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Development of Rough Terrain Vehicular Materials Handling Equipment for the Army

Joseph W. Beaudet,
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PRESENT CONCEPTS of warfare indicate that maintaining an effective supply system will become more and more difficult. There will no longer be prepared and semi-prepared roads available to move long convoys of vehicles carrying supplies to the front lines. Field units will be dispersed over a wide area and will be moving fast, complicating the logistics of modern warfare.

To meet the logistical problem, the Army has developed two systems capable of resupplying remote field units, that is, aerial drop and helicopter delivery. The problem of delivering vehicular equipment is even more critical and requires versatile, speedy, and rugged vehicles of compact design, adaptable to air transport.

MODERN LOGISTICS

The Army on the move means mobility of vehicles as well as personnel, and this means a new approach to vehicle development. While it is purely coincidental, it is nevertheless timely that army mobility is an urgent topic of discussion, for only recently President Kennedy discussed in an address to Congress the immediate need for improved army mobility. Where troop and supply movement are involved, mobility means many different things to many different people.

For example, to the Air Force and Navy commander, it generally relates to the speed, effort, and efficiency generated in transporting men and equipment by air or sea to various places throughout the world. To the Army troop commander, it also means speed, effort and efficiency in moving a body of troops to an objective. But to the engineer and designer, it means, basically, the ability of a vehicle successfully to traverse varying types of rough terrain with a minimum of breakdowns, maintenance, and downtime. At present, with emphasis being placed once again on the foot soldier to cope with limited type wars, all the meanings of mobility become doubly important.

It is a truism that the fighting man is only as effective as his supply system. Within the presently anticipated zones of combat, it is obvious that maintaining an effective supply system will become more and more difficult. The mammoth armies of the past, to a large extent using roads and semi-prepared surfaces to haul supplies over many hundreds of miles of combat zone, will in all likelihood be obsolete. Consequently, logistical vehicles, such as the rough terrain fork trucks of the Quartermaster Corps, are becoming and will continue to become more complex and more mobile to cope with off-road terrain.

DEVELOPMENT OF ROUGH TERRAIN EQUIPMENT

The Quartermaster Corps between the years 1948-1953 conducted user evaluations on all known makes and models of fork trucks for which manufacturers claimed some degree

ABSTRACT

Mobility of supplies and equipment is an important logistics problem of modern warfare. Airlift and ground transport must provide a system capable of fast delivery to troops on rough terrains. The Quartermaster Corps has developed a lightweight, 4000 lb capacity, fork lift truck (the Sandpiper) that is compatible with both supply methods. Design features include sectionalization for ease of transportation, pivoting front wheels for improved weight distribution, lighter vehicle weight to improve payload-to-vehicle weight ratio. A separate power pod makes the Sandpiper applicable to other types of vehicles. Similar trucks with capacities up to 10,000 lb have been projected.

of rough terrain performance ability. Analysis of the data obtained as a result of these tests indicated that specially designed military model, rough terrain, fork trucks would be required to meet operational needs. Accordingly, the Quartermaster Corps embarked on an extensive development program, utilizing the most advanced design features and improved techniques to solve these problems.

Prototypes - Design criteria were gathered, evaluated, and finalized by 1955, and by late 1956 one each of 6000 lb capacity (Fig. 1) and 10,000 lb capacity (Fig. 2) prototype trucks was ready for evaluation. These vehicles proved out well in tests, and by late 1957 procurement documents were available for production. Since that time, 450 of the 6000 lb capacity trucks have been procured, as have approximately 360 of the 10,000 lb capacity trucks. All manner of attachments have been developed for these vehicles. These include crane attachments, winterization kits, winches, and similar accessories (Fig. 3). It is especially noteworthy that the crane attachment for the 10,000 lb truck was developed in approximately five months' time and was accepted along with the truck for use at Nike Hercules missile sites.

In addition to these vehicles a 15,000 lb capacity, rough terrain, fork lift truck was developed by the Quartermaster Corps for handling CONEX containers (Fig. 4). It also has had several attachments developed for it (Fig. 5). This vehicle is currently being readied for procurement.

Although this family of rough terrain fork trucks, which we have named Teleforks, has been and continues to be effective, nevertheless its use is limited by the terrain that must be negotiated.

