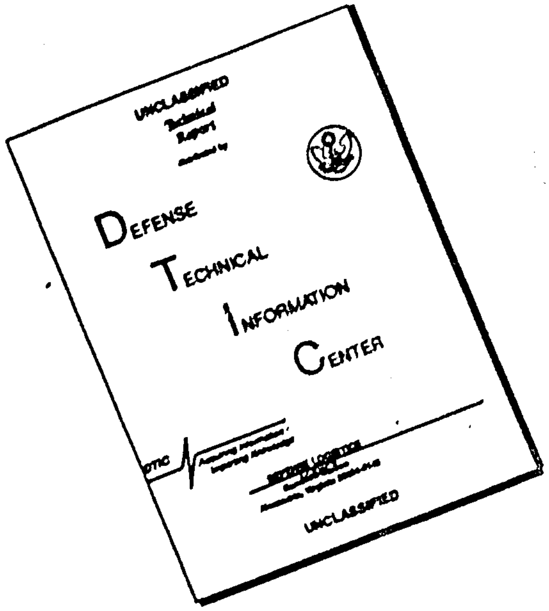
DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

QUALIFIED REQUESTERS MAY OBTAIN COPIES OF THIS REPORT FROM DDC.

FORWARDED BY THE CHIEF, BUREAU OF SHIPS

Encl. (4) to BUSHIPS ltr Ser. 210L-T395

FINAL REPORT
Of a
CONCEPT STUDY
For a
TRACKED AMPHIBIAN PERSONNEL AND
CARGO CARRIER
(LVTPX11)

VOLUME I

Prepared for

BUREAU OF SHIPS
DEPARTMENT OF THE NAVY
Washington 25, D. C.

By

Ordnance Division
FMC CORPORATION
San Jose, California

Reference: Contract No. NObs-4464

15 November 1961

TABLE OF CONTENTS

VOLUME I

SECTION I

INTRODUCTION

This report is submitted by the Ordnance Division of FMC Corporation in fulfilment of Bureau of Ships Contract Number NObs-4464. The reoort describes the concept study conducted for the Tracked Amphibian Personnel and Cargo Carrier, LVTPX11.

To more clearly present the study results, the conclusions are given in the form of complete vehicle designs. Components have been evaluated, and the comparisons, advantages, and disadvantages are presented in Volume I of this report. Substantiating data is included in Volumes II and IV as appendixes to the basic report. A discussion of the armor analysis is included as a separate volume (Volume III) to preclude applying a "Confidential" security classification to the entire report.

SECTION II

SUMMARY

The development of an improved Tracked Amphibian Personnel and Cargo Carrier which will meet the development characteristics specified for the LVTPX11 is feasible. The vehicle concepts resulting from this study will meet the operational requirements for Landing Force Amphibian Assault Vehicles.

OBJECTIVE

The objective of this study is to provide data, information, and a design concept of a vehicle for the transport of infantry, infantry weapons, and cargo, from ship to shore and to inland objectives, and to provide fire support in amphibious operations. Although the vehicle is envisioned as the basic configuration for a family of vehicles to accomplish this mission, the primary emphasis has been placed on the personnel and cargo carrier. Various other configurations to provide artillery support, air defense, mine and obstacle clearance, and recovery capability were studied only in sufficient detail to insure compatibility with the basic configuration.

APPROACH

There are several guidelines that were used in this study program: first, the "Development Characteristics", which established the ground rules; second, FMC's experience and knowledge gained from 20 years of designing and building amphibious vehicles; third, the state-of-the-art or the development status of materials and components. FMC's goal was to delineate vehicle concepts having optimum performance based on technological advances, using components and materials which would be realities, not promises, and which are producible in quantity at a reasonable price and on schedule.

In addition ot the general design considerations of simplicity, long trouble, free life, ease of maintenance, and economy of operation, the following specific considerations were essential, in order to obtain a meaningful result from this study.

- Ability of the vehicle to perform its mission - The final authority of this capability will of course be the user, however, in order to establish design parameters, it was necessary to investigate the tactical operational aspects and to establish a priority of requirements. A brief operational analysis is presented in Section 3.1. As a result of this study, two vehicles are presented in this report in equal detail. These are:

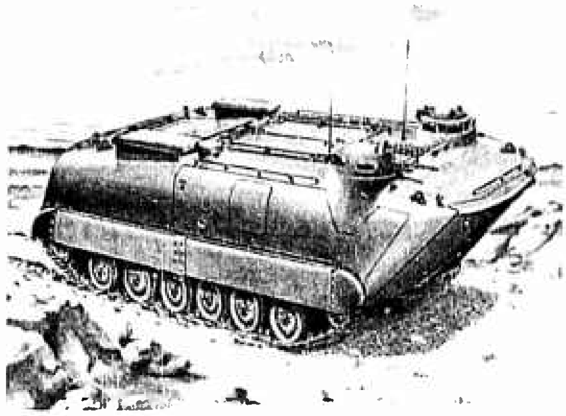
  - Maximum Armored Vehicle
  - Maximum Water Performance Vehicle

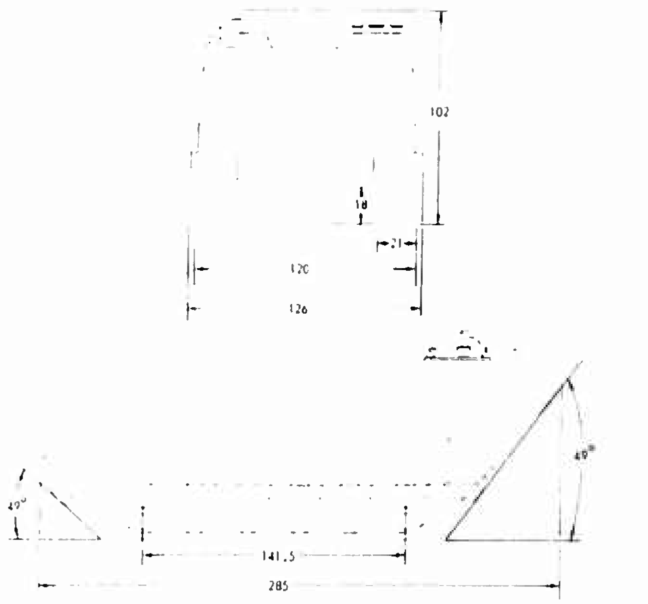
  The first has been optimized for land performance and has the maximum armor protection consistent with a 35,000-pound GVW. Tracks propel it in the water at speeds of from 7 to 7-1/2 mph. The second vehicle has been designed for increased water performance, 9 to 9-1/2 mph, and uses a propeller for water propulsion. This is the highest speed obtainable, using only the power required for land operations, as specified by the "Development Characteristics". A higher water speed can be obtained, if desired, by increasing the engine horsepower. The latter vehicle is also 28 inches longer and 6 inches narrower than the former, in order to decrease hull resistance and provide space for the propeller. To compensate for the approximately 1,500 pounds added for the propeller drive, there is less armor on this vehicle.

Before the final vehicle configurations were established, many different hull shapes were tow tested to determine the best lines and to obtain quantitative data on hull resistance. There is a detailed discussion with photos of all the configurations tested in Section 3.9 and in Appendix E. There is also a 16mm motion picture of the tests performed on the two optimum vehicles which is submitted as Appendix G.

One major deviation has been made from the requirements stated in the "Development Characteristics". In both of the vehicle configurations, the GVW of 35,000 pounds includes 6,000 pounds of cargo, instead of the 10,000 specified. This was done in order to provide the maximum amount of armor for the vehicle in its primary mission of carrying troops in combat. The 6,000 pounds is equivalent to the weight of 27 fully equipped troops. If a greater cargo capacity is mandatory within the 35,000-pound GVW, armor protection must be reduced. However, the vehicle presented can carry more than 6,000 pounds at a slight decrease in performance.

- Economical production of the LVTPX11 - This factor has been considered in arriving at the recommended configuration and in





MAXIMUM ARMORED VEHICLE

TECHNICAL DATA

GENERAL

Weight (curb)	29,000 lb
Weight (gross vehicle)	35,000 lb
C. of G. 154 in. Aft of Bow	49 in. Above Ground
Unit Ground Pressure 5.9 psi	GVW
Crew	2 (DRIVER, ASST. DRIVER)
Troop Capacity	27

ARMOR (See Fig. 2.3)

Material:	ALUMINUM ALLOY 5083
or composite:	ALUMINUM ALLOY 5083 AND TITANIUM ALLOY 6AL-4V OR ZIG-ZAG

VISION AND SIGHTING EQUIPMENT:

Periscope, Driver's Vision	TYPE M17 (8 ea)
Periscope, Driver's I.R.	TYPE M19 (1 ea)

ARMAMENT

Primary: GUN, MACHINE, 7.62mm M73C

AMMUNITION

1000 ROUNDS 7.62 mm

RUNNING GEAR

Suspension Type	INDIVIDUAL TORSION BAR
No. of Wheels	6 DUAL EA SIDE
Wheel Size	24 IN.
Track Type	BAND W/CROSS BARS
No. Sections/Track 11 Pitch	5.6 IN. Width 21 IN.
No. Bars/Section 8	
Tires: NO. 24 Type	SOLID RUBBER Size 24 IN. x 3-1/2

ELECTRICAL SYSTEM 24 V NOMINAL

Generator, Amperes	100 AC W/RECT. & REGULATOR
Battery, Type NI-CAD 12 V	Quantity 4
Ignition System	COMPRESSION (DIESEL)

COMMUNICATIONS

Radio Set COLLINS 618T or AN/PRC 47

FIRE EXTINGUISHER

Fixed 10 lb CO_2 Portable 5 lb CO_2

POWER PACKAGE

Engine

Make	CUMMINS Model V8-300 Type DIESEL
Displacement	785 cu. in. Bore 5-1/2 Stroke 4-1/8
Governed Speed	3000 RPM Compression Ratio 15 : 1
Fuel	DIESEL #1, #2, JP4, JP5, & MIXTURE 10 PTS GASOLINE TO 1 PT LUBE OIL W/KIT Capacity 125 GAL.
Max. Gross HP	300 3000 RPM
Max. Net HP (to transmission)	250 3000 RPM
Max Gross Torque	580 LB FT 2100 RPM
Max Net Torque	525 LB FT 1800 RPM
Main Cooling System	LIQUID
Oil Cooling System	OIL/WATER

Power Train (w/o Final Drive)

Type	ALLISON Model XTG-250
Hydraulic Converter	1 STAGE
Stall Multiplication	2.55 : 1
O.A. Usable Ratio	15.7 : 1
22.6 : 1 LOW	3.67 : 1 HIGH 17.2 : 1 REV_1 7.70 : 1 REV_2
Steering Ratio	1.475 : 1 G.S. & PIVOT
Turning Radius (to center vehicle)	31 FT G.S. 6 FT PIVOT
Steering Control	HYDRAULIC AND MECHANICAL
Brakes	MULTIPLE WET PLATE - SERVICE MECHANICAL - PARKING
Oil Cooling System	OIL/WATER

Final Reduction

Type	GEARED Ratio 2.82 : 1
Ft/Rev	5.5
Effective Sprocket Pitch Diameter	1.75 FT No. of Teeth 11

PERFORMANCE

Gross HP to Weight Ratio	17.2 HP/TON
Max. Tractive Effort	40,500 LB
Max. Speed	40 MPH LAND 7 to 7-1/2 MPH WATER
Max. Trench	8 FT
Max. Grade	70%
Max. Vertical Wall	29 IN.
Max. Side Slope	60%
Max. Surf	10 FT
Cruising Range	250 MI LAND MINIMUM 62 MI WATER @ MAX. POWER

FIGURE 2.1

selecting the major components. It is assumed that the LVTPX11 development program would culminate in production in 1965.

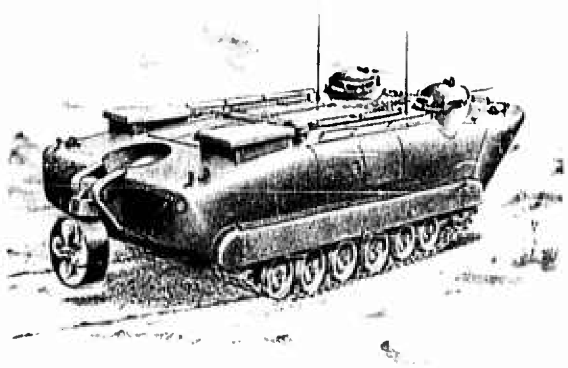
DEVELOPMENT FEASIBILITY

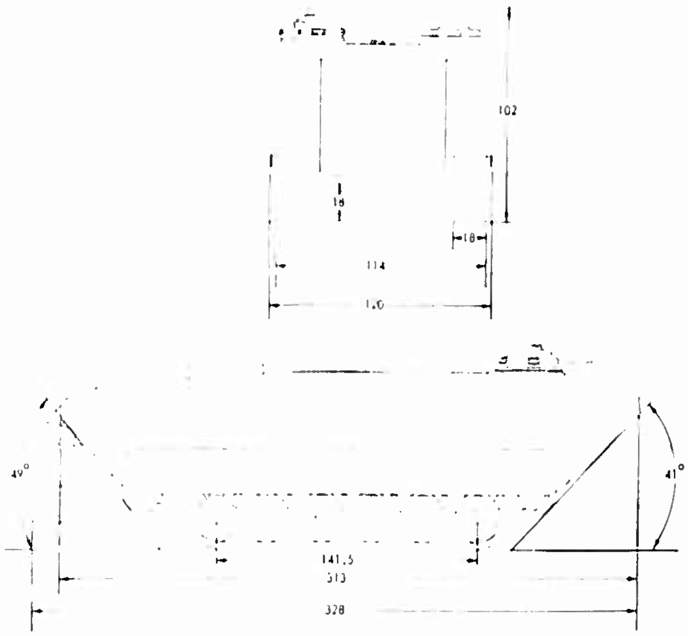
Both vehicle concepts presented include the same set of major components. The selected components are believed at this time to be the best available, based on the required development schedule. Many alternate components currently being developed by both Government and industry have been reviewed, and the details of some of these are included in this study. During the course of the design of an improved LVT, the current status and test experience of each new material and component should be reviewed for possible inclusion in the finalized design. Because of the continuing advances being made, it is essential that the vehicle designer use his background as a basis for review of each of the latest developments in materials and components, to assure that full advantage is taken of the latest accomplishments in technological development.

MAXIMUM ARMORED VEHICLE

The major operational and physical characteristics of this vehicle are shown in Figure 2.1. The salient features are:

- Welded Aluminum Hull
- Composite Armor (Aluminum-Titanium or Zig-Zag)
- Rounded Hull
- Front Ramp





MAXIMUM WATER PERFORMANCE VEHICLE
TECHNICAL DATA

GENERAL

Weight (curb)	29,000 lb
Weight (gross vehicle)	35,000 lb
C. of G. 163 in. Aft of Bow	49 in. Above Ground
Unit Ground Pressure 6.9 psi	GVW
Crew	2 (DRIVER, ASST. DRIVER)
Troop Capacity	27

ARMOR (See Fig. 2.4)

Material:	ALUMINUM ALLOY 5083
or composite:	ALUMINUM ALLOY 5083 AND TITANIUM ALLOY 6AL-4V OR ZIG-ZAG

VISION AND SIGHTING EQUIPMENT:

Periscope, Driver's Vision	TYPE M17 (8 ea)
Periscope, Driver's I.R.	TYPE M19 (1 ea)

ARMAMENT

Primary: GUN, MACHINE, 7.62mm M73C

AMMUNITION

1000 ROUNDS 7.62 mm

RUNNING GEAR

Suspension Type	INDIVIDUAL TORSION BAR
No. of Wheels	6 DUAL EA SIDE
Wheel Size	24 IN.
Track Type	BAND W/CROSS BARS
No. Sections/Track 11 Pitch	5.6 IN. Width 18 IN.
No. Bars/Section 8	
Tires: NO. 24 Type	SOLID RUBBER Size 24 IN. x 3-1/2

ELECTRICAL SYSTEM 24 V NOMINAL

Generator, Amperes	100 AC W/RECT. & REGULATOR
Battery, Type NI-CAD 12 V	Quantity 4
Ignition System	COMPRESSION (DIESEL)

COMMUNICATIONS

Radio Set COLLINS 618T or AN/PRC 47

FIRE EXTINGUISHER

Fixed 10 lb CO_2 Portable 5 lb CO_2

POWER PACKAGE

Engine

Make CUMMINS Model V8-300 Type DIESEL
Displacement 785 cu. in. Bore 5-1/2 Stroke 4-1/8
Governed Speed 3000 RPM Compression Ratio 15 : 1
Fuel DIESEL #1, #2, JP4, JP5, & MIXTURE 10 PTS GASOLINE TO 1 PT LUBE OIL W/KIT Capacity 125 GAL.

Max. Gross HP	300	3000 RPM
Max. Net HP (to transmission)	250	3000 RPM
Max. Gross Torque	580 LB FT	2100 RPM
Max. Net Torque	525 LB FT	1800 RPM
Main Cooling System	LIQUID	
Oil Cooling System	OIL/WATER	

Power Train (w/o Final Drive)

Type ALLISON Model XTG-250
Hydraulic Converter 1 STAGE
Stall Multiplication 2.55 : 1
O.A. Usable Ratio 15.7 : 1
22.6 : 1 LOW 3.67 : 1 HIGH 17.2 : 1 REV_1 7.70 : 1 REV_2
Steering Ratio 1.475 : 1 G.S. & PIVOT
Turning Radius (to center vehicle) 31 FT G.S. 6 FT PIVOT
Steering Control HYDRAULIC AND MECHANICAL
Brakes MULTIPLE WET PLATE - SERVICE, MECHANICAL - PARKING
Oil Cooling System OIL/WATER

Final Reduction

Type GEARED Ratio 2.82 : 1
Ft/Rev 5.5
Effective Sprocket Pitch Diameter 1.75 FT No. of Teeth 11

Propeller

Type 4 BLADE KAPLAN W/KORT NOZZLE
Diameter 32 IN. Pitch 32 IN.
Speed 700 RPM MAXIMUM

PERFORMANCE

Gross HP to Weight Ratio	17.2 HP/TON
Max. Tractive Effort	40,500 LB
Max. Speed	40 MPH LAND 9-9 1/2 MPH ON WATER
Max. Trench	8 FT
Max. Grade	70%
Max. Vertical Wall	29 IN.
Max. Side Slope	60%
Max. Surf	10 FT
Cruising Range	250 MI LAND MINIMUM 78 MI WATER @ MAX. POWER

FIGURE 2.2

- Major Components Proven or Under Development
- Flexibility to Incorporate Future Developments
- Rear Drive
- Track Propulsion for Land and Water
- Lightweight Components
- Improved Land Mobility
- Compatible with a Family of Vehicles

MAXIMUM WATER PERFORMANCE VEHICLE

The major operational and physical characteristics of this vehicle are shown in Figure 2.2. The salient features are identical with those listed above for the Maximum Armored Vehicle, except:

- Propeller for Water Operation
- Longer Narrower Hull
- Decreased Armor
- Increased Cost

COMPONENTS

The major components recommended as a result of this study are either available now or in the later stages of their development. A brief description of these components follows:

Hull

The hull configuration represents a minimum size to accommodate the required crew and troops, since supporting equipment such as a Field Artillery

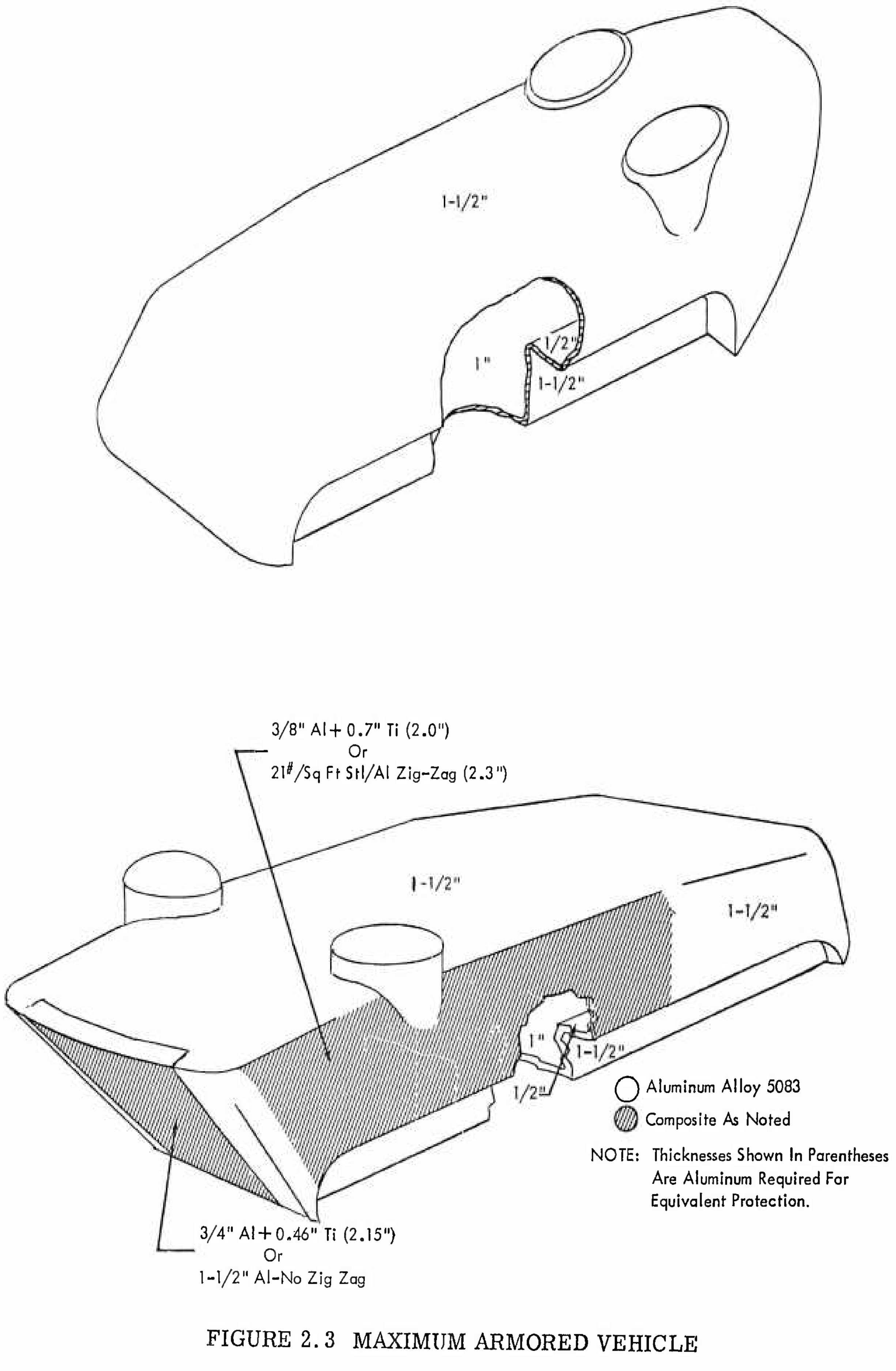


FIGURE 2.3 MAXIMUM ARMORED VEHICLE

Hull (Continued)

Weapon will be mounted on specially adapted hulls rather than transported internally. Note that the ramp is in front and the machinery in the rear of the hull. This provides the bow-up trim under all normal loading conditions which is essential to satisfactory surf operation.

A rounded hull of welded aluminum was chosen to achieve maximum rigidity at minimum weight while retaining ease of fabrication. For ballistic protection, this report offers three equal-weight alternatives, as shown in Figures 2.3 and 2.4: all-aluminum, aluminum-titanium composite, and zig-zag. The all-aluminum approach, which is similar to that used on other armored vehicles in this weight class, offers the least protection against small arms of the three methods (1.5 inches of aluminum). The aluminum-titanium composite consists of titanium plates mechanically attached to the hull's vertical surfaces outside the personnel area. This offers protection against small arms approximately equal to that provided by 2 inches of aluminum. The zig-zag alternative consists of thin corrugated panels of steel mechanically attached to the aluminum structure on the vertical surfaces outside the personnel areas. This scheme offers protection against small arms approximately equal to that of 2.3 inches of aluminum. This method is currently being tested at Aberdeen Proving Ground and is under serious consideration as a method of up-armoring the M113. The degree of ballistic protection offered by these three methods cannot be presented here without the inclusion of classified data; therefore, this information has been bound separately as Volume III, Appendix H. These three approaches will provide blast and thermal radiation protection at approximately 3/4 mile from a 100 KT nuclear weapon.

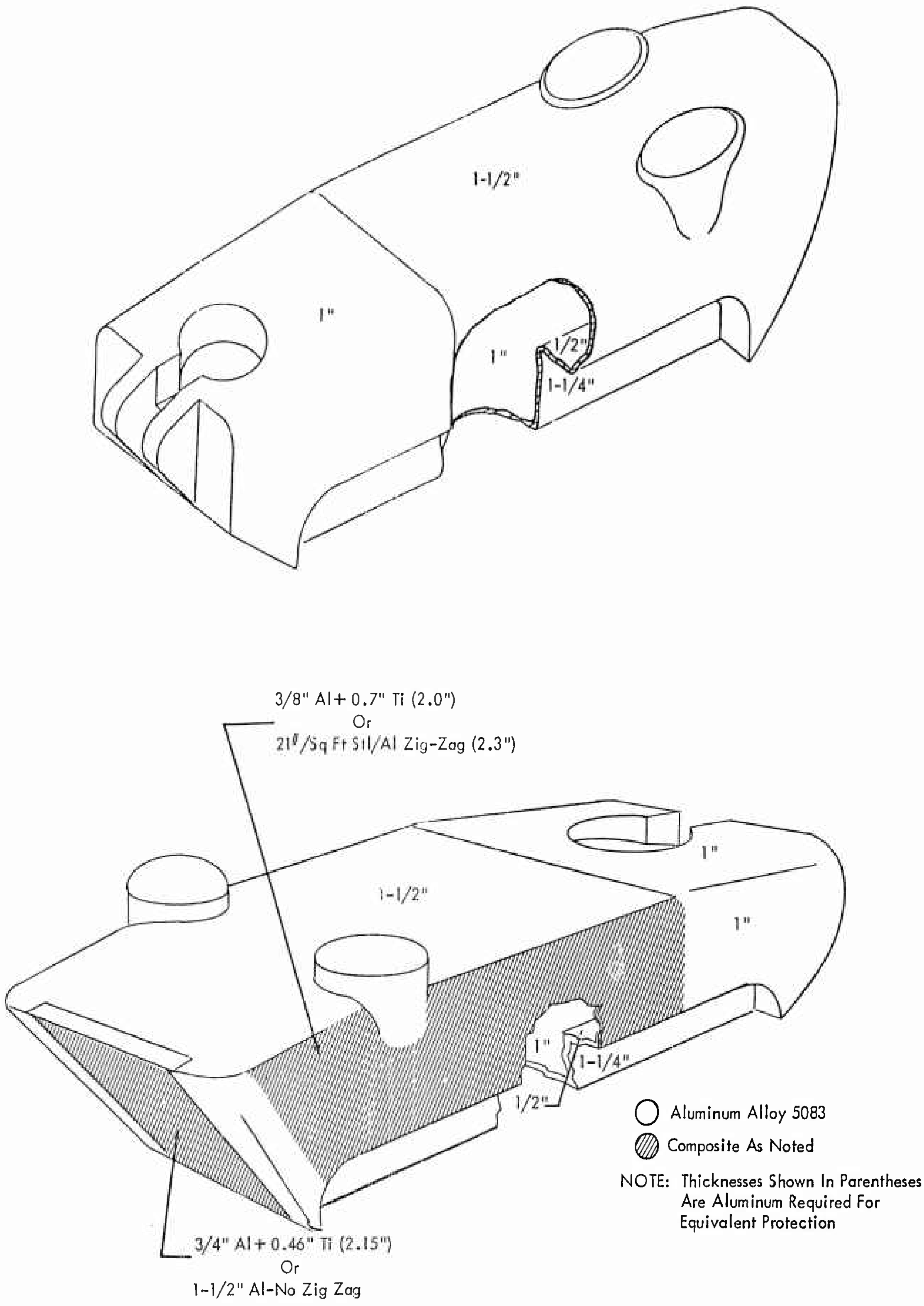


FIGURE 2.4 MAXIMUM WATER PERFORMANCE VEHICLE

Machinery

All machinery components are the lightest feasible that are in existence or currently in late stages of development. Second choices have been made for those components having any substantial development aspects remaining. The Cummins Diesel Engine and the Allison XTG250 Power Train are recommended as the major power package components. Lightweight components are available for vehicles up to 35,000 pounds GVW. The next larger family of components is designed for a 42,000 pound GVW which reaffirms the necessity for maintaining the specified maximum GVW of 35,000 pounds.

Suspension

Many suspension systems were studied. From the point of view of reliability, cost, weight, and performance, rubber-tired aluminum road wheels, individually mounted on steel torsion bars, were selected as first choice. The high front idler required for obstacle climbing necessitates the use of return support rollers. Other suspension types showed some promise and should be re-evaluated at a later date. Two basic types of tracks were studied, the block track similar to that used on the M113 APC and the band track under development for the XM551 ARV. It was concluded that a long-lived, reliable, block track can be developed for the LVTPX11; however, since weight is so critical, it is felt that the band track should be given first consideration. There are several reasons for this decision. The Cadillac Division of General Motors, under OTAC supervision, designed and tested a band track for the M59 AIV, at 36,000 pounds GVW, which tests indicated to have a life of 2,700 miles. OTAC will have time to do extensive testing on the XM551

Suspension (Continued)

track before it is required for this LVT. If the XM551 track is not proved satisfactory, a block track could be developed in a short time.

Controls

Controls are provided at the driver's station only. In order to conserve weight, only two cupolas are provided, the driver's and the commander's. This requires that the troop commander act as machine gunner until just before debarkation, at which time the assistant driver can take over to furnish covering fire. Simple, easily maintained, inexpensive mechanical control linkages are recommended. In the Maximum Armored Vehicle, control operations for water operation are limited to closing the engine cooling air intake and starting the bilge pumps. Additional operations would be necessary for the Maximum Water Performance Vehicle, namely, lowering the propeller, engaging the propeller drive, and declutching the track drive.

SPECIAL-PURPOSE VEHICLES

Special-purpose vehicle adaptations of the basic personnel carrier have been considered in sufficient detail to establish compatibility with existing equipment designs. Once the LVTPX11 has been developed, designs for the whole family of vehicles would undoubtedly be formulated. However, the recommended configurations can definitely be adapted as a:

Command Vehicle

Recovery Vehicle

Anti-Mechanized Weapon Vehicle

Field Artillery Weapon Vehicle

Air Defense Weapon Vehicle

Engineer Mine-Clearance Vehicle

These applications are shown in Section 4.14.

Development Program

Based upon discussions with various Government personnel, it has been determined that the desired target for production deliveries of an improved LVT is 1965. Component recommendations have been based upon this time frame. An accelerated development schedule of 2 years and 8 months, based upon FMC accomplishments in many prior vehicle programs, is outlined in Section IV. FMC believes this to be an entirely feasible program to provide the best new LVT.

SECTION III

TECHNICAL REPORT

3.1 PRELIMINARY ANALYSIS

The first phase in the performance of this concept study for the LVTPX11 was reexamination of all possible configurations that would permit meeting or exceeding the requirements stated in the "Development Characteristics". Ignoring the conventional approach to LVT design, what new or basically different approaches could be considered? Also, since the "Development Characteristics" did not specify an order of priority for the requirements, an operations analysis was required to establish this priority for armor, water speed, and payload capability.

3.1.1 Operational Modes

To determine the best approach to the LVTPX11 design, the following water operational modes were investigated:

- Above water - Ground-effects machine, for example.
- Fully submerged - Operate as a submarine, or as a "bottom crawler".
- Surface flotation - Conventional displacement craft.

3.1.1.1 Above-Water Vehicle

One of the shortcomings of existing LVT design is the low water-speed capability. Since this capability is related to the resistance offered by the water, consideration was given to operating above the water as a ground-effects machine. Although this operational mode is technically

Operational Modes (Continued)

feasible, brief examination disclosed several disadvantages, as follows:

- Size - For a 35,000 lb armored vehicle, approximately four times the area available would be required.

- Complexity - The fans, plenums, additional machinery, and closures would add insurmountable complexity to the vehicle.

- Vulnerability - Assault forces operating in this mode present a completely exposed vehicle during the entire water-operation cycle, even though for a shorter period of time.

Thus, after a preliminary examination, this approach was discarded.

3.1.1.2 Fully Submerged Vehicle

FMC recently completed a contracted feasibility study for OTAC on submerged operation of combat vehicles. Although the study was devoted to river and lake crossings, the conclusions are of interest to this study.

It is possible to operate a vehicle on the bottom of a stream, lake, or river through the use of an engine aspiration system based upon the decomposition of Hydrogen Peroxide (H_2O_2). However, this requires prior reconnaissance of the bottom, in order to establish trafficable paths. Other disadvantages inherent in the approach combine to negate the advantage of coming ashore relatively unexposed: one - during deepwater operation, the vehicle would have to operate as a submarine, which would require additional space and machinery for ballasting; two - navigation and communication become major problems; and three - there are psychological factors involved in this mode of troop transport. These problems are

Operational Modes (Continued)

vastly more complex, when operating at sea, due to the water depth, distances, and wave action. This approach did not warrant further study effort.

3.1.1.3 Surface Flotation

It became apparent that the more conventional method of floating on the surface, despite its problems, still offered the most feasible approach, so the study effort was directed toward developing a vehicle with improved water and land characteristics.

3.1.2 Operations Analysis

3.1.2.1 Purpose

In order to establish a priority for the primary characteristics of the vehicle, a brief operations analysis was conducted. Ironically, the best design for one characteristic is usually detrimental to another (e.g., maximum armor protection is not compatible with light weight, and auxiliary water propulsion devices for increasing water speed complicate the power train).

The primary characteristics, considered from an operational standpoint, are as follows:

- Payload
- Armor
- Water Speed
- Land Mobility

Operations Analysis (Continued)

These factors were analyzed for the vehicle when used as a personnel-and-cargo carrier. Conclusions can also be drawn from this analysis as to the vehicle's suitability as a cargo carrier.

3.1.2.2 Conclusions

1. Increased water speed is desirable if the LVTPX11 is to be debarked at distances exceeding 15 miles offshore.

2. Increased water speed will not appreciably reduce vehicle vulnerability while waterborne.

3. The LVTPX11 does not compare favorably with a vehicle designed specifically for cargo transport.

4. The cargo-carrying rate is approximately proportional to the cargo capacity.

5. The cargo-carrying rate is not directly proportional to the vehicle speed.

6. A vehicle designed as both a carrier and a logistical cargo carrier is not economically feasible.

3.1.2.3 Analysis

It is recognized that the longer a vehicle or group of vehicles is exposed on open water between debarkation and landing points, the greater the risk of loss or damage due to enemy action. The vehicles recommended in this study require the following time intervals to reach shore from a point five miles offshore.

Operations Analysis (Continued)

Maximum Armored Vehicle - 42 minutes, at 7-1/4 mph

Maximum Water Performance Vehicle - 32 minutes, at 9-1/4 mph

At a fixed time interval between debarkation of vehicle waves, an increase in speed results in an increased spacing between waves. For a time interval of one minute, the spacing for the two recommended vehicles as follows:

Maximum Armored Vehicle - 213 yards

Maximum Water Performance Vehicle - 272 yards

Extrapolation of existing data (105 mm and 155 mm bursts at 50 ft and 90 ft) on protection provided by armor shows that, for a shell burst halfway between the two waves, complete protection is provided by the LVTPX11 armor, even at spacings less than the 213 yards noted above.

Assuming that there is a maximum interval which troops in a water-borne LVT can tolerate, a maximum offshore distance for a given vehicle speed can be calculated. Further assuming that this maximum time is about 2 hours and allowing some margin over average speed for maximum vehicle water speed, then:

30 mph max, 25 mph avg = 50 miles
15 mph max, 12-1/2 mph avg = 25 miles
9-1/2 mph max 7-1/2 mph avg = 15 miles
7-1/2 mph max, 6 mph avg = 12 miles

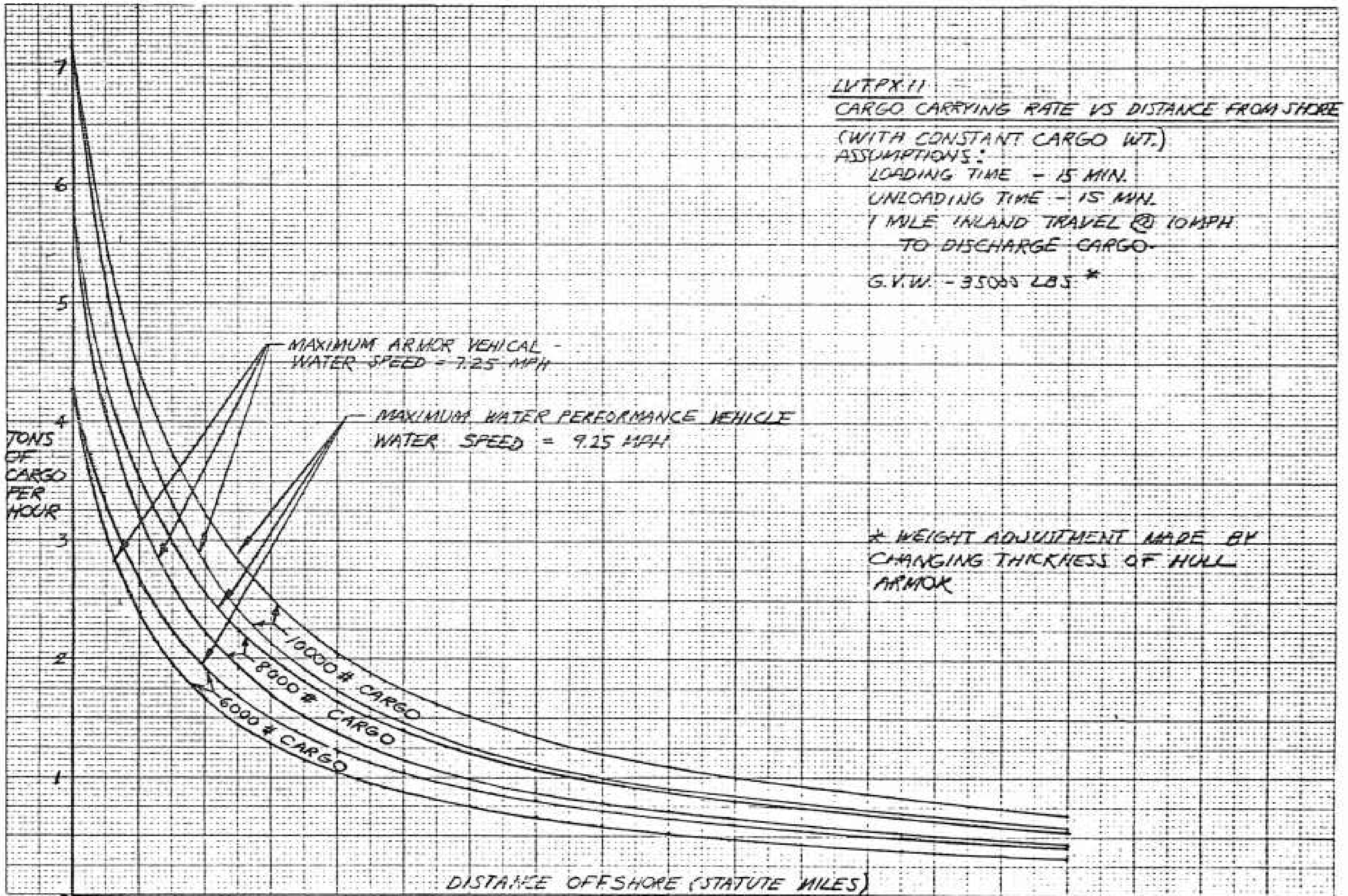

LVTPX-11
CARGO CARRYING RATE VS DISTANCE FROM SHORE
(WITH CONSTANT CARGO WT.)
ASSUMPTIONS:
LOADING TIME - 15 MIN.
UNLOADING TIME - 15 MIN.
1 MILE INLAND TRAVEL @ 10MPH TO DISCHARGE CARGO
G.V.W. - 35000 LBS *
MAXIMUM ARMOR VEHICAL - WATER SPEED = 7.25 MPH
MAXIMUM WATER PERFORMANCE VEHICLE WATER SPEED = 9.25 MPH
10000 # CARGO
8000 # CARGO
6000 # CARGO
* WEIGHT ADJUSTMENT MADE BY CHANGING THICKNESS OF HULL ARMOR
TONS OF CARGO PER HOUR
DISTANCE OFFSHORE (STATUTE MILES)
0
10
20
30
1
2
3
4
5
6
7

FIGURE 3 1 1

Operations Analysis (Continued)

An additional fact to be considered in establishing the desirable water speed is the past experience regarding vehicle vulnerability. It is well known that World War II LVT's were virtually invulnerable to shore-based fire while waterborne. This is attributable to the fact that, even at relatively low speed, an LVT presents a very small and elusive target.

Although the "Development Characteristics" are for a personnel-and-cargo carrier, the cargo capability has been specifically analyzed. Figure 3.1.1 is a plot of cargo-carrying rate-versus-offshore distance for the two vehicles with cargo capacities of 6,000, 8,000, and 10,000 lb. For comparison, the following assumptions have been made:

- Turnaround time - Will vary considerably and is dependent upon type of cargo, but has been assumed as 15 minutes.
- Land travel distance - Assumed as 1 mile between the beach and the cargo unloading point.
- Land travel speed - Assumed as 10 mph.

As shown in Figure 3.1.1, the cargo rate does not increase in direct proprotion to an increase in water speed. The speed of the Maximum Water Performance Vehicle (9-1/4 mph) is 27.6% greater than the speed of the Maximum Armored Vehicle (7-1/4 mph), yet for a 6,000 lb cargo and an offshore distance of 5 miles, the carrying rates are as follows:

- Maximum Armored Vehicle - 1.44 Tons/Hr.

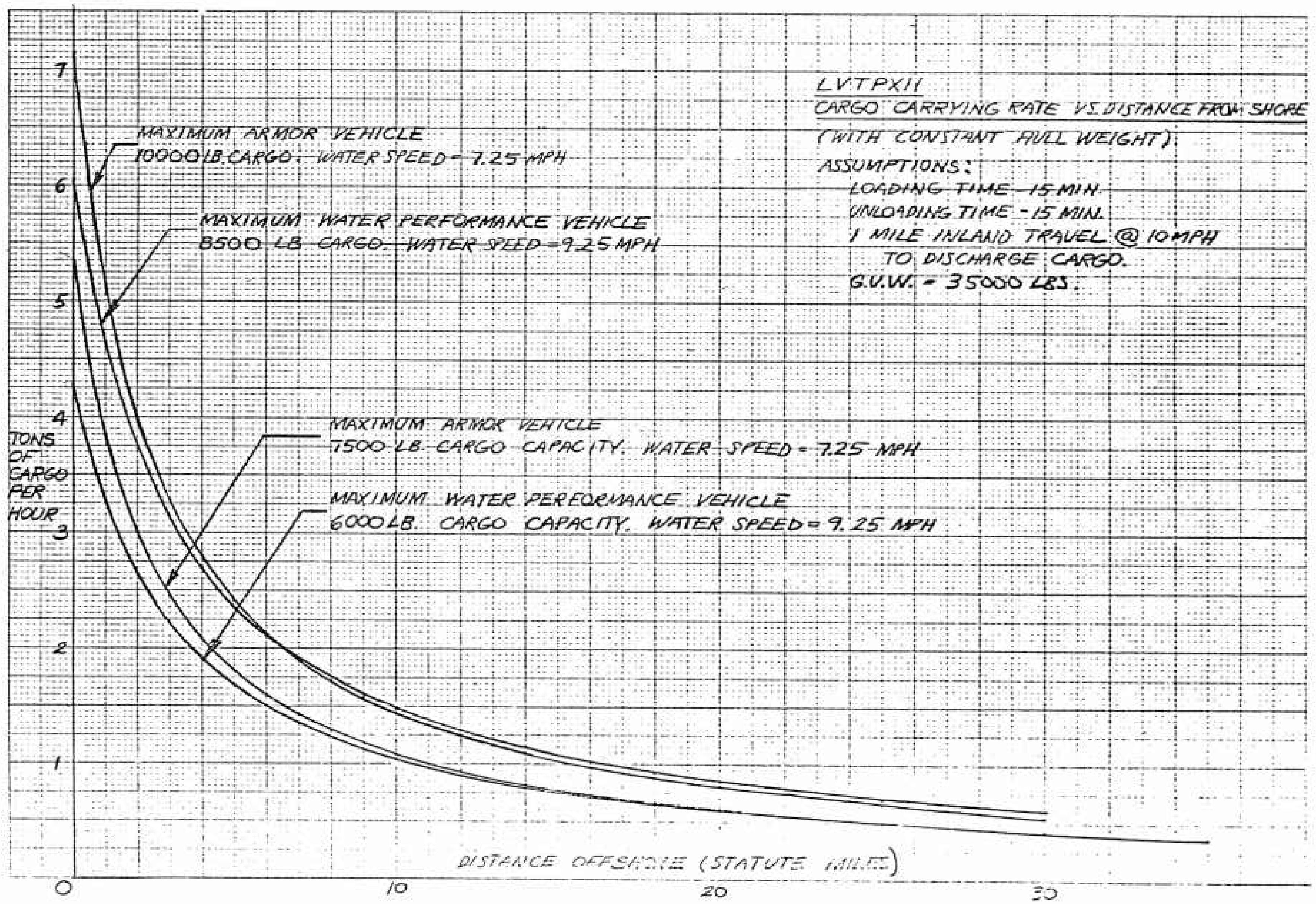

LVTPX11
CARGO CARRYING RATE VS. DISTANCE FROM SHORE
(WITH CONSTANT HULL WEIGHT)
ASSUMPTIONS:
LOADING TIME - 15 MIN.
UNLOADING TIME - 15 MIN.
1 MILE INLAND TRAVEL @ 10 MPH
TO DISCHARGE CARGO.
G.V.W. = 35000 LBS.
MAXIMUM ARMOR VEHICLE
10000 LB. CARGO. WATER SPEED = 7.25 MPH
MAXIMUM WATER PERFORMANCE VEHICLE
8500 LB CARGO. WATER SPEED = 9.25 MPH
MAXIMUM ARMOR VEHICLE
7500 LB. CARGO CAPACITY. WATER SPEED = 7.25 MPH
MAXIMUM WATER PERFORMANCE VEHICLE
6000 LB. CARGO CAPACITY. WATER SPEED = 9.25 MPH
TONS OF CARGO PER HOUR
1
2
3
4
5
6
7
DISTANCE OFFSHORE (STATUTE MILES)
0
10
20
30

FIGURE 3.1 2

Operations Analysis (Continued)

- Maximum Water Performance Vehicle - 1.68 ton/hrs.

This represents only a 14.3% difference in rate, despite the 27.6% difference in speed.

At an offshore distance of 10 miles, the cargo rate for the two vehicles drops to 0.87 tons/hr and 1.05 tons/hr, or a difference of 17.1%. As the offshore distance increases, the difference in cargo rate approaches, but never reaches, the 27.6% speed difference.

An equal degree of armor protection is not provided in the vehicles considered in the above analysis, since the 1,500 lb weight of the propeller drive subtracts from the armor weight. To arrive at a more equal comparison basis, the plot shown in Figure 3.1.2 was made. In this comparison, the Maximum Armored Vehicle is credited with an additional 1,500 lb of cargo capacity at the expense of armor thickness. Using the same assumptions as before, Figure 3.1.2 shows the plot of cargo-carrying rate-versus-offshore distance as two sets of curves.

The Maximum Armored Vehicle, with a cargo capacity of 7,500 lb, shows an initial advantage in cargo-carrying rate at distances up to 10 miles. Beyond 10 miles, the curves are nearly coincident, and they intersect at a distance of 31 miles. Beyond this point, the Maximum Water Performance Vehicle provides the greater cargo-carrying rate.

Comparing the two vehicles with cargo capacities of 8,500 and 10,000 lb, the Maximum Armored Vehicle holds an advantage for offshore distances up to 6 miles.

Operations Analysis (Continued)

It is concluded that, for reasonable offshore distances, little advantage can be shown in terms of cargo-carrying rate for the difference in speed obtainable with a propeller drive.

An additional comparison can be made with a vehicle designed specifically for the logistic role such as the Landing Vehicle, Hydrofoil (LVH). This vehicle has a maximum speed of 35 knots and a cargo capacity of 10,000 pounds. It is in the same size and weight range as the LVTPX11. Assuming the same values for loading and unloading time and the same distance inland to discharge cargo as in the previous analysis, and assuming an average waterborne speed of 30 mph, the following cargo rates can be calculated:

5 miles offshore - 4.8 tons/hr
20 miles offshore - 2.5 tons/hr

By comparing these values with the preceding curves for the LVTPX11, it can be seen that the LVTPX11 is a poor cargo carrier in comparison with the LVH.

An analysis of the requirements of the logistic role versus the tactical role indicates that a logistic vehicle should emphasize water usage over land usage about in the ratio of 80/20, and that the reverse is true for a tactical vehicle. It can therefore be concluded that a dual-purpose vehicle would be rated 50/50 land-to-water usage. From a design standpoint, this would result in a diminution of both the land and water maximum capabilities. It is believed that requirements for both tactical vehicles and logistic vehicle exist simultaneously. On this premise, it will be more economical to build two classes of vehicles, each with its own mission.

3.2 MAXIMUM ARMORED VEHICLE

If due consideration is given to the requirement that the LVTPX11 will operate 80% on land and 20% on water, then a vehicle designed for optimum land performance is required. The vehicle shown in Figures 3.2.1 and 3.2.2, although optimized for land performance, still offers superior water-speed capability, when compared to existing LVT's. The salient features of this vehicle are summarized below, while the factors that led to the adoption of these features are presented later in this report.

- Welded aluminum hull - Shown by the study to offer greatest armor protection and maximum rigidity, while still permitting economical fabrication.

- Maximum armor - The 35,000 lb GVW limitation will permit a composite armor of aluminum and titanium equivalent to 2 inches of aluminum, and a composite armor of aluminum and zig-zag steel equivalent to 2.3 inches of aluminum.

- Rounded hull - Generous radii offer both improved water performance and increased ballistic protection.

- Front ramp - The rear engine and front ramp permit a bow-up trim under all load conditions. The front ramp also provides for good visibility of loading and unloading operations by the vehicle driver.

- Major components proven or under development - As directed by the "Development Characteristics", special consideration was given to new component development, and all advantages offered were weighed against the probability of component availability and

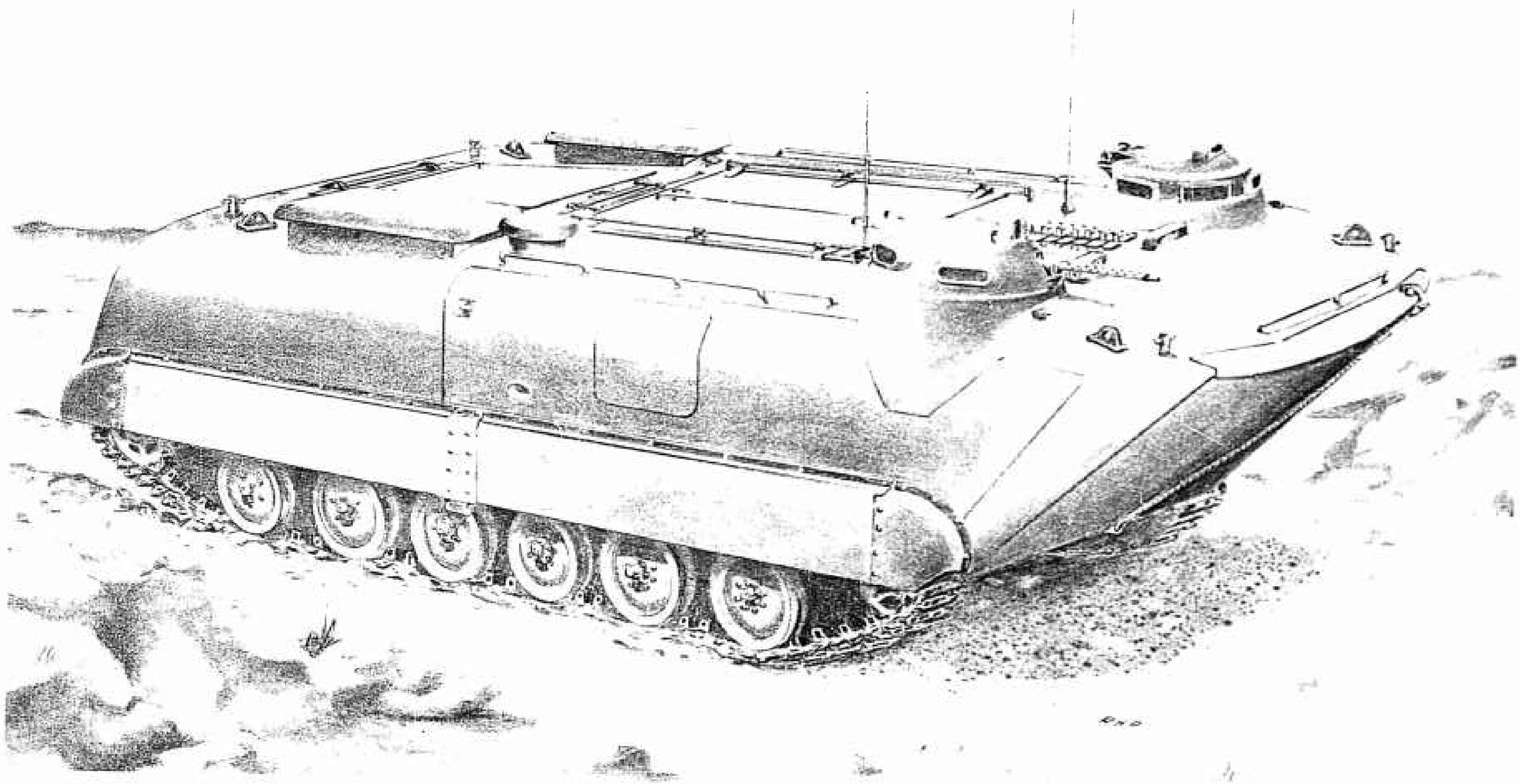
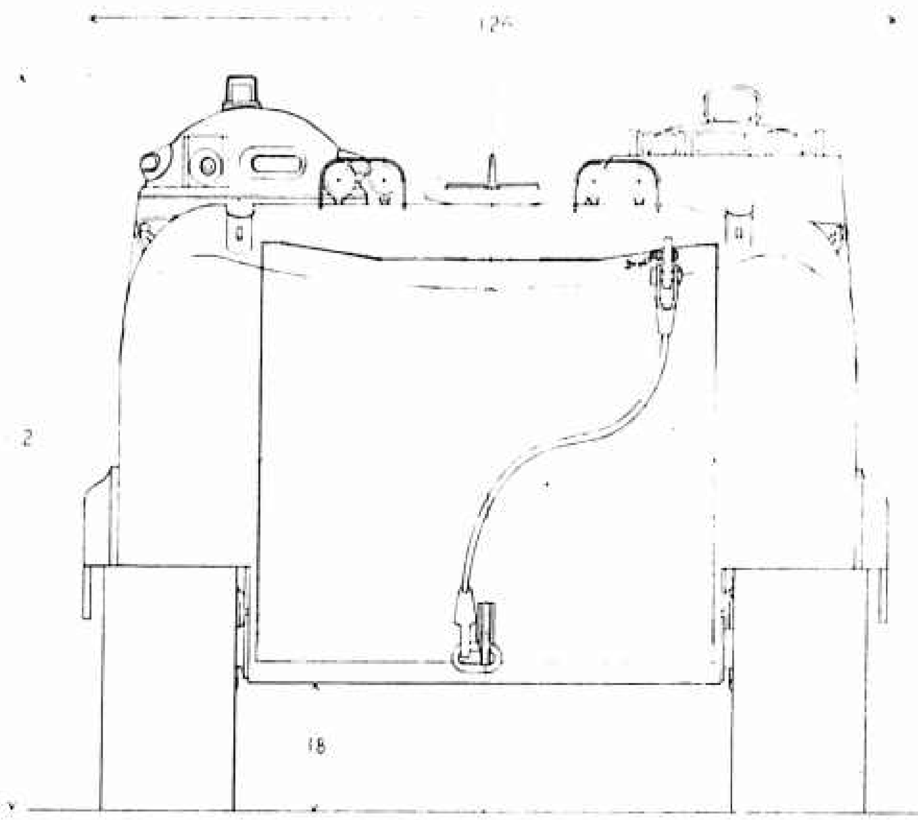
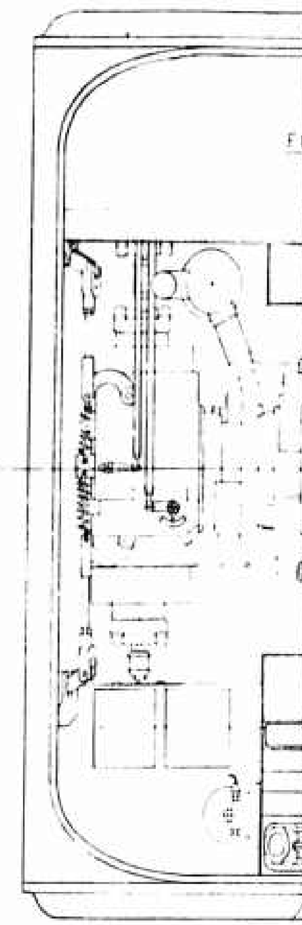


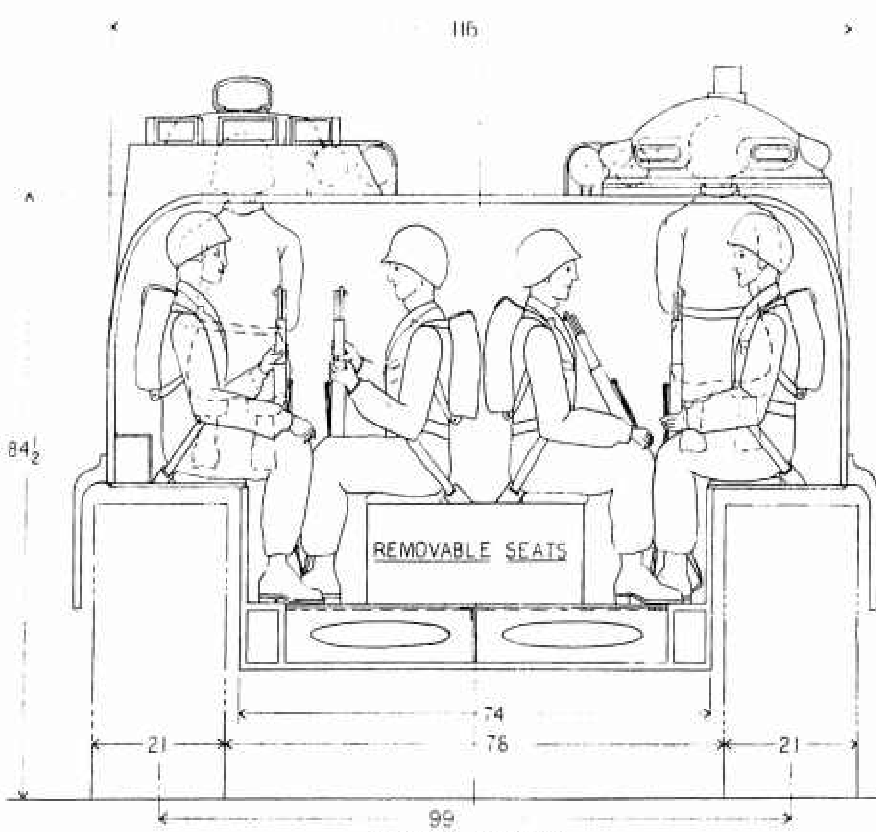
FIGURE 3.2.1 MAXIMUM ARMORED VEHICLE



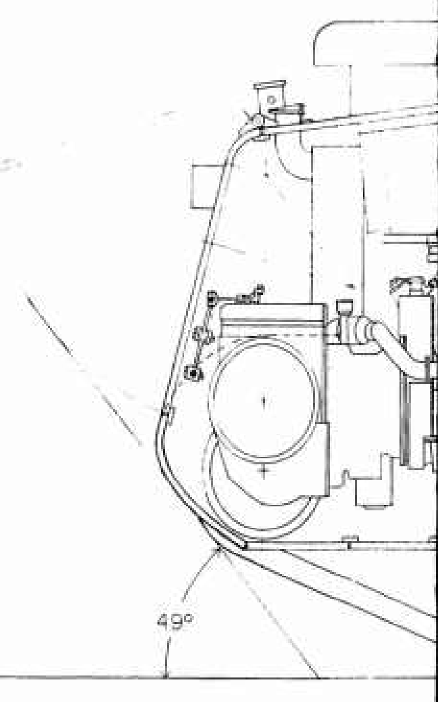
FRONT VIEW

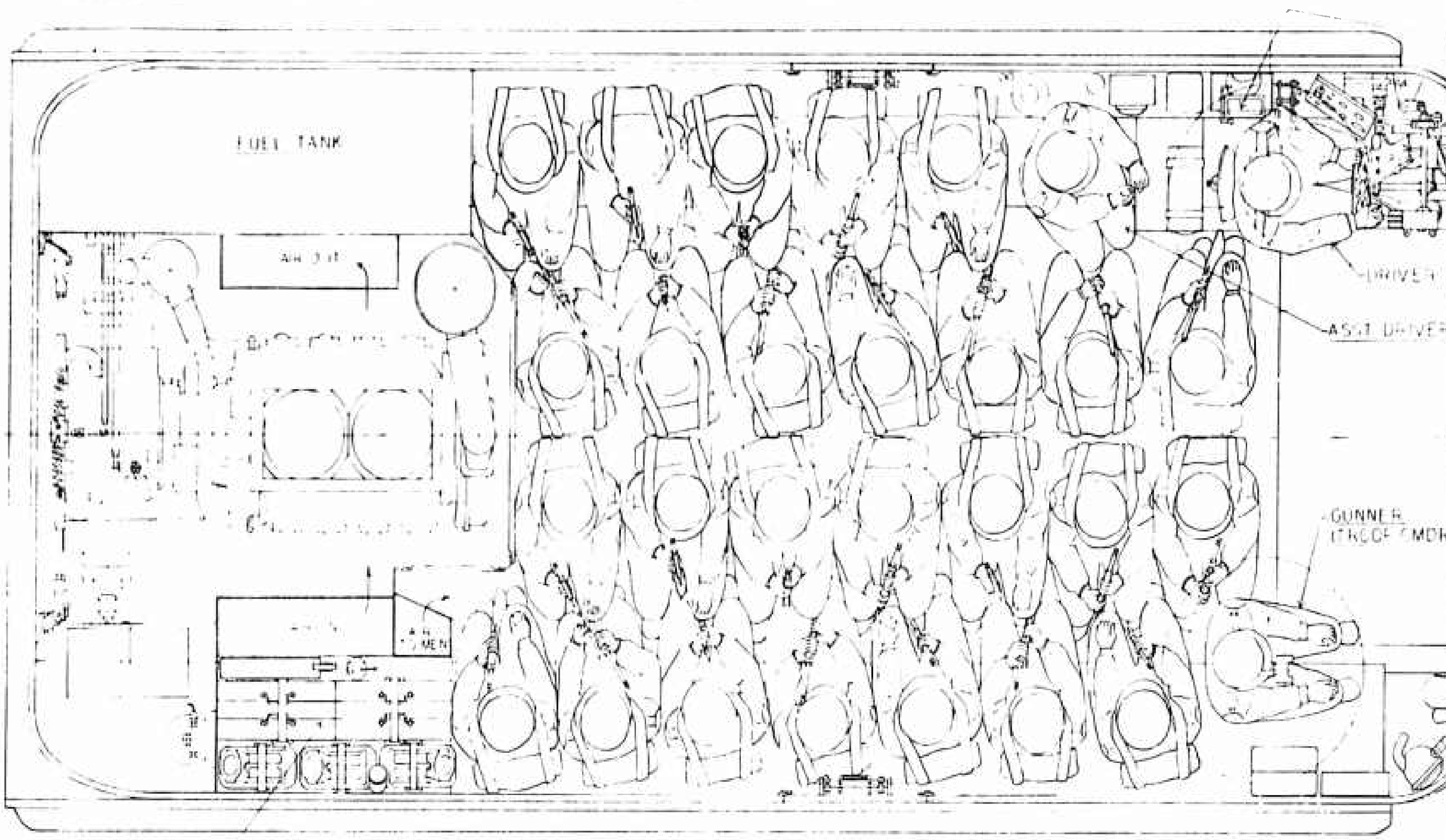
1





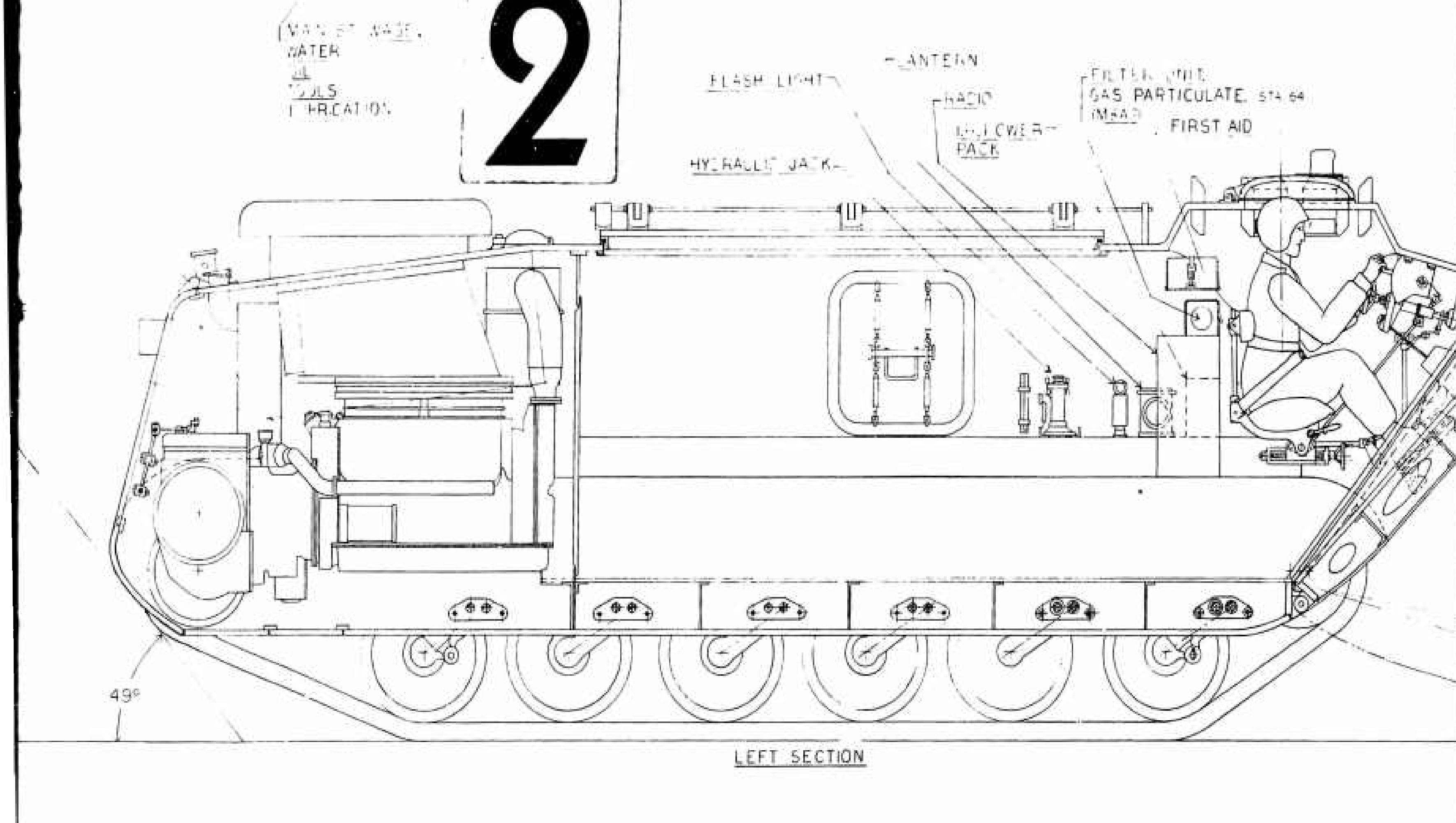
TYPICAL SECTION



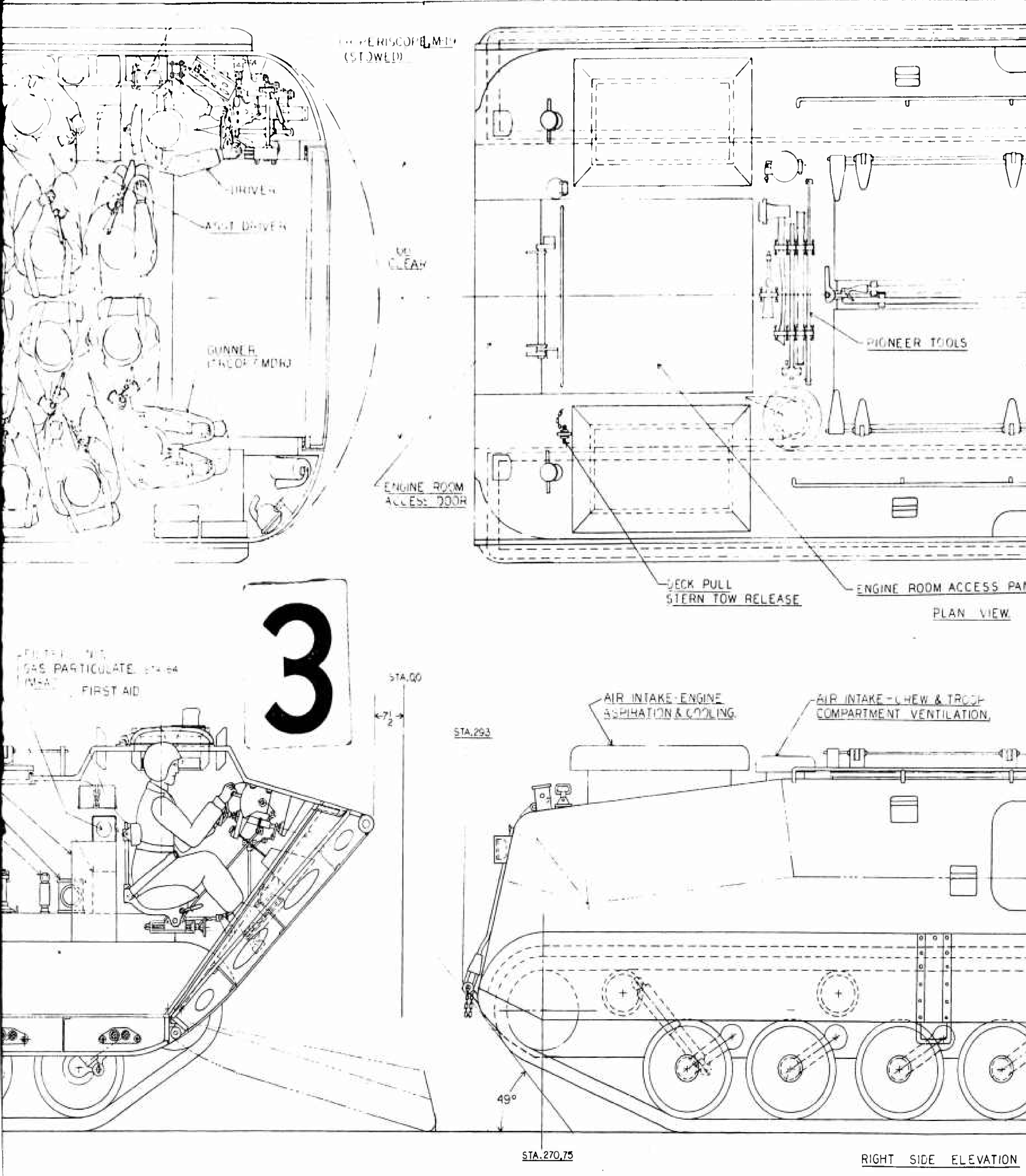


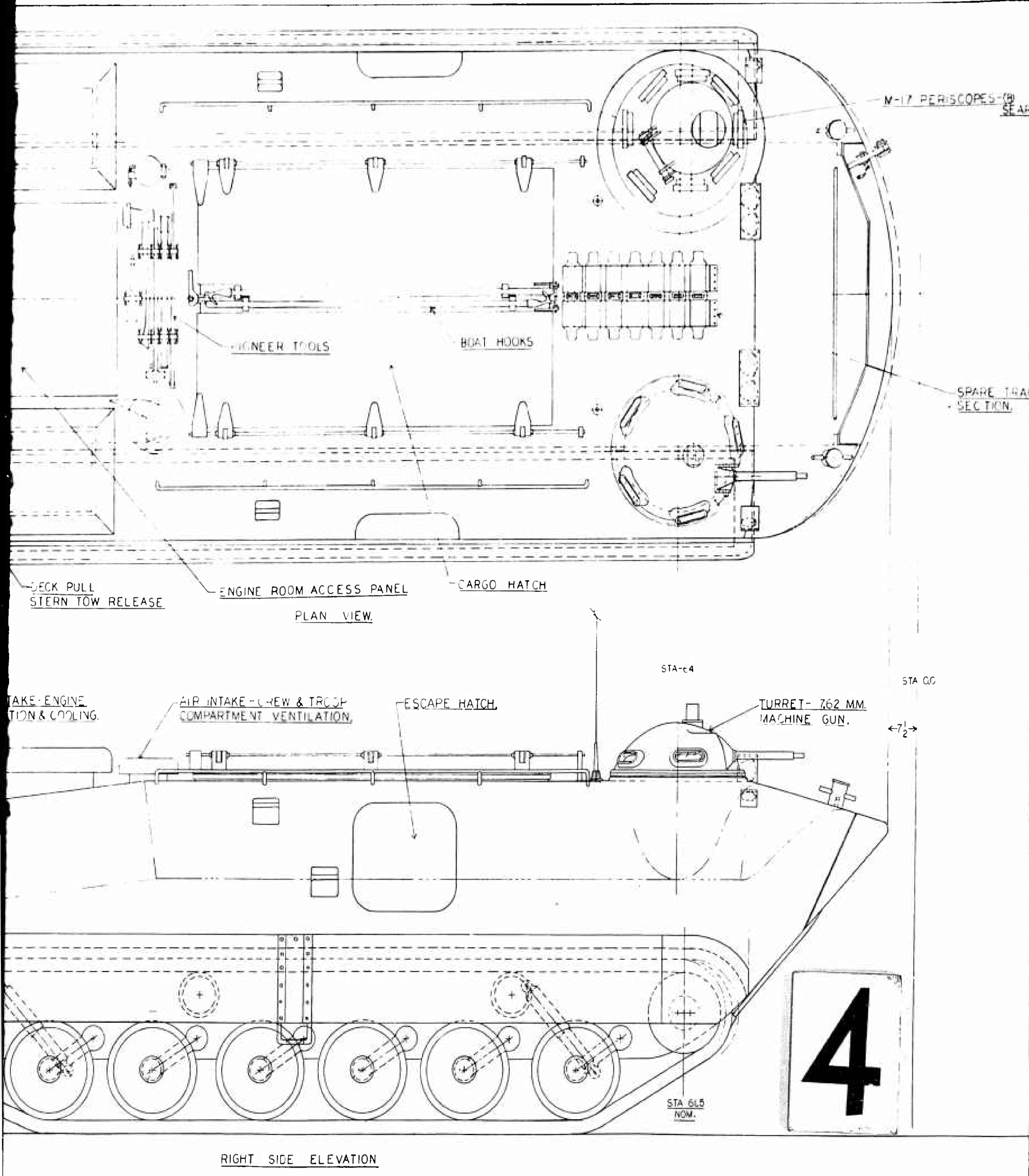
PLAN SECTION

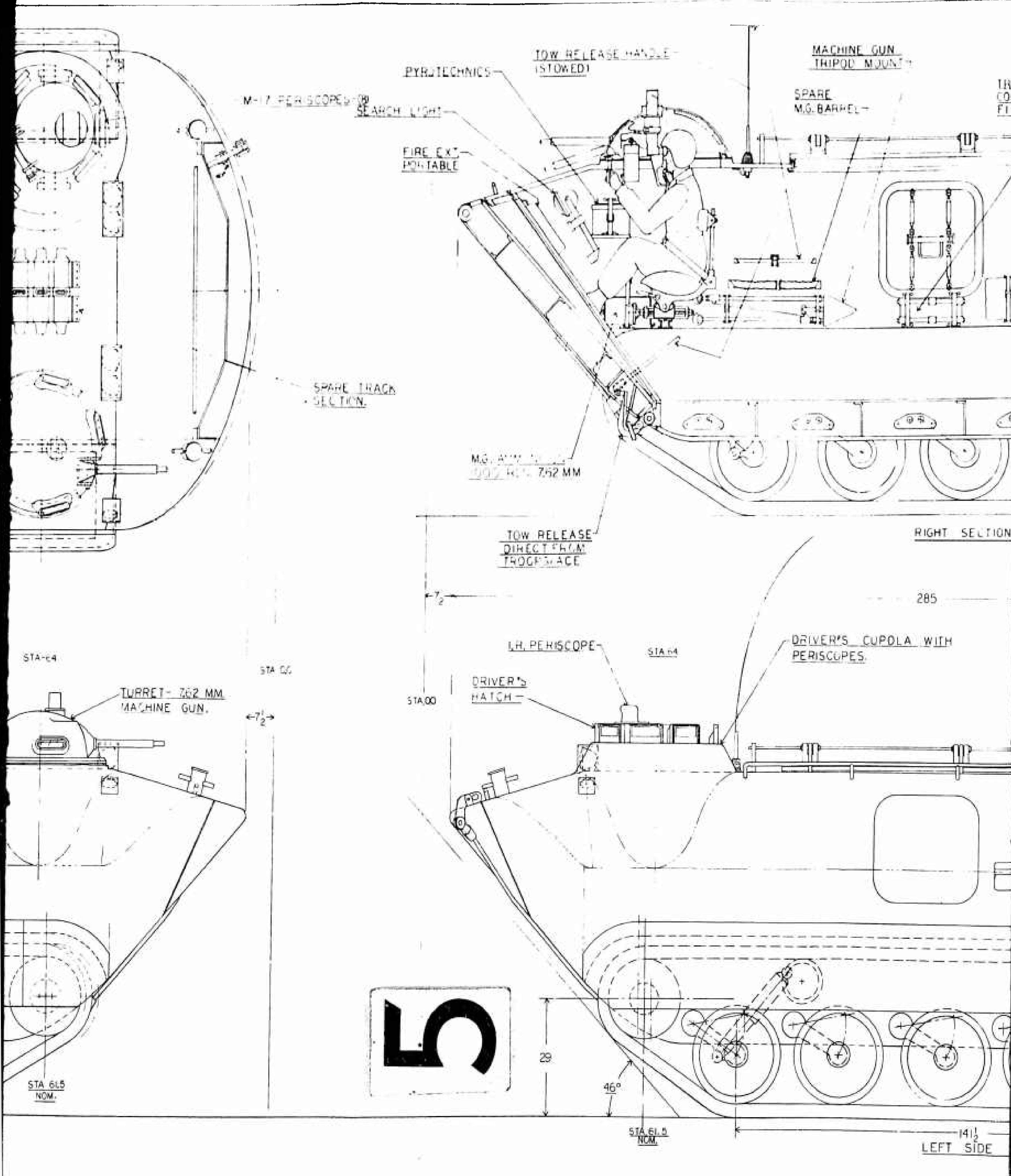
2

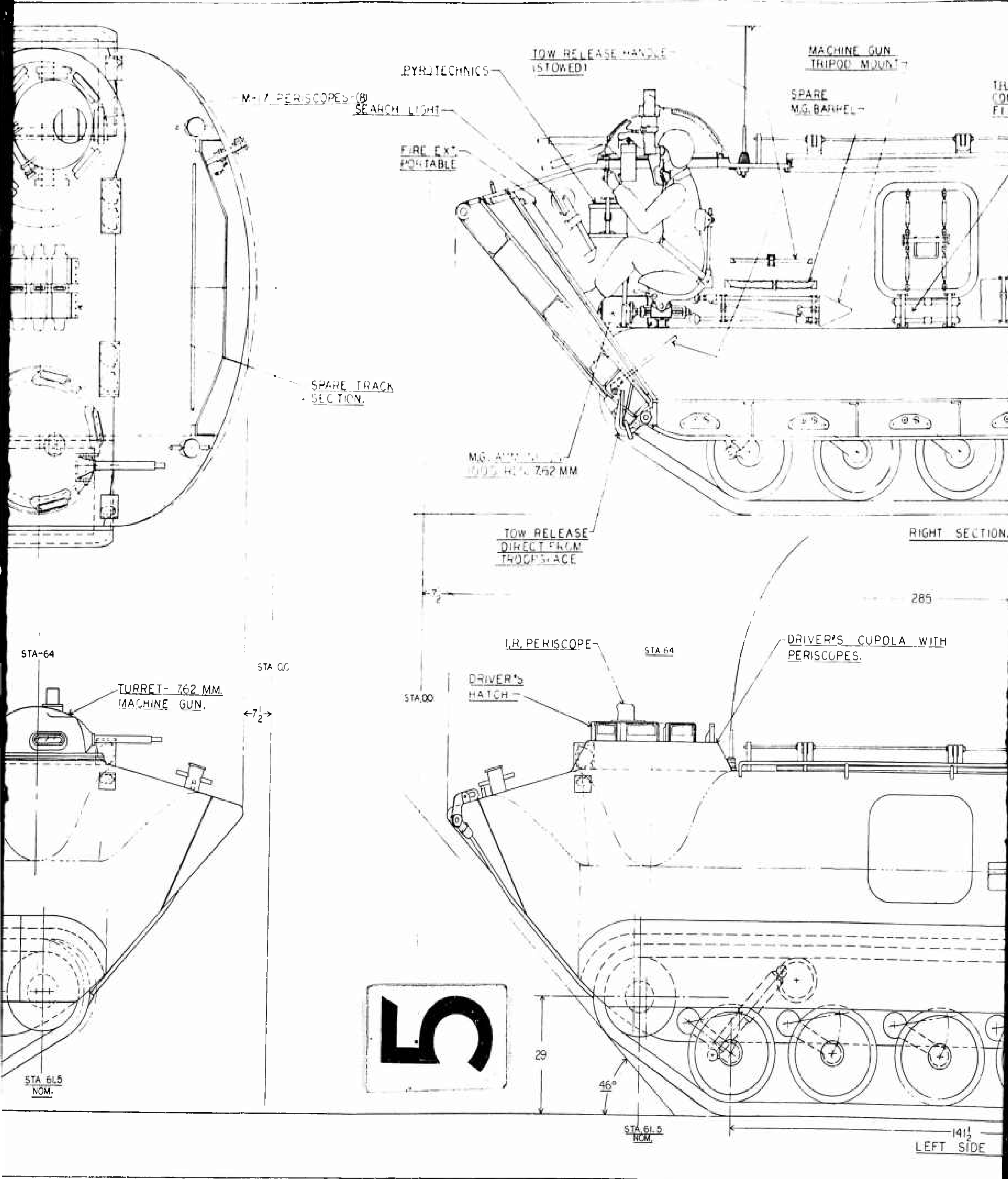


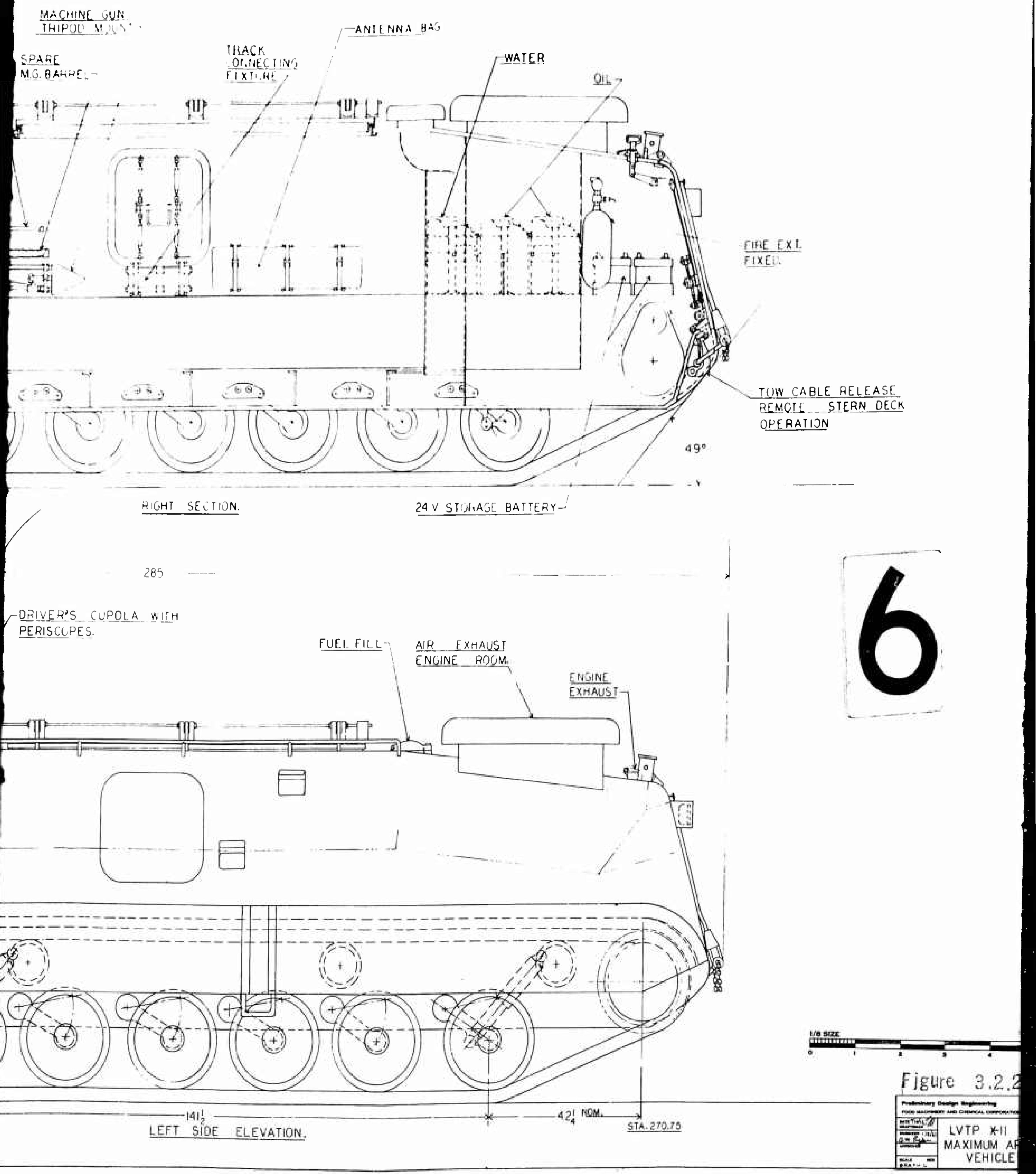
LEFT SECTION


PERISCOPE M19 (STOWED)
DRIVER
ASST DRIVER
CLEAR
GUNNER
ENGINE ROOM ACCESS DOOR
PIONEER TOOLS
DECK PULL
STERN TOW RELEASE
ENGINE ROOM ACCESS PAN
PLAN VIEW
3
GAS PARTICULATE
FIRST AID
STA.00
7 1/2
STA.293
AIR INTAKE-ENGINE ASPIRATION & COOLING
AIR INTAKE-CREW & TROOP COMPARTMENT VENTILATION
49°
STA.270.75
RIGHT SIDE ELEVATION


M-17 PERISCOPES-(8)
SPARE TRAC
SECTION.
PIONEER TOOLS
BOAT HOOKS
DECK PULL
STERN TOW RELEASE
ENGINE ROOM ACCESS PANEL
CARGO HATCH
PLAN VIEW.
STA-64
STA 0.0
TAKE-ENGINE
TION & COOLING.
AIR INTAKE - CREW & TROOP
COMPARTMENT VENTILATION.
ESCAPE HATCH.
TURRET- 7.62 MM.
MACHINE GUN.
$7\frac{1}{2}$
STA 6L5
NOM.
4
RIGHT SIDE ELEVATION

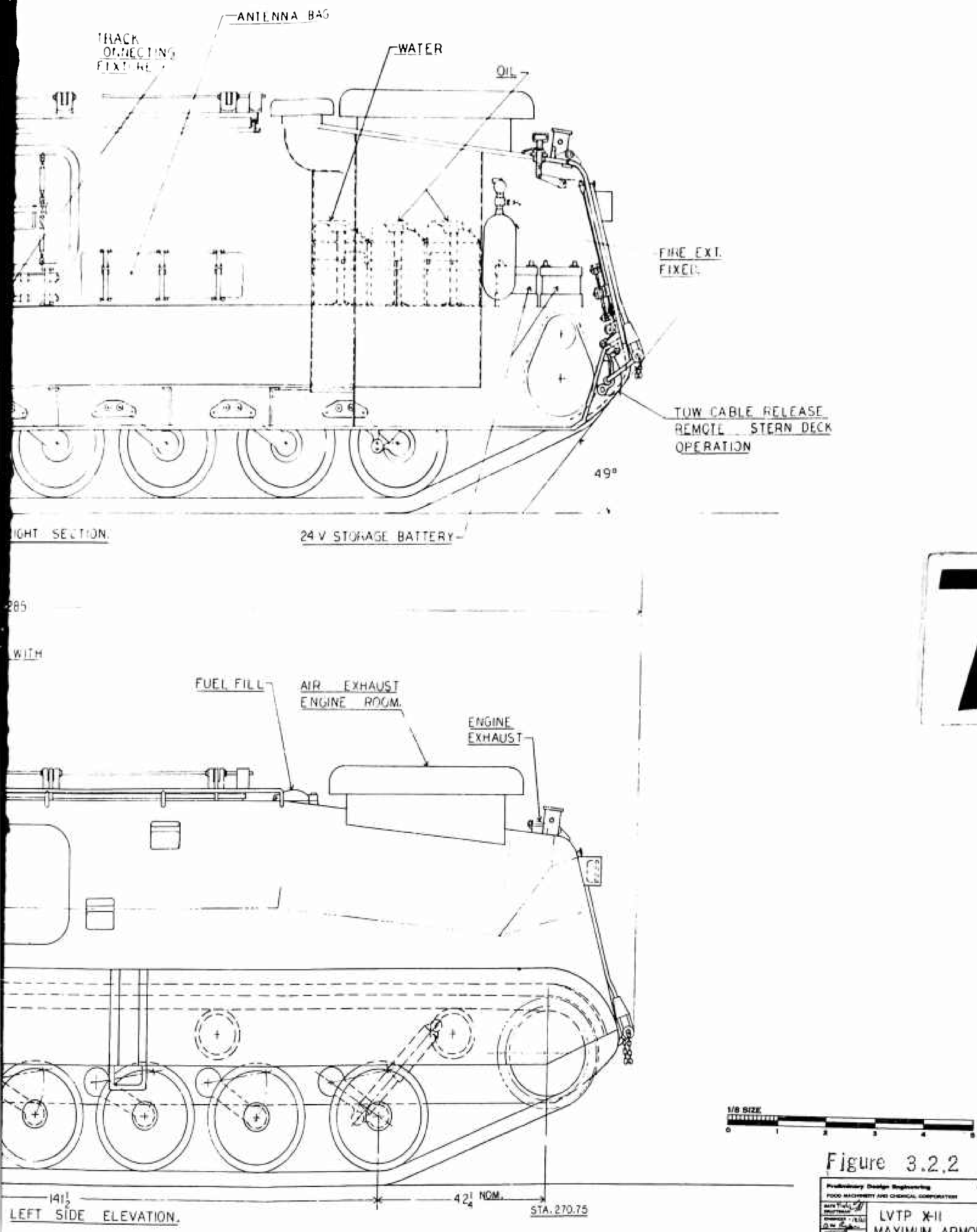

TOW RELEASE HANDLE (STOWED)
PYROTECHNICS
M-17 PERISCOPES (8)
SEARCH LIGHT
MACHINE GUN TRIPOD MOUNT
SPARE M.G. BARREL
FIRE EXT. PORTABLE
SPARE TRACK SECTION.
M.G. AMMO
7.62 MM
TOW RELEASE DIRECT FROM TROOPSPACE
RIGHT SECTION.
285
I.R. PERISCOPE
STA 64
DRIVER'S CUPOLA WITH PERISCOPES.
STA-64
STA 00
DRIVER'S HATCH
TURRET- 7.62 MM MACHINE GUN.
29
46°
STA 61.5 NOM.
STA 61.5 NOM.
141½
LEFT SIDE
5


M-17 PERISCOPES-(8)
SEARCH LIGHT
PYROTECHNICS
TOW RELEASE HANDLE (STOWED)
MACHINE GUN TRIPOD MOUNT
SPARE M.G. BARREL
FIRE EXT. PORTABLE
SPARE TRACK SECTION.
7.62 MM
TOW RELEASE DIRECT FROM TROOPSPACE
RIGHT SECTION.
285
STA-64
STA 0.0
TURRET- 7.62 MM. MACHINE GUN.
7 1/2
I.R. PERISCOPE
STA 64
DRIVER'S CUPOLA WITH PERISCOPES.
DRIVER'S HATCH
STA.00
29
46°
STA 61.5 NOM.
141 1/2
LEFT SIDE
5



MACHINE GUN TRIPOD MOUNT
ANTENNA BAG
SPARE M.G. BARREL
TRACK CONNECTING FIXTURE
WATER
OIL
FIRE EXT. FIXED
TOW CABLE RELEASE REMOTE STERN DECK OPERATION
49°
RIGHT SECTION.
24 V STORAGE BATTERY
285
DRIVER'S CUPOLA WITH PERISCOPES.
FUEL FILL
AIR EXHAUST ENGINE ROOM.
ENGINE EXHAUST
6
141½
42¼ NOM.
STA. 270.75
LEFT SIDE ELEVATION.
1/8 SIZE
Preliminary Design Engineering
LVTP X-11
MAXIMUM AF
VEHICLE

Figure 3.2.2



7

Figure 3.2.2

Preliminary Design Engineering — FOOD MACHINERY AND CHEMICAL CORPORATION — ORDNANCE DIVISION, SAN JOSE, CALIFORNIA

LVTP X-11 MAXIMUM ARMOR VEHICLE

K1077325

suitability. As a result, the recommended components have either been proven or are in late stages of development with a reasonable certainty of success.

- Flexibility - To take maximum advantage of advances in the state-of-the-art and to permit the use of newly developed components such as electric and hydraulic drives and new armor materials, extensive studies were conducted in these areas. FMC staff specialists visited military agencies, such as OTAC and Aberdeen Proving Grounds, and contacted industrial firms, such as Sundstrand, Louis-Allis, General Electric, and Vickers, to obtain firsthand knowledge of new products that should be considered for future incorporation in the LVTPX11.

- Track propulsion for both land and water - This permits maximum simplicity of both machinery and controls.

- Lightweight components - Components were chosen for lightness, to permit maximum weight (within the 35, 000 lb GVW limitation) to be applied to armor.

- Improved land mobility - By providing a softer suspension featuring increased roadwheel travel and lower ground-pressure (5.8 psi compared to 9.2 psi for the LVTP5), land mobility is improved above existing LVT's.

- Compatibility - The vehicle design shown in Figure 3.2.1 accommodates the proposed vehicle family of:

    Command Vehicle
    Recovery Vehicle
    Amphibian Assault Antimechanized-Weapon Vehicle
    Amphibian Field-Artillery-Weapon Vehicle
    Amphibian Light-Air-Defense-Weapon Vehicle
    Engineer Mine-Clearance Vehicle.

3.3 MAXIMUM WATER PERFORMANCE VEHICLE

The vehicle shown in Figures 3.3.1 and 3.3.2 offers the following salient features in addition to the features discussed in the preceding section 3.2, entitled "Maximum Armored Vehicle."

- Propeller for water operation - Provides higher water propulsion efficiency and a higher water speed of 9 to 9-1/2 mph, plus greater range in the water.
- Longer, narrower hull - Presents less hull resistance in the water.

These features are obtained at compromises in armor protection, due to the increased hull size and the weight of the propeller drive, compared with the "Maximum Armored Vehicle" design. There is also a cost penalty, due to the addition of a propeller drive and the extended hull.

The propeller is retractable and stows into the upper deck to prevent snagging and to provide a good angle of departure.

