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CONCEPTS FOR DESIGN OF LIGHTWEIGHT TRACK FOR
THE U.S. MARINE LANDING VEHICLE ASSAULT (LVA)

ALUMINUM COMPANY OF AMERICA

PREPARED FOR
DAVID W. TAYLOR NAVAL SHIP
RESEARCH AND DEVELOPMENT CENTER

20 FEBRUARY 1976

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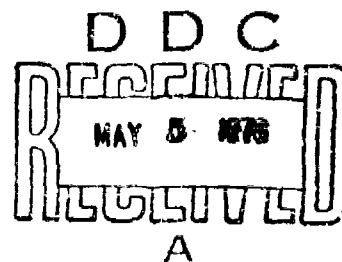
FINAL REPORT

PREPARED FOR
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ABSTRACT

Future military vehicles require significant attention to vehicle weight if the desired advantages of battlefield mobility are to be achieved. Advancements in power-train and material technology will contribute to the design improvements necessary for these vehicles. Use of high strength to weight ratio materials is being stressed, wherever technically advisable and economically cost effective.

As part of the design considerations for a future U. S. Marine Corps amphibious personnel carrier type vehicle, Landing Vehicle Assault (LVA), the feasibility of using a lightweight aluminum track has been examined. Four concepts for a LVA track that would achieve significant weight savings compared to existing steel tracks are examined. Two concepts are suggested for further evaluation, prototyping, and vehicle testing. Preliminary weight and production price estimates are made.

FOREWARD

This effort is in support of the Landing Vehicle Assault (LVA) Development Program under the management of the Naval Sea Systems Command, Code 03221. The work was done under contract to the David Taylor Naval Ship Research and Development Center, with technical monitoring by DTNSRDC, Code 112.

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- Concept 1. B-100504-AE, Single pin with end drive
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(Drawings in pocket, back cover)

SECTION I

INTRODUCTION TO LVA VEHICLE AND TRACK REQUIREMENTS

A future mix of U. S. military combat vehicles is now being proposed for limited warfare scenarios that require high battlefield mobility. These vehicles must also provide increased armor protection and battlefield firepower effectiveness to combat the increased threats of future enemy hardware. High vehicle mobility will be achieved by advancements in power-train technology and use of high strength, low weight materials where they are most cost-effective. Throughout these designs there is a simply stated, but not so simply achieved, necessity to minimize gross vehicle weight. Proper choice and practical utilization of lightweight materials is essential if the advantages of battlefield mobility are to be achieved.

The U. S. Marine Corps has identified the operational need for an amphibious vehicle that will meet the surface mobility and combat support requirements of the post-1980 time frame. Development of this vehicle, the Landing Vehicle Assault (LVA), is to include examination of designs that will be capable of transporting and supporting assault forces during "over the horizon" amphibious landings and subsequent operations ashore.¹

As part of the LVA design considerations, the feasibility of using an aluminum track has herein been examined. Aluminum tracks have been proposed, tested, and used on several production vehicles since the late 1950's. Recent programs have demonstrated the advantage of lighter weight aluminum tracks for heavy battle-tank type vehicles.² The effort under this David Taylor Naval Ship Research and Development Center contract has been to examine concepts for a Landing Vehicle Assault track that will achieve significant weight savings compared to existing steel tracks used

on this type of tracked vehicle. The track and suspension system of the present vehicle, the LVTP-7, was used as the basis for these design concepts. The goal of this study was to suggest the design(s) for the lightest weight aluminum track that might meet the track requirements of a vehicle in the weight and performance classification of the LVTP-7; this design(s) concept could then be further developed and evaluated for the LVA³. As such the following general guidelines were followed:

1. 21" track width
2. 50,000 lb. class vehicle
3. Track performance equal to LVTP-7 track
4. Replaceable road surface pads
5. Interchangeability of component parts with existing tracks where possible (without increasing weight or degrading performance)

The study focused on those areas that have historically been identified as possible deficiencies in the operation of a single-pin aluminum track. Special attention was given to field and/or depot replacement of critical wear areas, particularly the sprocket engagement and centerguide areas of the track shoe body. This replacement of selected, preidentified, life-limited track components would extend the operational use of the basic track shoe body to its maximum life (determined by metal fatigue limit or failure/wear of rubber components).

Possible follow-on programs utilizing experimental stress analysis and laboratory testing of actual prototype hardware to more fully examine and refine the most promising design(s) are identified in Section V.

SECTION II

BASIS FOR TRACK DESIGN CONCEPTS

Historically there have been several concerns with aluminum track systems:

1. Abrasion resistance of the drive areas
2. Strength of the basic shoe body under track tension, bending, and torsional loads
3. Strength and wear resistance of the centerguide area

Throughout this analysis, special attention was placed on resolving the strength and abrasion resistance concerns of the drive and centerguide locations.

Several previous aluminum track programs have examined and demonstrated the advantages of a double-pin (versus single-pin) design in eliminating items 1 and 3 above by using separate hardened steel components in critical wear areas. Examples of double-pin designs are the T-142 track used on the M60 and M48 battle tanks (shown in its aluminum version in Figures 1 and 2) and the aluminum T-144 Hawk Missile Loader Vehicle track (shown in cross section in Figure 3). By comparison, the shoe body of a single-pin track (the T-130) is shown in Figure 4. The double-pin design is penalized in weight by the addition of the second pin and separate connecting hardware, but it uses a simpler block design than a single-pin track. The additional pin does result in lower rubber bushing loads, a definite advantage for increasing the lifetime of a heavily loaded track.

The challenge herein was to examine "lightweight" design concepts that would meet the LVA requirements. Therefore, both double- and single-pin tracks were examined. Four track concepts were studied, one of which is a double-pin design similar to the M109 Howitzer's steel T-136 track; the remaining three single-pin tracks are based on the LVTP-7 track. It was felt the single-pin design offered a weight advantage but created problems in prevention of sprocket and centerguide area wear. Single-pin aluminum tracks are not proven in service, as are several double-pin tracks, but it was felt a single-pin design should be thoroughly reviewed for the LVA because of its advantages for weight reduction.

Attention was first placed on the centerguide, with the basic decision that the centerguide would be integral to the block to achieve maximum shoe area at minimum weight. This is opposed to a separate centerguide bolted to the pin, as in the case of the T-142. This type of design (used in the T-136, T-144, and the LVTP-7 tracks) would require protecting the aluminum "horn" with the steel "cap." Several concepts have been examined and proven successful over the years. Pictured in Figure 3 is a cross section of the aluminum Hawk Missile Loader Vehicle T-144 track, its centerguide is integral to the track body and its steel protection is bonded to the aluminum by rubber. This concept has worked in production, and the bond has proven to be durable in vehicle operation. This rubber bonded cap concept, if restricted to the over-all dimensions of the LVTP-7 track guide, would not provide sufficient lateral strength in the guide and would possibly even be too thin to forge economically in a typical forging operation. This type of protective cap could be used successfully on the LVA if the road-wheel guide area were widened to permit a thicker guide horn, particularly at the horn base. A disadvantage of the rubber bonded steel cap is that it cannot be replaced without rerubberizing the entire track body. It would not be field repairable and therefore is not felt to be cost effective in extending the over-all track life.

Throughout this effort, concepts to fully utilize components that could be replaced not only for routine maintenance but also for emergency field repair were stressed. Therefore, a centerguide concept was envisioned in which the centerguide would be made of a steel casting or forging and held in place by bolts through the aluminum block. This concept could be made to the dimensions of the existing LVTP-7 and would allow the desired field replacement of worn components. In each of the four basic designs evaluated under this contract, the replaceable centerguide

concept is suggested. In all designs, the centerguide location has been toward the forward area of the body so that the track centerguide comes into contact with the roadwheel prior to application of the full weight of the wheel on the track, thus providing a better alignment of the track system and less wear. Worst-case centerguide side loads have been computed and are included in Appendix A. Some consideration might be given to using the same bolt assembly for retaining both the track pad and the centerguide as a possible step to further reduce weight and the number of hardware parts.

The other track area requiring abrasion resistance, namely the sprocket engagement location, was likewise considered for a replaceable, easy maintenance component. In the case of the double-pin design, the drive system utilizes "end connectors" of hardened steel that could be replaced as required. In the case of a single-pin design such as used on the LVTP-7, the replacement of sprocket wear areas requires replacement of the entire shoe. In fact, the U. S. Marine Corps has said that the main reason for replacement of the LVTP-7 track is wear of the track body sprocket drive area. Therefore, to counter the known problems with an aluminum forging in this application, and also to provide the desired ease of maintenance, a separate body insert or end drive system was included in each of the four designs considered. (Note that the insert concept (Number 4) would require minimum alteration to the existing LVTP-7 suspension.) By careful consideration, the anticipated problems with wear have been overcome in these designs through utilization of replaceable steel components.

The basic track block concept is a redesign of the existing steel LVTP-7 track (single pin) or the T-136 track (double pin). It is assumed that the LVA as it is finally designed will be of the same weight class and have similar land performance requirements as the existing LVTP-7. Attempts were not made under this contract to describe a general purpose track but

rather to refine the existing track and drive systems so that a lighter weight track could be used successfully. A basic consideration in the design philosophy was also that the vehicle never will be operated without the road surface pads, and that the replaceable feature of the pad is for simple replacement of worn out pads (as opposed to providing a combat configuration; i.e., without pads). Therefore, all designs have included a replaceable road surface pad that will be in place at all times. Track loads are also assumed to be essentially the same as that of the existing tracks since the vehicle weight and performance requirements have not been appreciably changed. In all cases, hardware components such as the pins, pads, bushings, and nuts and bolts have been designed, wherever possible, to be the same as those used in existing, fielded tracks. In cases where it was felt additional strength or dimensional changes were required, new hardware components have been suggested, although detailed specific designs are beyond the scope of this effort.

SECTION III

TRACK CONCEPTS

Concept 1 - Single-pin with end drive (Drawing No. B-100504-AE).

This design was the first considered, and was derived from the LVTP-7 track by modifying the section properties where necessary. The section property analysis of this redesign is contained in Appendix B. Basically, this design utilizes a replaceable steel centerguide in conjunction with sprocket engagement on a steel sleeve over the end of the shoe body. In this concept the steel sleeve drive area is not truly replaceable although the shoe could be refurbished in a maintenance depot. The steel sleeve could fit either over the forging itself or ride on a separate bushing assembly. As

pictured, the sleeve fits directly on the aluminum shoe, although this could result in abrasion and wear of the aluminum forging if the sleeve began to rotate on the forging. If this system were to be field replaceable, it would be necessary to provide a bushing for the drive sleeve to fit directly on the pin. This bushing could be made free to rotate, thereby distributing the wear over the sleeve surface and reducing power loss to friction between the track and sprocket. With minor alterations, the shoe pad and bolt assembly would be the same as the existing track. The pin and bushings likewise could be the existing parts. It was felt in this analysis that because of higher loads at the ends of the block due to the drive mechanism location, this portion of the track body should be strengthened and possibly a 1-inch (diagonal distance) octagonal pin used instead of the current 13/16-inch octagonal pin. The estimated weight for this design in a complete assembly is 22.8 pounds per pitch or approximately 45.6 pounds per running foot of track. The 6-inch pitch and 21-inch width have been retained from the existing LVTP-7 track. This concept would obviously require a different sprocket hub than the existing vehicle since the sprocket must engage over the ends of the track pins and not in the block itself; the same sprocket design might be used, however.

Concept 2 - Single pin with end drive, modified (Drawing No. B-100508-AE). This concept utilizes the basic type of end drive as proposed in Concept 1 with modifications for additional strength through the shoe body, particularly in the drive location. Also included is a heavier pin to take the increased loads at the drive location. The sprocket engagement area in this case is a separate steel component riding directly on a pin bushing; and the drive assembly is held in place by the pin nut and an auxiliary bolt into the shoe body. Load conditions were examined for a general end drive type design, particularly through Section Y-Y, and additional strength

was suggested to maintain a satisfactory design margin. These analyses are shown in Appendix C. The centerguide used in this concept is the same as that proposed in Concept 1. An alternate guide proposal is shown in View 2 that uses a single 1/2-inch bolt for attachment of the centerguide (as opposed to using two 1/4-inch bolts). This change was for ease of handling during assembly and maintenance of the track, and to strengthen the assembly. The end drive component for the drive sprocket engagement is essentially the same physical size as the existing engagement area on the LVTP-7 so that, other than sprocket location, the same sprocket could be used (as also indicated for Concept 1). Use of the 1-inch pin causes a weight increase of approximately 1-1/2 pounds over the existing 13/16-inch pin but it is felt that it will be required because of the increased load on the pin at the drive location. Additional analysis may reduce this weight penalty by demonstrating that a hollow or smaller pin is adequate. Concept 2 as shown uses a three-lobe track body as opposed to the five-lobe body of the LVTP-7; the change is to permit strengthening the body at the end drive location. The road surface pad, as in the preceding concept, is replaceable and bolted through the center of the track block. The pad configuration has not been specifically defined but is expected to be similar to the LVTP-7. In both of these drive systems, the existing type of octagonal pin and separate rubber bushings is retained.

Concept 2 is essentially a refinement of Concept 1 improving the areas identified as having possible weaknesses. This track would require slight suspension redesign from the LVTP-7 (drive sprockets), and would not use existing pin or bushing hardware. The estimated weight for Concept 2 is 25.6 pounds per shoe, or 51.2 pounds per foot.

Concept 3 - Double-pin with end drive (Drawing No. B-100513-AE).

This double-pin track concept is basically a revision of the 15-inch T-136

track used on the M108/M109 self-propelled howitzer. The track body contains an integral centerguide. The track width would be extended to the total 21-inches suggested for the LVA and the pitch opened to 6-inches. As opposed to T-142 double-pin track (Figures 1 and 2), this concept uses a single block with a centerguide directly attached to the track block itself. The centerguide arrangement is basically that suggested on the previously described single-pin designs. The track pad, like the other designs, is replaceable and held in place by a nut and bolt through the track body. As this is a more extensive redesign of the T-136, the hardware (i.e. the pads and pins) would not be those used in production for the current track. The double-pin design does have an advantage in being driven off the steel end connectors and it has been proven in actual field use of aluminum tracks. Also, the track body geometry is less susceptible to stress concentrators that could cause failures. Thus, this track is a lower risk development than the single-pin track although it does weigh more due to its double pin and more massive block arrangement. The centerguide concept here shown in Section AA and BB could use a riveted steel cap as an alternate method of providing protection to the aluminum horn. The centerguide would then not be replaceable except by refurbishment in a maintenance depot, although a weight reduction and simplification of track parts would result. This concept is estimated to weigh 32.8 pounds per shoe or 65.6 pounds per foot.

Concept 4 - Single pin with track body drive (Drawing No. B-100514-AE).

This design physically is the closest to the existing LVTP-7 track, and retains the basic five-lobe design with chevron-type grouser and replaceable rubber pads. The same octagonal pin and bushing arrangement is also retained. The block design and section properties are basically the same as those

proposed in Concept 1. The centerguide would be the bonded or riveted "cap" or the bolted design discussed previously. The significance difference in this concept is the use of a replaceable steel insert in the track block drive area. These steel inserts are held in place by a retaining strap bolted into the body. As opposed to the previous concepts, and more like a conventional single-pin track, the area of sprocket engagement is in the track block. To prevent possible entrapment of foreign matter that would create sprocket/track block interference and misguiding, the block is open through the engagement area. Because of the drive location, the grouser sectional area may be limited relative to that suggested in Concepts 1-3. This could restrict enlarging the rubber pad (to reduce the vehicle ground pressure); larger pads would be possible in the other concepts. However, the track would be directly replaceable on the LTVP-7 with little, if any, change to the existing vehicle. The steel drive inserts are themselves a weight penalty of approximately two to three pounds per block. Weight reduction in this area might be achieved by hollowing a portion of the steel inserts, and providing a single bolt attachment for the retaining strap. The drive area is slightly smaller than that of the existing track but is large enough to accommodate the sprocket as currently designed. As shown, this design would weigh 25.7 pounds per shoe or 51.4 pounds per foot of track.

SECTION IV

ALUMINUM ALLOY DOCUMENTATION;

WEIGHT AND PRODUCTION COST ESTIMATES

The four designs considered are based on use of the mechanical properties of 2014-T61 die forgings. The alloy, as characterized in Figure 5, has seen wide use in aircraft and ordnance parts where high

tensile and yield strengths are required. It is a good, economical forging alloy and has good machinability with acceptable resistance to corrosion for this application. The T-144 and T-142 tracks have been made in 2014 with resulting excellent field performance. Figures 5 and 6 summarize the characteristics and typical mechanical properties of die forgings in a number of aluminum alloys. Higher strength alloys, such as 7075 are available and might provide a higher margin in the design and/or allow weight reduction in the track body, but at a higher cost. Additional analysis is required on actual hardware (Section V) to define specific stress levels before making alloy or design refinements.

A weight summary of the four proposed concepts is included in Figure 7. This summary shows Concept 1, the single-pin with end drive is the lightest of the four concepts at 45.6 pounds per foot. The double-pin track, Concept 3, is the heaviest at 65.6 pounds per foot. Intermediate are the modified single pin, Concept 2, at 51.2 pounds per foot, and the track body drive single pin, Concept 4, at 51.4 pounds per foot.

Recommendations included in Section V suggests Concepts 2 and 4 be pursued for hardware analysis and prototype testing. Production cost estimates have been made for these concepts, and are given in Figure 8. It should be noted that these estimates are made without complete details of the actual finished designs, and are in 1976 dollars.

