**MH TEST FILLER
FORCE LIMITATIONS**

Keith A. Primdahl

10 / 2 / 90

D-Zero Engineering Note

#3740.225-EN-261

Keith Primdahl

The OH modules for the D0 end calorimeter are being tested by supporting a load to simulate the MH, IH, and EM modules. This test structure, the MH filler, is inserted into the previously assembled OH modules, and then loaded with hydraulic jacks.

The maximum test load applied by the jacks is 78,600 lb, which is via the two downstream jacks at 130% of the nominal load. Bill Cooper's memo of 9/10/90 is include as appendix C.

This note presents calculations for the AISC maximum allowable stresses/loads of the various parts of the testing assembly. Furthermore, calculations show that the actual test load is less than the AISC allowable. The limiting cases for each assembly component are summarized in Table 1. The calculations are included in appendix A; related drawings can be found in appendix B.

Table One
Critical Stress Limiting Cases

<u>ELEMENT</u>	<u>LIMITING CASE</u>	<u>Maximum AISC Allowable</u>	<u>Actual test Maximum force</u>	<u>Page Apx. A</u>
Bridge Beam	Bending	161,000 lb/jack	78,600 lb/jack	2
	Shear	312,000 lb/jack	78,600 lb/jack	2
Bridge to beam connector plate	Tension	210000 lb/jack	78,600 lb/jack	3
	Bearing on pin	189,000 lb/jack	78,600 lb/jack	3
	Shear on weld	89,000 lb/jack	78,600 lb/jack	3
Bridge bar	Tension	207,000 lb/jack	78,600 lb/jack	4
	Bearing on pin	189,000 lb/jack	78,600 lb/jack	4
	Dbl. shear on pin	98,000 lb/jack	78,600 lb/jack	4
	Shear on weld	174,000 lb/jack	78,600 lb/jack	4
Filler beam	Bending	150,000 lb/jack	78,600 lb/jack	6
	Shear	312,000 lb/jack	78,600 lb/jack	6
Bridge weld	Shear & bending	174,000 lb/jack	78,600 lb/jack	15
Bridge plate	Tension & bending	333,000 lb/jack	78,600 lb/jack	13
Beam brace	Buckling	105,000 lb	2,370 lb	5
	Tension	24,000 lb	2,370 lb	5
	Dbl. shear on bolt	9,000 lb	2,370 lb	5
	Bearing on bolt	5,000 lb	2,370 lb	5
	Shear on weld	8,000 lb	2,370 lb	5
DU Glacier	Compression	67,500 lb/pad	27,600 lb/pad	7
Half Moon plate	Buckling	89,413 psi	4,500 psi	8
MH filler lifting beams	Shear on bolts	37000 lb	7300 lb	10
	Shear on weld	155000 lb	7300 lb	10
	Bending of welds	71,000 lb	7300 lb	10
	Bending of beams	157000 lb	7300 lb	10

Appendix A

Force Calculations

Note #3740.225-EN-261

$$F_F = (2 \text{ JACKS})(64,900 \text{ LB/JACK}) = 129,800 \text{ LB}$$

$$F_B = (2 \text{ JACKS})(78,600 \text{ LB/JACK}) = 157,200 \text{ LB}$$

$$\begin{aligned} \sum M_{R_B} &= (129,800 \text{ LB})(80.0) - (157,200 \text{ LB})(9.9') \\ &\quad - (R_F)(57.3') = 0 \end{aligned}$$

$$R_F = 154,100 \text{ LB} \quad (2 \text{ JACKS})$$

$$\sum F_y = 129,800 \text{ LB} + 157,200 \text{ LB} - 154,100 \text{ LB} - R_B = 0$$

$$R_B = 132,900 \text{ LB} \quad (2 \text{ JACKS})$$

R_F , R_B ARE VERTICAL REACTION FORCES
ON ENTIRE HALF MOONS.

FROM BILL'S MEMO OF 11-11-90, THE MAXIMUM
MH/ON RADIAL FORCE IS:

$$\frac{55,184 \text{ LB}}{2 \text{ PADS}} \cong 27,600 \text{ LB/PAD}$$

ASSL ALLOWABLE:
67,500 LB/PAD

• BENDING

POINT OF MAXIMUM MOMENT IS JACK LOCATION:

$$L_{\text{MOMENT ARM}} = \frac{144.6 - 102.5}{2} = 21.1 \text{ in}$$

$$C = 9 \text{ in}$$

$$I = 1330 \text{ in}^4$$

$$P_{\text{MAX}} = \frac{(0.66)(\sigma_y)I}{L C}$$

$$P_{\text{MAX}} = \frac{(0.66)(35,000 \text{ psi})(1330 \text{ in}^4)}{(21.1 \text{ in})(9 \text{ in})} = 161,000 \text{ LB}$$

• SHEAR

$$P_{\text{MAX}} = (.4)(35,000 \text{ psi})(22.3 \text{ in}^2) = 312,000 \text{ LB}$$

RESULT IS "LB PER JACK"

CONSIDER TWO PLATES AT EACH CONNECTION

• TENSION

$$P_{MAX} = (2)(.6)(35,000 \text{ psi})(8\text{in} - 3\text{in})(1\text{in}) = 210,000 \text{ LB}$$

• BEARING ON PIV

$$P_{MAX} = (2)(.9)(35,000 \text{ psi})(3\text{in})(1\text{in}) = 189,000 \text{ LB}$$

• SHEAR ON WELD

$$P_{MAX} = (2)(.3)(35,000 \text{ psi})(.75\text{in})(.707)(8\text{in}) = 89,000 \text{ LB}$$

RESULT IS "LB PER JACK"

• TENSION

$$P_{MAX} = (.6)(35,000 \text{ psi})(8 \text{ in} - 3.063 \text{ in})(2 \text{ in}) = 207,000 \text{ LB}$$