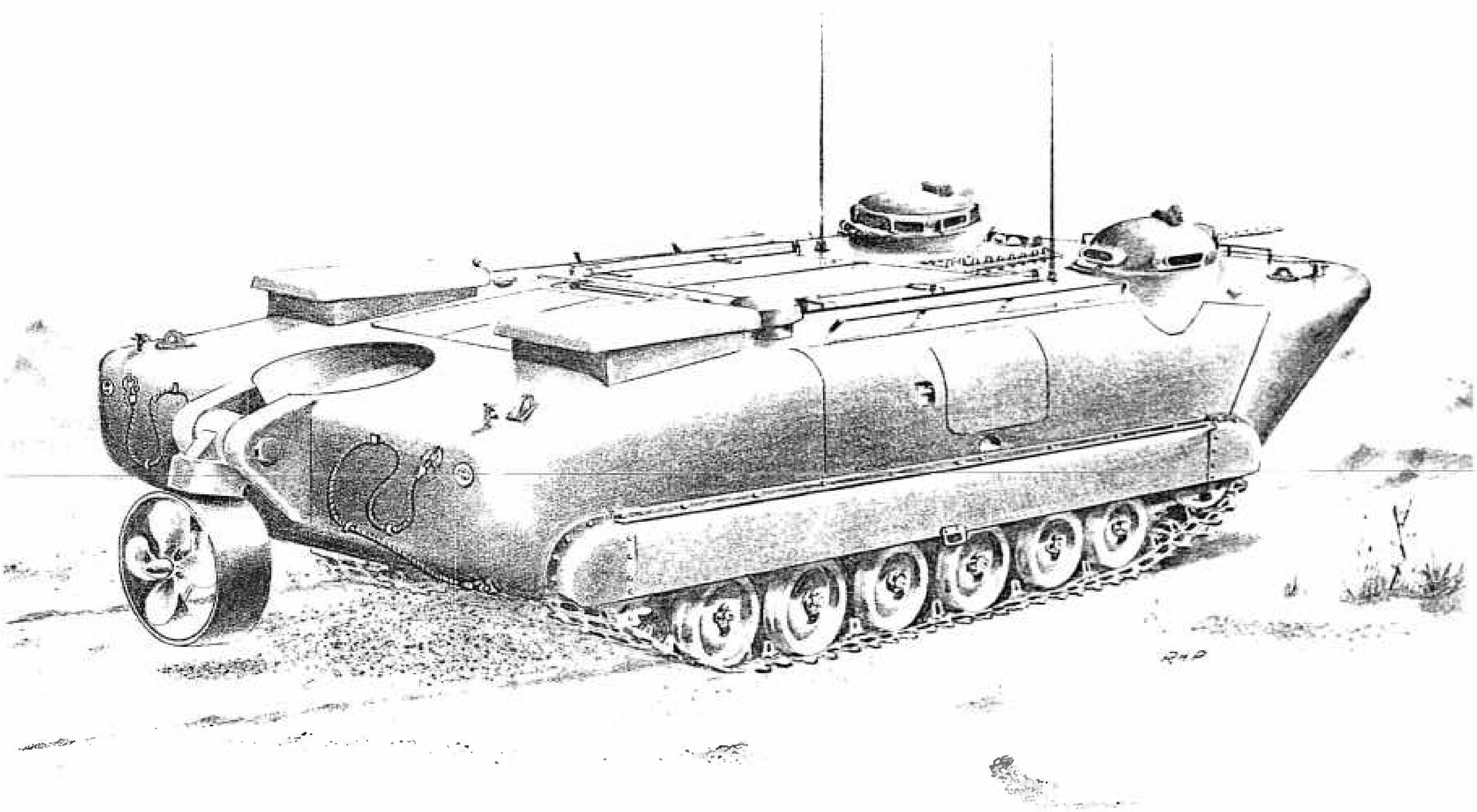
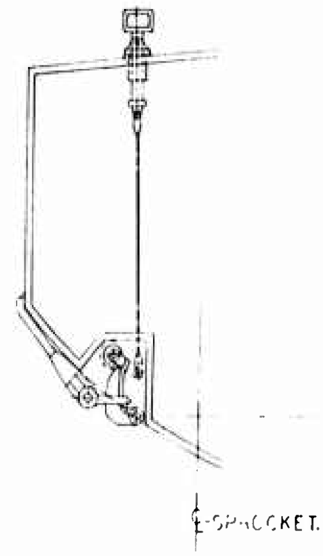


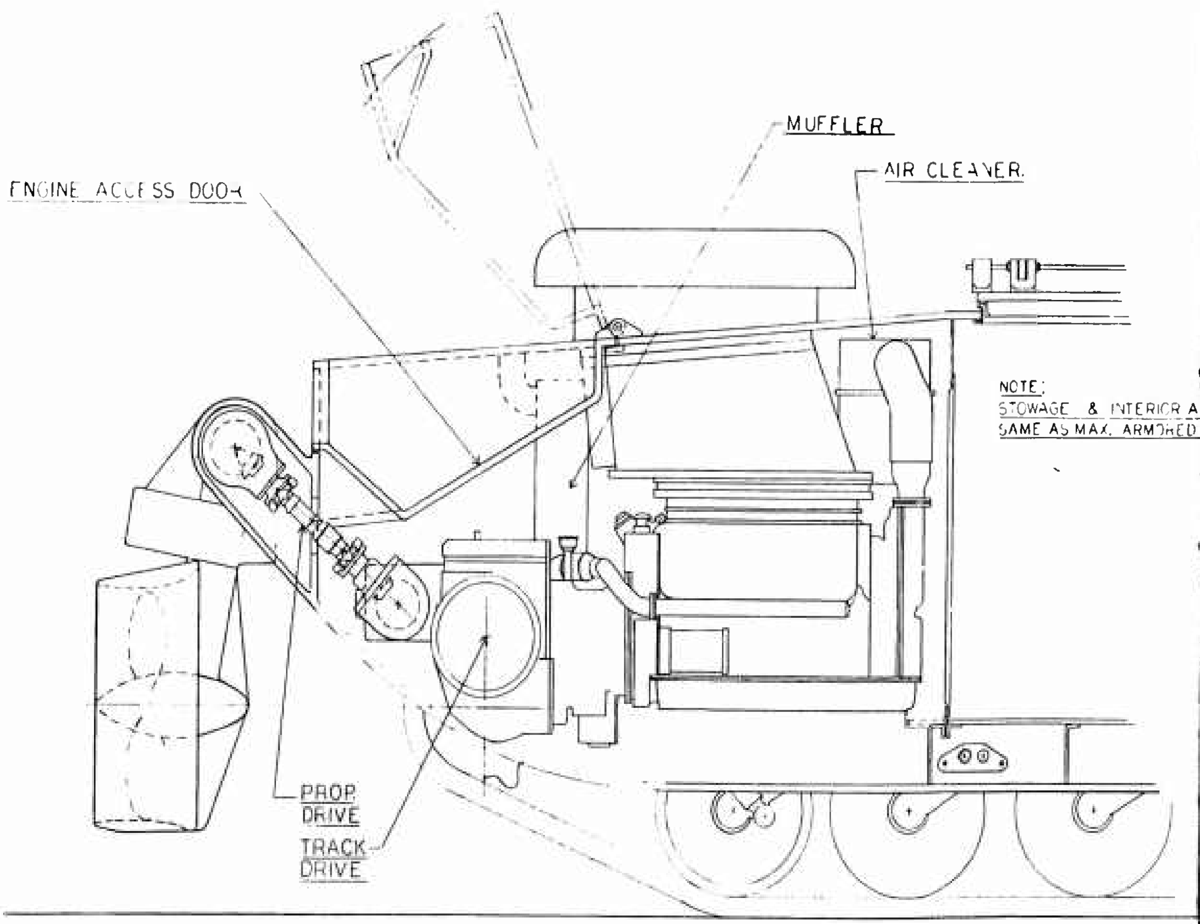
FIGURE 3. 3. 1   MAXIMUM WATER PERFORMANCE VEHICLE

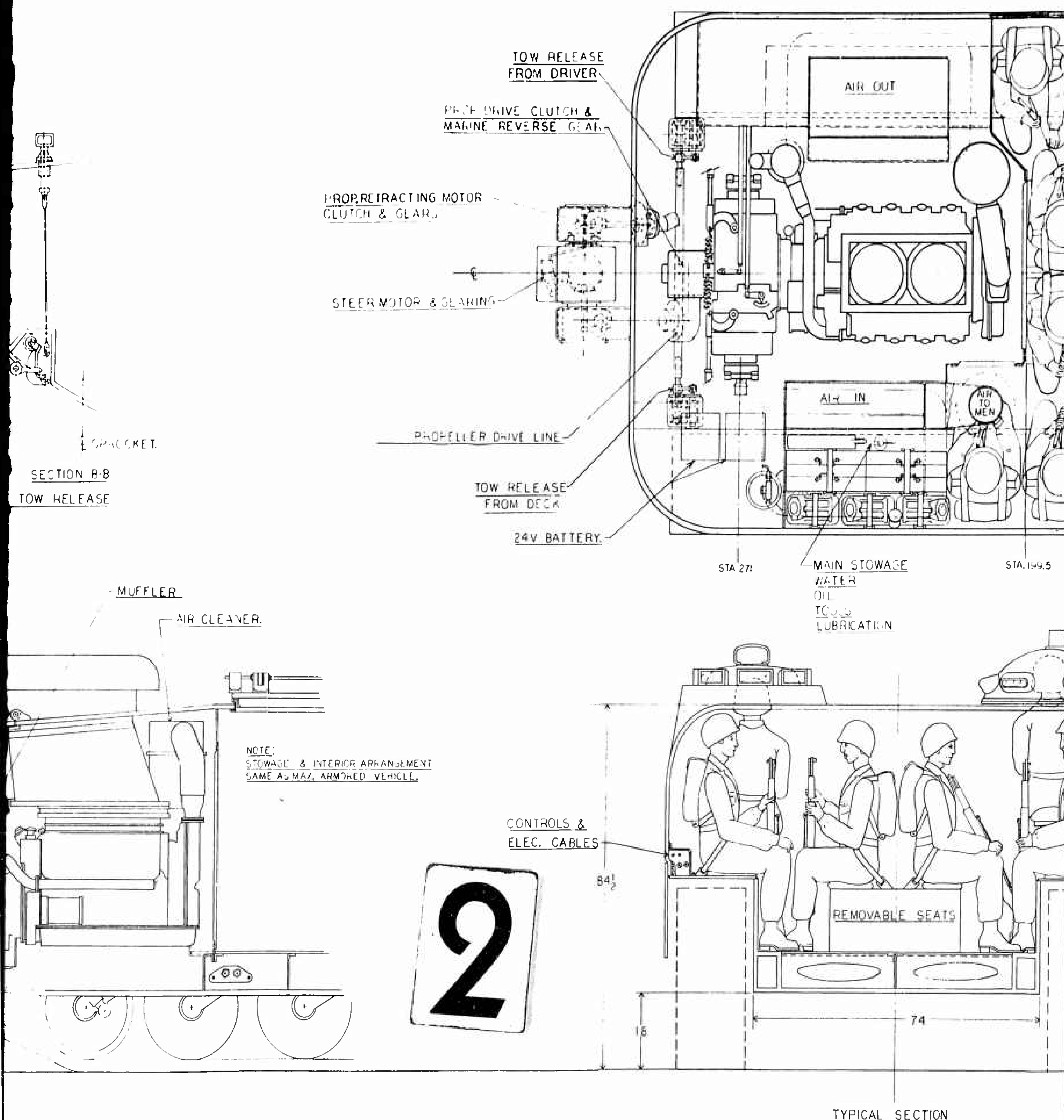
1

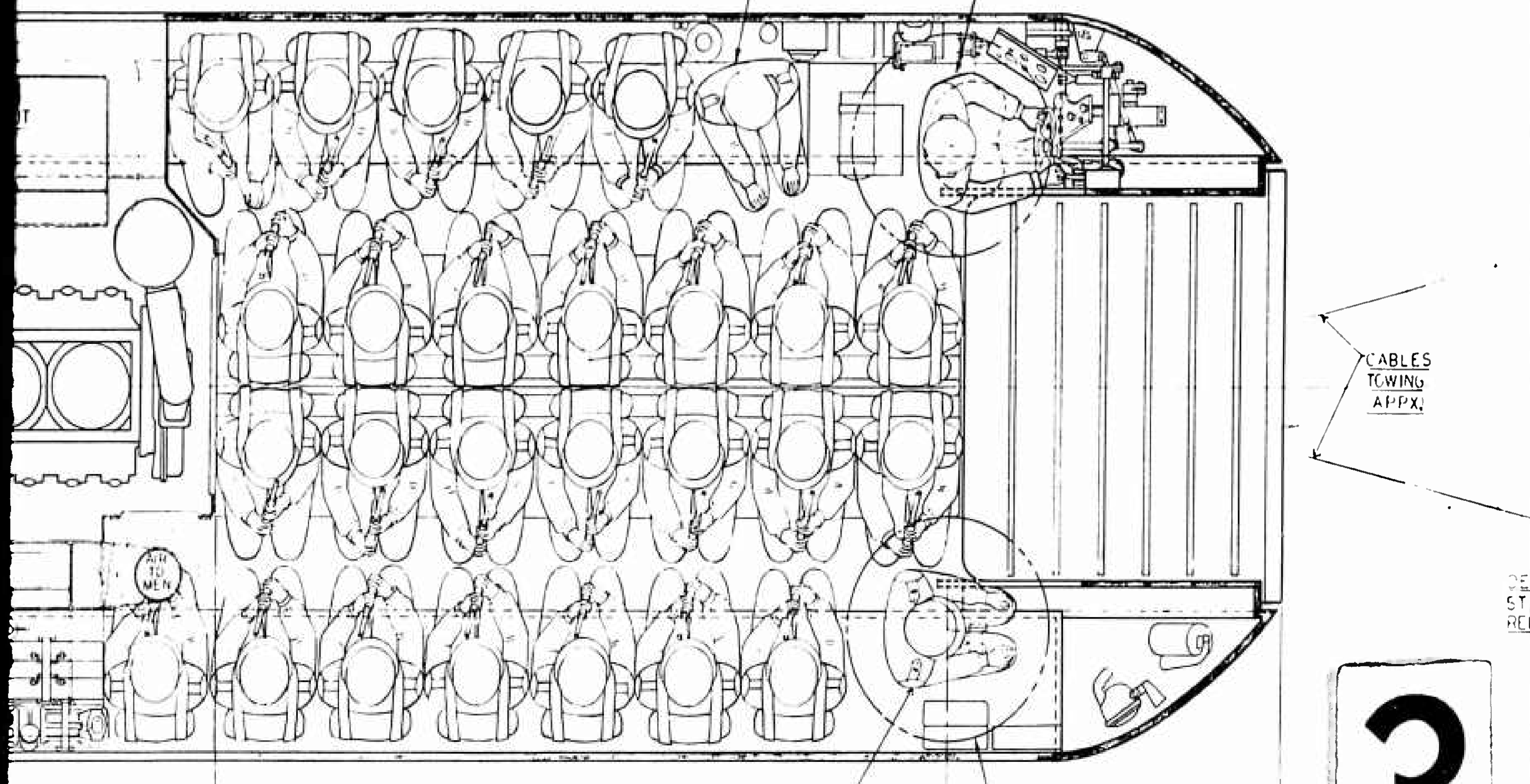


SECTION B-B

AFT TOW RELEASE

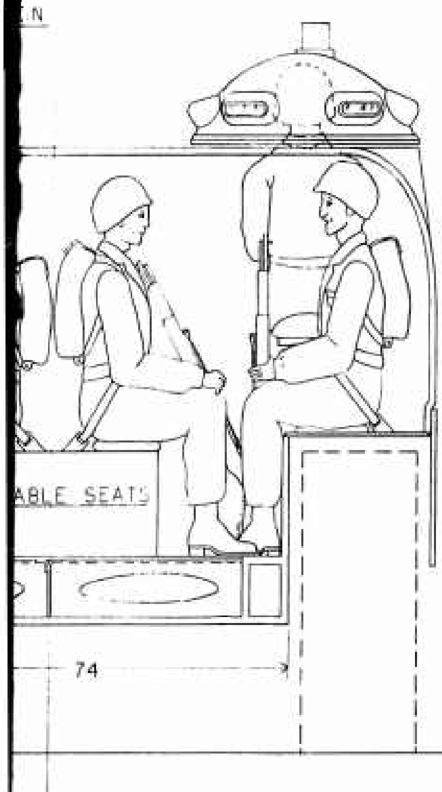


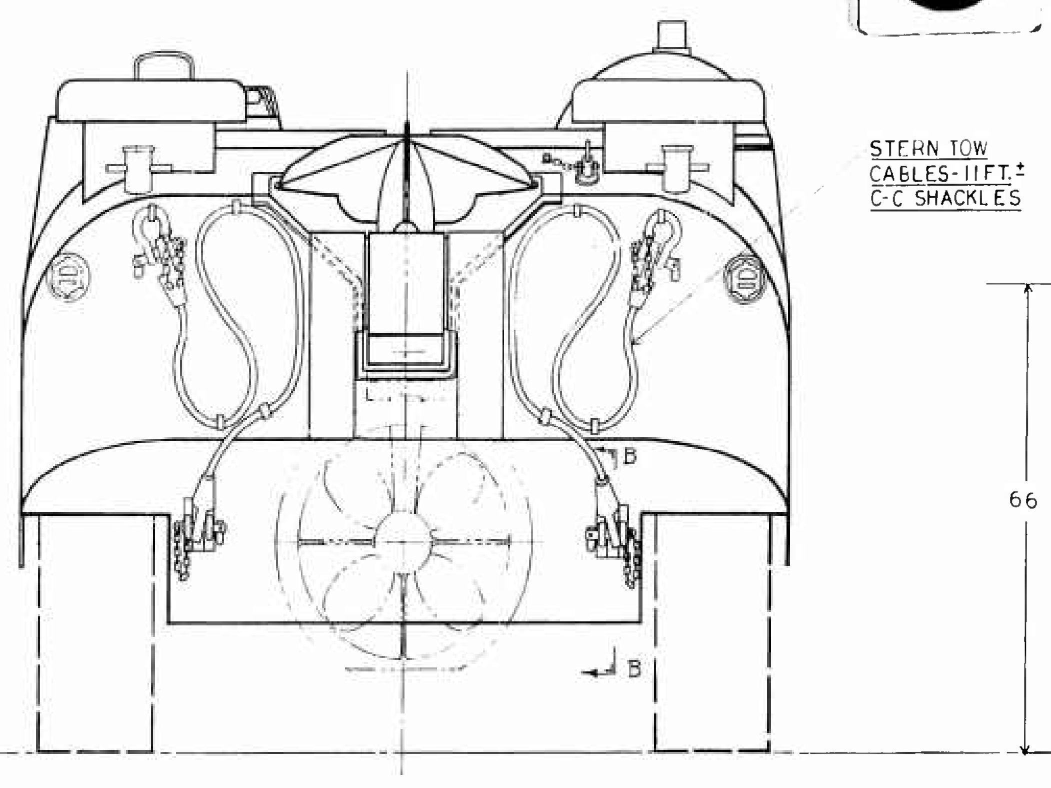

TOW RELEASE FROM DRIVER
MARINE REVERSE GEAR
PROP. RETRACTING MOTOR
STEER MOTOR & GEARING
PROPELLER DRIVE LINE
TOW RELEASE FROM DECK
24V BATTERY
AIR OUT
AIR IN
AIR TO MEN
STA 271
STA. 199.5
MAIN STOWAGE
WATER
OIL
LUBRICATION
SPROCKET
SECTION B-B
TOW RELEASE
MUFFLER
AIR CLEANER
NOTE:
STOWAGE & INTERIOR ARRANGEMENT
SAME AS MAX. ARMORED VEHICLE.
CONTROLS &
ELEC. CABLES
84½
REMOVABLE SEATS
74
18
2
TYPICAL SECTION



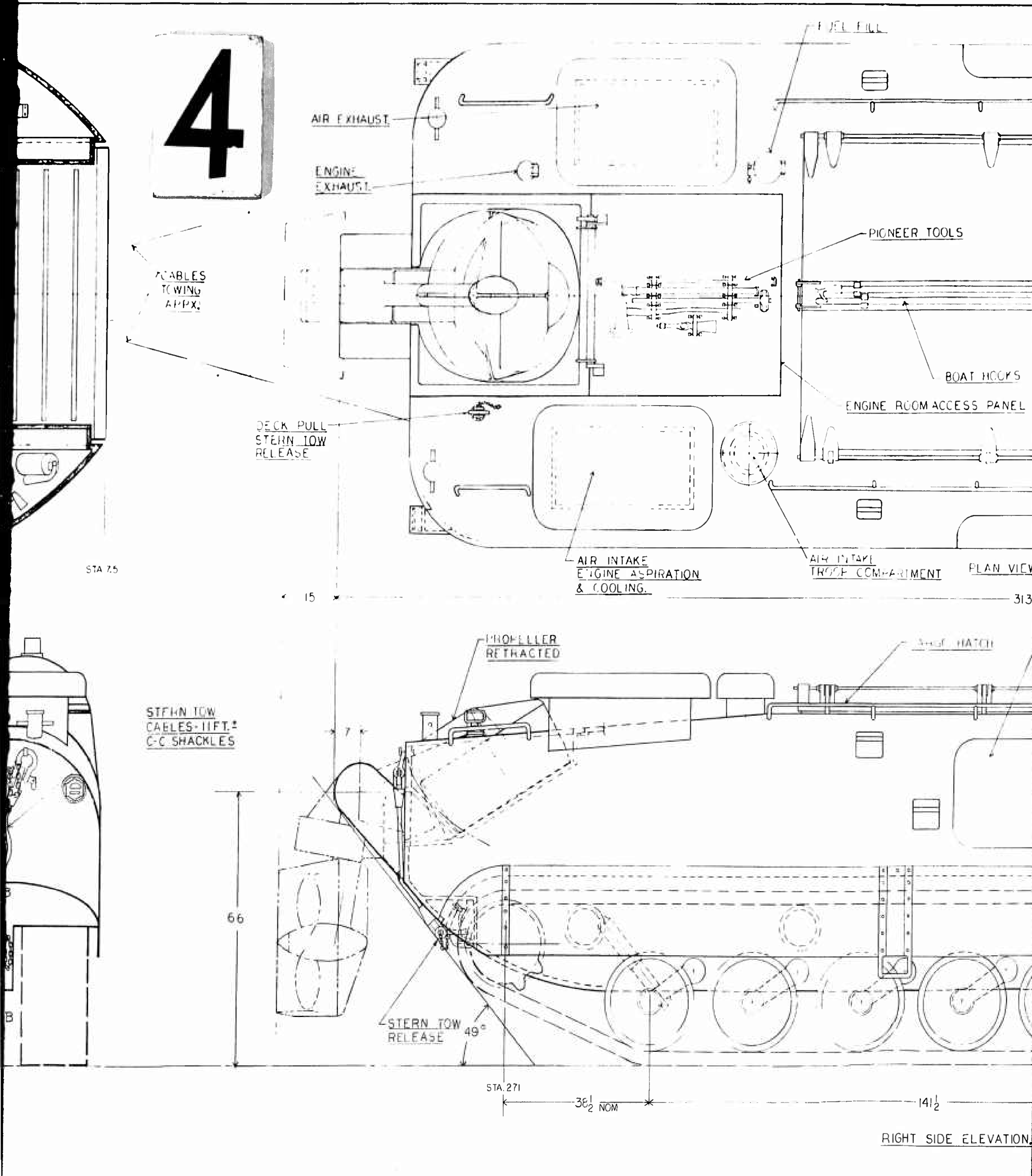
PLAN SECTION

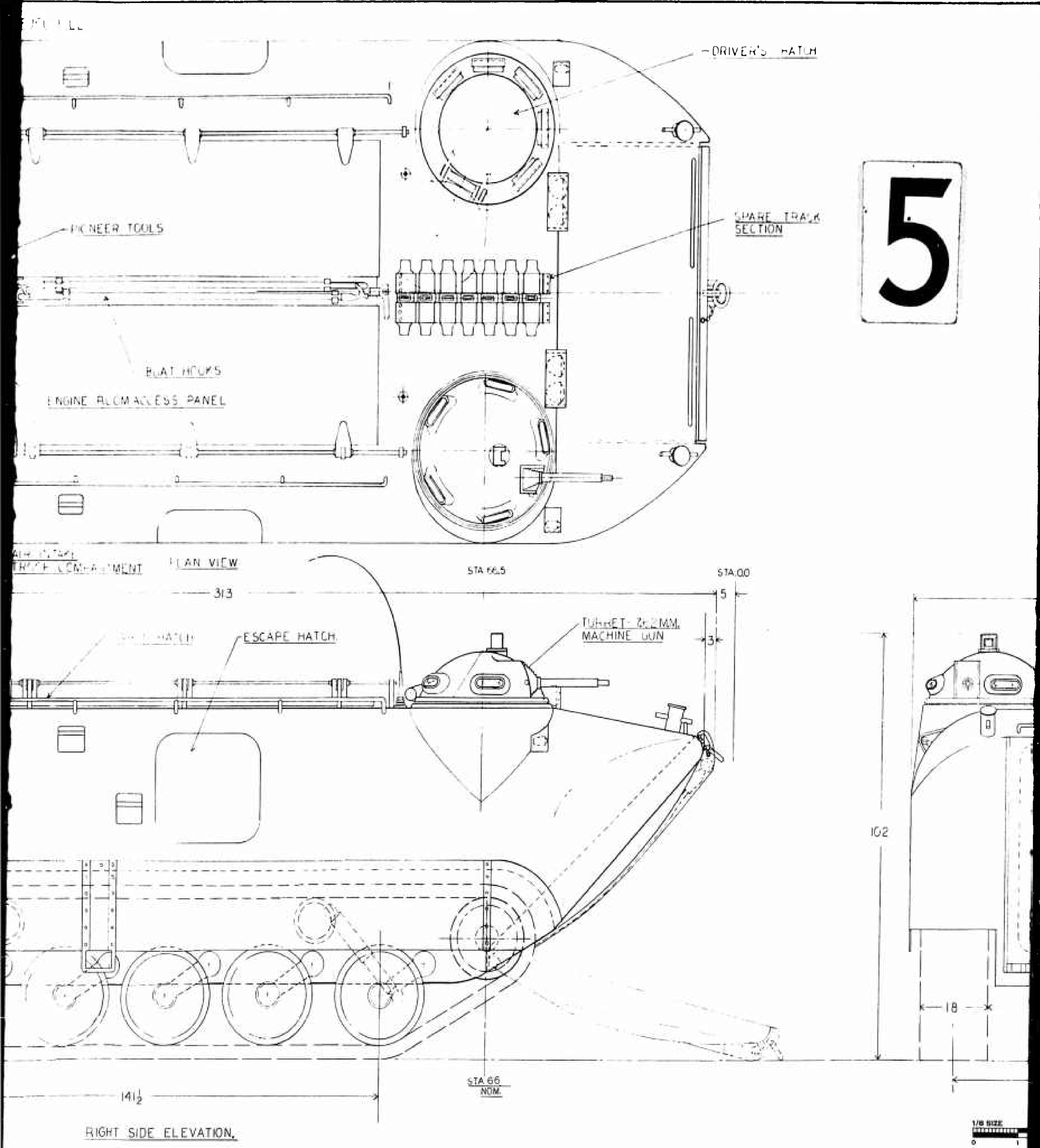
3





REAR VIEW


4
FUEL FILL
AIR EXHAUST
ENGINE EXHAUST
PIONEER TOOLS
CABLES TOWING APPX.
BOAT HOOKS
ENGINE ROOM ACCESS PANEL
DECK PULL STERN TOW RELEASE
STA 7.5
AIR INTAKE ENGINE ASPIRATION & COOLING.
PLAN VIEW
15
313
PROPELLER RETRACTED
STERN TOW CABLES-11FT.± C-C SHACKLES
7
66
STERN TOW RELEASE
49°
STA. 271
38½ NOM
141½
RIGHT SIDE ELEVATION



RIGHT SIDE ELEVATION.

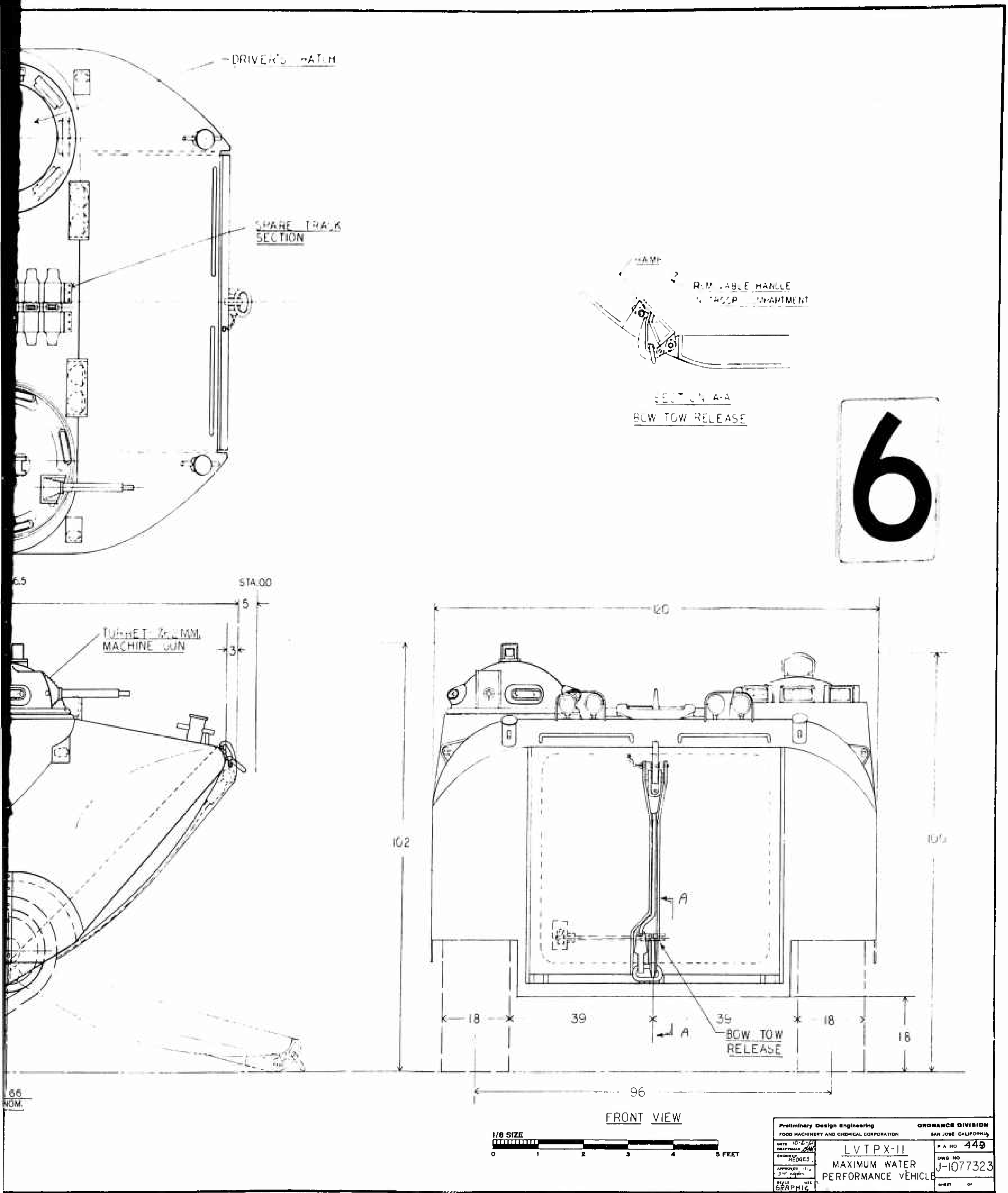

DRIVER'S HATCH
SPARE TRACK SECTION
SECTION A-A
BOW TOW RELEASE
6
STA. 0.0
5
3
MACHINE GUN
120
102
A
18
39
39
18
18
BOW TOW RELEASE
96
66 NOM.
FRONT VIEW
1/8 SIZE
0 1 2 3 4 5 FEET
Preliminary Design Engineering
FOOD MACHINERY AND CHEMICAL CORPORATION
ORDNANCE DIVISION
SAN JOSE CALIFORNIA
HEDGES
GRAPHIC
LVTPX-11
MAXIMUM WATER
PERFORMANCE VEHICLE
P.A. NO 449
DWG NO J-1077323

Figure 3.3.2

3.4 AREAS OF FURTHER DEVELOPMENT

In the performance of this study, it has been assumed that the LVTPX11 should be in production in 1965, as shown in Section IV. Using this assumption, a tentative development schedule was established which governed the degree to which new components could be recommended for this vehicle.

A team of FMC engineers visited OTAC and Aberdeen Proving Grounds and contacted industrial firms, such as Sundstrand, General Electric, Louis-Allis, and Lycoming, to realistically determine what new component development might add to the effectiveness of this vehicle. The Materials Branch of OTAC and the Ballistic Test Section of Aberdeen Proving Grounds were also visited to investigate the latest developments in the field of armor. This effort is in addition to the constant day-to-day monitoring of all fields for new ideas, which is a part of the FMC research policy.

The components selected, therefore, are the best possible choices to permit production of the LVTPX11 within the assumed time-frame. As discussed below, there are new and interesting possibilities in the fields of power trains, armor, and vehicle suspension. Detailed studies of these components have been included in the nature of appendixes to this report.

3.4.1 Drive Trains

A mechanical drive train has been selected for the LVTPX11. It consists of the Cummins V8-300 water-cooled diesel engine, the Allison XTG-250 power train and FMC designed final drives. An alternate drive train, comprised of the Lycoming AVM-625, diesel cycle, multifuel, air-cooled

Drive Trains (Continued)

engine, the Allison XTG-250, and FMC final drives. These power trains have been selected because they offer sound means of power transmission and because of the timely availability of the components.

However, study has also been devoted to electric, hydrostatic, and hydro-mechanical power trains because of their inherent advantages. The electric drive, in particular, offers:

- Better fuel economy
- Smoother operation
- Superior performance
- Simplified maintenance
- A source of auxiliary power

Considerable development work, requiring both time and money, remains to be done to insure the availability of any of these items. To meet the assumed development program, the power train chosen must be mechanical. Throughout this study, these items have been examined to determine their possible configuration and their compatability with the vehicle design. It is recommended that this field be monitored during the vehicle design phase for possible incorporation of an alternate power train in a prototype vehicle.

3.4.2 Suspension

3.4.2.1 Springing

As discussed in Section 3.8, FMC recommends that the walking-beam suspension shown in Figure 3.8.13 be further developed for incorporation in one of the prototype vehicles, so that direct comparisons may be made with other systems. It is known from the computer analysis completed during this study that the walking-beam suspension offers improved riding characteristics over certain types of terrain.

3.4.2.2 Tracks

To avoid the cost of development of an entirely new track, FMC recommends that the track currently being developed for the ARV XM551 be modified for use on the LVTPX11. These modifications will consist of redesign of the grouser bars, in the case of a band track, or the addition of waterwings to a block track, and are necessary to achieve the predicted water performance.

The ARV XM551 program includes the development of both a band and a block track. Present information on the program indicates that a 2,500-mile band track is progressing successfully, therefore, this track has been selected for the LVTPX11. Should this track prove unsuccessful during its testing and evaluation, FMC recommends that a lightweight block track be developed for the LVTPX11.

3.5 PERFORMANCE

3.5.1 Land Performance

Figure 3.5.1 is the horsepower-versus-speed curve for the recommended vehicles. Figure 3.5.2 is the tractive effort curve. These curves are based upon 550 lb ft input torque to the torque converter, as shown in the calculations included in Appendix D (Volume II).

The drive train ratios provide a balance between top speed, gradability, and cross-country operation. A summary of the predicted land performance is given below:

Gross hp-to-weight ratio	17.1 hp/ton
Maximum tractive effort (locked tracks)	40,500 lbs
Maximum speeds	
Level road	40 mph
70% slope	2-1/2 mph
8% slope	17 mph
Trench crossing ability	8 feet
Obstacle climbing ability	29 inches

3.5.2 Water Performance

The hull resistances determined by model testing at the FMC Tow Basin and the calculations included in Appendix E (Volume II) indicate that the "Maximum Armored Vehicle" will achieve a top speed of 7 to 7-1/2 mph, and the "Maximum Water Performance Vehicle" will achieve 9 to 9-1/2 mph water speed.

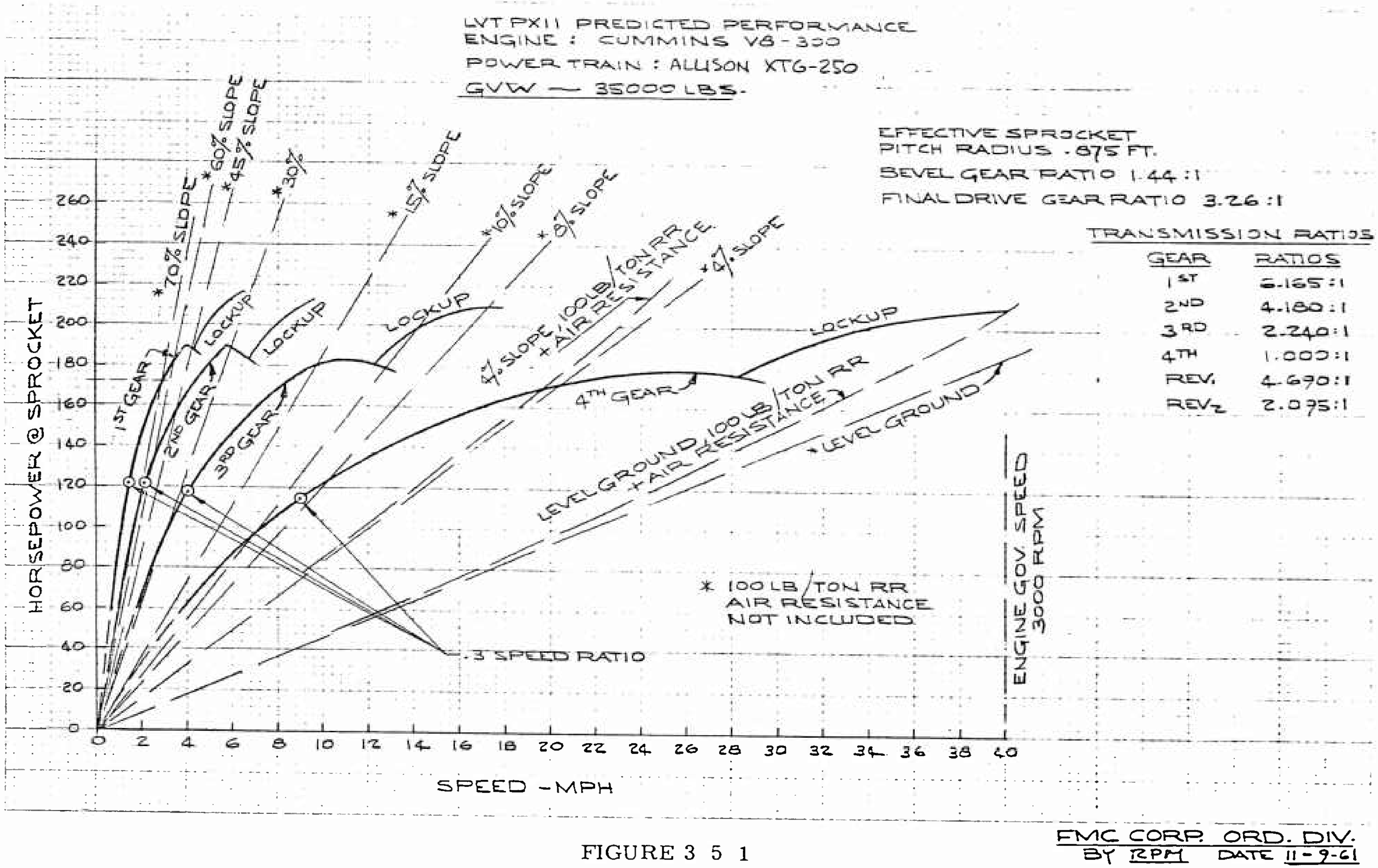
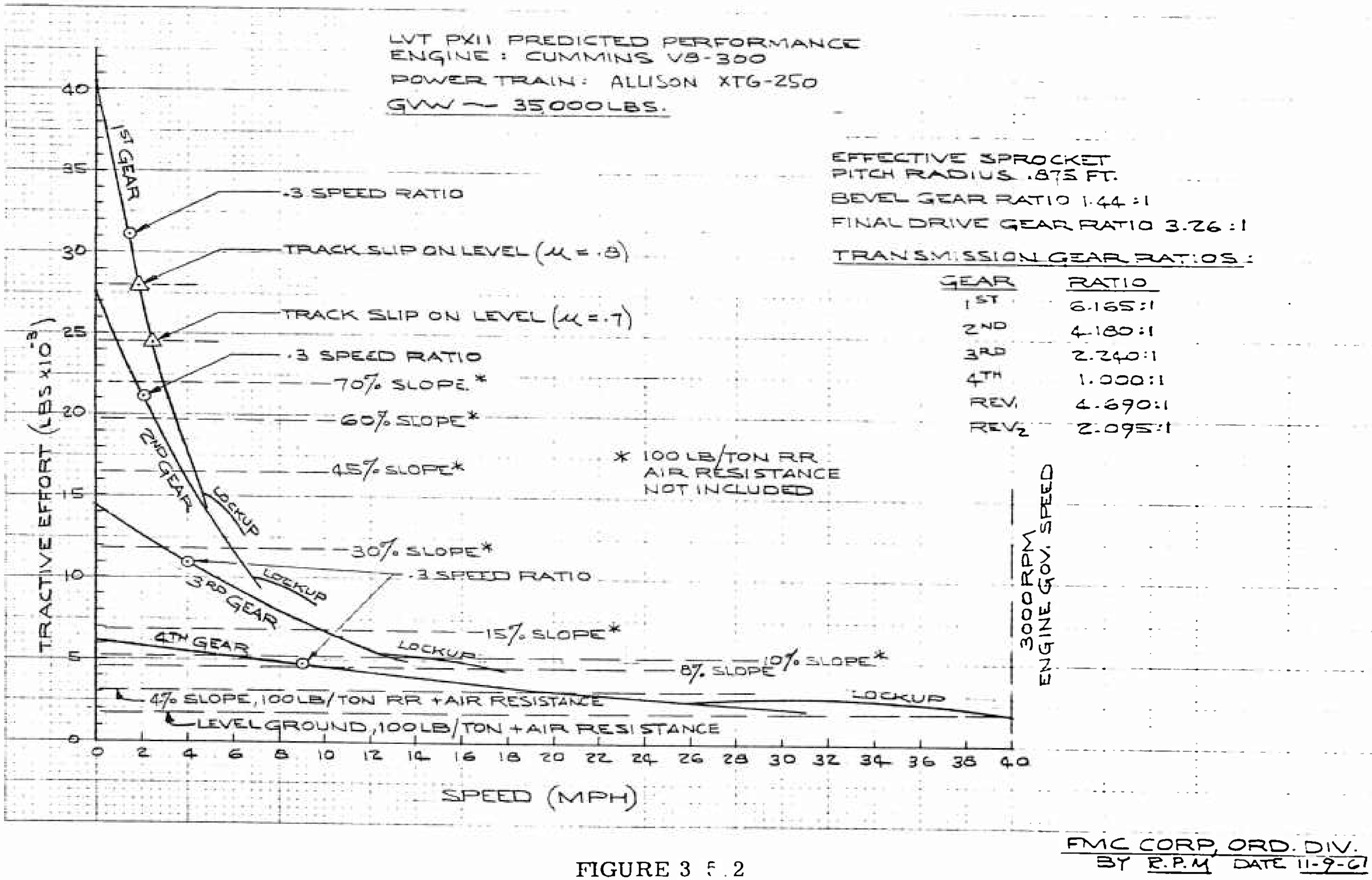

LVT PX11 PREDICTED PERFORMANCE
ENGINE : CUMMINS V8-300
POWER TRAIN : ALLISON XTG-250
GVW — 35000 LBS.
EFFECTIVE SPROCKET PITCH RADIUS .875 FT.
BEVEL GEAR RATIO 1.44:1
FINAL DRIVE GEAR RATIO 3.26:1
TRANSMISSION RATIOS
GEAR RATIOS
1ST 6.165:1
2ND 4.180:1
3RD 2.240:1
4TH 1.000:1
REV1 4.690:1
REV2 2.075:1
*70% SLOPE
*60% SLOPE
*45% SLOPE
*30%
*15% SLOPE
*10% SLOPE
*8% SLOPE
4% SLOPE, 100 LB/TON RR + AIR RESISTANCE
*4% SLOPE
1ST GEAR
2ND GEAR
3RD GEAR
4TH GEAR
LOCKUP
LEVEL GROUND, 100 LB/TON RR + AIR RESISTANCE
*LEVEL GROUND
.3 SPEED RATIO
* 100 LB/TON RR AIR RESISTANCE NOT INCLUDED
ENGINE GOV. SPEED 3000 RPM
HORSEPOWER @ SPROCKET
SPEED - MPH
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
0 20 40 60 80 100 120 140 160 180 200 220 240 260
FMC CORP. ORD. DIV.
BY RPM DATE 11-9-61

FIGURE 3 5 1



LVT PXII PREDICTED PERFORMANCE
ENGINE: CUMMINS V8-300
POWER TRAIN: ALLISON XTG-250
GVW ~ 35,000 LBS.
EFFECTIVE SPROCKET PITCH RADIUS .875 FT.
BEVEL GEAR RATIO 1.44:1
FINAL DRIVE GEAR RATIO 3.26:1
TRANSMISSION GEAR RATIOS:
GEAR RATIO
1ST 6.165:1
2ND 4.180:1
3RD 2.240:1
4TH 1.000:1
REV1 4.690:1
REV2 2.095:1
1ST GEAR
2ND GEAR
3RD GEAR
4TH GEAR
LOCKUP
.3 SPEED RATIO
TRACK SLIP ON LEVEL (μ = .8)
TRACK SLIP ON LEVEL (μ = .7)
70% SLOPE*
60% SLOPE*
45% SLOPE*
30% SLOPE*
15% SLOPE*
10% SLOPE*
8% SLOPE
4% SLOPE, 100 LB/TON RR + AIR RESISTANCE
LEVEL GROUND, 100 LB/TON + AIR RESISTANCE
* 100 LB/TON RR AIR RESISTANCE NOT INCLUDED
3000 RPM ENGINE GOV. SPEED
TRACTIVE EFFORT (LBS x10^-3)
SPEED (MPH)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
0 5 10 15 20 25 30 35 40
FMC CORP, ORD. DIV.
BY R.P.M. DATE 11-9-61

FIGURE 3 5.2

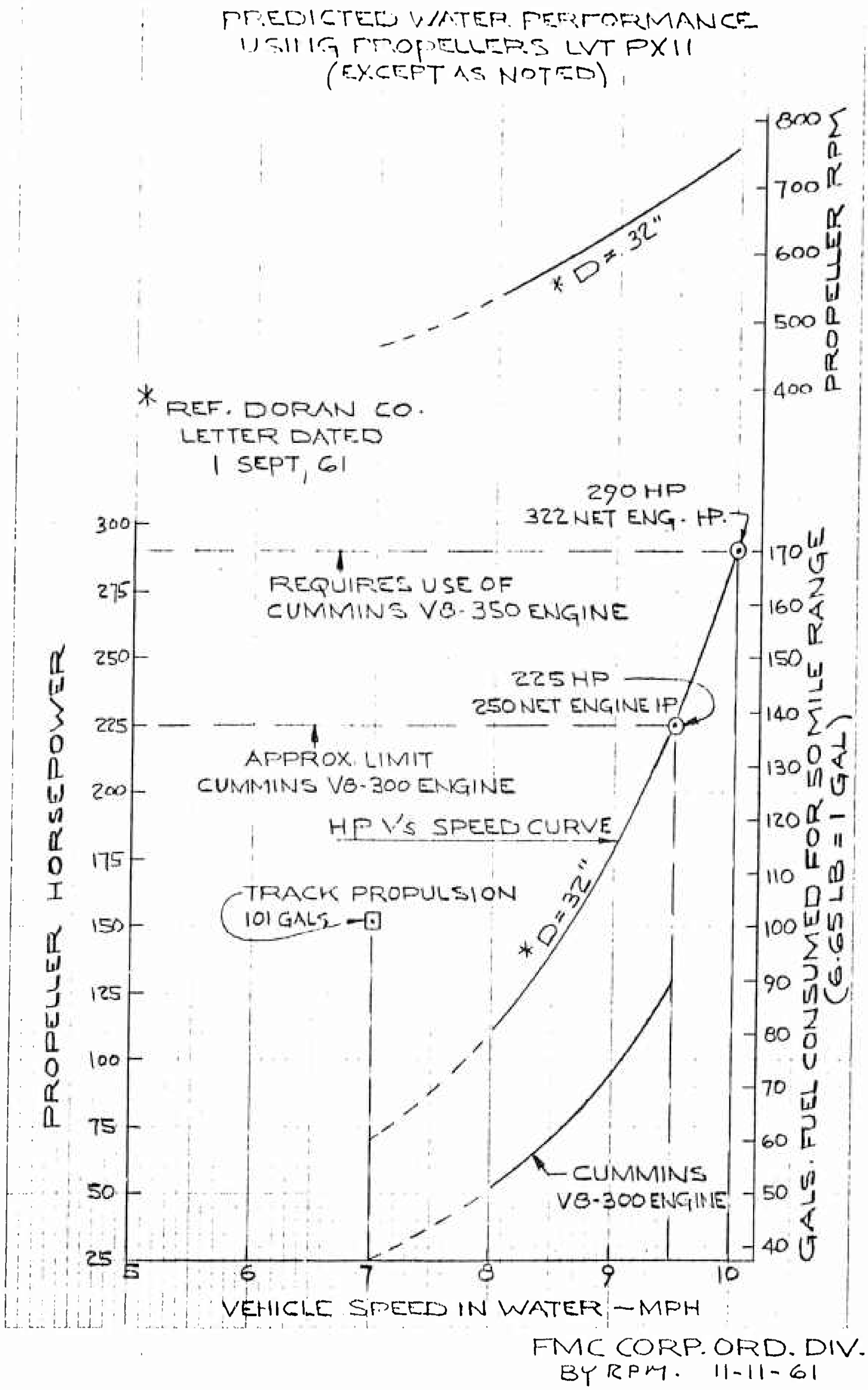

PREDICTED WATER PERFORMANCE
USING PROPELLERS LVT PX11
(EXCEPT AS NOTED)
* REF. DORAN CO.
LETTER DATED
1 SEPT, 61
* D=32"
290 HP
322 NET ENG. HP.
REQUIRES USE OF
CUMMINS V8-350 ENGINE
225 HP
250 NET ENGINE HP
APPROX. LIMIT
CUMMINS V8-300 ENGINE
HP V'S SPEED CURVE
TRACK PROPULSION
101 GALS
CUMMINS
V8-300 ENGINE
PROPELLER HORSEPOWER
PROPELLER RPM
GALS. FUEL CONSUMED FOR 50 MILE RANGE
(6.65 LB = 1 GAL)
VEHICLE SPEED IN WATER — MPH
FMC CORP. ORD. DIV.
BY RPM. 11-11-61

FIGURE 3 5 3

Water Performance (Continued)

To demonstrate the predicted water performance of these vehicles, a 16mm motion picture film of the tow tests is included as Appendix G, under separate cover.

These maximum speeds are established by the power limitation of 250 net engine hp, the maximum requirement for land operation, although the engine is capable of producing up to 322 net hp in its turbocharged version.

Figure 3.5.3 shows the predicted water performance with the Cummins V8-300 engine and mechanical power train.

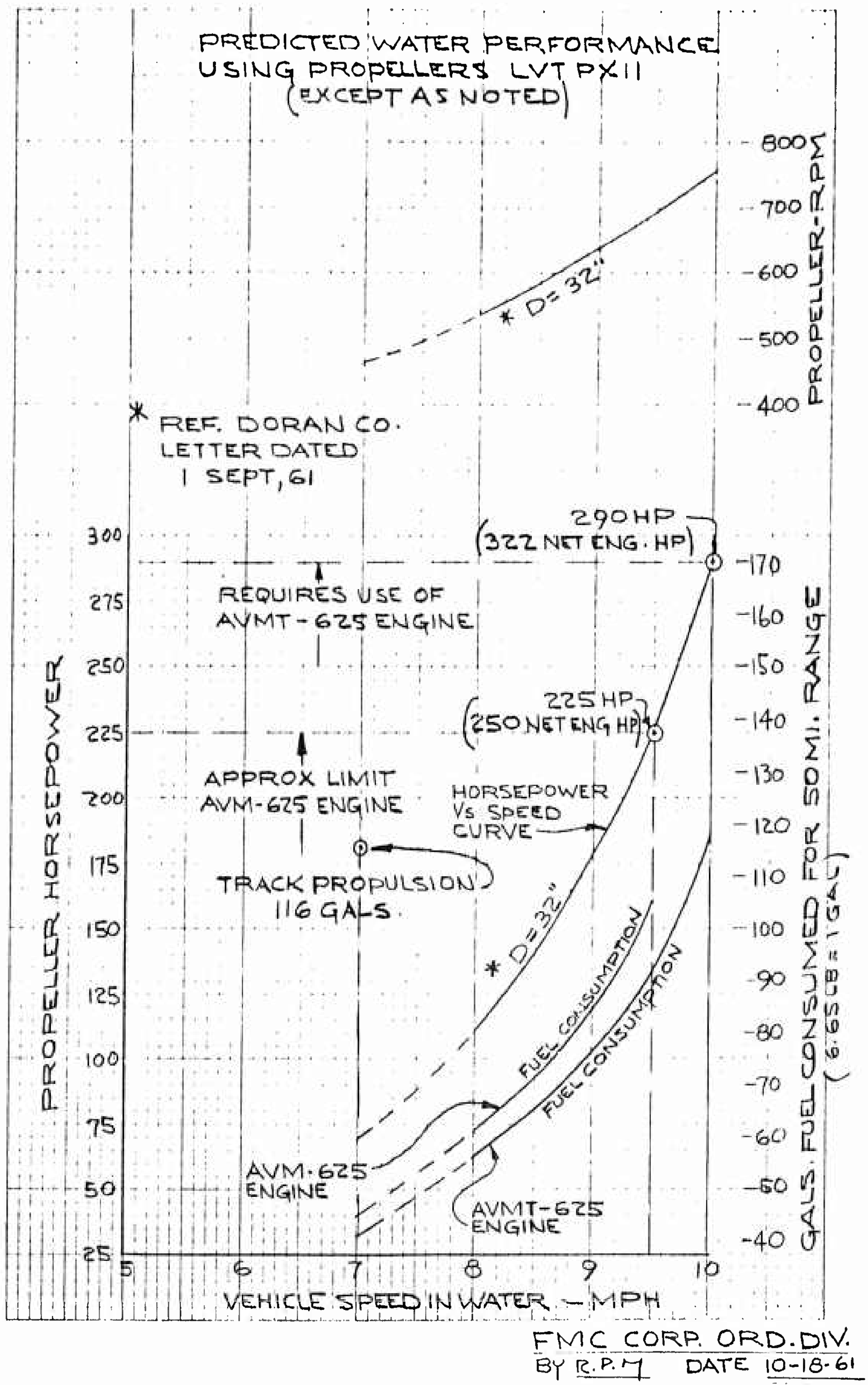
Figure 3.5.4 shows the predicted water speeds of the LVTPX11 with both the turbocharged and nonturbocharged Lycoming engines. The turbocharged engine permits water speeds of 10 mph for the "Maximum Water Performance Vehicle", but the XTG-250 transmission requires modification to accept the increased horsepower, since it has a 250 hp limit. Also, a means to limit the horsepower to the 250 net engine hp must be incorporated for land operation, to protect the rest of the power train.

3.5.3 Fuel Consumption

- Land

  To obtain the specified 250-mile land range for the LVTPX11 equipped with the Cummins engine, 125 gallons of fuel is provided. This capacity has been calculated using the average of the requirements for the 25 mph operating conditions given below:

  - 25 mph on level road - 84 gallons
  - 25 mph at maximum power - 169 gallons



PREDICTED WATER PERFORMANCE
USING PROPELLERS LVT PX11
(EXCEPT AS NOTED)
* REF. DORAN CO. LETTER DATED 1 SEPT, 61
* D=32"
290 HP (322 NET ENG. HP)
225 HP (250 NET ENG HP)
REQUIRES USE OF AVMT-625 ENGINE
APPROX LIMIT AVM-625 ENGINE
HORSEPOWER Vs SPEED CURVE
TRACK PROPULSION 116 GALS.
FUEL CONSUMPTION
FUEL CONSUMPTION
AVM-625 ENGINE
AVMT-625 ENGINE
PROPELLER HORSEPOWER
PROPELLER-RPM
GALS. FUEL CONSUMED FOR 50 MI. RANGE (6.65 LB = 1 GAL)
VEHICLE SPEED IN WATER — MPH
FMC CORP. ORD. DIV.
BY R.P.M DATE 10-18-61

FIGURE 3.5.4

Fuel Consumption (Continued)

It has been assumed that the average operating condition will be somewhere between the two extreme conditions listed above. Supporting calculations are included in Appendix D (Volume II).

- Water

  The "Maximum Armored Vehicle" will have a range of 62 miles when equipped with the Cummins engine and 125 gallons of fuel, and a range of 65 miles when equipped with the Lycoming engine and 150 gallons of fuel, as shown in Figures 3.5.3 and 3.5.4.

  The "Maximum Water Performance Vehicle", due to the difference in propulsive efficiency, will have a range of 78 miles when equipped with the Cummins engine and 125 gallons of fuel. At speeds less than the 9-1/4 maximum, this range will increase (e.g., at 7-1/4 mph, it is 156 miles). When equipped with the Lycoming engine and 150 gallons of fuel, the above ranges are 85 miles and 160 miles, respectively.

3.6 HULL

As a result of this study, the welded aluminum hull configuration shown in Figure 3.6.3 is utilized for the LVTPX11. The hull lines were established after careful consideration of land capabilities, water performance, and armor protection.

The alternate approach shown in Figure 3.6.4 offers a hull with improved hydrodynamic characteristics: however, this shape results in increased fabrication costs and decreased armor protection, the decrease being due to the 1,500 lb weight of the propeller drive penalizing the armor rather than the 6,000 lb payload capability or the 35,000 lb GVW.

3.6.1 Hull Weight

Since the "Development Characteristic" specified a target Gross Vehicle Weight of 35,000 lb, FMC investigated the weight area to determine if this was also the optimum weight for the LVTPX11

In the current development of power trains and suspension components for military vehicles, there are two "breakpoints" in Gross Vehicle Weight limits for vehicle components in the LVTPX11 weight range. One group of components has a 35,000 lb GVW limitation, and the next group is for vehicles weighing over 42,000 lb GVW. A vehicle with a GVW between 35,000 and 42,000 lb would naturally require the heavier components. Between the two groups, the difference in weight of the power train and suspension components is approximately 3,000 lb. This means that, with equal hull weight, a 38,000 lb vehicle does not provide any more payload capability than a 35,000 lb vehicle. Therefore, the specified target weight

	VEHICLE "A"	VEHICLE "B"	VEHICLE "C"	VEHICLE "D"	VEHICLE "E"	VEHICLE "F"	VEHICLE "G"
GROSS VEHICLE WEIGHT (LB)	30, 125	35, 000	35, 000	35, 000	35, 000	42, 000	42, 000
HULL WEIGHT (LB)	5, 800	5, 800	10, 675	12, 675	14, 675	14, 700	18, 700
PAYLOAD CAPACITY (LB)	10, 000	14, 875	10, 000	8, 000	6, 000	10, 000	6, 000
RANGE OF HULL PLATE THICKNESS (IN.)	Maximum of 1/4	Maximum of 1/4	3/8 - 3/4	1/2 - 1	1/2 - 1-1/2	1/2 - 1-1/2	3/4 - 2

FIGURE 3. 6. 1 ARMOR VS PAYLOAD COMPARISONS
TRACK PROPELLED VEHICLES

	VEHICLE "H"	VEHICLE "J"	VEHICLE "K"	VEHICLE "L"	VEHICLE "M"	VEHICLE "N"	VEHICLE "P"
GROSS VEHICLE WEIGHT (LB)	31, 300	35, 000	35, 000	35, 000	35, 000	42, 000	42, 000
HULL WEIGHT (LB)	5, 800	5, 800	9, 500	11, 500	13, 500	13, 500	17, 500
PAYLOAD CAPACITY (LB)	10, 000	13, 700	10, 000	8, 000	6, 000	10, 000	6, 000
RANGE OF HULL PLATE THICKNESS (IN.)	Maximum of 1/4	Maximum of 1/4	3/8 - 5/8	1/2 - 7/8	1/2 - 1-1/4	1/2 - 1-1/4	3/4 - 1-3/4

FIGURE 3. 6. 2 ARMOR VS PAYLOAD COMPARISONS
PROPELLER DRIVEN VEHICLES

Hull Weight (Continued)

of 35,000 lb has been accepted as the desirable limit.

In conjunction with the Operations Analysis, Section 3.1, and the Armor Analysis, Appendix H (Volume III), the area of payload capability-versus-armor protection was examined for possible trade-offs. These trade-offs are summarized in Figure 3.6.1. The hull dimensions used for this comparison are given in Figure 3.6.3 and represent a vehicle using the tracks for both land and water propulsion. Because the study conclusions are presented as two complete vehicle concepts, one utilizing a propeller for water operation and the other utilizing tracks, a further comparison is shown in Figure 3.6.2 for the propeller-driven concept. The vehicle overall size is the same as shown in Figure 3.6.4.

Vehicle "A", Figure 3.6.1, presents an unarmored vehicle with the hull weight of 5,800 lb based upon the structural requirements alone. With an allowance of 10,000 lb payload, Vehicle "A" would have a GVW of 30,125 lbs.

Since Vehicles "A" through "E", Figure 3.6.1, utilize the same power train and suspension, the vehicle described above can be projected further by allowing 14,875 lb for payload, thus having a 35,000 lb GVW. This is Vehicle "B" in the table. To provide the maximum possible armor, while maintaining both the 10,000 lb payload capability and the 35,000 lb GVW, the hull weight can be increased to 10,675 lb, thus permitting a maximum hull plate thickness of 3/4 inch, as shown for Vehicle "C".

Vehicles "D" and "E" both show the results of trading payload capacity for armor protection. Vehicle "D" permits a maximum plate thickness of 1

Hull Weight (Continued)

inch and has a payload capacity of 8,000 lb. Vehicle "E", with a plate thickness of 1-1/2 inches, has a 6,000 lb payload capacity.

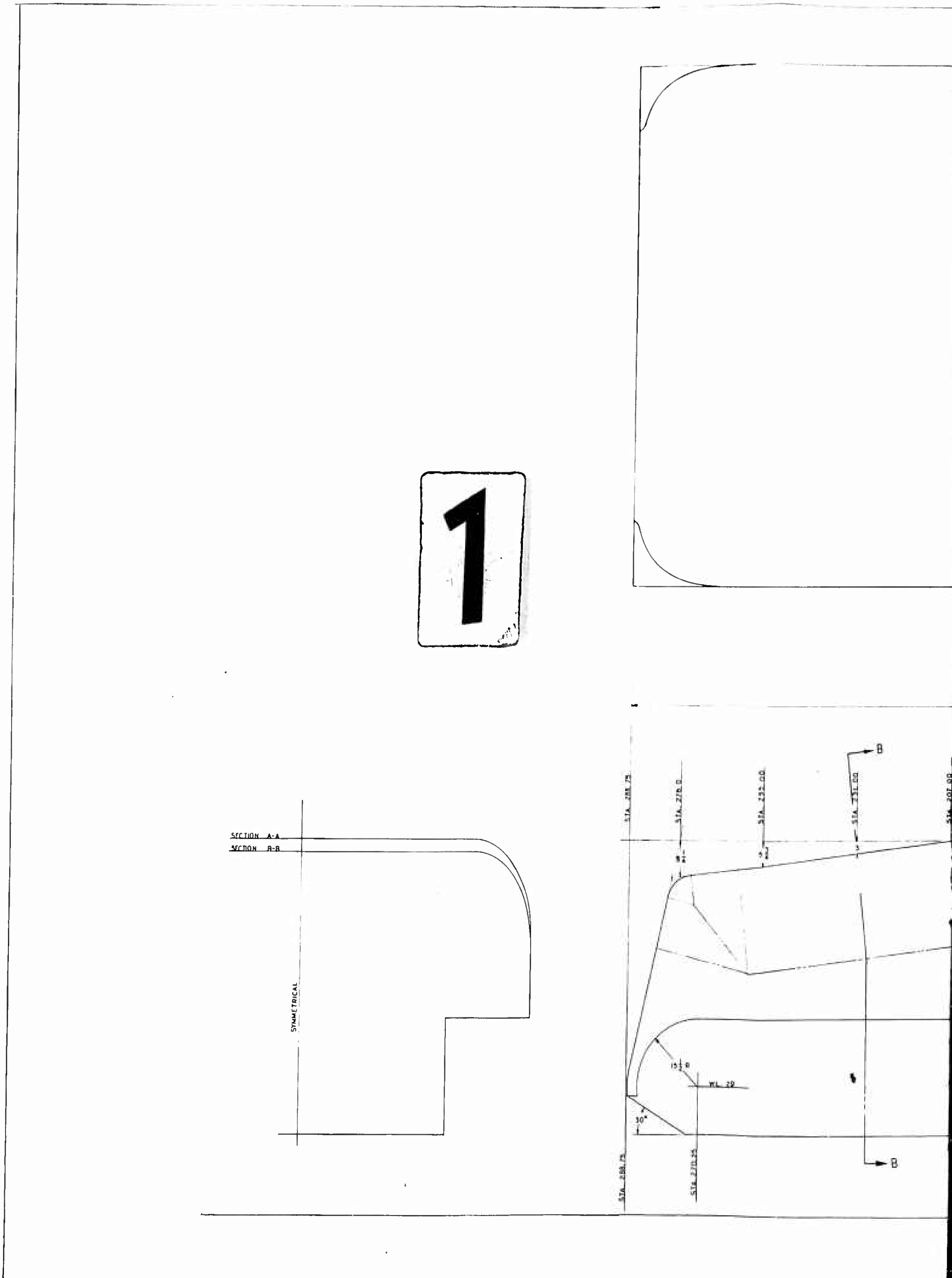
Vehicles "F" and "G", with 42,000 lb GVW's, utilize heavier power trains and suspension components than the other vehicles shown in Figure 3.6.1. Vehicle "F" offers a 10,000 lb payload capacity but has not permitted any increase in the degree of armor protection. Vehicle "G" permits a plate thickness of 2 inches and maintains the 42,000 lb GVW, but has decreased the payload capacity to 6,000 lb.

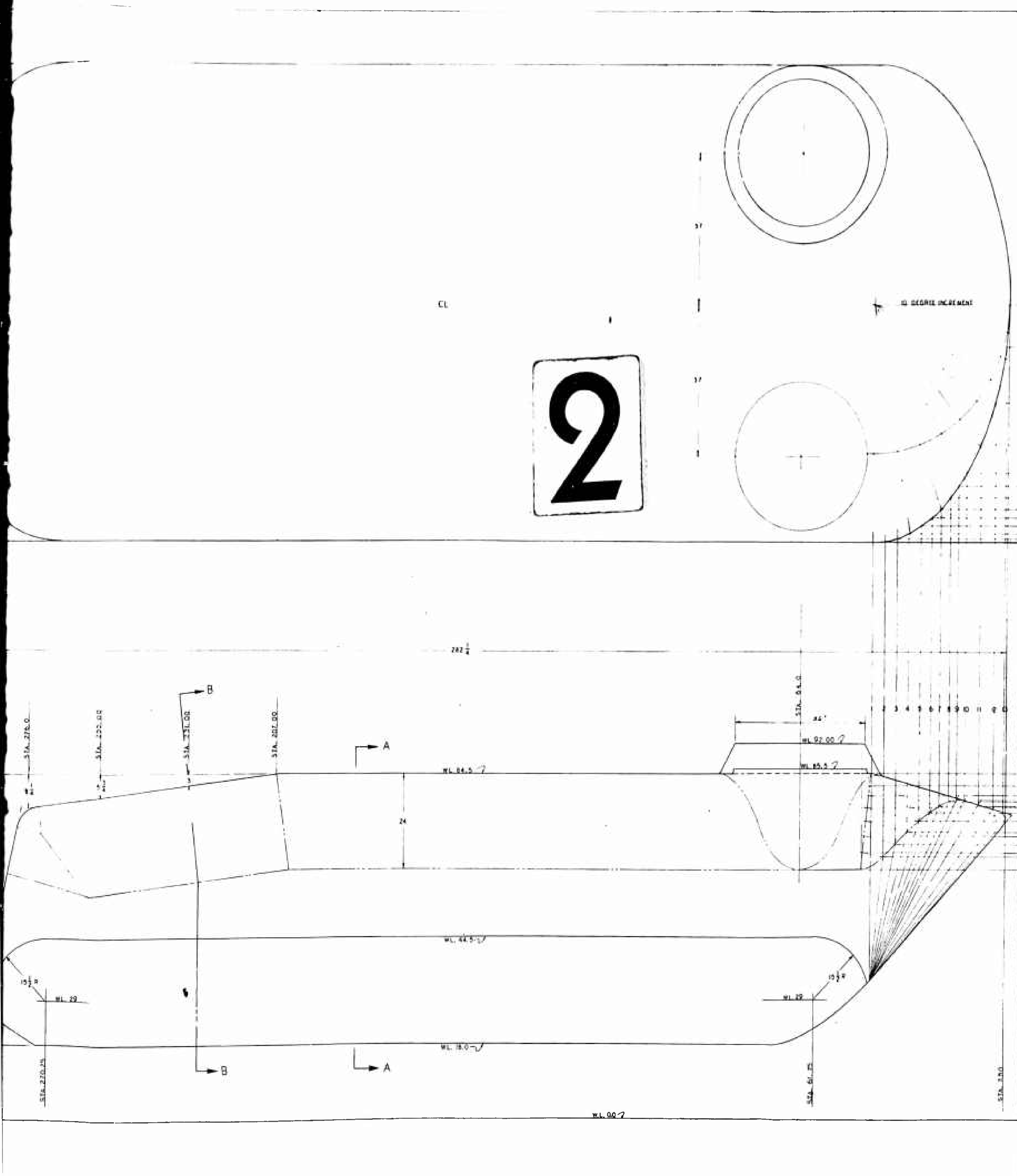
The comparisons in table 3.6.2 charge the 1,500 lb propeller-drive weight to the hull allowance, except for the minimum-weight hulls shown for Vehicles "H" and "J".

The results of the Armor Analysis, Appendix H (Volume III), and the weight trade-offs described above led to selection of the vehicles shown in Figures 3.2.2 and 3.3.2. Figure 3.2.2, the "Maximum Armored Vehicle", is shown in Figure 3.6.1 as Vehicle "E", and the "Maximum Water Performance Vehicle" is shown in Figure 3.6.2 as Vehicle "M".

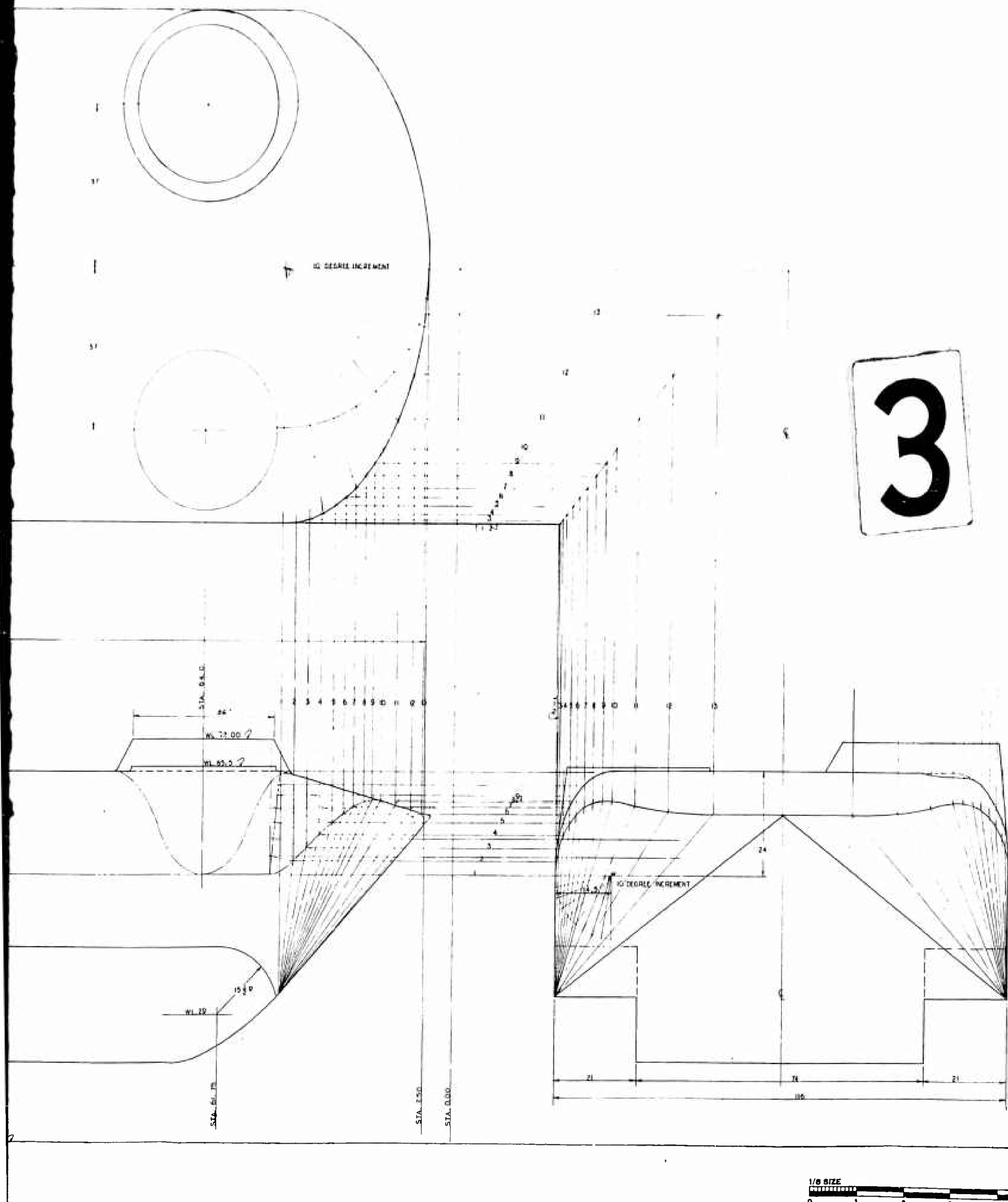
The trade-off in payload capacity for armor thickness was made for the following reasons:

- The weight of 27 fully equipped troops (5,940 lb) is less than the 6,000 lb capacity provided.
- Under emergency conditions, either of the recommended vehicles could carry up to 10,000 lb payload, at a reduced performance level.


1
SECTION A-A
SECTION B-B
SYMMETRICAL
STA 288.75
STA 276.0
STA 252.00
STA 231.00
B
B
15½ R
WL 29
30°
STA 288.75
STA 270.25



CL
2
10 DEGREE INCREMENT
282 1/4
STA. 276.0
STA. 231.00
STA. 207.00
STA. 64.0
WL 92.00
WL 85.5
WL 84.5
24
WL 44.5
15 1/2 R
WL 29
WL 18.0
A
B
STA. 270.25
STA. 61.75
STA. 350
W.L. 00



10 DEGREE INCREMENT
STA. 84.0
WL 71.00
WL 85.5
10 DEGREE INCREMENT
WL 29
STA. 61.75
STA. 2.50
STA. 0.00
21
74
21
106
1/8 SIZE
0 1 2 3 4 5 FEET

3

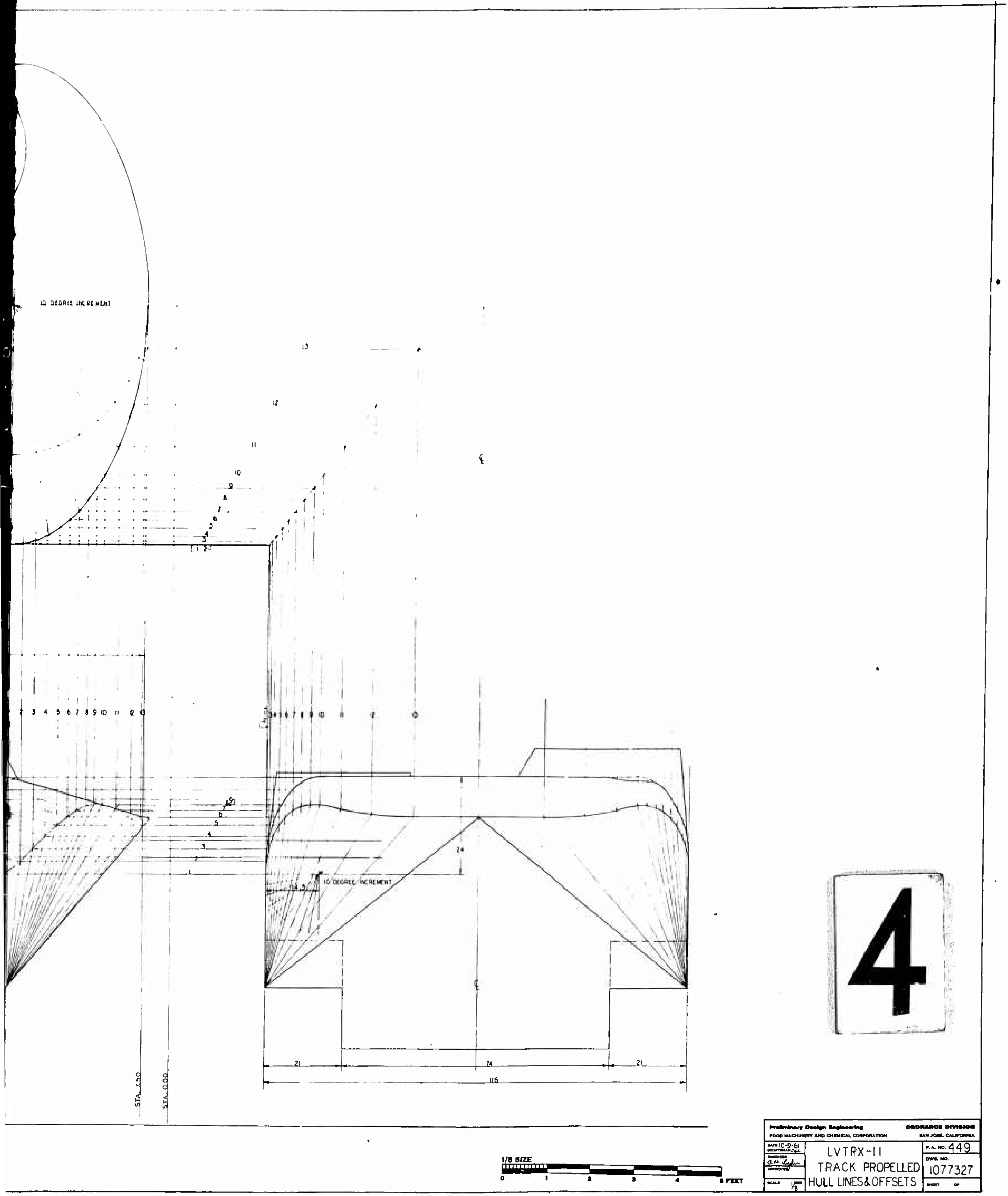
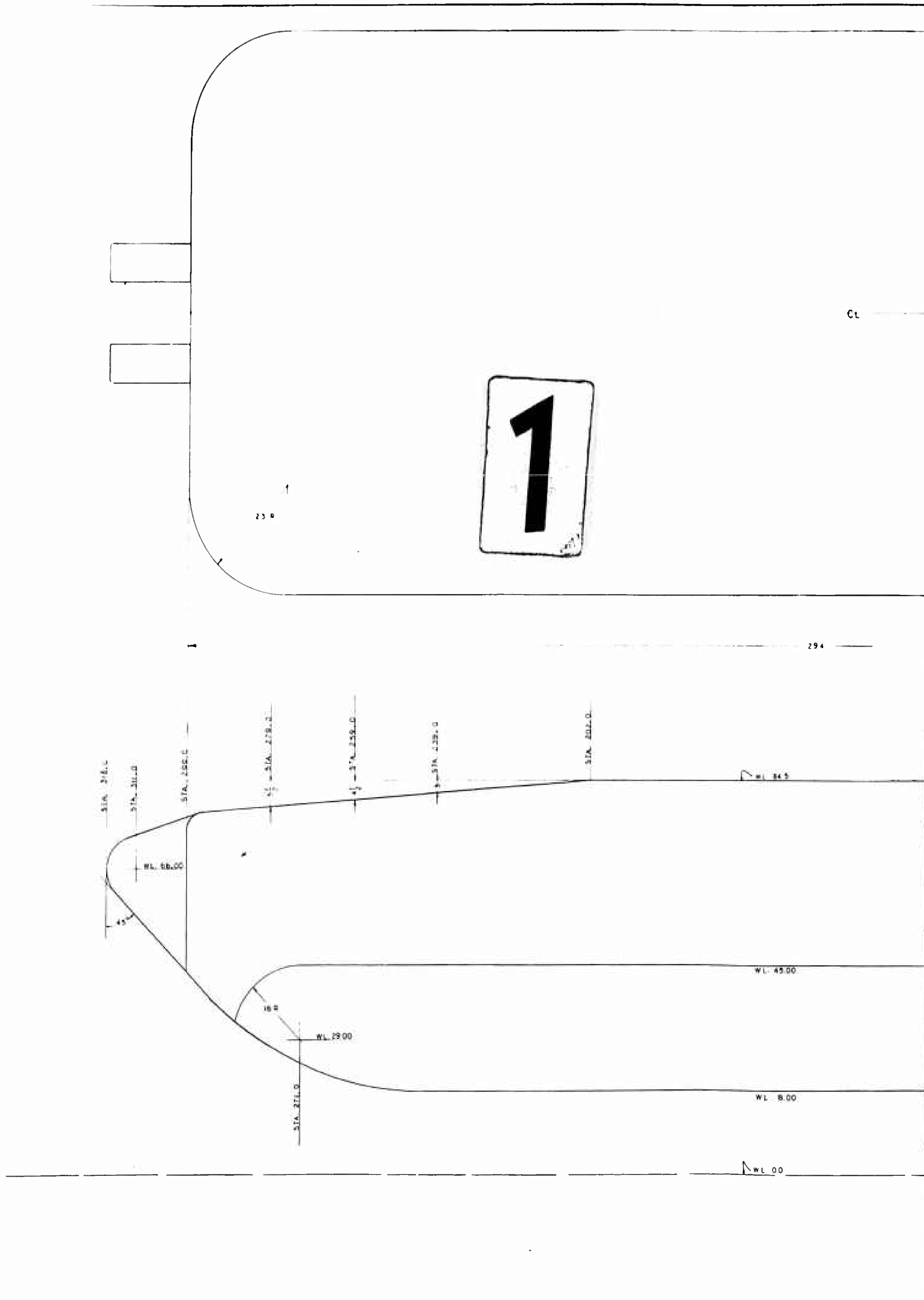
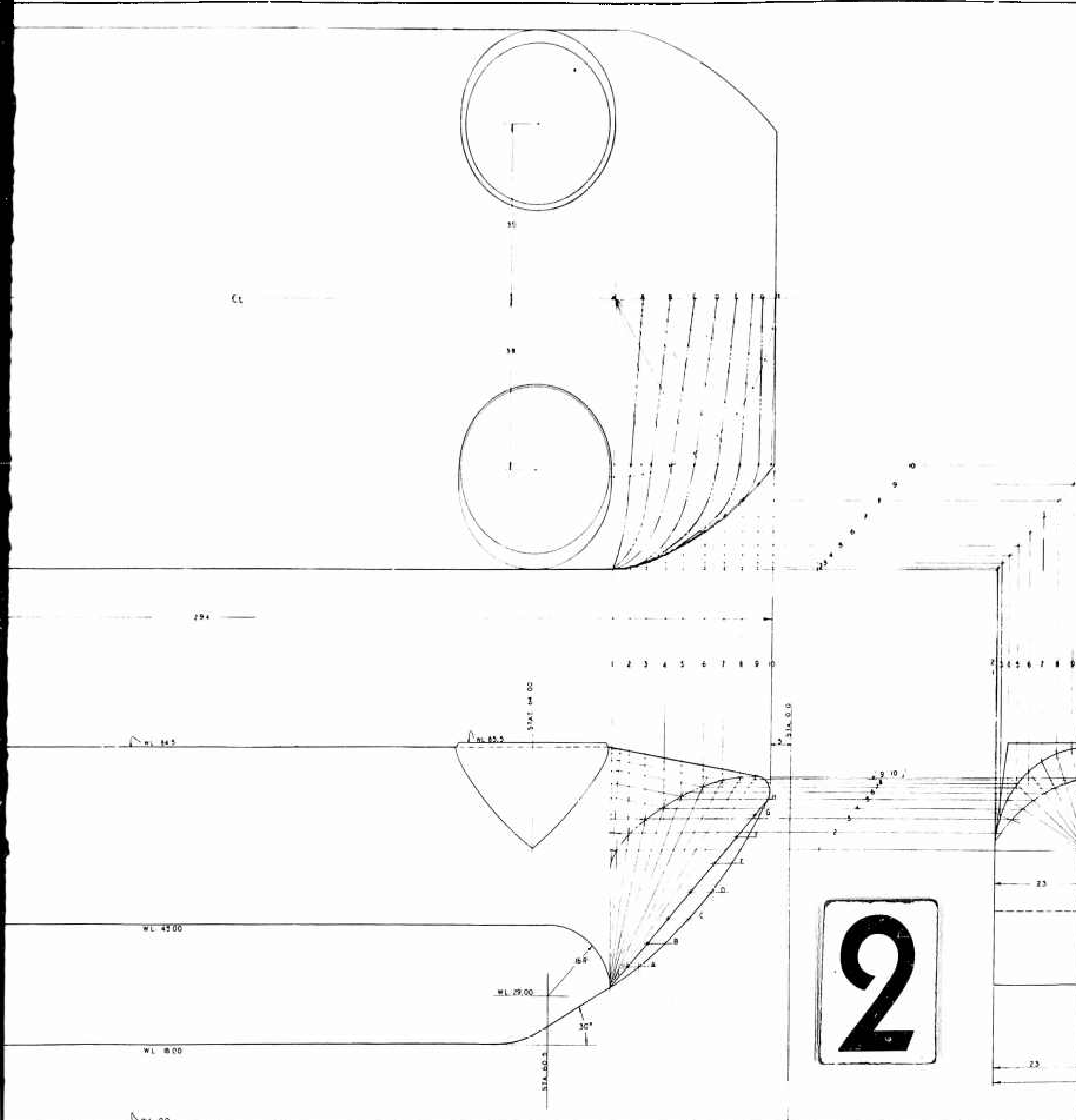
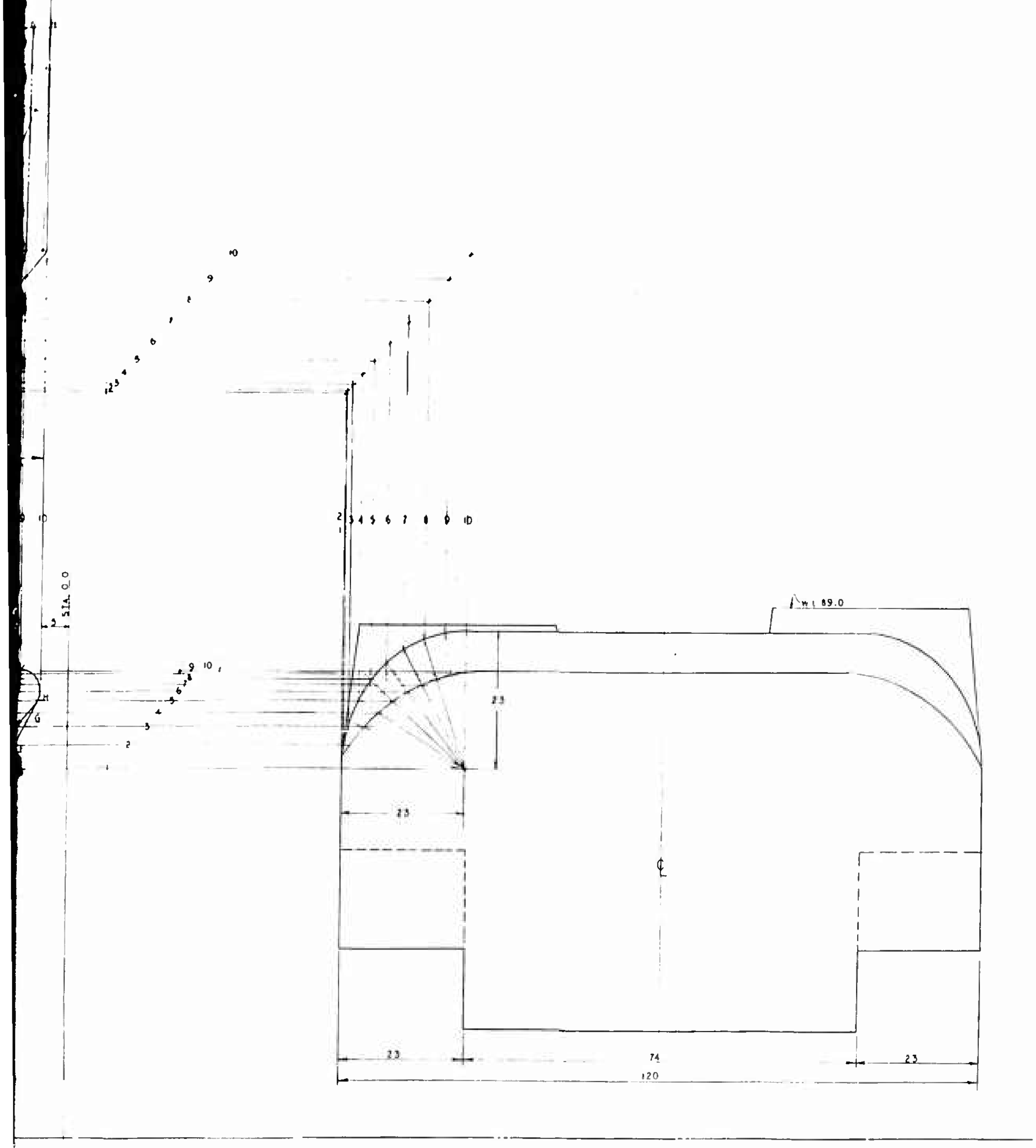

10 DEGREE INCREMENT
STA 7.50
STA 0.00
10 DEGREE INCREMENT
24
21
74
21
116
1/8 SIZE
0
1
2
3
4
5 FEET
4
Preliminary Design Engineering
FOOD MACHINERY AND CHEMICAL CORPORATION
ORDNANCE DIVISION
SAN JOSE, CALIFORNIA
DATE 10-9-61
DRAFTSMAN
ENGINEER
APPROVED
SCALE 1/8
LVTPX-11
TRACK PROPELLED
HULL LINES & OFFSETS
P. A. NO. 449
DWG. NO. 1077327
SHEET OF

Figure 3.6.3


CL
294
STA. 316.0
STA. 311.0
STA. 290.0
STA. 279.0
STA. 259.0
STA. 239.0
STA. 202.0
WL 84.5
WL 66.00
45°
WL 45.00
WL 29.00
STA. 271.0
WL 8.00
WL 00


CL
294
WL 45.00
WL 29.00
WL 18.00
WL 00
16R
30°
2



3

1/8 SIZE
0 1 2 3 4 5 FEET

Preliminary Design Engineering FOOD MACHINERY AND CHEMICAL CORPORATION		**ORDNANCE DIVISION** SAN JOSE, CALIFORNIA
DATE DRAFTSMAN JA	LVTPX-11	P A NO 934
ENGINEER	PROPELLER DRIVEN	DWG NO 1077326
APPROVED	HULL LINES & OFFSET	
SCALE SIZE		SHEET OF

Figure 3.6.4

3.6.2 Armor

A thorough analysis of armor was conducted to determine the choice of material for the hull. To make this selection, recourse had to be made to classified material to evaluate the degree of ballistic protection that could be provided. To avoid placing a security classification on the entire report, this material is included under separate cover as Appendix H, Volume III.

In this analysis, the following materials were investigated.

- Steel
- Aluminum alloys
- Magnesium-Lithium alloy
- Titanium
- Nonmetallic armors
- Composite armors

These materials were evaluated on the basis of:

- Cost
- Availability during a national emergency
- Ease of fabrication
- Corrosion resistance

As analyzed in Appendix H, aluminum is recommended as the primary material for the hull due to its lighter weight, greater rigidity, and additional protection against fragmentation. Figure 3.6.5 shows the degree of aluminum armor that could be provided for the "Maximum Armored Vehicle" without exceeding the 35,000 lb GVW. This provides 1-1/2-inch-thick aluminum through the bow, stern, sides, and deck areas. The bottom is of 1-inch aluminum and the sponson plates are of 1/2-inch aluminum.

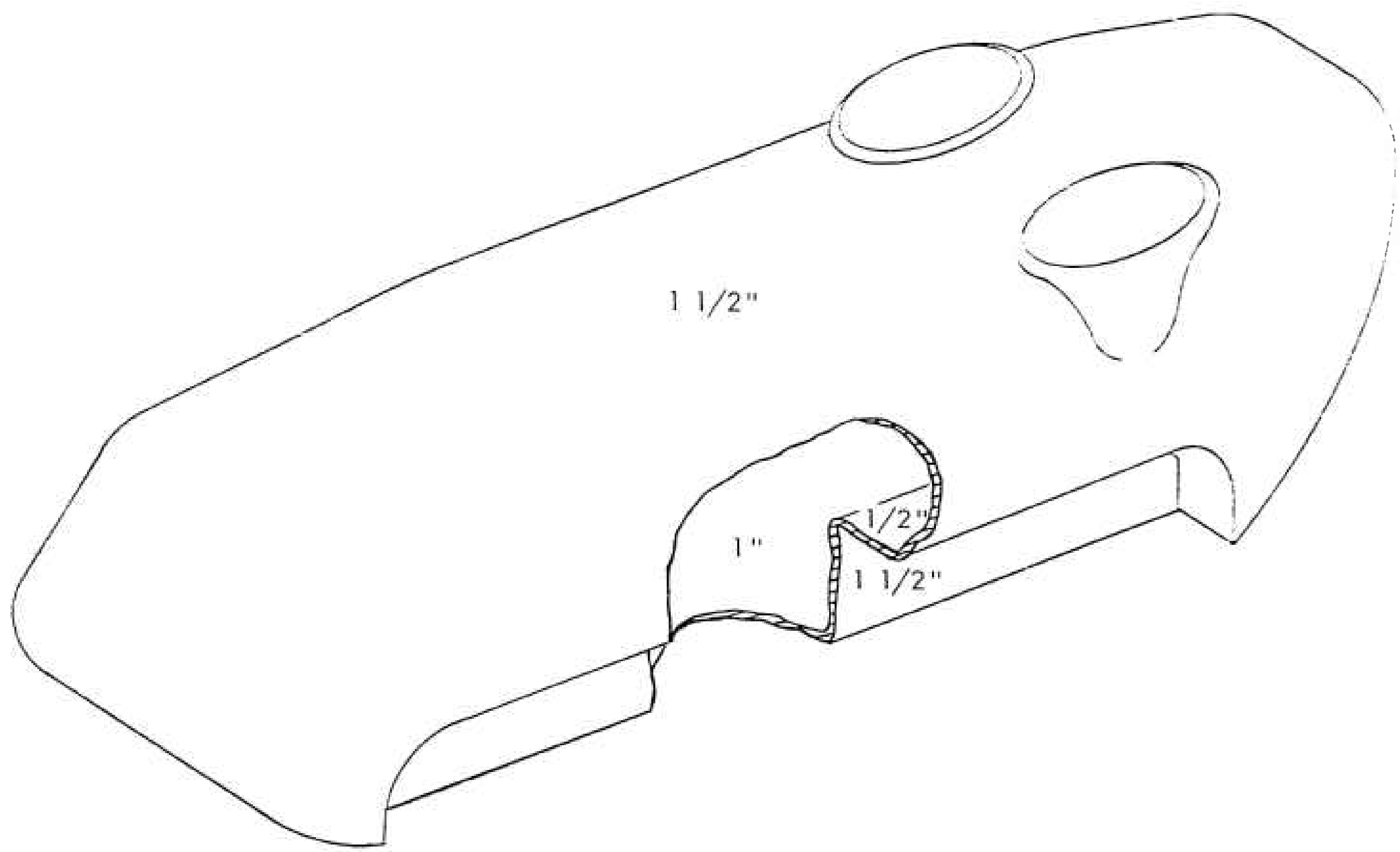


FIGURE 3 6.5 MAXIMUM ARMORED VEHICLE
WITH ALUMINUM ARMOR

Armor (Continued)

Figure 3.6.6 shows the degree of composite armor of aluminum and titanium and zig-zag armor of aluminum and steel that could be provided. The equivalent thicknesses of aluminum armor are shown. The composite armor is shown in the typical section of the vehicle, Figure 3.6.7, with the zig-zag armor shown in Figure 3.6.8.

The "Maximum Water Performance Vehicle" is shown in Figure 3.6.9. Aluminum armor can be provided to the degree shown. Figure 3.6.10 shows the equivalent aluminum thicknesses of composite aluminum-and-titanium armor and of aluminum-and-steel zig-zag armor.

3.6.3 Hull Structure

3.6.3.1 Hull Lines

The basic hull shapes shown in Figures 3.6.3 and 3.6.4 evolved as a compromise between the land and water performance factors specified in the "Development Characteristics". Scale models have been built and tested in the FMC Tow Basin to verify performance of the configurations shown.

The "Maximum Armored Vehicle" hull dimensions were established as follows:

- Length - the 285-inch (23'-9") length is the minimum length required for troops and the drive train, and was selected to provide the maximum weight allowance for armor protection.
- Width - the 126-inch width is the specified maximum in the "Development Characteristics".
- Height - the 102-inch height is the minimum required by the troop seating for a vehicle with 18-inch ground clearance.