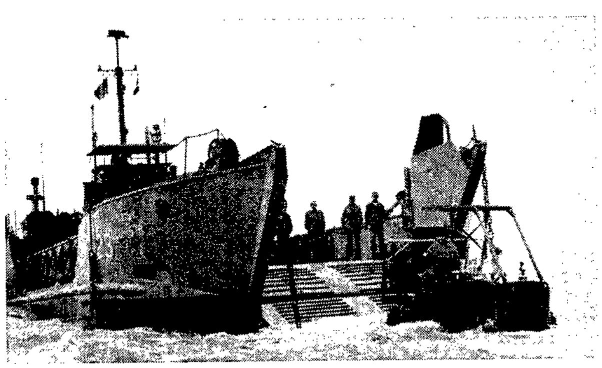


Fig. 1 - Fork lift truck for rough terrain; capacity 6000 lb

Fig. 2 - Truck capacity, 10,000 lb

Model "Sandfly." From data accumulated by tests and observations, it was concluded that greater mobility could be achieved by vehicles possessing lighter weight, very low ground bearing pressures, and better weight distribution.

Investigation indicated that the new Goodyear Terra tire, with its extremely large footprint area and high shock absorption characteristics, would permit the use of lightweight construction to produce a vehicle with ground bearing pressures as low as 4 psi. This approach was used to initiate the design and fabrication of a rough terrain fork lift truck.

The new design has proved successful and will become the forerunner of a family of rough terrain fork trucks that will include 7000 lb and 10,000 lb capacities. This prototype vehicle has been designed for 6000 lb capacity and has been named the "Sandfly" (Fig. 6). The vehicle utilizes low ground-bearing pressure, hub-driven Goodyear Terra tires mounted on walking beams up front, and a free oscil-

Fig. 3 - Truck capacity, 10,000 lb; with crane attachment for assembling Nike Hercules missiles

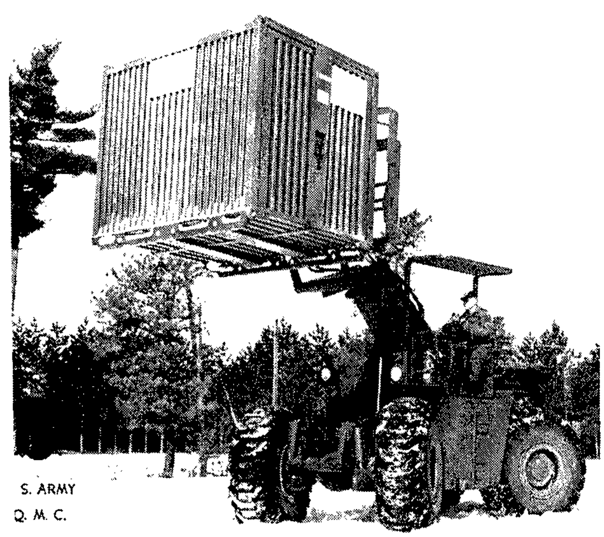


Fig. 4 - Truck capacity, 15,000 lb

lating axle in the rear. Also, as many proven components as possible have been utilized in this vehicle. The lift mechanism is a folding boom type, which is hydraulically actuated. In operation the load is retracted onto the vehicle chassis, resulting in an equal weight distribution on all six tires and an improved rideability of the load over rough terrain. A crane attachment has also been developed for the Sandfly (Fig. 7).

Model "Sandpiper" - As is well known, the Army currently has the difficult problem of getting supplies to remote field units. Two distinct systems of supply to these units include aerial drop and helicopter delivery. The problem is extremely critical in delivering equipment, especially of the vehicular type, because most of the existing standard vehicular equipment was not designed for either aerial drop or helicopter delivery. This incompatibility has dictated development of special, lightweight, simple, high strength vehicular equipment by the responsible Technical Services. The Quartermaster Corps, to meet its responsibility under this program, has under development a lightweight, 4000 lb capacity, rough terrain fork truck called the "Sandpiper" (Fig. 8).

