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R-CR-74-028

**MONOLITHIC HIGH STRENGTH
ALUMINUM BOTTOM CARRIAGE
STRUCTURE FOR
155mm HOWITZER, XM198**

May 1974

Final Report



PREPARED BY

NORTHERN ORDNANCE DIV. - FMC CORP.
MINNEAPOLIS, MN 55421

CONTRACT NO. DAAF03-73-C-0065

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ARTILLERY & ARMORED WEAPONS SYSTEMS DIRECTORATE**

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Technical Report: R-CR-74-028, dated May 1974

Title: MONOLITHIC HIGH STRENGTH ALUMINUM BOTTOM CARRIAGE STRUCTURE
FOR 155MM HOWITZER, XM198

Author: Northern Ordnance Div - FMC Corporation

Replace ~~the following~~ pages with pages attached:
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Insert new Appendix D (attached) after Page 107
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19 REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER RIA-R CR-74-028	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 9	
4. TITLE (and Subtitle) MONOLITHIC HIGH STRENGTH ALUMINUM BOTTOM CARRIAGE STRUCTURE FOR 155MM HOWITZER, XM198.		5. TYPE OF REPORT & PERIOD COVERED FINAL REPORT. MAR 73-APR 74.	
7. AUTHOR(s) NORTHERN ORDNANCE DIVISION		6. PERFORMING ORG. REPORT NUMBER	
9. PERFORMING ORGANIZATION NAME AND ADDRESS FMC CORPORATION MINNEAPOLIS, MN 55421		8. CONTRACT OR GRANT NUMBER(s) 15 DAAF03-73-C-0065	
11. CONTROLLING OFFICE NAME AND ADDRESS ARTILLERY & ARMORED WEAPON SYSTEMS DIRECTORATE ROCK ISLAND, ILL 61201		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 16 1X664614D379	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 12 133p.		12. REPORT DATE MAY 1974	
		13. NUMBER OF PAGES 109	
16. DISTRIBUTION STATEMENT (of this Report) APPROVED FOR PUBLIC RELEASE DISTRIBUTION UNLIMITED		15. SECURITY CLASS. (of this report) U	
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A	
18. SUPPLEMENTARY NOTES			
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) HOWITZER, 155MM, XM198 BOTTOM CARRIAGE DESIGN ALUMINUM CASTING BOTTOM CARRIAGE STRESS ANALYSIS			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) THIS FINAL REPORT SUMMARIZES THE CONTRACTOR'S EFFORT TO CONDUCT ENGINEERING STUDIES AND TO PRODUCE A HIGH STRENGTH ALUMINUM BOTTOM CARRIAGE FOR THE XM198 155MM HOWITZER; THIS EFFORT IS A FOLLOW-UP TO CONTRACT NO. DAAF01-72-C-0150. ENGINEERING CALCULATIONS, TECHNICAL DATA, AND PHOTOGRAPHS OF THE FINISHED CASTING, THE MOLD, AND THE POURING OPERATION ARE PRESENTED. TECHNICAL PROGRESS REPORTS ARE ALSO INCORPORATED TO GIVE A CHRONOLOGICAL SYNOPSIS OF THE WORK ACCOMPLISHED.			

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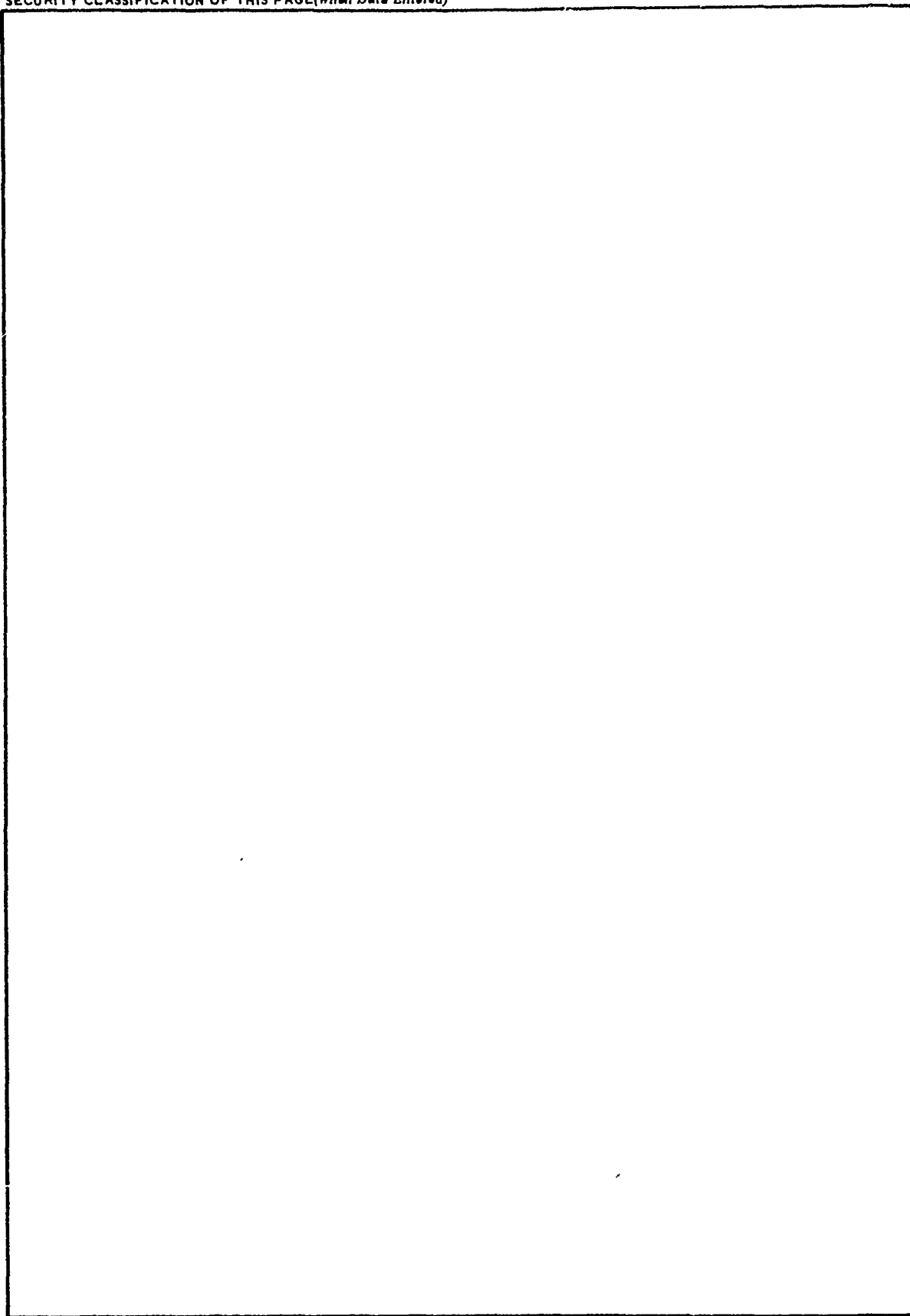
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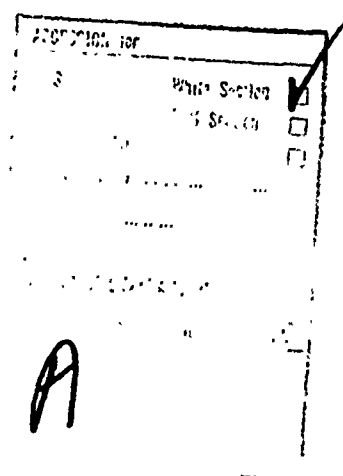
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CONTRACT DAAFO3-73-C-0065

MONOLITHIC HIGH STRENGTH ALUMINUM BOTTOM
CARRIAGE STRUCTURE FOR 155MM HOWITZER XM198

This report is submitted in accordance with item A003AA of DD Form 1423 which constitutes Exhibit A to Contract DAAFO3-73-C-0065.

INTRODUCTION

Contract DAAFO3-73-C-0065 was issued to FMC Corporation/Northern Ordnance Division on 12 March 1973. The contract requested four Aluminum Bottom Carriages for use on the 155mm Howitzer XM198. The amount of the contract was \$53,640.46 including a fixed cost of \$4,429.03. An address error in the original contract was corrected by Amendment 1 dated 30 March 1973. Amendment 2, dated 1 June 1973, extended the delivery schedule. Shipping information was changed by Amendment 3 dated 6 August 1973. Amendment 4, dated 29 October 1973, permitted defects up to 3/4 inch long to be acceptable in all areas except the hinge areas and the rear structure. Preliminary data in E.C. 950 Redesigned 155mm Howitzer Bottom Carriage Aluminum Casting Stress Analysis, was submitted to Rock Island Arsenal on 27 August 1973.

Weld repair attempts on four initial castings, while showing some improvement, were never 100% successful with new cracks developing as each repair was completed and heat-treated. These problems were brought to the attention of Mr. Avery Kearny, Chief Metallurgist

of the Olin Aluminum Division, who was one of the leaders in the development of the KO-1 aluminum alloy. It was his judgement that our basic problem was micro-shrinkage. The micro-shrinkage provided conditions causing propagation of new cracks as a result of stresses induced during weld repair of defects. It was suggested that the micro-shrinkage could be overcome by the judicious placement and increase in number of risers in making the mold. The risers help bring about controlled solidification of the casting.

Considering micro-shrinkage as the basic problem, it was established that all poured castings were unreparable. With a minimum amount of remaining funds, evaluation of a new course of action was necessary. Effort was directed to making pattern changes and to developing improved riser placement in order to overcome the micro-shrinkage.

On 6 November 1973, sufficient additional funds were added to the contract by telegram to permit completion and shipment of one casting. The initial casting, under the new effort, required a fair amount of repair, but comprehensive inspection indicated that most of the micro-shrinkage problem was solved.

Amendment 6, dated 18 December 1973, reduced the quantity of Aluminum Bottom Carriages from four to two, increased the estimated cost by \$6,305.00, extended the delivery schedule,

and deleted the draft copy of the final technical report. Re-manufacture of the first casting was completed and shipped on 18 December 1973. Manufacture of the second casting was completed and shipped in April 1974.

CASTING KO-1 ALUMINUM

KO-1 Aluminum is an aluminum alloy containing silver, manganese, magnesium, titanium, and copper. The aluminum alloy is as strong as steel, but is more desirable than steel due to its lightweight quality. The alloy melts from 1225° F to 1250° F. The alloy melt is superheated to 1400° F before it is poured into the mold. Two crucibles and two pouring ladles (figure B-5) fill the mold with the KO-1 Aluminum at 1325° F.

The mold has two sections — the drag half (figure B-1) and the cope half (figure B-3) — which together form the pattern for the casting. Sand is the molding medium. Air set is the process for solidifying the melt. The facing sand, the part of the mold that forms the pattern next to the melt, is a fine texture #97 sand treated with Chem Res 280 and phosphoric acid. The backup sand, outside of the facing sand, is a coarse texture #2 sand. Isocure bonded #97 sand forms the core material (figure B-2). The center of the core (figure B-2) is Isocure bonded-Zircon sand. To prevent excessive shrinking in some areas of the casting, metal strips, called chills, are placed in the mold where the

shrinkage occurs. The chills are composed of iron or steel strips and vary in thickness from 1/2 inch to 3 inches. The location of the chills used on the castings can be seen in figure B-10. The placement of the chills in the drag half of the mold can be identified in figure B-1 by the dark color of the metal strips compared to the light color of the sand background. Figure B-3 shows 13 risers that provide reservoirs of melt to the mold while the molten aluminum cools and contracts.

The melt solidifies and cools to room temperature in 5 days of natural aging before the casting is removed from the mold. To reduce stress and ensure uniformity of the metals in the alloy, the casting is heat-treated. Seven thermocouples monitor the casting during the heat-treatment. The temperature of the casting is raised to 940° F for 2 hours and then elevated to 986° F - 993° F for 20 hours. Next the casting is immersed in a 30% solution of Ucon Quenchant A in water. The casting does not fully immerse in the quenchant due to the large size of the casting and the limited size of the quenchant container. The part of the casting that is not immersed (figure B-11, sheet 1) is quenched with water applied by two fire hoses for 5 minutes.

The heat-treated casting is tested for defects using the dye penetrant inspection method in accordance with MIL-I-6866, type 1, method A. Defects found in the first delivered casting are shown in figure B-11; defects found in the second delivered casting are shown in figure B-12.

Defects were removed with a Carballoy cutter. After the casting was heated to the proper temperature, weld areas and surrounding areas were thoroughly cleaned with a stainless steel wire brush or wheel. The cleansed areas were then protected from contamination.

The welding position was usually horizontal. A few small surface welds (cosmetic welds) in noncritical areas were welded in the vertical position.

The time between joint preparation and weld repair was normally less than 15 seconds. When the type of welding process changed, the second weld machine was prepared beforehand to minimize the time delay. In this case, about 1/2 minute time delay occurred.

Pass times were not measured because welds were made as a continuous pass. Each weld area was given a generous fillet. No official record of weld repairs was made. If a weld repair was found defective, it was removed and rewelded.

A couple problems were encountered during weld repair. Wire stoppages in the Mig gun occurred due to the wire being seized in the gun. The Mig machine failed once due to an internal malfunction. No gas flow changes were observed.

Three welding processes are in general use; GMAW (Mig), GTAW (Tig), and PAW (Plasma). All three welding processes were hand operated.

WELDING PROCESS PARAMETERS

Parameter	Mig	Tig	Plasma
Amperage	160-220	180-250	50-100
Voltage	22-26	12-14	Not available
Wire feed	190 in./min at 170 amp +10 amps/+11 in./min	Not applicable	Not applicable
Filler metal			
Type	KO-1 Aluminum	KO-1 Aluminum	KO-1 Aluminum
Size	1/16-in. spooled wire	1/8- by 36-in. rod	1/8- by 36-in. rod
Cleanliness	No other wire used after machine was cleaned	Rod removed from container when used	Rod removed from container when used
Shielding gas			
Type	Argon	Argon	Helium
Flow rate	20-30 CFH	10-20 CFH	20-30 SCFH
Electrode type	Not applicable	Tungston with 2% Thorium	Not applicable
Unit used			
Make	AIRCO-Pulse Arc Power	Miller Heliarc	Thermal ARC
Mod	3-DCPA-224A	Model 340 AB-P	WC-100 Control
Welding configuration	Gun AIRCO AH-20P	Linde Heliarc torch HW18-300A	PWH/M-5A Plasma welding torch
Plasma			
Gas	Not applicable	Not applicable	Argon
Flow rate	Not applicable	Not applicable	2.0 SCFH

The defects in the first delivered casting (figure B-11) were corrected by mig, tig, and plasma welds. Mig welds use wire and argon gas; plasma welds use rods and ionized gas. Large surface welds are preheated for 3 hours at 800° F and postheated for 1 to 2 hours at 800° F. Small surface welds are preheated for 3 hours at 600° F and postheated for 1 to 2 hours at 600° F. Deep welds, difficult to reach, are preheated and postheated to 300° F. Defects in the second delivered casting (figure B-12) were corrected by mig welds only.

After all the detected defects are corrected by welds, the casting is heat-treated and inspected for defects once more. When the point of zero defects is reached, the casting is prepared for delivery. After the final heat-treatment, no repair welding is performed.

The actual weight of the casting is 1030 pounds. Machining the casting will reduce the weight to 890 pounds. The calculations for finished weight is found in Appendix A.

Appendix A consists of a stress analysis of the 155mm Howitzer XM198 redesigned bottom carriage aluminum casting E.C.950 and machined weight calculations based on a casting weight of 1030 pounds.

Appendix B contains photographs and drawings. The photographs (figure B-1 through B-8) show the mold, pouring operation, and views of the finished casting. The detail drawing of the bottom carriage casting (figure B-9) is also used to show the location

of chilled areas (figure B-10) and defects in the two castings (figures B-11 and B-12). Appendix C contains copies of the Technical Progress Reports that were submitted in accordance with item A00201 of DD Form 1423 (Exhibit A to Contract DAAF03-73-C-0065).

MAJOR PROBLEMS ENCOUNTERED

The seven Technical Progress Reports in Appendix C give a chronological synopsis of the work accomplished. In August 1973, two castings were poured. The first casting had too many defects to be given consideration for use as the first shipment. The second casting was poured with better results, but the sand set up too hard and was quite difficult to remove. The mold-making technique was improved by reducing the amount of binder in the sand to assure easier shake-out.

In September 1973, two more castings were poured. Both castings had cracks in the basic casting. A number of weld repairs by a variety of procedures, depending on size and location of the defect, were attempted with a certain degree of success; but we could not achieve a casting with zero defects. New cracks developed as repairs were corrected and heat-treated.

Internal cracks in the basic casting were reduced by increasing the number of risers in making the mold. The risers kept the top of the melt in a liquid form longer. This allowed the

solidification of the KO-1 Aluminum to proceed from the bottom to the top, instead of from the outside to the center. The first shipped casting had 13 risers in its mold and the second shipped casting had 43 risers in its mold.

To further reduce micro-shrinkage, the rough casting was heat-treated before weld repairs were attempted. The number of new cracks developed during weld repair was reduced.

Shrinkage of fillets and some heavy sections on the casting still posed a problem. The fillet shrinkage was solved by increasing the radii of the corners. This additional material will have to be machined, but this action did solve the problem of shrinkage and cracking at the fillets. Additional chills were used to reduce shrinking in the heavy sections.

CONCLUSION

Although each casting poured has had defects, improvement has been made in casting KO-1 Aluminum for the bottom carriages. KO-1 Aluminum is a critical material to cast in the bottom carriage configuration but we have produced some satisfactory castings under the prior development contract. The nature of KO-1 Aluminum is such that some repair may always be required but that successful castings should be achieved by paying close attention to the process developed for preparing the mold and for pouring the casting. The mold-making technique was improved

three ways: (1) by reducing the amount of binder in the core, (2) by placing a circular groove in the bottom of the core over the metal chills, and (3) by the additional use and placement of risers in the cope half of the mold.

Reducing the amount of binder prevents excessive hardness of the core sand to increase collapsibility and to ensure easier shake-out. Increasing the collapsibility of the core reduces the chances of cracking around the core as the casting contracts during solidification.

Placing a circular groove in the bottom of the core over the metal chills permits the chills to move as the casting contracts. Large cracks developed in the basic casting around the chills when the chills had no room for movement as the solidifying casting cooled.

The additional use and placement of risers in the mold permits a slower and more controllable solidification. The controlled solidification reduces internal stress and results in castings with fewer and smaller defects. In addition, the reduction of internal stresses is aided by the use of a preliminary heat-treatment prior to weld repair.

The number of new cracks appearing during weld repair has been substantially reduced. Future castings of the KO-1 Aluminum in the bottom carriage configuration should require one weld repair stage before the final heat-treatment.

Appendix A
ENGINEERING CALCULATIONS
and
TECHNICAL DATA

E. C 950
Sheet 1
Sheets 50

FMC CORPORATION
NORTHERN ORDNANCE DIVISION
Minneapolis, Minnesota

ENGINEERING DEPARTMENT

155MM HOWITZER
REDESIGNED BOTTOM CARRIAGE ALUMINUM CASTING
STRESS ANALYSIS

E. C. 950

CODE IDENT. NO. 44114

Prepared by: F. B. Morse, Jr.
R. H. Wiethoff
Examined by: D. L. Beihoffer
Date: 13 August 1973

FOREWORD

The structure analyzed in this report is a redesigned aluminum sand casting. It is similar to the first casting design that underwent successful simulated loading and actual firing tests. A stress analysis was performed on the first design in E.C. 922.

In the present design, modifications were made to reduce the stress caused by firing. As a result, the purpose of this calculation is to verify that the redesigned 155MM Howitzer Bottom Carriage can take the loads induced from firing. It is cast out of the same material as the first design, KO-1 aluminum alloy, supplied by Aluminum Division, Olin Corporation.

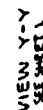
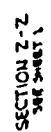
The stress analysis is based on gravity loads plus a maximum recoil brake load of 70,000 lb which was increased to 80,000 lb to account for dynamic effects. Other areas, loaded under various conditions, were examined for possible overstress and found to be safe. These minor stress calculations are not included in this report.

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III. Bottom Carriage With Trails: Geometry and Force Analysis

A. Gravity Loads at the Recoil Position

Using the diagrams shown on sheet 8, the force contribution due to gravity can be calculated for any angle Θ and β . The equations are then shown for $\beta = 0^\circ, 11.25^\circ$, and 22.5° with Θ allowed to vary from 0° to 75° .

$$\sum M_{F_1} = 0 = -(F_2 + F_3) 218.7 + 4800 \times 95.75 + 1226 \times 34.75 + 8150 (34.75 + 28.25 \cos \beta - 60 \cos \Theta \cos \beta)$$

$$(1) \quad F_2 + F_3 = 2591.306 + 1052.765 \cos \beta - 2235.96 \cos \Theta \cos \beta$$

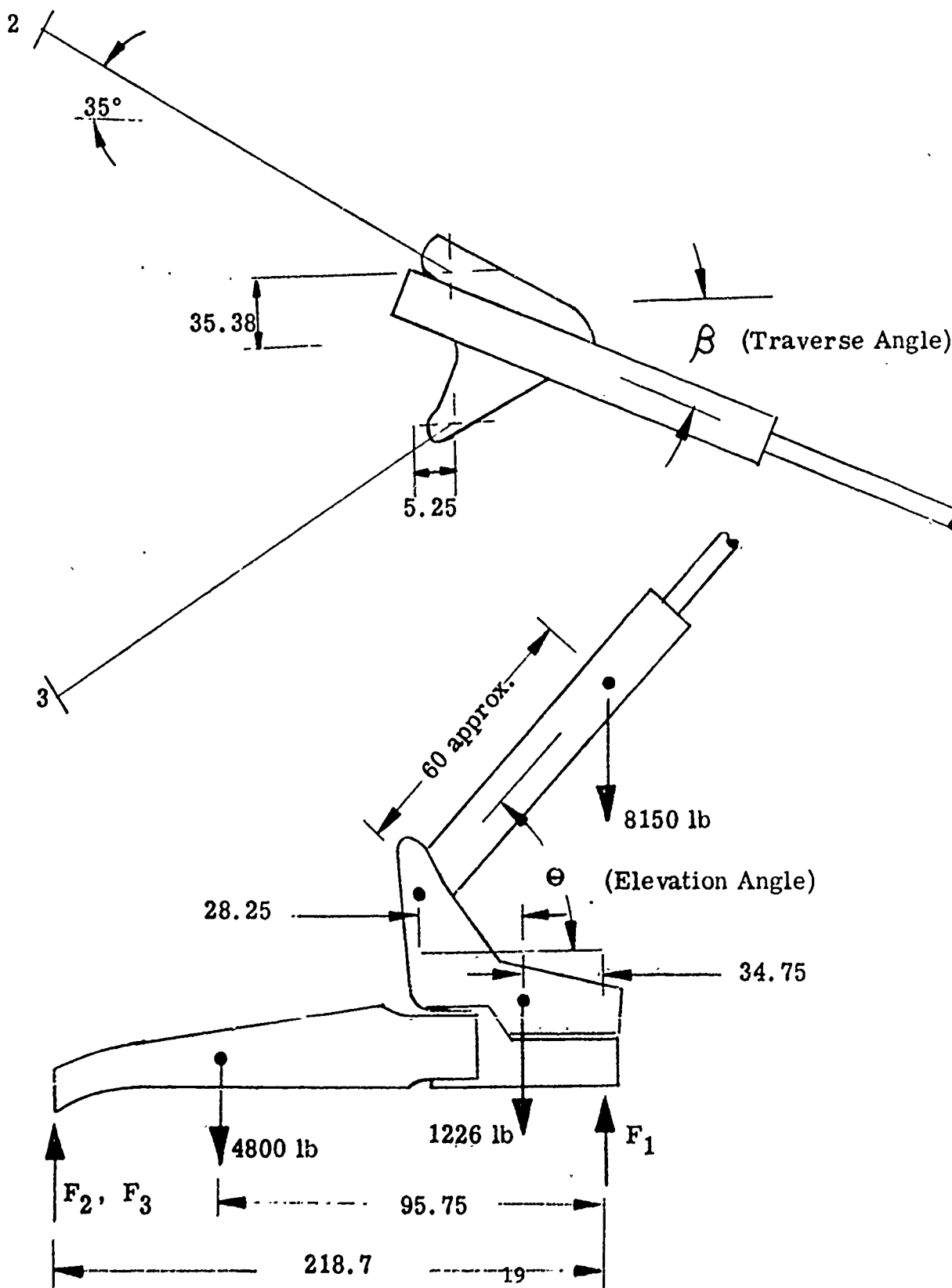
$$\sum M_{F_1} = -F_2 (196.5 \sin 35^\circ + 35.38) + F_3 (196.5 \sin 35^\circ + 35.38) + 8150 (28.25 \sin \beta - 60 \cos \Theta \sin \beta)$$

$$(2) \quad F_2 - F_3 = 1554.734 \sin \beta - 3302.091 \cos \Theta \sin \beta$$

$$\sum F_V = 0 = F_1 + F_2 + F_3 - 14,176$$

$$(3) \quad F_1 + F_2 + F_3 = 14,176 \text{ lb}$$

GRAVITY LOADS AT RECOIL



Solving for F_1 , F_2 and F_3 (g indicates gravity)

$$F_{1g} = 10,585 - \cos \beta (1,052 - 2,236 \cos \Theta)$$

$$F_{2g} = 1,796 + \sin \beta (777 - 1651 \cos \Theta) + \cos \beta (526 - 1118 \cos \Theta)$$

$$F_{3g} = 1,795 + \sin \beta (-778 + 1651 \cos \Theta) + \cos \beta (527 - 1118 \cos \Theta)$$

Because these equations will be combined with the recoil contribution, they are rewritten in terms of F (recoil force = 80,000 lb).

$$F_{1g} = F \left[.1323 - \cos \beta (.0132 - .0280 \cos \Theta) \right]$$

$$F_{2g} = F \left[.0225 + \sin \beta (.0097 - .0206 \cos \Theta) + \cos \beta (.0066 - .0140 \cos \Theta) \right]$$

$$F_{3g} = F \left[.0224 + \sin \beta (-.0097 + .0206 \cos \Theta) + \cos \beta (.0066 - .0140 \cos \Theta) \right]$$

The equations are then solved for various angles of β .

