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U. S. Marine Corps

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THE MARINE CORPS has a stated requirement for a 1-1/2 ton capacity marginal terrain vehicle. This requirement is for a vehicle capable of operating freely over the most extreme swamp and extensive waterway areas, as well as sand, rice paddies, muskeg, and hard surface and unimproved roads.

The vehicle will be used primarily to transport the rifle squad or company/battalion supplies and will replace the carrier, cargo, amphibious, M76 (otter) and M116 which are currently being utilized by Marine forces in Vietnam.

The vehicles will be assigned to an amphibian transport company, a subordinate unit of the force motor transport battalion. The company will be organized into three transport platoons equipped with 15 vehicles each. The unit will be available for both direct and general support missions.

HISTORY

In February 1965, the Marine Corps requested the Army to conduct a development program for a Marine Corps 1-1/2 ton marginal terrain vehicle based on the airoll principle. (Fig. 1) This principle was previously evaluated by the Marine Corps in a 1000 lb payload vehicle known as the landing vehicle airoll (LVAX1).

The airoll suspension is basically a conveyer type track consisting of a series of free-rolling low pressure tires, con-

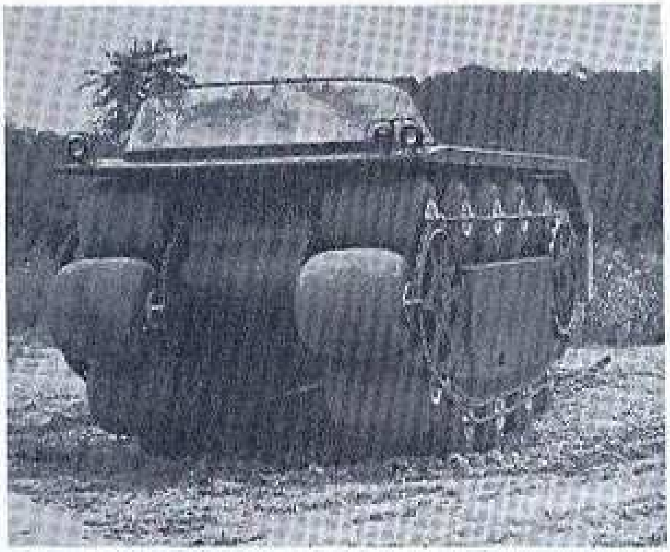

Fig. 1 - Marginal terrain vehicle based on airoll principle

nected by chains, which are in turn driven by conventional sprockets.

The vehicle actually sits on top of the tires. This creates two modes of operation; on firm terrain and roads, the vehicle will move as a track and a wheel resulting in a velocity of twice the chain speed; in soft soil, the tires become embedded and the vehicle moves in the track mode at chain

ABSTRACT

The U. S. Marine Corps, in conjunction with the U. S. Army, is developing a marginal terrain vehicle, based on the airoll principle, to replace the M76 and M116 vehicles. The first phase of the XM759 development program established the overall vehicle configuration. Following approval of the basic design, detail design and pilot fabrication were developed. Initial testing was considered unsatisfactory. However, after tire modifications involving a Chevron tread design, slope climbing capability was achieved with no reduction in mobility. Extensive mobility tests have verified that the marginal terrain vehicle can negotiate the most extreme soft soil conditions.

Table 1 - USMC XM759 Requirements

Item	Essential	Desirable
Payload		
	3000 lb	
	14 troops	
	2 pallets (44 x 52 in.)	
Speed		
Land	25 mph	35 mph
Water	7 mph	10 mph
Mobility		
Longitudinal slopes	60%	
Side slopes	30%	45%
Obstacle	3 ft	
Angle of approach	90 deg	
Angle of departure	60 deg	
Soft soil perf.		
50 pass. VCI	13	
1 pass. VCI	0	
Transportability		
	Rail	
	Sea	
	Air-VTOL	
	C130	
Maintainability		
Durability	400 hr	1000 hr
Reliability	20%	10%

Table 2 - Standard Requirements

1. Bilge pump
2. Electrical slave receptacle
3. Foldaway troop seats
4. Headlights, blackout lights, taillights, infrared lights
5. Tow pintle and towing hitches
6. 12 in. freeboard
7. Climatic inclosures
8. Kits:

   Radio Litter Weapons

   Armor Heater

speed. In the latter case, the tires are in effect large track grousers.

Approximately 10,000 miles of test were conducted on the 6 LVAX1 vehicles built for the Marine Corps. These tests disclosed that the airoll had outstanding soft soil mobility and swimming capability. The LVAX1 was never immobilized in any bottomless mud.

Adversely, this vehicle had unsatisfactory slope and breaking stability, and undesirable ride characteristics.

The principal requirements for the Marine Corps marginal terrain vehicle are shown in Table 1.

The vertical obstacle requirement applies primarily to the capability of negotiating abrupt variations in heights, such as the 2-1/2 - 3 ft high dikes that surround rice paddies. To negotiate the banks of water obstacles the vehicle must be capable of ascending and descending wet slopes.

The requirement for air transport in the C130 restricts the maximum width to 110 in. and height to 102 in. The 400 hr operation consists of 64% cross-country, 8% secondary road, 8% level primary road, and 20% water. Table 2 indicates some of the other standard type requirements.

CURRENT STATUS

In May 1965, the Marine Corps XM759 development program was initiated by the U. S. Army Tank-Automotive Command (TACOM), located at Warren, Michigan. The first phase was a parametric concept phase to establish the overall vehicle configuration. This entailed soil mechanics study by TACOM's land locomotion laboratory to determine optimum wheel size, shape and spacing; study of swimming performance; study of major components to determine the optimum power train and a computer ride characteristics study.

The result of these studies and special tests were then integrated into overall configuration concepts. In September 1965, the Marine Corps approved a TACOM configuration concept which met our stated requirements.

The original configuration provided for a diesel engine and a hydromechanical power train (Fig. 2). Vehicle length was 241-1/2 in., width was 110 in. and it had a reducible height of 87 in. Each track had 17 tires which were 24 in. in diameter and 21 in. wide. Engine and power train were located in the front. The cargo compartment would hold 14 personnel or 3 pallets internally. This concept provides a 90 deg approach angle, a 60 deg departure angle, and 30 in. ground clearance. Approximately 60% of the flotation is obtained from the tires and the remaining 40% is provided by the sponsons and hull. The weight was 14,030 lb.