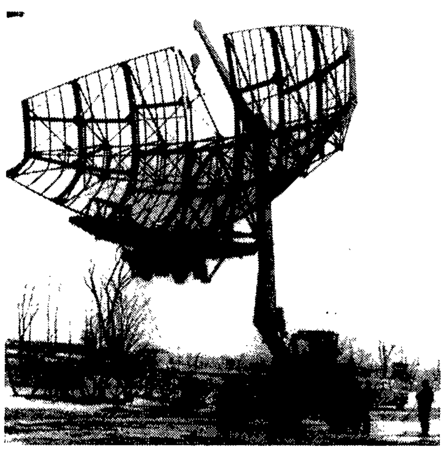


Fig. 5 - Truck capacity, 15,000 lb; with 57 ft crane attachment and winterization kit

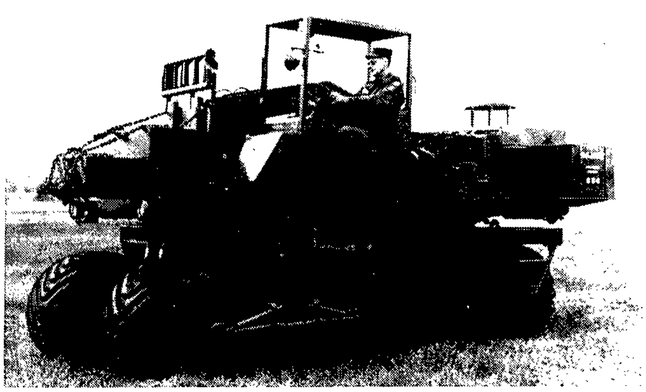


Fig. 6 - Truck capacity, 6000 lb (Sandfly L-62)

The Sandpiper is compatible with both aerial drop and helicopter transport supply methods. It will be especially useful in the "clean-up" of supplies in the aerial drop and versatile, it will nevertheless retain its ruggedness, mobility, and functionability to accomplish its purpose.

Since this particular vehicle is currently under development and utilizes several new design features, this paper will concern itself in the most part with the Sandpiper.

DESIGN OF THE SANDPIPER

The Sandpiper is made up of three major assemblies: a front powered working pod, a center torsion bar section, and a rear power pod. Since the rear pod is a self-sufficient drive unit, it will be possible in the future to couple it to any number of different front working pods, thereby increasing the vehicle's versatility. Working pods, such as a crane, earth-

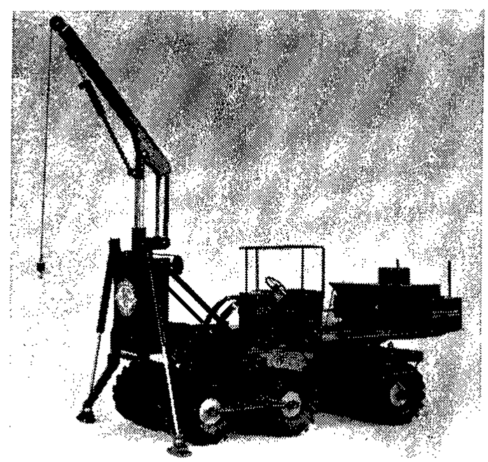


Fig. 7 - Truck capacity, 6000 lb; with crane attachment (Sandfly L-62)

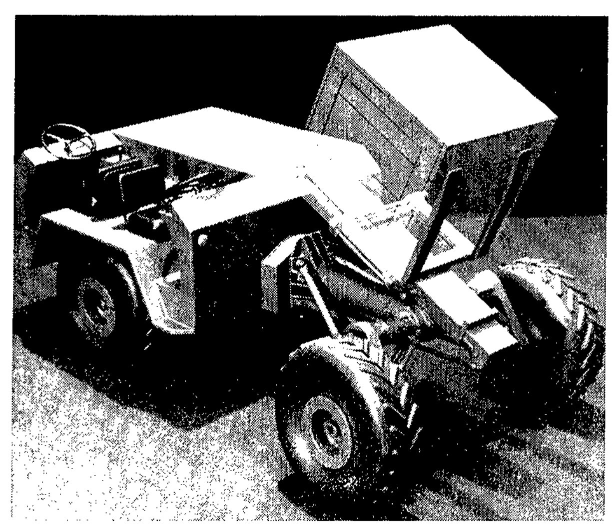


Fig. 8 - Sandpiper UL-42, 4000 lb capacity at 24 in. load center

loader, back-hoe, missile handler, or cable layer are only a few of the pods being considered at the present time.

In detailing the story of the Sandpiper, six categories are required to cover fully the necessary aspects:

1. Objectives.
2. Specific characteristic differences.
3. Present status.
4. Future development.
5. Utilization by the Armed Forces.

Objectives - First it is necessary to discuss the reasons for fork truck existence.