SECTION V

RECOMMENDATIONS

Three of the four concepts evaluated involve several distinctively different approaches to a lighter weight track for a future vehicle. (Note that Concept 2 is an evolution of Concept 1 that incorporates modifications aimed at eliminating weaknesses). Because of the emphasis on

lightweight, and the weight classification of the vehicle, a single-pin design offers over-all advantages and possible commonality of hardware with other vehicle tracks. The primary emphasis herein has been to reduce weight while maintaining the same performance level designed into present tracks. In addition, considerable attention has been placed on replacement of wear areas (the centerguide and track drive locations) to achieve maximum track life, and therefore cost effectiveness of the individual track components. The double-pin track represents less of a technical risk in that this type of track has been designed, tested, and produced for vehicle use and has performed satisfactorily. However the heavier weight is not desirable. The double-pin design is therefore not recommended for further evaluation. The single-pin designs described in Concepts 2 and 4 offer the best combination of weight savings, chance for technical success, potential cost effectiveness, and commonality with existing hardware that is desired for the LVA and other future vehicles.

Additional stress analysis of the basic track body is required before either of these designs be carried further. It is recommended that laboratory analysis of hardware (i.e. castings) be carried out to refine these designs and that the resultant final concept be made into prototype track for further qualification testing. This would include verification laboratory tests of actual production produced die forgings, and to be followed by assembly into track sections for vehicle testing.

SECTION VI
REFERENCES

1. Tentative Specific Operational Requirement, (MOB-1.05T) Landing Vehicle Assault (LVA).
2. "The Development and Use of Aluminum Track for Military Vehicles," W. J. Lane, September 1975.
3. "Proposal for a Design Study of Lightweight Track for the U. S. Marine Corps Landing Vehicle Assault (LVA)." May 23, 1975.
4. "Mechanical Engineering Design," J. E. Shigley, McGraw Hill, 1963, pp 158, 183.

APPENDIX A CENTERGUIDE LOAD ANALYSIS

Assumptions:

1. Maximum vehicle roll angle (side slope) is 40°
2. There are six road wheels on each side
3. The equivalent of at least one centerguide is in contact with each wheel (at any one time)
4. The worst possible case is for six centerguides to hold the maximum vehicle side load (ignores friction between roadwheel and track body)
5. Maximum vehicle weight is 50,000 pounds
6. The load on each centerguide is concentrated at a point 1-1/2 inches from the guide tip (center of observed wear pattern on LVTP-7 track)

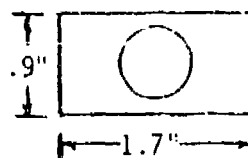
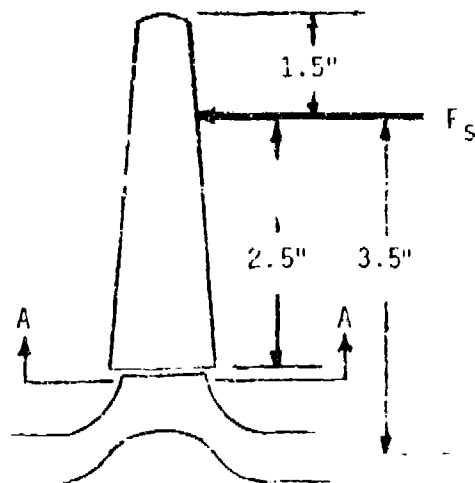
Then:

The side load on each guide is given by

$$F_s = \frac{(50,000 \text{ lb.})(\cos 50^{\circ})}{6}$$

$$F_s = 5,356 \text{ lbs.}$$

The centerguide sections are shown:



Section A-A

$$M = (2.5)(5356) = 13,400 \text{ in.-lb.}$$

$$I_{xx} = \frac{BH^3}{12} - 1 \text{ bolt hole, } 9/16" \\ = \frac{(1.7)(.9)^3}{12} - .005 = .098 \text{ in.}^4$$

Appendix A - Continued

The maximum stress at the guide base is given by

$$\sigma_{\max} = \frac{Mc}{I}$$

$$M = 13,400 \text{ in.-lb.}$$

$$c = .45 \text{ in.}$$

$$I = .098 \text{ in.}^4$$

$$\sigma_{\max} = 61,500 \text{ psi}$$

2014-T61 Typical Properties (from Figure 6)

Tensile strength 68,000 psi

Yield strength 56,000 psi

The above analysis depicts a suggested rare worst case situation, and does show yielding of the centerguiding area could occur. The centerguide area of the track block will, however, provide sufficient strength for generally encountered field conditions.

APPENDIX B

SECTION PROPERTIES

SUMMARY OF CONCEPTS 1 AND 2

CONCEPT 1 - Single pin with end drive; Drawing No. B-100504-AE

Section		Ixx	Iyy	Syy Left	Syy Right	Sxx Top	Sxx Bot.	Area	J _z
"X-X"	Steel	1.12	5.43	2.18	3.31	.989	.78	2.85	6.55
	Alum.	1.61	6.80	2.69	3.80	1.34	1.13	3.86	8.41
	% inc.	44%	25%	23%	15%	35%	45%	35%	
"Y-Y"	Steel	.33	.32	.55	.256	.400	.315	1.30	.65
	Alum.	.43	.45	.67	.38	.52	.41	1.71	.88
	% inc.	30%	41%	22%	48%	30%	30%	31%	
"Z-Z"	Steel	.156	.059	.11	.114	.207	.201	1.03	.215
	Alum.	.254	.083	.17	.145	.287	.330	1.26	.337
	% inc.	63%	40%	54%	27%	38%	64%	22%	
"O-O"	Steel	.012	124.38	11.85	11.85	.082	.015	2.62	124.4
	Alum.	.028	164.31	15.65	15.65	.182	.033	3.51	164.3
	% inc.	133%	32%	32%	32%	120%	120%	34%	
"B-B"	Steel	.010	16.43	3.46	3.46	.084	.012	2.18	16.44
	Alum.	.024	22.29	4.69	4.69	.159	.028	2.96	22.3
	% inc.	140%	35%	35%	35%	83%	133%	36%	
"A-A"	Steel	1.87	160.07	20.29	20.29	1.61	1.34	6.68	161.9
	Alum.	2.84	271.51	34.21	34.21	2.33	2.02	10.67	274.3
	% inc.	52%	70%	69%	69%	45%	51%	60%	

CONCEPT 2 - Single pin with end drive, modified; Drawing No. B-100508-AE

Section		Ixx	Iyy	Syy Left	Syy Right	Sxx Top	Sxx Bot.	Area	J _z
"A-A"	Steel	1.87	160.07	20.29	20.29	1.61	1.34	6.68	161.9
	Alum.	2.70	311.33	38.58	38.58	2.25	1.89	11.05	314.03
	% inc.	44%	94%	90%	90%	40%	41%	65%	
"X ₂ -X ₂ "	Steel	1.12	5.43	2.18	3.31	.989	.78	2.85	6.55
	Alum.	1.57	12.20	5.53	5.40	1.424	1.34	4.82	13.77
	% inc.	40%	125%	154%	63%	44%	72%	69%	
"Y-Y"	Steel	.33	.32	.55	.256	.400	.315	1.30	.65
	Alum.	.678	5.50	2.36	2.40	.653	.761	3.16	6.178
	% inc.	105%	1616%	511%	837%	63%	141%	151%	

SECTION PROPERTY DATA

DEFINITION OF RESULTS:

ARBITRARY AXIS

AREA-- AREA OF THE SECTION IN IN^2 .
WT/FT-- WEIGHT PER LINEAL FOOT IN POUNDS.
XBAR-- DISTANCE ALONG THE ARBITRARY X-AXIS FROM ITS ORIGIN TO THE NEUTRAL Y-AXIS IN INCHES.
YBAR-- DISTANCE ALONG THE ARBITRARY Y-AXIS FROM ITS ORIGIN TO THE NEUTRAL X-AXIS IN INCHES.
IXXA-- MOMENT OF INERTIA ABOUT THE ARBITRARY X-AXIS IN IN^4 .
IYYA-- MOMENT OF INERTIA ABOUT THE ARBITRARY Y-AXIS IN IN^4 .
IXYA-- PRODUCT OF INERTIA ABOUT THE ARBITRARY ORIGIN IN IN^4 .

NEUTRAL AXES

FOUR VALUES OF SECTION MODULUS IN IN^3 .
SXXTOP---IXXN/DISTANCE FROM AXIS XXN TO EXTREME FIBER AT TOP OF SECTION.
SXXBOT---IXXN/DISTANCE FROM AXIS XXN TO EXTREME FIBER AT BOTTOM OF SECTION.
SYLEFT---IYYN/DISTANCE FROM AXIS YYN TO EXTREME FIBER AT LEFT SIDE OF SECTION.
SYRIGHT---IYYN/DISTANCE FROM AXIS YYN TO EXTREME FIBER AT RIGHT SIDE OF SECTION.

IXXN-- MOMENT OF INERTIA ABOUT THE NEUTRAL X-AXIS (XXN) IN IN^4 .
IYYN-- MOMENT OF INERTIA ABOUT THE NEUTRAL Y-AXIS (YYN) IN IN^4 .
IXYN-- PRODUCT OF INERTIA ABOUT THE CENTROID IN IN^4 .
IUUN-- A PRINCIPAL (MIN. OR MAX.) MOMENT OF INERTIA, AXIS UUN BEING THE ROTATED NEUTRAL X-AXIS (XXN) IN IN^4 .
IVVN-- A PRINCIPAL (MIN. OR MAX.) MOMENT OF INERTIA, AXIS VVN BEING THE ROTATED NEUTRAL Y-AXIS (YYN) IN IN^4 .
BETA-- THE ANGLE BETWEEN THE U-AXIS (UUN) AND THE NEUTRAL X-AXIS (XXN), MEASURED FROM THE NEUTRAL X-AXIS (XXN) IN DEGREES (+ COUNTERCLOCKWISE).
RXXN-- RADIUS OF GYRATION WITH RESPECT TO THE NEUTRAL X-AXIS (XXN) IN INCHES.
RYYN-- RADIUS OF GYRATION WITH RESPECT TO THE NEUTRAL Y-AXIS (YYN) IN INCHES.
JZZN-- POLAR MOMENT OF INERTIA.

FOR FURTHER EXPLANATION OF THESE PROPERTIES SEE:

1. "FORMULAS FOR STRESS AND STRAIN" BY RAYMOND J. ROARK. PUB. MCGRAW-HILL BOOK COMPANY, INCORPORATED.
2. "MECHANICS" BY J. L. MERIAM. PUB. JOHN WILEY & SONS, INCORPORATED.
3. "ALCOA STRUCTURAL HANDBOOK".



THE FOLLOWING SECTION PROPERTY DATA ARE
SUPPLIED BY ALCOA AS A SERVICE TO:

TRUCK SHOCK

SECT X-X STEEL

INPUT DATA

I	X	Y	R	F
1	0.000	0.000	0.000	0.000
2	0.000	2.250	0.000	0.000
3	0.156	1.906	0.000	0.000
4	0.187	1.625	0.000	0.000
5	0.250	1.280	0.000	0.000
6	3.060	1.280	0.001	0.000
7	3.156	0.070	0.000	0.000
8	3.620	0.000	0.000	0.000
9	3.750	0.697	0.001	0.000
10	3.870	0.687	0.000	0.000
11	3.980	1.625	0.000	0.000
12	4.000	1.925	0.000	0.000
13	4.125	2.250	0.000	0.000
14	4.125	2.562	0.000	0.000
15	3.593	2.562	0.000	0.000
16	3.500	1.530	0.000	0.000
17	0.456	1.530	0.000	0.000
18	0.562	2.562	0.000	0.000
19	0.000	2.562	0.000	0.000
20	0.000	0.000	0.000	0.000

SECTION NOT SYMMETRICAL ABOUT X OR Y AXIS

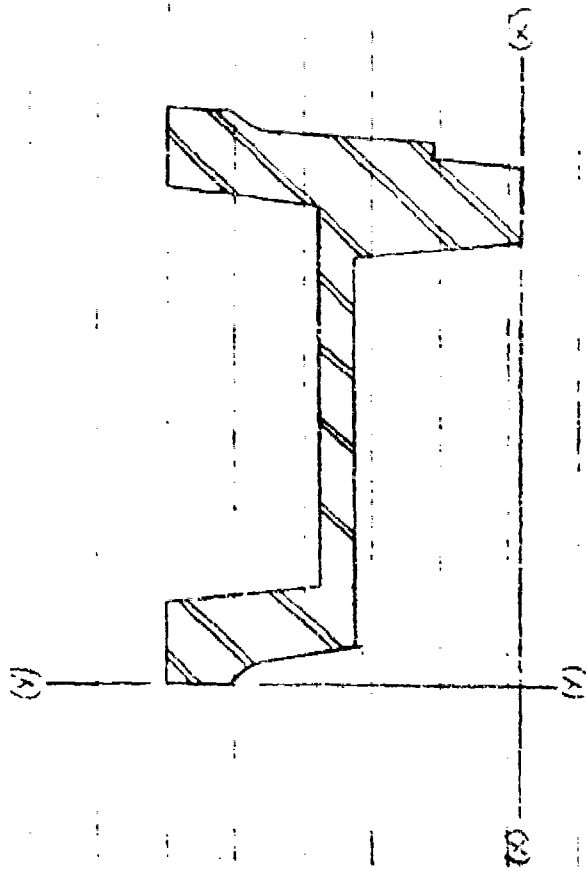
THE RESULTS ARE

ARBITRARY AXIS

AREA	2.84892
WTF	3.55072
YBAR	2.48968
YBAR	1.41283
IXXA	6.96572
IYYA	23.03567
IXYA	9.23516
IXXA	4.125
IYYA	0.000
IXYA	2.562
IYYA	0.000

SYX	2.18580
SYX	2.18580
IXXA	1.11690
IYYA	5.43321
IXYA	-0.91163
IYYA	0.91734
IXYA	5.61778
IXYA	-11.44761
IXYA	0.62613
IXYA	1.32098

SYX	0.99619
SYX	0.99619
IXXA	1.11690
IYYA	5.43321
IXYA	-0.91163
IYYA	0.91734
IXYA	5.61778
IXYA	-11.44761
IXYA	0.62613
IXYA	1.32098

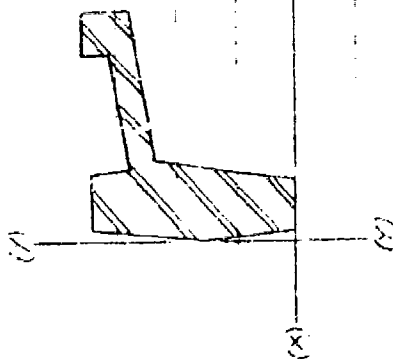


LVTB-7 1

CHS 254

15345 A-5 1238

TWENTY-THREE



REPLY TO THE CHAIRMAN OF THE SELECT COMMITTEE ON THE DEPARTMENT OF THE ARMY

1479 ST. LOUIS AVE.

TEMPERATURE AXIS

[illegible]

44

Variable	Mean	Std. Dev.	Minimum	Maximum
AGE1	1.2640	.0000	1.0000	1.5000
AGE2	1.0000	.0000	1.0000	1.0000
AGE3	.5749	.0000	.5000	.6000
AGE4	1.0432	.0000	1.0000	1.1000
AGE5	1.7471	.0000	1.5000	2.0000
AGE6	1.4632	.0000	1.0000	2.0000
AGE7	1.0432	.0000	1.0000	1.1000
AGE8	1.0000	.0000	1.0000	1.0000
AGE9	1.0000	.0000	1.0000	1.0000
AGE10	1.0000	.0000	1.0000	1.0000
AGE11	1.0000	.0000	1.0000	1.0000
AGE12	1.0000	.0000	1.0000	1.0000
AGE13	1.0000	.0000	1.0000	1.0000
AGE14	1.0000	.0000	1.0000	1.0000
AGE15	1.0000	.0000	1.0000	1.0000
AGE16	1.0000	.0000	1.0000	1.0000
AGE17	1.0000	.0000	1.0000	1.0000
AGE18	1.0000	.0000	1.0000	1.0000
AGE19	1.0000	.0000	1.0000	1.0000
AGE20	1.0000	.0000	1.0000	1.0000
AGE21	1.0000	.0000	1.0000	1.0000
AGE22	1.0000	.0000	1.0000	1.0000
AGE23	1.0000	.0000	1.0000	1.0000
AGE24	1.0000	.0000	1.0000	1.0000
AGE25	1.0000	.0000	1.0000	1.0000
AGE26	1.0000	.0000	1.0000	1.0000
AGE27	1.0000	.0000	1.0000	1.0000
AGE28	1.0000	.0000	1.0000	1.0000
AGE29	1.0000	.0000	1.0000	1.0000
AGE30	1.0000	.0000	1.0000	1.0000
AGE31	1.0000	.0000	1.0000	1.0000
AGE32	1.0000	.0000	1.0000	1.0000
AGE33	1.0000	.0000	1.0000	1.0000
AGE34	1.0000	.0000	1.0000	1.0000
AGE35	1.0000	.0000	1.0000	1.0000
AGE36	1.0000	.0000	1.0000	1.0000
AGE37	1.0000	.0000	1.0000	1.0000
AGE38	1.0000	.0000	1.0000	1.0000
AGE39	1.0000	.0000	1.0000	1.0000
AGE40	1.0000	.0000	1.0000	1.0000
AGE41	1.0000	.0000	1.0000	1.0000
AGE42	1.0000	.0000	1.0000	1.0000
AGE43	1.0000	.0000	1.0000	1.0000
AGE44	1.0000	.0000	1.0000	1.0000
AGE45	1.0000	.0000	1.0000	1.0000
AGE46	1.0000	.0000	1.0000	1.0000
AGE47	1.0000	.0000	1.0000	1.0000
AGE48	1.0000	.0000	1.0000	1.0000
AGE49	1.0000	.0000	1.0000	1.0000
AGE50	1.0000	.0000	1.0000	1.0000
AGE51	1.0000	.0000	1.0000	1.0000
AGE52	1.0000	.0000	1.0000	1.0000
AGE53	1.0000	.0000	1.0000	1.0000
AGE54	1.0000	.0000	1.0000	1.0000
AGE55	1.0000	.0000	1.0000	1.0000
AGE56	1.0000	.0000	1.0000	1.0000
AGE57	1.0000	.0000	1.0000	1.0000
AGE58	1.0000	.0000	1.0000	1.0000
AGE59	1.0000	.0000	1.0000	1.0000
AGE60	1.0000	.0000	1.0000	1.0000
AGE61	1.0000	.0000	1.0000	1.0000
AGE62	1.0000	.0000	1.0000	1.0000
AGE63	1.0000	.0000	1.0000	1.0000
AGE64	1.0000	.0000	1.0000	1.0000
AGE65	1.0000	.0000	1.0000	1.0000
AGE66	1.0000</			

THE FOLLOWING SECTION PROPERTY DATA WAS
SUPPLIED BY AUCSS AS A SERVICE TO THE

..... TRACK SHEET

11-SEP-75

SECT 2-Z SHEET
.....

