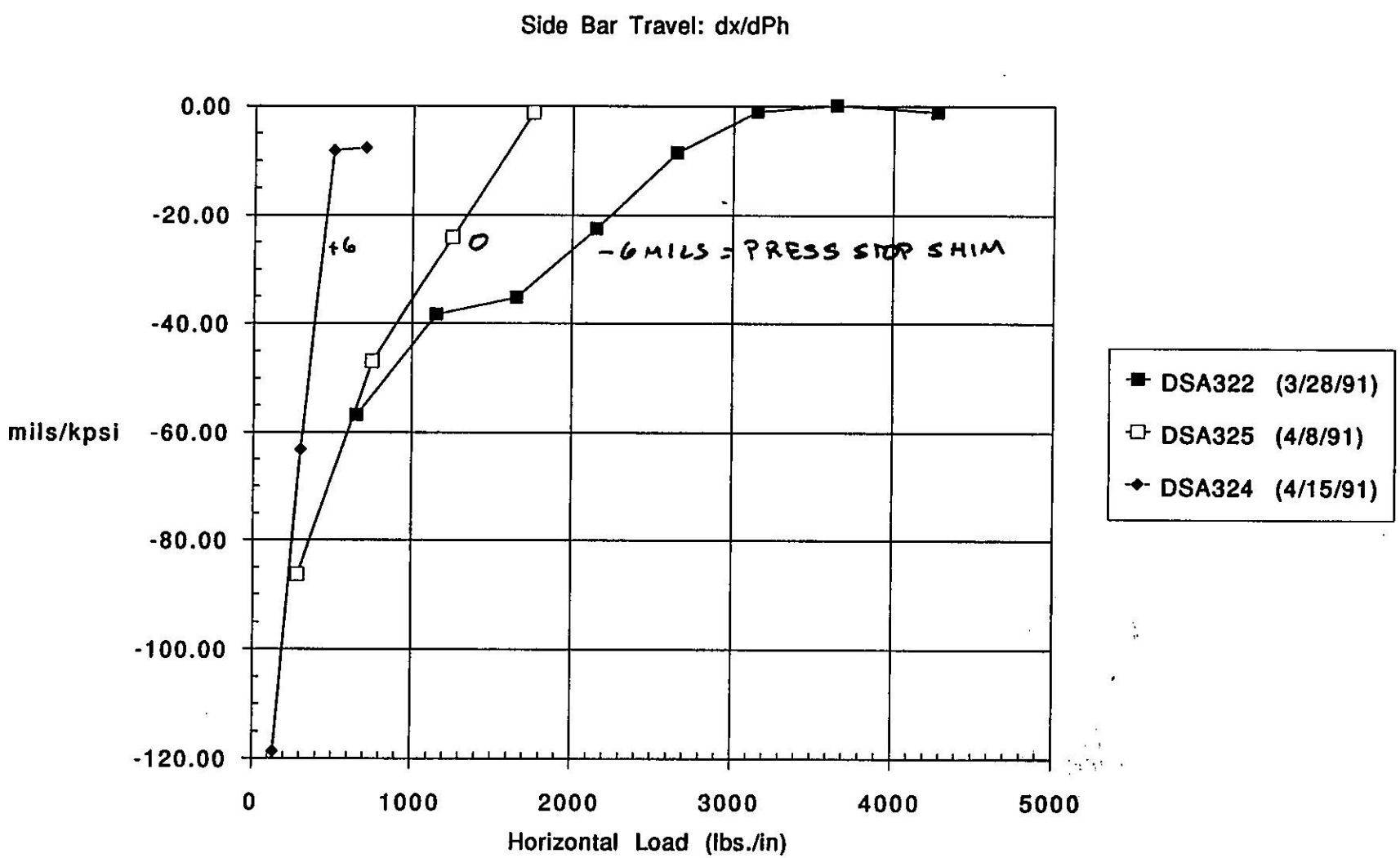