For $\beta = 0^\circ$

$$F_{1g} = F(.1191 - .0280 \cos \Theta)$$

$$F_{2g} = F_{3g} = F(.0290 - .0140 \cos \Theta)$$

For $\beta = 11.25^\circ$

$$F_{1g} = F(.1194 + .0275 \cos \Theta)$$

$$F_{2g} = F(.0310 - .0177 \cos \Theta)$$

$$F_{3g} = F(.0290 - .0097 \cos \Theta)$$

For $\beta = 22.5^\circ$

$$F_{1g} = F(.1201 + .0259 \cos \Theta)$$

$$F_{2g} = F(.0323 - .0208 \cos \Theta)$$

$$F_{3g} = F(.0248 - .0050 \cos \Theta)$$

B. Recoil Loads

In a similar manner, the reaction forces due to recoil are calculated. The force diagram on sheet 12 is used and is reprinted from U.S. Army Government Document DAAF03-73-Q-0068.

$$\sum F_v = 0 = F_1 + F_2 + F_3 - F \sin \Theta$$

$$(1) \quad F_1 + F_2 + F_3 = F \sin \Theta$$

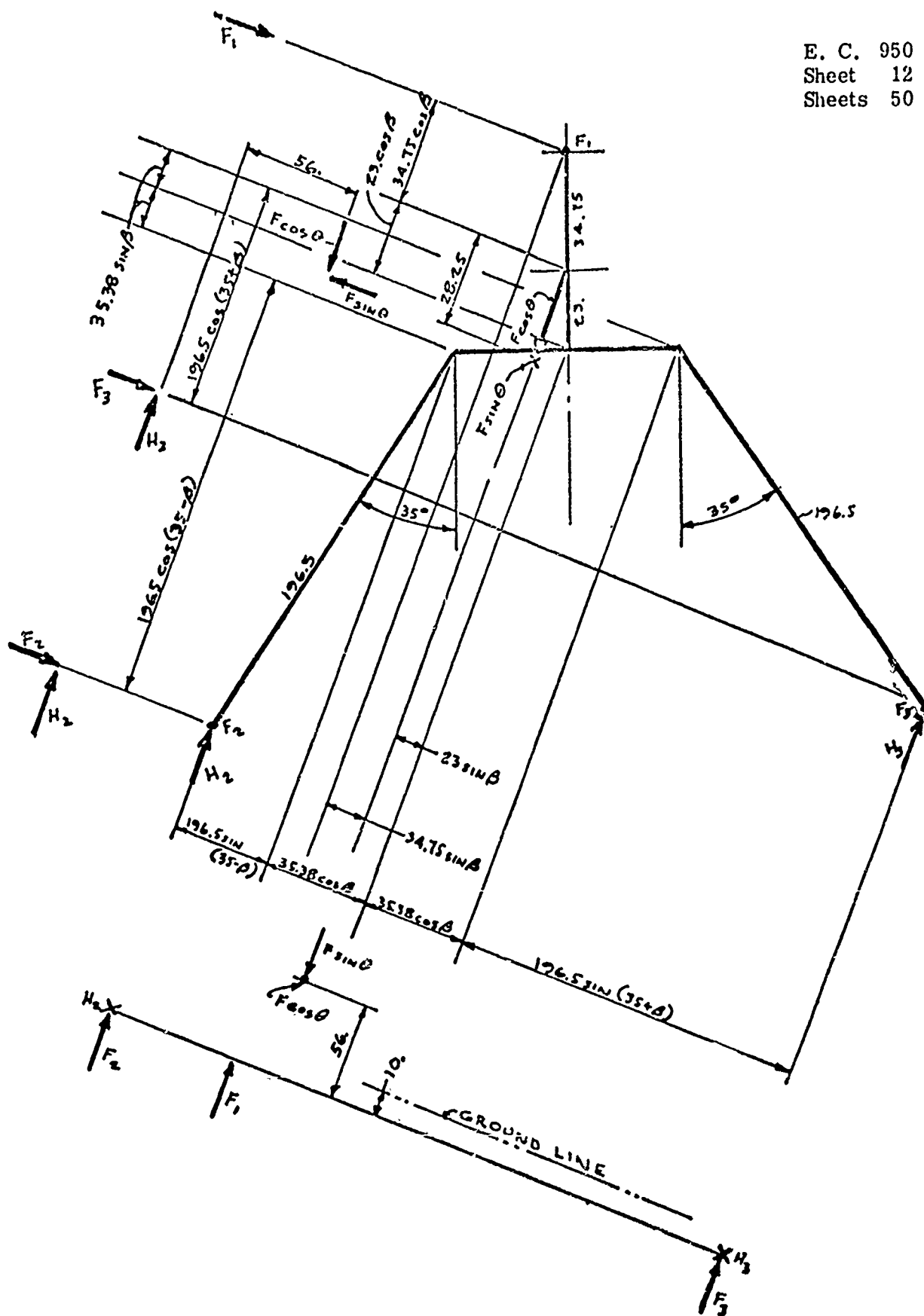
$$\sum F_H = 0 = F \cos \Theta - H_2 - H_3$$

$$(2) \quad H_2 + H_3 = F \cos \Theta$$

$$\begin{aligned} \sum M_F = 0 = & \left[196.5 \sin (35^\circ - \beta) + 35.38 \cos \beta - 23 \sin \beta \right] H_2 \\ & - \left[196.5 \sin (35^\circ + \beta) + 35.38 \cos \beta + 23 \sin \beta \right] H_3 \end{aligned}$$

$$\begin{aligned} (3) \quad & \left[196.5 \sin (35^\circ - \beta) + 35.38 \cos \beta - 23 \sin \beta \right] H_2 \\ & = \left[196.5 \sin (35^\circ + \beta) + 35.38 \cos \beta + 23 \sin \beta \right] H_3 \end{aligned}$$

E. C. 950
 Sheet 12
 Sheets 50



$$\sum M_{F_1} = 0 = \left[196.5 \sin(35^\circ - \beta) + 35.38 \cos \beta - 23 \sin \beta - 34.75 \sin \beta \right] F_2$$

$$+ 34.75 F \sin \beta \sin \Theta - \left[196.5 \sin(35^\circ + \beta) + 35.38 \cos \beta + 23 \sin \beta + 34.75 \sin \beta \right] F_3$$

$$(4) \left[196.5 \sin(35^\circ - \beta) + 35.38 \cos \beta - 23 \sin \beta - 34.75 \sin \beta \right] F_2$$

$$- 196.5 \sin(35^\circ + \beta) + 35.38 \cos \beta + 23 \sin \beta + 34.75 \sin \beta F_3 =$$

$$- 34.75 F \sin \beta \sin \Theta$$

$$\sum M_{F_1} = 0 = \left[34.75 \cos \beta + 23 \cos \beta + 35.38 \sin \beta + 196.5 \cos(35^\circ - \beta) \right] F_2$$

$$+ \left[34.75 \cos \beta + 23 \cos \beta - 35.38 \sin \beta + 196.5 \cos(35^\circ + \beta) \right] F_3$$

$$- 56 F \cos \Theta - (34.75 \cos \beta + 28.25) F \sin \Theta$$

$$(5) \left[57.75 \cos \beta + 35.38 \sin \beta + 196.5 \cos(35^\circ - \beta) \right] F_2$$

$$+ \left[57.57 \cos \beta - 35.38 \sin \beta + 196.5 \cos(35^\circ + \beta) \right] F_3$$

$$= 56 F \cos \Theta + (34.75 \cos \beta + 28.25) F \sin \Theta$$

As before, simplifying equations and writing in terms of recoil force F for various angles of β . (r indicates recoil)

For $\beta = 0^\circ$

$$F_{1r} = F (.7120 \sin \Theta - .2560 \cos \Theta)$$

$$F_{2r} = F_{3r} = F (.1440 \sin \Theta + .1280 \cos \Theta)$$

$$H_2 = H_3 = .5 F \cos \Theta$$

For $\beta = 11.25^\circ$

$$F_{1r} = F (.7144 \sin \Theta - .2511 \cos \Theta)$$

$$F_{2r} = F (.1614 \sin \Theta + .1624 \cos \Theta)$$

$$F_{3r} = F (.1242 \sin \Theta + .0887 \cos \Theta)$$

$$H_2 = .6236 F \cos \Theta$$

$$H_3 = .3764 F \cos \Theta$$

For $\beta = 22.5^\circ$

$$F_{1r} = F (.7218 \sin \Theta - .2366 \cos \Theta)$$

$$F_{2r} = F (.1756 \sin \Theta + .1907 \cos \Theta)$$

$$F_{3r} = F (.1026 \sin \Theta + .0459 \cos \Theta)$$

$$H_2 = .7573 F \cos \Theta$$

$$H_3 = .2427 F \cos \Theta$$

C. Combined Loads: Gravity Plus Recoil

All load combinations and solutions have been listed up to this point. However, only certain loads are necessary to calculate the stress in the bottom carriage. These are listed below. $F_{2t} = F_{2r} + F_{2g}$

For $\beta = 0^\circ$

$$F_{2t} = F (.0290 + .1140 \sin \Theta + .1140 \cos \Theta)$$

$$H_2 = .5 F \cos \Theta$$

For $\beta = 11.25^\circ$

$$F_{2t} = F (.0310 + .1614 \sin \Theta + .1447 \cos \Theta)$$

$$H_2 = .6236 F \cos \Theta$$

For $\beta = 22.5^\circ$

$$F_{2t} = F (.0323 + .1756 \sin \Theta + .1699 \cos \Theta)$$

$$H_2 = .7573 F \cos \Theta$$

IV. Calculation of Bending Moment

The bending moment is determined by calculating the reduction of load along the load axis of the base. Maximum stresses are assumed to occur when $\beta = 22.5^\circ$ and $\Theta = 57^\circ$. Upper carriage loads are distributed at 24 equally spaced points on the bearing circle. The reaction load on axis 2, R_2 , from any load P on bearing is

$$R_2 = \frac{P L_3}{(L_2 + L_3)}$$

Using the sketch on sheet 18, additional relationships are determined.

$$L_2 = \sec 16.49^\circ \left[34.75 \sin 31.49^\circ - 20(\sin 22.5^\circ + \alpha - 31.49^\circ) \right]$$

$$L_2 = 18.9303 - 20.8579 \sin (\alpha - 8.99^\circ)$$

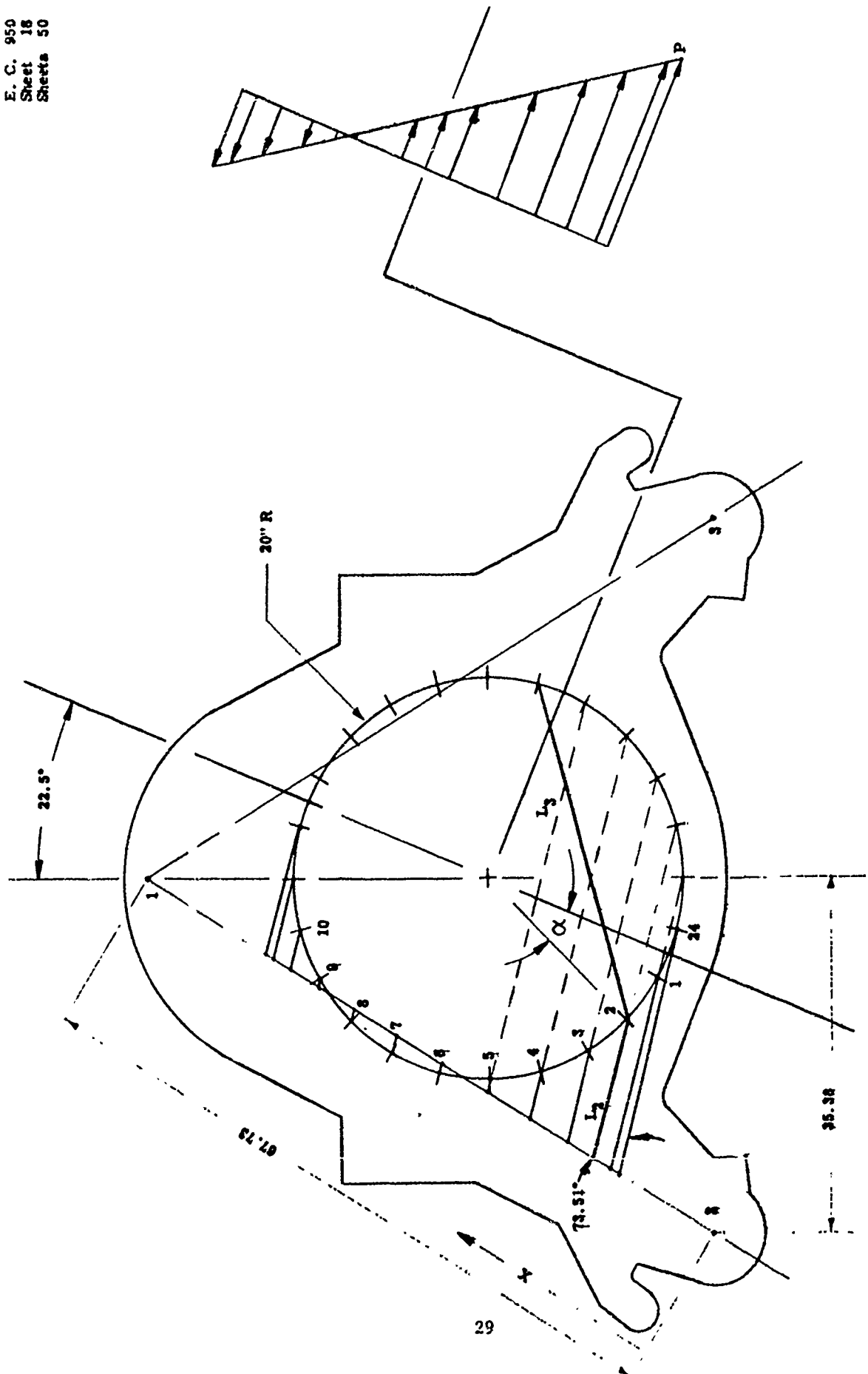
$$L_3 = \sec 16.49^\circ \left[20 \sin (\alpha + 53.99^\circ) + 34.75 \sin 31.49^\circ \right]$$

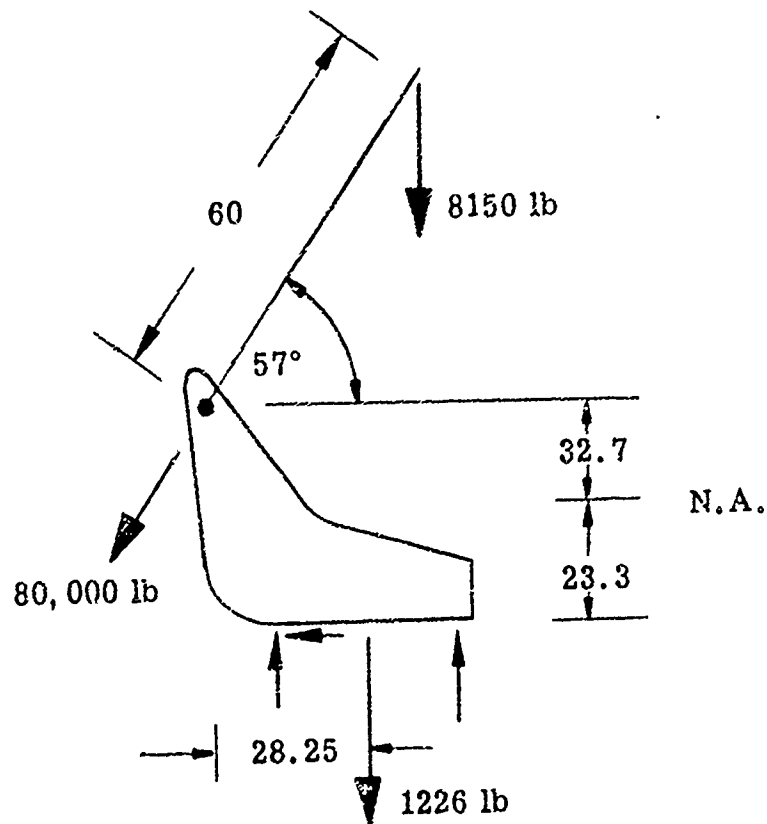
$$L_3 = 18.9303 + 20.8579 \sin (\alpha + 53.99^\circ)$$

$$\frac{L_3}{L_2 + L_3} = \frac{.9076 + \sin (\alpha + 53.99^\circ)}{1.8152 + \sin (\alpha + 53.99^\circ) - \sin (\alpha - 8.99^\circ)}$$

$$X_2 = 32.73 - 20 \cos (\alpha - 8.99) + 5.92 (\sin \alpha - 8.99)$$

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Sheet 50





UPPER CARRIAGE LOADS

$$P_n = K r \cos \alpha_n$$

$$\text{Moment } P = K r^2 \cos^2 \alpha_n$$

$$M = \sum_m P_1^{24} K r^2 \cos^2 \alpha_n = K r^2 \sum_{n=1}^{24} \cos^2 \alpha_n = 12 K r^2$$

$$K = \frac{M}{12 r^2}$$

$$P_n = \frac{M \cos \alpha_n}{12 r} = \frac{M}{240} \cos \alpha_n$$

$$M = 80,000(28.25 \sin 57^\circ + 32.7 \cos 57^\circ) - 8,150(60 \cos 57^\circ - 28.25)$$

$$M = 3,284,080 \text{ lb in.}$$

$$V = 80,000 \sin 57^\circ + 8,150 + 1,226 = 76,470 \text{ lb}$$

$$H = 80,000 \cos 57^\circ = 43,571 \text{ lb}$$

$$P_r = P_v + P_m = 3,186 + 13,684 \cos \alpha_n$$

$$P_v = \frac{76,470}{24} = 3,186 \text{ lb}$$

$$P_m = \frac{3,284,080}{240} \times \cos \alpha_n = 13,684 \cos \alpha_n$$

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<u>n</u>		<u>α</u>	<u>P_m</u>	<u>P_n</u>
24	1	7.5	13,567	16,753
23	2	22.5	12,642	15,828
22	3	37.5	10,856	14,042
21	4	52.5	8,330	11,516
20	5	67.5	5,237	8,423
19	6	82.5	1,786	4,972
18	7	97.5	- 1,786	1,400
17	8	112.5	- 5,237	- 2,051
16	9	127.5	- 8,330	- 5,144
15	10	142.5	-10,856	- 7,670
14	11	157.5	-12,642	- 9,456
13	12	172.5	-13,567	-10,381

<u>n</u>	<u>α</u>	<u>$(\alpha - 8.99)$</u>	<u>X_2</u>	<u>$\frac{L_3}{L_2 + L_3}$</u>	$\times$	<u>P_n</u>	$=$	<u>f_{2n}</u>
1	7.5	-1.49	12.58	.6568		16,753		11,003
2	22.5	13.51	14.67	.7361		15,828		11,651
3	37.5	28.51	17.98	.8159		14,042		11,457
4	52.5	43.51	22.30	.8949		11,516		10,306
5	67.5	58.51	27.33	.9698		8,423		8,169
6	82.5	73.51	32.73	1.0332		4,972		5,137
7	97.5	88.51	38.13	1.0712		1,400		1,500
8	112.5	103.51	43.16	1.0601		- 2,051		- 2,174
9	127.5	118.51	47.48	.9683		- 5,144		- 4,981
10	142.5	133.51	50.79	.7738		- 7,670		- 5,935
11	157.5	148.51	52.88	.5000		- 9,456		- 4,728
12	172.5	163.51	53.59	.2262		-10,381		- 2,348
13	187.5	178.51	52.88	.0317		-10,381		- 329
14	202.5	193.51	50.79	- .0601		- 9,456		568
15	217.5	208.51	47.48	- .0712		- 7,670		546
16	232.5	223.51	43.16	- .0332		- 5,144		171
17	247.5	238.51	38.18	.0302		- 2,051		62

18	262.5	253.51	32.73	.1052	1,400	147
19	277.5	268.51	27.33	.1841	4,972	915
20	292.5	283.51	22.30	.2639	8,423	2,223
21	307.5	298.51	17.98	.3432	11,516	3,952
22	322.5	313.51	14.67	.4219	14,042	5,924
23	337.5	328.51	12.58	.5000	15,828	7,914
24	352.5	343.51	11.87	.5781	16,753	9,685

Now

$$F_2 = F (.0323 + .1756 \sin \Theta + .1699 \cos \Theta)$$

$$F_2 = 21,768 \text{ lb for } F = 80,000 \text{ lb and } \Theta = 57^\circ$$

$$H_2 = .7573 F \cos \Theta$$

$$H_2 = 33,000 \text{ lb}$$

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 Sheets 50

"Since F_2 is not based on a length of 264.2, the loads f_{2n}' (next sheet) should be artificially increased by the ratio 1.2126 so that the moments on the X-axis will reduce to zero.

$$F_2 = 21,768 \text{ lb}$$

$$\begin{array}{rcl} \text{less } 2,913 & = & 33,000 \times \frac{23.32}{264.23} \\ \hline & & 18,855 \text{ lb} \end{array}$$

$$\frac{18,855}{15,549} f_{2n}' = 1.2126 f_{2n}' = F_{2n}$$

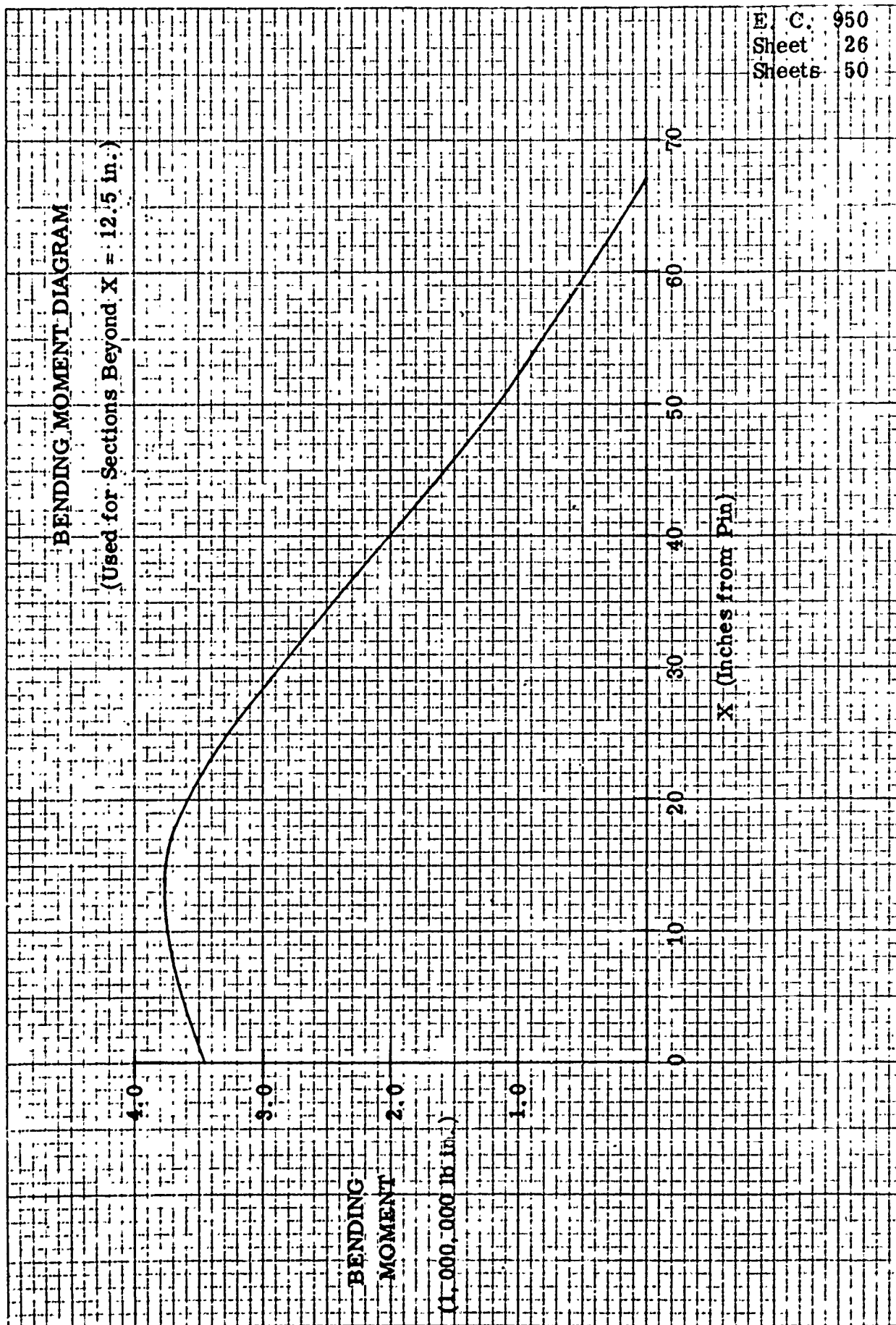
The moment along the X-axis is:

$$M_x = 21,768 (196.5 + x) - 33,000 \times 23.32 - \sum F_n (x - x_n)$$

A graph of the values calculated from the above equation is shown on sheet 26.

