(12)

DTNSRDC-84/005

# DAVID W. TAYLOR NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Maryland 20084

AD-A143 795

## DEVELOPMENT AND TESTING OF A LIGHTWEIGHT ALUMINUM TRACK FOR THE U.S. MARINE CORPS

by


Steven S. Scharf


APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

SYSTEMS DEVELOPMENT DEPARTMENT
TEST AND EVALUATION REPORT



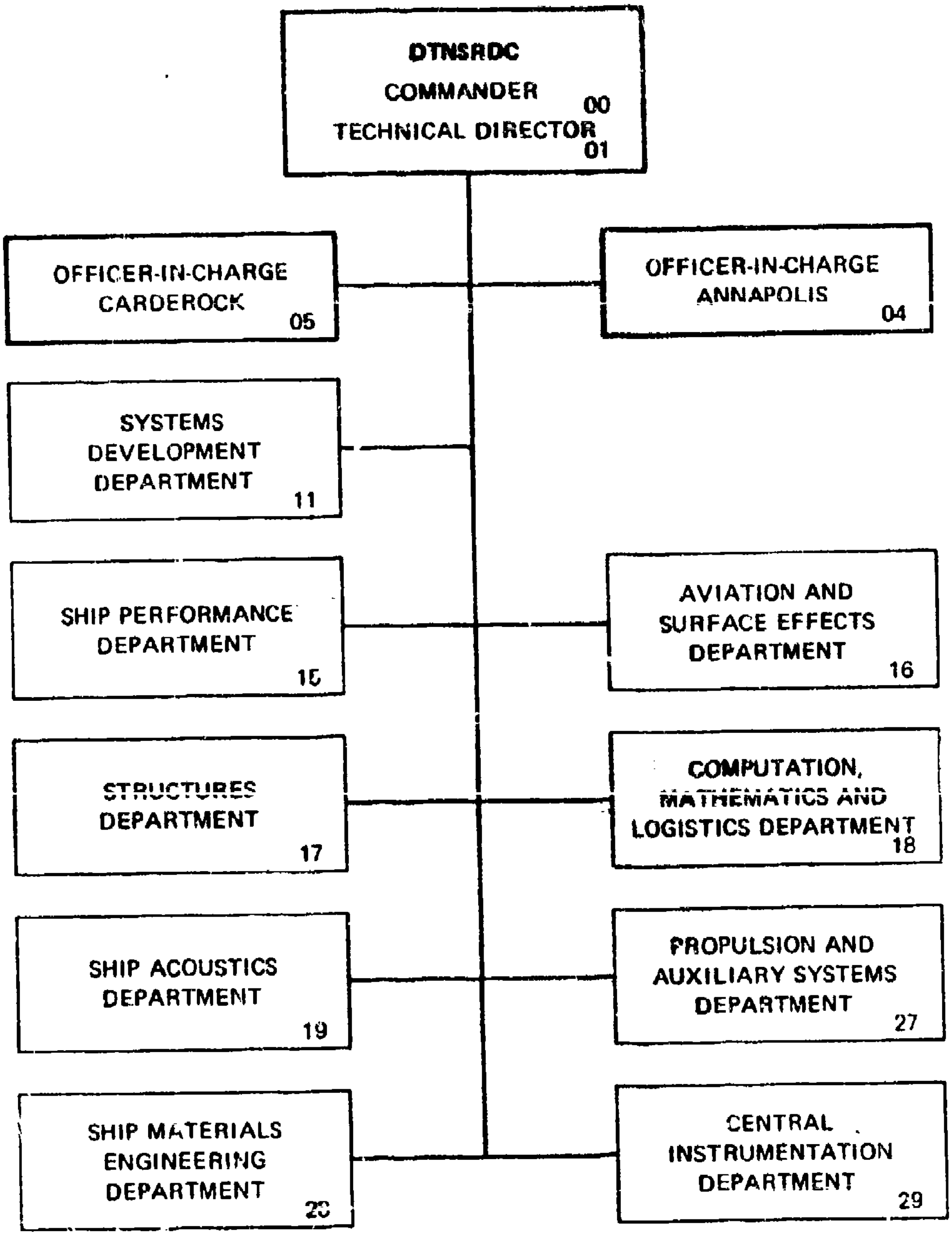
April 1984

DTNSRDC-84/005



DEVELOPMENT AND TESTING OF A LIGHTWEIGHT ALUMINUM TRACK FOR THE U.S. MARINE CORPS

## MAJOR DTNSRDC ORGANIZATIONAL COMPONENTS



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|---|
| 1. REPORT NUMBER<br>DTNSRDC-84/005 | 2. GOVT ACCESSION NO.<br>AD-A143795 | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE (and Subtitle)<br>DEVELOPMENT AND TESTING OF A LIGHTWEIGHT ALUMINUM TRACK FOR THE U.S. MARINE CORPS | | 5. TYPE OF REPORT & PERIOD COVERED<br>Final<br>6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s)<br>Steven S. Scharf | | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>David W. Taylor Naval Ship Research and Development Center<br>Bethesda, Maryland 20084 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS<br>Program Element 62543N<br>Task Area CF43455332<br>Work Unit 1120-021 |
| 11. CONTROLLING OFFICE NAME AND ADDRESS<br>Marine Corps Development & Education Command<br>Code D 093<br>Quantico, VA 22134 | | 12. REPORT DATE<br>April 1984<br>13. NUMBER OF PAGES<br>66 |
| 14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) | | 15. SECURITY CLASS. (of this report)<br>UNCLASSIFIED<br>15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Lightweight Amphibious Tracks
Aluminum Tracked Vehicles
Amphibious Vehicles

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Marine Corps Surface Mobility Program, technically managed by the David Taylor Naval Ship Research and Development Center (DTNSRDC), has as a major thrust area, the development of lightweight, affordable, and reliable components for future Marine Corps amphibious vehicles. In a tracked combat vehicle which must also operate in the salt water environment, it is essential

(Continued on reverse side)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(Block 20 continued)

that gross vehicle weight be minimized. One area for significant weight reduction potential is track and suspension.

The Aluminum Company of America (ALCOA), under contract to DTNSRDC has designed and fabricated an aluminum track which is compatible for installation on the Marine Corps LVT7 family of amphibious vehicles. The initial test track underwent limited testing at the Amphibian Vehicle Test Branch (AVTB), Camp Pendleton, California. During these tests, several material problems were identified, resulting in the termination of tests, and a redesign of the track utilizing materials more suited to the marine environment. This second generation track, referred to as the Improved Aluminum Track (IAT), has successfully completed in excess of 260 h of operating time, accumulating 3744 miles at AVTB without major failure. Although not ready for production, this extremely successful exploratory development effort has demonstrated the feasibility of an affordable low risk track which offers a nominal 23% weight reduction over conventional steel track.

TABLE OF CONTENTS

| | Page |
|---|---|
| LIST OF FIGURES | iii |
| LIST OF TABLES | v |
| ABSTRACT | 1 |
| ADMINISTRATIVE INFORMATION | 1 |
| METRIC CONVERSION | 2 |
| INTRODUCTION | 2 |
| BACKGROUND | 2 |
| TRACK DESCRIPTION | 5 |
| HOST VEHICLE DESCRIPTION | 8 |
| ALUMINUM TRACK TEST PLAN | 8 |
| TEST RESULTS AND EVALUATION | 11 |
| LVA ALUMINUM TRACK (A-TRACK) | 11 |
| IMPROVED ALUMINUM TRACK (IAT) | 15 |
| DISCUSSION AND CONCLUSIONS | 22 |
| RECOMMENDATIONS | 24 |
| ACKNOWLEDGMENTS | 25 |
| APPENDIX A - LVA, TEST OF ALUMINUM TRACK (A-TRACK) | 27 |
| APPENDIX B - IMPROVED ALUMINUM TRACK FINAL REPORT OF TEST | 43 |
| REFERENCES | 59 |

LIST OF FIGURES

| | |
|---|---|
| 1 - LVA "Body Drive" Concept | 4 |
| 2 - LVA "End Drive" Concept | 4 |
| 3 - The 21-Inch Aluminum Track Block Assembly | 6 |

| | Page |
|---|---|
| 4 - The LVTP-7 Aluminum Track Installation | 10 |
| 5 - Camp Pendleton Test Course | 12 |
| 6 - Cracked Drive Ring (A-Track) | 13 |
| 7 - Cracked Center Guide Cap (A-Track) | 13 |
| 8 - Aluminum Track Wear Measurement Locations | 16 |
| 9 - Grouser Wear | 17 |
| 10 - End Drive Wear | 17 |
| 11 - Center Guide Cap Wear | 18 |
| 12 - End Drive/Sprocket Misalignment Wear | 18 |
| 13 - Top Surface Wear | 20 |
| 14 - IAT Modified to Accept LVT7 Road Pads | 21 |
| 15 - IAT Modified with Steel Grousers on End Drives | 21 |
| A.1 - Wear Measurements | 32 |
| A.2 - Aluminum Track Sprocket Wear (Port Side, 25- and 48-Hour Tests) | 33 |
| A.3 - Aluminum Track Sprocket Wear (Starboard Side, 25- and 48-Hour Tests) | 34 |
| B.1 - Sprocket Profile, Port/Starboard at 0/260 Hours | 47 |
| B.2 - Original Blocks Showing Total Wear | 48 |
| B.3 - New Blocks After 100 Hours Showing Total Wear | 48 |
| B.4 - Steel Grousers Showing Total Wear | 49 |
| B.5 - Steel Pads Showing Total Wear | 49 |
| B.6 - New Track Block | 50 |
| B.7 - 260-Hour Track Block | 52 |
| B.8 - 260-Hour Center Guide Cap | 54 |

Page

B. 9 - Measurement Plate . . . . . . . . . . . . . . . . . . . . . . . . 57

B.10 - Link Pin Bushing Material . . . . . . . . . . . . . . . . . . . . . 58

LIST OF TABLES

1 - Aluminum Track Characteristics. . . . . . . . . . . . . . . . . . . 7

2 - LVTP-7 Standard Characteristics . . . . . . . . . . . . . . . . . . 9

3 - The A-Track Test Results. . . . . . . . . . . . . . . . . . . . . . 14

4 - Modified IAT Blocks . . . . . . . . . . . . . . . . . . . . . . . . 19

5 - Comparison of Aluminum versus Steel Track . . . . . . . . . . . . . 22

A. 1 - A-Track Failures. . . . . . . . . . . . . . . . . . . . . . . . . 35

A. 2 - Land Acceleration and Maximum Speed Results (Steel Track) . . . . . . . . . . . . . . . . . . . . . . . . . . 37

A. 3 - Land Acceleration and Maximum Speed Results (A-Track) . . . . . . . . . . . . . . . . . . . . . . . . . . . . 38

A. 4 - Track Block Wear Dimensions on Port Side at 25:05 Hours. . . . . . . . . . . . . . . . . . . . . . . . . . . 39

A. 5 - Track Block Wear Dimensions on Starboard Side at 25:05 Hours. . . . . . . . . . . . . . . . . . . . . . . . . . . 40

A. 6 - Track Block Wear Dimensions on Port Side at 48:25 Hours. . . . . . . . . . . . . . . . . . . . . . . . . . . 41

A. 7 - Track Block Wear Dimensions on Starboard Side at 48:25 Hours. . . . . . . . . . . . . . . . . . . . . . . . . . . 42

## ABSTRACT

The Marine Corps Surface Mobility Program, technically managed by the David Taylor Naval Ship Research and Development Center (DTNSRDC), has as a major thrust area, the development of lightweight, affordable, and reliable components for future Marine Corps amphibious vehicles. In a tracked combat vehicle which must also operate in the salt water environment, it is essential that gross vehicle weight be minimized. One area for significant weight reduction potential is track and suspension.

The Aluminum Company of America (ALCOA), under contract to DTNSRDC, has designed and fabricated an aluminum track which is compatible for installation on the Marine Corps LVT7 family of amphibious vehicles. The initial test track underwent limited testing at the Amphibian Vehicle Test Branch (AVTB), Camp Pendleton, California. During these tests, several material problems were identified, resulting in the termination of tests, and a redesign of the track utilizing materials more suited to the marine environment. This second generation track, referred to as the Improved Aluminum Track (IAT), has successfully completed in excess of 260 h of operating time, accumulating 3744 miles at AVTB without major failure. Although not ready for production, this extremely successful exploratory development effort has demonstrated the feasibility of an affordable low risk track which offers a nominal 23% weight reduction over conventional steel track.

## ADMINISTRATIVE INFORMATION

This project is part of the Marine Corps Surface Mobility Exploratory Development Program at the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) which is sponsored by the Marine Corps Development and Education Command (D 093), Quantico, Virginia. Funds were provided under Program Element 62543N, Task Area CF43455332, and Work Unit 1120-021.

## METRIC CONVERSION

1 in. = 2.54 cm

1 lb = $4.536 \times 10^{-1}$ kg

1 mile = 1.609 km

1 psi = 6.895 $N^2$

1 hp = 746 w

1 ton (short) = $9.07 \times 10^2$ kg

## INTRODUCTION

Future Marine Corps tracked vehicles will be designed to enhance battlefield mobility, survivability, and transportability. Also, the future Marine Corps tracked amphibians will likely have an added requirement for increased waterborne speeds to minimize ship to shore exposure times. All of these requirement trends lead to the need to develop lightweight, and/or high-horsepower-to-weight ratio vehicles.

The objective of the Marine Corps aluminum track effort was to support one of the end item goals, that of achieving a lightweight vehicle. The plan involved reducing the weight of the track by substituting aluminum track for steel track, while achieving competitive performance and cost when compared against the current steel track.

## BACKGROUND

Among the efforts previously devoted to the development of aluminum tracks for heavy vehicles, one of the most intensive was the development program to design an aluminum block for the double pin, T-142 track for the M60 series tank.[1-4*] An experimental T-142 hard-coated aluminum track was designed, fabricated, and tested by the Aluminum Company of America (ALCOA), and subsequently tested at the U.S. Army Aberdeen Proving Grounds to determine the performance and endurance characteristics of the track during 5000 miles of typical operations. At the completion of the 5000 miles, 82% of the original aluminum track shoes had completed the mileage with only one failure directly attributed to the aluminum block.

---

*A complete listing of references is given on page 59.

Because of insufficient durability data, the test was extended by 2000 miles, and then extended again for another 1545 miles, at which point the track assembly generally became unserviceable. During the accumulated 8545 miles, two shoes were changed because of aluminum block failures, and 47 others were changed because of a variety of other problems.

The U.S. Marine Corps aluminum track program built upon the technology established by the U.S. Army effort. The Marine Corps effort was initiated as part of a concept study directed by the Naval Sea Systems Command, and technically managed by the David Taylor Naval Ship Research and Development Center (DTNSRDC) to provide a new Landing Vehicle Assault (LVA) for the Marine Corps. Critical to the success of this concept was the development of lightweight components, the suspension system being a major area for potential weight savings. This system typically accounts for 22% of the gross vehicle weight (GVW), with the track accounting for over 50% of that suspension weight. Thus track weight reduction is a highly desirable objective.

In 1976, DTNSRDC contracted sole source with ALCOA to conduct a preliminary design concept study of lightweight track. One double pin and three single-pin concepts were investigated.[5] The double-pin design was not recommended for further study on the basis that it would not provide a significant weight reduction. Two of the single-pin concepts, providing nominally a 20% weight savings (versus comparable steel track) were recommended for further study. One concept (Figure 1) provided a ferrous insert within the track block for the sprocket drive ("body drive"), while the second concept (Figure 2) incorporated the sprocket drive at the outer extremities of the shoe ("end drive"). These concepts were then further evaluated to determine their structural suitability.[5] These analyses led to the configurational choice of the "end drive" track block.