The detail design and pilot fabrication phase was initiated immediately after approval of the design concept. In addition to detail vehicle design, this phase included a water model study by Davidson Laboratory, Steven's Institute and concept design of armor, weapons, heater, arctic and ambulance kits. Fig. 3 details some of the design features.

The hull shell is an all aluminum, welded structure. The floor, sides and sponson top and bottom are constructed of standard aluminum extrusions. The fenders are constructed of aluminum honeycomb material and are a primary structural element. Sheet aluminum is used for the hull front,

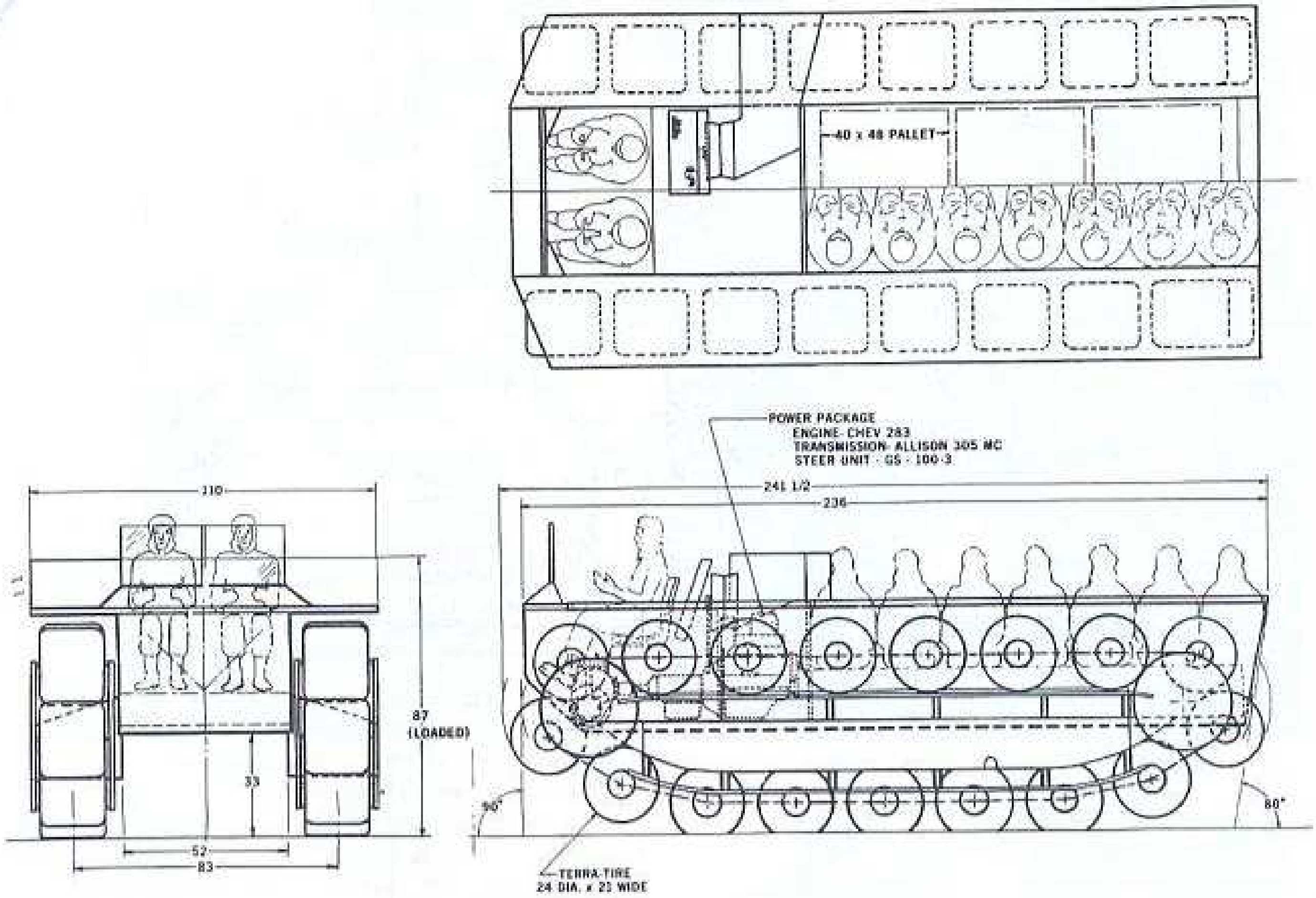

Fig. 2 - Configuration for diesel engine and hydromechanical power train

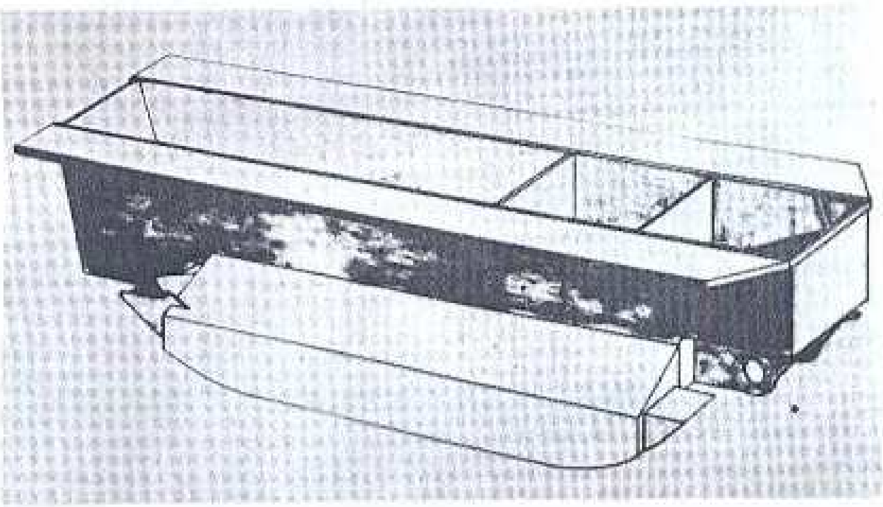

Fig. 3 - Design features of vehicle

the bulkhead, the sponson sides and the cargo floor. This system of hull construction was selected because of its simplicity and weight. Bulkheads separate engine compartment from the crew compartment and the cargo compartment. A manually operated watertight tailgate is hinged to the floor at the rear and can be removed to permit dock loading.