INPUT DATA
.....

I	X	Y	R	F
1	0.000	0.000	0.000	0.000
2	0.000	0.410	0.000	0.000
3	0.375	0.410	0.000	0.375
4	0.410	0.000	0.000	0.000
5	0.410	0.000	0.000	0.000
6	0.875	0.750	0.000	0.000
7	0.900	1.050	0.000	0.000
8	1.000	1.410	0.000	0.000
9	1.000	1.530	0.000	0.000
10	1.0	1.530	0.000	0.000
11	0.000	1.530	0.000	-1.000
12	0.000	0.530	0.000	0.000
13	0.000	0.000	0.000	0.000

SECTION NOT SYMMETRICAL ABOUT X OR Y AXIS

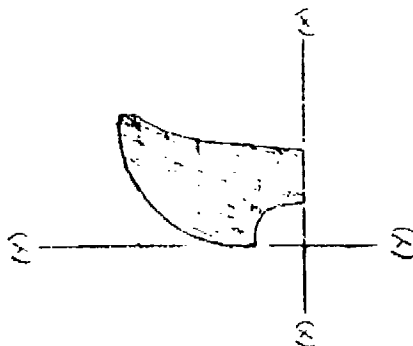
THE RESULTS ARE
.....

$\bar{X}$

ARBITRARY AXIS
.....

NEUTRAL AXIS
.....

AREA--	1.02908	SYLLEFT--	SXITCD--	0.20756	0.11371
WT--	1.42254		SXITCD--	0.10989	0.20142
XBAG--	0.53905		SXITCD--		
YBAG--	0.75460		SXITCD--		
IXA--	0.77467		IXA--	0.15540	
IYA--	0.35824		IYA--	0.05924	
IYA--	0.45307		IYA--	0.02733	
YBAG--	1.000		IYA--	0.16129	
YBAG--	0.000		IYA--	0.06435	
YBAG--	1.530		IXA--	-12.34321	
YBAG--	0.000		IXA--	0.35965	
			IXA--	0.23092	



THE FOLLOWING SECTION BEING A 12" X 12" SECTION
 SHOWN IN FIGURE 15 & 16 OF THE T-10

TABLE 1000

17-SEP-74

SECTION 1000 STEEL

INPUT DATA:

I	A	Y	R	T
1	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000
3	10.500	0.000	0.000	0.000
4	10.500	0.000	0.000	0.000
5	10.000	0.000	0.000	0.000
6	10.000	0.000	0.000	0.000
7	7.250	0.000	0.000	0.000
8	7.250	0.000	0.000	0.000
9	2.175	0.000	0.000	0.000
10	2.175	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000

SECTION SYMMETRICAL ABOUT Y AXIS

THE RESULTS ARE:

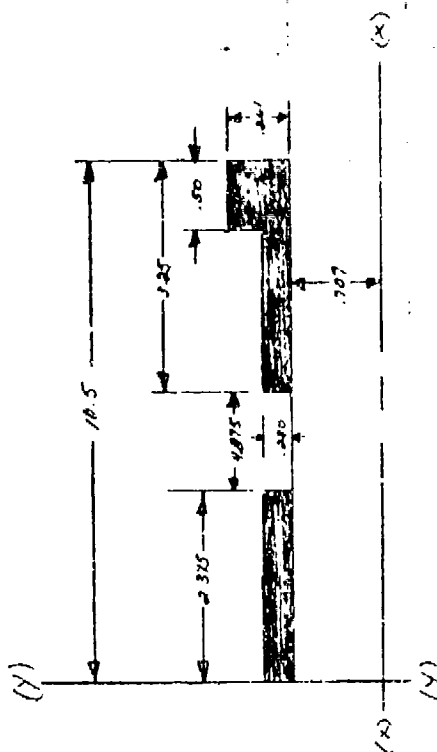
ARBITRARY AXIS

AREA	2.61850
WGT	3.14000
XBAR	0.00000
YBAR	0.00000
IXXA	1.78789
IYYA	124.38223
IXYA	0.00000
IXXA	1.78789
IYYA	124.38223
IXYA	0.00000
IXXA	1.78789
IYYA	124.38223
IXYA	0.00000
IXXA	1.78789
IYYA	124.38223
IXYA	0.00000

NEUTRAL AXIS

SYNLEFT	11.84593
SYNRIGHT	11.84593
SYNLEFT	0.01449
SYNRIGHT	0.01449

8.91



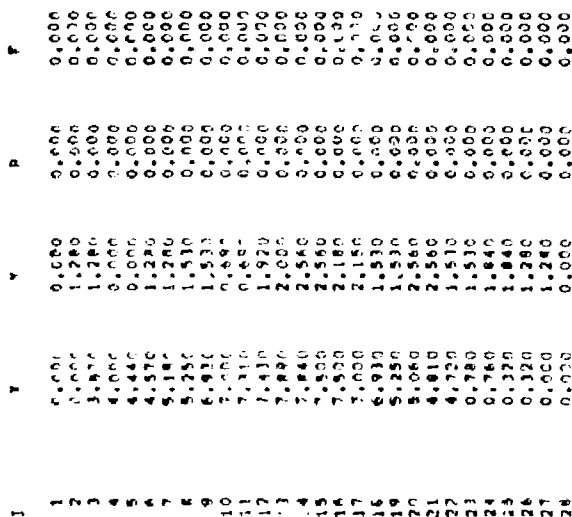
LVTP-7 4

7-2-0 5415

11-954-79

5570 1-1-1

INPUT DATA:



RECTION SYMMETRIC APPROXIS

PHOTOGRAPH BY

PROPERTY 2218

22.75

REFUTED AXYS

1974-75	4,000	2,200	1,800
1975-76	4,000	2,200	1,800
1976-77	4,000	2,200	1,800
1977-78	4,000	2,200	1,800
1978-79	4,000	2,200	1,800
1979-80	4,000	2,200	1,800
1980-81	4,000	2,200	1,800
1981-82	4,000	2,200	1,800
1982-83	4,000	2,200	1,800
1983-84	4,000	2,200	1,800
1984-85	4,000	2,200	1,800
1985-86	4,000	2,200	1,800
1986-87	4,000	2,200	1,800
1987-88	4,000	2,200	1,800
1988-89	4,000	2,200	1,800
1989-90	4,000	2,200	1,800
1990-91	4,000	2,200	1,800
1991-92	4,000	2,200	1,800
1992-93	4,000	2,200	1,800
1993-94	4,000	2,200	1,800
1994-95	4,000	2,200	1,800
1995-96	4,000	2,200	1,800
1996-97	4,000	2,200	1,800
1997-98	4,000	2,200	1,800
1998-99	4,000	2,200	1,800
1999-00	4,000	2,200	1,800
2000-01	4,000	2,200	1,800
2001-02	4,000	2,200	1,800
2002-03	4,000	2,200	1,800
2003-04	4,000	2,200	1,800
2004-05	4,000	2,200	1,800
2005-06	4,000	2,200	1,800
2006-07	4,000	2,200	1,800
2007-08	4,000	2,200	1,800
2008-09	4,000	2,200	1,800
2009-10	4,000	2,200	1,800
2010-11	4,000	2,200	1,800
2011-12	4,000	2,200	1,800
2012-13	4,000	2,200	1,800
2013-14	4,000	2,200	1,800
2014-15	4,000	2,200	1,800
2015-16	4,000	2,200	1,800
2016-17	4,000	2,200	1,800
2017-18	4,000	2,200	1,800
2018-19	4,000	2,200	1,800
2019-20	4,000	2,200	1,800
2020-21	4,000	2,200	1,800
2021-22	4,000	2,200	1,800
2022-23	4,000	2,200	1,800
2023-24	4,000	2,200	1,800
2024-25	4,000	2,200	1,800
2025-26	4,000	2,200	1,800
2026-27	4,000	2,200	1,800
2027-28	4,000	2,200	1,800
2028-29	4,000	2,200	1,800
2029-30	4,000	2,200	1,800
2030-31	4,000	2,200	1,800
2031-32	4,000	2,200	1,800
2032-33	4,000	2,200	1,800
2033-34	4,000	2,200	1,800
2034-35	4,000	2,200	1,800
2035-36	4,000	2,200	1,800
2036-37	4,000	2,200	1,800
2037-38	4,000	2,200	1,800
2038-39	4,000	2,200	1,800
2039-40	4,000	2,200	1,800
2040-41	4,000	2,200	1,800
2041-42	4,000	2,200	1,800
2042-43	4,000	2,200	1,800
2043-44	4,000	2,200	1,800
2044-45	4,000	2,200	1,800
2045-46	4,000	2,200	1,800
2046-47	4,000	2,200	1,800
2047-48	4,000	2,200	1,800
2048-49	4,000	2,200	1,800
2049-50	4,000	2,200	1,800
2050-51	4,000	2,200	1,800
2051			

1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352</
------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	--------

LYTP-7 5

THE FOLLOWING SECTION PROPERTY DATA ARE
 SUPPLIED BY ALCONA & A SERVICE, INC.

TRUCK 8-75

17-SEP-75

SECT B-A STEPL

INPUT DATA

I	X	Y	B	F
1	0.000	0.000	0.000	0.000
2	0.000	0.707	0.000	0.000
3	4.750	0.707	0.000	0.000
4	4.750	0.917	0.000	0.000
5	0.000	0.917	0.000	0.000
6	0.000	0.000	0.000	0.000

SECTION SYMMETRICAL ABOUT Y AXIS

THE RESULTS ARE:

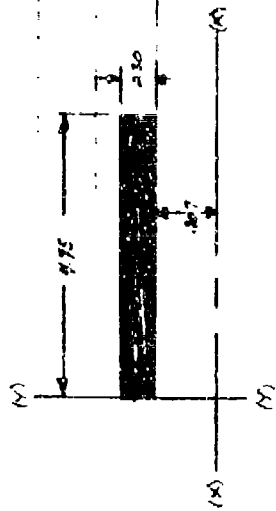
ARBITRARY AXIS

AREA	2.18500
W777	2.40000
XBAR	0.00000
YBAR	0.82200
IXX	1.48600
IYY	16.43302
IXY	0.00000
IXX1	4.750
IXY1	0.000
IYY1	0.937
IXY1	0.000

NEUTRAL AXIS

SYLPT	3.45086
SYLPT	0.01172
IXX	0.00963
IYY	16.43302
IXY	0.00000
IYY	0.00963
IXX	16.43302
IYY	0.00000
IXY	0.00963
IXY	2.18241

3.45950



LVTP-7 6

TOP SECRET

23-829-75

0000000000
NNNY X-X :JTB

INPUT DATA:

I	II	Y	III	IV	V
1	0.000	0.000	0.000	0.000	0.000
2	0.000	2.240	0.000	0.000	0.000
3	0.070	2.250	0.000	0.000	0.000
4	0.150	2.120	0.000	0.000	0.000
5	0.210	2.000	0.000	0.000	0.000
6	0.265	1.730	0.000	0.000	0.000
7	0.312	1.109	0.000	0.000	0.000
8	2.906	1.109	0.000	0.000	0.000
9	3.000	0.000	0.000	0.000	0.000
10	3.720	0.000	0.000	0.000	0.000
11	3.840	0.687	0.000	0.000	0.000
12	3.930	0.687	0.000	0.000	0.000
13	4.047	1.750	0.000	0.000	0.000
14	4.094	2.000	0.000	0.000	0.000
15	4.130	2.120	0.000	0.000	0.000
16	4.234	2.250	0.000	0.000	0.000
17	4.312	2.340	0.000	0.000	0.000
18	4.412	2.625	0.000	0.000	0.000
19	3.990	2.625	0.000	0.000	0.000
20	3.900	1.395	0.000	0.000	0.000
21	0.730	1.395	0.000	0.000	0.000
22	4.487	2.625	0.000	0.000	0.000
23	0.000	2.625	0.000	0.000	0.000
24	0.000	0.000	0.000	0.000	0.000

SECTION NOT SYMMETRICAL ABOUT Z OR Y AXIS

THE RESULTS ARE

SIXTY-SEVEN

SECRET

```

AREA-- 3.85637
WC7PS- 4.58174
XBAR-- 2.52325
YBAR-- 1.42340
YBAR-- 9.47716
IYXA-- 31.36144
IYTA-- 12.8110
IYXA-- .....
IYTA-- .....
XMAI-- 4.312
IXTOP-- 1.33911
EYPMIN- 3.79844
EYLEFT-- 2.49247
IXBOT-- 1.13031
IYX-- 1.40897
IYVM-- 6.79404
IYX-- -1.04800
IYVM-- 1.40514
IYVM-- 6.99787

```

YMLINE	0.00	RETR	1.0513
YMLINE	2.476	PLINE	0.64576
YMLINE	0.00	RYLINE	1.3248

B-100504-AE 1

SECTION NOT SYMMETRICAL ABOUT X OR Y AXIS

1-100 5-100

RECT Y-Y AXIS

INPUT DATA

T	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.781	1.125	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	1.000	1.348	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	1.143	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	1.324	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.854	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	0.825	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.030	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.840	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	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	0.000	0.000	0.000	0.000	0.000	0.000	0.000

SECTION NOT SYMMETRICAL ABOUT X OR Y AXIS

THE RESULTS ARE:

ARBITRARY AXIS

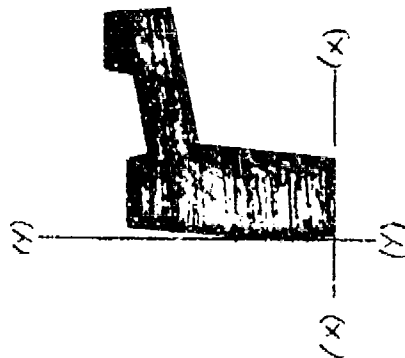
AREA--	1.71022
MT/FT--	2.03174
ISAP--	0.07905
YBAR--	1.04288
IXXA--	2.76736
IXYA--	1.24394
IXYL--	1.44437

IXM--	1.890
IXN--	0.000
IXO--	1.870
IXP--	0.000

SUPPLY AXIS

SIXTC--	0.51811
SIXTC--	0.67058
SIXTC--	0.41127

IXXA--	0.42073
IXYA--	0.45534
IXYL--	0.24372
IXM--	0.19797
IXN--	0.48613
IXO--	0.41770
IXP--	0.50083
IXQ--	0.51810



THE FOLLOWING SECTION PROPERTY DATA ARE
 COMPUTED BY SECTION 4. A SUMMARY FOR

TRACE AND

15-SEP-74

RECT 2-2 ALUM

INPUT DATA

I	X	Y	Z	P
1	0.000	0.000	0.000	0.000
2	0.786	0.000	0.000	0.000
3	0.812	0.120	0.000	0.000
4	0.875	0.875	0.000	0.000
5	0.906	1.180	0.000	0.000
6	1.061	1.510	0.000	0.000
7	1.080	1.455	0.000	0.000
8	1.000	1.450	0.000	0.000
9	0.000	1.650	0.000	-1.000
10	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000

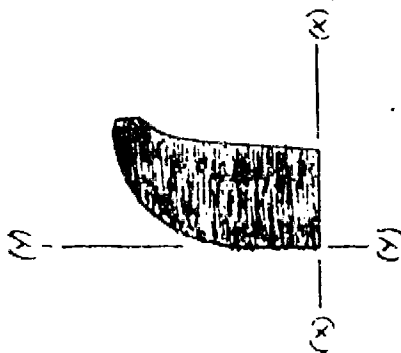
SECTION NOT SYMMETRICAL ABOUT X OR Y AXIS

THE RESULTS ARE:

ARBITRARY AXIS

NEUTRAL AXIS

AREA=	1.76181	SYTOP=	0.16887	SYXTOP=	0.28748	SYHEIGHT=	0.14486
WT/LFT=	1.49903	SYLEFT=	0.16887	SYXLEFT=	0.33022		
XBAR=	0.48943						
YBAR=	0.76797						
IXX=	0.99767						
IYY=	0.58491						
Ixy=	0.52870						
XMAX=	1.060						
XMIN=	0.000						
YMAX=	1.650						
YMIN=	0.000						
IXX=	0.25158						
IYY=	0.08205						
Ixy=	0.05445						
IXX=	0.25845						
IYY=	0.06475						
Ixy=	-16.25135						
IXX=	0.44829						
IYY=	0.25541						