Two generations of this track were eventually built by ALCOA (under contract to DTNSRDC) and tested by the Marine Corps on a Landing Vehicle Tracked, Personnel, Model 7 amphibian (LVTP-7) at the Amphibian Vehicle Test Branch (AVTB), Camp Pendleton, California. The first generation track (A-Track) failed prematurely due to stress corrosion attributed to the unsuitability of the track block materials in a salt water environment. The second generation "Improved Aluminum Track" (IAT), developed under the Marine Corps Surface Mobility Program,

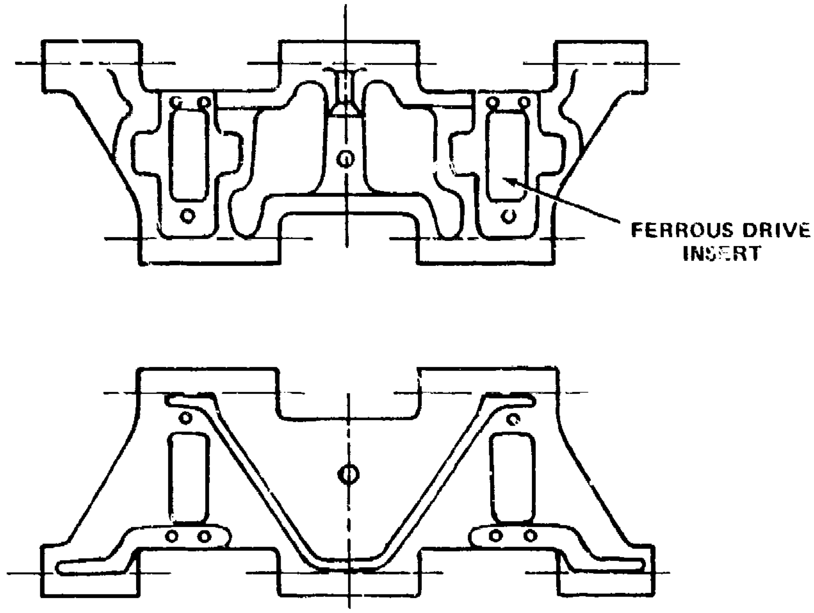



Figure 1 - LVA "Body Drive" Concept

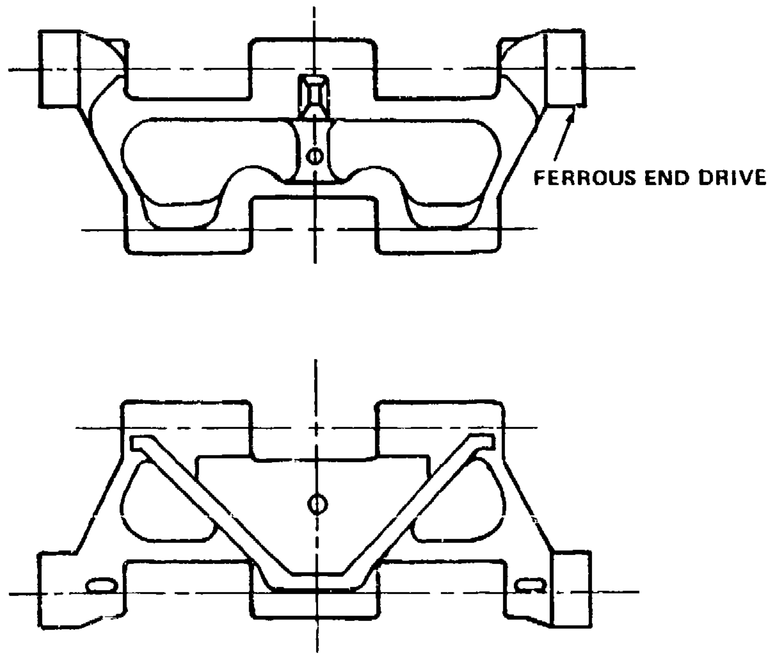



Figure 2 - LVA "End Drive" Concept

incorporated the basic design of the A-Track but utilized materials and processing techniques more suited to the environment. This track survived in excess of 260 h of vehicle operation, accumulating 3744 miles at AVTB without major failure. It also provided a 23% weight savings over comparable steel track (4300 lb versus 5611 lb).

## TRACK DESCRIPTION

Both the A-Track and IAT are 21-in. wide, single-pin, rubber-bushed tracks with a 6-in. pitch. Externally, they both look the same (Figure 3). In both cases, the shoe bodies are aluminum with steel center guide caps and end drives. Both track blocks were designed to accommodate the same road pad, which, because of structural considerations, was nominally 23% smaller than the standard LVT7 road pad. During the IAT tests, selected blocks were modified to accommodate the larger LVT7 road pad. Some were modified by welding a steel grouser to each of the two steel drive rings; the modified blocks will be discussed later. Table 1 summarizes the track physical characteristics; weights shown are based on actual A-Track weights. The weights of the IAT assembled block sections differ due to aluminum alloy and center guide cap differences, and are 0.1-lb and 0.6-lb lighter than the A-Track for the 7075T73 and the 6061T6IAT aluminum alloy block, respectively. Note: the weight of the standard LVT7 steel track block is 33.4 lb per assembled block section.

The A-Track was fabricated utilizing 2014T6 aluminum alloy, the same material previously tested by the Army in the successful T-142 aluminum track. This material later proved to be susceptible to stress corrosion in a marine environment. A total of 225 blocks were fabricated of this material (the LVT7 uses 168 blocks after initial track break-in).

For the IAT, a total of 245 blocks were fabricated, of which 220 were 6061 alloy, and 25 were 7075 alloy. Both alloys were chosen because of their superior performance in stress-corrosion susceptible environments, even though their tensile strength was lower then that of 2014T6 aluminum alloy. Both IAT alloys proved to be of adequate strength and environmentally suitable, and no incidents of block failure were reported throughout the duration of the IAT test program.

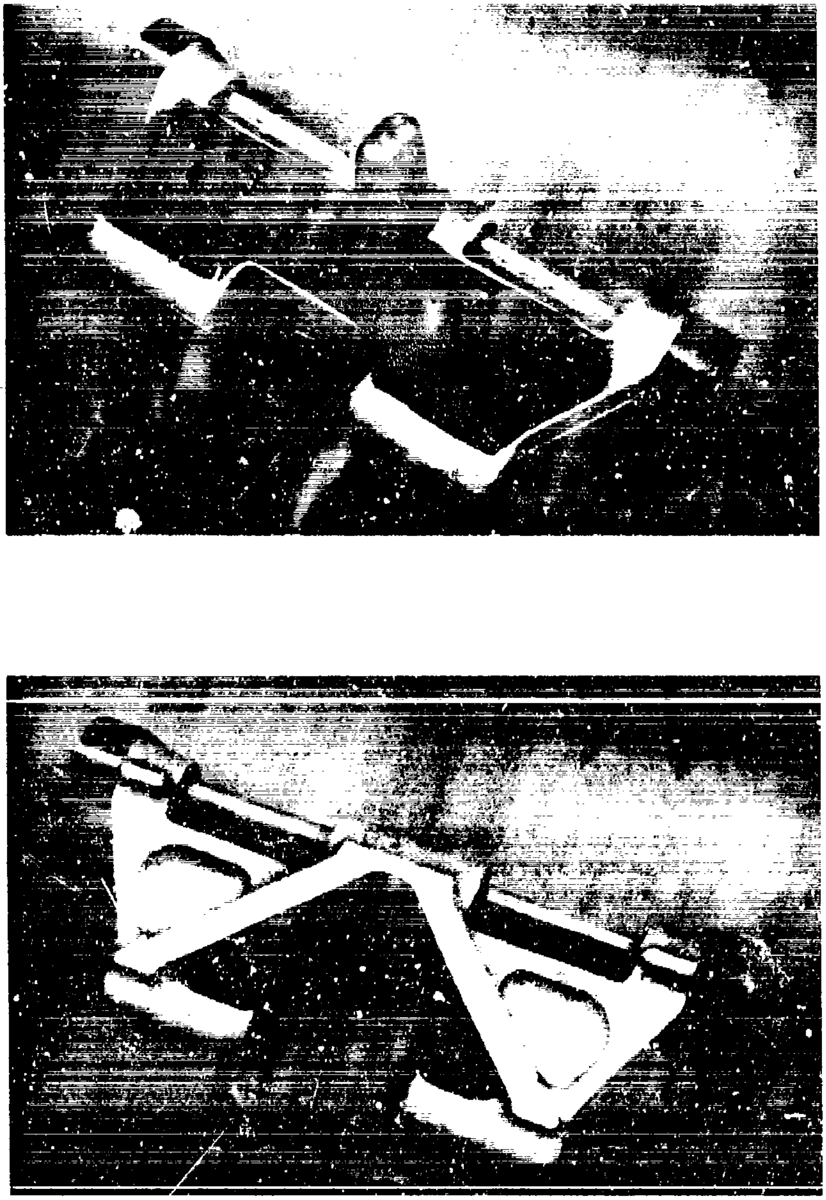


Figure 3 - The 21-Inch Aluminum Track Block Assembly

TABLE 1 - ALUMINUM TRACK CHARACTERISTICS

| | | |
|---|---|---|
| **Weights** | | |
| Basic Block w/Center Guide Cap | | A-Track 17.0 lb<br>IAT (6061) 16.4 lb<br>IAT (7075) 16.9 lb |
| Assembled Block Section* w/Road Pad and Pin | | A-Track 26.2 lb<br>IAT (6061) 25.6 lb<br>IAT (7075) 26.1 lb |
| **Dimensions** | | |
| Pitch Length | | 6 in. |
| Width | | 21 in. |
| Pad Thickness | | 1.5 in. |
| Grouser Height | | 1.1 in. |
| Center Guide Height | | 3.8 in. |
| Type Bushing | | LVT7 |
| Type Pin | | LVT7 |
| **Materials** | A-Track | IAT |
| Track Block (aluminum) | 2014T6 | 6061T6 & 7075T73 |
| Center Guide Cap (steel) | cast 4140 | wrought 4130 |
| End Drives (steel) | 4140 (48Rc) | 4135 (25Rc) |
| Road Pads | SBR | SBR |
| Production Cost Estimate (FY 82 $) | | $225.00/ft |

*For comparison, LVT7 steel block assembly weighs 33.4 lb.

Additional modifications of the IAT included (1) the use of wrought center-guide caps in lieu of the cast caps used in the A-Track, and (2) a material and hardness change in the steel end drives. The center guide cap modification was incorporated as a solution to the numerous failures encountered during the A-Track testing, attributed to poor casting quality (porosity) and stress corrosion. The end-drive material and tempering change was made to provide a solution to the hydrogen embrittlement failures experienced with the A-Track end drives.

## HOST VEHICLE DESCRIPTION

The host vehicle used for the testing of the aluminum track was a Marine Corps LVTP-7 amphibious personnel carrier. The nominal operating weight of the vehicle during the test was 24.5 tons, a GVW which included 10,000 lb of cargo, but did not include ordnance weights. The characteristics of interest for the LVTP-7 are given in Table 2.

To accommodate the aluminum track on the LVTP-7, some modifications were required to the host vehicle interface components. These modifications included: (1) the sprocket carrier had to be widened to accept the end drive track, (2) aluminum spacers had to be put between the tires of the dual roadwheels to provide for the increased thickness of the center guides, (3) an aluminum spacer was added to offset the idler wheels, and (4) longer wheel studs were required to properly torque the roadwheels. All changes were mandatory to achieve the necessary geometry for the end drive track. The weight penalty for these modifications was 284 lb. This additional weight is not inherent in the end drive track concept, and could be avoided if the vehicles had been initially designed to accommodate this type of track.

In addition to these hardware changes, the track tension had to be adjusted to compensate for the lighter track. Figure 4 shows the LVTP-7 with the aluminum track installed.

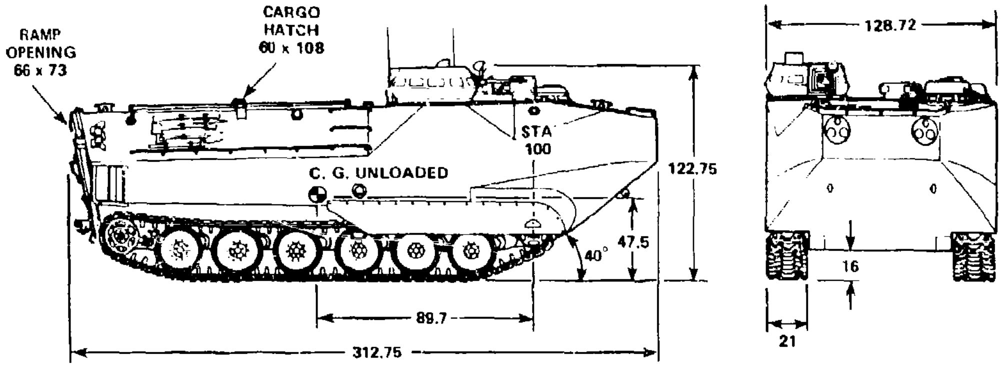
## ALUMINUM TRACK TEST PLAN

Master test plans were developed for both the LVA Aluminum Track (A-Track)[6] and the Improved Aluminum Track (IAT).[7] Both test plans were similar in objective, i.e., to determine the feasibility of an aluminum track for a Marine Corps amphibian vehicle. The target goal of both plans was to complete 2000 miles of testing in a salt water environment. In both cases, the test site was the Marine Corps Base at Camp Pendleton, California. The field testing was directed by the Amphibian Vehicle Test Branch.

The test was structured into several phases. A pretest phase included track and host vehicle inspections and a 50 mile "shakedown" test. The feasibility test phase (50 h) concentrated on the design aspects of the track, including the aluminum track impact on vehicle performance. The durability test phase (150 h)

TABLE 2 - LVTP-7 STANDARD CHARACTERISTICS

(All dimensions are in inches.)




| | |
|---|---|
| 1. General | |
| Weight (cargo loaded) | 50,350 lb |
| Weight Unloaded (less crew & fuel) | 38,451 lb |
| Weight During Testing | 49,000 lb |
| Unit Ground Pressure (cargo loaded) | 7.7 psi |
| 2. Performance | |
| Gross Horsepower to Weight Ratio | 15.9 hp/ton |
| Net Horsepower to Weight Ratio | 10.6 hp/ton |
| Drawbar Pull | 40,280 lb |
| Max Land Speed | 40 mph |
| 3. Running Gear | |
| Type: Torsion Bar & Tube Suspension, Front Sprocket, Raised Rear Idler | |
| No. of Wheels: 6 Rubber Tired, Dual per Side, 26 in. Diameter | |
| No. of Return Idlers: | 1 per side, 20 in. diameter wheels |
| Sprocket: | 11 teeth, 5.5 ft per revolution |
| Standard Track: | |
| Type: | Steel, single pin, rubber bushed with replaceable road pad (body drive) |
| No. of Blocks: | 84 per side |
| Pitch: | 6 in. |
| Weight per Block: | 33.4 lb |
| Weight per Side: | 2806 lb |
| 4. Fuel: | 180 gal |
| 5. Crew: | 3 |

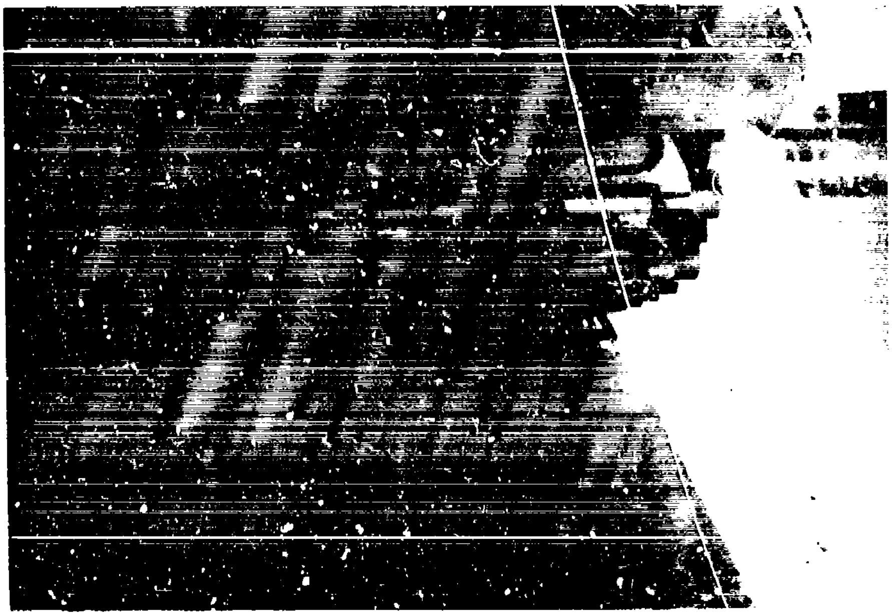


Figure 4 - The LVTP-7 Aluminum Track Installation

concentrated on repetitive operation through the AVTB test course (Figure 5) to monitor wear and component durability. The final phase included a post-test inspection to verify the final condition of the track and other components that could be (or were) influenced by the characteristics of the track.

