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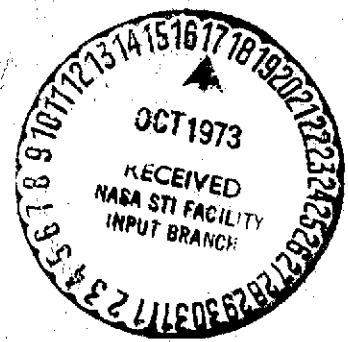
ASD-ASTN-1745

Summary Report

TEST FIXTURE DESIGN FOR BORON-ALUMINUM AND BERYLLIUM TEST PANELS

(NASA-CR-124401) TEST FIXTURE DESIGN FOR BORON-ALUMINUM AND BERYLLIUM TEST PANELS Summary Report (Teledyne Brown Engineering) 140 p HC \$9.00	CSCL 14B	N73-32337 Unclas 15544
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August 1973



**TELEDYNE
BROWN ENGINEERING**

SUMMARY REPORT
ASD-ASTN-1745

TEST FIXTURE DESIGN FOR
BORON-ALUMINUM AND BERYLLIUM TEST PANELS

By

C. G. Breaux

August 1973

Prepared For

ENGINEERING DIVISION
ASTRONAUTICS LABORATORY
GEORGE C. MARSHALL SPACE FLIGHT CENTER

Contract No. NAS8-29901

Prepared By

ENGINEERING ANALYSIS DEPARTMENT
AEROSPACE SUPPORT DIVISION
TELEDYNE BROWN ENGINEERING
HUNTSVILLE, ALABAMA

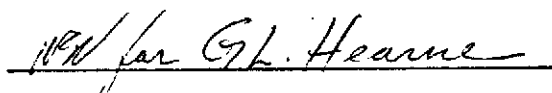
FOREWORD

The work reported herein was performed under the sponsorship of the Engineering Division, Astronautics Laboratory, George C. Marshall Space Flight Center. Mr. Walter D. Medenica, S&E-ASTN-ET, is the NASA representative on this contract. The work was accomplished under contract NAS8-29901.

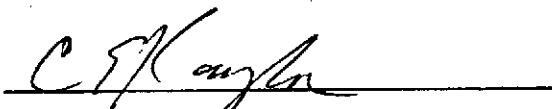
The work was performed by the Aerospace Support Division, Teledyne Brown Engineering, Huntsville, Alabama. The Strength Analysis Branch of the Engineering Analysis Department was responsible for project management. They were supported by the Design Engineering Department. Key Teledyne Brown Engineering personnel associated with the program and their respective areas of responsibility are:

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ABSTRACT

A detailed description of the test fixture design and the backup analysis of the fixture assembly and its components are presented in this report. The test fixture will be required for the separate testing of two boron-aluminum and two beryllium compression panels.

This report is presented in conjunction with a complete set of design drawings on the test fixture system, DRW 90M05028.

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SECTION I. INTRODUCTION

The development of two boron-aluminum and two beryllium experimental compression test panels (Figures 1 through 14) by Marshall Space Flight Center (MSFC) has necessitated the design of a suitable test fixture system. All four panels are to be tested in compression and subjected to a 600 °F temperature environment during load application. A concentrated load is to be applied to two of the specimens and a uniform load applied to the remaining two. The overall dimensions of the four specimens are:

- MDAC Boron-Aluminum Point Loaded: 48 by 72 in.
- Lockheed Beryllium Point Loaded: 48 by 75.5 in.
- Lockheed Beryllium Uniform Loaded: 86 by 29 in.
- Convair Boron-Aluminum Uniform Loaded: 80 by 29 in.

The decision was made by NASA to design a single test fixture system to accommodate all four panels since enough similarity exists in their overall dimensions and test requirements. Each specimen is to be tested separately and certain minor adjustments and modifications to the test fixture design or setup must be made for the testing of each respective panel. For this reason, it is recommended that the McDonnell Douglas Astronautics Company (MDAC) panel be tested first since some gusset plates must be field-welded to the enclosure frame for the test setup on the uniform loaded beryllium panel. These gussets may interfere with the side constraint devices on the MDAC panel test setup.

The two basic parts of the test fixture system are the loading column and the heat enclosure. The loading column consists of one hydraulic cylinder, one load cell, two partially tubular connecting rods, and two monoball lug and pin connectors at each end. The top lug and pin connector attaches to the crosshead of the 2,000,000-lb Gilmore testing machine (Building 4619) which will function as an attach and reaction point for the loading column. The loading column structure was designed to withstand the 350,000-lb test load with a required factor of safety. The lower part of the column which is located within the heat enclosure is exposed to the 600 °F thermal environment during testing. This exposed area is wrapped with insulation and a simple cooling system was designed to prevent overheating of the load cell and the hydraulic cylinder.

The required thermal condition is accomplished by enclosing the specimen within an insulated rectangular structure, then forcing hot air from an independent heat source through a duct system connected to the heat enclosure. The framework of the heat enclosure must also provide lateral and base support for the compression panels. The structure around the passage hole in the ceiling provides lateral support to the loading column. The enclosure which is 4.17 ft wide by 6.03 ft long by 11.68 ft high is a steel-framed rectangular box covered with sheet metal and externally insulated over the walls and ceiling with two layers of 2-in. thick mineral wool boards. The entire enclosure rests on the steel floor of the Gilmore machine; however, a 1-in. thick insulation pad (Marinite-36) is sandwiched between the bottom of the enclosure and the steel floor. In order to have free access to the panels for instrumentation and inspection, and also to allow for easy loading and removal of the specimens, the top and two broad side panels of the enclosure are removable.

SECTION II. DESCRIPTION

The development of a workable test fixture system for the testing of the four panel specimens required a total system design which included some existing hardware and some newly designed components. One of the existing items which is part of the overall fixture system is the 2, 000, 000-lb Gilmore testing machine (Figures 5 and 6). This large testing machine which is located in Building 4619 simply provides a convenient location for the test fixture. The Gilmore machine will not be used to apply the compression load to the specimen; a separately designed loading column will be suspended from the cross-head of the test machine. This loading column will produce the required compression loads; whereas, the crosshead functions as a convenient reaction point for the loading column's force. Also, the crosshead can be adjusted to various elevations (up to 22 ft from floor); thus, it provides a means of raising and lowering the loading column as required for the various tests. The heat enclosure will be bolted to the steel floor of the Gilmore machine in four locations; two of these locations will be at existing threaded holes and the other two locations will require tap drilling into the steel floor.

The next item, the heat source (Figures 7 and 8) was procured by NASA for this specific test. The only required work associated with the heat source involved the design of the interface connection between the duct system and the heater's supply and return ports.

The remaining three assembly items that complete the test fixture system and were designed under this contract are:

- Heat enclosure
- Loading column
- Duct system.

The insulated enclosure and its framework must perform as a heat retainer, and provide lateral and base support for the four specimens. The loading column's function is to apply the concentrated and/or uniform compression loads to the compression panels. The duct system (Figures 7 and 8) consists of two insulated air ducts, supply and return, which interface between the heat source and the heat enclosure. A more detailed description of the above design items will follow.

A. Heat Enclosure

The heat enclosure (Figures 9 and 10) is a steel framed rectangular box covered with 1/8-in. -thick sheet metal and externally insulated over the walls and ceiling with two sheets of 2-in. -thick mineral wool boards. All of the frame members are A-36 steel, wide flange beams; most of which are W 6 by 15.5. The two sheets of mineral wool board are overlapped at the seams to lessen heat loss through the seams. The wool boards are fastened to the metal panels with weld pins which are available from the insulation vendor. The weld pin attachment technique involves welding a 12-gage nail pin to the sheet metal at 18-in. intervals; then placing the insulation against the sheet metal whereby the pin completely penetrates the thickness of the insulation. At this point, self locking rectangular washers are placed over all of the protruding pins. Insulation is also required between the base of the heat enclosure and the steel floor of the Gilmore machine. In this design, a 1-in. thick heavy duty insulation board, Marinite-36, is sandwiched between the steel floor and the enclosure.

The top, front, and rear panels are removable to allow easy loading and removal of the specimens. Handles are attached to these panels to permit ease of handling during removal and replacement. The front and rear removable panels have angle stiffeners near their borders to maintain rigidity of the sheet metal during the removal process. The top panel is made up of two panel segments to allow the loading head to be lifted out of the enclosure. The top front wide flange beam (Figure 10) is also removable to allow possible loading of the panel specimens with a small crane.

The top panel provides lateral support for the loading column at the passage hole. Two semicircular rings are permanently attached to the skin of the top panel; one per panel segment. These half rings form a complete circle at the passage hole when the top panel is assembled. A floating collar which is placed around the rod of the loading column is bolted to the permanent ring after the column head is placed and set over the specimen.

The base support beam which is required to react the compression loads applied to the panels consists of a large wide flange beam (W 12 by 85) stiffened with gusset plates. After the gusset plates are installed, the top and bottom surfaces are machined for close tolerance (horizontal surface) and parallelism. This will encourage a uniform distribution of the compression load at the base of the specimen.

The supply and return interface connections for the ducts are located on the opposite narrow panels of the enclosure. A heat deflector is located on the inside of the enclosure at the supply duct interface connection. The deflector was installed to prevent hot spots from occurring on the panel specimen.

Another function of the enclosure is to provide lateral support to all four panels during their subsequent testing. Lateral support devices required for the McDonnell Douglas boron-aluminum point loaded panel are located on both sides and center of the panel at the four ring frame locations (12 points). The devices which interface between the specimen and the enclosure frame members consist of a wheel and track type system. This system restrains lateral movement but allows thermal growth in the vertical and side directions.

The Lockheed beryllium point loaded panel is supported along its sides at four points per side. The edges (sides) of the panel are clamped continuously with an angle and narrow plate arrangement. Four stiffened clip angles per side are used to interface between the specimen's sides and the side members of the enclosure. These clip angles will be installed in the field and used for this test only. The Lockheed beryllium uniform loaded panel is clamped and supported in a similar manner with four support points per side. However, since this panel is not as wide as the point loaded panel (48 versus 29 in.) the distance between the panel edge and the enclosure frame is considerably more. Thus, for this panel a horizontal "A-frame" type structure is used to interface between the specimen and the enclosure member. Again these side attachment members will be used for this test only.

The Convair boron-aluminum uniformly loaded panel is also laterally constrained at the edges but only at two points; one on each side of the ring frame. Again, a cantilevered "A-frame" interfaces between the specimen and enclosure. A lug type fitting was installed by the contractor (Convair) to provide a convenient attach point for the lateral constraint member. The pin connection will permit thermal growth in the vertical direction but will restrain lateral deflection. A simple support device was designed to be placed at the top and bottom of this specimen to simulate the required simple support condition. The device consists of a convex (cross-section) member placed within a concave (cross-section) member with a larger radius. Rocking motion can occur but lateral motion is restrained.

B. Loading Column

The loading column (Figure 11) consists of one load cell, one hydraulic cylinder, two partially tubular rods, lug and clevis connectors, a loading head, a coupling adapter and an adapter plate. The entire assembly is suspended from the crosshead of the Gilmore machine. Each item will be discussed starting with the attachment at the crosshead and working down.

The first component is an existing adapter plate which is bolted to the crosshead at existing bolt locations. Connected to the adapter plate is a lug (AISI 4130 steel) with monoball (swivel joint) which in turn connects to the clevis of the hydraulic cylinder. The connecting pin (AISI 4340 steel) between the lug and clevis is a 4-in. -diam pin with a 1-in. -diam hole through the core to permit heat treat to an ultimate tensile strength of 180 ksi. The heat treat was required for high stresses produced by pin bending. A spacer was required between the lug and the clevis because a standard monoball could not match both the existing pin hole diameter and the spacing of the ears on the permanent clevis of the hydraulic cylinder.

The hydraulic cylinder called for in the design is an existing NASA test equipment item: Hydro-Line N2C, 12-in. bore by 15-in. stroke. The rod of the cylinder attaches to a coupling adapter (AISI 4130 steel) which in turn connects to a 6-in. -diam rod. The rod (AISI 4130 steel) is a partially tubular member with two 5/8-in. -diam holes (orifice) which lead to a 1 3/4-in. -diam hole through the core of the rod. The rod necks down to a 4-in. -diam at the lower threaded end to mate with the load cell.

The load cell is an existing custom built cell with a 4-in. -internal diameter. Below the load cell is attached another 6-in. -diam rod. The center hole (core) and orifice on this rod are the same as those on the upper rod. However, this rod is made from AISI 4140 steel, cold drawn and has a close tolerance finish. This finish is required because of close tolerance requirements at the passage hole through the enclosure. AISI 4140 steel was selected because AISI 4130 steel was not available at the 6-in. -diam and the close tolerance finish. Connected to this rod is a lug with monoball (AISI 4130 steel) which is pinned to the lower clevis (AISI 4130 steel). The pin is identical to the pin used in the top lug; that is, AISI 4340 steel pin with a 4-in. -external diameter and 1-in. -internal diameter.

The lower clevis device (AISI 4130 steel) performs as a loading head for the beryllium point loaded panel, attaches to the loading plate for the boron-aluminum point loaded panel and to the stiffened loading beam which is required for the two uniformly loaded panels. This completes the listing of components in the loading column assembly.

The load cell and the hydraulic cylinder have limitations on the amount of heat they are allowed to absorb: a limiting temperature of 175 °F was placed on the load cell and a 150 °F limit on the hydraulic cylinder. Two steps were taken to prevent an excessive heat buildup in these components: a simple cooling system was designed and the portion of the column which is located in the enclosure was insulated.

The lower portion of the column is externally wrapped, insulated, with 4 layers of 3/4-in. -kaowool blanket to reduce the amount of surface area exposed to the high temperature environment. The cooling system consists of having tap water flow through the partially tubular rods and the tubular load cell. Tap water initiates flow at the two upper orifice holes, through the tubular rod, then through the tubular load cell, through the lower tubular rod, and discharges at the two lower orifice holes. The water is carried to and from the cooling system with a 5/8-in. -diam hose. This simple cooling system prevents excessive temperature buildup in the load cell and hydraulic cylinder.

C. Duct System

The duct system (Figures 7 and 8) consists of a supply and a return air duct which interface between the heat enclosure and the heat source. The supply duct is a rectangular sheet metal tube (10 1/8 by 9 1/2 in.) insulated with two layers of 2-in. -sheets of mineral wool board. Expansion joints are located at appropriate points to allow thermal expansion. The duct is supported by roller braces from the floor.

The return duct is a 8 5/8-in. -diam tubular sheet metal duct insulated with four layers of 3/4-in. -thick-kaowool blanket ($\rho = 8 \text{ lb/ft}^3$). The return ducts interface location on the enclosure is at a higher elevation than the supply line interface to encourage a uniform distribution of hot air flow. Expansion joints are included and the duct work is supported by roller brackets. A large portion of the return air duct is removable to allow easy access to the rear of the enclosure.

SECTION III. ANALYSIS SUMMARY

The two assemblies of the test fixture system which required some detail structural and thermal analyses are the heat enclosure and the loading column. A complete set of the calculations prepared in the structural analysis are presented in Appendix A. And likewise, the results of the thermal analysis on the loading column are included in Appendix A.

The thermal analysis performed on the heat enclosure to determine the required external insulation was conducted by NASA in a preliminary design study. The adequacy of the insulation used on the enclosure for the 600 °F temperature range was confirmed by Mr. Jerry Fowler of Ennis Insulation Company, Decatur, Alabama.

A complete structural analysis of the loading column and the heat enclosure was conducted in support of the design effort. A thermal study on the loading column was required to determine the heat buildup in the hydraulic cylinder and the load cell.

A. Structural Analysis

The structural analysis of the heat enclosure can be broken down into two basic categories: computer model analysis of the enclosure framework, and hand calculations for the various other components. The model analysis made use of the 1130 STRESS program. The model consisted of all wide flange members which comprise the enclosure framework. The most stringent lateral loads anticipated by the respective specimen contractors was applied to the structural model. In this case, the MDAC lateral loads and deflection limitations set the criteria for the enclosure design. The enclosure framework turned out to be a stiffness design; that is, the limitation on deflection determined the member sizes. In general, the member stress levels recorded on the computer printout were very low. The computer input and output are part of the analysis presented in Appendix A. The remainder of the analysis on the enclosure consisted of hand calculations on the various side and center constraint devices, lower support beam and other miscellaneous components.

The structural analysis on the loading column involved determining the strength capabilities of its components and their connections. Several threaded connections were analyzed and the two lug and pin

connectors (top and bottom) required a detail analysis to determine the pin bending stress. A high strength heat treated ($F_{tu} = 180$ ksi) pin was required at both locations. The partially tubular rods were checked for stress concentration around the 5/8-in. -diam orifice holes which are required in the cooling system design. The overall loading column was checked for its buckling capability as a compression member. Since the column assembly consists of components with varying cross-sections, a variable cross-section column analysis was required. However, in the available analytical approach only two variations in the cross-section are allowed. In this analysis, the two minimum cross-sections were used--a conservative approach. The resulting factor of safety was slightly less than the required 2.5; however, the fact that the column provided some lateral support at the passage hole was not considered in the analysis.

A summary of the safety factor and allowable stress criteria follows:

1. Allowable stresses for A-36 steel are to be taken directly from the Steel Construction Manual with no safety factor imposed.
2. For other materials such as AISI 4130 and 4340 steel, a factor of 2.0 will be imposed on yield strength (F_{ty}) and 2.5 on ultimate strength (F_{tu}).

B. Thermal Analysis

A thermal analysis of the loading column was necessary to determine if the cooling system design would adequately cool the load cell and the hydraulic cylinder. A thermal computer model of the column was developed in order to accurately determine the heat absorption in the two critical components. The results of the thermal analysis are presented in Appendix A. The assumption in the analysis is that it will require 6 hr to bring the specimen up to 600 °F and that the duration of the test will not exceed 6 hr, a total of 12 hr. The computer analysis was made with and without the tap water flowing through the tubular sections. The results from these two inputs indicate that the cooling system was required; and that the water flow keeps the region below the load cell at a temperature of 88 °F.

Note: Dimensions are in inches.

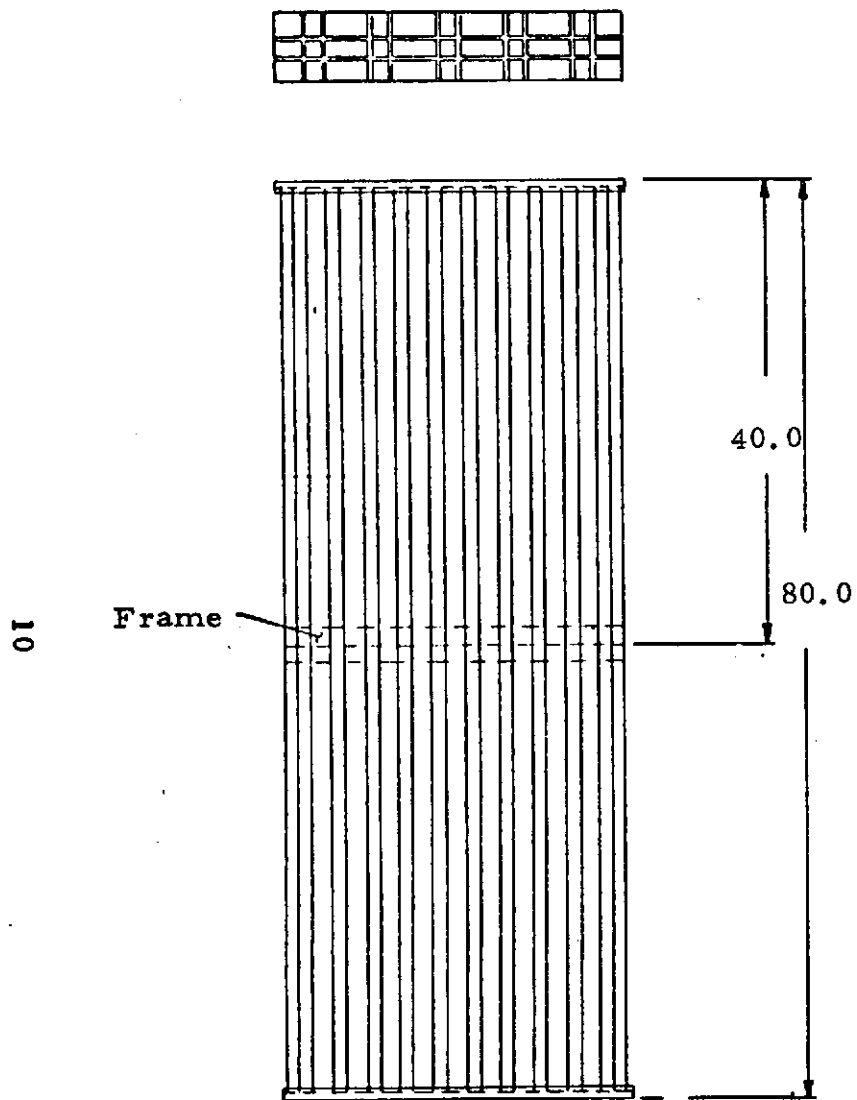


FIGURE 1. CONVAIR UNIFORMLY LOADED BORON-ALUMINUM COMPRESSION PANEL

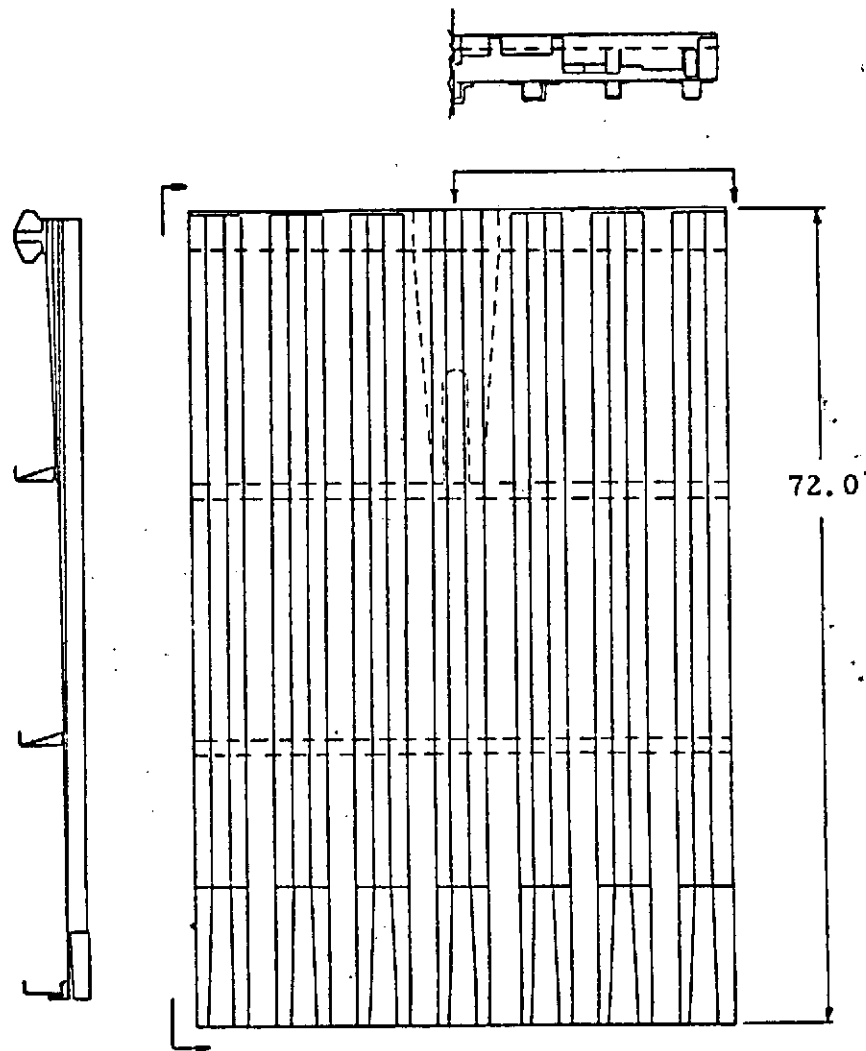


FIGURE 2. MDAC POINT LOADED BORON-ALUMINUM COMPRESSION PANEL

Note: Dimensions are in inches.

11

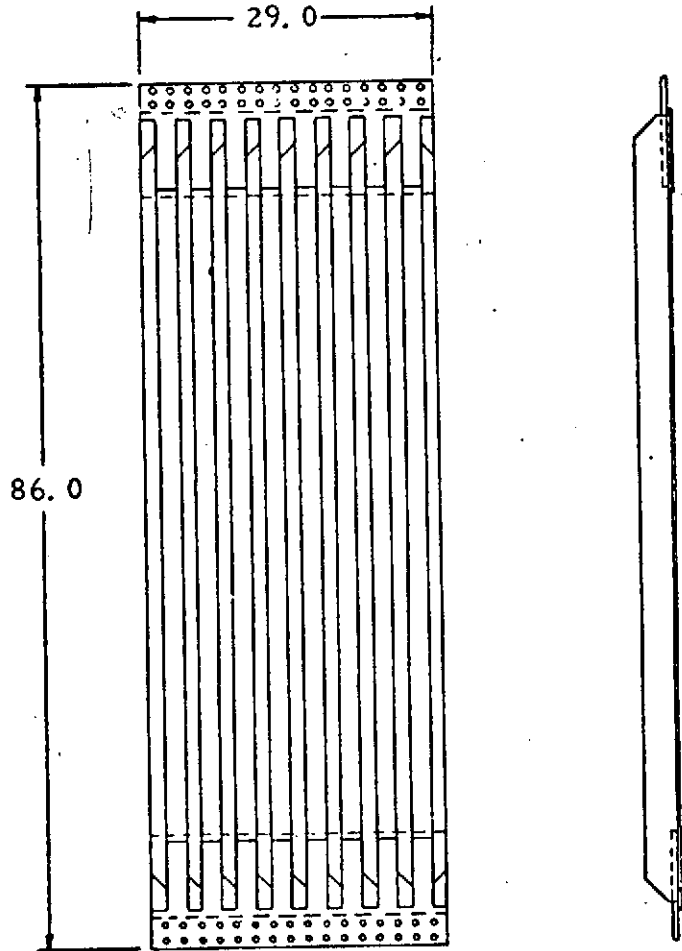


FIGURE 3. LOCKHEED UNIFORMLY LOADED BERYLLIUM COMPRESSION PANEL

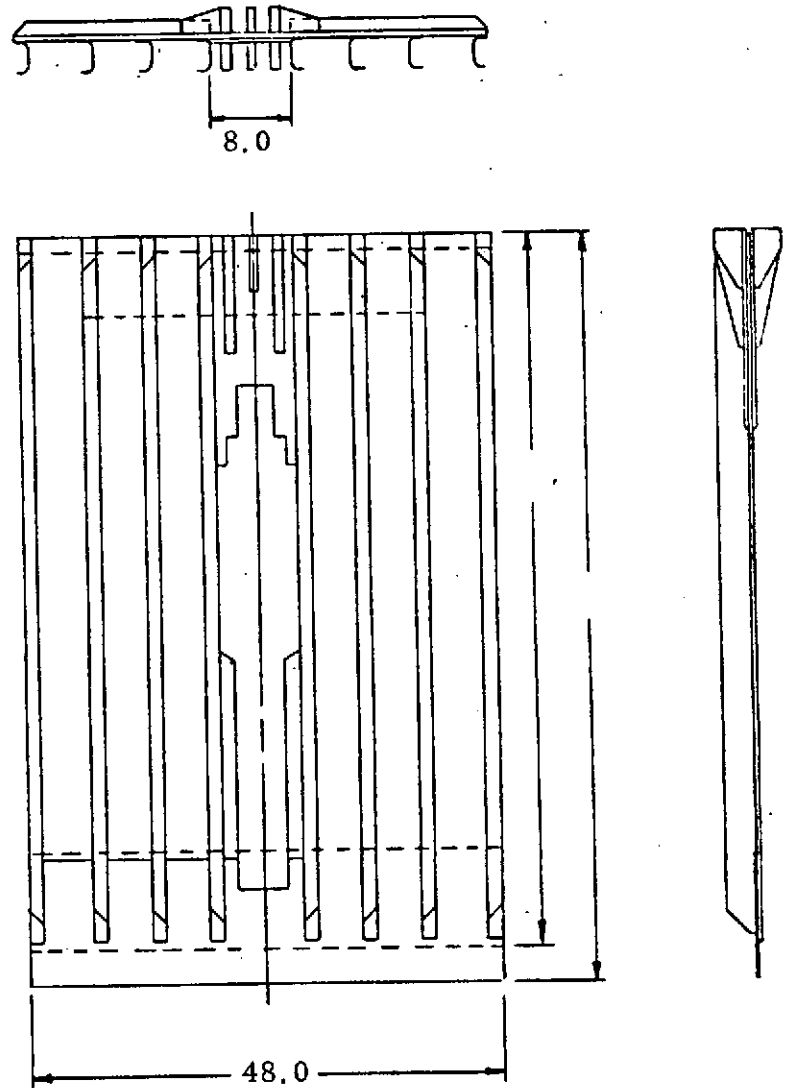


FIGURE 4. LOCKHEED POINT LOADED BERYLLIUM COMPRESSION PANEL

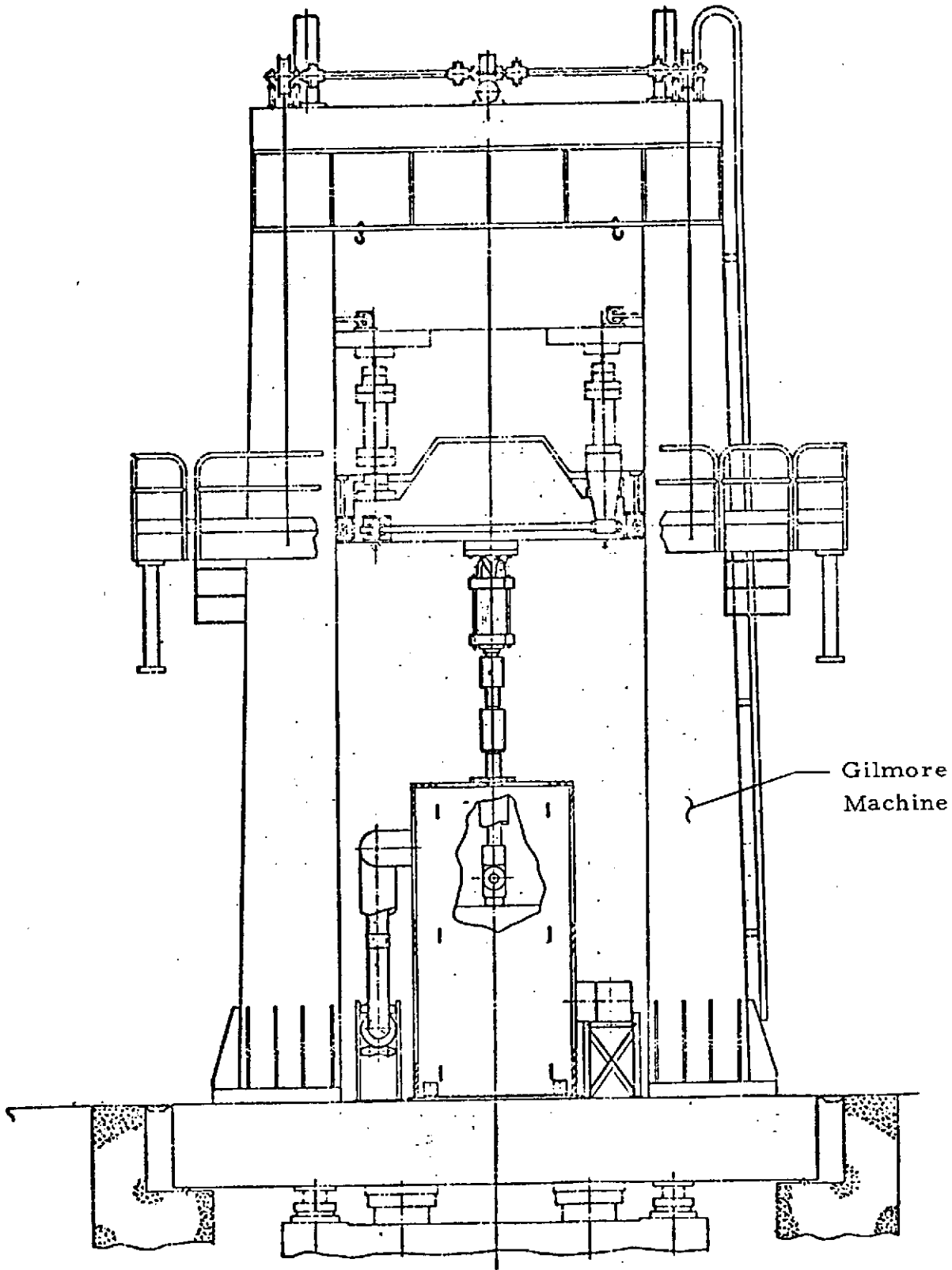


FIGURE 5. TEST FIXTURE ASSEMBLY

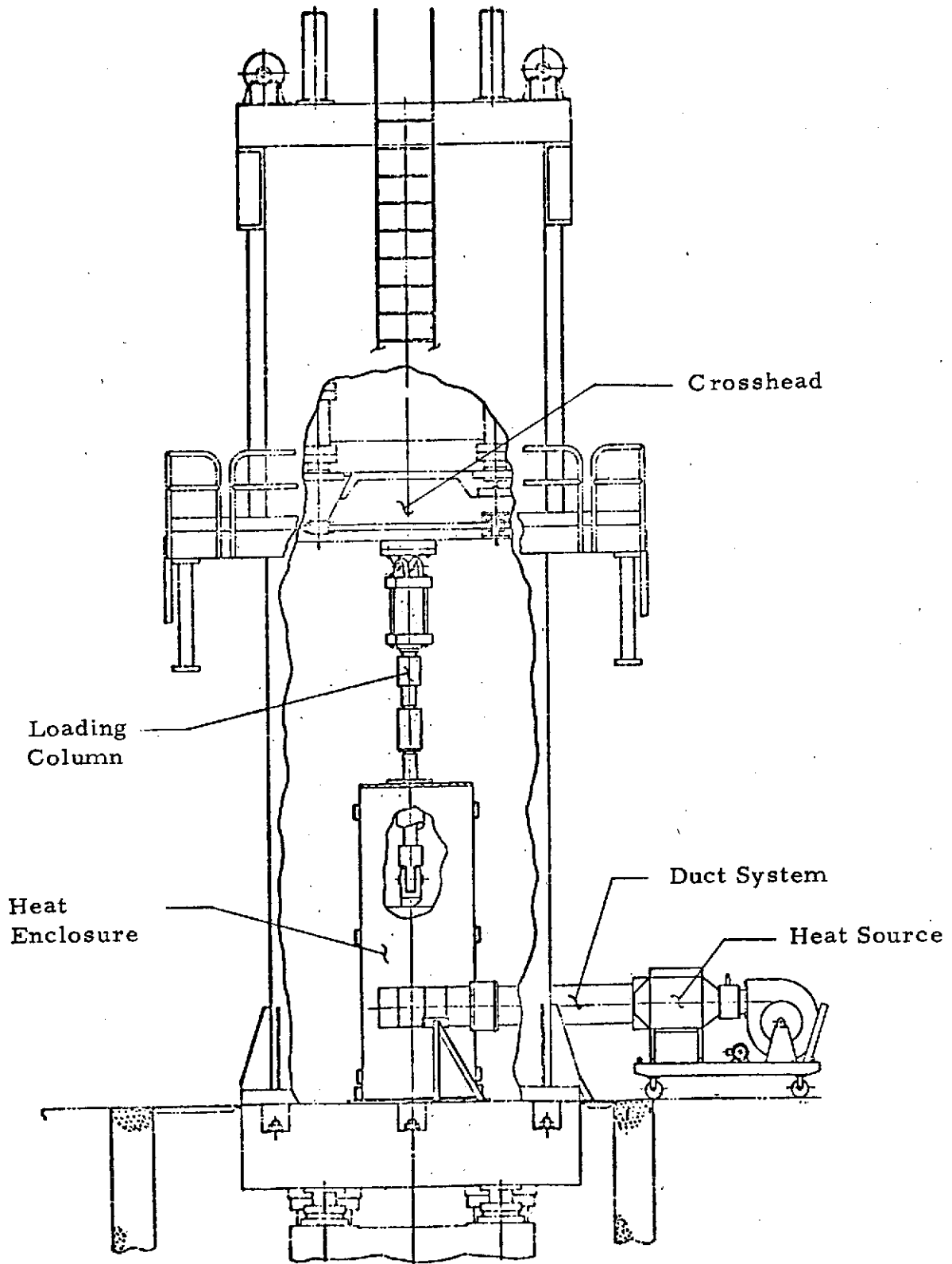


FIGURE 6. SIDE VIEW OF TEST FIXTURE ASSEMBLY

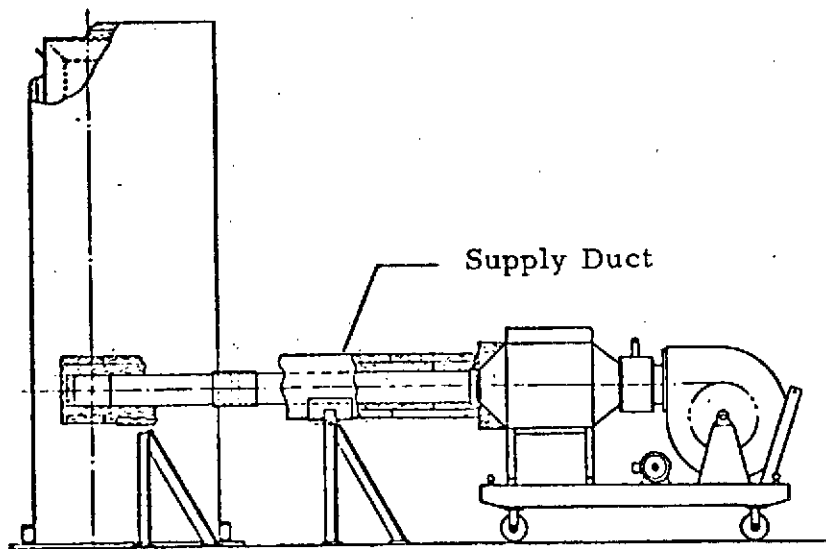
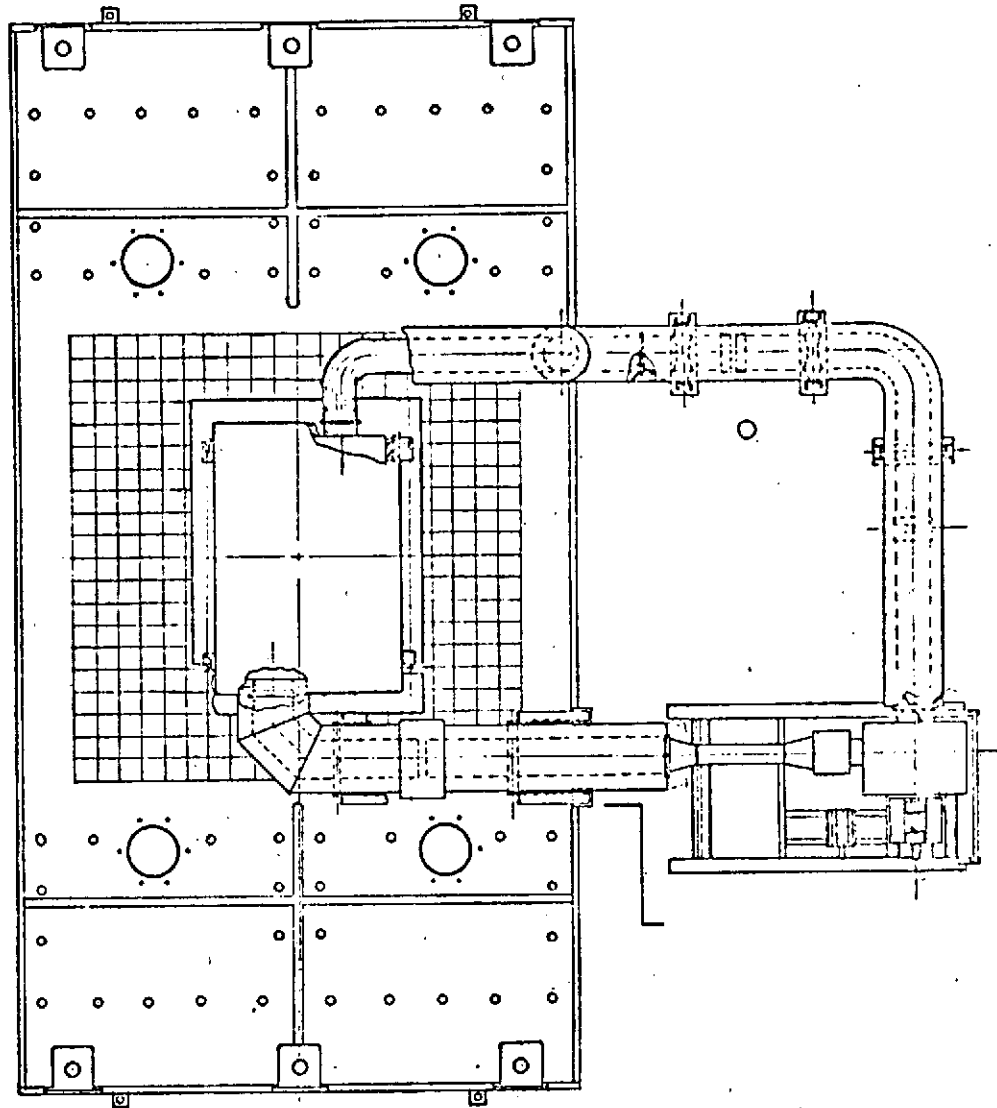