Modern tactics of military dispersal result in a logistics supply problem that will be considerably more difficult than was previously the case with massed armies. Instead of mass landing of supplies and equipment for a huge army in which one or two main roads could be used for movement to forward area troops, it will now be necessary to supply small troop units throughout the combat zone, and usually with no prepared roads over which to move supplies. As a result, the Army has been faced with an extensive problem of developing new systems of supply and mobile equipment compatible with these systems. This mobile equipment must be capable of being transported to and of traversing practically any type of rough terrain which might be encountered in the "supply build-up" of the forward area units.

Two distinct systems of supply to remote units include aerial drop and helicopter delivery. To the maximum possible extent, supplies and equipment for the new Army must be compatible with these supply systems as well as with the needs of using units on the ground. Generally, this problem is not too severe with respect to bulk supplies, as these are relatively flexible and can be packaged in sizes, shapes, and weights in accordance with their mode of delivery. The problem is extremely critical in delivering equipment, especially of the vehicular type. Most of the existing standard vehicular equipment was not designed for either aerial drop or helicopter delivery. This incompatibility has dictated development of special lightweight vehicular equipment by the responsible Technical Services. In addition to being lightweight, these newer vehicles must have rough terrain mobility characteristics, be simple in design for low maintenance, and yet in most cases be more rugged than the heavier, larger standard items.

The Sandpiper will be compatible with both aerial drop and helicopter transport supply methods. It will be especially useful in the "clean-up" of supplies in the aerial drop zone and will replace several pieces of mobile equipment now being employed for this purpose. While it will be extremely lightweight and versatile, it will not sacrifice any ruggedness, mobility, or functionability to accomplish its purpose.

Specific Characteristic Differences - Secondly, why is it different? Attempts have been made to sectionalize existing equipment for ease of transportation or for other reasons, but little has been done in designing a vehicle that is made up basically of self-sufficient units. After investigating several approaches to producing the lightest possible vehicle to fulfill Army requirements, it became apparent that the conventional idea of mounting all the components to a frame was not the answer. Further investigation indicated that for this application, a vehicle made up of three major assemblies would best suit the purpose. These major assemblies are the front powered pod, the center section, and the rear power pod (Fig. 9).

1. The front pod is made up of a simple rigid frame upon which is mounted the lift mechanism, the pivoting front wheel mounts with related hydraulic actuating cylinders for both, and the powered wheel units. The pivoting arms of the front pod represent one of the new features of the Sandpiper. Until now, it has been the practice with fork trucks to pick up a load and carry this load with its center of gravity forward of the front axle. This results in an unbalanced condition, so that approximately 85% of the gross load remains on the front wheels, thereby creating an extremely unstable condition, especially over rough terrain. As a result, it is important that an equal or near equal weight distribution on the front and rear wheels be designed into a rough terrain vehicle. The following four methods were considered for achieving this purpose in the Sandpiper:

(a) Extremely heavy counterweight, which renders the vehicle unstable (heavy in the rear) in the empty condition and defeats the lightweight concept.

(b) Powered extendible counterweight, which prohibitively lengthens the truck and defeats mobility and maneuverability requirements.

(c) Retraction of the lift mechanism and load, which results in a higher vehicle together with heavier hydraulic and structural components to move the heavy weight.

(d) Pivoting wheel mounted arms that can be retracted for picking up the load and which can be pivoted forward, resulting in an equal weight distribution on all wheels (Fig. 10). This system was accepted, as it represented the simplest, lightest, and least expensive method of the four considered. Sample stability calculations are shown on Fig. 11.

2. The center section consists of a torsion element that is easily attached to the front and rear pods, thereby allowing a sufficient radial movement between the front and rear pods to enable one wheel to be displaced 14 in. up or down while the other three wheels remain on the ground (Fig. 12).

3. The rear pod consists of the power package, the operator's cockpit with dual control system, and the steering mechanisms. Sample calculations of the torque requirements are shown on Fig. 13.