## TEST RESULTS AND EVALUATION

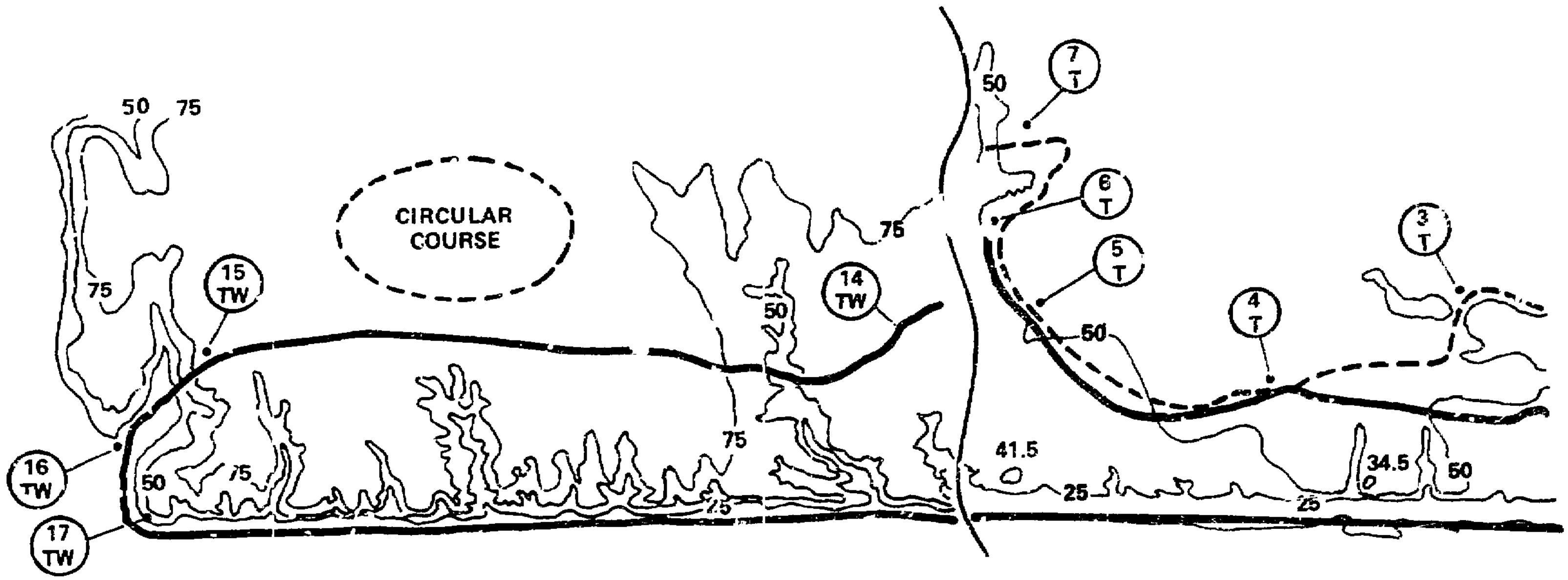
The format for this discussion is divided into two major segments. The first segment is on the test results and evaluation of the LVA Aluminum Track (A-Track), while the second one discusses the test results and evaluation of the Improved Aluminum Track (IAT).

### LVA ALUMINUM TRACK (A-TRACK)

The test of the A-Track was initiated at the Amphibian Vehicle Test Branch (AVTB), Camp Pendleton, California on 28 July 1978. This track was forged of 2014-T6 aluminum alloy with steel drive rings shrunk over the outer bushing hubs for the sprockets to drive on, and cast steel center guide caps, rubber bonded onto the aluminum center guide to provide track guidance and wheel wear protection. To accept this track, FMC Corporation[8] (under subcontract to ALCOA) modified the host vehicle by increasing the sprocket carrier width, making new sprockets, and providing aluminum spacers to increase the space between the tires of the dual roadwheels. This increased space accommodated the increased track guide width, and provided an aluminum spacer to offset the idler wheel.

After the first 50 miles of field testing, the sprockets exhibited excessive peening where the end drive rings made radial contact with the sprocket rings. The sprocket assembly was modified by adding a steel support between the sprocket carrier and the sprocket rings, and the test was continued. This problem did not recur.

After 25 h of testing, one end-drive ring came off and twelve (12) others were cracked (Figure 6), all on the starboard track. The shoes involved were replaced, and the test continued. At 43 h of testing, the starboard track failed and separated while the vehicle was negotiating a sharp turn on the cross-country course.




TEST COURSE CONSISTS OF

- PAVED ROADS – 5 MILES
- HILLY UNIMPROVED TANK TRAILS – 10 MILES
- LEVEL SANDY BEACH – 10 MILES

Figure 5 - Camp Pendleton Test Course

Figure 6 - Cracked Drive Ring (A-Track)

Inspection of the track revealed that the catastrophic failure of one center boss initiated the separation. Later, it was revealed that seven other shoe bosses had also cracked. Further field inspection also revealed two missing center guide caps, and cracks occurring in 37 others (Figure 7). At this point,

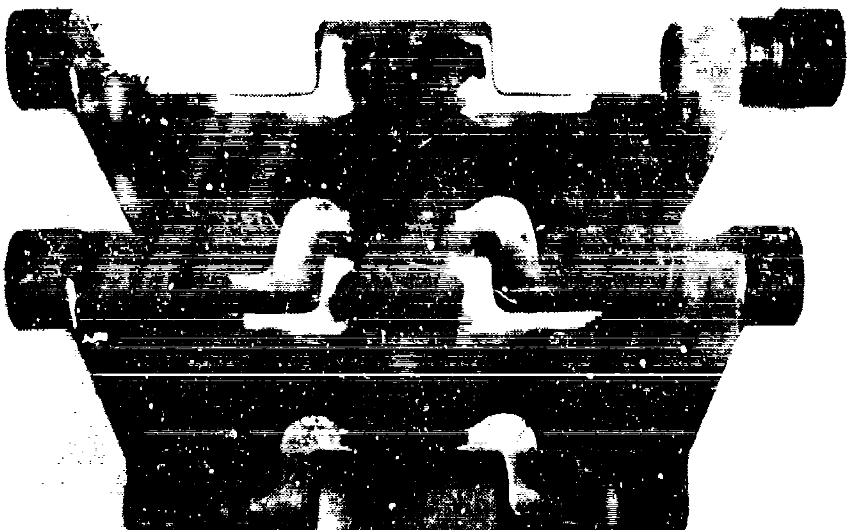


Figure 7 - Cracked Center Guide Cap (A-Track)
Note: Drive Ring Separation and Wear

after 48:25 hours and 551 miles of testing, the test was terminated due to safety considerations. Appendix A provides further details of the A-Track testing. Table 3 is a summary of the pertinent test results which also include the final failure count.

TABLE 3 - THE A-TRACK TEST RESULTS

| | | | | |
|---|---|---|---|---|
| Dates of Testing: | 28 July 1978 to 4 December 1978 | | | |
| Cumulative Hours: | 48 h 25 min | | | |
| Cumulative Miles: | 551 miles (511 land, 40 water) | | | |
| Average Total Wear (in.): | Grouser | Pad | Drive Ring | Center Guide |
| Port Track | 4/64 | 9/64 | 1/32 | 3/64 |
| Starboard Track | 3/64 | 9/64 | 3/64 | 1/32 |
| Sprocket Wear: | 1/8 in. average on drive surfaces | | | |
| Failure Summary: | 12 Failures due to Cracked Drive Bushings<br>10 Failures due to Cracked Bosses<br>39 Failures due to Cracked or Missing Center Guides<br>1 Failure due to Cracked Boss and Center Guide | | | |

The failures were analyzed by ALCOA, FMC, and DTNSRDC. It was determined that the end drive failures were caused by hydrogen embrittlement of the 4140 steel, resulting from residual stresses in the material, and were due to the shrink fit.* The shoe failures were found to be stress-corrosion failures of the 2014T6 alloy, which was later revealed to be a poor performer in a salt water environment.[9] Finally, the failures in the cast center guides were determined to be caused by poor castings, some stress corrosion, and improper heat treatment of the 4140 steel.** Solutions to these problems were identified prior to the initiation of the IAT contract with ALCOA.

---

*"Metallurgical Analysis of Wear Bushings from Landing Vehicle Assault (LVA) Aluminum Track," DTNSRDC Report TM-28-79/31 (7 Feb 1979).

**"Cracking in Centerguide Sleeve for LVTX; Analysis of," Memorandum from DTNSRDC Code 2813 to Code 1120 dated 3 May 1979.

IMPROVED ALUMINUM TRACK (IAT)

The IAT incorporated the same basic physical design as the A-Track. The major differences between the two tracks were: (1) the aluminum alloy material selection, (2) the heat treatment of the steel components, and (3) the fabrication procedures for the steel center guide caps (see Table 1).[10] The IAT was fabricated by ALCOA with vehicle integration hardware again provided by FMC Corporation under subcontract to ALCOA. The track was installed for testing at the AVTB in late April 1981.

Early testing revealed the locations of high track wear that would continue throughout the duration of the test program. These high wear locations included: (1) the aluminum grousers at the G1 and G3 locations (Figure 8), (with higher wear recorded on the inboard locations of both the port and starboard tracks (Figure 9)); (2) end-drive wear (R1 and R2 locations), caused by sprocket-ring engagement, and aggravated by the wear of the adjacent grousers (Figure 10); (3) center guide cap wear, casued by wear-ring contact (Figure 11); (4) and rubber wear and/or chunking on the roadwheel side rubber and track pads, which were smaller than the standard LVTP-7 track pad. In addition, early tests showed a tendency for the center guide caps to displace vertically from the aluminum block resulting in gaps of from 0.005 to 0.048 in., a situation which stabilized after approximately 30 h (400 miles) of operation.

At 60 h (Approximately 900 miles) all of the road pads were replaced and the test continued. Wear patterns remained typical from block to block, with the worst wear still occurring at the G1 and G3 locations. It was observed that both tracks had a tendency to drive to the starboard side, resulting in poor sprocket-to-end-drive contact, and wear on the aluminum block adjacent to the steel end drive (Figure 12). A possible explanation of this phenomenon is: most tracks have a tendency to drive outboard due to the suspension configuration. However, in the case of the IAT, the modified port sprocket carrier was supporting inboard and outboard sprocket rings that were out of register by approximately 3/8 in. This misalignment tends to bias the track in the direction of the leading sprocket. This could explain why the port track moved inboard instead of outboard.

The 100-h inspection (at 1428 miles) revealed: two lost center guides, excessive wear on the new pads (likely caused by long term storage at Camp Pendleton), excessive "cupping" of the sprocket rings, and accelerated wear on the end connectors.