In Fig. 4, a standard radiator surge tank and fan is located behind the codriver's seat. Ambient air is drawn di-

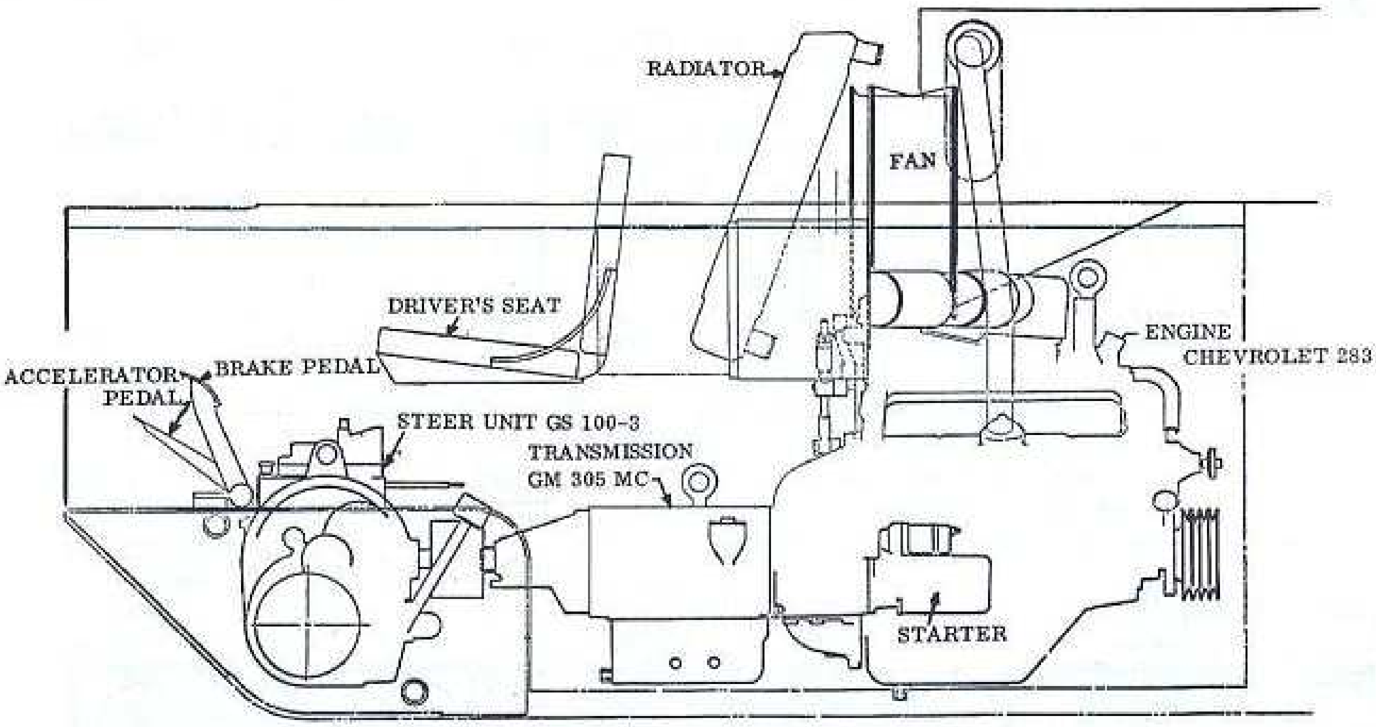

Fig. 4 - MTV power package

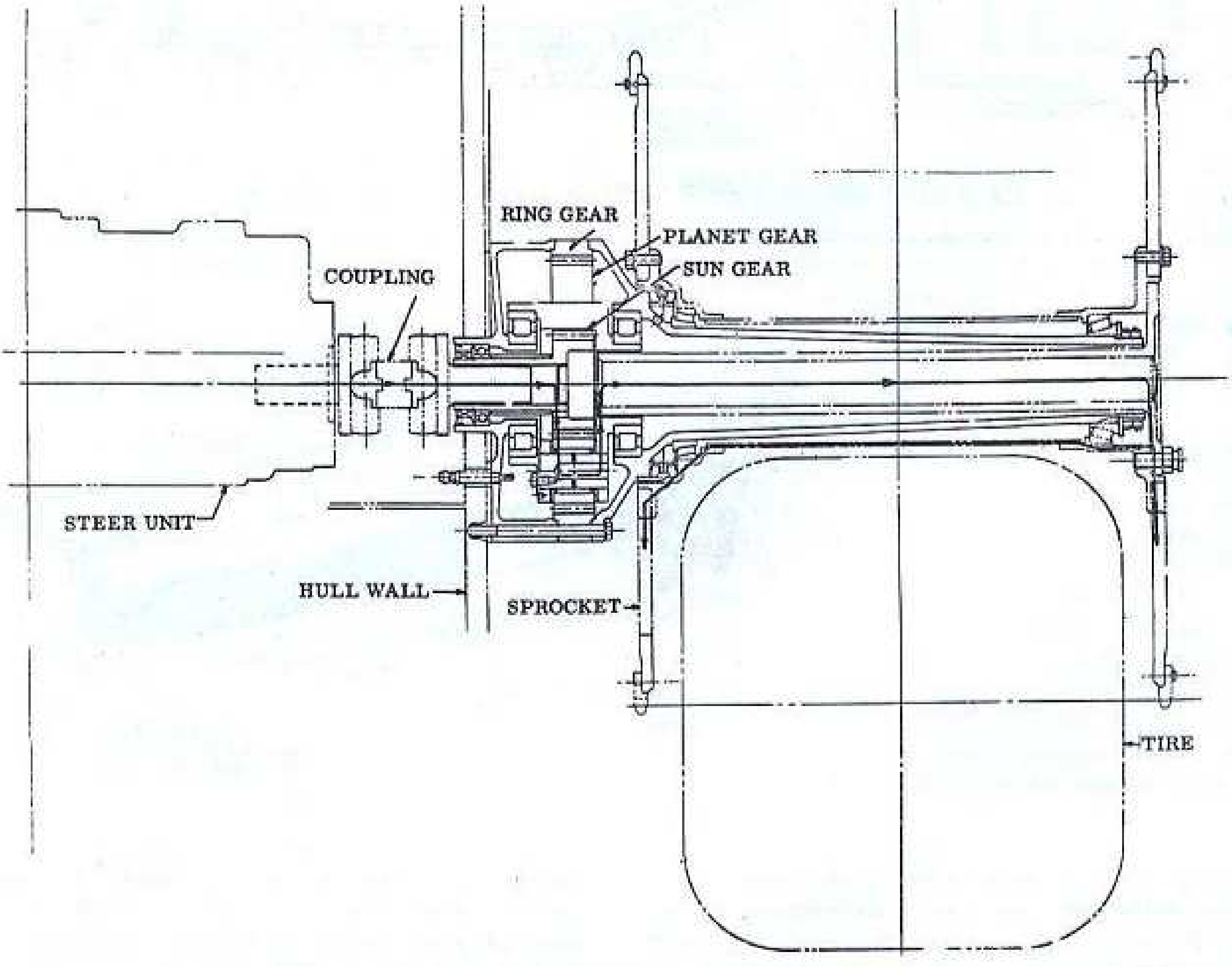

Fig. 5 - Transmission or power from steer unit through planetary final drive

rectly through the radiator and discharged through a duct over the right fender. A standard military 24V, waterproof electrical system is used throughout.

Power is transmitted from the steer unit through a planetary final drive to the drove sprockets as shown in Fig. 5. The planetary final drive configuration was selected so that the power package could be located as far forward as possible.

The fuel system for the vehicle consists of a rectangular bladder type fuel cell, mounted in each sponson, an externally mounted fuel pump and a fuel level transmitter. The fuel cell shown in Fig. 6 is being folded prior to installation in the sponson.

The control system for vehicle operation, as shown in Fig. 7, includes steering, accelerator, brake and transmission shift plus a steer unit high-low range shift lever. Rods and bell cranks are used on all control linkages to permit ease of maintenance, adjustment and use of standard parts.

Bench type troop seats extend the length of the cargo compartment. See Fig. 2. They can be folded against the hull side to permit loading of 40 x 48 in. cargo pallets or removed to permit use of the full width of the compartment which is 52 in. wide by 132 in. long.

To aid in vehicle self-recovery, two capstan drums and a length of nylon rope are provided (Fig. 8). In use, the capstan drums are attached to the drive or idler sprockets, one per vehicle side, and the suspension put into motion. The drums are normally carried on the vehicle and can be installed and removed without the use of tools.

Hand holds, boarding steps for crew and troop use, lifting eyes, towing lugs, a tow pintle, vehicle tie-downs and cargo tie-down rings are also provided.

Daily service access to the powerplant system is accomplished by raising the hinged driver's seat and opening the engine compartment top deck doors. Access openings in the hull floor permit draining of the oil and filter servicing. The engine top deck, including the fan and radiator are removed for engine and transmission removal.