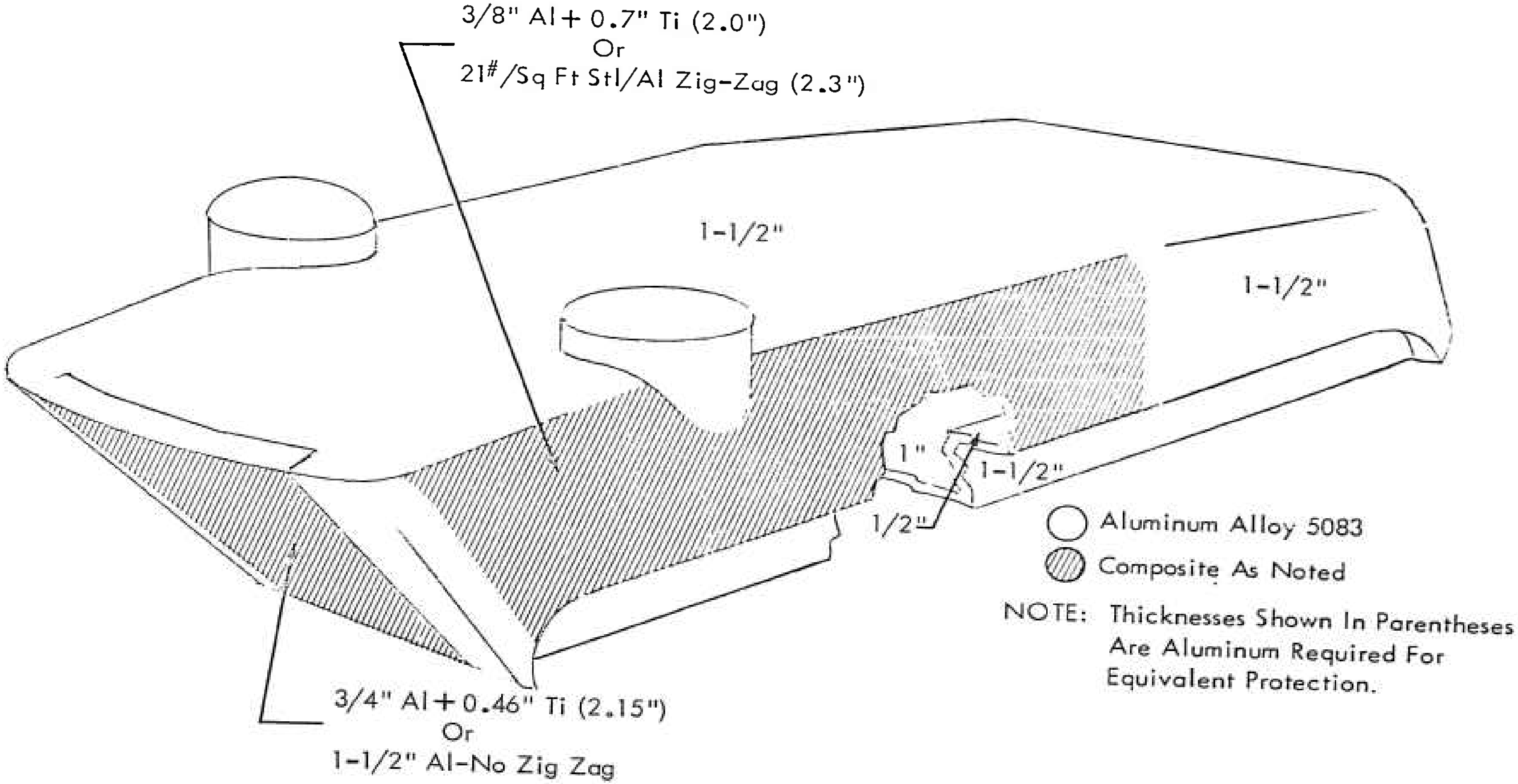
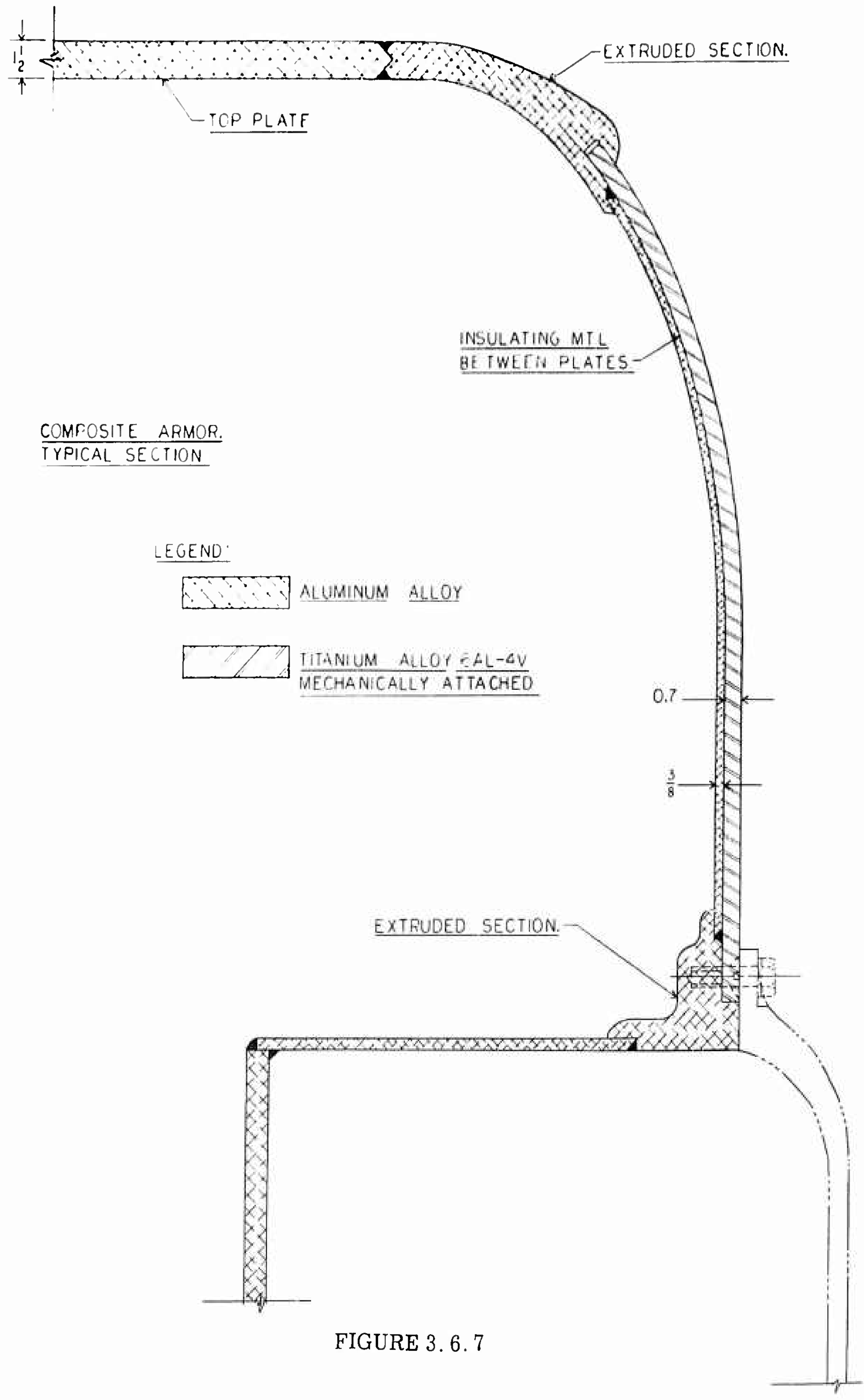


FIGURE 3 6 6 MAXIMUM ARMORED VEHICLE
ALUMINUM AND COMPOSITE OR ZIG-ZAG ARMOR



1/2
TOP PLATE
EXTRUDED SECTION.
INSULATING MTL
BETWEEN PLATES
COMPOSITE ARMOR.
TYPICAL SECTION
LEGEND:
ALUMINUM ALLOY
TITANIUM ALLOY 6AL-4V
MECHANICALLY ATTACHED
0.7
3/8
EXTRUDED SECTION.

FIGURE 3.6.7

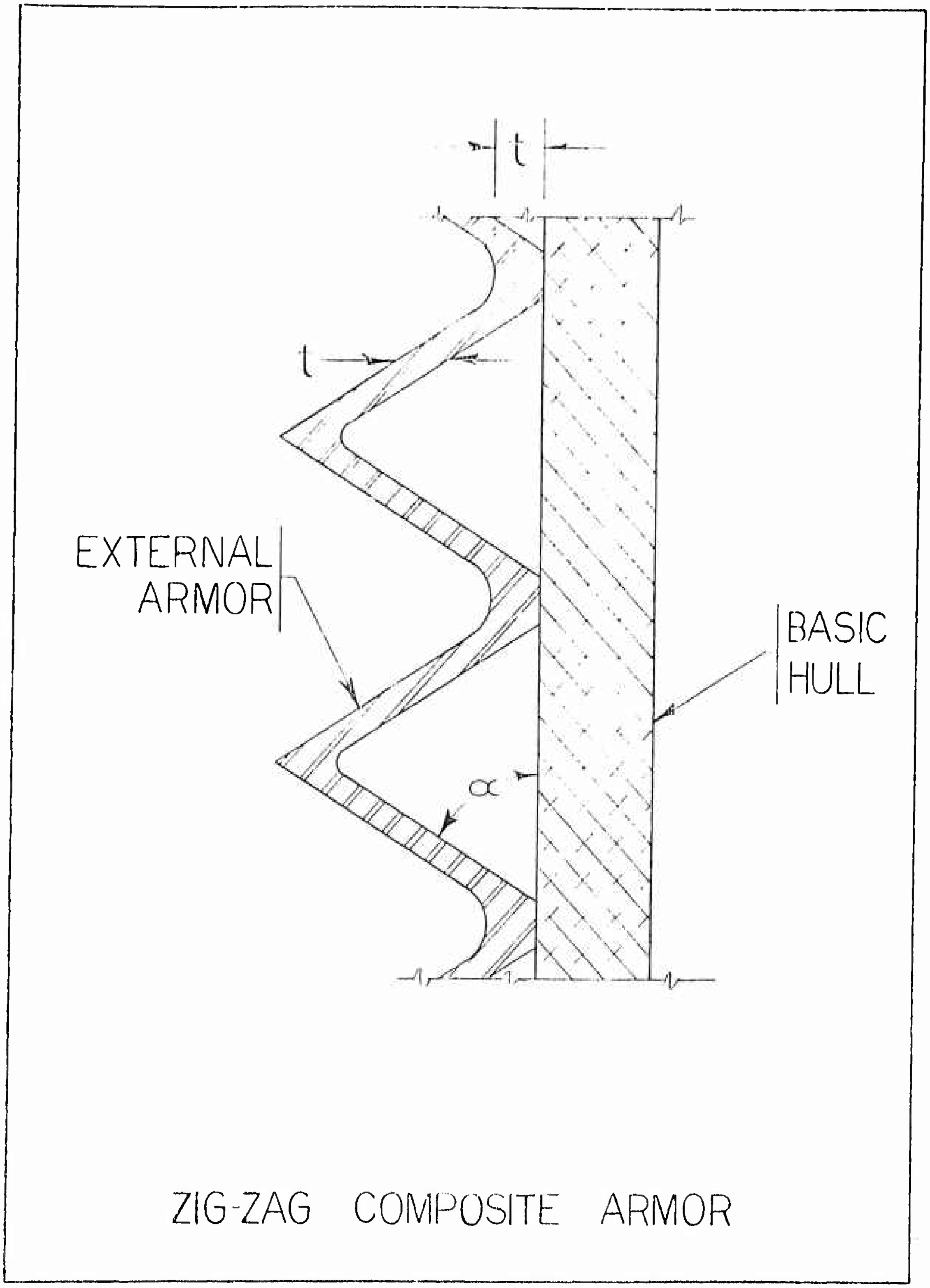


FIGURE 3 6 8

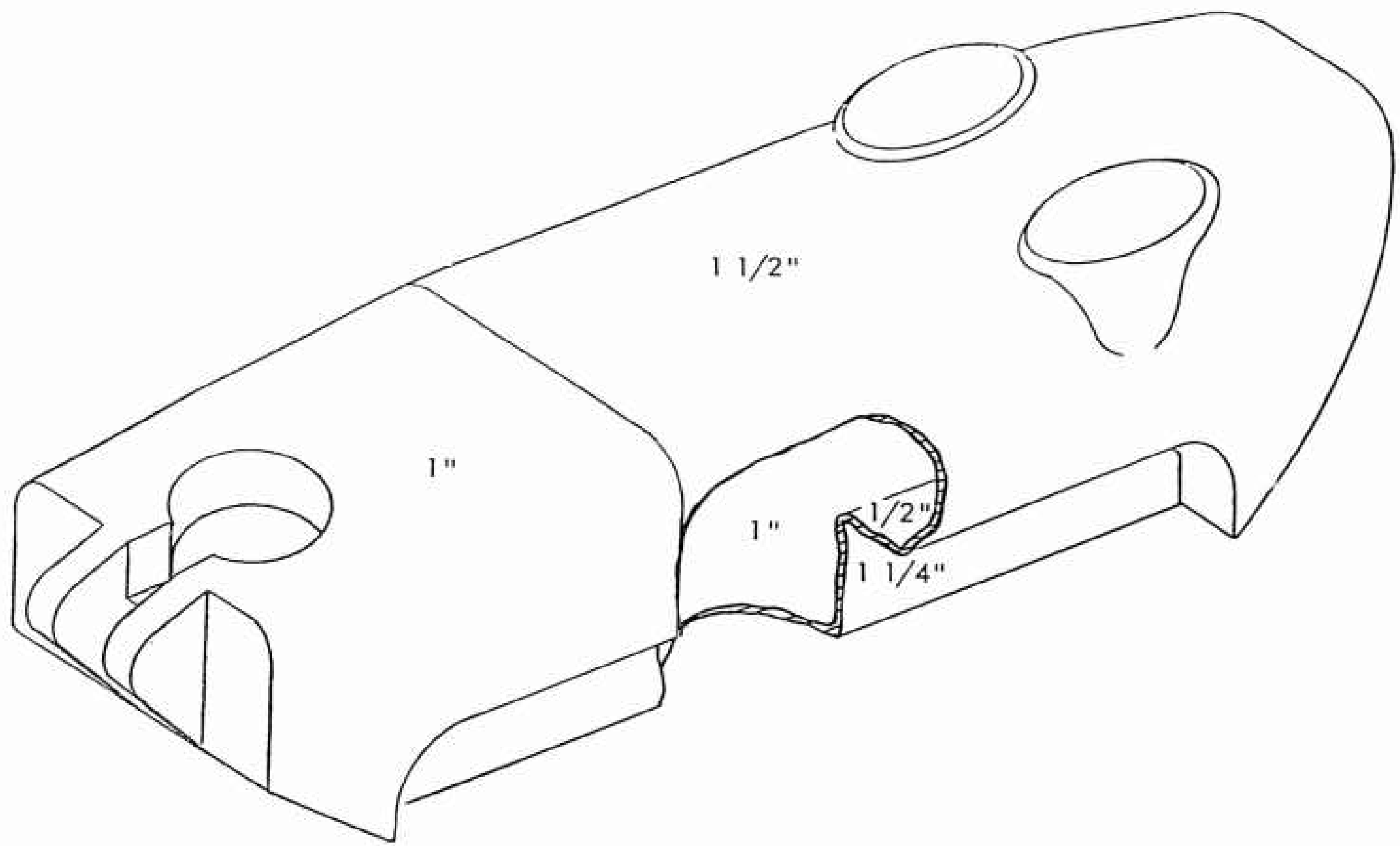


FIGURE 3.6.9 MAXIMUM WATER PERFORMANCE VEHICLE WITH ALUMINUM ARMOR

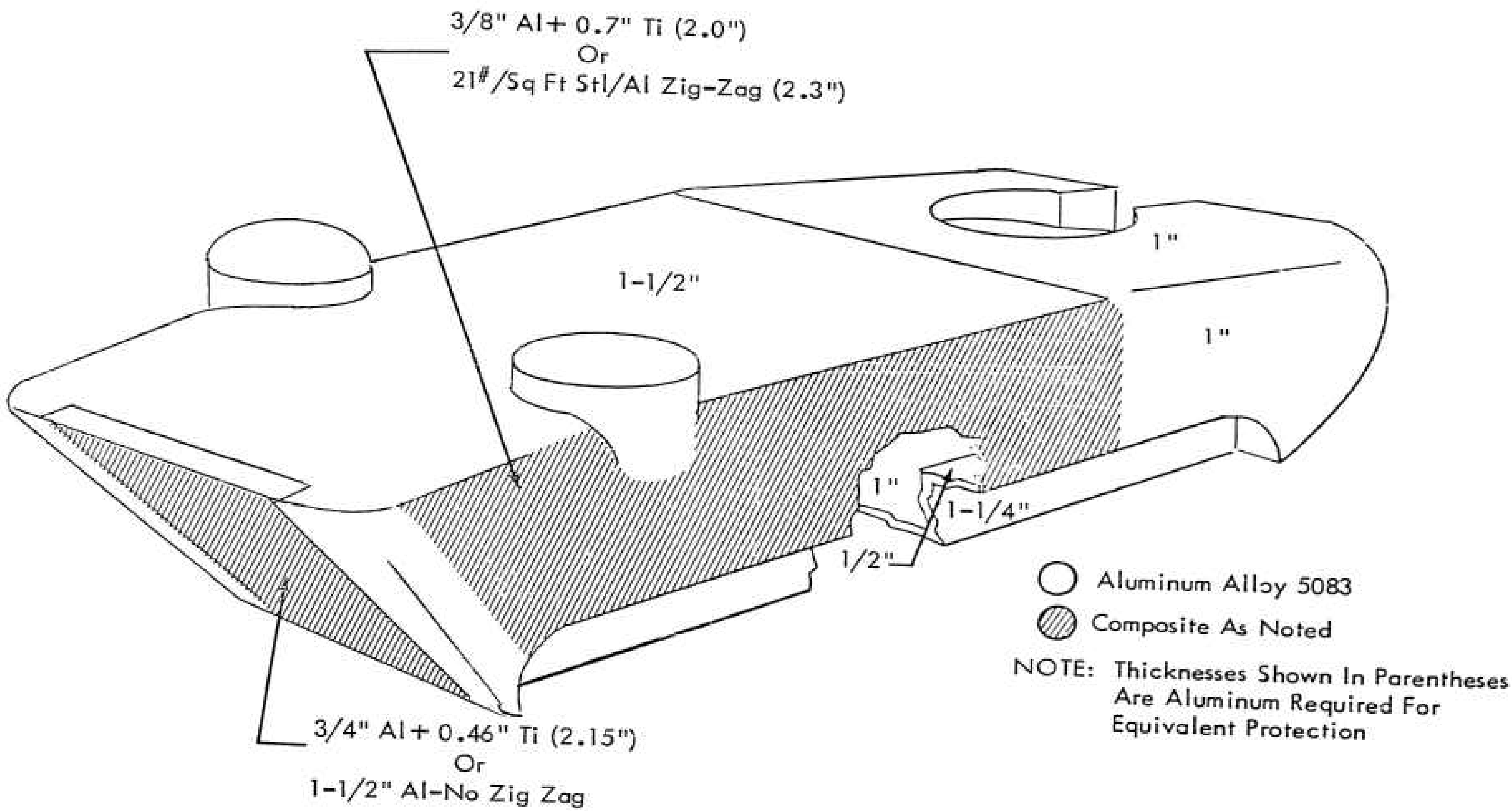


FIGURE 3 6 10 MAXIMUM WATER PERFORMANCE VEHICLE
ALUMINUM AND COMPOSITE OR ZIG-ZAG ARMOR

Hull Structure (Continued)

The "Maximum Water Performance Vehicle" dimensions were established as follows:

- Length - the 313-inch (26'-1") length is the specified maximum and was selected to provide the maximum length-to-width ratio and an improved bow shape for lower water resistance.

- Width - the 120-inch width is the minimum that will accommodate the troops and machinery.

- Height - the 102-inch height is the same as the "Maximum Armored Vehicle".

The basic design of the hull is the same for both vehicles, except that the stern of the "Maximum Water Performance Vehicle" is modified to allow for the propeller installation.

The front-ramp and rear-engine arrangement was selected to provide a slight bow-up trim under all conditions of loading. The front-ramp location also provides for driver visibility during ramp operation.

A long, sloping, lower bow has been selected to improve the water performance as much as possible without unduly sacrificing land performance, obstacle-climbing ability, and vehicle approach-angle. The upper bow is sloped downward to permit good visibility for the driver.

The rear deck is sloped downward to reduce the stern weight and to improve performance under following seas.

The rounded bow, stern, and deck edges minimize both hull drag and hull

Hull Structure (Continued)

weight and provide increased ballistic protection. In addition, the hull rounding lessens the likelihood of ship damage during loading and unloading operations at sea. This protection factor has also influenced the location of both cupolas, which are somewhat inboard.

The engine compartment is isolated by a transverse bulkhead, permitting control of the flow of cooling air and fumes.

3.6.4 Nuclear Weapon Effects

3.6.4.1 Blast Effects

The effect of blast loading and thermal radiation on the LVTPX11 have been investigated for a weapon yield of 100 KT. Computations were based on information in "The Effects of Nuclear Weapons", prepared by the U. S. Department of Defense, and "The Response of Hypothetical Missile Transport Equipment to Nuclear Blast", prepared by the Rand Corporation (ASTIA Document Number AD 205871).

The critical distance for the vehicle was assumed to be that at which overturning was iminent and was found to be 0.79 mile from ground zero. Instability of the vehicle is caused by the reflected overpressure and dynamic pressure. The reflected overpressure, which is due to the shock-front striking the surface of the vehicle, is 39.2 psi, at the critical distance. The peak overpressure for this condition is 13 psi. The reflected overpressure acts for only a fraction of a second; therefore, it is not an important factor when considering overturning. The predominant part of the blast loading arises from the dynamic pressure. This pressure, Nuclear Weapon Effects (Continued)

which is due to wind velocity, exerts a positive force on the windward side of the vehicle and a partial vacuum on the leeward side. Essentially, it is this force, if of sufficient magnitude, that will overturn the vehicle about the leeward tracks. For the 100 KT burst at a distance of 0.79 mile, the peak dynamic pressure would amount to 3.6 psi. Although the vehicle would theoretically not overturn under these conditions if loaded to 35,000 pounds GVW, it would be moved sideways and, in all probability, suffer damage to air intake and exhaust structure.

3.6.4.2 Thermal Effects

Detrimental effects due to thermal radiation are:

- Flash burns inflicted on personnel
- Excessive heating of structural components

The degree of damage caused by thermal radiation depends upon the total thermal energy emitted and the rate of emission. At the critical distance of 0.79 mile, the total energy emitted is 150 cal/cm^2, and the maximum rate is 165 cal/cm^2/sec. It is found that the peak rate is reached at 0.32 seconds after the explosion, and that this decays very rapidly, with 82% of the energy having been emitted in 3.2 seconds.

Assuming an absorption factor of 0.94 for the dark-colored paint on the vehicle and using 82% of the total 150 cal/cm^2 energy emitted, it is found that a 1-inch plate on the vehicle hull will experience a 135°F rise in temperature. This rise is inversely proportional to plate thickness, thus a 1-1/2-inch plate will increase only 90°F under the same conditions. These increases will not appreciably effect the strength of the aluminum plates.

FIGURE 3.6.13 TROOPS DEBARKING FROM MOCK-UP

Nuclear Weapon Effects (Continued)

Troops within the vehicle will be adequately protected from flash burns which would be considerably worse than third degree burns if the troops were exposed.

Radioactive dust will be pulled into the vehicle unless adequate filters are installed on the air inlets. These would be the same as those required for chemical warfare protection and are discussed in that section.

3.6.5 Hull Openings

3.6.5.1 Ramp

Figure 3.6.13 shows troops debarking from the 58-inch-high x 66-inch-wide ramp opening of the "Maximum Armored Vehicle" hull mock-up. This opening size was selected to permit rapid exit of personnel and efficient cargo loading and unloading operations.

For the all-aluminum hull, the ramp structure consists of a 1/2-inch-thick formed outer plate and a 1-inch-thick inner plate coated with a nonskid compound. For the composite armor, both inner and outer plates would be of 3/8-inch aluminum.

The ramp, hinged along its lower edge, is raised to the closed position by a hydraulic cylinder and a cable and is hydraulically snubbed into its lowered position. Two over-center latches, actuated by a single handle at the driver's position, lock the ramp against the watertight rubber seals.

3.6.5.2 Air Intake and Exhaust

The engine cooling-air intake and exhaust outlet are located on the aft deck, as shown in Figures 3.2.2 and 3.3.2. The intake opening is located on the

Hull Openings (Continued)

starboard side and the exhaust on the port side, to minimize possible recirculation of heated exhaust air through the intake.

Ballistic protection is provided by covering the openings with aluminum hoods the same thickness as the topdeck. The hoods overlap the openings in the deck and slope down towards the deck at their outer edges, to provide ballistic protection against small arms fire and shell bursts to the side of the vehicle.

3.6.5.3 Cargo Hatch

Two torsion-bar-hinged doors in the topdeck, as shown in Figure 3.2.2, provide a cargo loading opening measuring 60 inches wide x 96 inches long. These doors are equipped with rubber seals to maintain the watertight integrity of the hull. Dog-type latches, operable from inside or outside the vehicle, are also provided and can be locked from inside the vehicle.

3.6.5.4 Maintenance Access

Maintenance access to the engine compartment is provided in the following manner, as shown in Figure 3.2.2.

- Access panels between the cargo area and the engine compartment
- Removable topdeck plate at the stern
- Hinged access door on the hull rear plate
- Removable plate in hull bottom at rear

Access Panels Between Cargo Area and Engine Compartment

There are two aluminum access panels in the bulkhead between the cargo

Hull Openings (Continued)

area and engine compartment. These panels are of sandwich-type construction, two outer aluminum plates with an insulation layer between them. The panels are held in place by quick-opening latches, to permit rapid access to the engine compartment from within the vehicle. Since there will be negative pressure in the engine compartment, the sealing of these panels is not critical.

Removable Topdeck Plate at Stern

A removable section of the topdeck, approximately 44 inches x 55 inches, is large enough to permit removing the engine and transmission package as a unit. The engine-cooling ducting directly above the engine and transmission readily accessible. This removable plate, made of aluminum, is secured with bolts.

Hinged Access Door on Hull Rear Plate

An external access door to the engine compartment is provided at the stern. Approximately 44 inches x 39 inches, it is hinged along its top edge to the removable plate described above. There is a sealed joint all the way around this door, and the door is secured in place by bolts. This door, made of aluminum, provides excellent access to the rear portion of the engine compartment.

Removable Plate in Hull Bottom at Rear

An external access plate of aluminum, approximately 12 inches in diameter, is provided in the bottom plate of the hull beneath the engine and transmission, to permit draining oil from these units. This sealed access plate is secured with bolts.

Hull Openings (Continued)

3.6.5.5 Hatches

The 20-inch-diameter hatch is located on the forward left portion of the deck. This position was selected to provide maximum forward and downward visibility for the driver, for both land and water operation. Eight vision blocks are located around the driver's hatch and five around the turret, to provide full 360° vision, as shown in Figures 3.2.2 and 3.3.2. An infrared periscope is located in the top of the driver's hatch, and a spare periscope and head stowed alongside the driver.

The driver's hatch is torsion-bar-hinged, to aid in opening and closing, and is equipped with a hasp to permit padlocking from the outside of the vehicle.

3.6.5.6 Escape Provisions

Emergency exit is provided through the side hatches shown in Figure 3.2.2. These hatches are equipped with quick-opening latches, operable from inside the vehicle, and with watertight seals.

3.6.5.7 Personnel Compartment Ventilation

When the LVTPX11 is completely "closed up," ventilating air is supplied to the personnel compartment through a vent in the deck just forward of the engine compartment and is exhausted into the engine compartment.

The incoming air and any water that enters the mushroom-shaped vent are ducted directly to the bilge area, from which the water is removed by the bilge pumps.

Hull Openings (Continued)

The air flows up through openings in the floor plate at the front of the cargo area and travels aft to the engine compartment bulkhead through a controllable vent to the engine cooling-air intake area.

3.6.6 Fittings

3.6.6.1 Hull Interior

- Cargo Tie-downs - Tie-down rings are provided in the cargo area, located and spaced to provide the flexibility required to restrain many different cargo configurations.

- Troopseats - Several different arrangements were studied to provide the capability of carrying 27 fully equipped troops. The selected arrangement, shown in Figure 3.2.2, was chosen primarily because of the easy egress from the vehicle permitted by the longitudinal placement of the seats.

  To check various arrangements, a plywood mock-up was constructed. Figures 3.6.14 and 3.6.15 are photographs of troops seated in the vehicle mock-up. These photos illustrate the feasibility of the selected arrangement. Based upon the mock-up effort, FMC believes that the nineteen-inch space allocation is the absolute minimum that should be used, particularly when Arctic-equipped troops are considered. Attempts were made to seat all of the troops between the sponsons, thus reducing height, width, and weight of the vehicle; however, this led to an increase in length, without any weight advantage, and a crowded seating arrangement.

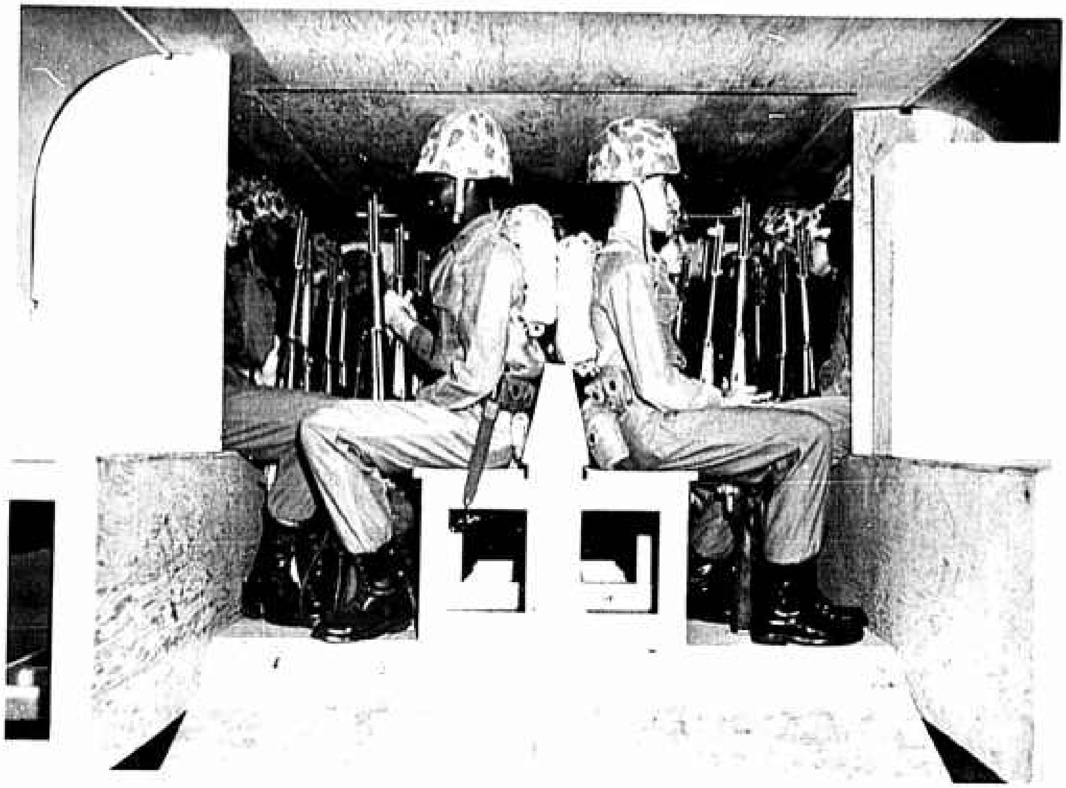


FIGURE 3.6.14 TROOPS SEATED IN MOCK-UP—RAMP DOWN

FIGURE 3.6.15 TROOPS SEATED IN MOCK-UP—TOP REMOVED

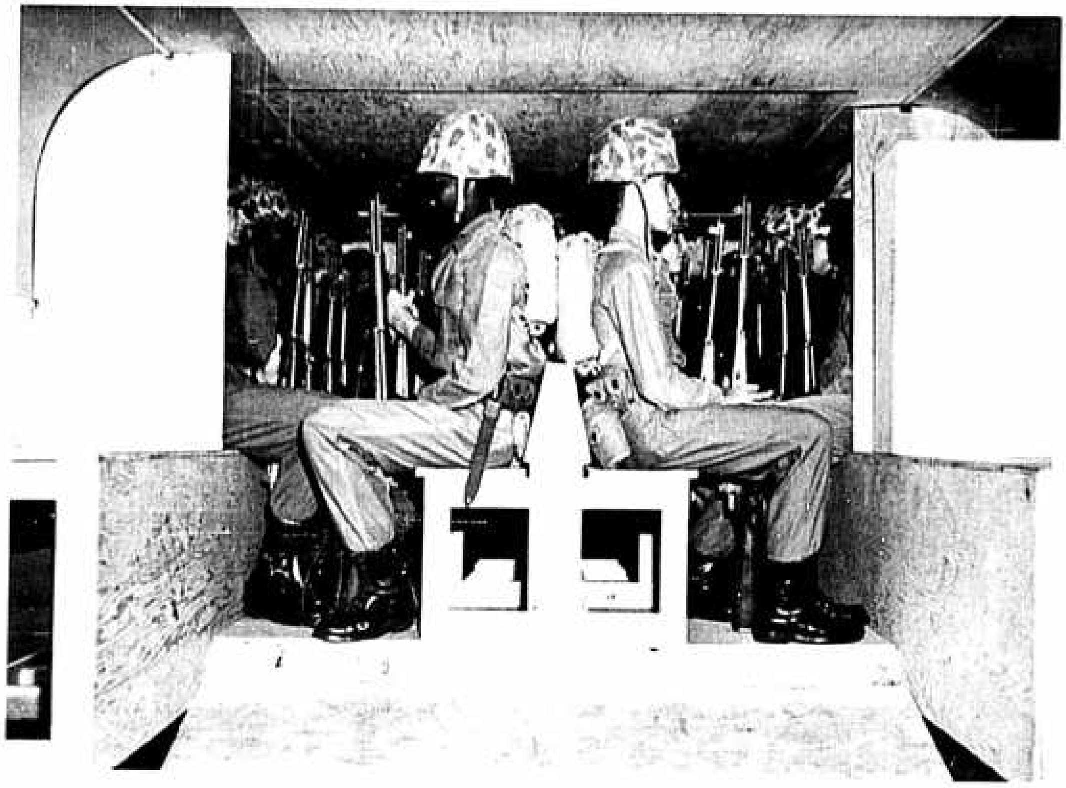


FIGURE 3.6.14 TROOPS SEATED IN MOCK-UP—RAMP DOWN

FIGURE 3.6.15 TROOPS SEATED IN MOCK-UP—TOP REMOVED

Fittings (Continued)

The troop seats are designed to be fabricated from aluminum or high-strength plastics or a combination of these materials. The seats in the center of the cargo area are designed to be stowed on the sponsons when the vehicle is used as a cargo carrier. Both seat belts and safety rails are provided for troop safety.

3.6.6.2 Exterior Fittings

Lifting eyes capable of supporting the vehicle gross weight are located at each corner of the deck, as shown in Figures 3.2.1 and 3.2.2. Mooring bitts are also provided. A quick-release towing pintle, operable from the top deck, is provided at each end of the vehicle. Tow cables are externally stowed at the bow and stern. Although this exceeds the requirements of the "Development Characteristics", two cables are supplied so that vehicles may be attached to one another during water operation. Boarding steps are recessed in the hull and personnel grab handles are supplied along the deck.

3.7 MACHINERY

3.7.1 Selected Drive Train

The drive train shown in Figure 3.7.1 is the drive train selected for the "Maximum Armored Vehicle". It is comprised of the Cummins V8-300 water-cooled diesel engine, the Allison XTG-250 transmission and steering unit, and FMC-designed final drives. The "Maximum Water Performance Vehicle" uses the same drive train plus the propeller drive from the transmission power take-off.

The alternate recommended drive train is shown in Figure 3.7.2 and also could be used for either vehicle. It consists of the Lycoming AVM-625 air-cooled, diesel cycle, multifuel engine, the Allison XTG-250 transmission and steering unit, and FMC-designed final drives.

3.7.2 Power Requirements

The "Development Characteristic" establishes the following summarized requirements for land operation of the LVTPX11:

> Sufficient horsepower to permit speeds of 40 mph on improved roads and 20 mph cross-country
>
> Sufficient horsepower to negotiate a 70% forward slope

Horsepower calculations included in Appendix D (Volume II) show the following requirements for the above conditions:

Power Requirements (Continued)

210 hp at the sprockets for the 40 mph condition

168 hp at the sprockets for the 20 mph condition

170 hp at the sprockets for the 70% slope condition

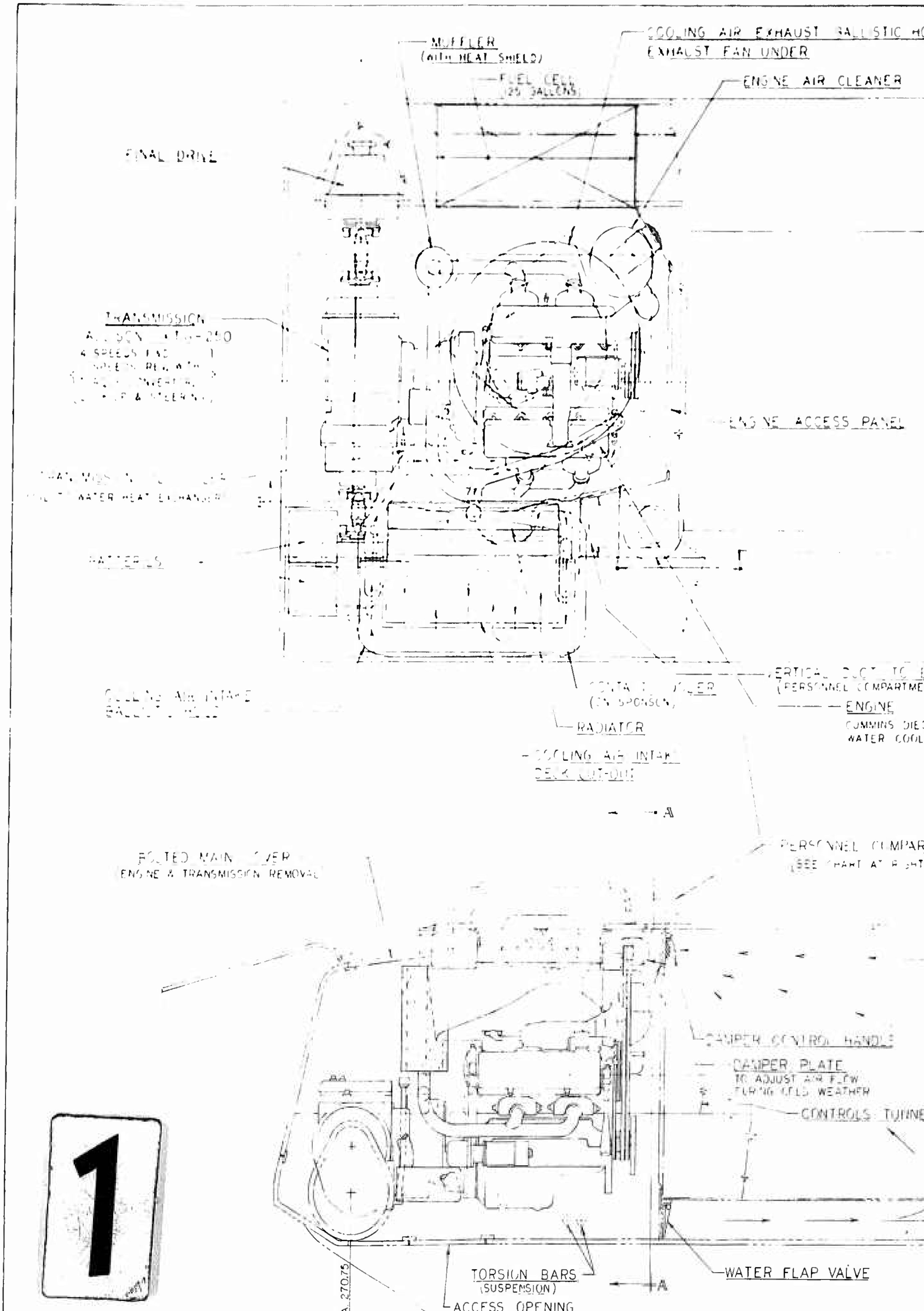
3.7.3 Engines

The sprocket horsepower requirements, after compensating for drive train efficiency losses, indicated that an engine in the 325 hp range is required for the LVTPX11. The following types of engines were considered:

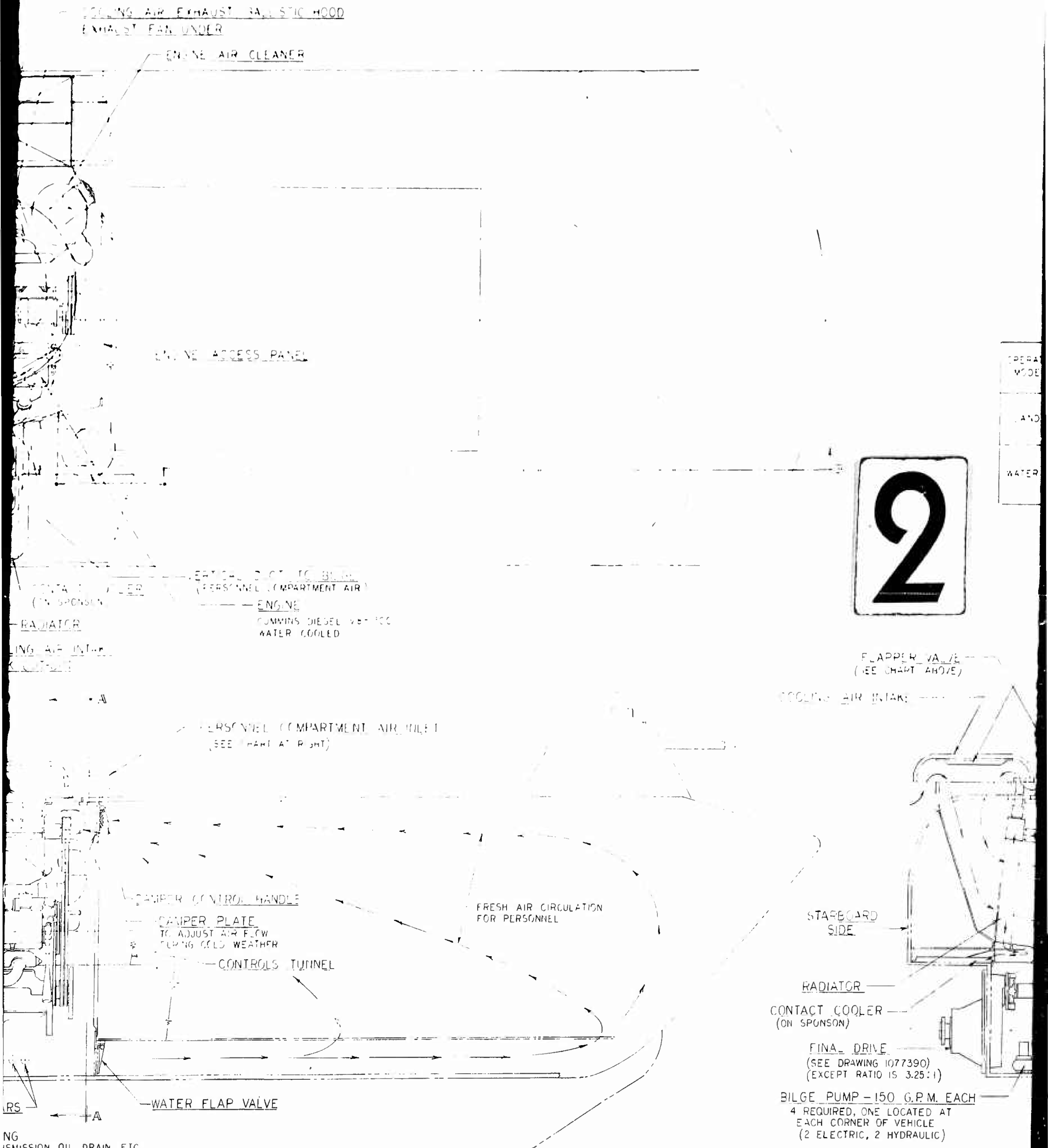
- Diesel
- Gas Turbine
- Gasoline
- Fuel Cells

In the evaluation of the different types of engines, the following factors were used:

- Weight
- Development status
- Cost
- Fuel consumption



LONGITUDINAL SECTION B-B

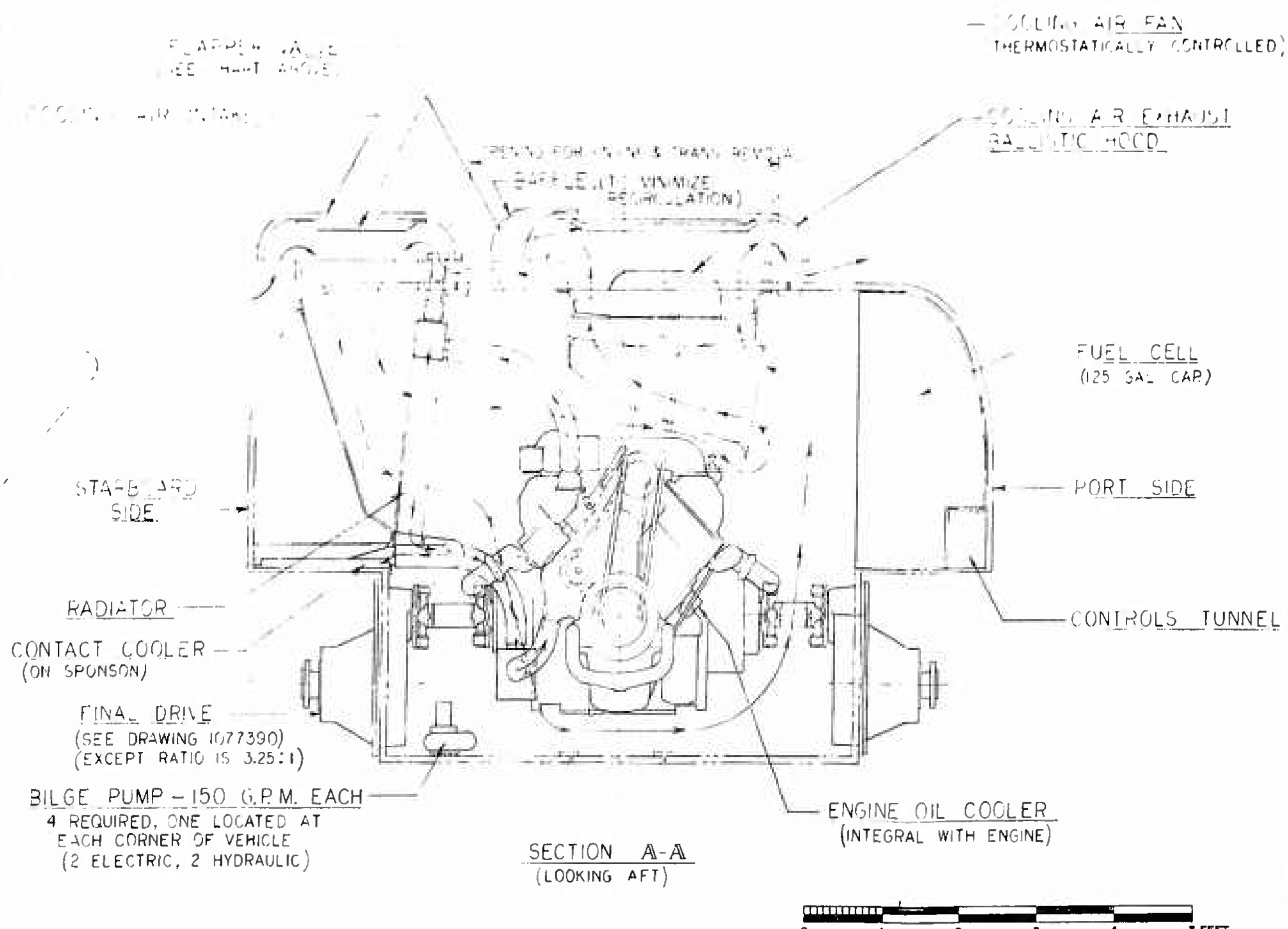


LONGITUDINAL SECTION B-B

OPERATION MODE	* AIR INTAKE FLAPPER VALVE	* EXHAUST AIR FLAPPER VALVE	PERSONNEL COMPARTMENT AIR INLET
LAND	FULL OPEN	FULL OPEN	OPEN (FIXED)
WATER	CLOSED	PARTIAL OPEN (EXHAUST AIR FROM PERSONNEL COMPARTMENT INLET)	OPEN (FIXED)

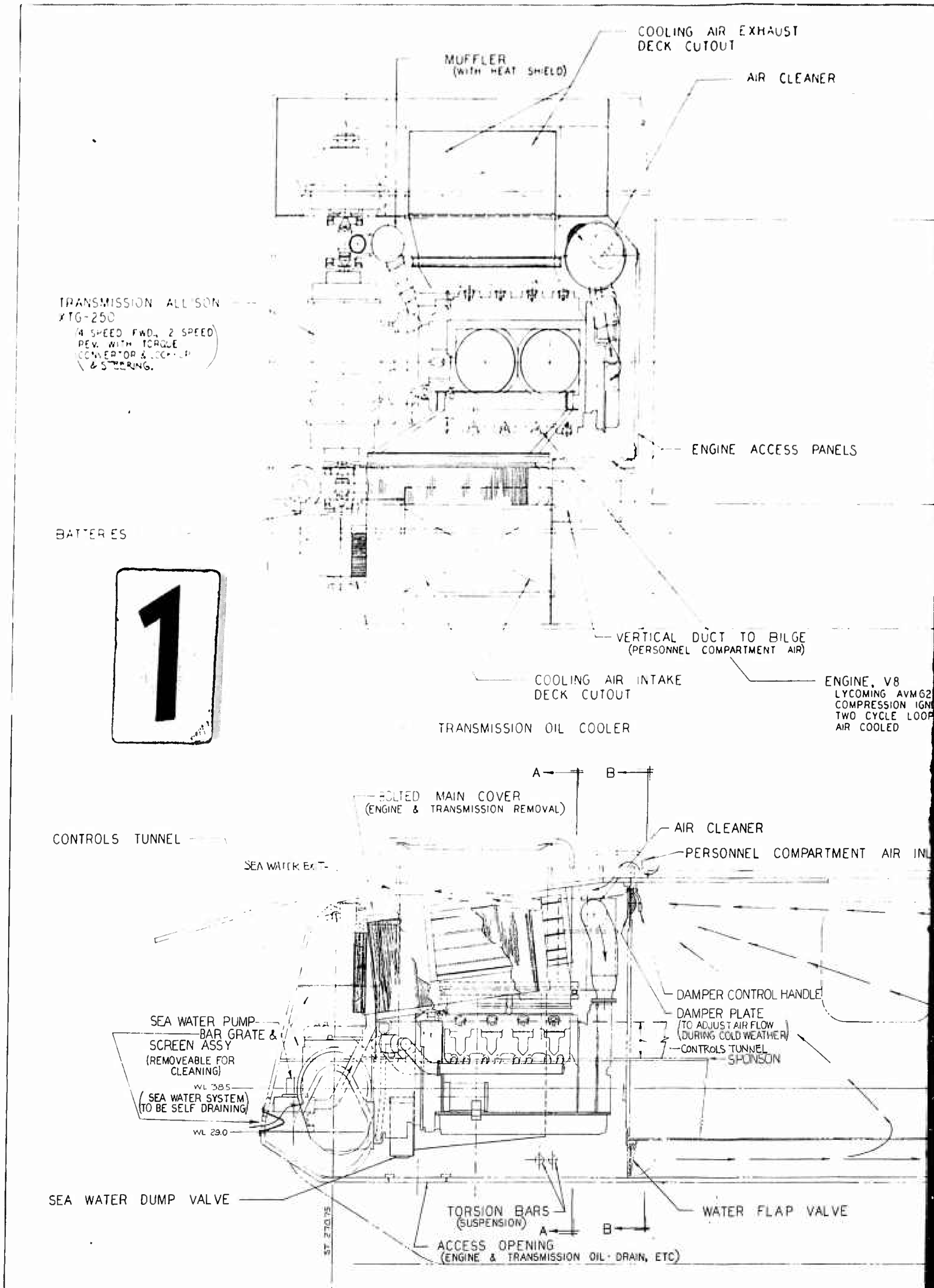
* CONTROLLED BY DRIVER

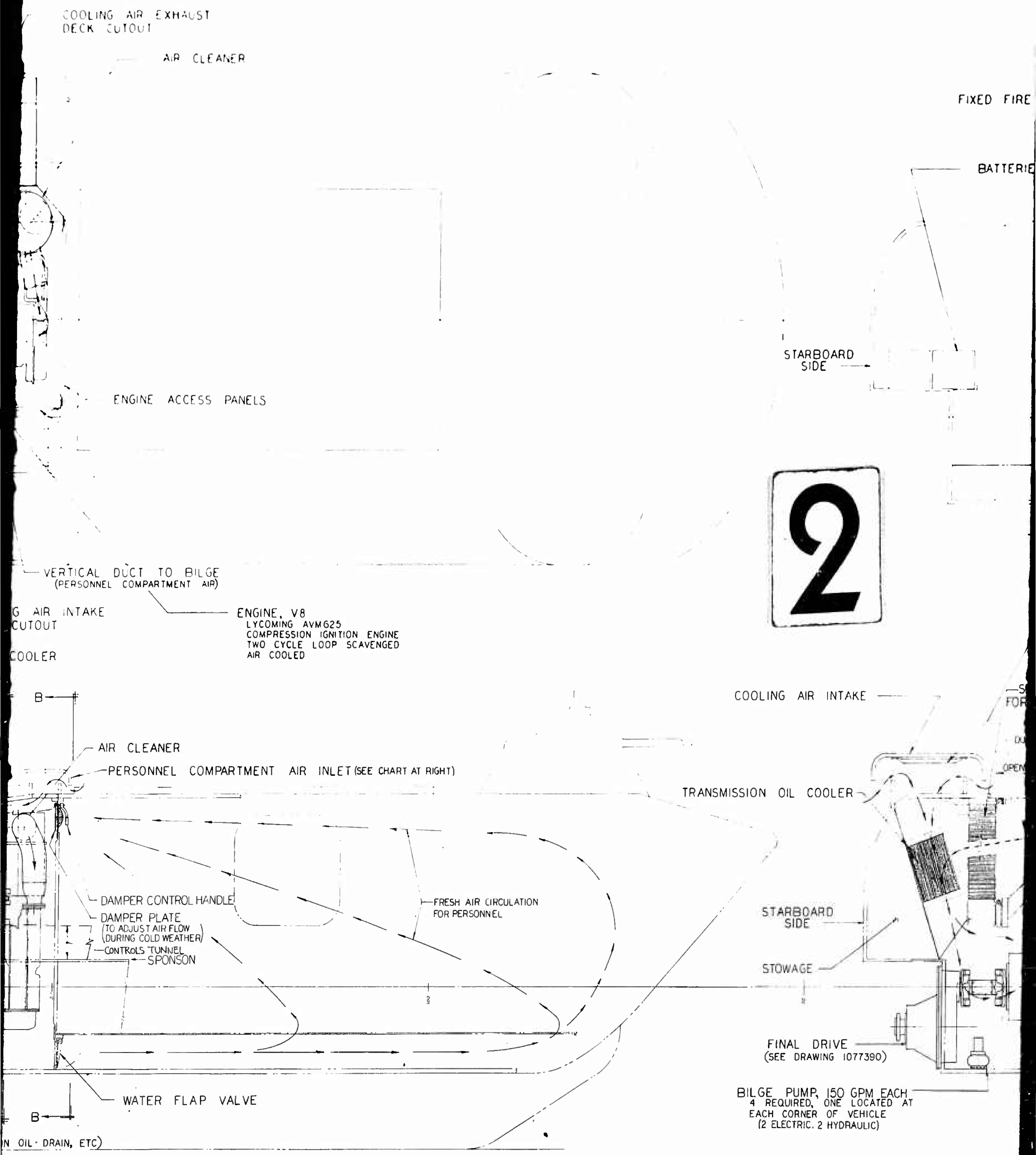
3

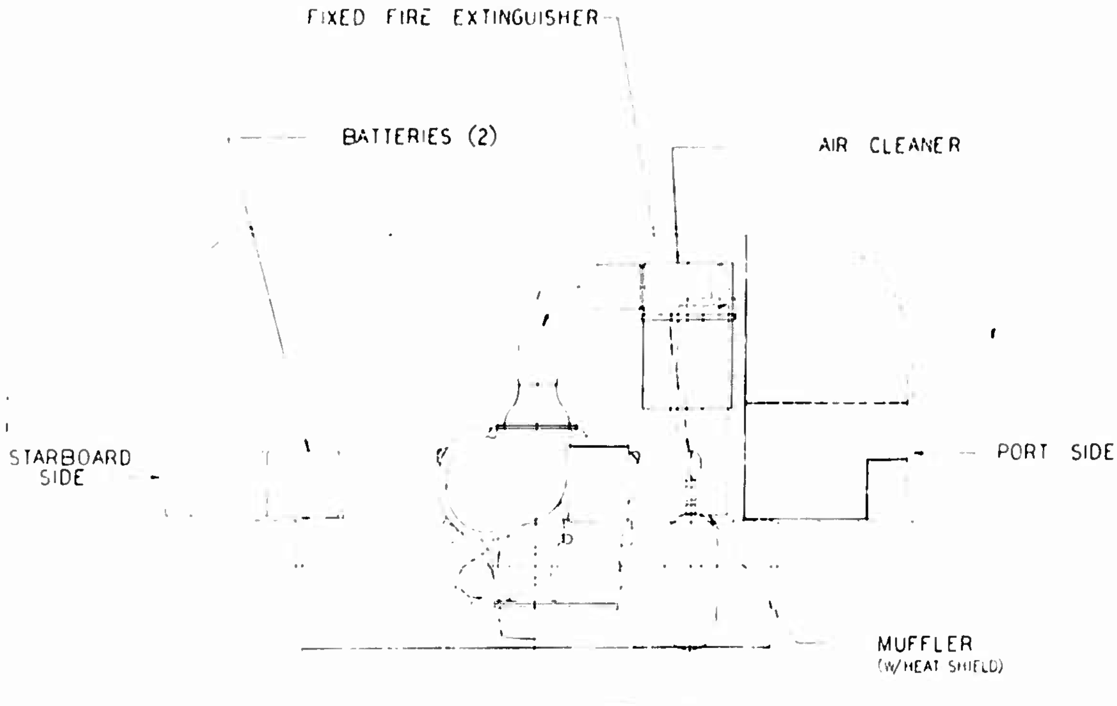


Preliminary Design Engineering FOOD MACHINERY AND CHEMICAL CORPORATION		ORDNANCE DIVISION SAN JOSE, CALIFORNIA
DATE 10 NOV. 61 DRAFTSMAN A.K.R.	MACHINERY INSTALLATION	P.A. NO. 449
ENGINEER	LVTPX II 35000# GVW	DWG. NO. J 1077396
APPROVED	CUMMINS V8-300 ENG.	
SCALE GRAPHIC	W/ALLISON XTG-250 TRAN.	SHEET 1 OF 1

Figure 3.7.1

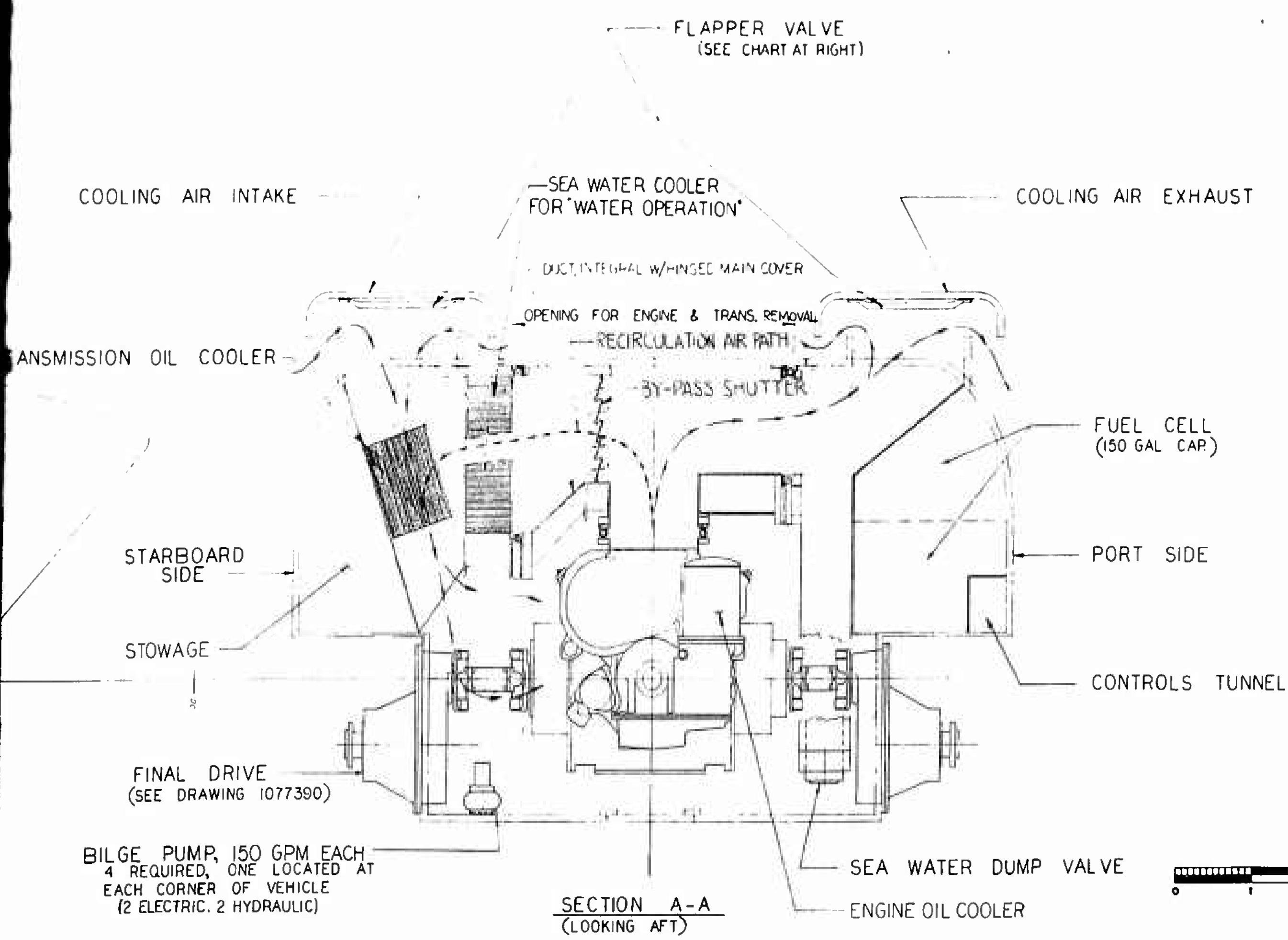

COOLING AIR EXHAUST
DECK CUTOUT
MUFFLER
(WITH HEAT SHIELD)
AIR CLEANER
ENGINE ACCESS PANELS
BATTERIES
1
VERTICAL DUCT TO BILGE
(PERSONNEL COMPARTMENT AIR)
COOLING AIR INTAKE
DECK CUTOUT
ENGINE, V8
TRANSMISSION OIL COOLER
A
B
MAIN COVER
(ENGINE & TRANSMISSION REMOVAL)
CONTROLS TUNNEL
AIR CLEANER
PERSONNEL COMPARTMENT AIR
DAMPER CONTROL HANDLE
DAMPER PLATE
(TO ADJUST AIR FLOW
DURING COLD WEATHER)
CONTROLS TUNNEL
SPONSON
SEA WATER PUMP
BAR GRATE &
SCREEN ASSY
(REMOVEABLE FOR
CLEANING)
WL 38.5
(SEA WATER SYSTEM
TO BE SELF DRAINING)
WL 29.0
SEA WATER DUMP VALVE
TORSION BARS
(SUSPENSION)
WATER FLAP VALVE
ACCESS OPENING
(ENGINE & TRANSMISSION OIL - DRAIN, ETC)


COOLING AIR EXHAUST
DECK CUTOUT
AIR CLEANER
FIXED FIRE
BATTERIE
STARBOARD SIDE
ENGINE ACCESS PANELS
2
VERTICAL DUCT TO BILGE
(PERSONNEL COMPARTMENT AIR)
G AIR INTAKE
CUTOUT
COOLER
ENGINE, V8
LYCOMING AVM625
COMPRESSION IGNITION ENGINE
TWO CYCLE LOOP SCAVENGED
AIR COOLED
COOLING AIR INTAKE
B
AIR CLEANER
PERSONNEL COMPARTMENT AIR INLET (SEE CHART AT RIGHT)
TRANSMISSION OIL COOLER
DAMPER CONTROL HANDLE
DAMPER PLATE
(TO ADJUST AIR FLOW
DURING COLD WEATHER)
CONTROLS TUNNEL
SPONSON
FRESH AIR CIRCULATION
FOR PERSONNEL
STARBOARD SIDE
STOWAGE
FINAL DRIVE
(SEE DRAWING 1077390)
WATER FLAP VALVE
B
BILGE PUMP, 150 GPM EACH
4 REQUIRED, ONE LOCATED AT
EACH CORNER OF VEHICLE
(2 ELECTRIC, 2 HYDRAULIC)
N OIL - DRAIN, ETC)



SECTION B-B
(LOOKING AFT)

3



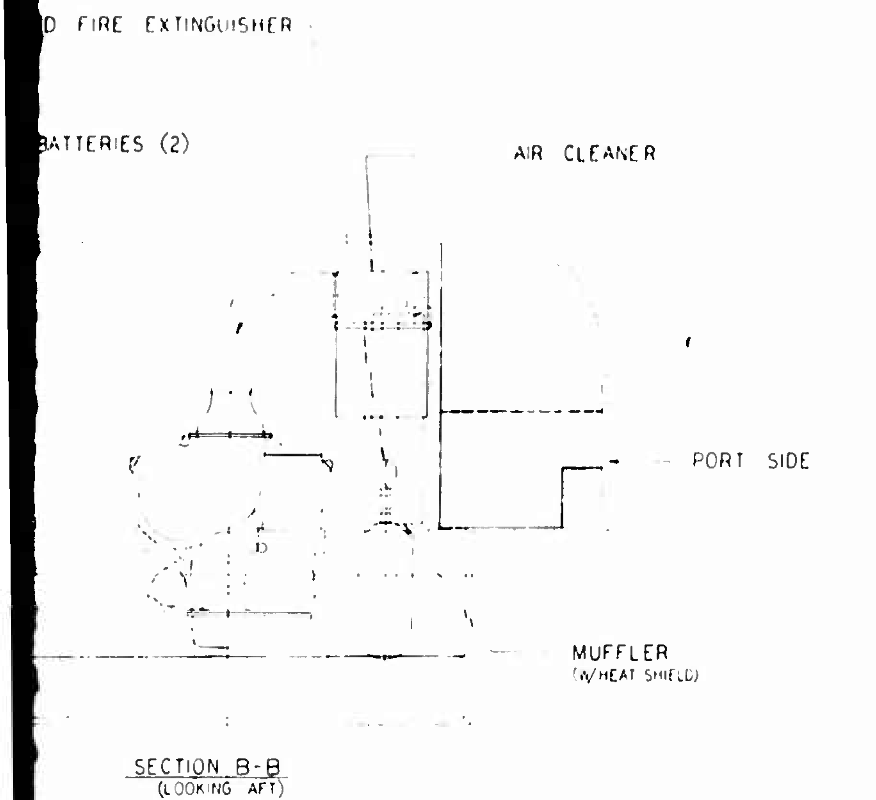
SECTION A-A
(LOOKING AFT)

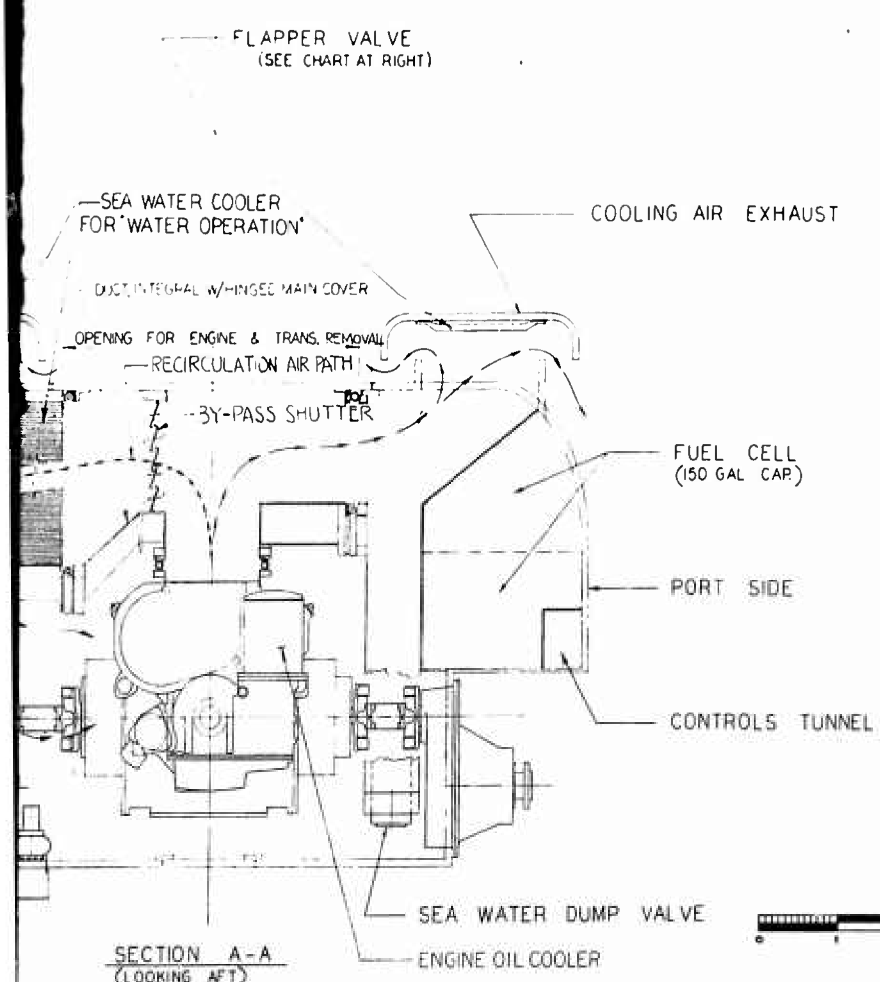
OPERATION MODE	*INTAKE GRILLE FLAPPER VALVE	* EX... GR... FLA... VA...
LAND	FULL OPEN	F... OP...
WATER	CLOSED	PARTI... TO EX... AIR PERS... COMP... I...

* CONTROLLED BY DRIVE...
Ø LINKED TO INLET AND ... VALVES TO PROVIDE S...

0 1 2 3 4 5 FEET

4





OPERATION MODE	*INTAKE GRILLE FLAPPER VALVE	* EXHAUST GRILLE FLAPPER VALVE	ø BY-PASS SHUTTER	PERSONNEL COMPARTMENT AIR INLET
LAND	FULL OPEN	FULL OPEN	CLOSED	OPEN (FIXED)
WATER	CLOSED	PARTIAL OPEN TO EXHAUST AIR FROM PERSONNEL COMPARTMENT INLET	OPEN	OPEN (FIXED)

* CONTROLLED BY DRIVER

ø LINKED TO INLET AND EXHAUST FLAPPER VALVES TO PROVIDE SINGLE CONTROL

Preliminary Design Engineering — FOOD MACHINERY AND CHEMICAL CORPORATION — ORDNANCE DIVISION, SAN JOSE, CALIFORNIA

DATE 9/26/61

MACHINERY INSTALLATION LVTPXII 35,000# GVW

LYCOMING AVM-625 ENG W/ALLISON XTG-250 TRANS

SCALE GRAPHIC

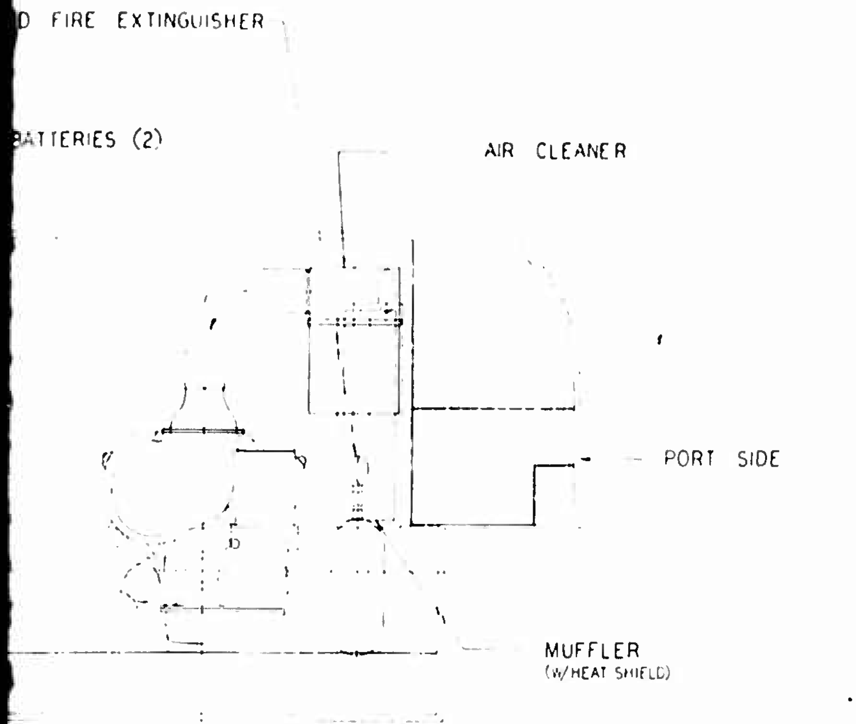
P.A. NO 449

DWG NO 1077381

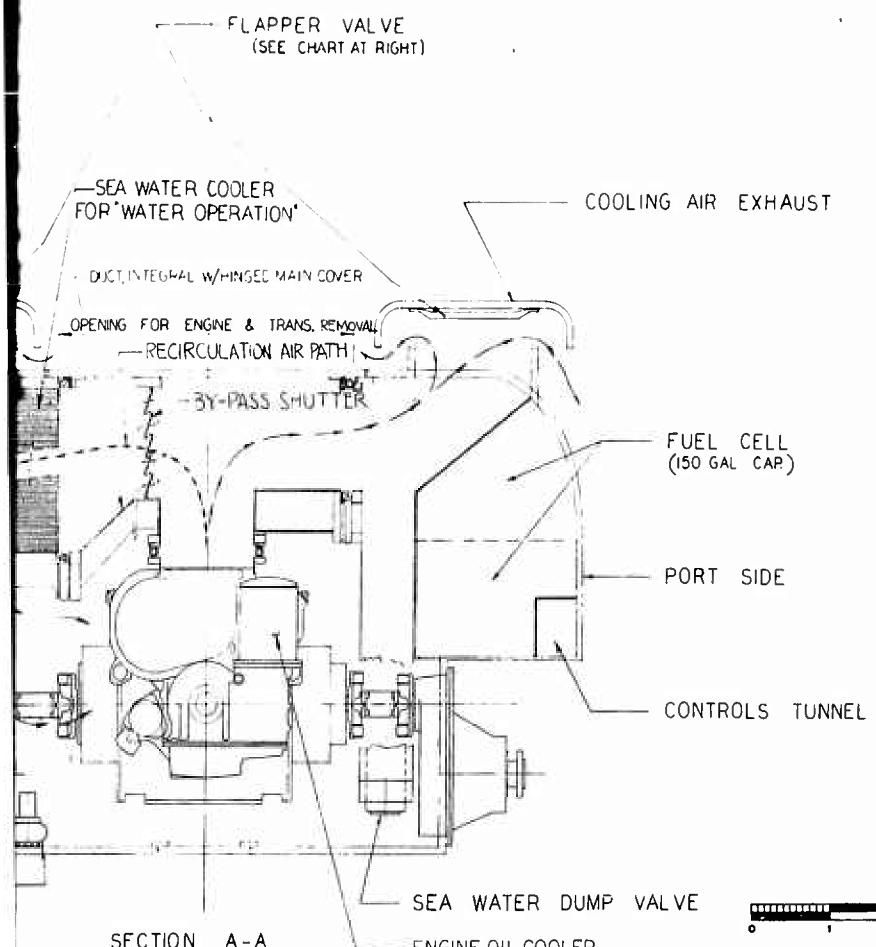
SHEET 1 OF 1

Figure 3.7.2

4



SECTION B-B
(LOOKING AFT)



SECTION A-A
(LOOKING AFT)

OPERATION MODE	*INTAKE GRILLE FLAPPER VALVE	* EXHAUST GRILLE FLAPPER VALVE	ø BY-PASS SHUTTER	PERSONNEL COMPARTMENT AIR INLET
LAND	FULL OPEN	FULL OPEN	CLOSED	OPEN (FIXED)
WATER	CLOSED	PARTIAL OPEN TO EXHAUST AIR FROM PERSONNEL COMPARTMENT INLET	OPEN	OPEN (FIXED)

* CONTROLLED BY DRIVER
ø LINKED TO INLET AND EXHAUST FLAPPER VALVES TO PROVIDE SINGLE CONTROL

0 1 2 3 4 5 FEET

Preliminary Design Engineering — FOOD MACHINERY AND CHEMICAL CORPORATION	ORDNANCE DIVISION — SAN JOSE, CALIFORNIA
DATE 9/26/61	MACHINERY INSTALLATION LVTPXII 35,000# GVW
P.A. NO 449	DWG NO 1077381
SCALE GRAPHIC	LYCOMING AVM-625 ENG W/ALLISON XTG-250 TRANS
SHEET 1 OF 1	

Figure 3.7.2

Engines (Continued)

- Air requirements
- Multifuel capability
- Maintenance

On the basis of the above factors, a diesel engine was selected for the LVTPX11.

3.7.5.1 Diesel Engines

Figure 3.7.3 is a tabulation of the diesel engines evaluated. The Cummins V8-300, water-cooled diesel engine, with a dry weight of 1,425 lb, was selected for this vehicle and is shown in Figure 3.7.4. This automotive diesel, while not offering a multifuel capability, has been thoroughly road tested and is currently being placed in production. It is currently being planned for the LARC-5.

As an alternate engine, the Lycoming AVM-625, 8-cylinder, air-cooled, diesel cycle, multifuel engine, with a dry weight of 1,060 lb, was selected. This engine, shown in Figures 3.7.5 and 3.7.6, is currently being developed for the XM551 ARV. This engine offers weight savings, but has the disadvantage of high fuel consumption. Although a BSFC of 0.41 to 0.48 is predicted for this engine, the test version now being run exhibits a BSFC greatly in excess of the predicted value.

Because of the desire to provide maximum armor and still maintain the 35,000 lb GVW, all components selected must be as lightweight as practical; however, to confirm the compatibility of the vehicle design, various other

Engines (Continued)

diesel engine installations were investigated. Figure 3.7.7 shows the Caterpillar D-333 liquid-cooled diesel with mechanical drive train, and a hydromechanical drive train with the Continental AVDS-550 air-cooled diesel is shown in Figure 3.7.8.

3.7.3.2 Gas Turbines

One of the major considerations in the selection of an engine for this type of operation is the degree of induction air flow which must be provided during surfing. The gas turbine is at a disadvantage here, due to the excessive air volume required. Since all the air must pass through the engine, it must be reasonably free of water; therefore, the installation of a gas turbine would require extendable intake and exhaust stacks. Stacks become a significant disadvantage, due to their vulnerability to wave forces during surfing. As shown in Figure 3.7.9, the air volume is so large that it cannot be taken from within the vehicle.

The light weight of the gas turbine is offset by the greater brake specific fuel consumption (BSFC) and the increased logistics of fuel supply. A typical example from Figure 3.7.9, the Boeing Model 520-3 has a BSFC of 0.8 lb/bhp/hr, as compared with the predicted 0.4 lb/bhp/hr for the Cummins diesel engine. Although gas turbines have been designed with recuperators or regenerators approaching a BSFC of 0.5 lb/bhp/hr, none in the horsepower range required has been developed to date, and it would require a 2- to 5-million-dollar development program to produce such an engine. There is still a question as to the effectiveness of a recuperator, due to eventual contamination of the heat transfer surfaces,

1

							MILITARY RATING		
Engine	Model	Type	Cycle	Dry Weight (lb)	Block	Turbo	Gross HP @ 125°F	Gross HP @ 60°F	Rated Speed
Cummins	V8-300	All except [1] gasoline	4	1425	Alum	No	280	300	3000
Lycoming	AVM-625	M.F.	2 (loop)	[4] 960	Alum	No (Mech. Blower	297	315	2600
Cummins [7]	V8-350	All except [1] gasoline	4	1425	Alum	No	327	350	3000
Lycoming	AVMT-625	M.F.	2 (loop)	[4] 1060	Alum	Yes	370	393	2600
Continental	AVDS-750	M.F.	4	2592	Alum	Yes		[6] 368	2400
Continental	AVDS-550	M.F.	4	1560	Alum	Yes		[5] 320	2800
Caterpillar	D333	• M.F.	4	2000	Iron	Yes	310	320 @ 90°F	2400
Caterpillar	D333	M.F.	4	1600	Alum	Yes	310	320 @ 90°F	2400
Caterpillar	D333	M.F.	4	1600	Alum	Yes	325	332 @ 90°F	2400
Detroit Diesel	6-71T	M.F.	2 (uniflow)	1820	Alum	Yes	292	310	2300
Detroit Diesel	6-71T	M.F.	2 (uniflow)	2220	Iron	Yes	292	310	2300
Detroit Diesel	6V71T	M.F.	2 (uniflow)	1855	Alum	Yes	292	310	2300
Detroit Diesel	6V71T	M.F.	2 (uniflow)	2030	Iron	Yes	292	310	2300
Detroit Diesel	8V71	M.F.	2 (uniflow)	2605	Iron	No (Mech. Blower)	317	336	2300
Harnischfeger	887H-18	M.F.	2 (uniflow)	2300	Alum	Mech. Blower		360	1800
Ford	No engine available for this application.								
Hercules	No engine available for this application.								
Allis Chalmers	21000	D	4	3040	Iron	Yes		350	2100
Cerlist		M.F.	2 (loop)	2 Engs 1880	Alum	No	324	340	3000

NOTES:

1 Can burn gasoline, using kit and 10:1 ratio - gasoline/lube oil.

2 Predicted

3 Predicted from engine family already built.

4 Without alternator (100 amp).

5 410 gross HP rating can be obtained with development.

6 550 gross HP rating

7 Cummins V8-350 is
for LARC-5); incre
V8-300 currently av
V8-315 on test "AB

	← MILITARY RATING →			CFM Induction	Based Gross HP									
	Gross HP @ 125°F	Gross HP @ 60°F	Rated Speed	Air Req'd @ Rated Speed	BSFC Rated HP	BSFC 1/2 Rated HP	Approx. Length (in.)	Cooled	No. Cyl. & Type	Displ. (in.^{3})	Heat Rej. btu/hp/min	Width	Height	Cooli Air Fl
	280	300	3000	600			39-3/4	Water	V8	785	35	34-1/2	38-3/4	
h.	297	315	2600	1430	[2] .48	[2] .41	43-5/16	Air	V8	624	39			11,3
	327	350	3000	600			39-3/4	Water	V8	785	35	34-1/2	38-3/4	
	370	393	2600	1430	[2] .45	[2] .40	46-5/16	Air	V8	624	39			
		[6] 368	2400	850			47-7/8		V8	746		52	37-1/2	13,8
		[5] 320	2800	750	[3] .40	[3] .40	33-1/4		V6	560		42-1/4	29-3/8	9,0
	310	320 @ 90°F	2400	780	.41	.43	50	Water	ST.6	525	45			
	310	320 @ 90°F	2400	780	.41	.43	50	Water	ST.6	525	40			
	325	332 @ 90°F	2400	780	.41	.43	50	Water	ST.6	525	40			
	292	310	2300	720	.42	.52	51-1/2	Water	ST.6	425				
	292	310	2300	720			51-1/2	Water	ST.6	425				
	292	310	2300	720			37-1/2	Water	V6	425				
	292	310	2300	720			37-1/2	Water	V6	425				
h.)	317	336	2300	955			43-1/2	Water	V8	567				
		360	1800	1000	Not Available		46	Water	V8	700	50	42	36	
		350	2100		.38		57-1/4	Water	ST.6	844				
	324	340	3000	1500 2 Engs.	.5	.45	49.35	Water	Twin V6	676 2 Engs.		68.63	35.12	

e oil.

6 550 gross HP rating can be obtained with development.

7 Cummins V8-350 is same basic engine as V8-300 (planned for LARC-5); increased rating based on development.

V8-300 currently available

V8-315 on test "ABC Universal Tractor".

2

Cooled	No. Cyl. & Type	Displ. (in.^{3})	Heat Rej. btu/hp/min	Width	Height	Cooling Air Flow	Comment HP for 35,000# GVW-Mech Dr.	Comments
Water	V8	785	35	34-1/2	38-3/4		ok	• V8-300 planned for LARC-5.
Air	V8	624	39			11,350	ok	• Being developed for "XM551" vehicle by OTAC. 8 cylinder to be running Nov. 61. Performance predicted from 4 cylinder engine. Test in progress to improve poor fuel economy and oil consumption.
Water	V8	785	35	34-1/2	38-3/4		(ok for 40,000# GVW)	
Air	V8	624	39				(ok for 40,000# GVW)	
	V8	746		52	37-1/2	13,800	Too Long	• V8-350, VTG-290 available late '62 in cast iron. • V8-350, VTG-290 available 2nd half '63 in aluminum.
	V6	560		42-1/4	29-3/8	9,000	ok	
Water	ST.6	525	45				ok	
Water	ST.6	525	40				ok	• Aluminum prototype engines to be running Feb. '62. *Multifuel under development.
Water	ST.6	525	40				Long	
Water	ST.6	425					ok	• Relatively long.
Water	ST.6	425					ok	• Availability in aluminum questionable. • Relatively heavy.
Water	V6	425					ok	
Water	V6	425					ok	
Water	V8	567					ok	
Water	V8	700	50	42	36			
Water	ST.6	844					Heavy	
Water	Twin V6	676 2 Engs.		68.63	35.12		Too Wide	

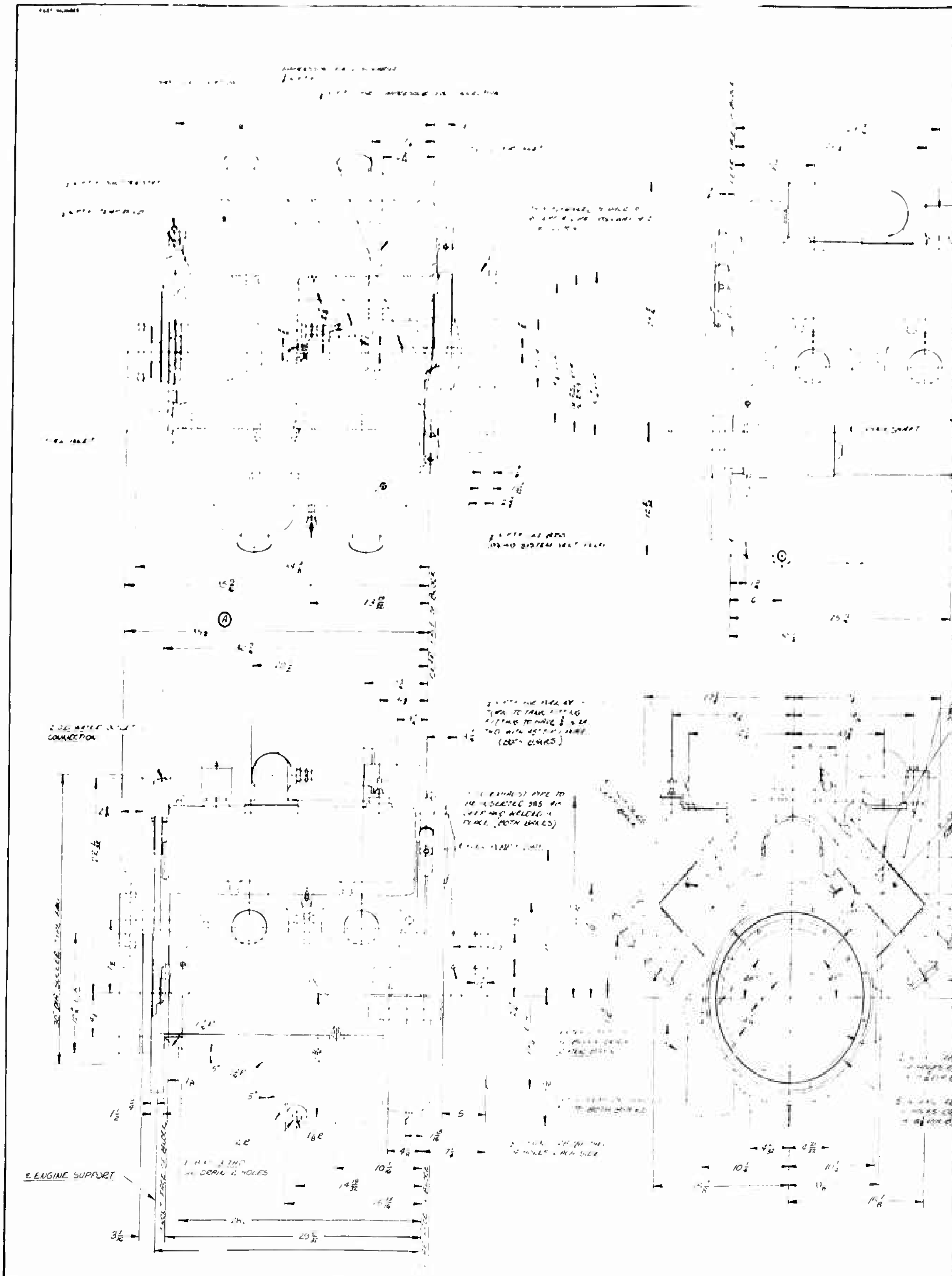


Figure 3.7.4

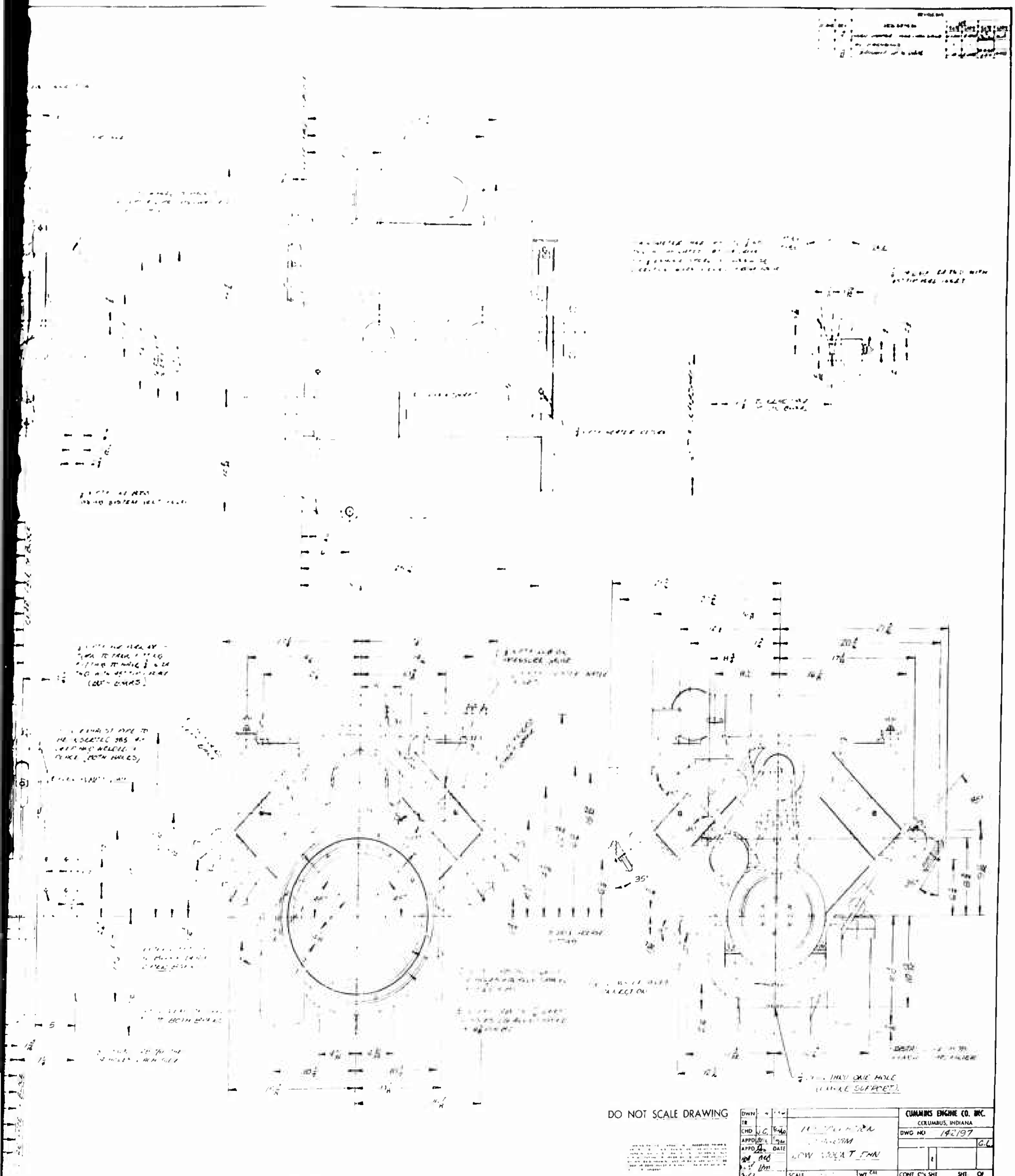
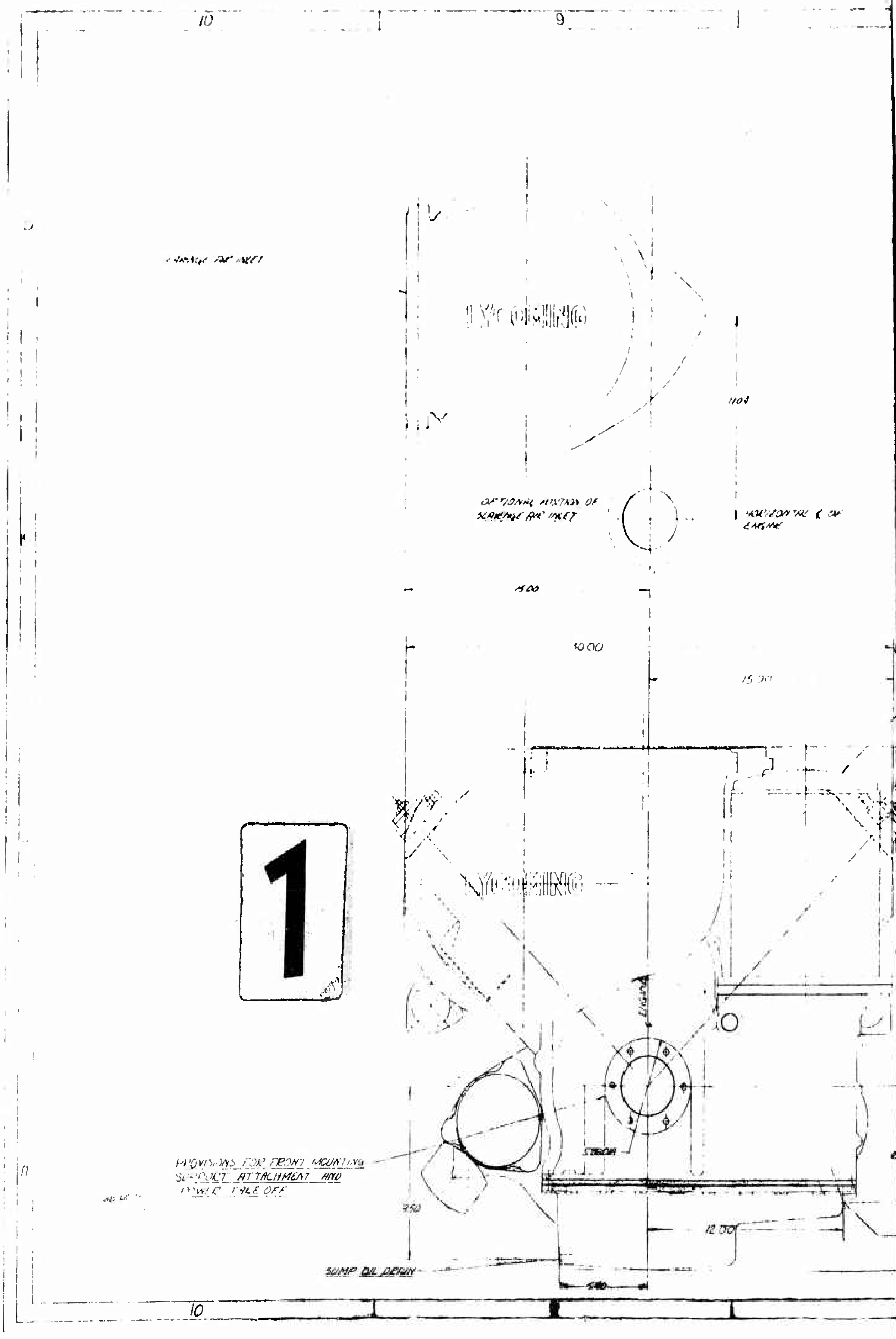
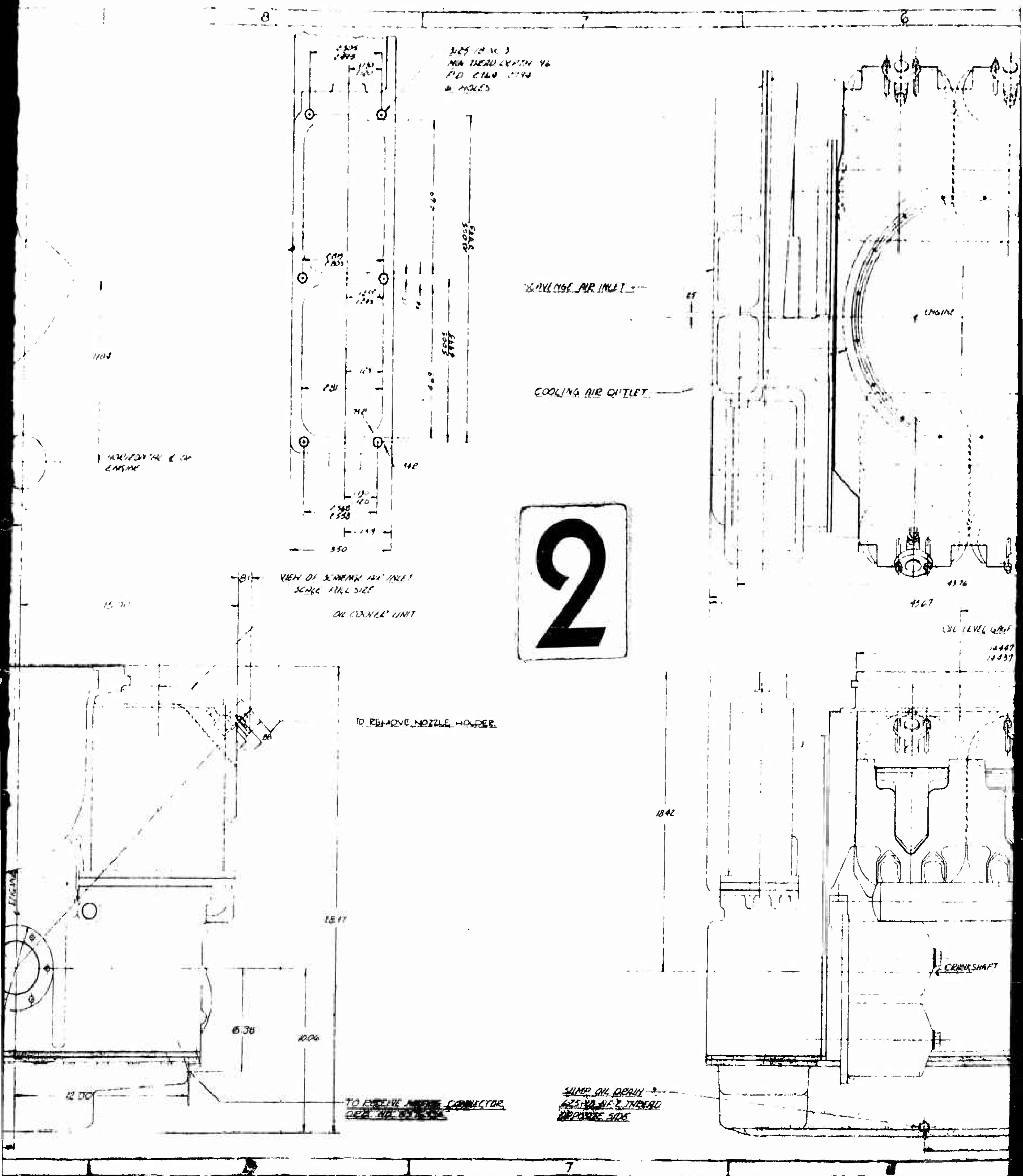

THRU ONE HOLE
DO NOT SCALE DRAWING
DWN
TR
CHD
APPD
APPD
DATE
SCALE
WT CAL ACT
CUMMINS ENGINE CO. INC.
COLUMBUS, INDIANA
DWG NO 142197
CONT ON SHT
SHT
OF