TRACK SHOW

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Year	X	Y	M	P
1	0.09	0.06	0.00	0.00
2	0.00	0.70	0.00	0.00
3	10.50	0.70	0.00	0.00
4	10.50	1.01	0.00	0.00
5	7.20	1.01	0.00	0.00
6	7.20	0.70	0.00	0.00
7	2.35	0.70	0.00	0.00
8	2.35	1.01	0.00	0.00
9	0.00	1.01	0.00	0.00
10	0.00	0.00	0.00	0.00

SECTION SYMMETRICAL ABOUT Y AXIS

THE RESULTS ARE:

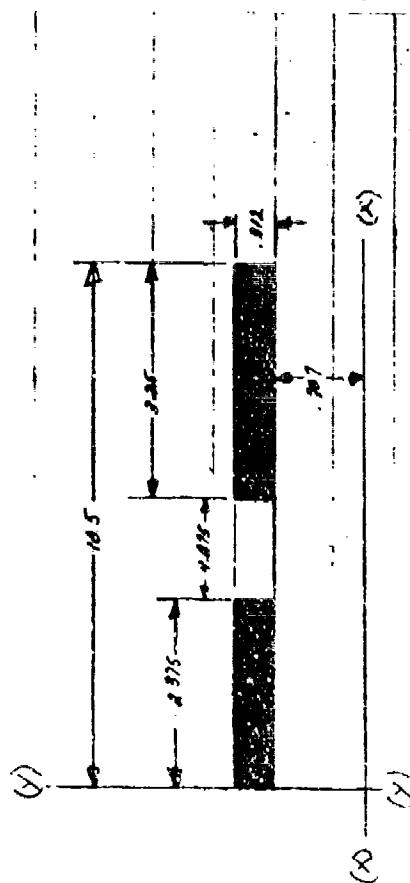
LIBRARY AXIS

UNSUBS. 4718

```

AREA-- 3.31000
WV/FT-- 4.14988
XAM-- 0.0000
YBR-- 0.98300
IXA-- 2.64261
IYA-- 166.30621
IYA-- 0.00000
-----
XAX-- 10.500
XMIN-- 0.300
IYAX-- 1.019
YMIN-- 0.920

```



B-100504-AE 4

TRACE 8804

23-SEP-78

SECT A-A ALUM

INPUT DATA

I	X	Y	R	P
1	0.000	0.000	0.000	0.000
2	0.000	1.189	0.000	0.000
3	3.687	1.189	0.000	0.000
4	3.812	0.000	0.000	0.000
5	1.440	0.000	0.000	0.000
6	4.880	1.189	0.000	0.000
7	6.960	1.189	0.000	0.000
8	7.000	0.687	0.000	0.000
9	7.830	0.687	0.000	0.000
10	7.360	1.670	0.000	0.000
11	7.937	1.937	0.000	0.000
12	7.870	2.625	0.000	0.000
13	7.310	2.625	0.000	0.000
14	7.280	2.187	0.000	0.000
15	7.020	2.156	0.000	0.000
16	6.960	1.399	0.000	0.000
17	5.156	1.595	0.000	0.000
18	5.060	2.625	0.000	0.000
19	4.450	3.623	0.000	0.000
20	4.560	1.595	0.000	0.000
21	0.703	1.595	0.000	0.000
22	0.487	1.810	0.000	0.000
23	0.128	1.610	0.000	0.000
24	0.128	1.189	0.000	0.000
25	0.000	1.189	0.000	0.000
26	0.000	0.000	0.000	0.000

SECTION SYMMETRICAL ABOUT Y AXIS

THE RESULTS ARE:

ARBITRARY AXIS	NEUTRAL AXIS
AREA= 10.64869	SIXTOP= 2.32938
WT/FT= 12.67460	SIXLEFT= 34.20779
XBAR= 0.00000	SIXRIGHT= 34.20779
YBAR= 1.40741	SIXBOT= 2.01322
IXXA= 23.96877	IXXN= 2.83624
IXYA= 271.50723	IXYN= 271.50723
IXXA= 0.00000	IXYN= 0.00000

IXXA= 0.00000	IXYN= 2.83624
IXYA= 7.937	IXYN= 271.50723
IXXA= 0.000	IXYN= 0.00000
IXYA= 2.625	IXYN= 0.51560
IXXA= 0.000	IXYN= 5.04470

B-100504-AE 5

THE FOLLOWING IS THE PROPOSED DATA AND
 SUBSTITUTION BY SIGMA AS A 50.000000

TRACE SHEET

17-SEP-79

SECT R-2 ALON

INPUT DATA

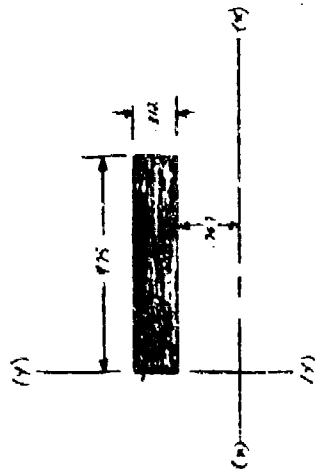
I	X	Y	R	F
1	0.000	0.000	0.000	0.000
2	0.000	0.707	0.000	0.000
3	4.750	0.707	0.000	0.000
4	4.750	1.019	0.000	0.000
5	0.000	1.019	0.000	0.000
6	0.000	0.000	0.000	0.000

SECTION SYMMETRICAL ABOUT Y AXIS

THE RESULTS ARE

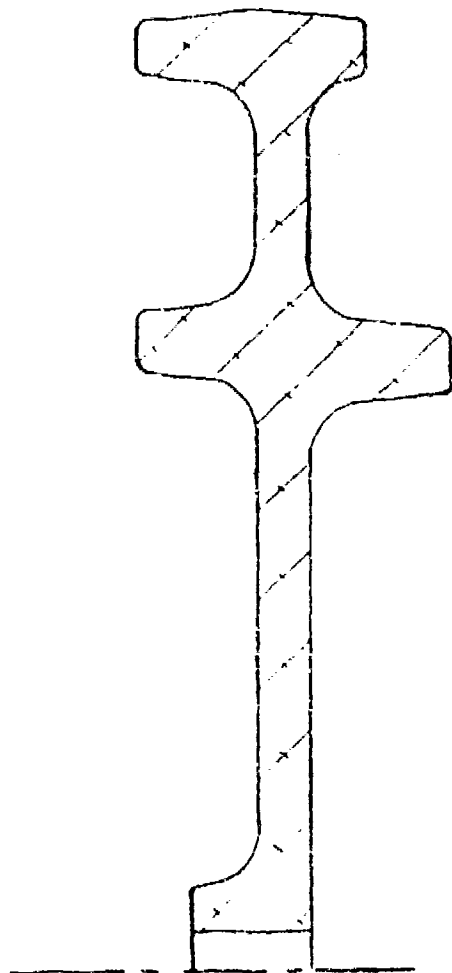
ARBITRARY AXIS

AREA--	2.96400	SYNLEFT--	0.15413	SYNRIGHT--	4.69300
WT/FT--	3.52123	SYNLEFT--	4.69300	SYNRIGHT--	0.02786
XBAR--	0.00000	SYNLEFT--	4.69300	SYNRIGHT--	0.02786
YBAR--	0.66300	SYNLEFT--	4.69300	SYNRIGHT--	0.02786
IXX--	2.23154	SYNLEFT--	4.69300	SYNRIGHT--	0.02786
IYY--	22.29175	SYNLEFT--	4.69300	SYNRIGHT--	0.02786
IXY--	0.00000	SYNLEFT--	4.69300	SYNRIGHT--	0.02786
XMAT--	4.750	SYNLEFT--	4.69300	SYNRIGHT--	0.02786
XMING--	0.000	SYNLEFT--	4.69300	SYNRIGHT--	0.02786
YMAT--	1.019	SYNLEFT--	4.69300	SYNRIGHT--	0.02786
YMING--	0.000	SYNLEFT--	4.69300	SYNRIGHT--	0.02786



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INPUT DATA

i	X	Y	P	F
1	0.000	0.000	0.000	0.000
2	0.000	1.060	0.000	0.000
3	0.001	0.000	0.000	0.000
4	0.012	0.000	0.000	0.000
5	0.006	0.643	0.000	0.000
6	3.593	0.043	0.000	0.000
7	3.634	0.000	0.000	0.000
8	4.187	0.000	0.000	0.000
9	4.310	1.290	0.000	0.000
10	4.350	1.290	0.000	0.000
11	4.444	2.280	0.000	0.000
12	3.454	2.280	0.000	0.000
13	3.375	1.249	0.000	0.000
14	0.906	1.249	0.000	0.000
15	0.012	2.380	0.000	0.000
16	0.003	2.380	0.000	0.000
17	0.000	1.050	0.000	0.000
18	0.000	0.000	0.000	0.000

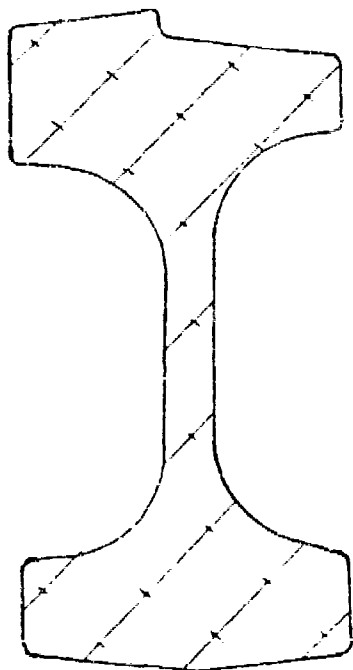
SECTION NOT SYMMETRIC: MARKUP X UP Y AXIS

THE RESULTS ARE:

APPENDIX A

SI 100-117-21 4811

444100	6.472821	SYTTCDOOO	1.42415	
WT/IT=	7.272202	6.83110	SYVFLGLT=	5.30407
BA2000	2.20451		SYVGLT=	1.13245

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APPENDIX C

DRIVE LOAD ANALYSIS

I. SINGLE PIN, CONCEPTS 1 AND 4

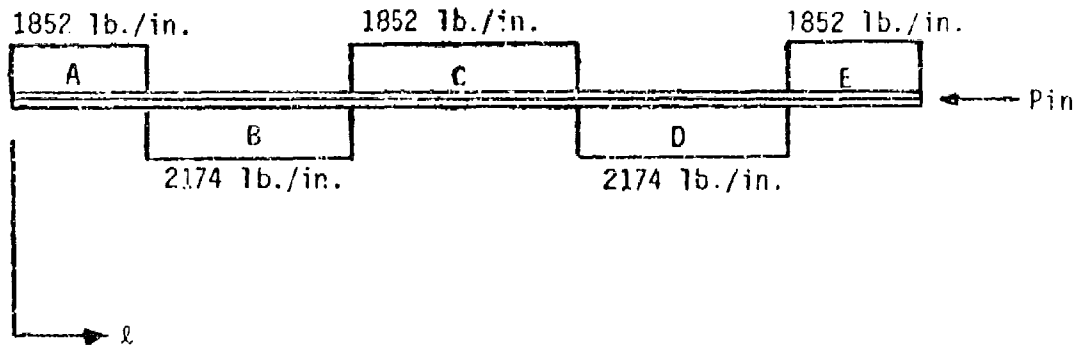
This analysis specifically addresses Concept 1, single pin with end drive (Drawing B-100504-AE). The section properties are those described in Appendix B. Because of block design similarity with the drive insert single-pin concept (4), this analysis generally applies to both single-pin concepts 1 and 4, except for the drive area itself.

A. Track Tension Loading

Track operating conditions:

20,000 lbs. tension
67,000 in.-lb. torsion

Tension loading:

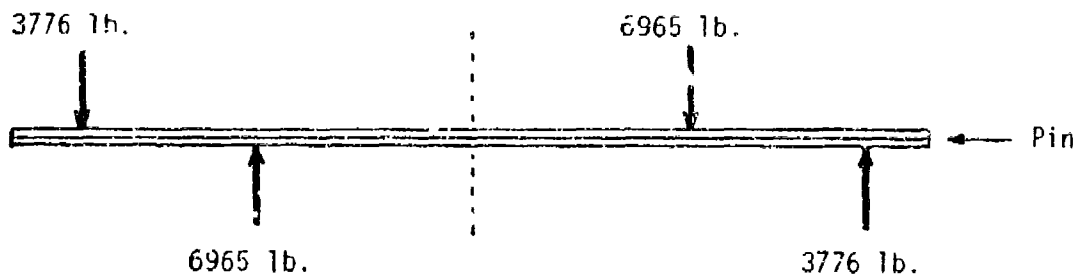


These loads are analyzed by assuming concentrated loads applied at the "hinge" locations, as below:

A	-	5,740 lbs.	at $l = 1.55''$
B	-	10,000 lbs.	at $l = 5.51''$
C	-	8,520 lbs.	at $l = 10.42''$
D	-	10,000 lbs.	at $l = 15.23''$
E	-	5,740 lbs.	at $l = 19.29''$

Appendix C - Continued

B. Track Torsional Loading

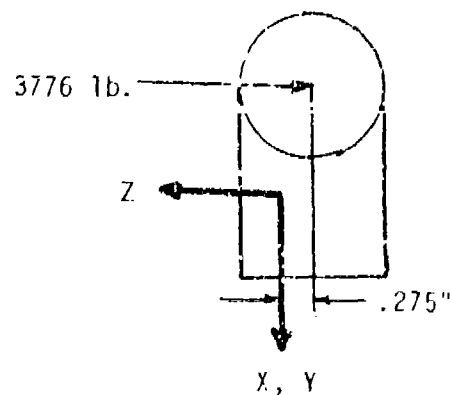
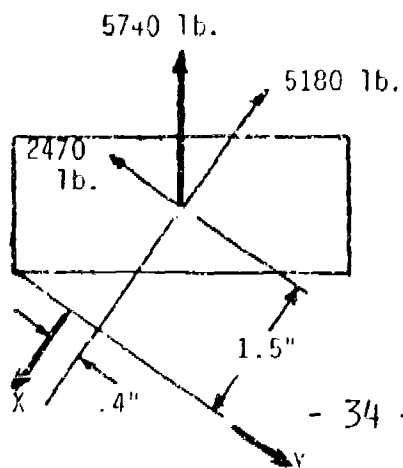
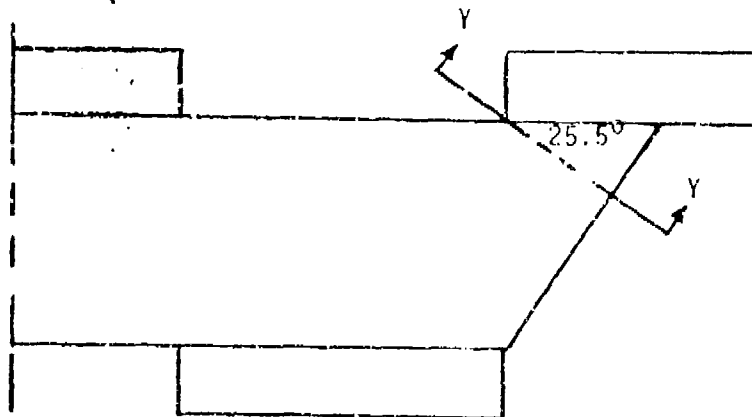


Assume the 67,000 in.-lb. moment about the track center is composed of concentrated loads acting at same locations as tensile loads, as indicated below.