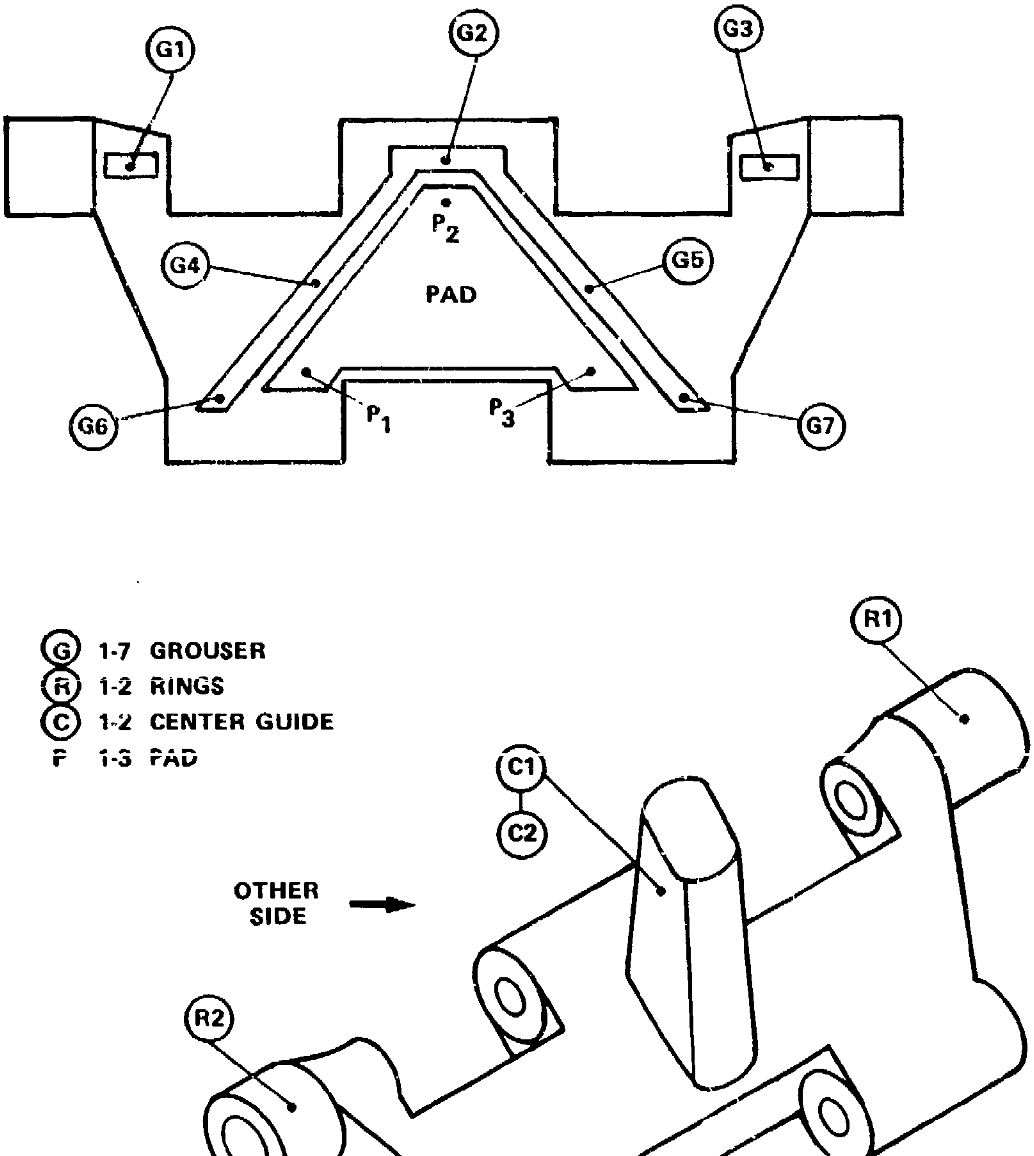



Figure 8 - Aluminum Track Wear Measuremen Locations

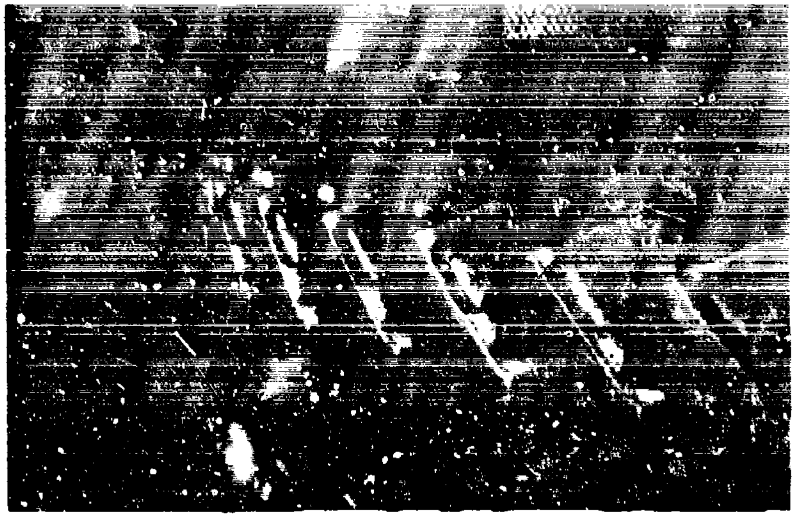


Figure 9 - Grouser Wear

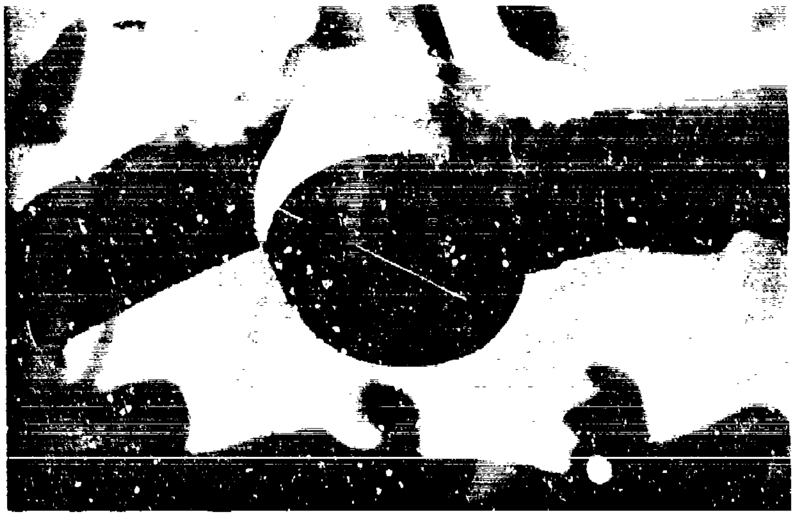


Figure 10 - End Drive Wear

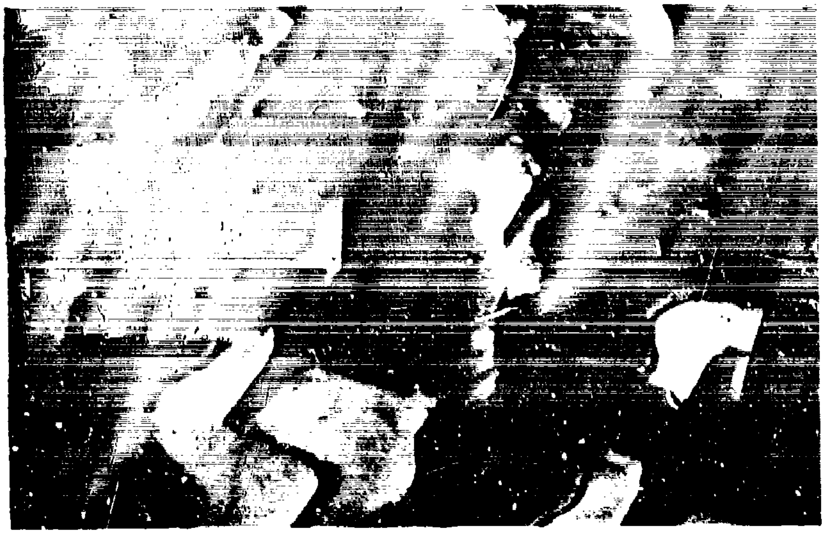


Figure 11 - Center Guide Cap Wear

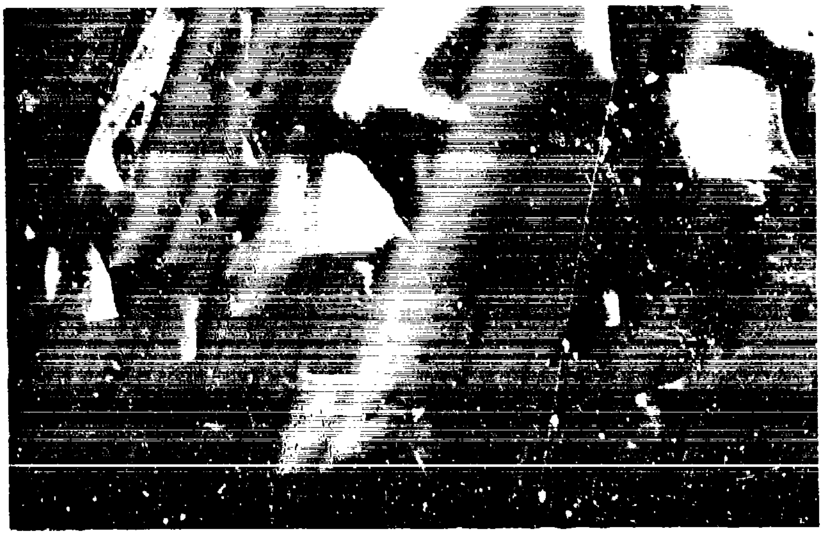


Figure 12 - End Drive/Sprocket Misalignment Wear

At the completion of the 100-h inspection, it was decided to delay further testing until new track pads could be fabricated. During this delay, several track blocks were modified, including: accommodations to fit the standard P7 road pad, the addition of welded steel grousers on the end drives, and various applications of flame spray materials. The modified blocks were then integrated into the track as described in Table 4. In addition, 10 new track blocks were added to both the port and starboard tracks to permit the accumulation of comparative data. New road pads were also installed throughout the track set.

TABLE 4 - MODIFIED IAT BLOCKS
(All put on port track)

- 4 blocks modified to accommodate P7 road pads
- 3 blocks modified by flame spraying the center guides and end drives and installing a steel "V" grouser shoe around the road pad
- 3 blocks modified by flame spraying center guides, end drives, and grousers
- 2 blocks modified by removing steel center guide cap and replacing with a flame sprayed center guide built up to original thickness
- 1 block flame sprayed steel center guide cap built up to original thickness
- 6 blocks modified by the addition of steel grouser extensions welded onto the end drives

The test program resumed in April 1982 after approximately a seven-month delay awaiting road-pad delivery. When reinstalled, the track and sprockets were intentionally reversed, thus presenting new wear surfaces. No operational or vehicle performance problems or degradation were encountered because of the track reversal.

At 125 h (1666 miles), it became obvious that the flame-spray applications were unsuccessful, with most failures occurring within the first 5 h of operation. Furthermore, those blocks fitted with LVTP-7 road pads exhibited reduced wear, as did those fitted with the steel grousers on the end drives. No block failures were recorded.

The testing continued to 209 h (3119 miles) with wear patterns typically remaining the same. However, some reduction was noted in wear rate. The blocks fitted with the P7 road pads and steel grousers on the end drive continued to exhibit superior wear performance.

At this point, the formal testing was completed; however, a decision was made to continue running the IAT until it failed or was determined to be no longer serviceable. The testing continued to 260 h during which the track accumulated a total of 3744 miles. The test was terminated in January 1983 due to (1) increased wear on the top surface of the track block in the area of the center boss (Figure 13), and (2) continued losses of the center guide caps. Additional test results including photographs of the track and track components and track wear data may be found in Appendix B. Photographs of modified blocks are shown in Figures 14 and 15.

Throughout the span of this test program, the vehicle speed averaged 15 mph. The total accumulation of mileage represents only landborne miles; with waterborne transit not recorded. Finally, and most significant, not a single aluminum block failure was recorded throughout the length of the entire test program.

Figure 13 - Top Surface Wear

Figure 14 - IAT Modified to Accept LVT7 Road Pads

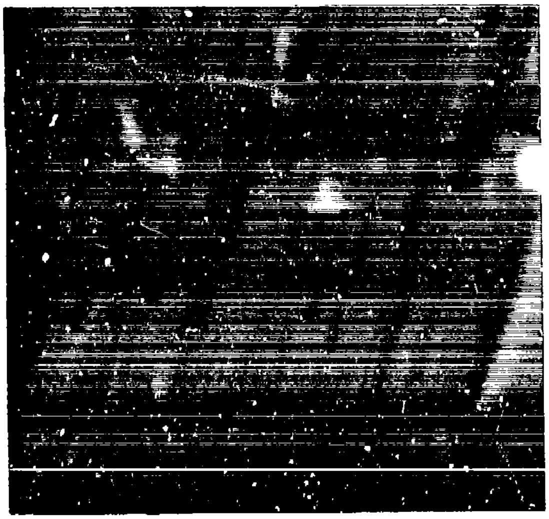


Figure 15 - IAT Modified with Steel Grousers on End Drives

## DISCUSSION AND CONCLUSIONS

The lightweight aluminum track program represents a significant achievement in the development of lightweight components for tracked amphibious vehicles. The IAT demonstrated the feasibility of using selected aluminum alloy track blocks to achieve a nominal 23% weight savings over comparable steel track while achieving an equivalent track life without degrading the performance of the vehicle. Table 5 compares the aluminum and steel track. The performance data on the steel track is based upon prototype LVT7 tests conducted by AVTB at Camp Pendleton, California.

TABLE 5 - COMPARISON OF ALUMINUM VERSUS STEEL TRACK

| | STEEL (LVT7) | IAT |
|---|---|---|
| Type | Single Pin, Bushed | Single Pin, Bushed |
| Drive | Body Drive | End Drive |
| Width | 21-in. | 21-in. |
| Shoe Material | 4045 or 1345 | 6061T6 |
| Weight of Assembled Block | 33.4 lb (shoe & pin) | 25.6 lb (shoe & pin) |
| Weight Savings for LVT | -- | 1311 lb |
| Demonstrated Life | 3717 miles (235 h)* | 3744 miles (260 h) |
| Production Cost (FY 82) | $90/Shoe | $112/Shoe (estimate) |

*Represents demonstration and operational test averages for tests conducted at AVTB for the LVTX-12 family of vehicles.

The importance of proper material selection became apparent early in this program. The utilization of environmentally suitable materials with proper mechanical properties is critical to the marine application. Both 6061T6 and 7075T73 aluminum alloy are suitable materials for this application, but additional effort is required to minimize wear.

Two factors appear to have reduced the wear rate without sacrificing the structural integrity of the track: (1) the adaptation of selected IAT blocks to the larger LVT7 road pad, and (2) the addition of steel grousers to the end drive of other selected blocks. Those changes should be incorporated in any future iteration of the track. Furthermore, additional effort should be expended on improving the steel center guide cap, as many of them were lost, and most were worn through by the end of the test program.

Interestingly, the wear monitored throughout the test program was not the cause for test termination. The critical wear area which finally resulted in the termination of the IAT tests was on the roadwheel side of the block, in the area of the center boss. This wear did not become apparent until over 200 h into the test program. To compensate for this wear, future iterations of this track should increase the thickness of the boss cross section. Note, that in no cases did the application of flame-sprayed materials prove successful, and future efforts in this area are not recommended.

Several observations were made during this test program relative to the operational suitability of the track. In adjusting track for proper tension, it is necessary to account for the lighter weight of the track. Therefore, the "rule of thumb" for the steel track, i.e., 5/8 in. of play over the second roadwheel, does not apply for lighter track. In fact, for the aluminum track, tension was adjusted by measuring 5/8 in. of play over the third roadwheel. In addition, it does not appear that the track has a preferred direction of installation. After reversing the track at 100 h to present new end drive wear surfaces, no impact on performance was noted. In fact the reversing of steel track is standard operational procedure for the 2nd Assault Amphibian Battalion located at Camp Lejeune, North Carolina. This procedure will increase the useful life of any track.

Finally, future track developments must take into account the dynamic behavior of the track and its interface components. For example, the track tended to drive to the starboard side of the vehicle. This phenomenon results in uneven and increased center guide and idler wear, and it accelerates the deterioration of both the track and its vehicle interface components. Efforts expended in better understanding track dynamics and geometry may provide important insights to improving track design and, therefore, track life.

## RECOMMENDATIONS

The Improved Aluminum Track represents a significant potential for the weight reduction of tracked vehicles, while providing comparable performance at a competitive cost to steel track. In this perspective, the following recommendations have been prepared in the hope that follow-on efforts will result.

The IAT in its present form should be transitioned into Advanced Development, whose activities should include further improvement of wear characteristics of the aluminum track, particularly the end drives and the center guide caps. Furthermore, the wear improvements incorporated in the latter part of this program, including the use of larger road pads and integral end drive grousers, should be incorporated into any future designs. Such improvements will likely result in a track life in excess of 4000 miles.

In the design of future tracks, expanded efforts should be made to achieve a better understanding of the track/vehicle interface. Sprocket alignment and dynamics can significantly impact track life, as can center guide clearances between dual roadwheels and idler assemblies.

The feasibility of designing a track with modular/replaceable wear surfaces should be investigated. Modularity options should be considered for both the end drives and center guide caps. Also, the application of a replaceable wear surface on the roadwheel side of the track should be investigated. Such improvements could significantly reduce the track life cycle cost by prolonging the integrity of the forged block.

The potential for achieving further weight reduction in the forged block should be investigated. The fact that no block failures occurred over the life of the IAT tests suggests the possibility of forged-block overdesign.

Finally, the aluminum track should be exposed to a variety of environments to identify potential limitations. Future tests at Camp Lejeune, Twenty Nine Palms, and Pickle Meadows might be considered, along with shipboard trials, to validate amphibious performance.

## ACKNOWLEDGMENTS

The author wishes to express his appreciation to the following persons for their interest, support, and guidance given throughout this effort: Mr. John Long of ALCOA, Mr. Donald Gibson of FMC, Messers Edwin O'Neill, Paul Holsberg, Terry Morton, Donald Vreeland, and Ms. Barbara Voshardt of the Center.

Special acknowledgment is given to the Marine Corps personnel at both MCDEC and AVTB who supported and conducted the vehicle test program, and to Mr. David Overgard who enthusiastically and professionally managed the engineering effort at the Amphibian Vehicle Test Branch.

APPENDIX A

LVA, TEST OF ALUMINUM TRACK (A-TRACK)

1. Purpose. To determine the feasibility of a light weight aluminum track design (A-Track) for use with the LVA amphibian vehicle.

2. Method. The following tests were conducted by the Amphibian Vehicle Test Branch, Marine Corps Tactical Systems Support Activity, Marine Corps Base, Camp Pendleton, California during the period 28 July 1978 to 4 December 1978.

a. Test No. 1 - Identification, Installation, and Initial Checkout. To provide identification markings and insure the test items were properly installed, functional and ready to begin testing.

b. Test No. 2 - Pre-Test Shakedown. To "break-in" the A-Track and suspension components at gradually increasing speeds.

c. Test No. 3 - Land Acceleration and Maximum Speed. To determine the A-Track's effect of the vehicle's acceleration and maximum speed.

d. Test No. 4 - Durability and Maintainability. To determine the durability and maintainability characteristics of the A-Track.

3. Discussion. Tests No. 1 and No. 2 were completed with no significant problems encountered, and were observed by representatives of DTNSRDC, FMC Corporation, and ALCOA. Test No. 3 - Land Acceleration and Maximum Speed - was conducted and indicated a marked degradation of performance. The test bed was again checked for malfunctioning and this test repeated with the same results. This may be accounted for by the increased effective pitch diameter of the A-Track/sprocket over the standard sprockets. Test No. 4 - Durability and Maintainability - resulted in 62 track block failures (listed in Table A.1). In addition, the inside drive rings of each side were contacting the No. 1 torsion tubes, causing damage; and, perhaps as a result of the extended condition of the sprockets, the inboard grousers were wearing rapidly at the ground contact surface.

4. Conclusion. The A-Track, in its present configuration, is not durable enough for use on an LVA.

5. Recommendations. That prior to additional testing of a single-pin, aluminum track, the design be reevaluated and redesigned to improve durability and eliminate problems noted above.

DETAILS OF TESTS

1. Test No. 1 - Identification, Installation, and Initial Checkout

a. Purpose

(1) To provide identification markings.

(2) To insure that the test items were properly installed and ready for the start of testing.

b. Method

(1) The A-Track was assembled and each block stamped with identification markings in the location shown in Figure A.1 so the marks were outboard when installed on the test bed.

(2) The A-Track sprockets and road wheel spacers were installed on an Amphibian Vehicle Test Branch LVTP-7 test bed and track tension adjusted in accordance with applicable LVTP-7 technical manuals.