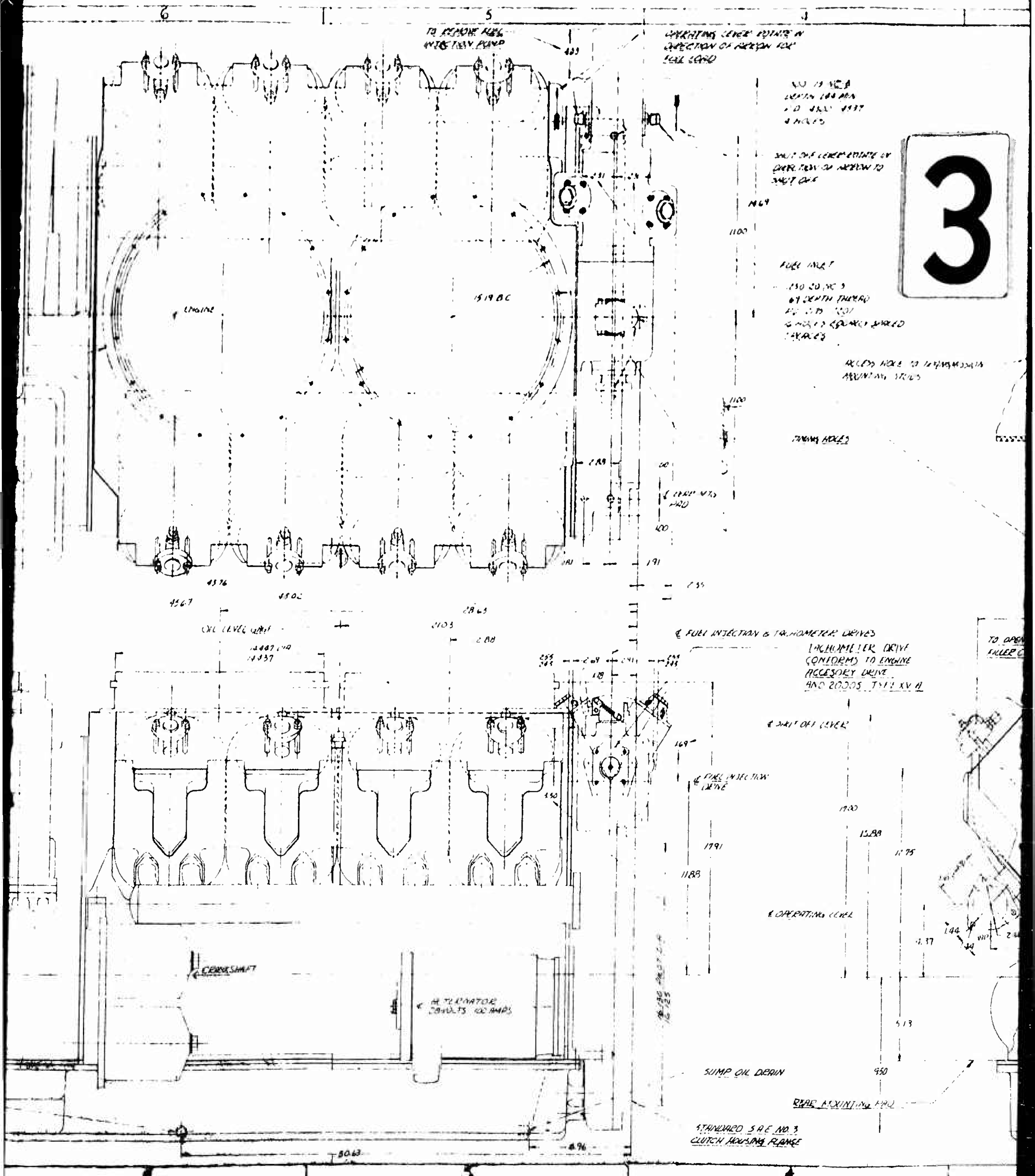
Figure 3.7A



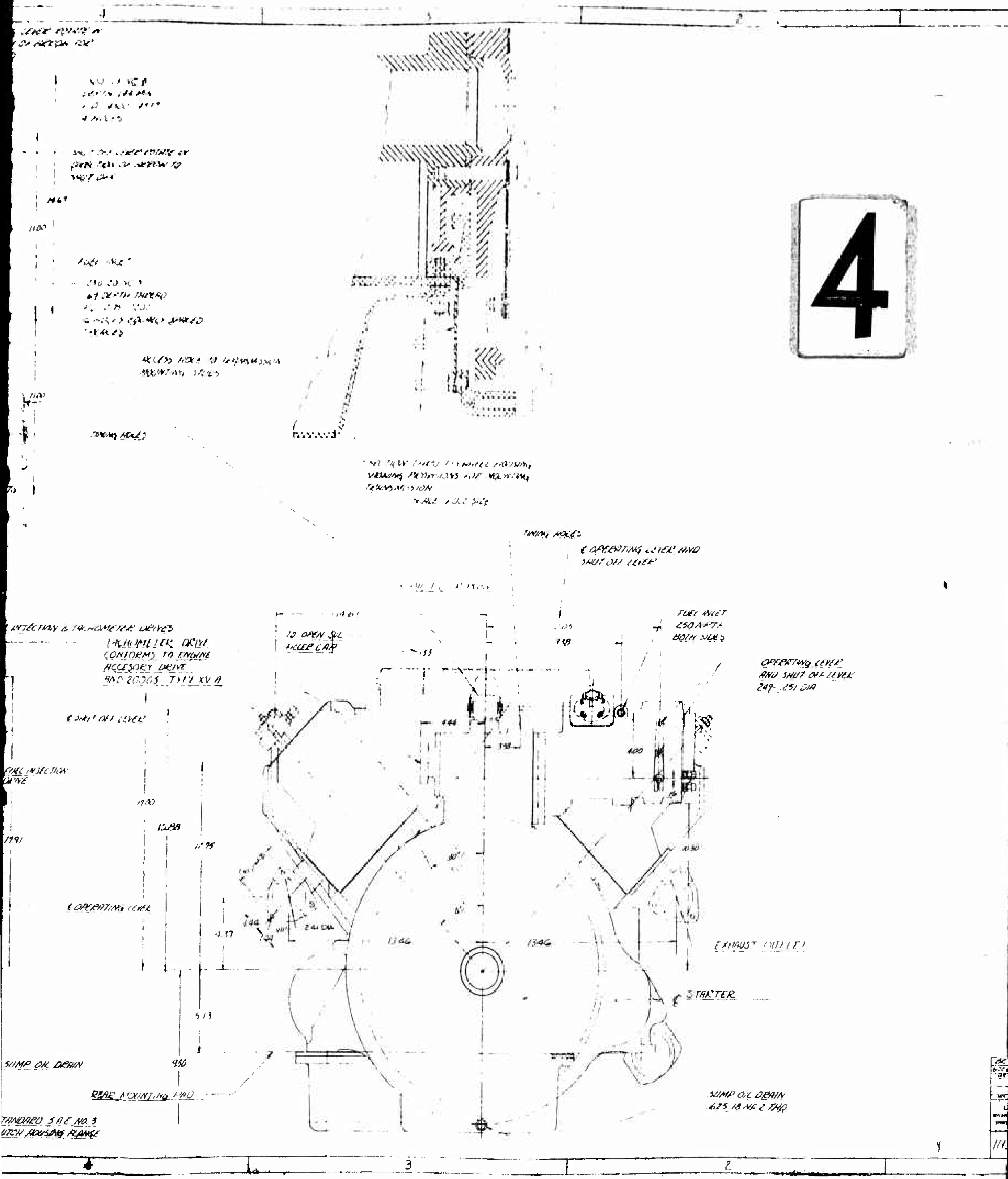
10
9
LYCOMING
1104
15.00
10.00
LYCOMING
1
PROVISIONS FOR FRONT MOUNTING SUPPORT ATTACHMENT AND POWER TAKE OFF
9.50
12.00
SUMP OIL DRAIN
10



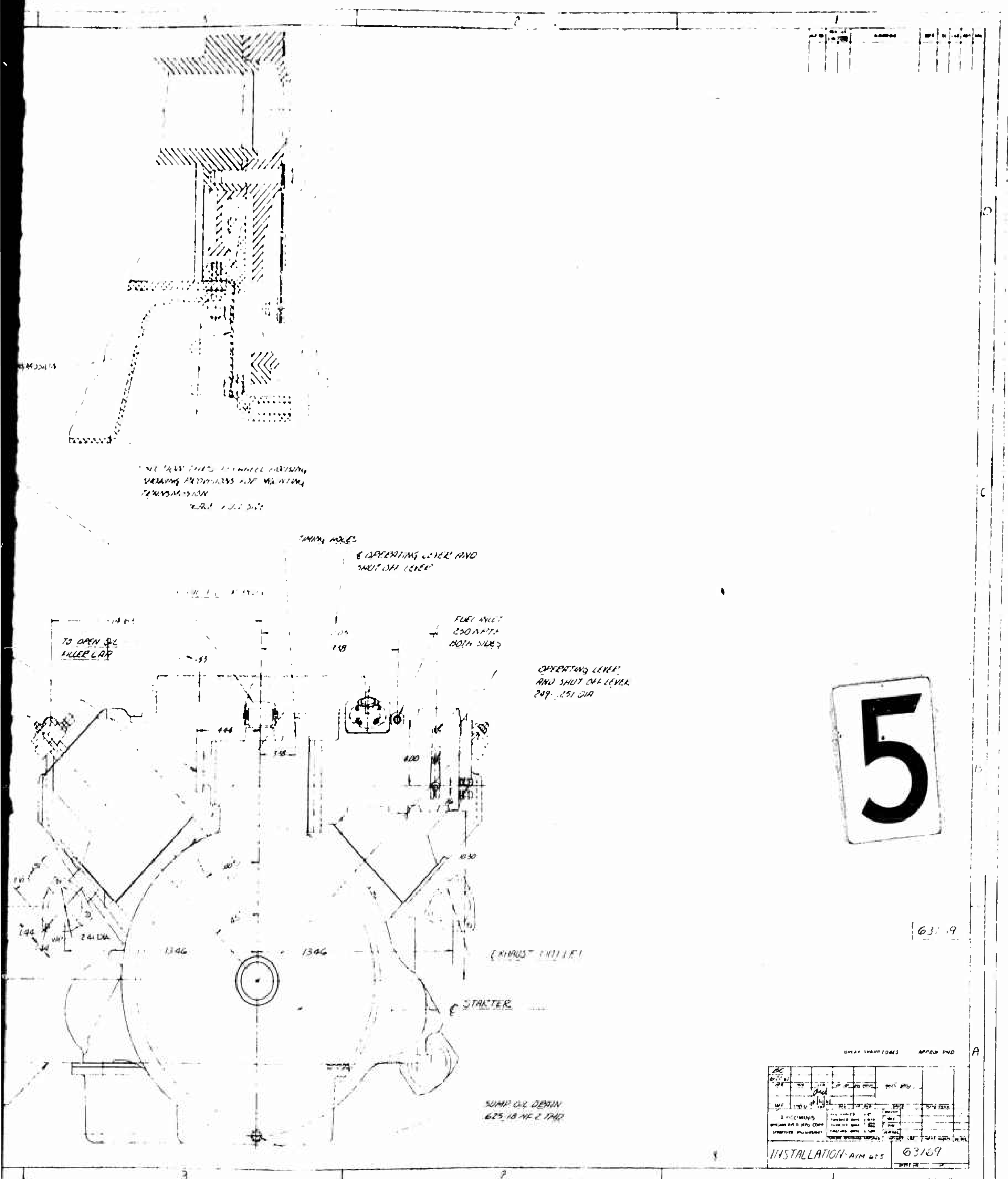
SCAVENGE AIR INLET
COOLING AIR OUTLET
HORIZONTAL ℄ OF ENGINE
VIEW OF SCAVENGE AIR INLET
SCALE FULL SIZE
OIL COOLER UNIT
TO REMOVE NOZZLE HOLDER
ENGINE
OIL LEVEL GAGE
CRANKSHAFT
SUMP OIL DRAIN
OPPOSITE SIDE
6.38
10.06
12.00
18.42
3.50
2



TO REMOVE FUEL INJECTION PUMP
OPERATING LEVER ROTATE IN DIRECTION OF ARROW FOR FULL LOAD
SHUT OFF LEVER ROTATE IN DIRECTION OF ARROW TO SHUT OFF
3
15.19 B.C
FUEL INLET
ACCESS HOLE TO TRANSMISSION MOUNTING STUDS
TIMING HOLES
OIL LEVEL GAGE
℄ FUEL INJECTION & TACHOMETER DRIVES
TACHOMETER DRIVE CONFORMS TO ENGINE ACCESORY DRIVE
℄ SHUT OFF LEVER
℄ FUEL INJECTION DRIVE
℄ OPERATING LEVER
℄ CRANKSHAFT
℄ ALTERNATOR 28 VOLTS 100 AMPS
SUMP OIL DRAIN
REAR MOUNTING PAD
STANDARD S.A.E. NO. 3 CLUTCH HOUSING FLANGE



4
FUEL INLET
ACCESS HOLE TO TRANSMISSION MOUNTING STUDS
TIMING HOLES
TRANSMISSION
SCALE FULL SIZE
TIMING HOLES
℄ OPERATING LEVER AND SHUT OFF LEVER
FUEL INJECTION & TACHOMETER DRIVES
TACHOMETER DRIVE CONFORMS TO ENGINE ACCESORY DRIVE AND 20005 TYPE XV A
TO OPEN OIL FILLER CAP
FUEL INLET .250 NPTF BOTH SIDES
OPERATING LEVER AND SHUT OFF LEVER .249-.251 DIA
℄ SHUT OFF LEVER
FUEL INJECTION DRIVE
17.00
15.88
11.75
17.91
℄ OPERATING LEVER
2.41 DIA
4.37
13.46
13.46
EXHAUST OUTLET
STARTER
5.13
9.50
SUMP OIL DRAIN
REAR MOUNTING PAD
SUMP OIL DRAIN .625-18 NF 2 THD
STANDARD S.A.E. NO. 3 CLUTCH HOUSING FLANGE
4
3
2



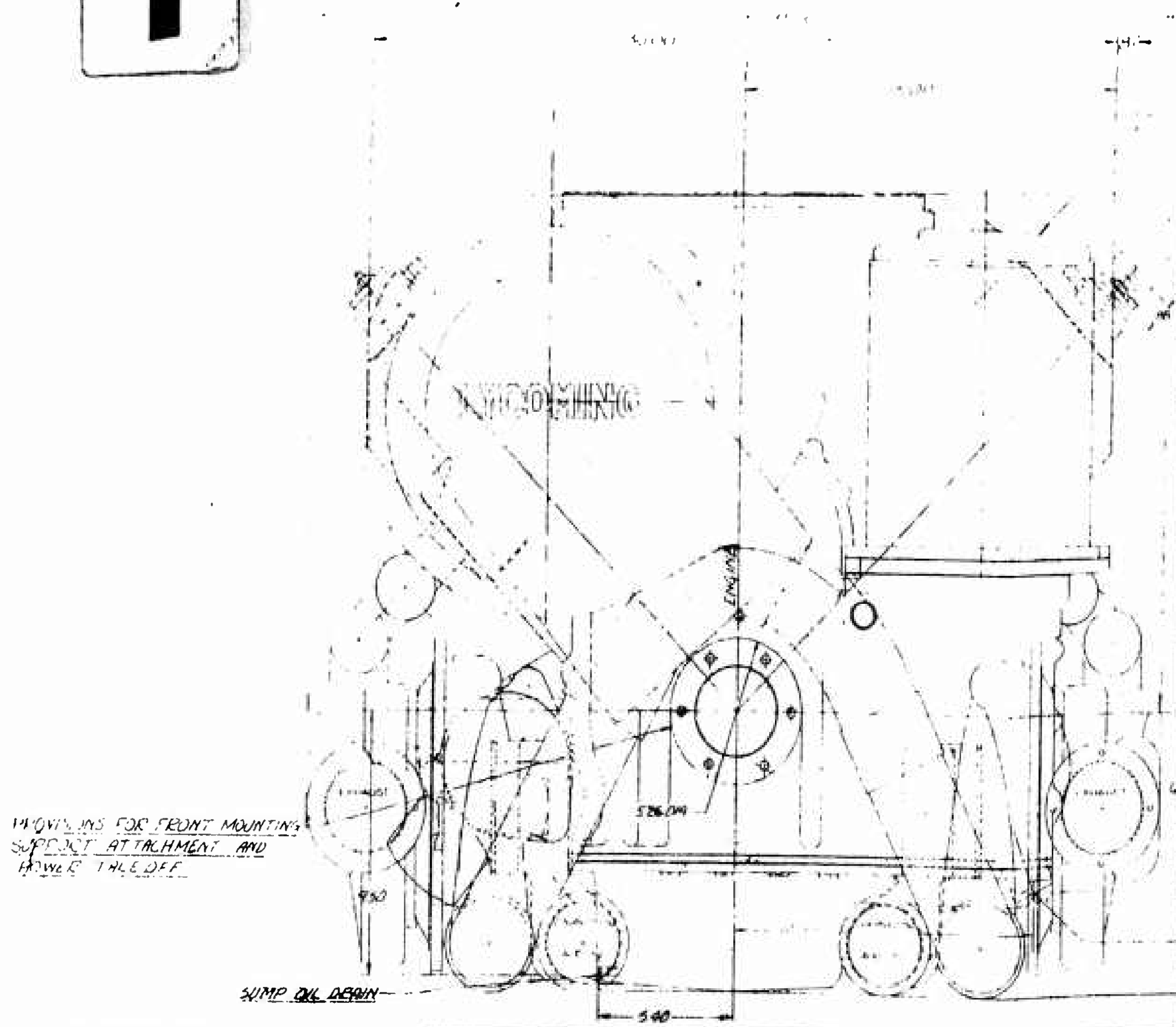
TO OPEN OIL FILLER CAP
FUEL INLET
250 NPTF
BOTH SIDES
OPERATING LEVER
AND SHUT OFF LEVER
249-.251 DIA
EXHAUST OUTLET
STARTER
SUMP OIL DRAIN
625-18 NF-2 THD
INSTALLATION
63169

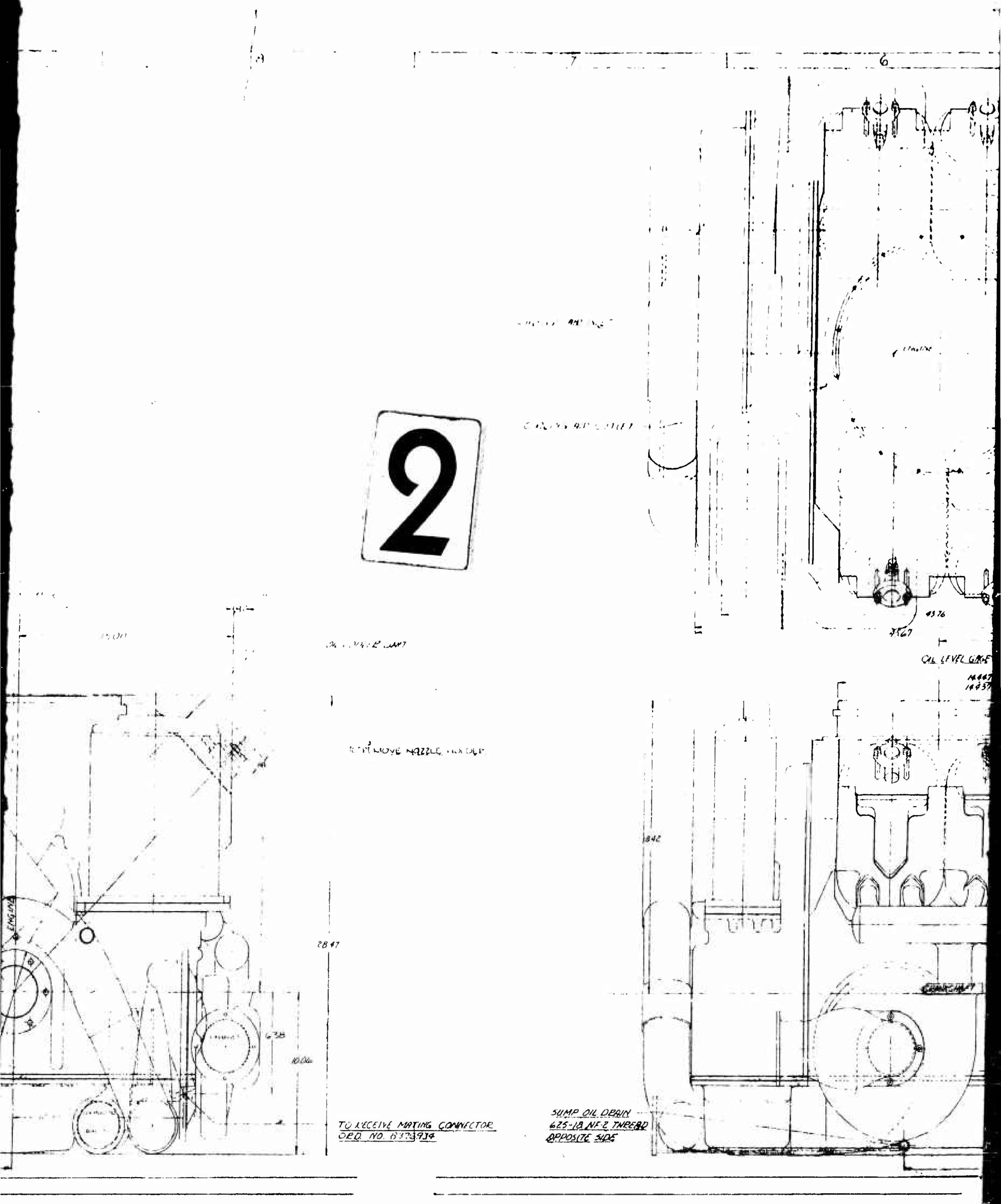
5

Figure 3.7.5

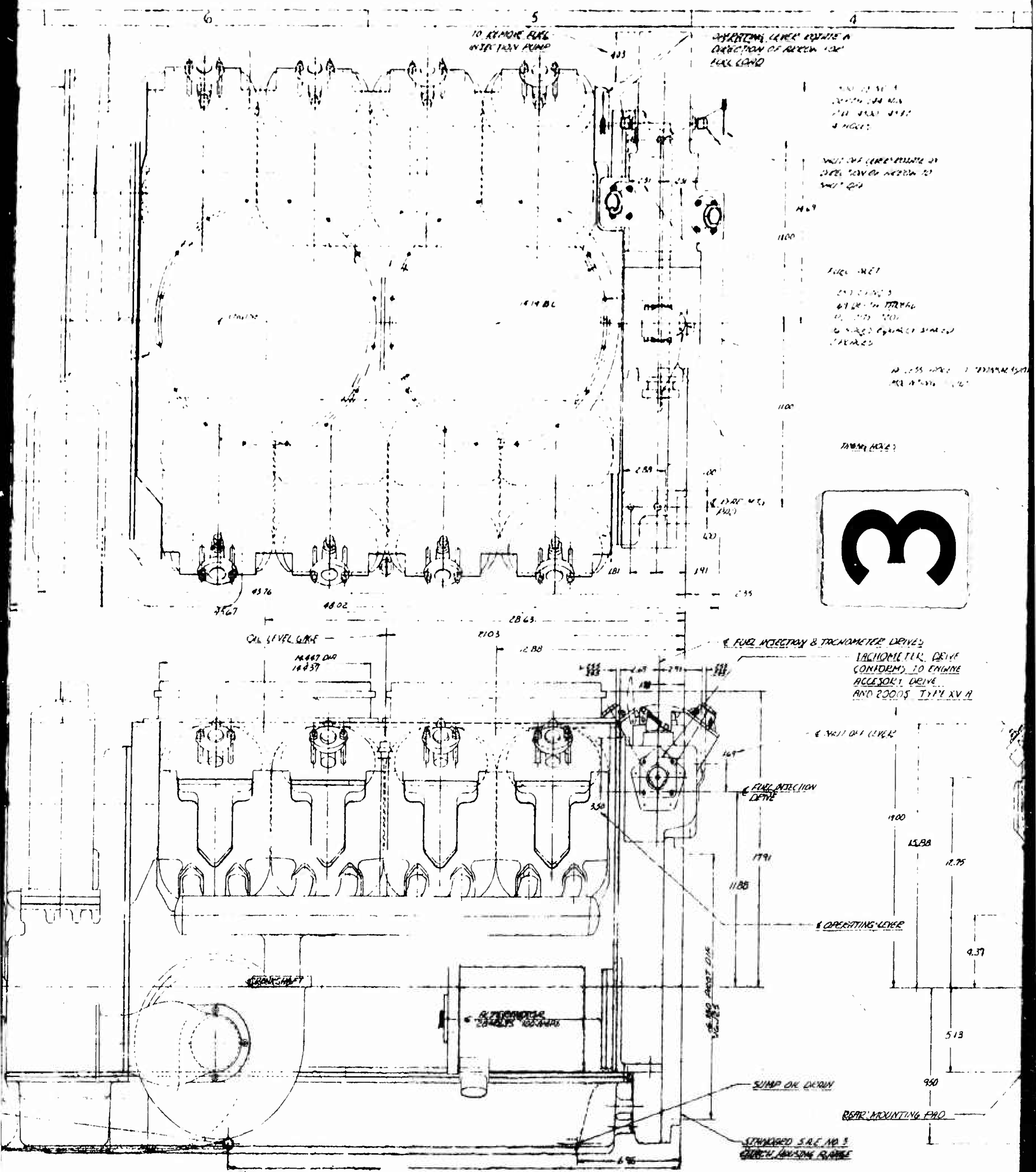
10 9 8

1


LYCOMING
ENGINE
5.26 DIA
9.50
PROVISIONS FOR FRONT MOUNTING SUPPORT ATTACHMENT AND POWER TAKE OFF
SUMP OIL DRAIN
5.40

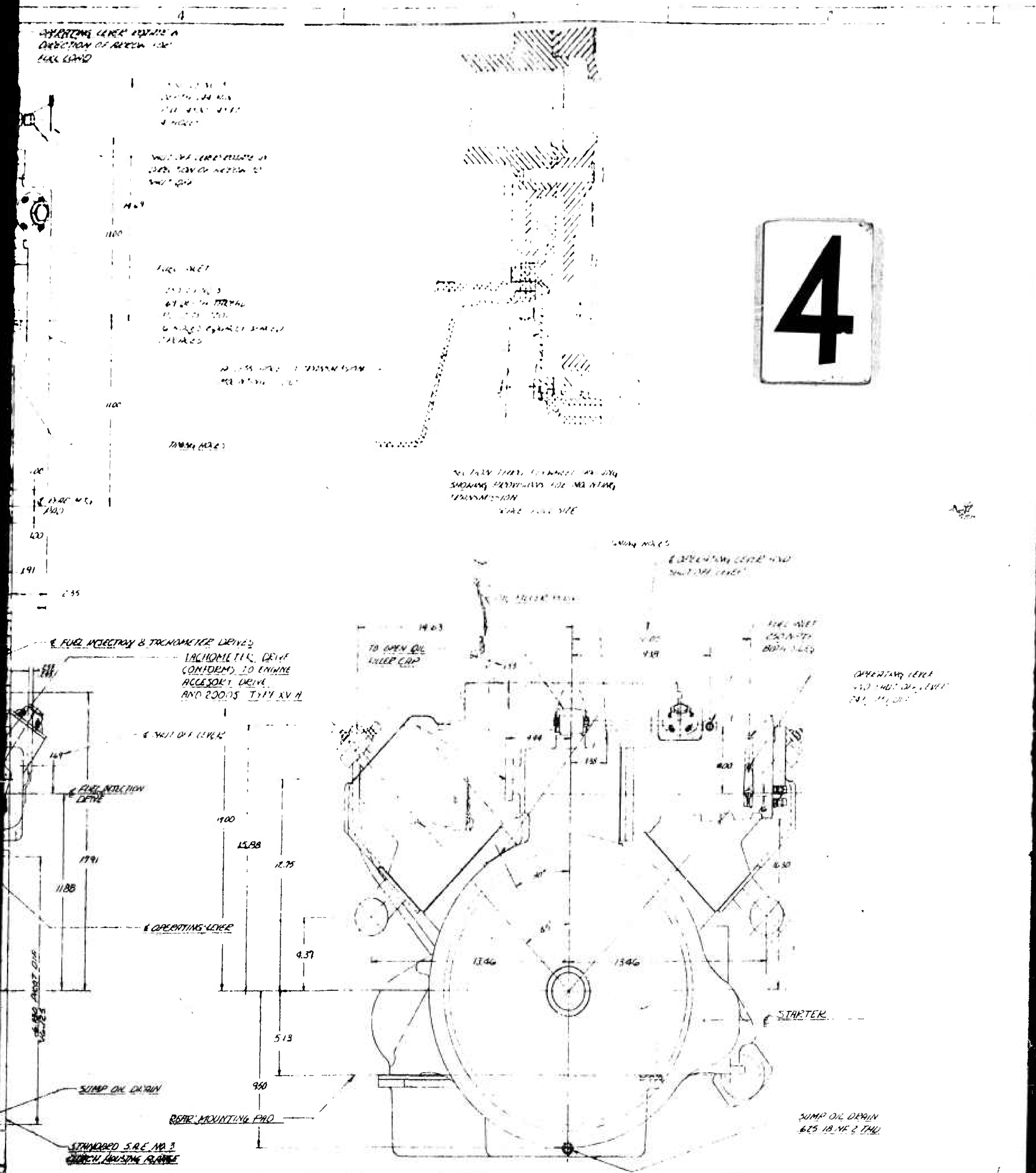


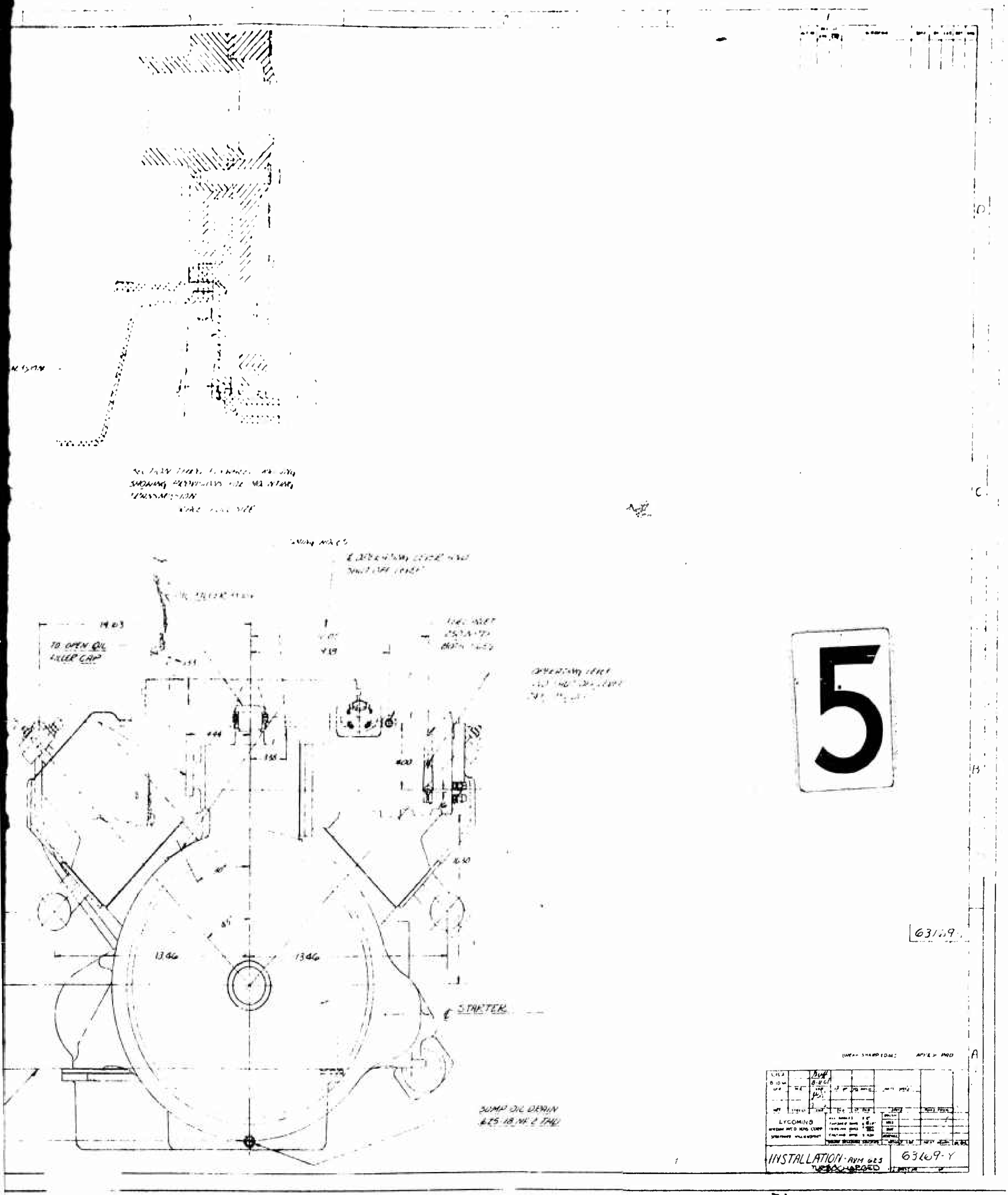
7
6
2
OIL LEVEL GAGE
28.47
6.38
10.06
TO RECEIVE MATING CONNECTOR
ORD. NO. 8373934
SUMP OIL DRAIN
.625-18 NF-2 THREAD
OPPOSITE SIDE



TO REMOTE FUEL INJECTION PUMP
OPERATING LEVER ROTATE IN DIRECTION OF ARROW FOR FULL LOAD
FUEL INLET
TAPPED HOLES
OIL LEVEL GAGE
℄ FUEL INJECTION & TACHOMETER DRIVES
TACHOMETER DRIVE CONFORMS TO ENGINE ACCESORY DRIVE AND 20005 TYPE XV A
℄ SHUT OFF LEVER
℄ FUEL INJECTION DRIVE
℄ OPERATING LEVER
CRANKSHAFT
ALTERNATOR
SUMP OIL DRAIN
REAR MOUNTING PAD
STANDARD S.A.E. NO. 3 BENCH HOUSING FLANGE

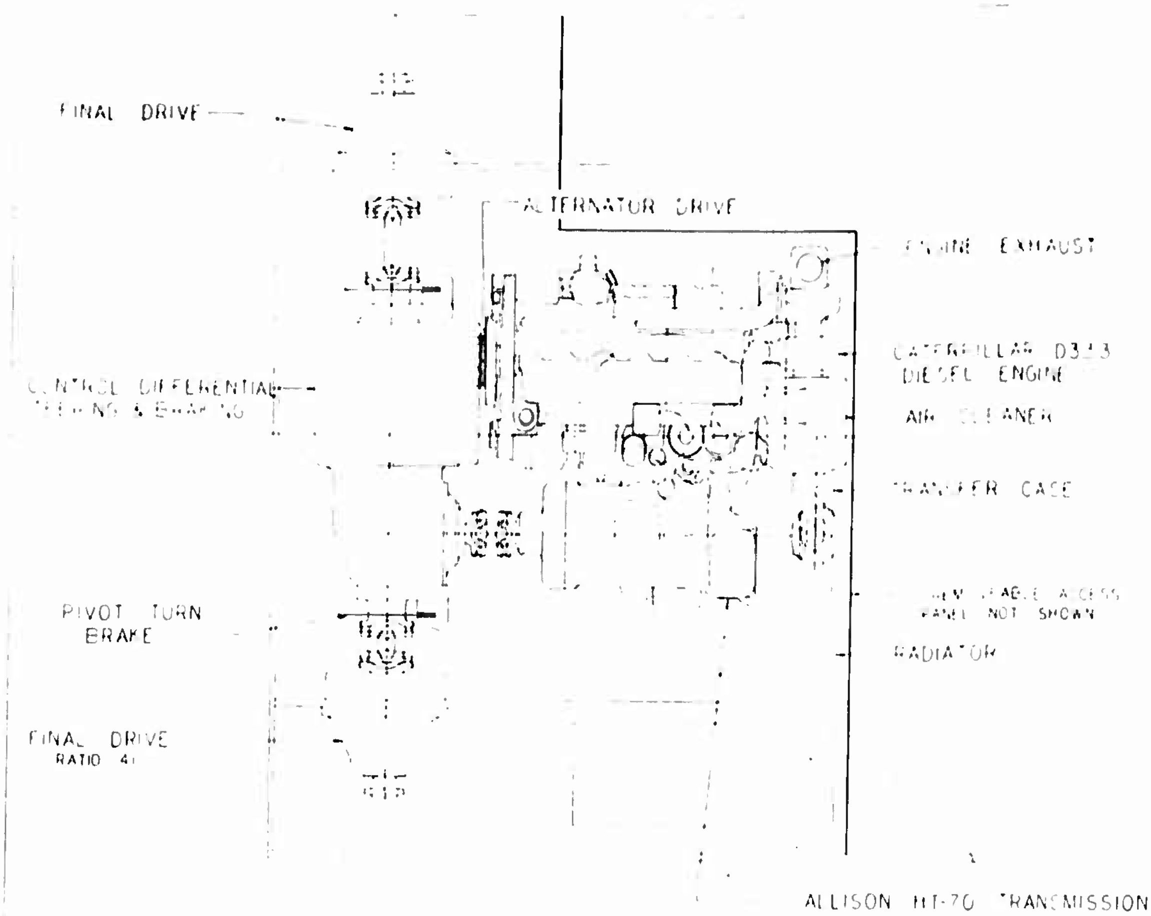
3


OPERATING LEVER ROTATE IN DIRECTION OF ARROW FOR FULL LOAD
4
℄ FUEL INJECTION & TACHOMETER DRIVES
TACHOMETER DRIVE CONFORMS TO ENGINE ACCESORY DRIVE AND 20005 TYPE XV A
℄ SHUT OFF LEVER
℄ FUEL INJECTION DRIVE
℄ OPERATING LEVER
TO OPEN OIL FILLER CAP
14.63
19.00
15.88
12.75
17.91
11.88
4.37
5.13
9.50
13.46
13.46
STARTER
SUMP OIL DRAIN
REAR MOUNTING PAD
STANDARD S.A.E. NO. 3 CLUTCH HOUSING FLANGE
SUMP OIL DRAIN .625 18 NF 2 THD

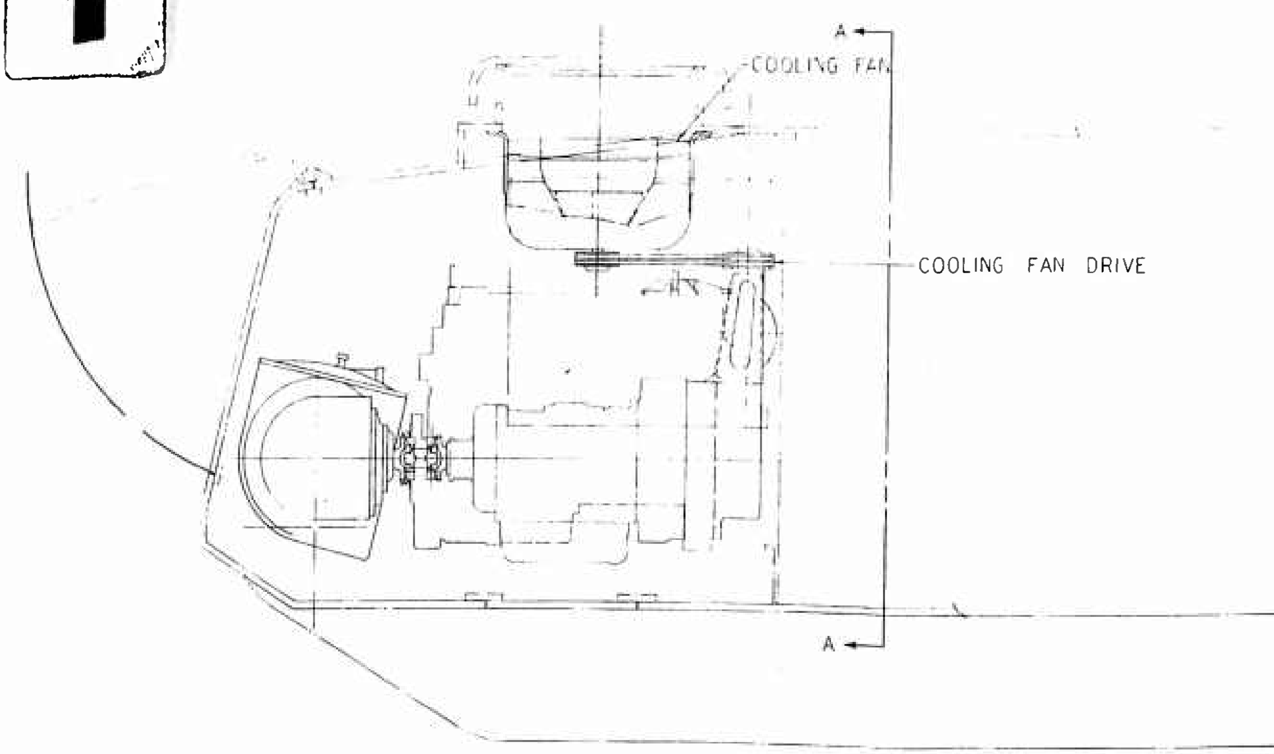


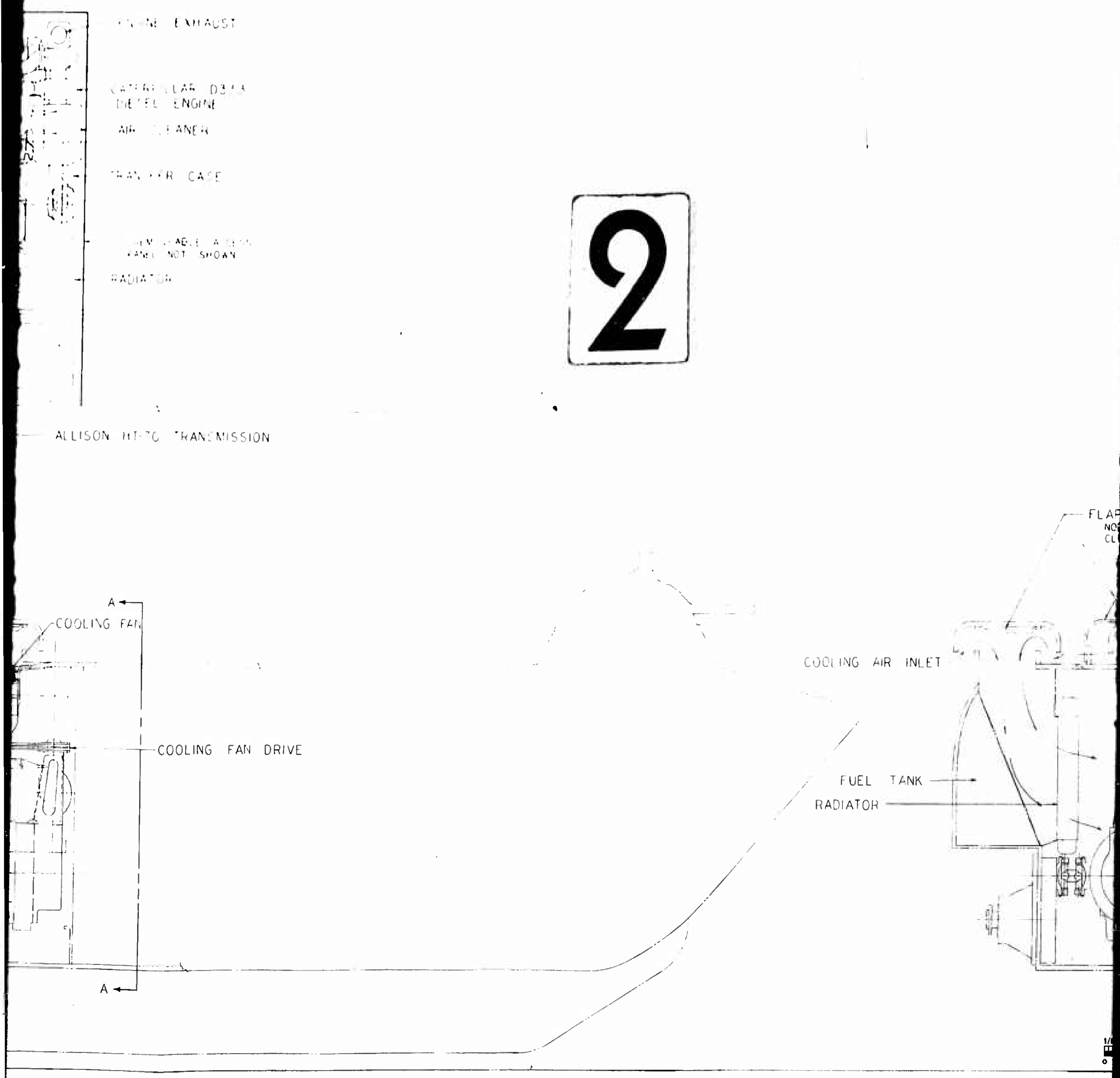
TO OPEN OIL FILLER CAP
14.03
13.46
13.46
STARTER
SUMP OIL DRAIN .625-18 NF-2 THD
LYCOMING
INSTALLATION - AVM 625 TURBOCHARGED
63609-Y

Figure 3.7.6

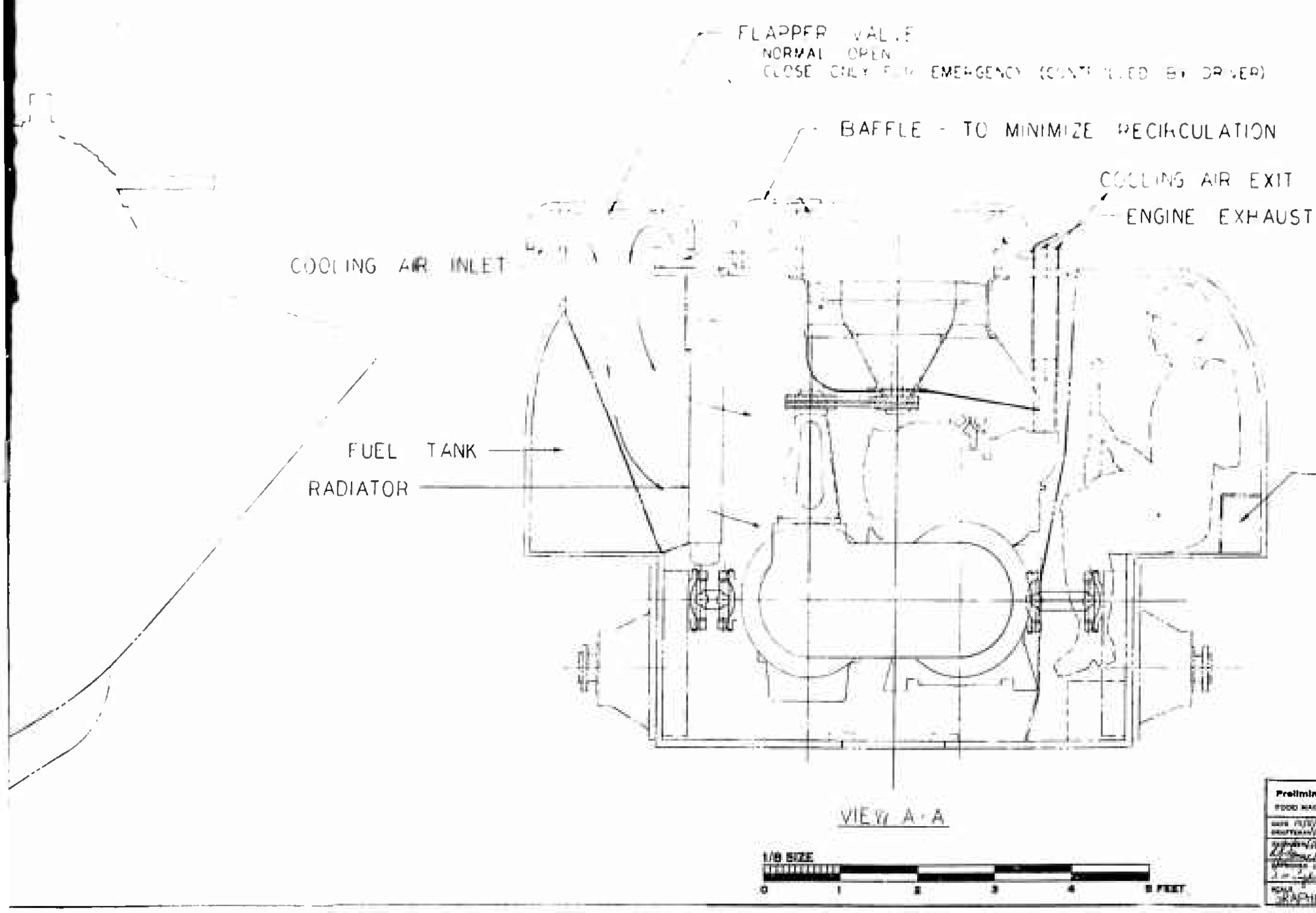

FINAL DRIVE
PIVOT TURN
BRAKE
FINAL DRIVE
RADIATOR
ALLISON HT-70 TRANSMISSION

1


COOLING FAN DRIVE
A
A


2
RADIATOR
TRANSMISSION
A
COOLING FAN DRIVE
COOLING AIR INLET
FUEL TANK
RADIATOR
A

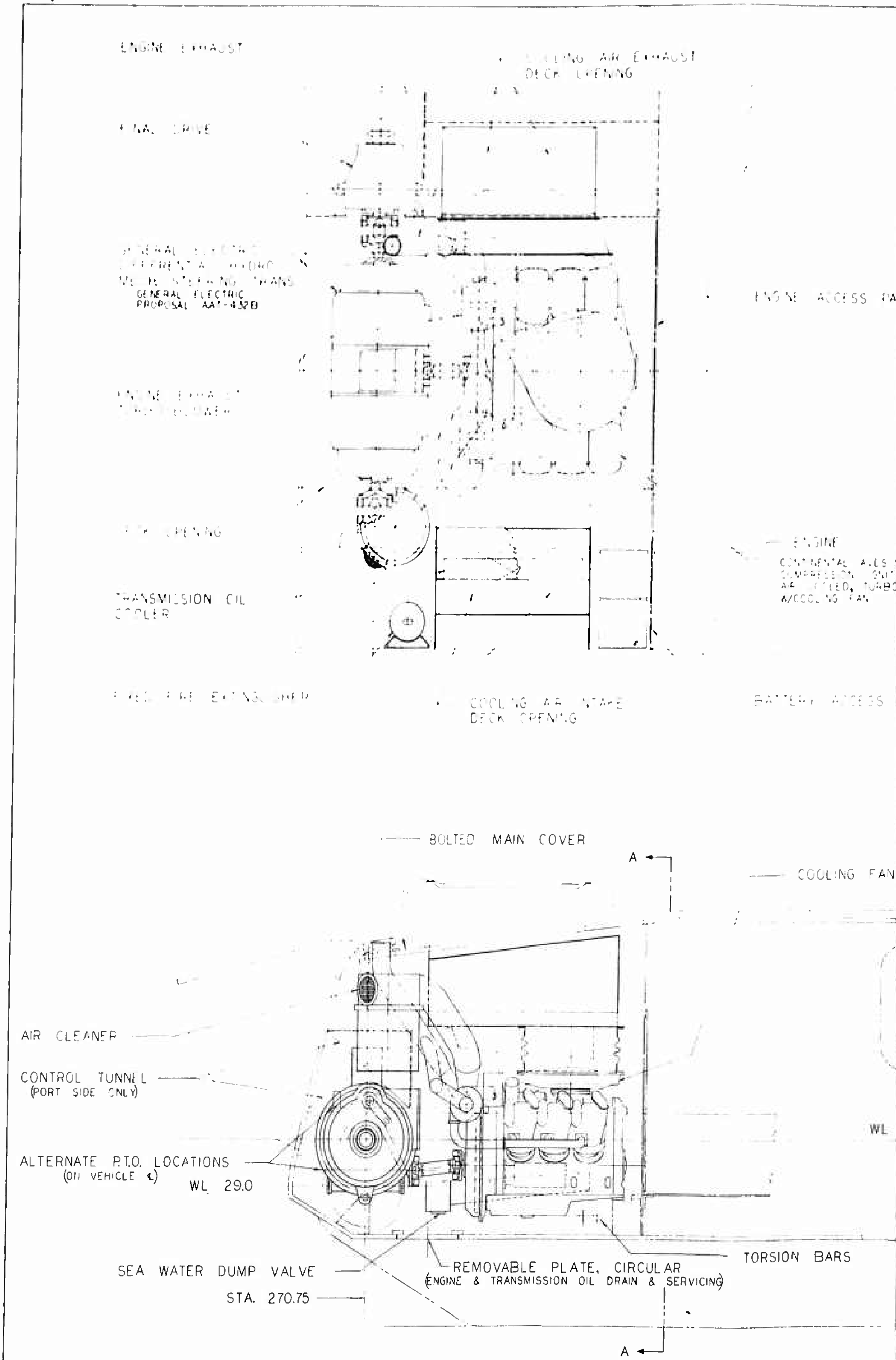
3

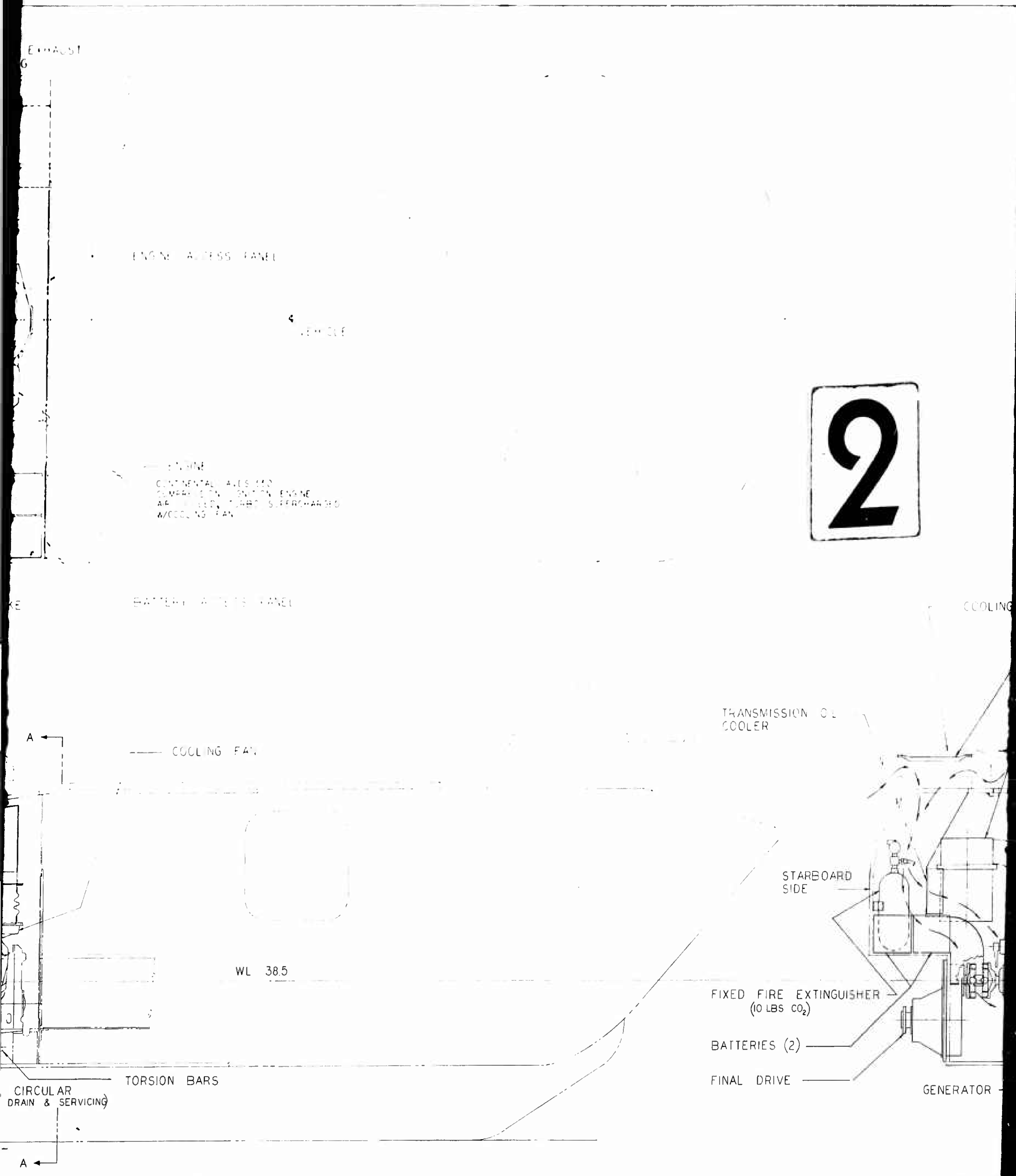


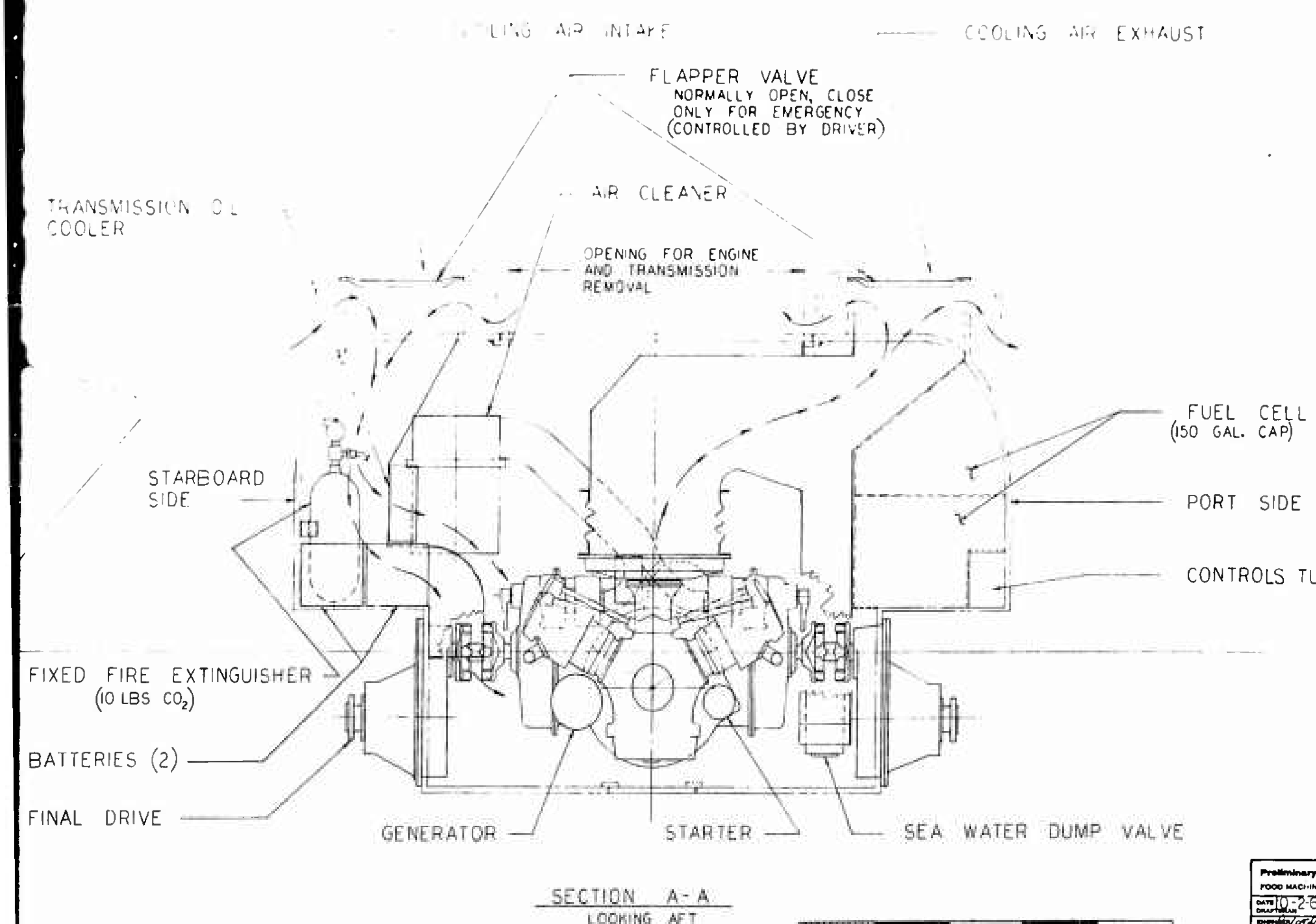
Preliminary Design Engineering AND CHEMICAL CORPORATION	**ORDNANCE DIVISION** SAN JOSE CALIFORNIA
SCALE GRAPHIC	MACHINERY INST. LVT-PXII CATERPILLAR D333 ENG - ALLISON HT-70 & CONTROL DIFFERENTIAL
P A NO 443	DWG NO 10__403
SHEET 1 OF 1	

Figure 3.7.7

1


ENGINE EXHAUST
FINAL DRIVE
GENERAL ELECTRIC
PROPOSAL AA?-432B
TRANSMISSION OIL COOLER
COOLING AIR INTAKE
DECK OPENING
BOLTED MAIN COVER
A
COOLING FAN
AIR CLEANER
CONTROL TUNNEL
(PORT SIDE ONLY)
ALTERNATE P.T.O. LOCATIONS
(ON VEHICLE ℄)
WL 29.0
WL
SEA WATER DUMP VALVE
STA. 270.75
REMOVABLE PLATE, CIRCULAR
(ENGINE & TRANSMISSION OIL DRAIN & SERVICING)
TORSION BARS
A


2
COOLING FAN
TRANSMISSION OIL COOLER
STARBOARD SIDE
WL 38.5
FIXED FIRE EXTINGUISHER (10 LBS CO2)
BATTERIES (2)
FINAL DRIVE
GENERATOR
TORSION BARS
CIRCULAR
DRAIN & SERVICING
A



Preliminary Design Engineering FOOD MACHINERY AND CHEMICAL CORPORATION		ORDNANCE DIVISION SAN JOSE, CALIFORNIA
DATE 10-2-61	MACHINERY INSTL LVT-PXII 35,000# GVW	P.A. NO. 449
DRAFTSMAN	CONTINENTAL AVDS-550 ENG. W/GENERAL ELECTRIC HYDRO-MECH STEERING TRANS	DWG. NO 1077389
SCALE GRAPHIC		SHEET 1 OF 1

3

Figure 3...

Mfr & Model	BHP	BSFC Full Power	Fuel (lb/hr)	Fuels	HP or Torque Limited	Output Speed (rpm)	Induction Air at Turbine Ambient lb sec	Induction Air at Turbine Ambient cfm	Envelope Dimensions (in.)	Size Applicable to LVTPX11	Weight (lb)	Remarks
Allison GMT-306 (proposed for XM551 ARV)	266 @ 100°F	.443 @ 100°F	-	-----	-	4,000 (max)	3.66				955 (1055 incl. air cleaner and oil cooler)	Regenerative
Allison GMT-306	300 @ 80°F	.425 3	-	-----	-	4,000	3.82		46.5 L 31.25 W 27.75 H	Yes		Regenerative
AiResearch Solid shaft or free shaft	300	.505 3	-	JP-4 & JP-5 diesel 1 & diesel 2 combat gasoline	Will be provided	6,000	4.5 60°F	3520 @ 60°F	58.0 L 30.0 W 32.0 H	Yes	850 solid shaft, 950 free shaft	Heat recovery
AiResearch Free shaft	250	.575 3	-	Same as above	Available	6,000	3.75 60°F	2940 @ 60°F	Same as above	Yes	850	Heat recovery
Ford 704	300	.56 (.48 @ 50% power)	-		No		2.71 (Std air)	2160 @ 60° F	38.17 L 29.32 W 31.00 H		650	Recuperative (Plate and shell)
Pratt & Whitney 2	245 @ 100°F	.575 @ 100°F	-	-----	-	---	---		---		1155	Recuperative
Boeing 520-3 Free shaft	300 @ 125°F	.75	234	Diesel fuel std. Multi-fuel available	HP limited	6,000	Not specified		58.32 L 25.14 W 23.40 H	Yes	360	No heat recovery
Solar T-350 Solid shaft 1	250 @ 125°F	.86	291.2	Combat & aviation gasoline, jet fuels, kerosene, diesel	HP limiter can be provided	6,000	6.5 60°F	5200 @ 60°F	38.0 L 26.35 W 24.02 H	Yes	185	No heat recovery
Continental 217-5A	500	.70	-	-----	No	Not listed	-				245	
Continental 231-7 2	493	.67	-	JP-4 kerosene gasoline	-	5,854	-				275	
Waukesha	400 @ 100°F	-	-	-----	-	3,600	-		50.0 L 28.0 W ---- H		620	Free or fixed shaft
Chrysler CR-2A	140 @ 85°F	.51	-	Gasoline JP-4 kerosene diesel	No	4,570	2.2		36.0 L 35.0 W 27.0 H	Would require two turbines	450 each	Regenerative

FIGURE 3.7.9

GAS TURBINE COMPARISON

NOTES:
1 Limited by gearbox.
2 Not made in U.S.A.
3 Predicted fuel consumption.

Engines (Continued)

In addition, a turbine installation requires a special control to limit the maximum power level (with respect to the induction air temperature) to a value acceptable to the transmission.

However, to indicate the vehicle design compatibility, should accelerated turbine development provide a suitable engine, an installation of the AiResearch gas turbine and the XTG-300 transmission is shown in Figure 3.7.10.

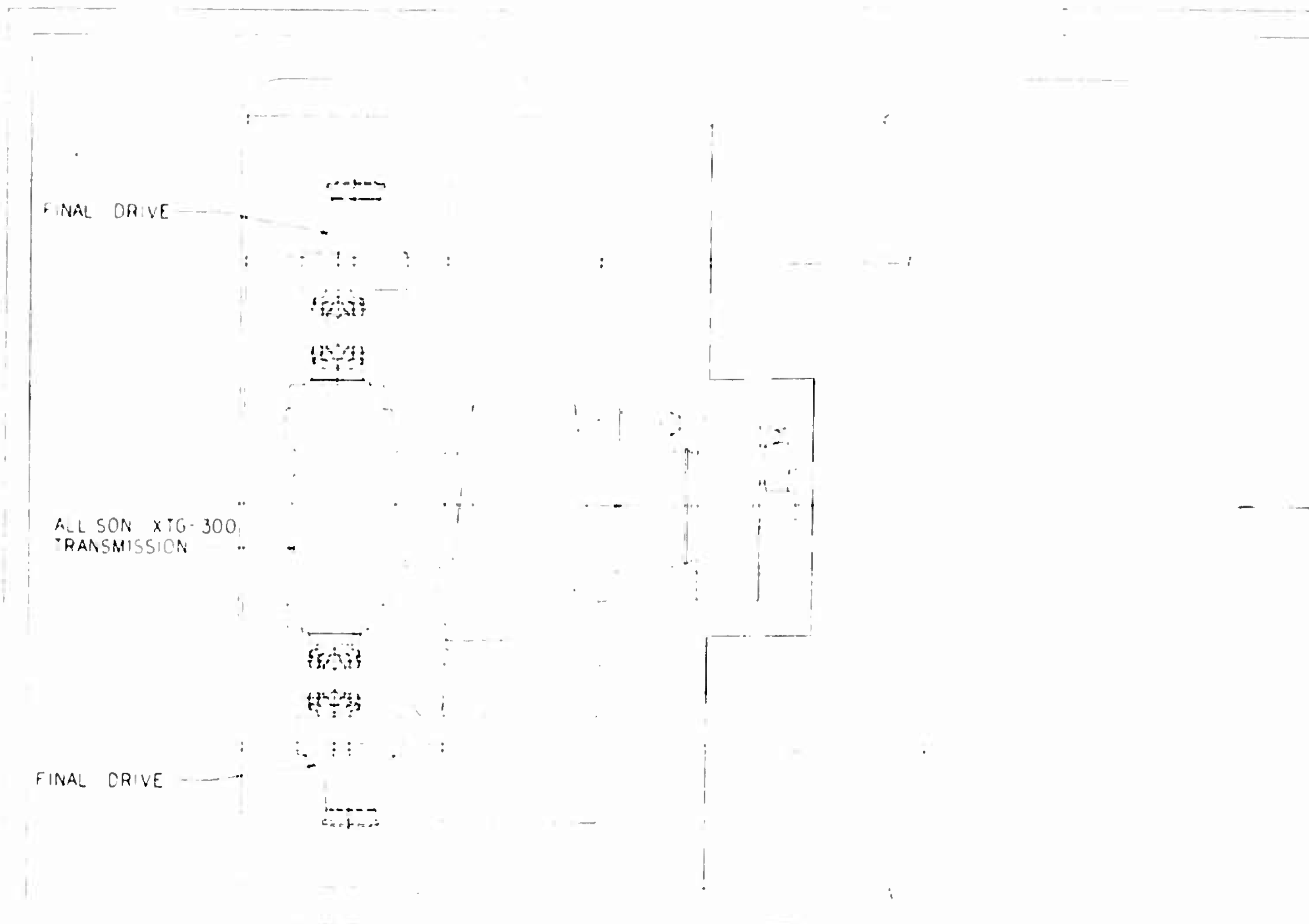
3.7.3.3 Gasoline Engines

Typical gasoline engines shown in Figure 3.7.11, while offering lighter weight than most diesel engines, present both a higher BSFC and a lack of multifuel capability. This and the higher volatility of the required fuel preclude their use.

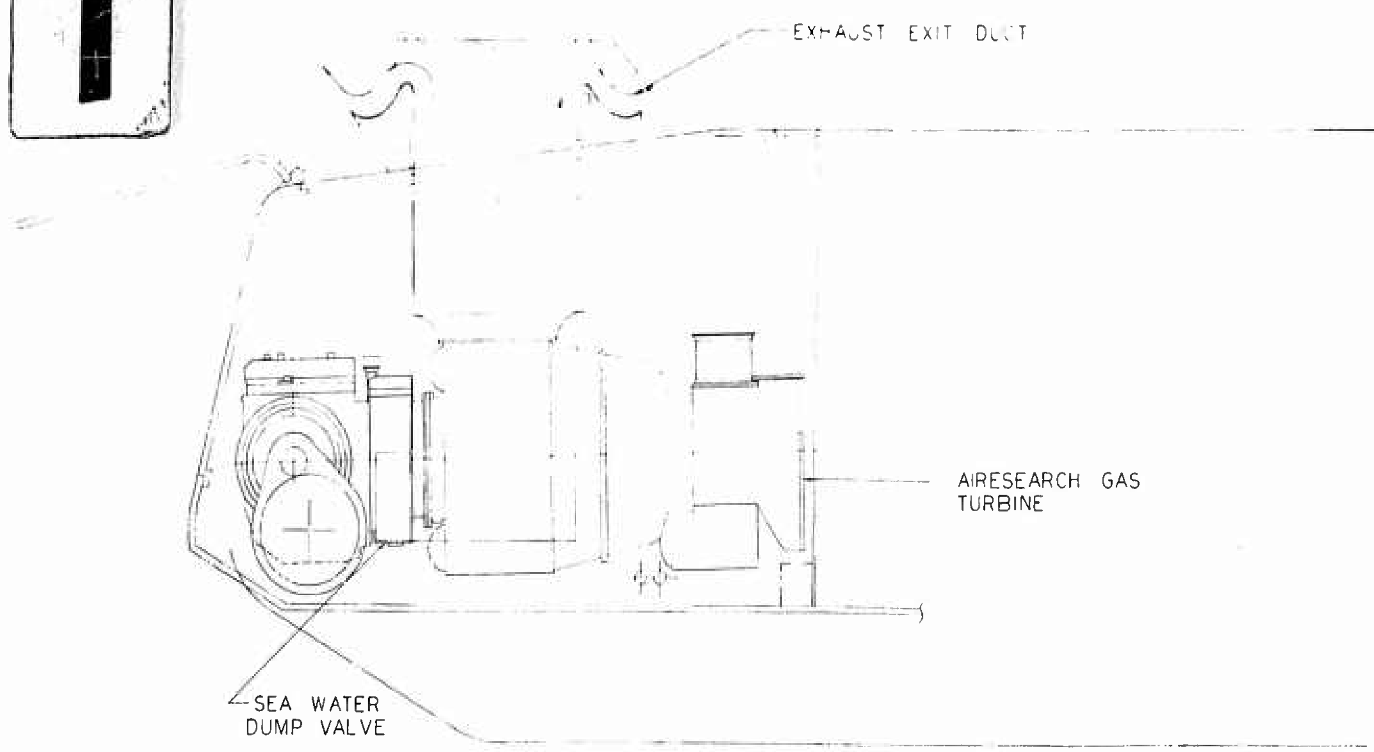
3.7.3.4 Fuel Cells

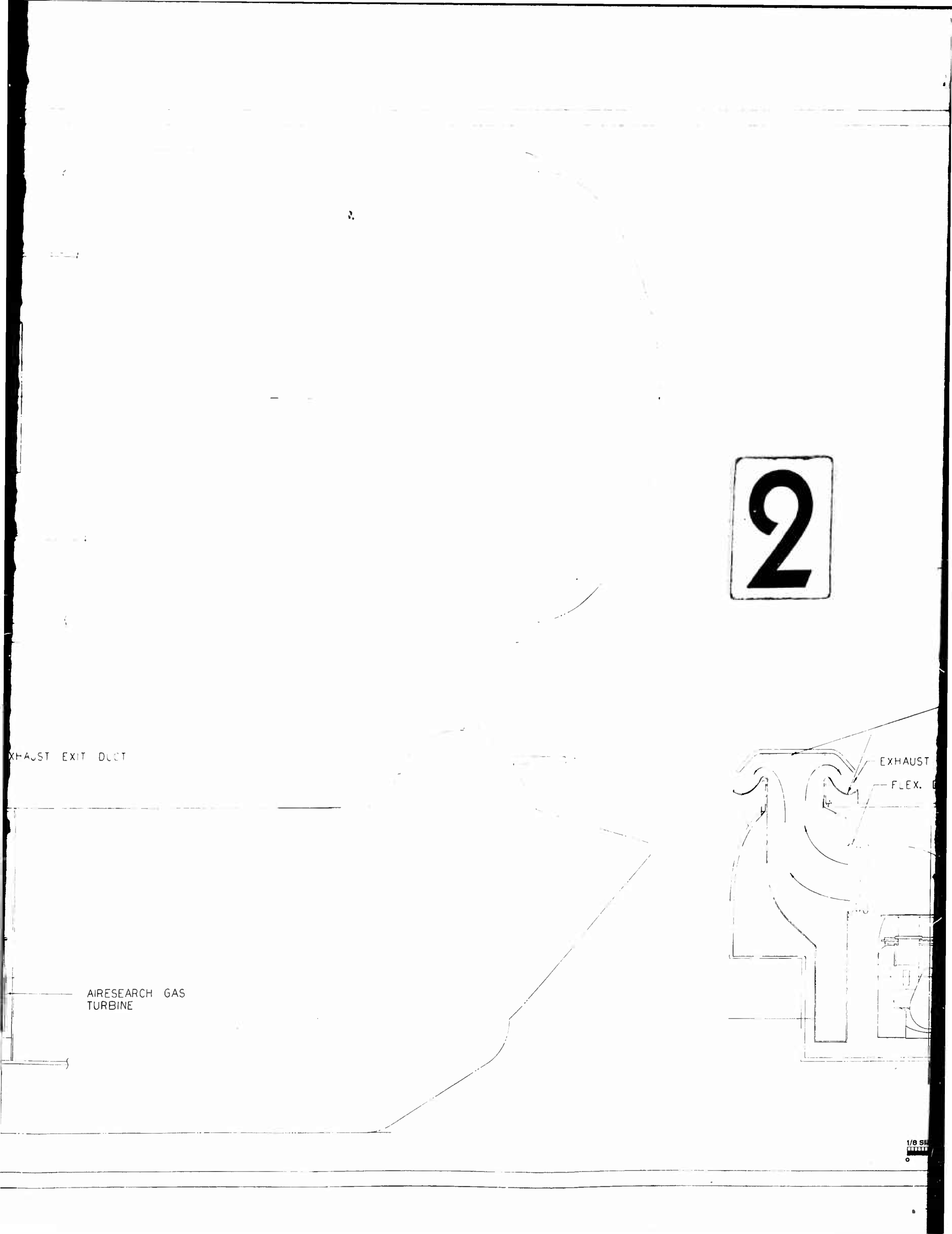
Even though this field is in the embryonic stage, any study of future vehicle design must certainly consider fuel cells as a vehicle power source, because of the following advantages:

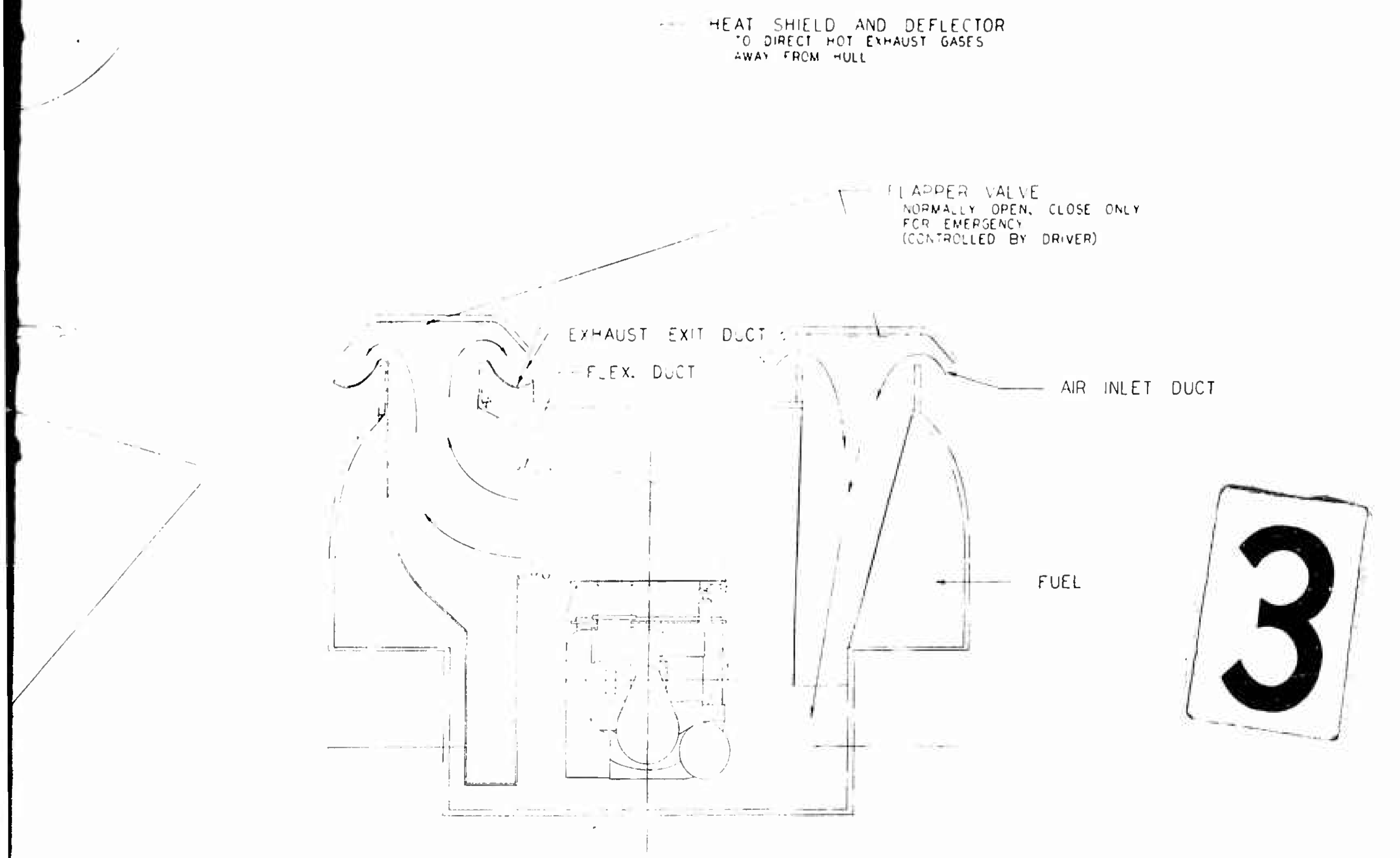
- Efficiency - Theoretically 100%, not limited by the Carnot cycle
- Simplicity - No moving parts
- Configuration - May be assembled to take advantage of presently unusable space


FINAL DRIVE
ALLISON XTG-300
TRANSMISSION
FINAL DRIVE

1


EXHAUST EXIT DUCT
AIRESEARCH GAS
TURBINE
SEA WATER
DUMP VALVE


2
XHAUST EXIT DUCT
EXHAUST
FLEX.
AIRESEARCH GAS TURBINE
1/8



Preliminary Design Engineering — **ORDNANCE DIVISION**
FOOD MACHINERY AND CHEMICAL CORPORATION — SAN JOSE, CALIFORNIA

DATE 10/5/61 DRAFTSMAN FWF	MACHINERY INST.	P. A. NO. 449
ENGINEER	LVT-PXII	DWG. NO. 1077392
APPROVED	AIRESEARCH GAS TURBINE AND ALLISION XTG-300	
SCALE 1/8	TRANSMISSION	SHEET OF

Figure 3.[illegible].10

Engine	Model	HP & Speed	BSFC	Wt (lb)	Heat Rej.	Air Flow	Coolant Flow	Length (in.)	Width (in.)	Height (in.)	Comments
General Motors	702 Twin 6	380 3800 rpm	.552 W.O.T. .504 2200	1484 Dry	15,250 BTU at W.O.T.	628 cfm	179 gpm	55.0	31.47	38.52	Too long
General Motors	702 Twin 6 Lightw't	Same as above	Same as above	1420 Dry	Same as above	Same as above	Same as above	Same as above	Same as above	Same as above	Too long
Waukesha	MT-H884 V8	330 2800 rpm	.59 W.O.T. .48 1600	2100 Dry	52 BTU at W.O.T.		82 gpm @ 5 psi 2400 rpm	44.44	35.75	44.25 est.	Heavy

FIGURE 3 7 11 GASOLINE ENGINE COMPARISON

Engines (Continued)

- Logistics - Can be designed for fuels which can be manufactured close to the operational area

- Lack of noise and vibration

Although promising, there are many problems to be solved in the fuel cell, some of which are as follows:

- Power density - Present 1 kilowatt per cubic foot must be increased to at least 5.

- Electrode corrosion - Oxidation of the electrode due to the cell reaction must be minimized

- Ruggedness - Design to withstand vehicle shock and vibration must be improved

- Reliability - Present cells have a potential of 0.1 volt and require series connections. Failure of one cell deactivates that complete string.

In summation, fuel cells cannot be considered available for operational vehicles before 1970.

3.7.4 Power Trains

The fundamental purpose of a power train is to match the engine power output characteristics to the vehicle requirements. In a tracked vehicle, the power train must also serve other functions. Steering becomes a power

Power Trains (Continued)

train function, because it requires control of both the speed and direction of rotation of the tracks relative to each other, and the power train usually provides vehicle braking.

Figure 3.7.12 shows the power trains investigated during this study. For comparative purposes, considering the relation between the input and output characteristics of speed and torque, power trains can be divided into three basic types, as follows:

- Fixed ratio
- Limited variable ratio
- Continuously variable ratio

An example of the fixed-ratio type is a multiratio gearbox with either a friction clutch or a fluid coupling, providing no output multiplication other than the fixed ratios.

An example of the limited variable ratio type is a torque converter, with or without a gearbox. The output speed is independently variable up to a limit of less than the input speed. Stall torque is produced by power dissipation, because slip isused to generate torque.

An example of the continuously variable ratio transmission is a hydrostatic (or hydromechanical) type. Output speed and torque are independent of input speed and torque. Input power is determined by output power, but can be produced at any desirable combination of speed and torque compatible with the engine characteristics.

Power Trains (Continued)

In this study, the above types of transmissions were evaluated under one of the following classifications, in this section.

- Mechanical Transmissions
- Hydrostatic and Hydromechanical Power Trains
- Electrical Power Trains

Although a good response was received from the manufacturers of continuously variable ratio or nonmechanical types of transmissions based upon the present state-of-the-art, these units are not advanced enough in their development to be recommended at this time; however, progress in both electrical and hydrostatic drives should be actively monitored during the LVTPX11 development, since it may become desirable to incorporate one of these units at a later date.

3.7.4.1 Mechanical Transmissions

Because of the compactness and inherent light weight of Ordnance units, this area was thoroughly investigated. For a 35,000 lb GVW, two power trains are available, the XTG-250 and the XTG-300. Since the XTG-300 is a turbine-driven power train, the XTG-250 is the only Ordnance unit available in this torque range. The units investigated are shown in Figure 3.7.12. The selected power train, the Allison XTG-250 Transmission and Steering Unit shown in Figure 3.7.13, offers the following salient features:

- Light weight
- Pivot-steer capability
- Currently under development
- Full-power shift capability
- Four forward speeds - two reverse speeds

1

Transmission or Power Train	Type			General Description	Max Input Torque (ft-lb)	Max Input Speed (rpm)	Approx Design Input (hp)	Dry Weight w/o F D (lb)	Proj C
Allison XTG-250	Mech.		Ord. type	4-speed fwd, 2-speed rev., manual full power shift with torque converter, lock-up clutch, and engine driven p.t.o.	520	2800	250 (max)	1190	Engi p.t.o anica lic d
FMC	Mech.		Ord. type	4-speed fwd and 2-speed reverse manual full power shift with torque converter, lock-up clutch and engine driven p.t.o.			290	1525	Engin p.t.o anica lic dr
Allison HT-70	Mech.	Heavy duty truck type		6-speed fwd, 1-speed reverse, automatic within range selection engine drive p.t.o., converter and lock-up clutch.	750	2500	275	925	Engin p.t.o be mo of con
Allison XTG-300	Mech.		Ord. type*	5-speed fwd, 2 ranges, automatic 2nd range w/4 ratios, 2-speed reverse engine driven p.t.o.	700	4000	250 (max)	1100	
Clark Modified Series 5000	Mech.	Heavy duty truck type		4-speed fwd and reverse, manual full power shift with torque converter, lock-up clutch and engine driven p.t.o.	690	2800		1125 w/o conv.	
Allison XTG-411	Mech.		Ord. type	4-speed fwd, 2-speed reverse, manual range control with torque converter and lock-up clutch.	1360	2300	500	2343	
General Electric	Differential hydro-mech.		Developed for this study	Infinitely variable speed, torque ratio 0 - 40 mph fwd, 0 - 10 mph rev., engine driven p.t.o. two units each with var. disp. motor & fixed disp. pump			300	779	Propo propel approx mech. drive.
Sundstrand P/N 4000114	Hydrostatic		Developed for this study	Infinitely variable speed, torque ratio 0 - 40 mph fwd & reverse. Single variable displacement pump, & two variable disp. motors.			270 (capable 290)	1268	Use sa for pr
Stratos GT/HMPT/300	Hydro-mech.			Two variable displacement pumps, six variable disp. motors, w/four of the motors geared thru clutches to output shaft.			250		
Vickers SK-3344	Hydro-mech.			Three speed range changes accomplished automatically w/no power on clutches			270	1150	Propos propell
Jered ST-300-H	Hyrdo-mech.			Dual speed range: LO - hydraulic HI - hydraulic-mechanical				1000	
Electrical				A.C. system w/silicon controlled rectifier frequency converter				1800 **	
Curtis Wright SK-928	Toroidal		Developed for this study	Includes dual range fwd, fwd & reverse clutches, w/8:1 ratio in toroidal unit				1300	

*For turbine drives
**Including control cables

al Description	Max Input Torque (ft-lb)	Max Input Speed (rpm)	Approx Design Input (hp)	Dry Weight w/o F D (lb)	Propeller Drive Comments	Steering	Comments	Notes
, 2-speed rev., manual hift with torque conver- up clutch, and engine o.	520	2800	250 (max)	1190	Engine driven p.t.o. for mechanical or hydraulic drive.	Geared steer clutch brake pivot steer	• Unable to obtain any indication of cost. For use XM 551 ARV.	
d and 2-speed reverse power shift with torque lock-up clutch and en- p.t.o.			290	1525	Engine driven p.t.o. for mechanical or hydraulic drive.	Differential & pivot steer		
, 1-speed reverse, auto- n range selection engine , converter and lock-up	750	2500	275	925	Engine driven p.t.o. box. Can be mounted on top of converter hsg.	Differential & pivot steer when used w/ FMC differential assy		
, 2 ranges, automatic /4 ratios, 2-speed ine driven p.t.o.	700	4000	250 (max)	1100		Geared steer clutch brake pivot steer	• Unable to obtain any indication of cost.	
d and reverse, manual hift with torque conver- up clutch and engine o.	690	2800		1125 w/o conv.		Differential & pivot steer		
vd, 2-speed reverse, ge control with torque nd lock-up clutch.	1360	2300	500	2343		Geared steer clutch brake		
riable speed, torque mph fwd, 0 - 10 mph e driven p.t.o. two units r. disp. motor & fixed			300	779	Proposal incl. propeller drive approx 90% mech. eff. prop. drive.	Differential	• Design does not include clutches and/or range shifts. All 4 hydraulic elements basically same.	See Mfgr Proposal in Appendix.
riable speed, torque mph fwd & reverse. ble displacement pump, ble disp. motors.			270 (capable 290)	1268	Use same pump for prop. drive	Axis steer	• No clutches or range shifts; uses newly developed high efficiency cross-head design.	See Mfgr Proposal in Appendix.
e displacement pumps, disp. motors, w/four s geared thru clutches aft.			250			Axis steer	• Design proposed for 30,000 lb GVW OTAC study.	See Mfgr Proposal in Appendix.
range changes accom- matically w/no power			270	1150	Proposal incl. propeller drive	Axis steer	• Design developed for other study.	See Mfgr Proposal in Appendix.
range: raulic raulic-mechanical				1000				
n w/silicon controlled equency converter				1800 **			• See Electrical section for more complete information.	
l range fwd, fwd & ches, w/8:1 ratio in				1300			• Development item. No advantage seen over current mechanical hydrostatic (item 8) or differential hydro-mechanical (item 7).	

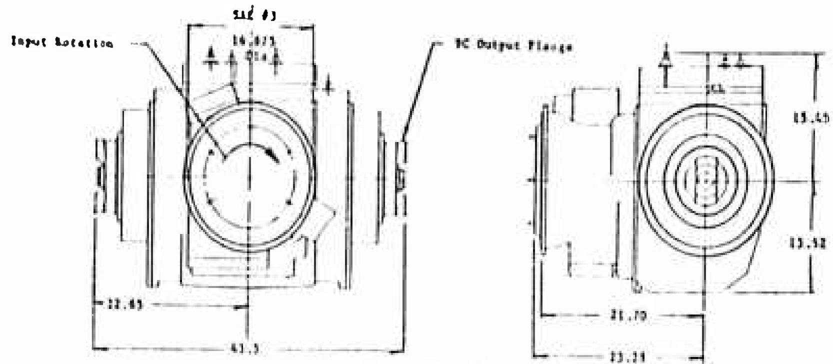
*For turbine drives
**Including control cables

2

Figure 3.7.12

PRELIMINARY
CHARACTERISTIC SHEET

Component: Power Train, X-Drive, Model XTG-250 Hydraulic Torque Converter, Planetary Gear Type, all Torque Shifting.



PRELIMINARY ENVELOPE DRAWING
XTG-250 POWER TRAIN (LESS FINAL DRIVES)

The XTG-250 includes a hydraulic torque converter with a lockup clutch. The planetary range gearing in combination with the steer and output planetary sets provides four forward and two reverse ranges. The transmission also incorporates geared steer, clutch brake, and pivot steer systems and full vehicle brakes as outlined in the following specifications:

GENERAL SPECIFICATIONS

Rating:
- Max. Input Torque Lbs. Ft. -- 520
- Max. Input Speed RPM --2800
- Max. Input HP --- 250

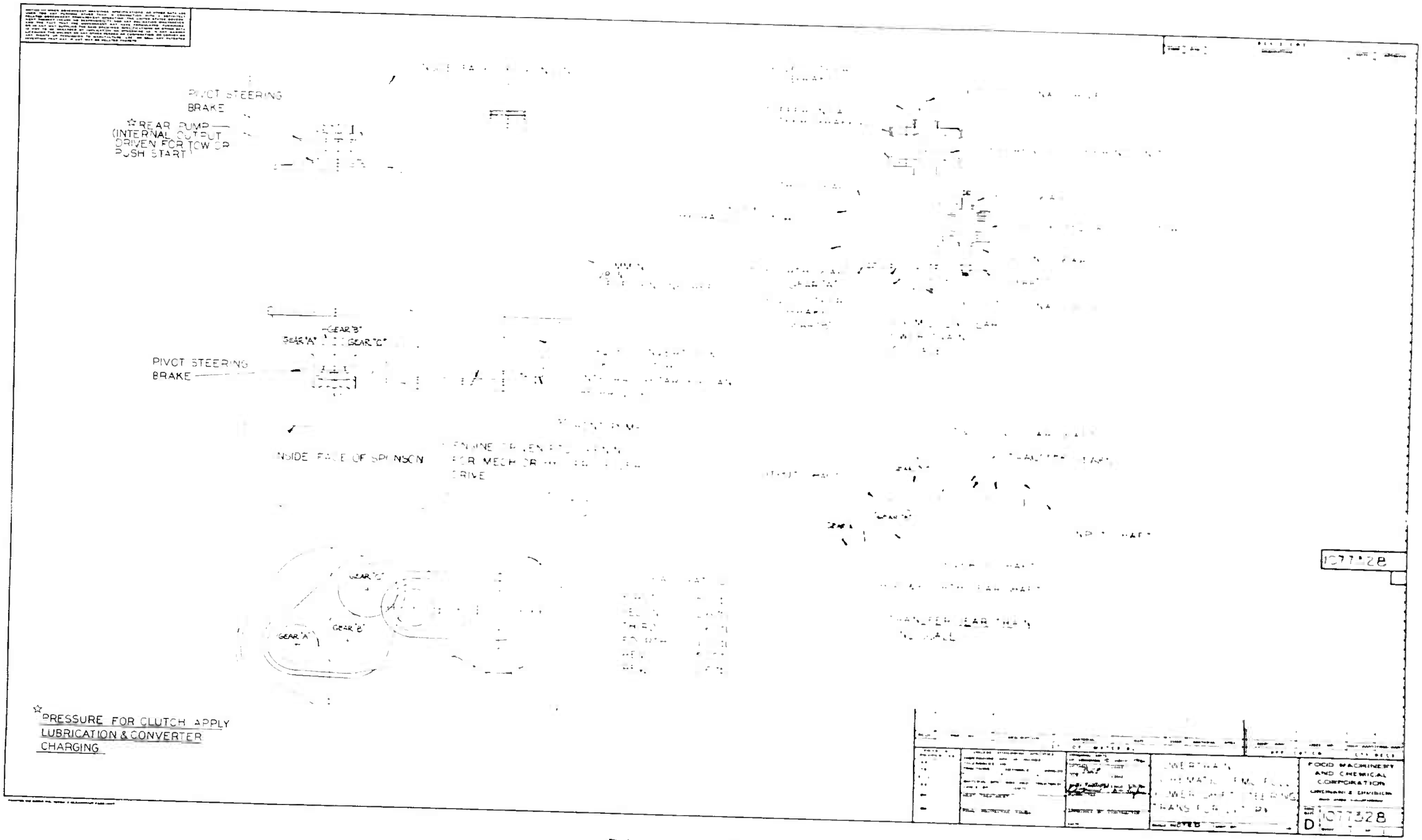
Manufacturer ------------------------------------Allison Division, GMC
Model ---XTG-250
Drive Ranges--Fourth, Third, Second, First, Neutral, Reverse 1, and Reverse 2
Drive Range, Steering, and Shift Control (External) -------------Mechanical
Shift and Steering Mechanism (Internal Control)-------Hydraulic & Mechanical
Steering Type --Geared Steer
Clutch Brake
Pivot Steer
Power Take-off ---Turbine Driven
Rating (Continuous Operation) ----------------------------------470#'
Type of Clutches (All Ranges)------Multiple Plate, Engaged by Oil Pressure
Brake--------Multiple Wet Plate, Steering, Service, and Parking, Mechanical Application
Hydraulic Torque Converter-------Single Stage, Multiple Phase with Lockup Clutch
Maximum Converter Multiplication ---------------------------------2.55:1

Range Position	Gear Ratio	Steering Normal	Steering Pivot
R_2	2.095:1	C.B.	Pivot
R_1	4.69:1	C.B.	Pivot
N	-	-	-
1	6.16:1	C.B.	Pivot
2	4.18:1	G.S.	Pivot
3	2.24:1	G.S.	G.S.
4	1.00:1	G.S.	G.S.

Bevel Gear Ratio --- 1.44:1
Output Steer Planetary Ratios:
- Under Drive -- 1.475:1
- Direct --- 1.00:1

Oil Specifications ---MIL-L-2104A, Grade 10
Oil Capacity, Gal. --- (Est.) 10
Transmission Dry Weight Lbs. ---------------------------------------(Est.) 1190

FIGURE 3.7.13


PIVOT STEERING
BRAKE
☆REAR PUMP
(INTERNAL OUTPUT
DRIVEN FOR TOW OR
PUSH START
GEAR "B"
GEAR "A"
GEAR "C"
PIVOT STEERING
BRAKE
INSIDE FACE OF SPONSON
GEAR "C"
GEAR "B"
GEAR "A"
☆PRESSURE FOR CLUTCH APPLY
LUBRICATION & CONVERTER
CHARGING
FOOD MACHINERY
AND CHEMICAL
CORPORATION
1C77328
D
1C77328

Power Trains (Continued)

The XTG-250 Transmission is now in prototype production at the Allison Division of General Motors and is being developed for the XM551 ARV.

There are several heavy-duty commercial units available, as shown in Figure 3.7.12. However, these are transmissions only, and so must include a controlled differential and service brakes to be comparable to the Ordnance units, which places them at a large weight disadvantage.

The selected power train offers 4 forward and 2 reverse speeds with geared steering, service brakes, clutch brake and pivot-steer system, torque converter, and a power take-off. The combined package weighs 1,190 lbs.

In an effort to provide a simple, straightforward transmission design, FMC has been working for some time on the approach shown in Figures 3.7.14 and 3.7.15. This power train will offer the following:

- Lower Cost
- Simplicity of design as compared with current Ordnance power trains
- Easier maintenance due to design simplicity
- Better ratio spread compared with current Ordnance power trains
- Higher rating - design rating of 40,000 lb GVW
- Less space - provides a vehicle weight equivalent to the vehicle with the selected power train, by permitting a decrease in hull length.

Power Trains (Continued)

3.7.4.2 Hydrostatic and Hydromechanical Power Trains

As shown in Figure 3.7.12, the study revealed a limited number of mechanical units available within the required weight range. Because of the potential advantages offered by hydrostatic and hydromechanical power trains, this area was thoroughly investigated.

