

# MCH Back Ring Fasteners

D-Zero Engineering Note #3740.225-EN-223

Jerry Leibfritz  
7-20-89

Approved by Keith Primdahl

*Keith Primdahl*

This report presents design calculations and testing results for the fasteners to be used on the back of the Middle Coarse Hadronic ring of the End Calorimeter. The calculations show that the design is acceptable for AISC code. The test verified that the design was acceptable.

## Background

In the End Calorimeter of the D-zero experiment, uranium and stainless steel plates are assembled into modules which are to be installed into the cryostat as individual units. A single inner module will be surrounded by 16 middle modules, which are surrounded by 16 outer modules. The 16 modules which comprise the middle ring are to be fastened at the outer radius by a link, which is pinned to each back plate. These links are connected by eccentric pins. Some of the pins have an eccentric large diameter, where the link between modules fits; while the others have an eccentric small diameter, where the cover link fits. These pins are placed in the modules in a specific alternating pattern. The link plates are then connected and the tolerance between the modules is decreased by turning the large diameter eccentric pins. A center spacer block and two 0.5 in. end spacers, which allow .183 in. of space to accommodate modules of slightly different lengths, are then attached. The cover plates are then connected over the pins. Tolerances here are eliminated by turning the small diameter eccentric pins. See Appendix 1 for detail drawings.

The expected forces at each of the 16 connections vary from 1400 lb to 69,000 lb (fastener force calculations are included in engineering note #3740.225-EN-195). At the inner radius, the forces are known to be compressive; hence, the edges of the back plates will be allowed to bear directly upon one another. Furthermore, it was observed that the static forces between the modules of the ring are all less than 69,000 lb, and with a coefficient of friction of 0.2 included for thermal motion are all less than 73,000 lb. At this time, the exact loads are only estimates since it has not been determined how the MH ring will be supported on the OH ring. As a result, a design load of 80,000 lb was used. This capability is sufficient for any of the current designs under consideration. Since it is desirable to minimize the volume of material used, Inconel 718 was chosen for the linkage plate and pins of the bottom half, where the load is

greatest. The same design using S.S. 304 can be assumed to be good for 1/5 the design load of Inconel, or 16,000 lb. Although only the Inconel fasteners were tested, the pins, link plates, and cover plates of the top half can be made of S.S. 304 because the maximum expected force on the upper half is only 7,700 lb. Clearly, the S.S. 304 parts are acceptable for a 7,700 lb load, if the Inconel is acceptable for 80,000 lb.

The spacer used has a hole for a set screw which prevents the pin from rotating in place. In the test, the set screw was not used, but the eccentric pin was situated so as to test the worst case; that is, the orientation where the pin would be most likely to slip (in rotation) due to the eccentricity.

### Test Setup

We tested an Inconel linkage plate, a stainless steel cover plate, and a portion of a stainless steel back plate, using two Enerpac model RCS-1002 hydraulic cylinders. The cylinders were powered by the same pump, with an effective total area of 39.28 in<sup>2</sup>. The Inconel plate and pins had been solution annealed, then age-hardened (a heat-treatment) to realize the full capability of Inconel. Dimensions were carefully measured before assembly.

The Inconel linkage plate was assembled between the back plate and the stainless steel cover plate, and secured with an Inconel pin. To measure strain of the Inconel link plate, seven 0-60<sup>0</sup>-120<sup>0</sup> rosette strain-gages were employed. The movement of the pin end center points was measured with four separate surveyor's sighting instruments, all calibrated to the same reference point. The difference between the pin heights was used to determine the elongation between the pins (figure 1).

### Procedure

Base readings were taken at 200 psi. Then, starting at 500 psi, the load was increased by increments of 500 psi, recording the strain gage readings and elongation at each interval. The combined surface area of the hydraulic jacks was 39.28 in<sup>2</sup>; accordingly, each successive 500 psi increase generated an additional 19,640 lb.

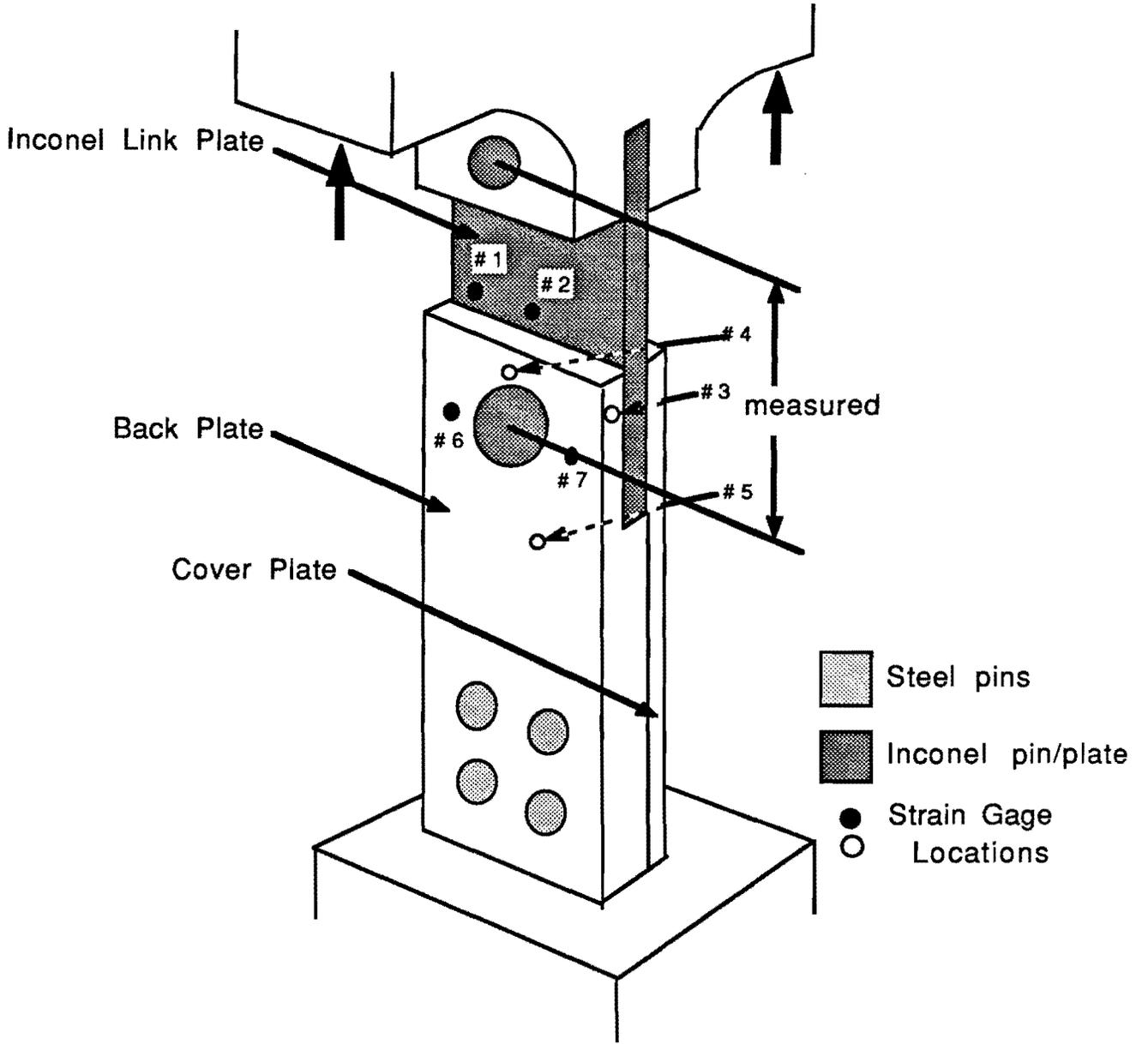


Figure 1: Test Set up

Pressure was decreased in similar increments back down to 200 psi. Two cycles to 98,200 lb resulted in consistent data.

The load was then increased, in 500 psi increments, until permanent deformation was evident. Finally, the fastener was disassembled and dimensions checked against those from before testing.

### Results

When tested to 100,000 lb, the pin to pin elongation of the back plate increased elastically at a slightly greater rate than the cover link. Beyond 100,000 lb, the slopes of the elongations spread apart further showing that yielding had occurred (figure 2). The measurements of the tested parts showed that there was no elongation of the holes in either plate larger than the design tolerances. At 162,000 lb, the pin failed catastrophically; that is, shear fracture through the small diameter occurred.

The first two cycles of the strain gage results show nearly uniform slopes of the stress intensities for loading up to 1.25 times the design load and for unloading. When the load was further increased (cycle #3), all seven strain gages showed uniform slopes until about 100,000 lb, where the slope began to increase. This verifies that 100,000 lb is the yield point (Appendix 3).