In June 1966, the marginal terrain vehicle program was reoriented into a two prong approach: one being a highly accelerated program for fielding the MTV to Vietnam at the earliest time; the other being a normal development program. The accelerated program was based on the use of a power train, proven in two currently standard military light tracked vehicles (M114 and M116). This power package consists of the V8-283 cu in. gasoline engine, an automatic transmission and a geared differential steer unit. The normal program was a continuation of the original advanced developmental power train version which is identified as the XM759E1. The principal emphasis has since been primarily directed to the accelerated program. TACOM initiated fabrication of five R&D prototypes in July 1966. These were completed from February through May 1967. Simultaneous with pilot fabrication, a three phase, advanced production engineering, production and engineering support contract was competitively solicited. The resultant contract was awarded to Pacific Car & Foundry Co. in February 1967 who

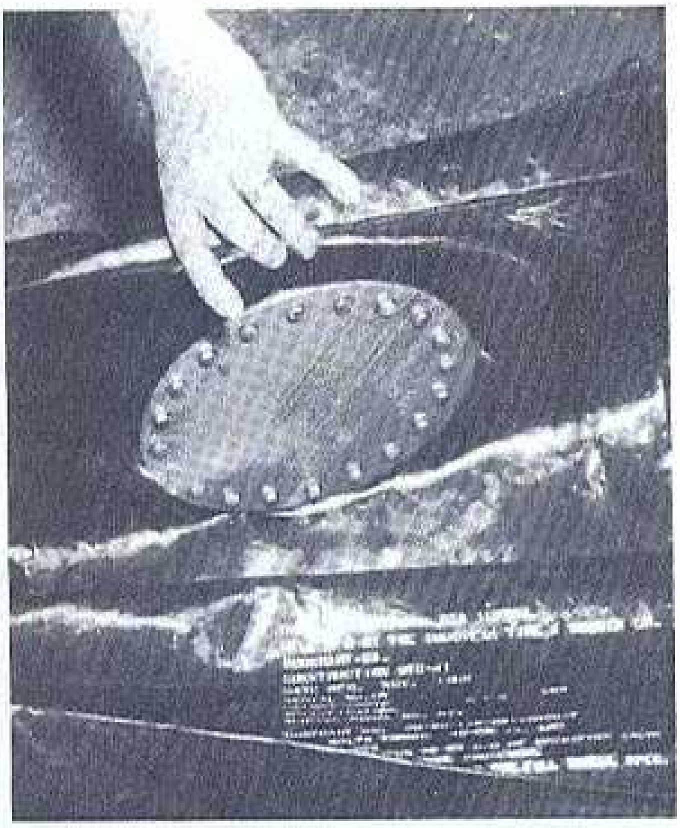

Fig. 6 - Fuel cell

immediately initiated the phase one advanced production engineering effort. Phase two is production of an operational quantity of vehicles, initiation of which is contingent on achieving satisfactory test results. The engineering and service test was initiated by the Army test and evaluation command in March 1967. The principal test categories being performance, mobility and durability. Agencies participating in the tests include Yuma Proving Ground, Yuma, Arizona; Aberdeen Proving Ground in Aberdeen, Maryland; General Equipment Test Activity located in Fort Lee, Virginia; Waterways Experiment Station in Vicksburg, Mississippi and the Marine Corps Development Center. The mobility and performance tests are essentially completed. The durability test is continuing. The extensive mobility test conducted in 15 locations in Virginia and Louisiana has verified that the XM759 has outstanding soft soil mobility.