• BEARING ON PEN

$$P_{MAX} = (.9)(35,000 \text{ psi})(3 \text{ in})(2 \text{ in}) = 189,000 \text{ LB}$$

• DOUBLE SHEAR ON PEN

$$P_{MAX} = (.4)(35,000 \text{ psi})(3 \text{ in})^2 \frac{\pi}{4} = 98,000 \text{ LB}$$

• SHEAR ON WELD

$$P_{MAX} = (.3)(35,000 \text{ psi})(.375 \text{ in})(.707)(62.6 \text{ in}) = 174,000 \text{ LB}$$

2" x 8" x 107.3" STEEL BAR

$W = 501 \text{ LB}$

W18 x 76" BEAM

$W = 1368 \text{ LB}$

$W_{\text{TOTAL}} = (2)(501 \text{ LB}) + (1368 \text{ LB}) = 2370 \text{ LB}$

FOR 2.5" x $\frac{1}{4}$ " ANGLE

$A_{\text{LUGS-SECTION}} = 1.19 \text{ in}^2$

$I = .703 \text{ in}^4$

• BUCKLING

$$P_{\text{CR}} = \frac{\pi^2 EJ}{L^2} = \frac{\pi^2 (30 \times 10^6 \text{ psi}) (.703 \text{ in}^4)}{(44.4 \text{ in})^2} = 105,500 \text{ LB}$$

• TENSION

$$P_{\text{MAX}} = (.6)(35,000 \text{ psi})(1.19 \text{ in}^2) = 24,000 \text{ LB}$$

• DOUBLE SHEAR ON BOLT

FOR A $\frac{3}{4}$ -10 UNC

$A_{\text{STRESS}} = .334 \text{ in}^2$

$$P_{\text{MAX}} = (.4)(2)(35,000 \text{ psi})(.334 \text{ in}^2) = 9000 \text{ LB}$$

• BEARING ON BOLT

$$P_{\text{MAX}} = (.9)(35,000 \text{ psi})(.75 \text{ in})(.25 \text{ in}) = 5000 \text{ LB}$$

• SHEAR ON WELD

$$P_{\text{MAX}} = (.3)(35,000 \text{ psi})(2)(.25 \text{ in})(.707)(2.25 \text{ in}) = 8000 \text{ LB}$$

$\therefore W_{\text{TOTAL}} = 2370 \text{ LB}$ IS ACCEPTABLE

• BENDING

MAXIMUM MOMENT IS AT UPSTREAM CONNECTION
TO W10x45 BEAM

$$L_{\text{MOMENT ARM}} = 22.7 \text{ in}$$

$$c = 9 \text{ in}$$

$$I = 1330 \text{ in}^4$$

$$P_{\text{MAX}} = \frac{(66)(\sigma_y)I}{Lc}$$

$$P_{\text{MAX}} = \frac{(66)(35,000 \text{ psi})(1330 \text{ in}^4)}{(22.7 \text{ in})(9 \text{ in})} = 150,000 \text{ LB}$$

• SHEAR

$$P_{\text{MAX}} = (.4)(35,000 \text{ psi})(22.7 \text{ in}^2) = 312,000 \text{ LB}$$

- COMPRESSION OF DUCALUX

$$A_{PAD} = (1.25 \text{ in})(5.000 \text{ in}) = 6.25 \text{ in}^2$$

$$(\sigma_{MAX})_{DUCALUX} = 12,000 \text{ psi}$$

$$P_{MAX}/PAD = (.9)(1.25 \text{ in})(5.000 \text{ in})(12,000 \text{ psi})$$

$$P_{MAX}/PAD = 67,500 \text{ LB}$$

- COMPRESSION OF STEEL IS CLEARLY
A LESS SEVERE CRITERIA

CONSIDER BUCKLING OF HALF MOON PLATE:

NOTES: TABLE 35, CASE 1

$$\sigma' = K \frac{E}{1-\nu^2} \left(\frac{t}{b} \right)^2 \quad (\text{ALL EDGES SIMPLY SUPPORTED})$$

$$a = 39 \quad (\text{MAX HEIGHT OF PLATE})$$

$$b = 97.5 \quad (\text{APPROX EFF WIDTH OF PLATE})$$

$$\frac{a}{b} = \frac{39}{97.5} = .4$$

$$K = 6.92$$

$$\sigma' = (6.92) \frac{(28.3 \times 10^6 \text{ psi})}{1 - (.28)^2} \left[\frac{2 \text{ in}}{97.5 \text{ in}} \right]^2 = 89,413 \text{ psi}$$

↑ CRITICAL STRESS (BUCKLING OCCURS)

WE WON'T REACH ANYWHERE NEAR THIS STRESS. SEE "MAX/OH SUPPORT POINTS."

IN OTHER WORDS: "FAILURE BY COMPRESSION WILL OCCUR BEFORE BUCKLING"

$$\sigma_{\text{MAX}} = 89,413 \text{ psi}$$

4,500 psi MAX OVER SMALL AREAS

$$\frac{27600 \text{ LB/IN}^2}{(1.25 \text{ in})(5.00 \text{ in})} = 4500 \text{ psi}$$

14.90
↓

WELD 4" EVERY 12" ($\frac{3}{8}$ " FILLET)

$$L_{\text{WELD}} = 40"$$

$$W_{\text{WELD}} = \left(\frac{3}{8} \text{ in}\right)(.707) = .265 \text{ in}$$

$$I = \frac{(40 \text{ in})(.265 \text{ in})^3}{12} = .062 \text{ in}^4$$

$$I' = 2 \left[(.062 \text{ in}^4) + (.265 \text{ in})(40 \text{ in})(1.132 \text{ in})^2 \right] = 27.29 \text{ in}^4$$

$$\sigma_{\text{MAX}} = (.3)(35,000 \text{ psi}) = 10,500 \text{ psi}$$

$$M = (39 \text{ in})(F_H) \quad (\text{ASSUMES ALL } F_H \text{ AT TOP})$$

$$\sigma_{\text{MAX}} = \frac{(39 \text{ in})(F_H)(1.265 \text{ in})}{27.29 \text{ in}^4} = 10,500 \text{ psi}$$

$$F_H = 5800 \text{ LB}$$

$$\tan^{-1} \frac{5800 \text{ LB}}{80,000 \text{ LB}} = 4.15^\circ$$

$$(39 \text{ in})(\sin 4.15^\circ) = 2.82 \text{ in}$$

SO, FOR FOLDING TO OCCUR,
HALF MOON MUST BE ASSEMBLED
OUT OF THE VERTICAL PLANE
BY 4.15° (OR 2.82 in DIFFERENT
FROM TOP TO BOTTOM). THIS
IS W/O CREDIT FOR BOX
BEAMS.