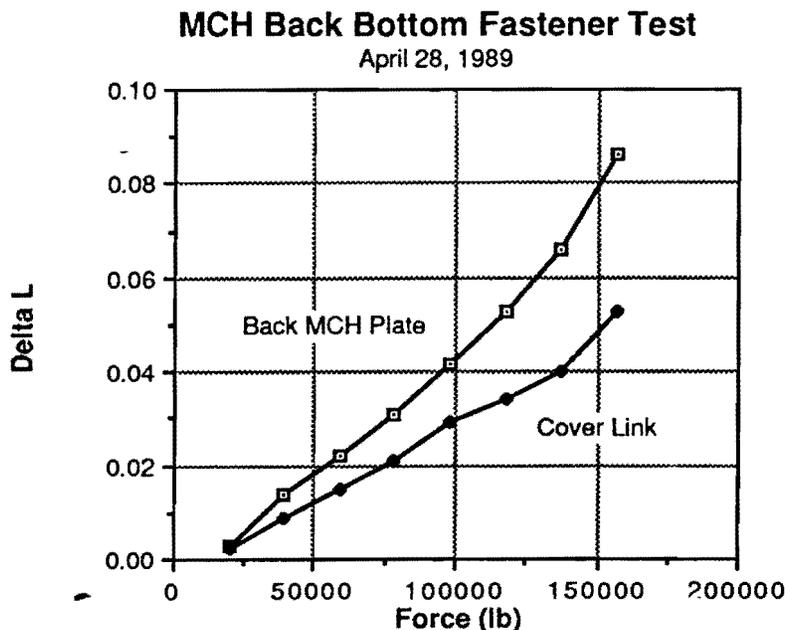


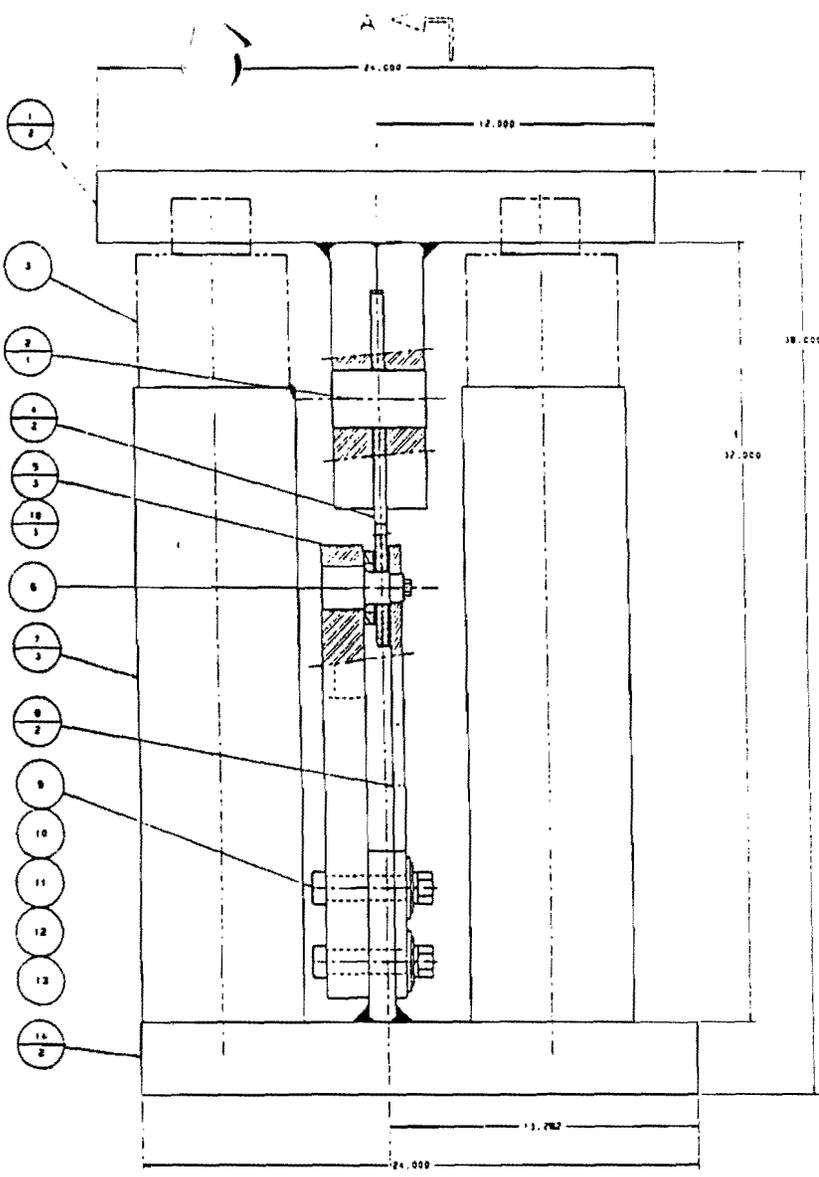
Figure 2: Pin to Pin Elongation

## Conclusion

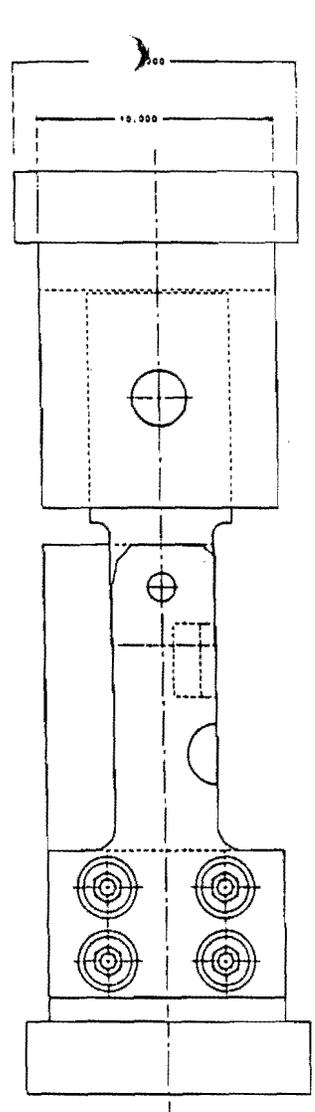
The pin did not slip (in rotation) during the test. Therefore, the actual installation, using the set screw, will be adequate to prevent movement of the pin. The results also verify that the fastener links perform elastically up to 100,000 lb, which is 1.25 times the design load of 80,000 lb. Therefore, the fastener design is acceptable for the loads expected between modules of the back of the MCH ring.

Appendix 1

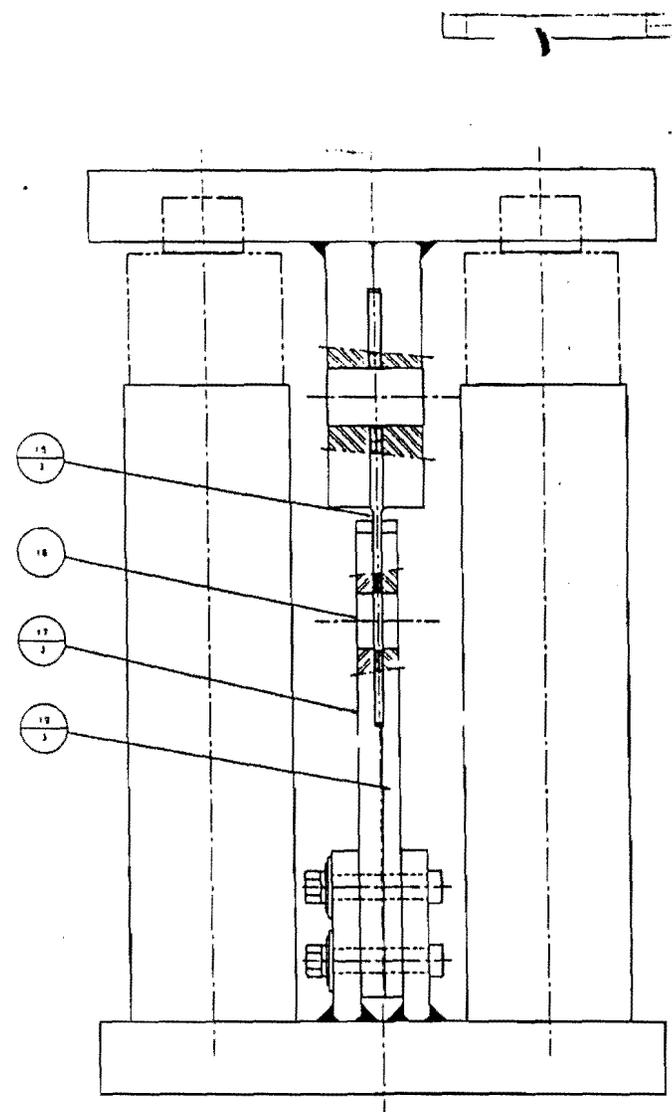
Drawings



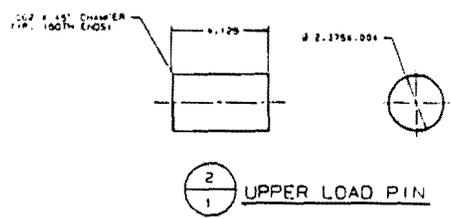
A ←  
MCH BACK LINKAGE TEST PULL CONFIGURATION



SECTION VIEW A-A



MFH FRONT LINKAGE TEST PULL CONFIGURATION



ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
10		MCH TEST YIG BAR	1
11		STAINLESS STEEL 1/2 DIA	1
12		BACK LINKAGE PIN SPACER & LOCK	1
13		FRONT TEST PRESSURE LOCK WASHER	1
14		FRONT ECCENTRIC LINKAGE PIN	1
15		MCH TEST LINKAGE PLATE	1
16		TOP WELDED WELDED	1
17		SPACER WELDED PLATE	1
18		TOP WELDED WELDED	1
19		SPACER WELDED PLATE	1

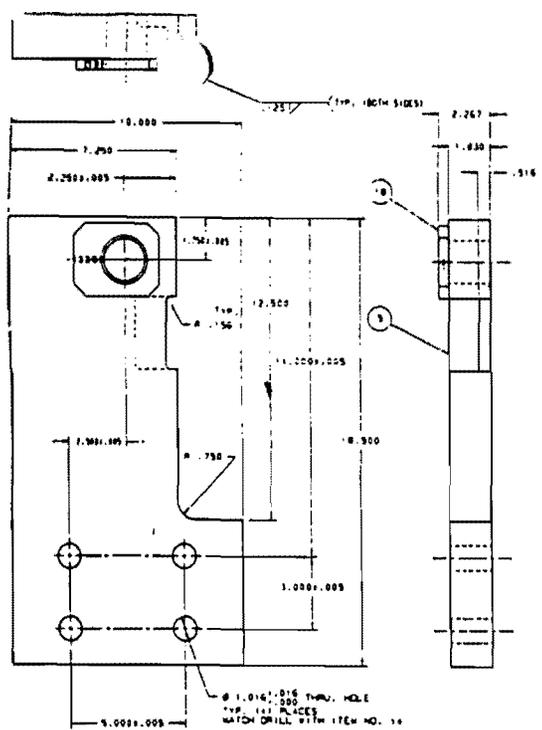
PARTS LIST	
10	MCH TEST YIG BAR
11	STAINLESS STEEL 1/2 DIA
12	BACK LINKAGE PIN SPACER & LOCK
13	FRONT TEST PRESSURE LOCK WASHER
14	FRONT ECCENTRIC LINKAGE PIN
15	MCH TEST LINKAGE PLATE
16	TOP WELDED WELDED
17	SPACER WELDED PLATE
18	TOP WELDED WELDED
19	SPACER WELDED PLATE

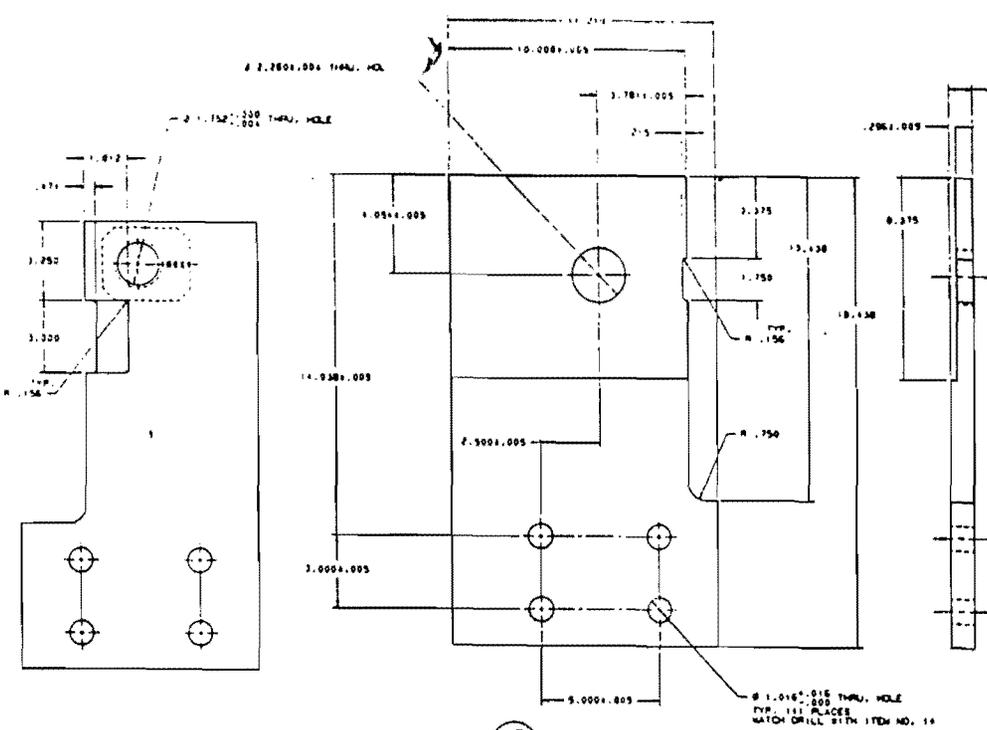
PARTS LIST	
10	MCH TEST YIG BAR
11	STAINLESS STEEL 1/2 DIA
12	BACK LINKAGE PIN SPACER & LOCK
13	FRONT TEST PRESSURE LOCK WASHER
14	FRONT ECCENTRIC LINKAGE PIN
15	MCH TEST LINKAGE PLATE
16	TOP WELDED WELDED
17	SPACER WELDED PLATE
18	TOP WELDED WELDED
19	SPACER WELDED PLATE