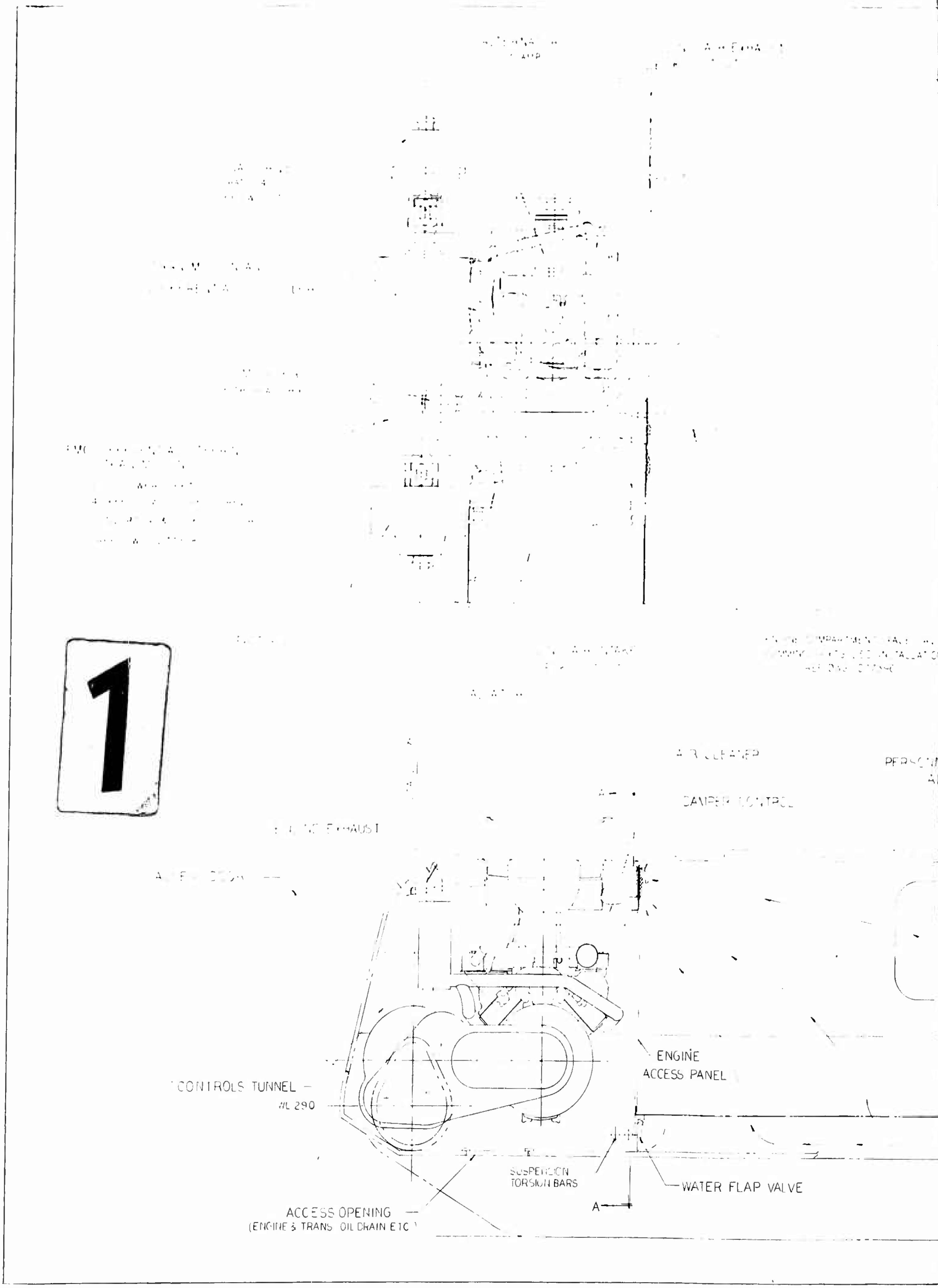
FMC compiled a specification covering all the desired power train features and contacted the following leading manufacturers of hydrostatic and hydromechanical units:

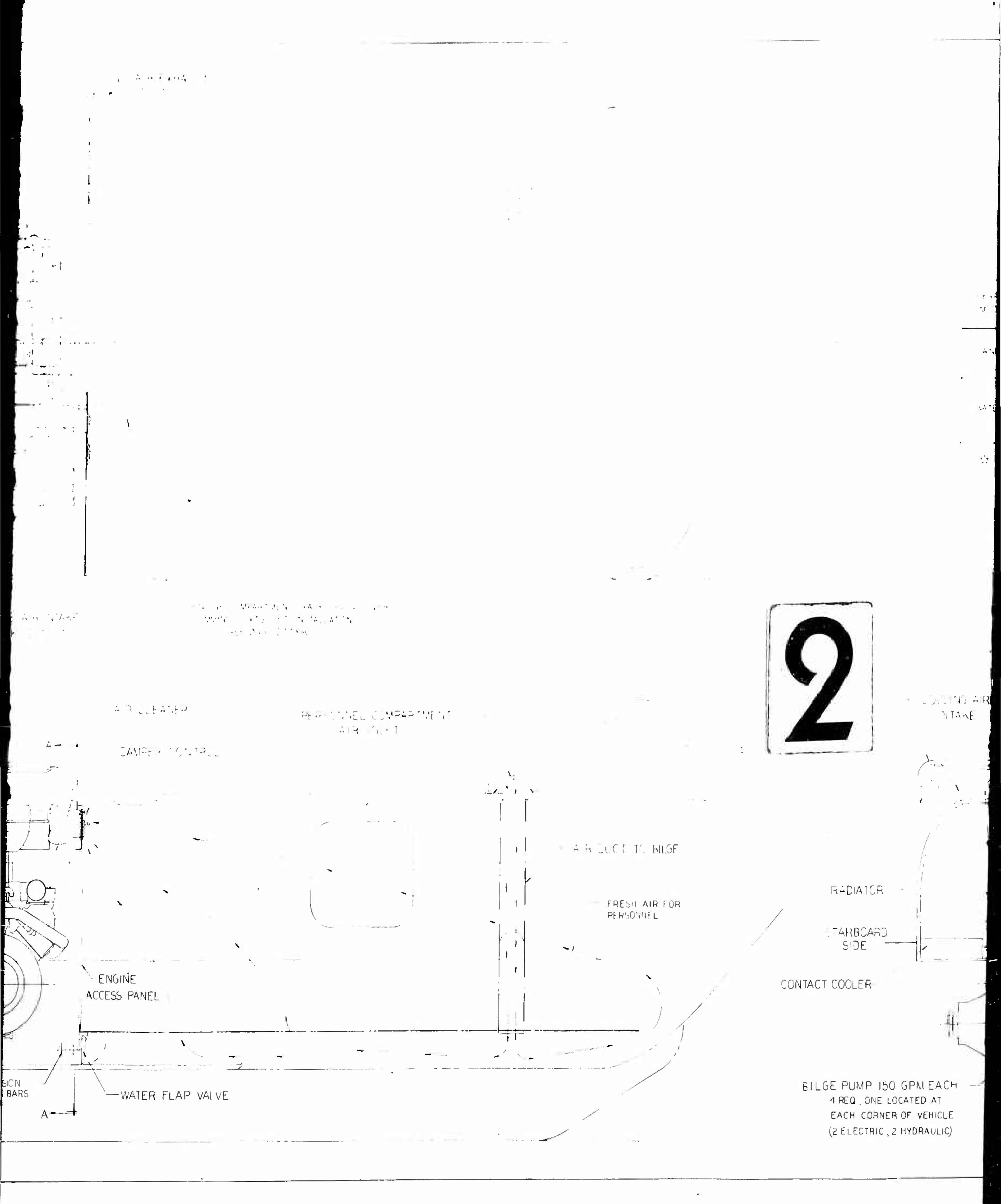
- General Electric
- Sundstrand
- Stratos
- Vickers

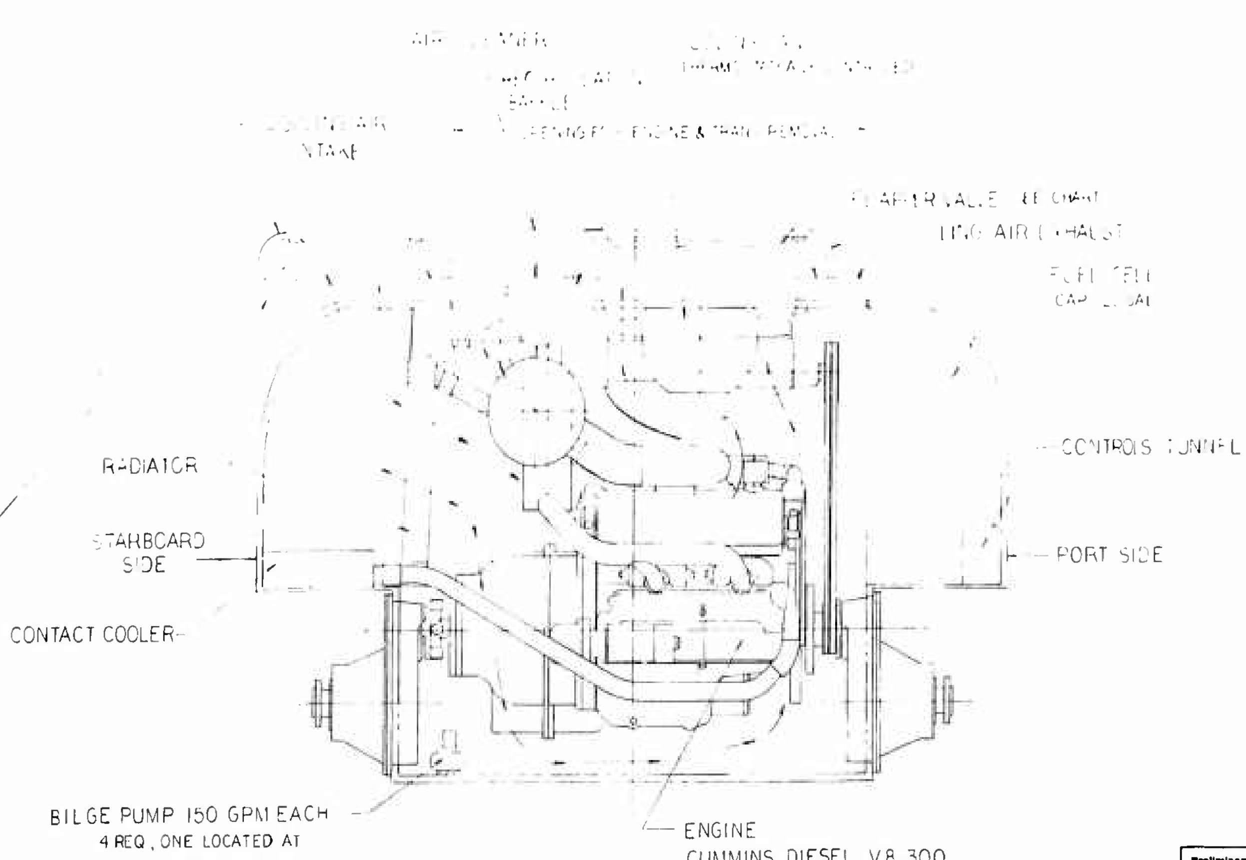
Each of these companies responded with a power train design, all of which are included in Appendix J (Volume IV). Comparative features of these units are summarized in Figure 3.7.12.

Of the designs received, two (General Electric and Sundstrand) incorporate most of the specified characteristics. Both of these designs are infinitely variable over the entire vehicle speed range and offer relatively high efficiencies. Comparative predicted performance of these units with the Allison XTG-250 power train is shown in Figure 3.7.16. Both of these units provide more available horsepower at the sprockets, on the average, than does the mechanical power train, although they both "fall off" at the maximum-speed condition.

1


ENGINE
ACCESS PANEL
CONTROLS TUNNEL
WL 290
SUSPENSION
TORSION BARS
WATER FLAP VALVE
ACCESS OPENING
(ENGINE & TRANS OIL DRAIN ETC)
A

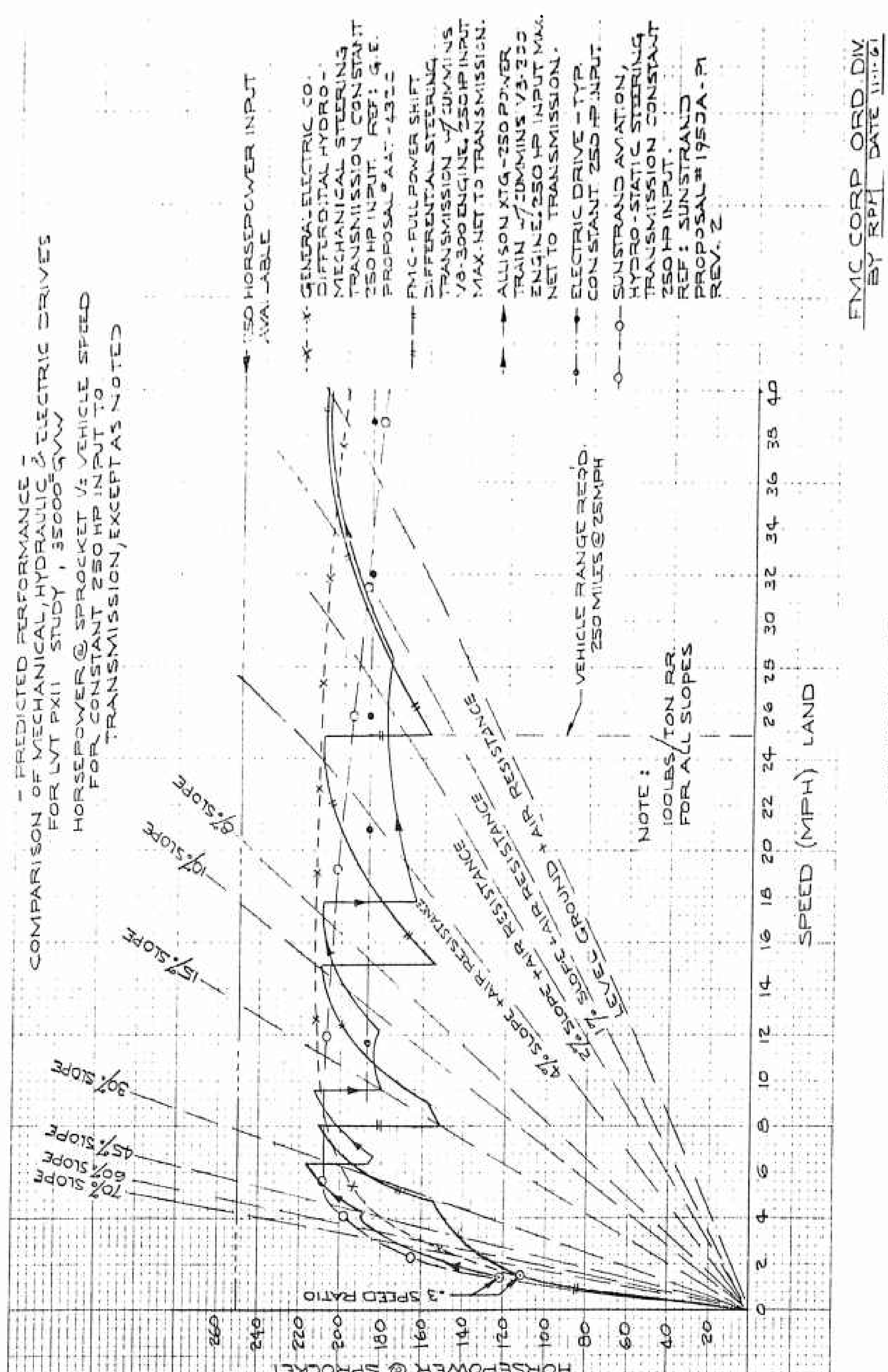

2
ENGINE ACCESS PANEL
WATER FLAP VALVE
FRESH AIR FOR PERSONNEL
RADIATOR
CONTACT COOLER
BILGE PUMP 150 GPM EACH
4 REQ. ONE LOCATED AT
EACH CORNER OF VEHICLE
(2 ELECTRIC, 2 HYDRAULIC)



SECTION A-A
(LOOKING AFT)

Preliminary Design Engineering FOOD MACHINERY AND CHEMICAL CORPORATION		ORDNANCE DIVISION SAN JOSE CALIFORNIA
DATE DRAFTSMAN ENGINEER APPROVED SCALE GRAPHIC	MACHINERY INSTALLATION LVTPXII 35000# GVW CUMMINS V8-300 ENGINE W/FMC STEERING TRANS	P A NO 449 DWG NO 1077329 SHEET 1 OF 1

Figure 3.7.15



PREDICTED PERFORMANCE -
COMPARISON OF MECHANICAL, HYDRAULIC & ELECTRIC DRIVES
FOR LVT PX11 STUDY, 35000# GVW
HORSEPOWER @ SPROCKET Vs VEHICLE SPEED
FOR CONSTANT 250 HP INPUT TO
TRANSMISSION, EXCEPT AS NOTED
250 HORSEPOWER INPUT AVAILABLE
GENERAL ELECTRIC CO. DIFFERENTIAL HYDRO-MECHANICAL STEERING TRANSMISSION CONSTANT 250 HP INPUT. REF: G.E. PROPOSAL # AAT-4312
FMC - FULL POWER SHIFT DIFFERENTIAL STEERING TRANSMISSION W/CUMMINS V8-300 ENGINE, 250 HP INPUT MAX. NET TO TRANSMISSION.
ALLISON XTG-250 POWER TRAIN W/CUMMINS V8-300 ENGINE, 250 HP INPUT MAX. NET TO TRANSMISSION.
ELECTRIC DRIVE - TYP. CONSTANT 250 HP INPUT.
SUNSTRAND AVIATION, HYDRO-STATIC STEERING TRANSMISSION CONSTANT 250 HP INPUT. REF: SUNSTRAND PROPOSAL # 1953A-P1 REV. 2
FMC CORP. ORD. DIV.
BY RPH DATE 11-1-61
HORSEPOWER @ SPROCKET
SPEED (MPH) LAND
3 SPEED RATIO
70% SLOPE
60% SLOPE
45% SLOPE
30% SLOPE
15% SLOPE
10% SLOPE
8% SLOPE
5% SLOPE + AIR RESISTANCE
4% SLOPE + AIR RESISTANCE
2% SLOPE + AIR RESISTANCE
1% SLOPE + AIR RESISTANCE
LEVEL GROUND + AIR RESISTANCE
VEHICLE RANGE REQD. 250 MILES @ 25 MPH
NOTE: 100 LBS/TON RR. FOR ALL SLOPES

FIGURE 3.7 16

Power Trains (Continued)

These units require the use of a control device which schedules engine speed and transmission ratio to provide the most efficient operation of the engine-transmission (and the best fuel economy) for any particular operating condition.

A hydraulic propeller drive description is included with the power train information in Appendix J (Volume IV). The General Electric system, with an over-all efficiency of 90%, requires 2 to 2-1/4 inch ID lines for the 1,800 psi system shown; a reduction in line size is possible with an increase in system pressure. The requirements that the propeller be retractable and steerable would necessitate the use of either flexible lines or swivel couplings. The required line size and system pressure would result in a propeller strut and hub significantly larger than that needed for a mechanical drive.

Because the Differential Hydromechanical and Hydrostatic Power Trains require a certain amount of development time which is not compatible with the assumed development program, the mechanical power train was selected for its proven capabilities. However, because of the many possible advantages of the differential hydromechanical and hydrostatic power trains over the mechanical power train, it is recommended that consideration be given to testing one of these in one of the prototype vehicles, or on a testbed, using an LVTP6 reduced to 40,000 lb GVW.

3.7.4.3 Electrical Power Trains

For some time, FMC has studied and evaluated developments of both AC and DC systems in the electric drive field. The recent advent of new

Power Trains (Continued)

types of power control components, made possible by advances in the state-of-the-art, has permitted reduction of an electric drive system's weight. An electric drive system for the "Maximum Armored Vehicle", as shown in Figure 3.7.17, would weigh 3,250 lbs, compared to the 3,890 lb weight of the selected mechanical drive train.

While DC systems have many desirable features, they are heavier than AC systems. The use of commutators and wound rotors limits the speed at which DC motors may be operated, thus prohibiting a weight reduction which would be possible with higher speeds.

The AC system shown in Figure 3.7.17 stems from the recent development of the silicon-controlled rectifier. This rectifier lends control flexibility to the AC system similar to that of a DC system and utilizes only solid-state components. The primary system consists of a high-frequency alternator, frequency converter and control, and traction motors. An advantage of the electric drive system is that, in the case of the "Maximum Water Performance Vehicle", the propeller is driven by an integral electric motor in the propeller hub.

The incorporation of an electrical drive system will entail a development cost of approximately one-half-million dollars, including two complete sets of prototype equipment. It is estimated that a complete production set of motors, alternator, and controls would cost twenty-thousand dollars, as compared with approximately seven-thousand dollars for the transmission and final drives of a mechanical drive line. The high development and production costs of an electrical drive system do not permit its use

Power Trains (Continued)

in the LVTPX11 at this time; however, further developments in this field may increase its desirability.

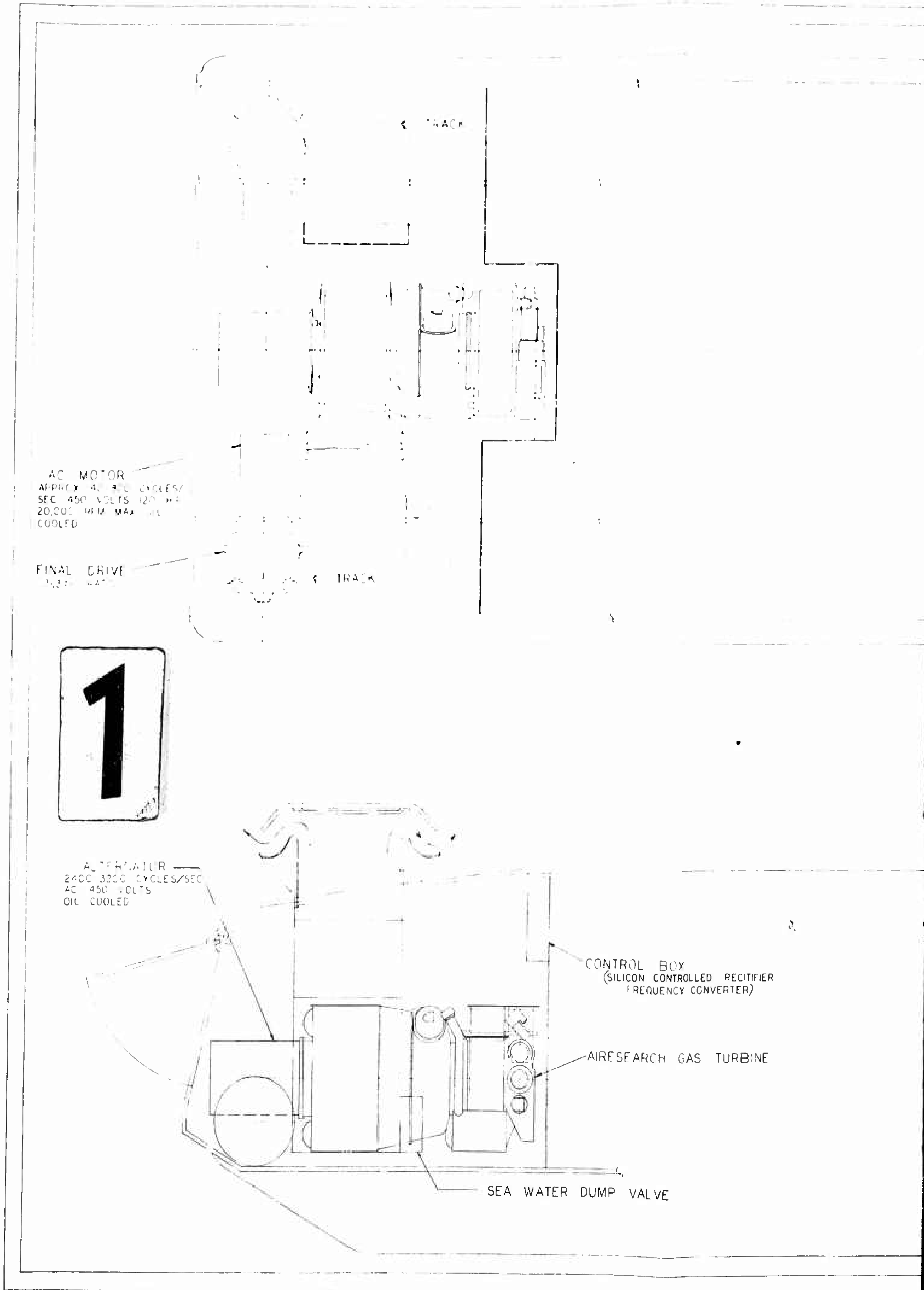
The advantages of an electrical drive system are as follows:

- Improved Fuel Economy
- Improved Tractive Effort
- Increased Steering Versatility
- Improved Braking
- Simplified Controls
- Improved Vehicle Design Flexibility
- Better Weight Distribution
- Better Utilization of Space
- Reduced Quantity of Spare Parts
- Improved Power Train Durability, Reliability, and Ease of Maintenance
- Universal Electric Power Source Capability

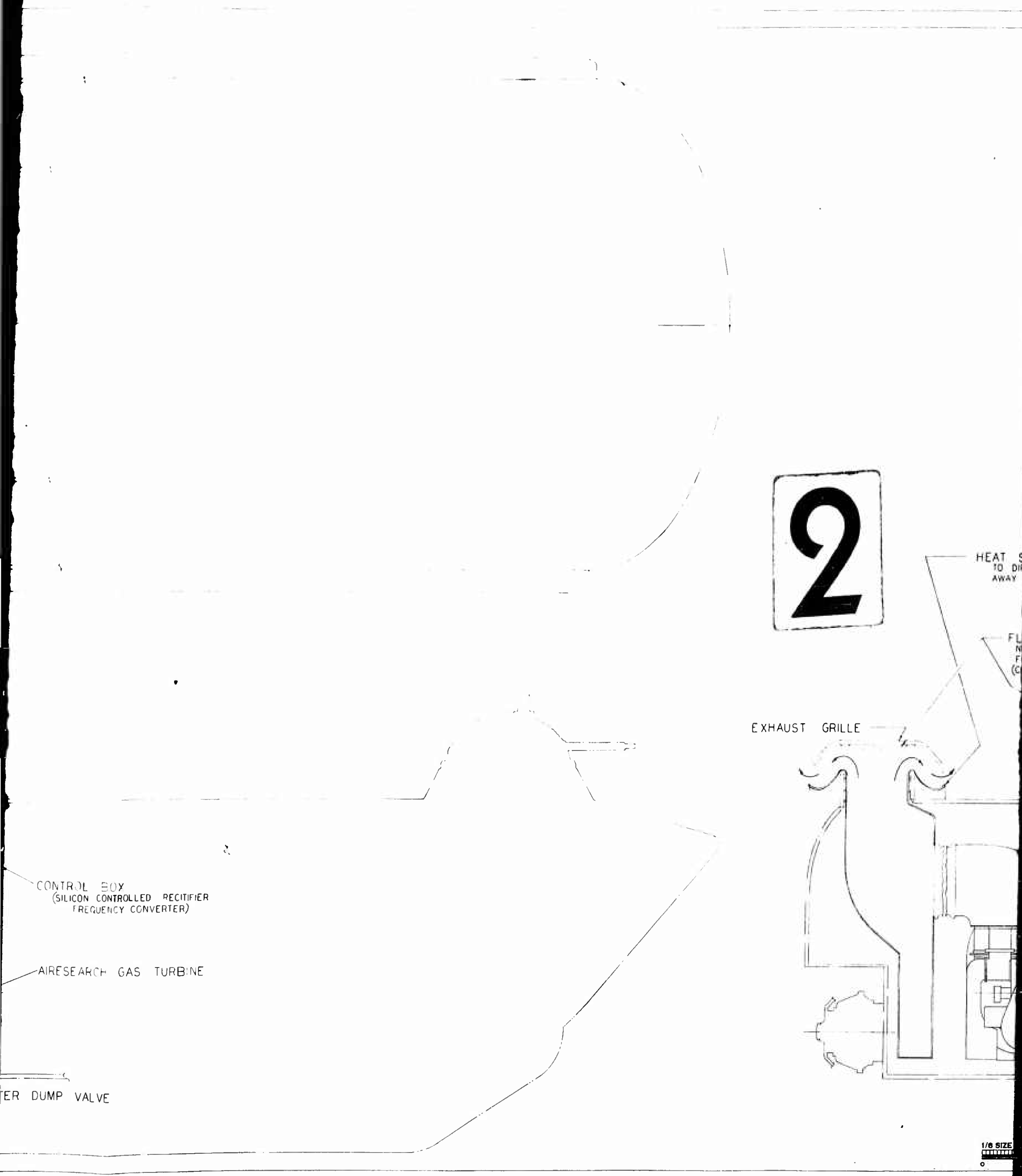
Additional information is included in Appendix J (Volume IV).

3.7.5 Drive Trains

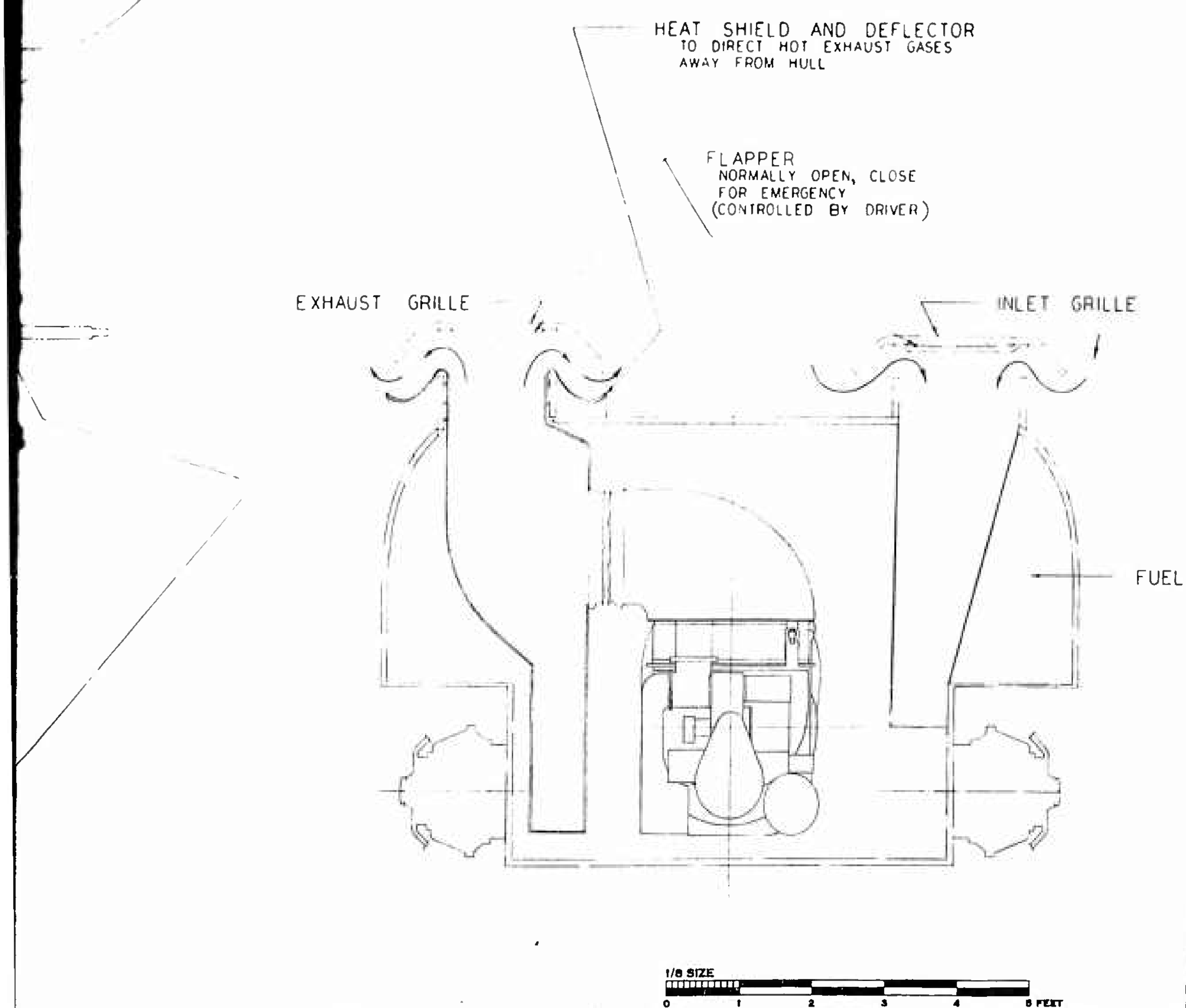
Figure 3.7.18 is a comparison table of the drive train combinations investigated. The drive train selected for the LVTPX11 shown in Figure 3.7.1, consists of the Cummins V8-300 water-cooled diesel engine, the Allison XTG-250 power train, and FMC final drives. The final drive is shown in Figure 3.7.19. The installed weight of the selected drive train is 3890 lb.



TRACK
AC MOTOR
COOLED
FINAL DRIVE
TRACK
1
ALTERNATOR
OIL COOLED
CONTROL BOX
(SILICON CONTROLLED RECITIFIER
FREQUENCY CONVERTER)
AIRESEARCH GAS TURBINE
SEA WATER DUMP VALVE


2
HEAT S
EXHAUST GRILLE
CONTROL BOX
(SILICON CONTROLLED RECITIFIER
FREQUENCY CONVERTER)
AIRESEARCH GAS TURBINE
TER DUMP VALVE
1/8 SIZE

3



Preliminary Design Engineering — FOOD MACHINERY AND CHEMICAL CORPORATION
ORDNANCE DIVISION — SAN JOSE, CALIFORNIA

DATE 9/23/61 DRAFTSMAN	MACHINERY INSTL LVT-PXII AIRESEARCH TURBINE AND ELECTRIC DRIVE	P.A. NO. 449
ENGINEER		DWG. NO. 1077391
APPROVED 10-9-61		
SCALE GRAPHIC SIZE		SHEET OF

Figure 3.7.17

Drive Type Comb	Dwg No	Engine	Wt	Transmission	Wt	Transfer Case	Wt	Steering Differential & Pivot Brakes	Wt	Power Train (Transmission & Steering Assy)	Wt	Fan & Gear Box Assy	Wt	Radiator	Wt	Final Drives (Qty - 2)	Wt	Air Cleaner	Wt	Oil Coolers as Applicable	Wt	Vehi[cle] Cont[rol] Cool[ing] Syste[m] (for l[iquid] cool[ed] engi[ne])
				Individual Powertrain Components						Integral Powertrain Package												
	(1077396) Fig 3.7.1	Cummins V8-300 (Alum) (water cooled) 1	1425							Allison XTG-250	1190	FMC	85	Typ Heavy Duty	120	FMC (1077390)	380	Dry Type	30	Power Train Only (engine oil cooler incl. w engine)	35	FM
	(1077381) Fig 3.7.2	Lycoming (Multifuel air-cooled) AVM-625	960							Allison XTG-250	1190					FMC (1077390)	380	Dry Type	30	Power Train Only (engine oil cooler incl. w engine)	20	
	(1077329) Fig 3.7.15	Cummins V8-350 (Alum) (water-cooled) 1 2	1425							FMC (1077328)	1525		85		120	FMC (1077390)	380	Dry Type	30	Power Train Only (engine oil cooler incl. w engine)	35	FMC
		Continental AVDS-550 (air-cooled)	1560							Allison XTG-250	1190					FMC (1077390)	380	Dry Type	30	Incl. with Engine Wt.		
	(1077403) Fig 3.7.7	Caterpillar (Multifuel 332 hp water-cooled) D333 - Alum	1600	Allison HT-70 (6-speed automatic with converter)	925	FMC	160	FMC	750			FMC	85	Typ. Heavy Duty		FMC (1077390)	380	(Incl. with engine weight)		Engine Transmission Differential	50	FMC
		Caterpillar (Multifuel 332 hp water-cooled) D333 - Alum	1600	Clark Modified Series 5000 (4-speed manual power shift with converter)	1500			FMC	750			FMC	85	Typ. Heavy Duty	120	FMC (1077390)	380	(Incl. with engine weight)		Engine Transmission Differential	50	FMC
		Lycoming (Multifuel air-cooled) AVM-625	960							General Electric Differential Hydro-Mechanical	779					FMC (1077390)	380	Dry Type	30	Power Train	20	
	(1077389) Fig 3.7.8	Continental (Multifuel air-cooled) AVDS-550	1560							General Electric Differential Hydro-Mechanical	779					FMC (1077390)	380	Dry Type	30	Incl. with Engine Wt.		
		Continental (Multifuel air-cooled) AVDS-550	1560							Sundstrand Hydro-Static 4000112	1050					FMC (1077390)	380	Dry Type	30	Incl. with Engine Wt.		
		AiResearch Gas Turbine w Recouperator	890							Allison XTG-300	1100					FMC (1077390)	380	(Incl. in turbine weight)				
		Boeing 520-3 (hp limited 250)	360							Allison XTG-300	1100					FMC (1077390)	380	With Turbine			20	
		Allison Gas Turbine GMT-306	800							Allison XTG-300	1100					FMC (1077390)	380					
		Allison Gas Turbine w Regenerator GMT-306	800	——		——		——		General Electric Differential Hydro-Mechanical	779	——		——		FMC (1077390)	380					
	(1077391) Fig 3.7.17	AiResearch Gas Turbine w/Recouperator	890	——		——		——		Typ. Components (2) Motors Generator Controls Cables, Etc.	1000 400 200 200 1800	——		——		FMC (1077390)	440					

Notes:

Multifuel capabilities under development.

NOTE: No attempt made to show every possible combination.

1 All fuels except gasoline; can burn combat gas using kit 10:1 gasoline lube oil.

For further information on engine or power train components see Figures 3.7.3, 3.7.9, 3.7.11, 3.7.12.

2 Cummins V8-350 is same basic engine as V8-300 (to be used on LARC-5); increased rating based on development.

3 E

4 E

1

2

Integral Powertrain Package: ...r Train ...mission ...eering ...ssy)	Wt	Fan & Gear Box Assy	Wt	Radiator	Wt	Final Drives (Q6) 2	Wt	Air Cleaner	Wt	Oil Coolers as Applicable	Wt	Vehicle Cooling System During Surfing: Contact Cooler System (for liq cooled engines)	Wt	Vehicle Cooling System During Surfing: Air Seawater Heat Exchanger System	Wt	Wt Sub Total (Dry)	A — LAND: Gal Fuel (6.65 lb gal) Req'd 250 mi @ 25 mph: Level & 25 mph 100 lb ton	B — LAND: 2½ Slope & 25 mph RR & Air Res	WATER: Gal Fuel (6.65 lb gal) 50 mi: Tract Propulsion (?mph)	WATER: Propeller @ 1.4 mph	GVW Limitation	Total Weight (Incl Fuel) (Col A & B)	Comments
...lison ...G-250	1190	FMC	85	Typ Heavy Duty	120	FMC (1077390)	380	Dry Type	30	Power Train Only (engine oil cooler incl. w engine)	35	FMC	120			3385	84 (559#)	169 (1124#)	101 (671#)	92 (611#)	35,000# (Limited by XTG-250)	4227	• Engine to be used on LARC-5 production vehicle • Engine has better fuel economy than Lycoming predicted values.
...lison ...G-250	1190					FMC (1077390)	380	Dry Type	30	Power Train Only (engine oil cooler incl. w engine)	20			Harrison 20x40x8 Al-Alclad	275	2855	97 (640#)	188 (1250#)	116 (770#)	105 (700#)	35,000# (Limited by XTG-250)	3600	• This is one engine and power train being developed by OTAC for XM551 "ARV Vehicle." • Engine development in process to improve poor fuel economy and oil consumption.
FMC (...77328)	1525		85		120	FMC (1077390)	380	Dry Type	30	Power Train Only (engine oil cooler incl. w engine)	35	FMC	120			3720	84 (559#)	169 (1124#)	101 (671#)	92 (611#)	40,000#	4562	• FMC designed power train provides simplified design, easy to maintain by average mechanic, low cost, etc • Better ratio spread then XTG-250
...lison ...G-250	1190					FMC (1077390)	380	Dry Type	30	Incl. with Engine Wt				Harrison 20x40x8	275	3435	86 (572#)	159 (1059#)	99 (665#)	88 (585#)	35,000# (Limited by XTG-250)	4251	• Proposed engine [illegible] funded development
		FMC	85	Typ. Heavy Duty		FMC (1077390)	380	(Incl. with engine weight)		Engine Transmission Differential	50	FMC	120			4210	86 gal. (572#)	148 (985#)	96 (640#)	81 (539#)	40,000#	4989	• This package similar to M113. • HT-70 transmission in production Jan '62 • Test of Alam D333 Engine - Feb '62
		FMC	85	Typ. Heavy Duty	120	FMC (1077390)	380	(Incl. with engine weight)		Engine Transmission Differential	50	FMC	120			4605	NOT DETERMINED				40,000#		• Weight without fuel very high
...neral ...ectric ...rential ...ydro-...hanical	779					FMC (1077390)	380	Dry Type	30	Power Train	20			Harrison 20x40x8	275	2444	NOT DETERMINED				40,000#		• Power train designed and developed specifically for this study
...neral ...ectric ...rential ...ydro-...hanical	779					FMC (1077390)	380	Dry Type	30	Incl. with Engine Wt				Harrison 20x40x8	275	3024	NOT DETERMINED				40,000#		
...dstrand ...ydro-...tatic ...00112	1050					FMC (1077390)	380	Dry Type	30	Incl. with Engine Wt.				Harrison 20x40x8	275	3295	NOT DETERMINED				40,000#		
...lison ...G-300	1100					FMC (1077390)	380	(Incl. in turbine weight)								2370	162 (1080#) @115°F	277 (1840#)	230 (1530#)	99 (660#)	30,000# (Limited by XTG-300)	3830	• Relatively high fuel consumption presents logistic supply problem.
...lison ...G-300	1100					FMC (1077390)	380	With Turbine			20					1860	259 (1720#) @115°F	304 (2020#)	232 (1540#)	177 (1180#)	35,000# (Limited by XTG-300)	3730	• Relatively high fuel consumption presents logistic supply problem.
...lison ...G-300	1100					FMC (1077390)	380									2280	NOT DETERMINED				30,000# (Limited by XTG-300)		• GMT 306 engine - possible use XM551 vehicle.
...neral ...ectric ...rential ...dro-...hanical	779	——		——		FMC (1077390)	380									1959	NOT DETERMINED				40,000#		• GMT 306 engine - possible use XM551 vehicle.
...yp. ...ponents Motors ...erator ...trols ...s, Etc.	1000 400 200 200 1800	——		——		FMC (1077390)	440									3130	NOT DETERMINED				35,000#		

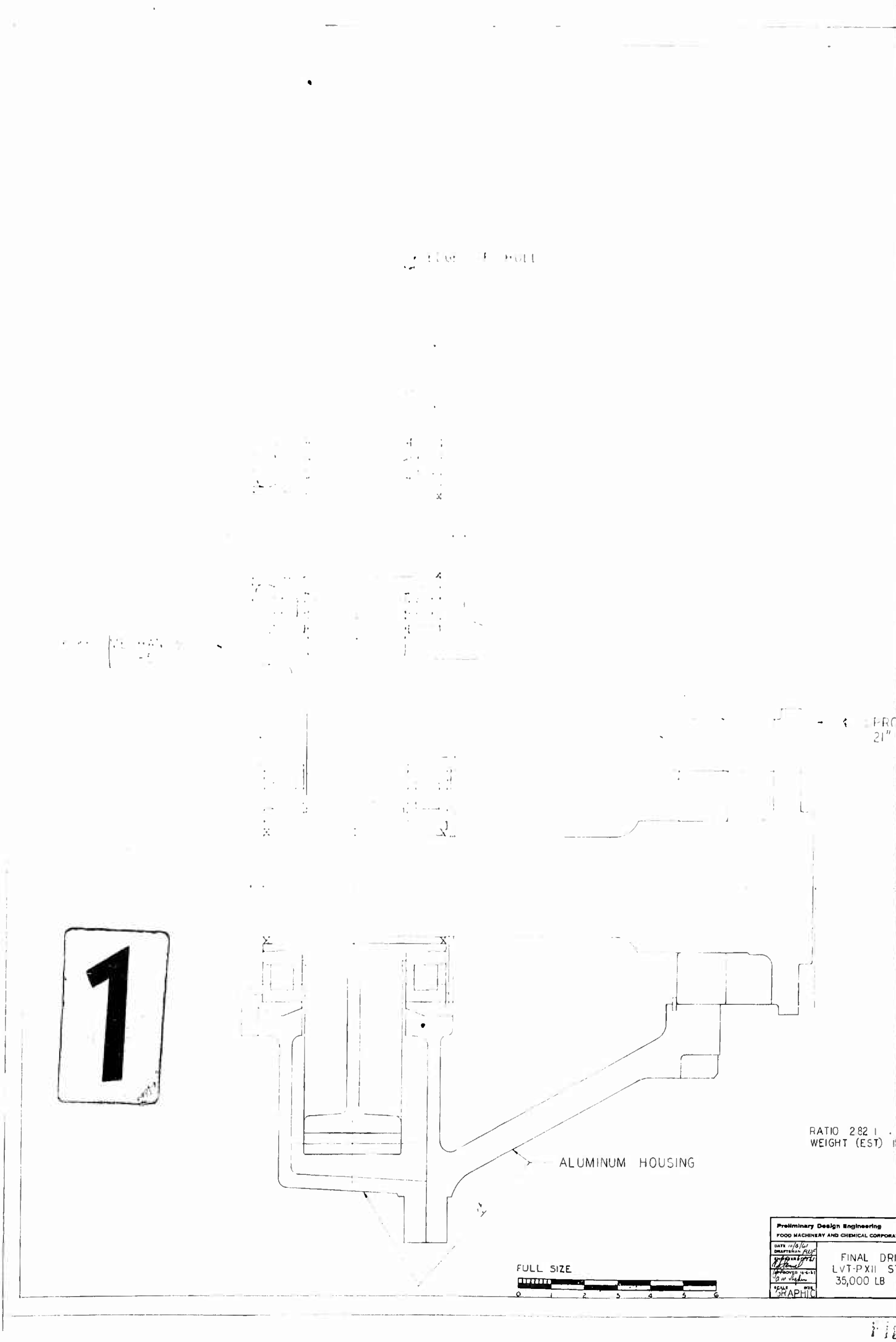
For further information on engine or power train components see Figures 3.7.3, 3.7.9, 3.7.11, 3.7.12.

2 Cummins V8-350 is same basic engine as V8-300 (to be used on LARC-5); increased rating based on development.

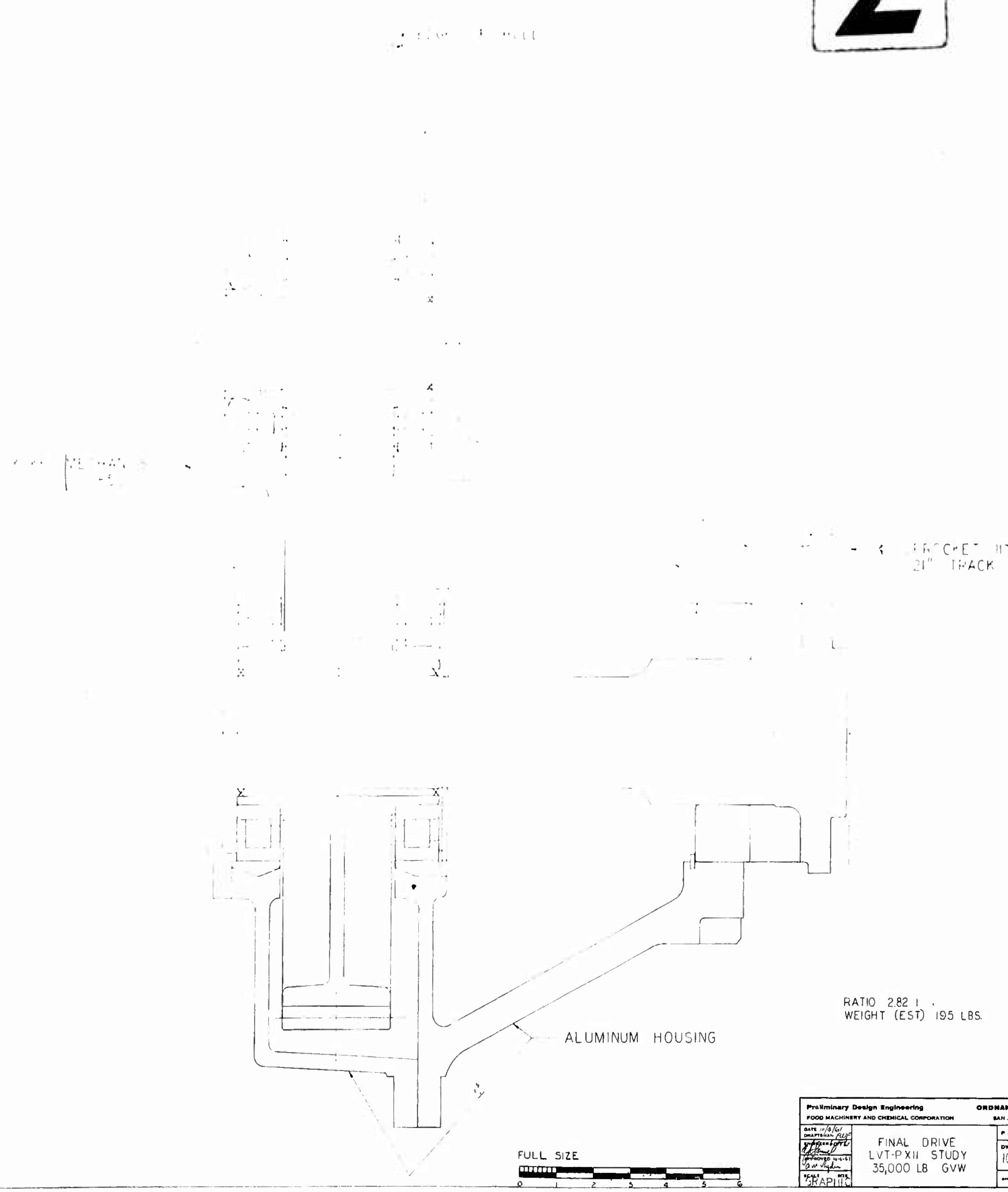
3 Based on predicted fuel economy figure.

4 Referring to Dwg. 1077329, note reduced size of engine compartment due to compactness of engine and power train, making possible reduction in vehicle length by 8 inches.

Figure 3.7.18


1
21"
RATIO 2.82 1
WEIGHT (EST)
ALUMINUM HOUSING
FULL SIZE
0 1 2 3 4 5 6
Preliminary Design Engineering
FOOD MACHINERY AND CHEMICAL CORPORAT
DATE 10/4/61
DRAFTSMAN
APPROVED
SCALE
GRAPHIC
FINAL DRI
LVT-PXII ST
35,000 LB

2



Preliminary Design Engineering FOOD MACHINERY AND CHEMICAL CORPORATION		ORDNANCE DIVISION SAN JOSE, CALIFORNIA
DATE 10/3/61	FINAL DRIVE LVT-PXII STUDY 35,000 LB GVW	P.A. NO. 449
APPROVED 10-4-61		DWG NO 1077390
SCALE GRAPHIC		SHEET 1 OF 1

Figure 3.7.10

Drive Trains (Continued)

An alternate drive train, composed of the Lycoming AVM-625 air-cooled diesel engine, the Allison XTG-250 power train, and FMC final drives, has also been selected. The weight of this drive train is 3405 lb.

3.7.5.1 Drive Train Cooling

The radiator and contact cooler are located on the starboard side of the engine compartment, the belt-driven fan is located under the exhaust hatch, and a transmission oil cooler is located at the right side of the engine, as shown in Figure 3.7.1.

During land operation, the horizontal aluminum flapper valves, located under the intake and exhaust hoods, are opened by the driver to permit unrestricted airflow through the engine compartment.

During water operation, these valves are lowered by the driver, closing the air intake and restricting the exhaust opening, to limit the amount of water taken into the engine compartment. Cooling is provided by the contact cooler, located on the right sponson. Both aspiration and make-up air are drawn from the personnel compartment air inlet, as shown.

The alternate drive train shown in Figure 3.7.2 includes an air-cooled diesel engine. Cooling airflow is shown in Figure 3.7.20. The Lycoming engine is equipped with integral cooling fans and an engine air cooler. A seawater radiator and circulating pump, also shown in Figure 3.7.20, are used to effect a slightly different means of cooling.

Drive Trains (Continued)

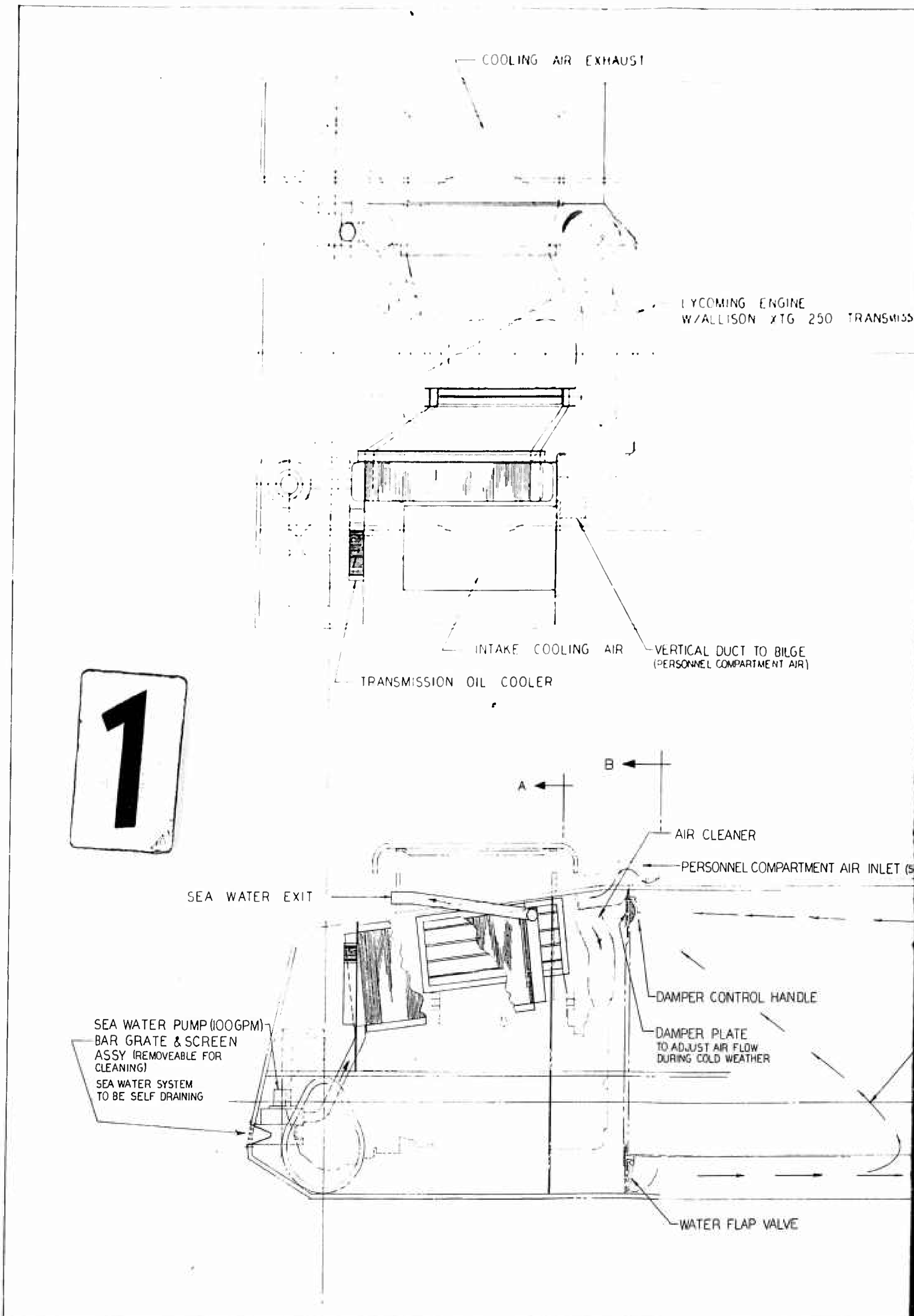
During land operation, the flapper valves are positioned to provide unrestricted airflow, as before.

During water operation, the intake flapper valve is completely closed by the driver, and the exhaust flapper is moved to restrict the air exhaust, thus limiting the amount of water taken aboard. The cooling air is recirculated within the engine compartment, utilizing a seawater radiator to cool the air. Aspiration and make-up air are provided as before.

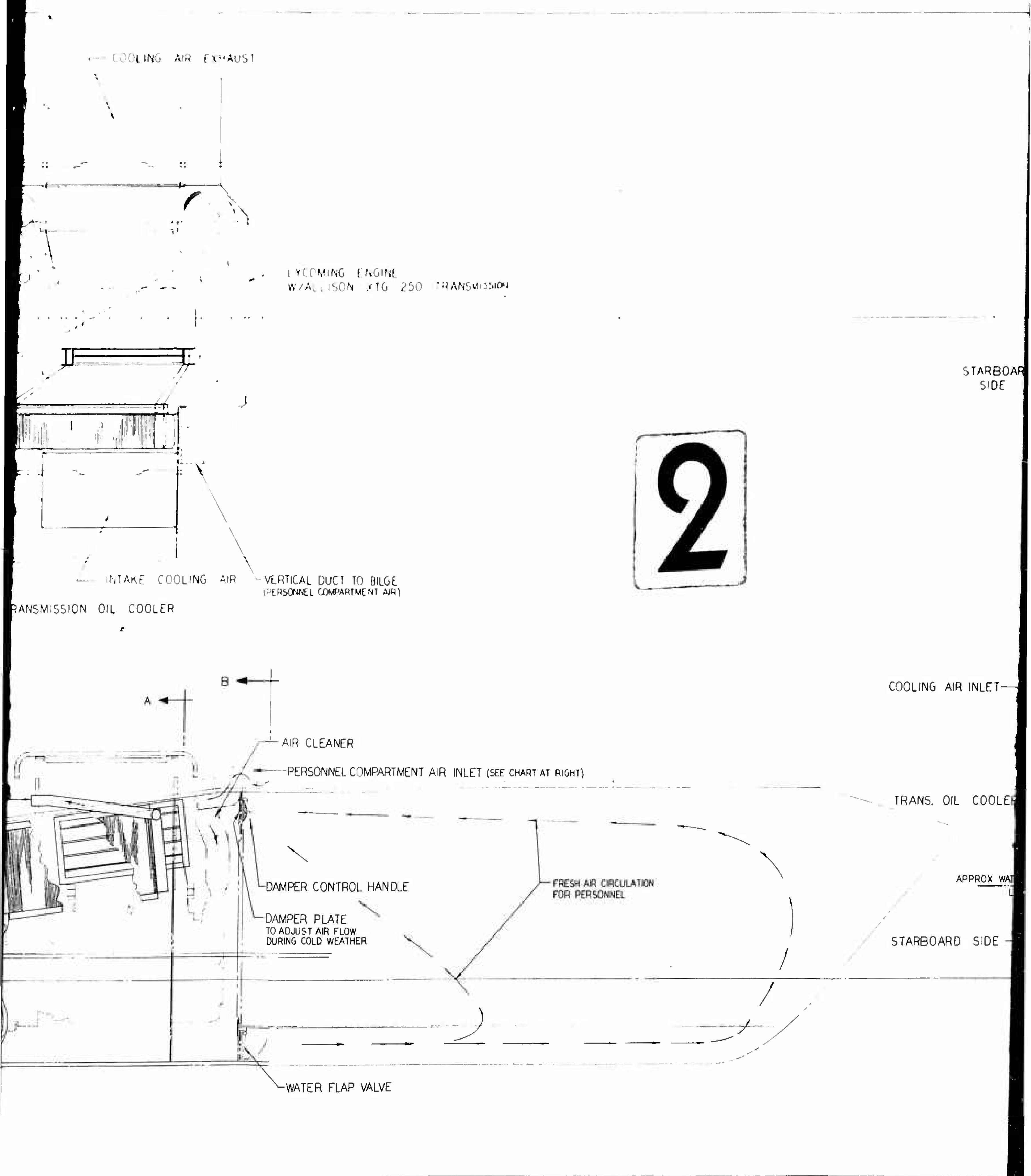
Land Operation Requirements - The fans provided with either engine are designed to move sufficient air through the ballistic grilles to cool the engine and power train under conditions ranging from operation at full speed and power to operation with the engine lugged down and the converter at 0.3 speed ratio, in an ambient of 125°F.

Water Operation Requirements - The heat-rejection capacity required for water operation is determined by the amount necessary to cool the engine while at full speed and power with the transmission converter in lock-up.

Several hundred feet of the motion picture film of the 1958 High Surf Tests, made by the Marine Corps Tracked Vehicle Test and Experimental Unit at Monterey, California, were reviewed in order to establish vehicle immersion times and depths. Going out through surf ranging up to twelve feet, the maximum immersion time was two seconds, the average depth of water above the vehicle was two feet, and wave periods were as low as seven seconds.

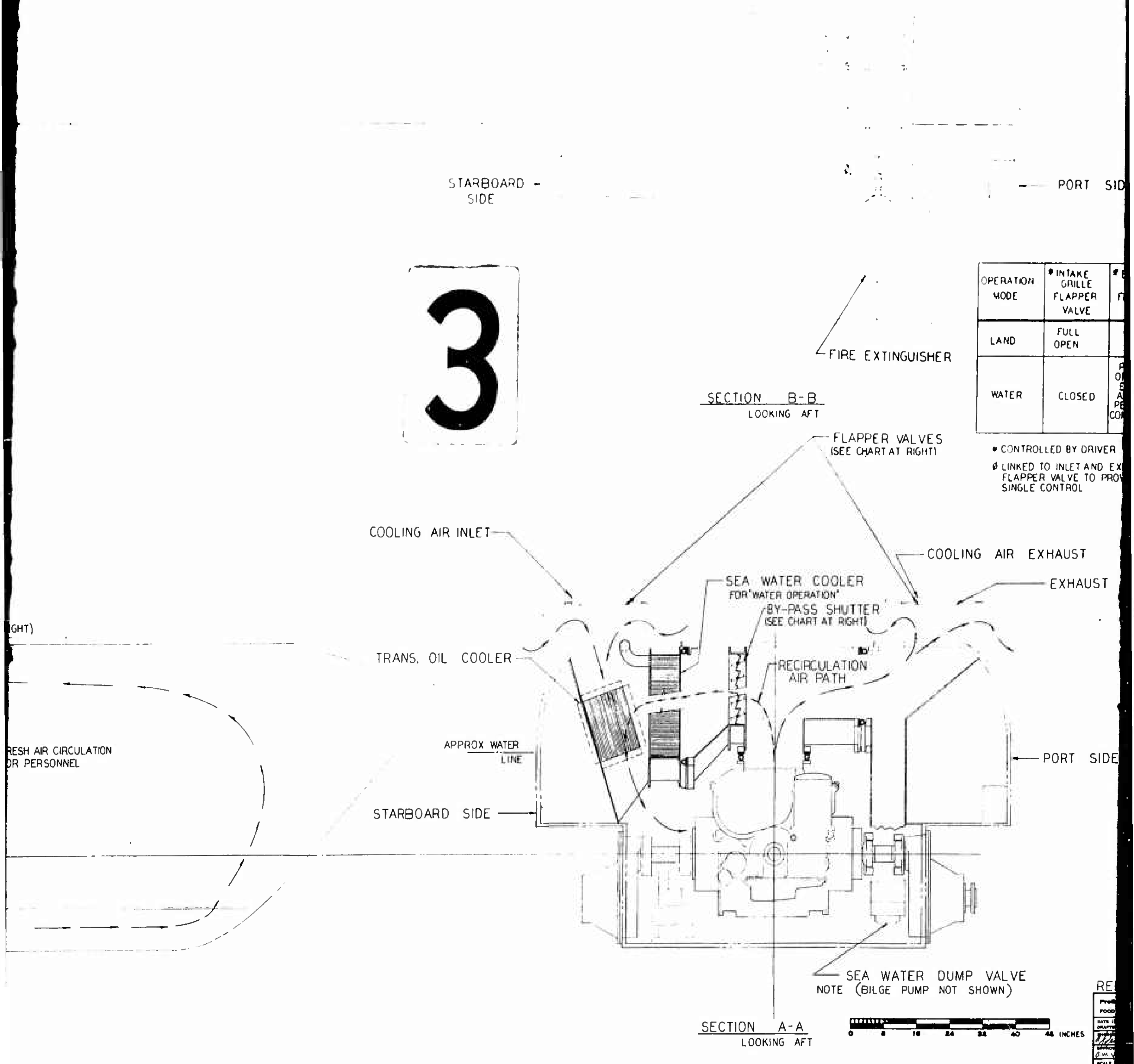


COOLING AIR EXHAUST
LYCOMING ENGINE
W/ALLISON XTG 250 TRANSMISSIO
INTAKE COOLING AIR
VERTICAL DUCT TO BILGE
(PERSONNEL COMPARTMENT AIR)
TRANSMISSION OIL COOLER
1
B
A
AIR CLEANER
PERSONNEL COMPARTMENT AIR INLET
SEA WATER EXIT
DAMPER CONTROL HANDLE
DAMPER PLATE
TO ADJUST AIR FLOW
DURING COLD WEATHER
SEA WATER PUMP (100GPM)
BAR GRATE & SCREEN
ASSY (REMOVEABLE FOR
CLEANING)
SEA WATER SYSTEM
TO BE SELF DRAINING
WATER FLAP VALVE



COOLING AIR EXHAUST
LYCOMING ENGINE
W/ALLISON XTG 250 TRANSMISSION
STARBOAR
SIDE
2
INTAKE COOLING AIR
VERTICAL DUCT TO BILGE
(PERSONNEL COMPARTMENT AIR)
RANSMISSION OIL COOLER
B
A
COOLING AIR INLET
AIR CLEANER
PERSONNEL COMPARTMENT AIR INLET (SEE CHART AT RIGHT)
TRANS. OIL COOLE
DAMPER CONTROL HANDLE
FRESH AIR CIRCULATION
FOR PERSONNEL
APPROX WA
DAMPER PLATE
TO ADJUST AIR FLOW
DURING COLD WEATHER
STARBOARD SIDE
WATER FLAP VALVE

3



OPERATION MODE	* INTAKE GRILLE FLAPPER VALVE	⌀ E... F...
LAND	FULL OPEN	
WATER	CLOSED	P... OI... E... A... PE... CON...

* CONTROLLED BY DRIVER

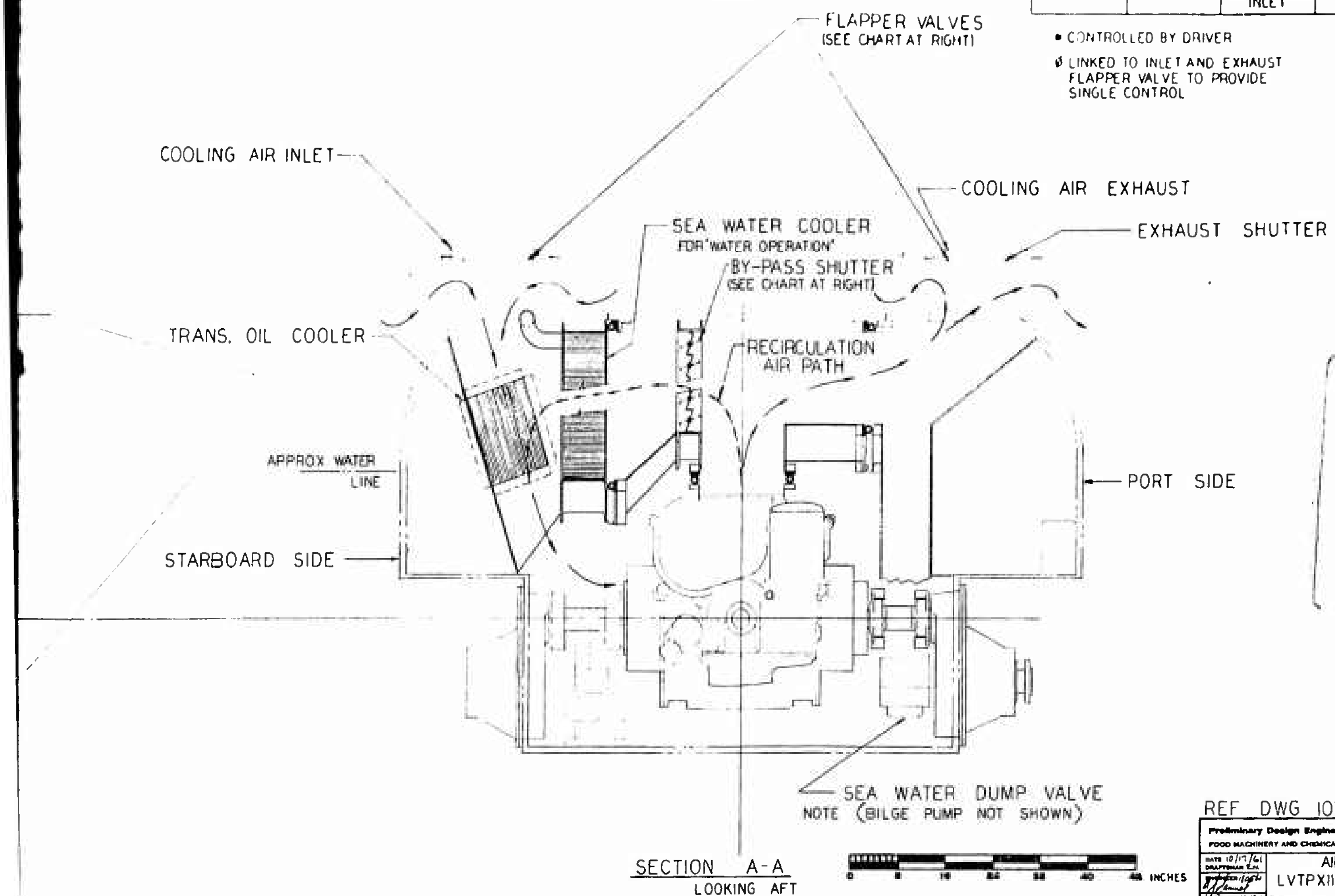
⌀ LINKED TO INLET AND EX... FLAPPER VALVE TO PRO... SINGLE CONTROL

SECTION B-B
LOOKING AFT

OPERATION MODE	* INTAKE GRILLE FLAPPER VALVE	* EXHAUST GRILLE FLAPPER VALVE	ø BY-PASS SHUTTER	PERSONNEL COMPARTMENT AIR INLET
LAND	FULL OPEN	FULL OPEN	CLOSED	OPEN (FIXED)
WATER	CLOSED	PARTIAL OPEN TO EXHAUST AIR FROM PERSONNEL COMPARTMENT INLET	OPEN	OPEN (FIXED)

* CONTROLLED BY DRIVER

ø LINKED TO INLET AND EXHAUST FLAPPER VALVE TO PROVIDE SINGLE CONTROL



SECTION A-A
LOOKING AFT

3

REF DWG 1077381

Preliminary Design Engineering, FOOD MACHINERY AND CHEMICAL CORPORATION		ORDNANCE DIVISION, SAN JOSE, CALIFORNIA
DATE 10/17/61	AIR FLOW	P.A. NO 449
	LVTPXII 35000# GVW	DWG NO 1077394
	LYCOMING AVM-625 ENG.	
SCALE GRAPHIC	W/ALLISON. XTG-250 TRANS.	SHEET 1 OF 1

Figure 3.7.20

Drive Trains (Continued)

Calculations of water intake through an open hatch, based on the above factors and substantiated by water test of a wooden mock-up of the hatch, indicated a bilge pump capacity of 1600 gpm would be required, to remove the water taken aboard. Therefore, the contact cooler and restriction of the air openings are recommended for the selected drive train.

3.8 SUSPENSION

The suspension system shown in Figure 3.8.1 was selected for both the "Maximum Armored Vehicle" and the "Maximum Water Performance Vehicle". This "high return" type system comprises the following items:

- Torsion bars
- Individually sprung road arms
- 24-inch-diameter road wheels
- Band type tracks
- Return rollers

This system was selected after an analysis based on the following:

- Ride characteristics
- Effect on water propulsion
- Weight
- Simplicity
- Component life

A careful analysis of all suspension components was made in order to recommend the lightest suspension consistent with the design requirements. The "Maximum Armored Vehicle" suspension has an estimated weight of 6,616 lb, and the "Maximum Water Performance Vehicle" 6,296 lb. The weight difference is due to the addition of paddles to the tracks of the "Maximum Armored Vehicle".

3.8.1 Suspension Requirements

With the advent of nuclear warfare, it has become increasingly desirable to provide greater unit dispersal through increased vehicle mobility. Mobility, under off-road conditions, is still limited primarily by the driver's ability to remain in control of the vehicle under the violent pitch and bounce conditions resulting from undulating terrain.

Two different series of tests were made during this study in order to select the best combination of springing and damping. One test consisted of a scale model instrumented to measure the vertical accelerations and pitching encountered on simulated cross-country courses. This test is included in Appendix E (Volume II). The second was a computer program which mathematically analyzed various systems produced by varying the following characteristics and conditions:

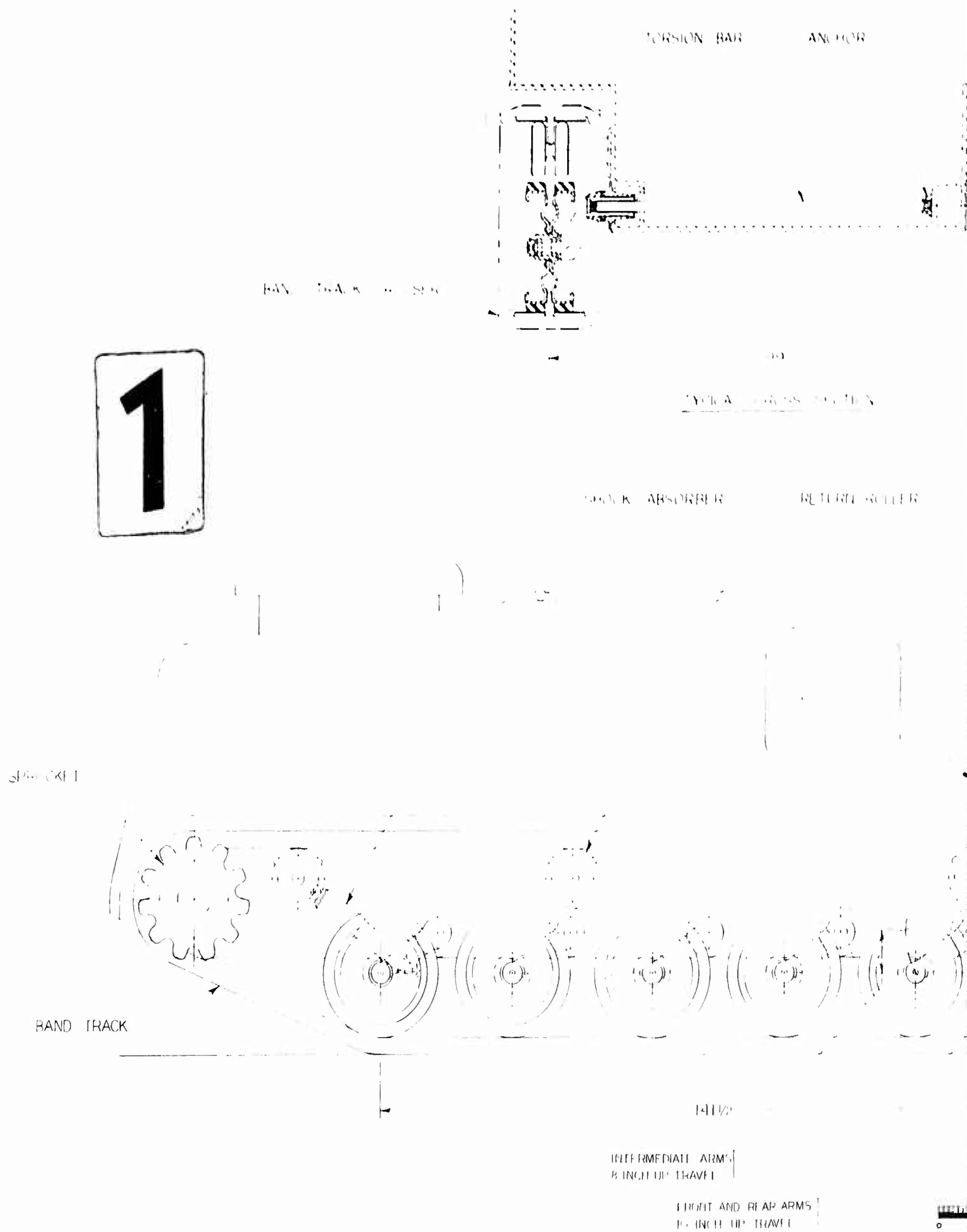
- Spring rates
- Snubbing rates
- Speeds
- Road profile
- Roadwheel amplitude
- Suspension configuration

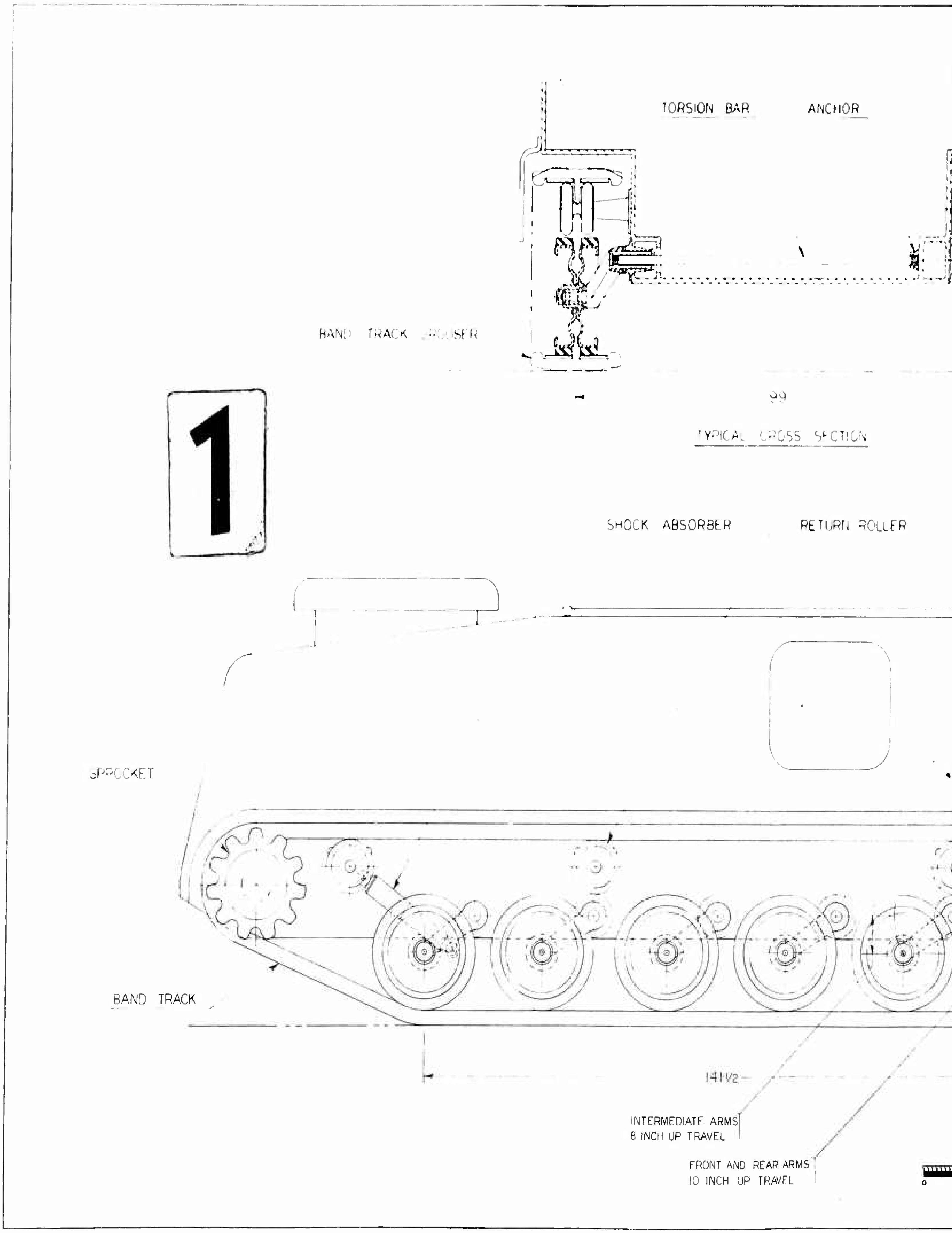
This test is included in Appendix A (Volume II).

3.8.2 Suspension Types

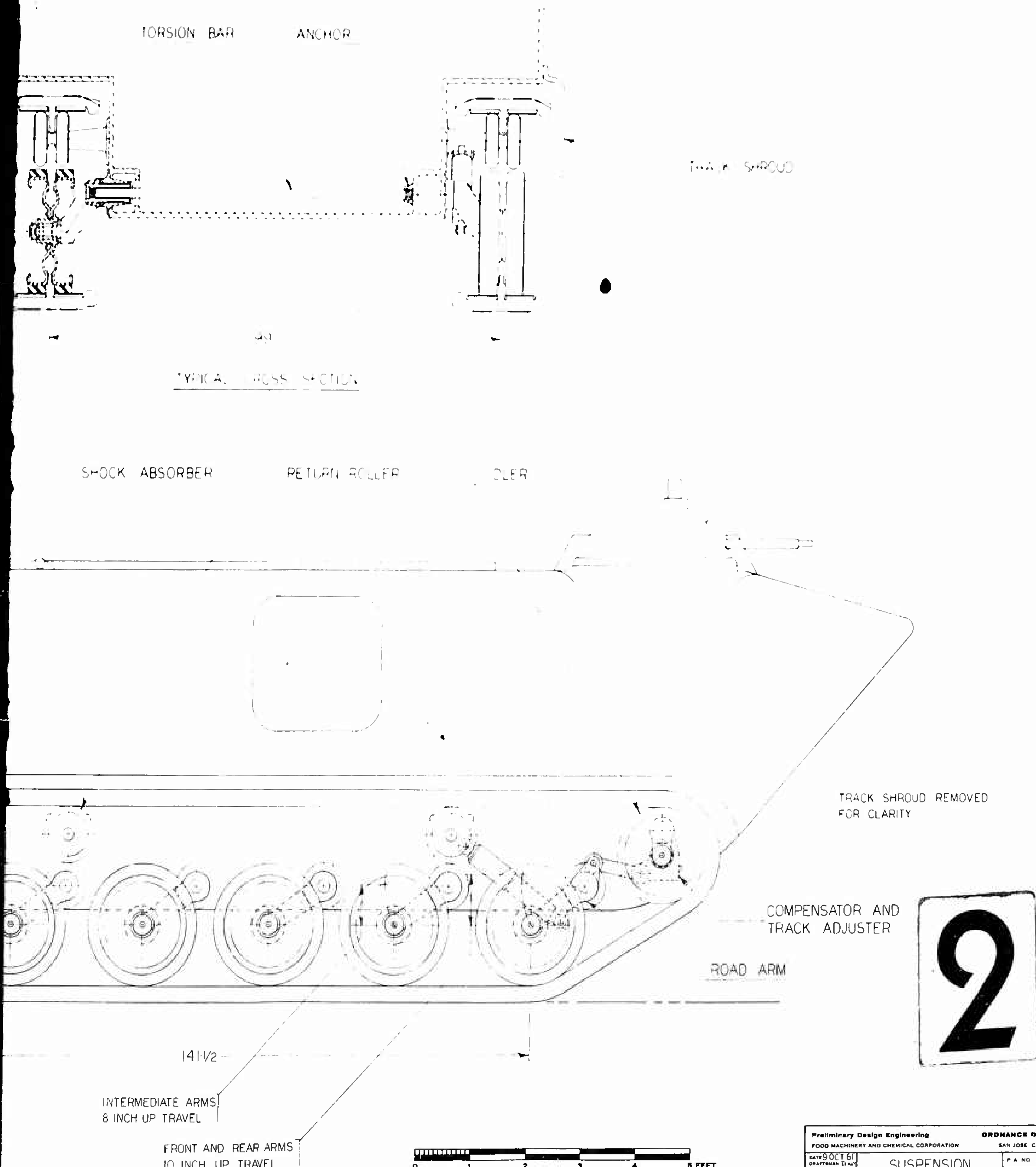
Tracked suspension systems can be placed in two basic categories, those employing a "high-return" track, as shown in Figure 3.8.2, and those using a "flat" track, as shown in Figure 3.8.3.

1





1
TORSION BAR
ANCHOR
BAND TRACK
99
TYPICAL CROSS SECTION
SHOCK ABSORBER
RETURN ROLLER
SPROCKET
BAND TRACK
141 1/2
INTERMEDIATE ARMS
8 INCH UP TRAVEL
FRONT AND REAR ARMS
10 INCH UP TRAVEL



Preliminary Design Engineering — FOOD MACHINERY AND CHEMICAL CORPORATION		ORDNANCE DIVISION — SAN JOSE CALIFORNIA
DATE 9 OCT 61	SUSPENSION ARRANGEMENT LVTPX11	P A NO 449
SCALE GRAPHIC		DWG NO 1077316

Figure 3.8.1

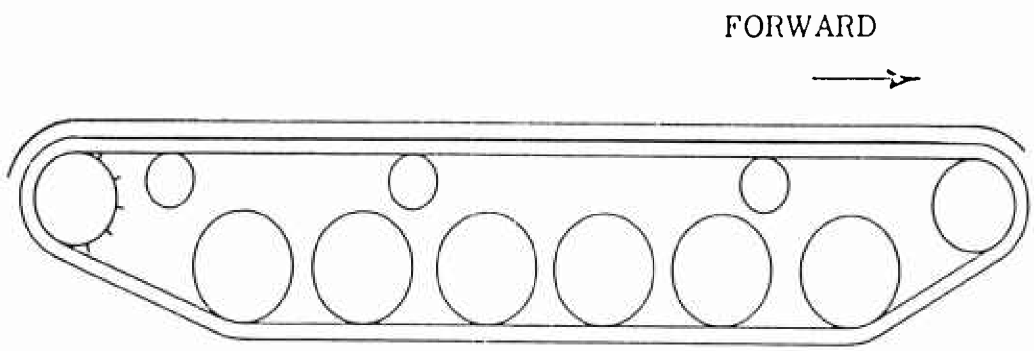


FIGURE 3.8 2 "HIGH RETURN" TRACK

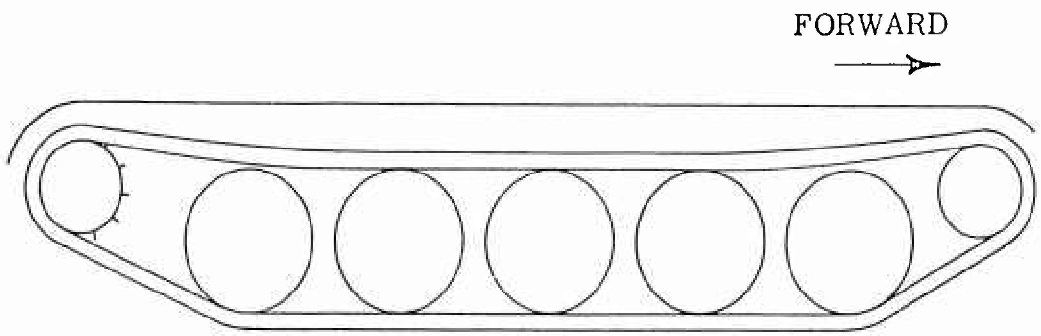


FIGURE 3 8 3 "FLAT" TRACK

Suspension Types (Continued)

The system selected for the LVTPX11 and shown in Figure 3.8.1 utilizes the high-return track and was selected because of the following advantages:

- Smaller road wheels - Road wheels are not required to support the return-track strand, and their upward travel is not restricted by the tension of the return track, resulting in a softer suspension.

- Better water propulsion characteristics - Tests have shown that the high return, in which the return track operates close to the sponson, creates less drag, resulting in greater net forward thrust for water propulsion.

- Greater roadwheel travel - Permits softer springing by allowing increased upward travel of the road wheels.

- Compatibility - Provides more space and better mounting conditions for shock absorbers.

The advantages offered by a flat track configuration (Figure 3.8.3), for this vehicle, are as follows:

- Less weight - Does not require a track tension compensator or return rollers.

- Fewer components - No return idlers

- Fewer hull stress problems

3.8.3 Tracks

FMC selected a 21-inch-wide band track for the "Maximum Armored Vehicle" and an 18-inch-wide band track for the "Maximum Water Performance Vehicle".

Both band-type and block-type tracks were evaluated during this study. Band tracks have been successfully used for some time on lightweight vehicles, but not on vehicles in the 35,000 lb class. A recent design program conducted by General Motors Technical Center for Detroit Arsenal, under Contract DA-20-018-ORD-14510, indicated that band tracks could be designed for this weight vehicle at a weight savings over block tracks. Figure 3.8.4 shows the data on tracks tested under this contract.

The XM551 Armored Reconnaissance Vehicle currently under development has both a band- and a block-track program to develop a 2,500-mile-life track. FMC recommends the use of the track developed for this vehicle for use on the LVTPX11. Evaluation tests of these tracks are scheduled for the near future. In the event of failure of this development, FMC recommends that a lightweight block track development program be initiated for the LVTPX11. A typical band track is shown in Figure 3.8.5. This 21-inch-wide track is estimated to weigh 36 lb/ft and the 18-inch-wide track 32 lb/ft. The 32 lb/ft data has been supplied from the XM551 ARV program.

The study also included both six-inch-pitch and four-inch-pitch steel-block tracks as well as aluminum blocks. A 21-inch-wide, single-pin, rubber-bushed, steel block is shown in Figure 3.8.6 and is estimated to weigh 60 lb/ft. Figure 3.8.7 shows a steel block track utilizing a bushed hollow pin. This track is estimated to weigh 56 lb/ft.

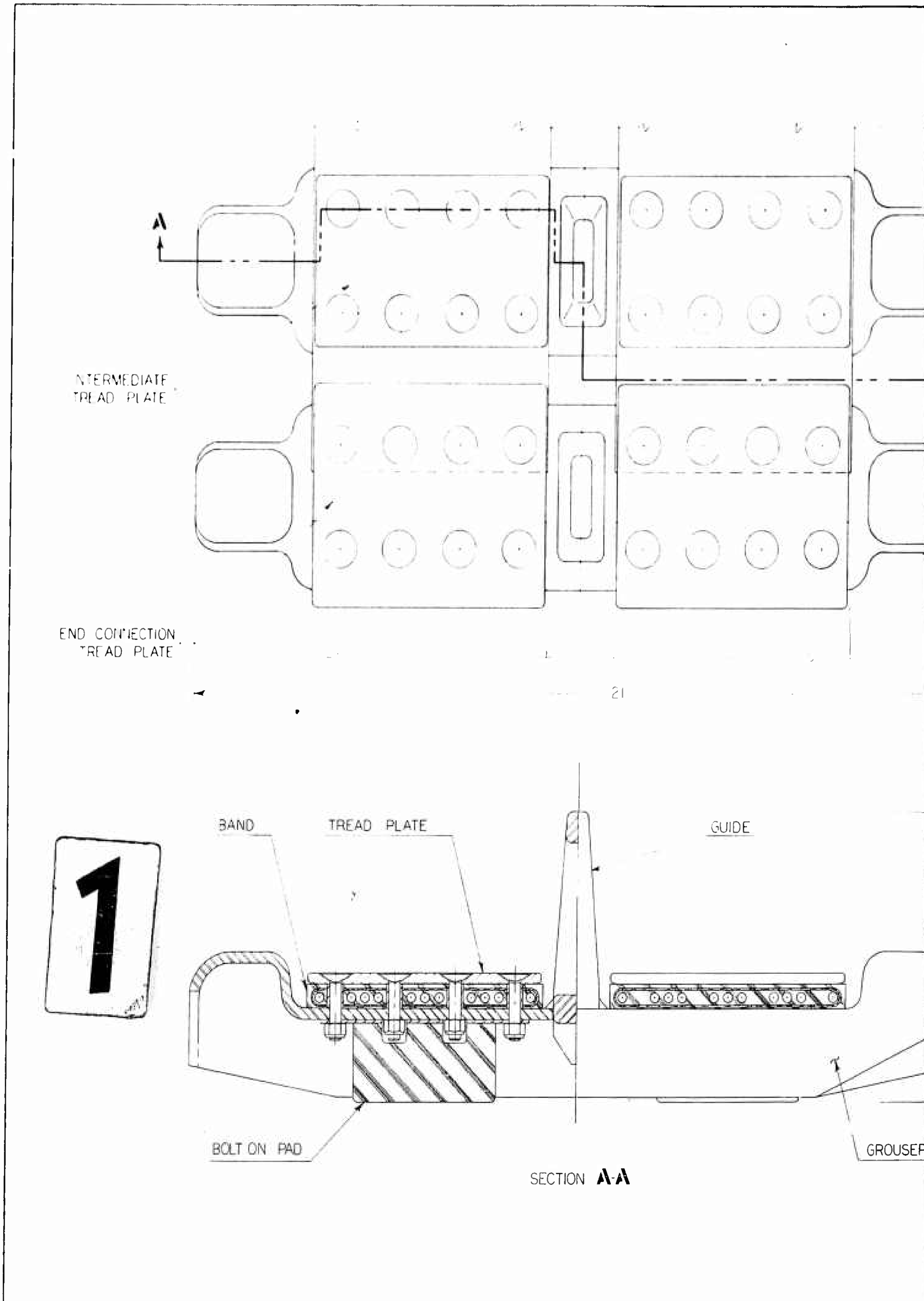
Tracks (Continued)

High-strength aluminum alloys permit an aluminum block design provided hard materials are applied to the primary areas of wear. Figures 3.8.8 through 3.8.11 show various ways of facing the wear surfaces. It is estimated that the 21-inch-wide aluminum block track will weigh 46 lb/ft.

Aluminum block tracks offer the possibility of a further reduction in suspension component weight, but are, as yet, unproven. FMC was recently awarded a contract by OTAC to continue the development work on such a track.