$$W = 7300 \text{ LB}$$

$$\bar{Z} = 33.9 \text{ in} \quad (\text{FROM BACK FACE OF LEFT PLATE})$$

- SHEAR ON 8 $\frac{3}{4}$ "-10 UNC BOLTS

$$P_{\text{MAX}} = (8)(.4)(35,000 \text{ psi})(.334 \text{ in}^2) = 37,000 \text{ LB}$$

- SHEAR ON WELD TO BOX BEAM

$$P_{\text{MAX}} = (2)(.3)(35,000 \text{ psi})(.375 \text{ in})(.707)(28 \text{ in}) = 155,000 \text{ LB}$$

- BENDING ON WELD TO BOX BEAM

$$I = \frac{(8.375 \text{ in})(6.375 \text{ in})^3}{12} - \frac{(8 \text{ in})(6 \text{ in})^3}{12} = 162.8 \text{ in}^4$$

$$I_{\text{TOT}} = 2 \left[(162.8 \text{ in}^4) + (.375 \text{ in})(28 \text{ in})(8 \text{ in})^2 \right] = 1670 \text{ in}^4$$

$$C = 16 \text{ in}$$

$$P_{\text{MAX}} = \frac{(.66)(\sigma_y)I}{L C}$$

$$P_{\text{MAX}} = \frac{(.66)(35,000 \text{ psi})(1670 \text{ in}^4)}{(33.9 \text{ in})(16 \text{ in})} = 71,000 \text{ LB}$$

- BENDING OF BOX BEAMS: $P_{\text{MAX}} > 71,000 \text{ LB}$
DUE TO $\frac{1}{2}$ " WALLS VS. $\frac{3}{8}$ " FELLOYS

NOTE: TWO BOX BEAMS WERE ADDED TO LEFT
WITH FORK LEFT:

$$P_{\text{MAX}} = (.3)(10 \text{ in})(4 \text{ WELDS})(\frac{3}{8} \text{ in})(35,000 \text{ psi}) = 157,000 \text{ LB}$$

14-90
↓

CONSIDER $\frac{1}{2}$ OF BRIDGE BEAM

$$F = F_{\text{VERTICAL PLATE}} = F_{\text{JACK}}$$

TO FIND θ AT LEFT END, USE ROARK'S TABLE 3,
CASE 1C

$$\theta = \frac{-Fa}{4EI} (L-a)^2$$

$$a = 22.7 \text{ in}$$

$$L = 72.3 \text{ in}$$

$$I = 1330 \text{ in}^4$$

$$E = 29 \times 10^6 \text{ psi}$$

$$\theta = \frac{(-F)(22.7 \text{ in})(72.3 \text{ in} - 22.7 \text{ in})^2}{(4)(29 \times 10^6 \text{ psi})(1330 \text{ in}^4)(72.3 \text{ in})}$$

$$\theta = (.22 \times 10^{-9} \text{ rad}) (-F)$$

THIS θ IS EQUAL TO θ FOR THE
"BENT" VERTICAL PLATE

TO FIND MOMENT IN VERTICAL PLATE,
USE ROARK'S, TABLE 3, CASE 3A:

$$\theta = \frac{-M(L-a)}{EI}$$

$$L = 83.1 \text{ in (FROM BEAM TO PIN)}$$

$$a = 0$$

$$E = 29 \times 10^6 \text{ psi}$$

$$I = \frac{(2 \text{ in})^3 (8 \text{ in})}{12 \text{ in}} = 5.3 \text{ in}^4$$

$$\theta = \frac{(-M)(83.1 \text{ in})}{(29 \times 10^6 \text{ psi})(5.3 \text{ in}^4)} = (541 \times 10^{-9} \text{ LB}^{-1} \text{ in}^{-1})(-M)$$

EQUATE THE EXPRESSIONS FOR θ :

$$(-M)(541 \times 10^{-9} \text{ LB}^{-1} \text{ in}^{-1}) = (-F)(.22 \times 10^{-3} \text{ LB}^{-1})$$

$$M = (.407 \times 10^{-3} \text{ in}^{-1})(F)$$

WRITE EXPRESSION FOR BENDING STRESS

$$\sigma_b = \frac{Mc}{I}$$

$$c = 9 \text{ in}$$

$$\sigma_b = \frac{(.407 \times 10^{-3} \text{ in}^{-1})(F)(9 \text{ in})}{(5.3 \text{ in}^4)}$$

$$\sigma_b = (.691 \times 10^{-3} \text{ in}^{-2})(F)$$

TENSION IN VERTICAL PLATE:

$$\sigma_T = \frac{F}{16 \text{ in}^2} = (.062 \text{ in}^{-2}) F$$

TO COMBINE TENSION AND BENDING,
I'LL REWRITE AISC EQN 1.6-1b:

$$\frac{\sigma_T}{.6 \sigma_y} + \frac{\sigma_B}{.66 \sigma_y} \leq 1.0$$

$$\sigma_y = 35,000 \text{ psi}$$

$$\frac{(.062 \text{ in}^{-2}) F}{(.6)(35,000 \text{ psi})} + \frac{(.691 \times 10^{-3} \text{ in}^{-2}) (F)}{(.66)(35,000 \text{ psi})} \leq 1.0$$