3,776 lbs. at $x = 1.55''$ and $19.29''$
 6,965 lbs. at $x = 5.61''$ and $15.23''$

C. Stress on End Drive Location of Track Body, Section Y-Y, Concept 1

Refer to drawing B-100504-AE. Section Y-Y is included at an angle of 25.5° to the pin as shown in the sketch below:



Appendix C - Continued

Stress conditions for the 67,000 in.-lb. torsional loads applied positive (as shown) and negative are calculated below:

+ 67,000 in.-lb. Torsion:

$$M_x = 3,776 (.4) + 2,470 (.275) \\ = 2,190 \text{ in.-lb.}$$

$$M_y = 3,776 (1.5) - 5,180 (.275) \\ = 4,240 \text{ in.-lb.}$$

$$M_z = -2,470 (1.5) - 5,180 (.4) \\ = -5,777 \text{ in.-lb.}$$

$$R_x = 5,180 \text{ lb.}$$

$$R_y = 2,470 \text{ lb.}$$

$$R_z = 3,776 \text{ lb.}$$

- 67,000 in.-lb. Torsion:

$$M_x = -3,776 (.4) + 2,470 (.275) \\ = -830 \text{ in.-lb.}$$

$$M_y = -3,776 (1.5) - 5,180 (.275) \\ = -7,090 \text{ in.-lb.}$$

$$M_z = -2,470 (1.5) - 5,180 (.4) \\ = -5,777 \text{ in.-lb.}$$

Bending and tensile stresses are then determined using the section properties shown in Appendix B for Section Y-Y.

$$\sigma \text{ Bending} = \frac{Mc}{I}$$

$$\sigma \text{ Tensile} = \frac{P}{A}$$

+ 67,000 in.-lb. Torsion:

$$\sigma \text{ B-Top} = \frac{-4,240 (1.87-1.042)}{.42874} = -8,190 \text{ psi}$$

$$\sigma \text{ B-Bottom} = \frac{4,240 (1.042)}{.42874} = 10,300 \text{ psi}$$

$$\sigma \text{ B-Inside} = \frac{-5,777 (.68)}{.45536} = -8,630 \text{ psi}$$

$$\sigma \text{ B-Outside} = \frac{-5,777 (.68-1.89)}{.45536} = 15,350 \text{ psi}$$

$$\sigma \text{ Tensile} = \frac{5,180}{1.7102} = 3,030 \text{ psi}$$

Appendix C - Continued

- 67,000 in.-lb. Torsion:

$$\sigma_{B-Top} = \frac{-7,090 (1.042-1.87)}{.42874} = 13,690 \text{ psi}$$

$$\sigma_{B-Bottom} = \frac{-7,090 (1.042)}{.42874} = -17,230 \text{ psi}$$

$$\sigma_{B-Inside} = \frac{-5,777 (.68)}{.45536} = -8,630 \text{ psi}$$

$$\sigma_{B-Outside} = \frac{-5,777 (.68-1.89)}{.45536} = 15,350 \text{ psi}$$

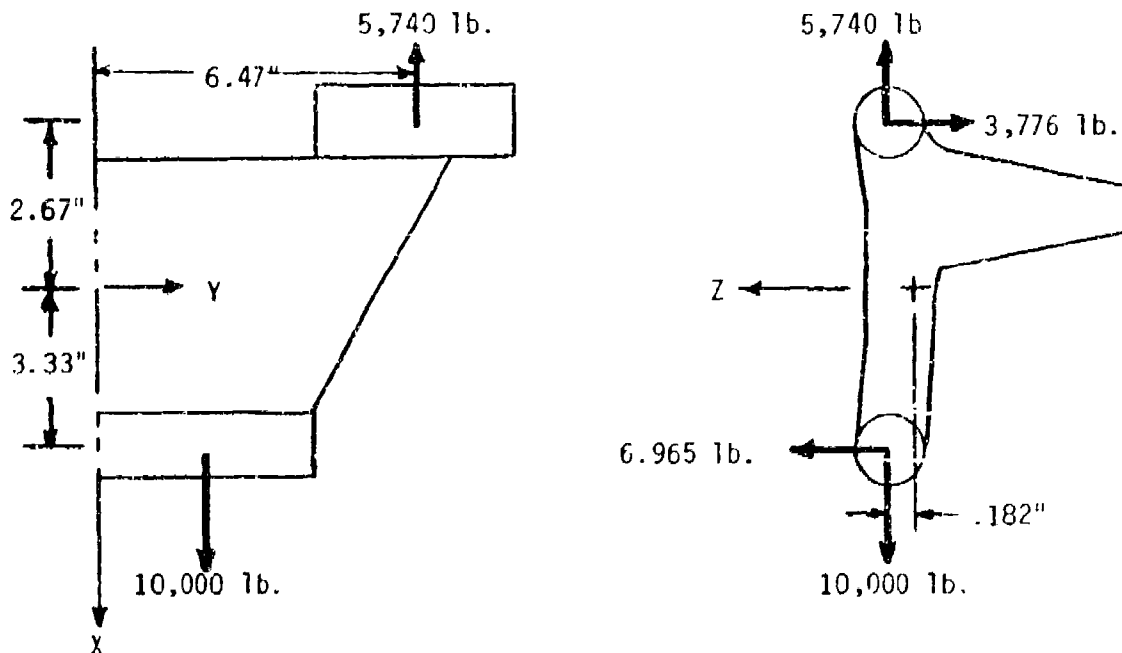
$$\sigma_{Tensile} = \frac{5,180}{1.7102} = 3,030 \text{ psi}$$

The worst stress condition in this section is then at the top, outside element where

$$\sigma_{Maximum} = 3,030 + 15,350 + 13,690 \\ = 32,070 \text{ lbs.}$$

This results in a factor of safety of 1.75 based on the typical yield strength of 2014-T6 die forgings. The life of this design is not infinite as indicated by this stress condition above the material's endurance limit (18,000 psi). Estimates of lifetime are not felt to be accurate within the scope of this analysis and are not made. Additional strengthening of this design might be indicated after a more precise determination of stress patterns (particularly stress concentrations) is made (e.g. by laboratory stress analysis as suggested in Section V).

D. Stresses Through Track Block, Section X-X



Appendix C - Continued

$$\begin{aligned} M_x &= \pm 3,776 (6.47) \mp 6,965 (2.41) \\ &= \pm 7,645 \text{ in.-lb. } (\pm \text{ torsion load}) \end{aligned}$$

$$\begin{aligned} M_y &= 5,740 (.182) \pm 3,776 (2.67) \pm 6,965 (3.33) - 10,000 (.182) \\ &= 32,500 \text{ in.-lb. } (+ \text{ torsion}) \\ &= -34,050 \text{ in.-lb. } (- \text{ torsion}) \end{aligned}$$

$$\begin{aligned} M_z &= 10,000 (2.41) - 5,740 (6.47) \\ &= -13,040 \text{ in.-lb.} \end{aligned}$$

$$\begin{aligned} R_x &= 5,740 - 10,000 \\ &= -4,260 \text{ lb.} \end{aligned}$$

$$R_y = 0$$

$$R_z = 3,776 - 6,965 = \mp 3,190 (\pm \text{ torsion})$$

$$\sigma \text{ Bending} = \frac{Mc}{I}$$

$$\begin{aligned} \sigma \text{ B-Top} &= \frac{7,645 (1.202)}{1.609} \\ &= \pm 5,710 \text{ psi } (\pm \text{ torsion}) \end{aligned}$$

$$\begin{aligned} \sigma \text{ B-Bottom} &= \frac{7,645 (1.423)}{1.609} \\ &= \mp 6,760 \text{ psi } (\pm \text{ torsion}) \end{aligned}$$

$$\begin{aligned} \sigma \text{ B-Front} &= \frac{-13,040 (1.789)}{6.794} \\ &= -3,430 \text{ psi } (\pm \text{ torsion}) \end{aligned}$$

$$\begin{aligned} \sigma \text{ B-Rear} &= \frac{13,040 (2.523)}{6.794} \\ &= 4,840 \text{ psi } (\pm \text{ torsion}) \end{aligned}$$

Tension loads normal to track surface are zero so that the worst stresses are at the top rear surface of the block, and are 10,550 psi; a safety factor of more than 5 over the typical yield strength of 2014-T61. Thus, Section X-X is adequate from the standpoint of gross stress levels; possible stress concentrations should be defined in laboratory tests of prototype hardware.

- E. Stress through track block assuming one block supports the entire vehicle weight (Section A-A).

Beam Loading:

$$\begin{aligned} M \text{ maximum} &= \frac{PL}{4} \\ &= \frac{(6) (50,000)}{4} \\ &= 75,000 \text{ in.-lb.} \end{aligned}$$

Appendix C - Continued

$$\sigma \text{ Bending} = \frac{M_C}{I}$$

$$\sigma \text{ B-Bottom} = \frac{(75)(1.407)}{2(2.836)} \\ = -18,600 \text{ psi}$$

$$\sigma \text{ B-Top} = \frac{(75)(1.218)}{2(2.836)} \\ = 16,100 \text{ psi}$$

Stresses are well within 2014-T61 yield strength with a safety factor of approximately 3 for this extreme loading condition.

II. Single Pin, Concept 2

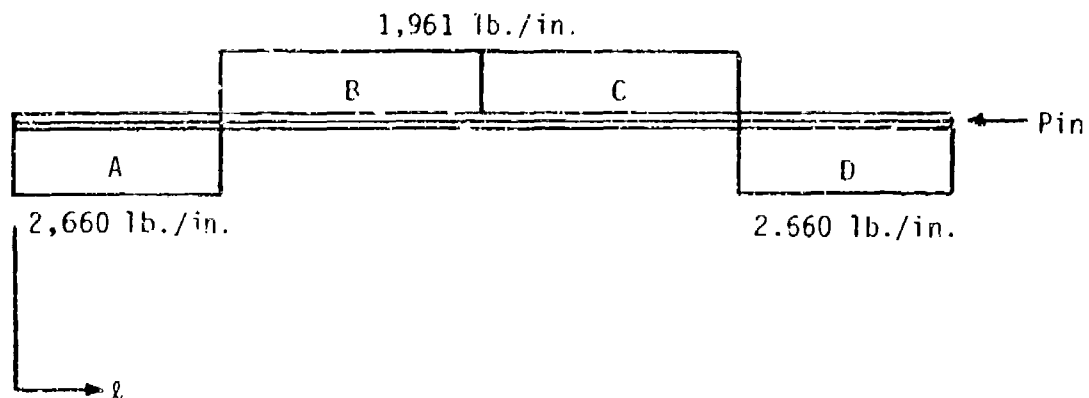
Refer to Drawing B-100508-AE

A. Track Tension Loading

Track operating conditions:

20,000 lbs. tension
67,000 in-lb. torsion

Tension loading:



Assume concentrated loads at "hinge" locations:

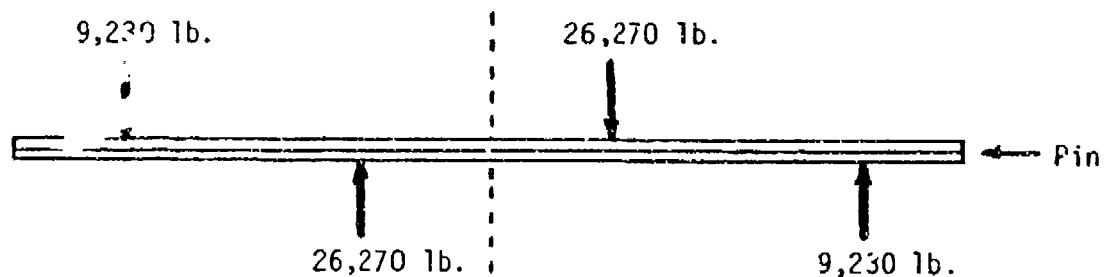
- A - 10,000 lbs. at $l = 1.96$
- B - 10,000 lbs. at $l = 6.67$
- C - 10,000 lbs. at $l = 11.77$
- D - 10,000 lbs. at $l = 16.48$

Appendix C - Continued

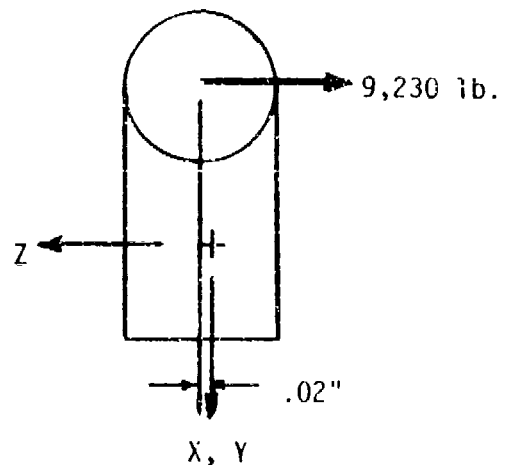
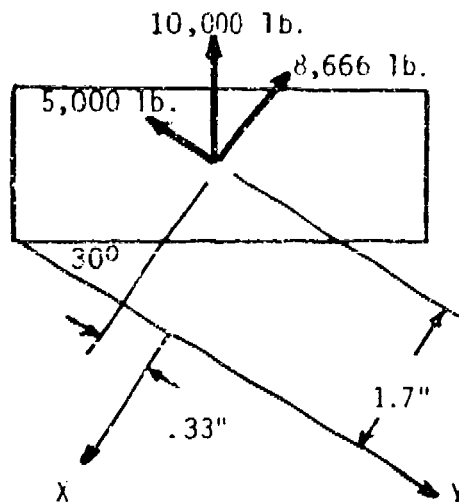
B. Track Torsional Loading.

The 67,000 in.-lb. torsional load is composed of concentrated loads acting at the same locations as above.

9,230 lbs. at $x = 1.96$ and 16.48
 26,270 lbs. at $x = 6.67$ and 11.77



C. Stress on End Drive Location of Track Body, Section Y-Y, Concept 2



Appendix C - Continued

$$R_x = 8,660 \text{ psi}$$

$$R_y = 5,000 \text{ psi}$$

$$R_z = \pm 9,230 \text{ psi } (\pm \text{ torsion})$$

$$M_x = -9,230 (.33) = \mp 11,710 \text{ psi } (\pm \text{ torsion})$$

$$M_y = 9,230 (1.7) = \pm 15,690 \text{ psi } (\pm \text{ torsion})$$

$$M_z = 8,660 (.33) - 5,000 (1.7) = -5,640 \text{ psi}$$

$$\sigma \text{ Tension} = \frac{P}{A} = \frac{8,660}{3.259} = 2,660 \text{ psi}$$

$$\sigma \text{ Top} = \frac{M_c}{I} = \frac{\pm (15.69) (1.04)}{.678} = \pm 24,000 \text{ psi}$$

$$\sigma \text{ Bottom} = \frac{M_c}{I} = \frac{\pm (15.69) (.8911)}{.678} = \pm 20,620 \text{ psi}$$

$$\sigma \text{ Front} = \frac{M_c}{I} = \frac{-(5.64) (1.636)}{5.5057} = -1,680 \text{ psi}$$

$$\sigma \text{ Rear} = \frac{M_c}{I} = \frac{(5.64) (2.294)}{5.5057} = 2,350 \text{ psi}$$

The worst stress condition is at top, rear

$$\sigma = 2,660 + 24,000 + 2,350 = 29,010 \text{ psi}$$

This is a safety factor of approximately 1.9 on yielding for typical 2014-T61 properties, but as in the case of Concept 1, the life of the design is not infinite. Further fatigue evaluation is left to laboratory stress analysis.

General comment -- Caution is advised in the interpretation of the calculations shown in this Appendix. The bending formula $\sigma = \frac{M_c}{I}$ assumes that the cross sectional dimensions of the beams are small compared to their lengths. Stresses could be larger than indicated, particularly at stress concentrations. These values are shown to suggest areas (such as the centerguide and end drive location) that might require additional strengthening. The sections are based on the LVTP-7 track (Appendix B) and are generally such that the aluminum track will be equal to the existing steel track. Final design refinement by laboratory stress analysis should be completed, as indicated in Section V.

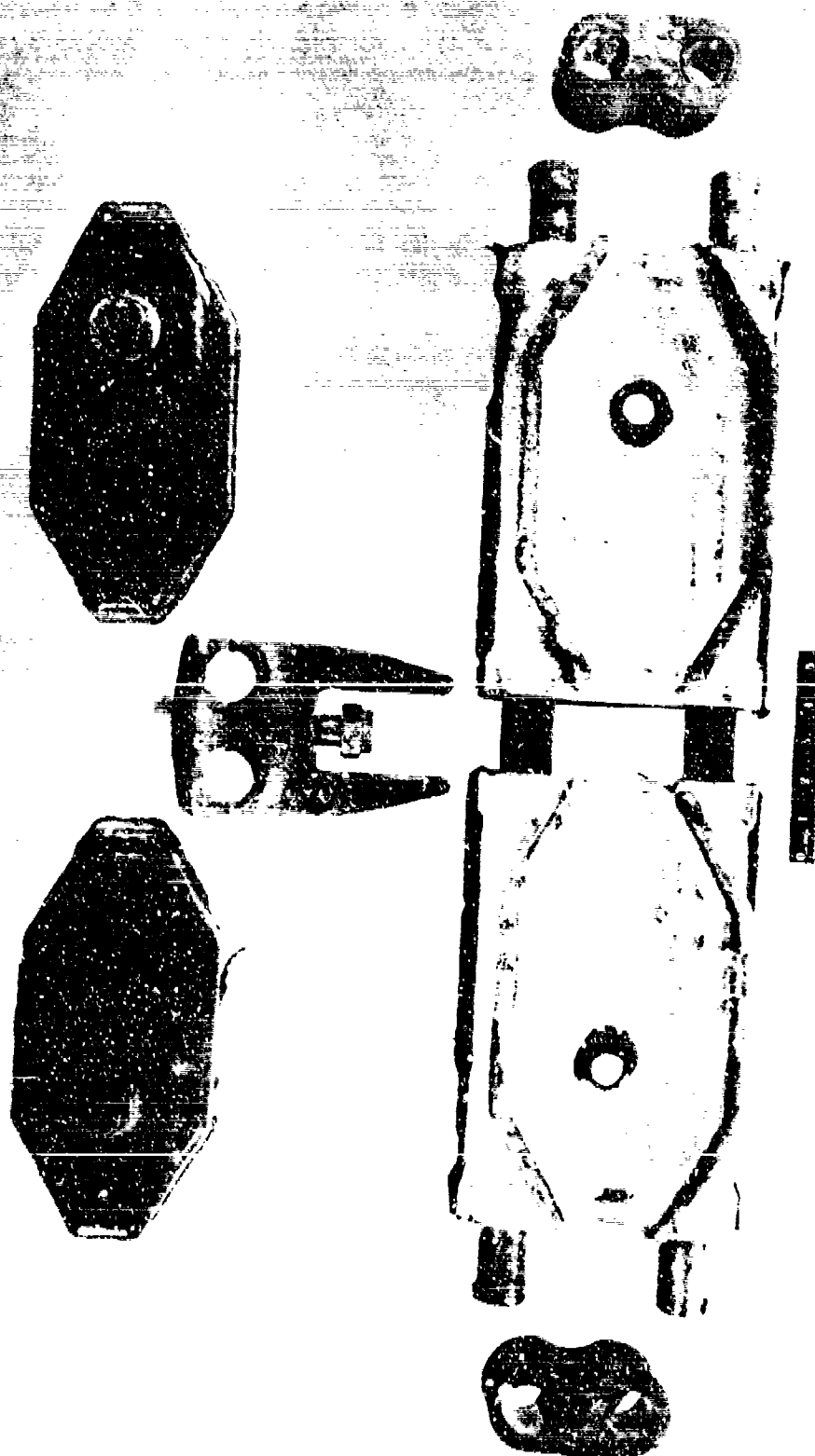


Figure 1. Aluminum T-142 Double-Pin Track. Single-piece alloy 2014-T61 forgings replace the standard production three-piece steel track blocks at a weight savings of 16.7 lbs. per pitch (assembled track shoe), a reduction of 22 percent. The production pins, end connectors, centerguide, and pads are used; the track is completely interchangeable with the steel T-142 and T-97 tracks presently used on the M48 and M60 vehicles.