As previously stated, the XM759 is being developed to replace the M76 and M116. Therefore, during the mobility test, an M116 was operated over the course as a comparison vehicle.

Fig. 9 shows the M116, a full tracked, amphibious cargo and personnel carrier, 185-1/2 in. long, 85-1/2 in. wide, weighing 11,000 lb and having the capability of carrying a 3000 lb payload or 13 troops. Table 3 shows a comparison between the M116 and the XM759.

The results of the mobility test disclose that although the XM759 could make repeated passes in soils of any bearing strength, the performance on firm, slippery clay or wet grass slopes was unsatisfactory due to the nontreaded tires slipping.

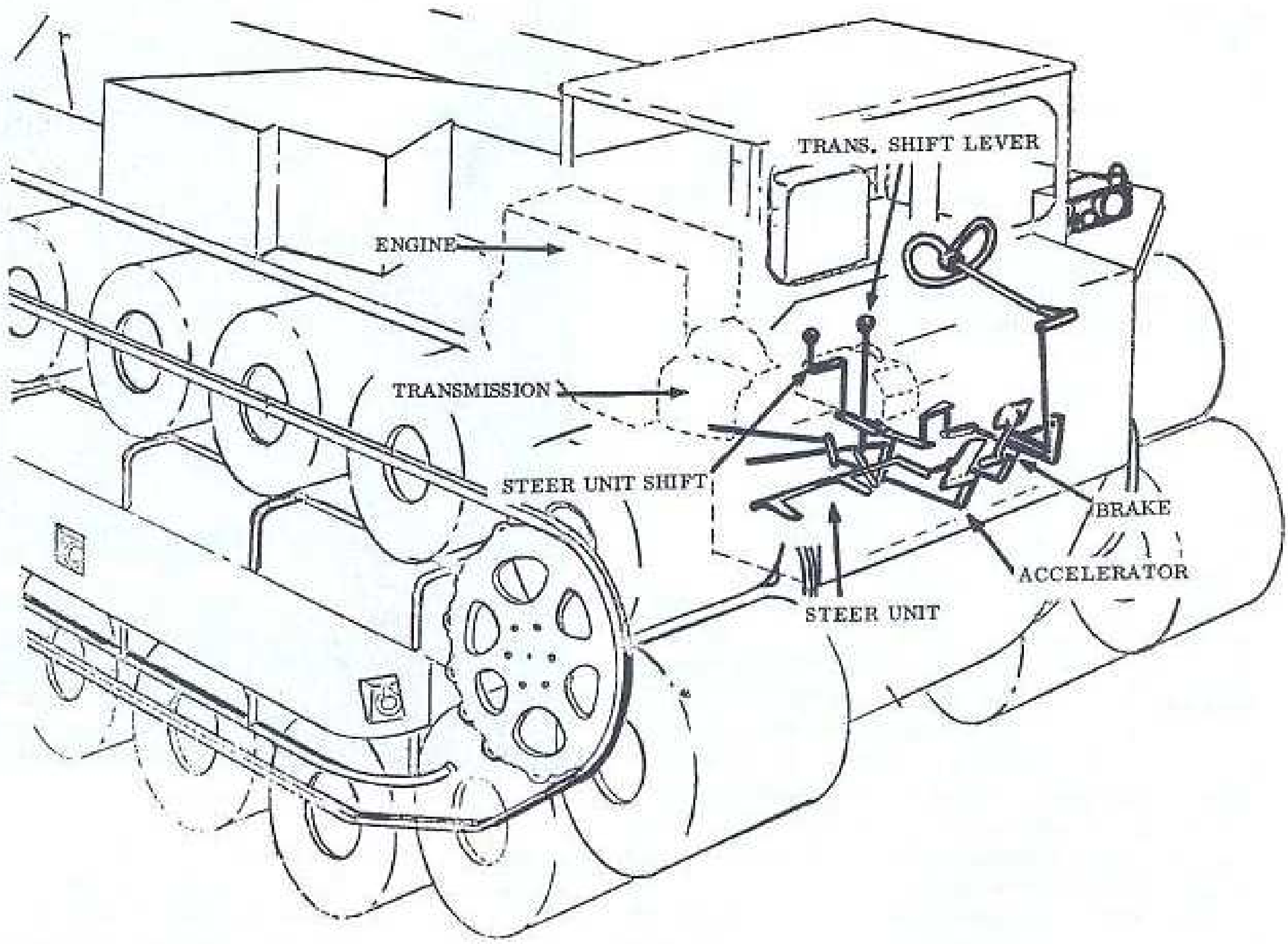

Fig. 7 - Control system for vehicle operation

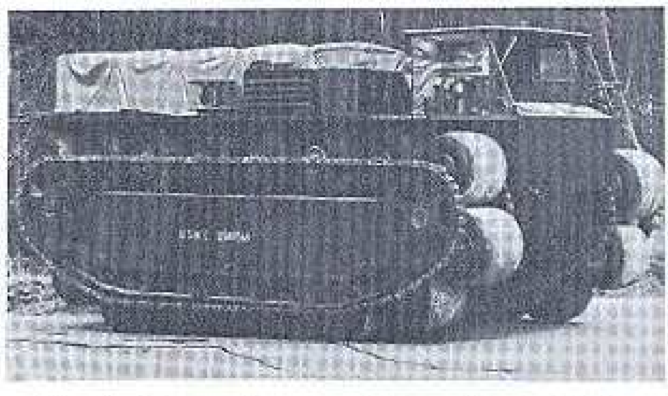

Fig. 8 - Capstan drums attached to side of vehicle

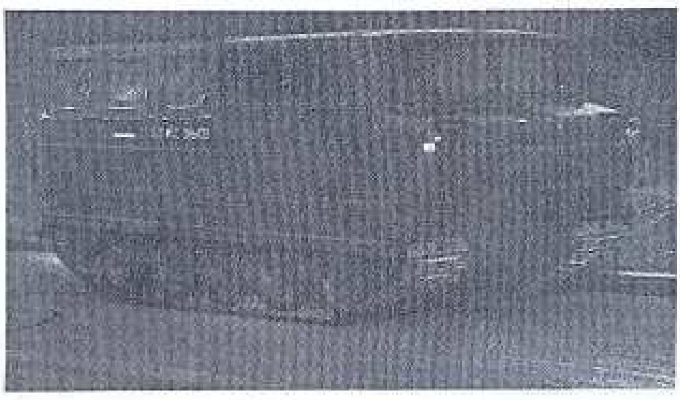

Fig. 9 - M116 amphibious cargo and personnel carrier

As shown in Table 4, laboratory and recent field tests verify that treaded tires effectively eliminate this impediment. However, subsequent tests revealed a mobility degradation due to the vehicle breaking through the vegetation mat.