$$(3.0 \times 10^{-6} \text{ in}^{-2}) F \leq 1.0$$

$$F = 333,000 \text{ LB}$$

MAX ALLOWABLE JACK FORCE

NOTE, FOR AXIAL TENSION ALONE:

$$F = (.6)(16 \text{ in}^2)(35,000 \text{ psi}) = 336,000 \text{ LB}$$

FIND BENDING STRESS IN WELD

$$I_1 = \frac{(.265'')^3 (8'')}{12} = .0124 \text{ in}^4$$

$$I_2 = \frac{(.265'')^3 (7'')}{12} = .0109 \text{ in}^4$$

$$I_3 = \frac{(16.3'')^3 (.265'')}{12} = 95.6 \text{ in}^4$$

$$I_{\text{TOTAL}} = 2 \left[.0124 \text{ in}^4 + (8'')(.265'')(9.227'')^2 \right. \\ \left. + .0109 \text{ in}^4 + (7'')(.265'')(8.282'')^2 \right. \\ \left. + 95.6 \text{ in}^4 \right] = 806.7 \text{ in}^4$$

$$\sigma_B = \frac{Mc}{I}$$

$$M = (.407 \times 10^{-3} \text{ in}^3)(F) \quad (\text{FROM P. 12})$$

$$c = 9.36 \text{ in}$$

$$I = 806.7 \text{ in}^4$$

$$\sigma_B = \frac{(.407 \times 10^{-3} \text{ in}^3)(F)(9.36 \text{ in})}{(806.7 \text{ in}^4)} = (4.7 \times 10^{-6} \text{ in}^{-2})(F)$$

I POSTULATE THAT THIS BENDING FORCE IS SEEN AS A SHEAR THROUGH THE WELD MATERIAL. IN ORDER TO COMBINE THE BEAM SHEAR AND BENDING SHEAR, I'LL SIMPLY SUM THE TWO RESULTS. THIS IS CONSERVATIVE SINCE THEIR RESPECTIVE PLANS OF MAXIMUM SHEAR WILL NOT BE ORIENTED THE SAME.

$$\tau_{\text{BEAM SHEAR}} = \frac{F}{(.265'')(62.6'')} = (60.3 \times 10^{-3} \text{ in}^{-2})(F)$$

$$\tau_{\text{BENDING SHEAR}} = (4.7 \times 10^{-6} \text{ in}^{-2})(F)$$

$$\tau_{\text{BEAM SHEAR}} + \tau_{\text{BENDING SHEAR}} = (.3) \sigma_y$$

$$(60.3 \times 10^{-3} \text{ in}^{-2})(F) + (4.7 \times 10^{-6} \text{ in}^{-2})(F) = (.3)(35,000 \text{ psi})$$

$$F_{\text{MAX}} = 174,000 \text{ LB} \quad \left(\begin{array}{l} \text{BENDING ON THE WELD} \\ \text{IS NEGLIGIBLE} \end{array} \right)$$