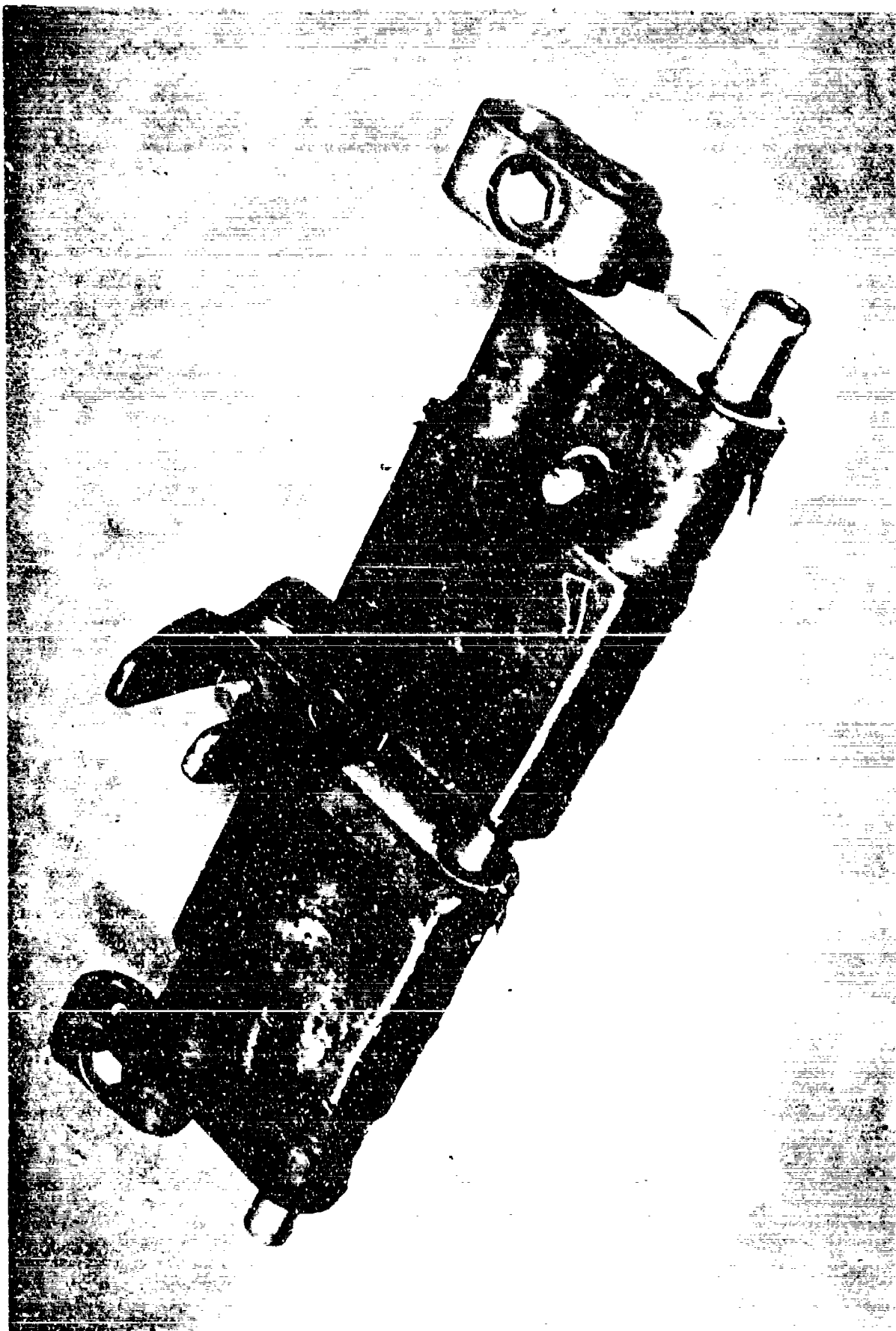


Figure 2. One Complete Pitch (Track Shoe Assembly) of the Aluminum T-142 Track. Track width, 28 inches; pitch, 6.937 inches; weight, 59.9 lbs. Roadwheel side rubber is molded to the aluminum blocks; road surface pads are replaceable.



Figure 3. Half Section of the T-144 Double-Pin Track Used on M501 Hawk Missile Loader Vehicle (sectioned through the centerguide). Track block is 2014-T6 aluminum forging encased in molded rubber. Steel protective cap for integral centerguide is bonded to the aluminum "horn" by the rubber casing.

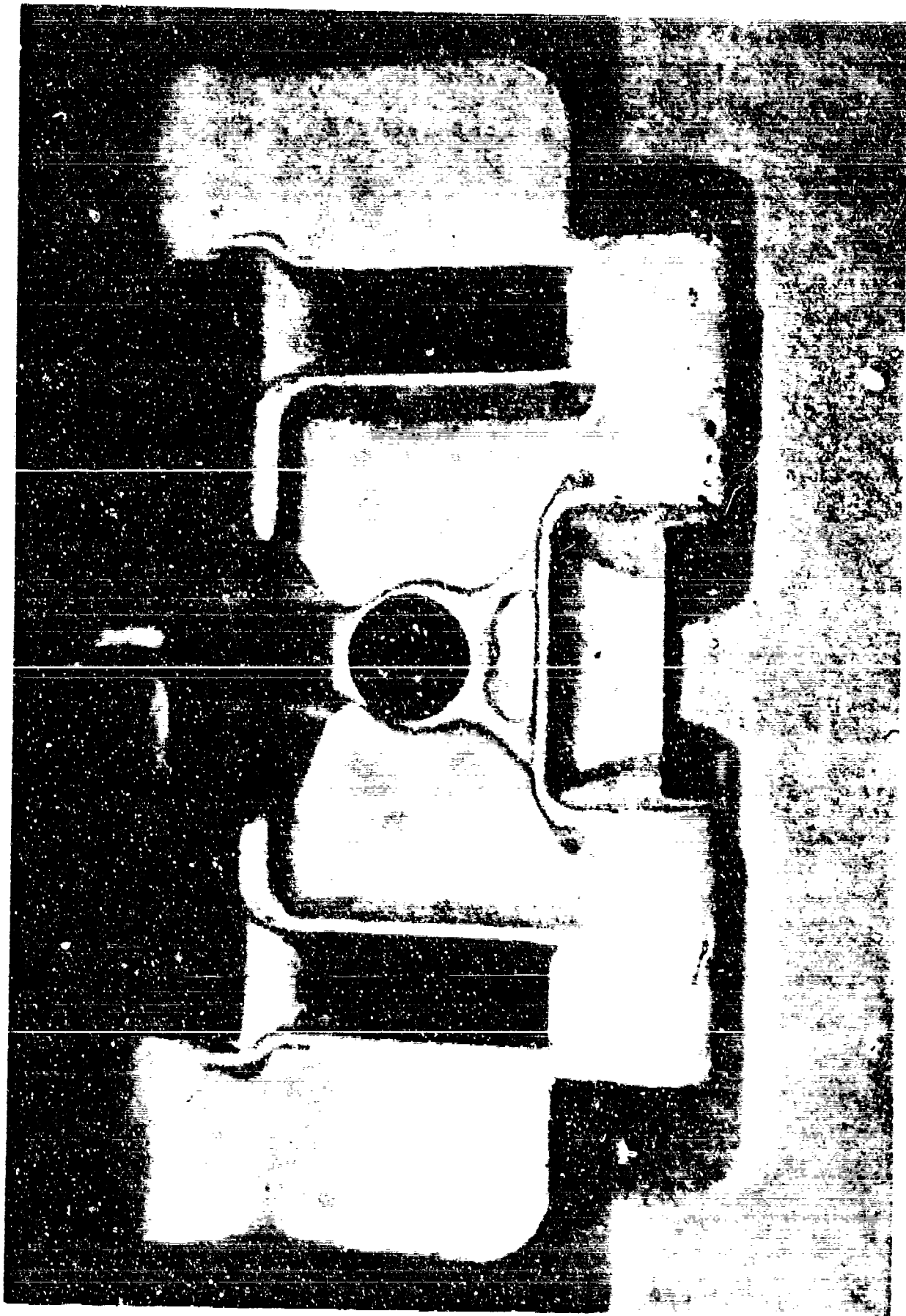


Figure 4. Single-Pin T-130 Track (M113 Personnel Carrier). Shown is an aluminum casting for laboratory stress analysis of the production steel T-130 track shoe. The integral centerguide and drive area in the track body are typical of single-pin designs.

FORGING ALLOYS - CHARACTERISTICS AND USES

Alloy	Temper generally used	General Characteristics	Typical Uses
1100	-0	Commercially pure aluminum not susceptible to heat treatment. Easily forged. Excellent resistance to corrosion.	Cooking utensil components; pipe fittings and other parts for chemical equipment. Cable clamps for electrical industry.
2014	-T6 -T61	High tensile and yield strength combined with good ductility. Good machinability. Fair forging characteristics.	Widely used for aircraft and other heavy-duty structural uses. For forgings of very large cross section, the alloy can be rough machined in F temper and then heat treated to obtain somewhat higher properties and alleviate distortion problems. Actual uses include airframe components, aircraft landing gear parts, truck wheel hubs, equalizer beams for trucks, ordnance and missile parts.
2024	-T6	Special purpose alloy not used for general forging applications. High strength but relatively poor forging characteristics.	Aircraft propellers.
2219	-T6 -T852	Good mechanical properties at room temperatures. Ability to retain strength after prolonged exposure at elevated temperature. Very good weldability and joint efficiency.	Tankage for liquid fuel rockets. Structural parts which must operate at elevated temperature for prolonged periods. Structural parts to be welded.
2618	-T61	Good mechanical properties at elevated temperature. Freedom from growth.	Aircraft cylinder heads and pistons. Tire molds. Jet engine accessories.
4032	-T6	Good elevated temperature strength. Lowest coefficient of expansion of forging alloys.	Forged pistons.
5083	-H111 -H112 -H117 -H131 -H321	High strength nonheat treatable alloy. Strengthened by cold working. Good for ballistic applications. Very good weldability. Good corrosion resistance.	Ballistic parts for military vehicles. Welded high strength structures. Marine applications.
5456	-H111 -H112 -H116/117 -H131 -H321	Similar to 5083. Slightly higher strength.	Ballistic parts for military vehicles. Welded high strength structures. Marine applications.

Figure 5

Alloy	Temper generally used	General Characteristics	Typical Uses
6061	-T6 -T652	Moderate yield and tensile strength combined with good ductility. Excellent forging characteristics.	Transportation equipment such as truck parts and automotive wheels, pipe flanges; chemical industry and water heater hardware requiring assembly by welding or brazing.
6151	-T6 -T652	Moderate mechanical properties. Good machining characteristics and resistance to corrosion. Excellent forging characteristics.	Intricate parts, aircraft engines, crankcases, automotive parts and hardware, machinery parts such as spool heads and spinning buckets for textile industry, trowel handles.
7075	-T6 -T652 -T73 -T7352	High strength aluminum forging alloy. Close control required in fabrication. Overaged (-T7) tempers have high resistance to stress-corrosion cracking. Tensile and yield strengths are about 10% less than 7075-T6.	Aerospace applications. Typical uses are airframe parts, landing gear and undercarriage parts. Structural parts requiring high resistance to stress corrosion cracking use overaged tempers.

Figure 5 - Continued

ALCOA FORGING ALLOY DATA

TYPICAL PHYSICAL PROPERTIES-- ALUMINUM FORGING ALLOYS

Alloy and temper	Density lb/cu in.	Melting range approximate °F	Electrical conductivity percent of International Annealed Copper Standard	Thermal conductivity at 25°C, CGS units
2014-T4	0.1012	950-1180	34	0.32
2014-T6	0.1012	950-1180	40	0.37
2014-T61	0.1012	950-1180	40	0.37
2024-T852	0.1005	935-1180	38	0.36
2219-T6	0.1023	1010-1190	32	0.30
2219-T852	0.1023	1010-1190	32	0.30
2618-T61	0.0999	1040-1185	39	0.36
4032-T6	0.0966	990-1060	35	0.33
5083-H111	0.0961	1075-1185	29	0.28
5083-H112	0.0961	1075-1185	29	0.28
5083-H131	0.0961	1075-1185	29	0.28
6061-T6	0.0976	1100-1205	43	0.40
6061-T652	0.0976	1100-1205	43	0.40
6051-T6	0.0977	1090-1200	45	0.41
6151-T652	0.0977	1090-1200	45	0.41
7075-T6	0.1013	890-1175	33	0.31
7075-T652	0.1013	890-1175	33	0.31
7075-T73	0.1013	890-1175	40	0.35
7075-T7352	0.1013	890-1175	40	0.36

Average Coefficient of Thermal Expansion—Aluminum Forging Alloys¹

Alloy	Temperature Range			
	-58° to 68°F	68° to 212°F	68° to 392°F	68° to 572°F
2014	11.7	12.5	13.1	13.6
2024	11.7	12.7	13.2	13.8
2219	11.7	12.5	13.1	13.6
2618	11.5	12.4	12.9	13.4
4032	10.1	10.8	11.3	11.7
5083	12.3	13.2	13.8	14.3
6061	12.1	13.0	13.6	14.1
6151	12.0	12.9	13.5	14.0
7075	12.1	13.0	13.6	14.1

Figure 6

TYPICAL MECHANICAL PROPERTIES--ALUMINUM DIE FORGINGS^{2,5}

Alloy and temper	Tensile strength, lb/sq in.	Yield strength, lb/sq in.	Elongation in 2 in. or 4D	Brinell hardness, 500 kg load 10mm ball	Shearing strength, lb/sq. in.	Endurance limit ³ lb/sq in.	Modulus elasticity ⁴ lb/sq in.
2014-T4	61,000	34,000	22	105	38,000	20,000	10.6×10^{-6}
2014-T6	70,000	60,000	13	140	42,000	18,000	10.6×10^{-6}
2014-T61	68,000	56,000	12	130	41,000	18,000	10.6×10^{-6}
2014-T652	70,000	60,000	13	140	42,000	18,000	10.6×10^{-6}
2024-T852	72,000	65,000	10	140	42,000	20,000	10.6×10^{-6}
2219-T6	64,000	45,000	14	115	37,000	15,000	10.6×10^{-6}
2618-T61	64,000	54,000	10	130	38,000	19,000	10.6×10^{-6}
4032-T6	55,000	46,000	9	120	38,000	16,000	11.4×10^{-6}
4032-T62	48,000	38,000	7	105	.....	.....	11.4×10^{-6}
4032-T72	44,000	34,000	8	95	.....	.....	11.4×10^{-6}
5083-H112	44,000	28,000	..	80	26,000	22,000	10.3×10^{-6}
6061-T6	47,000	43,000	17	100	31,000	14,000	10.0×10^{-6}
6061-T652	47,000	43,000	17	100	31,000	14,000	10.0×10^{-6}
6151-T6	48,000	43,000	17	100	32,000	11,000	10.2×10^{-6}
6151-T652	48,000	43,000	17	100	32,000	11,000	10.2×10^{-6}
7075-T6	80,000	70,000	14	150	46,000	23,000	10.4×10^{-6}
7075-T652	80,000	70,000	14	150	45,000	23,000	10.4×10^{-6}
7075-T73	73,000	63,000	13	140	44,000	22,000	10.4×10^{-6}
7075-T7352	73,000	63,000	13	140	44,000	22,000	10.4×10^{-6}

Figure 6 - Continued

CHEMICAL COMPOSITION LIMITS—ALUMINUM FORGING ALLOYS⁶

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Others		Al min. ⁷
										Each	Total	
2014	0.50-1.2	0.7	3.9-5.0	0.40-1.2	0.20-0.8	0.10	.....	0.25	0.15	0.05	0.15	Remainder
2024	0.50	0.50	3.8-4.9	0.30-0.9	1.2-1.8	0.10	.....	0.25	.....	0.05	0.15	Remainder
2219	0.20	0.30	5.8-6.8	0.20-0.40	0.02	.....	.....	0.10	0.02-0.10	0.05 ⁸	0.15	Remainder
2618	0.25	0.9-1.3	1.9-2.7	.....	1.3-1.8	.....	0.9-1.2	.....	0.04-0.10	0.05	0.15	Remainder
4032	11.0-13.5	1.0	0.50-1.3	.....	0.8-1.3	0.10	0.50-1.2	0.25	.....	0.05	0.15	Remainder
5083	0.40	0.40	0.10	0.30-1.0	4.0-4.9	0.05-0.25	.....	0.25	0.15	0.05	0.15	Remainder
6061	0.40-0.8	0.7	0.15-0.40	0.15	0.8-1.2	0.04-0.35	.....	0.25	0.15	0.05	0.15	Remainder
6151	0.6-1.2	1.0	0.35	0.20	0.45-0.8	0.15-0.35	.....	0.25	0.15	0.05	0.15	Remainder
7075	0.40	0.50	1.2-2.0	0.30	2.1-2.9	0.18-0.35	.....	5.1-6.1	0.20	0.05	0.15	Remainder
7175	0.15	0.20	1.2-2.0	0.10	2.1-2.9	0.18-0.30	.....	5.1-6.1	0.10	0.05	0.15	Remainder

1. To be multiplied by 10^{-6} (for example the coefficient of thermal expansion for alloy 2014 in column 2 is 12.5×10^{-6} which is 0.0000125 in./in./°F).
2. Values obtained from standard half-inch diameter test specimens machined from separately forged coupons representative of the forgings.
3. Based on 500,000 cycles of completely reversed stress using the R. R. MOORE type of machine and specimen.
4. Average of tension and compression moduli. Compression modulus is about 2 percent greater than tension modulus.
5. Values listed are average and cannot be considered guaranteed minima for design purposes.
6. Composition in percent maximum unless shown as a range.
7. Aluminum percentage determined by difference.
8. Vanadium 0.05-0.15, zirconium 0.10-0.25.