Tests to determine optimum tire configuration reveal that a modified Chevron tread design will provide the slope climbing capability with no reduction in mobility. Fig. 10 shows a representation of the tread designs included in the tests. Tire g is the modified Chevron design.

The durability and reliability tests uncovered several major problem areas, the first being sponson failures due to inadequate structure, the second being very rapid chain wear.

The sponson failures entailed collapsing of the sponson ends and cranking all along and across the bottom of the

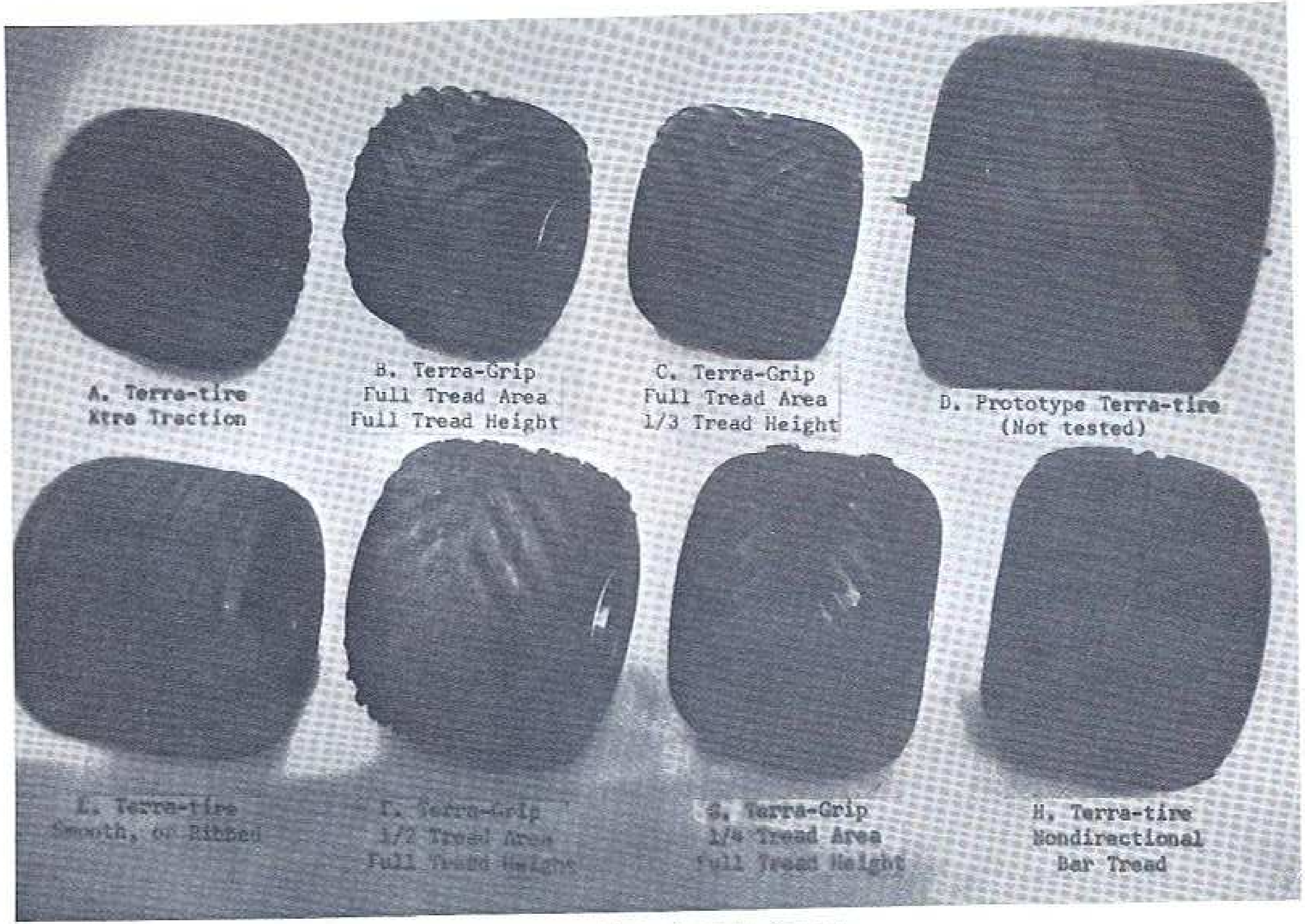

Fig. 10 - Tire tread designs included in field tests

Table 3 - Characteristics of M116 and XM 759

	M116	XM759
Length	185-1/2 in.	241-1/2 in.
Width	85-1/2 in.	110 in.
Height (reduced)	64 in.	87 in.
Payload	3000 lb or 13 personnel	3000 lb or 14 personnel
Weight (gvw)	11,000 lb	14,030 lb

Table 4 - Limited Mobility on Firm Slippery Slopes

WES Laboratory Tests - Chevron and Bar Treaded Tires provided 7:1 tractive increase over smooth tires.