Appendix B

Drawings

Note #3740.225-EN-261

PAGE 8 & 9

.875 DIA. DRILL THRU
8 HOLES AS SHOWN.
Ø .063

DETAIL "A"
SCALE: 1/4

ITEM	PART NO.	DESCRIPTION IN SIZE	QTY.
1	2720-ME-27B94B	END CALORIMETER	1
2	2720-ME-27B94B	END CALORIMETER	1
3	2720-ME-27B94B	END CALORIMETER	1
4	2720-ME-27B94B	END CALORIMETER	1
5	2720-ME-27B94B	END CALORIMETER	1
6	2720-ME-27B94B	END CALORIMETER	1
7	2720-ME-27B94B	END CALORIMETER	1
8	2720-ME-27B94B	END CALORIMETER	1
9	2720-ME-27B94B	END CALORIMETER	1
10	2720-ME-27B94B	END CALORIMETER	1
11	2720-ME-27B94B	END CALORIMETER	1
12	2720-ME-27B94B	END CALORIMETER	1
13	2720-ME-27B94B	END CALORIMETER	1
14	2720-ME-27B94B	END CALORIMETER	1
15	2720-ME-27B94B	END CALORIMETER	1
16	2720-ME-27B94B	END CALORIMETER	1
17	2720-ME-27B94B	END CALORIMETER	1
18	2720-ME-27B94B	END CALORIMETER	1
19	2720-ME-27B94B	END CALORIMETER	1
20	2720-ME-27B94B	END CALORIMETER	1
21	2720-ME-27B94B	END CALORIMETER	1
22	2720-ME-27B94B	END CALORIMETER	1
23	2720-ME-27B94B	END CALORIMETER	1
24	2720-ME-27B94B	END CALORIMETER	1
25	2720-ME-27B94B	END CALORIMETER	1
26	2720-ME-27B94B	END CALORIMETER	1
27	2720-ME-27B94B	END CALORIMETER	1
28	2720-ME-27B94B	END CALORIMETER	1
29	2720-ME-27B94B	END CALORIMETER	1
30	2720-ME-27B94B	END CALORIMETER	1
31	2720-ME-27B94B	END CALORIMETER	1
32	2720-ME-27B94B	END CALORIMETER	1
33	2720-ME-27B94B	END CALORIMETER	1
34	2720-ME-27B94B	END CALORIMETER	1
35	2720-ME-27B94B	END CALORIMETER	1
36	2720-ME-27B94B	END CALORIMETER	1
37	2720-ME-27B94B	END CALORIMETER	1
38	2720-ME-27B94B	END CALORIMETER	1
39	2720-ME-27B94B	END CALORIMETER	1
40	2720-ME-27B94B	END CALORIMETER	1
41	2720-ME-27B94B	END CALORIMETER	1
42	2720-ME-27B94B	END CALORIMETER	1
43	2720-ME-27B94B	END CALORIMETER	1
44	2720-ME-27B94B	END CALORIMETER	1
45	2720-ME-27B94B	END CALORIMETER	1
46	2720-ME-27B94B	END CALORIMETER	1
47	2720-ME-27B94B	END CALORIMETER	1
48	2720-ME-27B94B	END CALORIMETER	1
49	2720-ME-27B94B	END CALORIMETER	1
50	2720-ME-27B94B	END CALORIMETER	1
51	2720-ME-27B94B	END CALORIMETER	1
52	2720-ME-27B94B	END CALORIMETER	1
53	2720-ME-27B94B	END CALORIMETER	1
54	2720-ME-27B94B	END CALORIMETER	1
55	2720-ME-27B94B	END CALORIMETER	1
56	2720-ME-27B94B	END CALORIMETER	1
57	2720-ME-27B94B	END CALORIMETER	1
58	2720-ME-27B94B	END CALORIMETER	1
59	2720-ME-27B94B	END CALORIMETER	1
60	2720-ME-27B94B	END CALORIMETER	1
61	2720-ME-27B94B	END CALORIMETER	1
62	2720-ME-27B94B	END CALORIMETER	1
63	2720-ME-27B94B	END CALORIMETER	1
64	2720-ME-27B94B	END CALORIMETER	1
65	2720-ME-27B94B	END CALORIMETER	1
66	2720-ME-27B94B	END CALORIMETER	1
67	2720-ME-27B94B	END CALORIMETER	1
68	2720-ME-27B94B	END CALORIMETER	1
69	2720-ME-27B94B	END CALORIMETER	1
70	2720-ME-27B94B	END CALORIMETER	1
71	2720-ME-27B94B	END CALORIMETER	1
72	2720-ME-27B94B	END CALORIMETER	1
73	2720-ME-27B94B	END CALORIMETER	1
74	2720-ME-27B94B	END CALORIMETER	1
75	2720-ME-27B94B	END CALORIMETER	1
76	2720-ME-27B94B	END CALORIMETER	1
77	2720-ME-27B94B	END CALORIMETER	1
78	2720-ME-27B94B	END CALORIMETER	1
79	2720-ME-27B94B	END CALORIMETER	1
80	2720-ME-27B94B	END CALORIMETER	1
81	2720-ME-27B94B	END CALORIMETER	1
82	2720-ME-27B94B	END CALORIMETER	1
83	2720-ME-27B94B	END CALORIMETER	1
84	2720-ME-27B94B	END CALORIMETER	1
85	2720-ME-27B94B	END CALORIMETER	1
86	2720-ME-27B94B	END CALORIMETER	1
87	2720-ME-27B94B	END CALORIMETER	1
88	2720-ME-27B94B	END CALORIMETER	1
89	2720-ME-27B94B	END CALORIMETER	1
90	2720-ME-27B94B	END CALORIMETER	1
91	2720-ME-27B94B	END CALORIMETER	1
92	2720-ME-27B94B	END CALORIMETER	1
93	2720-ME-27B94B	END CALORIMETER	1
94	2720-ME-27B94B	END CALORIMETER	1
95	2720-ME-27B94B	END CALORIMETER	1
96	2720-ME-27B94B	END CALORIMETER	1
97	2720-ME-27B94B	END CALORIMETER	1
98	2720-ME-27B94B	END CALORIMETER	1
99	2720-ME-27B94B	END CALORIMETER	1
100	2720-ME-27B94B	END CALORIMETER	1

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PAGE 3 & 4

PARTS LIST	
QTY	DESCRIPTION OR SIZE
1	Ø 3.063 +.031 / -.000 DIA. THRU 2 HOLES IN LINE AS SHOWN.
1	Ø .813 DIA. DRILL THRU 2 HOLES IN LINE AS SHOWN.
MATERIAL LISTED ABOVE	
FEDERAL BUREAU OF INVESTIGATION	
UNITED STATES DEPARTMENT OF JUSTICE	
DO DETECTOR - END CALORIMETER	
MIM SIMULATOR ASSEMBLY	
BRIDGE	
1/8	720-ME-278947

REV.	DESCRIPTION	DATE	BY

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
PARTS LIST			
1	3740.220-4E	END CALORIMETER	1
2	3740.220-4F	END CALORIMETER	1
3	3740.220-4G	END CALORIMETER	1
4	3740.220-4H	END CALORIMETER	1
5	3740.220-4I	END CALORIMETER	1
6	3740.220-4J	END CALORIMETER	1
7	3740.220-4K	END CALORIMETER	1
8	3740.220-4L	END CALORIMETER	1
9	3740.220-4M	END CALORIMETER	1
10	3740.220-4N	END CALORIMETER	1
11	3740.220-4O	END CALORIMETER	1
12	3740.220-4P	END CALORIMETER	1
13	3740.220-4Q	END CALORIMETER	1
14	3740.220-4R	END CALORIMETER	1
15	3740.220-4S	END CALORIMETER	1
16	3740.220-4T	END CALORIMETER	1
17	3740.220-4U	END CALORIMETER	1
18	3740.220-4V	END CALORIMETER	1
19	3740.220-4W	END CALORIMETER	1
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21	3740.220-4Y	END CALORIMETER	1
22	3740.220-4Z	END CALORIMETER	1
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41	3740.220-4S	END CALORIMETER	1
42	3740.220-4T	END CALORIMETER	1
43	3740.220-4U	END CALORIMETER	1
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55	3740.220-4G	END CALORIMETER	1
56	3740.220-4H	END CALORIMETER	1
57	3740.220-4I	END CALORIMETER	1
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62	3740.220-4N	END CALORIMETER	1
63	3740.220-4O	END CALORIMETER	1
64	3740.220-4P	END CALORIMETER	1
65	3740.220-4Q	END CALORIMETER	1
66	3740.220-4R	END CALORIMETER	1
67	3740.220-4S	END CALORIMETER	1
68	3740.220-4T	END CALORIMETER	1
69	3740.220-4U	END CALORIMETER	1
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84	3740.220-4J	END CALORIMETER	1
85	3740.220-4K	END CALORIMETER	1
86	3740.220-4L	END CALORIMETER	1
87	3740.220-4M	END CALORIMETER	1
88	3740.220-4N	END CALORIMETER	1
89	3740.220-4O	END CALORIMETER	1
90	3740.220-4P	END CALORIMETER	1
91	3740.220-4Q	END CALORIMETER	1
92	3740.220-4R	END CALORIMETER	1
93	3740.220-4S	END CALORIMETER	1
94	3740.220-4T	END CALORIMETER	1
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97	3740.220-4W	END CALORIMETER	1
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99	3740.220-4Y	END CALORIMETER	1
100	3740.220-4Z	END CALORIMETER	1