FIGURE 7. HEAT ENCLOSURE AND HEAT SOURCE POSITIONED WITHIN GILMORE MACHINE

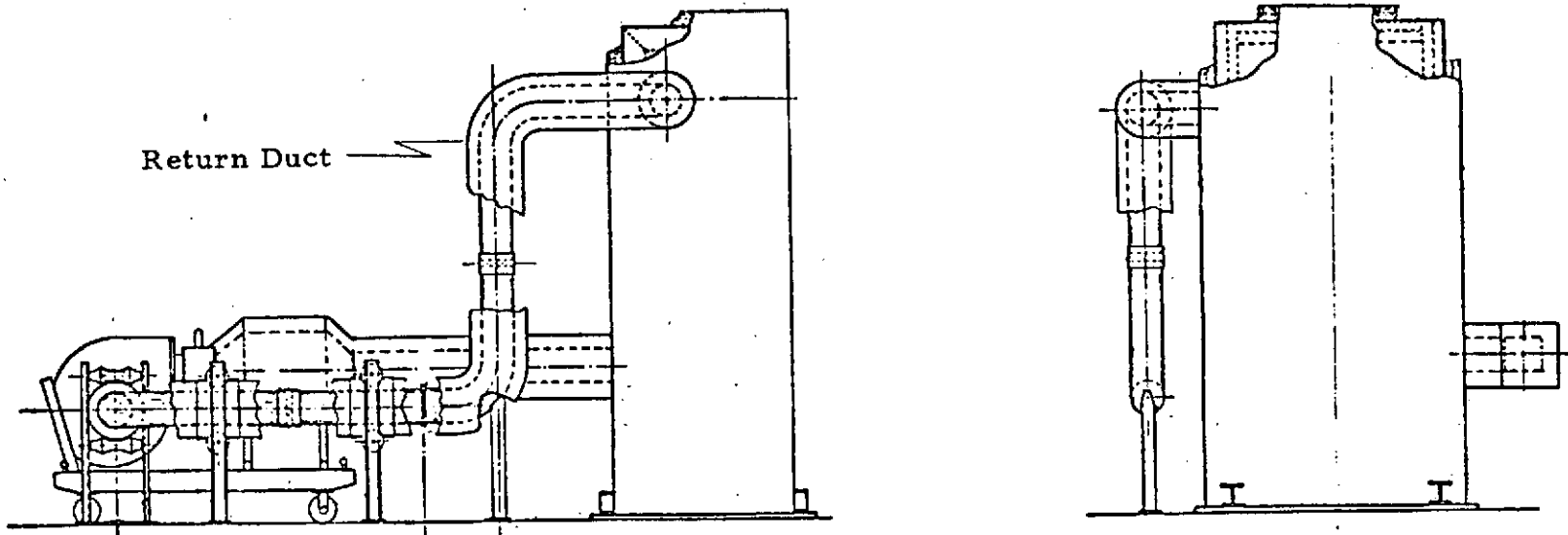


FIGURE 8. HEAT ENCLOSURE AND HEAT SOURCE SHOWING RETURN AIR DUCT

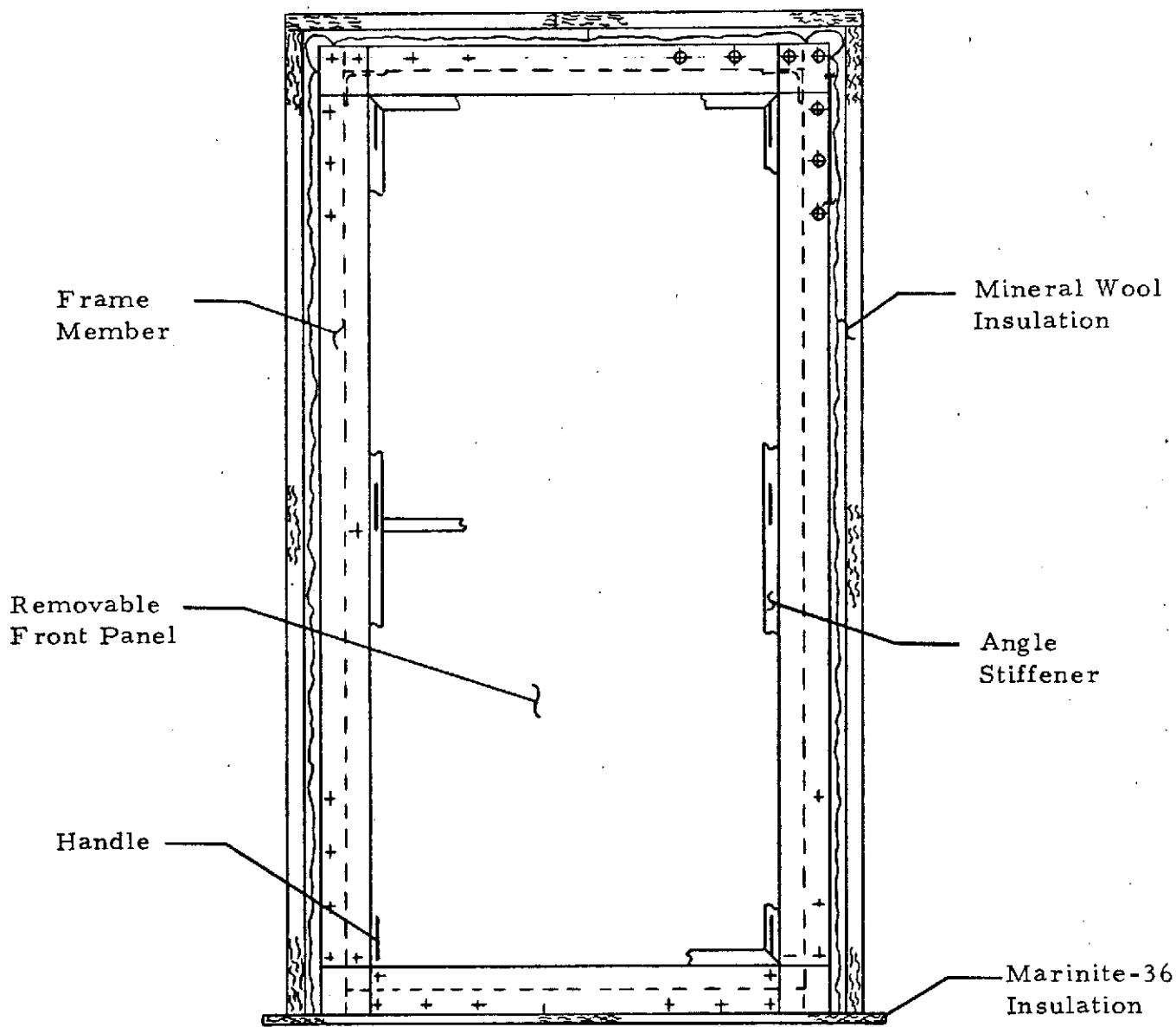


FIGURE 9. FRONT VIEW OF INSULATED HEAT ENCLOSURE

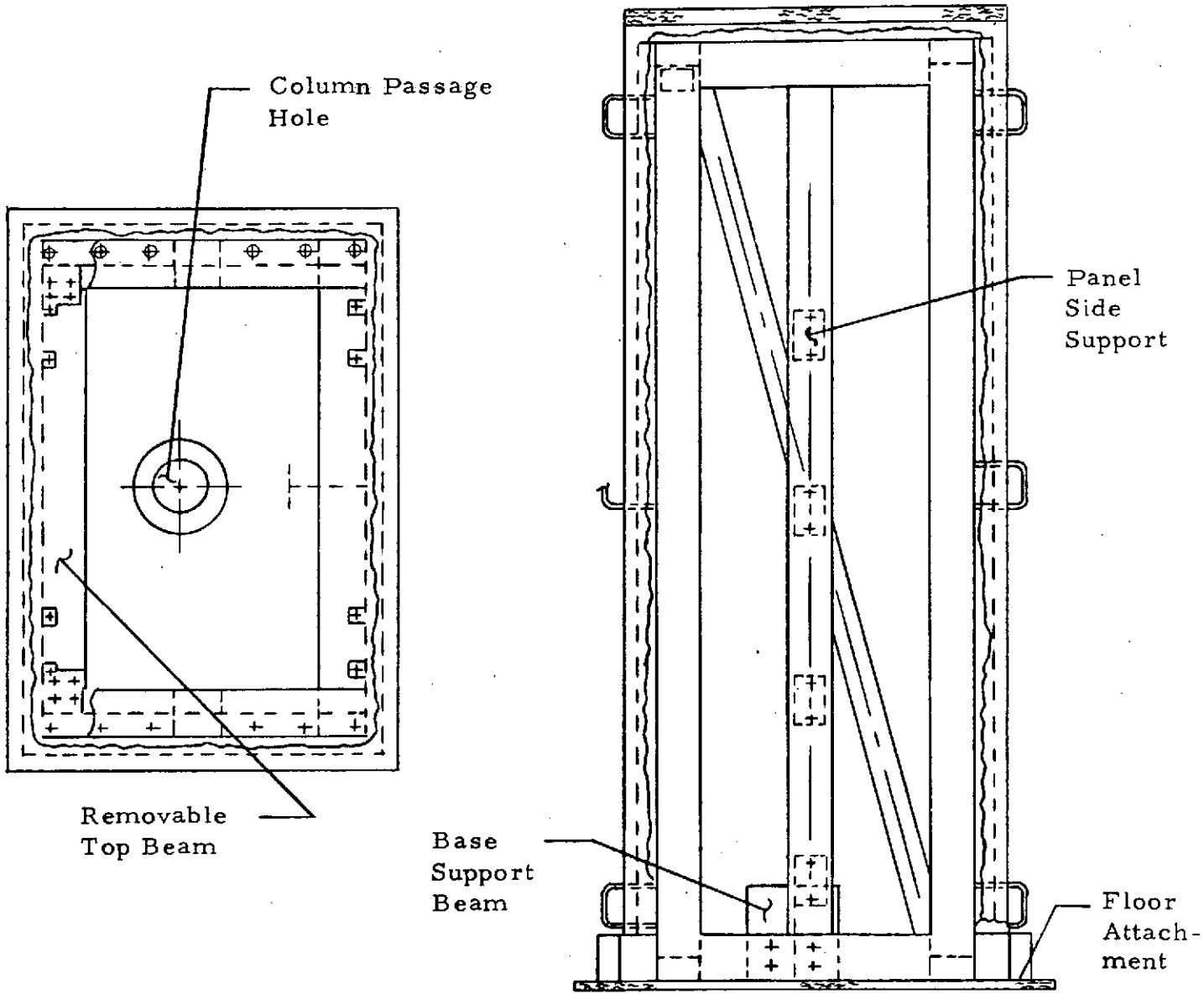


FIGURE 10. TOP AND SIDE VIEW OF HEAT ENCLOSURE

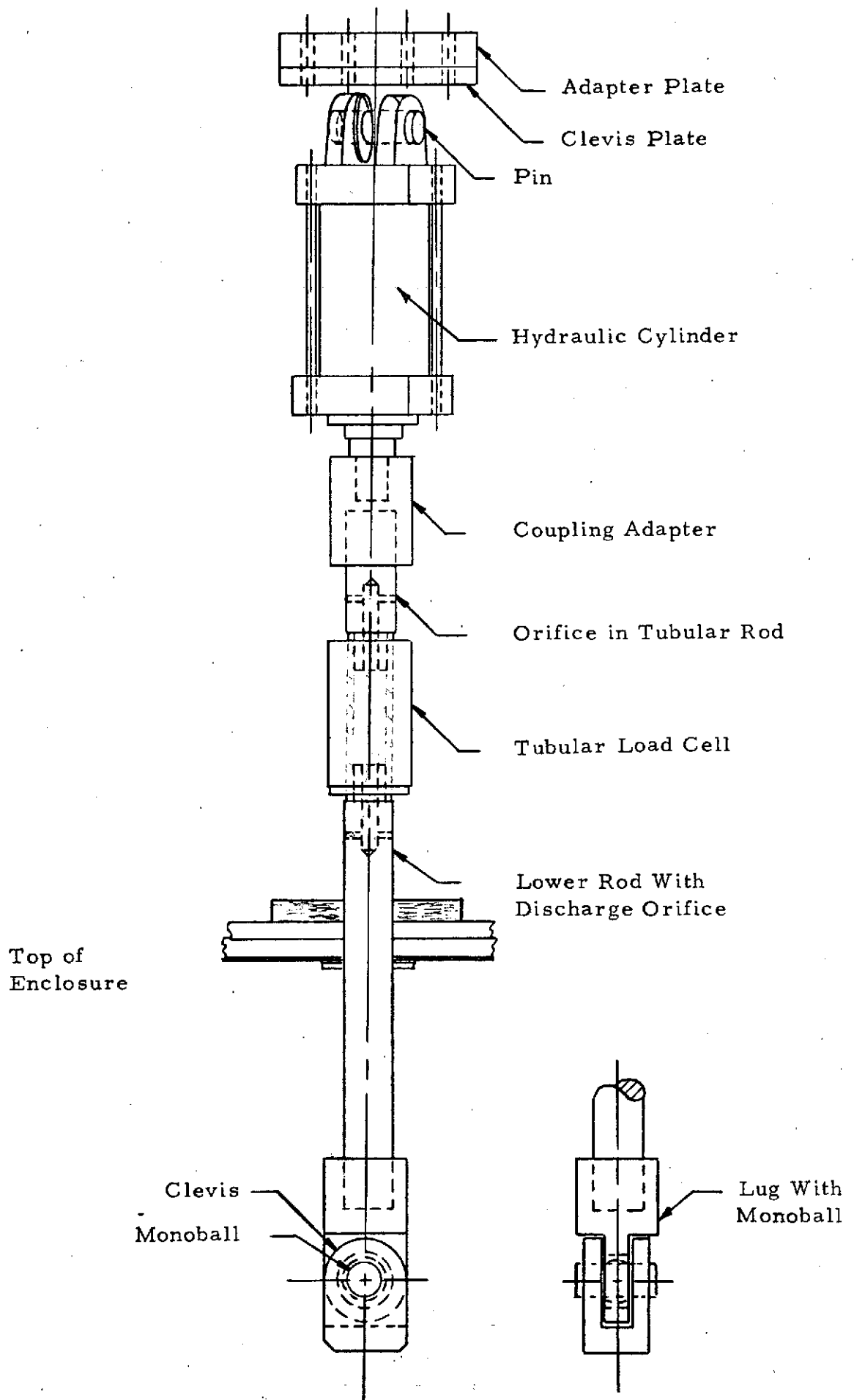


FIGURE 11. LOADING COLUMN ASSEMBLY

APPENDIX A

STRUCTURAL AND THERMAL ANALYSIS
OF TEST FIXTURE

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Prepared By _____ Date _____
Checked By _____ Date _____
Revised By _____ Date _____

 **TELEDYNE
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Page _____
Job No. _____
T. D. No. _____

Test Fixture

MATERIAL PROPERTIES

A-36 Structural Steel

Allowable Stresses

Ref. AISC Manual of Steel
Construction pg. 5-64

Tension: $F_t = 22.0$ ksi

Compression: $F_c = 22.0$ ksi or stability allowable

Bending: $F_b = 24.0$ ksi or stability allowable

Bearing: $F_p = 33.0$ ksi

Shear: $F_v = 14.5$ ksi

Modulus of Elascity

Ref. AISC Manual of Steel
Construction pg. 6-10

Room Temperature: $E = 29,000$ ksi

T = 600° F : $E = 26,446$ ksi

Test Fixture

MATERIAL PROPERTIES (Con't)

Ref. MIL-HDBK-5B
 Table 2.3.1.0(a) pg. 2-11

Mechanical Properties	AISI 4130		AISI 4340 Heat Treated to Obtain F_{tu}	
	RT	600° F	RT	600° F
F_{tu} , ksi	90	80.46	180	160.92
F_{ty} , ksi	70	55.44	163	129.09
F_{cy} , ksi	70	55.44	173	137.5
F_{su} , ksi	54	49.68	108	99.36
F_{bru} , ksi ($e/D=1.5$)	-	-	250	230.00
($e/D=2.0$)	190	174.80	326	299.92
F_{bry} , ksi ($e/D=1.5$)	-	-	230	211.60
($e/D=2.0$)	120	110.40	256	235.52
E , 10^6 psi	29.0	26.33	29.0	26.33
E , 10^6 psi	29.0	26.33	29.0	26.33
G , 10^6 psi	11.0	-	11.0	-

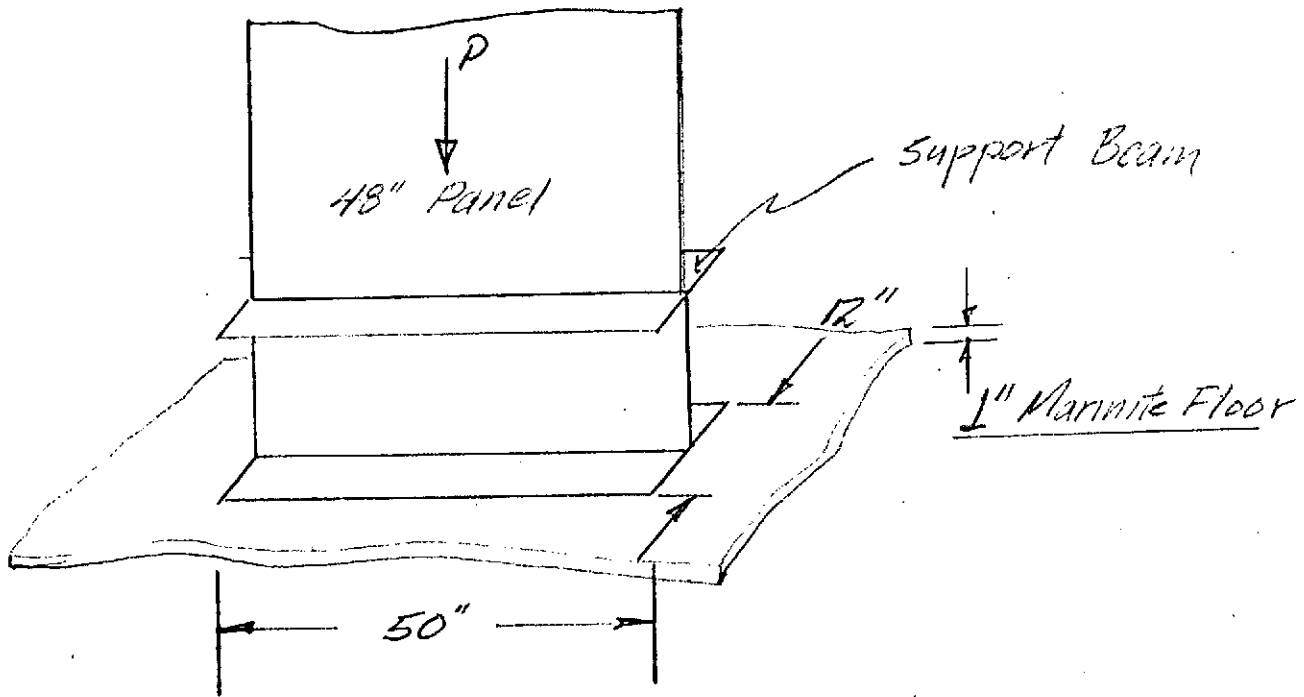
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HEAT ENCLOSURE STRENGTH ANALYSIS

TEST FIXTURE

HEAT ENCLOSURE

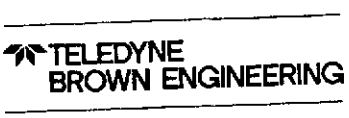
DEFLECTION OF MARINITE FLOOR UNDER COMPRESSION LOAD



Minimum Projected Area : $A = 50 \times 12 = 600 \text{ in}^2$

Ult. Deflection : $\delta = \frac{PL}{AE}$
 $\delta = \frac{2.5 (350) 1}{600 (360)}$
 $\delta = .00405 \text{ in}$

Prepared By Y. G. HOX Date 7/14/73
Checked By ALS Date 7/25/73
Revised By _____ Date _____



Page A1.2
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T. D. No. _____

TEST FIXTURE

MARXITE FLOOR (CONIT)

Stress

$$\frac{P}{A} = \frac{350 \times 2.5}{600} = 1.46 \text{ ksc}$$

Marxite Compressive Stress Allowable

$$F_{cu} = 14 \text{ ksc}$$

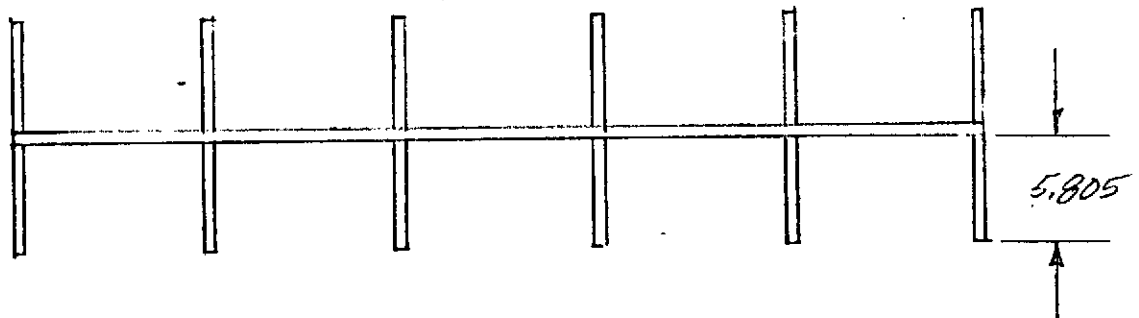
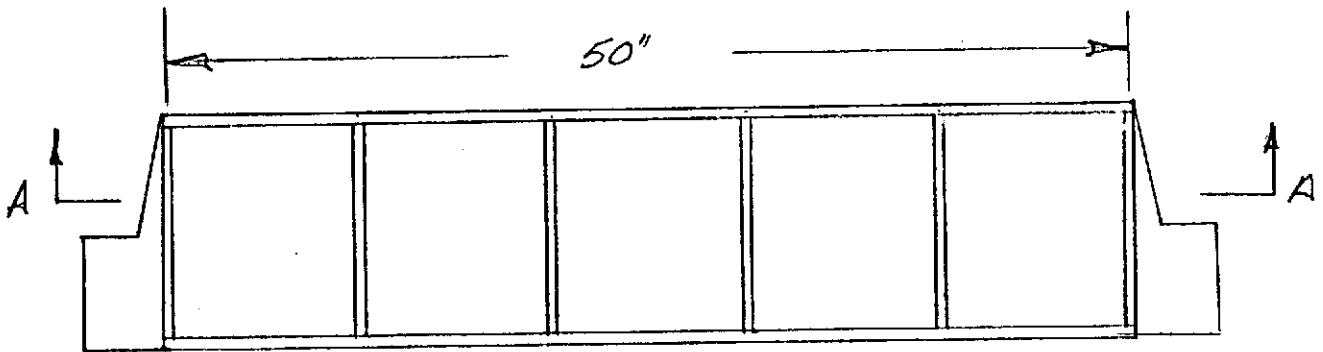
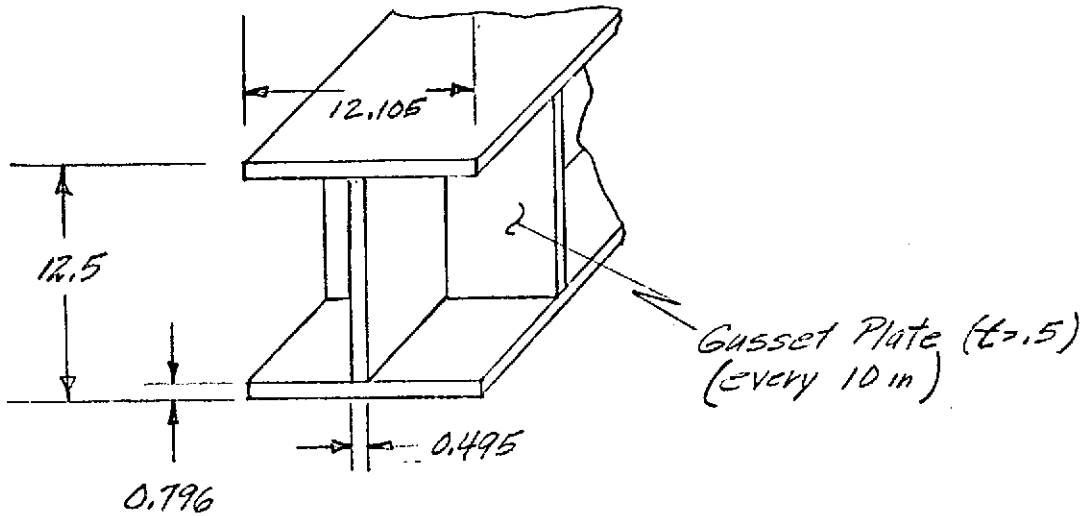
TEST FIXTURE

HEAT ENCLOSURE

BASE SUPPORT BEAM

12 WF 85

DRW 28
Sheet 2



TEST FIXTURE

BASE SUPPORT BEAM (CON4)

AREA Section A-A

$$A_{iv} = 50 \times 0.495 = 24.75$$

$$A_g = 12(5.805 \times 0.5) = 34.83$$

$$A_T = 59.58 \text{ in}^2$$

AXIAL STRESS:

$$\sigma = \frac{P}{A_T} = \frac{350}{59.58} = 5.874 \text{ ksi}$$

Buckling Allowable of Gusset Plate

$$\sigma = \frac{k \pi^2 E t^2}{12(1-\mu^2) b}$$

$$\sigma = \frac{0.425(9.87)(26,446)(.25)^2}{12(.91) 5.805}$$

$$\sigma = 4.38 \times 10^2 \text{ ksi high!}$$

M.S. - high!

Ref. Design of welded structures
pg 2.12-1

$$\left\{ \begin{array}{l} \mu = .32 \\ E = 26,446 \text{ ksi} \\ @ T = 600^\circ F \end{array} \right.$$

$$b = 5.805$$

$$k = 0.425 \text{ (SS)}$$

$$t = .5, t^2 = .25$$

TEST FIXTURE

HEAT ENCLOSURE

PRESSURE LOAD ON SKIN PANEL

DRW 28
 sheet 1

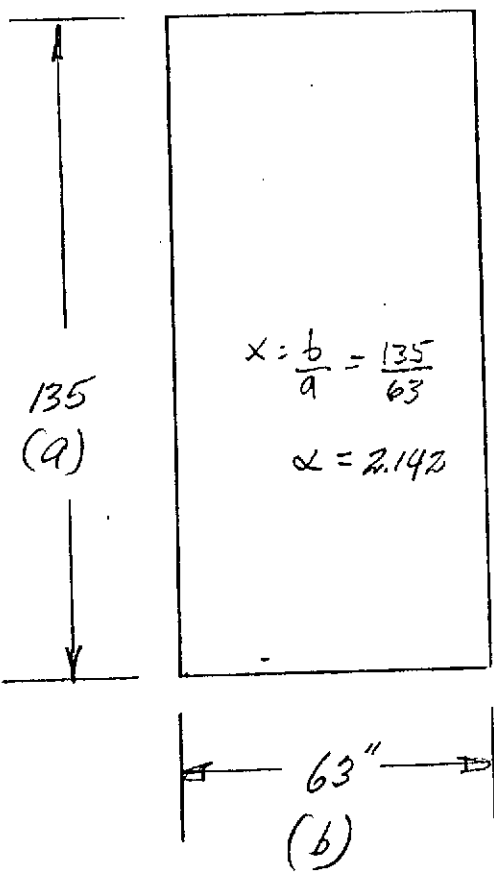
pressure = pressure produced by 12.7 m of water

$$p = \rho h$$

$$p = \frac{62.4}{1728} = .03611 \text{ lb/in}^2$$

$$p = 0.0361 (12.7)$$

$$p = 0.458 \text{ psi}$$



Max Stress due to Pressure

$$\sigma = \frac{0.75 w b^2}{t^2 (1 + 1.61 x^3)}$$

Ref: Rein. pg 203

or

Min Thickness

$$t^2 = \frac{0.75 (0.458) 4100}{22,000 [1 + 1.61 (2.143)^3]}$$

16.9

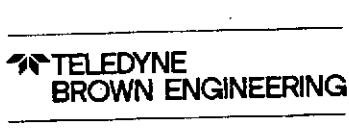
$$t^2 = .003782$$

$$t = .0614$$

Material A-36

Prepared By P. LEHUX
Checked By ALS
Revised By _____

Date 1/24/55
Date 7/25/73
Date _____



Page A.1.6
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T. D. No. _____

TEST FIXTURE

SKIN PANEL (COMIT)

Actual skin panel thickness: $t = 0.125$ in
 $t^2 = 0.0156$

Actual Stress

$$\sigma = \frac{0.75 (1.458) 4100}{(0.0156) (16.9)}$$

$$\sigma = \underline{5340 \text{ psi}}$$

Allowable Stress A-36, $F_b = 24 \text{ ksi}$

$$M.S. = \frac{24,000}{5340} - 1$$

$$\underline{M.S. = 3.49}$$

TEST FIXTURE

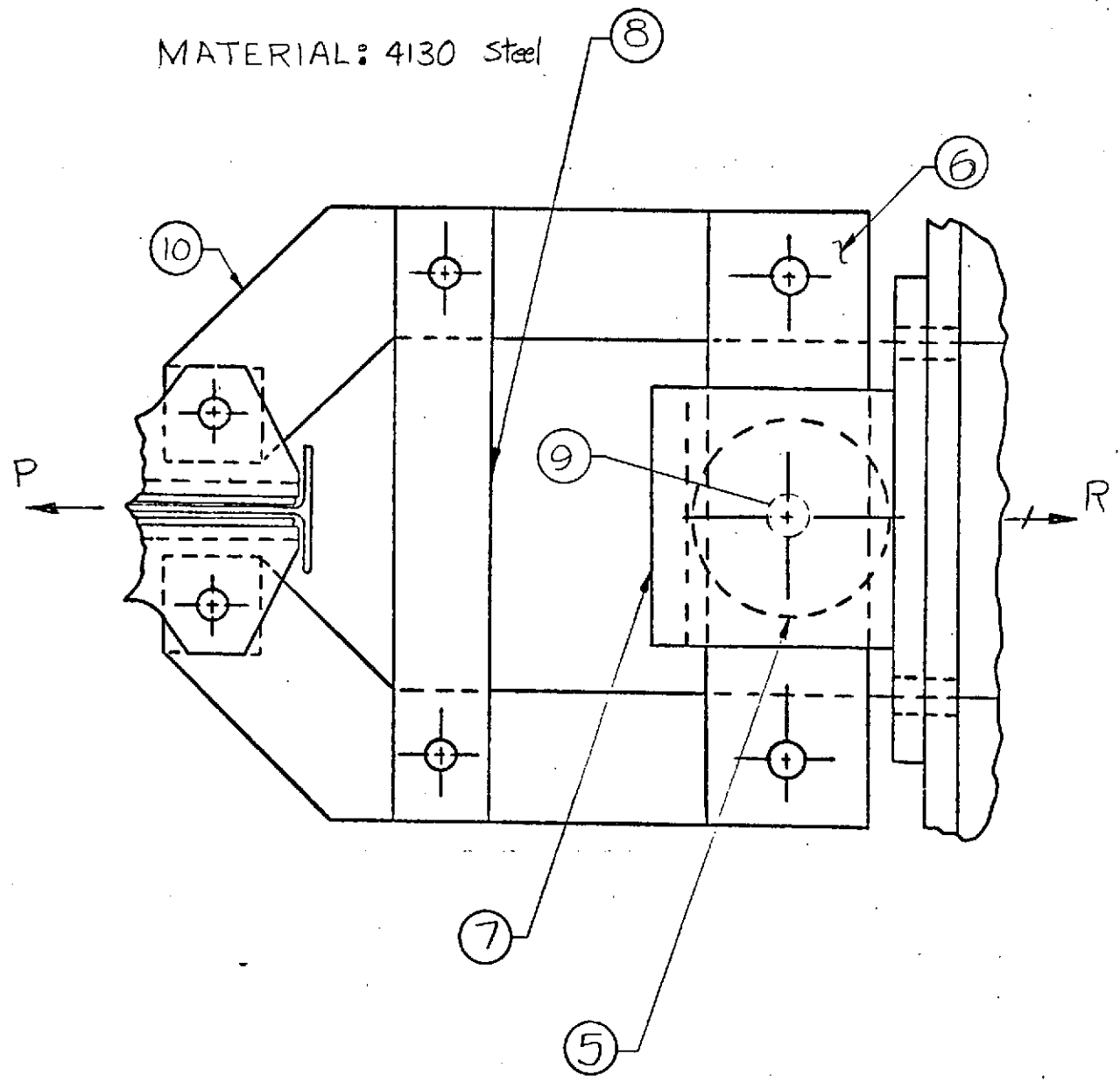
MDAC CENTER ATTACHMENT

TOP FRAME (1)

DRW. 28
SHEET 3

LOAD = 5394.0 lbs.