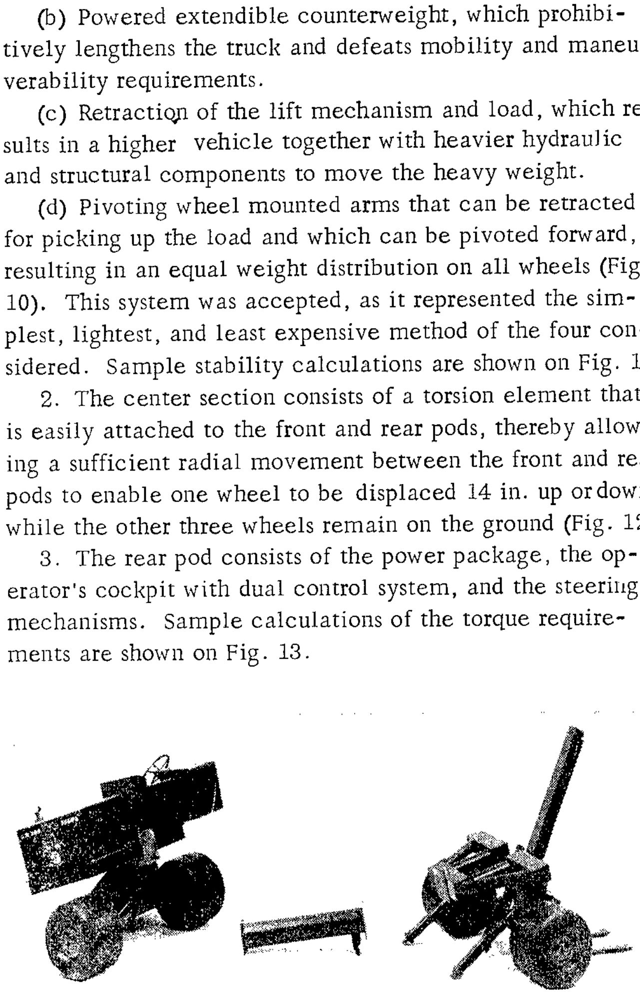


Fig. 9 - Sandpiper sectionalized

Present Status - Third, what is its present status?

The Sandpiper was designed and fabricated by Bergen Research & Engineering Corp., Teterboro, New Jersey, under contract to the government. The unit is currently undergoing the engineering test phase. Basically it has the following characteristics:

1. Capacity, 4000 lb at 24 in. L/C.
2. Lift height, 84 in.
3. Shipping weight, 5000 lb.
4. Width, 96 in.
5. Length (forks included), 210 in.
6. Height (retractable for shipment), 70 in.
7. Speed (forward with no load, max), 40 mph.
8. Turning radius (max) 15 ft.
9. Gradeability (with rated load), 45%.
10. Side slope stability (max rated load on forks), 30%.
11. Fordability (min), 30 in.
12. Underclearance (loaded) (min), (Fig. 8), 15 1/4 in.

The rear pod is the driving unit and consists of the following elements:

1. Engine, gasoline, approximately 60 hp at 2800 rpm, commercially available.
2. Torque converter, 2.16:1 stall torque ratio.
3. Transmission, Reversamatic (4 speed forward, 4 speed reverse).
4. Parking brake (mechanical on drive shaft).
5. Continuous power to fork end axle.
6. Driver selective power to opposite axle.
7. Limited slip differential (standard), both axles.

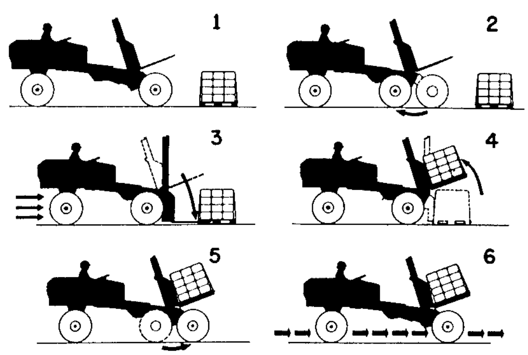
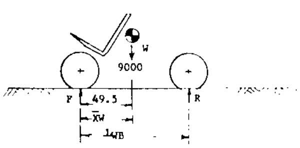


Fig. 10 - Loading sequence chart

CONDITION I
LEVEL GROUND
LOAD IN CARRY POSITION
WHEELS EXTENDED



$$R = \frac{W\bar{X}W}{L_{WB}} = \frac{(9000)\ (49.5)}{124} = 3600\#$$

$$F = W - R = 9000 - 3600 = 5400\#$$

WEIGHT DISTRIBUTION (%) ON FRONT $= \frac{F}{W} \times 100$

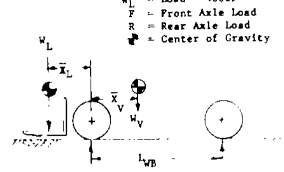
$$\frac{5400}{9000} \times 100 = 60\%$$

WEIGHT DISTRIBUTION (%) ON REAR $= \frac{3600}{9000} \times 100 = 40\%$

IN PICK-UP POSITION, THERE IS AMPLE STABILITY MARGIN AS SHOWN IN THE FOLLOWING CALCULATIONS:

CONDITION II
LEVEL GROUND
LOAD IN PICK-UP POSITION
WHEELS RETRACTED

σ = Stability Factor (SIGMA)
W_V = Weight of Vehicle (Empty) = 5000#
W_L = Load = 4000#
F = Front Axle Load
R = Rear Axle Load
(symbol) = Center of Gravity



$$\bar{X}_V = \frac{l_{WB}R}{W_V} = \frac{(98)\ (3400)}{5000} = 56.6 \text{ in}$$

$$\sigma = \frac{\bar{X}_V W_V}{\bar{X}_L W_L} = \frac{(56.6)\ (5000)}{(50)\ (4000)} = 1.42$$

Stability Margin (%) $= (\sigma - 1)100 = 42\%$

Fig. 11 - Sample stability calculations

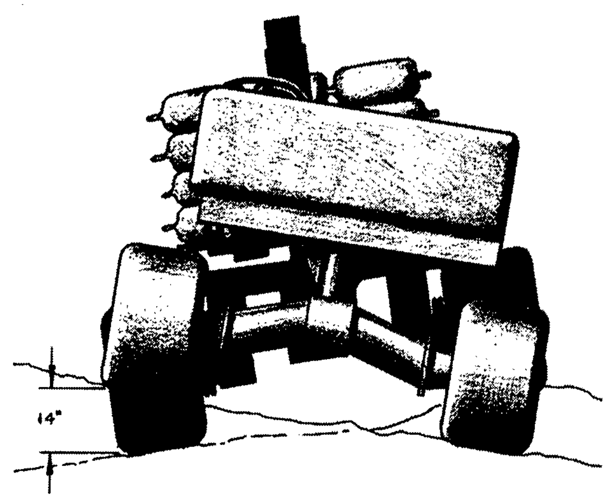
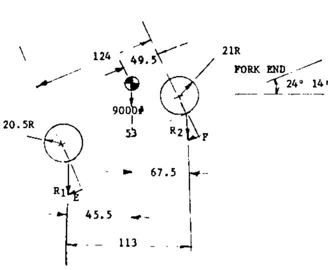


Fig. 12 - Rear view showing maximum oscillation of torque tube



$$R_E = \frac{(9000)\ (67.5)}{113} = 5360\# \qquad R_F = \frac{(9000)\ (45.5)}{113} = 3620\#$$

$$R_1 \text{ (Per Wheel)} = \frac{5360}{2} \qquad R_2 \text{ (Per Wheel)} = \frac{3620}{2}$$

$$R_1 = 2680\# \qquad R_2 = 1810$$

$$\text{SIN } 24°\ 14' = \frac{E}{2680} = .41 \qquad \text{SIN } 24°\ 14' = \frac{F}{1810} = .41$$

$$E = 1100\# \qquad F = 745\#$$

ENGINE WHEEL TORQUE T = LOADED TIRE RADIUS X E

T = (20.5) (1100)
T = 22600"-#

FORK WHEEL TORQUE

T = (21) (745)
T = 15,650"-#

Fig. 13 - Sample calculations of torque requirements

8. Axles (standard).
9. Drive wheels (standard vehicular wheel bearings).
10. Tires (Goodyear 46 x 18, 16R Terra tires).
11. Ackerman steering, one axle.
12. Hydraulic pumps and steering components (standard commercial items).
13. Operator compartment and controls (conventional).
14. Electrical system, 12 v.
15. Air compressor with air hose for tire inflation (standard commercially available).

The remarkable feature of the rear power pod is the maximum utilization of standard and commercially available components. Generally, only the frame, accessory mounting positions, and overall layout necessitated new design work.

The center section consists of the torsion assembly and following elements:

1. Inner lightweight aluminum bearing tube that allows lateral deflection.
2. Outer rigid tube that acts as a physical stop for the inner tube and also as the main structural member between the front and rear pods.
3. Bearings between inner bearing tube and outer tube.
4. Hydraulic hoses with quick disconnect fittings.
5. Fastening devices for attaching the three separate units together.
6. Drive shaft for power to fork end axle.