3740.220-4E-278846

MATERIAL: 1" THK. X 6" W. X 18.500 L.B.
H.R.S. 304 - ASTM A 304

FEPMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

DO DETECTOR - END CALORIMETER
MH SIMULATOR ASSEMBLY
BRIDGE TO BEAM CONNECTOR PLT.

DATE: 10/1/77
FULL: 3740.220-MD-278949
REVISION: 1.04
DRAWN BY: 2772

		APPROVAL	DATE

.125 X 45° CHAMFER
TYP. BOTH ENDS AS SHOWN.

.266 DIA. DRILL THRU
2 HOLES AS SHOWN.

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
PARTS LIST			
UNLESS OTHERWISE SPECIFIED		ORIGINATOR	PRIMOHL 8/25/89
FRACTIONS	DECIMALS	ANGLES	DRAWN HATESKI 8/25/89
$\pm 1/16$	$\pm .063$	$\pm 2^\circ$	CHECKED <i>[Signature]</i> 12/5/89
1. BREAK ALL SHARP EDGES 1/64" MAX.		APPROVED	
2. DO NOT SCALE DRAWING.		USED ON	
3. DIMENSIONING IN ACCORD S/AHSI Y14.5M-1002 STD.		3740.220-ME-278946	
4. ALL DIMENSIONS ARE IN INCHES.		MATERIAL 3" DIA. C.R.S.	
125 MAX. ALL MACHINED SURFACES		AISI 1018 - FINAL STR. #1530-5230	
FERMI NATIONAL ACCELERATOR LABORATORY UNITED STATES DEPARTMENT OF ENERGY			
DO DETECTOR - END CALORIMETER MH SIMULATOR ASSEMBLY BRIDGE TO BEAM CONNECTOR PIN			
SCALE	FULL	DRAWING NUMBER	REV.
		3740.220-MC-278950	
ICEMOON VERSION 1.64		USER NO.	775

REV.	DESCRIPTION	DATE	BY
A	44.906 WAS 47.400; 41.906 WAS 44.406	8-2-75	11

SEE PAGE 5

ITEM	PART NO.	DESCRIPTION OR SIZE	Q
PARTS LIST			
UNLESS OTHERWISE SPECIFIED	ORIGINATOR	PRINCIPAL	DATE
DESIGNED BY	DESIGNED	DESIGNED	DATE
CHECKED BY	CHECKED	PRINCIPAL	DATE
APPROVED BY	APPROVED		
USED ON			
3740.220-ME-278945			
MATERIAL			
1/2 X 2 1/2 X 1/4 ANGLE			
ASTM A 36 - F158, S15, 21525-1			
FERNI NATIONAL ACCELERATOR LABORATORY			
UNITED STATES DEPARTMENT OF ENERGY			
DO DETECTOR - END CALORIMETER			
MH SIMULATOR ASSEMBLY			
BRIDGE TO BEAM BRACE			
SCALE	PLANT	SHOWN AS	
HALF		3740.220-MD-278951	
ICECON VERSION 1.64			
95775			

DATE		APPROVED		SIGNATURE

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
PARTS LIST			
UNLESS OTHERWISE SPECIFIED		ORIGINATOR	PRIMOHL 8/25/89
FRACTIONS	DECIMALS	ANGLES	DRAWN MATESKI 8/25/89
$\pm 1/16$	$\pm .063$	$\pm 2^\circ$	CHECKED <i>Handwritten signature</i> 10/5/89
1. BREAK ALL SHARP EDGES 1/64 MAX.		APPROVED	
2. DO NOT SCALE DRAWING.		USED ON	3740.220-ME-278946
3. DIMENSIONING IN ACCORDANCE WITH ASME Y14.5-1986 STD.		MATERIAL	2 1/2 X 2 1/2 X 1/4 ANGLE
4. ALL DIMENSIONS ARE IN INCHES.			ASTM A 36 - FINAL STK. #1536-1170
125 MAX. ALL MACHINED SURFACES
FERMI NATIONAL ACCELERATOR LABORATORY UNITED STATES DEPARTMENT OF ENERGY			
D0 DETECTOR - END CALORIMETER MH SIMULATOR ASSEMBLY BRACE BLOCK			
SCALE	FULL	DRAWING NUMBER	3740.220-MC-278952
ICEMOON VERSION 1.64		USER NO.	95775

Appendix C

Memo

Note #3740.225-EN-261

From: FNAL::COOPER
To: ANDREWS
CC: COOPER
bj: OH Test Ring

11-SEP-1990 19:12:50.61

PRELIMINARY

September 10 ,1990

TO: R. ANDREWS
FROM: W. COOPER
SUBJECT: OH TEST RING

The assembly of the OH modules into a test ring has been completed in IB4. The last module was installed without interference with its neighbors. The effective mean inner surface ring radius is 60 mils larger than design at the upstream end and 48 mils larger than design at the downstream end. The modules have an RMS deviation from a circle of 40 mils. All of these values are consistent with the departure of actual module dimensions from design dimensions and with the module-to-module shims. Studs and shear keys have been installed at all module-to-module interfaces.