MATERIAL: 4130 Steel



Prepared By PJW Date 7-26-73
Checked By _____ Date _____
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TELEDYNE
BROWN ENGINEERING

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TEST FIXTURE

MDAC CENTER ATTACHMENT

TOP FRAME (1)

DRW. 28
SHEET 3

BRACKET (7), WHEEL (5), PIN (9) & PLATE (6)

THESE ITEMS HAVE BEEN CHECKED FOR
THE DESIGN LOAD OF 5394.0 lbs. FROM
THE ANALYSIS OF THE MDAC CENTER
ATTACHMENT, CENTER FRAMES (2&3),
PAGES A2.7 FOR THIS ANALYSIS.

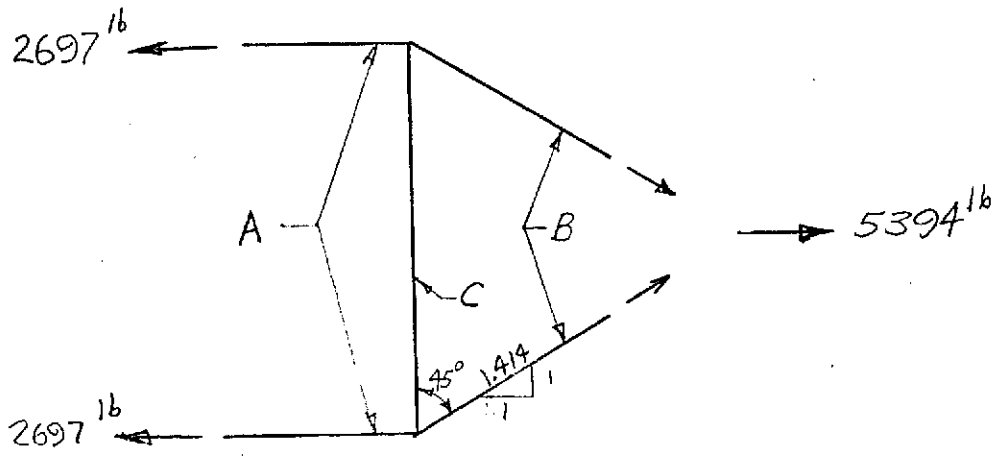
TEST FIXTURE

MDAC CENTER ATTACHMENT

TOP FRAME (1)

DRW. 28
 SHEET 3

LOADS



LOAD IN B

$$P_B = 1.414(2697) / 1 = 3810.0 \text{ lbs. TENSION}$$

LOAD IN C

$$P_C = 2697 \cdot \frac{1}{1} = 2697.0 \text{ lbs. COMPRESSION}$$

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TEST FIXTURE

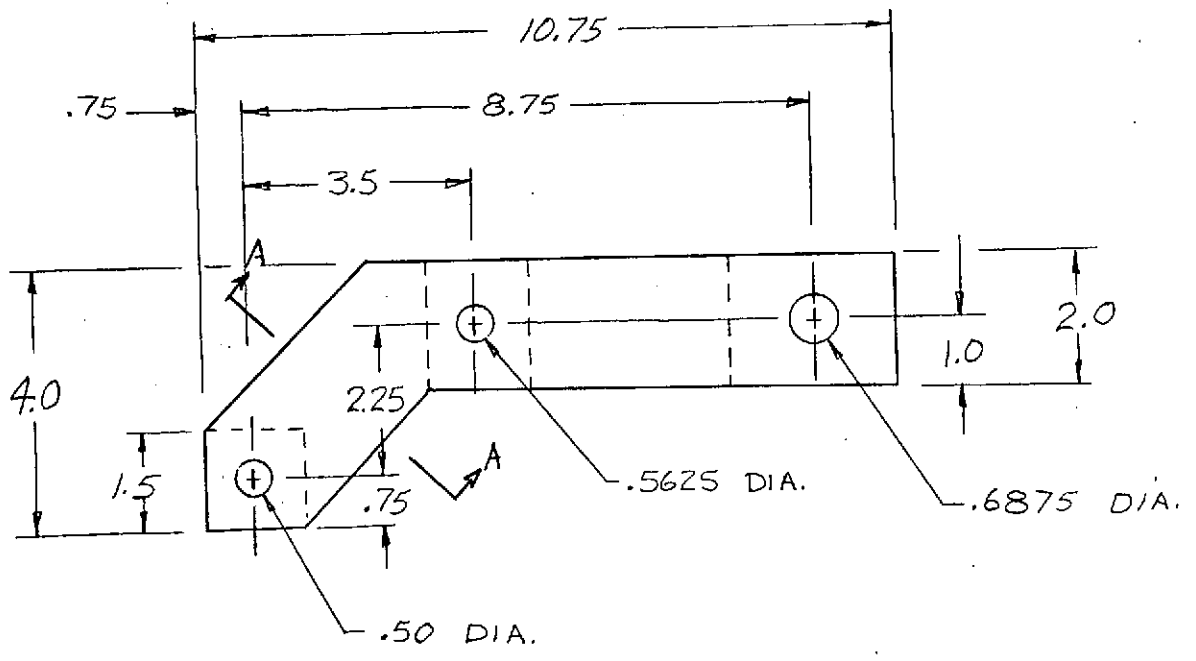
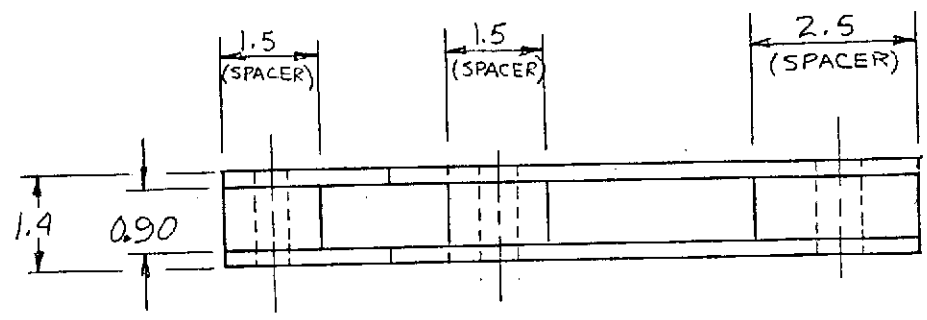
MDAC CENTER ATTACHMENT

TOP FRAME (1)

DRW. 28
SHEET 3

PLATE (10)

LOAD (Ref. Page A1.9)
MATERIAL: 4130 steel



TEST FIXTURE

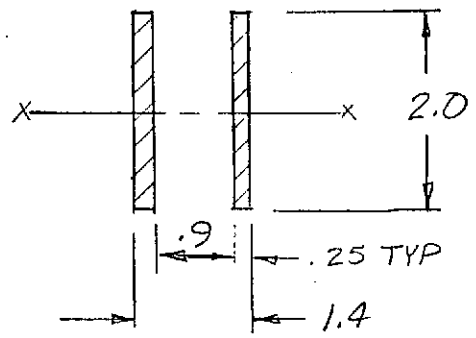
MDAC CENTER ATTACHMENT

TOP FRAME (1)

DRW. 28
SHEET 3

PLATE (10) CONT'

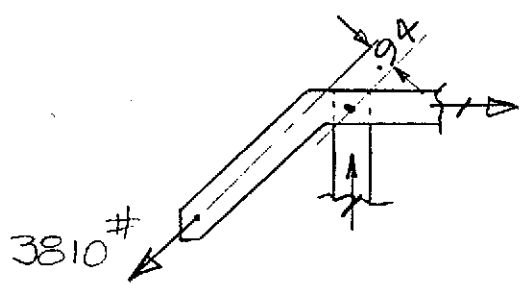
CHECK SECTION A-A FOR BENDING & AXIAL LOAD



$$A = 2[2. \times .25] = 1.0 \text{ IN}^2$$

$$I = 2\left[.25 \frac{(2.)^3}{12}\right] = .333 \text{ IN}^4$$

SECTION A-A
(REF. PAGE 4)



$$M_{A-A} = 3810 (.93)$$

$$M_{A-A} = 3540. \text{ IN-1b}$$

$$f_{\text{⑩}} = \frac{P}{A} + \frac{Mc}{I} = \frac{3810.}{1.0} + \frac{3540(.1)}{.333}$$

$$f_{\text{⑩}} = 14410. \text{ PSI}$$

$$F_t = 27720. \text{ PSI}$$

$$M.S. = \frac{27.72}{14.41} - 1. = \underline{\underline{+.92}} \quad \underline{\underline{GOOD}}$$

TEST FIXTURE

MDAC CENTER ATTACHMENT

TOP FRAME (1)

PLATE (10) CONT

DRW. 28
SHEET 3

@ BOLT, .5625 DIA.

$$f_{br} = \frac{P}{A_{br}} = \frac{3810}{2(.5625 \times .25)} = 13500. \text{ PSI Bearing}$$

$$F_{br} = 55.20 \text{ KSI}$$

$$M.S. = \frac{55.2}{13.5} - 1. = \underline{\underline{+3.1}} \quad \underline{\underline{GOOD}}$$

@ BOLT, .6875 DIA.

$$f_{br} = \frac{P}{A_{br}} = \frac{2697}{2(.6875 \times .25)} = 7850. \text{ PSI Bearing}$$

$$F_{br} = 55.2 \text{ KSI}$$

$$M.S. = \frac{55.2}{7.85} - 1. = \underline{\underline{+6.03}} \quad \underline{\underline{GOOD}}$$

Shear Out →

$$f_{s.o.} = \frac{P}{A_s} = \frac{2697./2}{2(1.25 \times .25)} = 2150. \text{ PSI Shear-Out}$$

$$F_s = 19.88 \text{ KSI}$$

$$M.S. = \frac{19.88}{2.150} - 1. = \underline{\underline{+8.23}} \quad \underline{\underline{GOOD}}$$

TEST FIXTURE

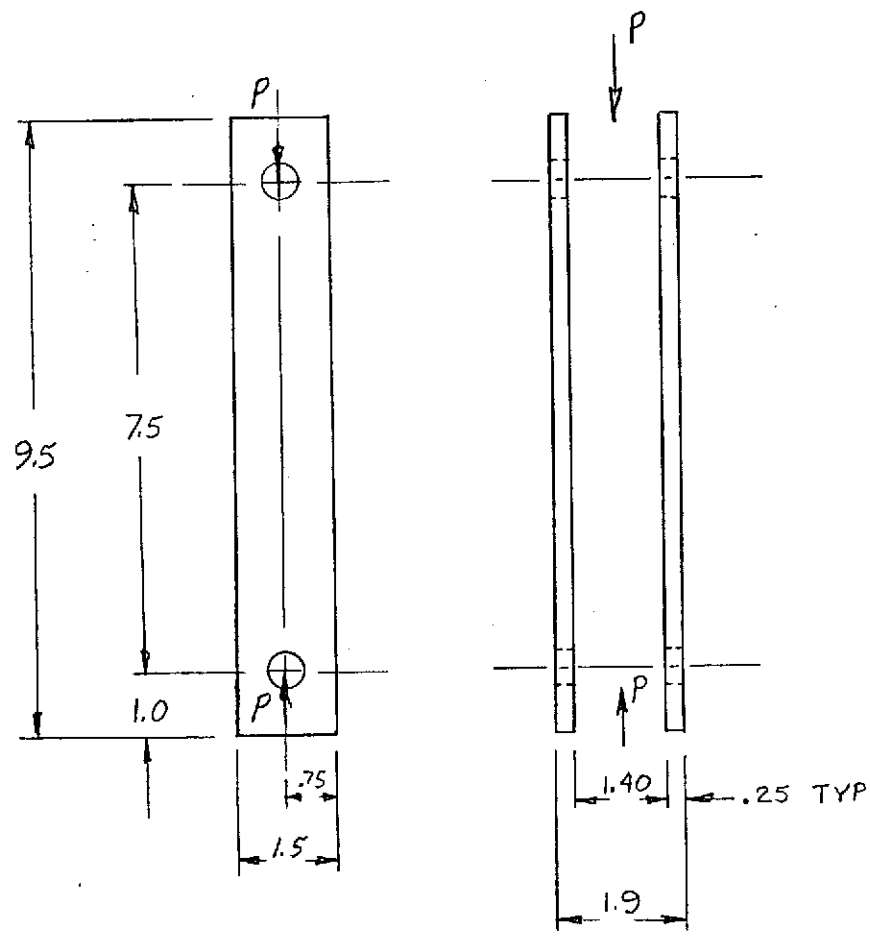
MDAC CENTER ATTACHMENT

TOP FRAME (1)

PLATE ⑧

DRW. 28
SHEET 3

LOAD (P) = 2697. lb. COMPRESSION
 MATERIAL: 4130 Steel



$$A = 2(1.5 \times .25) = .75 \text{ IN}^2$$

$$I_{min.} = 2(.75)(.825)^2 + \left[\frac{1.5(.25)^3}{12} \right] 2$$

$$I_{min} = 1.0239 \text{ IN}^4$$

TEST FIXTURE

MDAC CENTER ATTACHMENT

TOP FRAME (1)

DRW. 28
SHEET 3

PLATE (8) CONT'

consider the plates as a column

$$c = \sqrt{\frac{I}{A}} = \sqrt{\frac{1.0239}{.75}} = 1.167$$

$$L' = \frac{L}{\sqrt{c}} = \frac{7.5}{\sqrt{1.167}} = 7.5$$

where $c=1.0$

$$\frac{L'}{c} = \frac{7.5}{1.167} = 6.44 \ll 91$$

Ref. MIL-HDBK-58, 1 Sept. 1971, page 2-139,
Table 2.7.2.1

This is a short column

$$\frac{P}{A} = 79500 - 51.9 \left(\frac{L'}{c} \right)^{1.5}$$

Ref. "FORMULAS
FOR STRESS & STRAIN"
By R. J. ROARK, page
264, Table XI.

$$\frac{P}{A} = 79500 - 51.9 (6.44)^{1.5}$$

$$P/A = 78648 \text{ lb/in}^2$$

$$P = 59000 \text{ lbs. ULT. ALLOW. LOAD (R.T.)}$$

$$P = 23600 \text{ lbs. LIMIT ALLOW. LOAD (R.T.)}$$

$$P = 23600 \times .792 = 18700 \text{ lbs. LIMIT ALLOW. LOAD (600°F)}$$

$$M.S. = \frac{18.7}{2.697} - 1 = \underline{\underline{+5.93}} \text{ , } \underline{\underline{GOOD}} \leftarrow$$

Prepared By PJW Date 7-26-73
Checked By ALS Date 7/31/73
Revised By _____ Date _____

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TEST FIXTURE

MDAC CENTER ATTACHMENT

TOP FRAME (1)

DRW. 28
SHEET 3

PLATE (8) CONT'

@ BOLT, MATERIAL BEARING

$$f_{br} = \frac{P}{A_{br}} = \frac{2697/2}{.5625 \times .25} = 9580. \text{ PSI}$$

$$F_{br} = 55.2 \text{ KSI}$$

$$M.S. = \frac{55.2}{9.58} - 1. = \underline{\underline{+4.77}} \quad \underline{\underline{GOOD}}$$

TEST FIXTURE

MDAC CENTER ATTACHMENT

TOP FRAME (1)

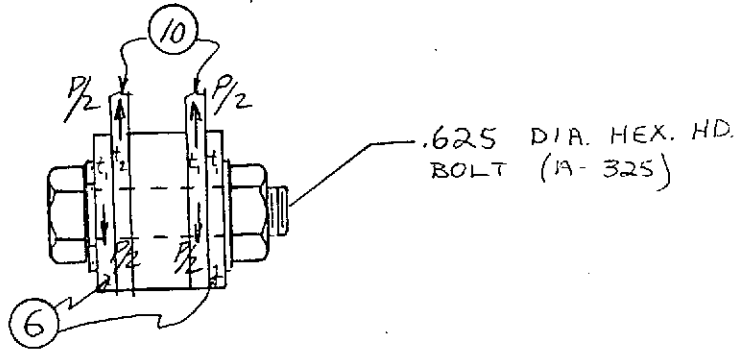
DRW. 28
SHEET 3

BOLTS

WHERE PLATES ⑥ & ⑩ JOIN

LOAD $P = 2697^k$
 MATERIAL: 4130 steel

$t_1 = t_2 = .25 \text{ IN}$



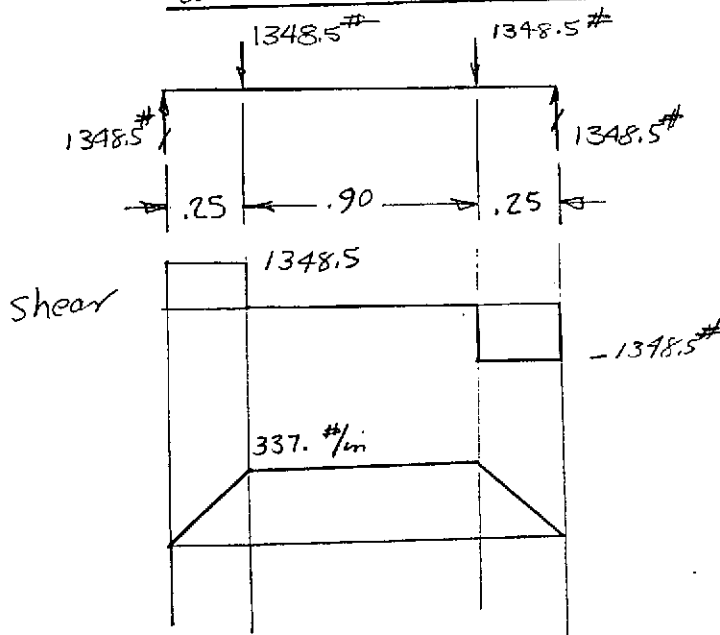
Shear on BOLT:

$f_s = \frac{P/2}{A_s} = \frac{2697/2}{.625 \times .25} = 8650 \text{ PSI}$

$F_s = 15.0 \text{ KSI}$

M.S. = $\frac{15.0}{8.65} - 1 = +.74$ GOOD

Consider Bolt as a beam to check PIN BENDING:



$M = 337 \text{ IN-16}$

$f_b = \frac{Mc}{I} = \frac{M}{S}$

$S = .098175(d)^3 = .098175(.625)^3$

$S = .02395 \text{ IN}^3$

$f_b = \frac{M}{S} = \frac{337}{.02395} = 14100 \text{ PSI}$

M.S. = $\frac{27.72}{14.1} - 1 = +.96$ GOOD

TEST FIXTURE

MDAC CENTER ATTACHMENT

DRW. 28
 SHEET 3

TOP FRAME (1)

BOLTS CONT'

WHERE PLATES (B) & (D)
 LOAD = 3810. lbs.

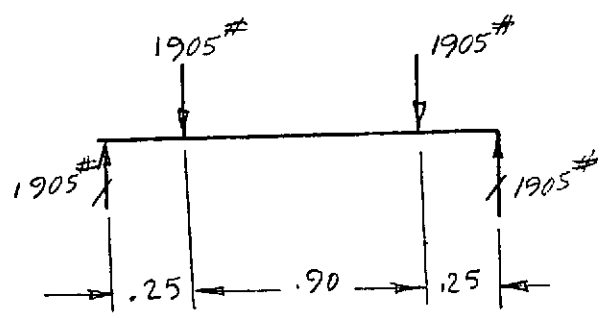
Refer to sketch on page A1.17 substituting
 (B) for (C) AND SIZE OF BOLT TO .5625 DIA.

Shear ON BOLT :

$$f_s = \frac{P/2}{A_s} = \frac{3810./2}{.625 \times .25} = 12200. \text{ PSI}$$

$$M.S. = \frac{15.0}{12.2} - 1. = \underline{\underline{+2.2}} \quad \underline{\underline{GOOD}}$$

Consider Bolt as a Beam to check PIN BENDING :



$$M = 1905 \times .25 = 477 \text{ IN-LB}$$

$$f_b = \frac{Mc}{I} = \frac{M}{S}$$

$$S = .02395 \text{ IN}^3$$

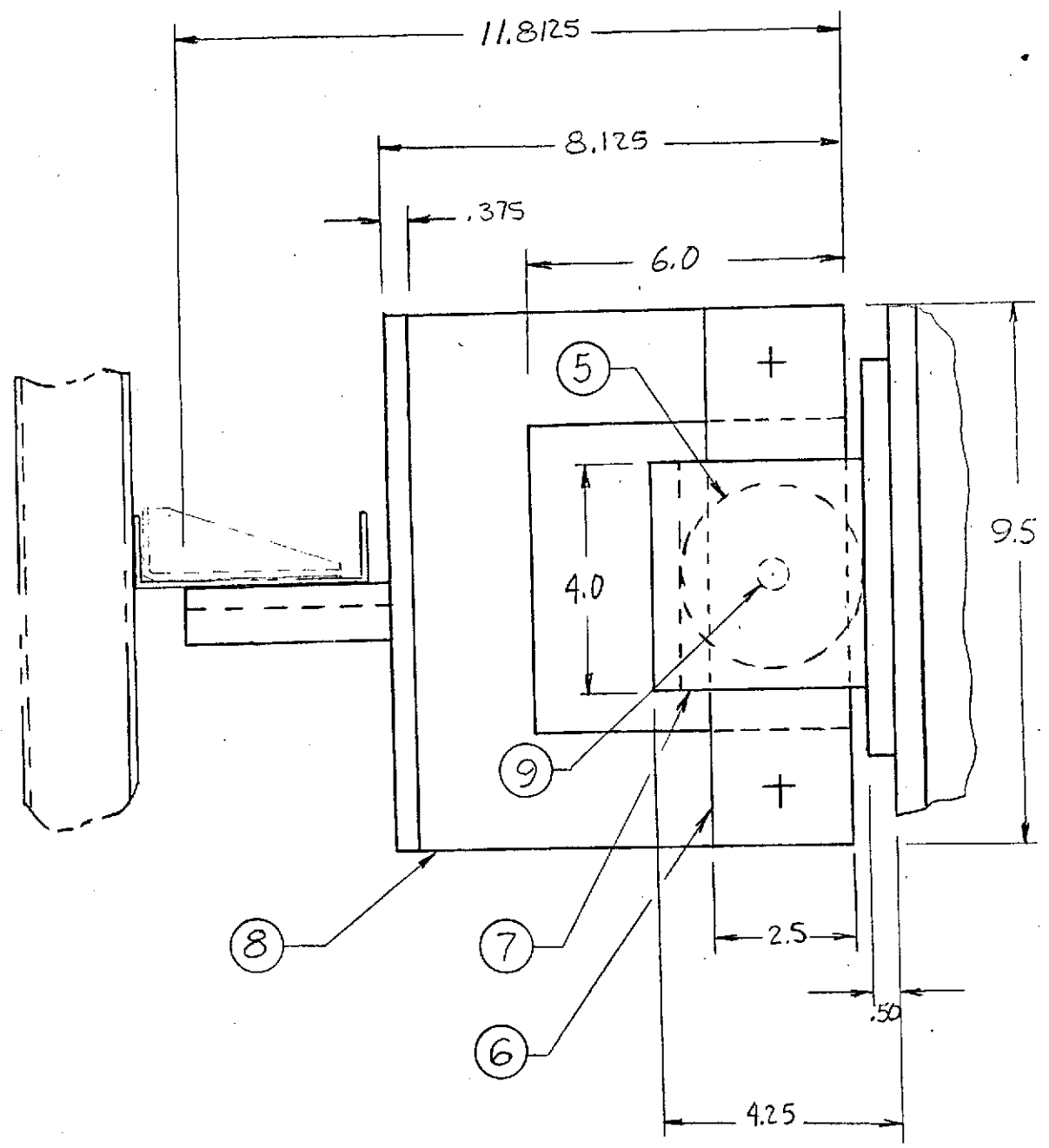
$$f_b = \frac{477}{.02395} = 19900. \text{ PSI}$$

$$M.S. = \frac{27.72}{19.9} - 1. = \underline{\underline{+3.9}} \quad \underline{\underline{GOOD}}$$

TEST FIXTURE

MDAC CENTER ATTACHMENT
MIDDLE FRAMES (2 & 3)

DRW. 28
SHEETS 3 & 4



TEST FIXTURE

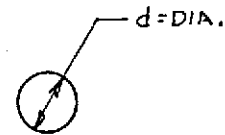
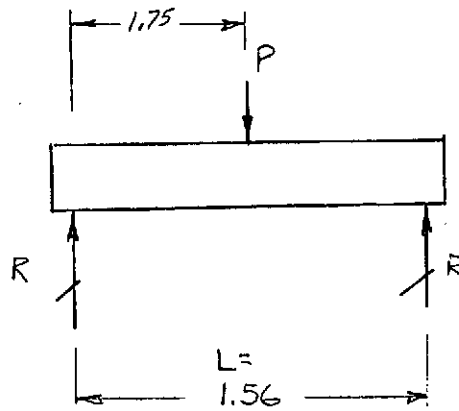
MDAC CENTER ATTACHMENT

MIDDLE FRAMES (2 & 3)

DRW. 28
SHEETS 3 & 4

DESIGN OF PIN (9)

LOAD = 5394 lbs.
 MATERIAL: 4130 Steel



$$M = \frac{PL}{4}$$

$$f_b = \frac{Mc}{I} = \frac{PL d/2}{.04908 d^4} = \frac{PL}{.09816 d^3} = \frac{(5394)(1.56)}{(.09816)(d^3)} = 27,700.$$

$$d_{ref} = 1.46 \text{ IN.} *$$

$$f_s = \frac{P}{2A} = \frac{P}{(2)(.7854) d^2} = \frac{5394}{(2)(.7854)(d^2)} = 19850.$$

$$d_{ref} = .415 \text{ IN.}$$

* ABOVE BENDING CALCULATION REQUIRES TOO LARGE OF A PIN THEREFORE A NEW CALCULATION IS SHOWN ON NEXT PAGE.

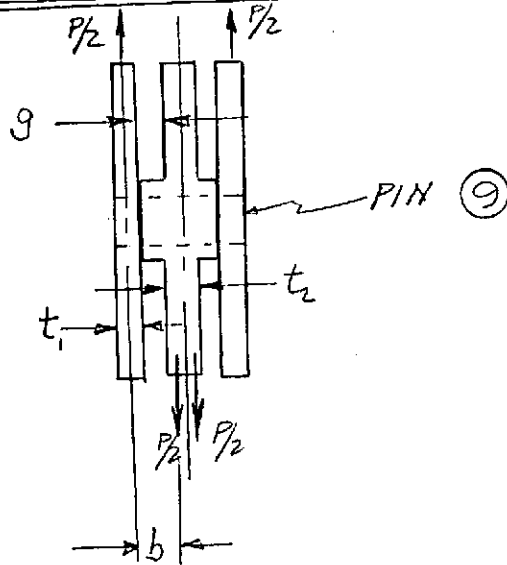
TEST FIXTURE

MDAC CENTER ATTACHMENT

MIDDLE FRAMES (2 of 3)

DRW. 28
SHEETS 3 of 4

DESIGN OF PIN (9) CONT'



LUG ANALYSIS APPROACH

$$b = .5t_1 + .25t_2 + g$$

$$= .5(.375) + .25(1.0) + 0.2$$

$$b = .6375$$

$$M = \frac{P}{2} b = \frac{5394}{2} (.6375)$$

$$M = 1718 \text{ IN-IN.}$$

S_{req} of PIN

$$S_{req} = \frac{M}{f_b} = \frac{1718}{27,720} = .062 \text{ IN}$$

$$S = .09816 d^3$$

$$d = \sqrt[3]{\frac{S}{.09816}} = \sqrt[3]{\frac{.062}{.09816}}$$

$$d = .858 \text{ IN.}$$

The pin is actually $d = .875 \text{ IN.}$

$$M.S. = \frac{.875}{.858} - 1 = +.02 \quad \underline{\underline{GOOD}}$$

Prepared By PJW Date 7-25-73
 Checked By ALS Date 7-26-73
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TEST FIXTURE

MDAC CENTER ATTACHMENT

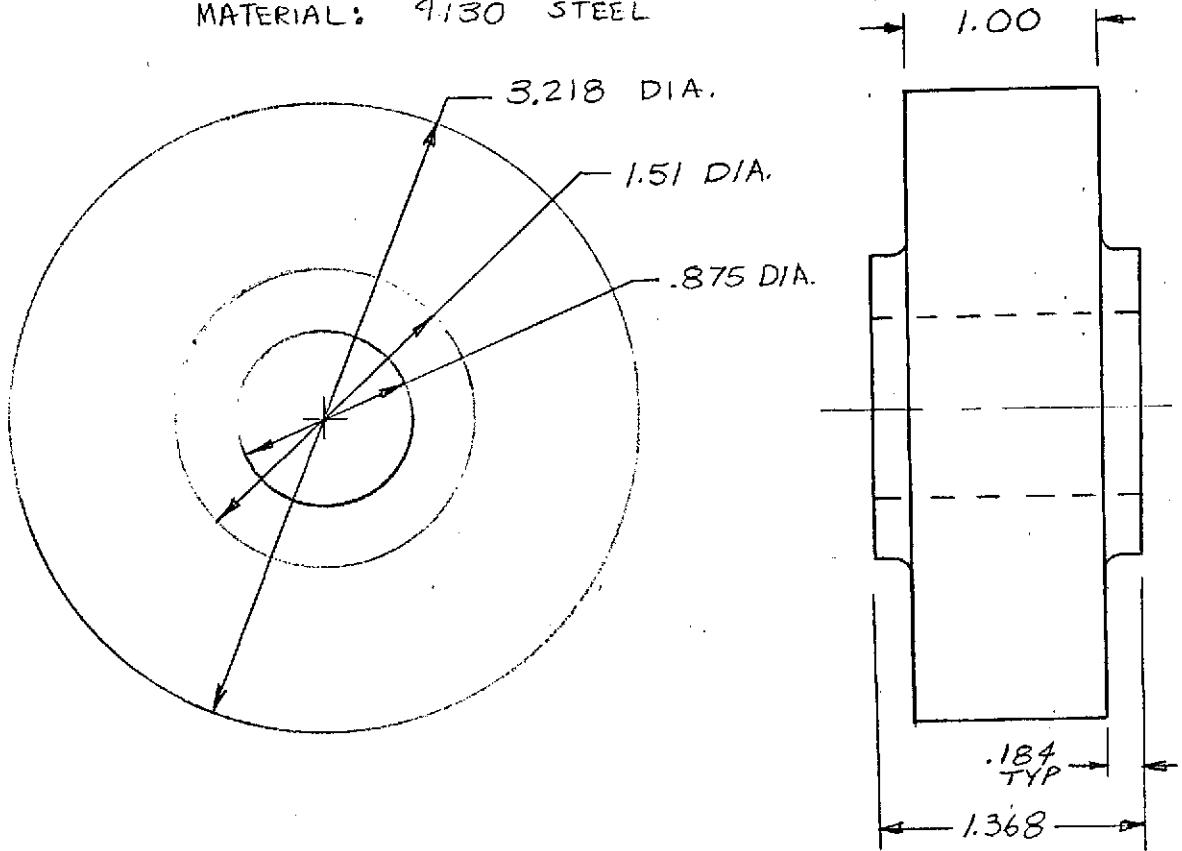
MIDDLE FRAMES (2 of 3)

DRW, 28
SHEETS 2 of 3

DESIGN OF WHEEL (5)

LOAD = 5394. lbs.

MATERIAL: 4130 STEEL



Contact Stress Analysis (Ref. "Manual of Steel Construction")
 Pp. 5-73

$$\text{Allowable Load} = 1.72 d = 1.72 (3.218) = 5.53 \text{ K/IN.}$$

WHEEL IS 1" WIDE

$$\therefore \text{LOAD CAPABILITY} = 5.53 \times 1 = 5.53 \text{ KIPS.}$$

$$M.S. = \frac{5.53}{5.394} - 1. = \underline{+0.026} \quad \underline{\text{GOOD}}$$

Prepared By PJW Date 7-25-73
Checked By ALS Date _____
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TEST FIXTURE

MDAC CENTER ATTACHMENT

MIDDLE FRAMES (2 & 3)

DRW. 28
SHEETS 2 & 3

DESIGN OF WHEEL (5) CONT'

PIN HOLE BEARING

$$f_{br} = \frac{P}{A_{br}} = \frac{5394}{1.368 \times .875} = 4500. \text{ lb/in}^2$$

$$F^{br} = 55.20 \text{ K/in}^2$$

$$M.S. = \frac{55.2}{4.5} - 1. = \underline{\underline{+11.3}} \quad \underline{\underline{GOOD}}$$

TEST FIXTURE

MDAC CENTER ATTACHMENT

MIDDLE FRAMES (2 of 3)

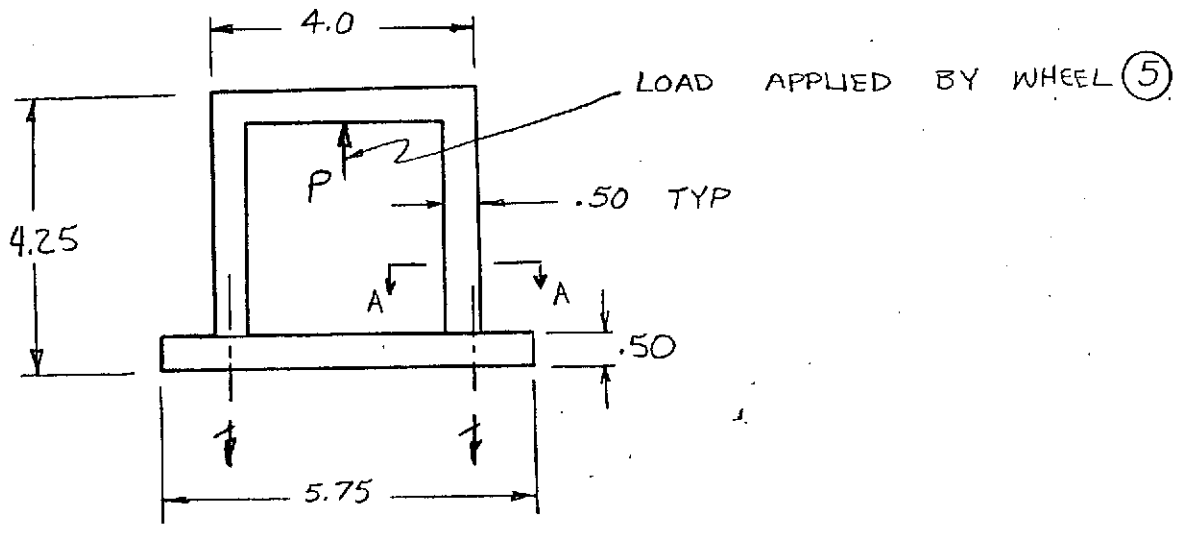
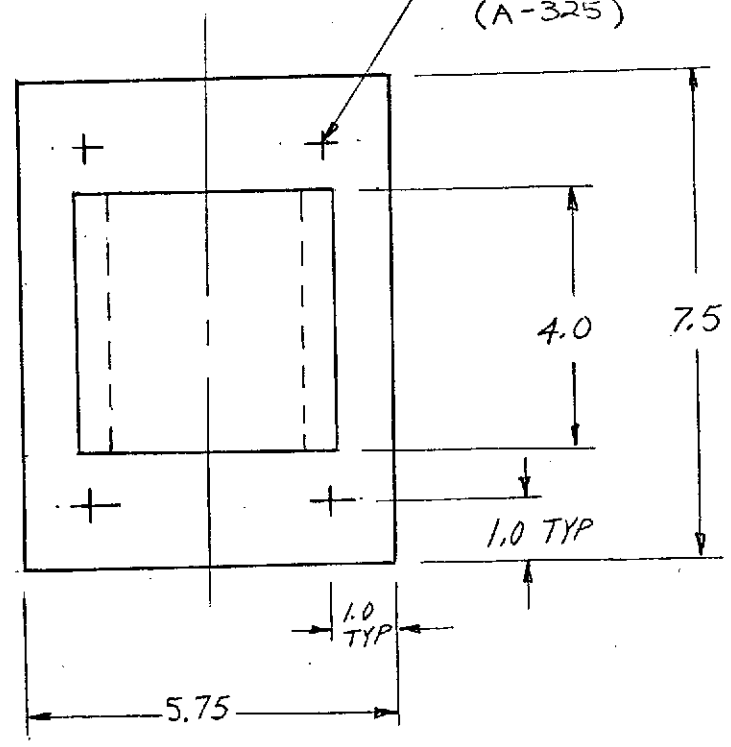
DRW. 28
SHEET 3

BRACKET (7)

LOAD = 5394. lbs.