DOO DETECTOR END CALORIMETER MIDDLE HADRONIC MODULE LINKAGE ASSY. PULL TEST

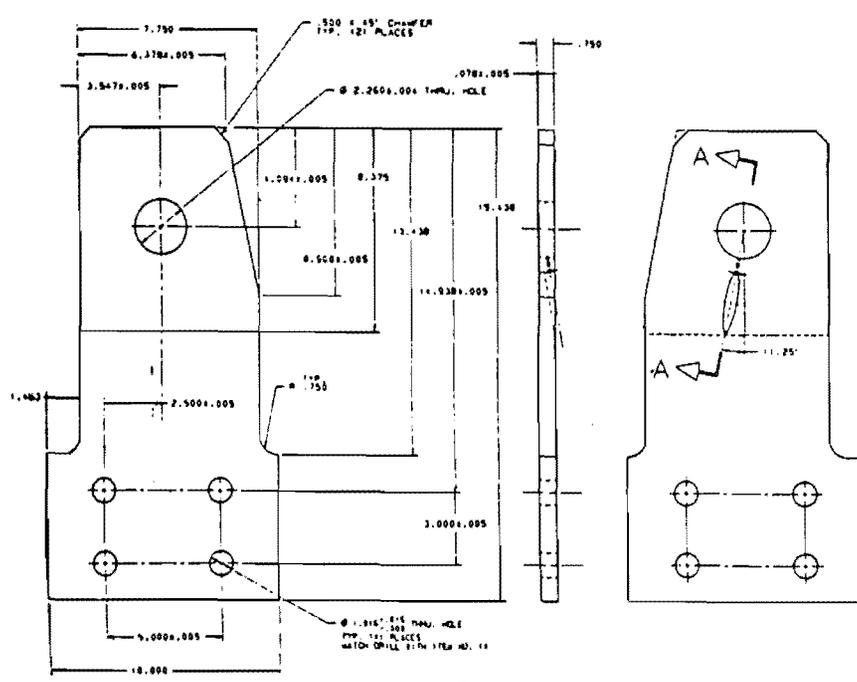




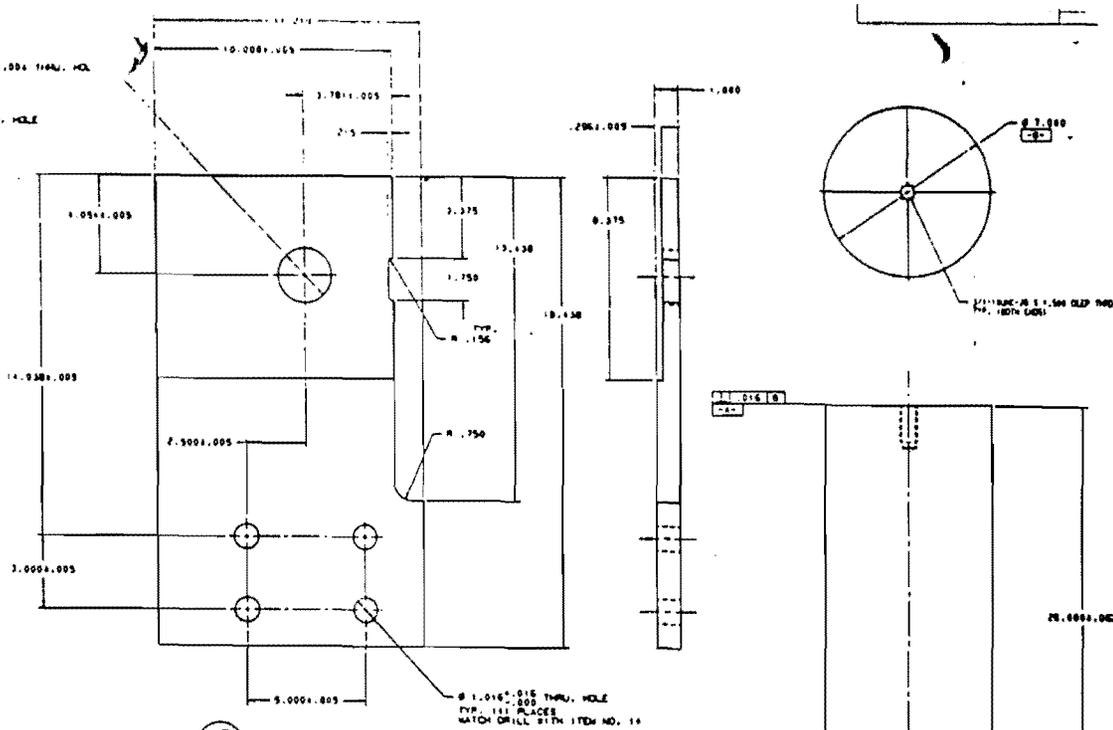
5  
J 18  
J TEST MCH BACK LIFTING PLATE ASSY.



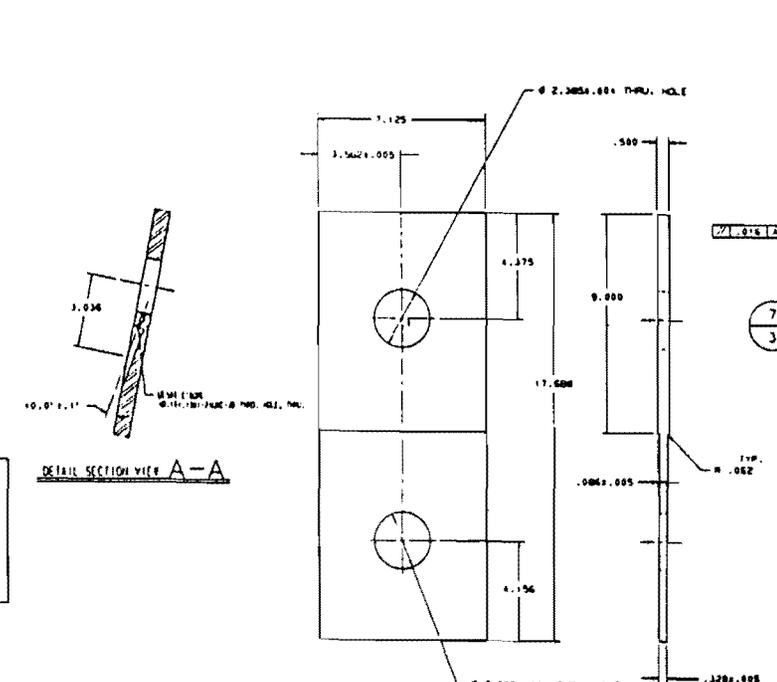
17  
3 MFH TEST FRONT END PLATE



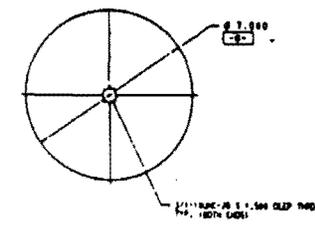
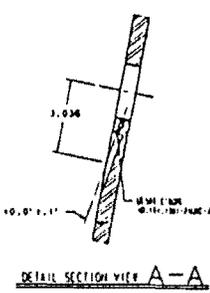
19  
J MFH TEST TIE BAR