Figure 6 - Continued

WEIGHT ESTIMATES OF PROPOSED DESIGN CONCEPTS WITH COMPARISON TO EXISTING TRACKS

<u>Part</u>	<u>CONCEPT</u>			
	<u>1</u> <u>Single Pin</u>	<u>2</u> <u>Single Pin</u>	<u>3</u> <u>Double Pin</u>	<u>4</u> <u>Single Pin</u>
Pin(s) and Nuts	3.3	4.8	9.6	3.3
Bushings	2.4	2.7	2.7	2.4
Pad	2.8	2.8	2.8	2.8
Body Rubber	1.0	1.0	1.0	1.0
Body	10.4	10.4	12.3	11.3
Centerguide	.9	.9	.9	.9
Drive Assembly	<u>2.0</u>	<u>3.0</u>	<u>3.5</u>	<u>4.0</u>
Total Weight Per Shoe	22.8	25.6	32.8	25.7
Weight per Foot of Track	45.6	51.2	65.6	51.4

Weight per foot of LVTP-7 Track
(Per NAVSHIPS LVTP-7 Characteristic
Data Sheet, May 1974)

62.8 Lbs.

Weight per foot of modified LVTP-7
Track for MICV (per U. S. Army Tank-
Automotive Command Drawing 12250718,
December 13, 1974)

66.0 Lbs.

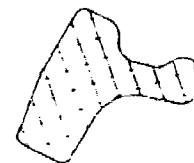
Figure 7

ESTIMATED PRODUCTION PRICE OF RECOMMENDED CONCEPTS

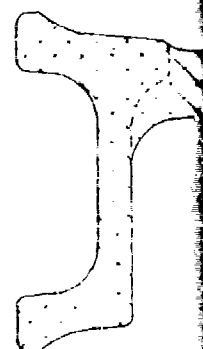
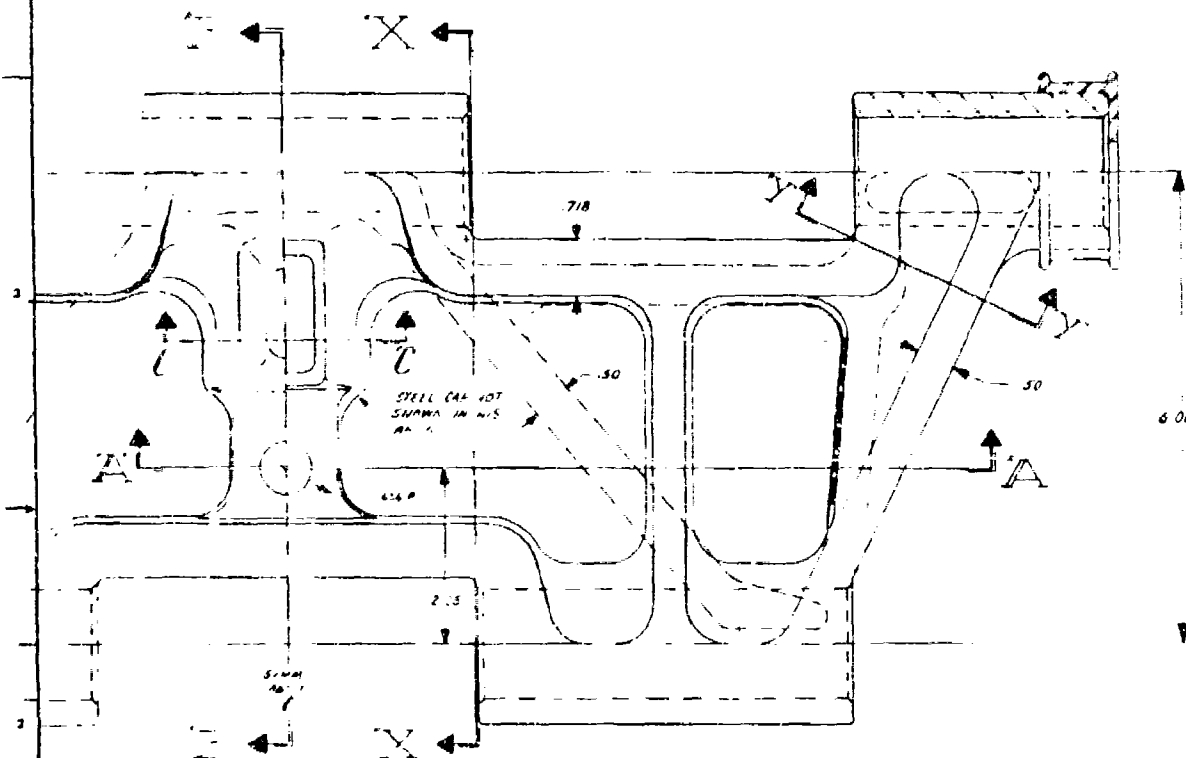
	<u>Concept 2</u>	<u>Concept 4</u>
Production Forging Dies	\$22,250	\$32,750
Production price (10,000 quantity) per pitch, assembled in sections, packaged for shipment	\$ 78	\$ 88

Figure 8

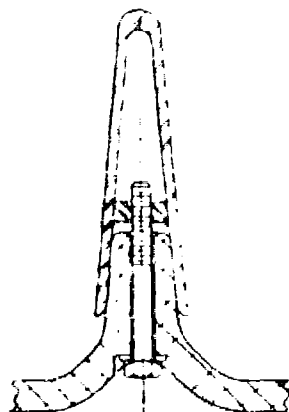
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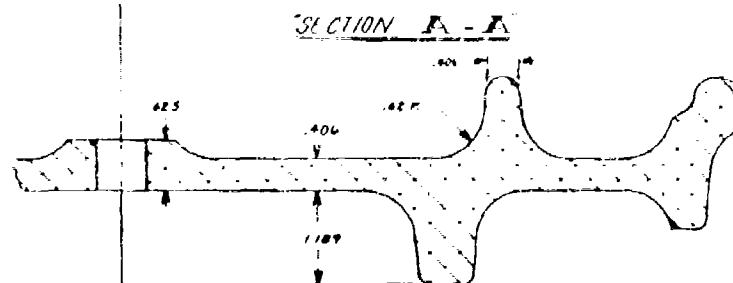
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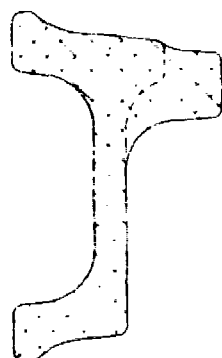
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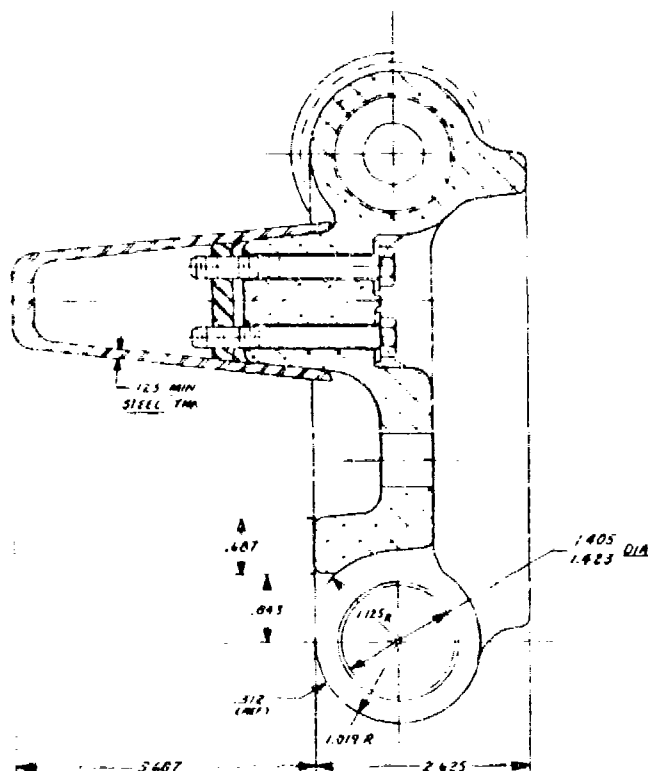
SECTION C-C



SECTION A-A



SECTION X-X



SECTION B-B

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TYP DRAFT 5°

(REF BUREAU OF SHIPS DWG. 2584017)

ALCOA		APPLICATION ENGINEERING DEPARTMENT	
PROPOSED LIGHTWEIGHT			
TRACK SHOE			
CUSTOMER: NAVAL SHIP REPAIR CENTER			
DATE: 2014-06-1	SCALE: FULL	DATE: SEPT. 30, 1945	
B-100534-A.E.		DRAWN BY: L.C.	
		CHECKED BY:	

B-100508-A.E.

SECTION 'Y-Y'

1/8" OCTAGONAL PIN
9/16" DIA. HOLES

SECTION 'X-X'

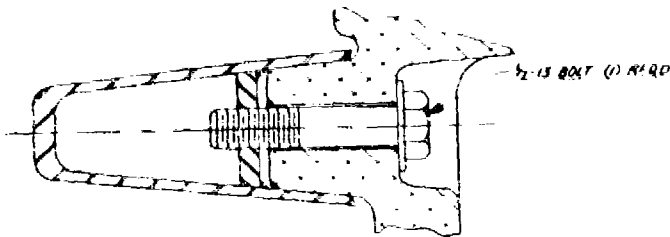
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SECTION 'C-C'

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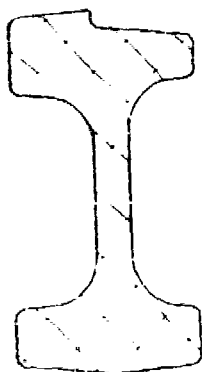
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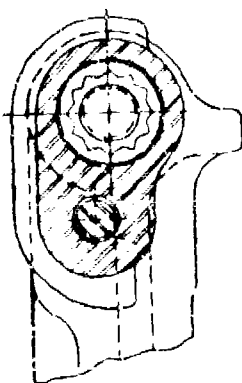


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(VIEW # 1)

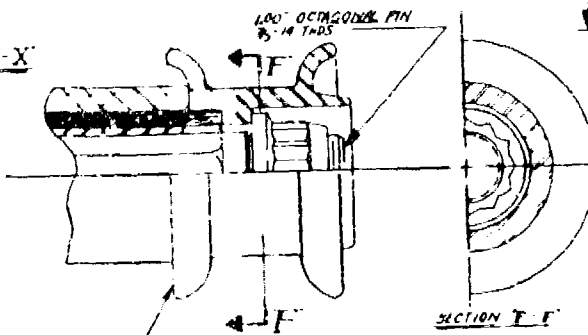
SECTIONAL PIN
R₁ 1/4 IN



SECTION X-X



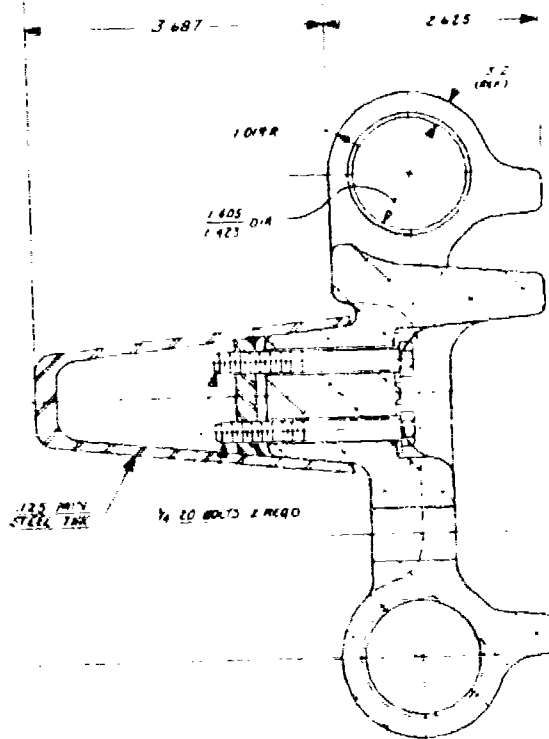
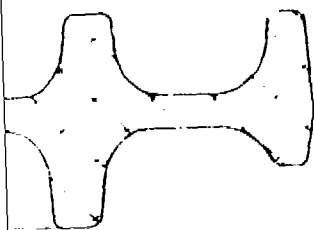
SECTION Z-Z
(SEE ALTERNATE
DRIVE PROPOSAL)



SECTION T-T

ALTERNATE DRIVE PROPOSAL

SECTION A-A



SECTION T-T

(SEE ALTERNATE
GUIDE PROPOSAL
VIEW # 1, 2)

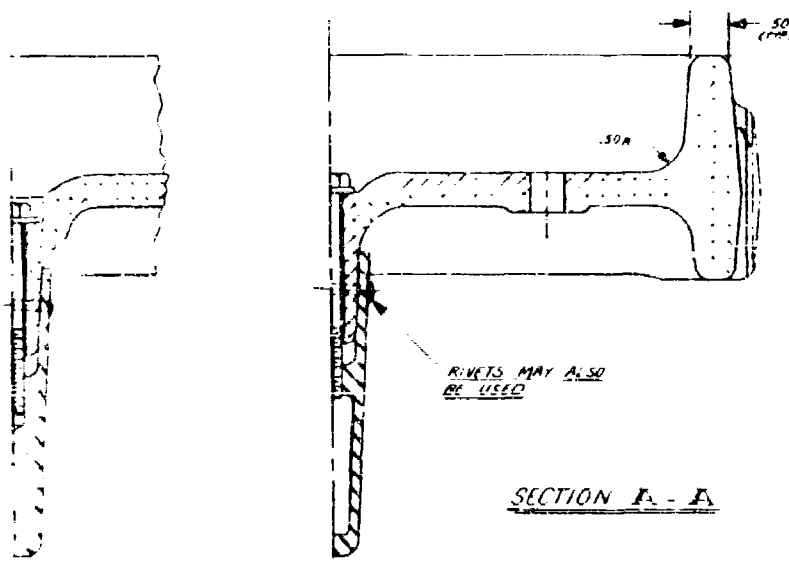
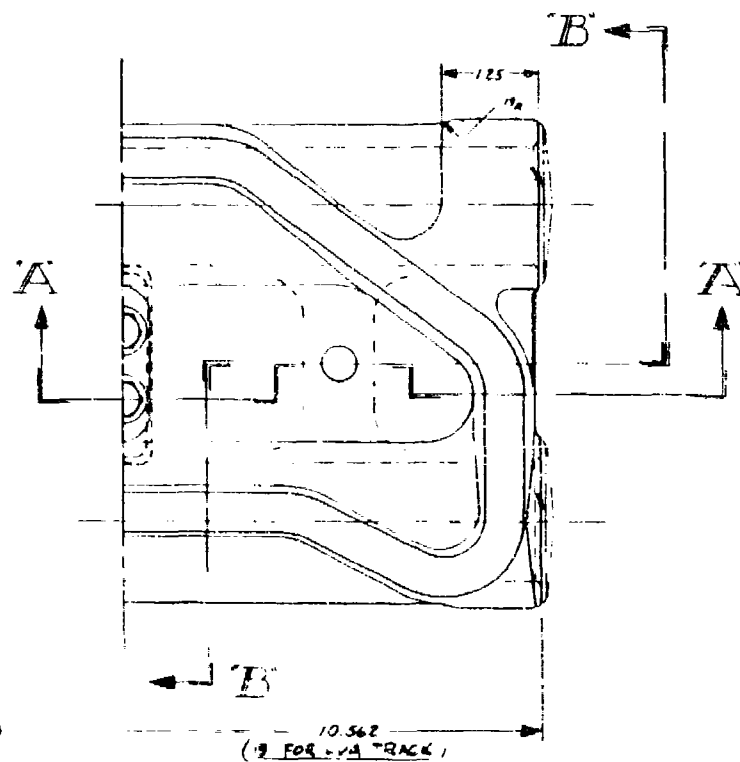
1/4 IN DRAFT 5°

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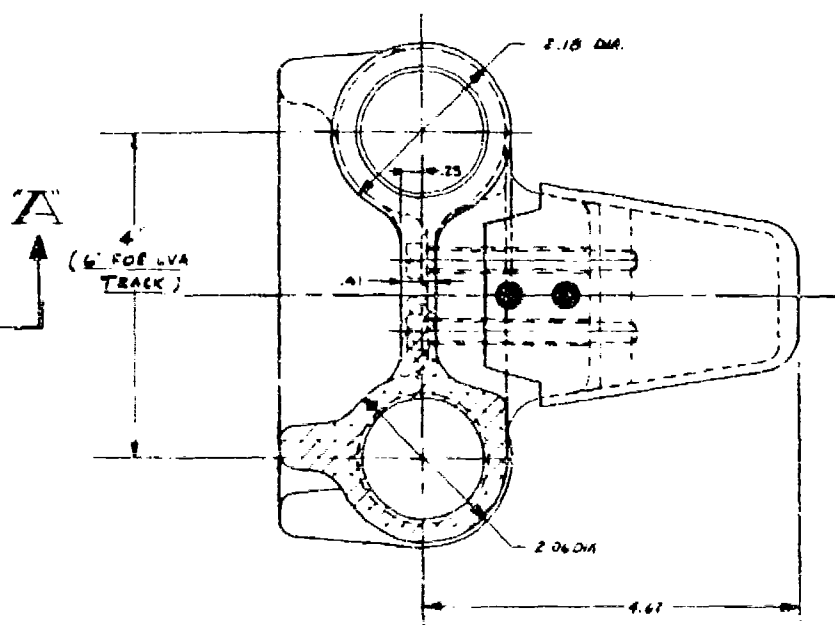
(REF BUREAU OF SHIPS DWG 230401)

ALCOA		APPLICATION ENGINEERING DIVISION	
PROPOSED LIGHTWEIGHT TRACK SHOE (3 LOBE DESIGN)			
CUSTOMER NAVAL SHIP RCD CENTER			
MAT'L 20M-T6	SCALE FULL	DATE NOV 4, 1975	
B-100508-A.E.		DRAWN BY L.C.	
		CHECKED BY	

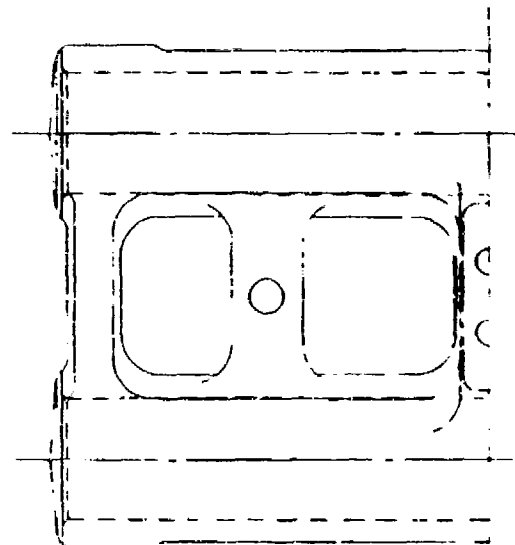
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A TE-NATE SECTION A-A



SECTION B-B



VIEW WITHOUT STEEL = DE - 100-100

UNLESS SPECIFIED;

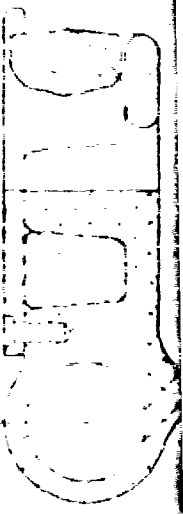
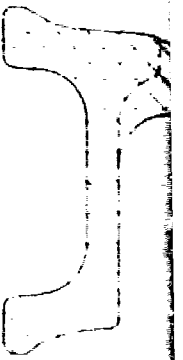
DRAFT ANGLES 5°
FILLET RADII .50 R.
CORNER RADII .19 R.