MATERIAL: 4130 STEEL

.50 DIA. HEX HD. BOLT (4 PLACES)
(A-325)



TEST FIXTURE

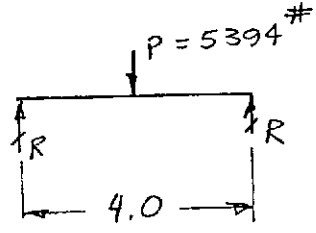
MDAC CENTER ATTACHMENT

DRW. 28
SHEET 3

MIDDLE FRAMES (2 & 3)

BRACKET (7) CONT'

Front Plate As Beam



$$M = \frac{PL}{4} = \frac{5394 \times 4}{4} = 5394 \text{ IN-lbs.}$$

$$f_b = \frac{M}{S}$$

$$S_{req} = \frac{M}{f_b} = \frac{5394.}{27720.} = 0.1946 \text{ IN.}$$

$$S = \frac{bt^2}{6}$$

$$t_{req} = \sqrt{\frac{6 S_{req}}{b}} = \sqrt{\frac{6 (.1946)}{4.0}}$$

$$t_{req} = .54$$

IF THE MATERIAL "MODULUS OF RUPTURE" IS CONSIDERED

$$F_{b4} = 72.0 \text{ KSI}$$

Ref.: "Astronautic Structures Manual", Sect. B-4, page 152
(corrected to Temp. = 600°F)

$$S_{req} = \frac{M}{F_{b4}} = \frac{5394.}{72000.} = .0758 \text{ IN.}$$

$$t_{req} = \sqrt{\frac{6 S_{req}}{b}} = \sqrt{\frac{6 (.0758)}{4.0}} = .337 \text{ IN.}$$

$$M.S. = \frac{.5}{.337} - 1. = +.48 \text{ GOOD}$$

TEST FIXTURE

MDAC CENTER ATTACHMENT

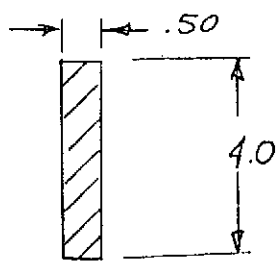
MIDDLE FRAMES (2 & 3)

DRW. 28
SHEET 3

BRACKET (7) CONT'

SIDE PLATE

LOAD = $P/2 = 2697$ lbs.



$f_t = \frac{P}{A} = \frac{2697}{4 \times .5} = 1348.5$ lb/in²

$F^t = 27720$ lb/in

SECTION A-A
(page 6)

M.S. = $\frac{27.72}{1.3485} - 1 = +19.5$ GOOD

.56 DIA. HEX. HD. BOLTS (A-325)

LOAD = $\frac{P}{4} = \frac{5394}{4} = 1348.5$ lbs. (TENSION)

$P^t = \frac{40}{\pi \left(\frac{.56}{4}\right)^2} = 204$ kIPS (TENSION)

($F_t = 40$ ksi for A-325 BC -
 Ref. "Steel Construction
 Manual" page 4-3)

M.S. = $\frac{204}{1.3485} - 1 = +150.4$ GOOD

TEST FIXTURE

MDAC CENTER ATTACHMENT

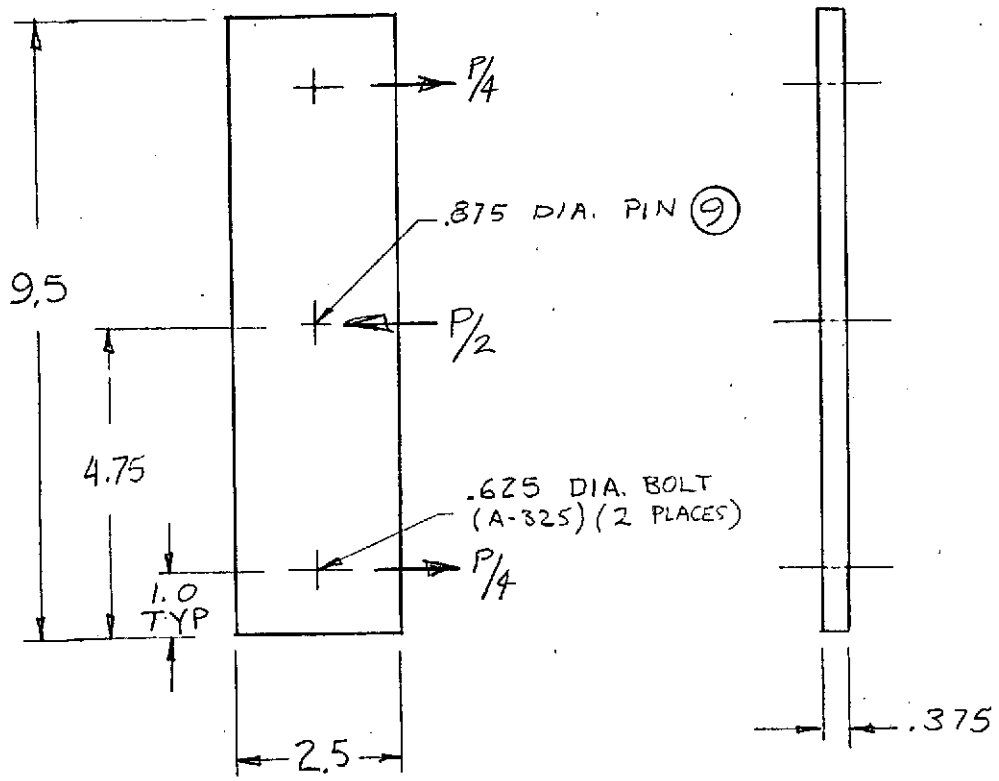
MIDDLE FRAMES (2 of 3)

DRW. 28
SHEET 3

PLATE ⑥

LOAD (P) = 5394. lbs

MATERIAL: 4130 STEEL



TEST FIXTURE

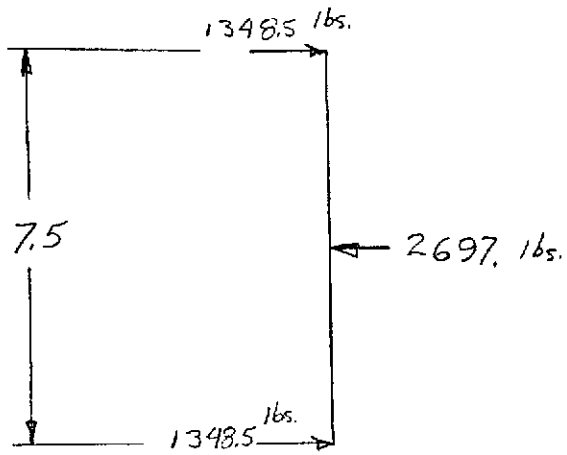
MDAC CENTER ATTACHMENT

MIDDLE FRAMES (2 of 3)

DRW. 28
SHEET 3

PLATE ⑥ CONT'

consider plate as a beam



$$M = \frac{PL}{4} = \frac{2697(7.5)}{4}$$

$$M = 5050 \text{ in-lbs.}$$

$$f_b = \frac{M}{S}$$

$$S_{req} = \frac{M}{f_b} = \frac{5050}{27720}$$

$$S_{req} = .182 \text{ IN}$$

$$S = \frac{tb^2}{6}$$

$$t_{req} = \frac{6S_{req}}{b^2} = \frac{6(.182)}{(2.5)^2}$$

$$t_{req} = .175 \text{ IN}$$

but $t = .375 \text{ IN}$

$$M.S. = \frac{.375}{.175} - 1 = \underline{\underline{+1.14}} \quad \underline{\underline{GOOD}}$$

stress level in ⑥

$$f_b = \frac{5050}{.391} = 12900 \text{ PSI}$$

Prepared By PJW Date 7-25-73
Checked By ALS Date 7-26-73
Revised By _____ Date _____

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TEST FIXTURE

MDAC CENTER ATTACHMENT

MIDDLE FRAMES (2 & 3)

DRW. 28
SHEET 3

PLATE (6) CONT'

BOLT HOLE CHECK

@ .625 DIA. BOLT:

$$\text{LOAD} = 1348.5 \text{ lbs.}$$

$$f_{br} = \frac{P}{A_{br}} = \frac{1348.5}{.375 \times .625} = 5750. \text{ PSI}$$

$$F_{br} = 55.20 \text{ KSI} \quad \text{Allow. Bearing}$$

$$\text{M.S.} = \frac{55.2}{5.75} - 1. = \underline{\underline{+8.6}} \quad \underline{\underline{\text{GOOD}}}$$

@ .875 DIA. PIN

$$\text{LOAD} = 2697. \text{ lbs}$$

$$f_{br} = \frac{P}{A_{br}} = \frac{2697.}{.875 \times .375} = 8225. \text{ PSI}$$

$$F_{br} = 55.20 \text{ KSI} \quad \text{Allow. Bearing}$$

$$\text{M.S.} = \frac{55.2}{8.225} - 1. = \underline{\underline{+5.7}} \quad \underline{\underline{\text{GOOD}}}$$

Prepared By PJW
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Revised By _____

Date 7-25-73
Date 7-26-73
Date _____



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TEST FIXTURE

MDAC CENTER ATTACHMENT

MIDDLE FRAMES (243)

PLATE (6) CONT'

check of .625 DIA. BOLT

$$f_s = \frac{P}{A_s} = \frac{5394/2}{\frac{2(.625)^2}{4}} = 13800. \text{ PSI}$$

$$F_s = 15000. \text{ PSI}$$

$$M.S. = \frac{15.0}{13.80} - 1. = \underline{\underline{+.088}} \quad \underline{\underline{GOOD}}$$

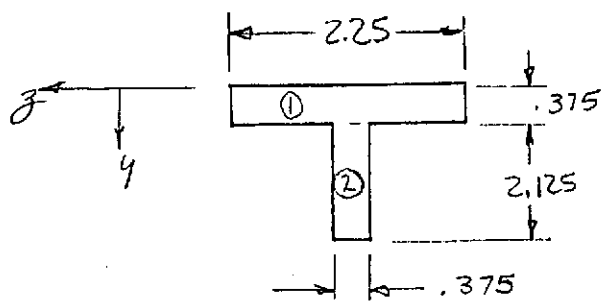
TEST FIXTURE

MDAC CENTER ATTACHMENT

MIDDLE FRAMES (2 & 3)

DRW. 28
SHEET 4

BRACKET (8) CONT'



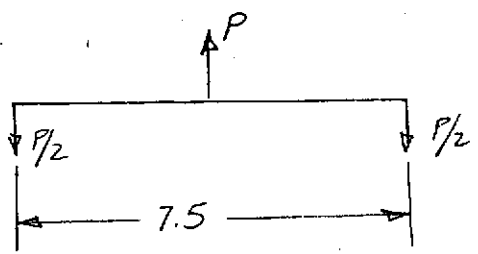
ELE	A	y	Ay	Ay ²	I ₃₀
1	.844	.1875	.158	.0297	.01
2	.798	1.4375	1.145	1.644	.3
TOTAL	1.642	-	1.303	1.6737	.31

SECTION B-B
(page 13)

$$\bar{y} = \frac{1.303}{1.642} = .793 \text{ IN}$$

$$I_{33} = 1.6737 + .31 - 1.642(.793)^2$$

$$I_{33} = 0.9517 \text{ IN}^4$$



$$M = \frac{PL}{4} = \frac{5394(7.5)}{4}$$

$$M = 10130. \text{ IN-lbs.}$$

$$f_b = \frac{Mc}{I} = \frac{10130(1.707)}{.9517} = 18130. \text{ PSI}$$

$$F_b = 27.72 \text{ KSI}$$

$$\text{M.S.} = \frac{27.72}{18.13} - 1. = \underline{\underline{+.51}} \quad \underline{\underline{GOOD}}$$

TEST FIXTURE

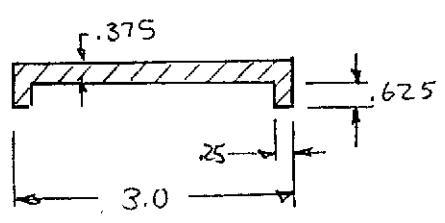
MDAC CENTER ATTACHMENT

MIDDLE FRAMES (2 & 3)

DRW. 28
SHEET 4

BRACKET (8) CONT'

check plate (section C-C, page 13)



$$A = 3 \times 0.375 + 2 \times 0.625 \times 0.25$$

$$A = 1.437 \text{ in}^2$$

$$f_t = \frac{P}{A} = \frac{5394}{1.437} = 3750 \text{ PSI}$$

$$F_t = 27.72 \text{ KSI}$$

$$M.S. = \frac{27.72}{3.75} - 1 = \underline{\underline{+6.4}} \quad \underline{\underline{GOOD}}$$

TEST FIXTURE

MDAC CENTER ATTACHMENT
 MIDDLE FRAMES (2 & 3)
BRACKET (8) CONT'

DRW. 28
 SHEET 4

WELDS

@ WELD 1 (Ref. page 13)

$$P_t = F_{tu} \times (Lt)$$

$$F'_{tu} = \frac{F_{tu}}{S.F.} \times (\text{Temp. Factor})$$

$$F_{tu} = 37.5 \text{ KSI}$$

$$L = 9.5 \times 2 = 19.0 \text{ IN}$$

$$t = .375 \text{ IN}$$

Ref. "Analysis & Design of Flight Vehicle Structures" page D2.4, Equation D2.1 & Table D2.2 (correct values for 600°F TEMP.)
 $F_{tu, RT} = 105.$

$$P_t = 37.5(19)(.375) = 267.0 \text{ KIPS}$$

$$M.S. = \frac{267.0}{5.394} - 1. = + \underline{48.6} \quad \underline{\text{GOOD}}$$

@ WELD 2 (Ref. page 13)

$$P_t = F_{tu} \times (Lt)$$

$$= 37.5(7.5 \times .375)$$

$$P_t = 105.5 \text{ KIPS}$$

$$M.S. = \frac{105.5}{5.394} - 1. = + \underline{18.6} \quad \underline{\text{GOOD}}$$

Prepared By PJW Date 7-26-73
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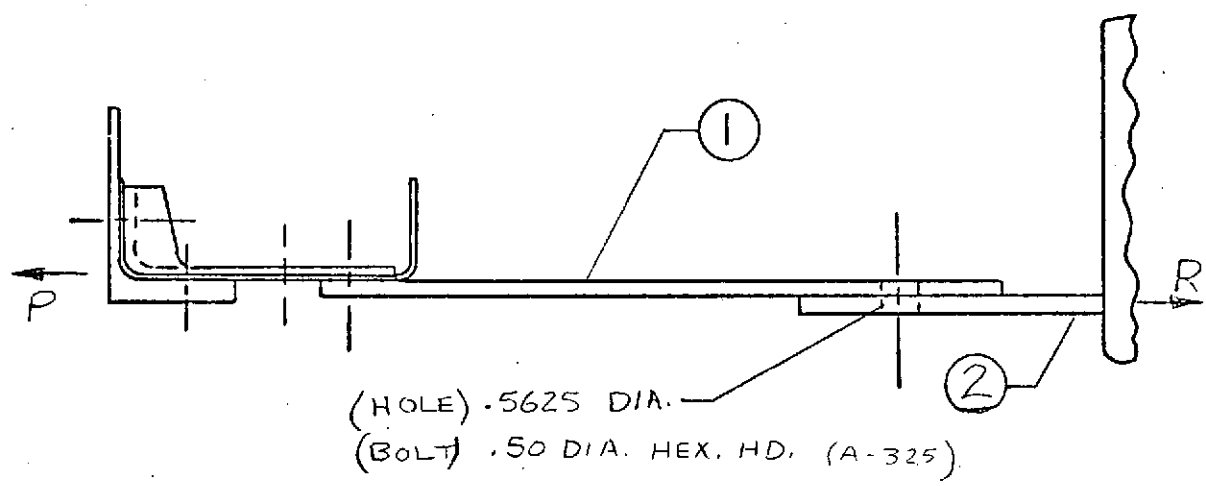
TEST FIXTURE

MDAC CENTER ATTACHMENT
BOTTOM FRAME (1)

DRW. 28
SHEET 4

LOAD = 5394 lbs.

MATERIAL: 4130 STEEL



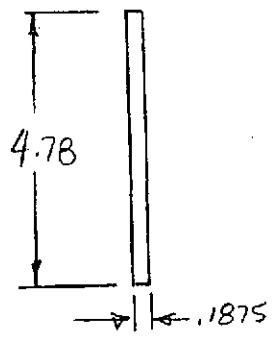
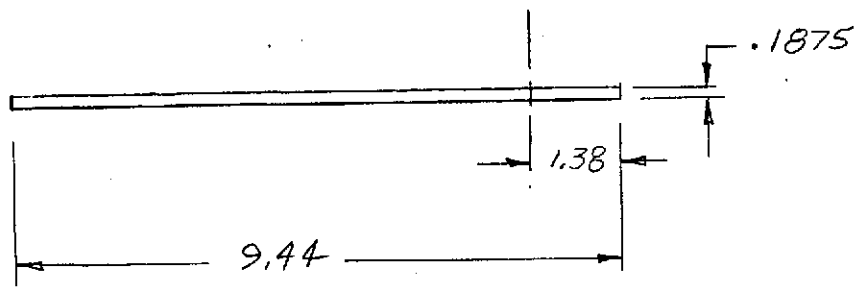
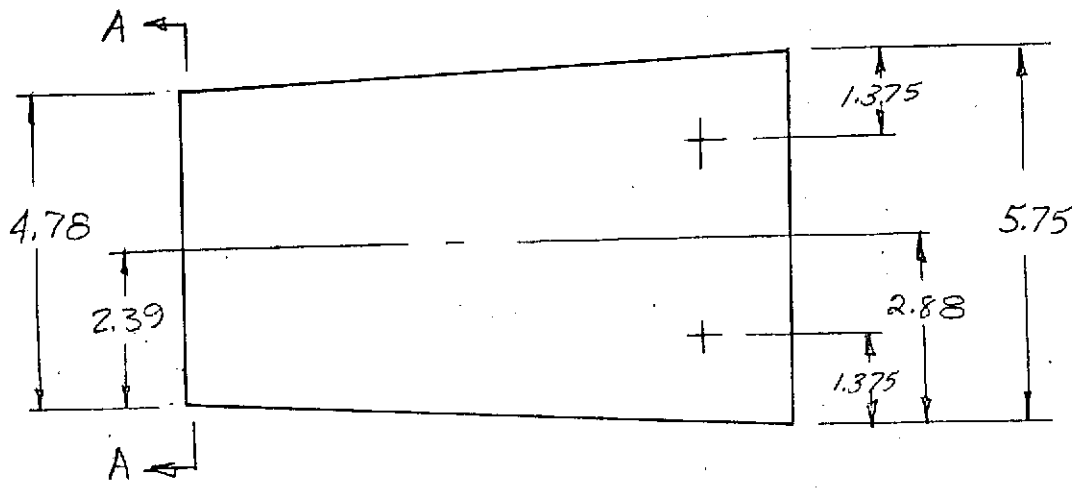
TEST FIXTURE

MDAC CENTER ATTACHMENT

BOTTOM FRAME (I)

DRW. 28
SHEET 4

PLATE ①



$$A = 4.78 \times 0.1875 = .896 \text{ IN}^2$$

$$f_t = \frac{P}{A} = \frac{5394}{.896} = 6000. \text{ PSI}$$

$$\text{M.S.} = \frac{27.72}{6.0} - 1. = \underline{\underline{\pm 3.62}} \quad \underline{\underline{\text{GOOD}}}$$

Prepared By PJW Date 7-26-73
Checked By ALS Date 7/31/73
Revised By _____ Date _____

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TEST FIXTURE

MDAC CENTER ATTACHMENT

DRW. 28
SHEET 4

BOTTOM FRAME (1)

PLATE ① CONT'

@ .5625 Bolt Hole - Bearing Check

$$f_{br} = \frac{P}{A_{br}} = \frac{5394.12}{.5625 \times .1875} = 25550. \text{ PSI}$$

$$F_{br} = 55.2 \text{ KSI}$$

$$M.S. = \frac{55.2}{25.55} - 1. = \underline{+1.16} \quad \underline{GOOD} \quad \text{Bearing} \quad \leftarrow$$

$$f_s = \frac{P}{A_s} = \frac{2697}{1.38 \times .25 \times 2} = 3910. \text{ PSI}$$

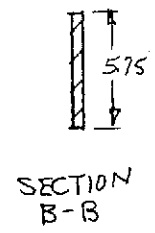
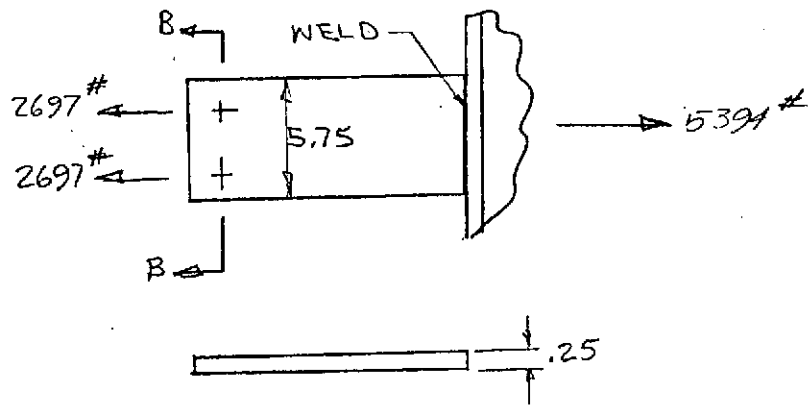
$$M.S. = \frac{19.88}{3.91} - 1. = \underline{+4.08} \quad \underline{GOOD} \quad \text{shear-out} \quad \leftarrow$$

TEST FIXTURE

MDAC CENTER ATTACHMENT
 BOTTOM FRAME (1)

DRW. 28
 SHEET 4

PLATE (2)



$A = 5.75 \times .25 = 1.4375$

$f_t = \frac{P}{A_t} = \frac{5394}{1.4375} = 3760 \text{ PSI}$

M.S. = $\frac{27.72}{3.76} - 1 = \underline{+6.37}$ GOOD Tension

$f_{br} = \frac{P}{A_{br}} = \frac{2697}{.5625 \times .25} = 19150 \text{ PSI}$

M.S. = $\frac{55.2}{19.15} - 1 = \underline{+1.88}$ GOOD Bearing

$f_s = \frac{P}{A_s} = \frac{2697}{2(.25 \times 1.38)} = 3910 \text{ PSI}$

M.S. = $\frac{19.88}{3.91} - 1 = \underline{+4.08}$ GOOD Shear-Out

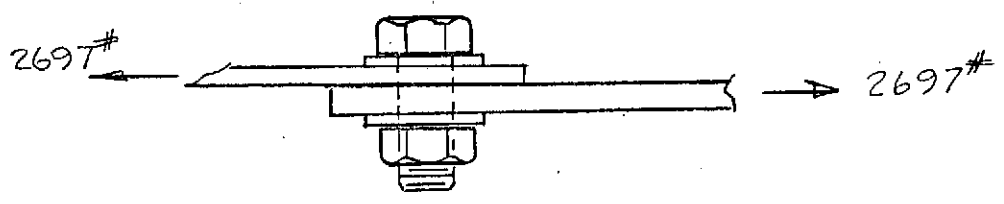
TEST FIXTURE

MDAC CENTER ATTACHMENT
BOTTOM FRAME (1)

DRW, 28
SHEET 4

BOLTS BETWEEN PLATES ① & ②

BOLT : .50 DIA HEX. HD. (A-325)



$$f_s = \frac{P}{A} = \frac{2697}{\frac{\pi(.5)^2}{4}} = 13725. \text{ PSI}$$

$$F_s = 15. \text{ KSI}$$

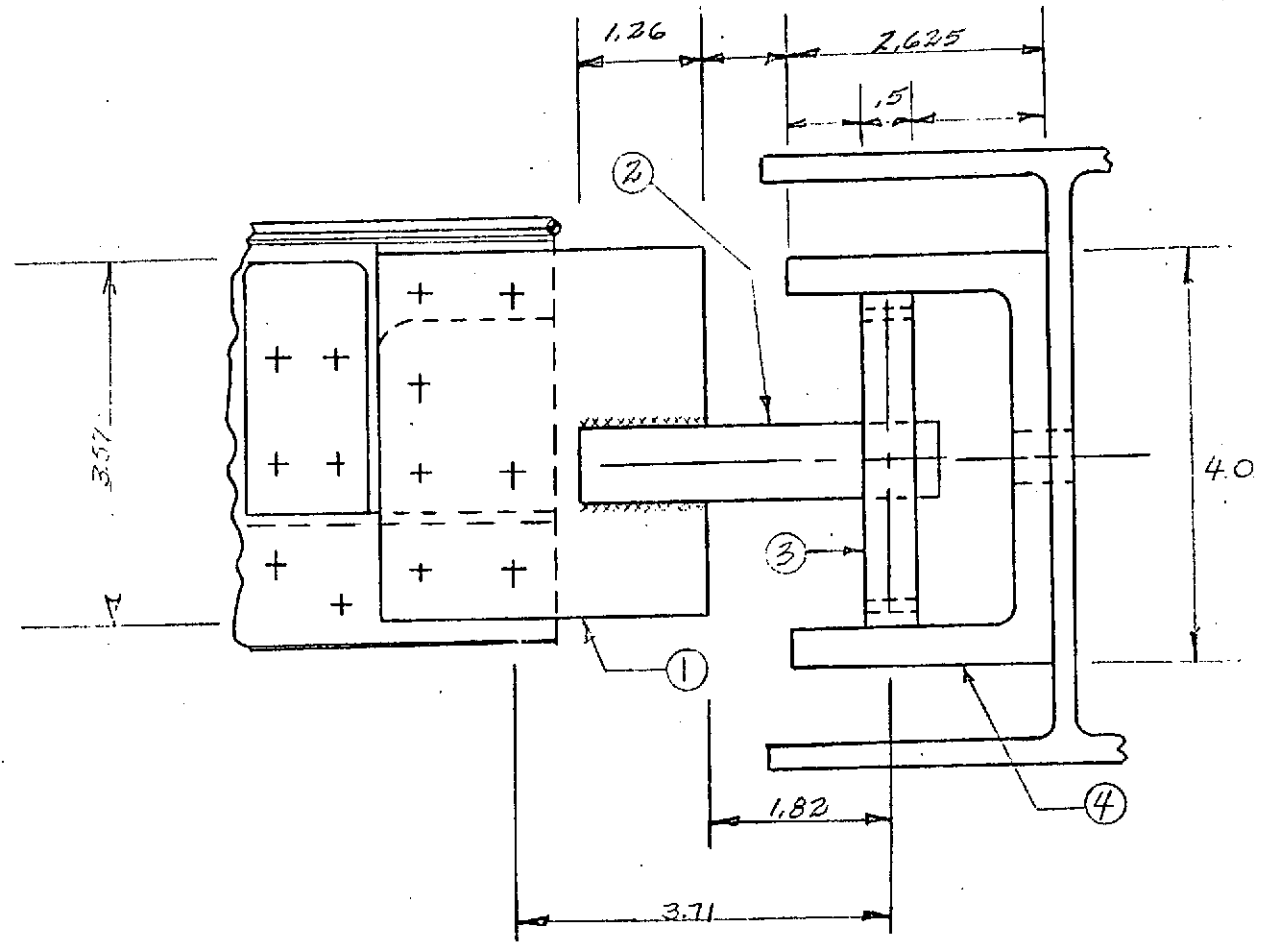
$$M.S. = \frac{15.0}{13.725} - 1. = \underline{+.09} \quad \underline{GOOD} \quad \text{BOLT SHEAR}$$

TEST FIXTURE

MDAC PANEL SIDE ATTACHMENT

TOP FRAME (1)

DRW 28
Sheet 5



TEST FIXTURE

MDPC PANEL SIDE ATTACHMENT

TOP FRAME

DEW 38
 Sheet 7
 (4135 steel)

DESIGN OF PLATE ① (t = .375)

$F_{t4} = 80.46 \text{ ksi}$ for AISI 4130 @ $T = 600^\circ F$

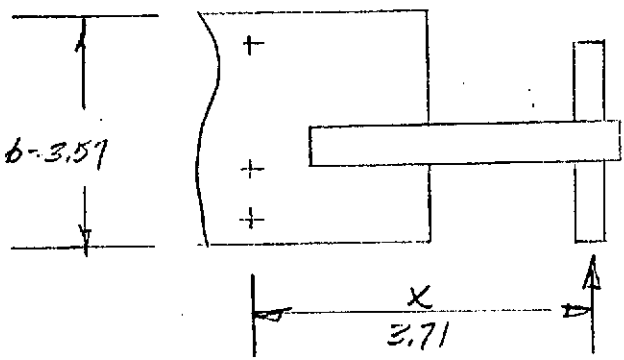
$F_{t4} = 55.44 \text{ ksi}$

Allowable tensile uli = $\frac{80.46}{2.5} = 32.18 \text{ ksi}$

Allowable tensile yield = $\frac{55.44}{2.0} = 27.720 \text{ ksi} (f_b)$

Moment produce by lateral load at wheel.

Use maximum side load predicted by MDPC: $P = 510 \text{ lb}$



$M = P \times x$

$M = 510 \times 3.71$

$M = 1890 \text{ in-kip}$

$f_b = \frac{M}{S}$

$S = \frac{M}{f_b} = \frac{1890}{27.72}$

$S = 0.0695$

$S = \frac{b t^2}{6}; t^2 = \frac{6S}{b}$

$t^2 = \frac{6(0.0695)}{3.57}$

$t^2 = 0.1168$

min $t = 0.342 \rightarrow MS = \frac{.375}{.342} - 1 = .098$

Prepared By BRETTIX
 Checked By ALS
 Revised By _____

Date 7/25/12
 Date 7/25/12
 Date _____

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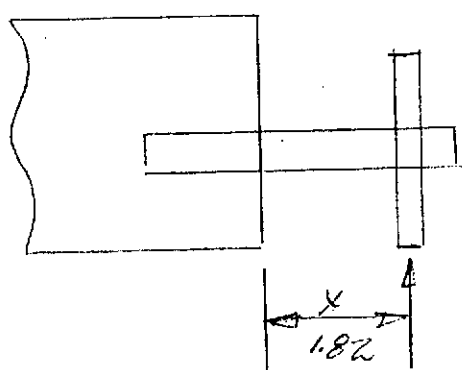
TEST FIXTURE

MDAC PANEL SIDE ATTACHMENT

TOP FRAMING

DESIGN OF AXLE (2) (d = 0.75)

DRW 28
 Sheet 7



$$M = P \times x$$

$$M = .51 (1.82)$$

$$M = 0.928 \text{ in-kip}$$

$$S = \frac{\pi d^3}{32}$$

$$S = 0.098175 d^3$$

$$d^3 = \frac{S}{0.098175}$$

$$d^3 = \frac{0.0335}{0.098175}$$

$$d^3 = 0.341$$

$$d = 0.700$$

$$\text{Req } S = \frac{M}{f_b}$$

$$S = \frac{0.928}{27.72}$$

$$S = 0.0335$$

$$MS = \frac{0.75}{0.70} - 1 = .07$$

Prepared By LT/GRN
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Revised By _____

Date 7/25/73
Date 7/25/73
Date _____

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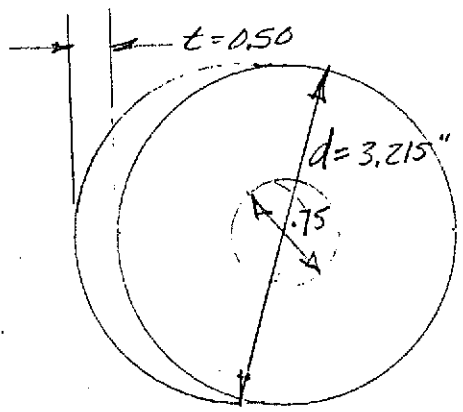
TEST FIXTURE

MDAC PANEL SIDE ATTACHMENT TOP FRAME

DESIGN OF Wheel (3)

DEW 23
Sheet 7

(Material: 4130 Steel)



Actual Load per inch

$$N = \frac{0.51}{0.50} = \underline{1.02 \text{ kip/in}}$$

Allowable Load

(Ref. AISC Manual of Steel Construction) →

$$N_b = 1.72d \\ = 1.72 (3.215)$$

$$N_b = \underline{5.53 \text{ kip/in}}$$

$$MS = \frac{5.53}{1.02} - 1 = \underline{4.43} \rightarrow$$

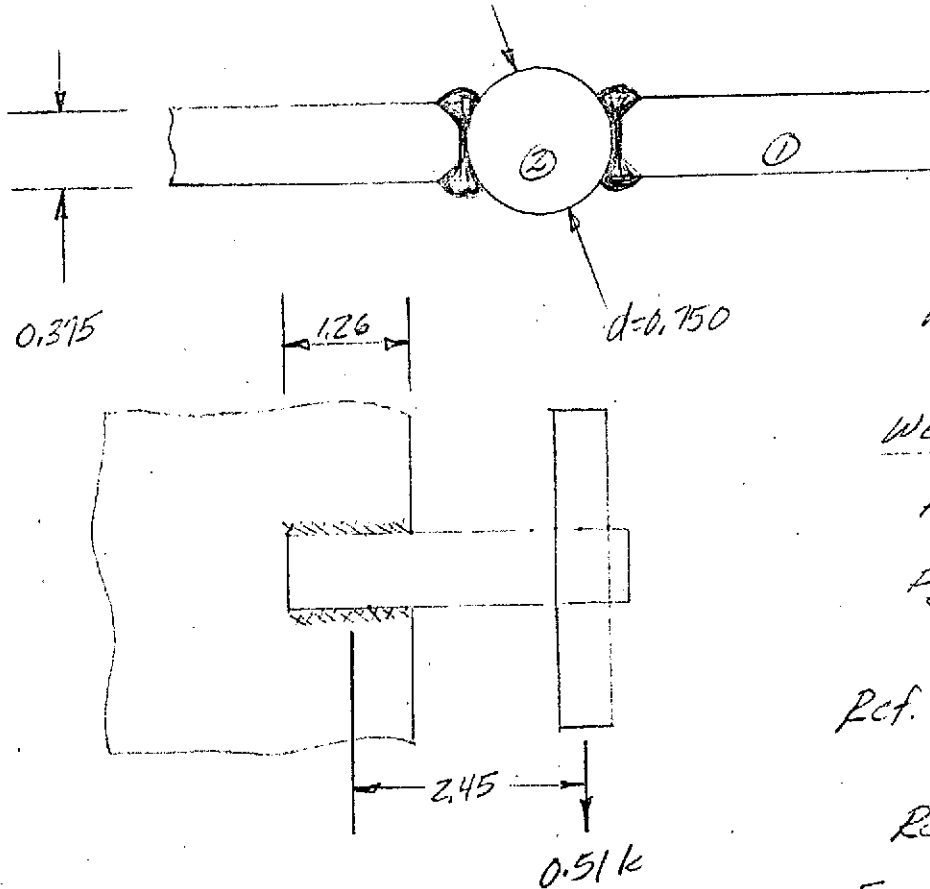
TEST FIXTURE

MDAC PANEL SIDE ATTACHMENT

TOP FRAME

WELDMENT OF PLATE ① TO AXLE ②

DCW 33
 Sheet 7



Material: 4130

WELD ALLOWABLES:

$F_{su} = 43 \text{ ksi}$

$F_{tu} = 72 \text{ ksi}$

Ref. Brinley Pg D2.4

Reduction 75% T & C

$F_{su} = .92(43) = 39.6 \text{ ksi}$

$F_{tu} = .894(72) = 64.3 \text{ ksi}$

BENDING:

$S = 2 \frac{b l^2}{6}$

$S = 2 \frac{(0.375)(1.26)^2}{6}$

$S = 0.1991$

$M = 0.51(2.45)$

$M = 1.25 \text{ in-kips}$

TEST FIXTURE

WELDMENT OF PLATE ① TO AXLE ② (Cont.)