15  
3 MFH TEST LINKAGE PLATE



7  
3 SUPPORT COLUMN

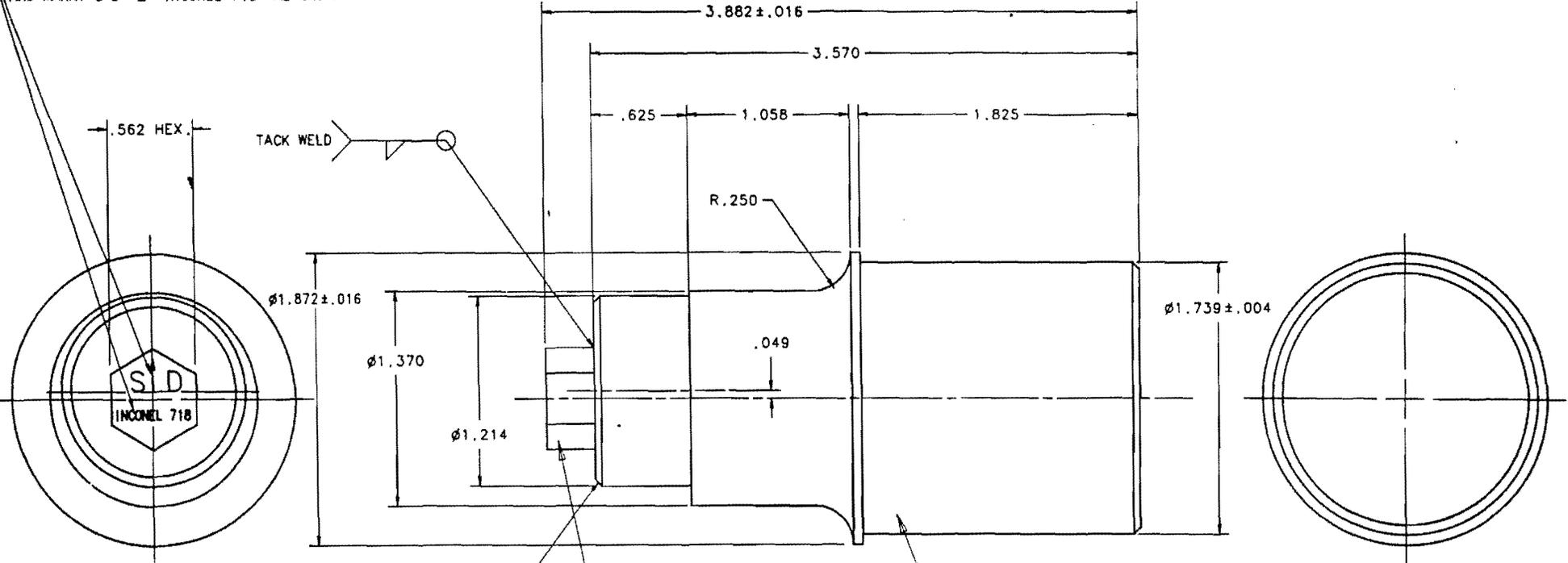


ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
PARTS LIST			
1	2.816	1/2" DIA. X 1.500	1
2	2.816	1/2" DIA. X 1.500	1
3	2.816	1/2" DIA. X 1.500	1
4	2.816	1/2" DIA. X 1.500	1
5	2.816	1/2" DIA. X 1.500	1
6	2.816	1/2" DIA. X 1.500	1
7	2.816	1/2" DIA. X 1.500	1
8	2.816	1/2" DIA. X 1.500	1
9	2.816	1/2" DIA. X 1.500	1
10	2.816	1/2" DIA. X 1.500	1
11	2.816	1/2" DIA. X 1.500	1
12	2.816	1/2" DIA. X 1.500	1
13	2.816	1/2" DIA. X 1.500	1
14	2.816	1/2" DIA. X 1.500	1
15	2.816	1/2" DIA. X 1.500	1
16	2.816	1/2" DIA. X 1.500	1
17	2.816	1/2" DIA. X 1.500	1
18	2.816	1/2" DIA. X 1.500	1
19	2.816	1/2" DIA. X 1.500	1
20	2.816	1/2" DIA. X 1.500	1
21	2.816	1/2" DIA. X 1.500	1
22	2.816	1/2" DIA. X 1.500	1
23	2.816	1/2" DIA. X 1.500	1
24	2.816	1/2" DIA. X 1.500	1
25	2.816	1/2" DIA. X 1.500	1
26	2.816	1/2" DIA. X 1.500	1
27	2.816	1/2" DIA. X 1.500	1
28	2.816	1/2" DIA. X 1.500	1
29	2.816	1/2" DIA. X 1.500	1
30	2.816	1/2" DIA. X 1.500	1
31	2.816	1/2" DIA. X 1.500	1
32	2.816	1/2" DIA. X 1.500	1
33	2.816	1/2" DIA. X 1.500	1
34	2.816	1/2" DIA. X 1.500	1
35	2.816	1/2" DIA. X 1.500	1
36	2.816	1/2" DIA. X 1.500	1
37	2.816	1/2" DIA. X 1.500	1
38	2.816	1/2" DIA. X 1.500	1
39	2.816	1/2" DIA. X 1.500	1
40	2.816	1/2" DIA. X 1.500	1
41	2.816	1/2" DIA. X 1.500	1
42	2.816	1/2" DIA. X 1.500	1
43	2.816	1/2" DIA. X 1.500	1
44	2.816	1/2" DIA. X 1.500	1
45	2.816	1/2" DIA. X 1.500	1
46	2.816	1/2" DIA. X 1.500	1
47	2.816	1/2" DIA. X 1.500	1
48	2.816	1/2" DIA. X 1.500	1
49	2.816	1/2" DIA. X 1.500	1
50	2.816	1/2" DIA. X 1.500	1
51	2.816	1/2" DIA. X 1.500	1
52	2.816	1/2" DIA. X 1.500	1
53	2.816	1/2" DIA. X 1.500	1
54	2.816	1/2" DIA. X 1.500	1
55	2.816	1/2" DIA. X 1.500	1
56	2.816	1/2" DIA. X 1.500	1
57	2.816	1/2" DIA. X 1.500	1
58	2.816	1/2" DIA. X 1.500	1
59	2.816	1/2" DIA. X 1.500	1
60	2.816	1/2" DIA. X 1.500	1
61	2.816	1/2" DIA. X 1.500	1
62	2.816	1/2" DIA. X 1.500	1
63	2.816	1/2" DIA. X 1.500	1
64	2.816	1/2" DIA. X 1.500	1
65	2.816	1/2" DIA. X 1.500	1
66	2.816	1/2" DIA. X 1.500	1
67	2.816	1/2" DIA. X 1.500	1
68	2.816	1/2" DIA. X 1.500	1
69	2.816	1/2" DIA. X 1.500	1
70	2.816	1/2" DIA. X 1.500	1
71	2.816	1/2" DIA. X 1.500	1
72	2.816	1/2" DIA. X 1.500	1
73	2.816	1/2" DIA. X 1.500	1
74	2.816	1/2" DIA. X 1.500	1
75	2.816	1/2" DIA. X 1.500	1
76	2.816	1/2" DIA. X 1.500	1
77	2.816	1/2" DIA. X 1.500	1
78	2.816	1/2" DIA. X 1.500	1
79	2.816	1/2" DIA. X 1.500	1
80	2.816	1/2" DIA. X 1.500	1
81	2.816	1/2" DIA. X 1.500	1
82	2.816	1/2" DIA. X 1.500	1
83	2.816	1/2" DIA. X 1.500	1
84	2.816	1/2" DIA. X 1.500	1
85	2.816	1/2" DIA. X 1.500	1
86	2.816	1/2" DIA. X 1.500	1
87	2.816	1/2" DIA. X 1.500	1
88	2.816	1/2" DIA. X 1.500	1
89	2.816	1/2" DIA. X 1.500	1
90	2.816	1/2" DIA. X 1.500	1
91	2.816	1/2" DIA. X 1.500	1
92	2.816	1/2" DIA. X 1.500	1
93	2.816	1/2" DIA. X 1.500	1
94	2.816	1/2" DIA. X 1.500	1
95	2.816	1/2" DIA. X 1.500	1
96	2.816	1/2" DIA. X 1.500	1
97	2.816	1/2" DIA. X 1.500	1
98	2.816	1/2" DIA. X 1.500	1
99	2.816	1/2" DIA. X 1.500	1
100	2.816	1/2" DIA. X 1.500	1

FOMI NATIONAL ACCELERATOR LABORATORY  
 UNITED STATES DEPARTMENT OF ENERGY  
 DD DETECTOR END CALORIMETER  
 MIDDLE HADRONIC MODULE  
 LINKAGE ASSY. PULL TESTER  
 1:2 3740.222-ME-2738

REV.	DESCRIPTION	DRAWN	DATE
		APPO.	DATE

MARK DIRECTION OF ECCENTRICITY AND MARK: \*S D\* & \*INCONEL 718\* AS SHOWN



.062 X 45° CHAMFER TYP. (2) PLACES

NOTE:

- PIN SHALL BE SILVER PLATED TO A .0002 THICKNESS.
- PIN SHALL BE AGE HARDEN BY PRECIPITATION HEAT TREATMENT:  
 PIN SHALL BE HEATED TO 1350±25°F AND HELD AT THAT TEMPERATURE FOR 8 HOURS.  
 PIN SHALL BE COOLED TO 1150±25°F IN THE FURNACE AND HELD AT THAT TEMPERATURE UNTIL TOTAL RECIPITATION HEAT TREATMENT TIME HAS REACHED 18 HOURS.  
 PIN SHALL BE AIR COOLED TO ROOM TEMPERATURE.

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
2		HEX. BAR STOCK SST TY-303	1
1		PIN INCONEL 718	1

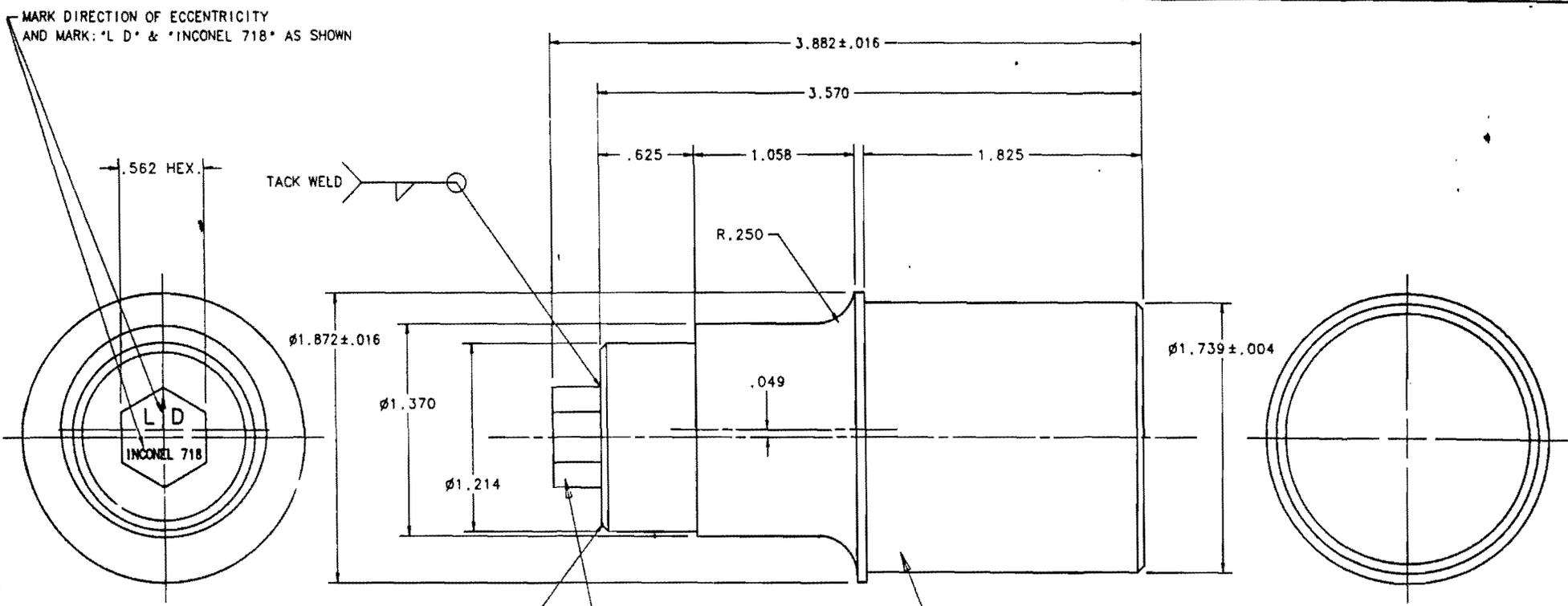
PARTS LIST			
UNLESS OTHERWISE SPECIFIED	ORIGINATOR	K. PRIMDAHL	2-21-89
.XX	.XXX	ANGLES	DRAWN
±	±.005	± 5°	CHECKED
1. BREAK ALL SHARP EDGES 1/64 MAX.	APPROVED		
2. DO NOT SCALE DRAWING.	USED ON		
3. DIMENSIONS BASED UPON ANSI Y14.5M-1982	MATERIAL		
4. MAX. ALL MACH. SURFACES			

**Fermi National Accelerator Laboratory**  
 UNITED STATES DEPARTMENT OF ENERGY

**DO DETECTOR END CALORIMETER  
 MIDDLE (COARSE) HADRONIC BOTTOM MODULE  
 SMALL ECCENTRIC DIA. BACK LINKAGE PIN**

SCALE	FILMED	DRAWING NUMBER	REV.
2:1		3740.222-MC-273870	

REV.	DESCRIPTION	DATE
		DATE



MARK DIRECTION OF ECCENTRICITY AND MARK: "L D" & "INCONEL 718" AS SHOWN

TACK WELD

②

①

.062 X 45° CHAMFER TYP. (2) PLACES

NOTE:

- PIN SHALL BE SILVER PLATED TO A .0002 THICKNESS.
- PIN SHALL BE AGE HARDEN BY PRECIPITATION HEAT TREATMENT:  
PIN SHALL BE HEATED TO 1350±25°F AND HELD AT THAT TEMPERATURE FOR 8 HOURS.  
PIN SHALL BE COOLED TO 1150±25°F IN THE FURNACE AND HELD AT THAT TEMPERATURE UNTIL TOTAL PRECIPITATION HEAT TREATMENT TIME HAS REACHED 18 HOURS.  
PIN SHALL BE AIR COOLED TO ROOM TEMPERATURE.