(3) Measurements were made of wear surfaces. These were used as a baseline for later recorded measurements.

(4) The test vehicle was operated over level terrain and all A-Track components reexamined for discrepancies.

c. Results

(1) Minor difficulty was encountered during installation. The guide plates on the sprocket, designed to control the track guide pins, were of a diameter that allowed them to contact and partially support the track. Trimming as requested by the FMC Corporation representative reduced the diameter to allow the track blocks to fully seat in the drive sprocket.

(2) No other problems were encountered.

2. Test No. 2 - Pre-Test Shakedown

a. Purpose To "break-in" the A-Track at gradually increasing speeds.

b. Method

(1) Initial vehicle operations were accomplished as follows on level terrain:

(a) 1.25 h @ 12 mph

(b) 0.75 h @ 20 mph

(c) 0.67 h @ 30 mph

(2) During the above test runs, thorough visual inspections were conducted at each 30- to 40-min interval.

c. Results

(1) Visual inspections during and after initial operations noted prominent wear to the sprocket teeth caused by the seating of the A-Track drive rings.

(2) No problems were encountered.

3. Test No. 3 - Land Acceleration and Maximum Speed

a. Purpose To determine if the A-Track has any effect on the vehicle's acceleration or maximum speed.

b. Method

(1) The standard Amphibian Vehicle Test Branch engine power check was accomplished to insure that the test bed's engine was functioning properly.

(2) The test bed was loaded with 10,000 lb and all original vehicle equipment (OVE) was aboard and properly stored.

(3) The test bed was instrumented to measure:

(a) Engine speed

(b) Vehicle speed

(c) Time

(4) Speed trap elapsed time instrumentation was set up at the Amphibian Vehicle Test Branch paved land-speed course.

(5) The time required to accelerate from zero to maximum speed under full throttle was measured, twice in each direction. The A-Track was inspected after each run to locate any heat build up or other problems.

(6) The data was compared to data of the same test vehicle equipped with standard steel track.

c. Results

(1) The first timed test run resulted in a degraded performance compared to the standard steel track performance. Analysis of the test vehicle's powertrain indicated a possible problem area. The engine and transmission were removed from the test vehicle, disassembly of the transmission revealed problem areas causing improper operation of the transmission. The transmission was repaired and reinstalled on the test vehicle. A timed test run was again held over the measured course; results of both the steel track and aluminum track test runs are listed in Tables A.2 and A.3, respectively.

(2) Both tests indicated some degradation of performance. The effective pitch diameter of the A-Track sprocket is approximately one inch greater than that of the standard steel track sprocket and is believed to be the reason for the slower maximum speed.

4. Test No. 4 - Durability and Maintainability

a. Purpose To determine the durability and maintainability characteristics of the A-Track.

b. Method

(1) The test vehicle with the test aluminum track installed was operated over the Amphibian Vehicle Test Branch (AVTB) land and water test course for 48:25 h of operations as follows:

(a) 42:00 land test hours for 511.0 miles or 87% of total operations; 6.25 water-test hours operation for 40 miles or 13% water operating time ratio. Failures to the A-Track prior to accumulation of additional water operation time accounted for the ratio unbalance of water operations to land operations.

(b) Payload was varied between 0 and 10,000 lb during all operational testing with both timed land-speed runs carrying 10,000 lb.

(c) Proper track tension and adjustment was maintained in accordance with applicable Technical Instructions.

(2) Prior to initial test operations and at each 25-h interval thereafter, the following procedure was accomplished and recorded:

(a) The A-Track was inspected visually for wear, damage or defects, and corrosion.

(b) The dimensions of one track block in each section were measured as outlined and recorded in Tables A.4 through A.7.

(c) The profiles of two 920 teeth per sprocket were traced. See Figures A.2 and A.3.

(3) Testing was terminated when the track was judged unserviceable based on failures.

c. Results

(1) Sixty-two (62) failures of track blocks were recorded at 48:25 h (at which time the starboard track broke at the junction of blocks S-67 and J). The majority of failures were small cracks on the guide pin cap. All failures are listed in Table A.1.

(2) Both No. 1 torsion arm left- and right-tube assemblies showed damage from contact with the A-Track drive rings.

(3) The greatest amount of wear shown on the blocks was to the inner leading grouser, totaling 5/32 in. at 48:25 h. The outer grouser wear was only 2/32 in., indicating an uneven distribution of weight and/or pressure upon the track.

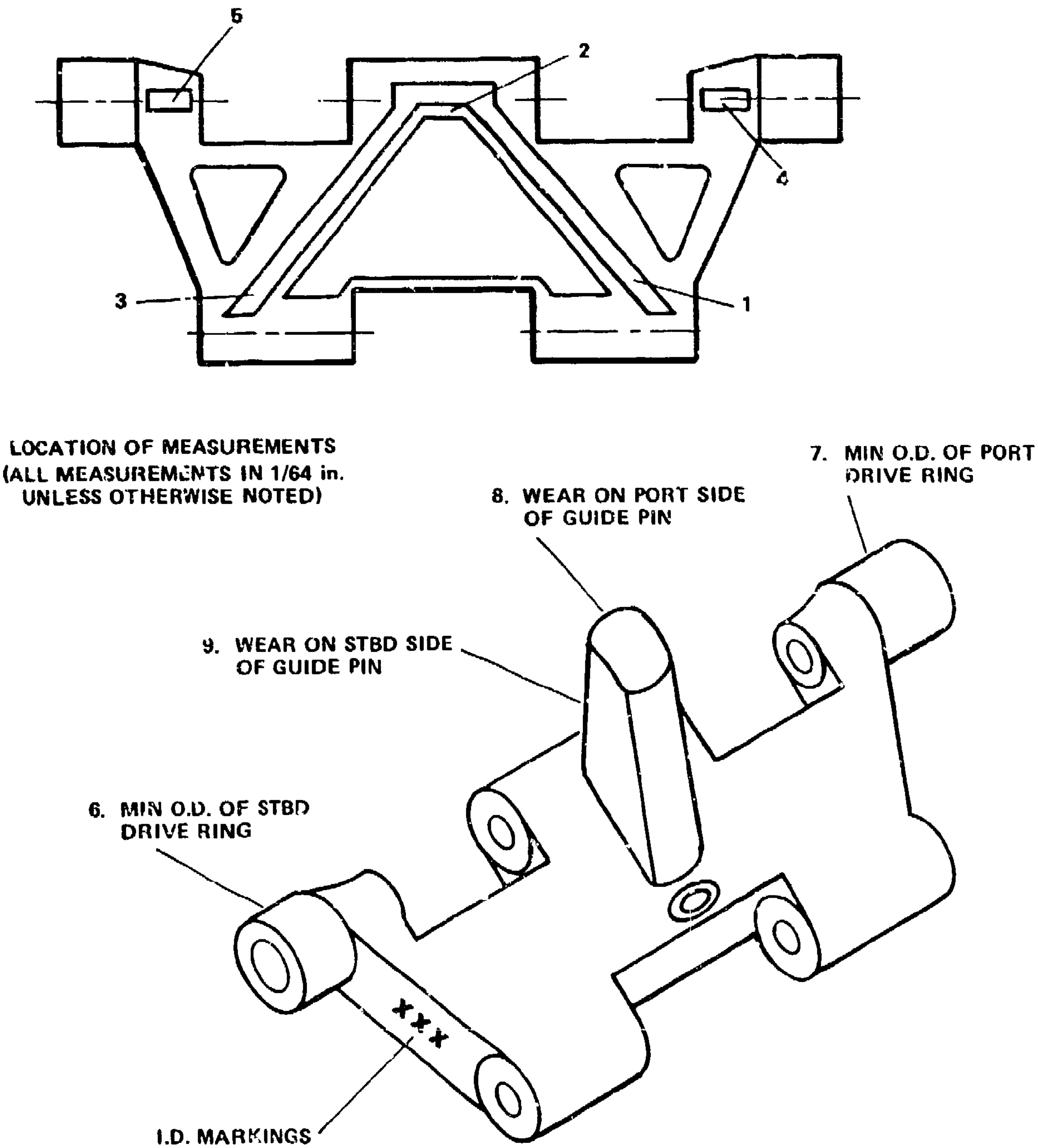



Figure A.1 - Wear Measurements

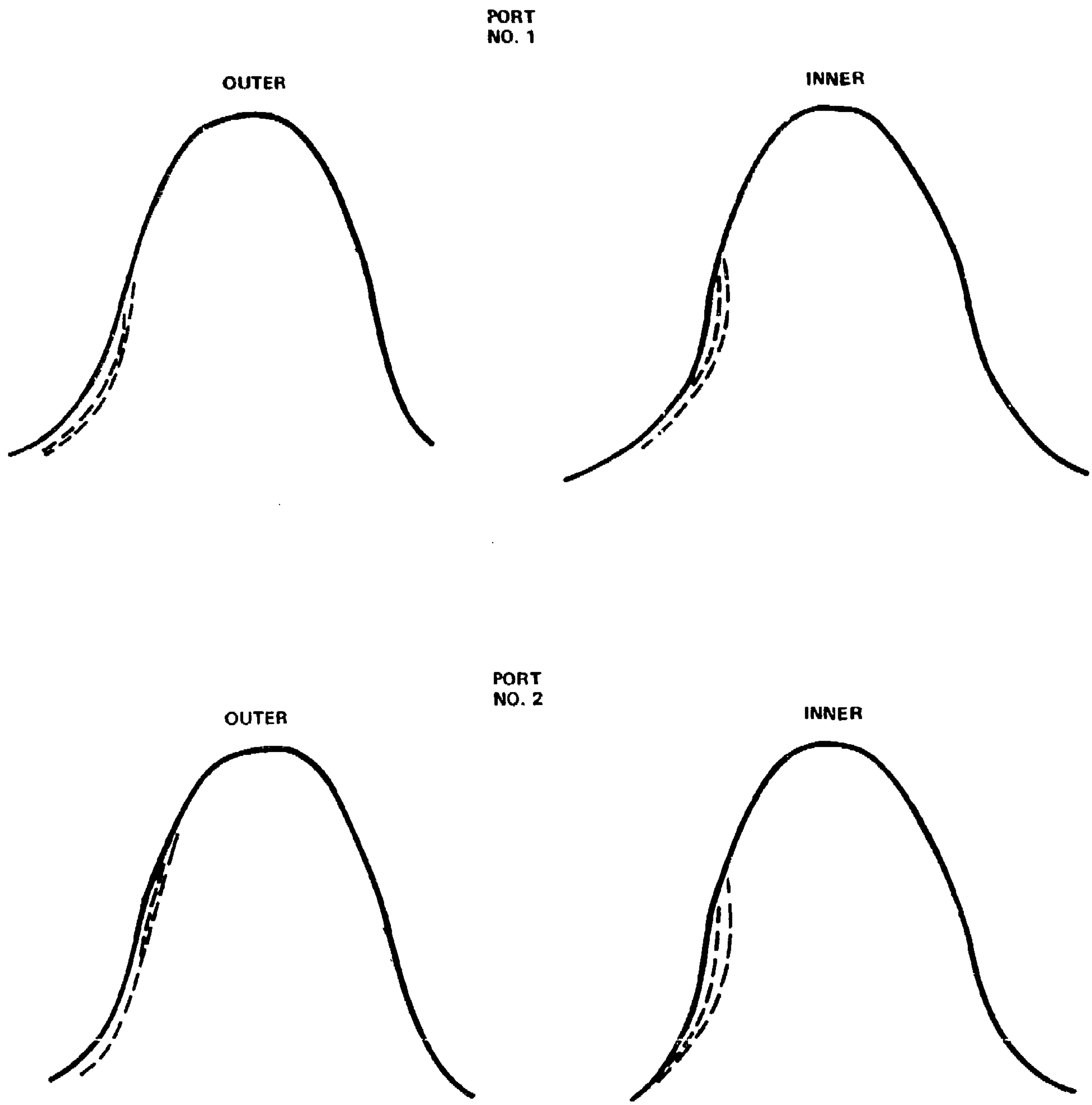



Figure A.2 - Aluminum Track Sprocket Wear (Port Side, 25- and 48-Hour Tests)

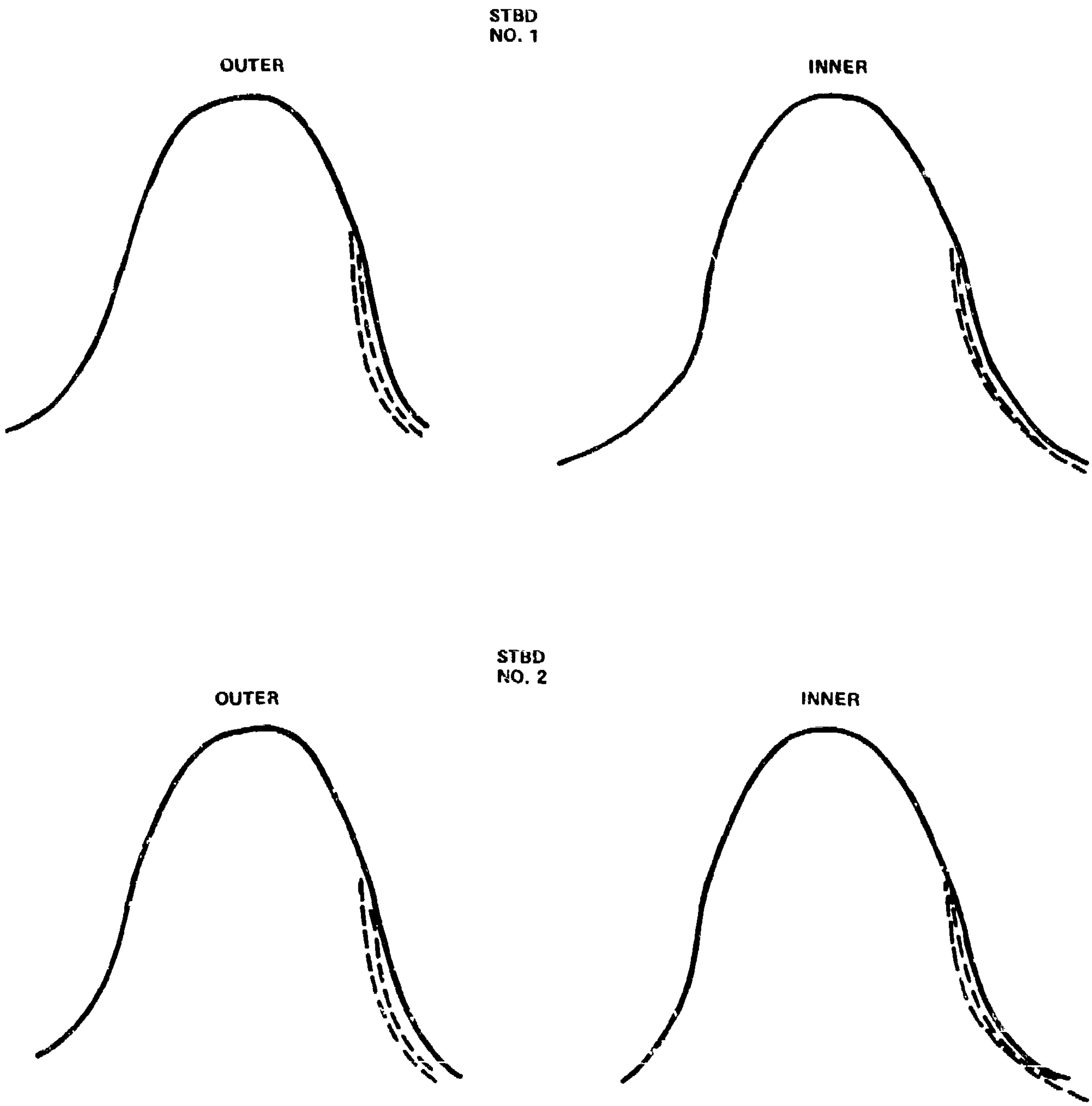



Figure A.3 - Aluminum Track Sprocket Wear (Starboard Side, 25- and 48-Hour Tests)