Bending Stress

$$f_b = \frac{M}{S} = \frac{1.25}{0.1991} = \underline{6.27 \text{ ksi}}$$

$$M.S. = \frac{64.3}{6.27} - 1 = \text{high}$$

Shear

$$M = 1.25 \text{ m-k}$$

$$V = \frac{M}{d} = \frac{1.25}{0.75} = 1.668 \text{ kip}$$

$$A_s = 0.375 \times 1.26 = 0.472 \text{ m}^2$$

$$\tau = \frac{V}{A} = \frac{1.668}{0.472} = \underline{3.56 \text{ ksi}}$$

$$M.S. - \text{high}$$

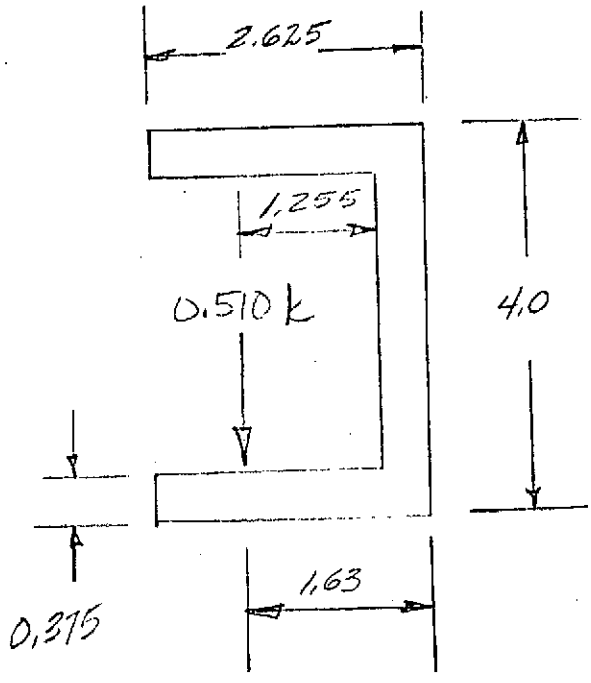
TEST FIXTURE

MDAC PANEL SIDE ATTACHMENT
 TOP FRAME

Draw 28
 Sheet 1

BRACKET (4)

MATERIAL 4130



Moment:

$$M = P \times x$$

$$M = 0.510 (1.63)$$

$$M = 0.831 \text{ in-kip}$$

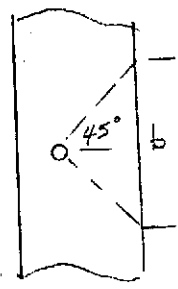
Section Modulus:

$$S = \frac{b t^2}{6}$$

$$t^2 = \frac{6 S}{b}$$

$$t^2 = \frac{6 (0.03)}{1.775} = 0.1013$$

$$t = 0.318$$



Assume effective width 45° from point of load application

$$b = 2 (1.707) 1.255$$

$$b = 1.775$$

Req $S = \frac{M}{f}$

$$S = \frac{0.831}{27.72}$$

$$S = 0.030$$

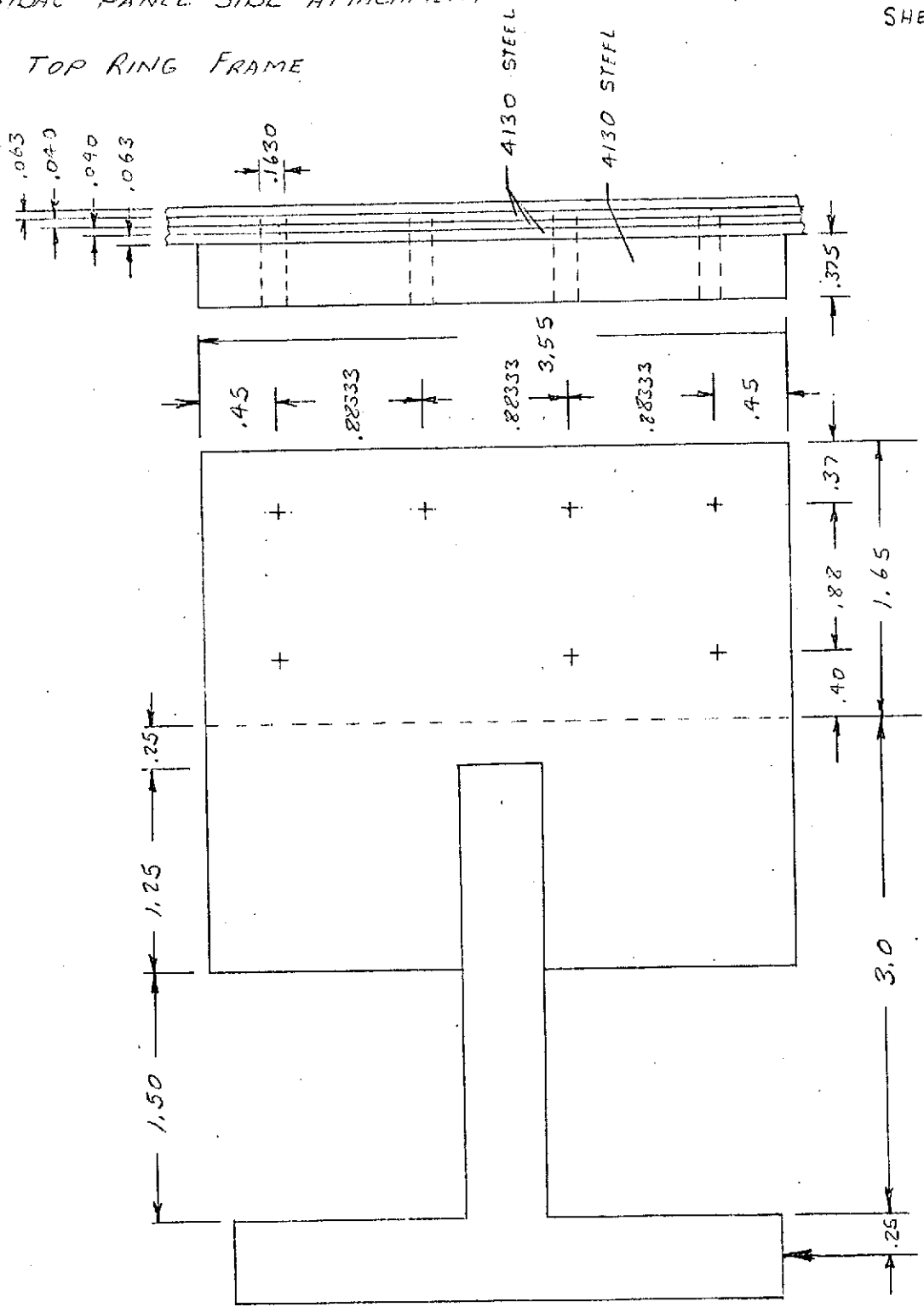
$$MS = \frac{.375}{.318} - 1 = 0.18$$

TEST FIXTURE

MDAC PANEL SIDE ATTACHMENT

DWG 28
 SHEET 7

TOP RING FRAME



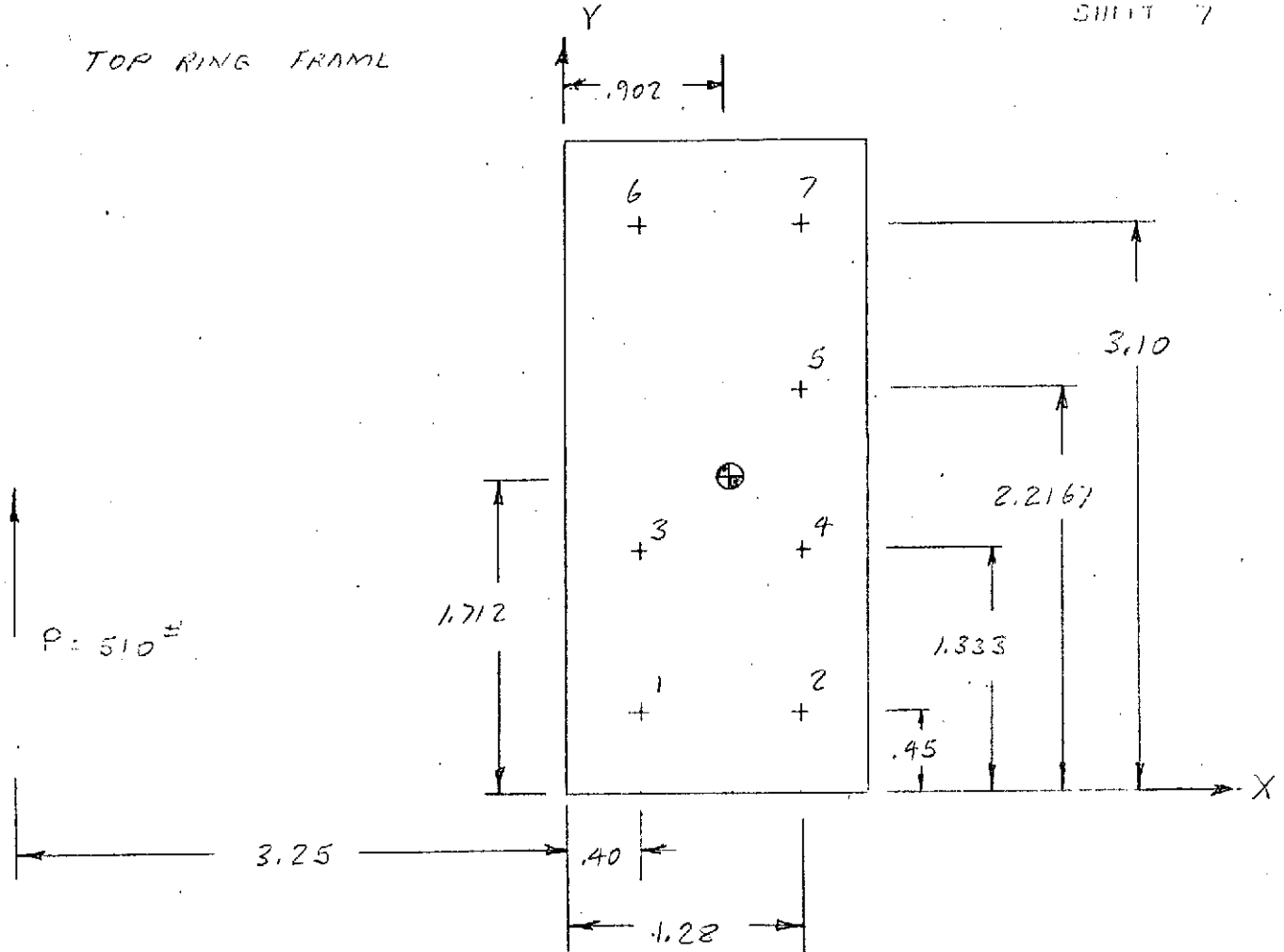
P = 510 lbs

TEST FIXTURE

MIDAC PANEL SIDE ATTACHMENT

DWG 28
 SHEET 7

TOP RING FRAME



BOLT	AREA	X	Y	AX	AY
1	.0209	.4	.45	.0084	.0094
2	.0209	1.28	.45	.0267	.0094
3	.0209	.4	1.3333	.0084	.0279
4	.0209	1.28	1.3333	.0267	.0279
5	.0209	1.28	2.2167	.0267	.0463
6	.0209	.4	3.10	.0084	.0648
7	.0209	1.28	3.10	.0267	.0648
				.132	.2505

$$\bar{Y} = \frac{\sum AY}{\sum A} = \frac{.2505}{.1463} = 1.712 \text{ IN}$$

$$\bar{X} = \frac{\sum AX}{\sum A} = \frac{.132}{.1463} = .902$$

TEST FIXTURE

MIDAC PANEL SIDE ATTACHMENT

DWG 28
SHEET 7

TOP RING FRAME

$$R = \sqrt{\left(\frac{P}{N_n}\right)^2 + \left(\frac{MC}{\sum X^2 + \sum Y^2}\right)^2 + 2\left(\frac{P}{N_n}\right)\left(\frac{MC}{\sum X^2 + \sum Y^2}\right)\cos\theta}$$

$$\left(\frac{P}{N_n}\right)^2 = \left(\frac{510}{7}\right)^2 = (72.857)^2 = 5302.16 \text{ LB}^2$$

$$M = PC = 510(3.25 + .902) = 2117.52 \text{ IN-LB}$$

$$C = \sqrt{(1.501)^2 + (1.388)^2} = \sqrt{.2252 + 1.9265} = 1.476$$

$$\frac{MC}{\sum X^2 + \sum Y^2} = \frac{(2117.52)(1.476)}{3(1.501)^2 + 4(1.388)^2 + 2(1.262)^2 + 2(.379)^2 + (.5017)^2 + 2(1.388)^2}$$

$$\frac{MC}{\sum X^2 + \sum Y^2} = \frac{3125.46}{.756 + .572 + 3.185 + .287 + .2597 + 3.253}$$

$$\frac{MC}{\sum X^2 + \sum Y^2} = \frac{3125.46}{8.902} = 350.86$$

$$\left(\frac{MC}{\sum X^2 + \sum Y^2}\right)^2 = (350.86)^2 = 123102.74$$

$$\tan\theta = \frac{1.388}{.378} = 3.672 \quad \theta = 74^\circ 46'$$

$$\cos\theta = .26275$$

$$R = \sqrt{5302.16 + 123102.74 + 2(72.857)(350.86)(.26275)}$$

$$R = \sqrt{5302.16 + 123102.74 + 13433.15} = \sqrt{141844.05}$$

$$R = 376.6 \text{ LB}$$

$$T = R/A = 376.6 / .0209 = \underline{18019} \text{ PSI}$$

REF: LOTHERS, JOHN E., DESIGN IN STRUCTURAL STEEL, PAGE 151

Prepared By JFM Date 7-3-73
Checked By ALS Date 7-31-73
Revised By _____ Date _____

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BROWN ENGINEERING

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TEST FIXTURE

MDAC PANEL SIDE ATTACHMENT

DWG. 28
SHEET 7

TOP RING FRAME

BOLTS: 3M248C02

BOLT SHEAR MINIMUM: 95000 PSI

$$M.S. = \frac{95000}{18019(2)} - 1 = 1.61$$

BEARING OF BOLT ON .063 & .040 THICKNESS A130 STEEL

$$A = (.163)(.206) = .0336 \text{ IN}^2$$

$$R = 376.6 \text{ LB}$$

$$\sigma = \frac{R}{A} = \frac{376.6}{.0336} = 11208 \text{ PSI}$$

$$M.S. = \frac{108000}{11208(2)} - 1 = 3.8$$

BEARING OF BOLT ON 3/8 PLATE A130 STEEL

$$A = .163(.375) = .061$$

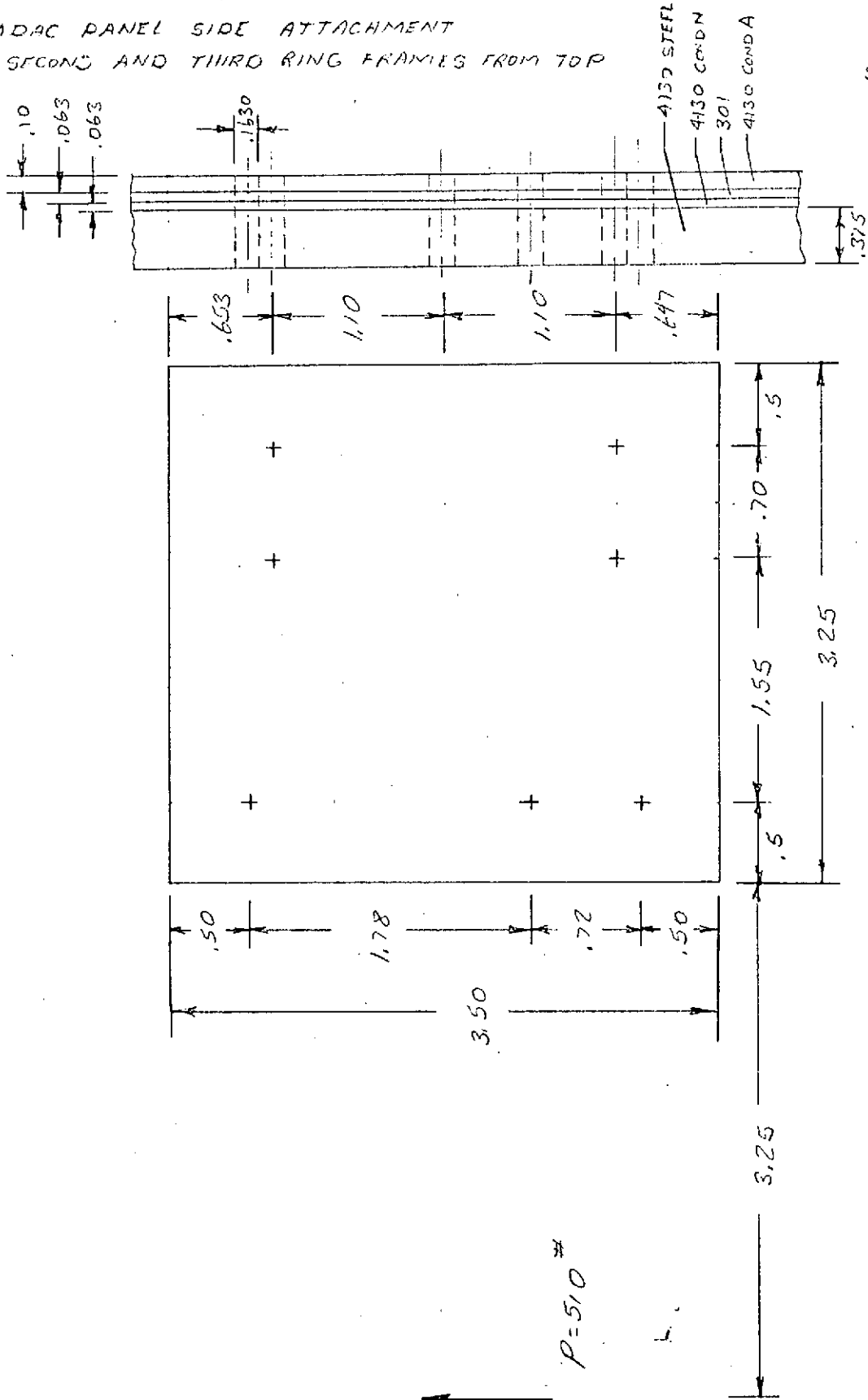
$$\sigma = \frac{376.6}{.061} = 6174 \text{ PSI}$$

$$M.S. = \frac{108000}{6174(2)} - 1 = 7.75$$

TEST FIXTURE

MDAC PANEL SIDE ATTACHMENT
 SECOND AND THIRD RING FRAMES FROM TOP

DWG 28
 SHEET 7

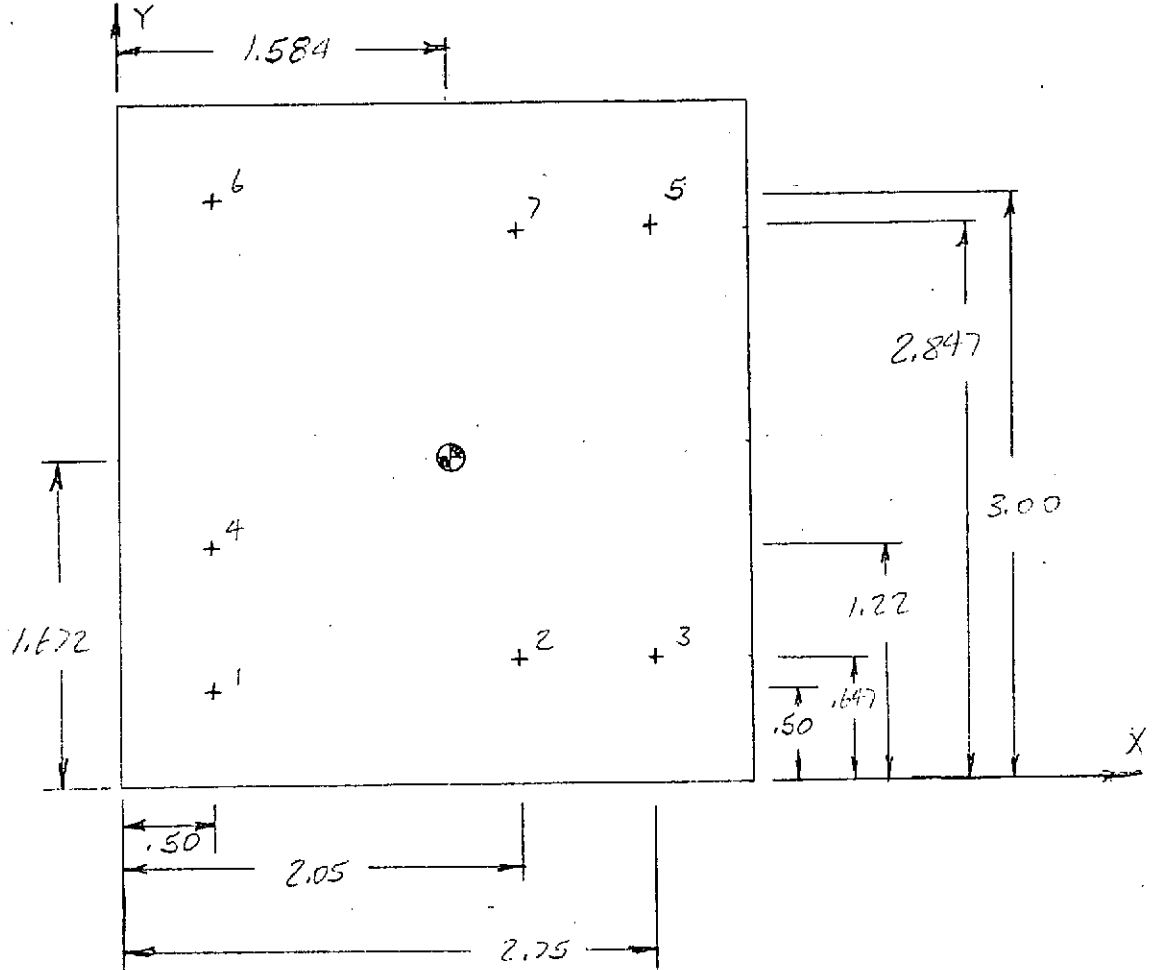


P=510 #

TEST FIXTURE

MDAC PANEL SIDE ATTACHMENT
 SECOND AND THIRD RING FRAMES FROM TOP

DWG 28
 SHEET 7



BOLT	AREA	X	Y	AX	AY
1	.0209	.50	.50	.0104	.0104
2	.0209	2.05	.647	.0428	.0135
3	.0209	2.75	.647	.0575	.0135
4	.0209	.50	1.22	.0104	.0255
5	.0209	2.75	2.847	.0575	.0595
6	.0209	.50	3.00	.0104	.0627
7	.0209	2.05	2.847	.0428	.0595
	<u>.1463</u>			<u>.2318</u>	<u>.2446</u>

$$\bar{X} = \frac{\sum AX}{\sum A} = \frac{.2318}{.1463} = 1.584$$

$$\bar{Y} = \frac{\sum AY}{\sum A} = \frac{.2446}{.1463} = 1.672$$

TEST FIXTURE

MDAC PANEL SIDE ATTACHMENT

DWG 28
 SHEET 7

SECOND AND THIRD RING FRAMES FROM TOP

$$R = \sqrt{\left(\frac{P}{Nh}\right)^2 + \left(\frac{Mc}{\Sigma X^2 + \Sigma Y^2}\right)^2 + 2\left(\frac{P}{Nh}\right)\left(\frac{Mc}{\Sigma X^2 + \Sigma Y^2}\right) \cos \theta}$$

$$\left(\frac{P}{Nh}\right)^2 = \left(\frac{510}{7}\right)^2 = (72.9)^2 = 5320.$$

$$M = Pe = 510(3.25 + 1.584) = 2463.$$

$$c = \sqrt{(1.084)^2 + (1.328)^2} = \sqrt{1.175 + 1.76} = \sqrt{2.935} = 1.713$$

$$\Sigma X^2 + \Sigma Y^2 = 3(1.084)^2 + 2(.466)^2 + 2(1.166)^2 + (1.172)^2 + 2(1.025)^2 + (.452)^2 + 2(1.175)^2 + (1.322)^2$$

$$\Sigma X^2 + \Sigma Y^2 = 3.525 + .454 + 2.719 + 1.374 + 2.101 + .204 + 2.76 + 1.764 = 14.181$$

$$\left(\frac{Mc}{\Sigma X^2 + \Sigma Y^2}\right)^2 = \left(\frac{(2463)(1.713)}{14.181}\right)^2 = (297.52)^2 = 88518.15$$

$$\tan \theta = \frac{1.328}{1.084} = 1.2251$$

$$\cos \theta = .63225$$

$$R = \sqrt{5320 + 88518.15 + 2(72.9)(297.52)(.63225)}$$

$$R = \sqrt{121264} = 348.$$

$$T = \frac{R}{A} = \frac{348}{.0209} = \underline{\underline{16650}} \text{ PSI}$$

Prepared By JEM Date 7-27-73
Checked By ALS Date 7-31-73
Revised By _____ Date _____

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TEST FIXTURE

MDAC PANEL SIDE ATTACHMENT

DWG 22
SHEET 7

SECOND AND THIRD RING FRAMES FROM TOP

BOLTS: 3M248C08
BOLT SHEAR MINIMUM: 95000 PSI

$$M.S. = \frac{95000}{16650(2)} - 1 = 1.85$$

BEARING OF BOLT ON 4130 AND 301 STEEL (.110 & .063 PLATES)

$$A = .163(.236) = .0368$$

$$R = 334.6 \text{ LB}$$

$$\sigma = \frac{R}{A} = \frac{334.6}{.0368} = 9092.4 \text{ PSI}$$

$$M.S. = \frac{108}{9092.4(2)} = 4.95$$

BEARING OF BOLT ON .375 PLATE

$$A = .163(.375) = .061$$

$$\sigma = \frac{334.6}{.061} = 5485 \text{ PSI}$$

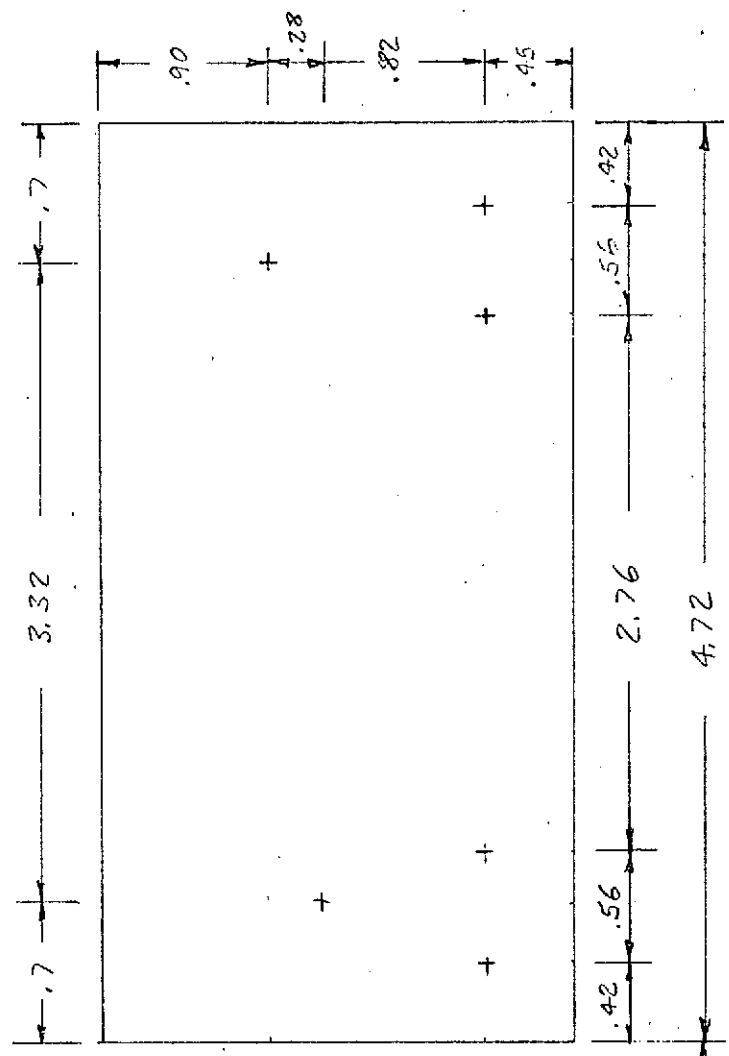
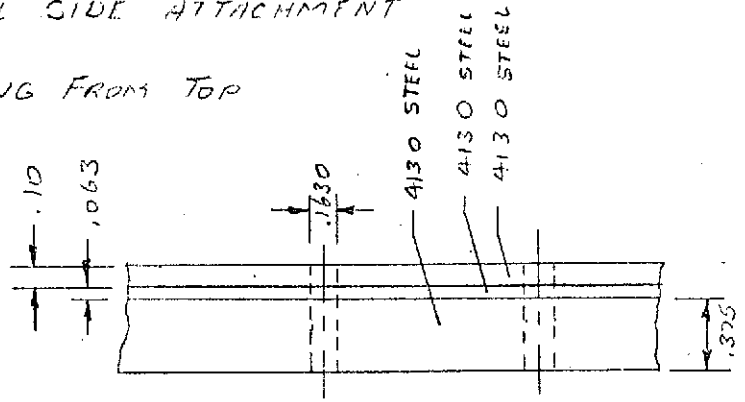
$$M.S. = \frac{108}{5485(2)} = 8.8$$

TEST FIXTURE

MDAC PANEL SIDE ATTACHMENT

DWG 28
SHEET 7

FOURTH RING FROM TOP



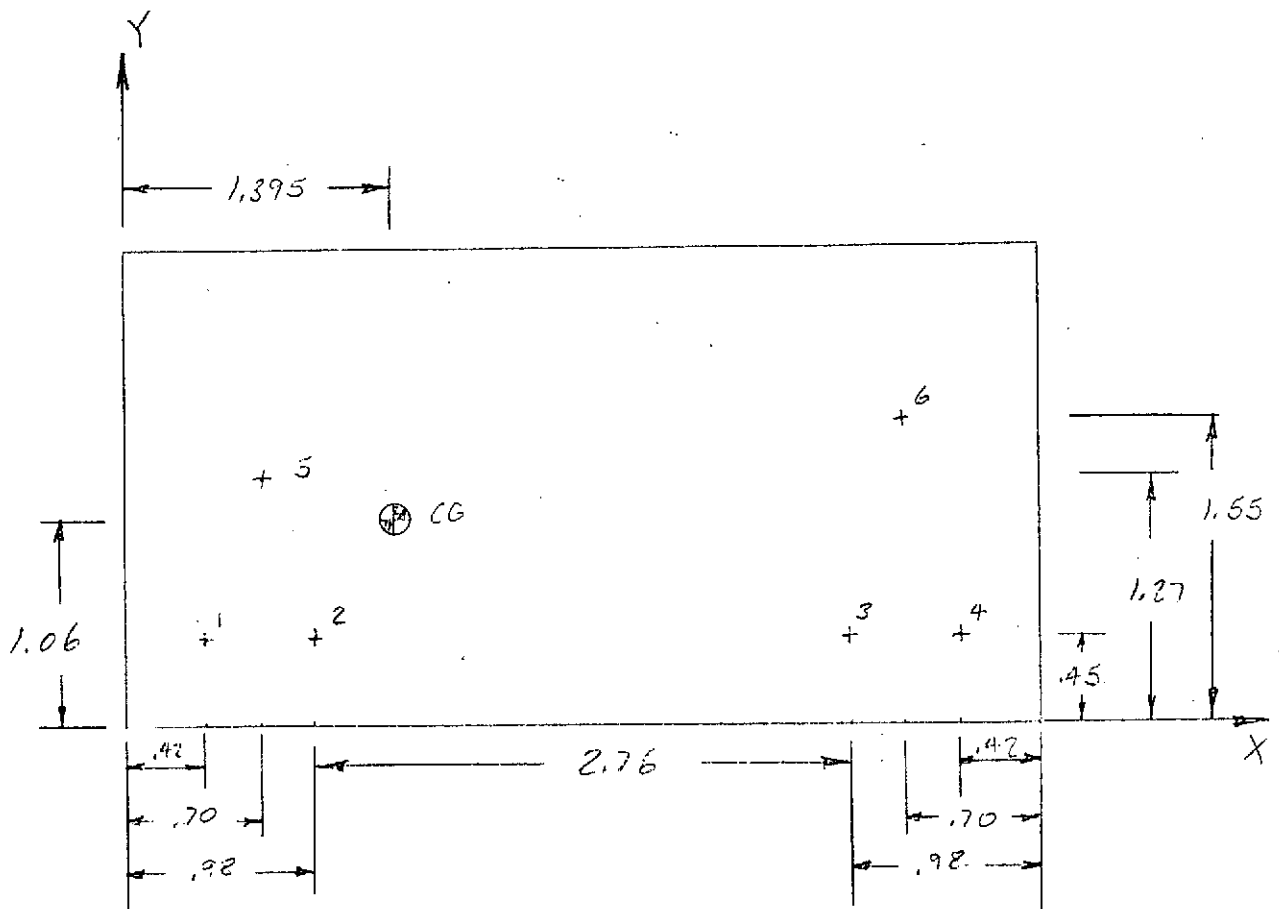
$\rho = 510 \mu$

TEST FIXTURE

MDAC PANEL SIDE ATTACHMENT

DWG 28
SHEET 7

FOURTH RING FROM TOP



BOLT	AREA	X	Y	AX	AY
1	.0209	.47	.45	.0088	.0094
2	.0209	.98	.45	.0205	.0094
3	.0209	3.74	.45	.0782	.0094
4	.0209	4.30	.45	.0879	.0094
5	.1963	.70	1.27	.0375	.2493
6	.0709	4.02	1.30	.0840	.0874
	<u>.3008</u>			<u>.4189</u>	<u>.3193</u>

$$\bar{X} = \frac{\sum AY}{\sum A} = \frac{.4189}{.3008} = 1.395 \text{ IN}$$

$$\bar{Y} = \frac{\sum AX}{\sum A} = \frac{.3193}{.3008} = 1.06 \text{ IN}$$

TEST FIXTURE

MDAC PANEL SIDE ATTACHMENT

DWG 28
SHEET 7

FOURTH RING FROM TOP

$$R = \sqrt{\left(\frac{P}{Nn}\right)^2 + \left(\frac{MC}{\Sigma X^2 + \Sigma Y^2}\right)^2 + 2\left(\frac{P}{Nn}\right)\left(\frac{MC}{\Sigma X^2 + \Sigma Y^2}\right)\cos\theta}$$

$$\left(\frac{P}{Nn}\right)^2 = \left(\frac{510}{6}\right)^2 = (85)^2 = 7225.$$

$$M = Pe = 510(3.25 + 1.395) = 510(4.645) = 2369.$$

$$C = \sqrt{(2.905)^2 + (.21)^2} = \sqrt{8.439 + .044} = \sqrt{8.483} = 2.912$$

$$\Sigma X^2 + \Sigma Y^2 = (1.075)^2 + (.415)^2 + (2.345)^2 + (2.905)^2 + 4(.61)^2 + (.21)^2 + (.49)^2$$

$$\Sigma X^2 + \Sigma Y^2 = 1.156 + .172 + 5.499 + 8.439 + 1.488 + .044 + .240 = 17.038$$

$$\left(\frac{MC}{\Sigma X^2 + \Sigma Y^2}\right)^2 = \left(\frac{2369 \cdot (2.912)}{17.038}\right)^2 = (404.89)^2 = 163936.$$

$$\tan\theta = \frac{.21}{2.905} = .0723$$

$$\cos\theta = .997$$

$$R = \sqrt{7225 + 163936 + 2(85)(404.89)(.997)}$$

$$R = \sqrt{239786} = 489. \text{ LB}$$

$$\tau = \frac{R}{A} = \frac{489.}{.0209} = 23397 \text{ PSI}$$

Prepared By J.P. Date 7-31-73
Checked By ALS Date 7-31-73
Revised By _____ Date _____