		TRACK	
GVW (LB)	TRACK TYPE	WIDTH (IN.)	WEIGHT/FT. (LB)
	Band	15	41.6
36,000	Band	15	42.8
	Block (T118)	15	43.7
40,000	Band	21	49.3
	Block (T91)	21	80.0
50,000	Band	21	69.5
	Block (T91)	21	80.0

FIGURE 3.8.4 TRACK TEST DATA


A
INTERMEDIATE TREAD PLATE
END CONNECTION TREAD PLATE
21
1
BAND
TREAD PLATE
GUIDE
BOLT ON PAD
GROUSER
SECTION A-A

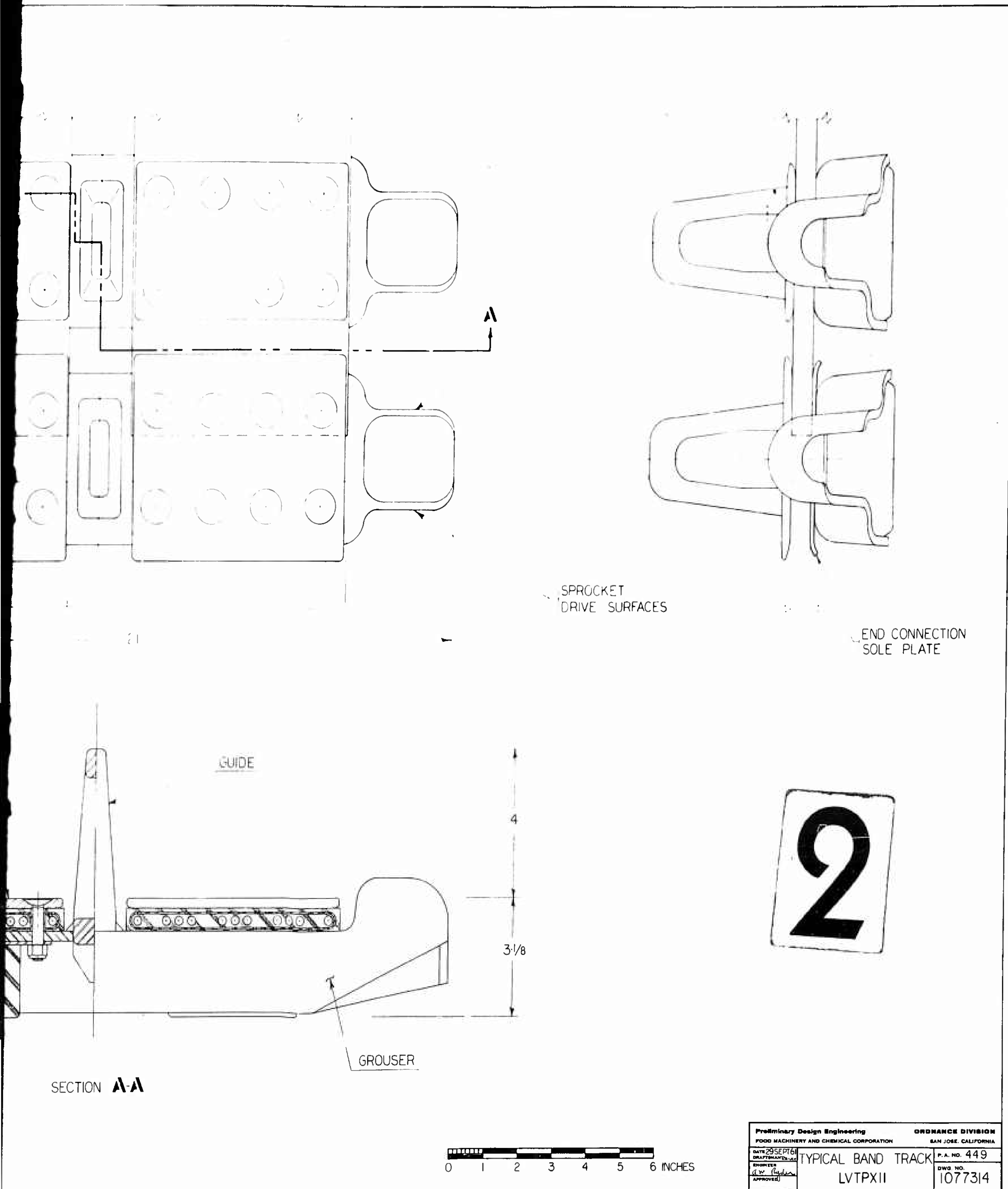
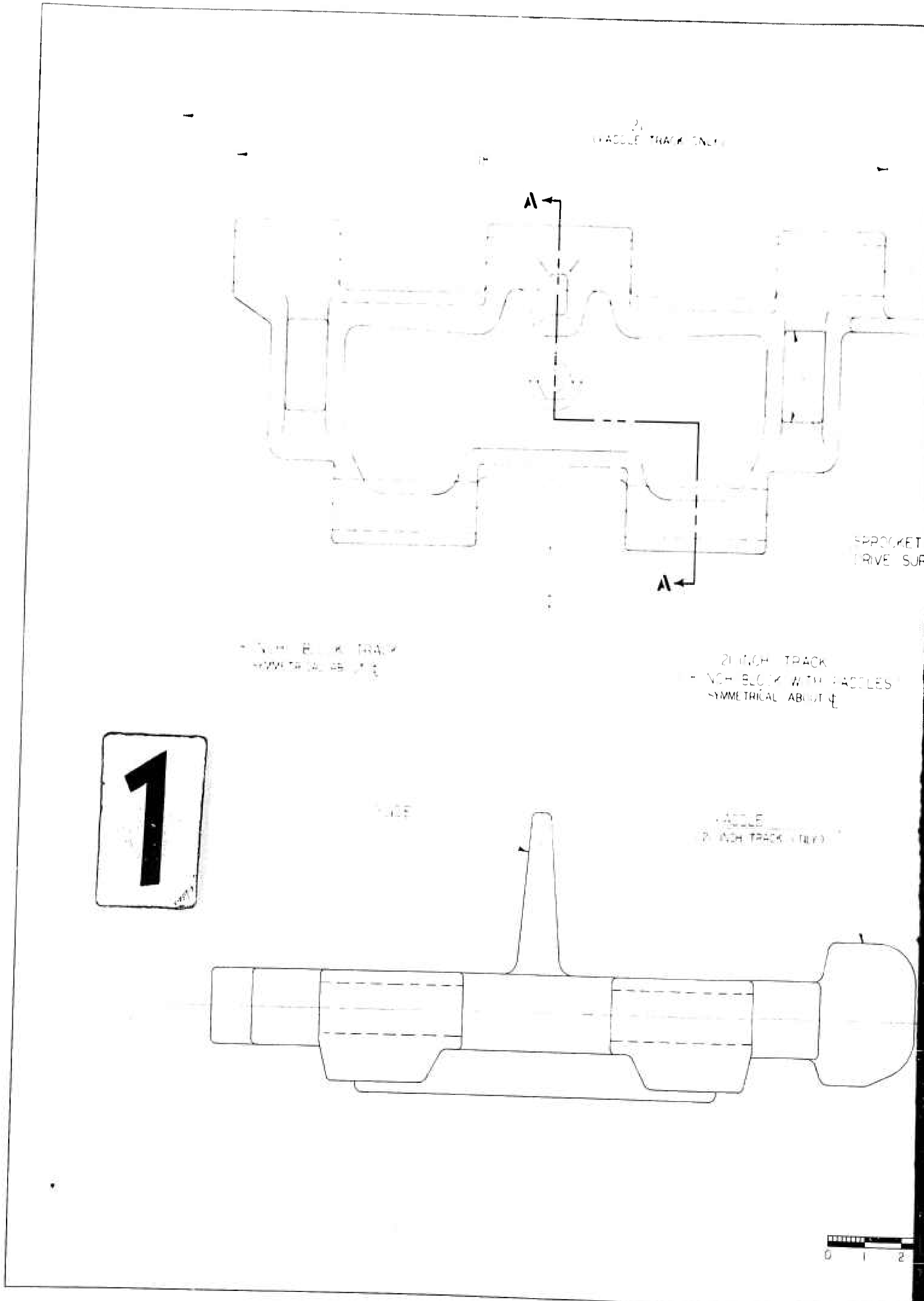

A
SPROCKET
DRIVE SURFACES
END CONNECTION
SOLE PLATE
GUIDE
4
3-1/8
GROUSER
SECTION A-A
0 1 2 3 4 5 6 INCHES
2
Preliminary Design Engineering
FOOD MACHINERY AND CHEMICAL CORPORATION
ORDNANCE DIVISION
SAN JOSE, CALIFORNIA
DATE 29SEPT61
TYPICAL BAND TRACK
LVTPX11
P.A. NO. 449
DWG NO. 1077314
SCALE GRAPHIC

Figure 3.8.5


A
A
21 INCH TRACK
SYMMETRICAL ABOUT ℄

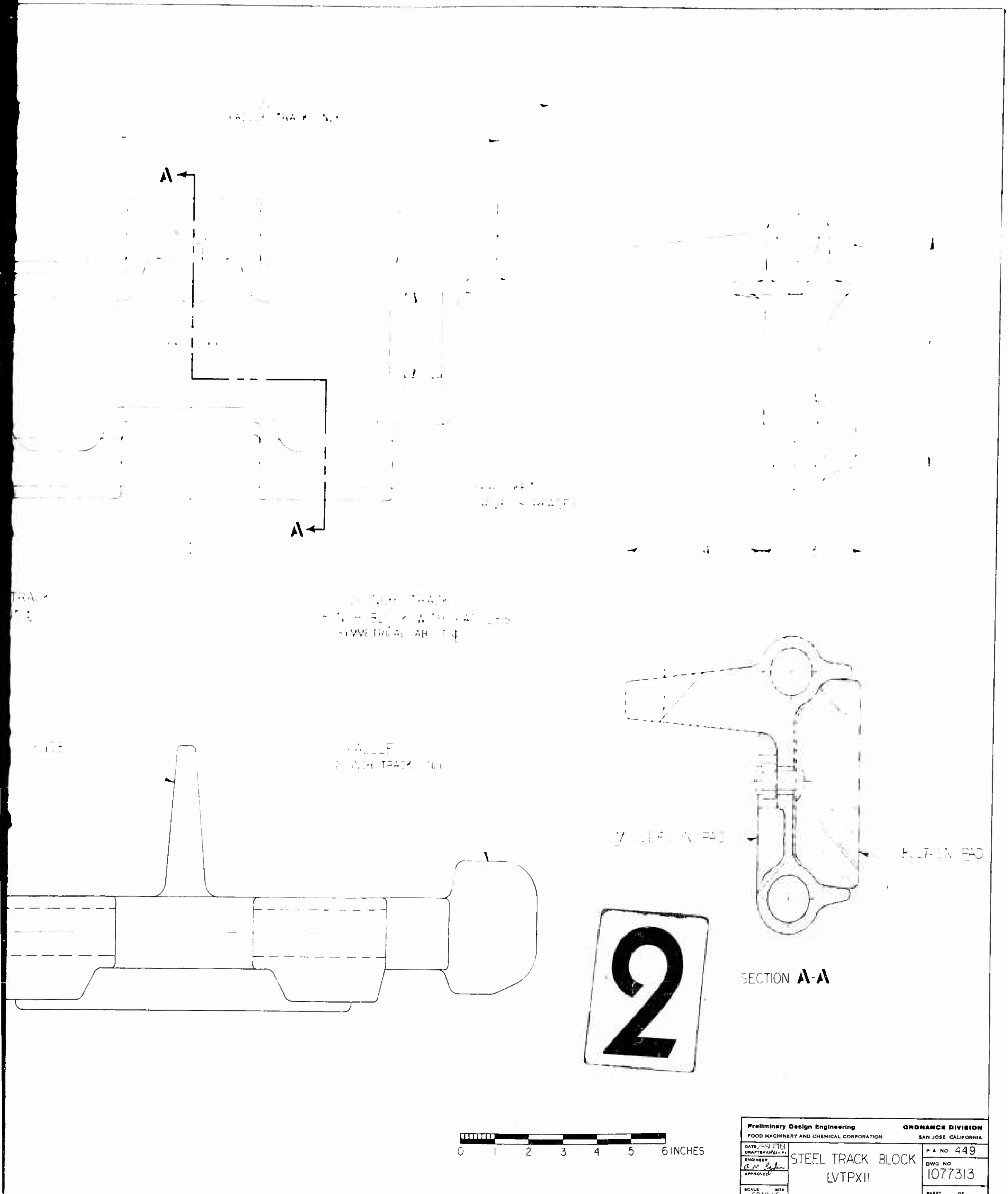

A
A
SECTION A-A
0 1 2 3 4 5 6 INCHES
Preliminary Design Engineering
FOOD MACHINERY AND CHEMICAL CORPORATION
ORDNANCE DIVISION
SAN JOSE CALIFORNIA
STEEL TRACK BLOCK
LVTPXII
P A NO 449
DWG NO 1077313
SCALE GRAPHIC

Figure 3.8.6

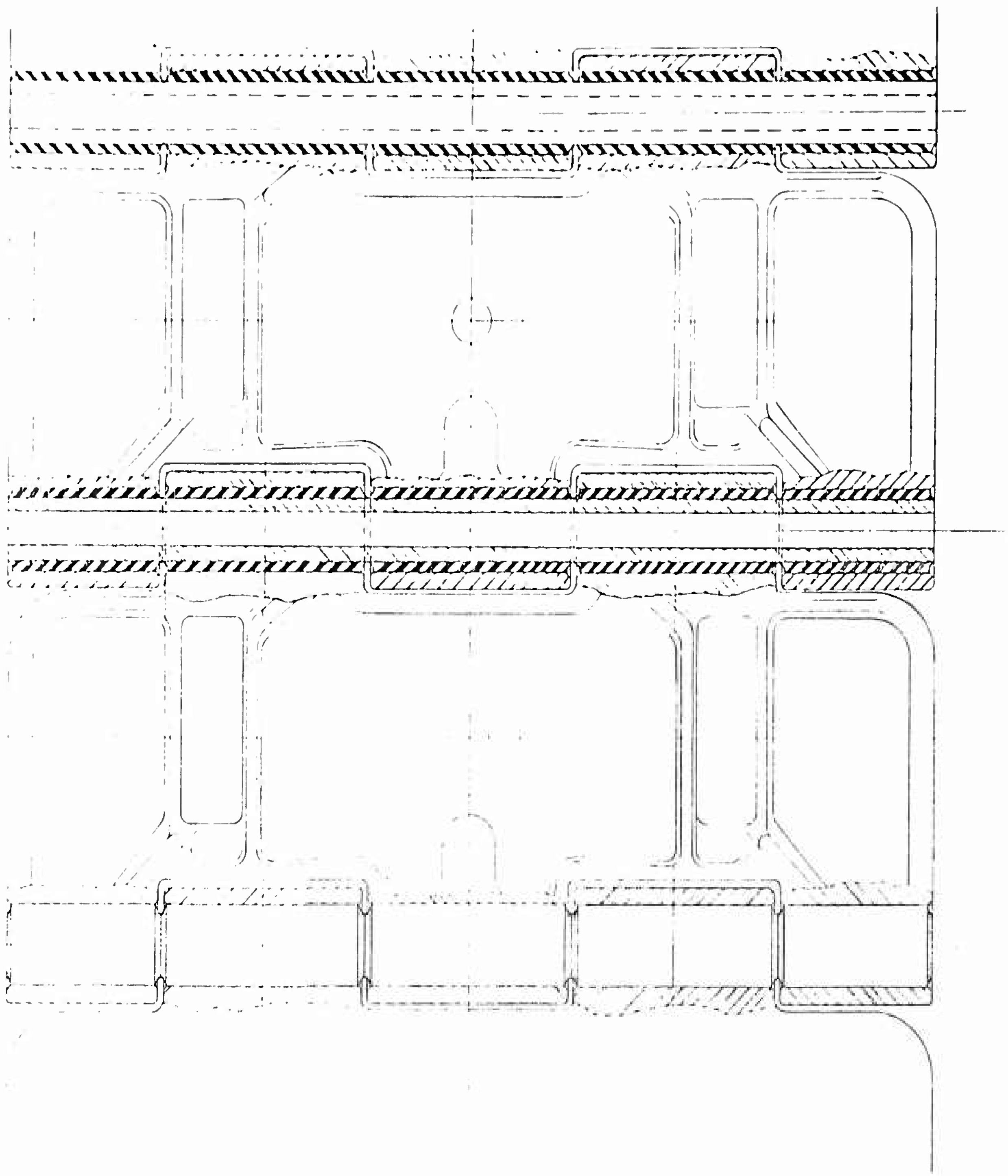


FIGURE 3.8.7

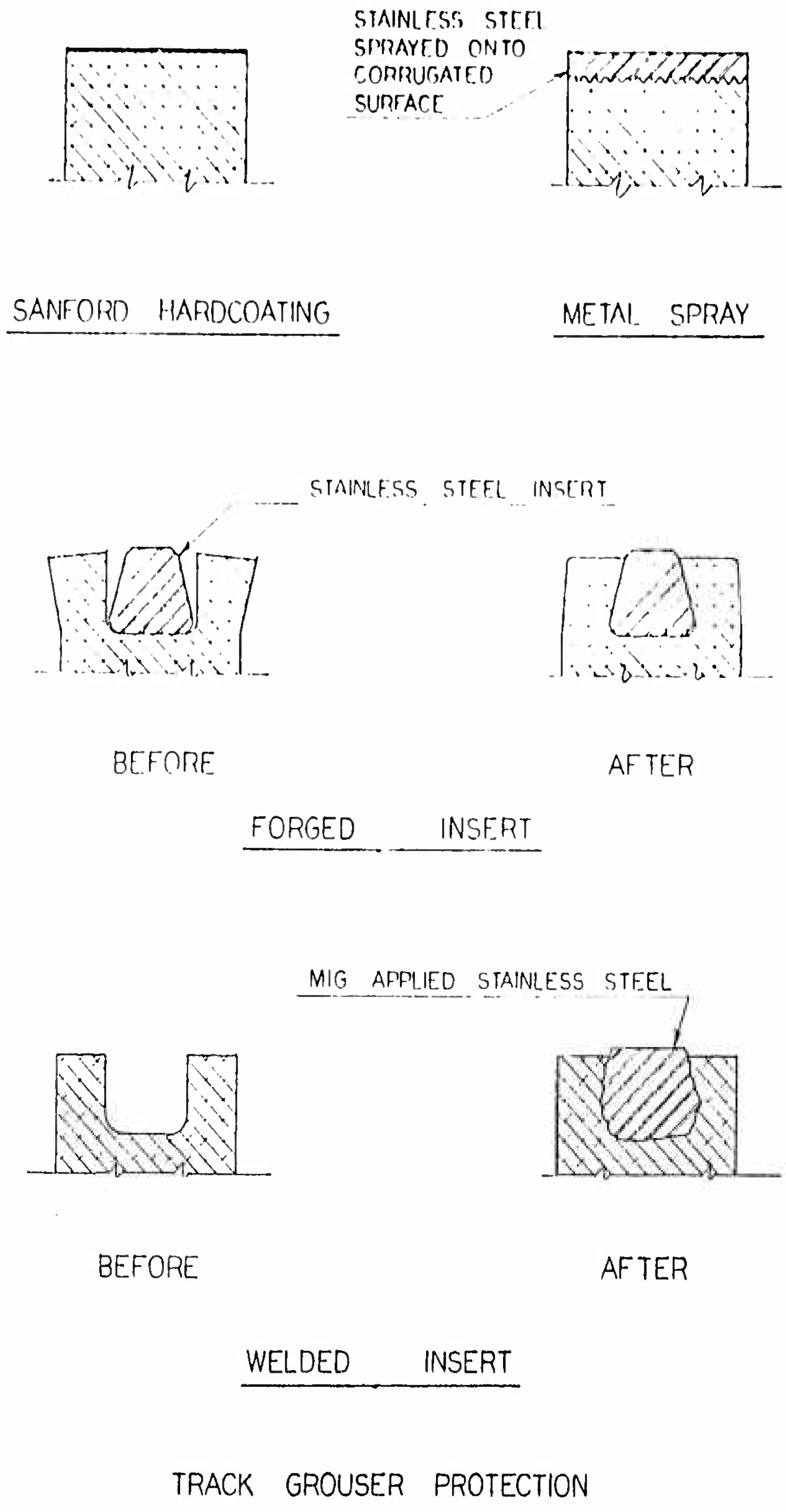
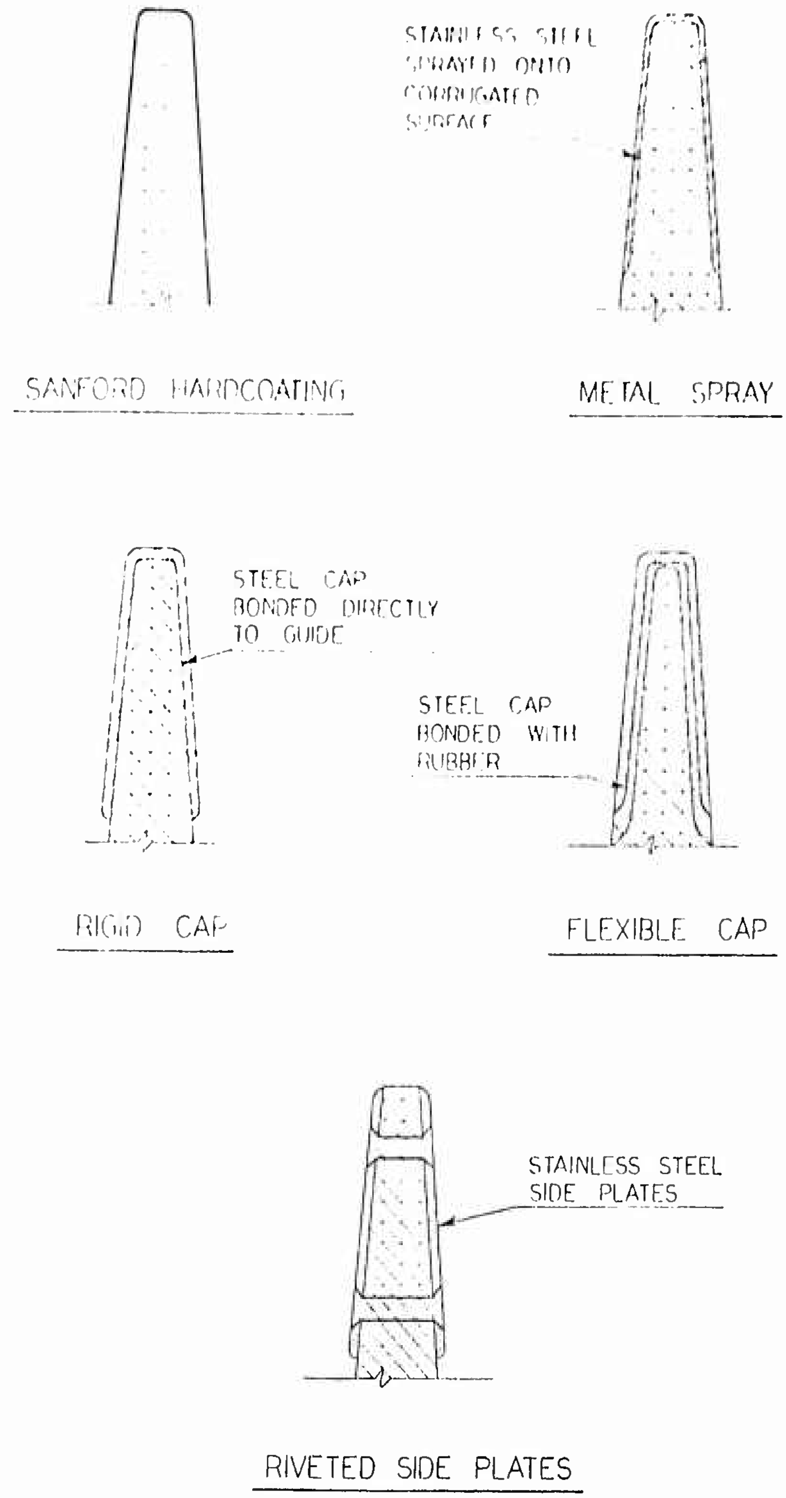
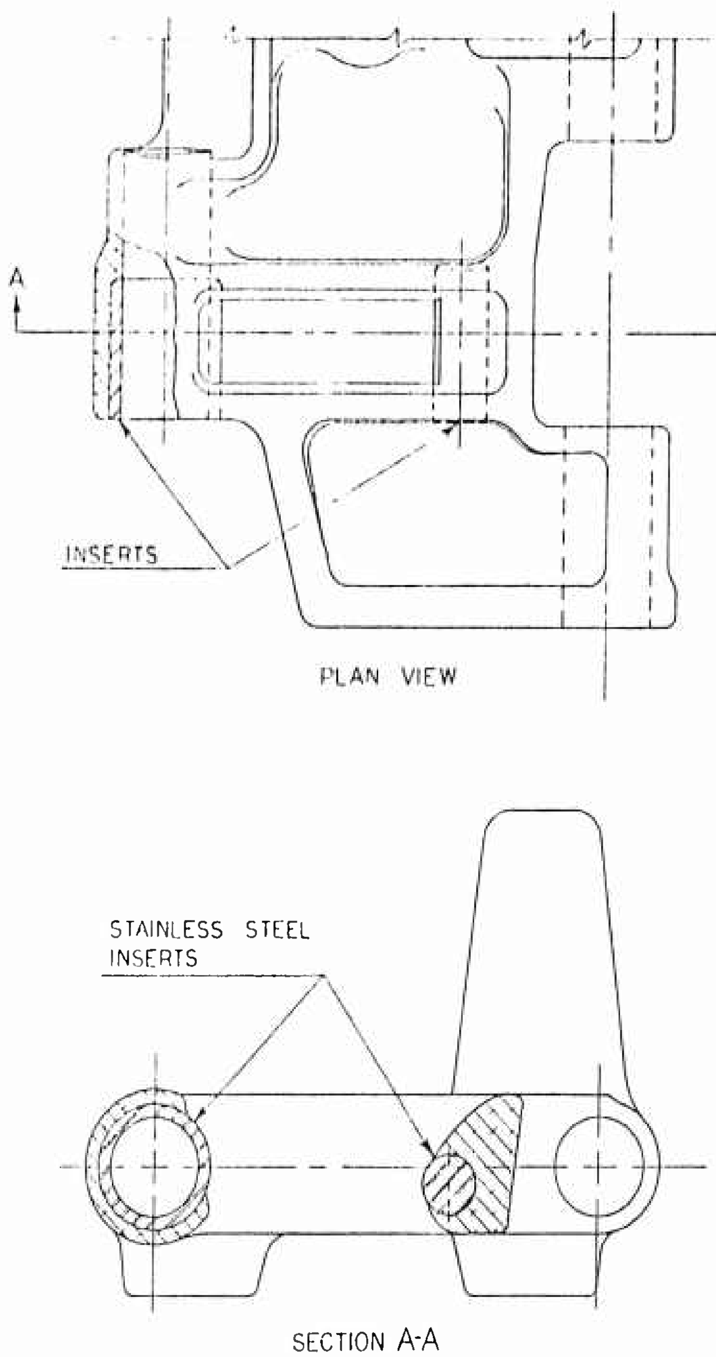


FIGURE 3.8.8 ALUMINUM TRACK BLOCKS



TRACK GUIDE PROTECTION

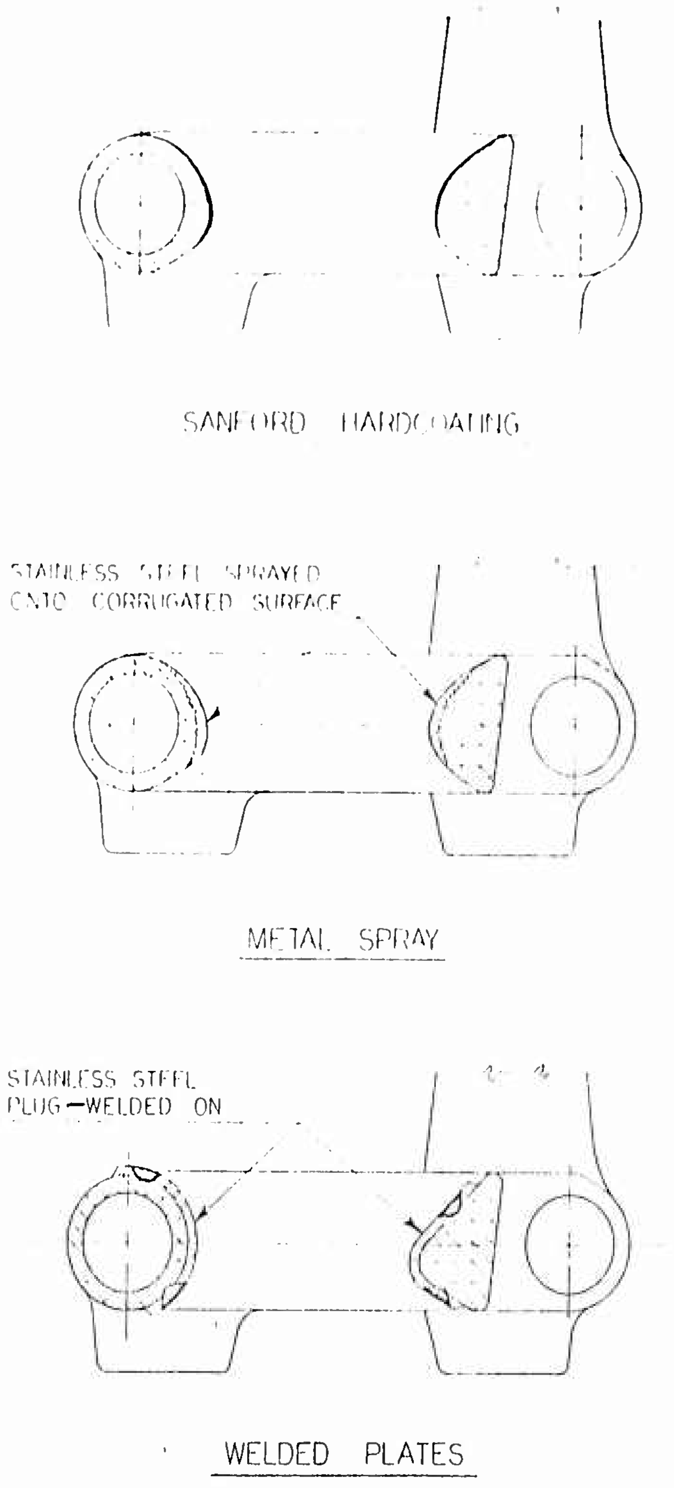
FIGURE 3.8.9 ALUMINUM TRACK BLOCKS



STEEL INSERTS

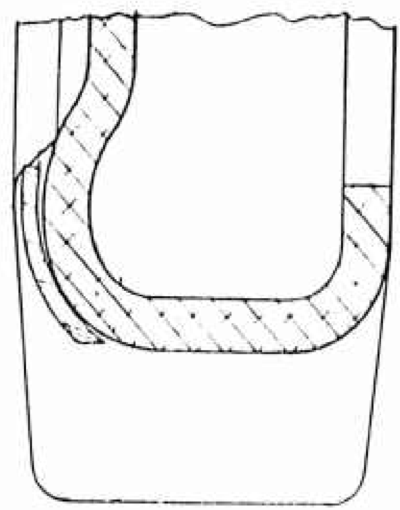
SPROCKET DRIVE SURFACE PROTECTION

FIGURE 3 8. 10 ALUMINUM TRACK BLOCKS



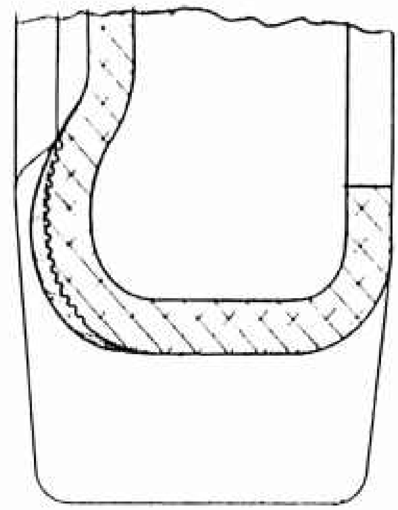
SPROCKET DRIVE—SURFACE PROTECTION

FIGURE 3 8 11 ALUMINUM TRACK BLOCKS



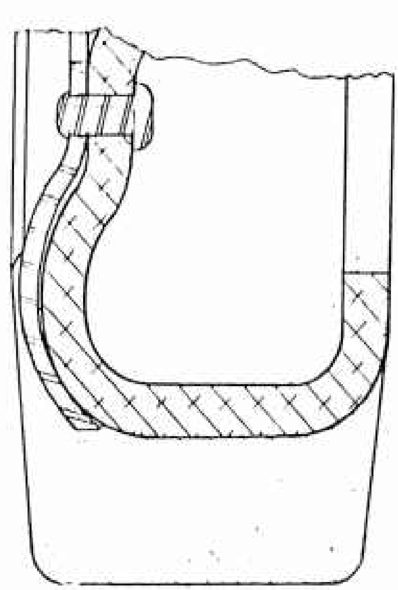
(a)

Bonded Wear Ring



(b)

Sprayed Wear Surfice



(c)

Riveted Wear Ring

FIGURE 3.8.11 ALUMINUM ROAD WHEELS WITH STEEL WEAR SURFACES

3.8.4 Sprockets

The necessity for providing a front ramp for improved vehicle trim greatly influenced the selection of a rear drive. Experience shows that the height of the rear sprocket is closely related to the track-throwing characteristics of a vehicle when operating in loose material, while the height of the front idler determines the obstacle-climbing ability. The optimum location must be compromised by the sponson height, to maintain a low vehicle silhouette. The front idler location shown in Figure 3.8.1 was also influenced by the configuration of the front fenders, both from a desire to minimize the fender projection forward of the hull and to still provide maximum fender wrap-around for water propulsion. The obstacle-climbing ability is improved by the sloping under-bow of the vehicle.

An alternate approach to the idler location can be obtained by moving the idler up and forward and elevating the sponson height locally. This could possibly cause a slight track-to-sponson contact in reverse operation.

An 11-tooth sprocket was selected to provide the minimum sprocket size commensurate with the track flexure angle.

3.8.5 Road Wheels

Twenty-four-inch-diameter aluminum road wheels were selected as the best compromise between roadwheel upward travel, return track height, and the available longitudinal space.

Current production aluminum road wheels consist of a formed center section welded to a rolled outer rim, with a steel wear ring riveted to the guide side of the rim. Movement between the wear ring and the wheel accelerates tire wear. FMC conducted a program which tested both bonded and sprayed wear

Road Wheels (Continued)

rings, some of which are shown in Figure 3.8.12. The sprayed wear ring, Figure 3.8.12 (b), proved superior to both the riveted and bonded rings.

Tests currently being conducted by FMC indicate a strong possibility that an explosive-formed road wheel can be used in the future, thus permitting a lighter wheel through better distribution of material.

Plastic road wheels were tested by the military, prior to this study, with very little success. Although they offer an area of substantial weight savings, they are very susceptible to the temperature extremes encountered in service.

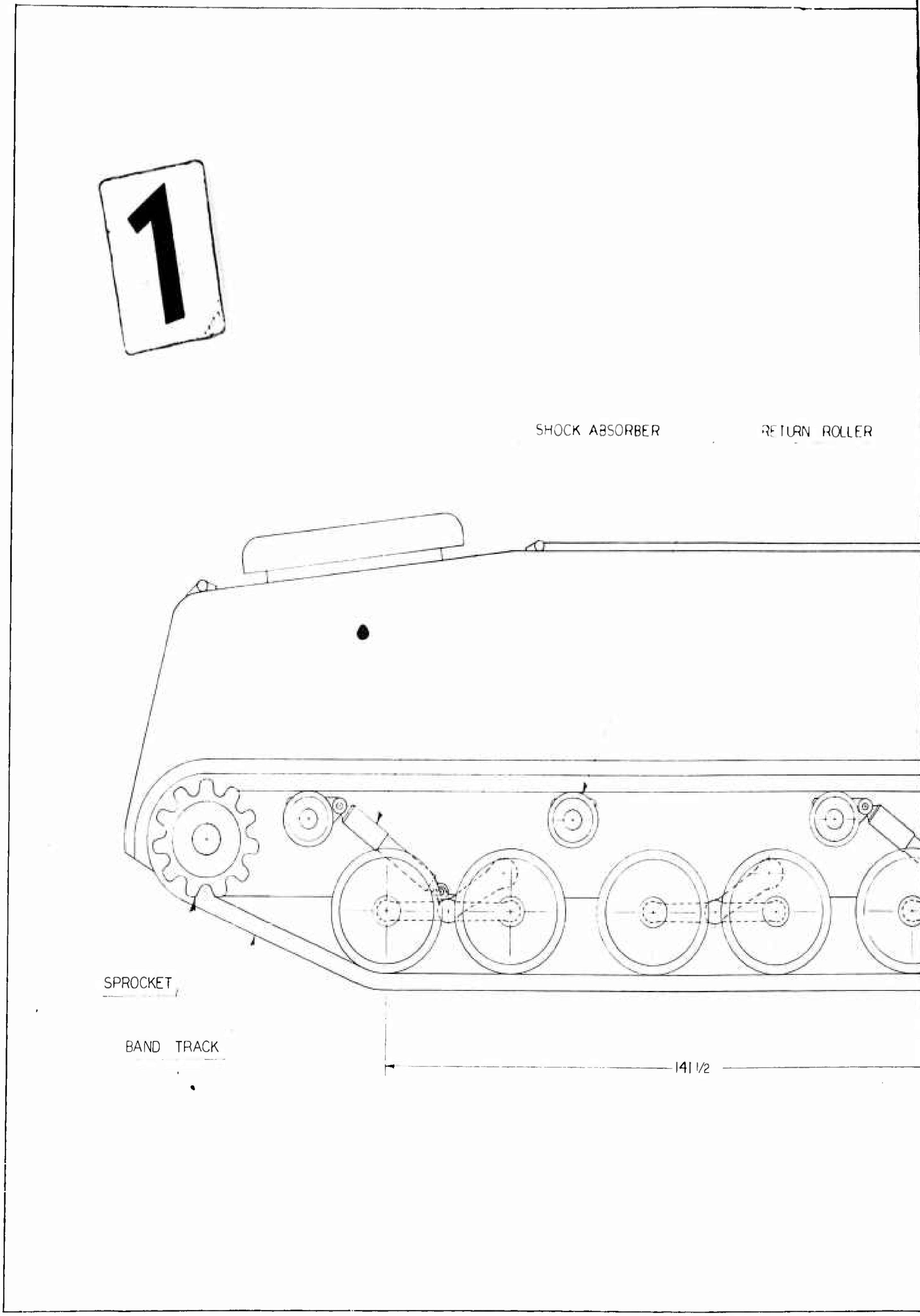
3.8.6 Road Arms

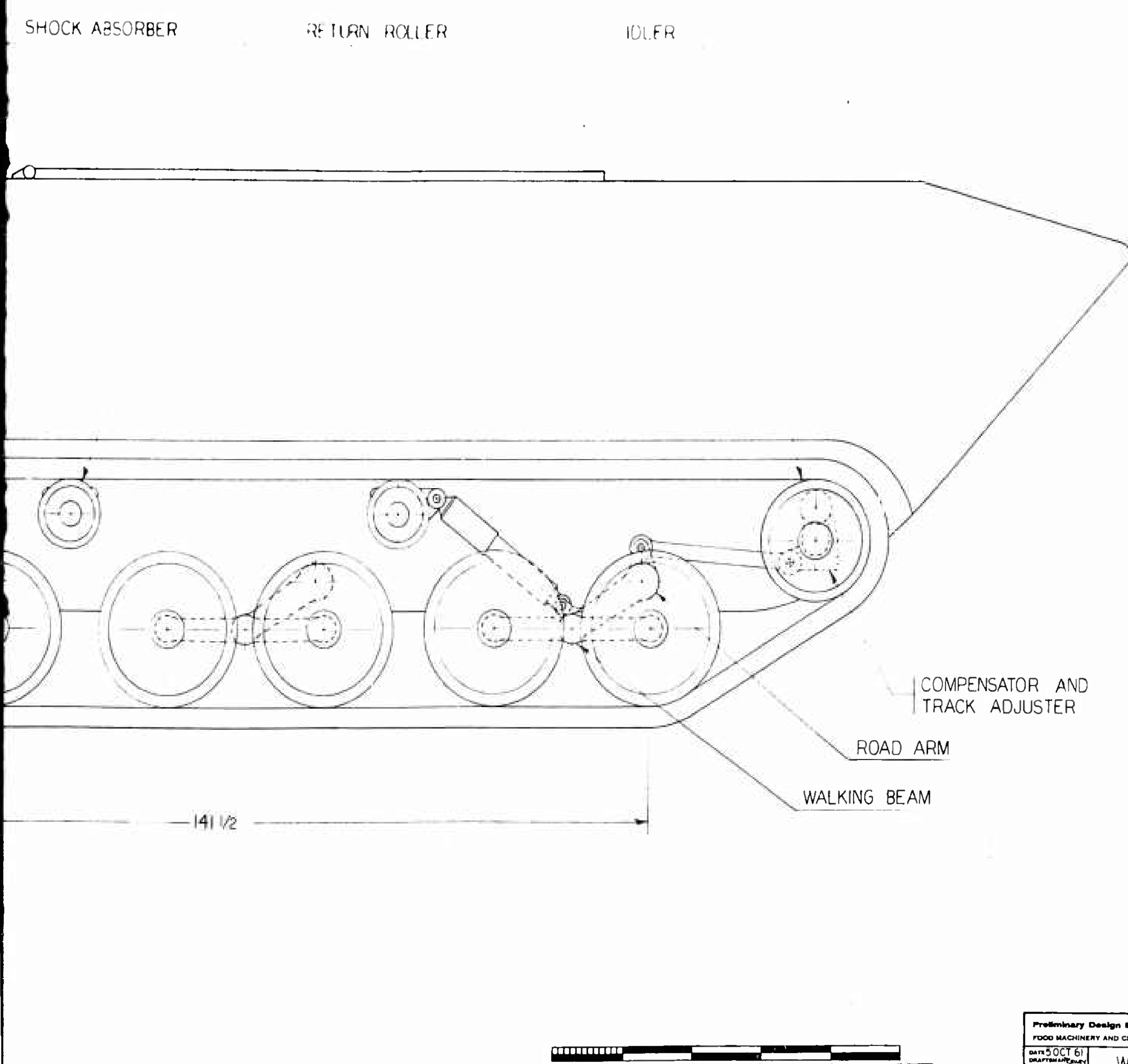
The selected suspension, shown in Figure 3.8.1, uses alloy steel front and rear road arms and aluminum intermediate arms to effect the maximum possible weight saving. Both individual arms and the walking-beam arrangement shown in Figure 3.8.13 were studied. The suspension analysis included in Appendix A (Volume II) shows certain advantages offered by the walking-beam arrangement whereby the road wheels are able to walk over certain types of obstacles with very small road arm movement. It is recommended that such a system be carried through the hardward stage to permit a side-by-side comparison with a conventional system.

3.8.7 Springs

Torsion bar springs were selected for the LVTPX11, after the following types of springs were investigated:

- Torsion bars
- Torsilastic springs
- Hydropneumatic springs


1
SHOCK ABSORBER
RETURN ROLLER
SPROCKET
BAND TRACK
141 1/2



2

Preliminary Design Engineering FOOD MACHINERY AND CHEMICAL CORPORATION		**ORDNANCE DIVISION** SAN JOSE, CALIFORNIA
DATE 5 OCT 61 / DRAFTSMAN / ENGINEER / APPROVED	WALKING BEAM SUSPENSION LVTPXII	P A NO 449
SCALE GRAPHIC / SIZE		DWG NO 1077315
		SHEET OF

Figure 3.8.13

3.8.7.1 Torsion Bars

Steel torsion bars are currently used on the majority of tracked vehicles and offer the following advantages:

- Simplicity
- Low cost
- Reliability
- Ease of maintenance

Experimental work in plastic torsion bars is presently being planned, but plastic torsion bars have not proven feasible at this time.

3.8.7.2 Torsilastic Springs

A typical installation is shown in Figure 3.8.14. Although a torsilastic installation is approximately equal in weight to a torsion bar installation, it presents different structural problems.

To provide the 10-inch roadwheel travel, a torsilastic spring must be approximately 16 inches in diameter, thus infringing upon either cargo space or ground clearance.

3.8.7.3 Hydropneumatic Springs

Several systems were investigated, and one typical system is shown in Figure 3.8.15. These systems offer the following advantages:

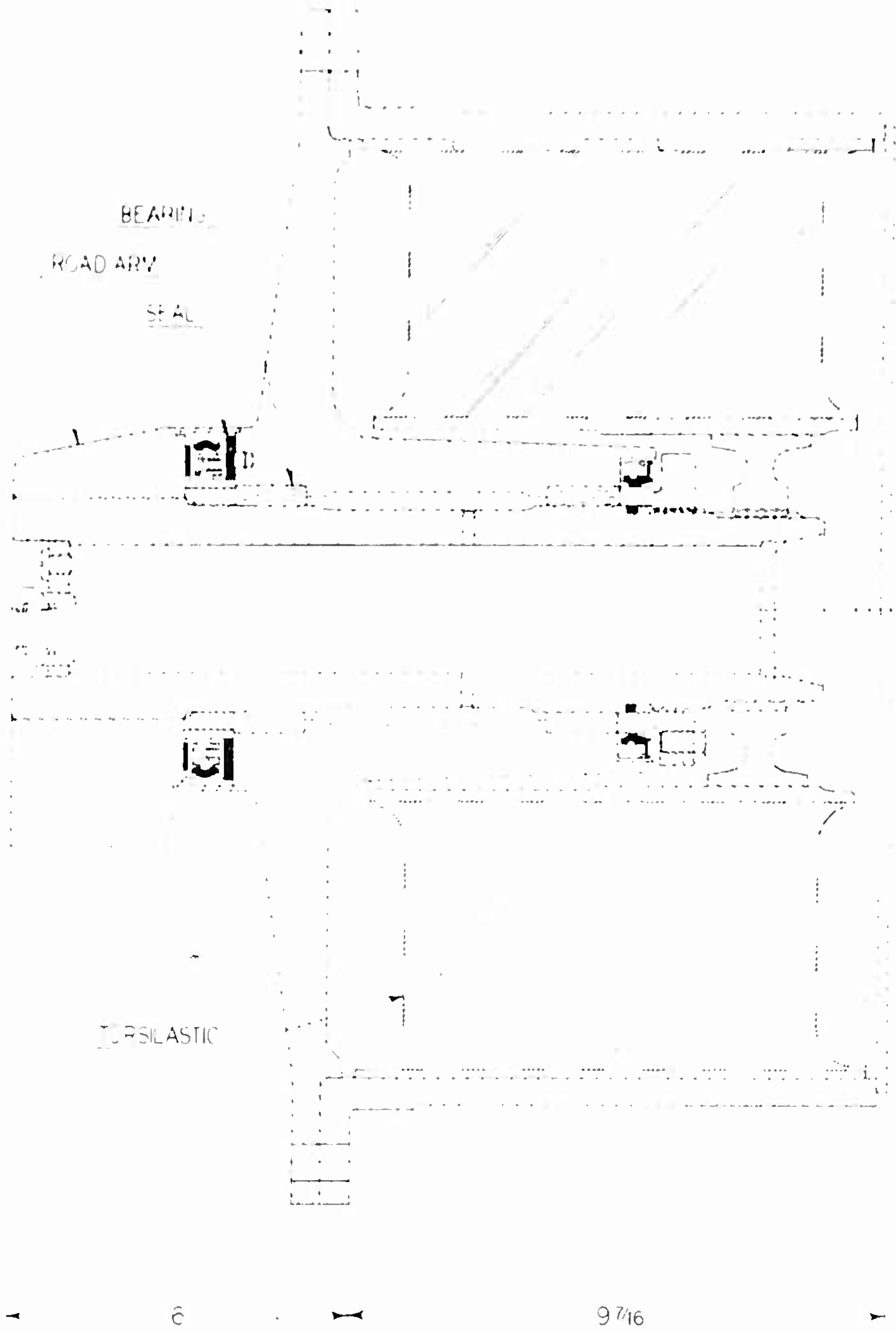
- Built-in shock absorbers
- Variable spring rate
- Suspension lock-out

Hydropneumatic Springs (Continued)

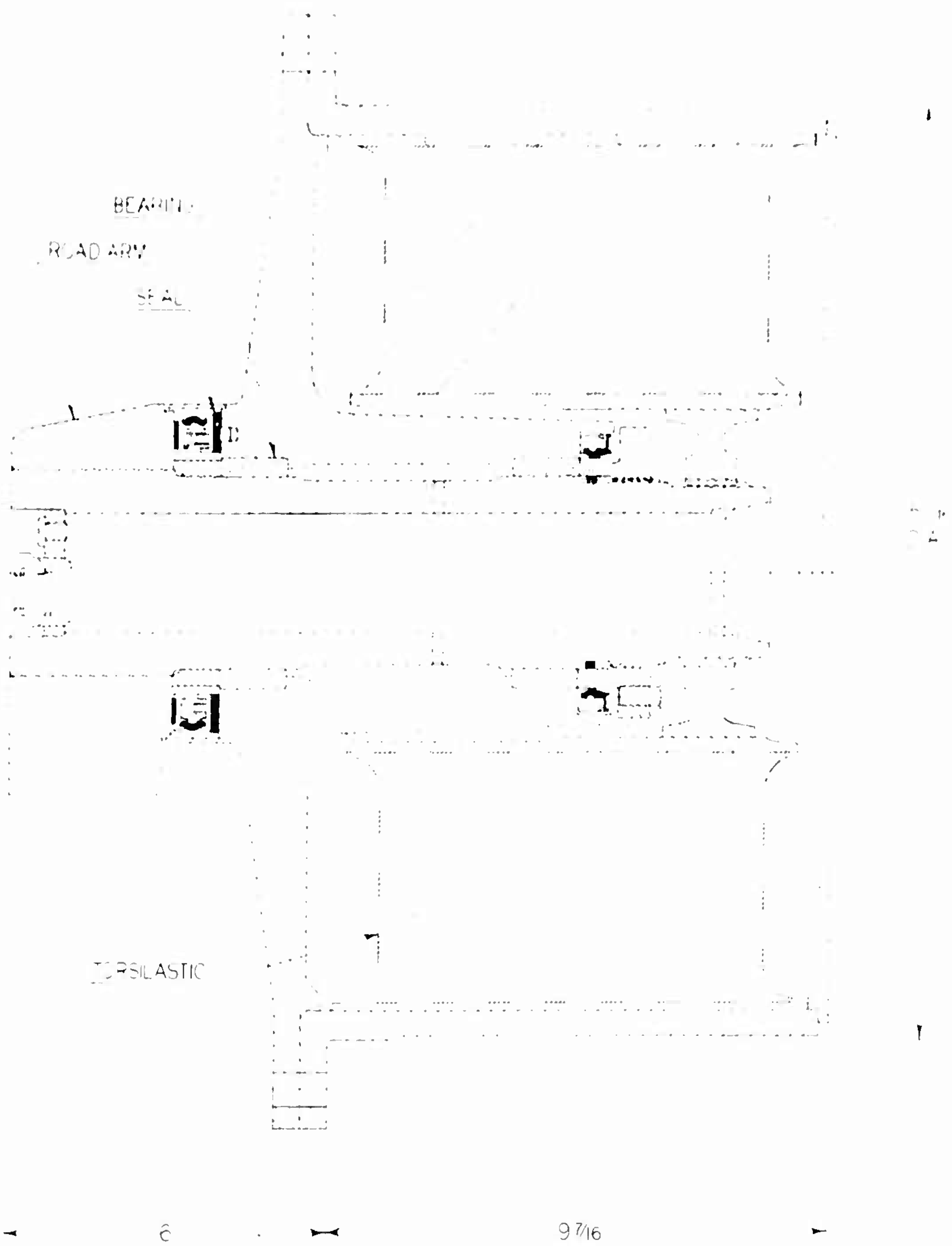
When the load is applied to the road arm in the rotary vane-type system shown in Figure 3.8.15, the rotary hydraulic cylinder is turned, forcing oil to one end of the cylinder.

As the oil is forced in, it moves the free piston, further compressing a gas on the other side of the piston. As the load on the road arm is reduced, the compressed gas forces the oil out of the cylinder, into the vane areas, thus returning the road arm to its original position. A balance between the oil and gas pressures supports the vehicle. A snubbing action is provided by a low-pressure accumulator connected to the exhaust side of the rotary hydraulic unit.

Although such systems offer several advantages, they are of most benefit to specialized vehicles. Their increased cost and complexity are not warranted for the LVTPX11.



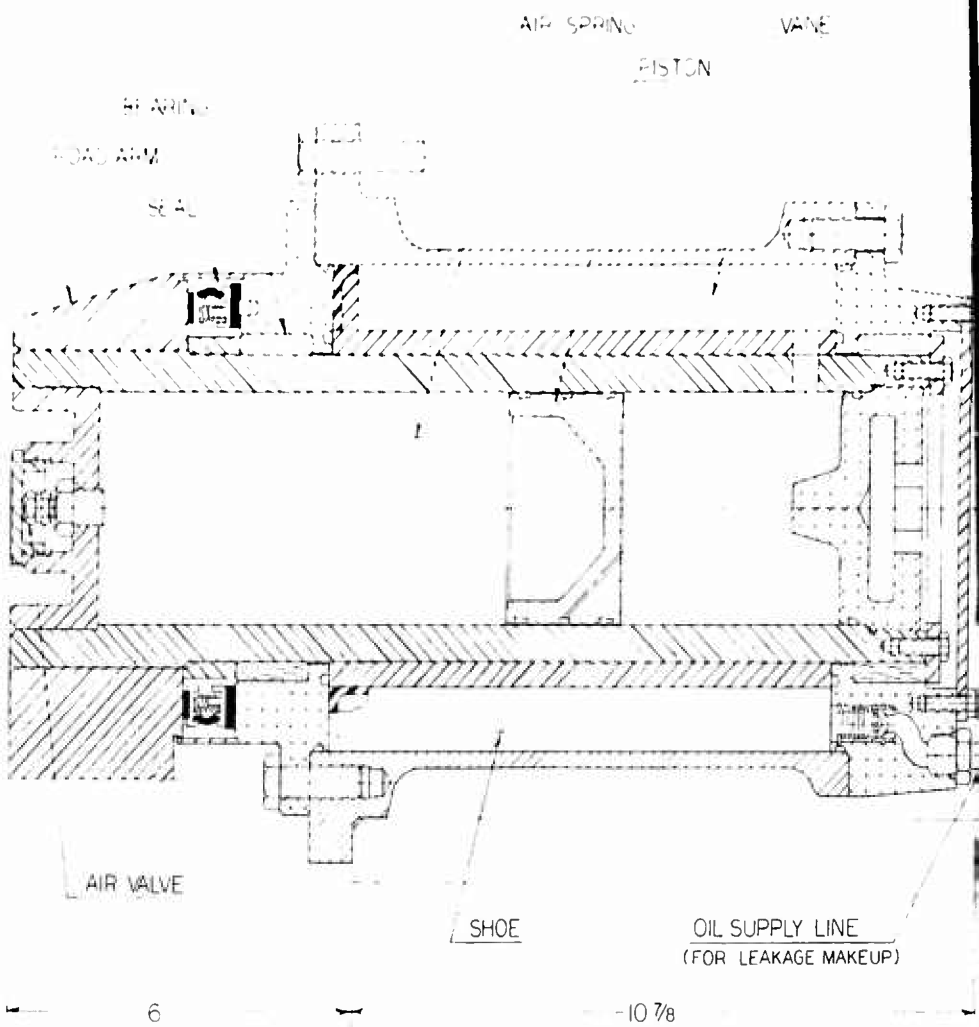
1



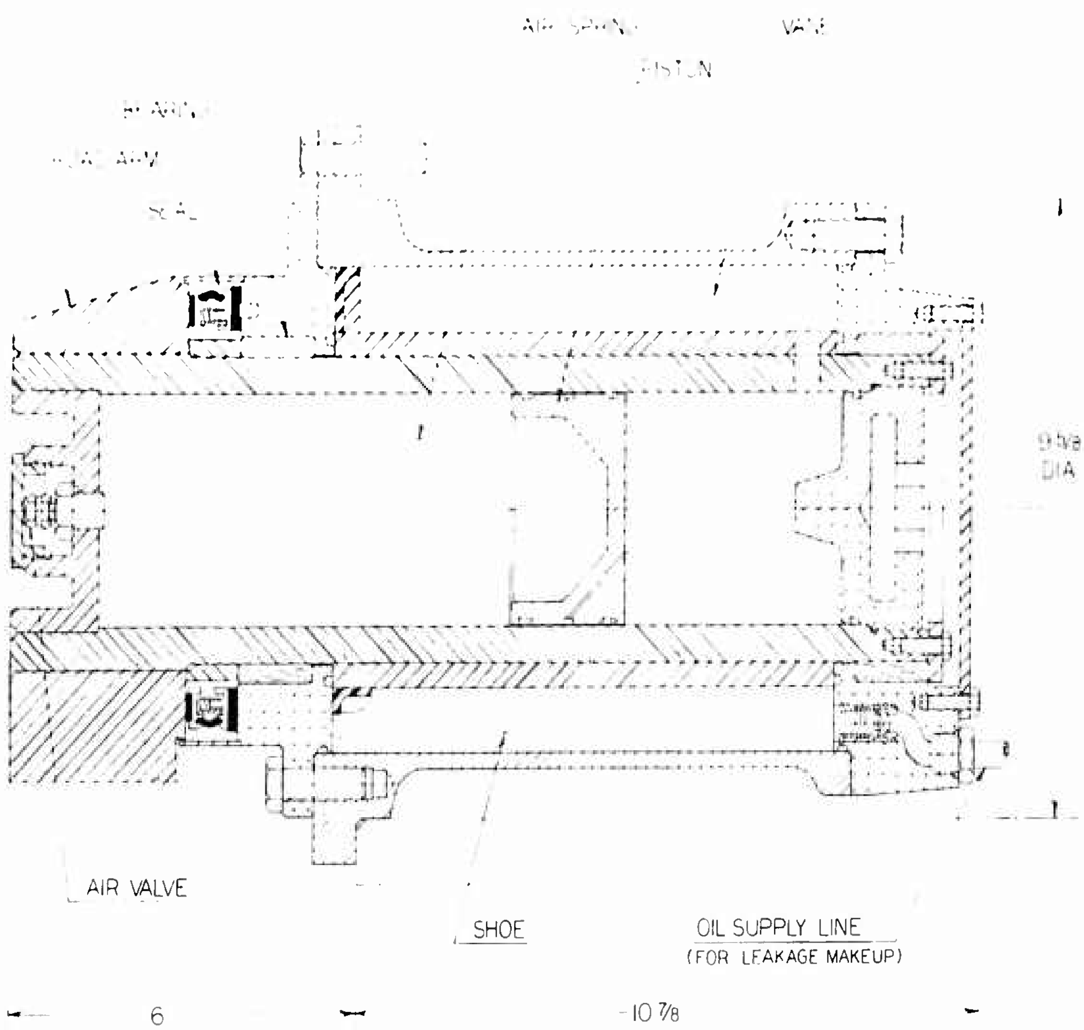
2

Preliminary Design Engineering FOOD MACHINERY AND CHEMICAL CORPORATION		ORDNANCE DIVISION SAN JOSE, CALIFORNIA
DATE 21SEPT60 DRAFTSMAN ENGINEER APPROVED	TORSILASTIC SPRING LVTPX11	P A NO 449 DWG NO 1077311
SCALE FULL SIZE		SHEET OF

Figure 3.8.14


AIR SPRING
VANE
PISTON
SEAL
AIR VALVE
SHOE
OIL SUPPLY LINE
(FOR LEAKAGE MAKEUP)
6
10 7/8

1



2

Preliminary Design Engineering FOOD MACHINERY AND CHEMICAL CORPORATION		ORDNANCE DIVISION SAN JOSE, CALIFORNIA
DATE 26SEPT61 DRAFTSMAN ENGINEER APPROVED	HYDRO-PNEUMATIC ROTARY SPRING LVTPX11	P.A. NO 449 DWG NO 1077312
SCALE FULL SIZE		SHEET OF

Figure 3.8.15

3.9 WATER PROPULSION

FMC concludes that track propulsion for water operation offers a 7-1/2 mph speed capability with a maximum of simplicity. This type of propulsion is shown on the "Maximum Armored Vehicle", Figure 3.2.1. The "Maximum Water Performance Vehicle", Figure 3.2.1, uses a propeller for water propulsion to achieve 9-1/2 mph.

The advantages and disadvantages of these, and other water propulsion methods, are evaluated in this section.

3.9.1 Hull Shape

Because an LVT is basically a land vehicle, the hull cannot be designed to the optimum water performance for a given available power. It must be designed to perform as efficiently as possible within the limitations imposed by the following considerations:

- Water performance
- Land performance
- Crew Vision
- Space requirements for crew, cargo, and machinery.

The above considerations dictate a short, wide hull with tracks extended well below the hull bottom. The limitations on the bow and stern overhang imposed by the approach and departure angles obviously are not conducive to low hull resistance to the water.

Hull Shape (Continued)

Being restricted to the short, wide hull shape, the following approaches were investigated to overcome the imposed limitations on water performance.

- Tandem operation - two or more vehicles operating in series.
- Inflatable hull extensions - hull length extended with inflatable bags to improve length to width ratio.
- Reversible hull - front for land operation becomes the stern for water operation.
- Simulated extended stern - hull extended by water curtain to improve length-to-width ratio.

3.9.1.1 Tandem Operation

A prior DTMB (David Taylor Model Basin) test report (No. 897) shows that the hull resistance of two vehicles, lashed together and operating in tandem, is equal to approximately 60% of the sum of the individual resistances. These vehicles were tested without an attempt to "fair" between the two hulls. This approach was considered for the LVTPXII, but was discarded for the following reasons:

One, testing with full scale LVTP6's at the FMC Test Basin showed little propulsive gain when operating in tandem, apparently due to the fact that the rearmost vehicle tracks were operating in turbulent water and contributed very little to the combined propulsive effort.

Two, these tests also indicated a very poor maneuverability characteristic with the vehicles tied together.

Hull Shape (Continued)

Three, the test pointed out the serious structural problems in providing adequate attachment strength to withstand the separating loads during surfing operations and still have a quick disconnect capability.

3.9.1.2 Inflatable Hull Extensions

In order to determine any advantages of inflatable bow and stern extensions, a scale model was extended to twice its normal length and was towed in the FMC Tow Basin. It indicated a potential increase in water speed of approximately 1 mph for the 35,000 lb gvw track propelled vehicle. However, it was concluded that this increase did not justify the increase in vehicle complexity, particularly when ruggedness, installation time, and stowage problems are considered. Figure 3.9.1 shows this model being towed at a prototype speed of 7-1/2 mph (6.5 knots). This model was identified as No. 1A.

3.9.1.3 Reversible Hull

A concept based on using one end of the vehicle as the front during water operation and the other end as the front during land operation, was investigated. Placing the driver at what would be the stern of the vehicle during water operation permitted an improvement of the bow lines, (the stern for land operation) within the limitations imposed by the departure angle. However, model testing indicated no increase in water speed as compared to the hull configuration finally chosen and the concept was discarded.

FIGURE 3.9.1 MODEL NO. 1A

3.9.1.4 Simulated Extended Stern

In order to improve the length-to-width ratio of the hull, a test was made with the model equipped with a horizontal water curtain along the bottom and sides of the vehicle stern. This water curtain served to propel the vehicle, improve the length-to-width ratio and, in a full-size vehicle, would reduce the bow wave by "drawing off" water from the bow.

Figure 3.9.2 is a photo of a stern jet model being tested in the FMC Tow Basin. This test showed no measurable reduction in hull resistance compared to tow tests of this model without the water curtain.

The long ducts required from bow to stern would also lead to high head losses resulting in reduced propulsion efficiency.

3.9.2 Model Tests

The following 1/16 scale models were designed and built for tow testing.

- Model No. 1 - Conventional Square-shape - Figure 4.9.3
- Model No. 1A - Inflatable Bow and Stern - Figure 4.9.3
- Model No. 2 - Rounded Bow and Stern - Figure 4.9.3
- Model No. 3 - Reversible - Figure 4.9.3
- Model No. 4 - Fully Rounded - Figure 4.9.4
- Model No. 5 - "Maximum Armored Vehicle" - Figure 4.9.4
- Model No. 7 - "Maximum Water Performance Vehicle" - Figure 4.9.4

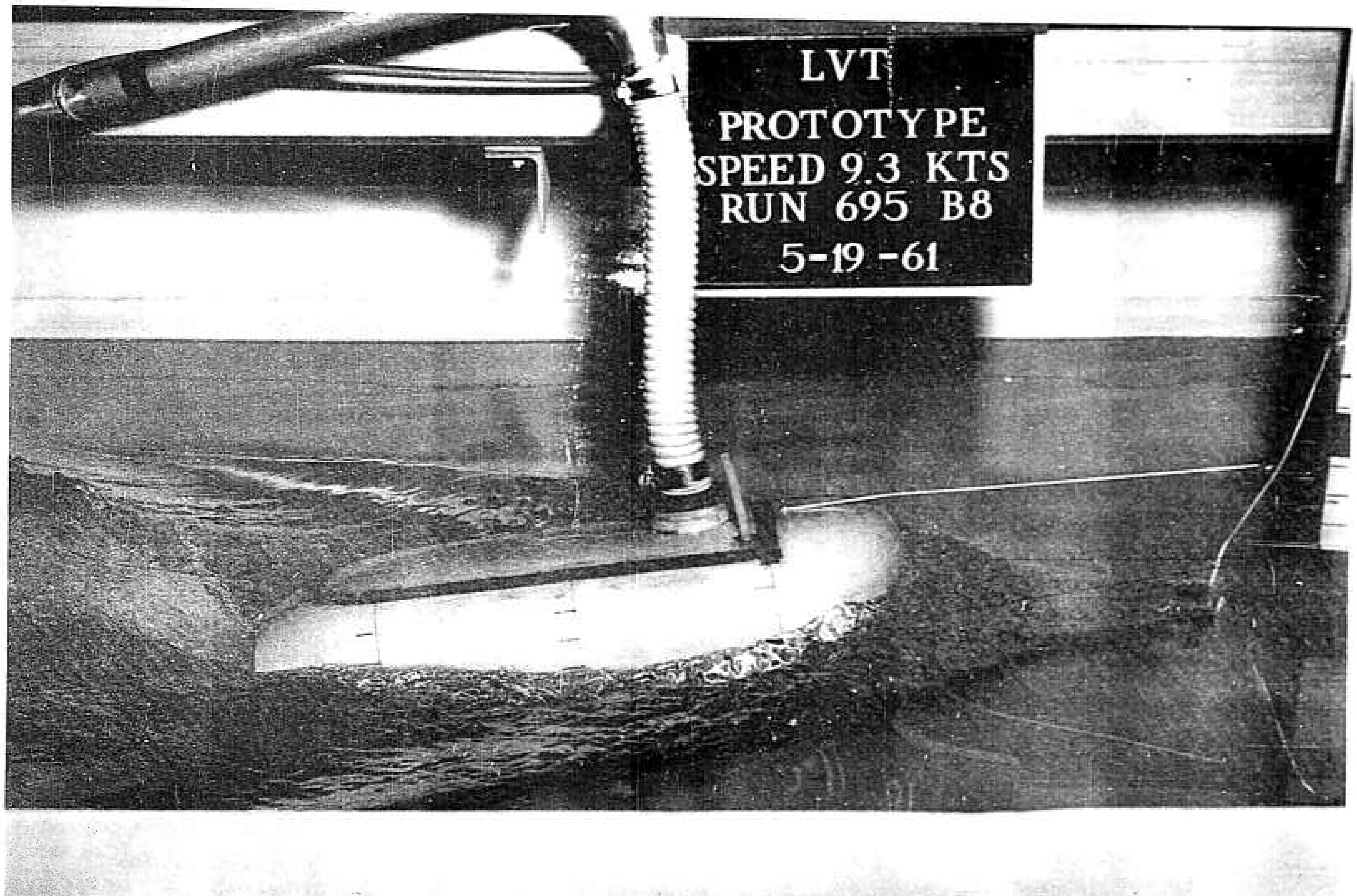
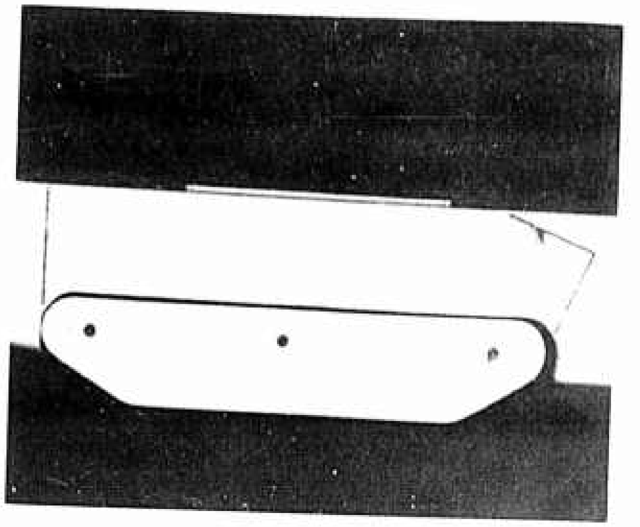
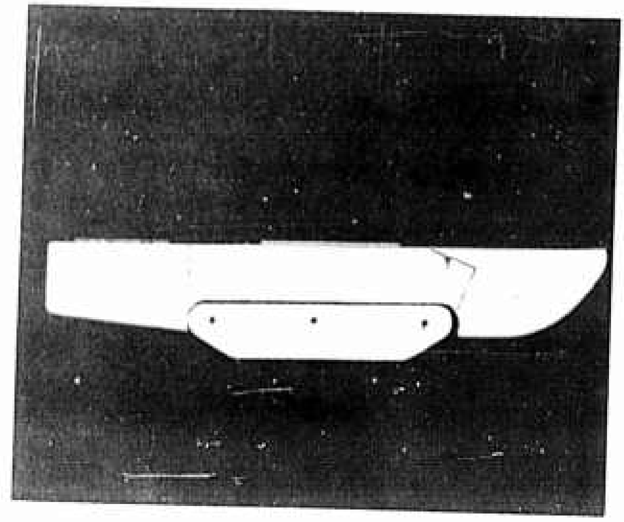


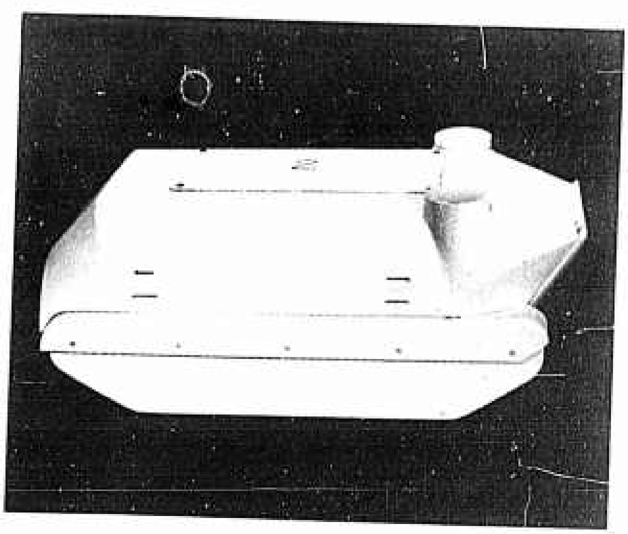
FIGURE 3.9.2 STERN JET MODEL



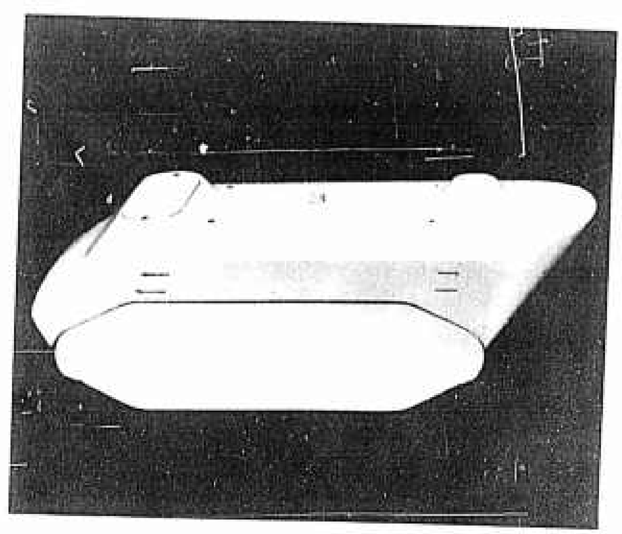
No. 1



No. 1A

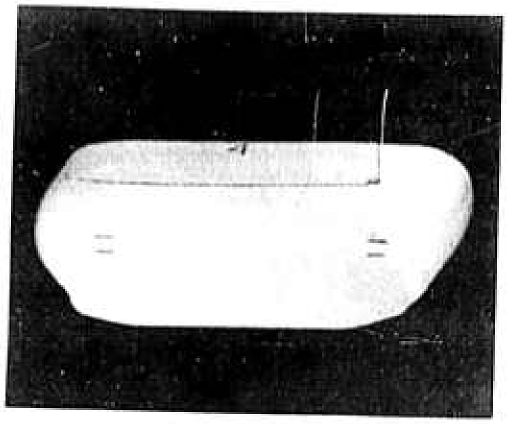


No. 2

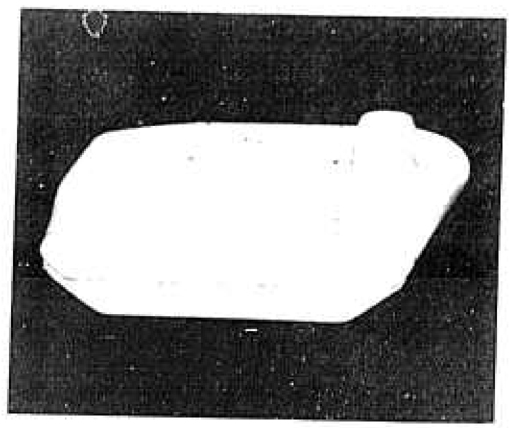


No. 3

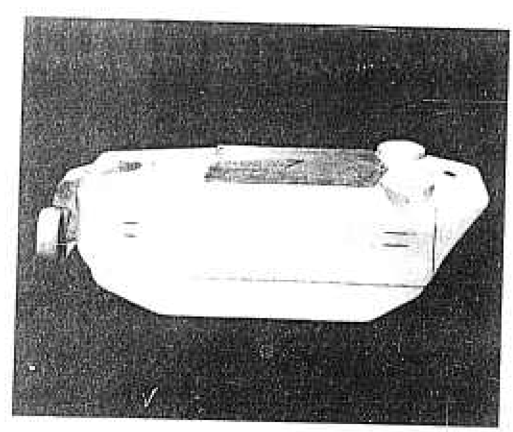
FIGURE 3.9.3



No. 4



No. 5



No. 7

FIGURE 3.9.4

3.9.2.1 Model No. 1

This model, a conventional LVT hull with square corners, was built and tested to establish a reference or basis of comparison for other model tests. Figure 3.9.5 shows this model being towed at a prototype speed of 6.9 mph (6 knots). Based upon the available power, it indicates a potential speed of 6.5 mph using tracks for propulsion. This craft, while similar to the LVTP6, owes its superior performance to its better displacement-to-length ratio (compared to the LVTP6).

3.9.2.2 Model No. 2

This rounded bow and stern model showed good performance capability through the range of speeds attainable by track propulsion. The primary objection to this configuration was the vulnerability of the exposed fenders and tracks to damage both to themselves and to ships and docks. Figure 3.9.6 shows this model being towed at a prototype speed of 9 mph (7.8 knots). It has a potential speed of 6.75 mph, based upon the available power using tracks for propulsion.

3.9.2.3 Model No. 3

This reversible hull model was discussed in paragraph 3.9.1.3. When towed at speeds above 7 mph, the model exhibited instability in the form of weaving from side to side. The bow was modified by using an inverted vee and this reduced but did not eliminate the yawing tendency. Figure 3.9.7 is a photo of the model being towed at a prototype speed of 7.5 mph (6.5 knots). Based on available power, it has a potential speed of 6.75 mph using tracks for propulsion.

FIGURE 3.9.5 MODEL NO. 1

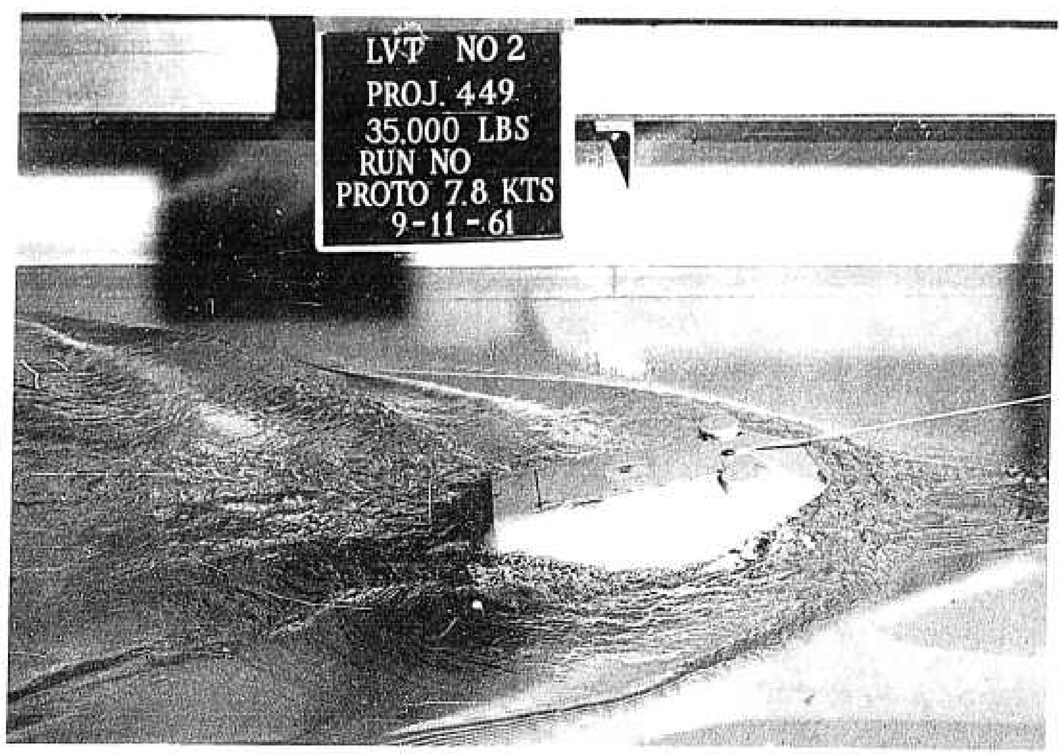


FIGURE 3.9.6 MODEL NO. 2

Hull Shape (Continued)

Another test made with this model was to simulate retraction of the tracks, resulting in a potential speed increase of 0.3 mph. This gain does not justify the increased cost and complexity required to effect track retraction.

3.9.2.4 Model No. 4

The model was the water jet model (Figure 3.9.2) reworked to conform to the width and length limitations given in the "Development Characteristic". This model exhibited the lowest hull resistance of Models 1 through 4, but is considered impractical from the standpoint of simple fabrication and restricts the size of the cargo compartment. It also penalizes land performance with its limited ground clearance and poor obstacle climbing ability. Figure 3.9.8 shows this model being towed at a prototype speed of 9.2 mph (8 knots).

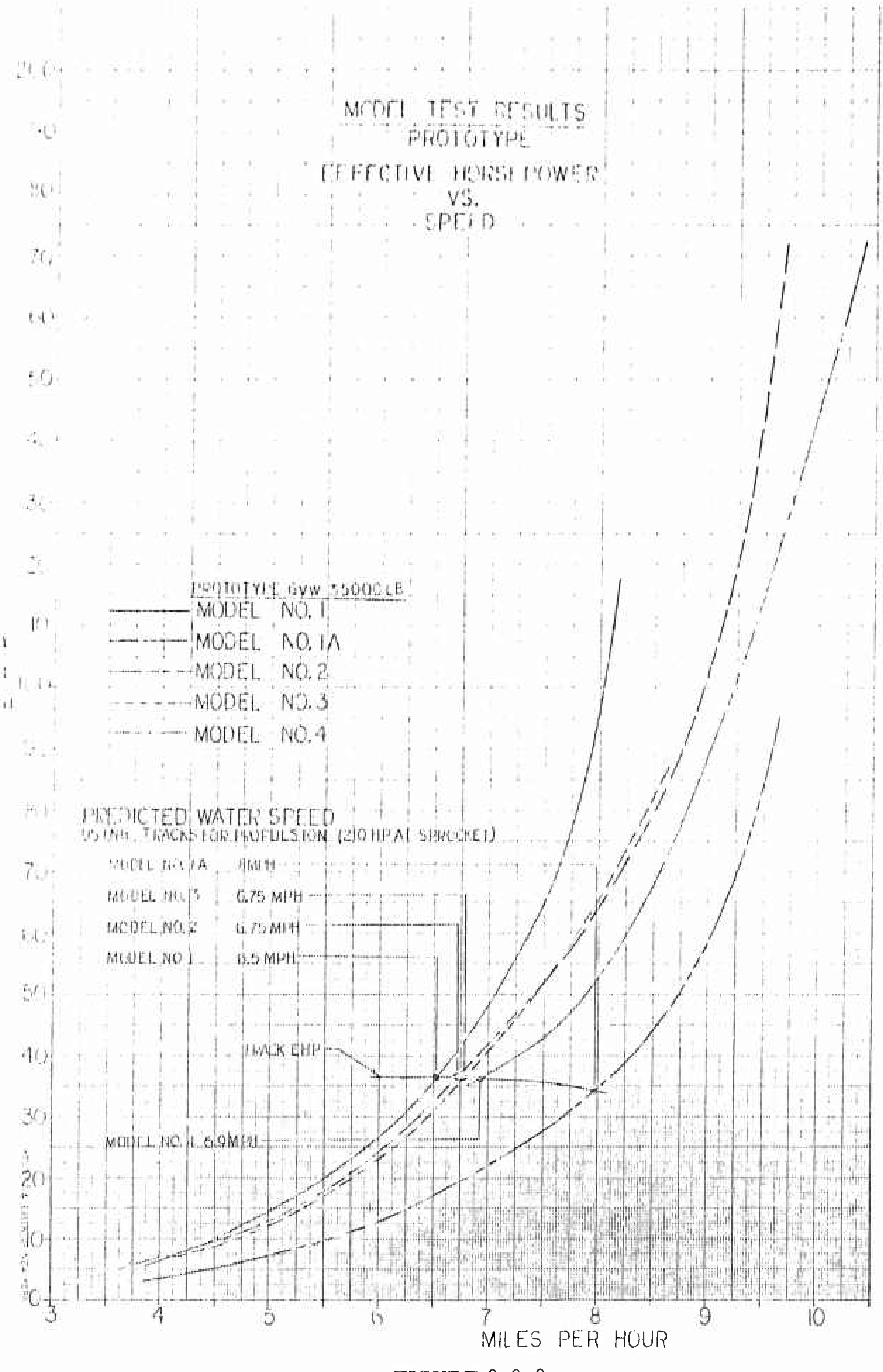
Figure 3.9.9 is a plot of hull resistance versus speed for Models 1 through 4 at 35,000 lb GVW.

3.9.2.5 Model No. 5

This hull shape is the "Maximum Armored" vehicle shown in Figures 3.2.1 and 3.2.2. It was tow tested at displacements of 25,000 and 35,000 lb up through speeds exceeding 8 mph, which is considered to be in excess of the speed attainable by track propulsion in the water. The model exhibited excellent stability through this range. Figure 3.9.11 shows the hull resistance versus speed curve with Figure 3.9.10 showing the model being towed

FIGURE 3.9.7 MODEL NO. 3

FIGURE 3.9.8 MODEL NO. 4



MODEL TEST RESULTS
PROTOTYPE
EFFECTIVE HORSEPOWER
VS.
SPEED
PROTOTYPE GVW 3500C LB
MODEL NO. 1
MODEL NO. 1A
MODEL NO. 2
MODEL NO. 3
MODEL NO. 4
PREDICTED WATER SPEED
6.75 MPH
6.75 MPH
6.5 MPH
TRACK EHP
10
20
30
40
50
60
70
3
4
5
6
7
8
9
10
MILES PER HOUR

FIGURE 3.9.9

Hull Shape (Continued)

at a prototype speed of 7.5 mph (6.5 knots), Included as Appendix G of this report is a 16mm film of this hull being towed.

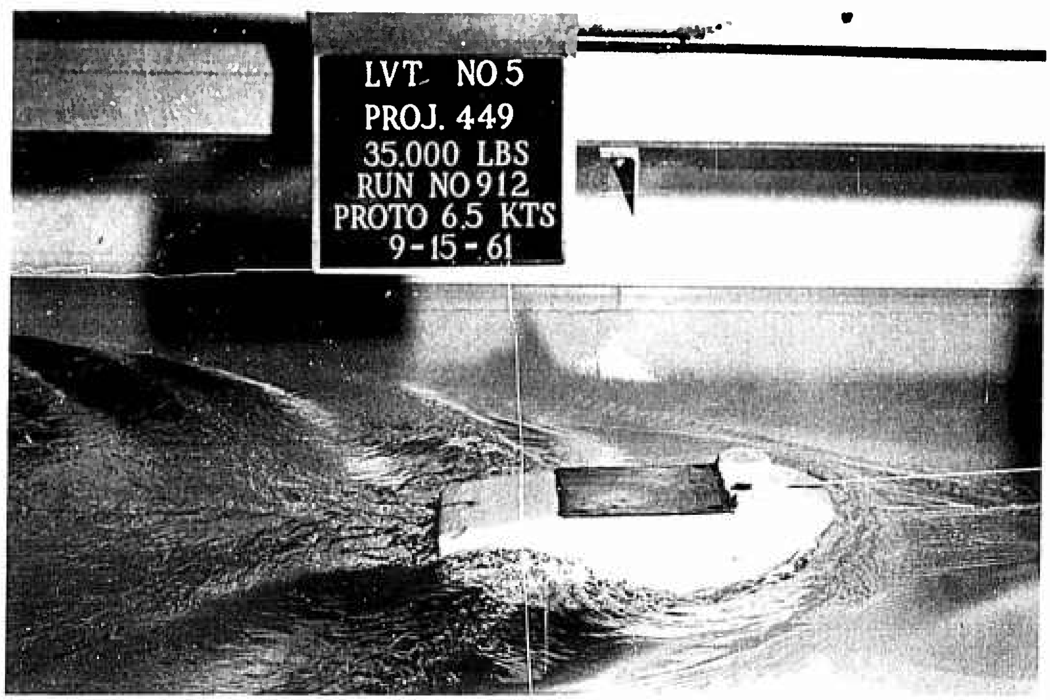


FIGURE 3.9.10 MODEL NO. 5

3.9.2.6 Model No. 7

The "Maximum Water Performance Vehicle", shown in Figures 3.3.1 and 3.3.2, is represented by this model. It is designed for the relatively higher speeds attainable by the use of a propeller. Figure 3.9.12 shows the model being towed at a prototype speed of 9-1/4 mph with the hull resistance versus speed curve shown in Figure 3.9.11.

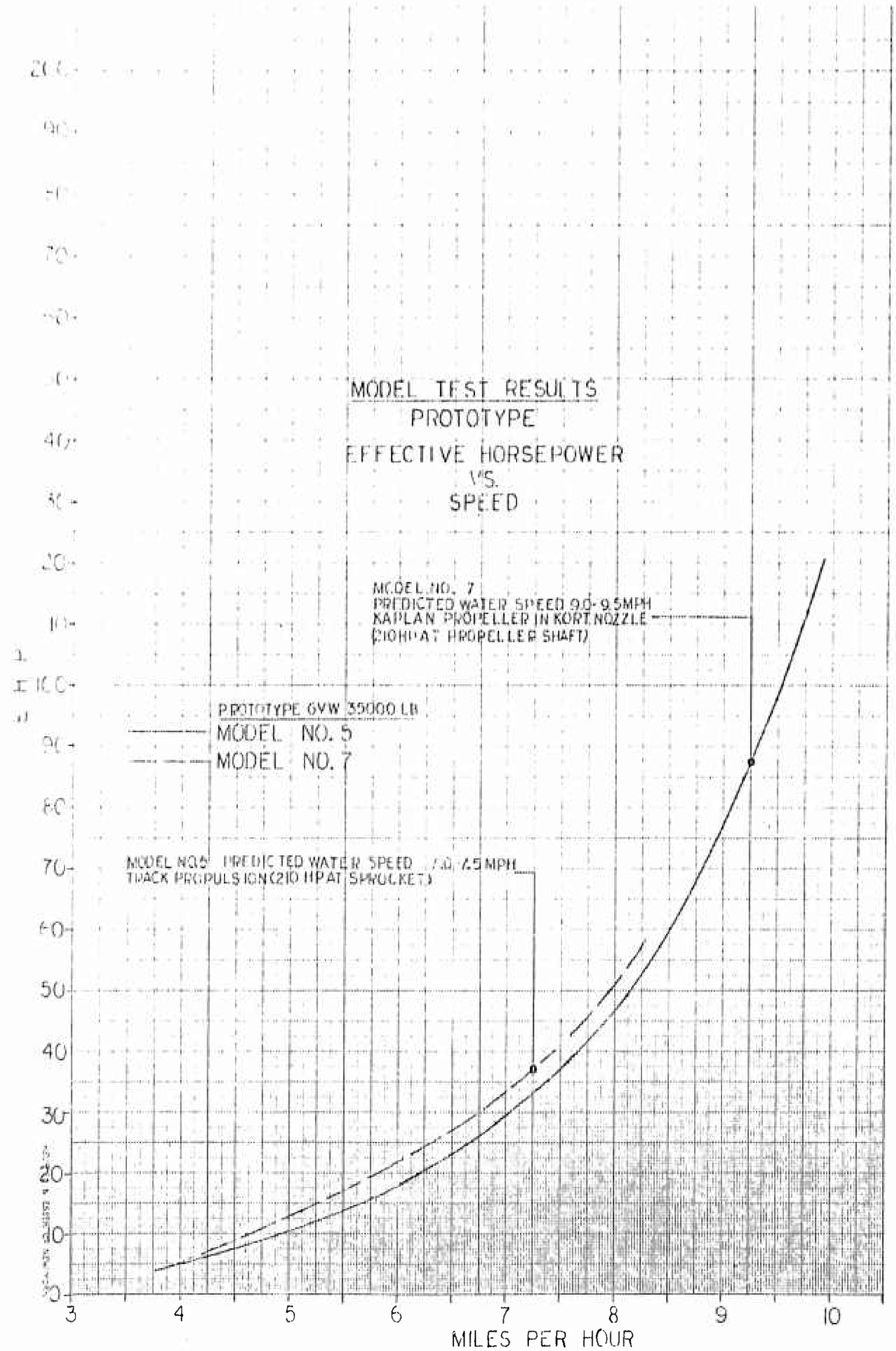

MODEL TEST RESULTS
PROTOTYPE
EFFECTIVE HORSEPOWER
VS.
SPEED
MODEL NO. 7
PREDICTED WATER SPEED 9.0-9.5MPH
KAPLAN PROPELLER IN KORT NOZZLE
(210HP AT PROPELLER SHAFT)
PROTOTYPE GVW 35000 LB
MODEL NO. 5
MODEL NO. 7
MODEL NO.5 PREDICTED WATER SPEED 7.0-7.5 MPH
TRACK PROPULSION (210 HP AT SPROCKET)
MILES PER HOUR

FIGURE 3.9.11

FIGURE 3.9.12 MODEL NO. 7—MAXIMUM WATER PERFORMANCE VEHICLE

Hull Shape (Continued)

The hull has been made as long as possible, but still allowing for the propeller installation at the rear, so that the overall vehicle length with the propeller stowed will not exceed the 313-inch limit given in the "Development Characteristic". It has also been narrowed to a width of 120 inches. To maintain a low silhouette, the height has been held to a minimum. With this configuration, the tow model exhibited excellent stability up to speeds of 10 mph, considered to be the upper limit for the propeller driven vehicle. Included as Appendix G, Volume II, is a 16mm film of this model being towed.

3.9.3 Propulsion Methods

With the object of obtaining the maximum water speed with the 250 net horsepower required for land operation, the following propulsive means were studied.

- Vehicle Tracks
- Hydrojets
- Propellers
- Other Devices

The evaluation factors used in the testing and study of the various propulsive means are given below:

- Effect on speed
- Size, weight, and cost
- Simplicity
- Power requirements

Propulsion Methods (Continued)

- Effect on mobility
- Ease of installation and removal
- Vulnerability
- Logistic requirements

3.9.3.1 Track Propulsion

To obtain the maximum water speed from a vehicle using tracks for propulsion it is necessary to carefully consider the design of the track fenders and shrouds and the track itself. The track serves the function of accelerating the water to a final discharge velocity and the fenders and shrouds serve the function of directing the water from the return track in a direction opposite to the direction of travel.

Unshrouded vehicle tracks without fenders will produce practically no useful thrust because the thrust from the upper and lower track strands cancel each other. The purpose of the shrouds and fenders then is to channel the water accelerated by the upper track strand and direct it so that it is discharged in the same direction as the water accelerated by the bottom strand. Fender and shroud modifications have little or no effect on the power required to move the vehicle track at a specified speed.

Thrust obtainable from tracks is directly proportional to the product of the volume of water accelerated and the difference between the discharge velocity of the accelerated water (relative to the vehicle) and the vehicle speed. Thrust and resultant vehicle speed can be increased by increasing the speed of the tracks (increasing both discharge velocity and volume of water accelerated) or

Propulsion Methods (Continued)

by increasing the amount of water picked up by the tracks. An increase in either requires an increase in power. Power required is directly proportional to the amount of water accelerated by the tracks and proportional to the product of the discharge velocity and the difference of the squares of the water discharge velocity and the velocity of the vehicle. In order to obtain the most thrust with the power available, it is desirable to keep the track velocity (and consequent water discharge velocity) relatively low and the amount of water picked up by the tracks high. A balance is required between track velocity and the amount of water carried to attain the desired water speeds at or near a peak power point of the engine.

To determine the most efficient arrangement of fenders and shrouds, a 1/4 scale self propelled model of the T113 was tested at the FMC Test Basin. The model static drawbar pull was measured for various configurations of fenders and shrouds. These tests also confirmed the results that have been reported previously (Sparkman and Stephens Report, dated 5-31-44). Figure 3.9.13 is the arrangement used as a "standard" of comparison and represents the design of current amphibious tracked vehicle fender and shroud configurations.

The results of these model tests, combined with previous testing of models and full-size vehicles, determined the fender and shroud arrangement shown in Figures 3.2.2 and 3.3.2.

- Track Design

In accordance with the "Development Characteristics", the horsepower

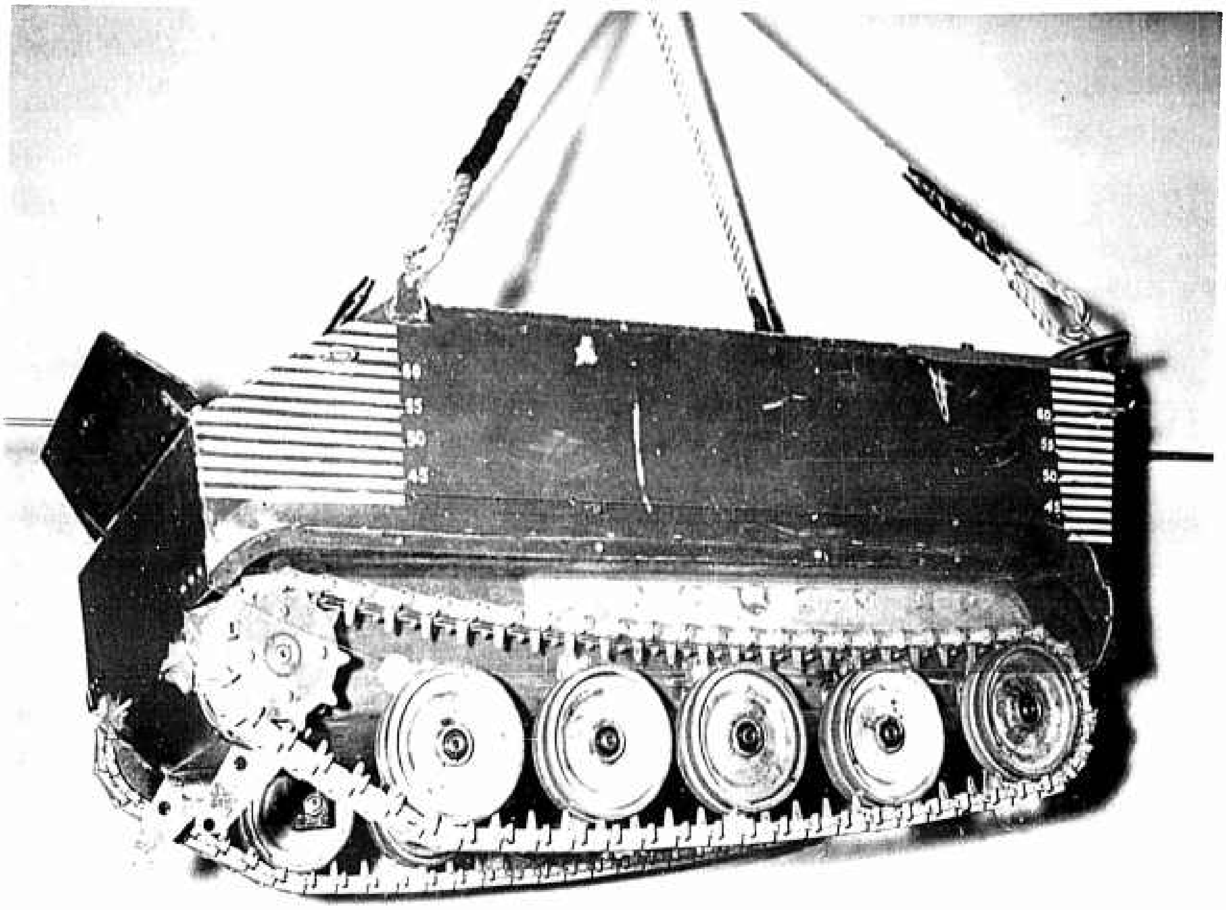


FIGURE 3.9.13 STANDARD FENDER AND SHROUD

Propulsion Methods (Continued)

available to the track was determined by the land performance requirements. Since the vehicle is primarily a land vehicle, the design of the track will be, to a great extent, dictated by the land performance.

As noted in Section 3.8, band-type tracks were selected in order to minimize the vehicle suspension weight. Design of the grousers must be tailored to both land and water requirements. It is desirable, for water operation, that a balance be reached between the track speed and the amount of water accelerated, so that reasonable vehicle water velocity can be obtained with the available power.

- Fender Arrangements

The following fender arrangements were tested to arrive at the configuration that would provide the greatest drawbar pull in the self-propelled model tests.

Figure 3.9.13 - Standard
Figure 3.9.15 - 90° Wrap-around
Figure 3.9.16 - 150° Wrap-around
Figure 3.9.17 - 150° Wrap-around with extension
Figure 3.9.18 - Flat plate

The tests indicated that the front fenders should wrap around the sprocket as far as possible. Extensions beyond the tangent point of the sprocket, approximately 150°, do not increase the forward thrust. Figure 3.9.14 is a tabulation of the relative static thrust obtained from the different configurations at a sprocket speed of 450 rpm.

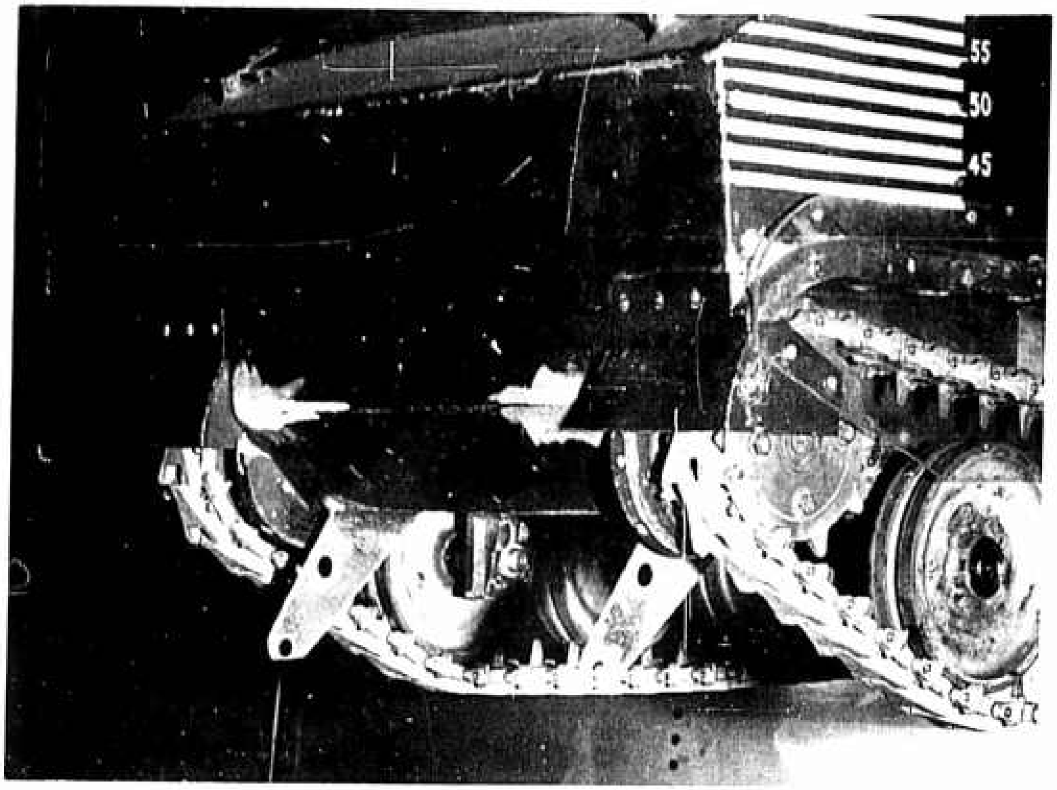


FIGURE 3.9.15 90° WRAP-AROUND FENDER

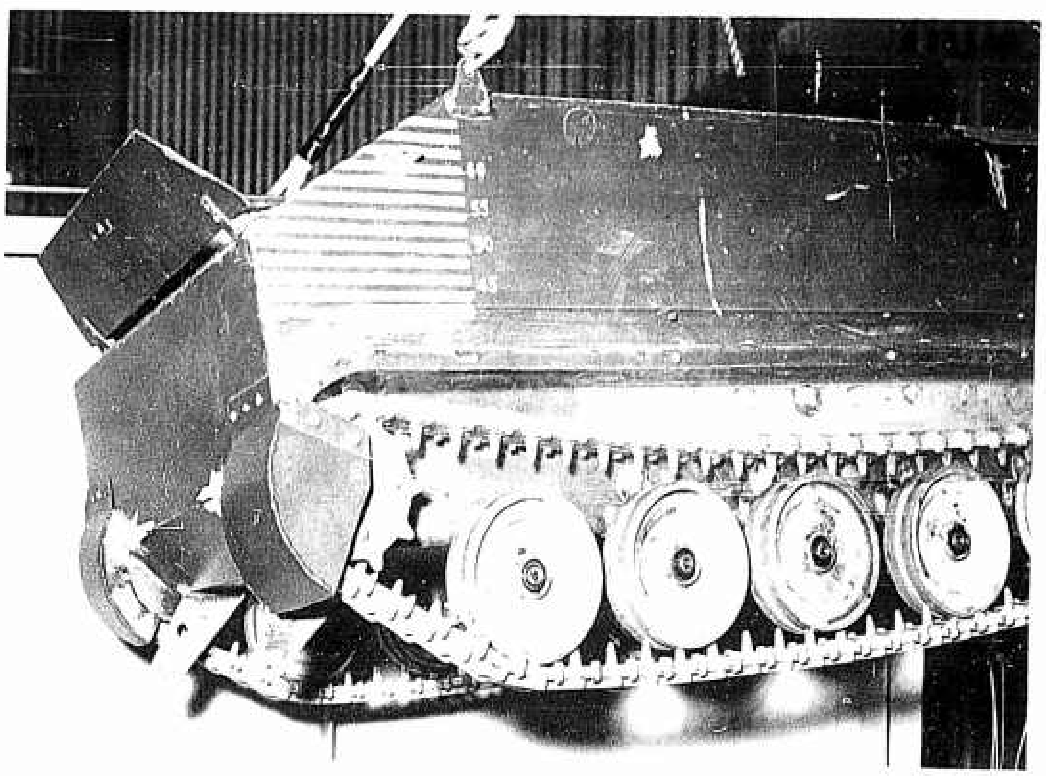


FIGURE 3.9.16 150° WRAP-AROUND FENDER

Propulsion Methods (Continued)

CONFIGURATION	FIG. NO.	RELATIVE STATIC THRUST
Standard	3.9.13	1.0
90° Wrap-around	3.9.15	1.4
150° Wrap-around	3.9.16	2.0
150° Wrap-around extended	3.9.17	2.0
Flat Plate	3.9.18	1.5

FIGURE 3.9.14

One test was run with the rear fenders completely removed. With the track rotating in the normal forward direction, static thrust was very slightly less than the thrust measured with the fenders installed. When the track rotation was reversed, the model still moved in a forward direction, but with very little thrust. This was evidently due to the front fenders deflecting a portion of the water flow created by the lower track. This test showed that no thrust for reverse propulsion is obtained without the rear fenders, and that they should wrap around the sprocket as far as possible. The rear fenders deflect the water flow from the upper track, thus adding to the thrust obtained by the lower track.