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
2		HEX. BAR STOCK SST TY-303	1
1		PIN INCONEL 718	1

PARTS LIST			
UNLESS OTHERWISE SPECIFIED	ORIGINATOR	K. PRIMDAHL	2-21-89
.XX	.XXX	ANGLES	DRAWN
±	± .005	± 5°	CHECKED
1. BREAK ALL SHARP EDGES 1/8" MAX.		APPROVED	
2. DO NOT SCALE DRAWING.		USED ON	
3. DIMENSIONS BASED UPON ANSI Y14.5M-1982		MATERIAL	
4. MAX. ALL MACH. SURFACES		BY	

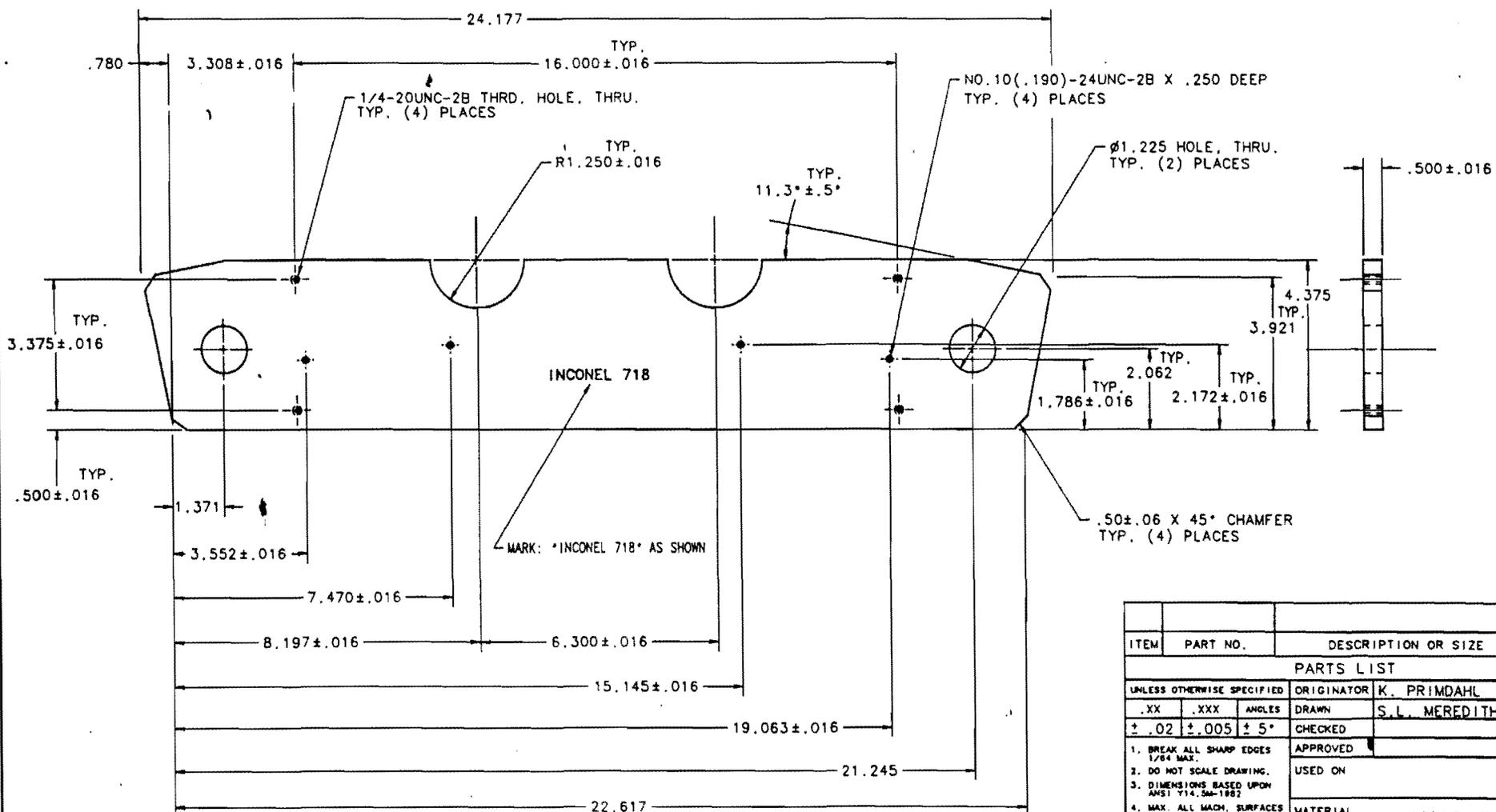
**FF** FERMION NATIONAL ACCELERATOR LABORATORY  
UNITED STATES DEPARTMENT OF ENERGY

DO DETECTOR END CALORIMETER  
MIDDLE (COARSE) HADRONIC BOTTOM MODULE  
LARGE ECCENTRIC DIA. BACK LINKAGE PIN

SCALE	FILMED	DRAWING NUMBER	REV.
2:1		3740.222-MC-273871	
CREATED WITH I-DEAS 4.0		USER NAME: SIMMIELEE	



REV.	DESCRIPTION	DRWN.	DATE
		APPD.	

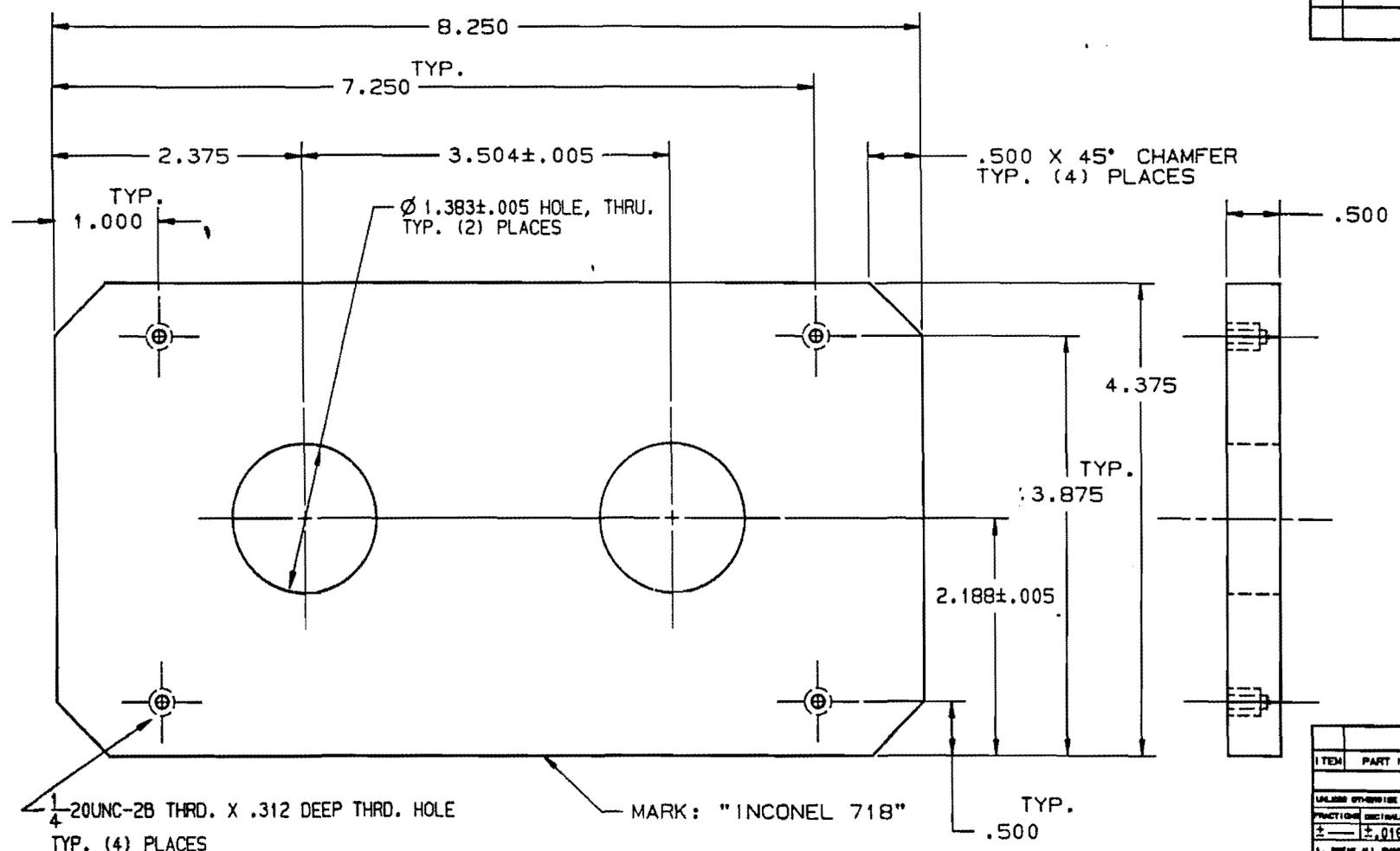


**NOTE :**

- UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE FROM SHARP CORNERS.
- TIE BAR SHALL BE SILVER PLATED TO A .0002 THICKNESS.
- TIE BAR SHALL BE AGE HARDED BY PRECIPITATION HEAT TREATMENT:  
TIE BAR SHALL BE HEATED TO 1350±25°F AND HELD AT THAT TEMPERATURE FOR 8 HOURS.  
TIE BAR SHALL BE COOLED TO 1150±25°F IN THE FURNACE AND HELD AT THAT TEMPERATURE UNTIL TOTAL PRECIPITATION HEAT TREATMENT TIME HAS REACHED 18 HOURS.  
TIE BAR SHALL BE AIR COOLED TO ROOM TEMPERATURE.

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
PARTS LIST			
UNLESS OTHERWISE SPECIFIED		ORIGINATOR	K. PRIMDAHL
.XX	.XXX	ANGLES	2-21-89
± .02	± .005	± 5°	CHECKED
1. BREAK ALL SHARP EDGES 1/64 MAX.		APPROVED	
2. DO NOT SCALE DRAWING.		USED ON	
3. DIMENSIONS BASED UPON ANSI Y14.5M-1982			
4. MAX. ALL MACH. SURFACES		MATERIAL	INCONEL 718
<b>FERMI NATIONAL ACCELERATOR LABORATORY</b> UNITED STATES DEPARTMENT OF ENERGY			
<b>DO DETECTOR END CALORIMETER  MIDDLE (COARSE) HADRONIC BOTTOM MODULE  BACK TIE BAR DETAIL</b>			
SCALE	FILMED	DRAWING NUMBER	REV.
1 : 2		3740.222-MC-273872	
CREATED WITH 1-DEAS 4.0		USER NAME: SIMMIELEE	

REV.	DESCRIPTION	DRWN	DATE
		APPR.	DATE



1/4 20UNC-2B THRD. X .312 DEEP THRD. HOLE  
TYP. (4) PLACES

MARK: "INCONEL 718"

**NOTE:**

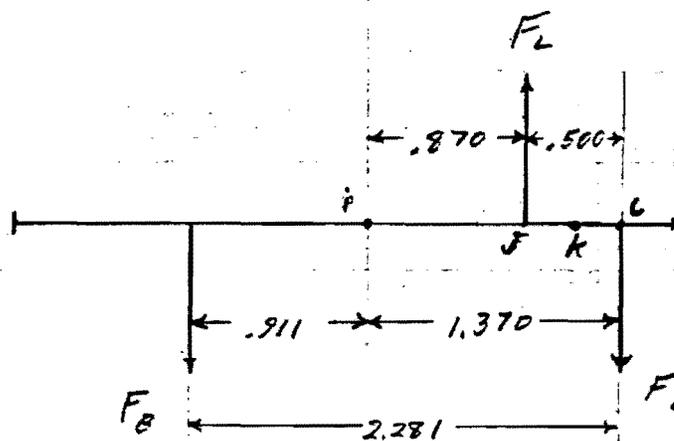
1. PLATE SHALL BE AGE HARDEN BY PRECIPITATION HEAT TREATMENT:

PLATE SHALL BE HEATED TO 1350±25°F AND HELD AT THAT TEMPERATURE FOR 8 HOURS.  
PLATE SHALL BE COOLED TO 1150±25°F IN THE FURANCE AND HELD AT THAT TEMPERATURE  
UNTIL TOTAL PRECIPITATION HEAT TREATMENT TIME HAS REACHED 18 HOURS.  
PLATE SHALL BE AIR COOLED TO ROOM TEMPERATURE.