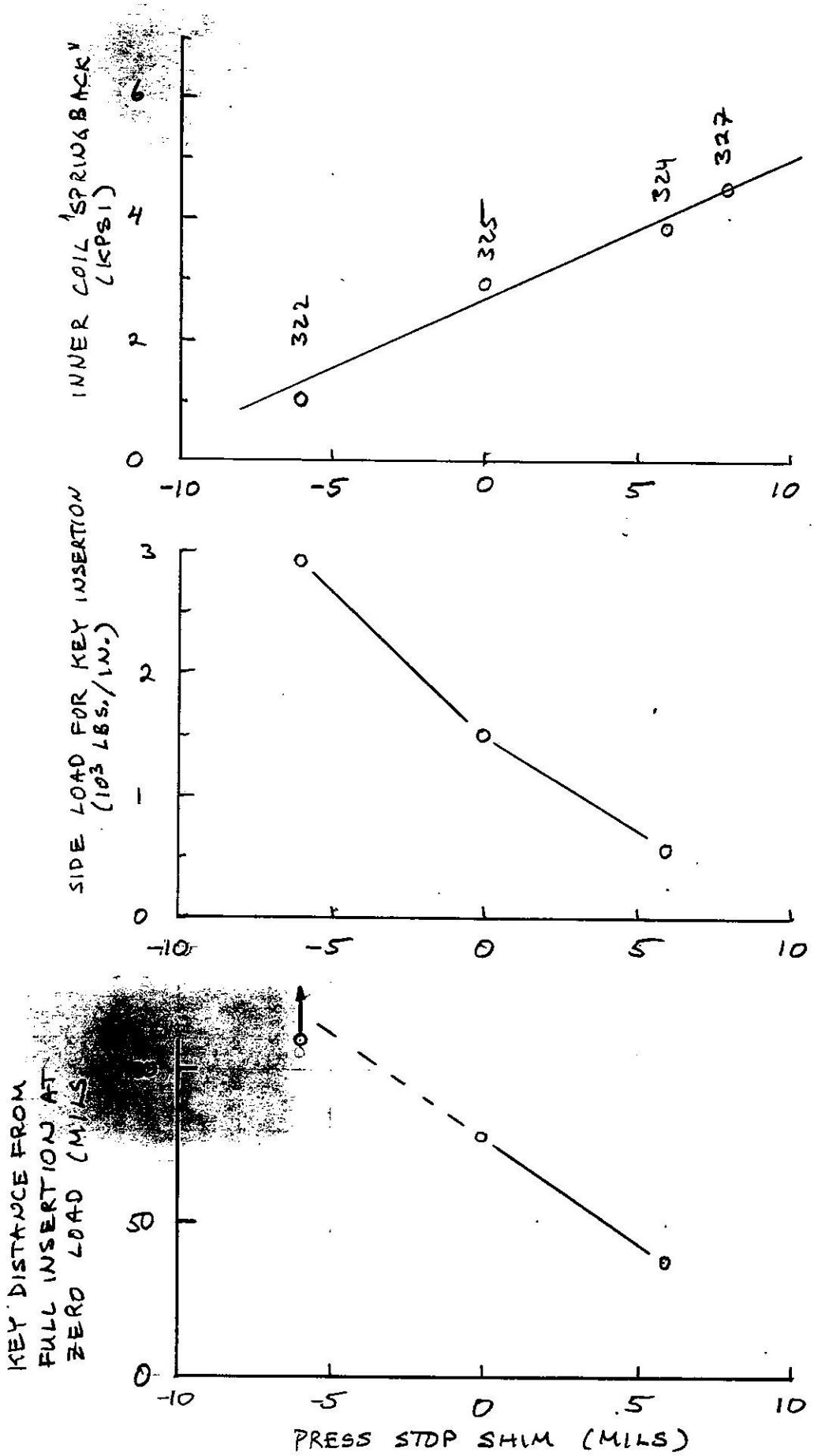