The equipment to apply a load to the OH test ring simulating the load of the EM, IH, and MH modules has been installed. Shims between the fixturing and the OH modules have been adjusted so that the effective shape of the fixture conforms to that of the OH ring at the 5 mil level.

We are prepared to carry out the OH test ring load test and request the Panel's agreement to proceed.

Following the Panel's verbal suggestion, dial indicators will be installed to measure the lateral motion of the two support posts which have DU glacier plate below them.

Measurements of the loading fixturing have been made. The hydraulic jacks to load the structure are at $z = -21.25''$ and $z = +68.81''$, where z is defined, as before, from the upstream inner radius corner of OH plate 1. Because of imperfections in the I-beams of the loading structure, the z 's of individual jacks differ from the values given by as much as $.25''$; the values given are the averages of two jacks.

Using these z -positions, the following hydraulic pressures to be applied to each jack and jack forces have been calculated.

Load step	% of nominal load	Upstream jack		Downstream jack		Total force (4 jacks) (lb)
		P(psi)	F(lb)	P(psi)	F(lb)	
0	0	0	0	0	0	0
1	50	2495	24950	3025	30250	110400
2	80	3990	39900	4840	48400	176600
	100	4990	49900	6050	60500	220800
	110	5490	54900	6655	66550	242900
5	120	5990	59900	7260	72600	265000
6	125	6240	62400	7560	75600	276000
7	130	6490	64900	7860	78600	287000

Our present intent is to increase the applied load in the steps indicated through step 6. We plan to limit the maximum applied load to values between those listed for step 6 and those listed for step 7, i.e., we will really crease the load to "step 6.5". At this time, the load will be decreased to zero in the same steps.

Three cycles will be made from step 0 through step 6.5 and back to step 0. On the last of the 3 cycles, a pause will be made at 100% load as loading is being increased; a survey will be made of the ring at 100% load and then the loading cycle will be continued to completion. A survey has already been made at zero load. A third survey will be made at zero load at the end of the testing.

Strain gages and dial indicators will be recorded at each load step. Our knowledge of initial strains is limited because of the substantial time that has elapsed between initial strain gage readings and the present time; a number of the original strain gages were damaged and have been replaced, also. For these reasons, strain gages will be seroed at the beginning of the load test sequence.

The Panel has been supplied with calculations of beam and strap stresses and of forces transmitted from the beam and strap assembly at 100% load, hence no further analysis of the beam and strap assembly should be needed. The load transfers from the OH modules to the beam and strap assembly have been calculated under the assumptions that friction is negligible and that the beam and strap assembly complies with the contour of the OH modules. Load transfers from the MH filler to the OH modules has been calculated with the following assumptions:

- 1) Friction is negligible.
- 2) The MH filler is rigid within a plane of fixed z.
- 3) The OH modules can be characterized with a radial compliance, i.e., (change in module radial dimension) = (constant) x (radial load carried through module).
- 4) The MH filler and OH module contours match at zero MH filler load.

To first order, the addition of the MH filler load affects module-to-module loads only at the module 3L-2L connection and below. Using the equations from earlier notes, the load transfers from the beam and strap assembly into the number 1, 2, and 3 modules at 100% load are:

$$F1B = 68803 \text{ lb}$$

$$F2B = 68803 \text{ lb}$$

$$F3B = 149961 \text{ lb.}$$

Each of thes forces acts inward toward the center of the ring.

Assume that the MH filler moves downward an amount (Δy) under load. The forces exerted upon the number 1, 2, and 3 modules are:

$$F1M = (\Delta y) (k) (\cos(11.25 \text{ degrees}))$$

$$F2M = (\Delta y) (k) (\cos(33.75 \text{ degrees}))$$

$$F3M = (\Delta y) (K) (\cos(56.25 \text{ degrees}))$$

where k is a constant. Each of these forces points radially outward. The sum of the vertical components of the forces must equal half of the 100% load. Therefore,

$$(\Delta y) (k) = (220779 \text{ lb}) / (2((\cos(11.25 \text{ degrees}))^2 + (\cos(33.75 \text{ degrees}))^2 + (\cos(56.25 \text{ degrees}))^2))$$

en

$$F1M = 55184 \text{ lb}$$

$$F2M = 46783 \text{ lb}$$

$$F3M = 31259 \text{ lb.}$$

These are the MH filler loads transmitted radially through the modules to the

beam and strap assembly.

The net forces acting radially inward on the three modules are

$$F1 = 68803 - 55184 = 13619 \text{ lb}$$

$$F2 = 68803 - 46783 = 22020 \text{ lb}$$

$$F3 = 149961 - 31259 = 118702 \text{ lb.}$$

These forces can be plugged into the equations used for OH module-to-module loads with OH only. the results are:

Location	F outer (lb)	F inner (lb)	F shear (lb)
1L-1R	+104011	-217599	0
2L-1L	+83913	-186842	-41383
3L-2L	+32666	-107590	-64654

Separating these into upstream and downstream portions by scaling from ANSYS results (as in the last analysis provided to the panel) gives:

Location	Upstream Shear	Downstream Shear	Total Shear
1L-1R	0	0	0
2L-1L	-17431	-23952	-41383
3L-2L	-27329	-37325	-64654

The shear loads are shared by the friction connections at the studs and by the shear keys. Although the shear key design loads would be exceeded if the shear were carried only by the shear keys, the shear keys plus the friction connections are more than sufficient to carry the shear loads. This will be discussed later.

Location	Upstream Studs	Downstream Stud	Stud Sum	Upstream Inner	Downstream Inner	Inner Sum
1L-1R	40356	63655	104011	-140569	-77030	-217599
2L-1L	32390	51523	83913	-120700	-66142	-186842
3L-2L	12380	20286	32666	-68750	-38849	-107590

The most highly loaded upstream studs are at the 1L-1R location. Four small Inconel studs are used. The load per stud is 10089 lb, which is .393 x design load and about .123 x ultimate load. The most highly loaded downstream stud is at the 1L-1R location. A large Inconel stud is used. The load of 63655 lb is .341 x design load and .106 x ultimate load.