F 950
2.4. 25
2.4. 50

<u>n</u>	<u>f_{2n}'</u>	<u>X₂</u>	<u>(67.73-X₂)</u> <u>f_{2n}' (67.73-X₂)</u> <u>264.23</u>	<u>F_{2n}</u>	<u>F_n</u> <u>(21,768-F_{2n})</u>	<u>Δ X</u>	<u>Δ M</u>	<u>M</u>
		0			21,768	11.87	258,386	3,507,852
24	9,685	11.87	55.86	11,744	10,024	.71	7,117	3,766,238
23, 1	18,917	12.58	55.15	22,939	-12,915	2.09	-26,992	3,773,355
22, 2	17,575	14.67	53.06	21,312	-34,227	3.31	-113,291	3,746,363
21, 3	15,409	17.98	49.75	18,685	-52,912	4.32	-228,580	3,633,072
20, 4	12,529	22.30	45.43	15,193	-68,105	5.03	-342,568	3,404,492
19, 5	9,084	27.33	40.40	11,015	-79,120	5.45	-427,248	3,061,924
18, 6	5,284	32.73	35.00	6,407	-85,527	5.40	-461,846	2,634,676
17, 7	1,438	38.13	29.60	1,744	-87,271	5.03	-438,973	2,172,830
16, 8	-2,033	43.16	24.57	-2,429	-94,842	4.32	-366,517	1,733,857
15, 9	-4,435	47.48	20.25	-5,378	-79,464	3.31	-263,026	1,367,340
14, 10	-5,367	50.79	16.94	-6,508	-72,956	2.09	-152,478	1,104,314
13, 11	-5,057	52.88	14.85	-6,132	-66,824	.71	-47,445	951,836
12	-2,348	53.59	14.14	-2,847	-63,977	14.14	-904,635	904,391
		67.73		15,549				-244

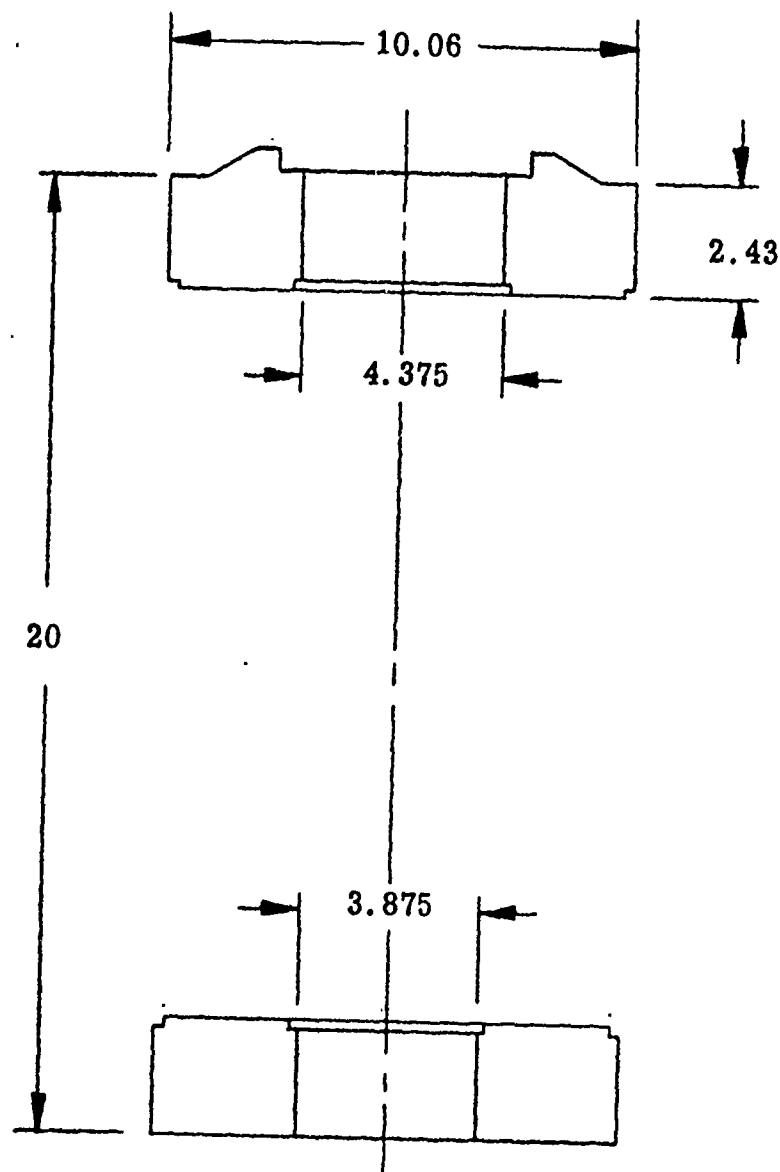


V. Stress Analysis of Bottom Carriage

A. Cross-Section Properties

The sketches shown on sheets 28 through 35 are $1/4$ scale cross-sections of the bottom carriage $X = 0$ in. through $X = 23.5$ in. toward the ground pan. The cross-sectional inertia I has been calculated along with the total section area A . The distance from the neutral axis to the most extreme fiber in tension or compression is also listed (y_t and y_c). Both the vertical and side (lateral) section properties are listed when needed.

X = 0 in. from Pin



Vertical Section Properties

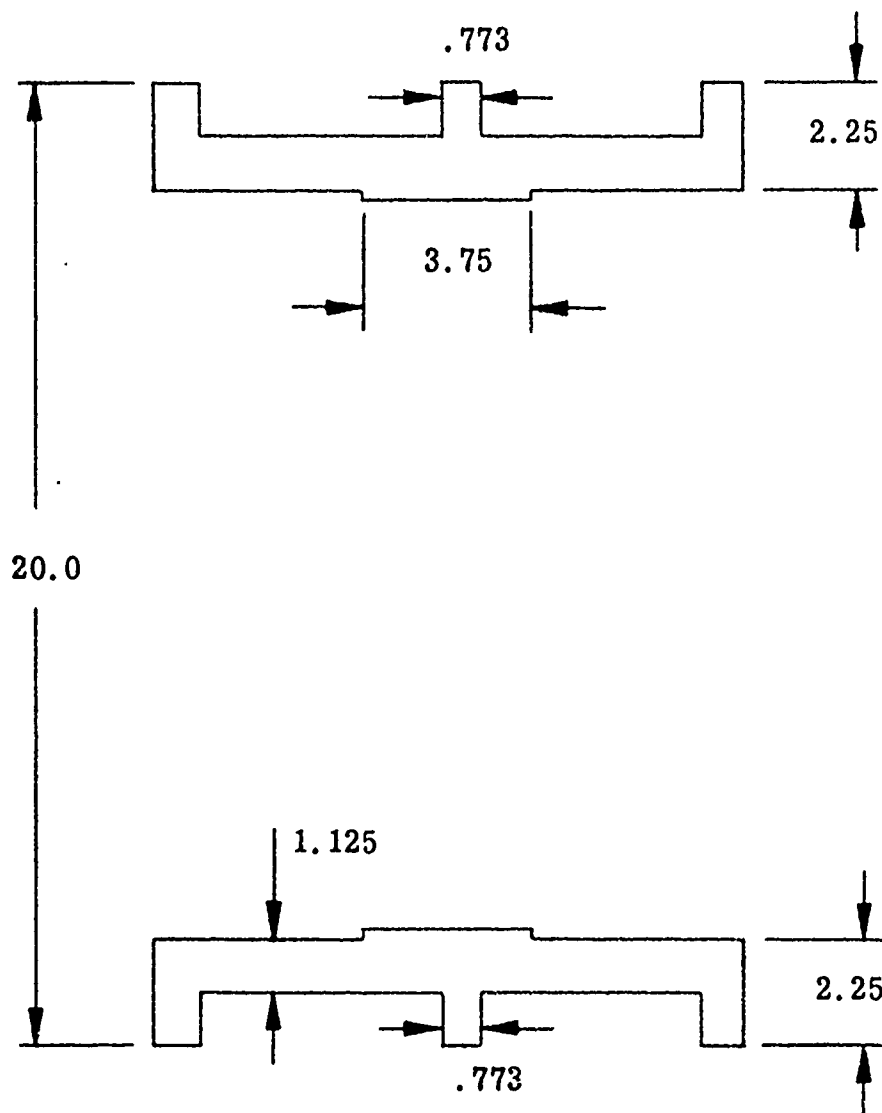
$$y_t = 9.925 \text{ in.}$$

$$y_c = 10.575 \text{ in.}$$

$$I = 2312 \text{ in.}^4$$

$$A = 29.43 \text{ in.}^2$$

X = 4.5 in. from Pin



Section Properties

Vertical
 $y_t = 10 \text{ in.}$

$y_c = 10 \text{ in.}$

$I = 2591 \text{ in.}^4$

$A = 35.936 \text{ in.}^2$

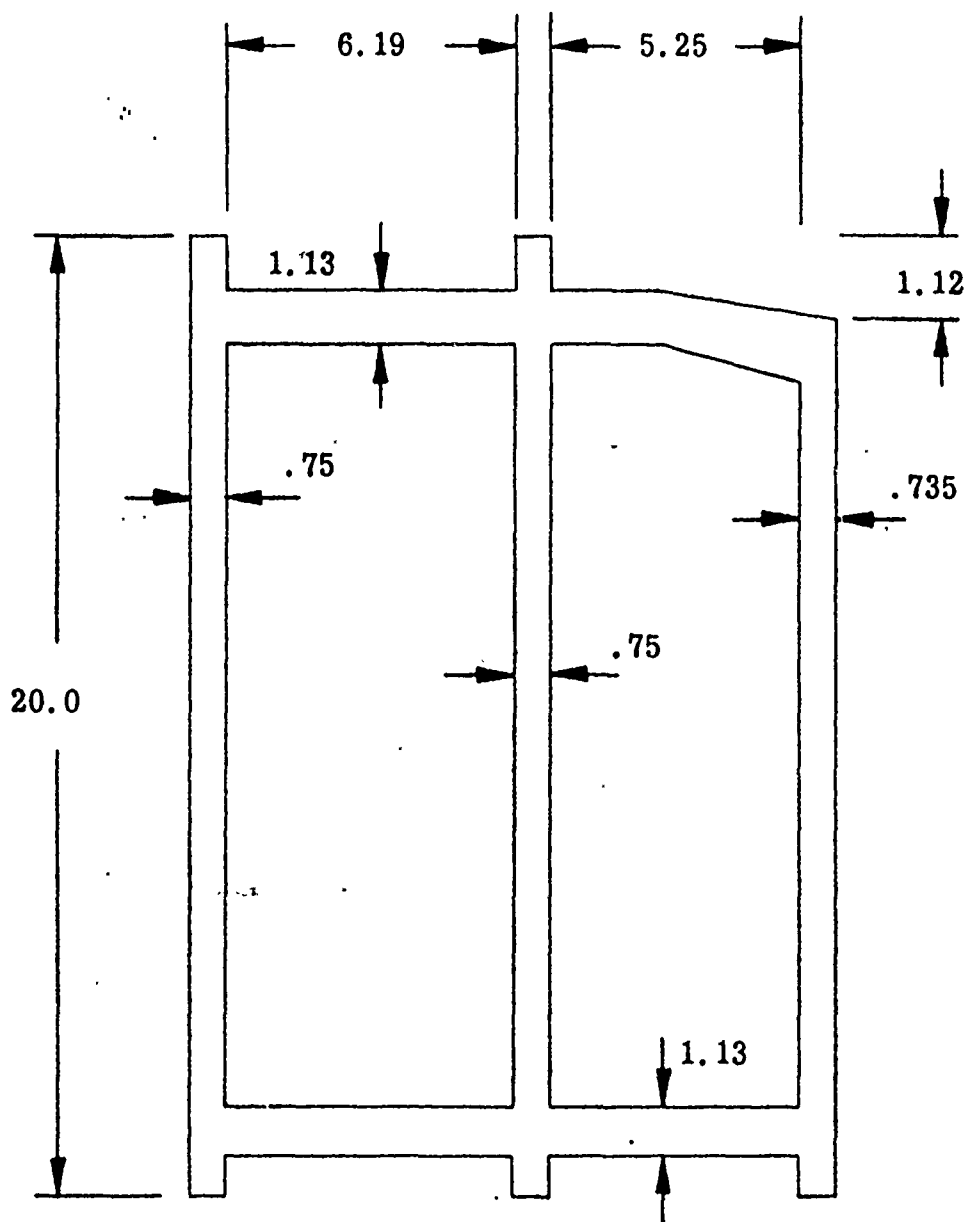
Side
 $y_t = 6.293 \text{ in.}$

$y_c = 6.397 \text{ in.}$

$I = 530 \text{ in.}^4$

$A = 35.936 \text{ in.}^2$

X = 6.5 in. from Pin

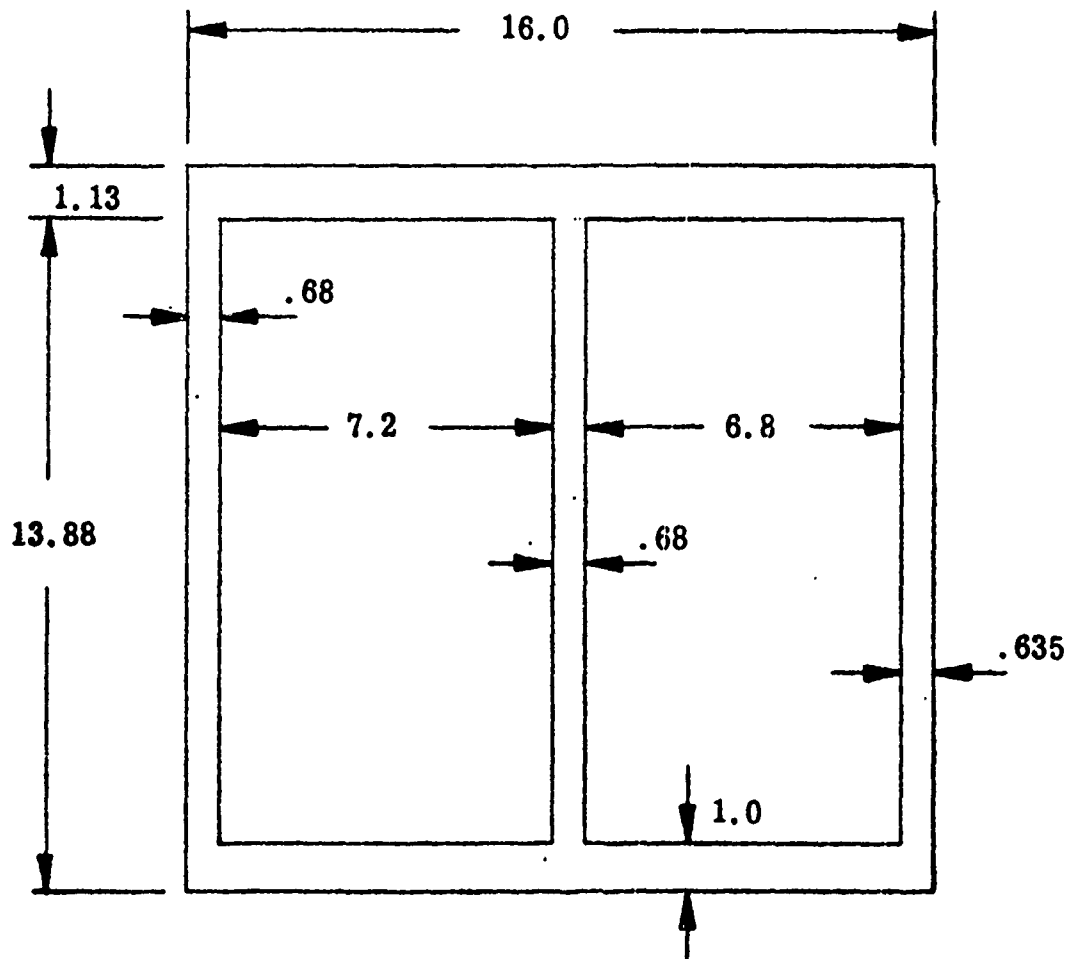


Section Properties

Vertical	Side
$y_t = 9.843 \text{ in.}$	$y_t = 6.8893 \text{ in.}$
$y_c = 10.157 \text{ in.}$	$y_c = 6.786 \text{ in.}$
$I = 3259 \text{ in.}^4$	$I = 1534 \text{ in.}^4$
$A = 69.731 \text{ in.}^2$	$A = 69.731 \text{ in.}^2$

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X = 12.5 in. from Pin

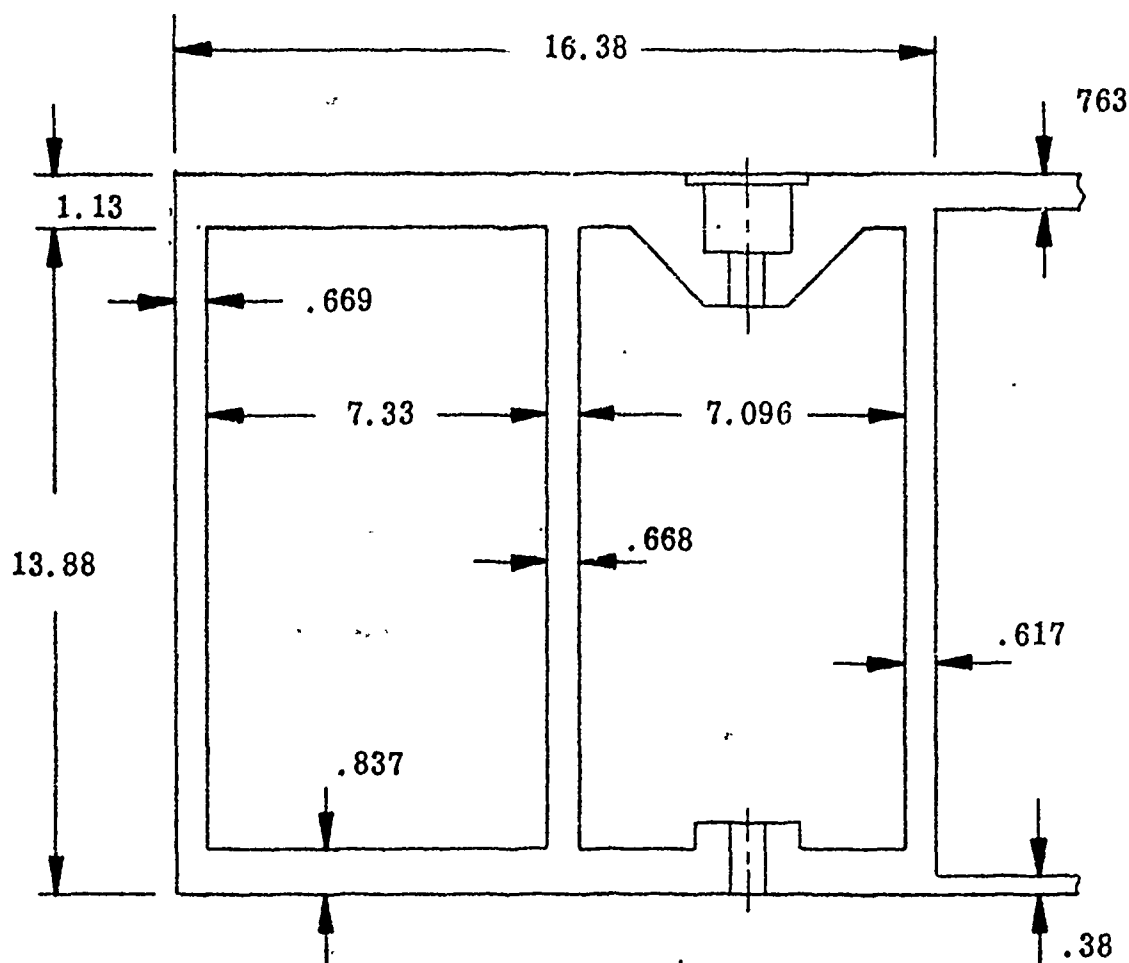


Section Properties

Vertical
 $y_t = 7.702 \text{ in.}$
 $y_c = 7.731 \text{ in.}$
 $I = 2012 \text{ in.}^4$
 $A = 59.771 \text{ in.}^2$

Side
 $y_t = 8.038 \text{ in.}$
 $y_c = 7.962 \text{ in.}$
 $I = 1725 \text{ in.}^4$
 $A = 59.771 \text{ in.}^2$