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TEST FIXTURE

MDAC PANEL SIDE ATTACHMENT

DWG 28

SHEET 7

FOURTH RING FRAME FROM TOP

BOLTS: 3M248C08

BOLT SHEAR MINIMUM: 95000 PSI

$$M.S. = \frac{95000}{23397 (2)} - 1 = 1.04$$

BEARING OF BOLT ON A130 STEEL (.110 & .063 PLATES)

$$A = .163 (.113) = .0266$$

$$R = 489.$$

$$\sigma = \frac{R}{A} = \frac{489.}{.0266} = 18383 \text{ PSI}$$

$$M.S. = \frac{108.}{18383 (2)} - 1 = 1.94$$

BEARING OF BOLT .375 PLATE

$$A = .163 (.375) = .061$$

$$\sigma = \frac{489.}{.061} = 8016. \text{ PSI}$$

$$M.S. = \frac{108}{8016 (2)} - 1 = 3.3$$

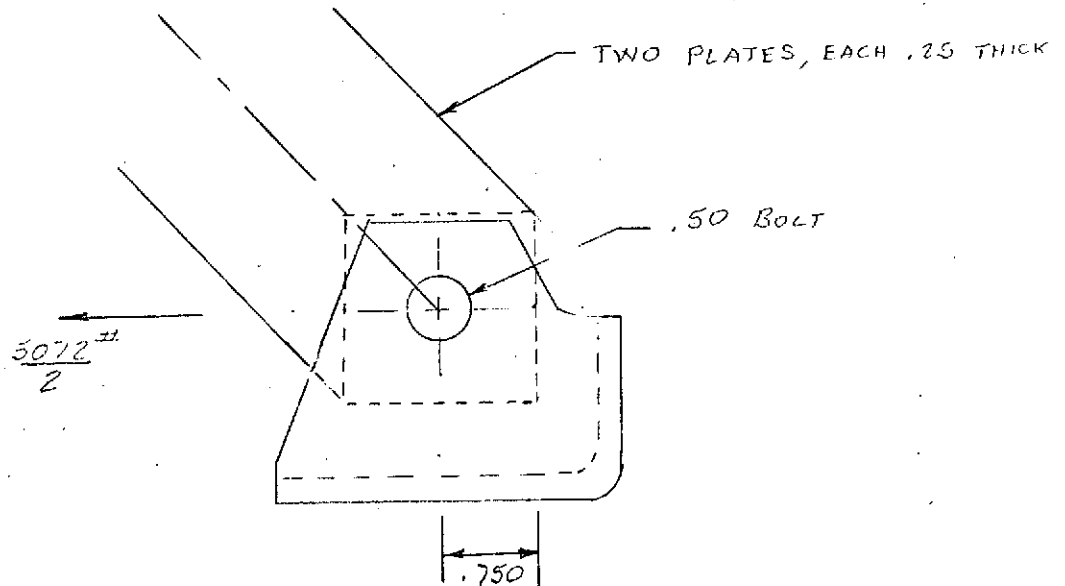
TEST FIXTURE

MDAC PANEL CENTER ATTACHMENT

DWG 28
SHEET 3

TOP RING FRAME

MATERIAL: 4130 STEEL



STRESS IN BOLT

$$\text{BOLT AREA} = A = \frac{\pi D^2}{4} = \frac{\pi (.5)^2}{4} = .196$$

$$\sigma = \frac{P}{A} = \frac{5072/2}{.196} = 12939 \text{ PSI}$$

$$M.S. = \frac{75000}{12939 (2)} - 1 = 2.67$$

SHEAROUT OF LUG

$$A = .5(.75 - .25) (2) = .50$$

$$\sigma = \frac{P}{A} = \frac{5072/2}{.50} = 5072 \text{ PSI}$$

$$M.S. = \frac{50}{5072 (2.5)} - 1 = 2.94$$

BEARING ON LUG

$$A = .5 (.5) = .25$$

$$\sigma = \frac{P}{A} = \frac{5072/2}{.25} = 10144 \text{ PSI}$$

$$M.S. = \frac{10810}{10144 (2)} - 1 = 4.3$$

TEST FIXTURE

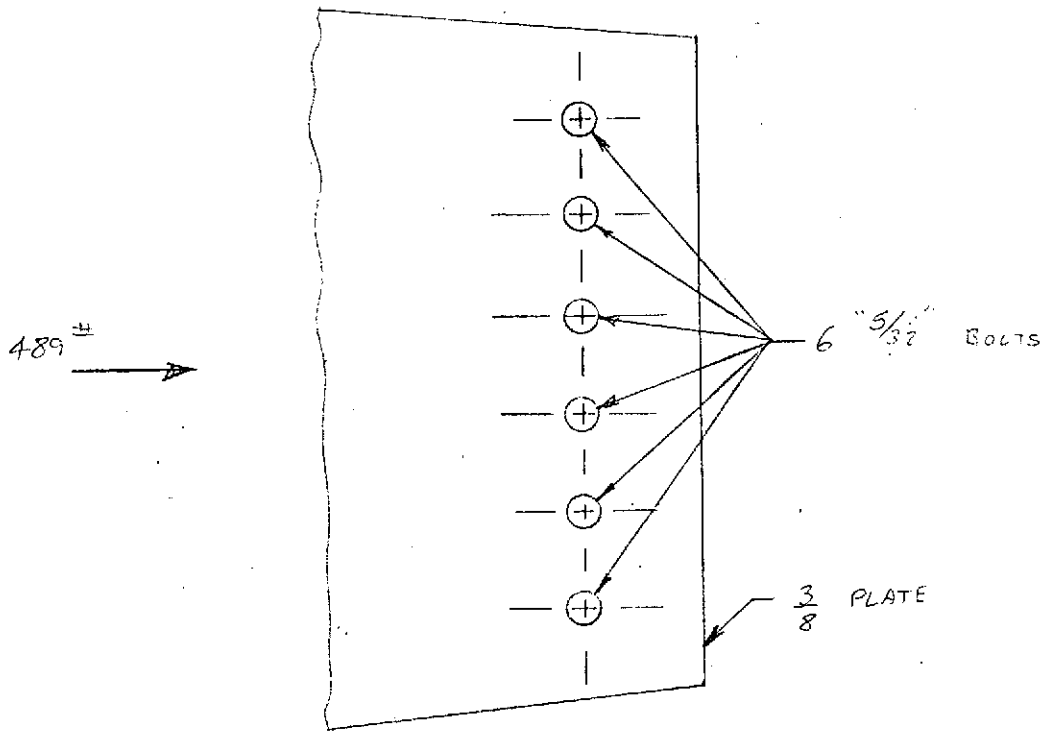
MOAC PANEL CENTER ATTACHMENT

DWG 28
SHEET 4

FOURTH RING FRAME FROM TOP

MATERIAL: 4130 STEEL

STRESS IN BOLTS



BOLT AREA

$$A_T = \frac{(6) \pi D^2}{4} = \frac{6 \pi (.15625)^2}{4} = .115 \text{ IN}^2$$

BOLT SHEAR

$$\sigma = \frac{P}{A} = \frac{489}{.115} = 4252 \text{ PSI}$$

$$M.S. = \frac{95000}{4252(2)} - 1 = 10.1$$

BOLT BEARING ON 3/8 PLATE

$$\text{AREA} = (.15625)(.375) = .0586 \text{ IN}^2$$

$$\sigma = \frac{489/6}{.0586} = 1391 \text{ PSI}$$

$$M.S. = \frac{102000}{1391(2)} - 1 = 37.$$

TEST FIXTURE

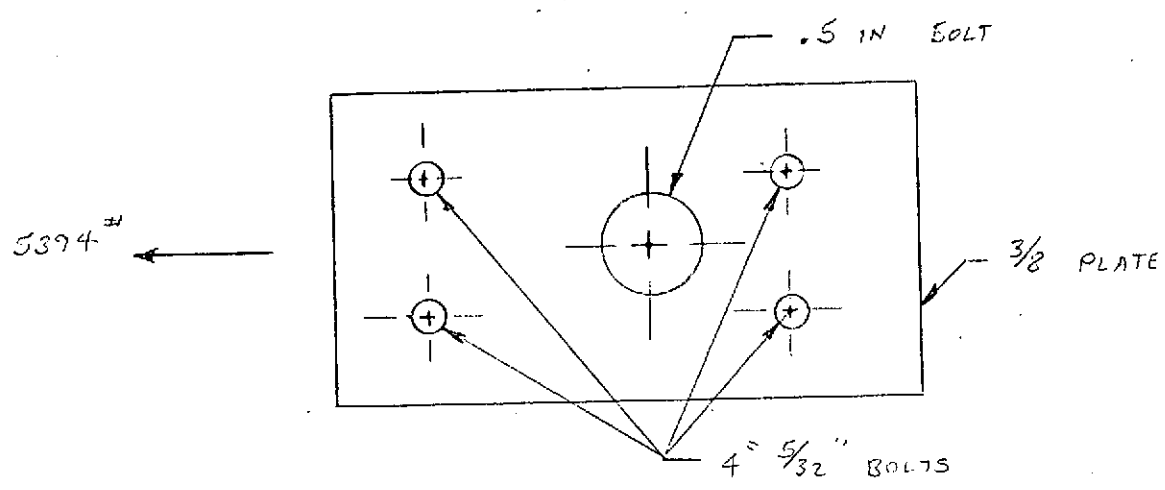
MDAC PANEL CENTER ATTACHMENT

DWG 28
SHEET 5

SECOND AND THIRD RING FRAMES FROM TOP

MATERIAL: A150 STEEL

STRESS IN BOLTS



4 5/32\"/>

$$A = \frac{1 \pi D^2}{4} = \pi D^2 = \pi (.15625)^2 = .077 \text{ IN}^2$$

1/2\"/>

$$A = \frac{\pi D^2}{4} = \frac{\pi (.5)^2}{4} = .1963$$

$$A_{TOTAL} = .1963 + .077 = .2733 \text{ IN}^2$$

STRESS IN BOLTS

$$\sigma = \frac{P}{A} = \frac{5394}{.2733} = 19737 \text{ PSI}$$

$$M.S. = \frac{25000}{19737(2)} - 1 = 1.4$$

BEARING OF BOLTS ON PLATE

$$A = (.375)[4(.15625) + (.5)] = .375(1.125) = .413 \text{ IN}^2$$

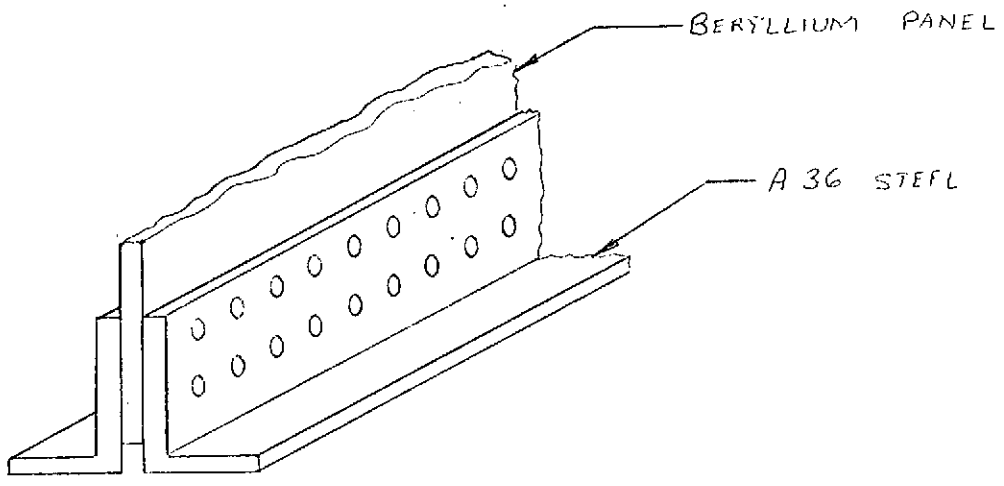
$$\sigma = \frac{5394}{.413} = 13060 \text{ PSI}$$

$$M.S. = \frac{108000}{13060(2)} - 1 = 3.15$$

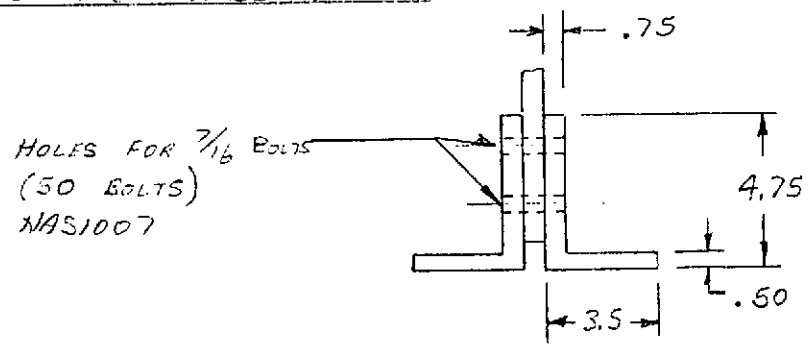
TEST FIXTURE

BERYLLIUM PANELS

UNIFORM LOADED



4.8 INCH WIDE PANEL



PANEL LOAD = 350 lb

$$\frac{350 \text{ lb}}{50 \text{ BOLTS}} = 7.0 \frac{\text{LBF}}{\text{BOLT}}$$

$$A = \pi \frac{D^2}{4} = \pi \frac{(.4375)^2}{4} = .150 \text{ IN}^2$$

Prepared By _____ Date _____
Checked By ALC Date _____
Revised By _____ Date _____

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TEST FIXTURE

BERYLLIUM PANELS

UNIFORM LOADING

BOLT SHEAR

BOLTS ARE IN DOUBLE SHEAR

$$\tau = \frac{V}{2A} = \frac{7000}{2(.150)} = 23333 \text{ PSI}$$

SHEAR ALLOWABLE AT 600°F

$$F_{SD} = 91000(.86) = 78260 \text{ PSI}$$

$$M.S. = \frac{157140}{2.5(23333)} = 1.34$$

BOLT BEARING ON ANGLE

$$\tau = \frac{7000}{2(.75)(.9375)} = 10667 \text{ PSI}$$

BEARING ALLOWABLE AT 600°F

$$F_{BA} = 81000(.70) = 56700 \text{ PSI}$$

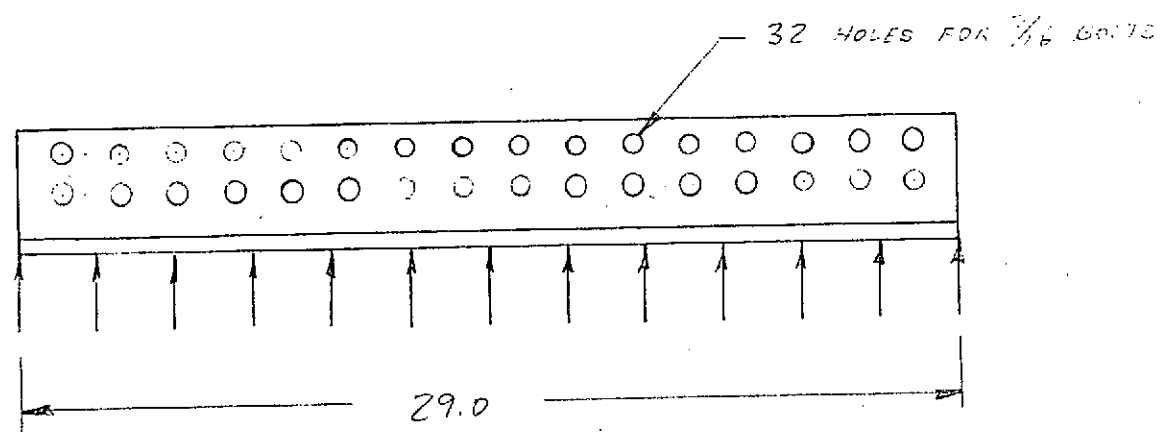
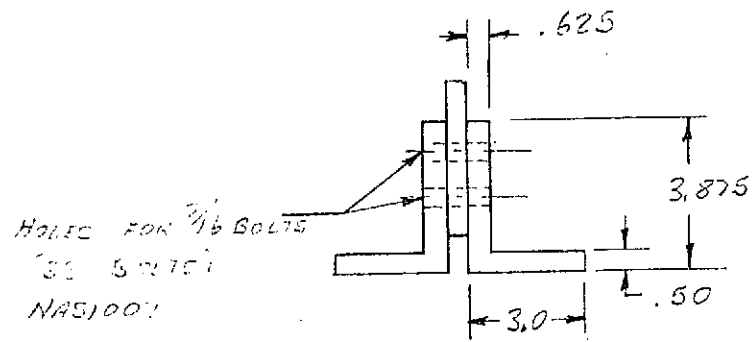
$$M.S. = \frac{81000}{2(10667)} = 2.8$$

TEST FIXTURE

ALUMINUM PANELS

WELDED TOGETHER

29 INCH WIDE PANEL



LOAD PER BOLT

$$\frac{209200 \text{ LB}}{32 \text{ BOLTS}} = 6531 \frac{\text{LB}}{\text{BOLT}}$$

$$A = \pi \frac{D^2}{4} = \frac{\pi (.4375)^2}{4} = .150 \text{ IN}^2$$

TEST FIXTURE

BERYLLIUM PANELS

UNIFORM LOADED

BOLT SHEAR

BOLTS ARE IN DOUBLE SHEAR

$$\tau = \frac{V}{2A} = \frac{6531}{2(.15)} = 21770 \text{ PSI}$$

SHEAR ALLOWABLE AT 600°F

$$F_{SD} = 91000(.85) = 78260 \text{ PSI}$$

$$M.S. = \frac{78260}{2.5(21770)} - 1 = .44$$

BOLT BEARING ON ANGLE

$$\sigma = \frac{6531}{2(.625)(.1375)} = 11943 \text{ PSI}$$

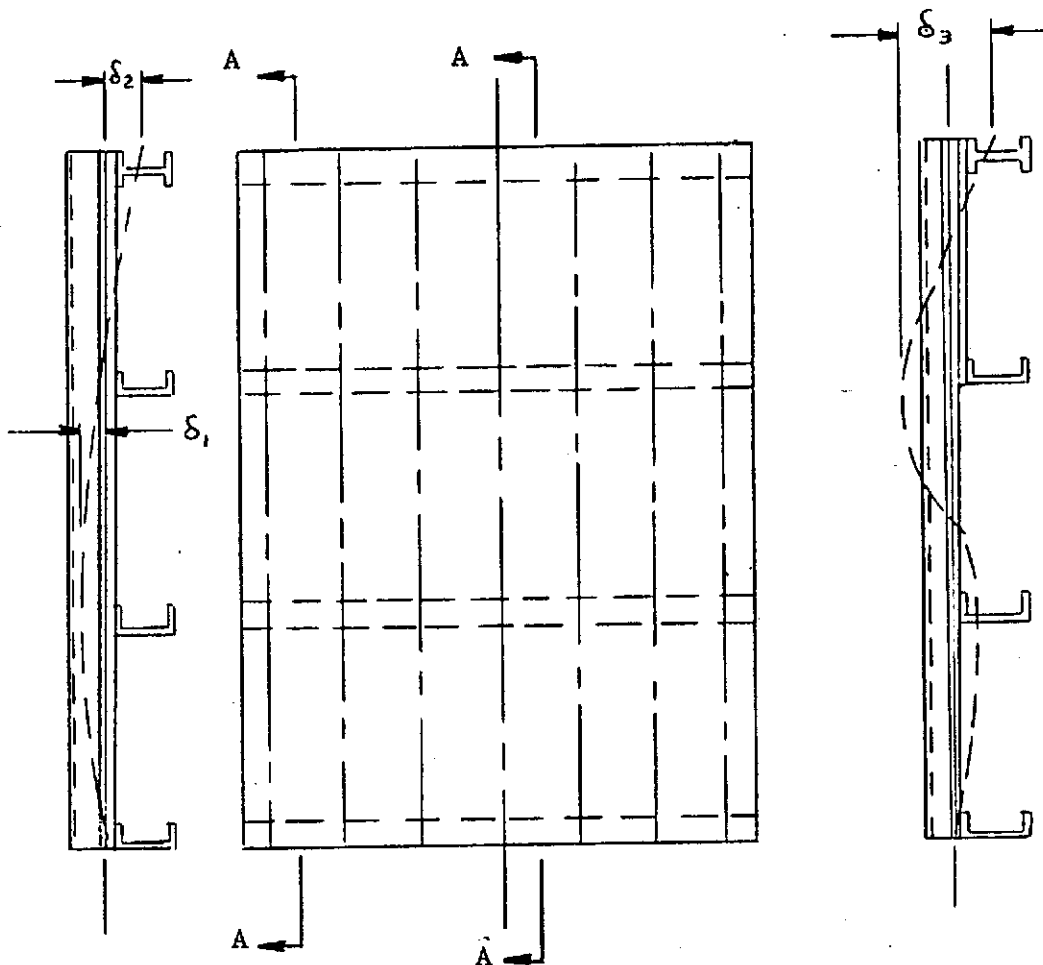
BEARING ALLOWABLE AT 600°F

$$F_{BR} = 90000(.90) = 81000 \text{ PSI}$$

$$M.S. = \frac{81000}{2(11943)} - 1 = 2.39$$

A2.0

HEAT ENCLOSURE COMPUTER ANALYSIS

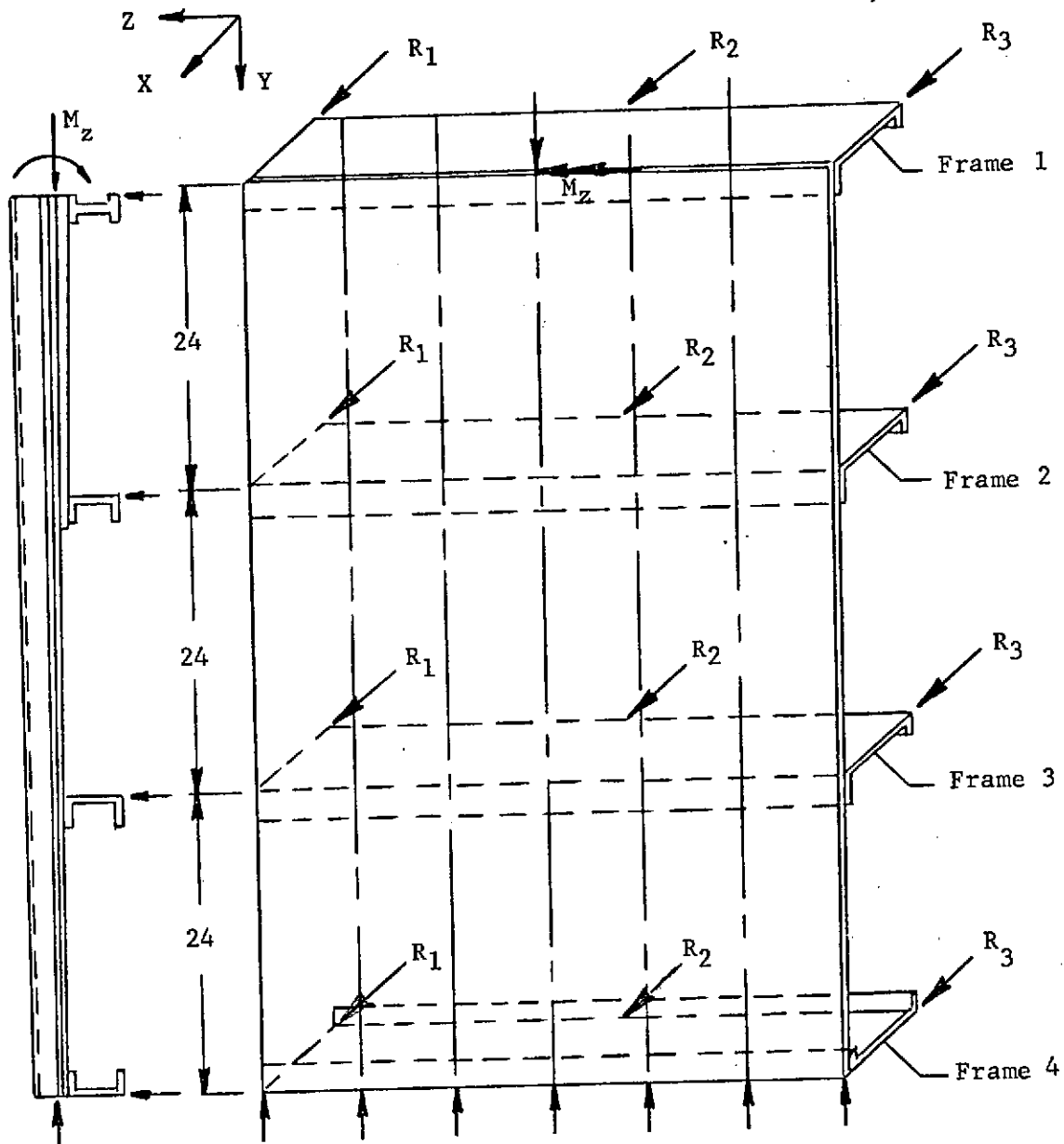


1) Deflection Requirements

- a) Deflection, δ_1 or δ_2 , from applied loads at any frame support point relative to plane x - z ≤ 0.030 in.
- b) Relative deflection, δ_3 , of support points on adjacent frames from applied loads ≤ 0.03 in.
- c) Maximum accumulated deflection at any point shall not exceed 0.06 in. Accumulated deflection is defined as the sum of deflections from installation, alignment and application of ultimate loads.
- d) Plane x - z is defined by the intersection of skin and stringers in the unloaded position. Plane x - y remains perpendicular to the fixed head of the loading machine.

- 2) Relative stiffness between support points on adjacent frames shall be > 200000 lb/in.

FIGURE 1. LATERAL DEFLECTION CRITERIA FOR MDAC B/AL POINT LOADED PANEL



FRAME	R ₁ (LBS)	R ₂ (LBS)	R ₃ (LBS)
1	149.	5072.	149.
2	114.	-5394.	114.
3	-426.	1179.	-426.
4	-510.	489	-510.

FIGURE 2. MDAC B/AL POINT LOADED PANEL. PREDICTED LATERAL LOADS AT TIME OF COMPRESSION LOAD APPLICATION

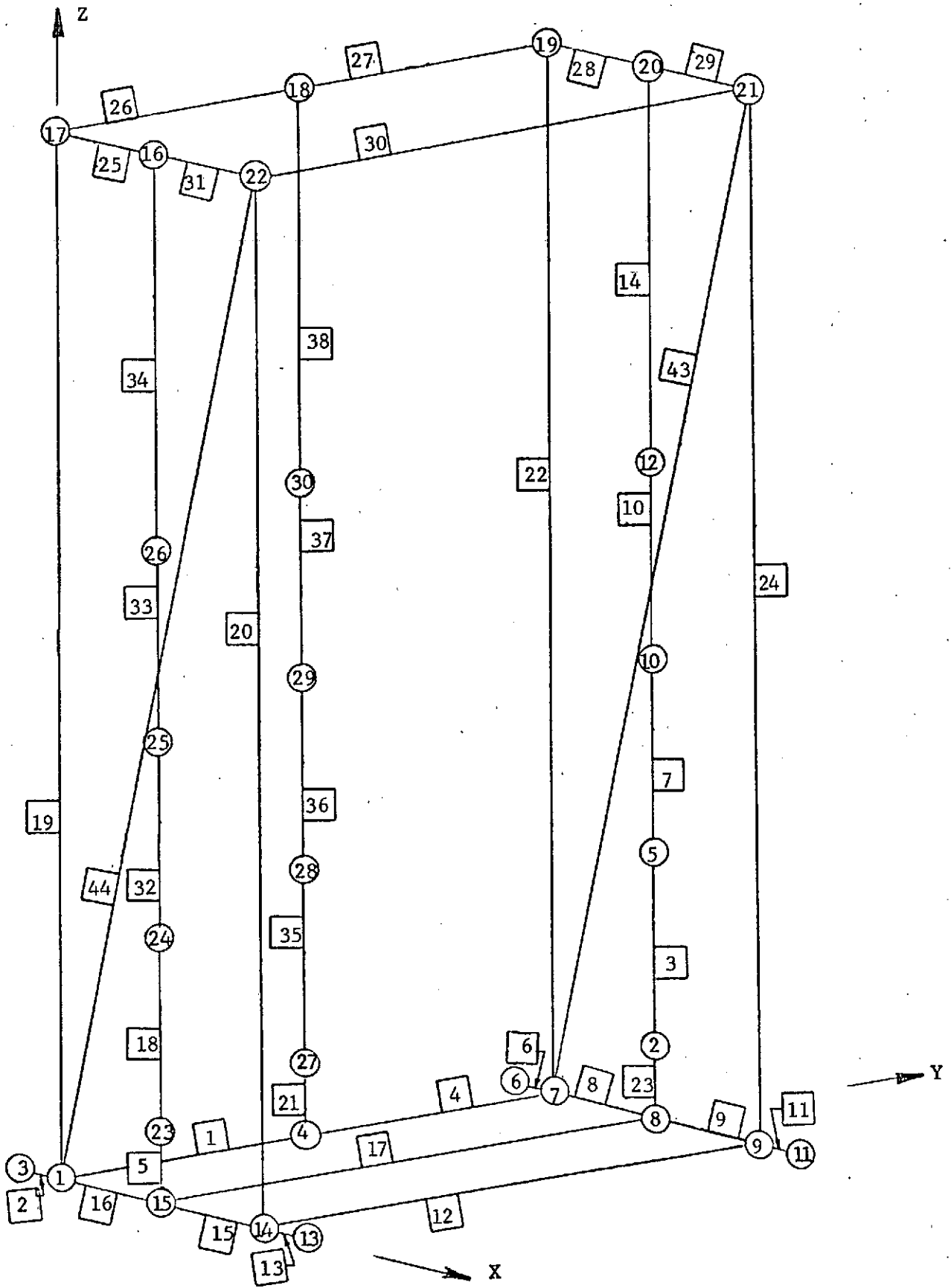


FIGURE 3. HEAT ENCLOSURE FRAMEWORK 1130 STRESS MODEL

TEST STRUCTURE

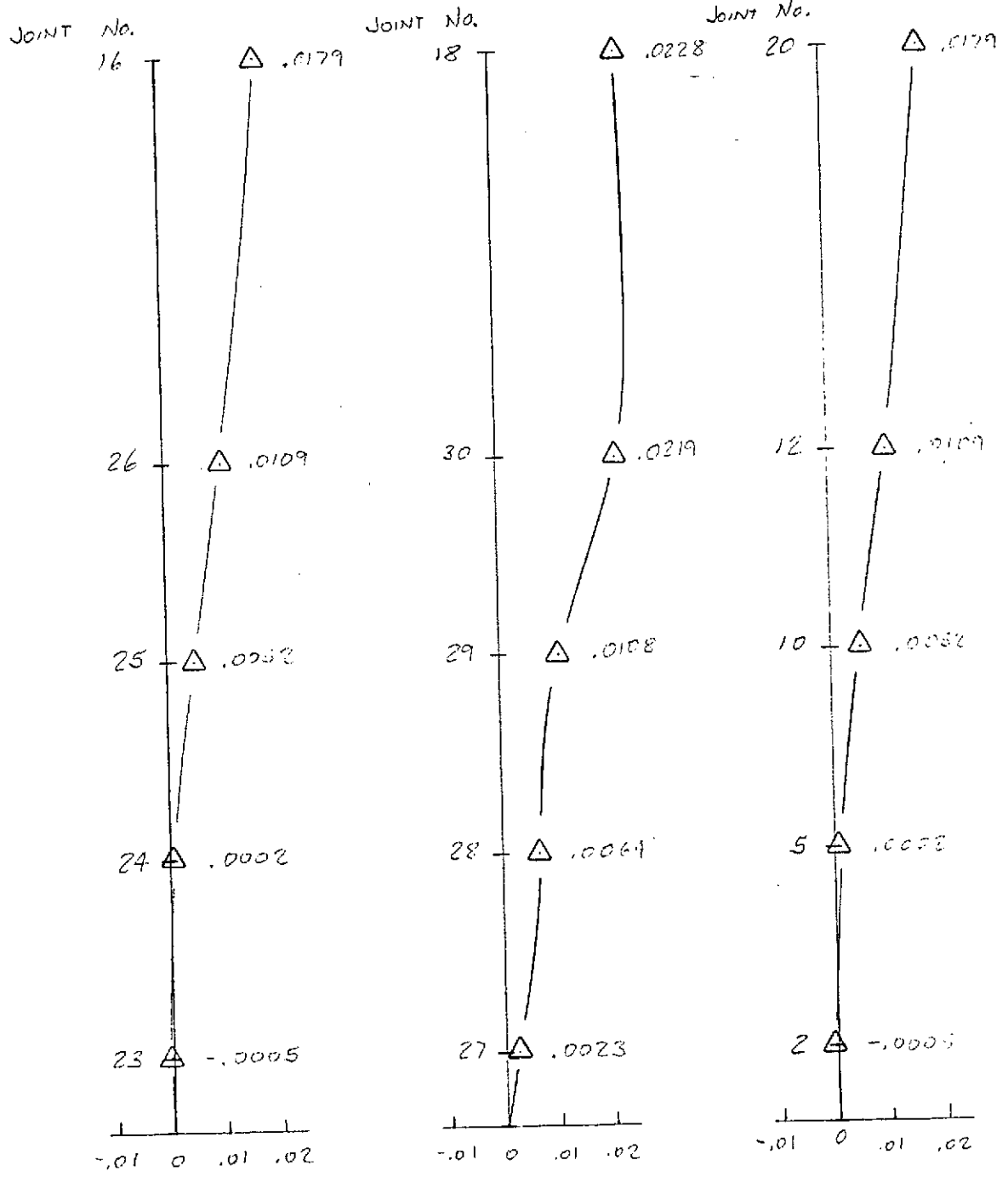


FIGURE 4. DEFLECTION AT SIDES AND CENTER ATTACH COLUMNS DUE TO LATERAL FORCES PRODUCED BY MDAC PANEL DURING TESTING

TEST FIXTURE ENCLOSURE

1130 STRESS PROGRAM

INPUT

STRUCTURE

TYPE SPACE FRAME

NUMBER OF JOINTS 30

NUMBER OF MEMBERS 44

NUMBER OF SUPPORTS 6

NUMBER OF LOADINGS 1

JOINT COORDINATES

1 0. 0. 0.
2 21.05 58.125 8.94
3 -6. 0. 0. S
4 0. 29.062 0.
5 21.05 58.125 32.94
6 -6. 58.125 0. S
7 0. 58.125 0.
8 21.05 58.125 0.
9 36.3 58.125 0. S
10 21.05 58.125 56.94
11 42.3 58.125 0. S
12 21.05 58.125 80.94
13 42.3 0. 0. S
14 36.3 0. 0. S
15 21.05 0. 0.
16 21.05 0. 129.5
17 0. 0. 129.5
18 0. 29.062 129.5
19 0. 58.125 129.5
20 21.05 58.125 129.5
21 36.3 58.125 129.5
22 36.3 0. 129.5
23 21.05 0. 8.94
24 21.05 0. 32.94
25 21.05 0. 56.94
26 21.05 0. 80.94
27 0. 29.062 8.94
28 0. 29.062 32.94
29 0. 29.062 56.94
30 0. 29.062 80.94

JOINT RELEASES

3 MOMENT X Y Z

6 MOMENT X Y Z

11 MOMENT X Y Z

13 MOMENT X Y Z

MEMBER INCIDENCES

1 1 4
2 3 1
3 2 5
4 4 7
5 15 23
6 6 7
7 5 10
8 7 8
9 8 9
10 10 12
11 9 11
12 14 9
13 14 13
14 12 20
15 15 14
16 1 15
17 15 8
18 23 24
19 1 17
20 14 22
21 4 27
22 7 19
23 8 2
24 9 21
25 17 16
26 17 18
27 18 19
28 19 20
29 20 21
30 22 21
31 16 22
32 24 25
33 25 26
34 26 16
35 27 28
36 28 29
37 29 30
38 30 18
*39 1 16
*40 15 22
*41 7 20
*42 8 21
43 7 21
44 1 22

MEMBER RELEASES

21 START MOMENT Y Z
38 END MOMENT Y Z
39 START MOMENT Y
39 END MOMENT Y
40 START MOMENT Y
40 END MOMENT Y
41 START MOMENT Y
41 END MOMENT Y
42 START MOMENT Y
42 END MOMENT Y
43 START MOMENT Y
43 END MOMENT Y
44 START MOMENT Y
44 END MOMENT Y

MEMB PROP PRIS 4.62 3.228 1.44 .103 30.3 9.69 90.