Side Bar Travel: dx/dPh
0.00
-20.00
-40.00
-60.00
-80.00
-100.00
-120.00
mils/kpsi
0
1000
2000
3000
4000
5000
Horizontal Load (lbs./in)
+6
0
-6 MILS = PRESS STOP SHIM
DSA322 (3/28/91)
DSA325 (4/8/91)
DSA324 (4/15/91)

Figure 8


INNER COIL "SPRINGBACK" (KPSI)
0
2
4
6
322
325
324
327
-10
-5
0
5
10
SIDE LOAD FOR KEY INSERTION (10^3 LBS./IN.)
0
1
2
3
-10
-5
0
5
10
KEY DISTANCE FROM FULL INSERTION AT ZERO LOAD (MILS)
0
50
-10
-5
0
5
10
PRESS STOP SHIM (MILS)

EVALUATION OF COLLAR & KEY DEFORMATION DUE TO DRIVING THE KEYS INTO DSA322

1) DIAMETERS (NEAR 0°, 45°, 90°) OF A COLLAR PACK ASSEMBLED WITH "VIRGIN" KEYS AND NO COIL BEFORE ASSEMBLY ONTO COIL.

2) HALF OF DSA322 WAS DISASSEMBLED BY PRYING THE KEYS OUT (SO AS TO NOT STRESS THE COIL ANY MORE THAN DURING KEYING).

3) HALF OF DSA322 WAS DISASSEMBLED BY OVERCOMPRESSING THE COLLARS IN THE PRESS AND REMOVING THE KEYS BY HAND (SO AS NOT TO DAMAGE THE COLLARS OR KEYS BEYOND THAT DONE DURING KEY INSERTION).

4) REMEASURE DIAMETERS OF COLLAR PACK ASSEMBLED WITH "VIRGIN" KEYS AND NO COIL.

	Δr
12°	+0.3 mils
53°	+0.6 mils
85°	+0.8 mil
L/R	+0.8 mils

5) MEASURE DEPTH OF GROOVES SCRAPED INTO KEYS BY THE EDGES OF THE COLLARS: $0.5 \lesssim$ DEPTH $\lesssim 1.0$ mils.

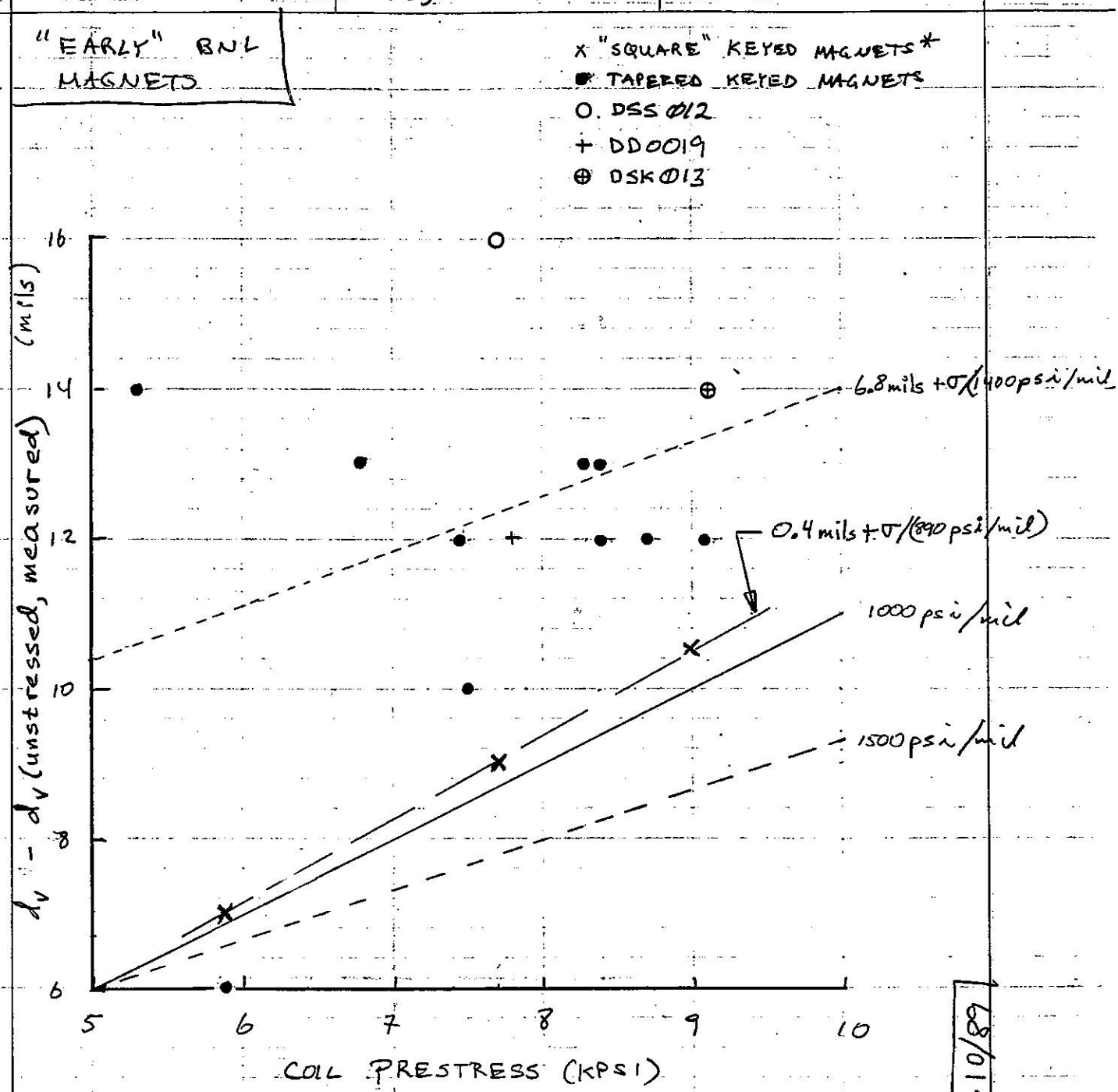
⇒ ADDITIONAL VERTICAL "OVALITY" OF ~ 1.5 mils ON THE RADIUS