X = 13.5 in. from Pin



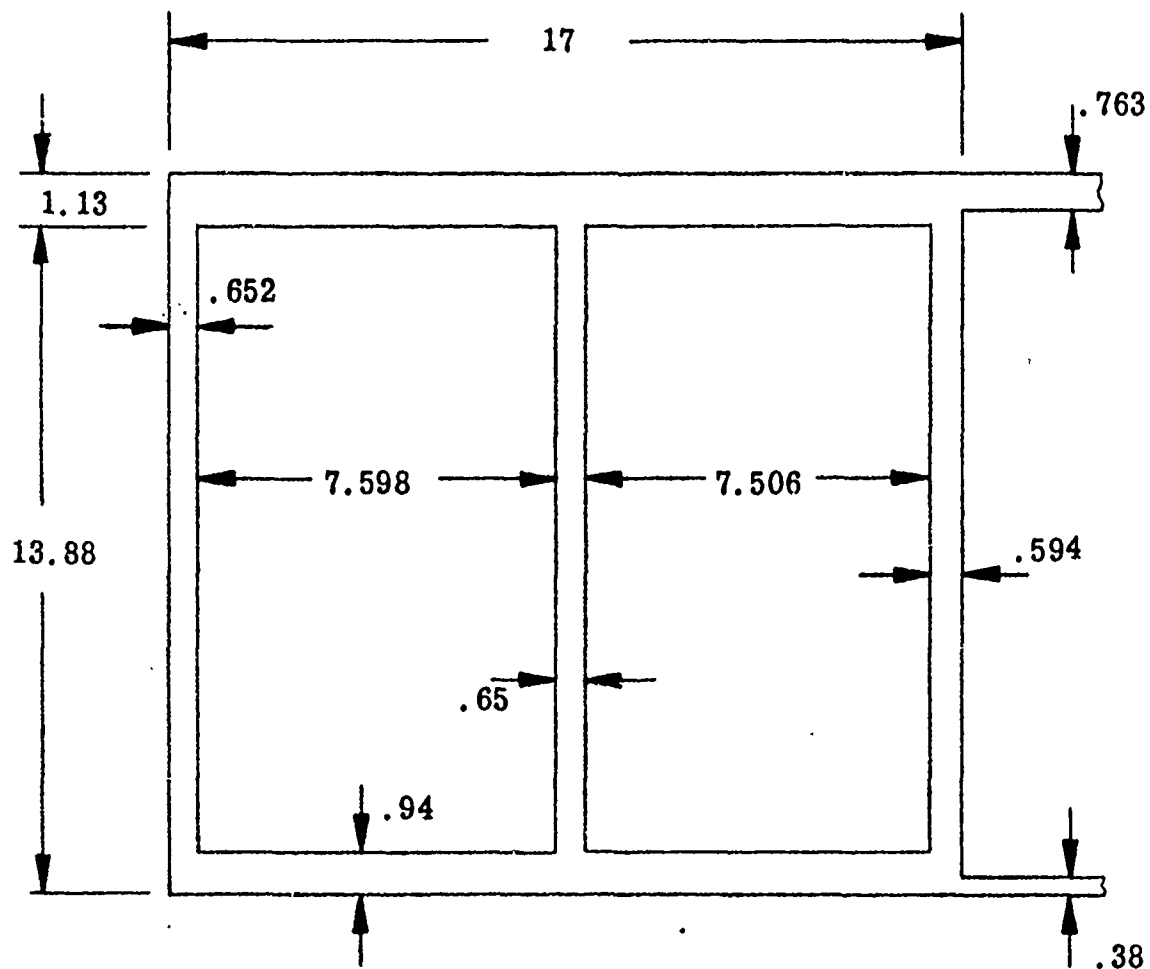
Vertical Section Properties

$$y_t = 8.165 \text{ in.}$$

$$y_c = 6.845 \text{ in.}$$

$$I = 2277 \text{ in.}^4$$

X = 15 in. from Pin



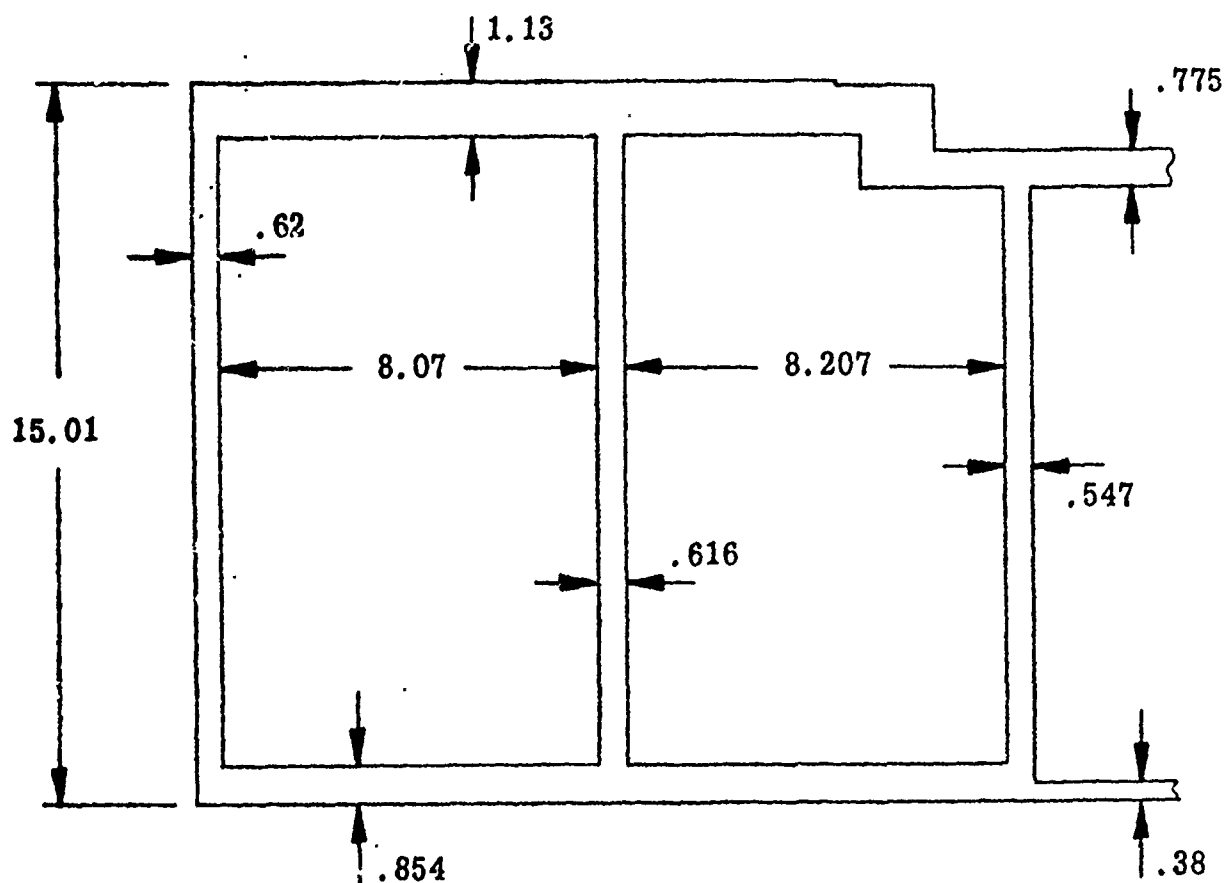
Vertical Section Properties

$$y_t = 8.166 \text{ in.}$$

$$y_c = 6.844 \text{ in.}$$

$$I = 2332 \text{ in.}^4$$

X = 18 in. from Pin



Vertical Section Properties

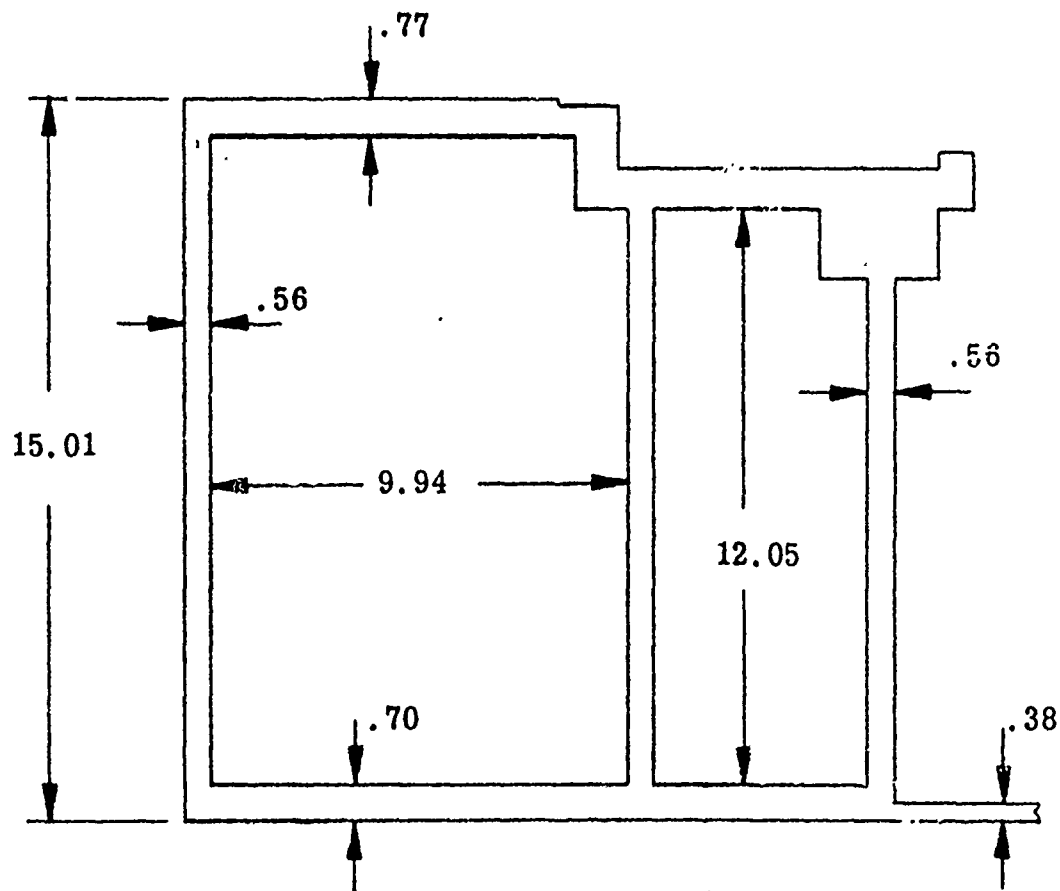
$$y_t = 8.210 \text{ in.}$$

$$y_c = 6.800 \text{ in.}$$

$$I = 2238 \text{ in.}^4$$

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Sheets 50

X = 23.5 in. from Pin



Vertical Section Properties

$$y_t = 7.754 \text{ in.}$$

$$y_c = 7.259 \text{ in.}$$

$$I = 1574 \text{ in.}^4$$

B. Equations Used to Calculate Force and Moments

A sketch of the bottom carriage left hinge is shown on sheet 37. It illustrates how the forces and moments are acting on the bottom carriage hinge. A similar type of loading occurs at the right hinge pin.

1. Left Side of Bottom Carriage (Hinge)

Compression Force

$$F_{cl} = H_2 \cos (35^\circ - \beta)$$

$$F_{cl} (\beta = 0^\circ) = -.4096 F \cos \Theta$$

$$F_{cl} (\beta = 11.25^\circ) = -.5708 F \cos \Theta$$

$$F_{cl} (\beta = 22^\circ) = -.7393 F \cos \Theta$$

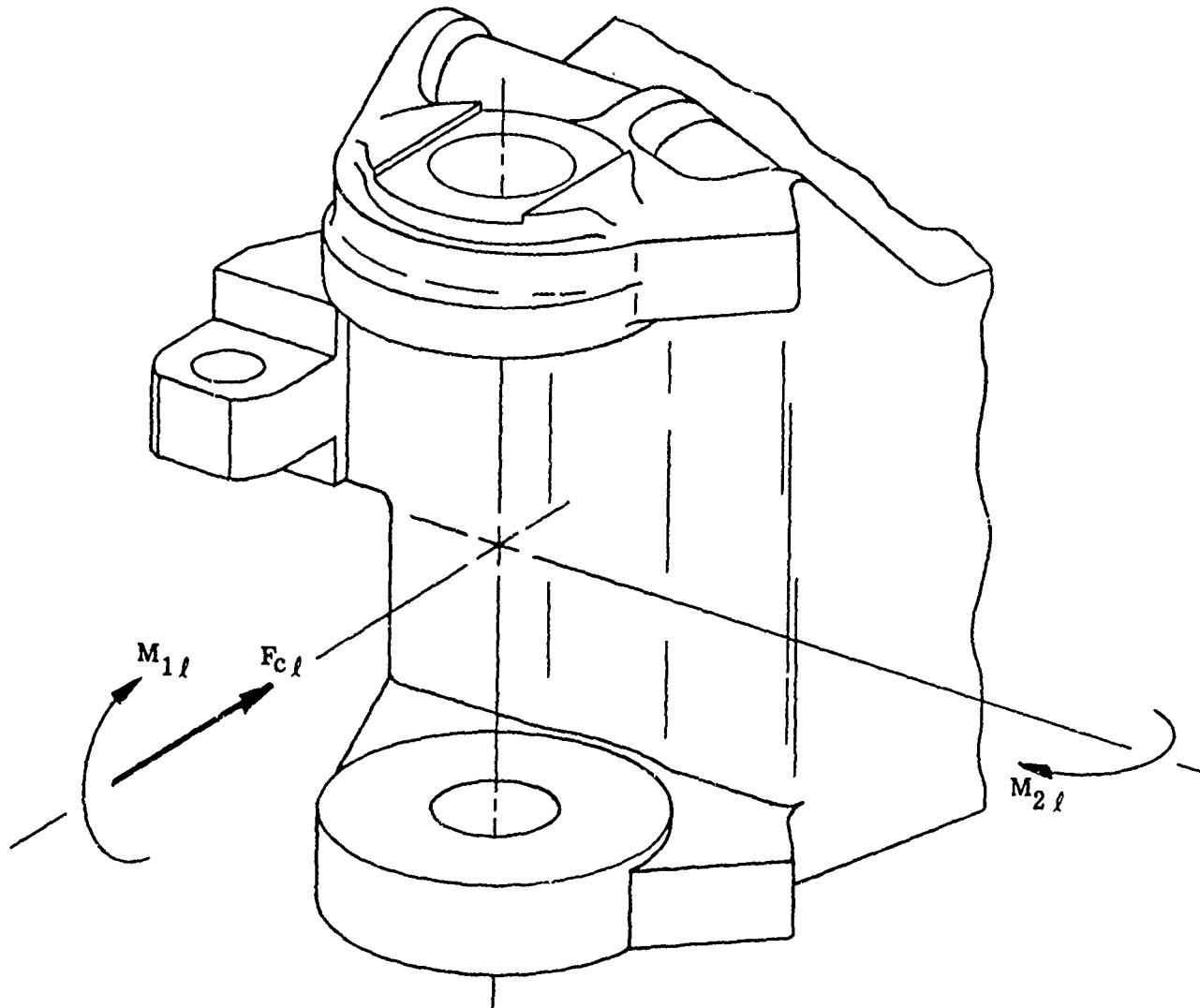
Side Bending Moment

$$M_{2l} = \left[H_2 \sin (35^\circ - \beta) (196.5 + X) \right] .2$$

$$M_{2l} (\beta = 0^\circ) = .0574 (196.5 + X) F \cos \Theta$$

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BOTTOM CARRIAGE LEFT HINGE
(FORCES AND MOMENTS)



$$M_{2l} (\beta = 11.25^\circ) = .0502 (196.5 + X) F \cos \Theta$$

$$M_{2l} (\beta = 22.5^\circ) = .0328 (196.5 + X) F \cos \Theta$$

Vertical Bending Moment

$$M_{1l} = F_2 (196.5 + X) - (16 + \bar{y}) H_2 \cos (35^\circ - \beta)$$

$$M_{1l} (\beta = 0^\circ) = (196.5 + X) F \left[.029 + .144 \sin \Theta + .114 \cos \Theta \right] \\ - (16 + \bar{y}) .4096 F \cos \Theta$$

$$M_{1l} (\beta = 11.25^\circ) = (196.5 + X) F \left[.031 + .1614 \sin \Theta + .1447 \cos \Theta \right] \\ - (16 + \bar{y}) .5708 F \cos \Theta$$

$$M_{1l} (\beta = 22.5^\circ) = (196.5 + X) F \left[.0323 + .1756 \sin \Theta + .1699 \cos \Theta \right] \\ - (16 + \bar{y}) .7393 F \cos \Theta$$

2. Right Side of Bottom Carriage (Hinge)

Compression Force

$$F_{cr} = H_3 \cos (35^\circ + \beta)$$

Side Bending Moment

$$M_{2r} = H_3 \left[\sin (35^\circ + \beta) (196.5 + X) \right] .2$$

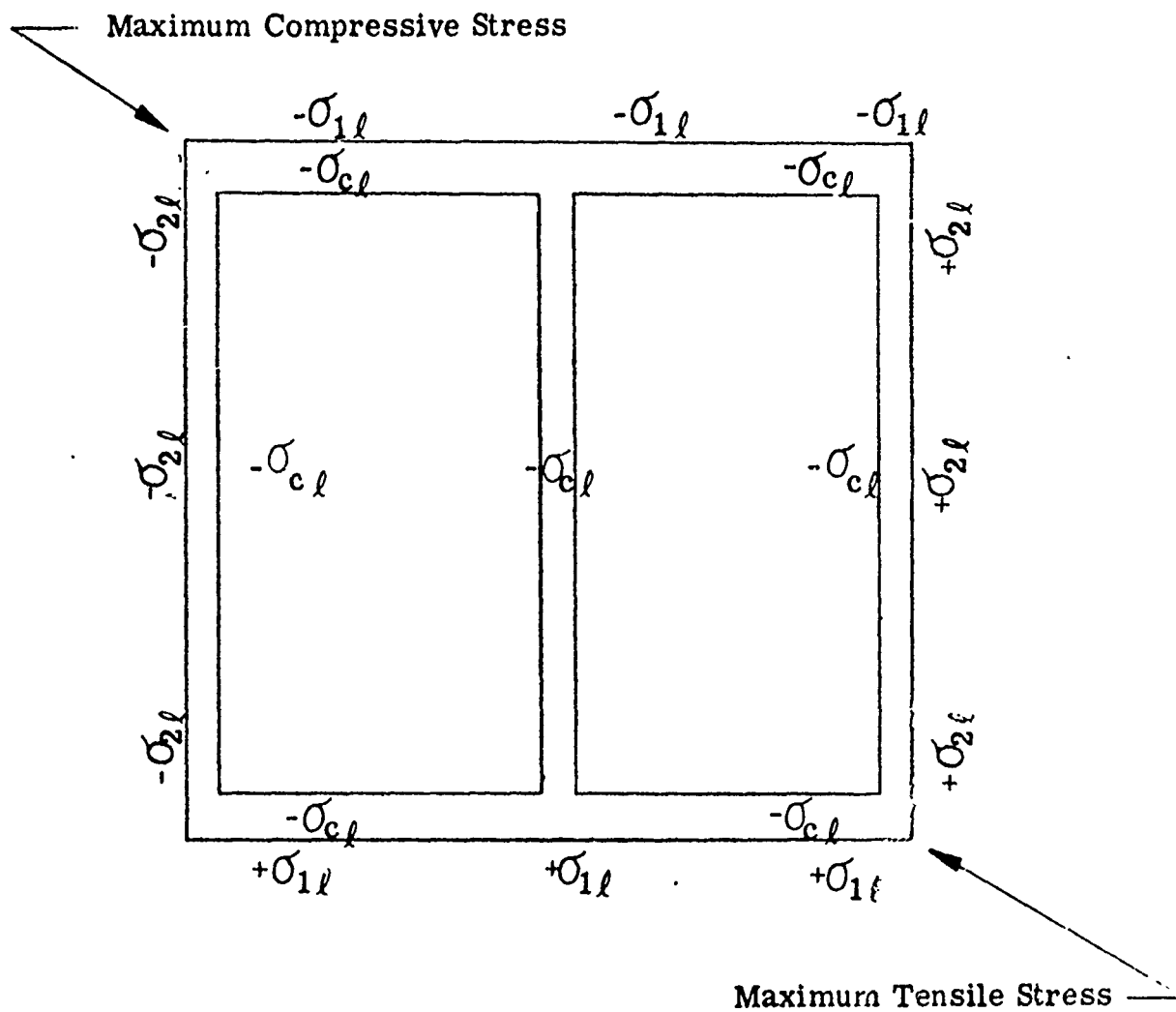
Vertical Bending Moment

$$M_{1r} = F_3 (196.5 + X) - (16 + \bar{y}) H_3 \cos (35^\circ + \beta)$$

C. Stress Calculation Method (High Stress Areas)

Detailed calculations are presented for $X = 0$ in., 12.5 in., and 23.5 in. with $\beta = 22.5^\circ$. These three calculations are representative of the methods used to calculate all the conditions. For sections up to and including $X = 4.5$ in., the example at $X = 0$ in. applies. For sections beyond $X = 4.5$ in. the example at $X = 12.5$ in. applies. Tensile and compressive stresses add such that the upper left hand corner of the section is the location

STRESS DISTRIBUTION (X = 5.5 in. through X = 12.5 in.)



of high compressive stress, and the lower right hand corner of the section is the location of high tensile stress. This is shown by the sketch on sheet 40. For sections beyond $X = 12.5$ in., the vertical bending moment developed in Part IV is used to calculate the bending stress. The three distinct methods are necessary because there are internal lateral webs at approximately $X = 4.5$ in. and $X = 12.5$ in. (see drawing on sheet 6). Also, beyond $X = 12.5$ in., the side bending moment and compressive force are not significant because the cross-section has widened out.

1. $X = 0$ in. from Pin, $\beta = 22.5^\circ$, $F = 80,000$ lb

For the area about the pin, see sheet 37, one compressive force and two moments add to produce the total stress. On sheet 28 the section is shown. The top part is in compression and the bottom part is in tension.

TOP PART

$$F_{cl} / 2 = \frac{-.7393}{2} F \cos \Theta = -.3697 F \cos \Theta$$

$$M_{2l} / 2 \times 10.5 = \frac{.0328}{2 \times 10.5} (196.5 + X) F \cos \Theta$$

$$M_{2l} / 2 \times 10.5 = .3069 F \cos \Theta$$

$$M_{1l} / 17.56 = \frac{1}{17.56} \left[F_2 (196.5 + X) - (16 + \bar{y}) H_2 \cos (35^\circ - \beta) \right]$$

$$M_{1l} / 17.56 = -F \left[.3614 + 1.965 \sin \Theta + .8098 \cos \Theta \right]$$

$$\sum F_p (\text{top}) = -F \left[.3614 + 1.965 \sin \Theta + .8726 \cos \Theta \right]$$

$$\frac{\partial \sum F_p}{\partial \Theta} = 0 = 1.965 \cos \Theta - .8726 \sin \Theta$$

$$\frac{\sin \Theta}{\cos \Theta} = \frac{1.965}{.8726} = 2.252$$

$$\Theta = \text{Arctan } 2.252 = 66.1^\circ$$

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 Sheets 50

Then

$$\sum F_p(\text{top}) = -200,915 \text{ lb (compression on Top Hole)}$$

$$\sigma_c = \frac{F}{A} = \frac{-200,915}{4.375 \times 2.43}$$

$$\sigma_c = -18,900 \text{ psi (Compressive Stress on Top Hole)}$$

BOTTOM PART

$$F_{c\ell/2} = -\frac{.7393}{2} F \cos \Theta = -.3697 F \cos \Theta$$

$$M_{2\ell/2 \times 10.5} = \frac{.0328}{2 \times 10.5} (196.5 + X) F \cos \Theta$$

$$M_{2\ell/2 \times 10.5} = .3069 F \cos \Theta$$

$$M_{1\ell}/17.56 = \frac{1}{17.56} \left[F_2 (196.5 + X) - (16 + \bar{y}) H_2 \cos (35^\circ - \beta) \right]$$

$$M_{1\ell}/17.56 = F \left[.3614 + 1.965 \sin \Theta + .8098 \cos \Theta \right]$$

$$\sum F_p (\text{bottom}) = F \left[.3614 + 1.965 \sin \Theta + .747 \cos \Theta \right]$$

$$\frac{\partial \sum F_p}{\partial \Theta} = 0 = 1.965 \cos \Theta - .747 \sin \Theta$$

$$\frac{\sin \Theta}{\cos \Theta} = \frac{1.965}{.747} = 2.631$$

$$\Theta = \text{Arctan } 2.631 = 69.2^\circ$$

then

$$\sum F_p (\text{bottom}) = 197,090 \text{ lb (tension on area of the eye)}$$

$$\sigma_t = \frac{F}{A} = \frac{197,090}{(10.06 - 3.875) 2.44}$$

$$\sigma_t = 13,060 \text{ psi (tensile stress on area of the eye)}$$

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Sheets 50

2. $X = 12.5$ in. from Pin, $\beta = 22.5^\circ$, $F = 80,000$ lb

The stress is calculated as explained on sheets 39 through 41 and as illustrated on sheet 40, upper left highest compression and lower right highest tension.

$$F_{cl} = -.7393 F \cos \Theta$$

$$M_{2l} = .0328 (196.5 + X) F \cos \Theta = 6.8552 F \cos \Theta$$

$$M_{1l} = F_2 (196.5 + X) - (16 + \bar{y}) H_2 \cos (35^\circ - \beta)$$

$$M_{1l} = F (6.7507 + 36.7004 \sin \Theta + 17.9964 \cos \Theta)$$

$$\sigma_{cl} = \frac{F_{cl}}{A} = - \frac{.7393 F \cos \Theta}{59.7706} = -.0124 F \cos \Theta$$

$$\sigma_{2l} = \pm \frac{M_{2l} y}{I}$$

where $y_t = 8.038 \text{ in.}$

$y_c = 7.962 \text{ in.}$

$I = 1725 \text{ in.}^4$

$$\sigma_{2l} = \begin{aligned} &+.0319 F \cos \Theta \\ &-.0316 F \cos \Theta \end{aligned}$$

$$\sigma_{1l} = \pm \frac{M_{1l} y}{I}$$

where $y_t = 7.702 \text{ in.}$

$y_c = 7.731 \text{ in.}$

$I = 2012 \text{ in.}^4$

$$\sigma_{1l} = \begin{aligned} &+ F (.0258 + .1405 \sin \Theta + .0689 \cos \Theta) \\ &- F (.0245 + .1333 \sin \Theta + .0653 \cos \Theta) \end{aligned}$$

TOP LEFT CORNER

$$\sum \sigma = \sigma_{c\ell} + \sigma_{2\ell} + \sigma_{1\ell} = -F \left[.0245 + .1333 \sin \Theta + .1093 \cos \Theta \right]$$

$$\frac{\partial \sum \sigma}{\partial \Theta} = 0 = .1333 \cos \Theta - .1093 \sin \Theta$$

$$\frac{\sin \Theta}{\cos \Theta} = \frac{.1333}{.1093} = 1.22$$

$$\Theta = \text{Arctan } 1.22 = 50.6^\circ$$

$$\sum \sigma_c = -15,750 \text{ psi (compression)}$$

BOTTOM RIGHT CORNER

$$\sum \sigma = \sigma_{c\ell} + \sigma_{2\ell} + \sigma_{1\ell} = F \left[.0258 + .1405 \sin \Theta + .0884 \cos \Theta \right]$$

$$\frac{\partial \sum \sigma}{\partial \Theta} = 0 = .1405 \cos \Theta - .0884 \sin \Theta$$

$$\frac{\sin \Theta}{\cos \Theta} = \frac{.1405}{.0884} = 1.589$$

$$\Theta = \text{Arctan } 1.589 = 57.8^\circ$$

$$\sum \sigma_t = 15,340 \text{ psi (tension)}$$

3. $X = 23.5 \text{ in.}, \beta = 22.5^\circ, F = 80,000 \text{ lb}$

Using the value for the vertical bending moment as shown on sheet 26, the bending stress is easily calculated.

$$\sigma = \frac{M y}{I}$$

where $M = 3,310,000 \text{ lb in.}$

$$y_t = 7.754 \text{ in.}$$

$$y_c = 7.259 \text{ in.}$$

$$\sigma_t = 16,310 \text{ psi (bottom surface)}$$

$$\sigma_c = -15,260 \text{ psi (top surface)}$$

As stated earlier the sections at 13.5, 15, and 18 are calculated in the same manner.