AISC appears to address allowable shear in friction type connections only in material specific ways: for each of the AISC permitted bolting materials and for each type of friction connection allowable shear forces are given. Because these allowable forces are given absolutely, rather than relative to yield or ultimate strengths of the materials in use, it isn't clear to me how to apply the AISC criteria to other materials. The AISC criteria are given in Table 1.5.2.1, Appendix E, and Commentary 1.5.2.1.

Although the holes in the ears roughly correspond to standard sized holes, based upon the stud thread diameter, the main portions of the studs are reduced in diameter. Accordingly, the holes for the friction connections will be considered to be oversized holes. Because the ear-to-ear interface contains no stud threads, AISC values with threads excluded from the shear plane will be used. AISC allowable stresses relative to yield and ultimate stresses are

compared with the OH connection stresses in the table which follows. The load carrying capacity of the shear keys is ignored.

Location	Stress Shear/ultimate	Shear/yield	Tension/ultimate	Tension/yield
AISC A325	.143	.185	.419	.543
AISC A490	.127	.146	.360	.415
Upstream stud				
1L-1R	.000	.000	.131	.157
2L-1L	.057	.068	.105	.126
3L-2L	.089	.106	.040	.048
Downstream stud				
1L-1R	.000	.000	.114	.137
2L-1L	.043	.051	.092	.111
3L-2L	.067	.080	.036	.044

Each of the ratios for the actual connections is substantially lower than the corresponding AISC ratio for either A325 or A490 bolts.

The table which follows compares loads with minimum preloads.

Location	Shear/preload	Tension/preload
AISC A325	.204	.599
AISC A490	.181	.514
Upstream stud		
1L-1R	.000	.390
2L-1L	.168	.313
3L-2L	.264	.119
Downstream stud		
1L-1R	.000	.330
2L-1L	.124	.267
3L-2L	.193	.105

The ratios of actual tension to preload are substantially lower than the corresponding AISC ratio. The ratios of shear to preload exceed the AISC ratios in some cases; however, if the shear capacity of the shear keys is subtracted from the shear load, the ratios are acceptable, as shown below.

Location	Shear/preload
Upstream stud	
1L-1R	.000
2L-1L	.033
3L-2L	.129
Downstream stud	
1L-1R	.000
2L-1L	.020
3L-2L	.090

The ring loads have been calculated assuming no connection between the 8L and 8R modules. In reality, the ring closed well and the stud and shear key connections were made at this location. Because this could be done

without distorting the ring, the ring loads calculated should be correct in the absense of MH filler load.

The radial spring constant of an OH module has been measured to be $(100000 \text{ lb})/ (.064 \text{ inch})$ at the downstream end and $(100000 \text{ lb})/ (.100 \text{ inch})$ at the downstream end where the 100000 lb is appropriately distributed to match the MH filler z distribution. This means that outer OH module surface should move radially inward $(31259)(.064")/ (100000) = .020"$ at the downstream end and $(31259)(.100")/ (100000) = .031"$ at the downstream end as the result of the application of 100% MH filler load. The overlap that would occur at the 8L-8R module interface if the modules were free to overlap is $2(.020')\cos(33.75 \text{ degrees}) = .033"$ at the downstream end and $2(.031')\cos(33.75 \text{ degrees}) = .052"$ at the upstream end. If the modules are constrained not to overlap at their inner contact points, the gaps at the studs are .013" at the downstream end and .020" at the upstream end. The strain from closing this gap is evenly distributed over 16 module-to-module interfaces, so it is .00081" per interface at the downstream end and .00125" per interface at the upstream end.

The downstream ear connection has been modelled by R. Wands ("Analysis of Bolted Ear Connection", 3740-222-EN-133). His results assume a bolt stress area of 3.56 sq. in. and are summarized at three bolt preloads: 30 ksi, 60 ksi, and 90 ksi. The actual tensile area of the large studs is 3.108 sq. in. and the minimum preload is 193000 lb. These correspond to a preload stress of 54.213 ksi for the bolt Bob modelled. Scaling Table III of the note to 54.213 ksi gives a bolt/member sharing such that the stud sees 39% of the external load. An increase in stud elongation of .00081" corresponds to an increase in stud load of 7800 lb or an increase in connection load of 20000 lb. This is an overestimate, since elastic deformation of the module plate accomodates a portion of the .00081", also. In any case, a 20000 lb increase takes the 1L-1R ad from 64000 lb to 84000 lb (stud design load = 186000 lb, ear design load = 130000 lb), which is still acceptable. A 20000 lb increase takes the most highly loaded SS stud from 15000 lb to 35000 lb (stud design load = 62000 lb, ear design load = 130000 lb). Hence, the downstream loads with an 8L-8R connection are satisfactory.

The design of the downstream ear was scaled from the design of the upstream ears. Although the upstream ears were not specifically modelled, they were designed for a load of 30000 lb per ear and should be 4.3 times as compliant as the downstream ear. Hence their load is expected to increase by $(20000 \text{ lb}) \times (.00125/ .0008)/ 4.3$ or 3900 lb. Then the 1L-1R connection load increases from 10089 lb/plate to 14000 lb/plate (ear design load = 30000 lb/plate, stud design load = 26000 lb/stud), which is satisfactory.

The expected lateral motion of the feet can be calculated from the elongation of the straps of the beam and strap assembly. At 100% MH filler load, the upstream strap tension increases by 20782 lb and the downstream strap tension increase by 71004 lb. The strap cross-section is 12 sq. in. and the elastic modulus is taken to be $28.3 \times 10^{+6}$ psi. Then the unit changes in strap length are 6.12×10^{-5} and 2.09×10^{-4} , respectively. The expected lateral motion of the feet is .008" upstream and .029" downstream.