Since these tests show the importance of the full wrap-around front fender to the vehicle water performance, they are utilized in the design; however, the protruding fenders present a vulnerability problem, particularly during off-shore loading. Figure 3.9.19 shows a retractable front fender arrangement that would minimize the

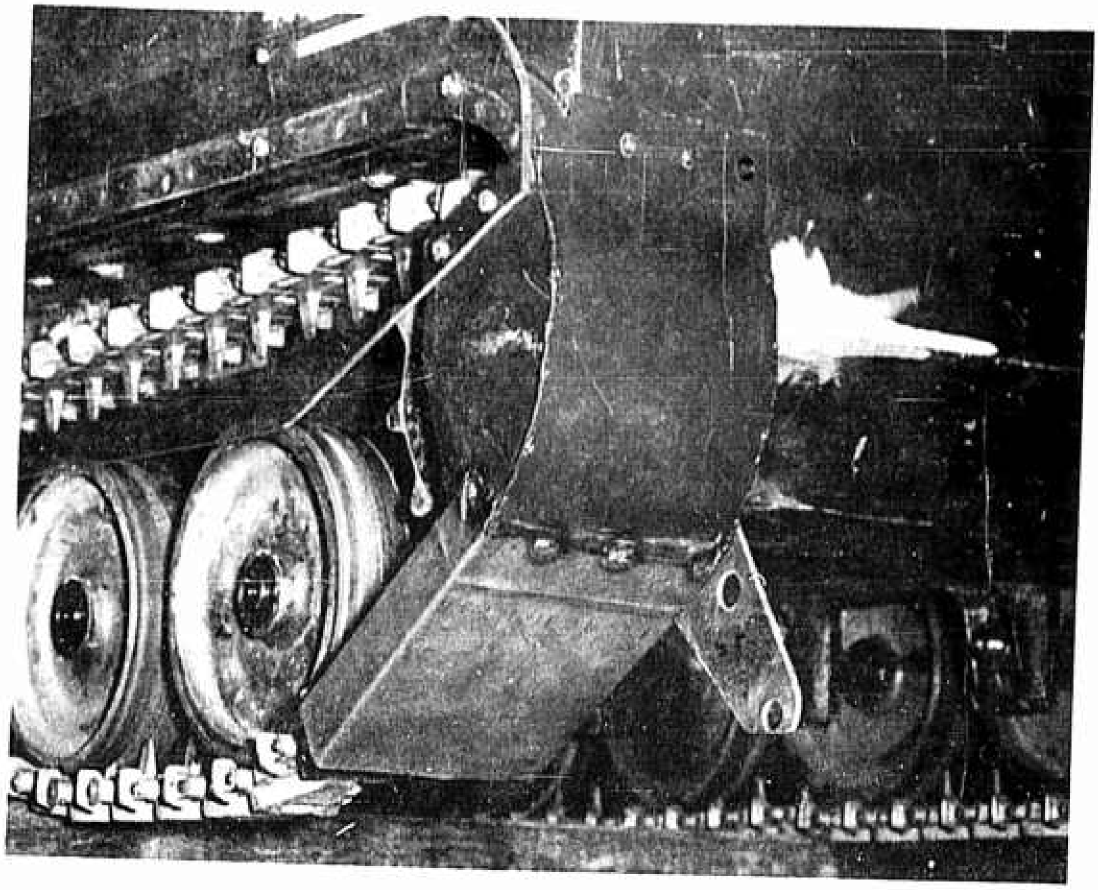


FIGURE 3.9.17 150° WRAP-AROUND FENDER-EXTENDED

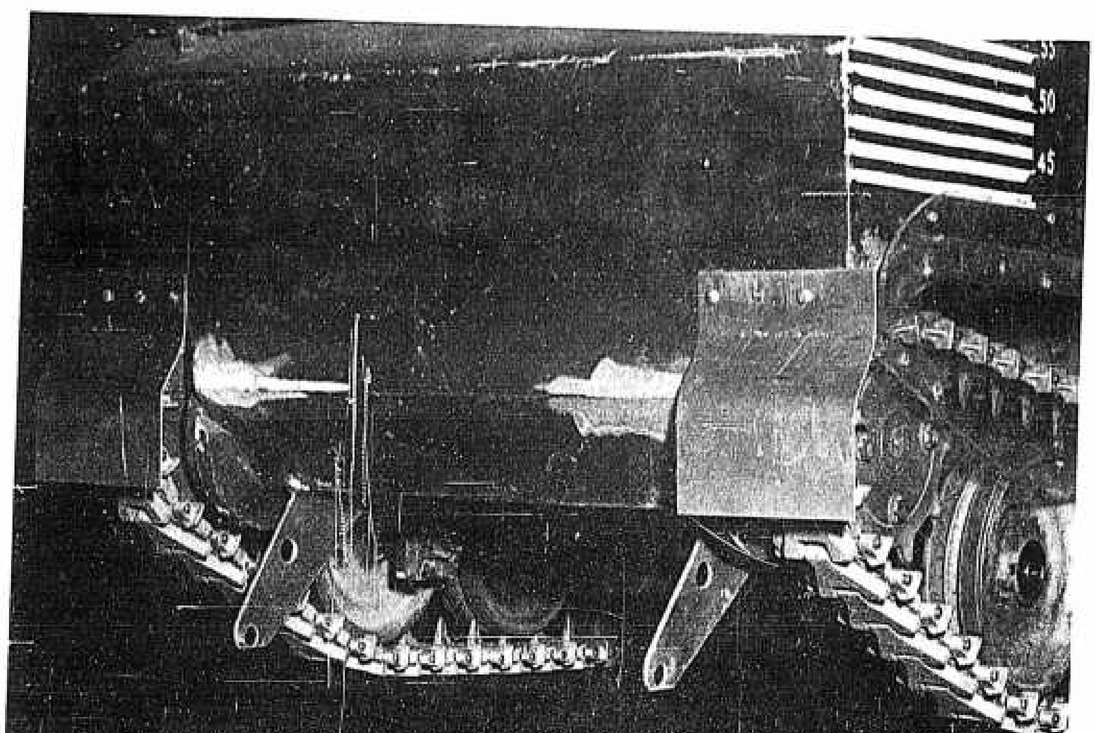
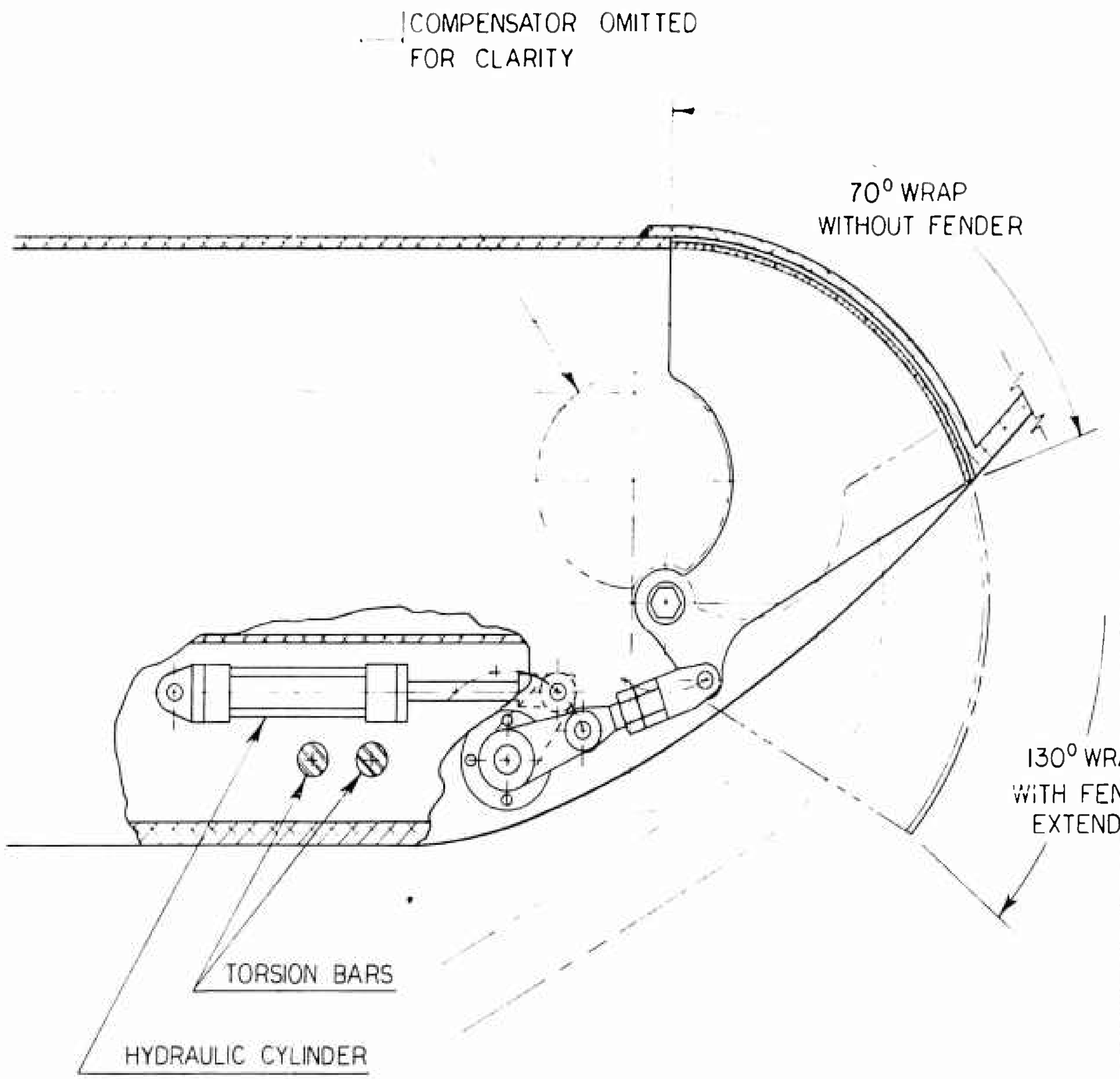
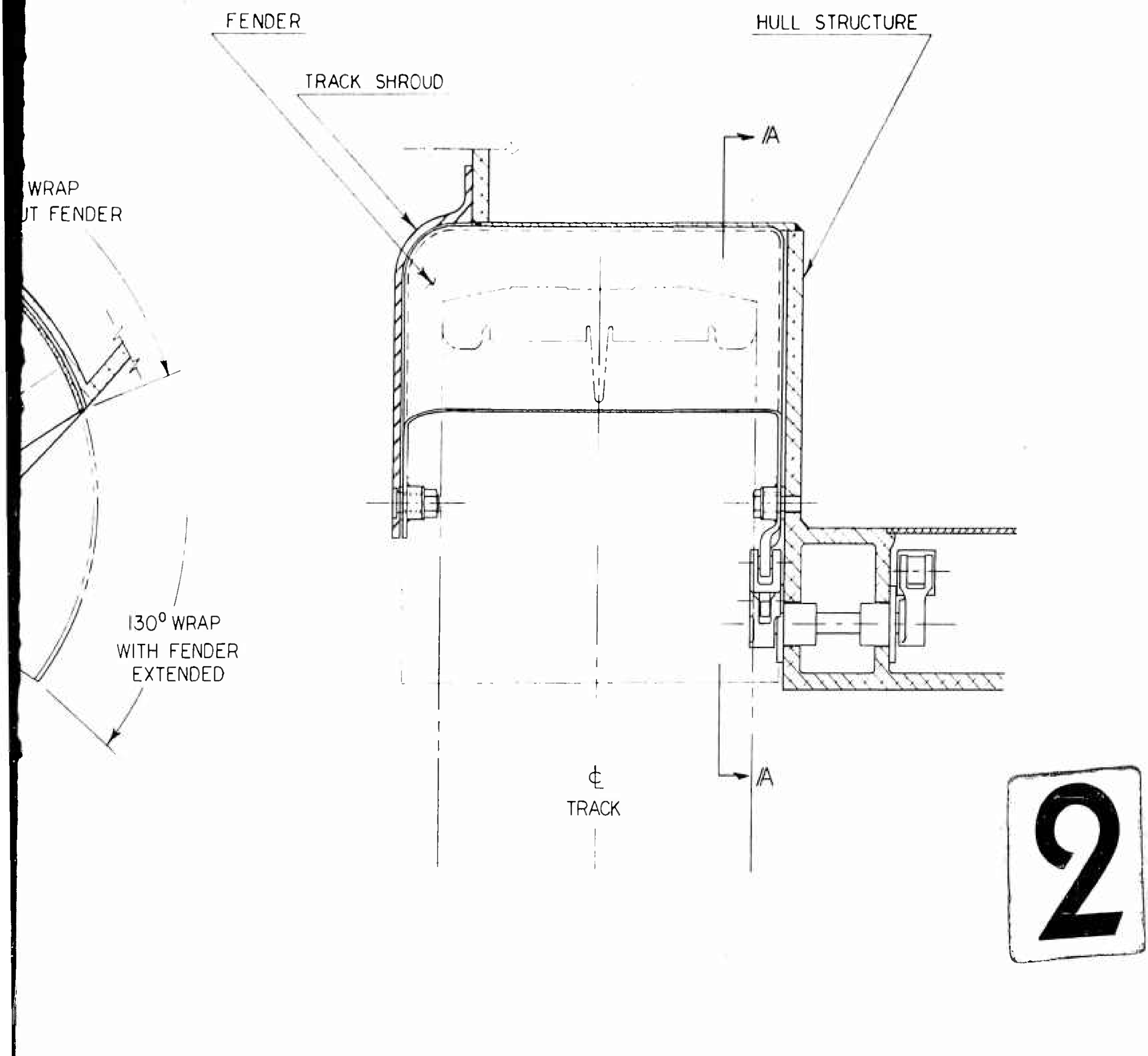


FIGURE 3.9.18 FLAT PLATE FENDER


COMPENSATOR OMITTED
FOR CLARITY
70° WRAP
WITHOUT FENDER
130° WRA
WITH FEN
EXTEND
TORSION BARS
HYDRAULIC CYLINDER

SECTION A-A

1



Preliminary Design Engineering FOOD MACHINERY AND CHEMICAL CORPORATION		**ORDNANCE DIVISION** SAN JOSE, CALIFORNIA
DATE 23 OCT 61 DRAFTSMAN Bailey ENGINEER 10-26-61 O.W. Ryder APPROVED	RETRACTABLE FENDER LVTPX 11	P.A. NO. 449 DWG. NO. 1077324
SCALE GRAPHIC SIZE		SHEET OF

Figure [illegible]

Propulsion Methods (Continued)

possibility of fender damage and the subsequent effect on water performance. It is recommended that such a fender configuration be designed for the prototype LVTPX11 for evaluation purposes.

- Reversing Vanes

In an attempt to improve the track thrust, curved reversing vanes were inserted in the upper track area to reverse the return water flow.

Figure 3.9.20 shows the model equipped with reversing vanes above the upper track. The purpose of the vanes was to reverse part of this water flow and eject it toward the rear of the vehicle, through an opening in the rear of the hull.

Figure 3.9.21 shows the model equipped with reversing vanes on the side of the track shroud. This arrangement also included deflector blades mounted diagonally on the bottom of the sponson plate.

These configurations did not show sufficient thrust increase to warrant further testing. Because of the limited nature of these tests, such devices should not be rejected completely. A more refined design of the reversing vanes might show an improvement in thrust. This must be a significant increase, to outweigh the vulnerability and added complexity.

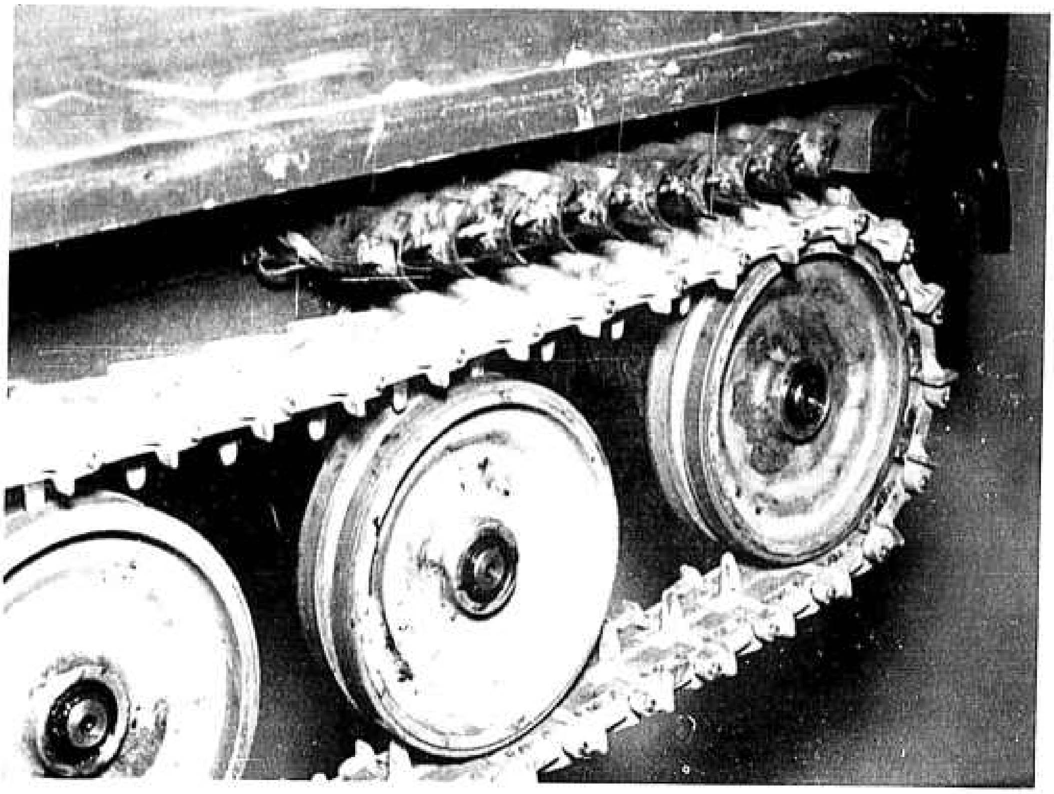


FIGURE 3.9.20 REVERSING VANES ABOVE TRACK

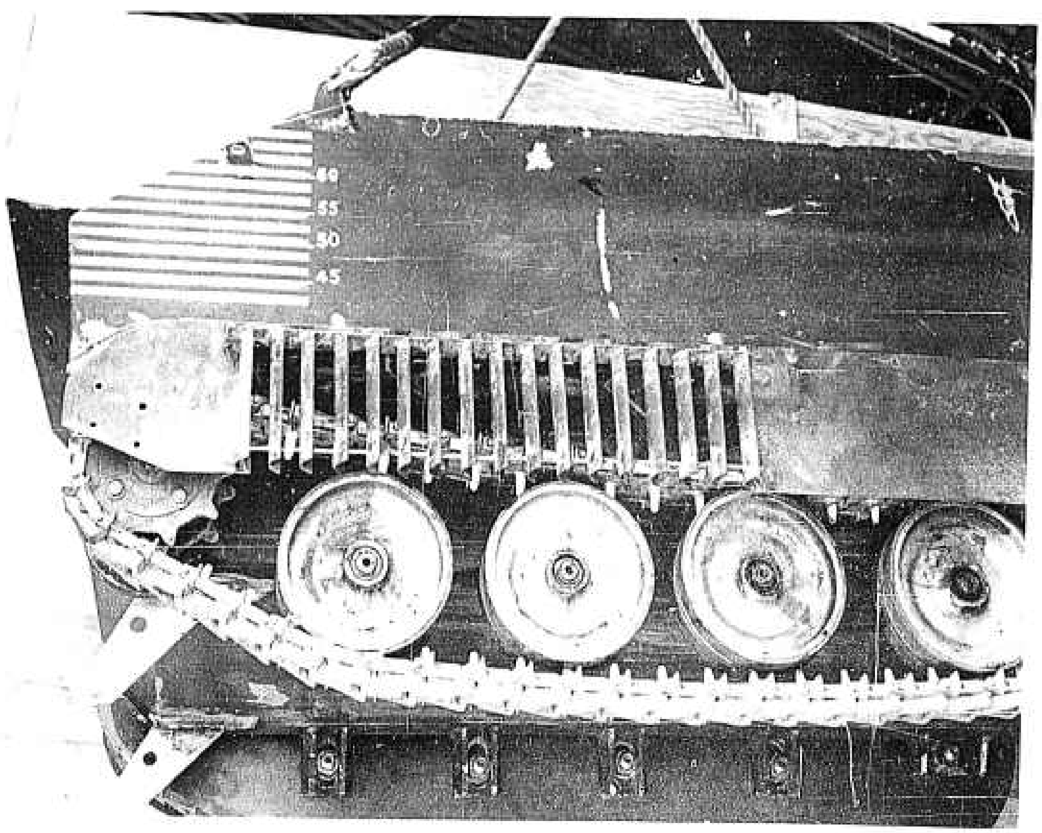


FIGURE 3.9.21 REVERSING VANES IN SHROUD

Propulsion Methods (Continued)

- Shroud Changes

Figure 3.4.23 shows the various shroud depths that were tested. The relative thrusts obtained are shown in Figure 3.9.22.

CONFIGURATION	RELATIVE THRUST
Standard	1.0
Deep shroud	1.0
Full Outside	0.8
Full outside and inside	0.1

FIGURE 3.9.22

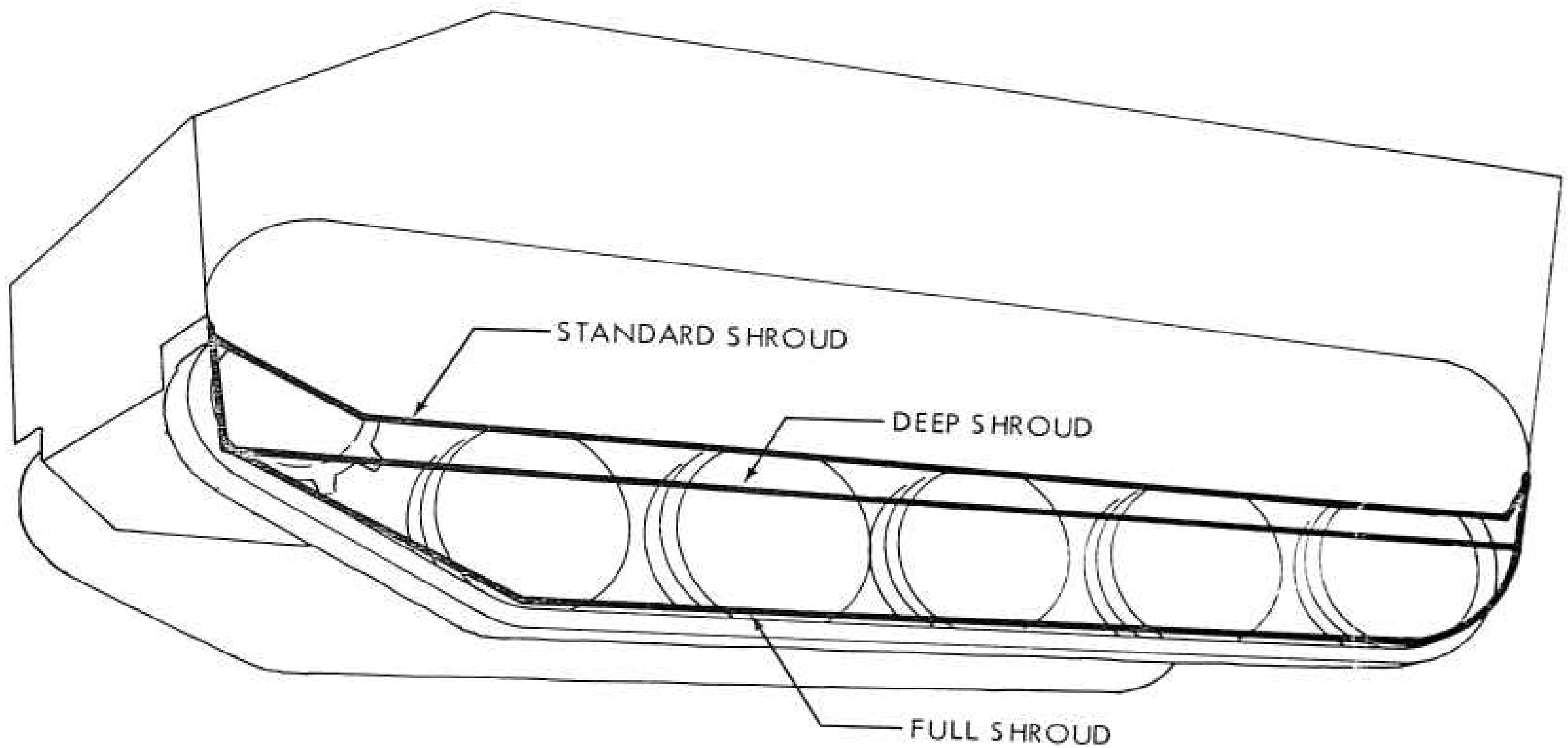
The tests indicate that the shroud depth may vary between the standard and deep shroud configuration, for maximum efficiency, but that the thrust is drastically reduced by excessively deep shrouds.

3.9.3.2 Hydrojets

A hydrojet is essentially a pump located within the vehicle, a duct connected to the pump inlet for picking up water outside the vehicle, and a nozzle connected to the pump outlet for discharging the water at a relatively high velocity.

The following manufacturers were consulted regarding the application of a hydrojet to the LVTPX11:

- Hydrodynamics Division
  FMC Corporation
  301 West Avenue 26
  Los Angeles, Calif.



SHROUD DEPTHS

FIGURE 3.9.23

Propulsion Methods (Continued)

- Machinery Consultants, Inc.,
  6101 Vermont Street
  Detroit 8, Michigan

- Berkeley Pump Company
  P. O. Box 7, Sta. A
  Berkeley, Calif.

- Curtiss-Wright Corporation
  Wright Aeronautical Division
  Wood-Ridge, New Jersey

- Hanley Hydrojet
  Prospect, Ohio

- Aerojet-General Corporation
  Azusa, Calif.

- Indiana Gear Works
  Division of the Buehler Corporation
  9000 Precision Drive
  Indianapolis, Indiana

While none of these companies is contemplating production of a unit of sufficient size for the LVTPX11, the information they furnished (included in Appendix E, Volume II) represents the state-of-the-art of hydrojet propulsion.

The ability of a pump to convert mechanical energy into the water's kinetic energy, or pump efficiency, is claimed to vary from 70% to 90% for present units. This does not take into account the losses in the LVTPX11 application

Propulsion Methods (Continued)

due to friction, inability to make full use of the velocity head induced by the vehicle speed, and imperfect flow through the duct.

Using a pump efficiency of 80%, a duct efficiency of 75%, and with 210 hp available at the hydrojet shaft, the following nozzle diameters would be required for a single hydrojet unit.

SPEED	NOZZLE DIA.	EFFICIENCY
8 mph	0.9 ft.	23.6%
9 mph	2.1 ft.	31.9%
9.5 mph	3.8 ft.	46.7%

Sample calculations for the above are included in Appendix E, Volume II.

A hydrojet unit with a 46-inch nozzle diameter would be required, to match the performance of a 32-inch Kaplan propeller mounted in a Kort nozzle.

Based on the assumptions used for the single unit, two discharge nozzles 32-1/2 inches in diameter would be required. The use of additional units was considered but discarded due to the space and machinery requirements.

The efficiency of a hydrojet can be increased by providing a scoop at the water inlet to more efficiently utilize the velocity pressure induced by the forward motion of the vehicle. However, such a scoop must be made retractable because of its vulnerability. Most of the present hydrojets discharge above the waterline to avoid the back pressure created by discharging under the water. This cannot be easily accomplished in the LVTPX11 design.

Propulsion Methods (Continued)

One of the largest factors against the use of the hydrojet principle is the loss of buoyancy and space caused by the required ducts. For these reasons as well as the size requirements, the propeller installation is recommended as a more practical means of water propulsion.

3.9.3.3 Propellers

Mr. V. K. Atkins of the Doran Company of Oakland, California, a firm specializing in marine propeller design, was consulted regarding the application of a propeller to the LVTPX11. Hull drag curves, vehicle configuration drawings, and power data were furnished by FMC for evaluation. Based on this data, a wake fraction of 0.35 and a thrust deduction factor of 0.25, the following propeller was recommended for 210 hp available at the propeller shaft:

K4.55 propeller in NSMB Nozzle 19

Diameter	- 32 in.
Type	- Kaplan (square-tipped)
No. of blades	- 4
Speed	- 700 rpm

Considering the relatively low vehicle speeds, the hull resistance, and the power available, it is desirable to use the largest possible propeller diameter; however, for this application, physical limitations require a compromise in the diameter.

The selected Kaplan propeller and its nozzle have a limiting dimension of approximately 38 inches diameter. To obtain equivalent propulsive characteristics, a 50-inch-diameter unshrouded propeller would be required.

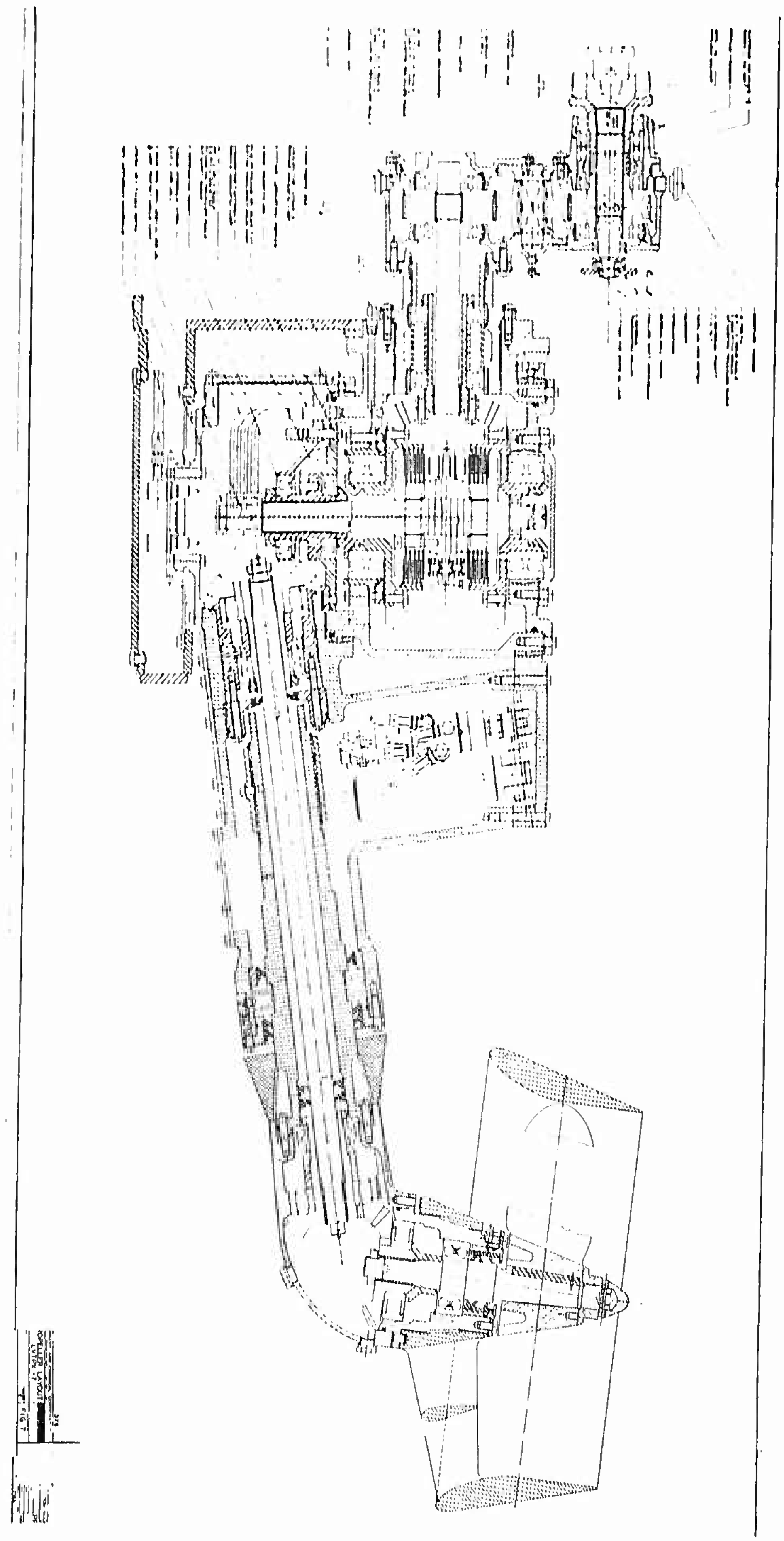


FIGURE 3 9 24

Propulsion Methods (Continued)

It is predicted that the 32-inch-diameter propeller will provide water speeds of 9 to 9-1/2 mph for the LVTPX11. This prediction was based on preliminary cavitation studies. It is suggested that a more complete study be made to verify this prediction.

Design of the LVTPX11 propeller should be similar to that shown in Figure 3.9.24, except that the forward and reverse gearing will be in a gearbox attached to the power take-off of the power train, as shown in Figure 3.3.2 . The propeller design should permit steering and retraction, and a kick-back feature for protection; consequently, it will not be as complex as the unit shown in Figure 3.9.24. The complete propeller and its drive installation are estimated to weigh 1500 lbs.

In order to reduce the propeller diameter, a twin propeller installation was investigated, but it was found that, to maintain the same propulsive efficiency, twin 24-inch-diameter propellers, operating at 970 rpm in Kort nozzles, would be required. Such an installation also poses the problems of increased weight and cost, additional controls, and increased maintenance.

The capability of increased speed is only one of the advantages of a propeller installation. Due to the efficiency increase (46% as compared to 17% for tracks), the water range is increased for a given amount of fuel.

Other propeller drive installations investigated included a propeller located in a tunnel, thus eliminating the retraction requirement and minimizing the vulnerability. However, to provide reasonable water entry to the propeller, the hull had to be lengthened. It was estimated that the tunnel-mounted propeller would provide only 75% of the efficiency of the propeller-nozzle combination.

Propulsion Methods (Continued)

3.9.3.4 Other Devices

Although the apparent intent of the "Development Characteristics" is to limit the use of propulsion devices requiring auxiliary power means, several such devices were given a preliminary evaluation. These devices included pulse jets and outboard motors. Since nothing in this area offered anything desirable for the LVTPX11, the effort was discontinued.

3.10 CONTROLS

3.10.1 Instruments

The following panel-mounted instruments are located immediately forward of the driver:

- Tachometer
- Speedometer
- Coolant-temperature gauge
- Fuel gauge
- Hydraulic oil pressure gauge
- High temperature-low pressure indicating lights

These instruments are supplemented by the conventional master switch, power switch, lighting switches, and bilge pump switch.

3.10.2 Controls

All engine and steering controls, as well as wiring and plumbing, are routed through the control tunnel above the left sponson.

For the "Maximum Armored Vehicle", steering for both land and water operation is accomplished with the same wheel-type control, actuating a mechanical linkage to the differential steering unit.

The "Maximum Water Performance Vehicle" utilizes a wheel-type control for land steering, but steering during water operation, prior to reaching the

Controls (Continued)

surf zone, is by means of a lever-type control that actuates the propeller hydraulic steering cylinder. In the surfing and beaching operations, the wheel control is used, since only the tracks are used for propulsion.

The gear selector is mounted in a quadrant to the right of the driver and is connected by mechanical linkage to the power train.

Mechanical controls are provided adjacent to the driver for adjustment of the air intake and exhaust openings.

The "Maximum Water Performance Vehicle" is also provided with a switch for hydraulically retracting or extending the propeller drive. A clutch, controlled by the driver, is incorporated in the power take-off for the propeller drive.

A mechanical control is located adjacent to the driver for operation of the ramp latches, with a switch controlling the hydraulic circuit utilized for ramp retraction.

3.11 SUBSYSTEMS

This section describes the following vehicle subsystems:

- Fuel system
- Hydraulic system
- Electrical system
- Bilge pumps
- Fire extinguishing system
- Communications system
- Winterization kit
- CBR protection

3.11.1 Fuel System

A 125-gallon fuel cell is located on the port side of the engine compartment, as shown in Figure 3.7.1. The selected location causes only a 2-1/2-inch total change of the transverse trim of the LVTPX11 between the full and empty conditions, which permits a nearly even transverse trim for the majority of the period use.

A manual shutoff valve and a fuel filter are located at the cell outlet. Fuel pressure is supplied by a standard Ordnance electric fuel pump.

The fuel cell filler neck is located at deck level and includes a telescoping section for refueling under rough sea conditions.

3.11.2 Hydraulic System

A 1,500 psi hydraulic system is required for the ramp cylinder and the two hydraulically driven bilge pumps. An engine-mounted hydraulic pump and a two-gallon

Hydraulic System (Continued)

reservoir are located in the engine compartment. The reservoir is provided with a filter and an easily accessible filler neck.

3.11.3 Electrical System

3.11.3.1 Electrical Power System

Twenty-eight volt electrical power is provided by the 100-ampere engine-mounted alternator. Four storage batteries furnish power when the engine is not operating. These are waterproof, nickel-cadmium, thin-sintered-plate batteries, connected to provide 200-ampere-hour capacity for optimum performance at high current demands during cold-weather operation. Battery location is shown in Figure 3.7.1. The capacity of 200-ampere-hours will provide starting capability to 0°F without engine preheating. For operation below this temperature, the engine and battery compartments should be preheated.

A slave receptacle, Ordnance Part No. 7321299, is provided to permit auxiliary engine starting or battery charging. In addition, this receptacle may be used as an external source of power for maintenance tools. One MS 35107-3 maintenance light is provided in the engine compartment and one in the personnel compartment, for both blackout and service lighting. Utility outlets are also provided.

3.11.3.2 Lighting Systems

Land Lighting - The following lights are provided in the land lighting circuit:

Quantity	Nomenclature	Ord. Part. No.
2	Headlamp, service	8735874
2	Headlamp, blackout	8735875

Electrical System (Continued)

Quantity	Nomenclature	Ord. Part No.
2	Lamp Assy, blackout marker	8741644
1	Lamp Assy, right tail and stop	8738786
1	Lamp Assy, left tail and stop	8378785

The left tail lamp assembly incorporates both the service tail and stop lamp and a blackout marker lamp. The right tail lamp assembly incorporates the blackout stop lamp and blackout marker.

Since the "Development Characteristics" require that the land lights be removable, provisions are incorporated for accomplishing this; however, it is recommended that these lamp assemblies be permanently fixed, due to the difficulty in establishing headlamp focus each time the lamps are installed. These lamps could be installed in suitably protected enclosures, as in past design of military vehicles.

A signal searchlight with detachable color lens is externally mounted, as required, and is stowed in the personnel compartment.

Marine Lighting System - To comply with the U.S. Coast Guard "Rules of the Road" the following marine navigation lights are provided. All marine lighting is removable and is stowed in the personnel compartment.

- White bow lamp, BuShips No. 815-1197112 symbol 203, mounted on a portable mast that can be attached to the center of the forward ramp to extend the lamp above the cupola height. An outlet is provided in the deck for power.

Electrical System (Continued)

- White stern lamp, BuShips No. 9000-SG405-74100 symbol 211. This is also a portable lamp that can be attached at the stern.
- Green starboard lamp, BuShips No. 9000-SG405-73885 symbol 208.1.
- Red port lamp, BuShips No. 9000-SG405-73885 symbol 207.1.

3.11.4 Bilge Pumps

The LVTPX11 is equipped with four bilge pumps, as shown in Figure 3.2.2, with a total capacity of 600 gpm at 6-foot head. One pump forward and one pump aft are hydraulically driven, and the other pair are electrically driven. The pump locations provide pumping capability regardless of the trim attitude. The two different pump drives were chosen for the following reasons:

- Electric drive on two pumps permits a 300 gpm emergency pumping capability, in event of power failure, by utilizing the vehicle storage batteries.
- Hydraulically driving two pumps minimizes the electrical load on the battery and the alternator.

3.11.5 Fire Extinguishing System

Both a fixed system and portable extinguishers are provided for the LVTPX11. The fixed system is composed of a 10 lb CO_2 cylinder, located in the engine compartment, and its associated release cables, as shown in Figure 3.7.1. One pull handle is located adjacent to the driver and another on the deck, Fire Extinguishing System (Continued)

accessible from outside the vehicle. Operation of either handle de-energizes the electric fuel pump and discharges the cylinder. A portable 5 lb CO_2 cylinder is stowed in the personnel compartment.

3.11.6 Communications System

As specified in the "Development Characteristics" and as shown in Figure 3.2.2, sufficient space is provided for installation of a GFE radio, either the AN/PRC-47 or the Collins Radio Model 618T. Antenna base mounts are provided for both transmitting and receiving antennas.

3.11.7 Winterization Kit

Provision is made for the installation of a standard, Ordnance, multifuel, 60,000 BTU heater in the personnel compartment. Both combustion and conditioning air is drawn from the personnel compartment. Combustion exhaust is ducted through vent in the deck, and conditioned-air exhaust is ducted to the driver and vehicle commander stations and the personnel compartment. A duct is also provided to the battery compartment to aid in cold-weather starting.

3.11.8 Armament

The turret shown in Figures 3.2.1 and 3.3.1 is the same as the turret used on the LVTP5, but it must be modified to accept the 7.62 mm machine gun and redesigned in aluminum consistent with the hulls armor.

3.11.9 Chemical-Biological Protection

It is proposed that the LVTPX11 be equipped with a CBR filter Model M8A2. This

Chemical-Biological Protection (Continued)

is a three-man face mask assembly that provides 4 cfm of filtered air per man from a central unit. This would be used by the driver and the assistant driver, with the third mask being available for use in the machinegun cupola. Troops will use their own protective masks.

To provide on-vehicle protection for all personnel in the vehicle is feasible, but it would require a much more complex system. All openings into the crew compartment would require very tight fitting seals to keep the amount of escaping air to a minimum. Since the size of the filter unit is determined by the quantity of air being passed through it, this amount should be kept as close as possible to the minimum requirement for compartment ventilation. To insure that there is no leakage of outside air in through any of the seals, the compartment must be kept pressurized.

To maintain a clean atmosphere within the vehicle during combat operation, an airlock tent connected to the ramp opening would be necessary. This would provide a transition area where the troops could remove contaminated clothing or use a decontaminant. This would be a slow and vulnerable operation which would probably make it unadvisable.

A vehicle protection of this type lends itself more to the command center unit than to the combat vehicle.

3.12 WEIGHT AND STABILITY

3.12.1 Weight

Figure 3.12.1 is a summary of the weights of the "Maximum Armored Vehicle" and the "Maximum Water Performance Vehicle". A detailed weight analysis is included in Appendix B (Volume II).

These weights are based on a vehicle that provides reasonable armor protection and a cargo capacity of 6,000 lbs. Various trade-offs in armor versus cargo capacity are discussed in detail in Section 3.6, and an armor analysis is included in Appendix H (Volume III).

3.12.2 Stability

The transverse stability of the LVTPX11 is defined by its metacentric height, righting moment curves, and range of stability.

When the vehicle is displaced from the vertical, the center of buoyancy moves outward, providing a restoring moment. A vertical from the new center of buoyancy intersects the original vertical centerline at the metacenter. The distance between the metacenter and the center of gravity, metacentric height, is 25 inches for the "Maximum Armored Vehicle".

While the metacentric height is a measure of the initial transverse stability of the vehicle, the righting moment curve must be used to indicate the vehicle ability to react to external forces which produce large angles of roll.

Item	Maximum Armored Vehicle Weight (lb)	Maximum Water Performance Vehicle Weight (lb)
Hull and Fittings	14,794	13,701
Suspension	6,616	6,286
Drive Train	3,891	5,391
Electrical System	340	340
Miscellaneous	1,994	1,979
Fuel	831	831
Crew	440	440
Cargo	6,000	6,000
TOTAL	34,906	34,968

FIGURE 3.12.1 WEIGHT SUMMARY

Stability (Continued)

For a positive righting moment, the center of gravity must be below the metacenter. The range of stability is the angle of heel at which capsizing will occur. This angle, for the 35,000 lb GVW, is over 90° for the "Maximum Armored Vehicle", under static conditions.

3.12.3 Longitudinal Trim

Previous vehicle experience and model tow tests show that it is desirable for the vehicle to trim level or slightly down by the stern, when static in the water, to avoid bow submergence and the subsequent increase in hull resistance. However, since the stern will tend to trim down further, due to dynamic forces, when the vehicle is underway, the static trim should be such that the stern will not become awash when operating at maximum speed.

3.12.3.1 Trim - Maximum Armored Vehicle

Figures 3.12.2, 3.12.3, and 3.12.4 show the vehicle static trim in the unloaded, troop loaded, and cargo loaded conditions.

In the unloaded condition, the vehicle trims 2.4 inches down by the stern. When loaded with troops, it trims 0.3 inch down by the stern. In the cargo loaded condition, it trims 1.5 inches down by the stern. As previously noted, it trims down by the stern under all conditions when underway.

Longitudinal Trim (Continued)

3.12.3.2 Trim - Maximum Water Performance Vehicle

Figures 3.12.5 and 3.12.6 show the static trim of this vehicle in the unloaded and troop loaded conditions. Unloaded, it trims 5.6 inches down by the stern. The stern-down trim is 3.5 inches and 2.9 inches for the cargo-loaded and the troop-loaded conditions, respectively.

In the unloaded condition, the stern-down trim of 5.6 inches is particularly desirable, since this keeps the propeller submerged under this condition of minimum draft.

3.12.4 Transverse Static Trim

Both the "Maximum Armored Vehicle" and the "Maximum Water Performance Vehicle" trim essentially level for all conditions of symmetrical loading.

Figure 3.12.7 summarizes the static trim for the two vehicles under various conditions of loading. Supporting calculations are included in Appendix B (Volume II).

When fully fueled, the vehicles trim 0.4 inch down on the starboard side and, when empty of fuel, 2.2 inches down on the starboard side. This provides an essentially level trim condition for the major portion of the vehicle operating range.

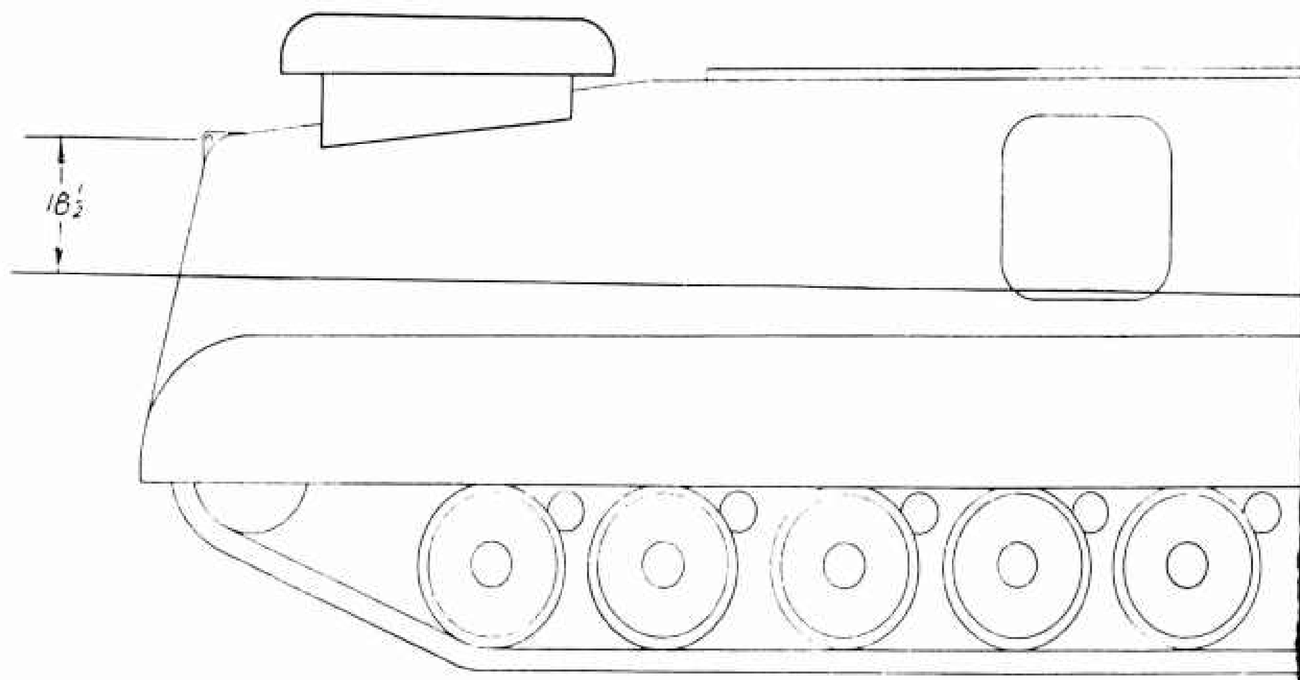
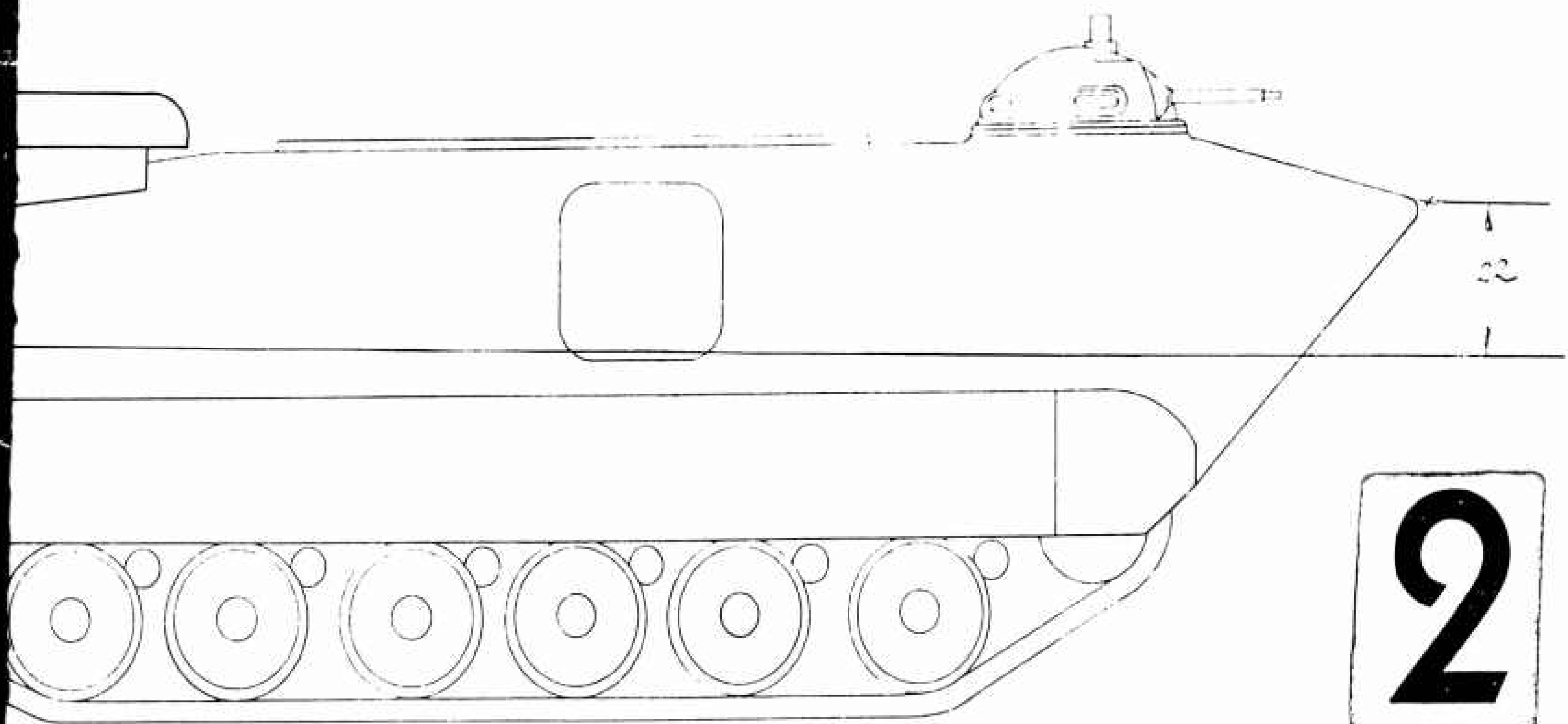


FIGURE 3.12.2 STATIC TRIM - "MAXIMUM ARMOR VEHICL
(29,000 lb Curb Weight)

1



2

URE 3. 12. 2 STATIC TRIM - "MAXIMUM ARMOR VEHICLE" VEHICLE EMPTY
(29, 000 lb Curb Weight)

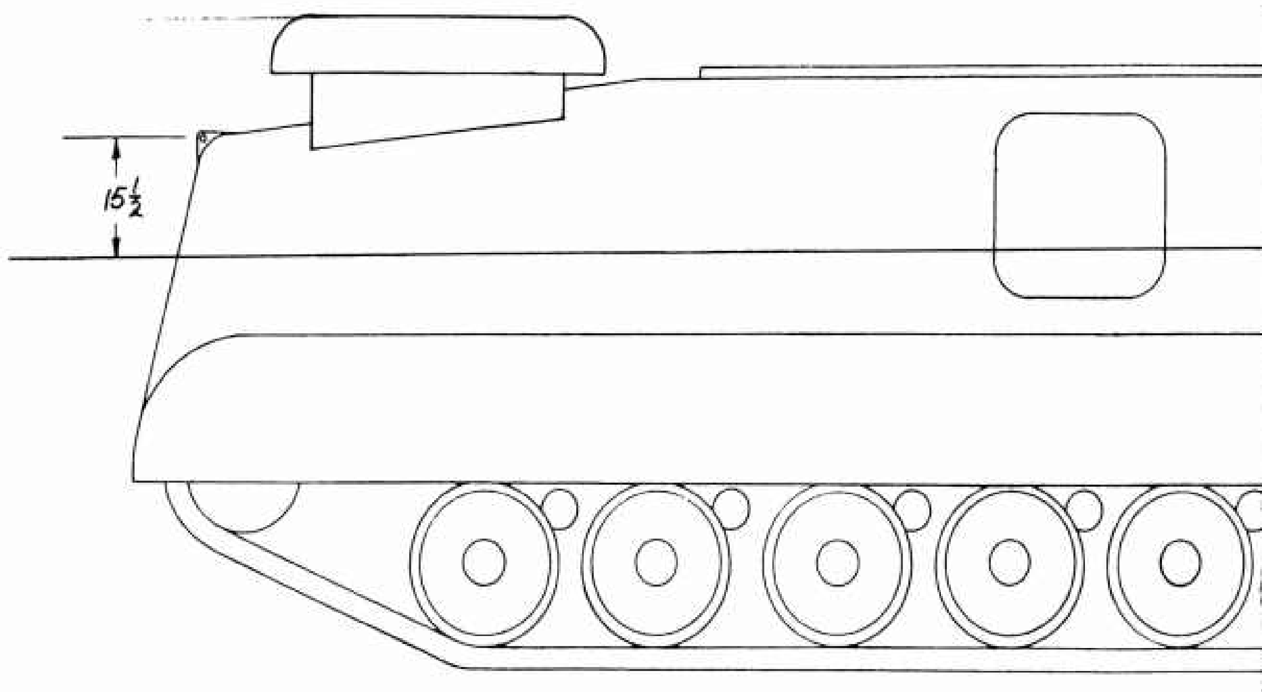
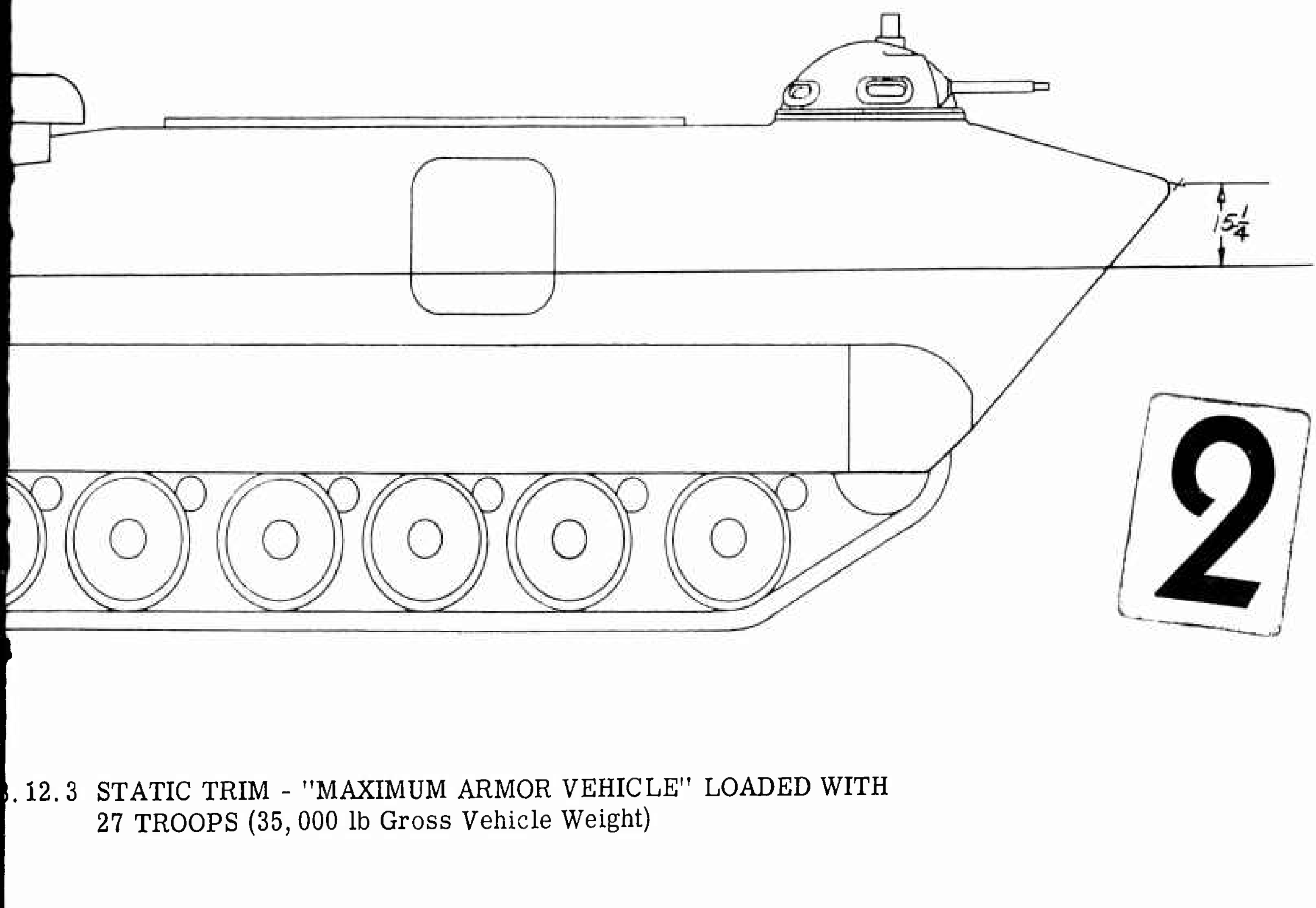


FIGURE 3.12.3 STATIC TRIM - "MAXIMUM ARMOR VEHIC
27 TROOPS (35,000 lb Gross Vehicle Weight

1



. 12. 3 STATIC TRIM - "MAXIMUM ARMOR VEHICLE" LOADED WITH 27 TROOPS (35, 000 lb Gross Vehicle Weight)

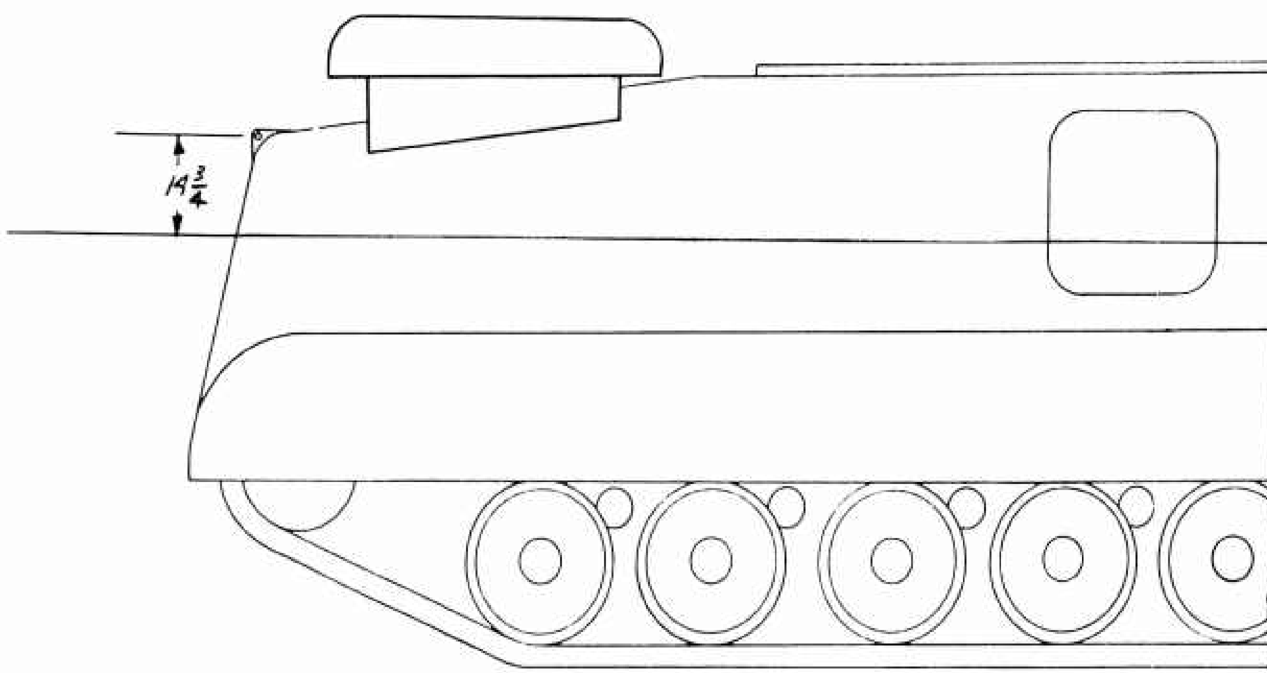
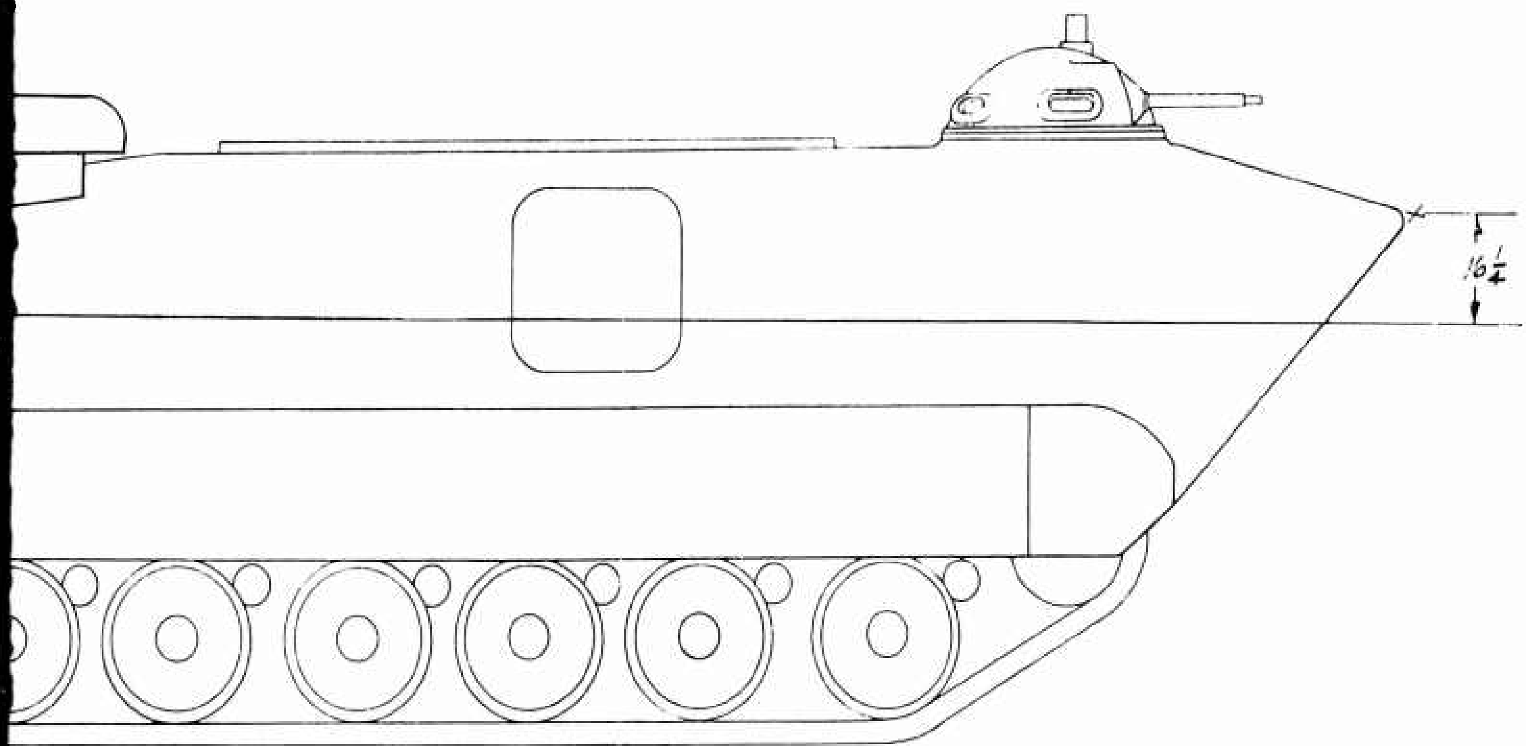


FIGURE 3. 12. 4 STATIC TRIM - "MAXIMUM ARMOR
AT CENTER OF CARGO HATCH (35,



URE 3.12.4 STATIC TRIM - "MAXIMUM ARMOR VEHICLE" 6,000 LB CARGO AT CENTER OF CARGO HATCH (35,000 lb Gross Vehicle Weight)

2

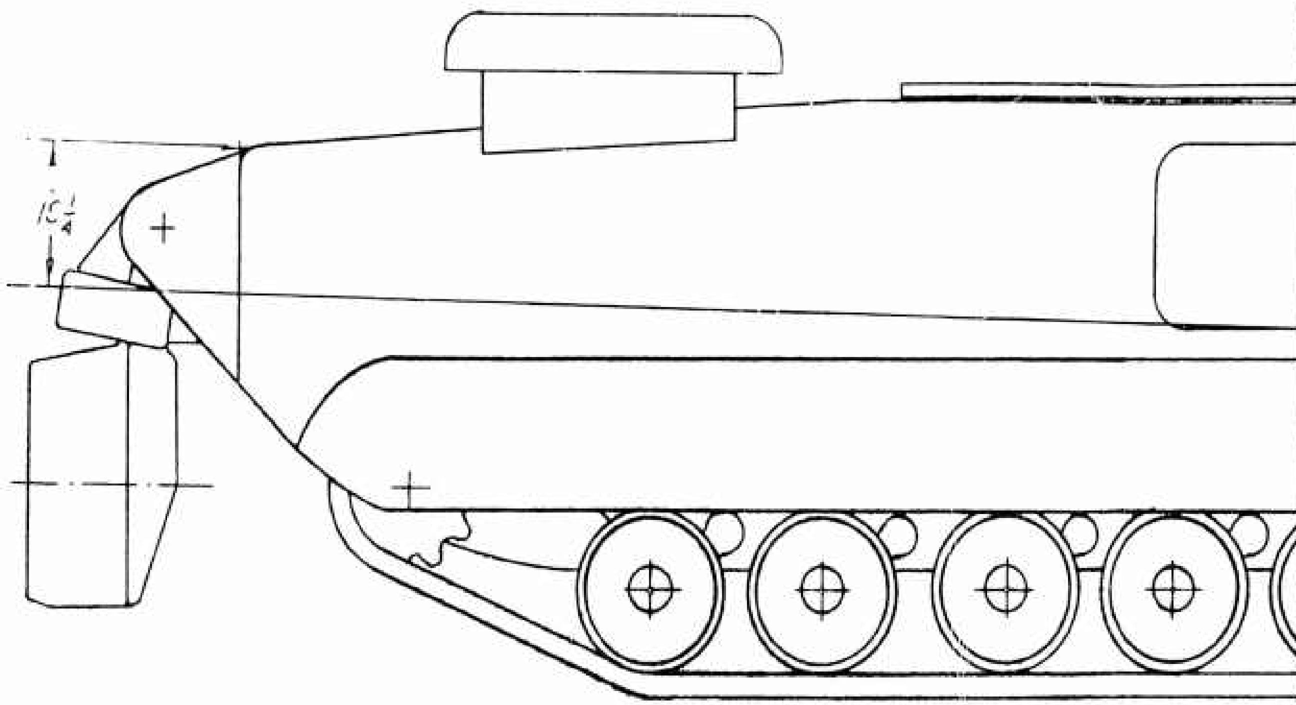
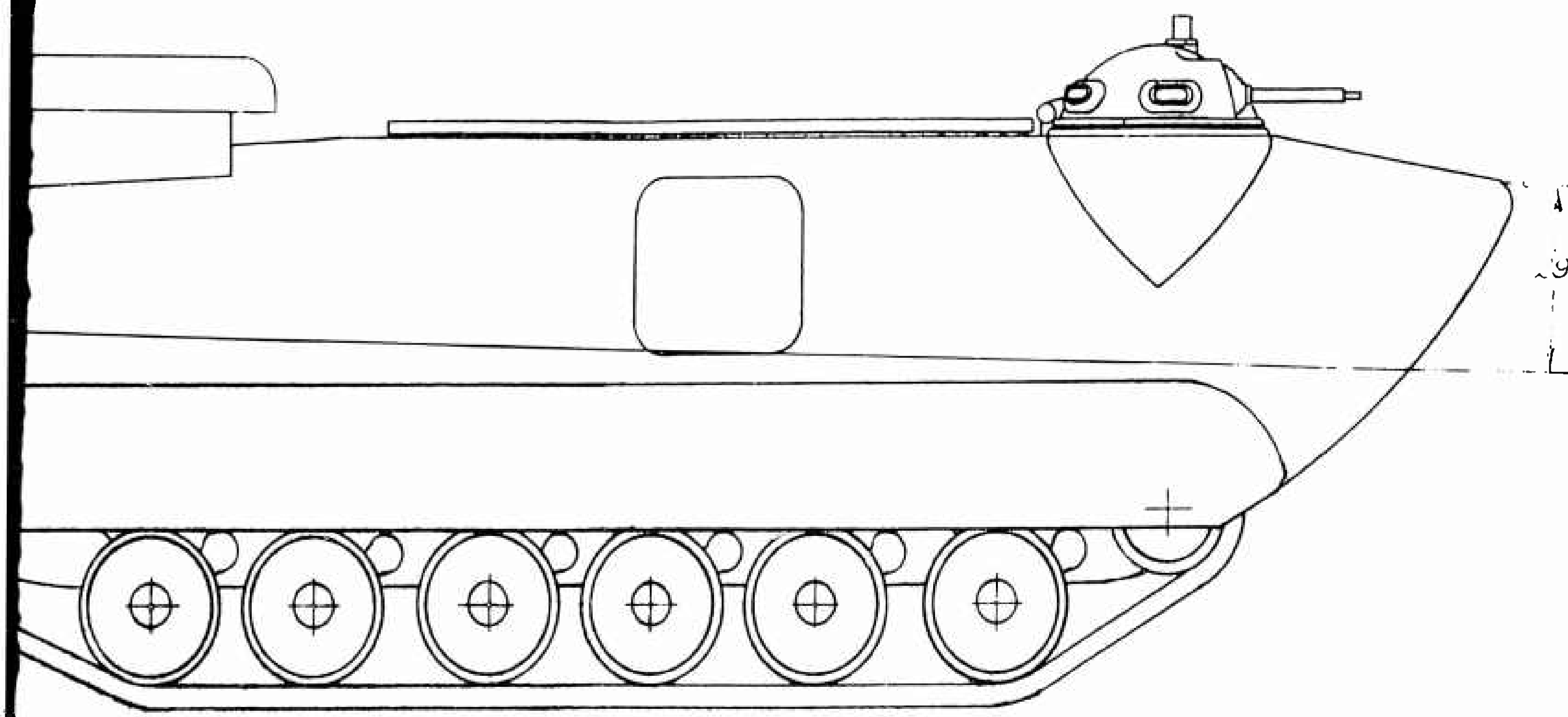


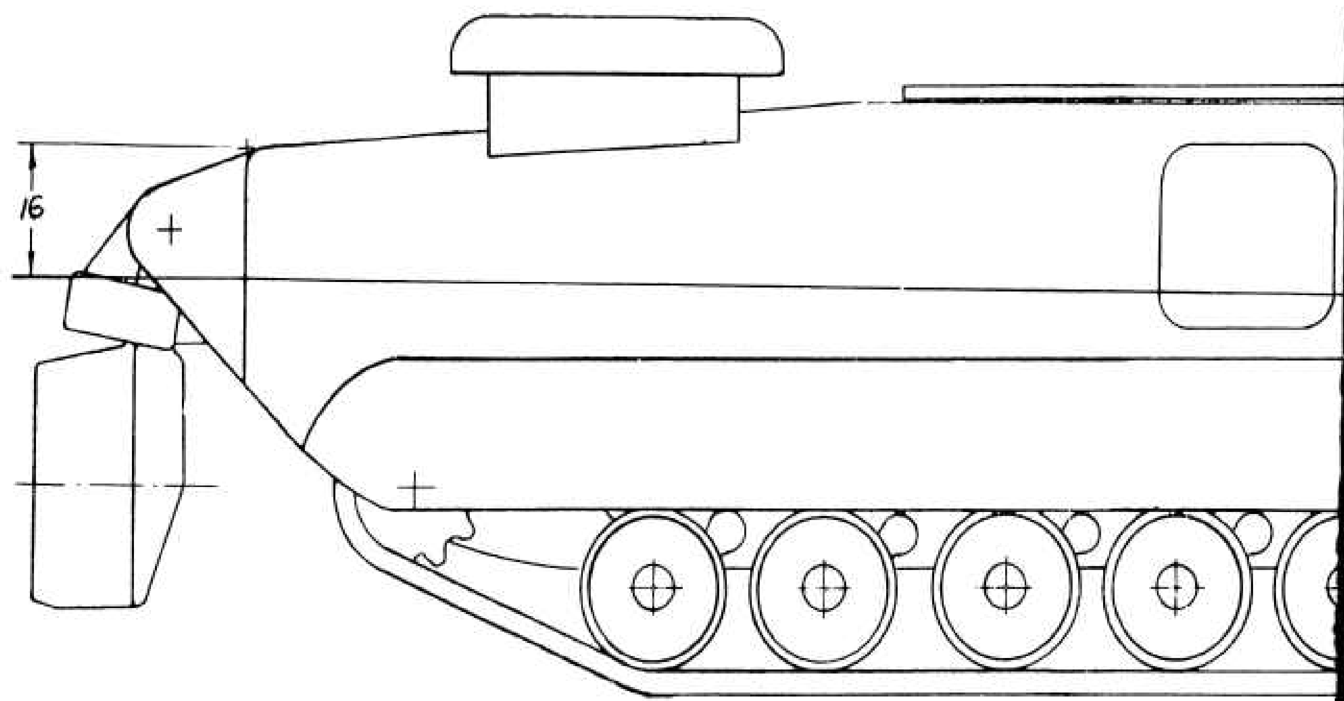
FIGURE 3.12.5 STATIC TRIM - "MAXIMUM WATER PE
VEHICLE EMPTY (29,000 lb Curb Weig

1



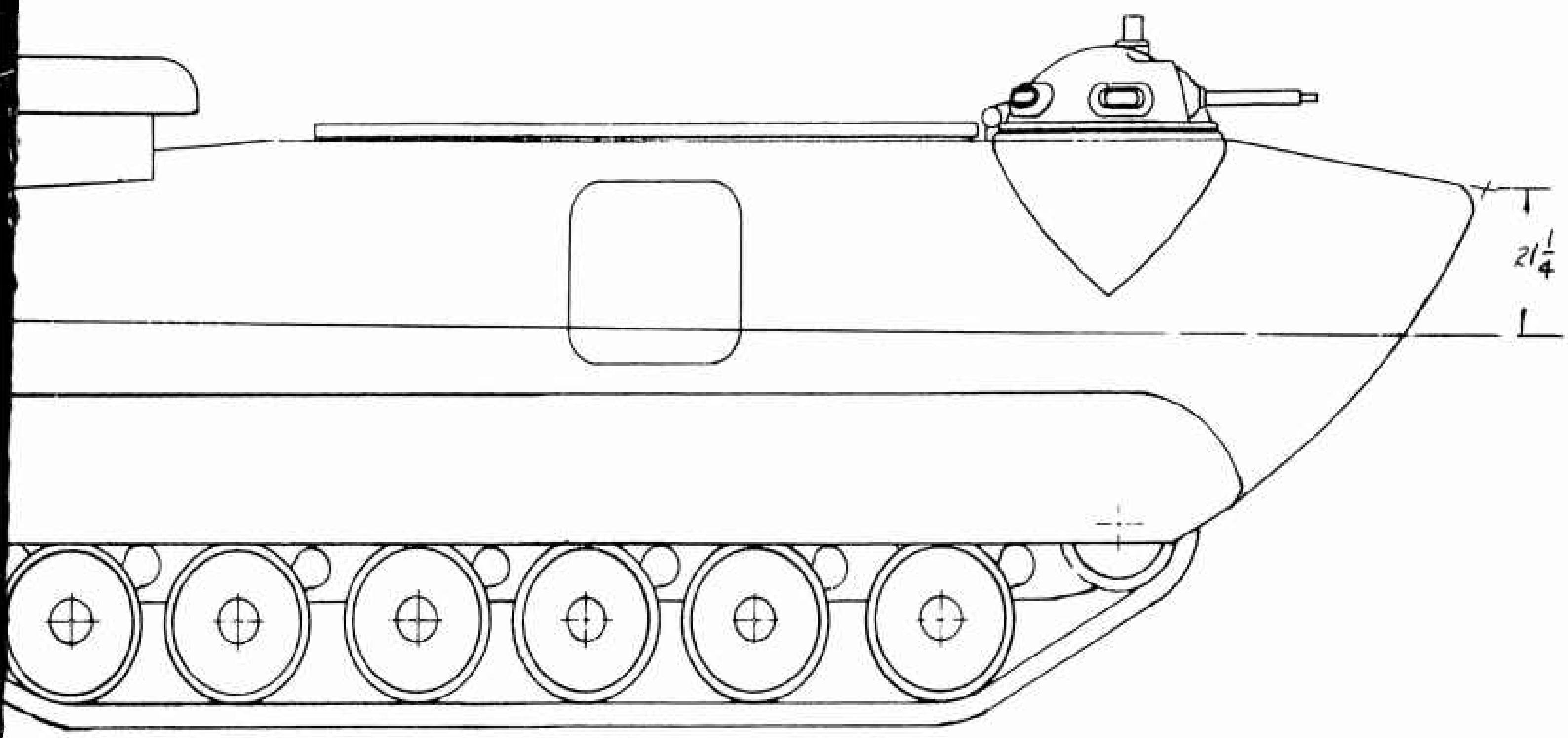
GURE 3.12.5 STATIC TRIM - "MAXIMUM WATER PERFORMANCE VEHICLE"
VEHICLE EMPTY (29,000 lb Curb Weight)

2



1

FIGURE 3.12.6 STATIC TRIM - "MAXIMUM WATER PE
LOADED WITH TROOPS (35,000 lb Gros



2

RE 3.12.6 STATIC TRIM - "MAXIMUM WATER PERFORMANCE VEHICLE"
LOADED WITH TROOPS (35,000 lb Gross Vehicle Weight)

Load Condition	Total Vehicle Weight (lb)	Longitudinal Trim (in.) Fwd	Longitudinal Trim (in.) Aft	Lateral Trim (in.) Full Fuel Cell R	Full Fuel Cell L	Empty Fuel Cell R	Empty Fuel Cell L
MAXIMUM ARMOR VEHICLE							
Empty	28,931	+2.4	-2.4	-.4	+.4	-2.2	+2.2
6,000 lb @ Cargo Door	34,931	+1.5	-1.5	-.4	+.4	-2.2	+2.2
Loaded with 27 Troops	34,871	+ .3	- .3	-.4	+.4	-2.2	+2.2
MAXIMUM WATER PERFORMANCE VEHICLE							
Empty	28,904	+5.6	-5.6	-.4	+.4	-2.2	+2.2
6,00 lb @ Cargo Door	34,904	+3.5	-3.5	-.4	+.4	-2.2	+2.2
Loaded with 27 Troops	34,844	+2.9	-2.9	-.4	+.4	-2.2	+2.2

FIGURE 3.12.7

3.14 OTHER APPLICATIONS

The recommended vehicle has been analyzed and found suitable for the following special-purpose configurations:

- Command vehicle
- Recovery vehicle
- Antimechanized weapon vehicle
- Field artillery weapon vehicle
- Air defense weapon vehicle
- Engineer mine-clearance vehicle

The BuShips "Development Characteristics" require that the basic hull, power train, and suspension arrangement should be adaptable to the above vehicles.

3.14.1 Command Vehicle

Figure 3.14.1 shows the recommended LVTPX11 equipped with the same communications components as the LVTP6 command vehicle, developed by FMC under Contract NObs-3880, Task Order No. 17. The equipment layout indicates no difficulty in developing a command vehicle as a member of the LVTPX11 family. New developments, particularly in the areas of transistorized communications equipment, will permit even better space utilization.

3.14.2 Recovery Vehicle

Figure 3.14.2 shows the LVTPX11 equipped with the recovery gear used on the LVTR1.

3.14.3 Antimechanized Weapon Vehicle

Figure 3.14.3 is a concept illustrating the ENTAC wire-controlled missile installed in the LVTPX11.

3.14.4 Field Artillery Weapon Vehicle

The turret-mounted 105mm Howitzer installation is shown in Figure 3.14.4. This installation is similar to the LVTHX4 and the LVTH6. Since the XM70 rocket-boosted artillery weapon is now being developed as a replacement for the 105mm Howitzer, it is shown in Figure 3.14.5.

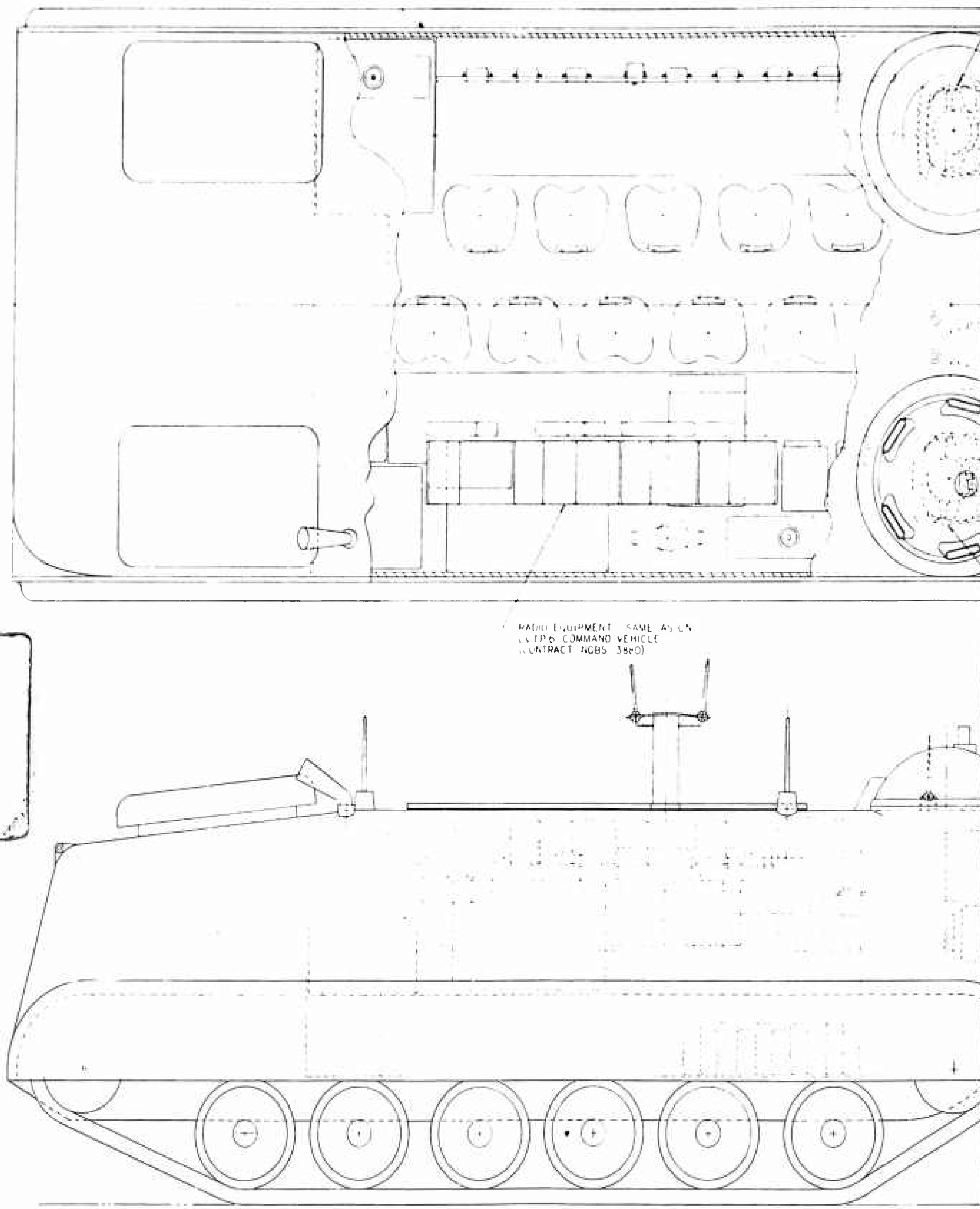
3.14.5 Air Defense Weapon Vehicle

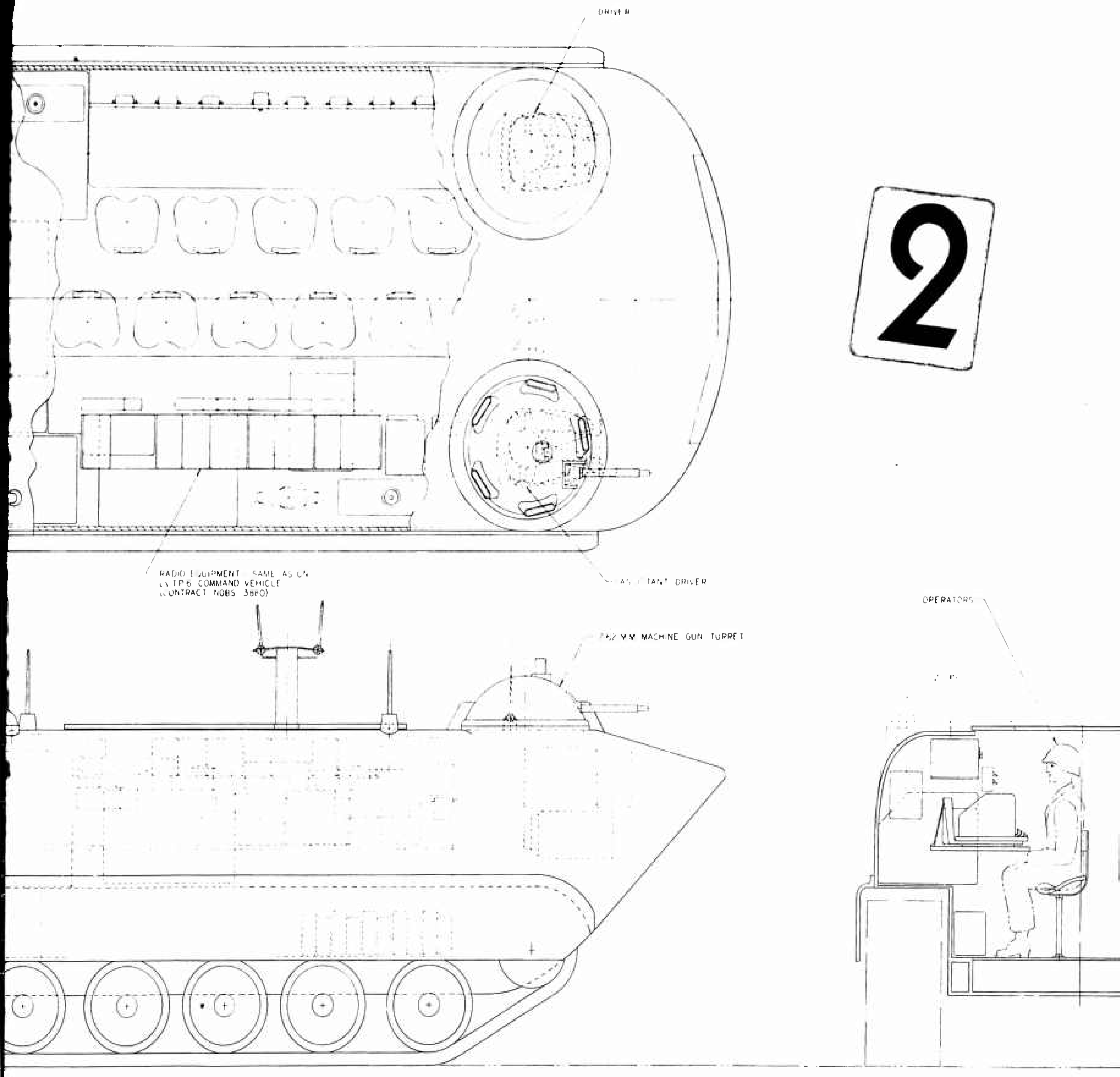
The Mauler system, currently being developed by the U.S. Army, can be used with the LVTPX11. The Mauler Launch Pod is shown on the recommended vehicle in Figure 3.14.6.

3.14.6 Engineer Mine-Clearance Vehicle

Figure 3.14.7 shows the recommended vehicle equipped with line-charge mine-clearance apparatus similar to that used on the LVTE1. Note that a mine excavator unit is not shown at the bow. It is believed that, with further improvement in line charges, it will not be necessary to carry the awkward and heavy excavator.