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 Sheet 49
 Sheets 50

VI Tabulation of Calculated Stresses

$$\underline{\beta = 0^\circ}$$

<u>X (in.)</u>	<u>σ_c (psi) Top</u>	<u>σ_t (psi) Bottom</u>
0	-14,830	11,780
4.5	-8,900	10,030
6.5	-12,080	11,190
12.5	-14,370	14,220

$$\underline{\beta = 11.25^\circ}$$

0	-16,910	12,680
4.5	-10,420	10,420
6.5	-12,940	11,790
12.5	-15,530	15,210

$$\beta = 22.5^\circ$$

<u>X (in.)</u>	<u>σ_c (psi) Top</u>	<u>σ_t (psi) Bottom</u>
* 0	-18,900	13,060
4.5	-11,350	11,130
6.5	-12,980	11,680
* 12.5	-15,750	15,340
13.5	-11,270	13,450
15	-10,920	13,030
18	-10,970	13,240
* 23.5	-15,260	16,310

* Indicates that sample calculations are shown in full detail
 in Part V, Section C, sheet 39.

Chips

1 Baggy line

$$\frac{\pi}{4} (7^2 - 6.5^2) (3.5 + 4.5) = 42.4 \text{ in}^3$$

$$\frac{\pi}{4} (7.5^2 - 6.5^2) .375 = 4.1$$

$$\frac{\pi}{4} (8.5^2 - 6.5^2) .38 = 9.0$$

$$55.5 \text{ in}^3$$

$$\times 2 \times .102 =$$

$$11.3 \text{ lb}$$

2 Upper stop

$$.312 \times 2 \times 2.12$$

$$= 1.32$$

$$\times 2 \times .102 =$$

$$.3$$

3 Lower stop

$$.312 \times 1 \times 1.12$$

$$.35$$

$$\times 2 \times .102 =$$

$$.1$$

4 Purgery back line

$$\frac{\pi}{4} \times 2.5^2 \times .25$$

$$1.23$$

$$\frac{\pi}{4} \times 2.12^2 \times .25$$

$$.88$$

$$\frac{\pi}{4} \times 1.46^2 \times .38$$

$$.63$$

$$\frac{\pi}{4} \times 1.25^2 \times 1.31$$

$$1.61$$

$$\frac{\pi}{4} \times 1.44^2 \times 9.47$$

$$15.41$$

$$.875^2 \times .597$$

$$.46$$

$$1.56$$

$$28.38$$

$$1.75$$

$$48.60 \text{ in}^3$$

$$\times 2 \times .102 =$$

$$9.9$$

$$9.46 \text{ in}^2 \times 3$$

$$28.38$$

$$1.75$$

$$1.75$$

$$1.75$$

$$1.75$$

$$1.75$$

$$1.75$$

$$1.75$$

$$1.75$$

$$1.75$$

$$1.75$$

5. Face

$$.25 \times 1.94 \times 12$$

$$5.82$$

$$\times 2 \times .102 =$$

$$1.2$$

6 Grease fitting hole

$$\frac{\pi}{4} \times 1^2 \times 1$$

$$.78$$

$$\frac{\pi}{4} \times .312^2 \times 4.62$$

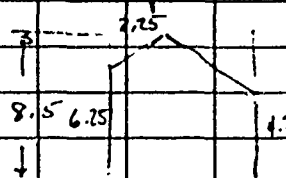
$$.35$$

$$\times 2 \times .102 =$$

$$.2$$

$$62$$

$$23.0$$

7	Ground plate pin hole								23.0
	$\pi/4 \times 4.25^2 \times .25 =$				3.55				
	$\pi/4 \times 2.75^2 \times 3.25 =$				19.31				
					22.86	$\times .102$	$=$	2.3	
8	Cylinder screw hole (reamed)								
	$\pi/4 \times 2.75^2 \times 3.25$				19.31				
	$4 \times .88 \times 3$				10.56				
					29.86	$\times .102$		3.1	
9	Side pads								
					59.61				
					19.12				
					7.53				
					38.16	$\times 2 \times .102$		1.9	
10	Top pads								
	$6 \times 6 \times .25$				9.0	$\times 2 \times .102$		1.9	
	$(10.75 \times 12.78 - 8.28 \times 9.88) .25$				13.78	$\times .102$		1.4	
	$(10.78 \times 8.78 - 8.28 \times 9.88) 1.0$				12.9	$\times .102$		1.3	
	$2 \times 2.5 \times .38$				1.9	$\times 2 \times .102$		.4	
11	Holes in bottom								
	$\pi/4 (3.5^2 - 3.0^2) .38$				.97	$\times .102$		.1	
	$\pi/4 (7.5^2 - 7.0^2) .38$				2.16	$\times 4 \times .102$		.9	
	$(10 \times 7.75 - 9.5 \times 7.25) .38$				3.28	$\times .102$		.3	
12	Center line								
	$\pi/4 (9.5^2 - 5.88^2) .51$				21.64				
	$.38 \times 2.88 \times 5 \times 6.75 \times \pi$				1.53				
	$\pi/4 (7.38^2 - 5.88^2) \times .25$				3.90				
	$\pi/4 (6.63^2 - 5.88^2) (3.12 + 2.62)$				42.22	$\times .102$		16.7	
	$\pi/4 (6.75^2 - 5.88^2) 10.94$				94.31			30.3	52.3
					143.60				

13	Slow pin hole								53.3
	$\pi/4 \ 2.53^2 \times .188$		94						
	$\pi/4 \ 1.875^2 \times 1.44$		3.97						
	$\pi/4 \ .75^2 \times 2.63$		1.16						
			6.07			$\times .102$		.6	
14	Trail hole legs								
	$4 \times 2.28 \times .25$		2.28						
	$4 \times 2.9 \times .25 \times 2$		4.38						
	$\pi/2 \times 2^2 \times .25 \times 2$		3.14						
	$2.5 \times .38 \times 2.23$		2.12						
	$\pi/4 \times 2^2 \times 2.23$		7.02						
			18.94			$\times 2 \times .102$		3.9	
15	Trail stop								
	$2.25 \times 4.5 \times .25$		2.53			$\times 4 \times .102$		1.0	
16	Trail pin holes								
	$\pi/4 \times (9.63^2 - 3.13^2) .25$		16.25						
	$\pi/4 \times (9.63^2 - 3.63^2) .25$		15.60						
	$\pi/4 \ (3.575^2 - 3.13^2) 2.44$		10.06						
	$\pi/4 \ (4.375^2 - 3.63^2) 2.50$		11.78						
	$5.375 \times 5.75 \times .75$		23.20						
	$.5 \times .25 \times .25 \times 2$		1.00						
	$\pi/4 \ (9.03^2 - 4.38^2) .031$		1.53						
	$\pi/4 \ (9.03^2 - 3.875^2) .031$		1.63						
			81.05			$\times 2 \times .102$		16.5	
17	To Surface								
	$6.5 \times 23 \times 2 \times .25$		74.7						
	$1 \times 52 \times .25$		13.0						
	$\pi/4 \ (47^2 - 45^2) .322$		46.5						
			134.2			$\times .102$		13.7	
								35.7	89.0
			64						