TABLE A.1 - A-TRACK FAILURES

| Block No. (starboard) | Time (h) | Miles | Failure |
|---|---|---|---|
| 6 | 48:25 | 551.0 | Cracked guide pin cap |
| 13 | 25:05 | 319.0 | Cracked inboard drive ring |
| 14 | 25:05 | 319.0 | Cracked inboard drive ring |
| 15 | 25:05 | 319.0 | Cracked inboard drive ring |
| 25 | 25:05 | 319.0 | Cracked inboard drive ring |
| 33 | 48:25 | 551.0 | Cracked central leading boss |
| 35 | 25:05 | 319.0 | Missing inboard drive ring |
| 38 | 48:25 | 551.0 | Cracked guide pin cap |
| 40 | 48:25 | 551.0 | Cracked guide pin cap |
| 41 | 48:25 | 551.0 | Cracked guide pin cap |
| 42 | 48:25 | 551.0 | Cracked guide pin cap |
| 48 | 48:25 | 551.0 | Cracked guide pin cap |
| 52 | 48:25 | 551.0 | Broken leading central boss |
| 63 | 25:05 | 319.0 | Cracked inboard drive ring |
| 64 | 48:25 | 551.0 | Cracked guide pin cap |
| 65 | 25:05 | 319.0 | Cracked guide pin cap |
| 66 | 25:05 | 319.0 | Cracked inboard drive ring |
| 67 | 48:25 | 551.0 | Leading central boss broken in conjunction with the "J" failure |
| 68 | 25:05 | 319.0 | Cracked inboard drive ring |
| 69 | 25:05 | 319.0 | Cracked inboard drive ring |
| 70 | 25:05 | 319.0 | Cracked inboard drive ring |
| 71 | 25:05 | 319.0 | Cracked inboard drive ring |
| 75 | 48:25 | 551.0 | Broken leading central boss |
| 81 | 25:05 | 319.0 | Cracked inboard drive ring |
| I (repl. S-63) | 23:20 | 232.0 | Cracked guide pin cap |
| J (repl. S-68) | 23:20 | 232.0 | Broken trailing bosses (mounted adjacent to S-67) |
| A (repl. S-13) | 23:20 | 232.0 | Cracked trailing boss |

| Block No. (port) | Time (h) | Miles | Failure |
|---|---|---|---|
| 1 | 48:25 | 551.0 | Cracked guide pin cap |
| 2 | 48:25 | 551.0 | Cracked guide pin cap |
| 4 | 48:25 | 551.0 | Cracked guide pin cap |
| 5 | 48:25 | 551.0 | Cracked guide pin cap |
| 7 | 48:25 | 551.0 | Cracked guide pin cap |
| 9 | 48:25 | 551.0 | Cracked guide pin cap |
| 11 | 48:25 | 551.0 | Cracked boss |
| 12 | 48:25 | 551.0 | Cracked guide pin cap |
| 15 | 48:25 | 551.0 | Cracked guide pin cap |
| 17 | 48:25 | 551.0 | Cracked guide pin cap |
| 27 | 48:25 | 551.0 | Cracked guide pin cap |
| 28 | 48:25 | 551.0 | Cracked guide pin cap |

TABLE A.1 (Continued)

| Block No. (port) | Time (h) | Miles | Failure |
|---|---|---|---|
| 33 | 48:25 | 551.0 | Cracked guide pin cap |
| 34 | 48:25 | 551.0 | Broken leading central boss |
| 38 | 48:25 | 551.0 | Cracked guide pin cap |
| 42 | 48:25 | 551.0 | Cracked guide pin cap |
| 44 | 48:25 | 551.0 | Cracked guide pin cap |
| 45 | 48:25 | 551.0 | Cracked guide pin cap |
| 47 | 48:25 | 551.0 | Cracked guide pin cap |
| 48 | 48:25 | 551.0 | Cracked guide pin cap |
| 49 | 48:25 | 551.0 | Missing guide pin cap |
| 52 | 48:25 | 551.0 | Cracked guide pin cap |
| 53 | 48:25 | 551.0 | Cracked guide pin cap |
| 54 | 48:25 | 551.0 | Cracked guide pin cap |
| 55 | 48:25 | 551.0 | Cracked guide pin cap |
| 60 | 48:25 | 551.0 | Cracked guide pin cap |
| 61 | 48:25 | 551.0 | Cracked guide pin cap |
| 62 | 48:25 | 551.0 | Cracked guide pin cap |
| 66 | 48:25 | 551.0 | Cracked boss |
| 68 | 48:25 | 551.0 | Cracked guide pin cap |
| 70 | 48:25 | 551.0 | Cracked guide pin cap |
| 71 | 48:25 | 551.0 | Cracked guide pin cap |
| 73 | 48:25 | 551.0 | Cracked guide pin cap and boss |
| 81 | 48:25 | 551.0 | Cracked guide pin cap |
| 82 | 48:25 | 551.0 | Cracked guide pin cap |

TABLE A.2 - LAND ACCELERATION AND MAXIMUM SPEED RESULTS (STEEL TRACK)*

| Test No. and Direction (North/South) | Time (h) | Speed (mph) | rpm | Time to Accel. to Max. Speed (s) |
|---|---|---|---|---|
| 1N | 1.908 | 35.7 | N/R | N/R |
| 2N | 1.851 | 36.8 | N/R | N/R |
| 3N | 1.851 | 36.8 | N/R | N/R |
| 4N | 1.835 | 37.2 | N/R | N/R |
| 5N | 1.839 | 37.1 | N/R | N/R |
| | | 36.7 avg. | | |
| 1S | 1.565 | 43.6 | N/R | N/R |
| 2S | 1.561 | 43.7 | N/R | N/R |
| 3S | 1.567 | 43.5 | N/R | N/R |
| 4S | 1.568 | 43.5 | N/R | N/R |
| 5S | 1.564 | 43.6 | N/R | N/R |
| | | 43.6 avg. | | |

Avg. max. speed: 40.1 mph

Wind 4 - 6 knots from West
Temperature: 66 - 68°F
Vehicle 074 equipped with
standard suspension

*Data taken significantly earlier than A-Track acceleration tests and therefore may not be comparable.

TABLE A.3 - LAND ACCELERATION AND MAXIMUM SPEED RESULTS (A-TRACK)

| Test No. and Direction (North/South) | Time (h) | Speed (mph) | rpm | Time to Accel. to Max. Speed (s) |
|---|---|---|---|---|
| 1N | 2.106 | 32.4 | 2220 | N/R* |
| 2N | 2.068 | 33.0 | 2260 | 57 |
| 3N | 2.047 | 33.3 | 2290 | 59 |
| 4N | 2.046 | 33.4 | 2300 | 58 |
| 5N | 2.025 | 33.7 | 2240 | 58 |
| | | 33.2 avg. | | |
| 1S | 1.571 | 43.4 | N/R | N/R |
| 2S | 1.572 | 43.4 | N/R | 65 |
| 3S | 1.564 | 43.6 | 2990 | 64 |
| 4S | 1.572 | 43.4 | 2950 | 63 |
| 5S | 1.565 | 43.6 | 2930 | 64 |
| | | 43.5 avg. | | |

Avg. max. speed: 38.3 mph

Wind 3 to 4 knots from West
Vehicle 074 equipped with A-Track
and related suspension components

*Not recorded

TABLE A.4 – TRACK BLOCK WEAR DIMENSIONS ON PORT SIDE AT 25:05 HOURS

| Block No. | Grouser Surface Wear | | | | | Pad | Drive Ring | Guide Pin | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 (P/S) | 8 | 9 |
| 1P | 0 | 0 | 1 | 5 | 0 | 3 | 2/2 | 2 | 2 |
| 8P | 0 | -1 | 1 | 6 | 1 | 2 | 2/2 | 2 | 2 |
| 15P | -1 | -1 | 2 | 6 | 0 | 4 | 2/2 | 2 | 2 |
| 22P | 1 | 0 | 0 | 7 | 1 | 4 | 2/2 | 2 | 2 |
| 29P | 0 | 1 | -1 | 6 | 2 | 4 | 2/2 | 2 | 2 |
| 36P | -1 | 0 | -2 | 8 | 1 | 3 | 2/2 | 2 | 2 |
| 43P | -1 | 0 | -1 | 7 | 0 | 4 | 2/2 | 2 | 2 |
| 50P | 0 | 0 | -1 | 5 | 0 | 3 | 2/2 | 2 | 2 |
| 57P | 0 | 0 | 0 | 5 | 0 | 4 | 2/2 | 2 | 2 |
| 64P | -2 | 0 | 0 | 5 | 0 | 3 | 2/2 | 2 | 2 |
| 71P | -1 | 0 | -1 | 6 | -1 | 5 | 2/2 | 2 | 2 |
| 78P | -2 | 1 | -1 | 6 | 2 | 4 | 2/2 | 2 | 2 |
| Avg. | -1 | 0 | 0 | 6 | 1 | 4 | 2/2 | 2 | 2 |

Hours: 25:05
Port pitch extension: Blocks 1 through 11 1/16 in.
Blocks 40 through 51 5/32 in.
Track adjuster extension: N/R (Not Recorded)

All measurements are in 1/64 in. unless otherwise noted. The symbol (-) designates a buildup of the surface due to upset of the metal or measurement error resulting from variations in measuring instrument tolerances. All measurements are accurate to 1/64 in.

TABLE A.5 - TRACK BLOCK WEAR DIMENSIONS ON STARBOARD SIDE AT 25:05 HOURS

| Block No. | Grouser Surface Wear | | | | | Pad | Drive Ring | Guide Pin | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 (P/S) | 8 | 9 |
| 1S | 0 | 0 | 0 | 1 | 3 | 4 | 2/2 | 2 | 2 |
| 8S | -2 | 0 | -1 | 1 | 3 | 4 | 2/2 | 2 | 2 |
| 15S | 1 | 1 | 1 | 1 | 3 | 5 | 2/2 | 2 | 2 |
| 22S | 0 | -1 | 0 | 1 | 2 | 5 | 2/2 | 2 | 2 |
| 29S | 1 | -1 | 1 | 0 | 3 | 4 | 2/2 | 2 | 2 |
| 36S | 0 | 2 | 2 | 2 | 5 | 3 | 2/2 | 2 | 2 |
| 43S | 0 | 0 | 0 | 0 | 4 | 3 | 2/2 | 2 | 2 |
| 50S | 3 | -1 | 2 | 1 | 2 | 6 | 2/2 | 2 | 2 |
| 57S | 0 | -1 | 0 | 1 | 4 | 5 | 2/2 | 2 | 2 |
| 64S | 0 | 2 | 1 | 3 | 3 | 5 | 2/2 | 2 | 2 |
| 71S | -1 | 1 | 2 | 1 | 3 | 5 | 2/2 | 2 | 2 |
| 78S | -1 | 0 | 1 | 0 | 3 | 4 | 2/2 | 2 | 2 |
| Avg. | 0 | 0 | 1 | 1 | 3 | 4 | 2/2 | 2 | 2 |

Hours: 25:05
Starboard pitch extension: Blocks 1 through 11 3/16 in.
Blocks 40 through 51 1/16 in.
Track adjuster extension: N/R

All measurements are in 1/64 in. unless otherwise noted. The symbol (-) designates a buildup of the surface due to upset of the metal or measurement error resulting from variations in measuring instrument tolerances. All measurements are accurate to 1/64 in.

TABLE A.6 - TRACK BLOCK WEAR DIMENSIONS ON PORT SIDE AT 48:25 HOURS

| Block No. | Grouser Surface Wear | | | | | Pad | Drive Ring | Guide Pin | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 (P/S) | 8 | 9 |
| 1P | 5 | 3 | 1 | 13 | 3 | 9 | 2/3 | 2 | 3 |
| K* | 5 | 0 | 0 | 12 | 2 | 8 | 2/3 | 2 | 4 |
| 15P | 4 | 0 | 1 | 12 | 1 | 9 | 2/2.5 | 3 | 2 |
| 22P | 4 | 1 | 1 | 12 | 2 | 9 | 2/2 | 2 | 3 |
| 29P | 4 | 1 | 0 | 12 | 3 | 8 | 2.5/2.5 | 2 | 4 |
| 36P | 5 | 0 | -1 | 12 | 2 | 9 | 2/2 | 2 | 3 |
| 43P | 2 | 0 | 1 | 11 | 2 | 8 | 2/2 | 2 | 3 |
| 50P | 4 | 1 | 0 | 10 | 3 | 7 | 2/2 | 2 | 3 |
| 57P | 4 | 0 | 0 | 11 | 3 | 9 | 2/2.5 | 2 | 4 |
| 64P | 4 | 0 | 1 | 10 | 2 | 8 | 2.5/2.5 | 2 | 3 |
| 71P | 4 | 1 | 1 | 9 | 0 | 10 | 2/2 | 2 | 3 |
| 78P | 5 | 1 | 0 | 11 | 3 | 10 | 2.5/2.5 | 2 | 3 |
| Avg. | 4 | 1 | 0 | 11 | 2 | 9 | 2/2.5 | 2 | 3 |

Hours: 48:25
Port pitch extension: N/R
Track adjuster extension: N/R

All measurements are in 1/64 in. unless otherwise noted. The symbol (-) designates a buildup of the surface due to upset of the metal or measurement error resulting from variations in measuring instrument tolerances. All measurements are accurate to 1/64 in.

*Hours: 23:20 as this is a replacement block.

TABLE A.7 - TRACK BLOCK WEAR DIMENSIONS ON STARBOARD SIDE AT 48:25 HOURS

| Block No. | Grouser Surface Wear | | | | | Pad | Drive Ring | Guide Pin | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 (P/S) | 8 | 9 |
| 1S | 1 | 0 | 1 | 3 | 7 | 9 | 2/3 | 2 | 2 |
| 8S | 0 | 0 | 3 | 3 | 7 | 9 | 2/3 | 3 | 2 |
| C* | 2 | 0 | 3 | 2 | 6 | 8 | 2/2 | 1 | 2 |
| 22S | 2 | 0 | 3 | 3 | 6 | 9 | 2/3 | 2 | 3 |
| 29S | 0 | 1 | 3 | 3 | 8 | 9 | 2.3 | 2 | 2 |
| 36S | 2 | 1 | 3 | 4 | 7 | 8 | 2/3 | 3 | 2.5 |
| 43S | 3 | 0 | 2 | 5 | 8 | 10 | 2/2 | 2 | 3 |
| 50S | 2 | 1 | 3 | 3 | 7 | 8 | 2/2 | 3 | 2 |
| 57S | 1 | 1 | 1 | 4 | 8 | 8 | 2.5/3 | 2.5 | 2.5 |
| 64S | 1 | 1 | 1 | 4 | 7 | 8 | 2/3 | 2 | 3 |
| M* | 0 | 0 | 2 | 3 | 5 | 7 | 1/2 | 2 | 2 |
| 78S | 2 | 0 | 4 | 2 | 7 | 9 | 2/3 | 2 | 4 |
| Avg. | 1 | 5 | 3 | 3 | 7 | 9 | 2/3 | 2 | 2.5 |

Hours: 48:25
Starboard pitch extension: N/R
Track adjuster extension: N/R
All measurements are in 1/64 in. unless otherwise noted.

*Hours: 23:20 as these are replacement blocks.

## APPENDIX B

## IMPROVED ALUMINUM TRACK (IAT) FINAL REPORT

1. Period of Test Coverage: 209:20 hours to 260:25 hours

   Dates of Test Coverage: 23 August 1982 to 15 March 1983

2. Durability Test Phase: 3,119 to 3,774 miles

3. Inspections Accomplished: Standard IAT inspections of port and starboard tracks

4. Test Status

   a. Grouser Wear

      (1) Grouser wear pattern as established did not change during the last 60 h of operation. G1 - G3 were still the highest wear areas. Inboard areas wear faster than the outboard areas. Areas protected by the track pad had the least wear. All other comments made at the 200-h report are still valid.

   b. Pad Wear

      (1) Pad wear is still dependent on the installed location; i.e., inboard always wears faster.

      (2) Size of the track pad is also a major influence on the wear rate. The larger standard LVTP-7 pad had the slowest wear rate.