1

4

12

26

27

30

MEMB PROP PRIS 4.62 3.228 1.44 .103 30.3 9.69

2

3

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31 THRU 34

MEMB PROP PRIS 8.53 5.799 2.95 .561 157.3 15.2

21

35 THRU 38

17 11.77 8.256 3.51 .830 310.1 44.1

MEMB PROP PRIS .75 .75 .75 .004 2.25 .001

39 THRU 42

43 3.82 2.801 1.165 .136 11.3 3.76

44 3.82 2.801 1.165 .136 11.3 3.76

CONSTANTS E 26444. ALL

TABULATE ALL

* MEMBERS 39, 40, 41, 42 REPRESENT EFFECTIVE SKIN

LOADING 1
JOINT LOADS

23 FORCE X -.51
24 FORCE X -.426
25 FORCE X .114
26 FORCE X .149
23 MOMENT Z .8899
24 MOMENT Z .7434
25 MOMENT Z -.1989
26 MOMENT Z -.26
2 FORCE X -.51
5 FORCE X -.426
10 FORCE X .114
12 FORCE X .149
2 MOMENT Z -.8899
5 MOMENT Z -.7434
10 MOMENT Z .1989
12 MOMENT Z .26
27 FORCE X .489
28 FORCE X 1.179
29 FORCE X -5.394
30 FORCE X 5.072

TRACE
SOLVE

PROBLEM CORRECTLY SPECIFIED, EXECUTION TO PROCEED. UNUSED RECORDS = 17719

20	22	130	170	4.61	10.10	3.22	-1.69	0.00	-0.04	0.00	-2.06	-0.00	-0.36	-0.20	-0.00	0.57	0.031
21	4	9	22	8.53	30.78	5.24	-0.00	-0.00	0.21	0.00	0.00	0.00	-0.00	0.00	0.00	0.00	0.000
21	27	9	22	8.53	30.78	5.24	0.00	0.00	-0.21	-0.00	-1.91	-0.00	0.00	-0.06	-0.00	0.06	0.003
22	7	130	170	4.61	10.10	3.22	-0.23	-0.00	0.05	-0.00	-4.31	0.01	-0.04	-0.42	0.00	0.48	0.026
22	19	130	170	4.61	10.10	3.22	0.23	0.00	-0.05	0.00	-2.79	-0.02	0.04	-0.27	-0.00	0.33	0.018
23	8	9	12	4.61	10.10	3.22	0.39	-0.00	-0.69	1.17	4.02	-0.03	0.08	0.39	-0.01	0.49	0.027
23	2	9	12	4.61	10.10	3.22	-0.39	0.00	0.69	-1.17	2.17	0.03	-0.08	0.21	0.01	0.31	0.017
24	9	130	170	4.61	10.10	3.22	1.69	0.00	0.04	0.00	-3.53	0.00	0.36	-0.35	0.00	0.71	0.039
24	21	130	170	4.61	10.10	3.22	-1.69	-0.00	-0.04	-0.00	-2.06	0.00	-0.36	-0.20	0.00	0.57	0.031
25	17	21	28	4.61	10.10	3.22	0.51	-0.13	-0.23	-0.00	2.79	-3.79	0.11	0.27	-1.17	1.56	0.086
25	16	21	28	4.61	10.10	3.22	-0.51	0.13	0.23	0.00	2.15	1.00	-0.11	0.21	0.31	0.63	0.035
26	17	29	38	4.61	10.10	3.22	0.13	0.00	-0.56	-0.00	3.79	0.02	0.02	0.37	0.00	0.41	0.022
26	18	29	38	4.61	10.10	3.22	-0.13	-0.00	0.56	0.00	12.65	0.12	-0.02	1.25	0.03	1.31	0.073
27	18	29	38	4.61	10.10	3.22	0.13	-0.00	0.56	-0.00	-12.65	-0.12	0.02	-1.25	-0.03	1.31	0.073
27	19	29	38	4.61	10.10	3.22	-0.13	0.00	-0.56	0.00	-3.79	-0.02	-0.02	-0.37	-0.00	0.41	0.022
28	19	21	28	4.61	10.10	3.22	0.51	0.13	-0.23	0.00	2.79	3.79	0.11	0.27	1.17	1.56	0.086
28	20	21	28	4.61	10.10	3.22	-0.51	-0.13	0.23	-0.00	2.15	-1.00	-0.11	0.21	-0.31	0.63	0.035
29	20	15	20	4.61	10.10	3.22	0.49	0.13	-0.08	-0.00	-0.74	1.00	0.10	-0.07	0.31	0.49	0.027
29	21	15	20	4.61	10.10	3.22	-0.49	-0.13	0.08	0.00	2.06	1.00	-0.10	0.20	0.31	0.62	0.034
30	22	58	76	4.61	10.10	3.22	-0.13	0.00	0.00	-0.00	1.00	0.00	-0.02	0.09	0.00	0.13	0.007
30	21	58	76	4.61	10.10	3.22	0.13	-0.00	-0.00	0.00	-1.00	-0.00	0.02	-0.09	-0.00	0.13	0.007
31	16	15	20	4.61	10.10	3.22	0.49	-0.13	-0.08	0.00	-0.74	-1.00	0.10	-0.07	-0.31	0.49	0.027
31	22	15	20	4.61	10.10	3.22	-0.49	0.13	0.08	-0.00	2.06	-1.00	-0.10	0.20	-0.31	0.62	0.034
32	24	24	31	4.61	10.10	3.22	0.39	0.00	0.24	0.45	-6.55	0.02	0.08	-0.64	0.00	0.74	0.041
32	25	24	31	4.61	10.10	3.22	-0.39	-0.00	-0.24	-0.45	0.72	-0.01	-0.08	0.07	-0.00	0.16	0.009
33	25	24	31	4.61	10.10	3.22	0.39	0.00	0.12	0.26	-0.72	0.01	0.08	-0.07	0.00	0.16	0.009
33	26	24	31	4.61	10.10	3.22	-0.39	-0.00	-0.12	-0.26	-2.37	-0.01	-0.08	-0.23	-0.00	0.32	0.018
34	26	49	64	4.61	10.10	3.22	0.39	0.00	-0.01	0.00	2.37	0.01	0.08	0.23	0.00	0.32	0.018
34	16	49	64	4.61	10.10	3.22	-0.39	-0.00	0.01	-0.00	-1.41	0.00	-0.08	-0.13	0.00	0.22	0.012
35	27	24	58	8.53	30.78	5.24	-0.00	-0.00	-0.27	0.00	1.91	-0.00	-0.00	0.06	-0.00	0.06	0.003
35	28	24	58	8.53	30.78	5.24	0.00	0.00	0.27	-0.00	4.68	-0.00	0.00	0.15	-0.00	0.15	0.008
36	28	24	58	8.53	30.78	5.24	-0.00	-0.00	-1.45	0.00	-4.68	0.00	-0.00	-0.15	0.00	0.15	0.008
36	29	24	58	8.53	30.78	5.24	0.00	0.00	1.45	-0.00	39.58	-0.00	0.00	1.28	-0.00	1.28	0.071
37	29	24	58	8.53	30.78	5.24	-0.00	-0.00	3.93	0.00	-39.58	0.00	-0.00	-1.28	0.00	1.28	0.071
37	30	24	58	8.53	30.78	5.24	0.00	0.00	-3.93	-0.00	-54.97	-0.00	0.00	-1.78	-0.00	1.78	0.099
38	30	49	118	8.53	30.78	5.24	-0.00	0.00	-1.13	0.00	54.97	0.00	-0.00	1.78	0.00	1.78	0.099
38	18	49	118	8.53	30.78	5.24	0.00	-0.00	1.13	-0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
39	1	131	28	0.75	0.74	0.01	-0.25	0.00	0.00	-0.00	0.00	0.00	-0.33	0.00	0.00	0.33	0.018
39	16	131	28	0.75	0.74	0.01	0.25	-0.00	-0.00	0.00	-0.00	0.00	0.33	-0.00	0.00	0.33	0.018
40	15	130	28	0.75	0.74	0.01	-0.02	0.00	0.00	-0.00	0.00	0.00	-0.03	0.00	0.00	0.03	0.002
40	22	130	28	0.75	0.74	0.01	0.02	-0.00	-0.00	0.00	-0.00	0.00	0.03	-0.00	0.00	0.03	0.002
41	7	131	28	0.75	0.74	0.01	-0.25	-0.00	0.00	0.00	0.00	-0.00	-0.33	0.00	-0.00	0.33	0.018
41	20	131	28	0.75	0.74	0.01	0.25	0.00	-0.00	-0.00	-0.00	-0.00	0.33	-0.00	-0.00	0.33	0.018
42	8	130	28	0.75	0.74	0.01	-0.02	-0.00	0.00	0.00	-0.00	-0.00	-0.03	-0.00	-0.00	0.03	0.002
42	21	130	28	0.75	0.74	0.01	0.02	0.00	-0.00	-0.00	-0.00	-0.00	0.03	-0.00	-0.00	0.03	0.002
43	7	134	146	3.82	5.43	1.85	-1.64	-0.00	0.00	0.00	0.00	0.01	-0.43	0.00	0.00	0.43	0.024
43	21	134	146	3.82	5.43	1.85	1.64	0.00	-0.00	-0.00	-0.00	-0.01	0.43	-0.00	-0.00	0.43	0.024
44	1	134	146	3.82	5.43	1.85	-1.64	0.00	0.00	-0.00	-0.00	-0.01	-0.43	-0.00	-0.00	0.43	0.024
44	22	134	146	3.82	5.43	1.85	1.64	-0.00	-0.00	0.00	-0.00	0.01	0.43	-0.00	0.00	0.43	0.024

TOTAL WEIGHT= 2457.(LB)

APPLIED FREE JOINT LOADS

JOINT	FORCE X	FORCE Y	FORCE Z	MOMENT X	MOMENT Y	MOMENT Z
1	-0.000	0.000	-0.000	-0.000	0.000	-0.000
2	-0.509	-0.000	-0.000	-0.000	-0.000	-0.889
4	-0.000	-0.000	-0.000	-0.000	0.000	0.000
5	-0.425	0.000	0.000	0.000	-0.000	-0.743
7	-0.000	0.000	0.000	0.000	0.000	0.000
8	-0.000	0.000	-0.000	0.000	-0.000	-0.000
10	0.114	-0.000	0.000	0.000	-0.000	0.198
12	0.149	0.000	-0.000	0.000	-0.000	0.259
15	-0.000	-0.000	0.000	-0.000	-0.000	0.000
16	-0.000	0.000	0.000	0.000	0.000	0.000
17	-0.000	-0.000	-0.000	-0.000	-0.000	0.000
18	-0.000	0.000	-0.000	-0.000	-0.000	0.000
19	-0.000	0.000	-0.000	-0.000	0.000	0.000
20	-0.000	-0.000	-0.000	0.000	-0.000	0.000
21	0.000	-0.000	-0.000	-0.000	0.000	-0.000
22	0.000	-0.000	-0.000	0.000	0.000	0.000
23	-0.509	-0.000	0.000	0.000	-0.000	0.889
24	-0.425	0.000	0.000	-0.000	-0.000	0.743
25	0.114	0.000	0.000	-0.000	-0.000	-0.198
26	0.149	-0.000	-0.000	0.000	-0.000	-0.259
27	0.489	0.000	0.000	0.000	0.000	-0.000
28	1.179	0.000	0.000	-0.000	-0.000	0.000
29	-5.394	0.000	-0.000	0.000	-0.000	0.000
30	5.072	0.000	0.000	-0.000	-0.000	-0.000

REACTIONS AND APPLIED SUPPORT JOINT LOADS

JOINT	FORCE X	FORCE Y	FORCE Z	MOMENT X	MOMENT Y	MOMENT Z
3	-0.305	-0.122	-1.633	0.000	-0.000	-0.000
6	-0.305	0.122	-1.633	0.000	0.000	-0.000
9	0.305	0.049	1.633	-0.001	-4.168	-0.188
11	0.000	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000
14	0.305	-0.049	1.633	0.001	-4.168	0.188

42.11

FREE JOINT DISPLACEMENTS

JOINT	DISPL X	DISPL Y	DISPL Z	ROTAT X	ROTAT Y	ROTAT Z
1	0.0000	-0.0000	0.0009	0.0000	-0.0000	-0.0000
2	-0.0005	0.0000	0.0000	-0.0000	-0.0000	-0.0096
4	0.0006	-0.0000	0.0010	0.0000	-0.0000	-0.0000
5	0.0002	0.0000	0.0000	-0.0000	0.0001	-0.0159
7	0.0000	0.0000	0.0009	-0.0000	-0.0000	0.0000
8	-0.0000	0.0000	0.0001	-0.0000	0.0000	-0.0000
10	0.0052	0.0002	-0.0000	-0.0000	0.0002	-0.0057
12	0.0109	0.0003	-0.0001	-0.0000	0.0002	-0.0000
15	-0.0000	-0.0000	0.0001	0.0000	0.0000	0.0000
16	0.0179	-0.0007	-0.0003	0.0000	0.0000	0.0000
17	0.0179	0.0000	0.0011	-0.0000	0.0001	-0.0001
18	0.0228	0.0000	0.0010	-0.0000	0.0001	-0.0000
19	0.0179	-0.0000	0.0011	0.0000	0.0001	0.0001
20	0.0179	0.0007	-0.0003	-0.0000	0.0000	-0.0000
21	0.0178	0.0000	-0.0018	-0.0000	0.0001	-0.0000
22	0.0173	-0.0000	-0.0018	0.0000	0.0001	0.0000
23	-0.0005	-0.0000	0.0000	0.0000	-0.0000	0.0096
24	0.0002	-0.0000	0.0000	0.0000	0.0001	0.0159
25	0.0052	-0.0002	-0.0000	0.0000	0.0002	0.0057
26	0.0109	-0.0003	-0.0001	0.0000	0.0002	0.0000
27	0.0023	0.0000	0.0010	-0.0000	0.0001	-0.0000
28	0.0064	0.0000	0.0010	-0.0000	0.0001	-0.0000
29	0.0108	0.0000	0.0010	-0.0000	0.0003	-0.0000
30	0.0219	0.0000	0.0010	-0.0000	0.0002	-0.0000

SUPPORT JOINT DISPLACEMENTS

JOINT	DISPL X	DISPL Y	DISPL Z	ROTAT X	ROTAT Y	ROTAT Z
3	0.0000	0.0000	0.0000	0.0000	-0.0000	-0.0000
6	0.0000	0.0000	0.0000	-0.0000	-0.0000	0.0000
9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

A3.0

LOADING COLUMN STRENGTH ANALYSIS

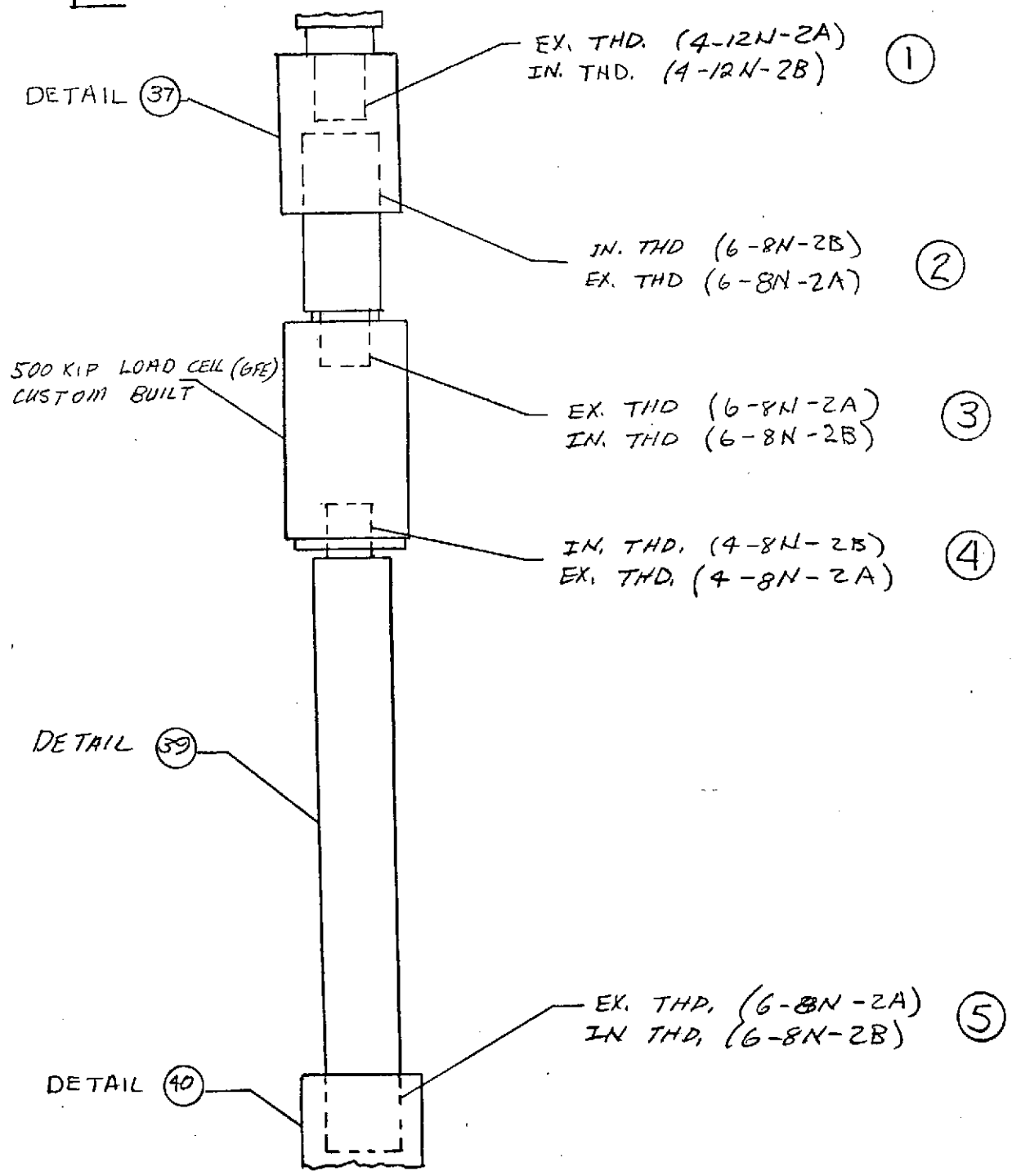
TEST FIXTURE

LOADING HEAD

DRW. 28
SHEET 8

THREADED CONNECTIONS

ALL THD. ALLOW. ARE Ref.: Boucher, R.C.,
STRENGTH OF THREADS, Product Engineering, Nov. 27, 1961



TEST FIXTURE

LOADING HEAD

THREADED CONNECTIONS

DRW. 28
SHEET 8

①

EX. THD. (4-12N-2A) Steel ($F_y = 100$ KSI)

$$A_s' = 6.9903 \text{ in}^2/\text{in}$$

$$A_s = 6.9903 \times 5.75 = 40.15 \text{ in}^2$$

$$f_s = \frac{350}{40.15} = 8.72 \text{ KSI}$$

$$F_s = 40.0 \text{ KSI}$$

$$\text{M.S.} = \frac{40.0}{8.72} - 1. = \underline{\underline{+3.58}} \quad \underline{\underline{\text{GOOD}}}$$

IN. THD. (4-12N-2B) 4130 Steel

$$A_s' = 9.0585 \text{ in}^2/\text{in}$$

$$A_s = 9.0585 \times 5.75 = 52.1 \text{ in}^2$$

$$f_s = \frac{350}{52.1} = 6.72 \text{ KSI}$$

$$F_s = 21.6 \text{ KSI}$$

$$\text{M.S.} = \frac{21.6}{6.72} - 1. = \underline{\underline{+2.21}} \quad \underline{\underline{\text{GOOD}}}$$

TEST FIXTURE

LOADING HEAD

THREADED CONNECTED

DRW. 28
SHEET 8

@ (2)

IN. THD. (6-8N-2B) 4130 Steel

$$A_s' = 13.7357$$

$$A_s = 13.7357 \times 6.375 = 87.7 \text{ in}^2$$

$$f_s = \frac{350}{87.7} = 3.99 \text{ KSI}$$

$$F_s = 21.6 \text{ KSI}$$

$$M.S. = \frac{21.6}{3.99} - 1. = \underline{\underline{+4.42}} \quad \underline{\underline{GOOD}} \quad \leftarrow$$

EX. THD. (6-8N-2A) 4130 Steel

$$A_s' = 10.6132 \text{ in}^2/\text{in}$$

$$A_s = 10.6132 (6.375) = 67.7 \text{ in}^2$$

$$f_s = \frac{350}{67.7} = 5.175 \text{ KSI}$$

$$F_s = 21.6 \text{ KSI}$$

$$M.S. = \frac{21.6}{5.175} - 1. = \underline{\underline{+3.18}} \quad \underline{\underline{GOOD}} \quad \leftarrow$$

TEST FIXTURE

LOADING HEAD

THREADED CONNECTION

DRW 28
SHEET 8

@ (3)

EX. THD (6-8N-2A) 4130 steel

$$A_s' = 10.6132 \text{ in}^2/\text{in}$$

$$A_s = 10.6132 \times 4.5 = 47.8 \text{ in}^2$$

$$f_s = \frac{350}{47.8} = 7.33 \text{ KSI}$$

$$F_s = 21.6 \text{ KSI}$$

$$M.S. = \frac{21.6}{7.33} - 1. = \underline{\underline{+1.95}} \quad \underline{\underline{GOOD}}$$

IN. THD (6-8N-2B) 4130 steel (F_{tu} = 155 KSI)

$$A_s' = 13.7357 \text{ in}^2/\text{in}$$

$$A_s = 13.7357 \times 4.5 = 61.8 \text{ in}^2$$

$$f_s = \frac{350}{61.8} = 5.67 \text{ KSI}$$

$$F_s = 37.9 \text{ KSI}$$

$$M.S. = \frac{37.9}{5.67} - 1. = \underline{\underline{+5.68}} \quad \underline{\underline{GOOD}}$$

TEST FIXTURE

LOADING HEAD

THREADED CONNECTION

DRW, 28
SHEET 8

@ (4)

IN. THD. (4-8N-2B) 4130 Steel (F_{tu} = 155 KSI)

$$A_s' = 9.2365 \text{ in}^2/\text{in}$$

$$A_s = 9.2365 \times 4.5 = 41.5 \text{ in}^2$$

$$f_s = \frac{350}{41.5} = 8.45 \text{ KSI}$$

$$F_s = 37.9 \text{ KSI}$$

$$\text{M.S.} = \frac{37.9}{8.45} - 1. = \underline{\underline{+3.48}} \quad \underline{\underline{\text{GOOD}}}$$

EX. THD. (4-8N-2A) 4130 Steel

$$A_s' = 7.0883 \text{ in}^2/\text{in}$$

$$A_s = 7.0883 \times 4.5 = 31.9 \text{ in}^2$$

$$f_s = \frac{350}{31.9} = 11.0 \text{ KSI}$$

$$F_s = 21.6 \text{ KSI}$$

$$\text{M.S.} = \frac{21.6}{11.0} - 1. = \underline{\underline{+96}} \quad \underline{\underline{\text{GOOD}}}$$

Prepared By PJW Date 7-28-73
Checked By ALS Date 7-31-73
Revised By _____ Date _____

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TEST FIXTURE

LOADING HEAD

THREADED CONNECTIONS

DRW. 28
SHEET 8

② ⑤

EX. THD. (6-8N-2A) 4130 Steel

$$A_s' = 10.6132 \text{ in}^2/\text{in}$$

$$A_s = 10.6132 \times 6.375 = 67.7 \text{ in}^2$$

$$f_s = \frac{350}{67.7} = 5.17 \text{ KSI}$$

$$F_s = 21.6 \text{ KSI}$$

$$M.S. = \frac{21.6}{5.17} - 1.1 = \underline{\underline{+3.17}} \quad \underline{\underline{GOOD}}$$

IN. THD. (6-8N-2B) 4130 Steel

$$A_s' = 13.7357 \text{ in}^2/\text{in}$$

$$A_s = 13.7357 \times 6.375 = 87.6 \text{ in}^2$$

$$f_s = \frac{350}{87.6} = 4.0 \text{ KSI}$$

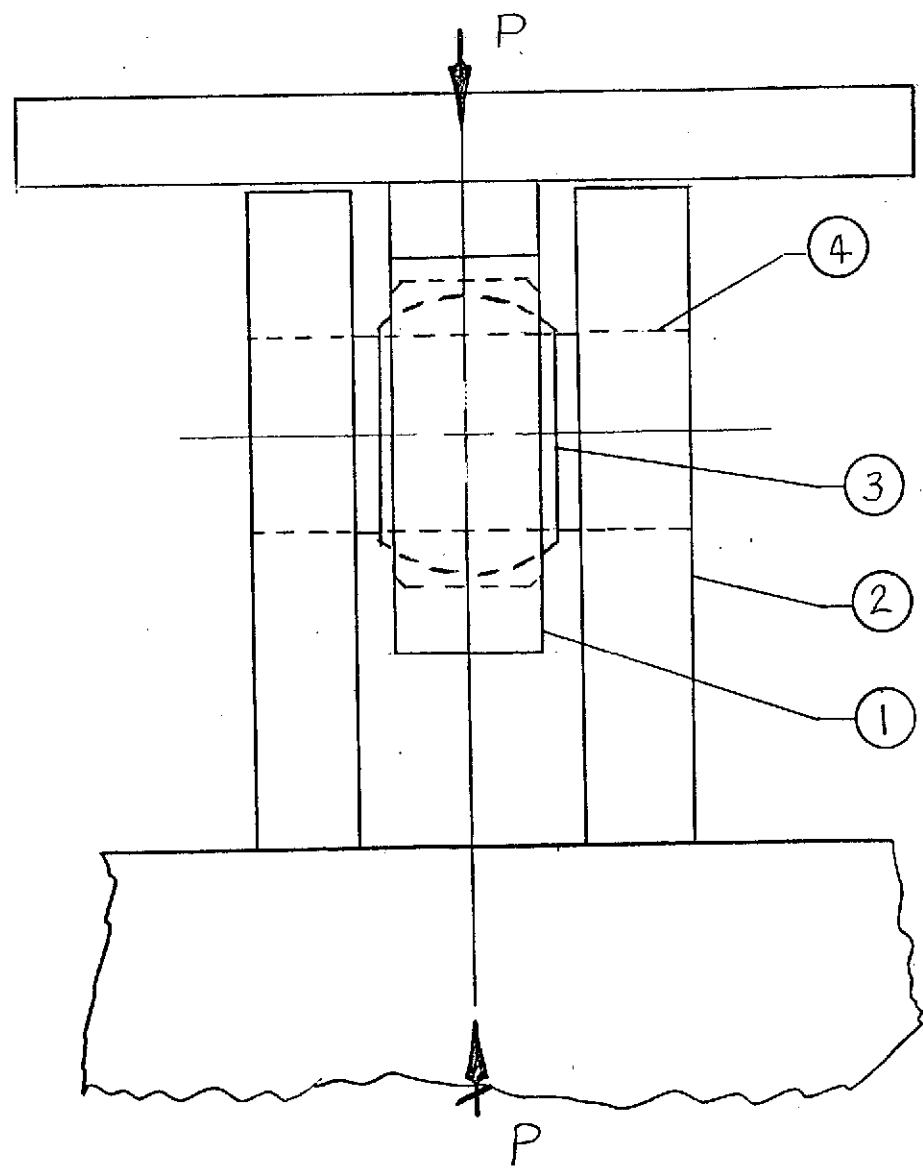
$$F_s = 19.88 \text{ KSI}$$

$$M.S. = \frac{19.88}{4.0} - 1.1 = \underline{\underline{+3.97}} \quad \underline{\underline{GOOD}}$$

TEST FIXTURE

LOADING HEAD
TOP LUG

DRW. 28
SHEET 8



LOAD (P) = 350 KIPS
MATERIAL: AS NOTED
IN ANALYSIS
TEMP.: Room Temp.

TEST FIXTURE

LOADING HEAD

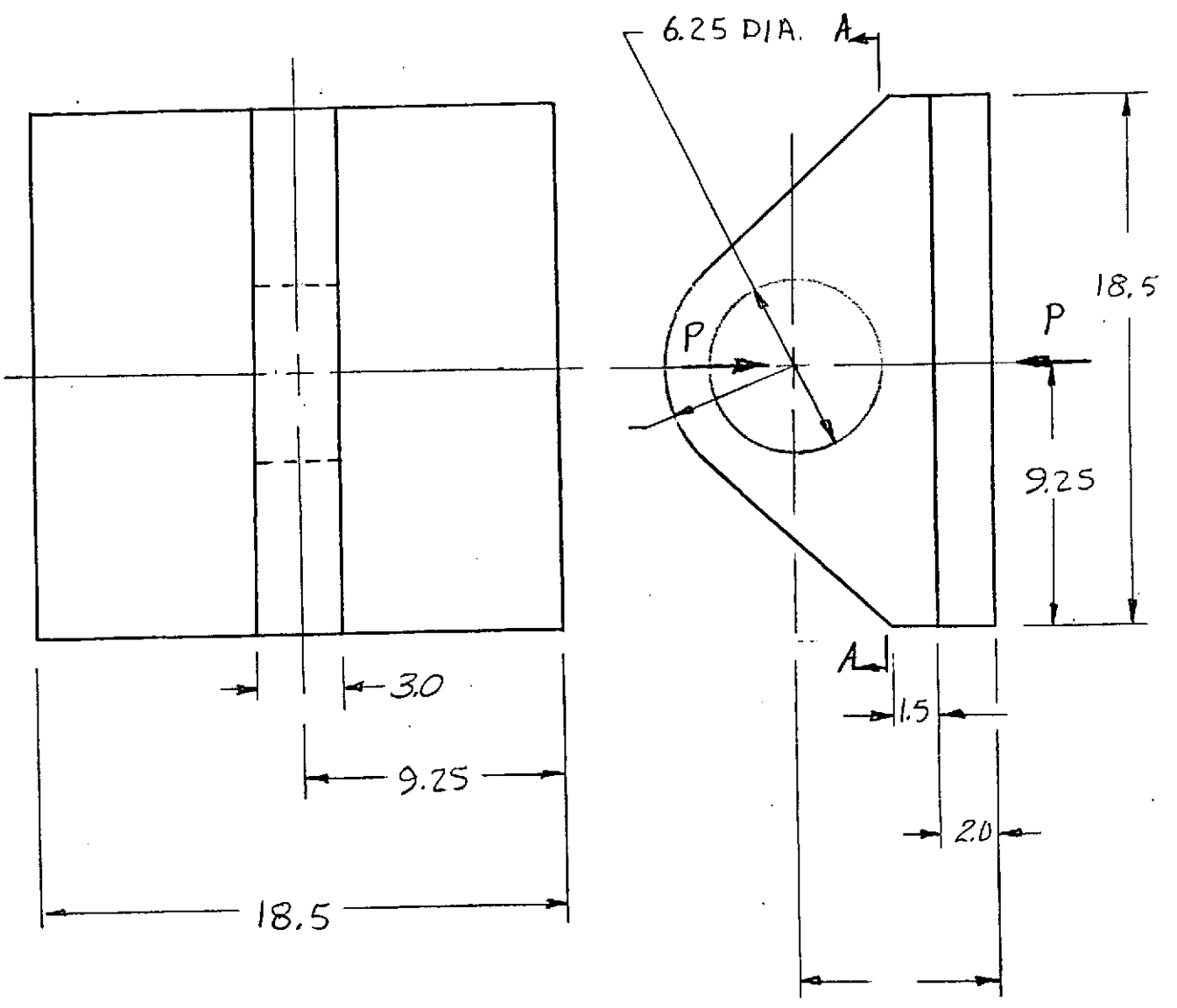
TOP LUG

DRW. 28
SHEET 8

FITTING ①

LOAD (P) = 350.0 KIPS

MATERIAL: 4130 STEEL



TEST FIXTURE

LOADING HEAD

TOP LUG

DRW. 28
SHEET 8

FITTING ①

Bearing check on 6.25 DIA. HOLE

$$f_{br} = \frac{P}{A_{br}} = \frac{350.}{6.25 \times 3.0} = 18.68 \text{ KSI}$$

$$F_{br} = 60.0 \text{ KSI}$$

$$M.S. = \frac{60.0}{18.68} - 1. = \underline{+2.21} \quad \underline{GOOD} \quad \text{Bearing}$$

Compression in stem @ section A-A

$$f_c = \frac{P}{A} = \frac{350.}{3.0 \times 18.5} = 6.30 \text{ KSI}$$

$$F_c = 35.0 \text{ KSI}$$

$$M.S. = \frac{35.0}{6.0} - 1. = \underline{+4.83} \quad \underline{GOOD} \quad \text{Compression}$$

TEST FIXTURE

LOADING HEAD

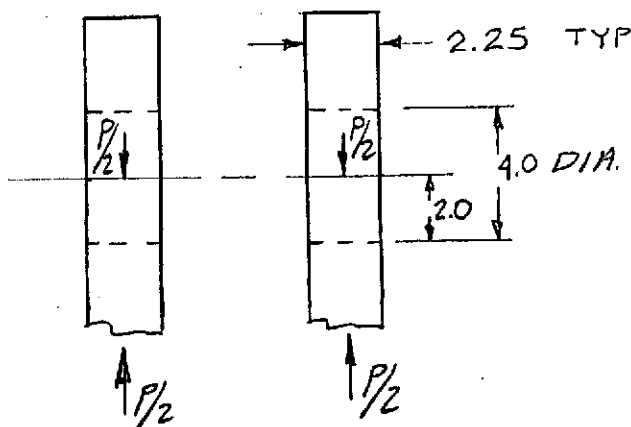
TOP LUG

DRW. 28
SHEET 8

FITTING ②

LOAD (P) = 350 KIPS

MATERIAL: 4130 Steel



Bearing check on 4.0 DIA. HOLE

$$f_{br} = \frac{P}{A_{br}} = \frac{350/2}{4 \times 2.25} = 19.45 \text{ KSI}$$

$$F_{br} = 60.0 \text{ KSI}$$

$$M.S. = \frac{60.0}{19.45} - 1. = \underline{\underline{+2.08}} \quad \underline{\underline{GOOD}}$$

Compression check of stem

$$f_c = \frac{P}{A} = \frac{350/2}{2.25 \times 10} = 7.78 \text{ KSI}$$

$$F_c = 35.0 \text{ KSI}$$

$$M.S. = \frac{35.0}{7.78} - 1. = \underline{\underline{+3.5}} \quad \underline{\underline{GOOD}}$$

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TEST FIXTURE

LOADING HEAD

TOP LUG

DRW 28
SHEET 8

BEARING ③

LOAD = 350.0 KIPS

MATERIAL: STAINLESS STEEL, (H.T.)