Appendix B
PHOTOGRAPHS
and
DRAWINGS

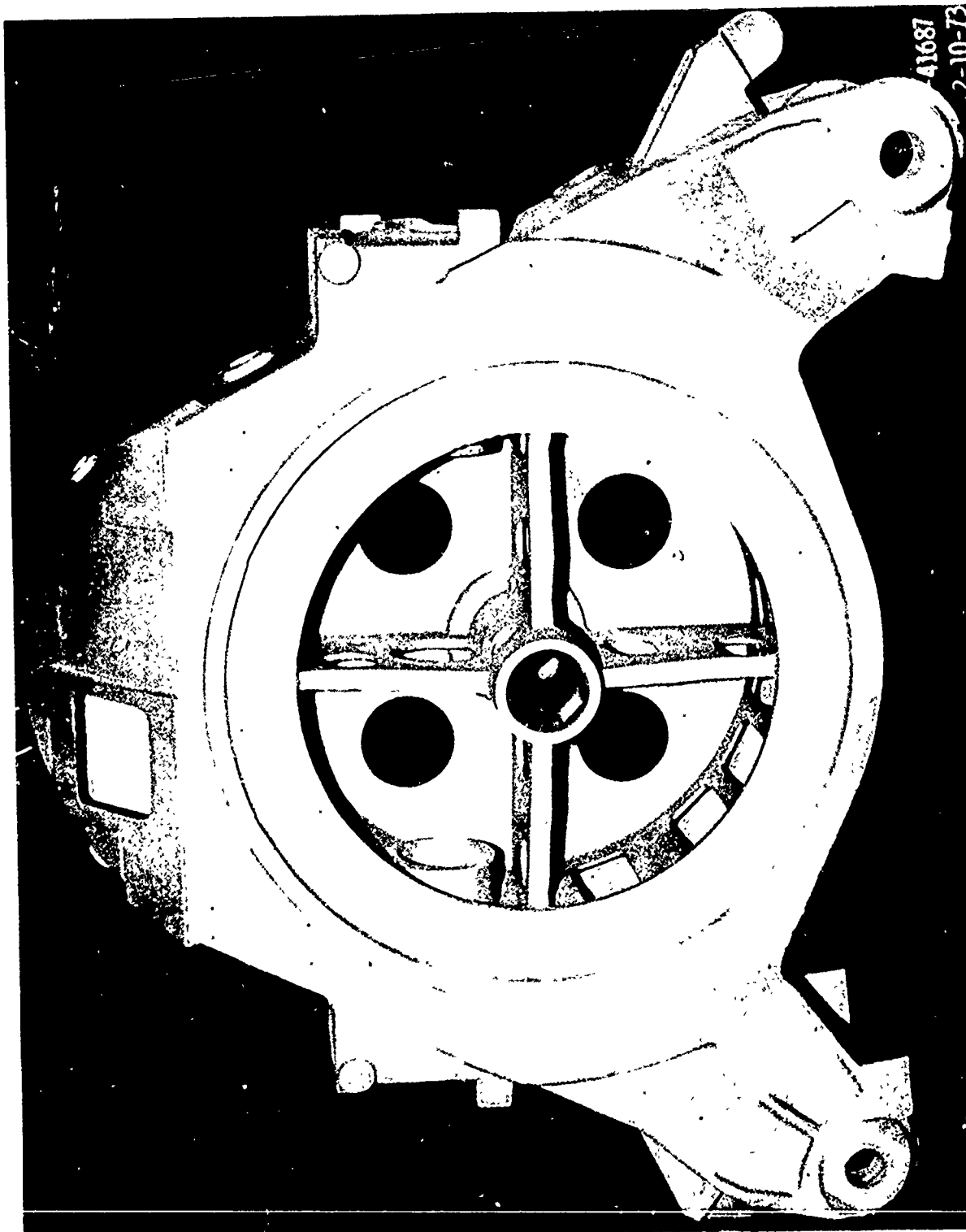


Figure 1-1. Bottom Carriage Structure, Casting for 155mm Howitzer XL198

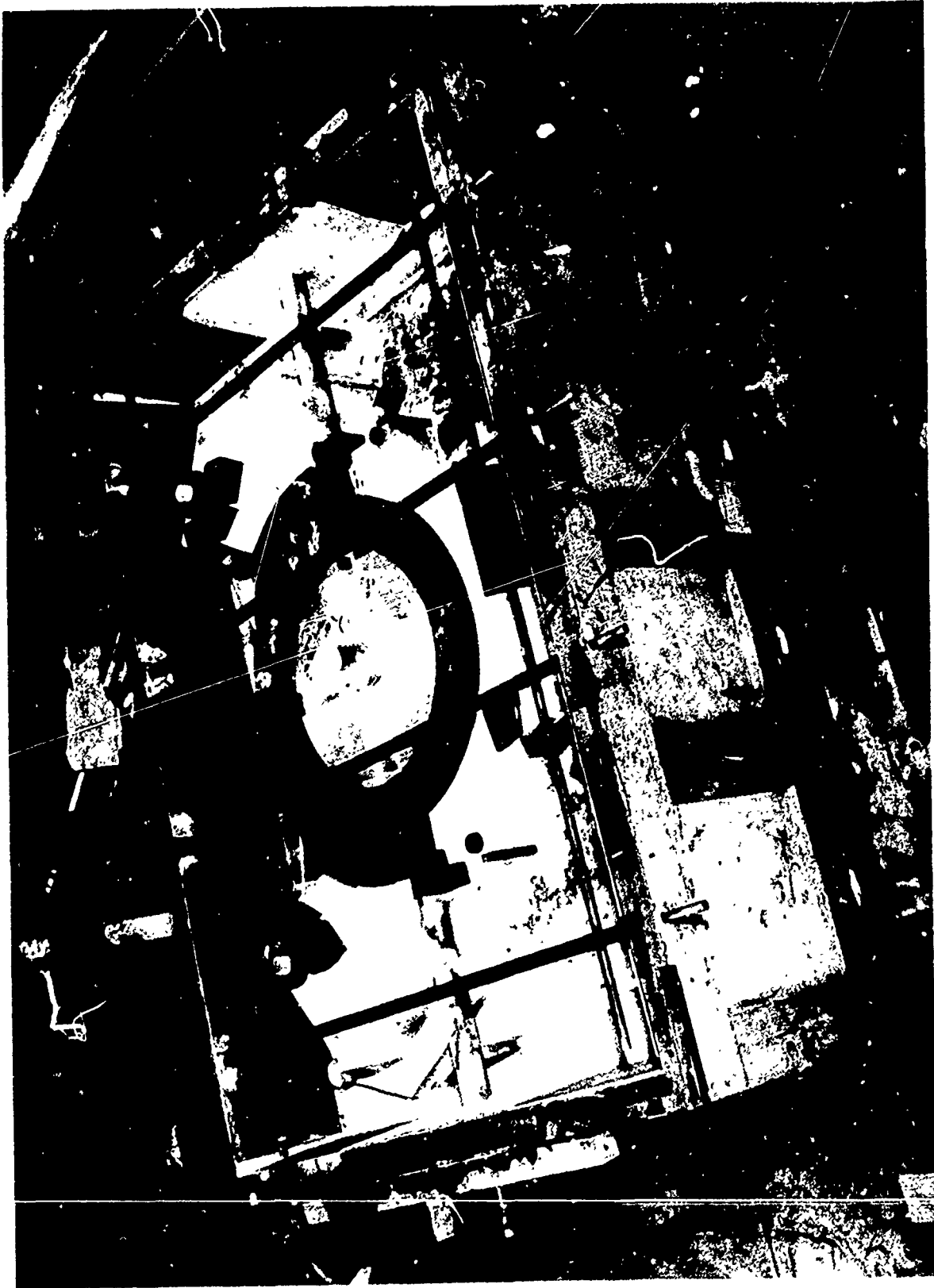


Figure B-1. Drag Half of Mold Without Core



Figure B-2. Drag Half of Mold With Core in Place

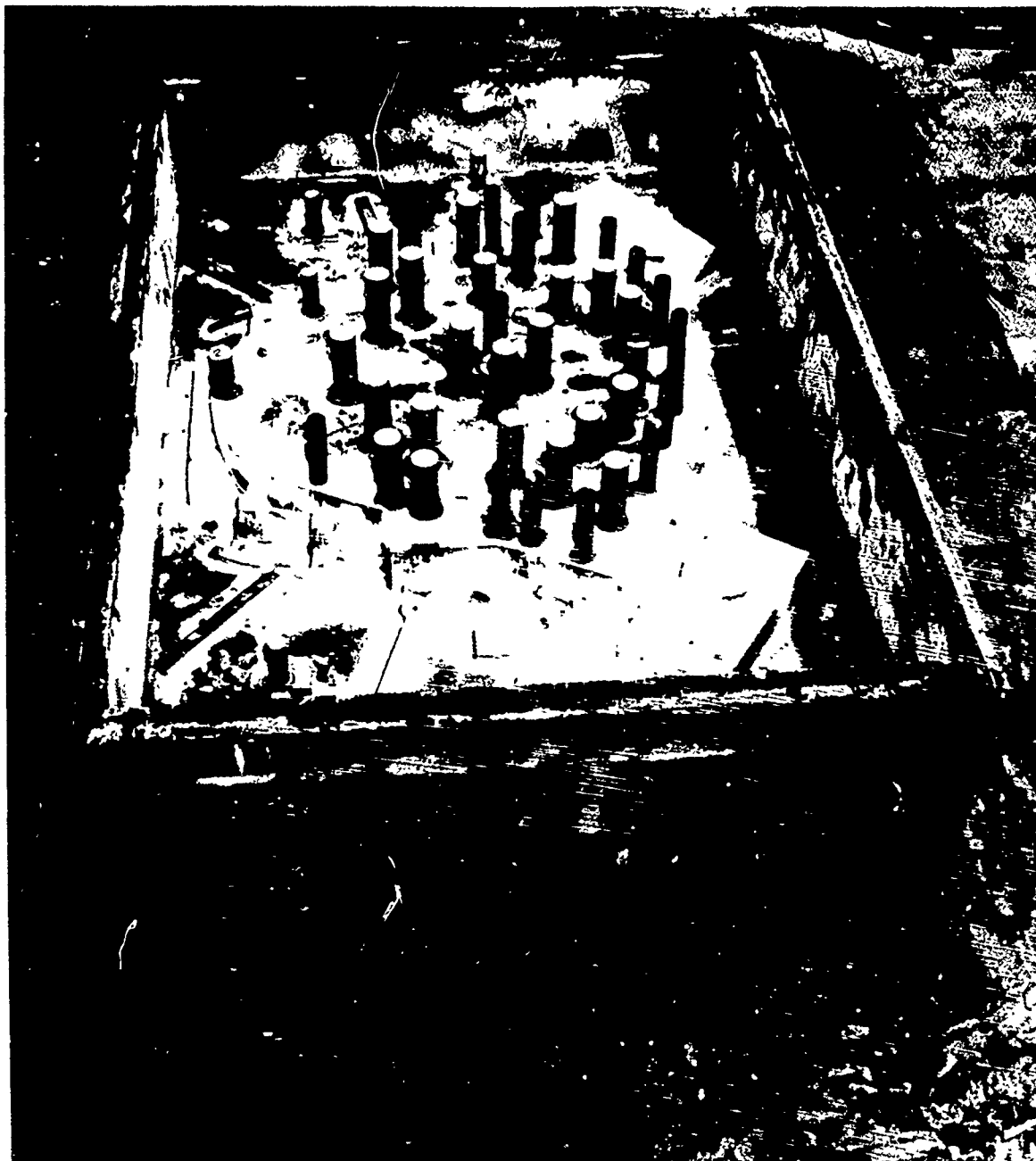


Figure B-3. Cope Half of Mold

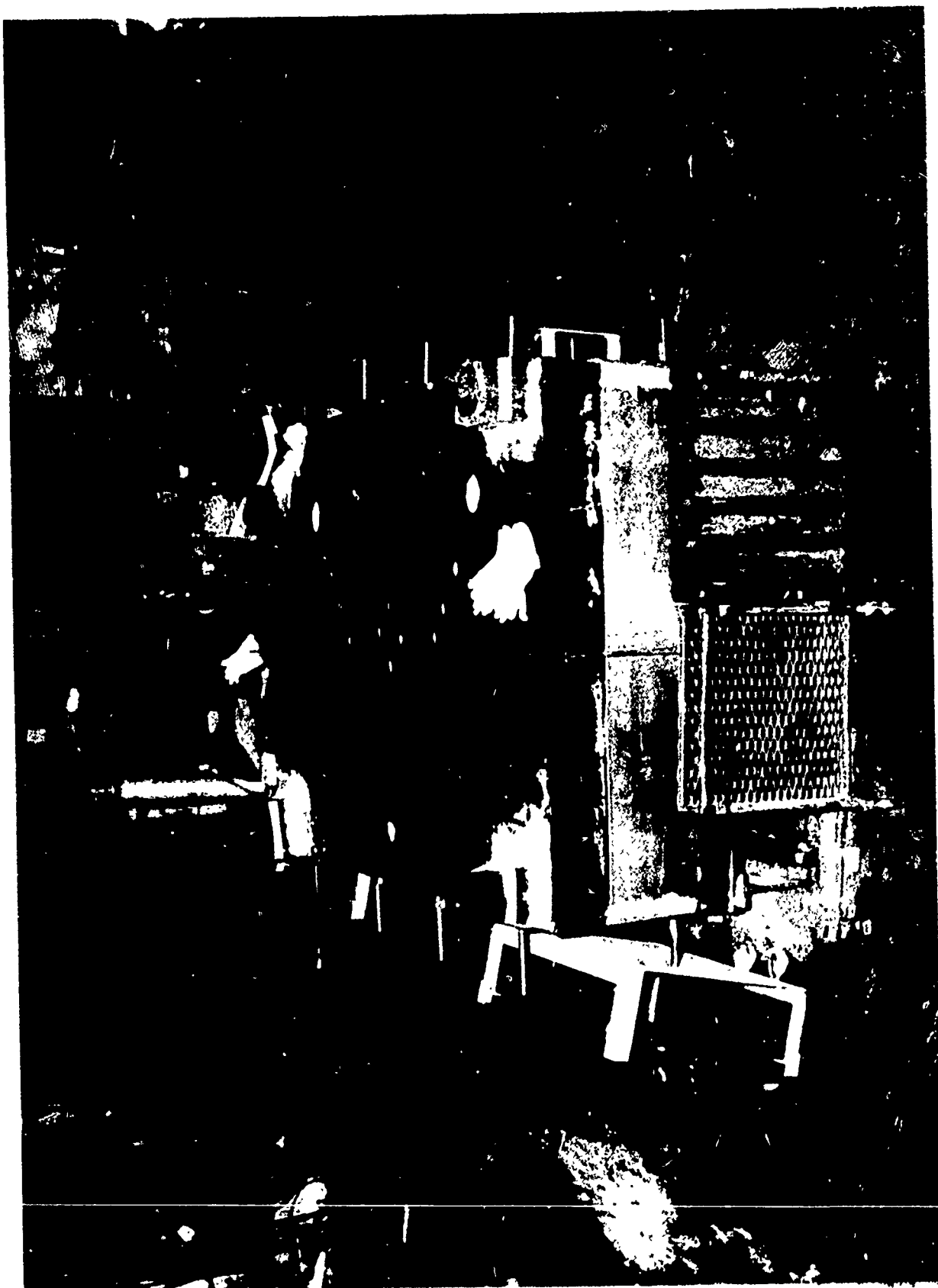


Figure B-4. Complete Mold, Ready for Pouring



Figure B-5. Pouring KO-1 Aluminum for Bottom Carriage Structure

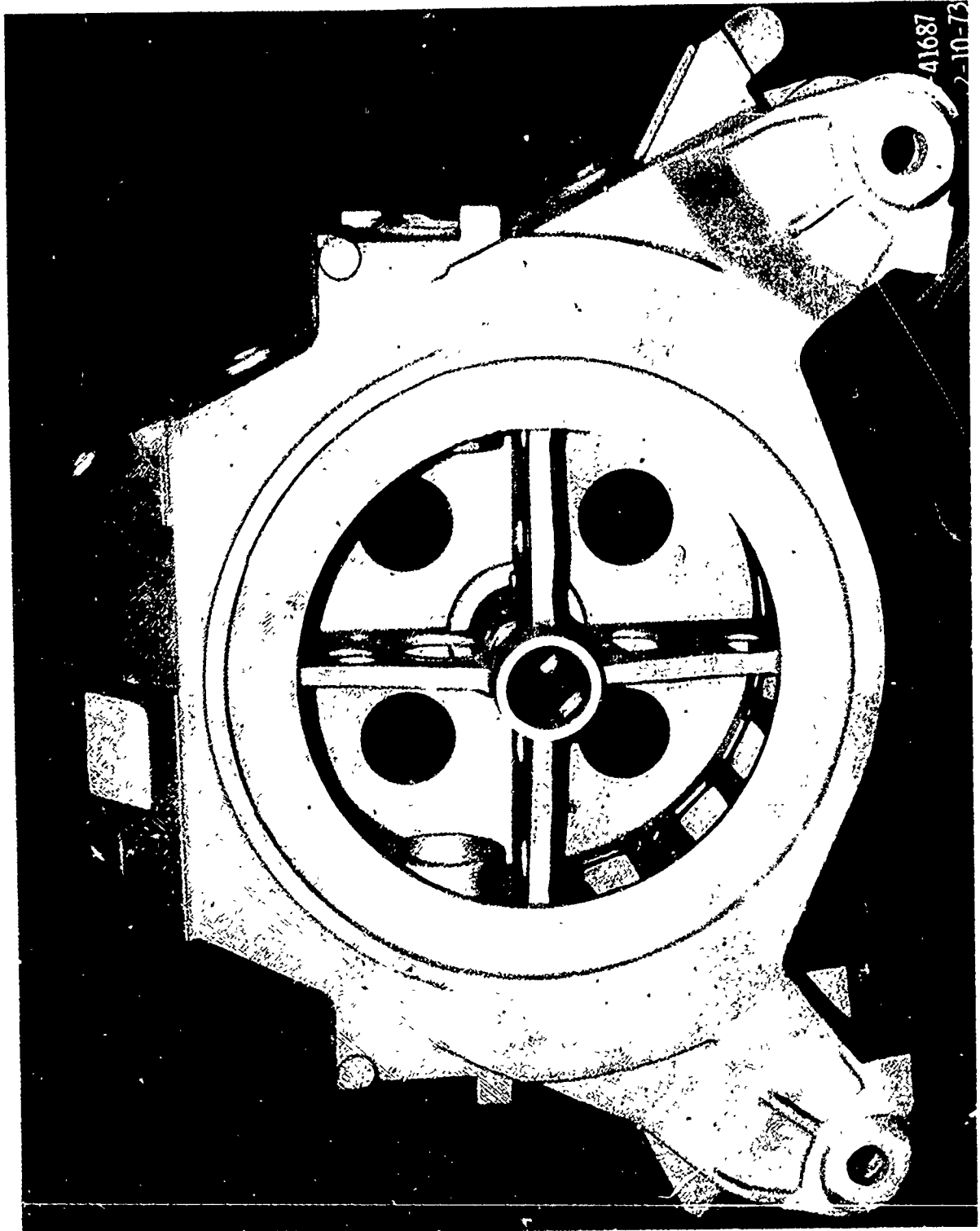


Figure B-6. Bottom Carriage Structure. Finished Casting, Top View



Figure B-7. Bottom Carriage Structure, Finished Casting, Bottom View

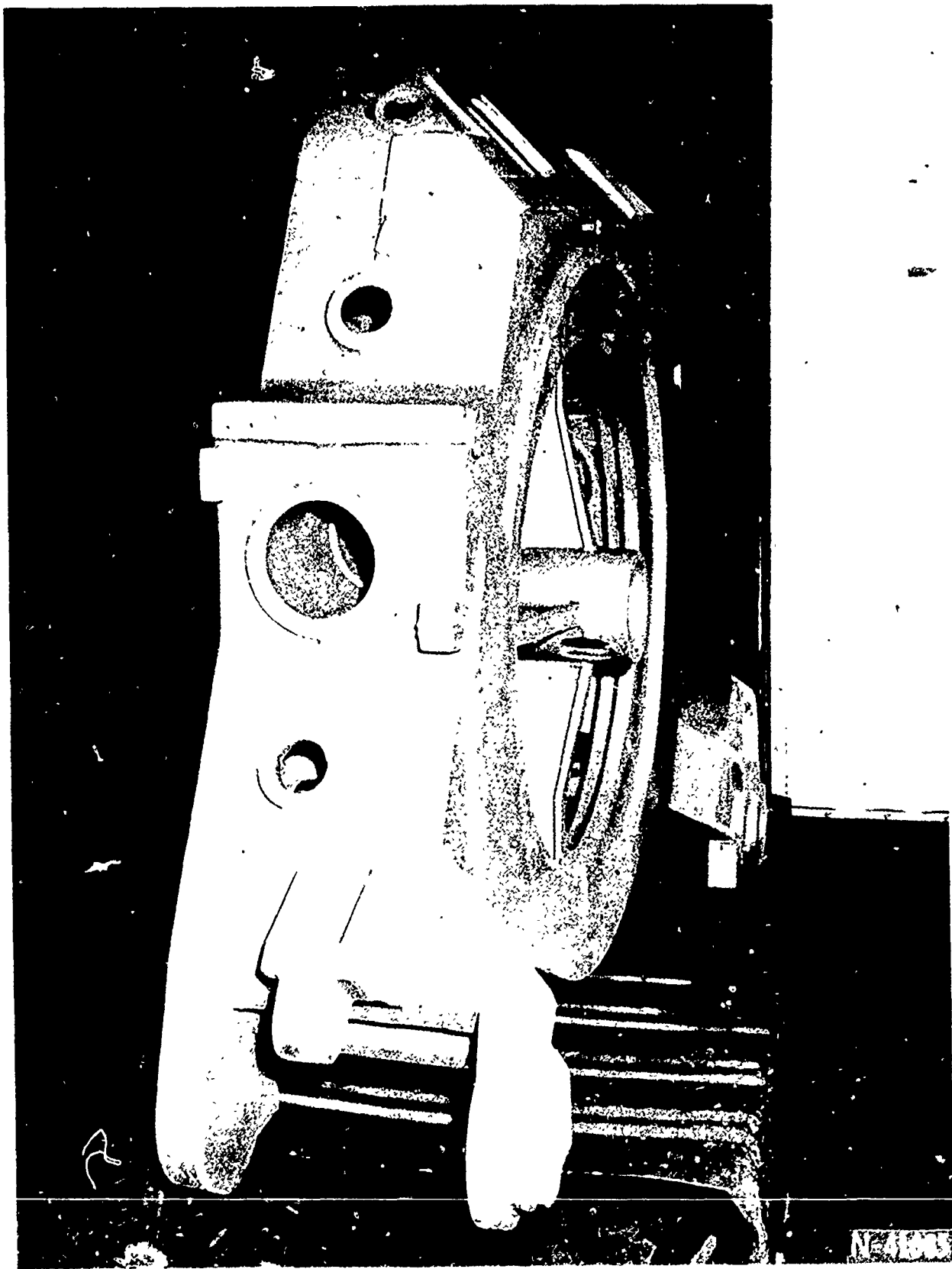
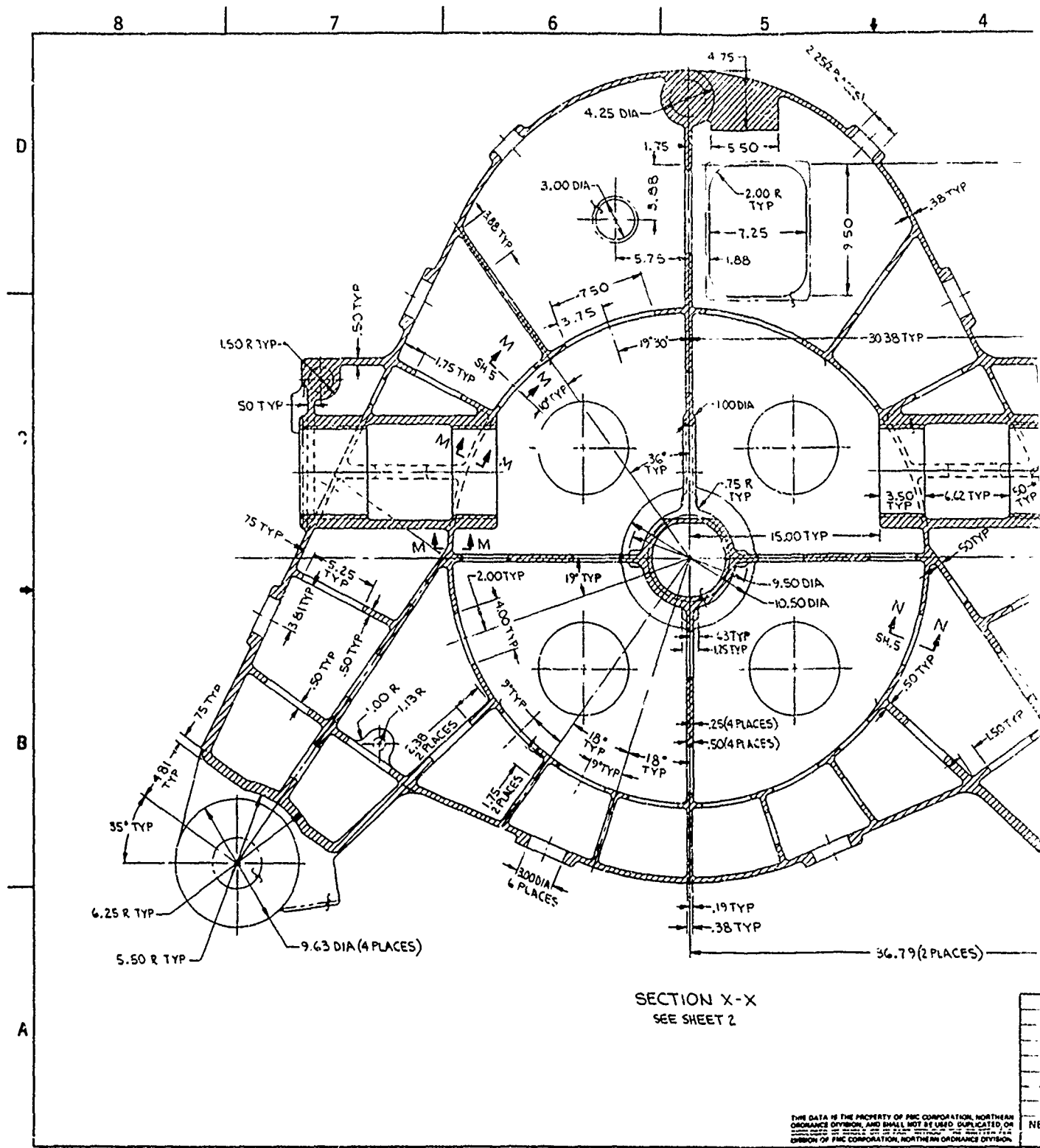


Figure B-8. Bottom Carriage Structure, Finished Casting, Side View

- 8
- 7
- 6
- 5
- 4
1. INTERPRET DRAWING IN ACCORDANCE WITH MIL-D-3000 FOR CATEGORY A AND FORM Z.
2. FOR MACHINING DRAWING, SEE RIA 14918.
3. ALL MACHINED SURFACES ARE MARKED
4. 1/4 MIN STOCK ALLOWED ON ALL MACHINED SURFACES.
5. CAST EDGES .250 R.
6. EXCEPT AS NOTED:
CAST FILLETS .38 R.
7. DRAFT ANGLE ALLOWED 1°.
8. RIA 14918 □ CAST INTEGRAL IN 3/8 CHARACTERS IN POSITION SHOWN.
9. PENETRANT METHOD OF INSPECTION ENTIRE CASTING IN ACCORDANCE WITH MIL-I-4866, TYPE I, METHOD A. NO LINEAR DEFECTS OVER 1/4 IN ARE ACCEPTABLE IN AREA DESIGNATED. NO LINEAR DEFECTS OVER 3/4 IN ARE ACCEPTABLE IN BALANCE OF CASTING.
10. INTEGRALLY CAST-ON COUPONS SHALL BE TESTED IN ACCORDANCE WITH MIL-A-21100. COUPONS MUST BE AS MASSIVE AS THE SECTION FROM THE TEST AREA AND UNCHILLED. TEST BARS WILL BE FROM THE CENTER OF THE COUPON. REMOVAL OF COUPONS FROM THE CARRIAGE STRUCTURE SHALL NOT DEGRADE THE STRUCTURAL INTEGRITY OF THE CASTING.
- D
- C
- B
- A
- 2.00 R TYP
- 10.75
- 8.28
- .38
- 1.23
- 11.25
- 18.75 R
- 45° (2 PLACES)
- 3.50 DIA (2 PLACES)
- 1.25
- 2.00 R TYP
- .50 TYP
- IDENT MARK-SEE NOTE 8
- 1.25
- 2 PLACES
- 23.50 R
- 8.31 TYP
- 7.00 DIA 4 PLACES
- 26.50 TYP
- 2.75 TYP
- 30.00 R TYP
- 14.00
- 7.5 R (2 PLACES)
- 24.25
- 1.88 TYP
- 35.58 TYP
- 22° 30' TYP
- 2.00 R TYP
- 1.50 TYP
- .75 TYP
- .50 TYP
- 25 TYP
- 50 TYP
- C.G.
- 45°
- SH.4
- SH.5
- SH.5 L
- SH.5
- SH.2
- SEE NOTE 9
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- NEXT A

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Fig1



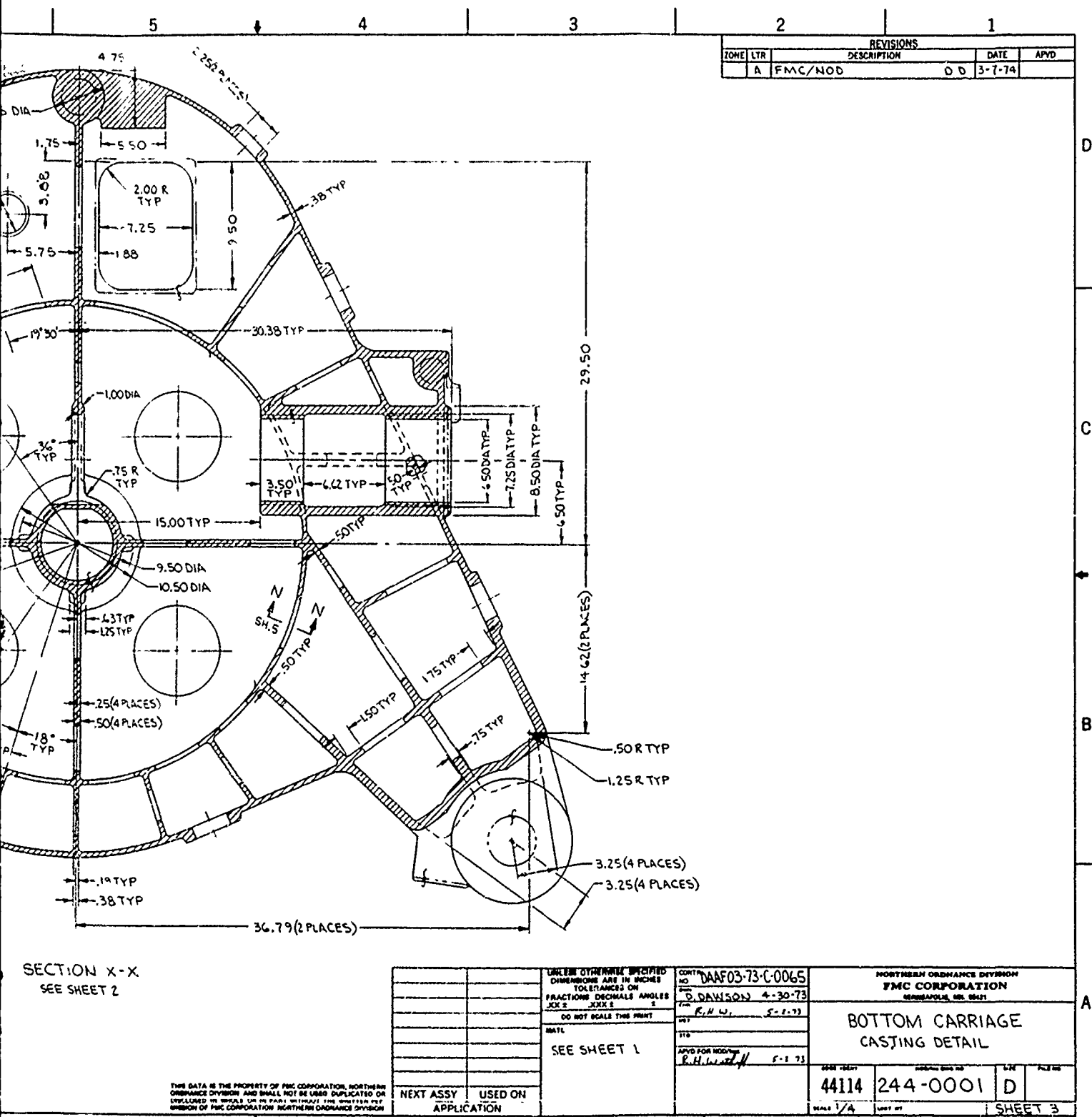
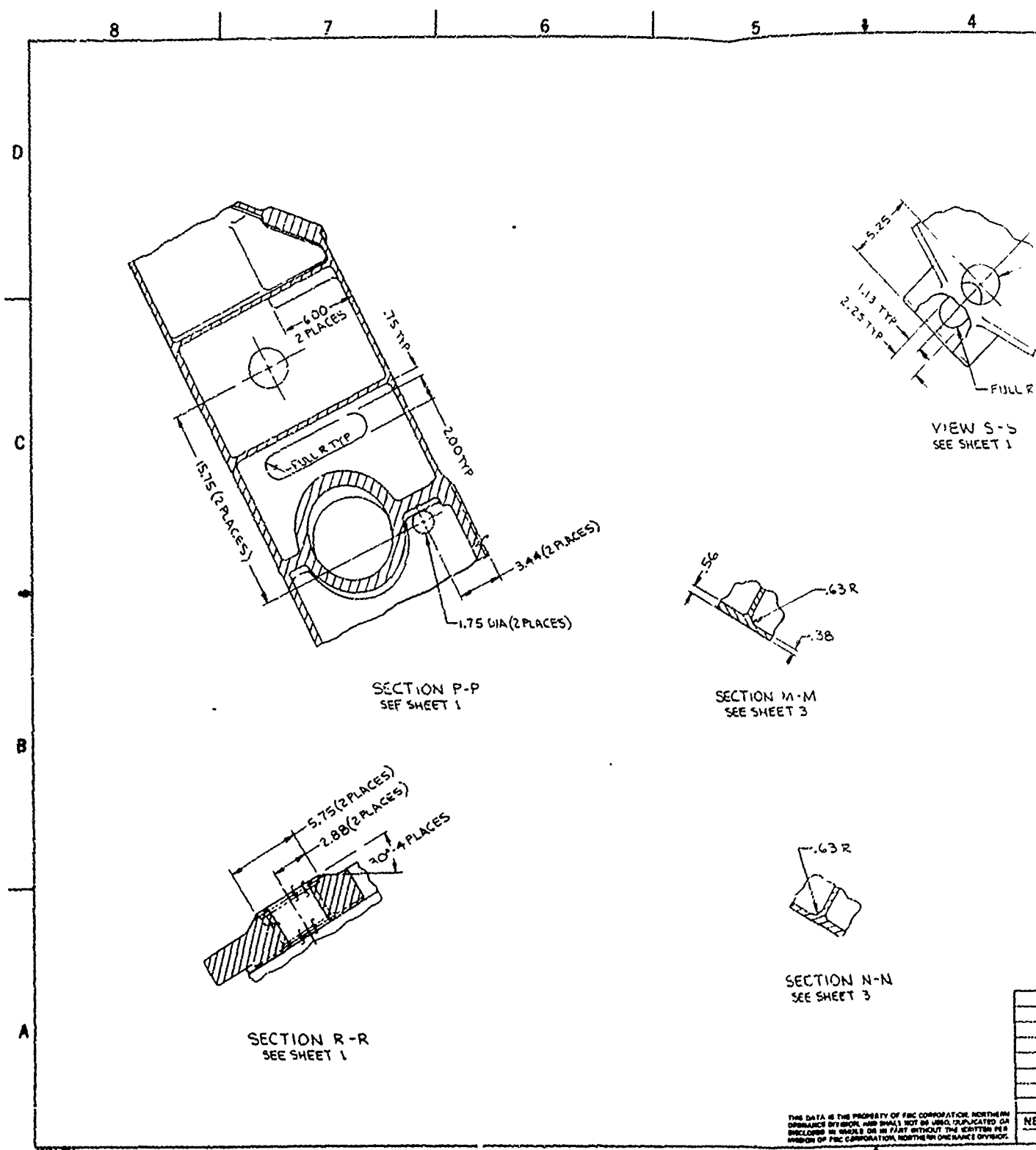


Figure B-9. Bottom Carriage Casting Detail (Sheet 3 of 5)

A cross-sectional diagram of a mechanical component, labeled "150 Z PLACES". The diagram shows a central rectangular block with a smaller rectangular feature on top. The central block has a width of 1.00 TYP and a height of 4.75 TYP. The top feature has a width of 1.50 (2 PLACES). The component is mounted on a base with a thickness of 0.75 (2 PLACES). The diagram includes hatching to indicate different materials or sections.

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79



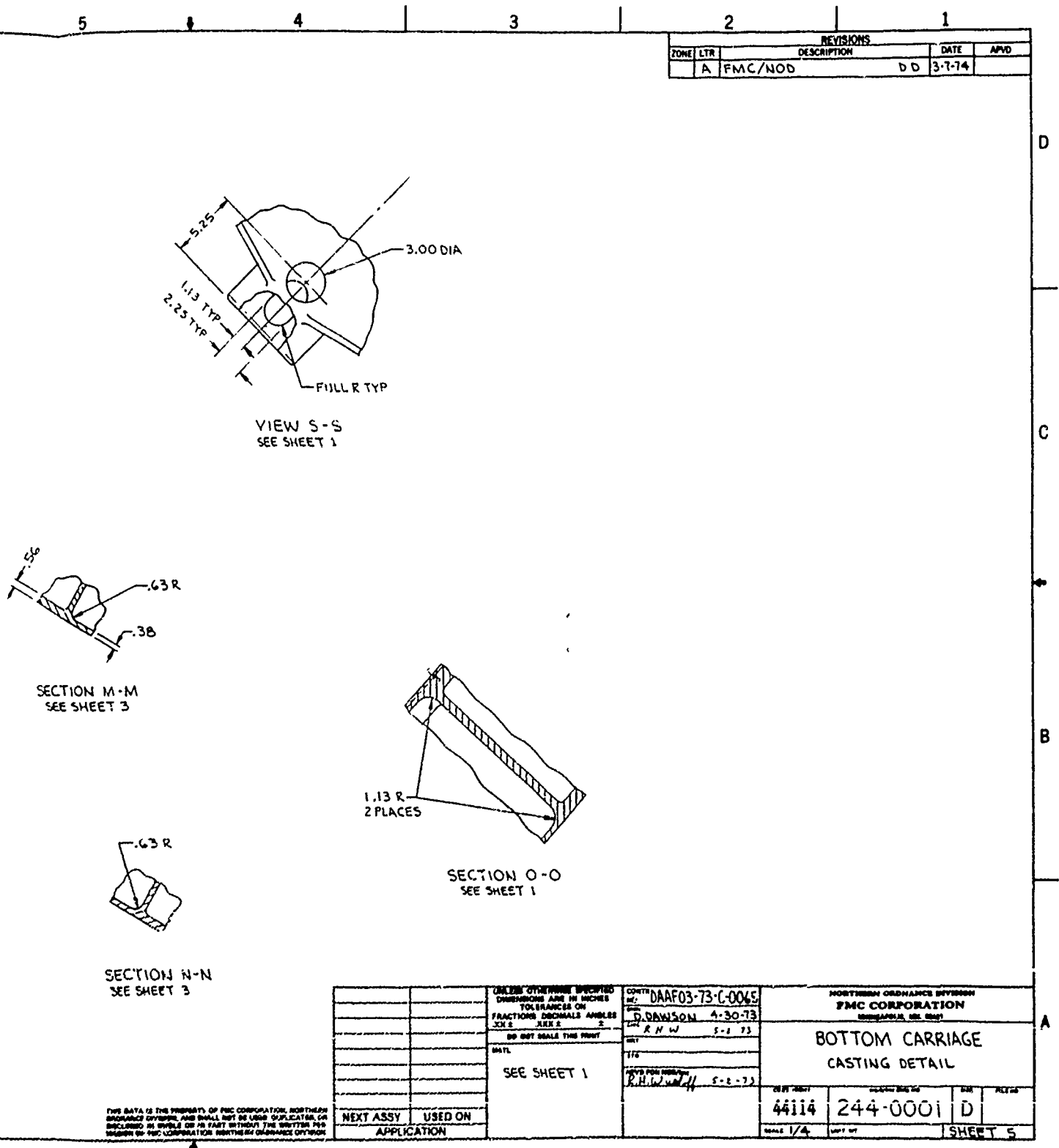


Figure B-9. Bottom Carriage Casting Detail (Sheet 5 of 5)