Vehicle field tests on slick clay slopes

Tire	MAX Slope, %
Smooth	9
Chevron Tread	19
Bar Tread	29*

*M116 could not negotiate.

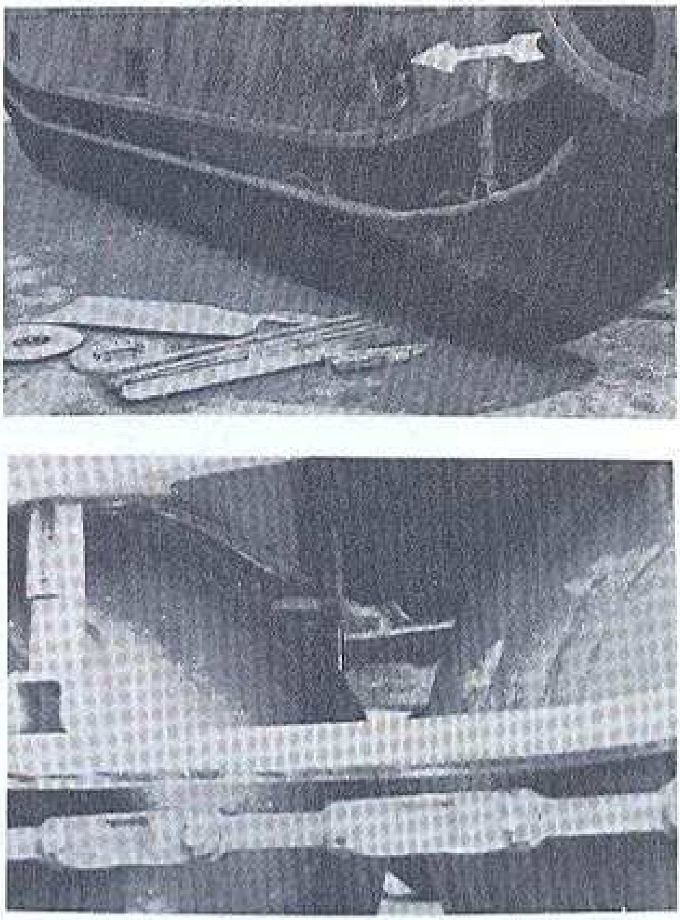

Fig. 11 - Test failure of sponson

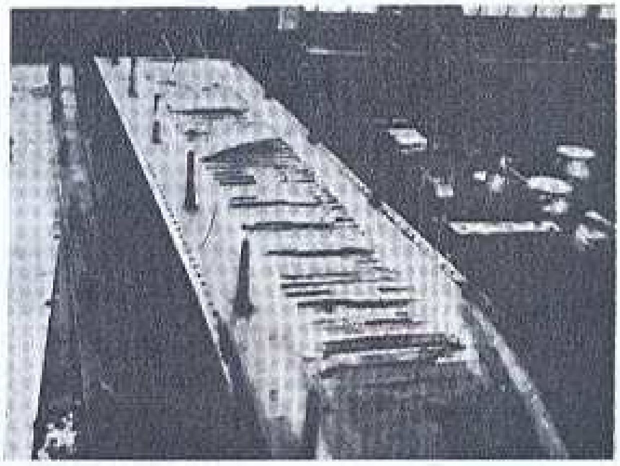

Fig. 12 - Upside down view of vehicle

sponsons,as shown in Fig. 11. Field repairs were made several times on the sponsons of the test pilots in order to continue testing. Continued testing of the Aberdeen pilot resulted in this complete failure of the bottom of the sponson.

The chain wear resulted in chain elongation. This was as high as 17 in. in 29 hr of operation which was the maximum life. These problems caused a significant slow down in the test program, and necessitated rebuilding several pilots with new sponsons and heavy duty chains. Subsequent testing of the first rebuild pilot revealed another major durability problem: this being rapid wear of the bottom of the sponsons.

Fig. 12 is a view of the vehicle turned upside down. The sponson wear plate has been worn through exposing the basic sponson structures. The wear plate was 3003 aluminum impregnated with aluminum oxide. Life was 108 hr. Incurrence of the wear plate necessitated further slipping of the production go-ahead. A mechanical laboratory test of different materials was underway in December. The sponson bottom not only requires long life, but must also have adequate friction to provide positive drive on the wheels.

The laboratory test results are shown in Table 5. Although these tests can not be considered as precisely correlating with full scale vehicle tests, they do give a general measure of comparison life. Material No. 1 which gave us 108 hr life in actual usage only provided 40 - 140 minutes in the laboratory. We feel that material No. 11 which lasted 13 hr and 22 minutes in the laboratory will provide us the desired 1000 hr durability on the vehicle.

Tests of a rebuilt pilot equipped with a rubber wear plate revealed the 4th major problem in January 1968 -- buckling of the hull and was attributed to mud/vegetation build-up on the sponsons.