      (3) Cure date of the rubber is also a major factor in the understanding of pad wear. The newer the rubber the longer it will wear.

   c. End Caps

      (1) End caps finally wore through to the aluminum base material. This failure was a major influence in stopping the test.

      (2) None of the caps separated from the aluminum block.

      (3) Wear of the end caps was accelerated by the improper fit of the sprockets to the track. The wear was aggravated by the wear of the track center guide allowing the improper fit to deteriorate faster.

      (4) The addition of the steel grousers did not affect the wear rates of the end caps.

   d. Center Guides. The last 60 h of testing did not change any of the earlier wear data.

      (1) The steel was worn through to the aluminum subbase on most guides.

      (2) More of the steel caps came off as expected.

      (3) None of the unprotected aluminum center guides broke off.

e. Track Stretch

(1) Throughout the test program, track stretch was maintained as two fingers clearance between the track and the third roadwheel.

(2) Track tension was never a problem. The test crew did not make any more adjustments than with the standard steel track.

(3) Ten block pitch at 260 h: port 60 and 9/16 in., starboard 60 and 9/16 in.

(4) The rubber bushings performed well. No IAT blocks were removed during the entire test because of a bushing failure.

f. Visual Inspection

(1) The IAT wore out and is no longer safe to operate.

(2) The fourth set of rubber pads installed at 22 h were wearing well, and probably could have gone another 40 h.

(3) The G1 - G3 grousers are no longer in existence and the steel end caps were then taking a direct loading. The other grousers flattened out and seem to be more pitted and mushroomed over.

(4) Over 80% of all the center guides have been worn through on the outboard side. At least 20 center guides have lost their steel cap completely.

(5) End caps have remained in place for the entire test, however, their shape is no longer circular but is now more oval. Many end caps are worn through to the aluminum subbase.

(6) Direction of track was reversed at 100 h and no difference was noticed in either track wear or vehicle performance. Since the 200-h inspection, wear to the end caps and center guide seems accelerated.

(7) Modifications made at the 100-h inspection provided some insight to the wear mode of the IAT.

(a) Steel grousers added to the steel end caps is an improvement and should be incorporated on the next generation of test track. No operational problems were encountered with their incorporation. G1 - G3 grouser wear on the steel grouser blocks was reduced by 144%/147%.

(b) Standard LVTP-7 steel pads incorporated into the IAT block increases the life of the block. G1 - G3 grouser wear was reduced by 111%/126%, and G6 - G7 was reduced by 166%/115%.

(c) New track pads installed at the 200-h inspection again verified the importance of using track pads before their shelf life is up. Rubber has a very definite life span and storage of the pads greatly affects the performance of the pad. Rubber pads must be stored in a cool, dry environment for the best performance of the rubber at time of use.

(d) When the IAT blocks were reworked to make room for the standard steel track pad, some aluminum was removed which does not seem to have created an unsafe block. With this knowledge verified by 160 h of testing, more areas of the IAT block should be looked at for more weight reduction opportunities.

(e) Two aluminum alloys were used during the IAT testing; the first was 6061-T6 and the other was 7075-T73. Visual inspection of the two alloys shows the 7075-T73 to have more surface pitting after the track has been out of operation for a period of time. With a constant operation, the abrasive action of the sand keeps both alloys polished fairly well. The 7075-T73 wore slightly better. The area of visual comparison is on the back side of the block where the roadwheels meet with the block. This is the area that finally dictated the conclusion to testing. New IAT blocks measure 0.650 in. from edge of bushing to the top surface. The 260-h blocks measured 0.350 in. to 0.420 in. Wear was thus over 0.250 in. or approximately 0.001 in. per hour. This was not an area of interest at the start of the test; therefore, there is no history or wear data other than post inspection of new spare blocks and 260-h blocks.

g. Sprocket Wear Profile

(1) Track-sprocket interface continued to shear metal from the track and the sprocket, which appears to have withstood the 260 h of operation fairly well. It survived the 260 h with no lost teeth and no thrown track. The sprocket is still functional, but with much reservation; see Figure B.1.

5. Problems. No major problems were encountered during the 260 h of testing. The track always performed and no mission aborts could be counted against the IAT. There was much downtime due to the rapid wear of pads and test item inspections, but no downtime for track failure.

6. Figures:

Figure B.1 - Sprocket Profile, Port/Starboard at 0/260 Hours

Figure B.2 - Original Blocks Showing Total Wear

Figure B. 3 - New Blocks After 100 Hours Showing Total Wear

Figure B. 4 - Steel Grousers Showing Total Wear

Figure B. 5 - Steel Pads Showing Total Wear

Figure B. 6 - New Track Block Showing (a) Front, (b) Back, (c) End Cap, and (d) Center Guide Cap

Figure B. 7 - 260-Hour Track Block Showing (a) Front, (b) Back, (c) End Cap, and (d) Center Guide Cap Wear

Figure B. 8 - 260-Hour Center Guide Cap Showing (a) Square Hole Wear, (b) Total Loss, (c) Port Sprocket Teeth Profile - Close Up, (d) Port Sprocket Teeth Profile, (e) Starboard Sprocket Teeth Profile - Close Up, and (f) Starboard Sprocket Teeth Profile

Figure B. 9 - Measurement Plate (a) Dial Indicator and (b) Steel Scale

Figure B.10 - Link Pin Bushing Material (a) New Block and (b) 260-Hour Block Wear

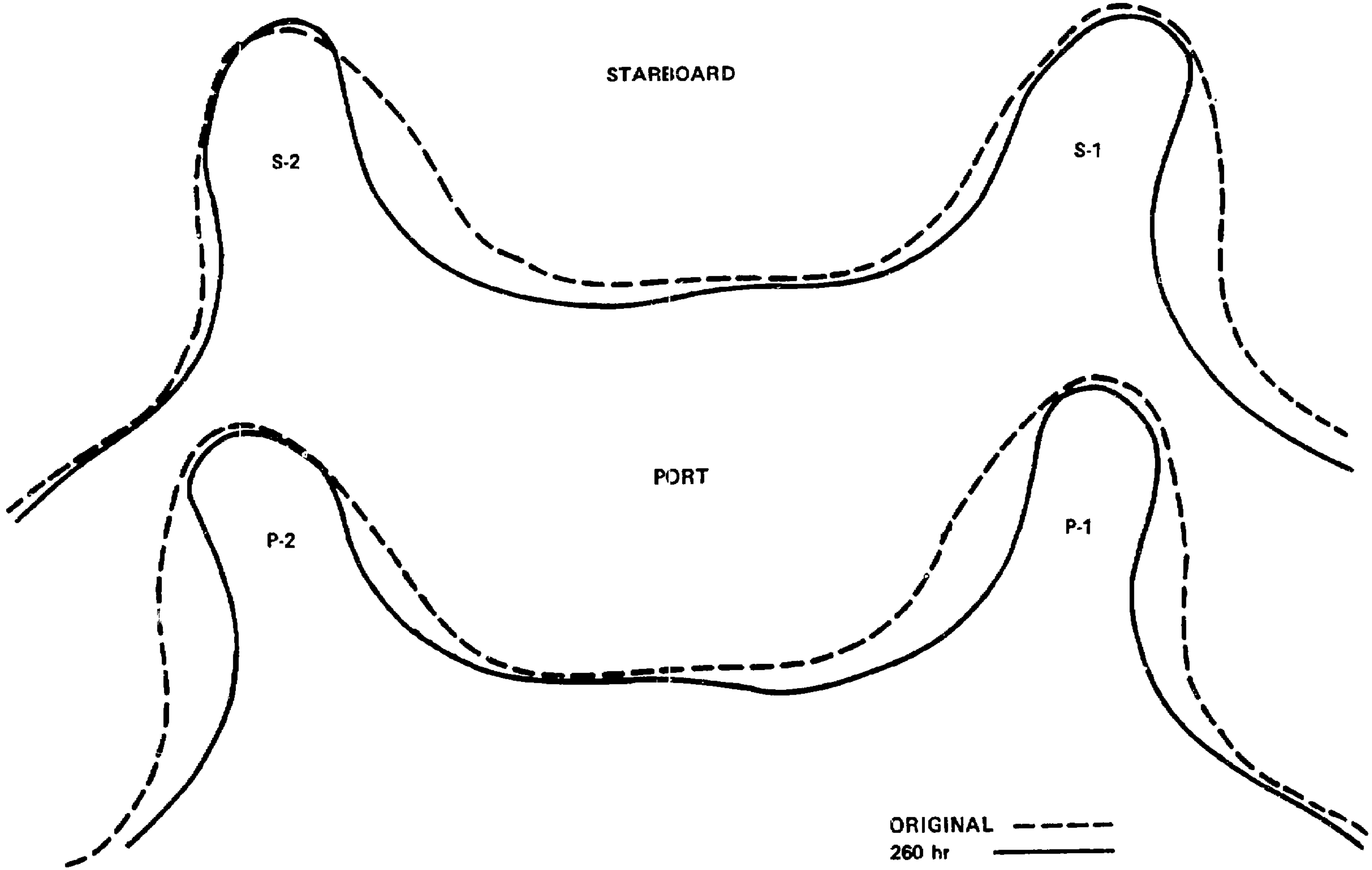



Figure B.1 - Sprocket Profile, Port/Starboard at 0/260 Hours

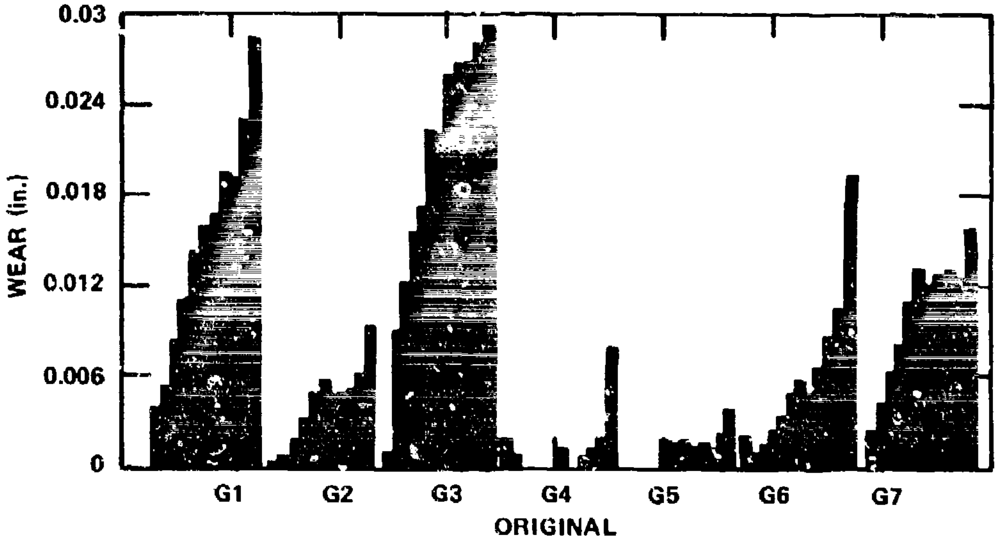



Figure B.2 - Original Blocks Showing Total Wear

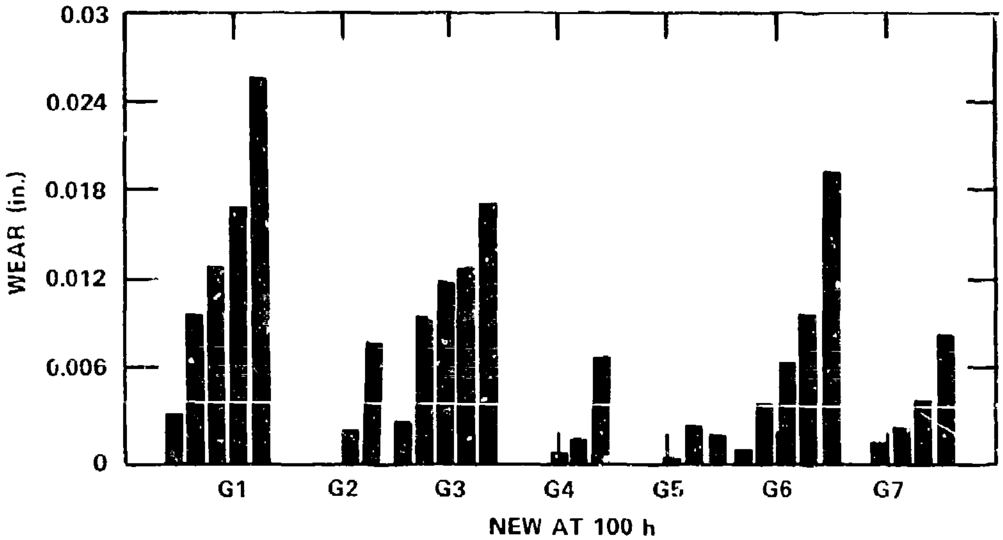



Figure B.3 - New Blocks After 100 Hours Showing Total Wear

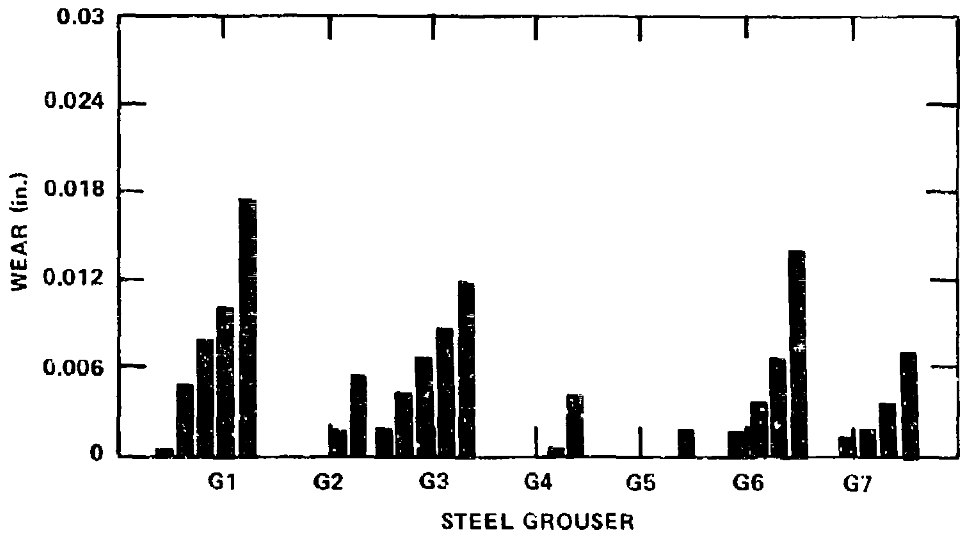



Figure B.4 - Steel Grousers Showing Total Wear

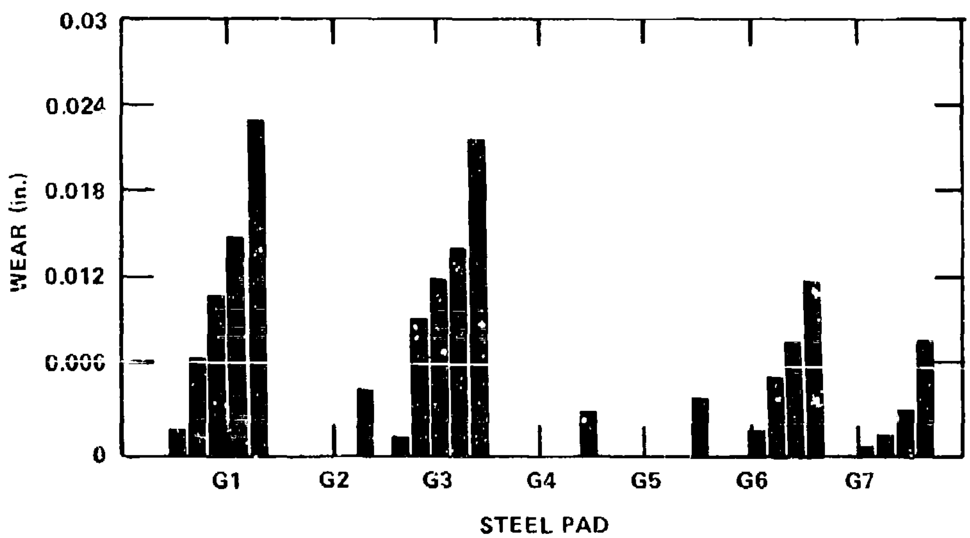



Figure B.5 - Steel Pads Showing Total Wear

Figure B.6 - New Track Block

Figure B.6a - Bottom

Figure B.6b - Top

Figure B.6 (Continued)