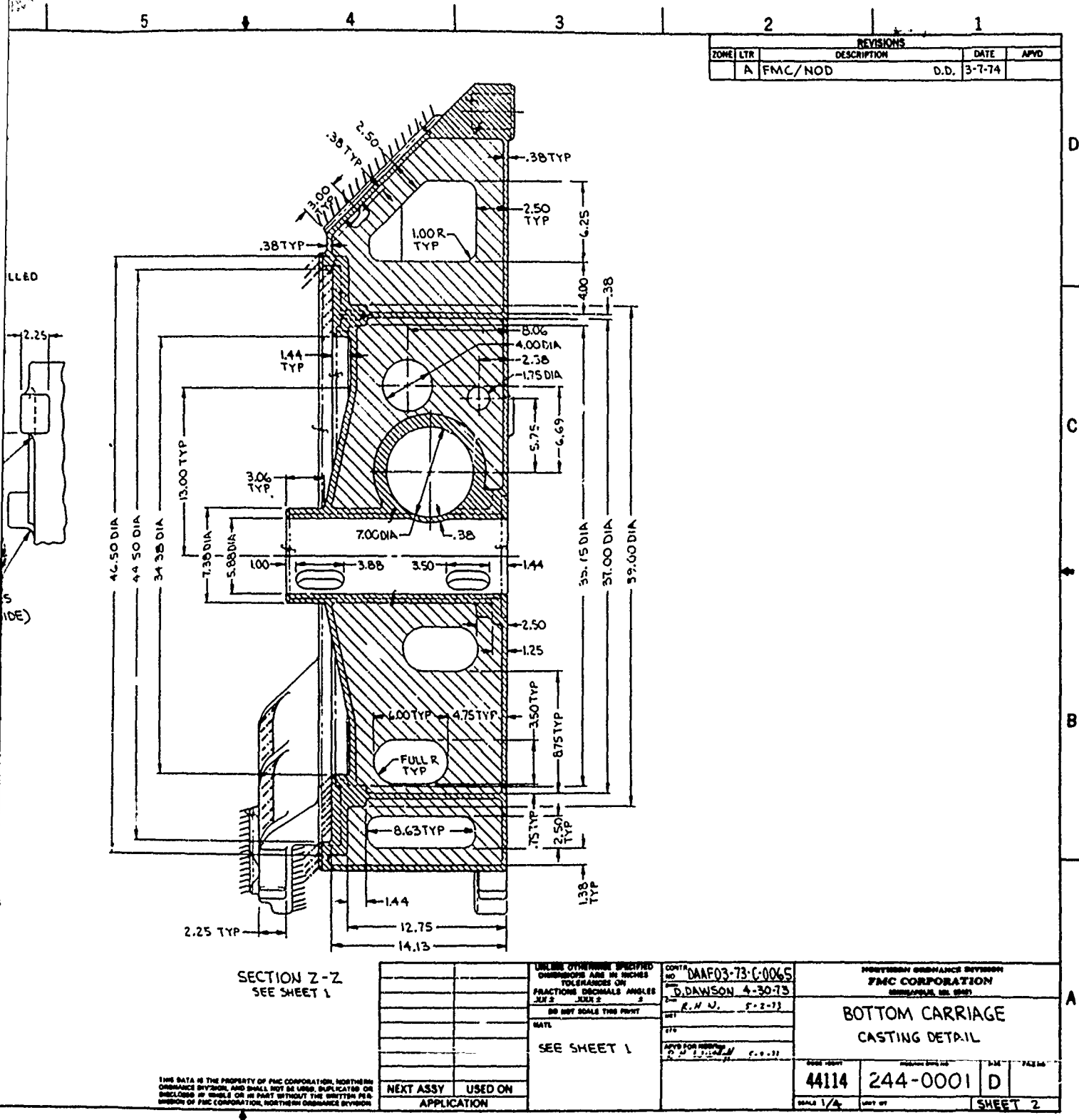


Figure B-10. Chilled Areas of Bottom Carriage Casting (Sheet 2 of 3)

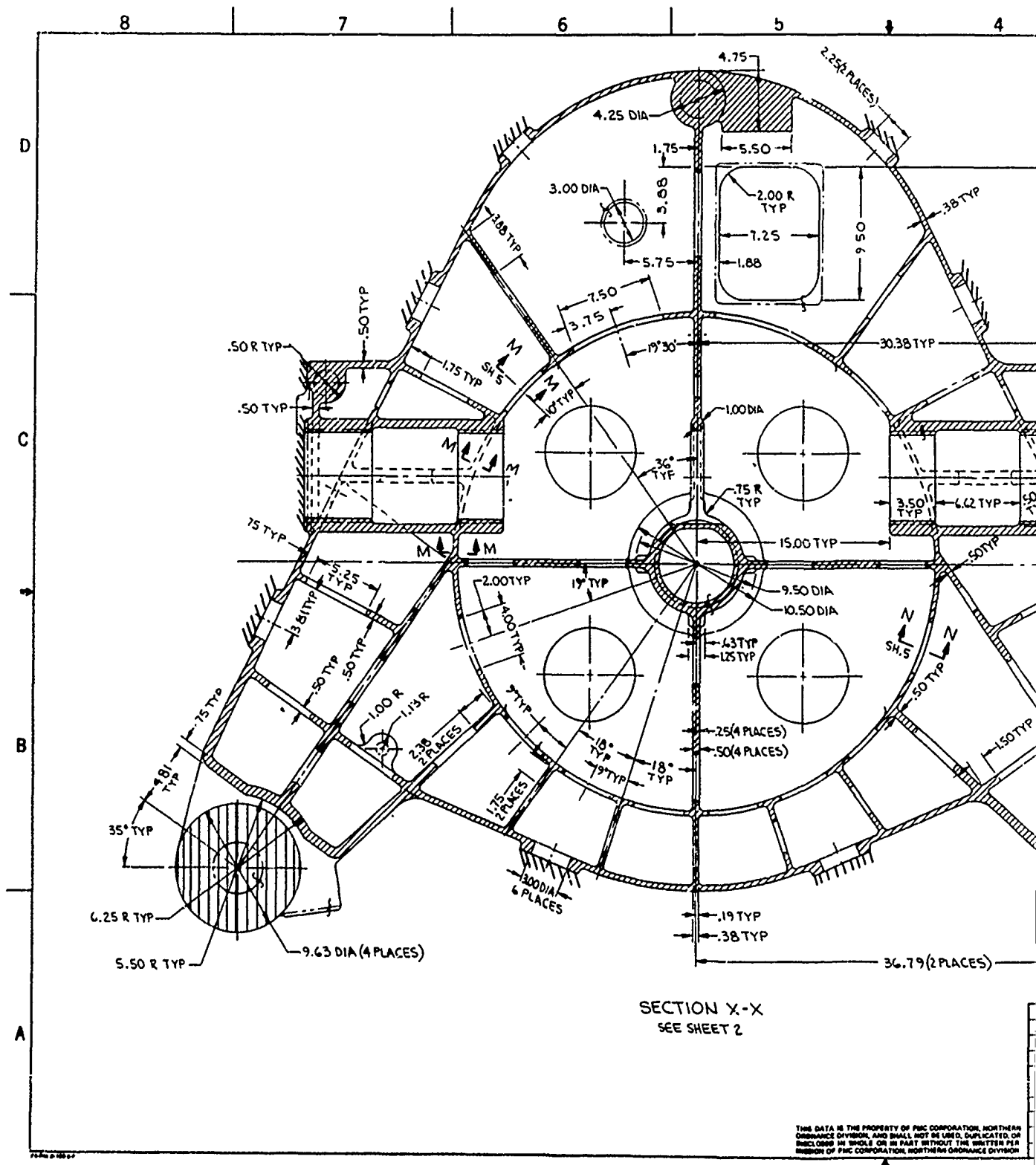


Figure B-10.



2

- [illegible]

Figure 1

Figure B-11. Location, Size, and Depth of Defects (Sheet 1 of 2)

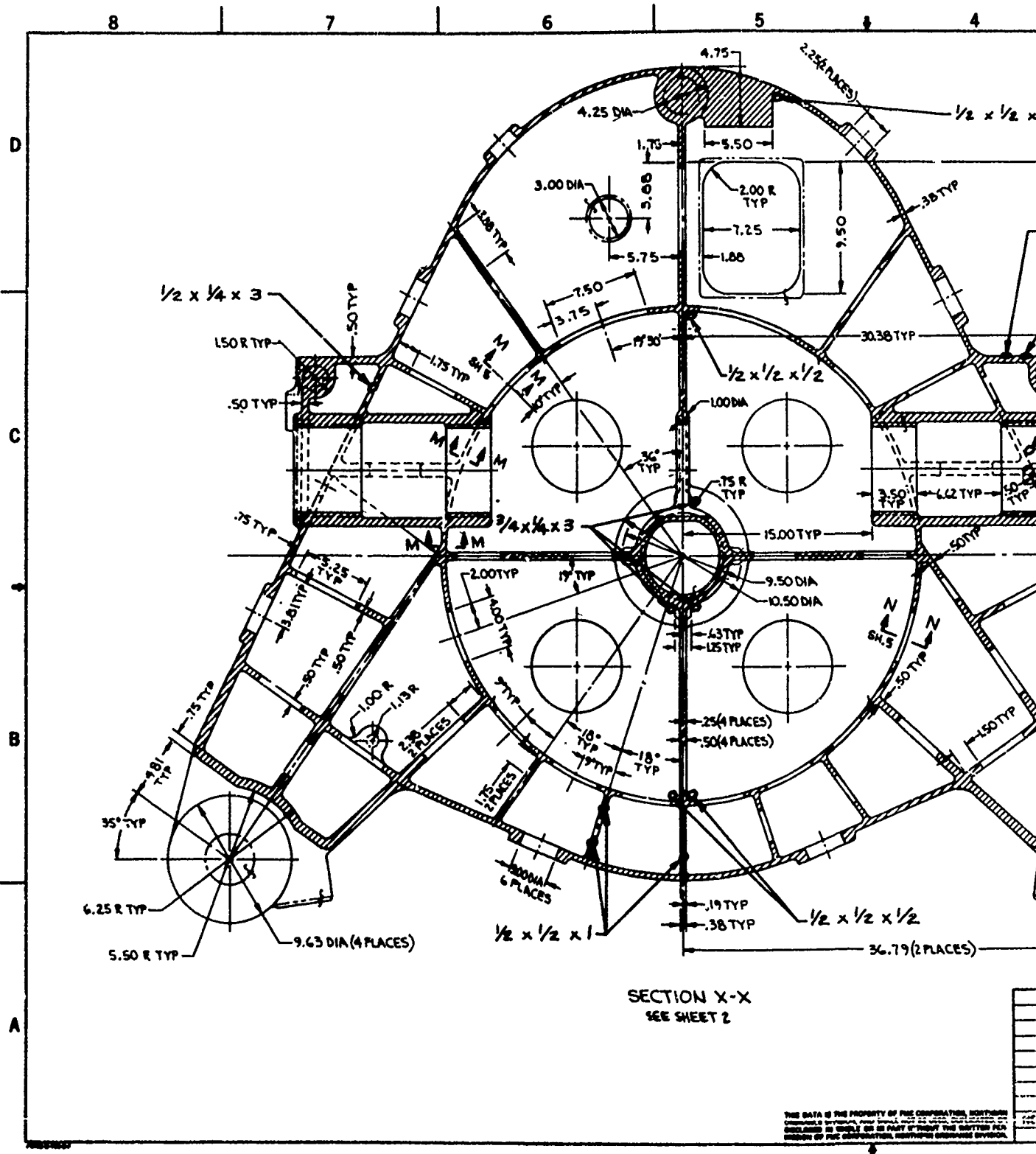
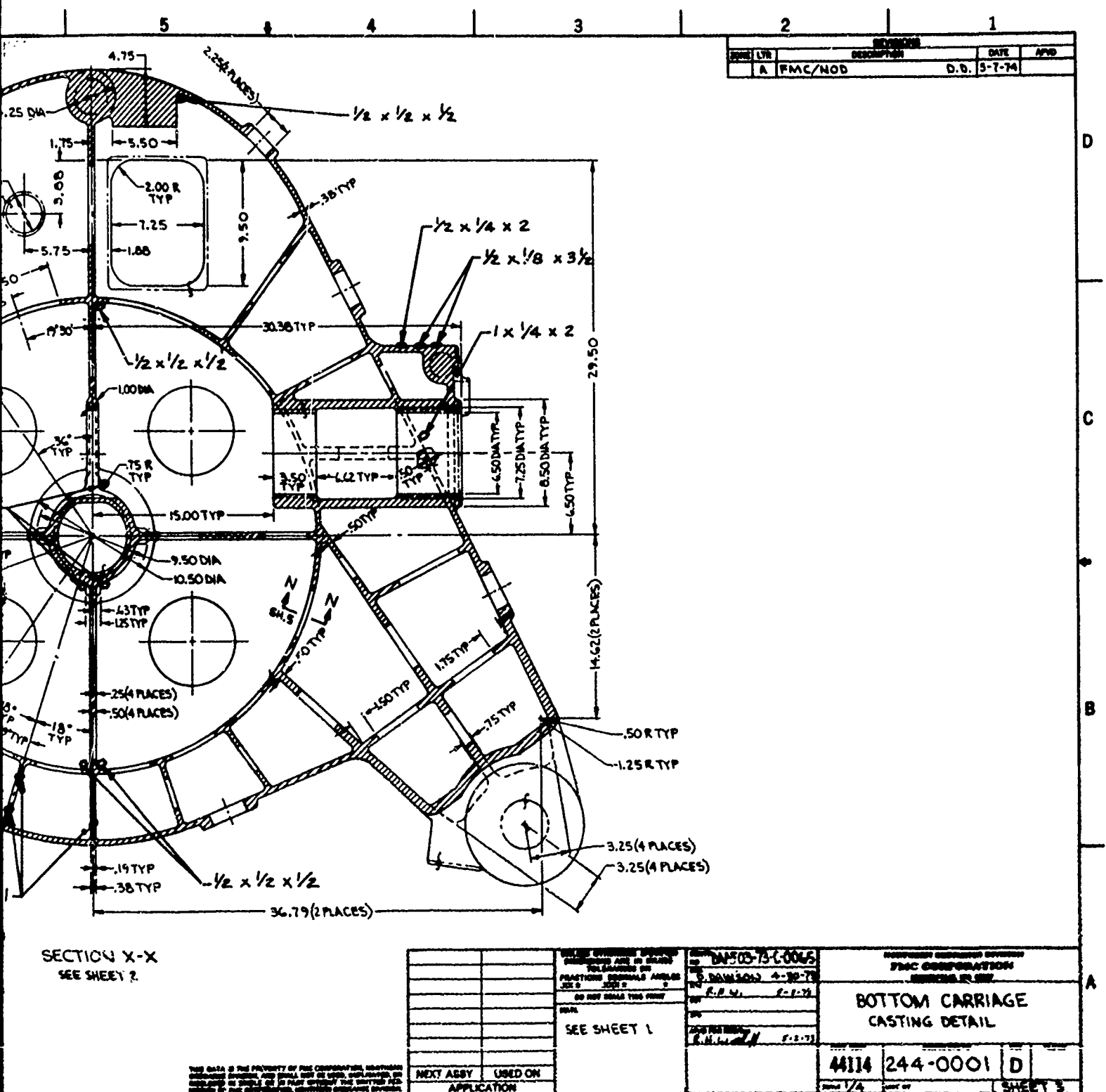
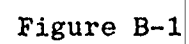


Figure B-





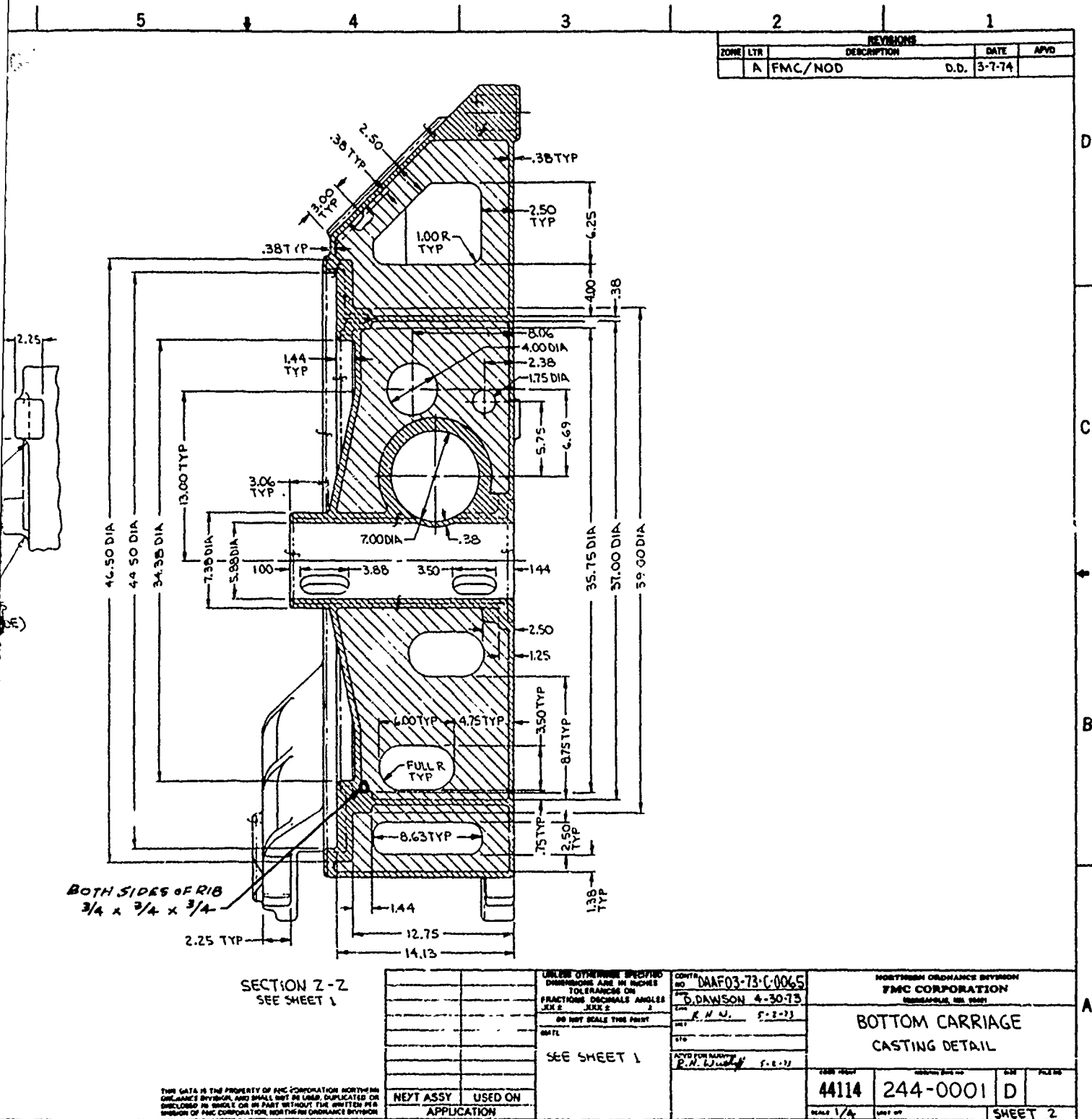


Figure B-12. Location, Size, and Depth of Defects (Sheet 2 of 3)

2

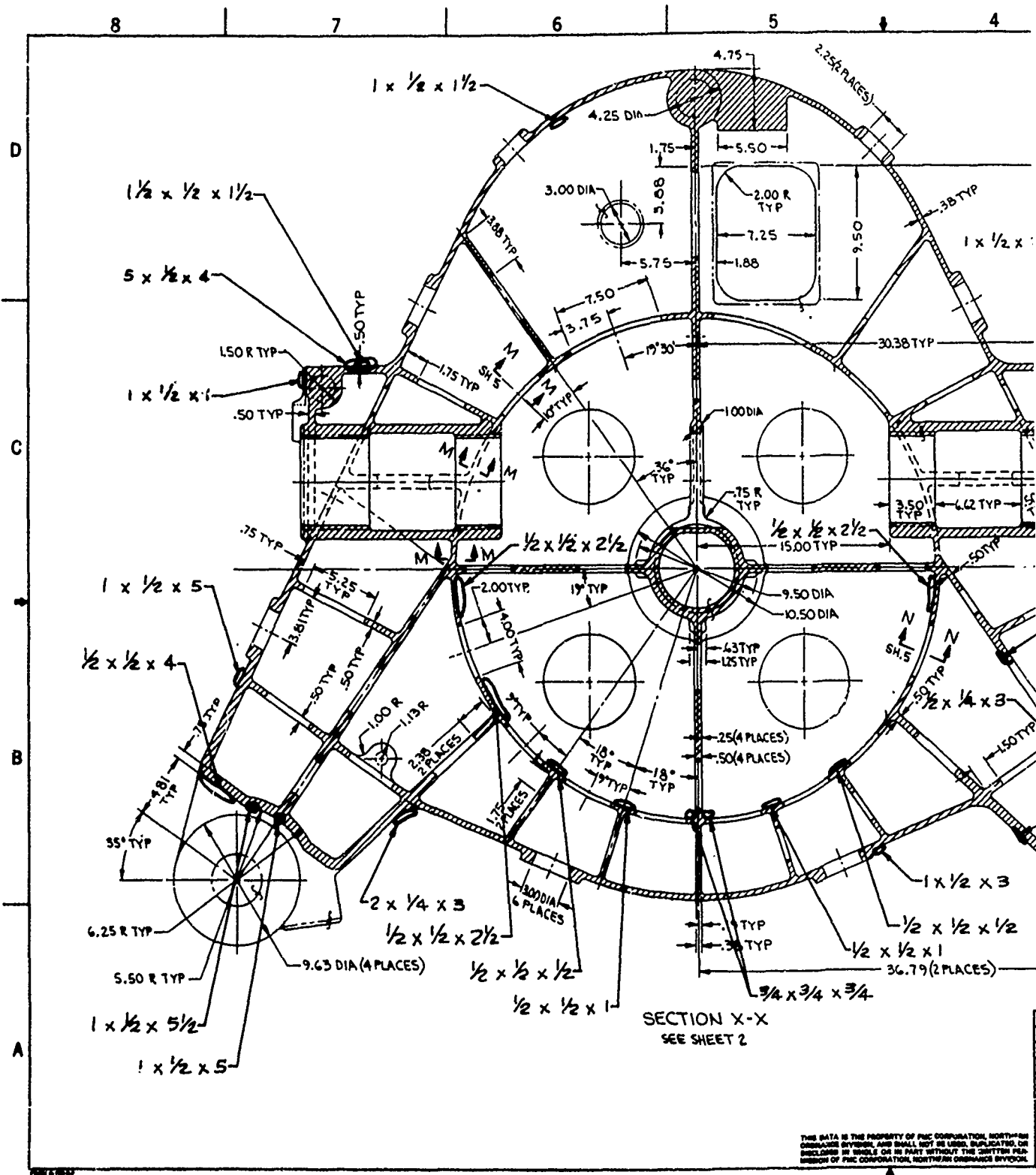


Figure 1

Appendix C
TECHNICAL PROGRESS
REPORTS



FMC CORPORATION

NORTHERN ORDNANCE DIVISION

COLUMBIA HEIGHTS POST OFFICE, MINNEAPOLIS, MINNESOTA 55121
TELEPHONE (TELECOPIER) (612) 566 9201

4 June 1973

Commander
U. S. Army Weapons Command
Rock Island, Illinois 61201

Attention: SWERR-A-TA

Subject:
Contract DAAF03-73-C-0065
Technical Progress Report No. 1

Enclosure:

- (1) Schedule - Delivery Status Report - Three (3) Copies
- (2) Two (2) Polaroid Photos of Present Pattern Status

- 1. In accordance with the requirements of the subject Contract, this Technical Progress Report for the period 12 March thru 31 May 1973 is forwarded for information and record. Enclosure (1) presents the schedule-delivery status of the program.
- 2. Milestones/Work Schedules for the Reporting Period
 - 2.1 Preliminary design calculations.
 - 2.2 Detail drawings.
 - 2.3 Weight calculations.
 - 2.4 Start final stress analysis.
 - 2.5 Furnish old pattern equipment to pattern maker and start redesign and fabrication of new pattern equipment.

4 June 1973
SWERR-A-TA
Page Two

3. Milestones/Work Accomplished During the Reporting Period

- 3.1 Preliminary design calculations were completed.
- 3.2 Preliminary detail drawings were completed and were submitted to Mr. C. Shaffer, SWERR-A, on 8 May 1973. (See Enclosure (1))
- 3.3 Weight calculations were completed.
- 3.4 Work on final stress analysis was started and is estimated to be 25% completed as of the end of this Reporting Period.
- 3.5 The old pattern equipment was received at our plant on 25 April 1973. It was checked and turned over to the pattern maker on 7 May 1973. Two (2) Polaroid camera photos reflecting current physical status are also enclosed. Partial utilization of the original pattern equipment is reflected by the reddish brown area in Photo #1. It is estimated that the pattern and core box effort is 20% complete.

4. No problems were encountered during the Reporting Period.

5. Milestones/Work to be Accomplished During the Next Reporting Period

- 5.1 Final stress analysis will be continued and may be completed.
- 5.2 An additional 60% to 70% of the pattern effort should be completed during the coming Reporting Period.

6. Percent of Total Task Completed

- 6.1 It is estimated that the engineering effort is 70% complete and the pattern effort 20% complete with the manufacturing waiting on completion of the new pattern equipment expected in July 1973.

FMC CORPORATION
Northern Ordnance Division

Albert E. Wickman
Albert E. Wickman
Senior Contract Administrator

AEW:sg

cc AMCM-CAWS (2)

*See John Lippert
Rex W. Weckhoff*



FMC CORPORATION

NORTHERN ORDNANCE DIVISION

COLUMBIA HEIGHTS POST OFFICE, MINNEAPOLIS MINNESOTA 55421

TELEPHONE (TELECOPIER) (612) 560 9201

5 July 1973

Commander
U. S. Army Weapons Command
Rock Island, Illinois 61201

Attention: SWERR-A-TA

Subject:
Contract DAAF03-73-C-0065
Technical Progress Report No. 2

Enclosure:

(1) Schedule - Delivery Status Report - Three (3) Copies

1. In accordance with the requirements of the subject Contract, this Technical Progress Report for the period 1 June thru 30 June 1973 is forwarded for information and record. Enclosure (1) presents the schedule-delivery status of the program.
2. Milestones/ Work Schedules for the Reporting Period
 - 2.1 Continue final stress analysis.
 - 2.2 An additional 60% to 70% of the pattern effort should be completed.
3. Milestones/ Work Accomplished During the Reporting Period
 - 3.1 Stress analysis effort was continued and is 50% complete.
 - 3.2 Corrected preliminary detail drawings covering the casting detail of the bottom carriage were submitted 6 June 1973.