1

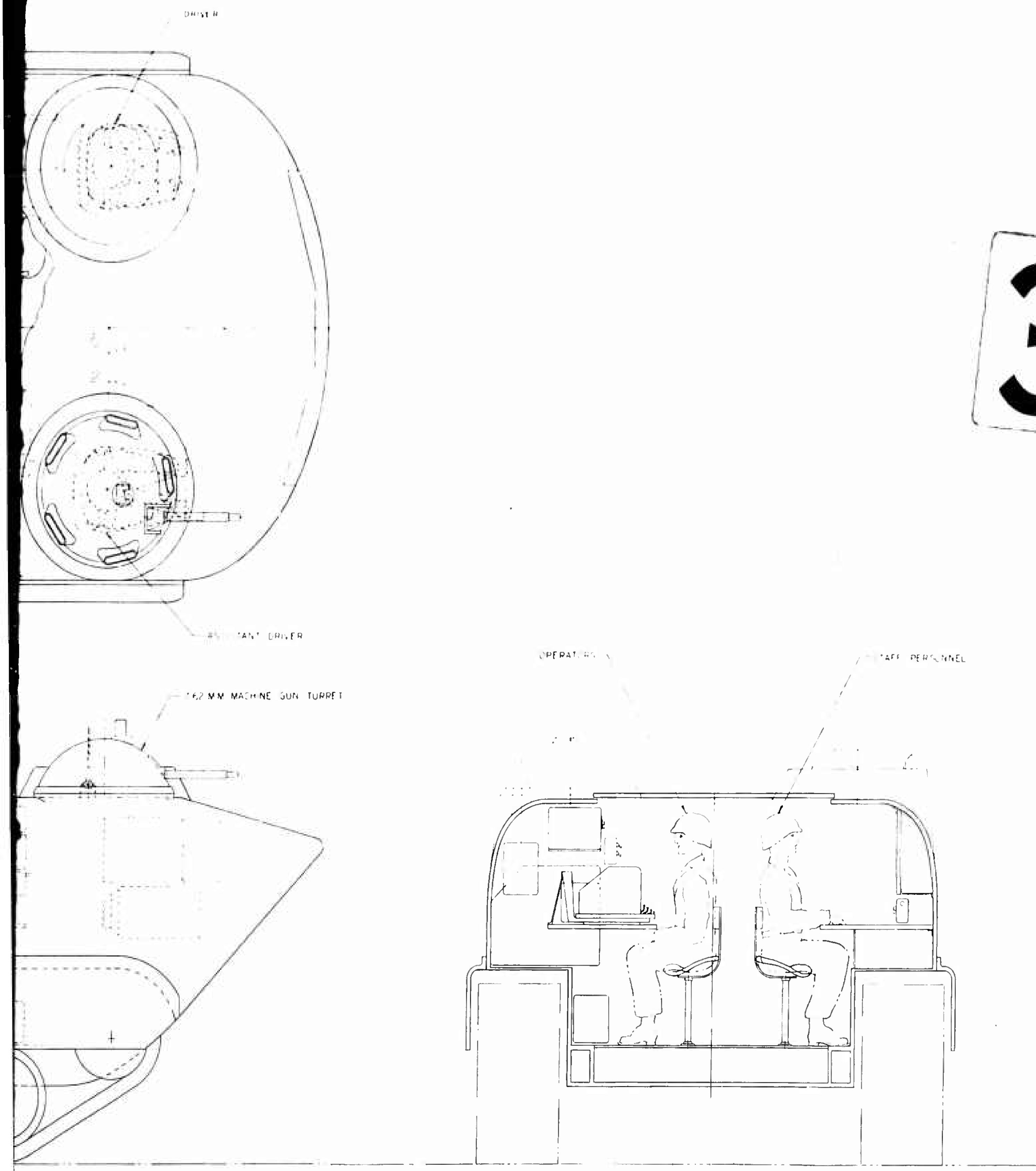

RADIO EQUIPMENT SAME AS ON
TP6 COMMAND VEHICLE
ONTRACT NOBS 3860)



DRIVER
2
RADIO EQUIPMENT SAME AS ON
LVTP6 COMMAND VEHICLE
(CONTRACT NOBS 3880)
ASSISTANT DRIVER
OPERATORS
7.62 MM MACHINE GUN TURRET

1/8 SIZE

0 1

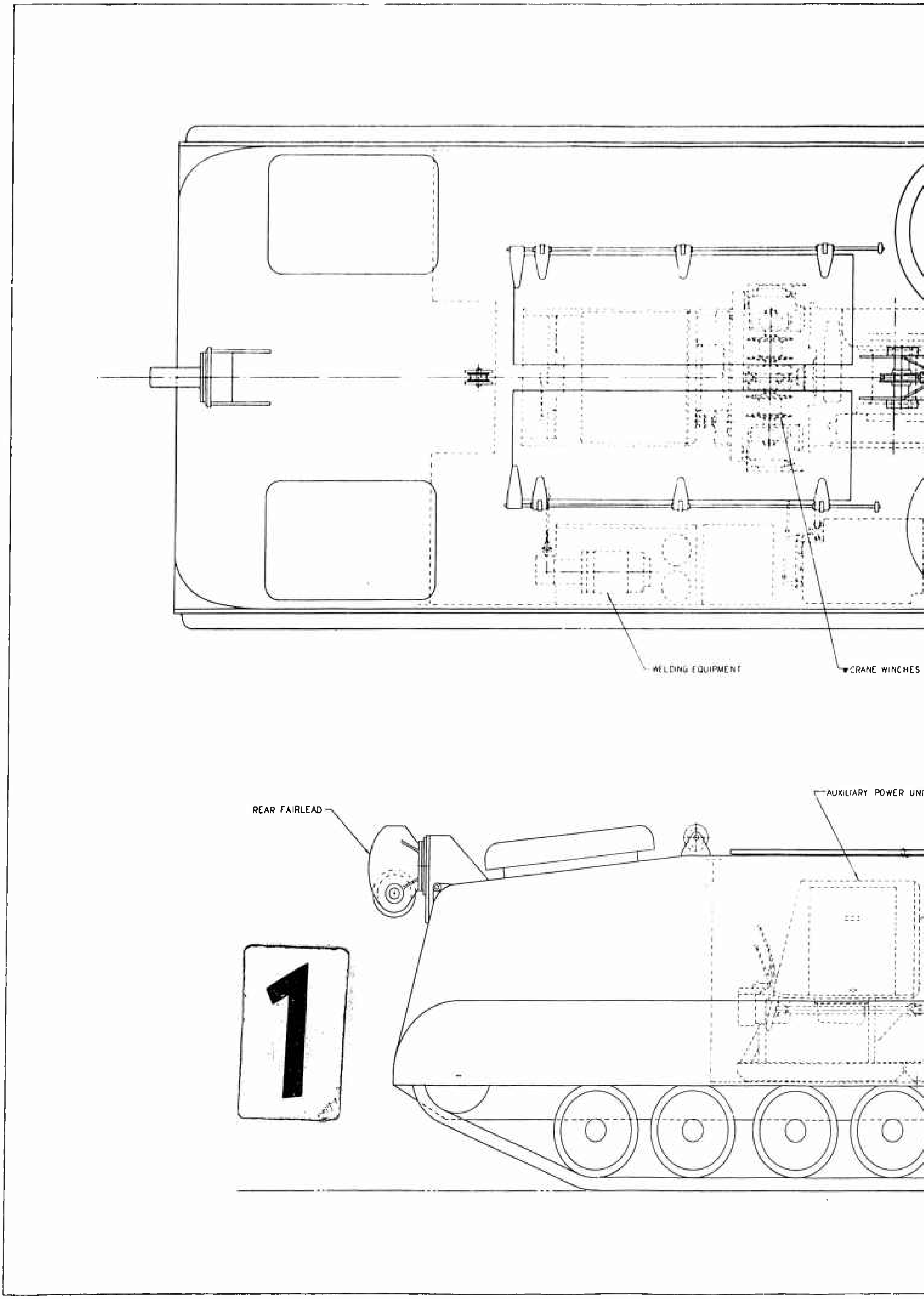


3

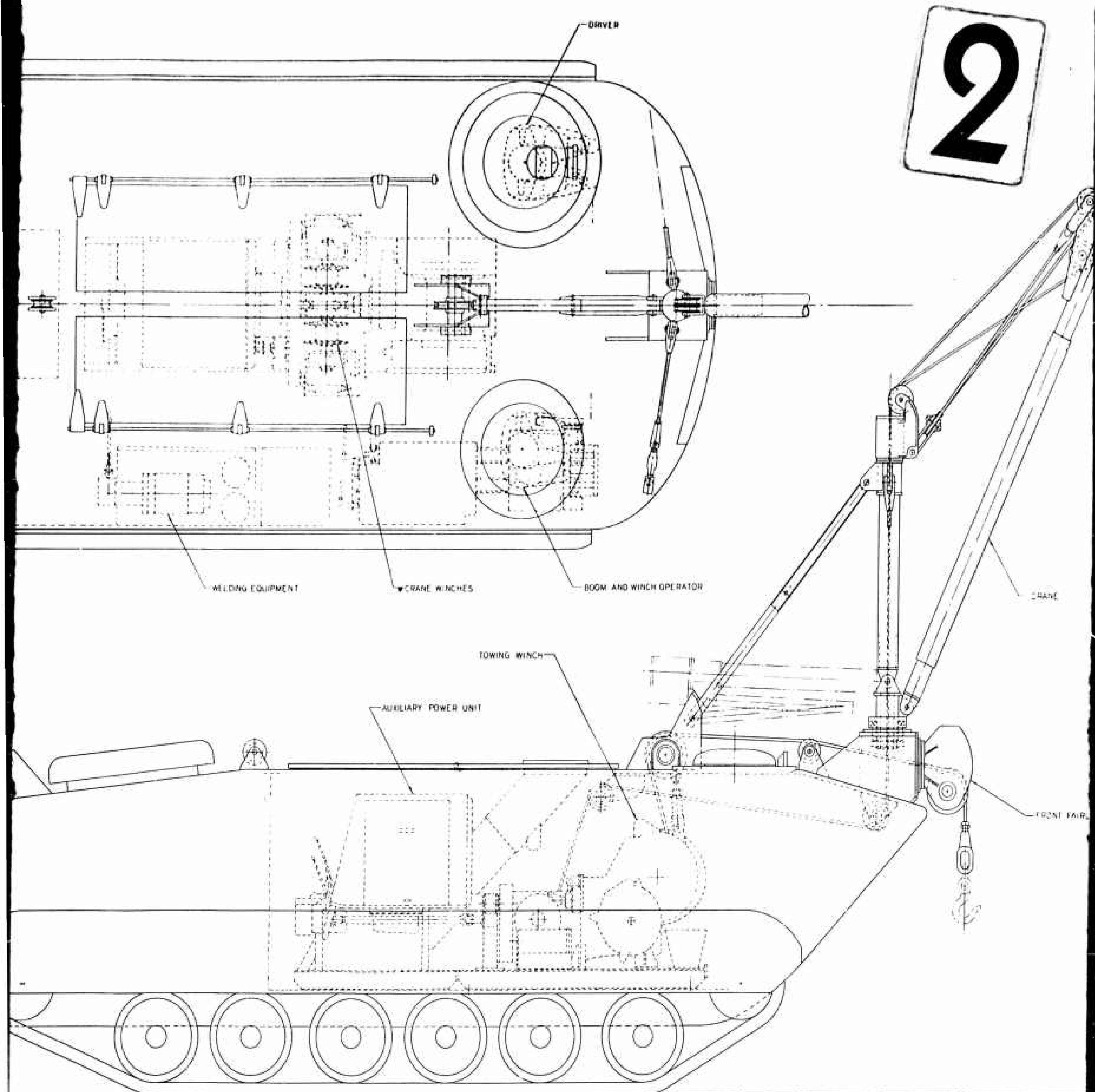
Preliminary Design Engineering
FOOD MACHINERY AND CHEMICAL CORPORATION
ORDNANCE DIVISION
SAN JOSE CALIFORNIA

COMMAND VEHICLE
LVTPX II FAMILY

SCALE GRAPHIC
P A NO 449
DWG NO 1077382



WELDING EQUIPMENT
CRANE WINCHES
AUXILIARY POWER UNIT
REAR FAIRLEAD
1


2
DRIVER
WELDING EQUIPMENT
CRANE WINCHES
BOOM AND WINCH OPERATOR
CRANE
TOWING WINCH
AUXILIARY POWER UNIT

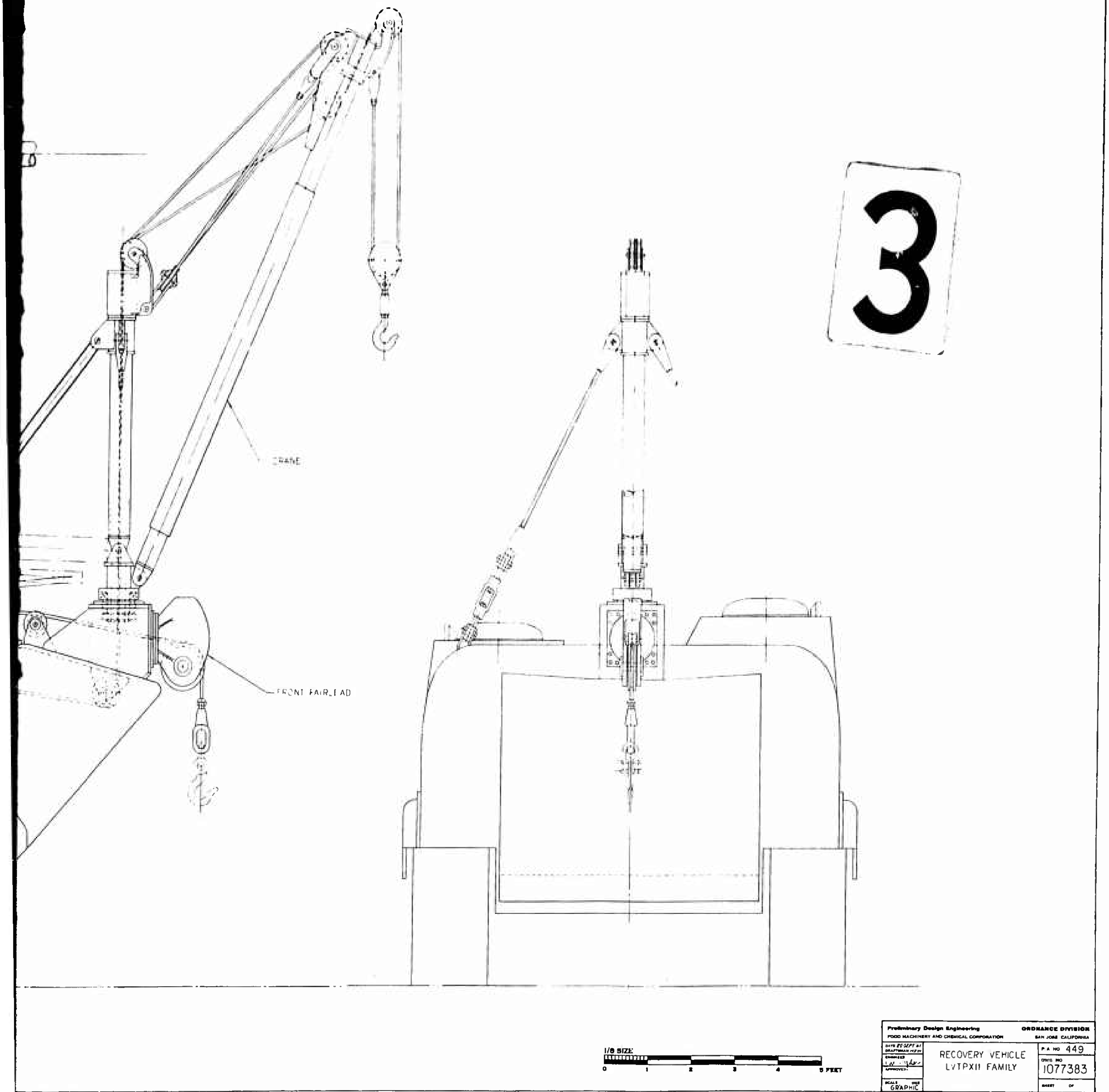
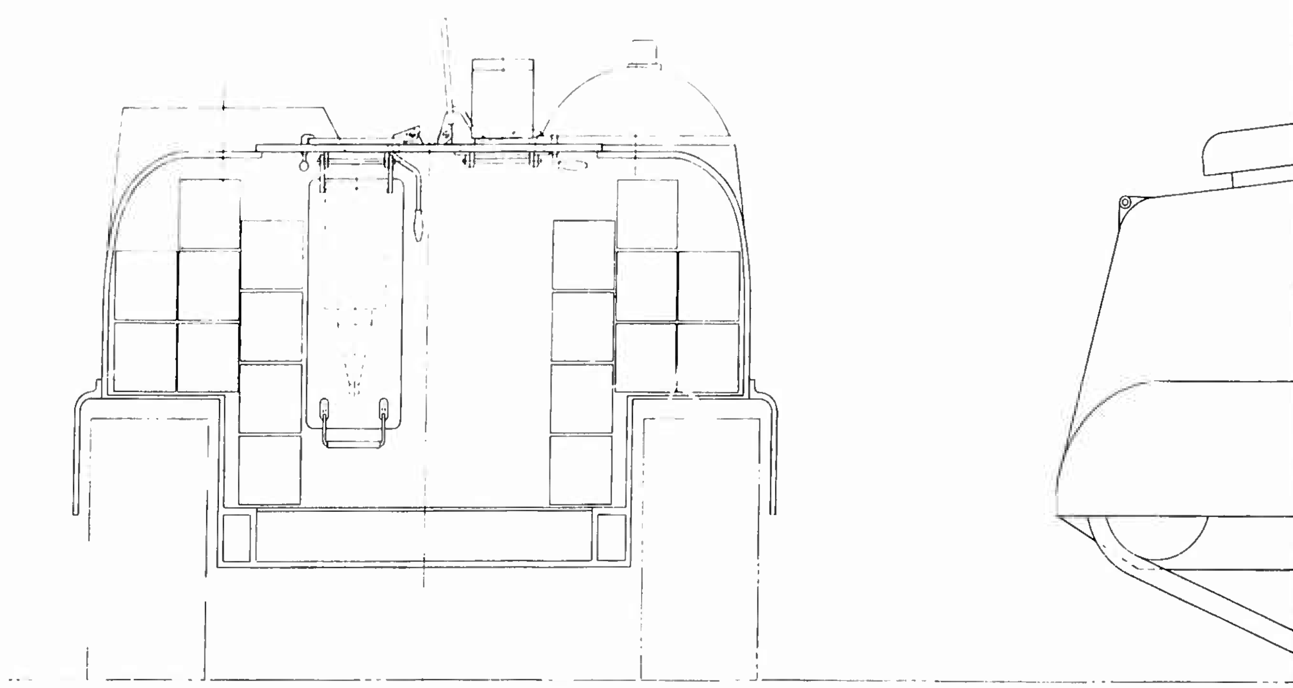
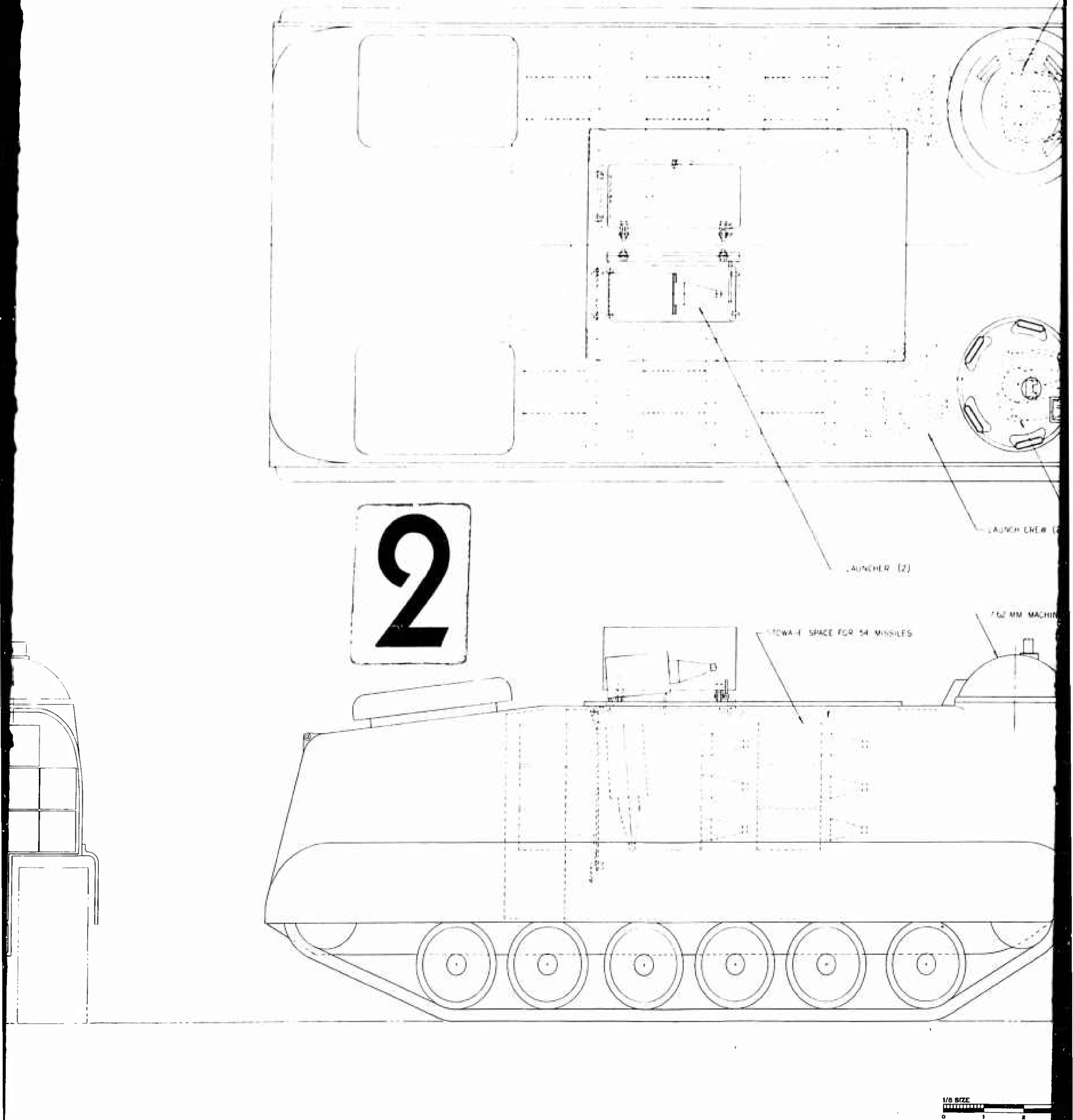
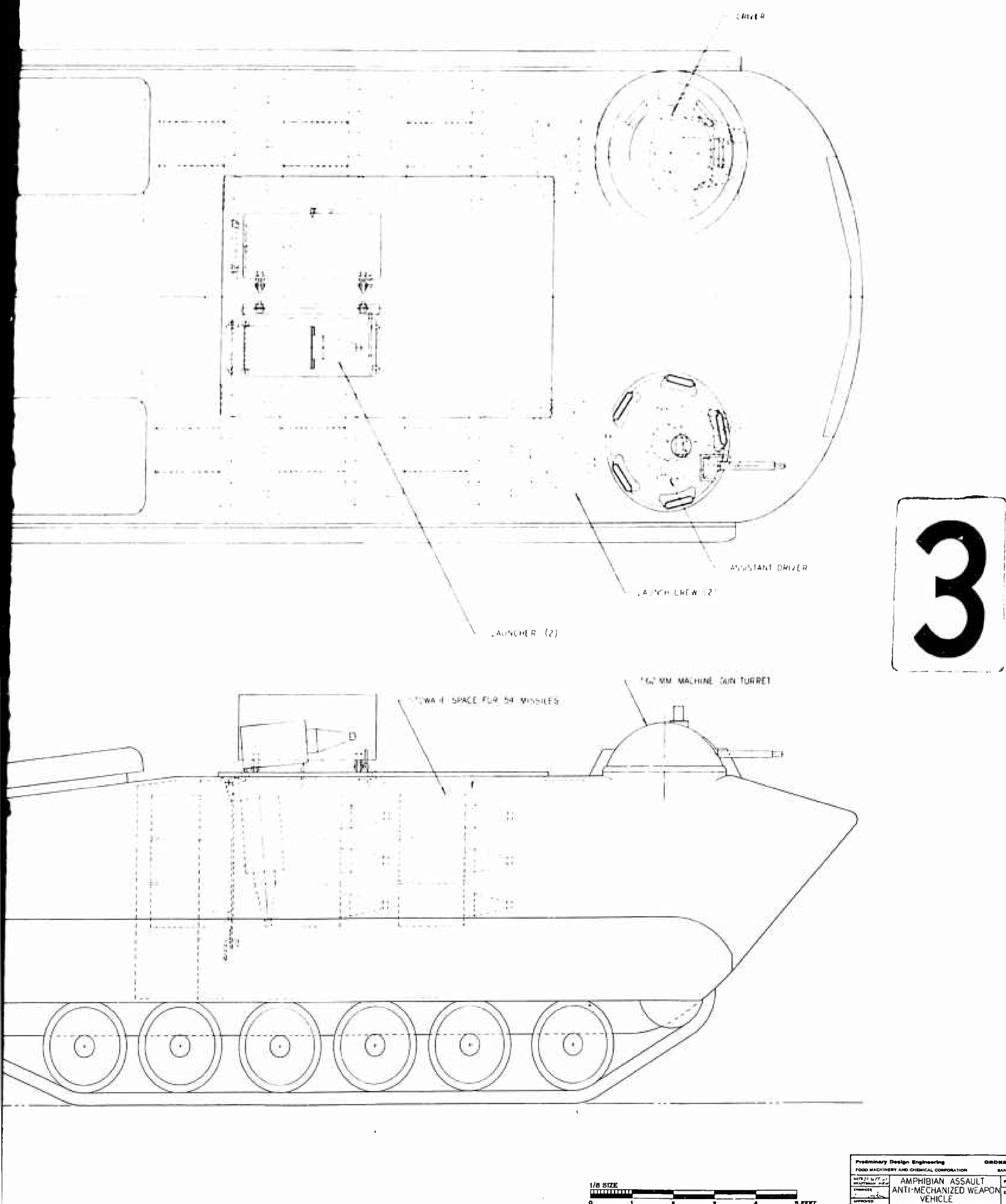

CRANE
FRONT FAIR-LEAD
3
1/8 SIZE
0
1
2
3
4
5 FEET
Preliminary Design Engineering
FOOD MACHINERY AND CHEMICAL CORPORATION
ORDNANCE DIVISION
SAN JOSE CALIFORNIA
DATE 25-SEPT 61
APPROVED
SCALE
GRAPHIC
RECOVERY VEHICLE
LVTPXII FAMILY
P A NO 449
DWG NO
1077383
SHEET
OF

Figure 3.14.2

1

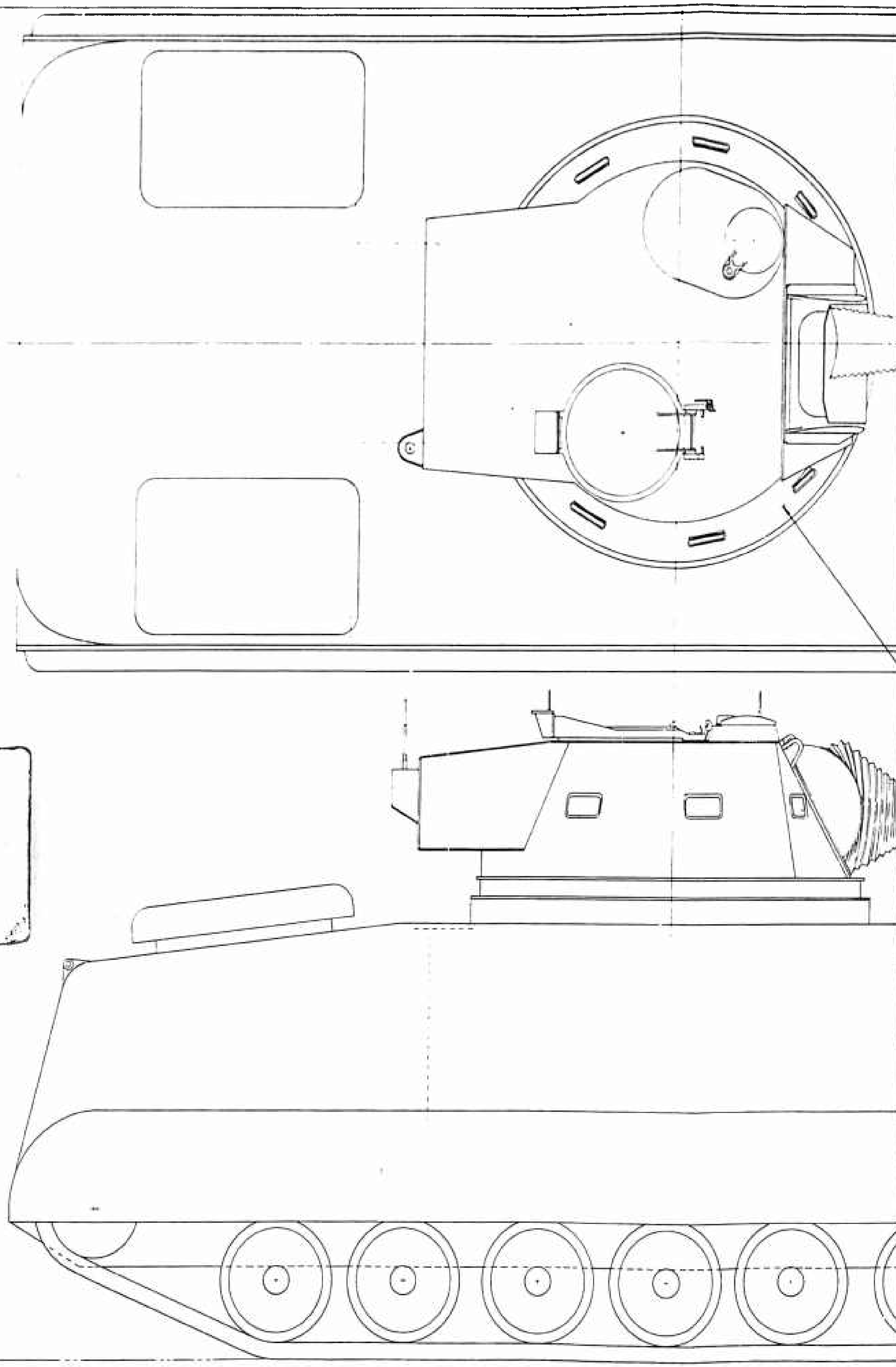



2
LAUNCH CREW (2
LAUNCHER (2)
7.62 MM MACHIN
STOWAGE SPACE FOR 54 MISSILES
1/8 SIZE
0
1
2

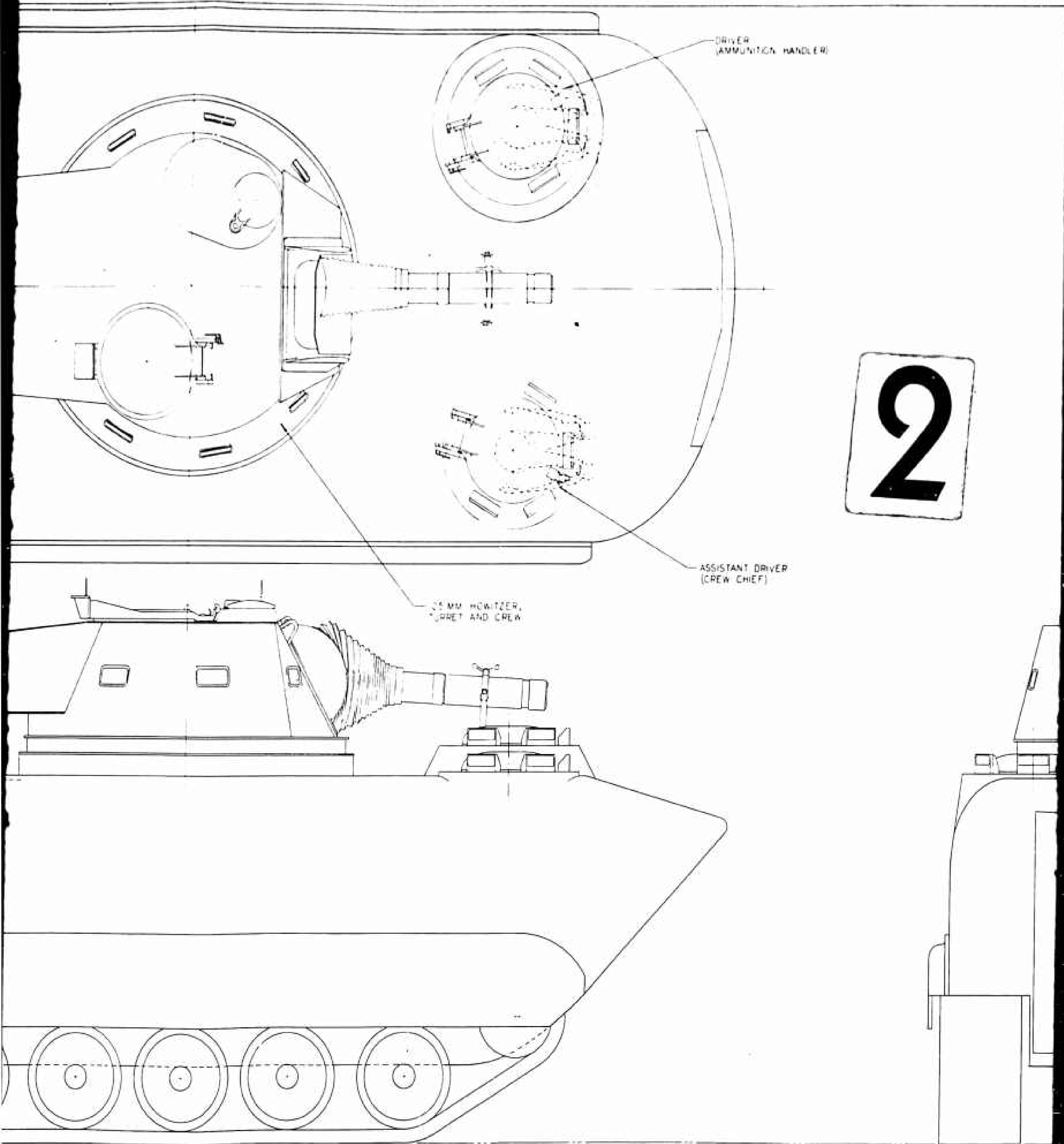


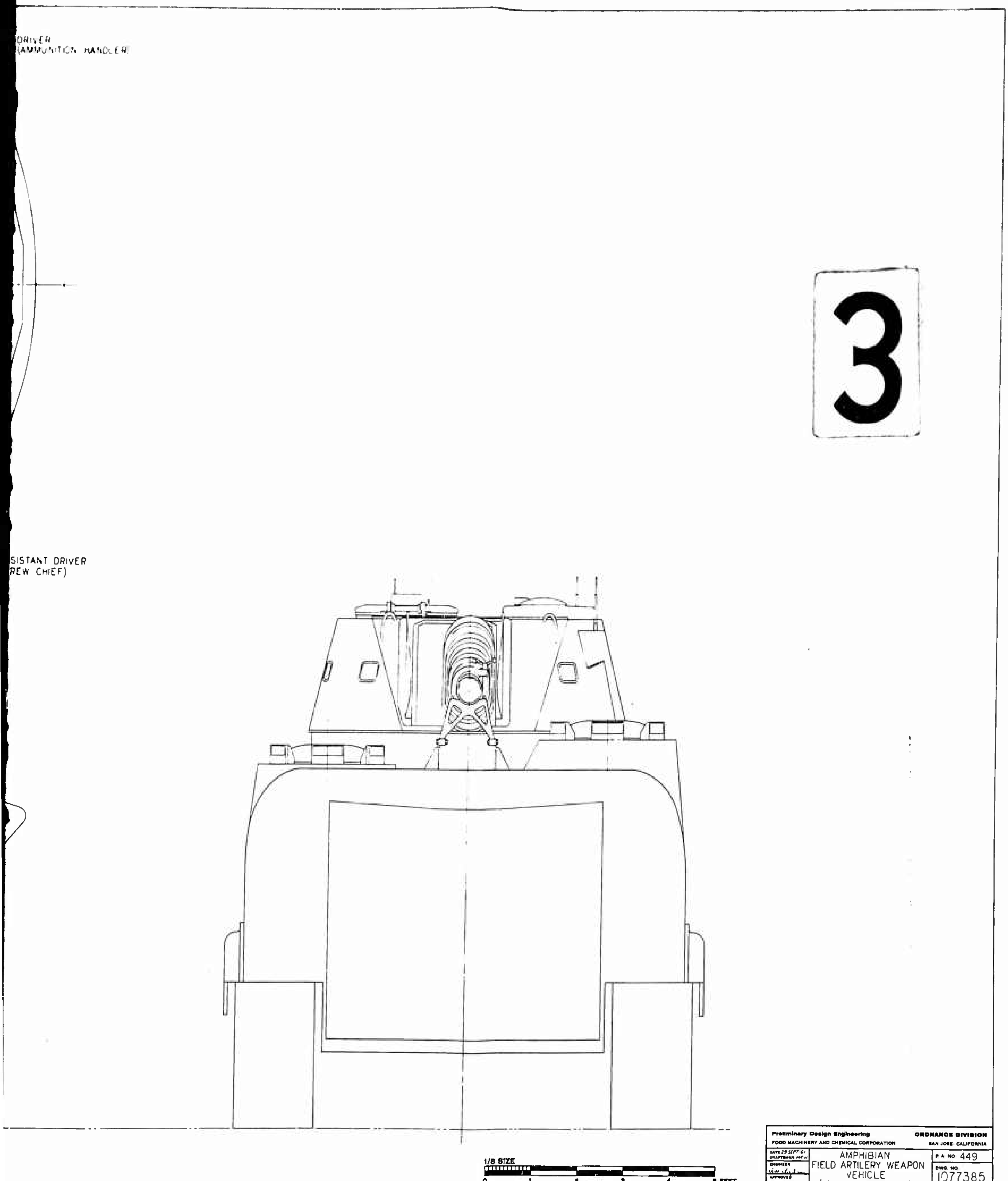
Preliminary Design Engineering FOOD MACHINERY AND CHEMICAL CORPORATION		**ORDNANCE DIVISION** SAN JOSE CALIFORNIA
	AMPHIBIAN ASSAULT ANTI-MECHANIZED WEAPON VEHICLE ('ENTAC' MISSILE) LVTPX11 FAMILY	P A NO 449
		DWG NO 1077384
SCALE GRAPHIC		SHEET OF

Figure 3.14.3



1

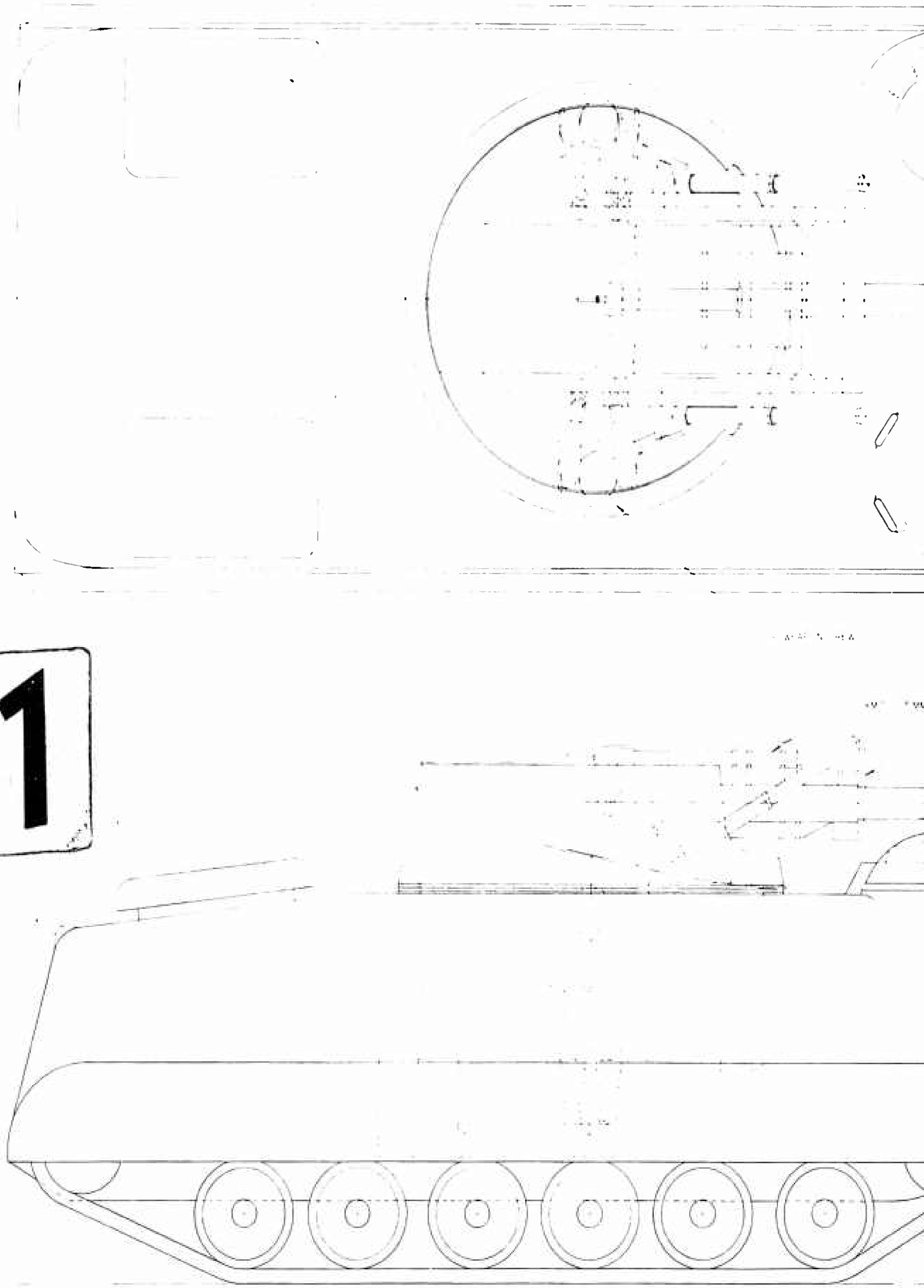

DRIVER
(AMMUNITION HANDLER)
ASSISTANT DRIVER
(CREW CHIEF)
MM HOWITZER,
URRET AND CREW
2

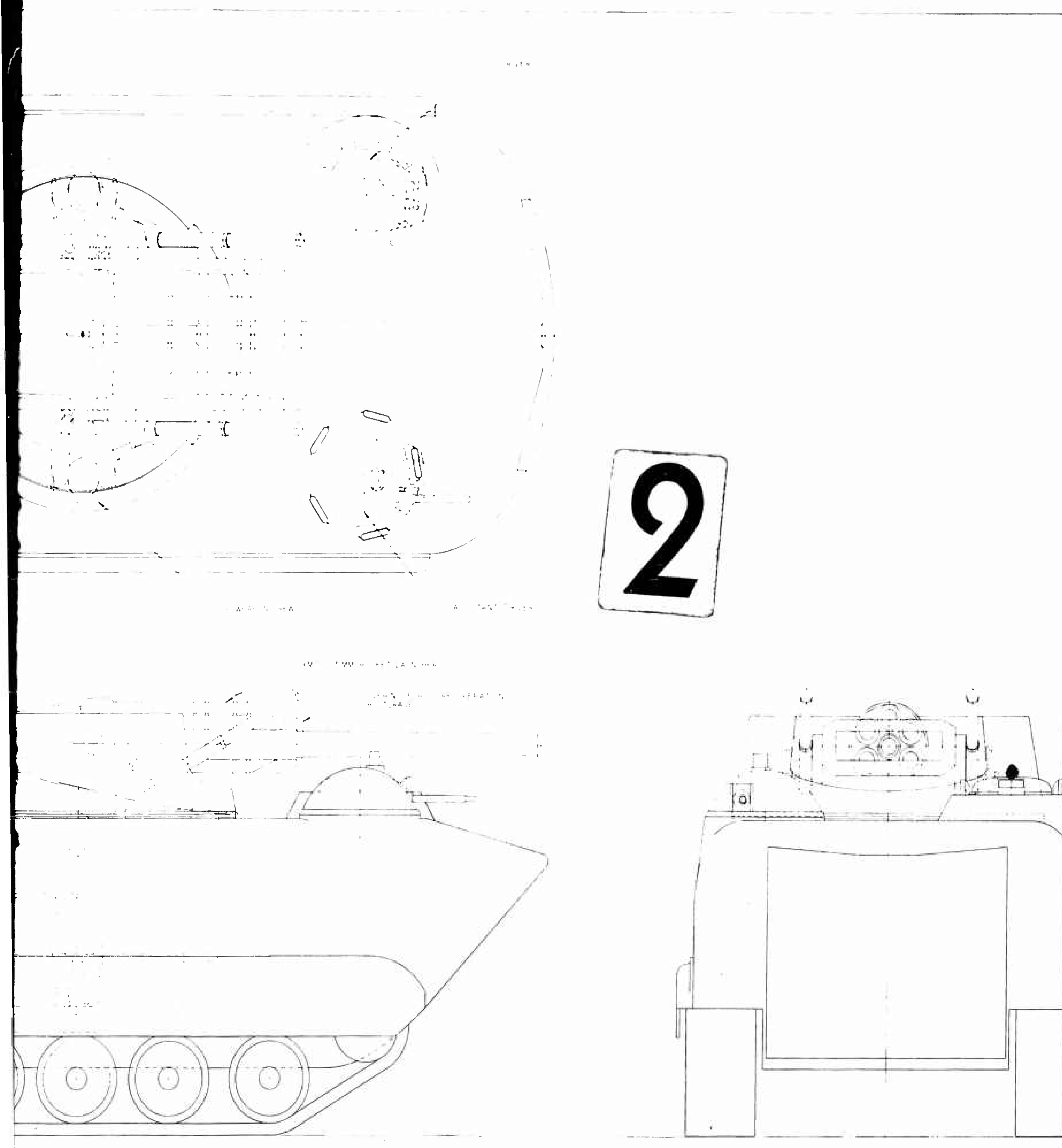


Preliminary Design Engineering FOOD MACHINERY AND CHEMICAL CORPORATION		ORDNANCE DIVISION SAN JOSE CALIFORNIA
DATE 29 SEPT 61 DRAFTSMAN MKW	AMPHIBIAN FIELD ARTILERY WEAPON VEHICLE (105 MM HOWITZER) LVTPX 11 FAMILY	P A NO 449
ENGINEER		DWG. NO 1077385
APPROVED		
SCALE SIZE GRAPHIC		SHEET OF

Figure 3.14.4

1





2

1/8 SIZE
0 1 2 3

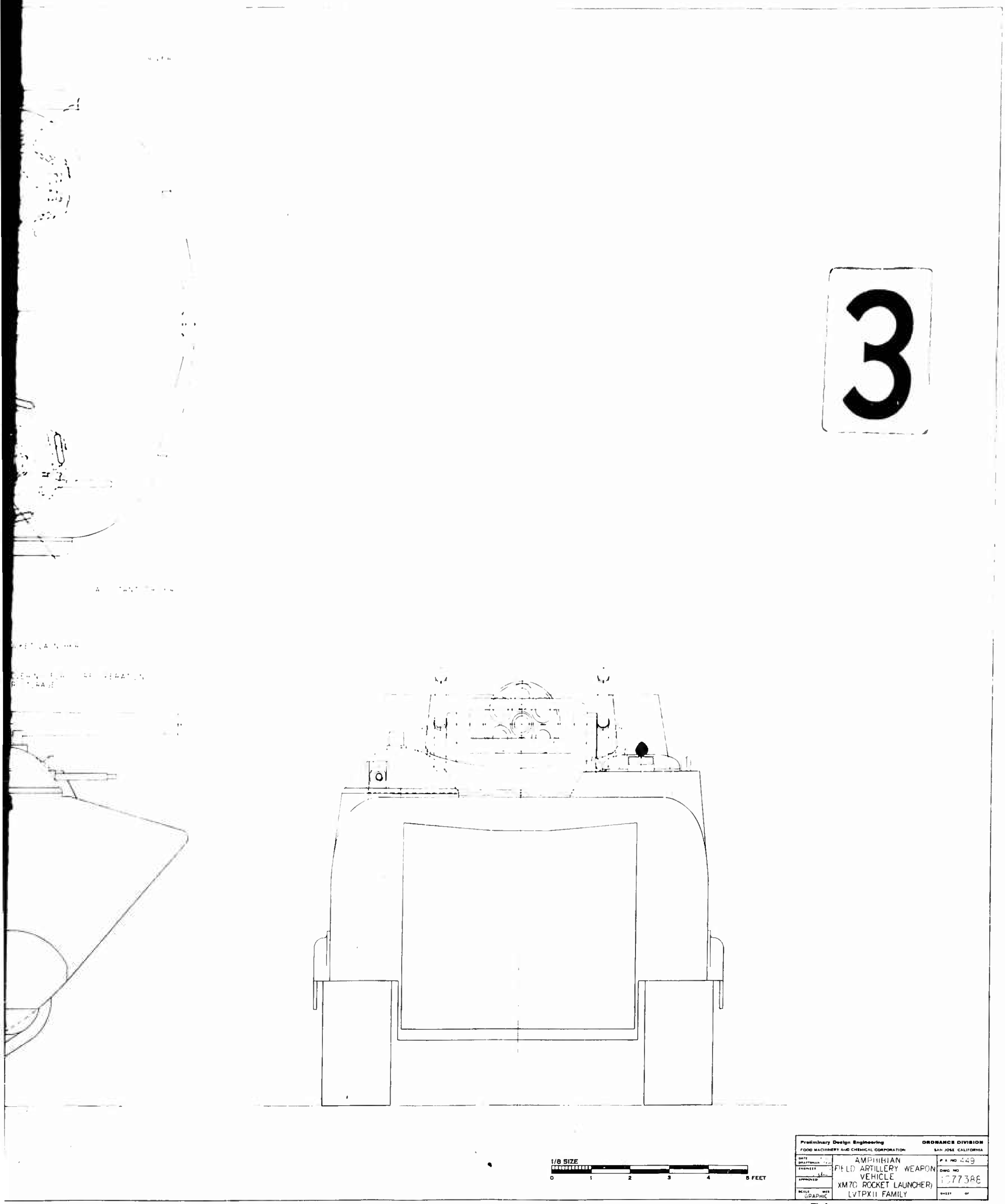
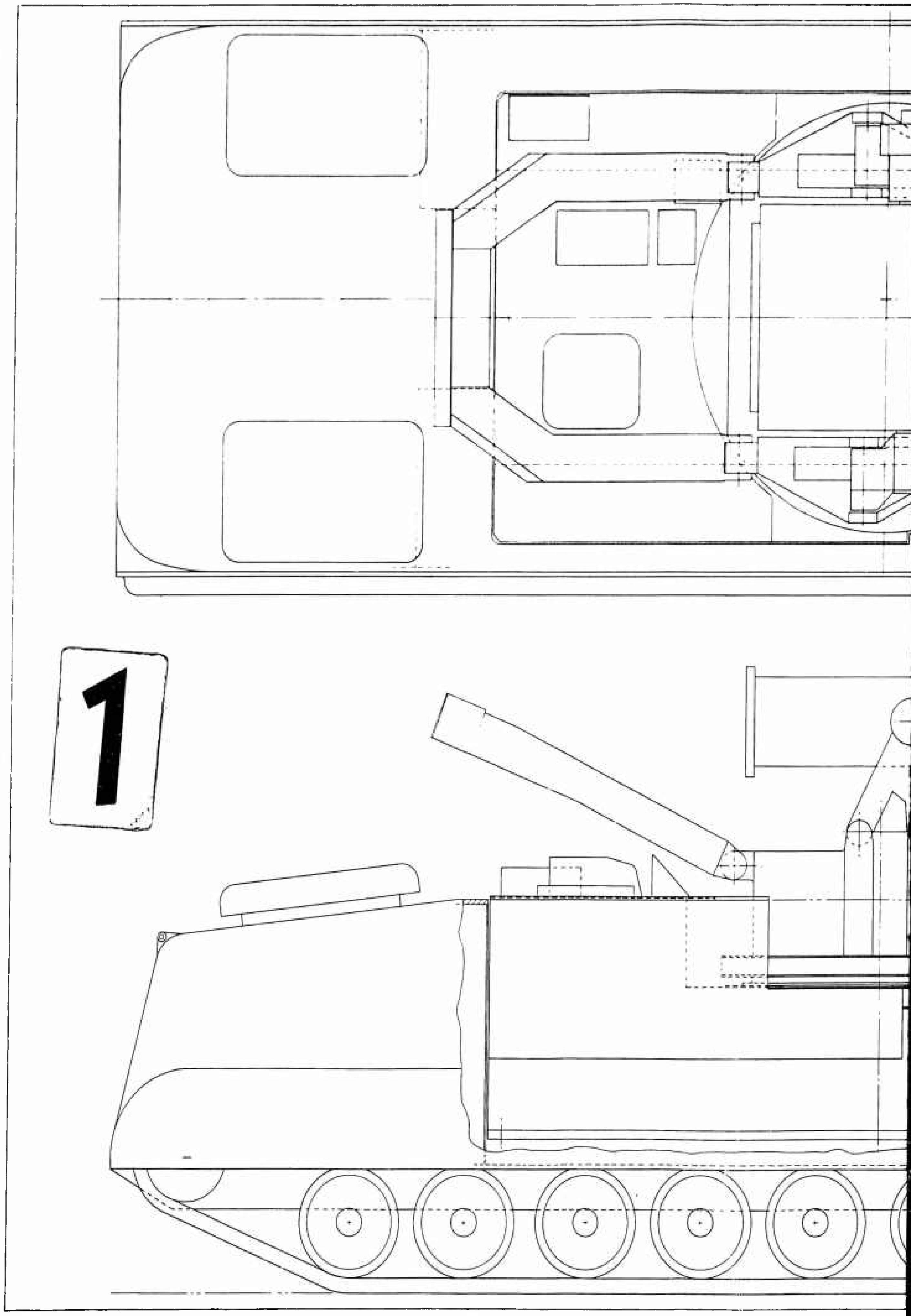
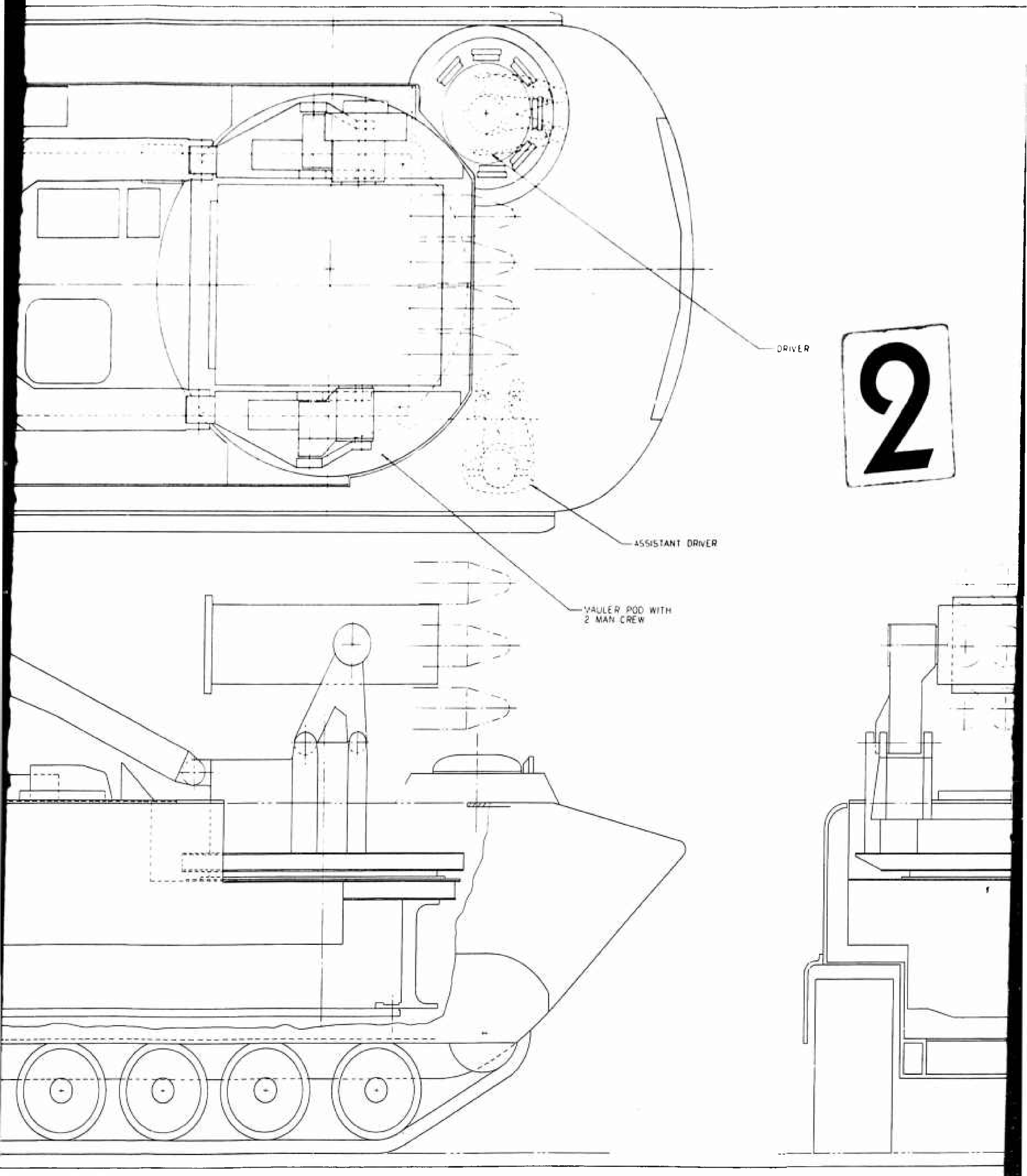

3
1/8 SIZE
0
1
2
3
4
5 FEET
Preliminary Design Engineering
FOOD MACHINERY AND CHEMICAL CORPORATION
ORDNANCE DIVISION
SAN JOSE CALIFORNIA
DATE
DRAFTSMAN
ENGINEER
APPROVED
SCALE
GRAPHIC
AMPHIBIAN
FIELD ARTILLERY WEAPON
VEHICLE
XM70 ROCKET LAUNCHER)
LVTPX11 FAMILY
P A NO 449
DWG NO
C77386
SHEET
OF

Figure 3.14.5



1


DRIVER
ASSISTANT DRIVER
VAULER POD WITH
2 MAN CREW
2

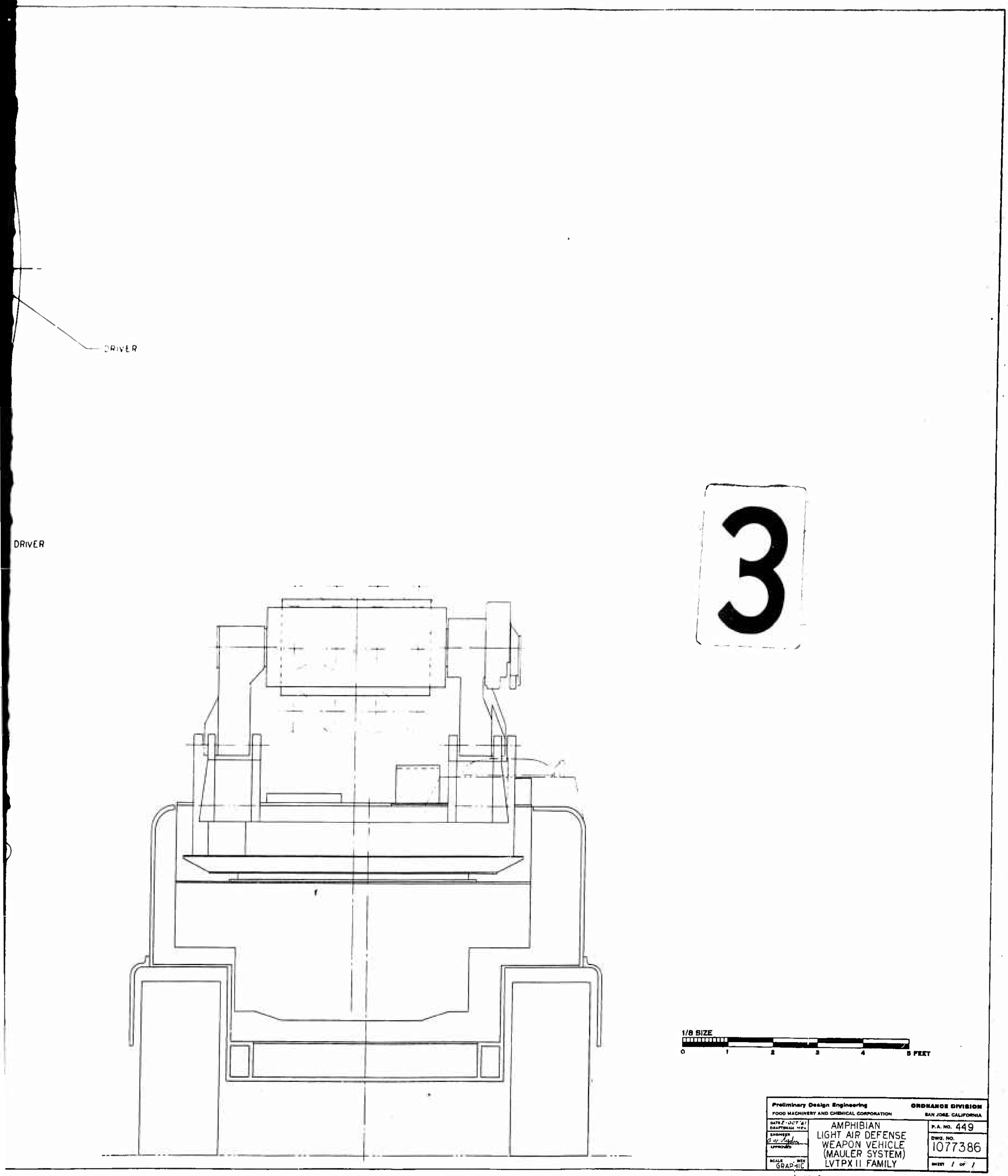
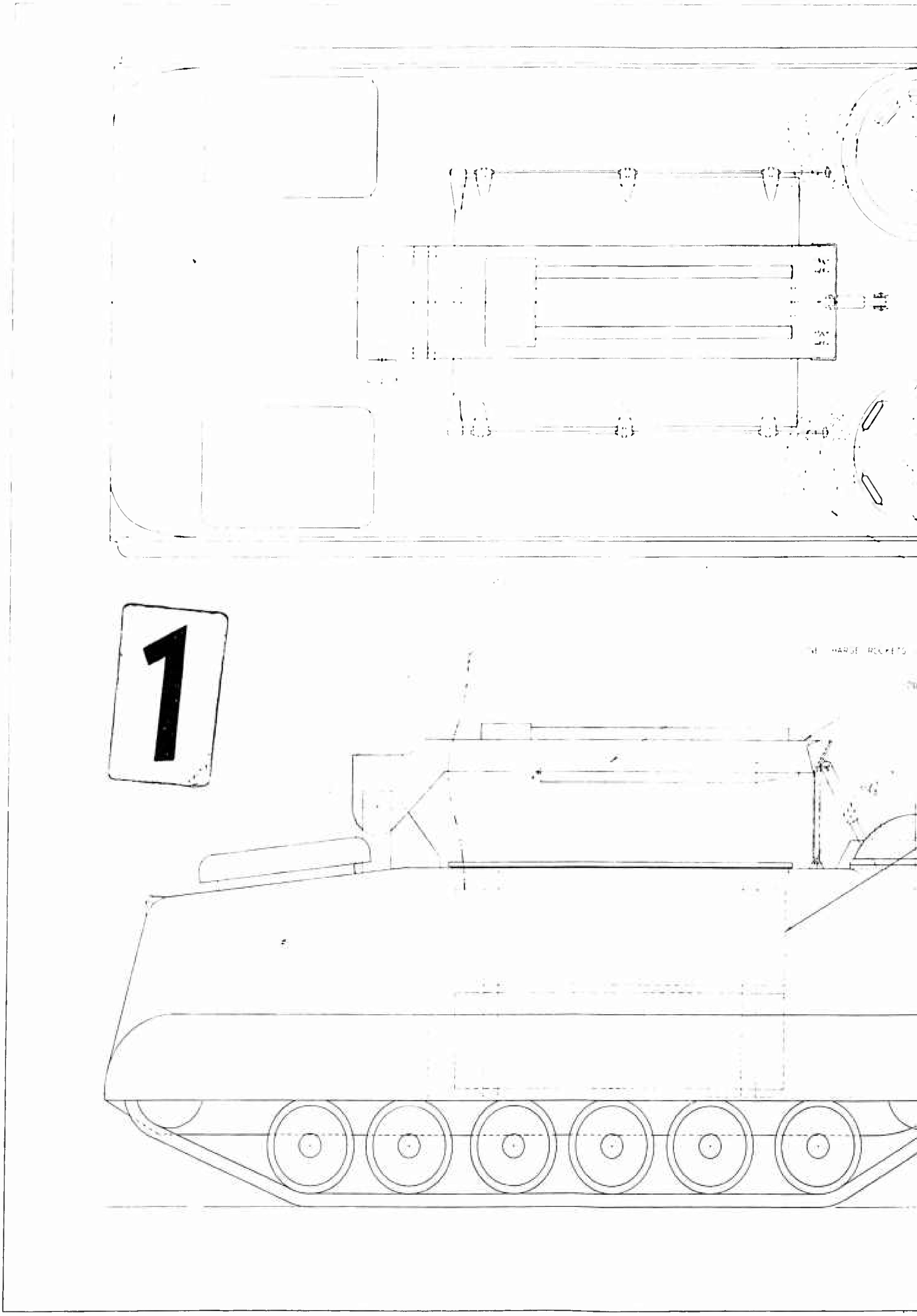
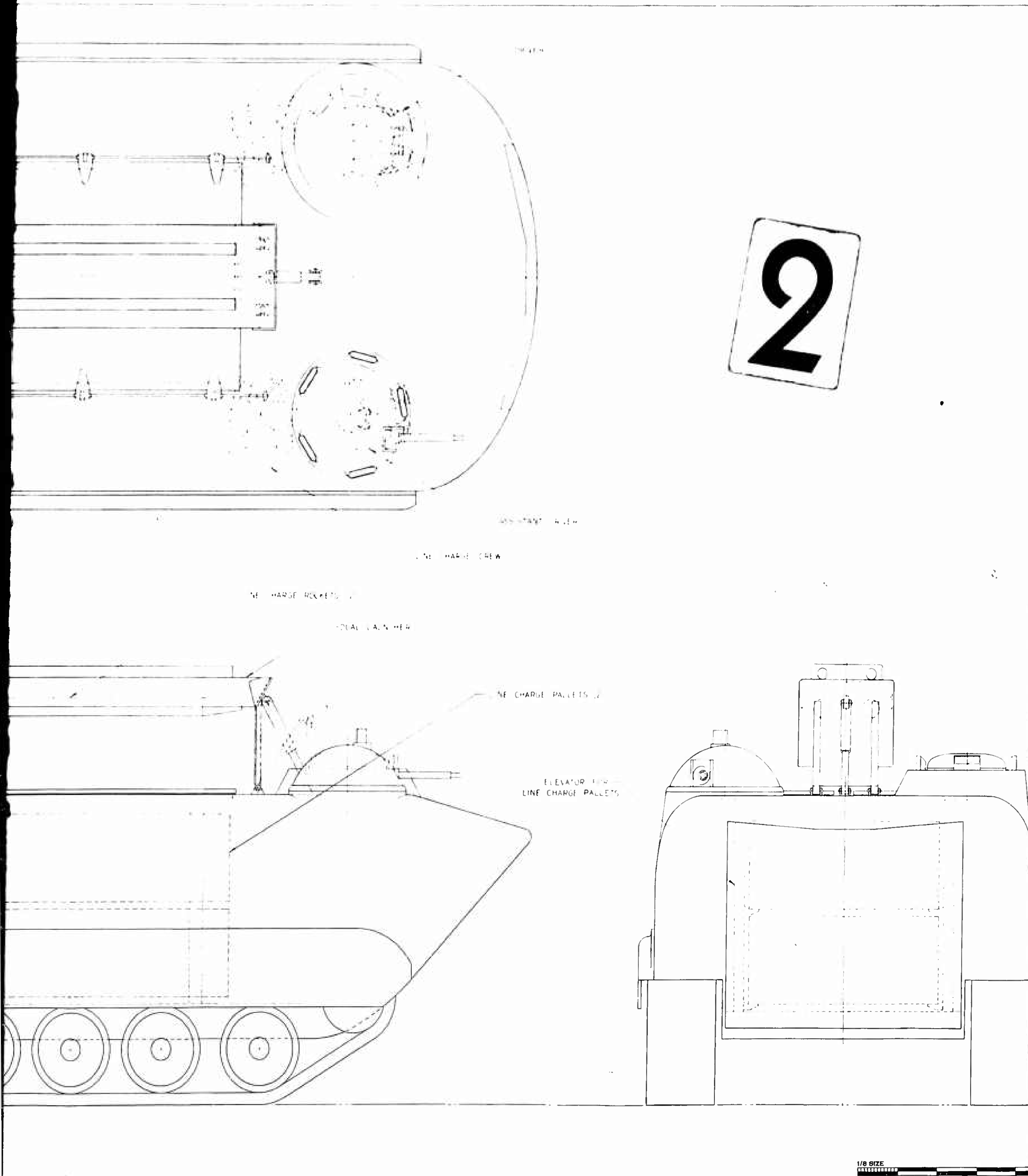
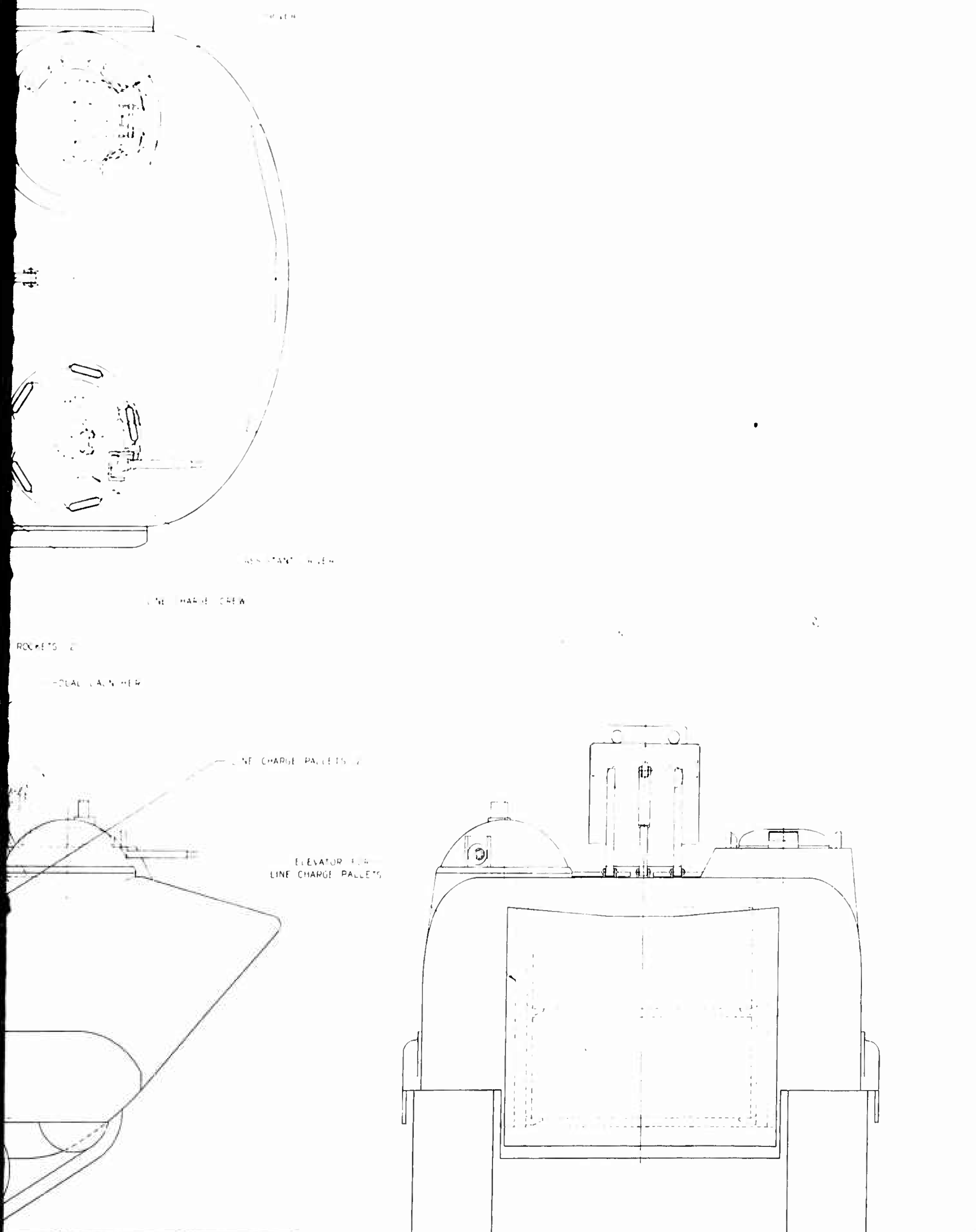

DRIVER
DRIVER
3
1/8 SIZE
0 1 2 3 4 5 FEET
Preliminary Design Engineering
FOOD MACHINERY AND CHEMICAL CORPORATION
ORDNANCE DIVISION
SAN JOSE, CALIFORNIA
DATE 2-OCT '61
AMPHIBIAN
LIGHT AIR DEFENSE
WEAPON VEHICLE
(MAULER SYSTEM)
LVTPX II FAMILY
P.A. NO. 449
DWG. NO. 1077386
SCALE GRAPHIC
SHEET 1 OF 1

Figure 3.14.6


1


2
ELEVATOR FOR
LINE CHARGE PALLETS
1/8 SIZE



3

Preliminary Design Engineering FOOD MACHINERY AND CHEMICAL CORPORATION		ORDNANCE DIVISION SAN JOSE CALIFORNIA
SCALE GRAPHIC	ENGINEER MINE CLEARANCE VEHICLE LVTPX 11 FAMILY	P A NO 449 DWG NO 1077387

Figure 3.14.7

SECTION IV

DEVELOPMENT PLAN

4.1 SCHEDULE

This section describes a program of seven phases covering the development of the LVTPX11. These phases are as follows:

- I Design
- II Manufacture Engineering Prototypes
- III Evaluation and Testing
- IV Incorporate Revisions
- V Preproduction Prototypes
- VI Testing
- VII Production

The schedule for accomplishing this program, shown in Figure 4.1, is based upon FMC's many years of experience in the field of vehicle design, development, and manufacturing. This schedule will permit the delivery of the first production vehicle 2 years and 8 months after the award of the initial design contract.

4.2 DISCUSSION

It has been assumed that the end result of the current concept studies will be the issuance of "Development Characteristics" for the LVTPX11 outlining the desired features from each of the studies, and the award of a development contract will be based upon a firm concept embodying these features. The following development plan is based upon these assumptions.

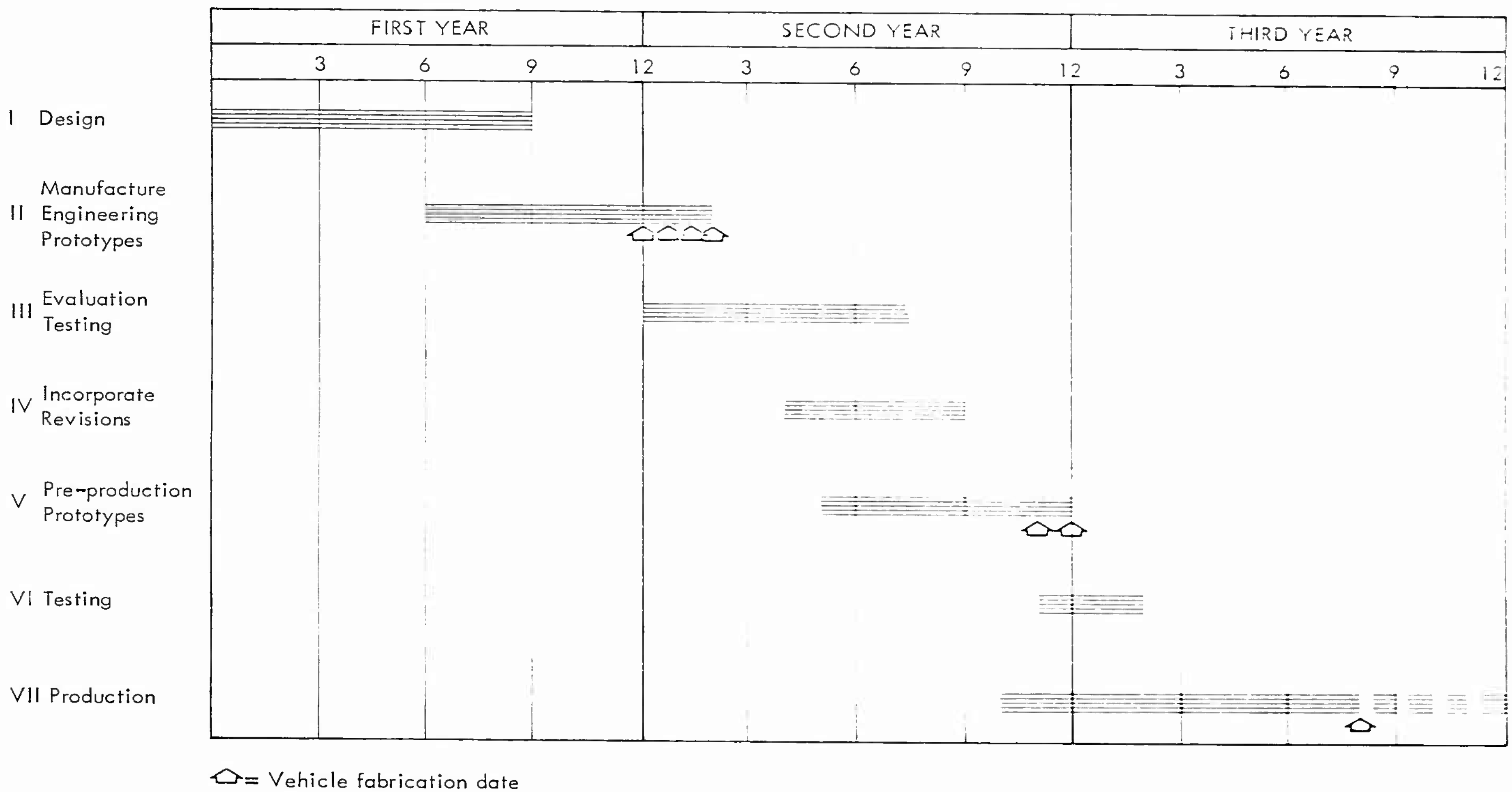


FIGURE 4.1 PROGRAM SCHEDULE

4.2.1 Phase I - Design

This phase would be devoted to the design finalization, including detail design layouts and calculations, preparation of vehicle mock-ups, detailed shop drawings, and process and operations specifications. After approval by the Bureau of Ships, the drawings and specifications would be released to the shops for fabrication.

This phase constitutes a nine-month interval, as shown in the Development Schedule, Figure 4.1.

4.2.2 Phase II - Manufacture Engineering Prototypes

In order to expedite the start of fabrication, a concurrent review of the design formulated in Phase I should be conducted by the Bureau of Ships. This will permit placing orders for materials and long-lead items. As shown in Figure 4.1, releases to the shop could start at approximately the sixth month, and continue throughout Phase I.

Phase II is based upon the fabrication of four engineering prototype vehicles, with the first unit completed at the 12th month, and the fourth at the end of the 14th month.

4.2.3 Phase III - Evaluation Testing

Upon completion of the first prototype vehicle, an evaluation and testing program of 7-1/2 months is scheduled. This would include both the manufacturer's engineering tests and acceptance tests by the military.

4.2.4 Phase IV - Incorporate Revisions

Early reports from the engineering and user tests will permit design changes and corrections to be incorporated into the drawings as the tests progress.

4.2.5 Phase V - Preproduction Prototypes

This seven-month phase will cover the preparation of production drawings and specifications and the fabrication of two pilot vehicles. These vehicles, while not produced from production tooling, will permit a check of the production drawings.

4.2.6 Phase VI - Testing

Final evaluation of the vehicle design is covered in this three-month phase, which will be completed 2 years and 2 months after award of the initial design contract.

4.2.7 Phase VII - Production

One year and ten months after the design contract award, production tooling should start. A lead time of ten months is required to permit tooling, procurement of components, incorporation of any final changes from Phase VI, and vehicle fabrication. Thus, the first production vehicle will be completed 2 years and 8 months after the initial design contract award. A review of past vehicle programs at FMC shows this to be a realistic schedule.

SECTION V

SPECIFICATION DISCUSSION

5.1 GENERAL

To briefly show how the proposed designs comply with each specification requirement, this section is organized in the same sequence as the "Development Characteristics for Tracked Amphibian Personnel and Cargo Carrier", realizing the repetition involved with Section III, the main section of the report. Where there are deviations from the specified requirements, reasons are briefly stated, with the evaluation factors and the detailed conclusions reserved for Section III of the report.

The study conclusions are presented as two complete vehicle designs. The first, referred to as the "Maximum Armored Vehicle", Figure 5.1, conforms as closely as possible to the specification, while providing the maximum armor within the 35,000-pound GVW limit. The second, referred to as the "Maximum Water Performance Vehicle", Figure 5.2, offers increased water performance capabilities, with a longer narrower hull and a propeller for increased water propulsion.

5.2 PURPOSE

This vehicle is envisioned as the basic configuration for a family of vehicles that would replace the LVTP5, LVTP5 (CMD), LVTH6, LVTR1, and LVTE1. The LVTPX11 provides sufficient troop, cargo, and artillery lift to support assult elements of a Marine Division and to provide support, air defense, and mine and obstacle clearance during beach assault and subsequent operations ashore.

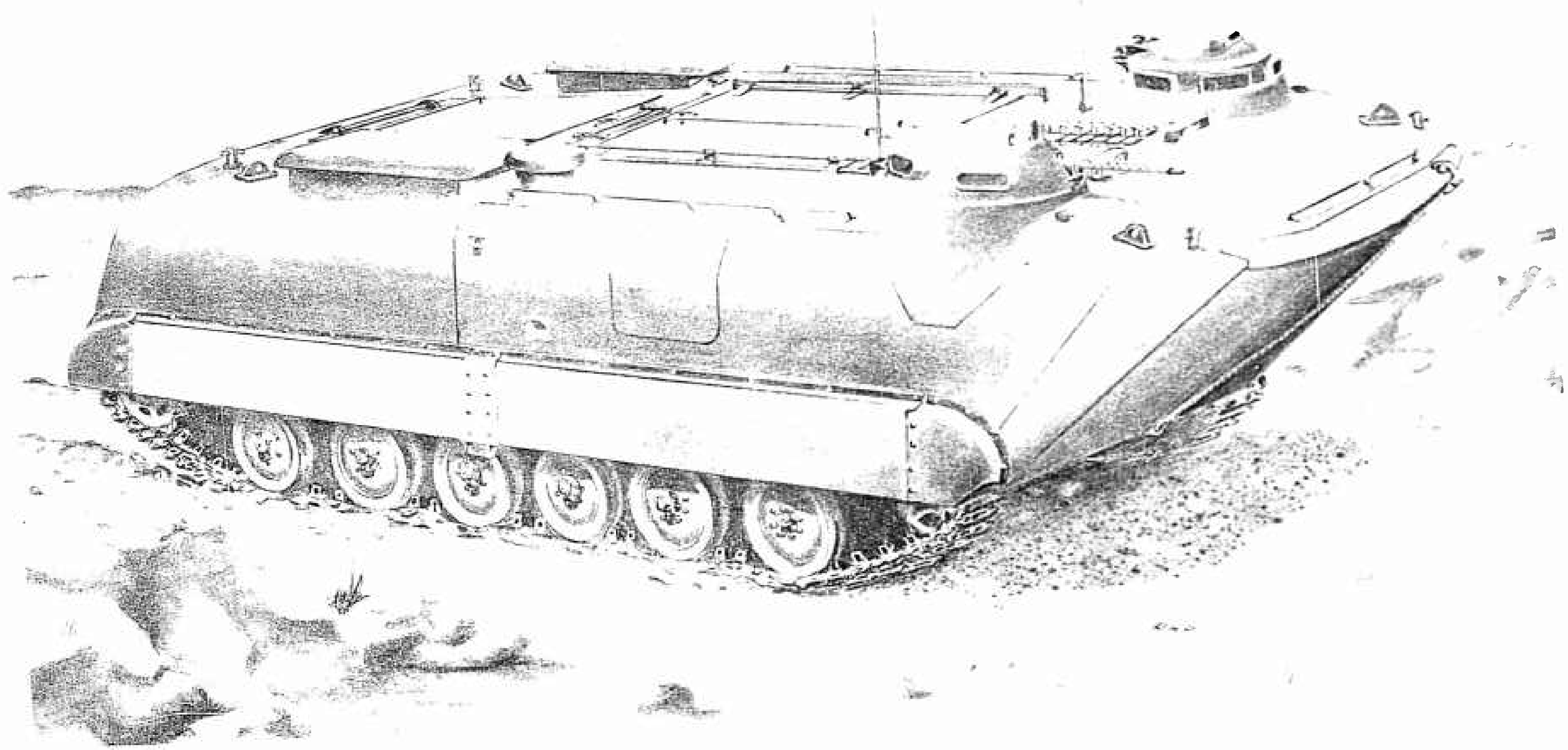


FIGURE 5. .1 MAXIMUM ARMORED VEHICLE

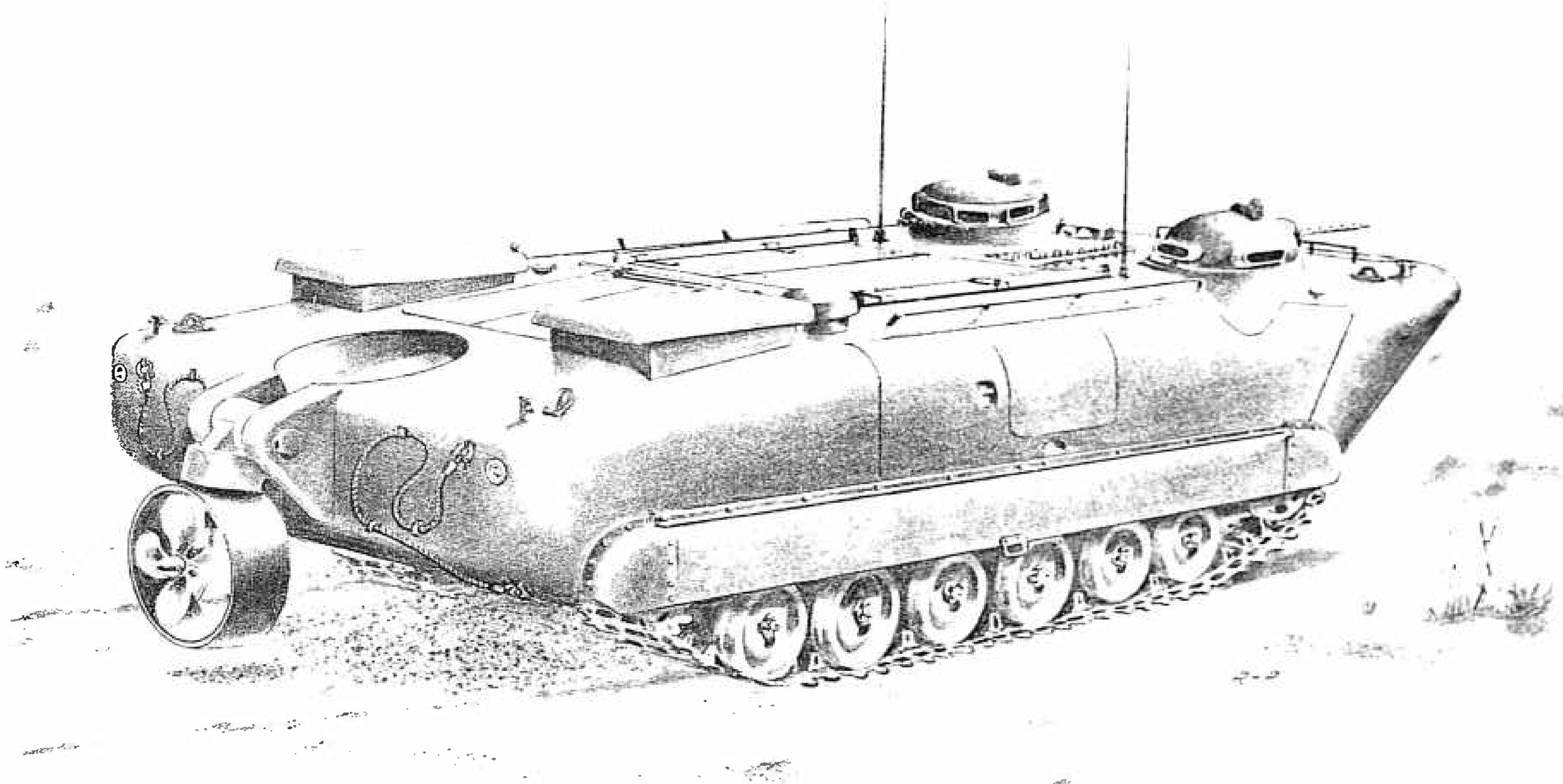


FIGURE 5. .2 MAXIMUM WATER PERFORMANCE VEHICLE

5.3 COORDINATION

Alternate recommendations are made for all factors that do not permit an efficient, simple design.

5.4 CHARACTERISTICS

5.4.1 General Considerations

The recommendations resulting from this study emphasize:

- Simplicity
- Long trouble-free life
- Ease of maintenance
- Economy of operation

The Concept Study was based upon 80% land and 20% sea operation, and every effort has been exerted to improve the performance beyond existing LVT's wherever possible.

In design, full consideration was given to economic manufacturing procedures for production-line fabrication. In selecting major components and materials, the first choice is those items that are most suitable and which will be sufficiently developed for incorporation into the vehicle within the proposed schedule, which calls for vehicle production in 1965.

It is recognized, however, that many components or systems now in the early stages of development may make significant contributions to the over-all vehicle at a later date. Some of these items could be developed on an accelerated schedule, but the program cost would be very high. Among the items in

General Considerations (Continued)

the development phase are the following:

- Hydrostatic transmissions
- Electric drives
- Gas turbines
- Band and block tracks
- Armor materials
- Hydropneumatic and torsilastic suspensions

5.4.2 Special Considerations

The basic hull, power train, and suspension arrangement are adaptable to other special-purpose vehicles, such as:

- Command Vehicle
- Recovery Vehicle
- Amphibian Assault/Antimechanized-Weapon Vehicle
- Amphibian Field-Artillery-Weapon Vehicle
- Amphibian Light-Air-Defense-Weapon Vehicle
- Engineer Mine-Clearance Vehicle

5.4.3 Operational Characteristics

- Payload - The reduced rated capacity of 6,000 lb is equivalent to the weight of 27 fully equipped troops, at 220 lb each. This permits the addition of 4,000 lb of armor to the hull without exceeding the 35,000 lb GVW. However, for intermittent operation, the vehicle may be loaded to 10,000 lb, at a reduced performance level as discussed in Section 3.6.

Operational Characteristics (Continued)

- Gross Vehicle Weight - 35,000 lb
- Troop Capacity - 27 fully equipped troops
- Crew - 2

5.4.3.1 Water Performance

- Speed (mph)

Speed (mph)	Forward	Reverse
Maximum Armored Vehicle	7 to 7-1/2	3-1/2 to 4
Maximum Water Performance Vehicle	9 to 9-1/2	4-1/2 to 5

- Range - The 125-gallon fuel supply permits a range of 62 miles for the Maximum Armored Vehicle at maximum speed. The Maximum Water Performance Vehicle has a range of 78 miles at maximum speed, or 156 miles at a reduced speed of 7-1/4 mph.

- Surfability - To provide the capability of negotiating 10-foot plunging breakers, in either seaward or shoreward direction, considerable emphasis has been placed upon the engine selection, air intakes, and vehicle stability.

- Stability - The LVTPX11 is laterally stable under all conditions of loading and is capable of righting from a 90° roll with full pay-load.

5.4.3.2 Land Performance

Improved roads - 40 mph

Operational Characteristics (Continued)

- Cross-country - 20 mph, under average conditions, but extremes of terrain influence speed. Cross-country speed is usually determined by the degree of driver comfort afforded by the suspension system. The suspension design used provides for increased roadwheel travel, thus permitting a softer suspension than existing LVT's.

- Gradability - 70% forward slope and 60% side slope

- Stability - The vehicle is capable of executing a 90° turn on a 60% side slope, with full payload.

- Range - Since the vehicle operating conditions vary between maximum power and the power required for level roads, these conditions have been averaged to provide a range of 250 miles at 25 mph.

- Vertical wall - 29 inches (36 inches desired)

- Trench span - 8 feet (8 feet specified minimum)

5.4.3.3 Terrain and Climatic Limitations

The vehicle presented here is capable of operating in temperate, tropic, and artic zones; over beach and desert sand, coral reefs, shoals, gravel, rocks, snow, and ice; and through forested areas with trees up to 3 inches in diameter.

It will operate in air temperatures ranging from 125°F to minus 25°F, with relative humidity as low as 5% at 125°F air temperature, as high as 97% at

Operational Characteristics (Continued)

temperatures from 80° to 85° F, and as high as 100% at temperatures lower than 80° F.

5.4.3.4 Physical Characteristics

	Maximum Armored Vehicle	Maximum Water Performance Vehicle
Length	285"	313"
Width	126"	120"
Height	102"	102"
Ground clearance	18"	18"
Approach angle	46°	41°
Departure angle	49°	49°

5.4.3.5 Required Characteristics

- Hull - After an analysis of all possible types of armor, a composite armor of aluminum and titanium, offering the equivalent of 2 inches of aluminum, has been selected for the LVTPX11. The selected hull designs are shown in Figures 5.1 and 5.2.

  The welded aluminum hull is equipped with a front ramp and rear power train, to provide a bow-up trim during water operation under all conditions of loading. The hull is divided into an engine compartment and a troop compartment, with the troop compartment equipped with fold-away seats. Cargo doors are provided in the top deck for loading cargo alongside ships and docks.

  Maximum visibility is provided for the two-man crew. Side hatches provide emergency exit for both crew and personnel, and boarding

Operational Characteristics (Continued)

steps for the crew are provided on both sides of the hull. Quick-release tow hitches, operable from the top deck, and tow cables are provided on both ends of the vehicle. Lifting eyes and mooring bitts are provided on each corner of the deck. Safety rails and grab handles are provided for the safety of the crew and troops. Cargo hold-downs are spaced throughout the troop compartment for securing cargo. Stowage brackets and clips are provided for securing spares, armament, and OVE.

Nonskid deck material is used inside and topside.

- Power train - A mechanical drive train provides the lightest possible drive train, at the lowest development cost, within the vehicle development time-frame.

  The selected drive train, weighing 3,890 lb, consists of the Cummins V8-300 water-cooled diesel engine, the Allison XTG-250 power train, and FMC-designed final drives.

  An alternate drive train, weighing 3,405 lb, and consisting of the Lycoming AVM-625 air-cooled diesel engine, the Allison XTG-250 power train, and FMC final drives, has been described.

  The engine aspiration and exhaust system is designed to prevent collection of fumes in the crew and troop compartments. A scavenging system clears fumes from the fuel storage areas.

- Controls - Vehicle controls are as simple as possible, with the recommended vehicle utilizing the same steering controls for both land and marine operation.

Operational Characteristics (Continued)

- Electrical - Service lights, providing both service and blackout lighting, navigation lights, and a signal searchlight are incorporated in the design. Service and blackout lights are provided for the troop and crew compartments. A slave receptacle is incorporated for an auxiliary starting aid.

- Auxiliary systems - Two electric and two hydraulic bilge pumps provide a pumping capacity of 600 gpm. The two electric pumps offer emergency bilge pump capability in the event of engine or hydraulic system failure, and the hydraulic pumps minimize the electrical requirements. These pumps are located to permit pumping under all conditions of vehicle trim.

  A 10 lb CO_2 fixed fire extinguishing system, operable from the driver's position or from the top deck, discharges in the engine compartment. A 5 lb portable extinguisher is located in the troop compartment.

  A winterization kit is provided for personnel comfort and cold weather starting.

  The 125-gallon fuel cell is equipped with an extendable filler neck for refueling at sea in rough water.

  An M8A2 Chemical Biological collective protective device is incorporated for the vehicle crew.

Operational Characteristics (Continued)

A turret mounting a 7.62mm machine gun provides a 360° field of fire. Stowage is provided for 1,000 rounds of belted ammunition and a ground mount for the gun.

5.4.3.6 Desired Characteristics

Lightweight materials are recommended in all possible areas to effect maximum weight savings.

5.4.3.7 Landing Force Aspects

The LVTPX11 is capable of being transported to the target area aboard amphibious ships of the LST, LSD, and LPD types.

5.4.4 Radio Frequency Compatibility

Provision is made for mounting of government-furnished radio transmitter-receiver equipment.

MAY 1961

DEVELOPMENT CHARACTERISTIC FOR TRACKED
AMPHIBIAN PERSONNEL AND CARGO CARRIER

1. PURPOSE.

a. Identification Item: The features, characteristics and capabilities stated herein are established as guides for the development of the Tracked Amphibian Personnel and Cargo Carrier.

b. Operational Employment and Effects on Present Equipment:

This vehicle will be used to transport infantry, infantry weapons and cargo from ship to shore and to inland objectives and to provide fire support in amphibious operations. The vehicle is envisioned as the basic configuration for a family of vehicles that would replace the LVTP5, LVTP5(CMD) (Command) LVTH6 (Amphibian Howitzer) LVTR1 (Recovery) and LVTE1 (Engineer mine clearance).

c. Organizational Concept. Units will be organized and equipped with various configurations of this carrier to provide sufficient troop, cargo and artillery lift to support the assault elements of a Marine Division and to provide support, air defense, mine clearance and obstacle clearance during beach assault and subsequent operations ashore.

2. COORDINATION

a. In any instance where attainment of a particular specification contained herein threatens the orderly progress or timely realization of this development, the contractor shall immediately advise the Bureau and shall make appropriate alternative remedial recommendations.

3. CHARACTERISTICS OF SYSTEM, EQUIPMENT, TECHNIQUE AND MATERIAL TO BE DEVELOPED.

a. General design considerations.

(1) Emphasis in design is to be placed on:

(a) Simplicity

(b) Long trouble free life

(c) Ease of maintenance

(d) Economy of operation.

(2) This vehicle will operate ashore 80% of its life and afloat 20% of its life. Optimum land performance is desired; commensurate with the requirements for simplicity, long trouble free life, ease of maintenance and economy of operation. Full consideration in design must be given to compatibility with economic manufacturing procedures for production line manufacture of quantities in excess of 100 vehicles. The design should be such that any qualified manufacturer could reasonably be expected to enter into competitive bidding for quantity production. The design should not incorporate features which could logically restrict production of the vehicle to the peculiar capabilities of a specific firm. In selecting major components such as power plant, power train, suspension and track special consideration should be given to new developments and materials. The machinery arrangement should provide enough flexibility to take advantage of newly developed items which prove to be desirable for incorporation in the prototype vehicles.

b. Special considerations.

(1) The basic hull, power train and suspension arrangement should be adaptable to other special purpose vehicles such as:

(a) Command vehicle.

(b) Recovery vehicle.

(c) Amphibian Assault/Anti-Mechanized Weapon Vehicle.

(d) Amphibian Field Artillery Weapon Vehicle.

(e) Amphibian Light Air Defense Weapon Vehicle.

(f) Engineer mine clearance vehicle.

c. Operational characteristics.

(1) Payload - 10,000 lbs. exclusive of crew, fuel, OVE and OVM.

(2) Gross Vehicle Weight - Minimum practicable, target 35,000 lbs.

(3) Troop Capacity - 27 fully equipped Marines.

(4) Crew - 2 (crew chief - driver, assistant driver).

(5) Water Performance

(a) Highest forward water speed consistent with the power required for the specified land performance.

(b) Highest reverse water speed consistant with simplicity of power train and required maneuverability in the water.

(c) Surfability - capable of negotiating 10 foot plunging breakers, with a full payload, going both seaward and ashore.

(d) Stability - Laterally stable under all conditions of loading and capable of righting from a 60 Degree roll to port or starboard while fully loaded.

(e) Range - minimum 50 miles acceptable.

(6) Land Performance.

(a) Improved Roads - 40 MPH

(b) Cross Country - 20 MPH

(c) Gradability - 70% forward slope and 60% side slope.

(d) Stability - must be capable of executing a 90 degree turn with full payload on a 60% side slope.

(e) Range - minimum 250 miles at 25 MPH

(f) Vertical wall - 36 inch

(g) Trench span - 8 foot minimum acceptable.

(7) Terrain and Climatic Limitations - The vehicle shall be capable of operating:

(a) In temperate, tropic and arctic zones.

(b) Over beach and desert sand, coral reefs, shoals, gravel, rocks, rice paddies, snow, ice, swamps, tundra, muskeg and through forested areas with trees up to 3 inches in diameter.

(c) In air temperatures ranging from 125°F. to minus 25°F. with relative humidity as low as 5% at air temperatures of 125°F., as high as 97% at temperatures from 80° to 85°F., and as high as 100% at all temperatures lower than 80°F.

d. Physical Characteristics

(1) Dimensions

(a) Length - Minimum Practicable

(b) Width - Minimum practicable; maximum allowable 10 feet 6 inches.

(c) Height - Minimum practicable

(d) Ground Clearance - 18 inches

(e) Approach and Departure angles 30°

e. Required Characteristics

(1) Hull to be inherently bouyant

(2) A ramp or other means will be provided for ease in loading troops and cargo. Controls for the ramp to be situated so as to be operable by the driver.

(3) Troop seats desired. If used they shall be of the quick fold away type so that the vehicle can switch from the personnel carrier role to the cargo carrier role with a minimum amount of time and effort.

(4) Infra-Red night driving equipment is to be incorporated in the design.

(5) Headlights and tail lights are required (normal and blackout types). These lights are to be normally carried inside the vehicle and mounted in place when required.

(6) Navigation lights for operating in inland and coastal waters of the U. S. are required. Should be stowed in the vehicle and mounted externally when required.

(7) Means shall be provided to allow cargo and personnel loading alongside ships and docks.

(8) Adequate means for escape from the vehicle shall be provided for both the normal and upside down condition.

(9) Fuel - The [illegible] of using at least one of the follow[illegible] combat, JP4, JP5, Navy Diesel Fuel, Army compression fuel. A multi-fuel capability is desirable.

(10) Maximum all around visibility under all driving conditions is required. Similar provisions to be incorporated for the assistant driver if such a station is incorporated in design.

(11) Towing devices:

(a) Quick release tow hitches are required fore and aft. These hitches should be operable by a crewman on the topside of the vehicle.

(b) A towing cable, mounted externally, will be provided.

(12) Adequate bilge pump capacity shall be provided. To be continuous operating when the main engine(s) is operating. Bilge pump suction lines to be arranged so that a sever list to either side or a severe down by the bow (or stern) trim will not adversely affect the operation of the bilge pumps.

(13) Fire extinguishers:

(a) An adequate fire extinguisher system is required. Capacity to be dependent upon the risk (i.e., type of fuel used gasoline, diesel, JP 4, etc.) System to be operable from inside and outside the vehicle.

(14) Lifting devices. Lifting eyes and a lifting sling are required, capable of lifting the vehicle at gross vehicle weight. (The sling is not to be OVE, stowage provisions not required).

(15) Mooring Devices: Four mooring bits are required topside, one near each corner of the vehicle.

(16) Safety rails and Grab Handles: to be provided inside and topside for the safety of crew and embarked personnel.

(17) Cargo Hold downs are to be provided, arranged in such a manner so as to provide a maximum of flexibility in securing various types of cargo.

(18) Ventilation of the Crew/Cargo compartment is required for the comfort of personnel during operation in tropic and temperate ~~zone operation~~, both afloat and ashore.

(19) If highly volatile fuel is used consideration must be given to the requirement to scavenge those closed spaces where fuel leakage will present a safety hazard.

(20) Signal Searchlight: A portable signal search-light with detachable color lens will be provided. This light will normally be carried inside the vehicle with provisions for exterior mounting when required.

(21) Inside lights, both white and blackout are required, to allow suitable illumination of the crew space, cargo/troop space and engine compartment.

(22) Boarding steps on each side of the vehicle are required. These steps to be recessed into the hull and to be of such design that sand, debris and extraneous matter cannot collect in them.

(23) Compass: A low cost, reliable, easily compensated compass will be provided.

(24) Cold weather starting aids and heaters for the comfort of embarked personnel are required but may be provided in kit form.

(25) Stowage brackets, cabinets and boxes are required for crew weapons, tools, equipment, on vehicle spares, armament and ammunition normally carried on the vehicle.

(26) Auxiliary starting aid shall be provided to allow one vehicle to start a similar vehicle.

(27) Refueling at sea: The vehicle must be capable of being refueled at sea in rough water without shipping water into the fuel fill opening.

(28) Armament: A turret with sighting equipment, mounting a single 7.62mm machine gun (M73) will be incorporated in the design in such a manner as to give maximum close in support and a 360° field of fire. Provisions for stowage of 1000 rounds of belted 7.62mm ammunition in boxes, plus a ground mount, for the gun is required.

(29) Armor - Sufficient armor to protect the crew and embarked personnel from small arms fire and shell fragments, commensurate with maximum vehicle weight specified.

(30) Chemical - Biological collective protective device for the crew similar to M8A1 or 2 is required. (Passengers will have their own protective masks).

(31) Passive Protection against the Blast, thermal and radiological effects of atomic explosions is required to the maximum extent possible, commensurate with specified vehicle weights.

(32) Controls to be the simplest possible.

(33) Instruments - Warning devices as listed below are the minimum required:

(a) Speedometer (record miles also)

(b) Tachometer (record hours also)

(c) Voltmeter

(d) Fuel level gauge.

(e) Warning lights as required for high coolant temperature or low oil pressure.

(34) Non skid deck covering material inside and top side.

(35) Engine aspiration and exhaust system to be of such a design that dangerous amounts of carbon monoxide cannot collect in the crew and passenger spaces during vehicle operation.

(36) All hatches, closures, doors and topside openings will be sealed against the entry of water.

(37) All hatches, closures, doors and openings will be provided with a means of positive locking from the inside, except one that shall have a provision for locking with a padlock from the outside.

f. Characteristics desired but not required

(1) Designer to make maximum use of fiber glass, high impact plastics and other light weight materials for interior covers, separators, boxes and bulkheads.

(2) Pivot steer.

(3) The transition from water to land (and vice versa) to be made with no requirement for the driver to actuate any special "Water steer" switch or open or close any "Water or land air intake ducts" etc.

g. Landing Force Aspects

(1) This vehicle will be transported to the target area aboard amphibious shipping of the LST, LSD, and LPD types hence it must negotiate the ramps of the various ships or any future amphibious ships in both ahead and astern direction. Bureau sketch 022970 LST 1-1152 class vehicle clearance through

tow, Bureau sketch 022971 LST 1153 class vehicle clearance through bow, LSD 1-27 class vehicle clearance through stern dated 31 December 1959, dimensions for clearances for tank and cargo stowage LST 1173 class, LSD 28-35 class vehicle clearance through stern dated 31 December 1959, and LPD 1 craft stowage information dated 6 January 1960 give pertinent dimensions.

4. RADIO FREQUENCY COMPATIBILITY

a. Provisions for permanent installation, in a waterproof box, of radio transmitter-receiver equipment must be made.

b. It is anticipated that the landing force radio equipment to be government furnished will be either the AN/PRC 47 or Collins Radio Model 618T. Approximate weight and space requirements are as follows:

	Collins 618T	AN/PRC 47
weight	55 pounds	Less than 55 pounds
height	12 inches	15 inches
width	24 inches	30 inches
depth	26 inches	18 inches

c. Antenna base mounts must be provided.