EFFECT OF THIS ON THE HARMONICS HAS NOT BEEN CALCULATED (PLANNED) BUT IS "PROBABLY" NOT TOO LARGE.

DSA320-322 Harmonics

Collared Coil	b_2	b_4	POLE SHIMS INNER	POLE SHIMS OUTER
DSA320	-2.4	0.57	0	0
~~DSA322 (1st assembly)~~	~~-6.2~~	~~0.89~~		
DSA322 (2nd assembly)	-2.9	0.48	0	0
DSA322 (3rd assembly)	-3.5	0.59	+5	-5
DSA322 (4th assembly)	-2.4	0.43	+5	-5
DSA324	-4.1	0.31	+5	-5
Calculated (w/o iron)	-4.0	0.14		
Complete Magnet				
DSA321	2.6	0.35		
Calculated (with iron)	0.2	0.07		

Figure 3



$\rho = \begin{cases} 0.37 & \text{(all points)} \\ 0.34 & \text{(tapered key, not DSSØ12)} \\ 1-2\times10^{-5} & \text{("square" keys)} \\ 0.29 & \text{(all tapered key)} \end{cases}$

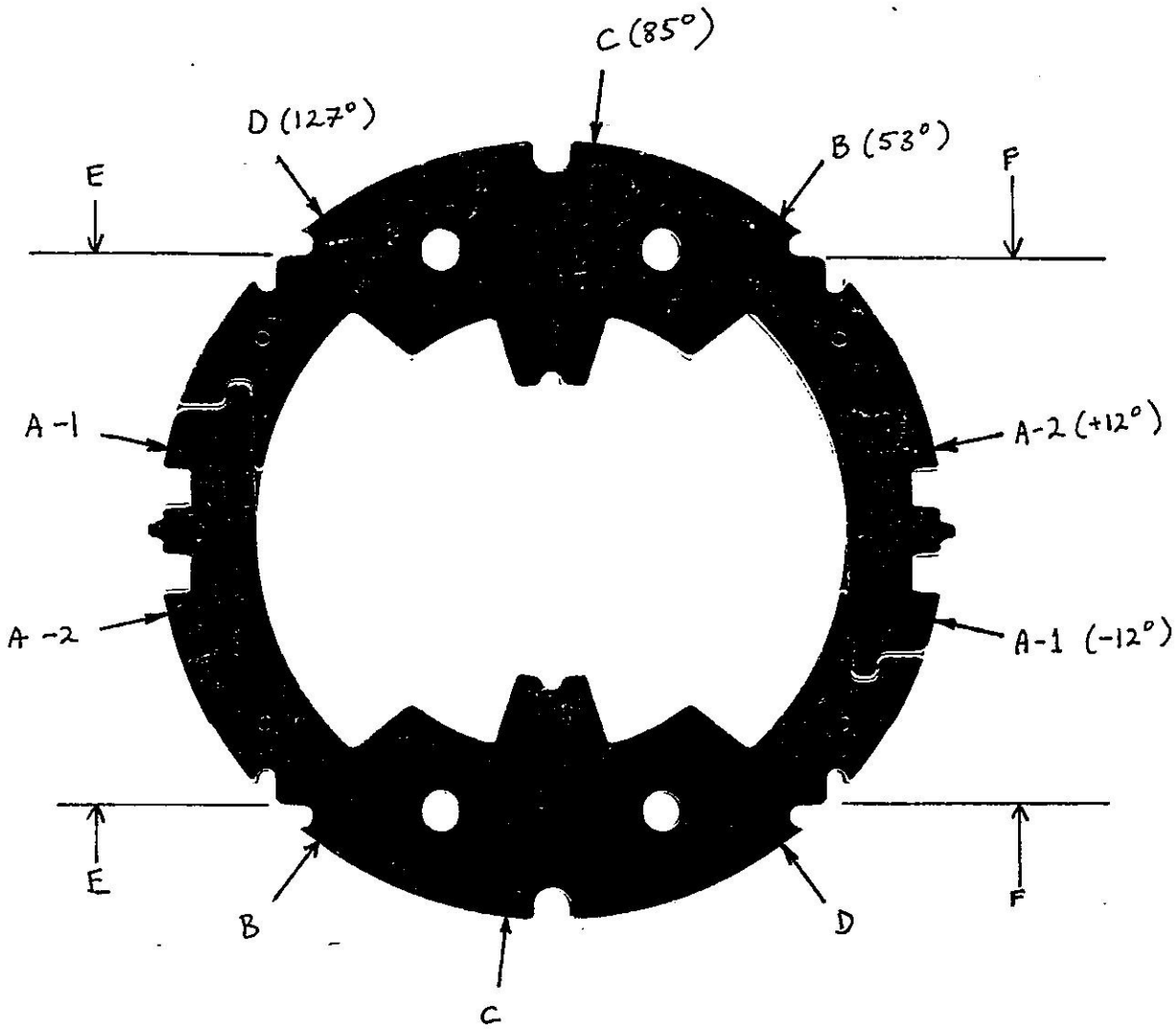
Data from DDØØ12, 14–19, DSSØ10, 12–14, DSKØ13

*Includes DSS14 which has tapered keys but was collared using square key procedures.

PRESENTED AT MSUM ~10/89

III. Second assembly

4) Measure collared coil diameters at the angular locations specified on the figure below. Measure the coil at the positions along the length of the coil specified on the table on the next page and recored the data there. (These correspond to two sets of measurements per standard collar pack, two sets on the strain gauge pack and one set each on the two end packs.)