5 July 1973
SWERR-A-TA
Page Two

- 3.3 Both halves of the pattern are basically complete except for some touch-up work and rounding of edges. One-half of the main core which will be plastic was poured on 29 June with the other half to be poured during the first week of July.
4. No problems were encountered during the Reporting Period.
5. Milestones/ Work to be Accomplished During the Next Reporting Period
 - 5.1 Final stress analysis will be completed. A target date of 16 July has been established for completion.
 - 5.2 The pattern and core box equipment will be completed and should be available to the Foundry by 17 July.
 - 5.3 Foundry effort will commence in preparation for pouring of the castings.
6. Percent of Total Task Completed
 - 6.1 It is estimated that the engineering effort is 83% complete and the effort on the pattern and core box equipment is 85% complete.

FMC CORPORATION
Northern Ordnance Division

Albert E. Wickman
Albert E. Wickman
Senior Contract Administrator

AEW:sg

cc: Commander
U. S. Army Weapons Command
Rock Island, Illinois 61201

Attention: AMCDM-CAWS

FMC Corporation

Northern Ordnance Division
Columbia Heights Post Office
48th and Marshall Street Northeast
Minneapolis Minnesota 55421
(612) 560 9201

7 September 1973



Commander
U. S. Army Weapons Command
Rock Island, Illinois 61201

Attention: SWERR-A-TA

Subject:
Contract DAAF03-73-C-0065
Technical Progress Report No. 3

Enclosure:

- (1) Schedule-Delivery Status Report
Three (3) Copies

1. In accordance with the requirements of the subject Contract, this Technical Progress Report for the period 1 August thru 31 August 1973 is forwarded for your information and record. Enclosure (1) presents the schedule-delivery status of the program.
2. Milestones/ Work Schedules For The Reporting Period
 - 2.1 Completion of final stress analysis.
 - 2.2 Shipment of first casting.
 - 2.3 Start of foundry effort and pouring of second casting.
3. Milestones/ Work Accomplished During The Reporting Period
 - 3.1 The final stress analysis was completed. A copy was mailed to Mr. C. Shaffer, SWERRA, on 27 August 1973.
 - 3.2 The first and second castings were poured during August.

✓ 4. Problems Encountered During The Reporting Period

- 4.1 Due basically to problems with the mold, the first casting had too many defects to be given consideration for use as the first shipment.
- 4.2 A second casting was poured with better results though there still are problems. The sand set up too hard and was quite difficult to remove. The casting did require a number of weld repairs.
- 4.3 Mold making technique is being improved as a result of experience on the first two including a reduction of the binder in the sand to assure easier shake out of future castings.
- 4.4 It is planned that all remaining castings will be poured during September, if possible, to enhance the chance of completing shipment on schedule.
- 4.5 Balancing worst and best possible conditions, Foundry management predicts shipment as follows:

First Casting	13 September 1973
Second Casting	28 September 1973
Third Casting	17 October 1973
Fourth Casting	9 November 1973

5. Milestones/Work To Be Accomplished During the Next Reporting Period

- 5.1 Pouring of all remaining castings due by the end of September.
- 5.2 Shipment of the first casting by 13 September and the second casting by 28 September.

U. S. Army Weapons Command
7 September 1973
Page three

6. Percent Of Total Task Completed

6.1 It is estimated that the Engineering effort is 96% complete
and that the Foundry effort is 26% complete.

FMC CORPORATION
Northern Ordnance Division

A. E. Wickman
A. E. Wickman
Senior Contract Administrator

AEW:mj

cc: Commander
U. S. Army Weapons Command
Rock Island, Illinois 61201
Attention: AMCPM-CAWS

FMC Corporation

Northern Ordnance Division
Columbia Heights Post Office
48th and Marshall Street Northeast
Minneapolis, Minnesota 55421
612/560-9201



11 October 1973

Commander
U. S. Army Weapons Command
Rock Island, Illinois 61201

Attention: SWERR-A-TA

Subject:
Contract DAAF03-73-C-0065
Technical Progress Report No. 4

Enclosure:

(1) Schedule-Delivery Status Report
Three (3) Copies

1. In accordance with the requirements of the subject Contract, this Technical Progress Report for the period 1 September through 30 September, 1973, is forwarded for your information and record. Enclosure (1) presents the schedule-delivery status of the program.
2. Milestones/ Work Schedules For The Reporting Period
 - 2.1 Pouring of all remaining castings due.
 - 2.2 Shipment of first and second castings.
3. Milestones/ Work Accomplished During The Reporting Period
 - 3.1 The third and fourth castings were poured during September.
4. Problems Encountered During The Reporting Period
 - 4.1 Due to cracks in the basic casting and problems in achieving successful weld repair, the two castings scheduled for shipment in September were not shipped.
 - 4.2 A number of weld repairs by a variety of procedures, depending on size and location of the defect, were tried with a certain degree of success but throughout the month we could not achieve a casting with zero defects.

U. S. Army Weapons Command
11 October 1973
Page two

4.3 A technique of heat treating the casting to relieve all stresses prior to weld repair will be tried in our next effort to achieve total satisfactory weld repair.

4.4 Anticipating reasonable success with this latest effort and evaluating current work load and work to be completed on each of the four castings, Foundry management predicts shipment as follows:

First Casting	19 October 1973
Second Casting	2 November 1973
Third Casting	16 November 1973
Fourth Casting	30 November 1973

5. Milestones/ Work To Be Accomplished During The Next Reporting Period

5.1 A fifth casting will be poured early in October to replace the initial casting which will be scrapped.

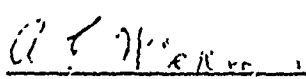
5.2 Shipment of the first casting is scheduled for 19 October.

5.3 Preliminary planning and data collection for compilation of the final technical report will be started.

6. Percent Of Total Task Completed

6.1 It is estimated that the Engineering effort is 97% complete and that the Foundry effort is 50% complete.

FMC CORPORATION
Northern Ordnance Division


A. E. Wickman
Senior Contract Administrator

mj

cc: Commander
U. S. Army Weapons Command
Rock Island, Illinois 61201
Attention: AMCPM-CAWS

Ed Beck
DCAS
FMC/NOD

FMC Corporation

Northern Ordnance Division
Columbia Heights Post Office
48th and Marshall Street Northeast
Minneapolis Minnesota 55421
(612) 560 9201

11 December 1973

FMC

Commander
U. S. Army Weapons Command
Rock Island, Illinois 61201

Attention: SWERR-A-TA

Subject:
Contract DAAF03-73-C-0065
Technical Progress Report No. 5

1. Problems encountered subsequent to Report No. 4 and the expenditure of most of the initial funding brought the program to a potential standstill with an indefinite future so the report for the end of October was delayed. Now that a new course of action has been defined with every indication that it will be funded, this correspondence is submitted as Technical Progress Report No. 5 for the period 1 October thru 30 November 1973.

2. Milestones/Work Schedules for the Reporting Period

- 2.1 Shipment of the first casting by 19 October.
- 2.2 Pouring of fifth casting to replace initial casting which will be scrapped.
- 2.3 Shipment of second, third and fourth castings in November.
- 2.4 Preliminary planning and data collection for compilation of the final technical report.

3. Milestones/Work Accomplished During the Reporting Period

- 3.1 The fifth casting was poured during October.

4. Problems Encountered During the Reporting Period

- 4.1 Weld repair attempts on the second, third and fourth castings, while showing gain or improvement, were never 100% successful with new cracks developing as each repair was completed and heat treated. Since the fifth casting was better in appearance and showed a minimum number of defects, it was planned that repair efforts would be concentrated on this casting when it became available.
- 4.2 Meanwhile, these problems were brought to the attention of Mr. Avery Kearny, Chief Metallurgist of the Olin Aluminum Division, who was one of the leaders in the development of the KO-1 aluminum material. Upon invitation, he came to our foundry on October 18 and 19 and looked over the castings on hand. It was his judgement that our basic problem was micro-shrinkage which provided conditions causing propagation of new cracks as a result of stresses induced during weld repair of any visible defects. It was Mr. Kearny's and our technical foundry personnel's opinion that the micro-shrinkage could be successfully overcome by judicious placement of, and an increase in, the number of risers in making the mold which would bring about controlled solidification after pouring of the casting.
- 4.3 Considering the aforementioned judgement which established all poured castings as unrepairable, and the minimum amount of remaining funds, evaluation of a new course of action was necessary. A proposal was developed and submitted on 26 October 1973 setting forth costs and outlining a new schedule for the completion and shipment of four new castings and the preparation and submission of a final report. Meanwhile, covered by the funds remaining, effort was initiated in making pattern changes and developing improved riser placement within the flask in order to overcome the micro-shrinkage condition.

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4.4 Messrs. Peter Hogberg and Charles Schaffer, of the Armament Command Project Office, visited our plant on 5 and 6 November to discuss the situation and to see the new casting which was poured on 31 October. It was agreed that we would proceed carefully and that no effort towards a second casting would be taken until we had completely studied the first casting and established all potential corrective adjustments or improvements that could be incorporated into the follow-on units.

4.5 Also, on 6 November, sufficient additional funds were added to the contract by telegram to permit completion and shipment of one casting. Discussion with the Contracting Officer as well as with Messrs. Hogberg and Schaffer indicated the likelihood that the quantity of castings required would be reduced from 4 to 2 since that quantity would satisfy the basic requirements and would minimize the additional expenditure required. A final Technical Report without a preliminary draft copy would also be required.

4.6 The initial casting under the new effort required a fair amount of repair but comprehensive inspection indicated that the micro-shrinkage problem had been overcome. It is anticipated that this casting will be shipped around the 17th or 18th of December.

5. Milestones/Work to be Accomplished During the Next Reporting Period

5.1 Ship first casting by 18 December.

5.2 Start preparation for pouring of second casting.
Estimated ship date - 22 January 1974.

4

U. S. Army Weapons Command

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6. Percent of Total Task Completed

- 6.1 It is estimated that the Engineering effort is 97% complete and that the foundry effort is 45% complete based on the reduced quantity of castings.

FMC CORPORATION
Northern Ordnance Division

A. E. Wickman

A. E. Wickman
Senior Contract Administrator

mj

cc: Commander
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Attention: AMCPM-CAWS

Ed Beck
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R. Wilhoff*

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2 January 1974

FMC

Commander
U. S. Army Weapons Command
Rock Island, Illinois 61201

Attention: SWERR-A-TA

Subject:
Contract DAAF03-73-C-0065
Technical Progress Report No. 6

1. In accordance with the requirements of the subject contract, this Technical Progress Report for the period 1 December thru 31 December, 1973, is forwarded for your information and record.
2. Milestones/Work Schedules for the Reporting Period
 - 2.1 Ship first casting by 18 December.
 - 2.2 Start preparation for pouring of second casting.
3. Milestones/Work Accomplished During the Reporting Period
 - 3.1 The first casting was shipped on 18 December 1973.
 - 3.2 In preparation for the second casting, alterations have been made to the pattern equipment to provide additional risers and collapsible chills are being developed.
4. Problems Encountered During the Reporting Period
 - 4.1 A considerable amount of weld repair was required to bring the initial casting into an acceptable state. The repairs were required on cracks that developed during the casting cooling period which we believe can be prevented by incorporation of more risers and collapsible chills into the mold for the second casting. As reported in 3.2 above, work is already in progress in applying the corrective measures.

2

U. S. Army Weapons Command

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5. Milestones/Work to be Accomplished During the Next Reporting Period

- 5.1 The mold should be ready for pouring of the second casting on 9 January.
- 5.2 The second casting should be shipped 22 January.
- 5.3 Initial effort, such as gathering of data, should begin during last week of January in preparation of the Final Technical Report.

6. Percent of Total Task Completed

- 6.1 It is estimated that the Engineering effort is 98% complete and that the foundry effort is 58% complete based on the reduced quantity of castings.
- 6.2 One hundred percent of the Final Technical Report effort remains to be accomplished.
- 6.3 Based on total expenditure of manpower and material, the program could be considered 80% complete.

FMC CORPORATION
Northern Ordnance Division

A. E. Wickman

A. E. Wickman
Senior Contract Administrator

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7 February 1974



Commander
U. S. Army Weapons Command
Rock Island, Illinois 61201

Attention: SWERR-A-TA

Subject:
Contract DAAF03-73-C-0065
Technical Progress Report No. 7

1. In accordance with the requirements of the subject contract, this Technical Progress Report for the period 1 January thru 31 January, 1974, is forwarded for your information and record.
2. Milestones/Work Schedules for the Reporting Period
 - 2.1 Pour second casting on 9 January.
 - 2.2 Ship second casting on 22 January.
 - 2.3 Start initial effort in preparation of Final Technical during last week of January.
3. Milestones/Work Accomplished During the Reporting Period
 - 3.1 Collapsible chills were developed and the mold completed so that the second casting was poured on 16 January. It was shaken out, gates and risers removed and underwent initial inspection on 27 January.
4. Problems Encountered During the Reporting Period
 - 4.1 While the casting at initial inspection basically appeared better than the first casting shipped and did not have the large cracks which were apparently overcome by the collapsible chills, the casting never-the-less had a large number of smaller cracks scattered over all areas. As a result, all milestones scheduled for January were missed.

U. S. Army Weapons Command

7 February 1974

5. Milestones/Work to be Accomplished During the Next Reporting Period

- 5.1 Since the casting must be preheated prior to weld repair and the welder can only make a limited number of weld repairs per each heat, a considerable number of days will be required to correct all defects and to produce a sound casting. A dye penetrant check is made on each group of repairs to determine success of the repair before going on to the next group. This effort was started 31 January 1974.
- 5.2 When the final group of weld repairs successfully pass the spot dye check, the casting will be cleaned and turned over to the Inspection Department for a total PT examination. Successfully passing of this examination will be followed by final casting heat treatment, cleaning and another total PT examination. With no major weld repair problem encountered, this milestone should be achieved by 22 February.
- 5.3 After final PT examination, the casting will undergo dimensional check and other necessary final inspection. Final papers will be prepared and the casting packaged, crated and shipped. This should be accomplished by 1 March 1974.
- 5.4 The initial effort, such as the gathering of the available data, should begin during the last week in February in preparation of the Final Technical Report.

6. Percent of Total Task Completed

- 6.1 It is estimated that the Engineering effort is 99% complete and that the foundry effort is 78% complete based on the reduced quantity of castings.

3

U. S. Army Weapons Command

7 February 1974

6.2 One hundred percent of the Final Technical Report effort remains to be accomplished.

6.3 Based on total expenditure of manpower and material, the program could be considered 91% complete.

FMC CORPORATION
Northern Ordnance Division

A. E. Wickman

A. E. Wickman
Senior Contract Administrator

mj

cc: Commander
U. S. Army Weapons Command
Rock Island, Illinois 61201
Attention: AMCPM-CAWS

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*bcc:
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1 ATTN: AMSAR-LMC

1 ATTN: AMSAR-TRADOC

2 ATTN: AMCPM-CAWS

Appendix D
CHEMICAL
and
MECHANICAL TEST REPORTS

MINNEAPOLIS, MINN.

DATE _____ 19____

MATERIAL: Ab. Casings
SUPPLIER: NO F&F

REL. NO./P.O. NO.

M. R. No.

20

FOR PART NO.

CUSTOMER

[illegible]

FROM ASK:

LAB. TECH. DS.

METALLURGIST-

R. M. W.

ON FILE

REPRESENTATIVE

6913

MECHANICAL TEST REPORT

MINNEAPOLIS, MINN.

DATE 12-11-13 19

MATERIAL: Aluminum

SPECIFICATION:

1001

REL. NO./P.O. No.

SUPPLIER:

TEST REQUESTED BY:—

Family

M. R. No.

FOR PART NO-

CUSTOMER:

S.O. No.

[illegible]

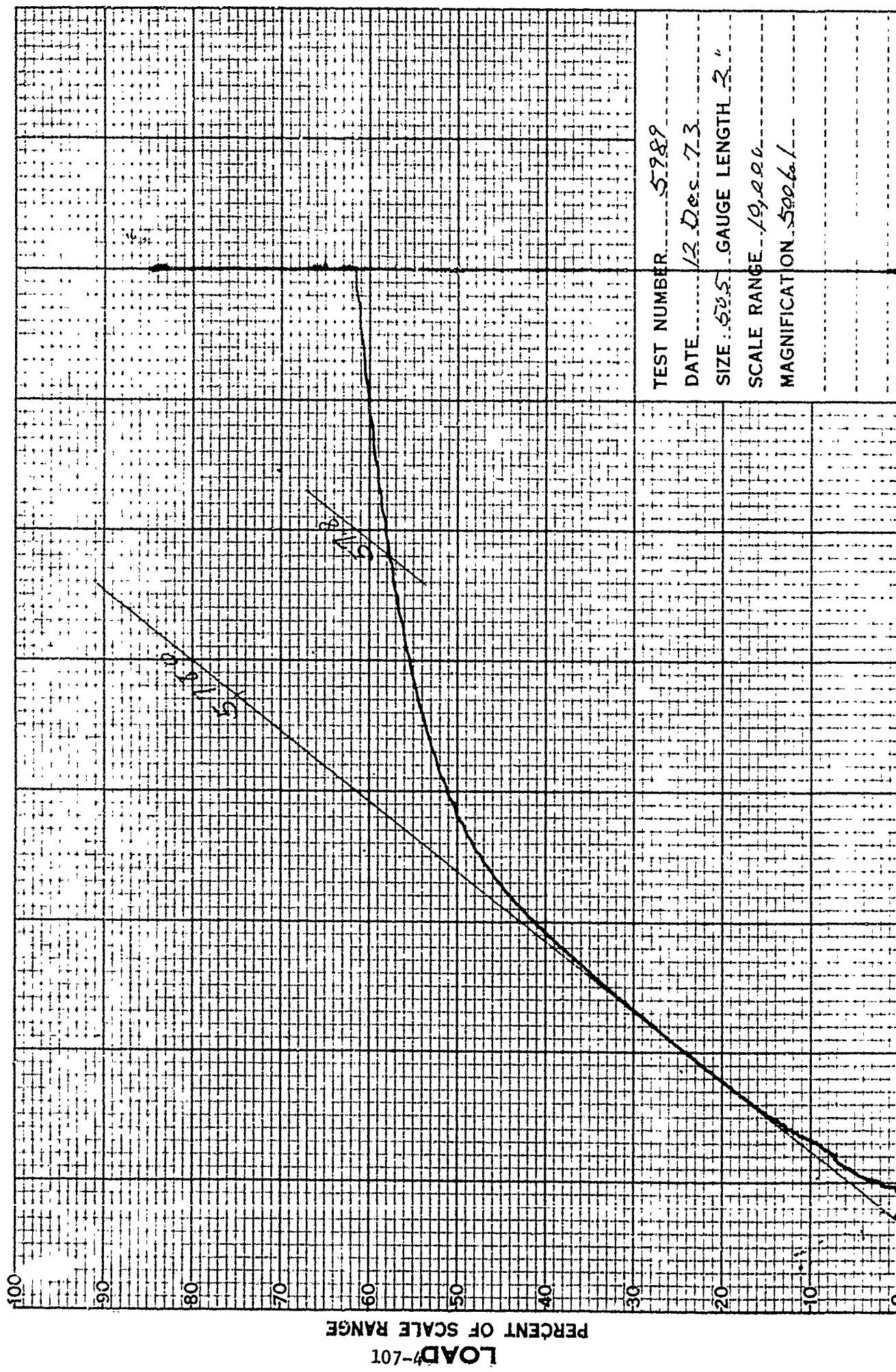
REMARK:

LAB. TECH.

METALLURGIST-

FILE NO.

5988



TEST NUMBER 5789
 DATE 12 Dec 73
 SIZE .505 GAUGE LENGTH 2"
 SCALE RANGE 10,000
 MAGNIFICATION 500x

STRAIN

DIVIDE BY MAGNIFICATION RATIO

CHEMICAL ANALYSIS

MINNEAPOLIS, MINN.

METALLURGICAL LABORATORY

DATE 4-2

MATERIAL: AL. CASTING
SUPPLIER: NO. 5 DAY

SPECIFICATION

REL. NO./P.O. NO.-

SUPPLIER NO FRY ANALYSIS REQUESTED BY S&S M. R. No.

N. R. N.

FOR PART NO-

CUSTOMER:

No. 5.

[illegible]

RESEARCH

LAB. TECH.

METALLURGIST-

FILE NO.

REPRESENTATIVE

2703

METALLURGICAL LABORATORY MECHANICAL TEST REPORT

Date: _____

4-64 1974

Material:

Material: Aluminum Specification: A286 Release No./ Purchase Order No. _____

Supplier:

Supplier: NOID EMC Test Requested By: Ferrisdy Miscellaneous Receiving No. _____

For Part No:

For Part No: _____
Customer: _____
Sale Order No. _____

Specification Requirement					
Identification	Cross Section Dimensions	Dial Reading		Maximum Minimum	Remarks
		Area	YP Lb		
14-A-9-LI		504 lbs	1995 6650	TS Lb 19080	
				YP PSI 33750	
				Actual YP PSI 40000	
				Elong in. % 5	
				Red. of Bend Test	
				Hardness	

Remarks

Laboratory Technician

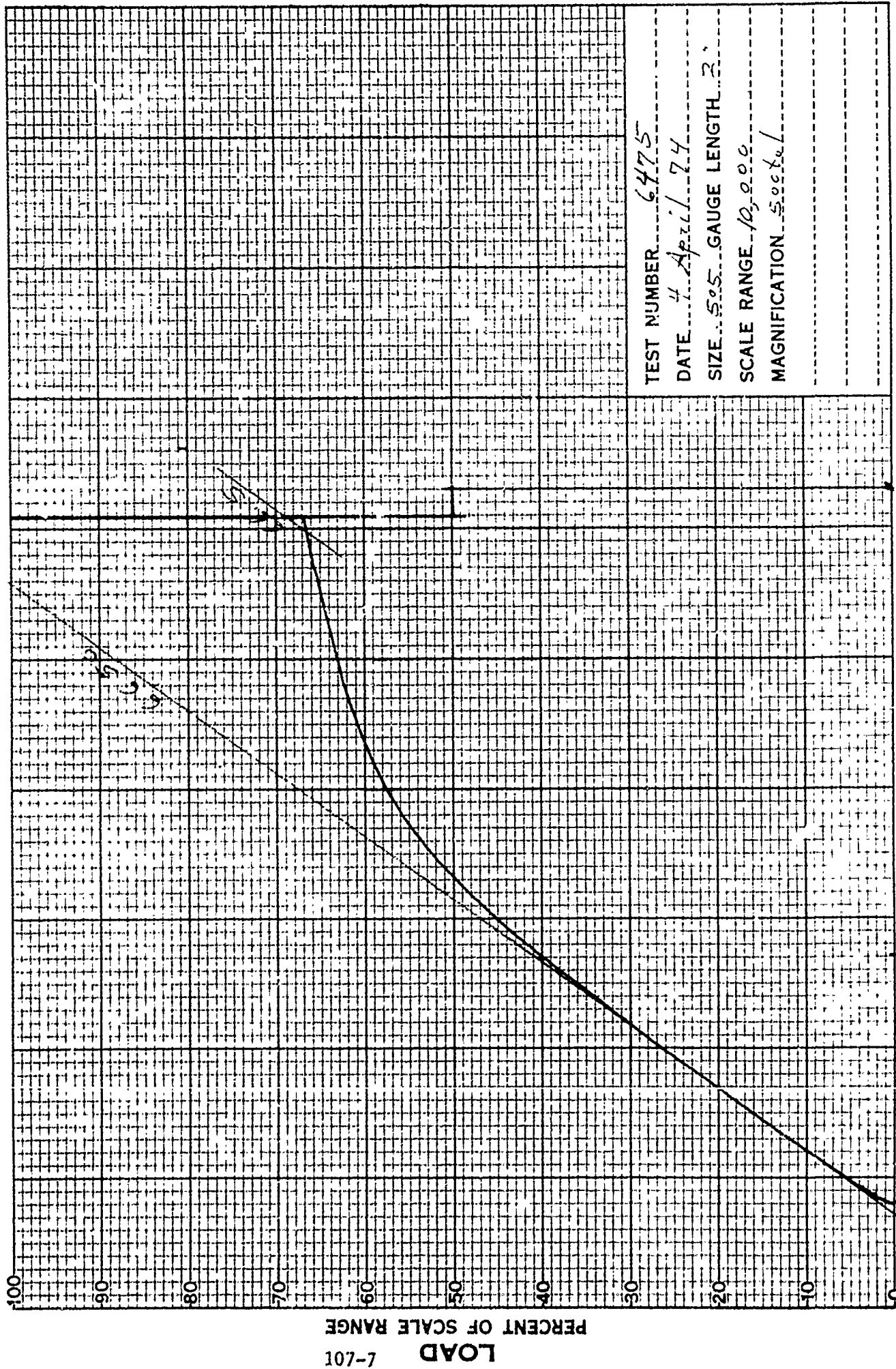
D. H.
Geo. Schuster

Metallurgist

R. M. W.

Representative

File No. 6475



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