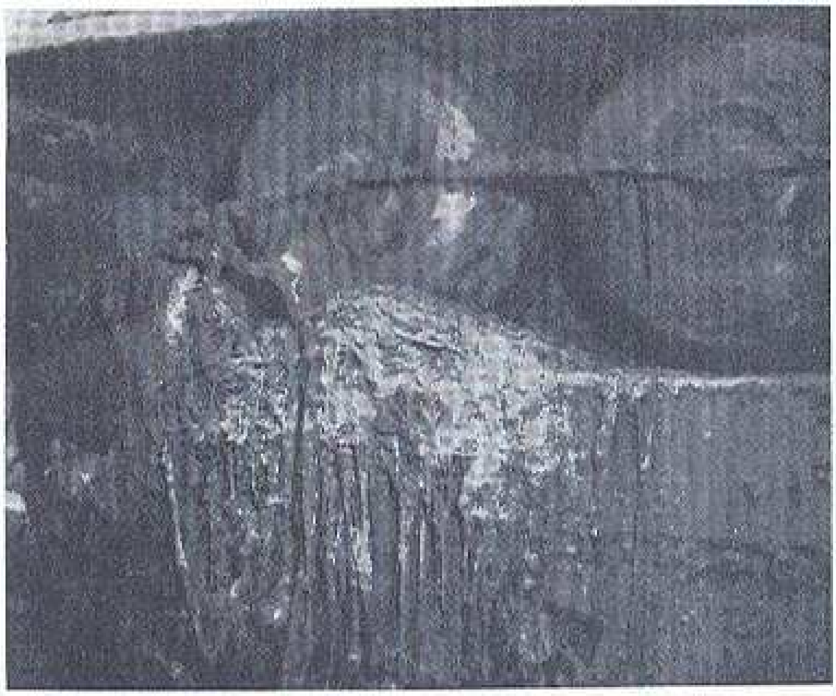

Fig. 13 - Build-up of mud/vegetation

Table 5 - Prony Brake Wear Plate Materials Test

Material	Durability
1. 3003 aluminum with fine grain aluminum oxide	40 min - 140 min (108 hr at apg on pilot #3)
2. 3003 aluminum with coarse grain aluminum oxide	3 hr
3. Tungsten carbide hot dipped coated on steel	15 - 35 min
4. 1/16 in. steel	12 hr, 8 min
5. Silicon carbide sheet	15 min.
6. Paint on silicon carbide	5 min
7. Grooved Buna S. rubber belting 3/8 in. thick	no appreciable wear after 4 hr
8. 1/8 in. polyurethane - Shore D 45	11 hr, 12 min
9. 1/8 in. polyurethane - Shore D 65	12 hr, 12 min
10. 1/8 in. polyurethane imbedded with fine abrasive	9 hr, 18 min
11. 1/8 in. polyurethane imbedded with coarse abrasive	13 hr, 22 min

Mud/vegetation build-up was first encountered in May 1967 at Camp Wallace. Of all the many sites tested, the Camp Wallace, Ft. Eustis area is the only place where significant build-up occurred. A number of conditions such as vegetation density, vegetation strength and root strength, mud consistency, soil strength, etc. must be just the right combination for build-up to occur.

Fig. 13 shows the first build-up. The principal accumulation occurred at the sponson rear top surface between the idler sprockets and on the inside of the sponson top along the vehicle hull. Testing at that time indicated that with continued operation the vegetation would build to this point. No problem was encountered with additional running unless the vehicle was reversed. This would cause the sprocket to lift the vegetation off the sponson top and jam the chains off the sprockets.

One of the modifications made to the sponson design was to allow more clearance between the sponsons and sprockets to allow the mud and vegetation to fall through. Subsequent testing showed that the sponson top area should be closed up rather than opened up. These subsequent tests also disclosed a chain throwing condition which subjected the vehicle to high tension loads.

The hull design has since been changed to provide more strength, a closed up sponson top area, and a hydraulic tension system with warning lights and pressure relief valves to preclude excessive tension pressure.

The chain throwing condition is being corrected by a tension hydraulic system and chain guards.

TIRES

The vulnerability of pneumatic tires has been recognized and efforts have been undertaken to investigate and develop a less vulnerable tire for the XM759. Although no positive results have been realized to date, several unique tire concepts are currently being tested and evaluated. Results of these tests could possibly eminate with a revolutionary safety tire which would have a significant effect on military and civilian wheeled vehicles of the future.

CABLE DRIVE

As a back-up support effort for the chain drive system, Pacific Car & Foundry Co. has designed and developed a cable drive system which appears to possess excellent potential. A prototype system is currently being tested. Should the cable drive system show a significant improvement over the chain drive, retrofit of the initial production vehicles and incorporation in the design for the improved version, XM759E1, is planned.

Designs for the improved version vehicle, the XM759E1, generally consist of improved sponsons and new structure for mounting to the vehicle hull, a simpler and cheaper construction of the hull, aluminum wheels for weight reduction, new and improved wheel axles, bearings and seals, improved windshield assembly, and an improved swim kit/water control system. The power train for the XM759E1 currently calls for a diesel engine and the hydromechanical power train transmission. Should a proven multifuel engine in the desired horsepower range become available prior to production of the improved version vehicle, the diesel engine would, accordingly, be substituted.

SUMMARIZATION

In summary, it is re-emphasized that throughout the design evolution of the marginal terrain vehicle, the soft soil requirements and overall mobility factors such as angle of approach, ground clearance, and power to weight ratio were maximized with minimum compromise to transportability and utility requirements. Extensive mobility tests have verified that the marginal terrain vehicle can negotiate the most extreme soft soil conditions. This is a needed capability and one which no other current military surface vehicle can satisfy.

Marine Corps, Army and industry know-how is being jointly and cooperatively applied to provide the Marine Corps with this unique vehicle for overcoming adverse terrain during military operations.

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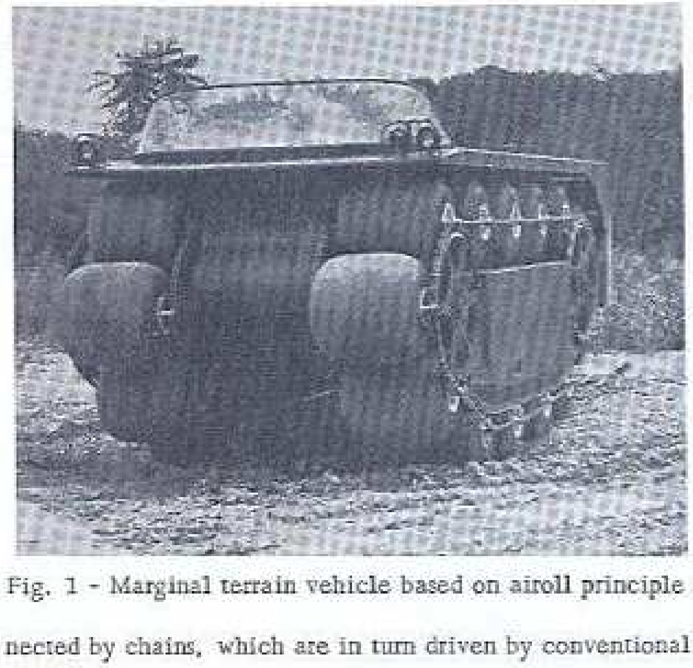

Fig. 1 - Marginal terrain vehicle based on airoll principle

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