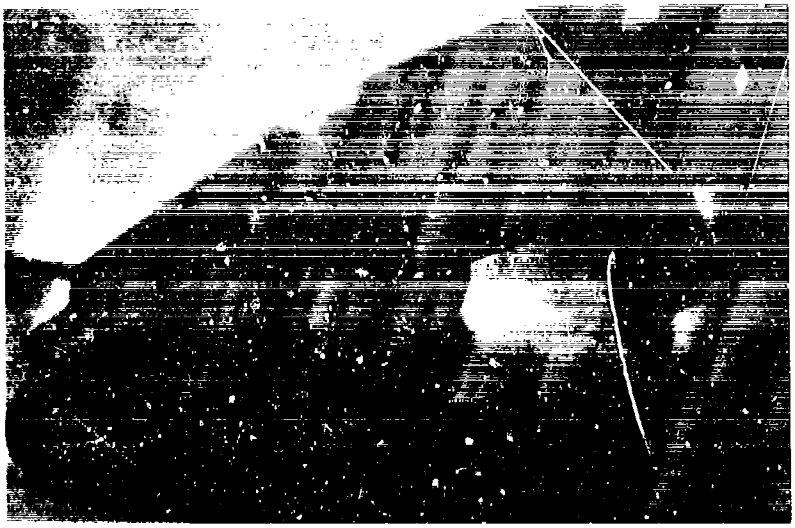


Figure B.6c - End Cap

Figure B.6d - Center Guide Cap

Figure B.7 - 260-Hour Track Block

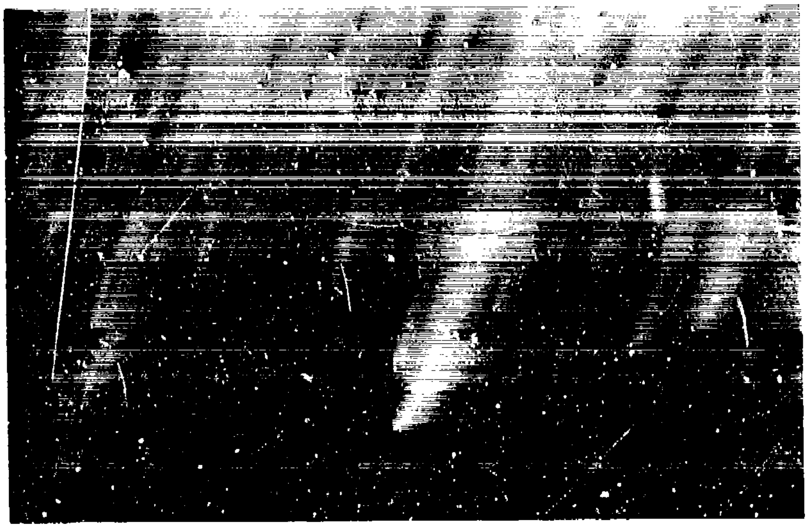


Figure B.7a - Bottom

Figure B.7b - Top

Figure B.7 (Continued)

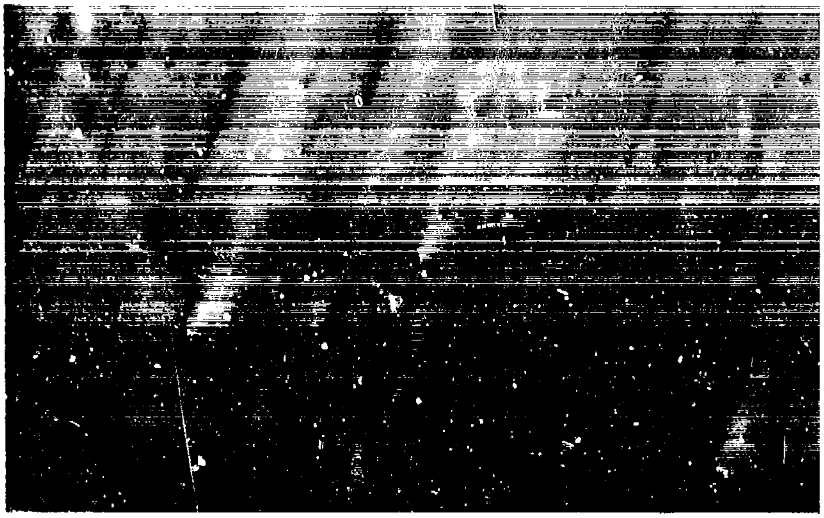


Figure B.7c - End Cap

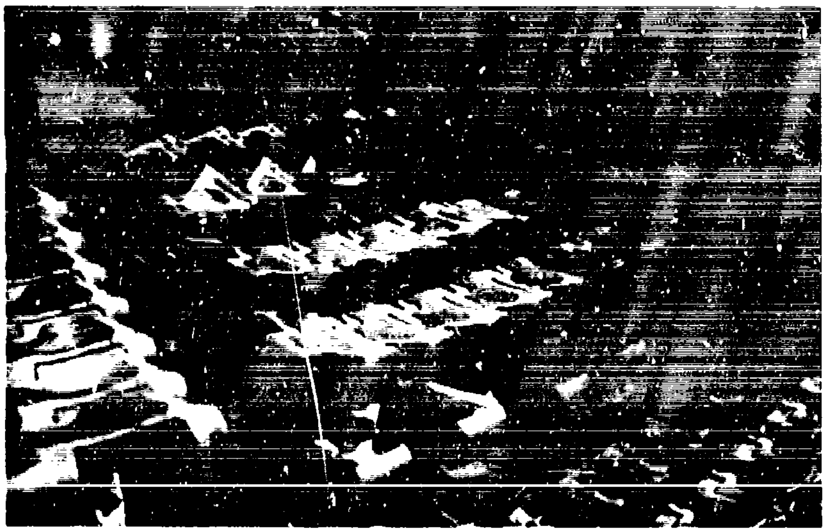


Figure B.7d - Center Guide Cap

Figure B.8 - 260-Hour Center Guide Cap

Figure B.8a - Square Hole Wear

Figure B.8b - Total Loss

Figure B.8 (Continued)

Figure B.8c - Port Sprocket Teeth Profile - Close Up

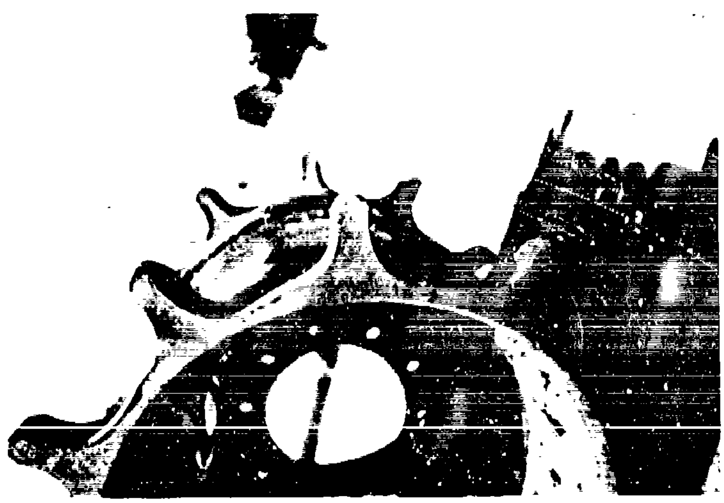


Figure B.8d - Port Sprocket Teeth Profile

Figure B.8 (Continued)

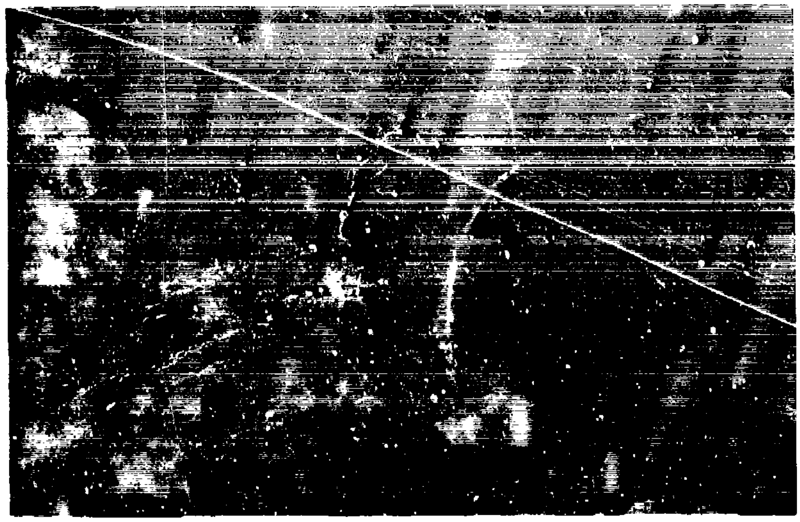


Figure B.8e - Starboard Sprocket Teeth Profile - Close Up

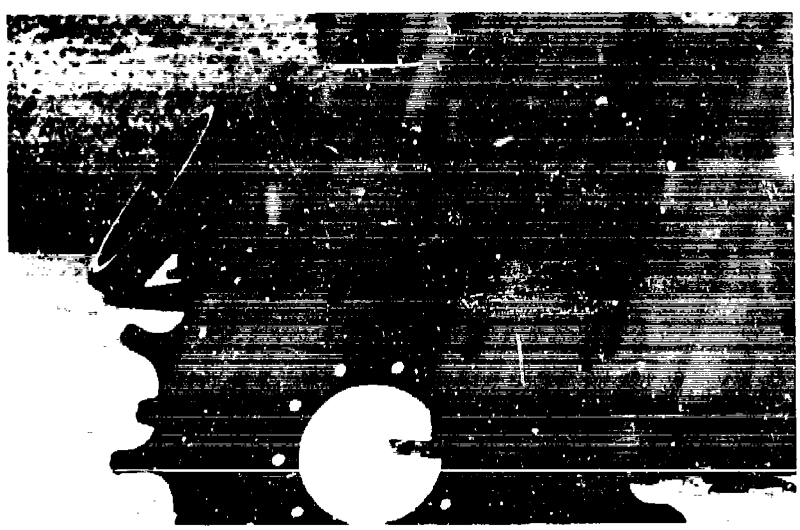


Figure B.8f - Starboard Sprocket Teeth Profile

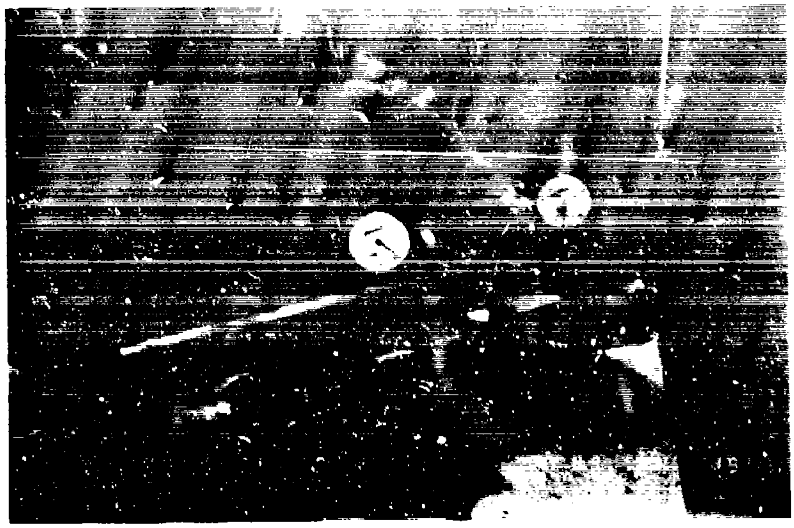


Figure B.9a - Dial Indicator

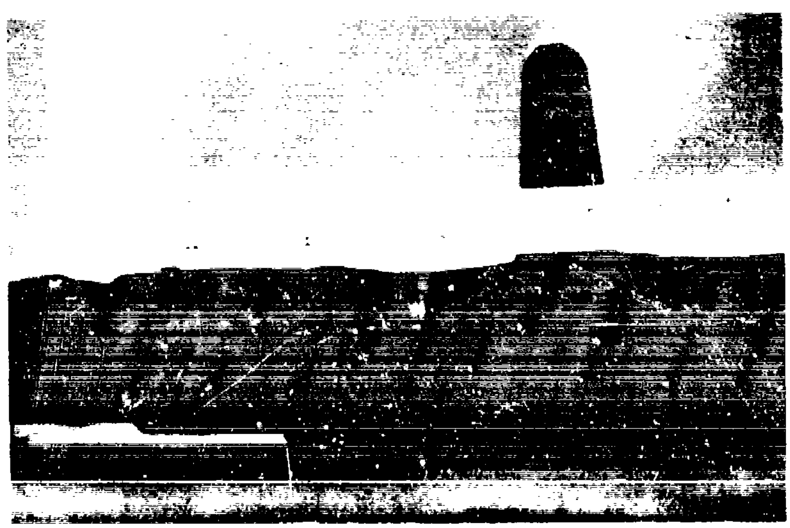


Figure B.9b - Steel Scale

Figure B.9 - Measurement Plate

Figure B.10a - New Block

Figure B.10b - 260-Hour Block Wear

Figure B.10 - Link Pin Bushing Material

## REFERENCES


1. Replogle, D.S., "Design, Laboratory Test, and Manufacture of A Double-Pin, Rubber-Bushed Track," Defense Operations Division, Chrysler Corporation, Detroit, Michigan (Feb 1970).

2. Garrett, R.L., "Aluminum Track Evaluation," Aluminum Company of America, Cleveland, Ohio (Oct 1973).

3. Wilkie, R., "Product Improvement Test of Hard-Coated Aluminum Track Shoes and Hard-Coated Road Wheels for M60 Series Tank (T142 Aluminum Track) Final Report," U.S. Army Aberdeen Proving Ground (Apr 1974).

4. Cummings, A.L., "Final Letter Report on Product Improvement Test of Hard-Coated Aluminum T142 Track for M60 Series Tanks," U.S. Army Aberdeen Proving Ground (Jul 1975).

5. "Design Analysis of Aluminum Track for U.S. Marine Corps Landing Vehicle Assault, Final Report," Aluminum Company of America (12 May 1982).

6. "Master Test Plan For The Feasibility Testing Of An LVA Aluminum Track (A-Track)," DTNSRDC, Systems Development Department (Jul 1978).

7. "Master Test Plan For The Feasibility Testing Of An Improved Aluminum Track (IAT) For Future Marine Corps Tracked Vehicles," DTNSRDC, Systems Development Department, Marine Corps Programs Office (Jan 1981).

8. "Final Report Of Aluminum Track Test," FMC Corporation (27 Feb 1979).

9. "LVA Aluminum Track - Vehicle Test Program, Amphibian Vehicle Test Branch (AVTB), Marine Corps, Camp Pendleton, California," Aluminum Company of America, Alloy Technology Division Report XC-501 (30 Jan 1979).

10. "Forged Aluminum Track Development for U.S. Marine Corps LVTP-7 - Improved Aluminum Track Program," Aluminum Company of America, Forging Division, Cleveland, Ohio (Jun 1983).

## INITIAL DISTRIBUTION

| Copies | |
|---|---|
| 5 | CG MCDEC<br>5 D093, LTCOL Riner |
| 3 | AVTB/LTCOL Collins |
| 3 | ALCOA/John Long |
| 12 | DTIC |

## CENTER DISTRIBUTION

| Copies | Code | Name |
|---|---|---|
| 1 | 00M | MCLNO |
| 1 | 1100 | |
| 11 | 1120 | |
| 1 | 1124 | |
| 1 | 2812 | Holsberg |
| 1 | 2813 | Morton |
| 10 | 5211.1 | Reports Distribution |
| 1 | 522.1 | TIC (C) |
| 1 | 522.2 | TIC (A) |