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
<b>PARTS LIST</b>			
UNLESS OTHERWISE SPECIFIED	ORIGINATOR	K. KREMPETZ 11-21-88	
FRACTION	DECIMALS	ANGLES	DRAWN
±	±	±	S.L. MEREDITH 11-21-88
±	±	±	CHECKED
1. BREAK ALL SHARP CORNERS	APPROVED		
2. USE 1/64" DIA.	USED ON		
3. USE 90° FILE SHARPEN	MATERIAL		
4. USE .001" DIA. FILE	INCONEL 718 PLATE		
5. USE ALL INCH SURFACES	<b>FERMIL NATIONAL ACCELERATOR LABORATORY</b>		
63	UNITED STATES DEPARTMENT OF ENERGY		
<b>D0 DETECTOR END CALORIMETER</b>			
<b>MIDDLE HADRONIC BOTTOM MODULE</b>			
<b>BACK MECHANICAL CONNECTOR PLATE</b>			
SCALE	FILED	ISSUING NUMBER	REV.
1 X		374	
		374	
CREATED WITH ICEMCON VERSION 1.64			

**Appendix 2**  
**Design Calculations**

FIND  $F_L$ , MAX BASED ON PIN BENDING



CASE 1, ALL SPACERS BETWEEN EACH PLATE AND LINK

$$\sum M_c = (2.281 \text{ in}) F_B - (.500 \text{ in}) F_L = 0$$

$$F_B = (.219) F_L \quad \text{OR} \quad F_L = (4.562) F_B$$

$$F_C = (.781) F_L \quad \text{OR} \quad F_L = (1.281) F_C$$

FOR CASE 2, ALL SPACER BETWEEN LINK  
AND COVER PLATE: .300 BECOMES .620

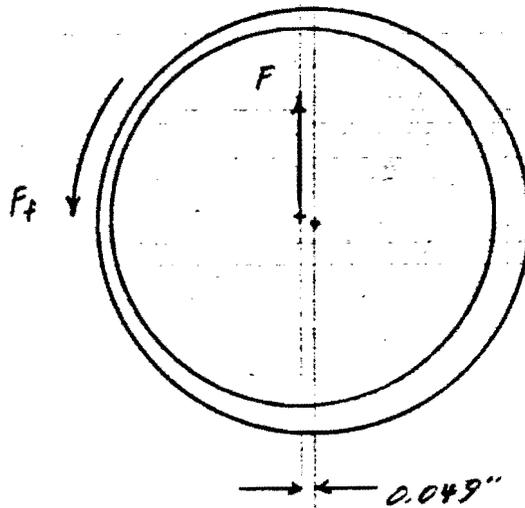
$$\sum M_c = (2.281 \text{ in}) F_B - (.620 \text{ in}) F_L$$

$$F_B = (.272) F_L \quad \text{OR} \quad F_L = (3.679) F_B$$

$$F_C = (.728) F_L \quad \text{OR} \quad F_L = (1.373) F_C$$

CONSIDER WHEAT CASE: SLIPPING

$$D = 1.156 \text{ in} \quad \text{USE } 1.152 \text{ in}$$



$$F_f = \mu F_L$$

$$\sum M = -(F_L)(.049 \text{ in}) + (F_f) \left[ \frac{1.152 \text{ in}}{2} + (.219) \frac{1.739 \text{ in}}{2} + (.57 \text{ in}) \right]$$

FROM PAGE 1

$$-(F_L)(.049 \text{ in}) + \mu F_L (1.277 \text{ in})$$

$$\mu = \frac{.049 \text{ in}}{1.277 \text{ in}} = .038$$

SO FOR  $\mu \leq .038$  SLIPPING OCCURS.

CASE 1: (NOTE: FIXED/GUIDED BEAM)

$$L = 1.37m - .25m = 1.12m$$

$$M_i = \frac{F_L}{2(1.12m)} [(1.12m)^2 - (.25m)^2] - \frac{F_c}{2}(1.12m)$$

$$M_i = (.532m)F_L - (.56m)F_c$$

$$M_i = [(.532m) - (.56m)(.791)]F_L$$

$$M_i = (.095m)F_L$$

CASE 2:

$$M_i = \frac{F_L}{2(1.12m)} [(1.12m)^2 - (.37m)^2] - \frac{F_c}{2}(1.12m)$$

$$M_i = (.499m)F_L - (.56m)F_c$$

$$M_i = (.499m)F_L - (.56m)(.728)F_L$$

$$M_i = (.591m)F_L \quad \text{SO DESIGN FOR CASE 1}$$

CASE 1: FIXED/GUIDED IS CONSERVATIVE HERE

$$M_k = \frac{F_c}{2(.500m)} [(.500m)^2 - (.250m)^2]$$

$$M_k = (.187m)F_c$$

$$M_k = (.187m)(.781m)F_L$$

$$M_k = (.146m)F_L$$

$$M_j = -M_i \quad \text{FOR EITHER CASE ABOVE}$$

$$D_i = 1.370 \text{ in}$$

$$D_k = 1.214 \text{ in}$$

$$I_i = \frac{\pi}{64} (1.370 \text{ in})^4 = .1729 \text{ in}^4$$

$$I_k = \frac{\pi}{64} (1.214 \text{ in})^4 = .1066 \text{ in}^4$$

$$C_i = \frac{(.055 \text{ in}) F_2 (1.370 \text{ in})/2}{.1729 \text{ in}^4} = (.376 \text{ in}^{-2}) F_2$$

$$C_k = \frac{(.146 \text{ in}) F_2 (1.214 \text{ in})/2}{.1066 \text{ in}^4} = (.831 \text{ in}^{-2}) F_2$$

$$F_{L, \text{max}} = \frac{(.66) \sigma_y}{.831 \text{ in}^{-2}} = \frac{23000 \text{ LB}}{119,000 \text{ LB}}$$

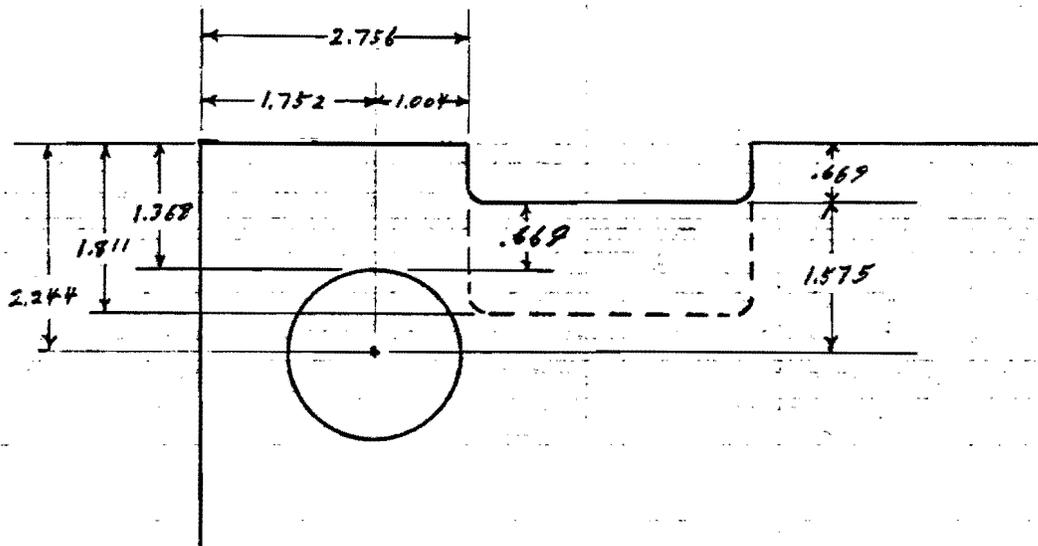
FIND  $F_{L, MAX}$  BASED ON PIN SHEAR

WORST CASE IS BETWEEN J &amp; K

$$A = \frac{\pi}{4} (1.214 \text{ in.})^2 = 1.158 \text{ in.}^2$$

$$F_{L, MAX} = (1.280) (1.158 \text{ in.}^2) (4) (\sigma_u) = 17,000 \text{ LB} \quad 88,000 \text{ LB}$$

$$F_{L, MAX} = (1.280) (1.158 \text{ in.}^2) (3) (\sigma_{UTS}) = 35,000 \text{ LB} \quad 88,000 \text{ LB}$$



FIND  $F_{LINK, MAX}$  BASED ON FRONT PLATE:

BEARING

55304

J-718

$$F_{MAX} = (3.679)(1.759 \text{ in})(1.822 \text{ in})(.9)(\sigma_y) = 314,000 \text{ LB} \quad -$$

TENSION

$$F_{MAX} = (3.679)(2)(.669 \text{ in})(1.319 \text{ in})(.6)(\sigma_y) = 116,000 \text{ LB} \quad -$$

SHEAR TEAR-OUT

↑ THICKNESS IN NOTCH AREA

$$F_{MAX} = (3.679)(2)(1.748 \text{ in})(1.822 \text{ in})(.4)(\sigma_y) = 281,000 \text{ LB} \quad -$$

FIND  $F_{t, \text{max}}$  BASED ON LINK

$$D = 1.383 \text{ in}$$

$$(1.383 \text{ in})(1.5) = 2.074 \text{ in} \quad \text{OKAY FOR SIDES \& ENDS}$$

BEARING

35304I-718

$$F_{t, \text{max}} = (1.520 \text{ in})(.5 \text{ in})(.9) \sigma_y = 17,000 \text{ LB} \quad 89,000 \text{ LB}$$

TENSION

$$F_{t, \text{max}} = (2.992 \text{ in})(.5 \text{ in})(.6) \sigma_y = 26,000 \text{ LB} \quad 134,000 \text{ LB}$$

SHEAR TENSILE

$$F_{t, \text{max}} = (2)(2.375 \text{ in})(.5 \text{ in})(.4) \sigma_y = 28,000 \text{ LB} \quad 142,000 \text{ LB}$$

TEST ALSO FOR  $F_{\text{TENSION}} \leq .50 \text{ CUTS}$ FOR SHEAR  $\text{TUTS} = 188,000 \text{ PSI}$ 

$$F_{t, \text{max}} = (2.992 \text{ in})(.5 \text{ in})(.5)(188,000 \text{ PSI}) = 134,000 \text{ LB}$$

FIND  $F_{L, MAX}$  BASED ON LOWER PLATE

$$D = 1.225 \text{ in}$$

$$w = 4.375$$

$$\frac{1.752 \text{ in}}{1.225 \text{ in}} = 1.43$$

MARGINALLY OKAY FOR END  
OKAY FOR EDGES

BEARING

SS304

J-718

$$F_{L, MAX} = (1.280)(1.225 \text{ in})(.5 \text{ in})(.9) \sigma_y = 21,000 \text{ LB} \quad 105,000 \text{ LB}$$

TENSION

$$F_{L, MAX} = (1.280)(3.150 \text{ in})(.5 \text{ in})(.6) \sigma_y = 36,000 \text{ LB} \quad 181,000 \text{ LB}$$

SHEAR TEAR OUT

$$F_{L, MAX} = (1.28)(1.752 \text{ in})(.5 \text{ in})(2)(.4) \sigma_y = 26,000 \text{ LB} \quad 134,000 \text{ LB}$$

TEST ALSO, TENSION:

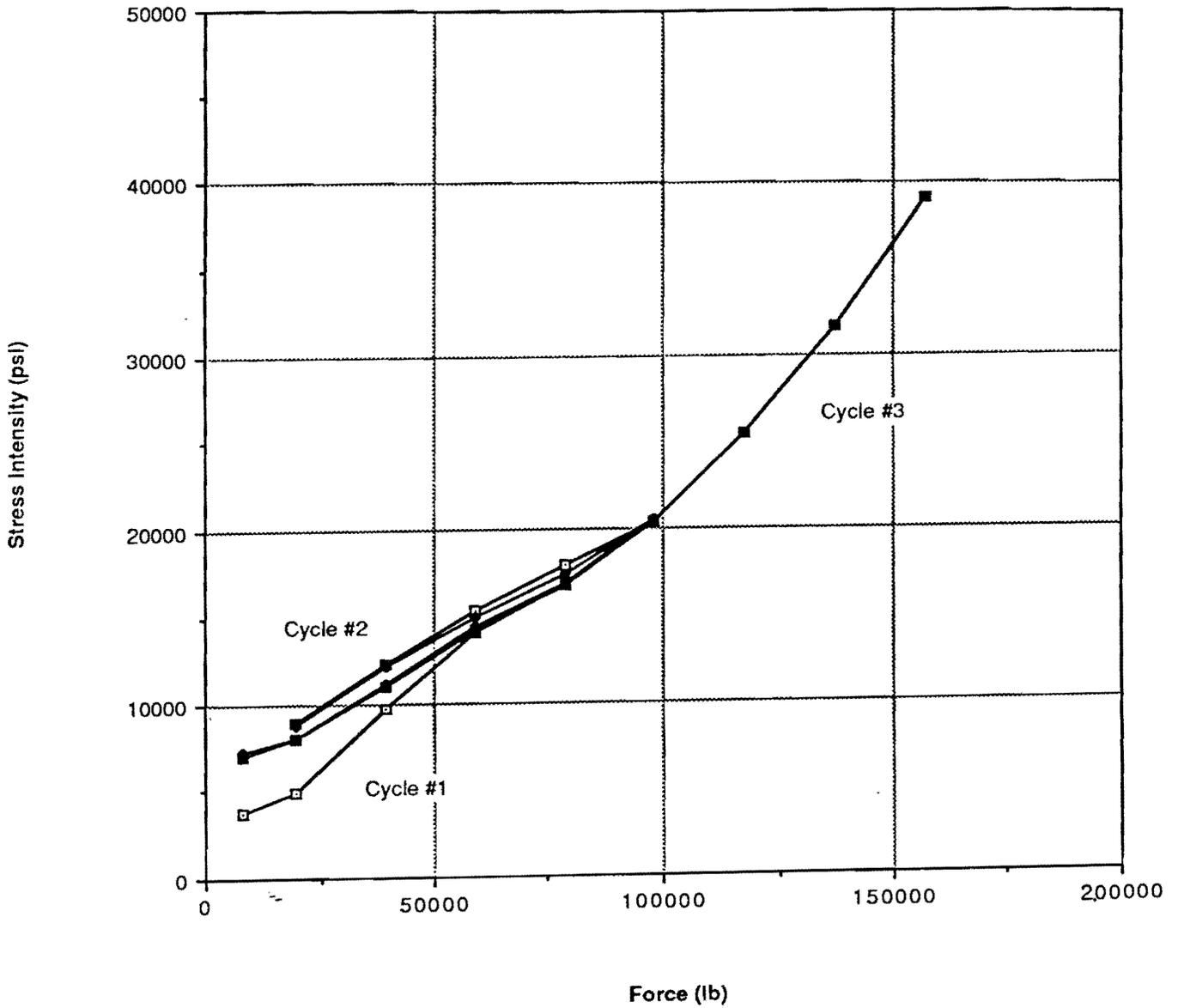
$$F_{L, MAX} = (1.28)(3.150 \text{ in})(.5 \text{ in})(.5) \sigma_{TTS} = 181,000 \text{ LB}$$

Appendix 3  
Strain Gage Results

# MCH Back Bottom Fastener

Cover plate, O.R. (near top pin)

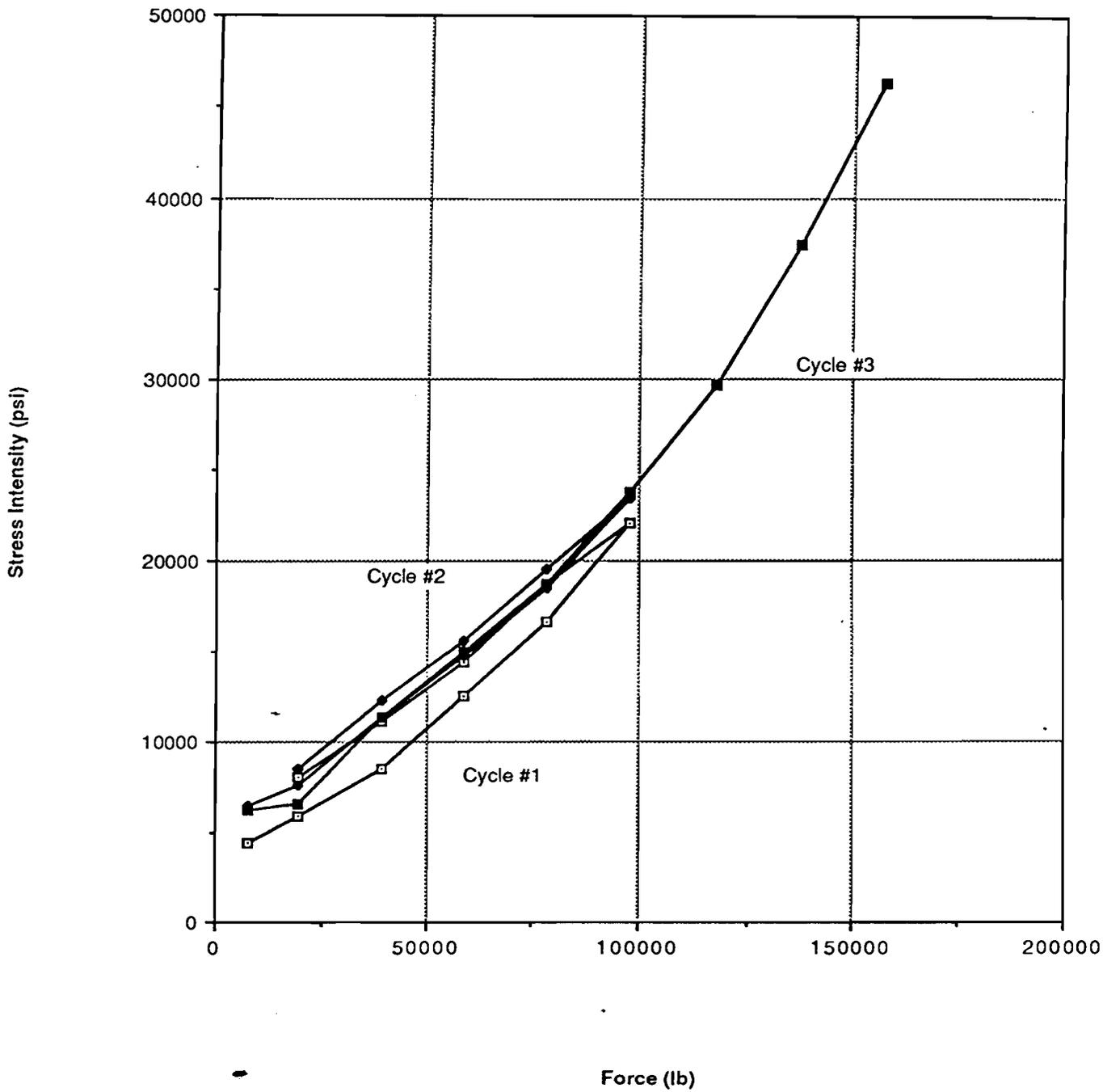
April 28, 1989



# MCH Back Bottom Fastener

Cover plate, I.R. (near top pin)

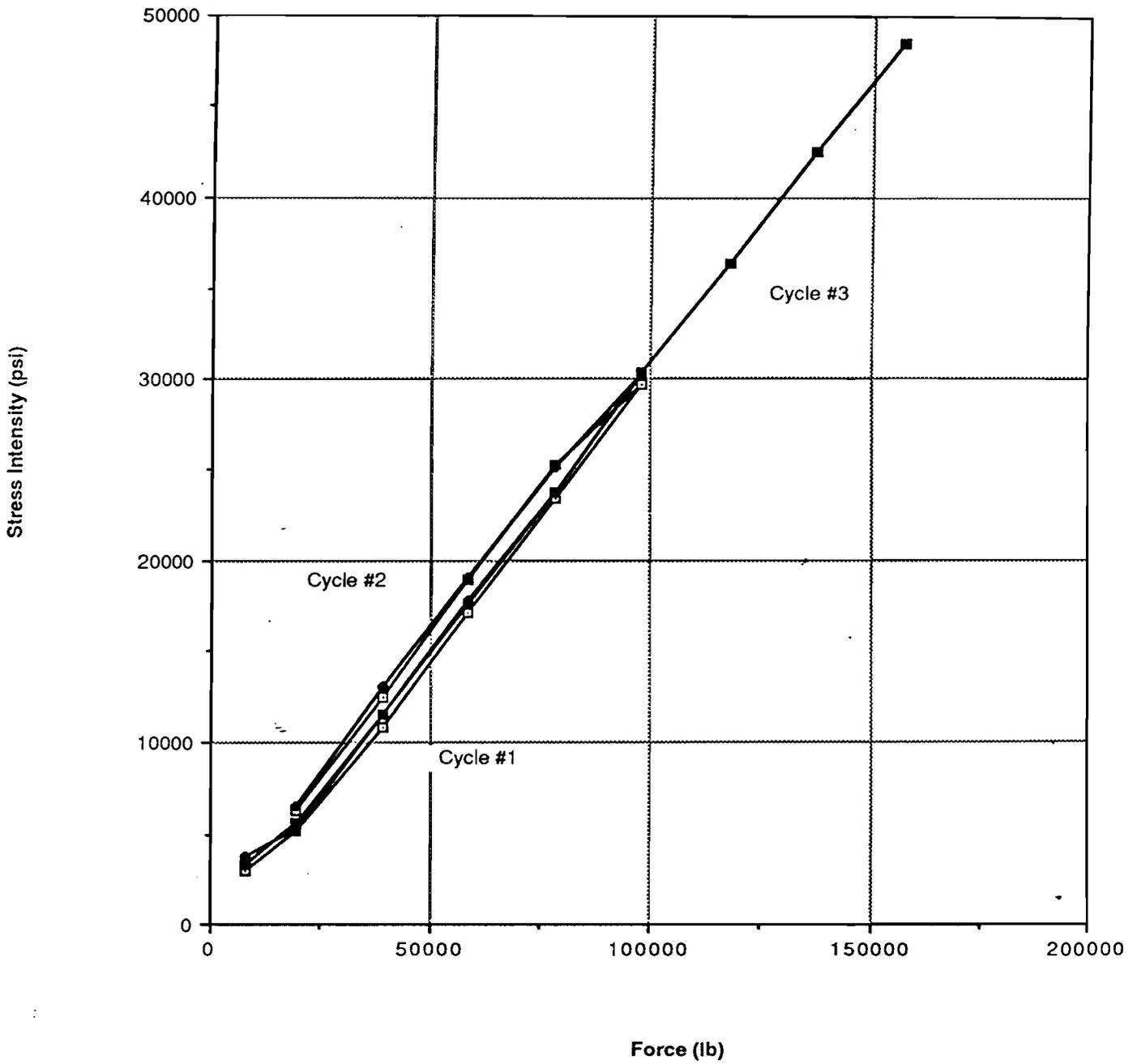
April 28, 1989



# MCH Back Bottom Fastener

Cover plate, (near cavity)