Collared Coil Viewed From the Lead End

Measurements are to be made approximately 1/8 inch from the nearest feature that breaks the circular outer surface: the key slots for dimensions A-1 and A-2, the lifting fixture features for dimensions B and D and the instrumentation wire slot for dimension C.

SUMMARY

1) FULL RANGE OF KEY INSERTION TYPES HAS BEEN COVERED BY VARYING THE PRESS STOP BY 14 mils.

2) PRESTRESS "SPRING BACK" AND FORCE REQUIRED TO DRIVE THE KEYS IN VARY ~ LINEARLY WITH AMOUNT OF INITIAL OVER COMPRESSION.

3) WITH "FULL" TAPERED KEY INSERTION (3000 LBS/IN TO DRIVE KEYS IN) COLLAR AND KEY DEFORMATIONS RESULT IN $\Delta r_{VERTICAL} \cong +1.5$ mils. EFFECT ON FIELD QUALITY IS BEING EVALUATED BUT IS EXPECTED TO BE "NOT TOO LARGE."

4) "FINAL" CHOICE OF PRESS STOP FOR LONG MAGNETS HAS NOT BEEN MADE BUT THE PREJUDICE IS FOR A "MIXED" METHOD (À LA DSA325) REQUIRING 1000 - 2000 LBS./IN. FOR KEY INSERTION.

5) INNER COIL SIZE ~ CORRECT.
OUTER COIL SIZE NEED FURTHER ADJUSTMENT.