BEARING PART NUMBER: BAR-69015
(Ref. Southwest Products Co., Monrovia, California)

ULTIMATE STATIC LOAD = 1,196.25 KIPS

$$F.S. = \frac{1196.25}{350.} = \underline{\underline{3.42}} > \underline{\underline{2.0}} \quad \underline{\underline{GOOD}}$$



TEST FIXTURE

LOADING HEAD

TOP LUG

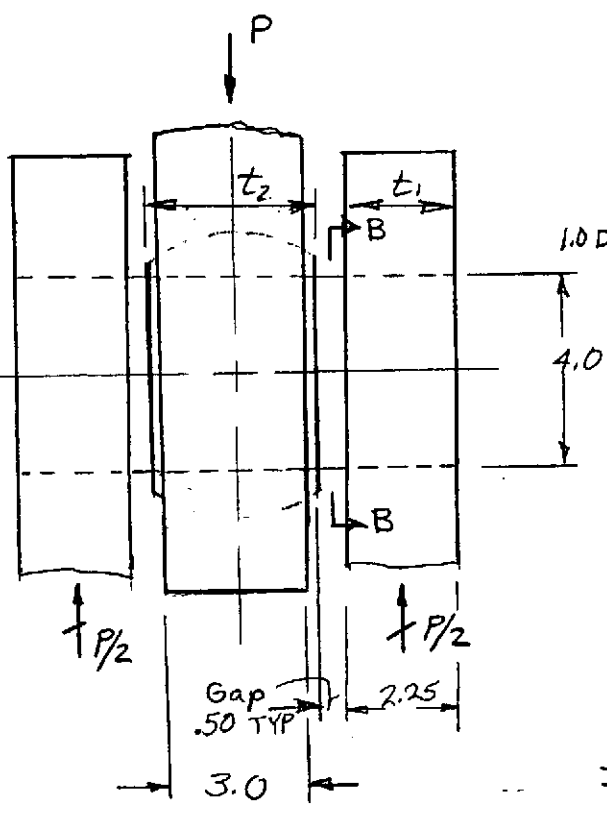
PIN ④

DRW. 28
SHEET 8

LOAD (P) = 350.0 KIPS

MATERIAL: 4340 Steel, H.T. to 180 KSI

REF.: ANALYSIS & DESIGN
OF FLIGHT VEHICLE
STRUCTURES by Bruhn
Page D1-9



Moment Arm on PIN (b)

$$b = .5t_1 + .25t_2 + \text{GAP}$$

$$= .5(2.25) + .25(.35) + .5$$

$$b = 2.497$$

Bending Moment on PIN, M

$$M = .5 P b = .5 (350)(2.497) = 437 \text{ IN-K}$$

$$f_b = \frac{M c}{I} = \frac{437(2.0)}{12.5} = 69.8 \text{ KSI}$$

$$F_b = 71.9 \text{ KSI (ULT)}$$

$$M.S. = \frac{71.9}{69.8} - 1. = +.03$$

SECTION B-B

$$A = .7854(D_o^2 - D_i^2)$$

$$= .7854(4^2 - 1^2)$$

$$A = 11.79 \text{ IN}^2$$

$$I = .04909(4^4 - 1^4)$$

$$I = 12.5 \text{ IN}^4$$

GOOD ←

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TEST FIXTURE

LOADING HEAD

TOP LUG

DRW. 28
SHEET 8

PIN ④ CONT'

check double shear on Pin

$$f_s = \frac{P}{2A_s} = \frac{350.}{2(11.79)} = 14.88 \text{ KSI}$$

$$F_s = 43.2 \text{ KSI}$$

$$M.S. = \frac{43.2}{14.88} - 1. = \underline{\underline{+1.90}} \quad \underline{\underline{GOOD}}$$

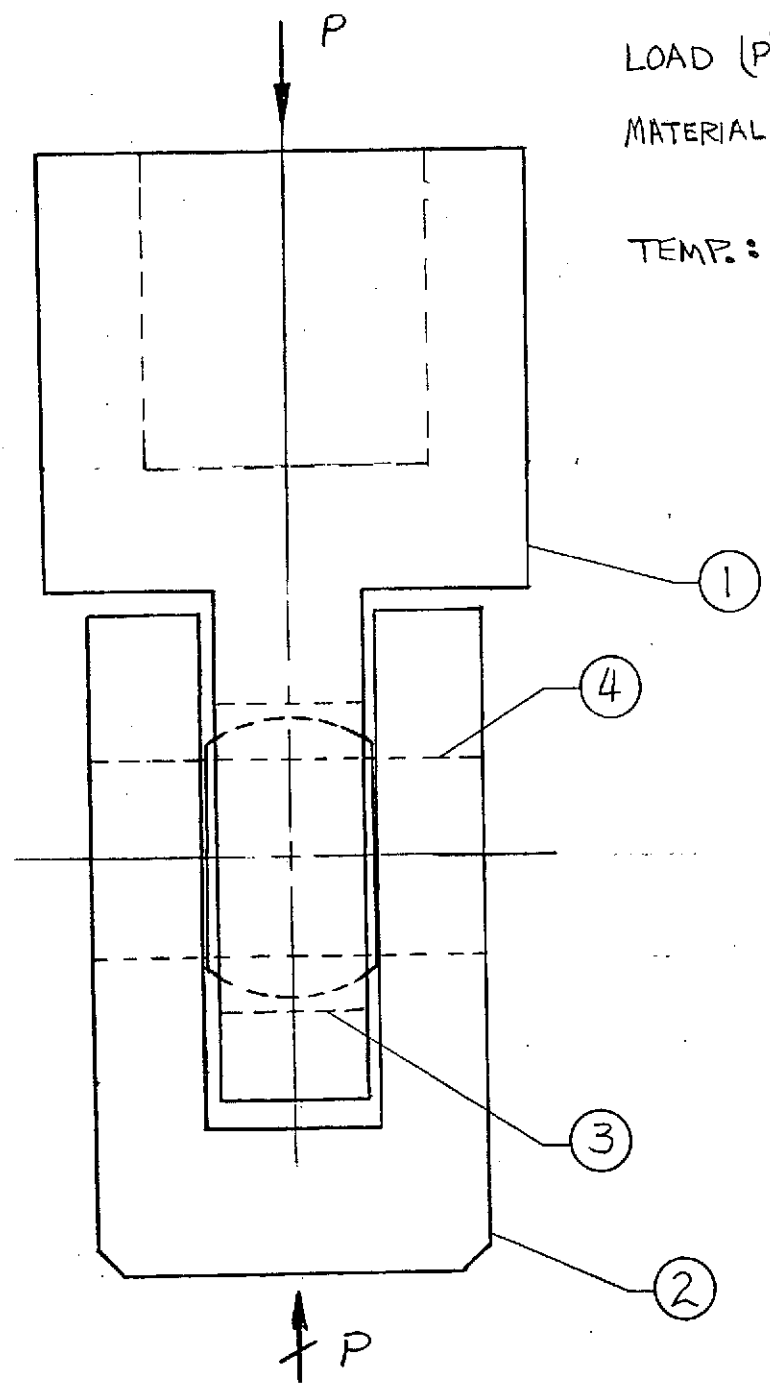


TEST FIXTURE

LOADING HEAD

BOTTOM LUG

DRW. 28
SHEET 8



LOAD (P) = 350.0 KIPS

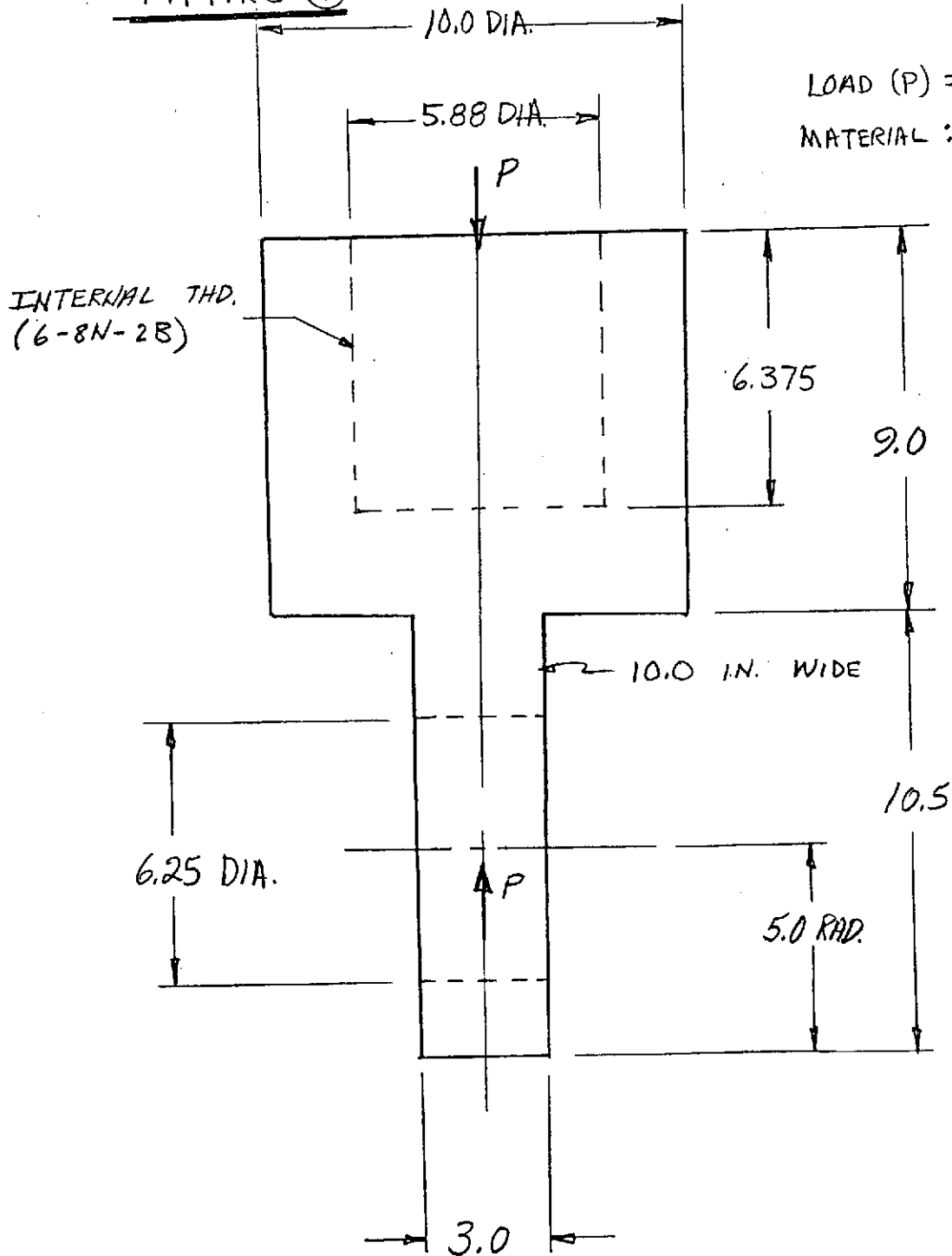
MATERIAL: AS NOTED
IN ANALYSIS

TEMP.: 600°F

TEST FIXTURE

LOADING HEAD
BOTTOM LUG
FITTING ①

DRW. 28
SHEET 8



LOAD (P) = 350.0 KIPS
MATERIAL : 4130 Steel

Prepared By PJW Date 7-28-73
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TEST FIXTURE

LOADING HEAD

BOTTOM LUG

DRW. 28
SHEET 8

FITTING ① CONT'

BEARING CHECK @ 6.25 DIA. HOLE

$$f_{br} = \frac{P}{A_{br}} = \frac{350.}{6.25 \times 3.0} = 18.68 \text{ KSI}$$

$$F_{br} = 55.7 \text{ KSI}$$

$$M.S. = \frac{55.7}{18.68} - 1. = \underline{\underline{+1.98}} \quad \underline{\underline{GOOD}} \quad \leftarrow$$

COMPRESSION IN STEM

$$f_c = \frac{P}{A} = \frac{350.}{10 \times 3} = 11.65 \text{ KSI}$$

$$F_c = 27.72 \text{ KSI}$$

$$M.S. = \frac{27.72}{11.65} - 1. = \underline{\underline{+1.38}} \quad \underline{\underline{GOOD}} \quad \leftarrow$$

Prepared By PJW Date 7-28-73
Checked By ALS Date 7-31-73
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TEST FIXTURE

LOADING HEAD

BOTTOM LUG

DRW. 28
SHEET 8

FITTING ① CONT'

INTERNAL THD. (6-8N-2B)

$$A_s' = 13.7357 \text{ in}^2/\text{in} \quad \left\{ \begin{array}{l} \text{Ref.: Boucher, R.C., Strength} \\ \text{of Threads, Product Engineering} \\ \text{Nov. 27, 1961} \end{array} \right.$$

$$A_s = 13.7357 \times 6.375 = 87.6 \text{ in}^2$$

$$f_s = \frac{P}{A_s} = \frac{350.}{87.6} = 4.0 \text{ KSI}$$

$$F_s = 19.88 \text{ KSI}$$

$$M.S. = \frac{19.88}{4.0} - 1. = \underline{\underline{+3.97}} \quad \underline{\underline{GOOD}} \quad \leftarrow$$

TEST FIXTURE

LOADING HEAD
 BOTTOM LUG
FITTING ②

DRW. 28
 SHEET 8

LOAD = 350.0 KIPS
 MATERIAL: 4130 steel

BEARING CHECK @ 6.25 HOLE

$$f_{br} = \frac{P}{A_{br}} = \frac{350}{6.25 \times 2.22} = 25.2 \text{ KSI}$$

$$F_{br} = 55.7 \text{ KSI}$$

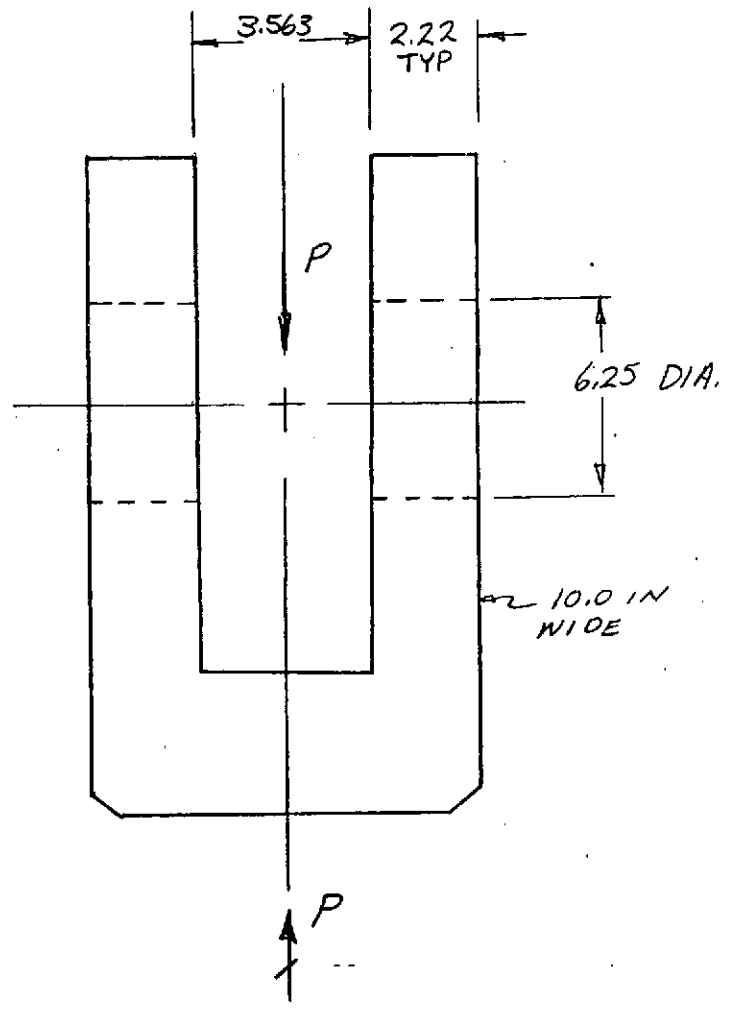
→ M.S. = $\frac{55.7}{25.2} - 1. = +1.21$ GOOD

COMPRESSION CHECK ON STEM

$$f_c = \frac{P}{A_c} = \frac{350/2}{10 \times 2.22} = 7.88 \text{ KSI}$$

$$F_c = 27.72 \text{ KSI}$$

→ M.S. = $\frac{27.72}{7.88} - 1. = +2.51$ GOOD



Prepared By PJW Date 7-28-73
Checked By ACS Date 7-31-73
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BROWN ENGINEERING

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TEST FIXTURE

LOADING HEAD

BOTTOM LUG

BEARING (3)

LOAD = 350.0 KIPS

MATERIAL : STAINLESS STEEL, (H.T.)

Bearing Part Number : BAR-64015
(Ref. Southwest Products Co., Monrovia, California)

ULTIMATE STATIC LOAD = 1196.25 KIPS
(LOADS APPROVED IN TEMP. 800°-1000°F)

$$F.S. = \frac{1196.25}{350.} = \underline{\underline{3.42}} > 2.5 \quad \underline{\underline{GOOD}}$$



TEST FIXTURE

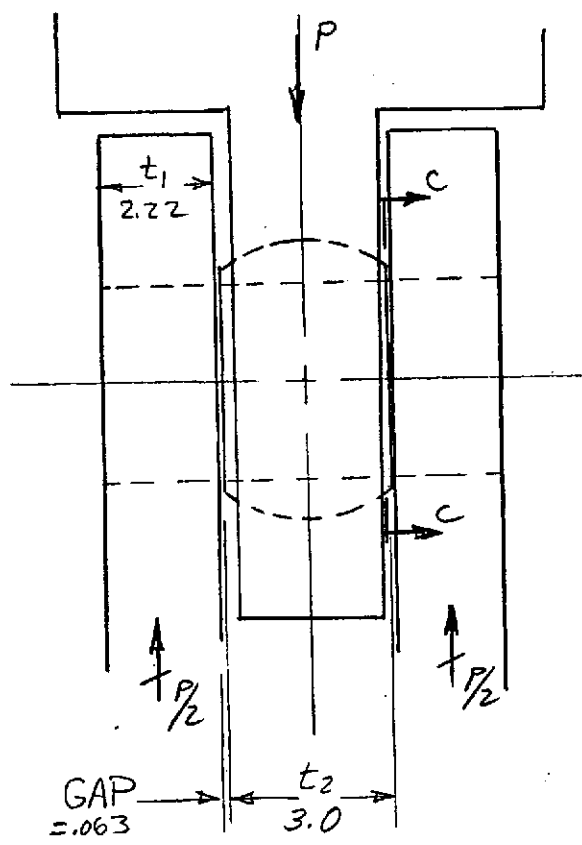
LOADING HEAD

BOTTOM LUG

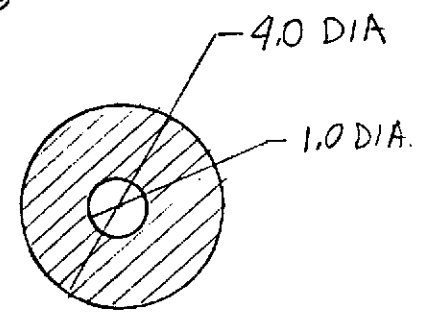
DRW. 28
SHEET 8

PIN ④

LOAD (P) = 350 KIPS
 MATERIAL: 4340 steel (H.T. to 180 KSI)



Ref.: ANALYSIS & DESIGN
 OF FLIGHT VEHICLE
 STRUCTURES, by Bruhn
 PP. D1-9



SECTION C-C
 $A = 11.79 \text{ IN}^2$
 $I = 12.5 \text{ IN}^4$

Moment Arm on PIN BENDING, (b)

$$b = \frac{t_1}{2} + \frac{t_2}{4} + \text{GAP} = \frac{2.22}{2} + \frac{3.0}{4} + 0.063$$

$$b = 1.923 \text{ IN.}$$

Bending Moment on PIN, M

$$M = \frac{Pb}{2} = \frac{350(1.923)}{2} = 336 \text{ IN-K}$$

$$f_b = \frac{Mc}{I} = \frac{336 \times 2}{12.5} = 53.75 \text{ KSI}$$

$$F_b = 64.3 \text{ KSI}$$

$$\text{M.S.} = \frac{64.3}{53.75} - 1 = \underline{\underline{+1.19}} \quad \underline{\underline{\text{GOOD}}}$$

Prepared By PJW Date 7-28-73
Checked By ALS Date 7-31-73
Revised By --- Date ---

 **TELEDYNE
BROWN ENGINEERING**

Page A3.21
Job No. ---
T. D. No. ---

TEST FIXTURE

LOADING HEAD

BOTTOM LUG

DRW. 28
SHEET 8

PIN (4) CONT'

check double shear on PIN

$$f_s = \frac{P}{2A_s} = \frac{350}{2(11.79)} = 14.88 \text{ KSI}$$

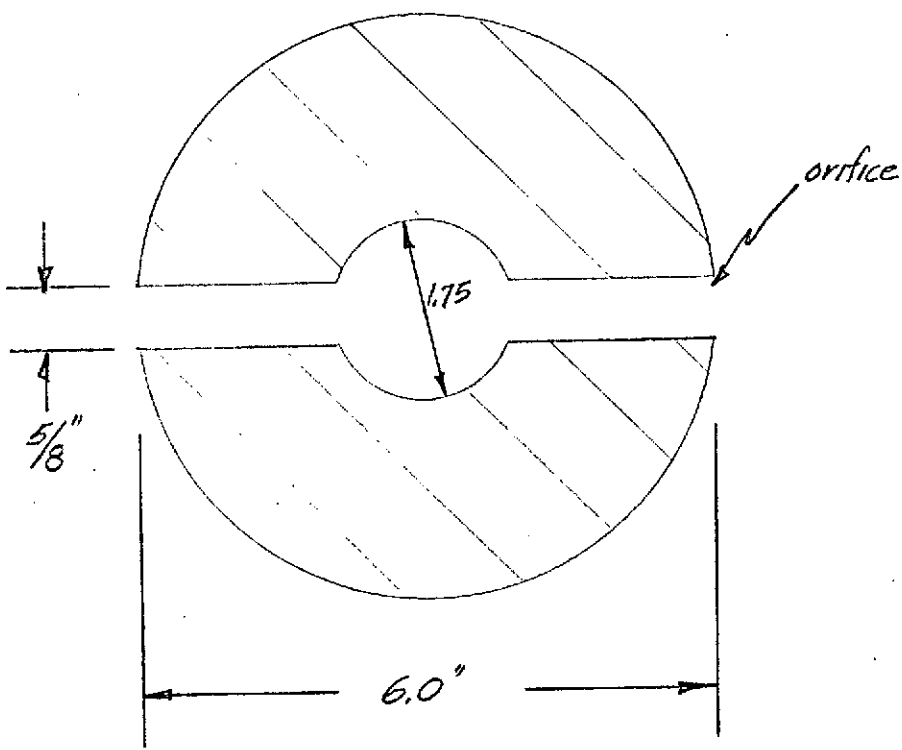
$$F_s = 39.8 \text{ KSI}$$

$$M.S. = \frac{39.8}{14.88} - 1. = \underline{\underline{+1.67}} \quad \underline{\underline{GOOD}} \quad \leftarrow$$

TEST FIXTURE

LOADING COLUMN
TUBULAR ROD

DRW
 Sheet



MATERIAL 4130

PROPERTIES:

$$F_{cu} = 90 \text{ KSI}$$

$$F_{cy} = 70 \text{ KSI}$$

Allowable Stresses

$$\frac{F_{cu}}{2.5} = \frac{90}{2.5} = 36 \text{ KSI}$$

$$\frac{F_{cy}}{2} = \frac{70}{2} = 35 \text{ KSI}$$

CROSS SECTION AREA AT FULL SECTION
 (∴ no orifice hole)

$$A_T = A_1 - A_2$$

$$A_T = 28.27 - 2.405$$

$$A_T = \underline{25.865 \text{ in}^2}$$

$$I_T = I_1 - I_2$$

$$I_T = 63.62 - 0.46$$

$$I_T = \underline{63.16 \text{ in}^4}$$

TEST FIXTURE

LOADING COLUMN

TUBULAR ROD (CON'T)

DRW
Sheet

STRESS CONCENTRATION AROUND ORIFICE HOLE

$$\frac{\sigma_{max}}{\sigma} = 2.53 \quad (\text{for hole with bead})$$

Ref. Strength of
Material, Part II,
Timo., pg 305

Stress concentration at edge of
hole :

$$\sigma_{max} = \frac{2.53 P}{A}$$

$$\sigma_{max} = \frac{2.53 (350)}{25.865}$$

$$\underline{\sigma_{max} = 34.2 \text{ ksi}}$$

$$MS = \frac{35.0}{34.2} - 1$$

$$\underline{MS = 0.0272}$$

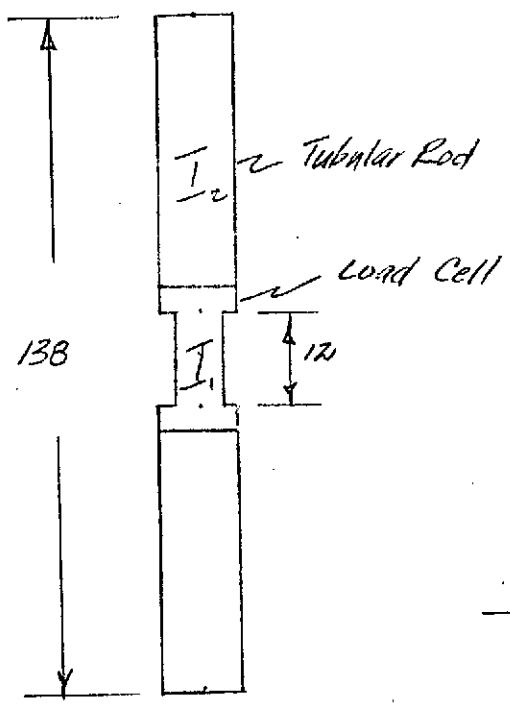
TEST FIXTURE

LOADING COLUMN

DRW
Sheet

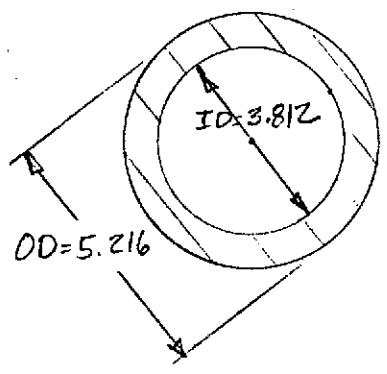
VARIABLE CROSS-SECTION COLUMN ANALYSIS

Ref: A. Structures Manual
C.1.4.0 pg 28



In the variable cross-section column analysis only two variations in the cross-section are allowed. The loading head consists of several parts which have distinct cross-sections. In this analysis, the two minimum cross-sections will be used; a conservative approach.

Load Cell: $I_1 = \frac{\pi}{64} (D^4 - d^4)$



$$I_1 = \frac{\pi}{64} (5.216^4 - 3.812^4)$$

$$I_1 = \frac{\pi}{64} (740.19 - 211.16)$$

$$I_1 = \frac{\pi}{64} (529)$$

$$\underline{I_1 = 25.968 \text{ in}^4}$$

Tubular Rod: $\underline{I_2 = 63.16 \text{ in}^4}$

from pg —

TEST FIXTURE

LOADING COLUMN

VAR. CROSS-SEC. COL. ANALYSIS (CONT)

$$P_c = \frac{\pi^2 (EI)_1}{m L^2}$$

$$\frac{(EI)_1}{(EI)_2} = \frac{E 25.968}{E 63.16}$$

$$P_c = \frac{9.89 (29,000) 25.968}{.51 (138)^2 \cdot 19000}$$

$$\frac{(EI)_1}{(EI)_2} = 0.41$$

and

$$P_c = 766 \text{ KIPS}$$

$$\frac{q}{L} = \frac{12}{138} = 0.086$$

$$\therefore m = 0.51$$

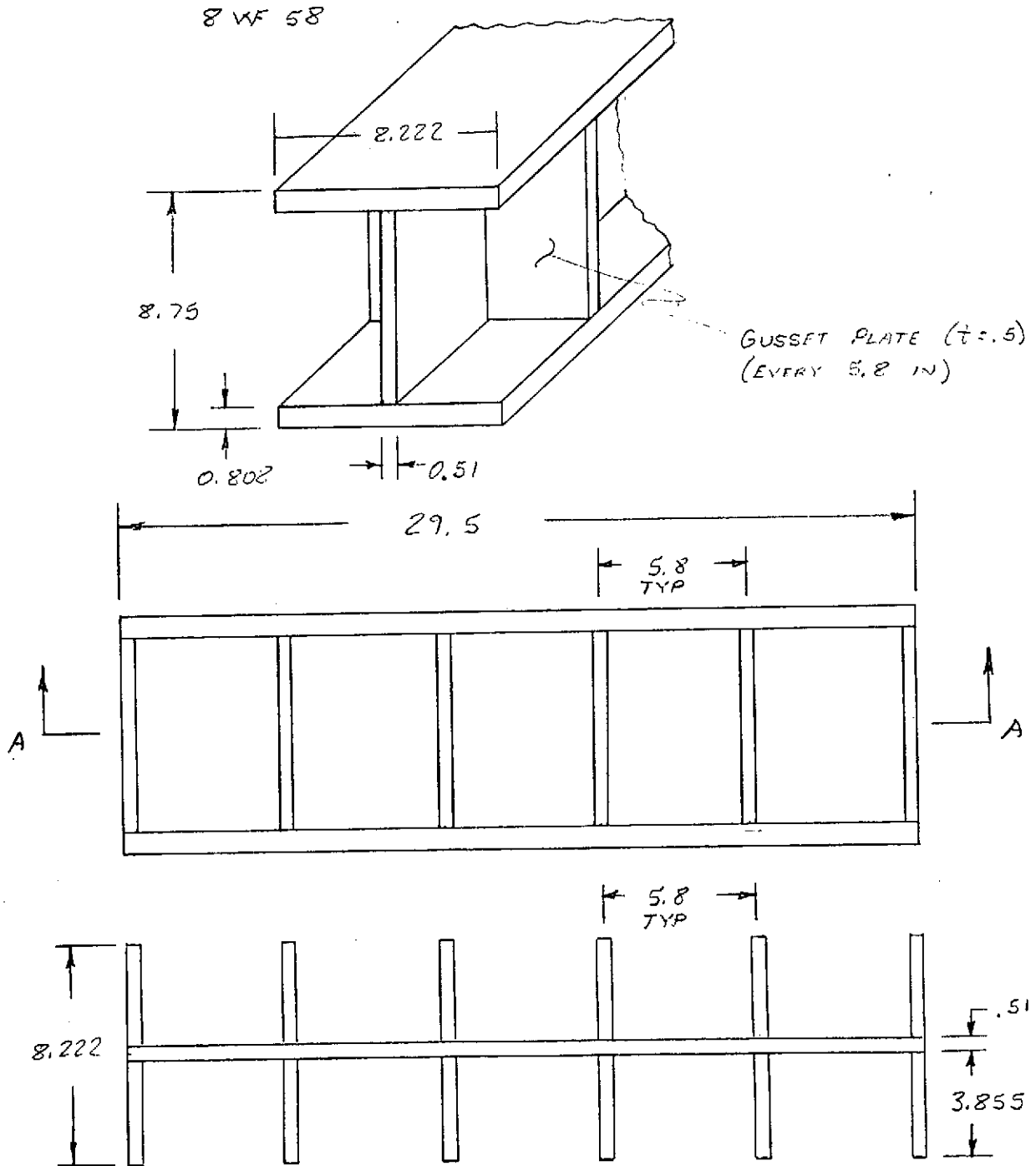
FACTOR OF SAFETY

$$FS = \frac{766}{350} = 2.19 < 2.5$$

TEST FIXTURE

LOADING BEAM

UNIFORM LOADED PANELS



SECTION A-A

TEST FIXTURE

LOADING BEAM

UNIFORM LOADED PANELS

AREA SECTION A-A

$$A_w = 29.5 (.51) = 15.045$$

$$A_g = 12 (3.855)(0.5) = \underline{23.13}$$

$$A_T = 38.175$$

AXIAL STRESS :

$$\sigma = \frac{P}{A} = \frac{209,000 \text{ LB}}{38.175 \text{ IN}^2} = 5475 \text{ PSI}$$

BUCKLING ALLOWABLE OF GUSSET PLATE

$$\sigma = \frac{K \pi^2 E t^2}{12 (1-\mu^2) b}$$

REF. DESIGN OF WELDED
STRUCTURES, PG 2.12-1

$$\sigma = \frac{K \pi^2 (26.24 \times 10^6) (.5)^2}{12 (.91) (3.855)}$$

$\sigma = \text{HIGH}$

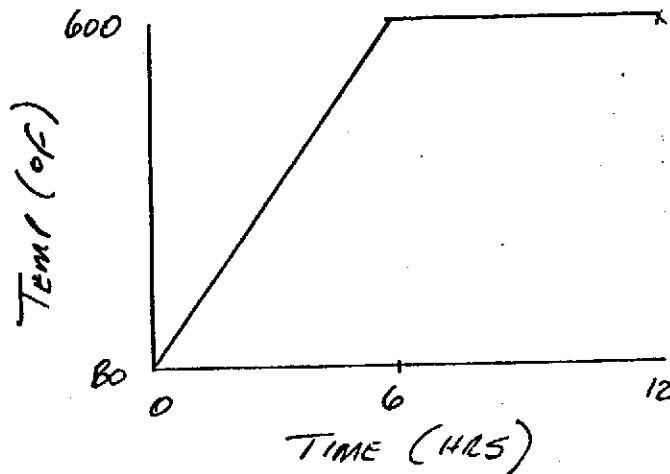
A4.0

LOADING COLUMN
THERMAL ANALYSIS RESULTS

LOADING HEAD THERMAL

A. ASSUMPTIONS:

1. COOLING WATER FLOWRATE OF 1000 GALL/HR @ 80°F
2. MAT'L IS A130 STEEL
3. COMPRESSION PANEL TEMPERATURE HISTORY AS SHOWN BELOW.



4. TUBULAR FITTINGS DIMENSIONS (6" O.D.; 2" DIA. BORE)
5. INITIAL TEST FIXTURE @ APPROX. 80°F.

B. RESULTS:

1. MAINTAINING LOAD CELL TEMPERATURES BELOW 175°F, CAN BE ACCOMPLISHED WITH PRESENT DESIGN. (SEE ATTACHED FIGURES.)
2. HYDRAULIC CYLINDER TEMPERATURE SHOULD REMAIN CONSTANT DURING TEST. (NO SOAK BACK FROM COMPRESSION PANEL)

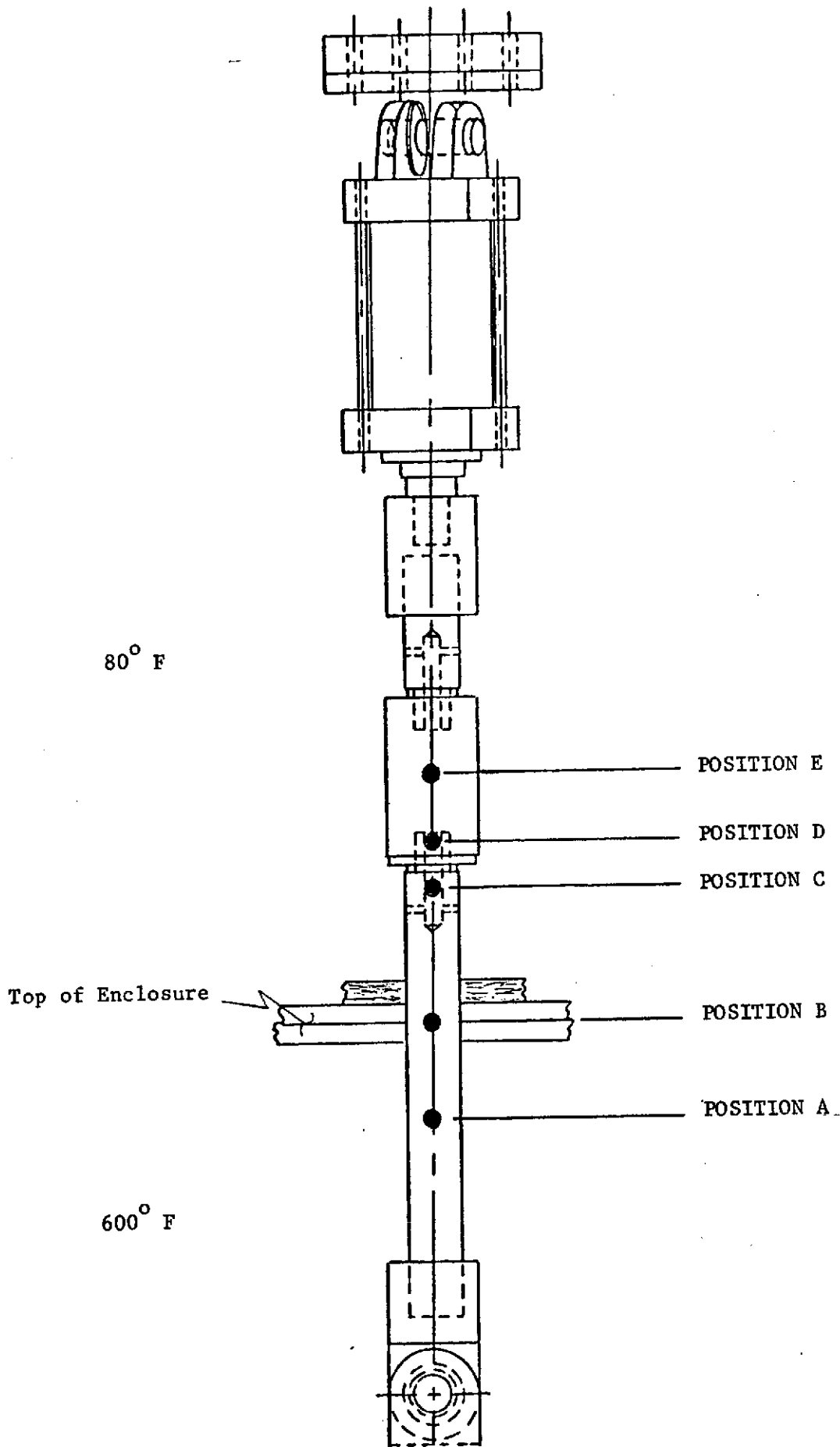
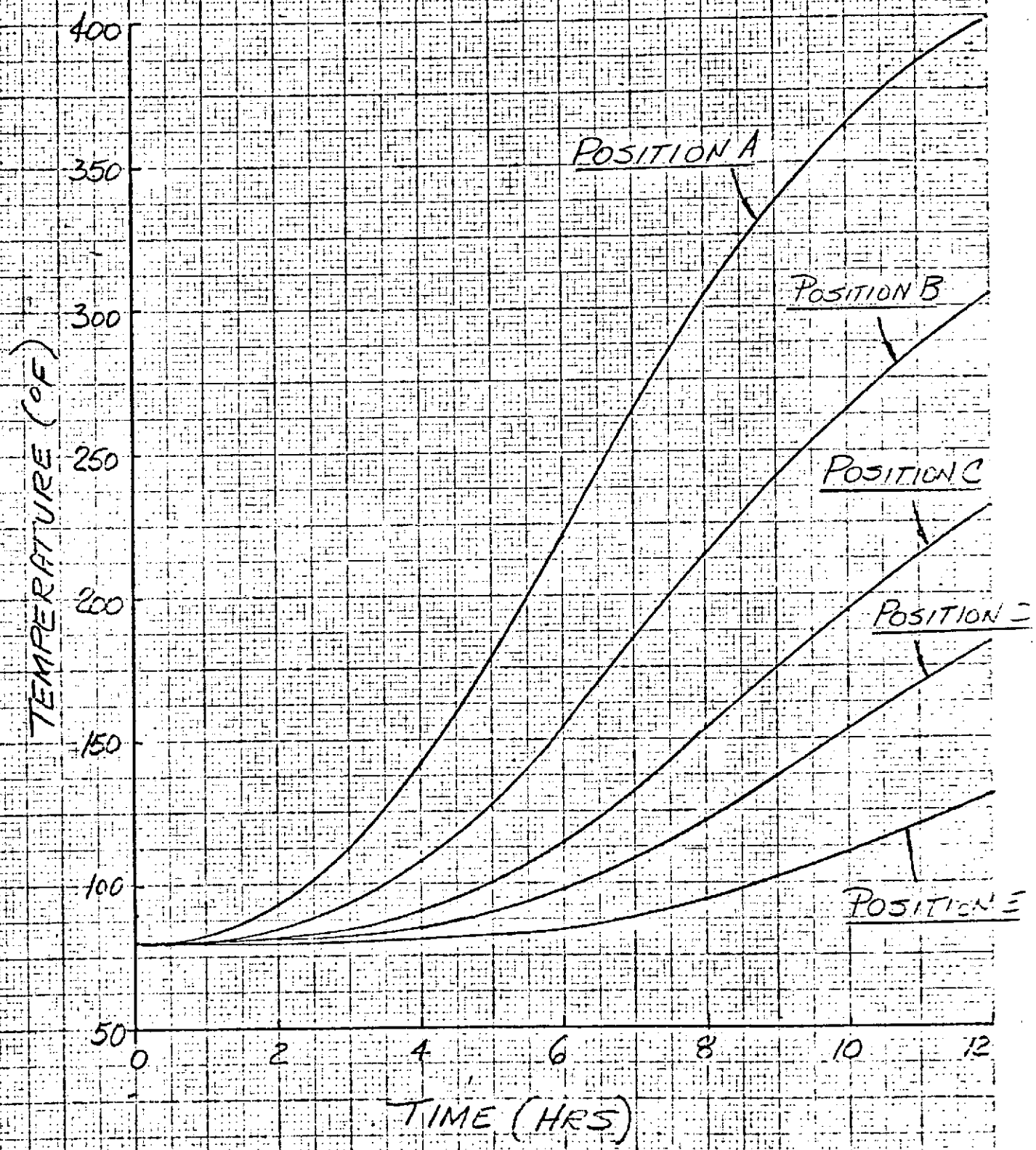


FIGURE 1. LOCATION OF THERMAL NODE POINTS ON THERMAL MODEL OF LOADING COLUMN

NOTES: 1. NO H₂O FLOW



LOADING HEAD TRANSIENT TEMPERATURES