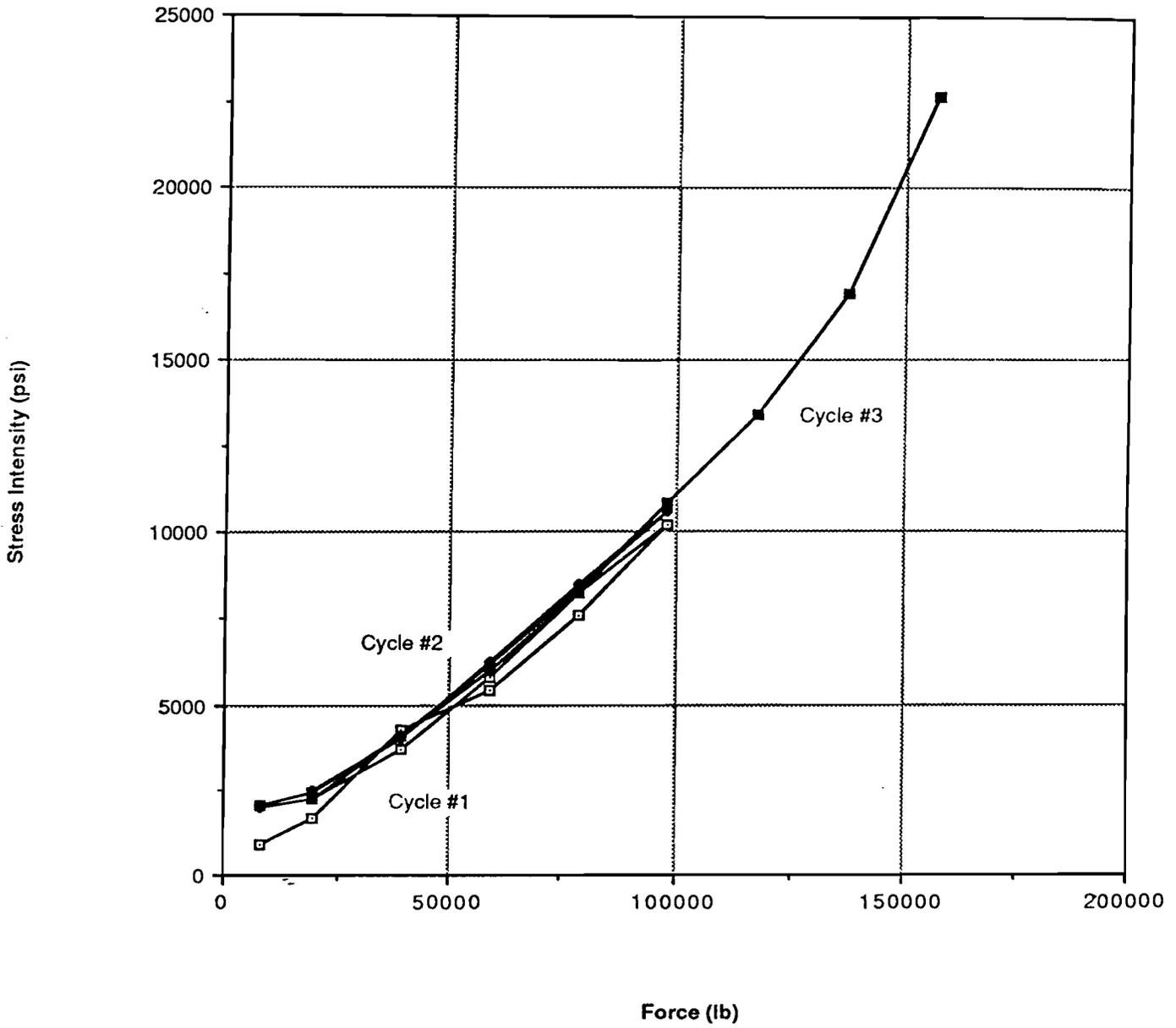
April 28, 1989



# MCH Back Bottom Fastener

Back Plate, O. R.

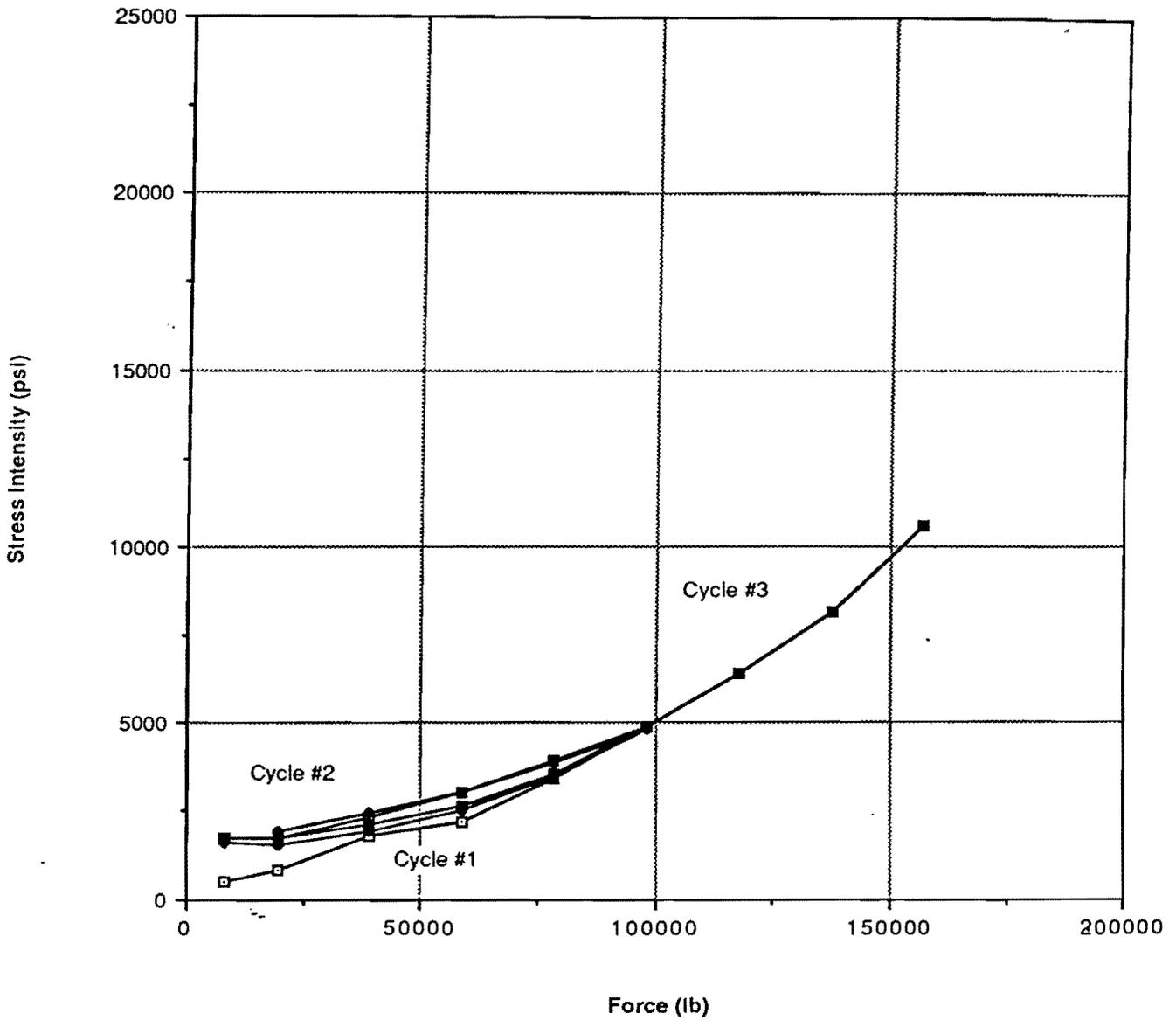
April 28, 1989



# MCH Back Bottom Fastener

Back plate, I.R.

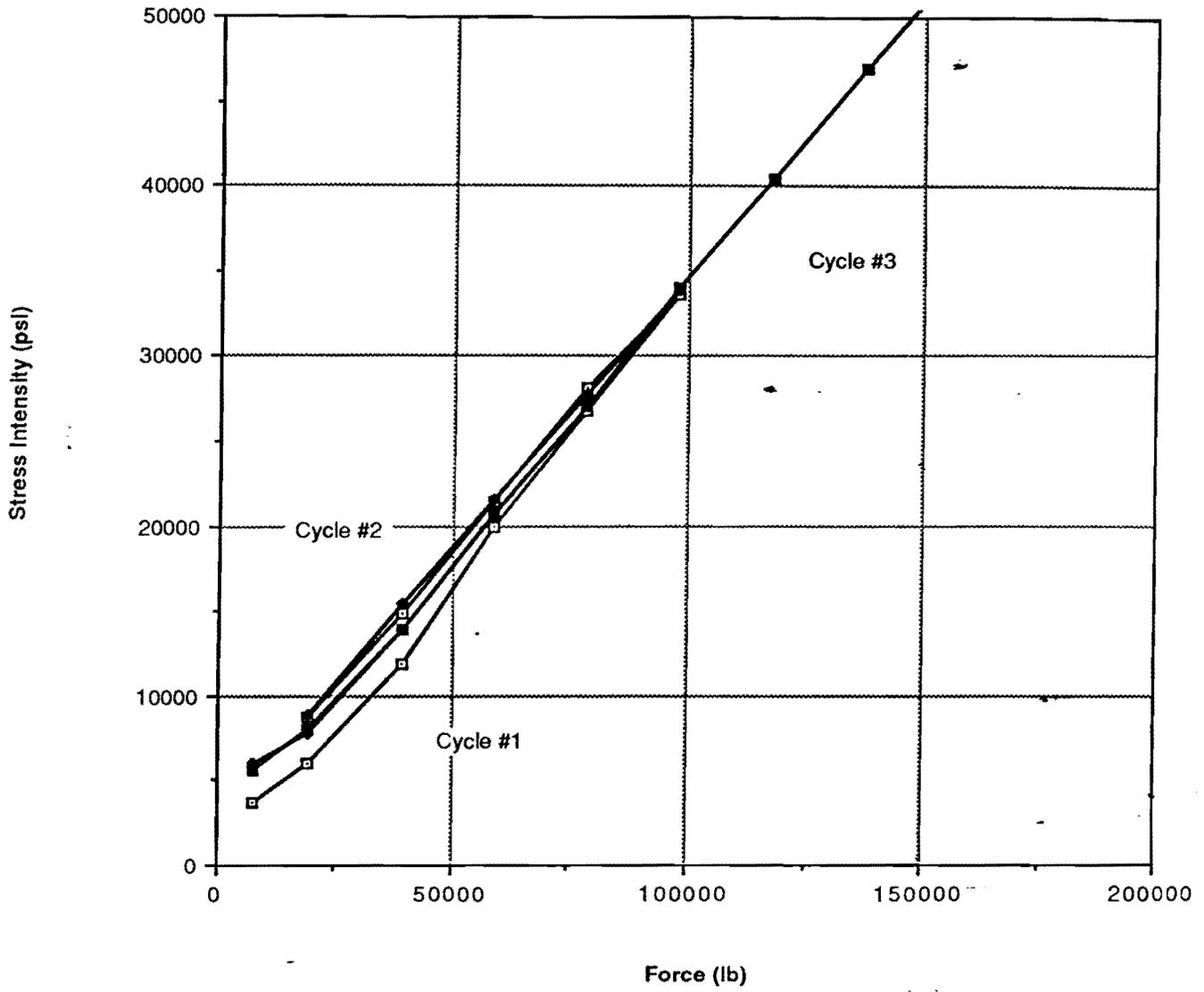
April 28, 1989



# MCH Back Bottom Fastener

Link plate, I.R. (near bottom pin)

April 28, 1989



# MCH Back Bottom Fastener

Center of Link Plate, (near bottom pin)

April 28, 1989