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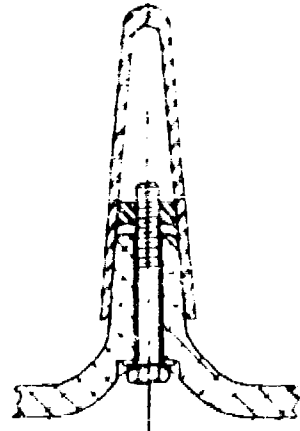
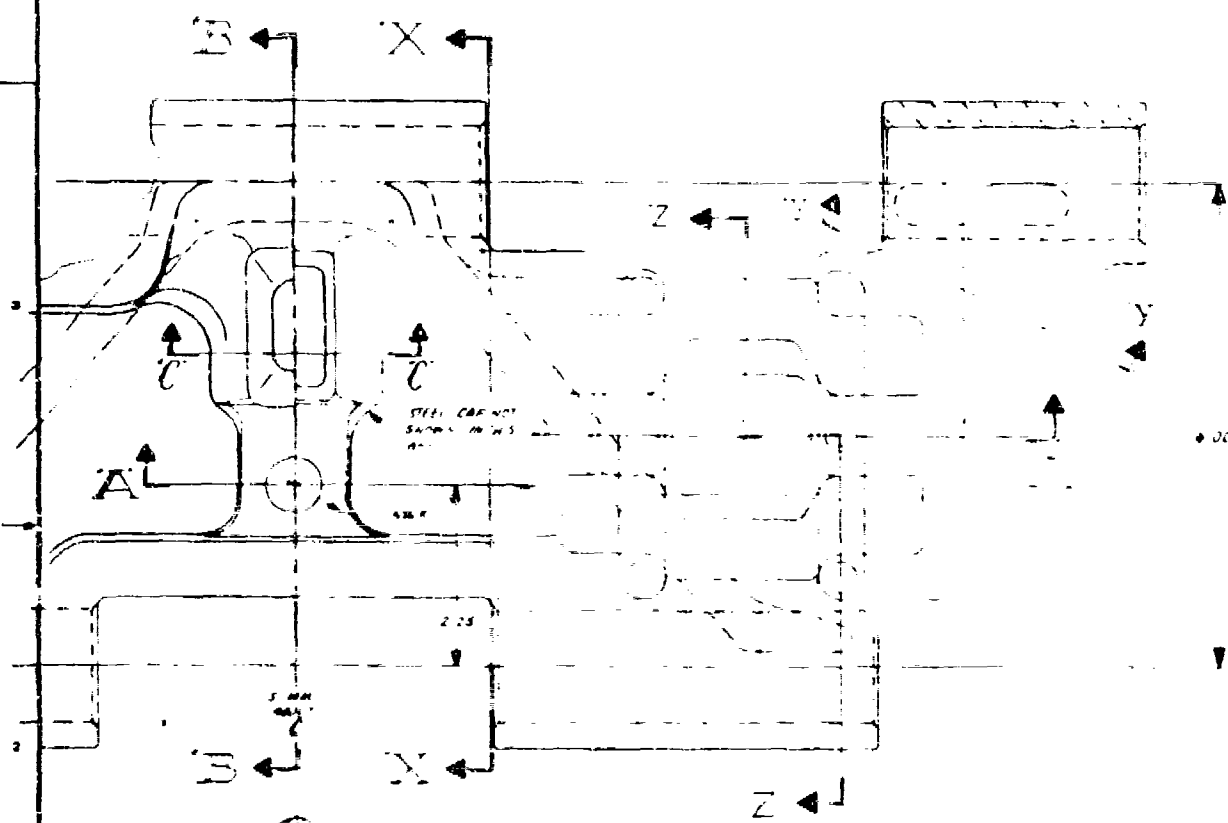
THIS DESIGN IS HEREBY A SUBMITTAL AND IT IS UNDERSTOOD THAT THE ALUMINUM COMPANY OF AMERICA SHALL BE USED IN THE PRODUCTION OF THIS DESIGN. THE ALUMINUM COMPANY OF AMERICA SHALL BE USED IN THE PRODUCTION OF THIS DESIGN. THE ALUMINUM COMPANY OF AMERICA SHALL BE USED IN THE PRODUCTION OF THIS DESIGN.		ALUMINUM COMPANY OF AMERICA ALCOA FORGED TRACK SHOE PROPOSAL DOUBLE END (WITH TELL SECTION IN RT) CHAMFER: 1/4" X 1/8" X 1/8"	
DATE: 2013-10-1	DESIGN: FULL	DATE: 10/1/13	DESIGN: 10/1/13
B-100513-AE		DESIGNED BY:	

B-1005 - A.E.

SECTION Y, Y

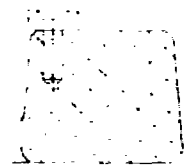
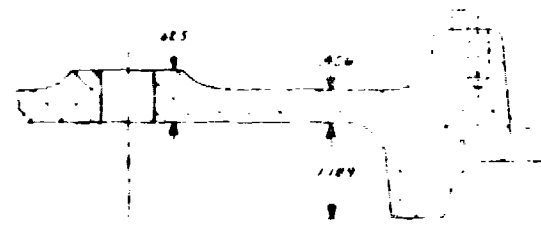


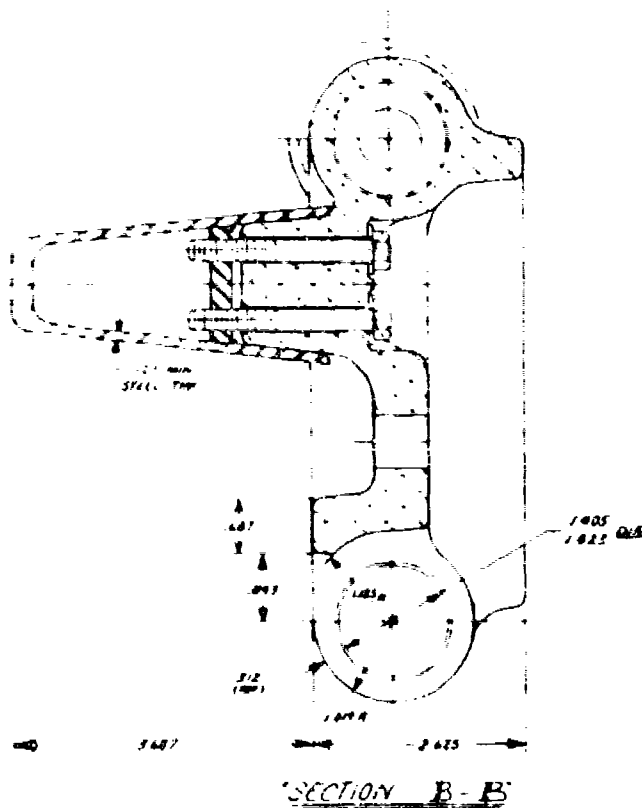
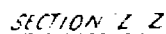
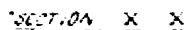
SECTION Z, Z



SECTION C-C

SECTION A-A





DMG NOT COMPLETE!

TYP DRAFT 5'



RE: BUREAU OF SMPS DW6 2504017)

1. <u>ALCOA</u> 2. <u>PROPOSED LIGHTWEIGHT</u> 3. <u>TRUCK CHASE</u> 4. <u>NAVAL SHIP REID CENTER</u>		5. <u>DATE</u> 6. <u>TIME</u> 7. <u>LOCATION</u> 8. <u>REMARKS</u> 9. <u>INITIALS</u> 10. <u>SIGNATURE</u> 11. <u>DATE</u> 12. <u>TIME</u> 13. <u>LOCATION</u> 14. <u>REMARKS</u> 15. <u>INITIALS</u> 16. <u>SIGNATURE</u> 17. <u>DATE</u> 18. <u>TIME</u> 19. <u>LOCATION</u> 20. <u>REMARKS</u> 21. <u>INITIALS</u> 22. <u>SIGNATURE</u> 23. <u>DATE</u> 24. <u>TIME</u> 25. <u>LOCATION</u> 26. <u>REMARKS</u> 27. <u>INITIALS</u> 28. <u>SIGNATURE</u> 29. <u>DATE</u> 30. <u>TIME</u> 31. <u>LOCATION</u> 32. <u>REMARKS</u> 33. <u>INITIALS</u> 34. <u>SIGNATURE</u> 35. <u>DATE</u> 36. <u>TIME</u> 37. <u>LOCATION</u> 38. <u>REMARKS</u> 39. <u>INITIALS</u> 40. <u>SIGNATURE</u> 41. <u>DATE</u> 42. <u>TIME</u> 43. <u>LOCATION</u> 44. <u>REMARKS</u> 45. <u>INITIALS</u> 46. <u>SIGNATURE</u> 47. <u>DATE</u> 48. <u>TIME</u> 49. <u>LOCATION</u> 50. <u>REMARKS</u> 51. <u>INITIALS</u> 52. <u>SIGNATURE</u> 53. <u>DATE</u> 54. <u>TIME</u> 55. <u>LOCATION</u> 56. <u>REMARKS</u> 57. <u>INITIALS</u> 58. <u>SIGNATURE</u> 59. <u>DATE</u> 60. <u>TIME</u> 61. <u>LOCATION</u> 62. <u>REMARKS</u> 63. <u>INITIALS</u> 64. <u>SIGNATURE</u> 65. <u>DATE</u> 66. <u>TIME</u> 67. <u>LOCATION</u> 68. <u>REMARKS</u> 69. <u>INITIALS</u> 70. <u>SIGNATURE</u> 71. <u>DATE</u> 72. <u>TIME</u> 73. <u>LOCATION</u> 74. <u>REMARKS</u> 75. <u>INITIALS</u> 76. <u>SIGNATURE</u> 77. <u>DATE</u> 78. <u>TIME</u> 79. <u>LOCATION</u> 80. <u>REMARKS</u> 81. <u>INITIALS</u> 82. <u>SIGNATURE</u> 83. <u>DATE</u> 84. <u>TIME</u> 85. <u>LOCATION</u> 86. <u>REMARKS</u> 87. <u>INITIALS</u> 88. <u>SIGNATURE</u> 89. <u>DATE</u> 90. <u>TIME</u> 91. <u>LOCATION</u> 92. <u>REMARKS</u> 93. <u>INITIALS</u> 94. <u>SIGNATURE</u> 95. <u>DATE</u> 96. <u>TIME</u> 97. <u>LOCATION</u> 98. <u>REMARKS</u> 99. <u>INITIALS</u> 100. <u>SIGNATURE</u> 101. <u>DATE</u> 102. <u>TIME</u> 103. <u>LOCATION</u> 104. <u>REMARKS</u> 105. <u>INITIALS</u> 106. <u>SIGNATURE</u> 107. <u>DATE</u> 108. <u>TIME</u> 109. <u>LOCATION</u> 110. <u>REMARKS</u> 111. <u>INITIALS</u> 112. <u>SIGNATURE</u> 113. <u>DATE</u> 114. <u>TIME</u> 115. <u>LOCATION</u> 116. <u>REMARKS</u> 117. <u>INITIALS</u> 118. <u>SIGNATURE</u> 119. <u>DATE</u> 120. <u>TIME</u> 121. <u>LOCATION</u> 122. <u>REMARKS</u> 123. <u>INITIALS</u> 124. <u>SIGNATURE</u> 125. <u>DATE</u> 126. <u>TIME</u> 127. <u>LOCATION</u> 128. <u>REMARKS</u> 129. <u>INITIALS</u> 130. <u>SIGNATURE</u> 131. <u>DATE</u> 132. <u>TIME</u> 133. <u>LOCATION</u> 134. <u>REMARKS</u> 135. <u>INITIALS</u> 136. <u>SIGNATURE</u> 137. <u>DATE</u> 138. <u>TIME</u> 139. <u>LOCATION</u> 140. <u>REMARKS</u> 141. <u>INITIALS</u> 142. <u>SIGNATURE</u> 143. <u>DATE</u> 144. <u>TIME</u> 145. <u>LOCATION</u> 146. <u>REMARKS</u> 147. <u>INITIALS</u> 148. <u>SIGNATURE</u> 149. <u>DATE</u> 150. <u>TIME</u> 151. <u>LOCATION</u> 152. <u>REMARKS</u> 153. <u>INITIALS</u> 154. <u>SIGNATURE</u> 155. <u>DATE</u> 156. <u>TIME</u> 157. <u>LOCATION</u> 158. <u>REMARKS</u> 159. <u>INITIALS</u> 160. <u>SIGNATURE</u> 161. <u>DATE</u> 162. <u>TIME</u> 163. <u>LOCATION</u> 164. <u>REMARKS</u> 165. <u>INITIALS</u> 166. <u>SIGNATURE</u> 167. <u>DATE</u> 168. <u>TIME</u> 169. <u>LOCATION</u> 170. <u>REMARKS</u> 171. <u>INITIALS</u> 172. <u>SIGNATURE</u> 173. <u>DATE</u> 174. <u>TIME</u> 175. <u>LOCATION</u> 176. <u>REMARKS</u> 177. <u>INITIALS</u> 178. <u>SIGNATURE</u> 179. <u>DATE</u> 180. <u>TIME</u> 181. <u>LOCATION</u> 182. <u>REMARKS</u> 183. <u>INITIALS</u> 184. <u>SIGNATURE</u> 185. <u>DATE</u> 186. <u>TIME</u> 187. <u>LOCATION</u> 188. <u>REMARKS</u> 189. <u>INITIALS</u> 190. <u>SIGNATURE</u> 191. <u>DATE</u> 192. <u>TIME</u> 193. <u>LOCATION</u> 194. <u>REMARKS</u> 195. <u>INITIALS</u> 196. <u>SIGNATURE</u> 197. <u>DATE</u> 198. <u>TIME</u> 199. <u>LOCATION</u> 200. <u>REMARKS</u> 201. <u>INITIALS</u> 202. <u>SIGNATURE</u> 203. <u>DATE</u> 204. <u>TIME</u> 205. <u>LOCATION</u> 206. <u>REMARKS</u> 207. <u>INITIALS</u> 208. <u>SIGNATURE</u> 209. <u>DATE</u> 210. <u>TIME</u> 211. <u>LOCATION</u> 212. <u>REMARKS</u> 213. <u>INITIALS</u> 214. <u>SIGNATURE</u> 215. <u>DATE</u> 216. <u>TIME</u> 217. <u>LOCATION</u> 218. <u>REMARKS</u> 219. <u>INITIALS</u> 220. <u>SIGNATURE</u> 221. <u>DATE</u> 222. <u>TIME</u> 223. <u>LOCATION</u> 224. <u>REMARKS</u> 225. <u>INITIALS</u> 226. <u>SIGNATURE</u> 227. <u>DATE</u> 228. <u>TIME</u> 229. <u>LOCATION</u> 230. <u>REMARKS</u> 231. <u>INITIALS</u> 232. <u>SIGNATURE</u> 233. <u>DATE</u> 234. <u>TIME</u> 235. <u>LOCATION</u> 236. <u>REMARKS</u> 237. <u>INITIALS</u> 238. <u>SIGNATURE</u> 239. <u>DATE</u> 240. <u>TIME</u> 241. <u>LOCATION</u> 242. <u>REMARKS</u> 243. <u>INITIALS</u> 244. <u>SIGNATURE</u> 245. <u>DATE</u> 246. <u>TIME</u> 247. <u>LOCATION</u> 248. <u>REMARKS</</u>	
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