The front pod consists of a simple frame onto which the following components are mounted:

1. The lift mechanism with related hydraulic cylinders for raising the forks and tilting the mast.
2. The front wheel assemblies, consisting of the wheels and their driving unit, the service brakes, the pivoting wheel mounts, and related hydraulic cylinders.

<u>Future Developments</u> - Fourth, what is its immediate future? The prototype is now in the engineering test phase to determine adequacy of concept and components. Along with the testing, an operational study will be conducted to utilize fully the novel features of the vehicle for meeting not only the basic requirements but also future requirements and pos-

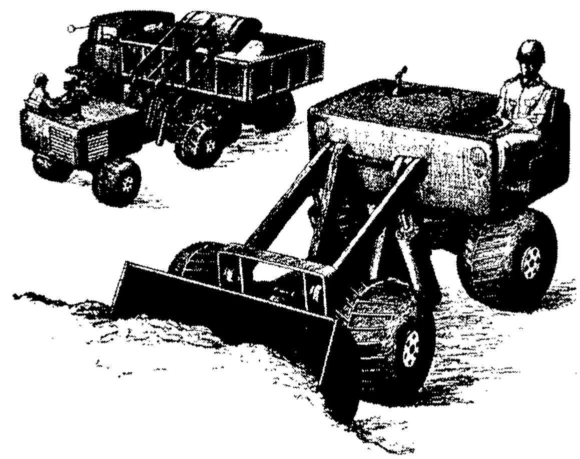


Fig. 15 - Front end loader

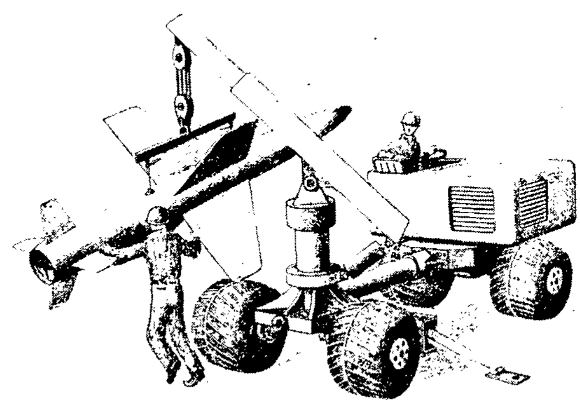


Fig. 16 - Slewing boom crane

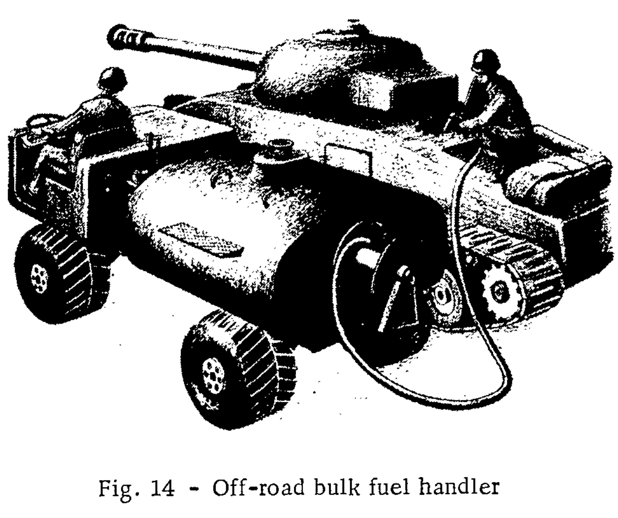


Fig. 14 - Off-road bulk fuel handler

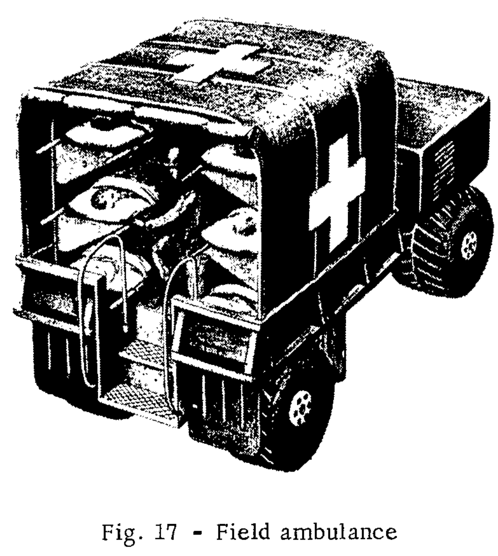


Fig. 17 - Field ambulance

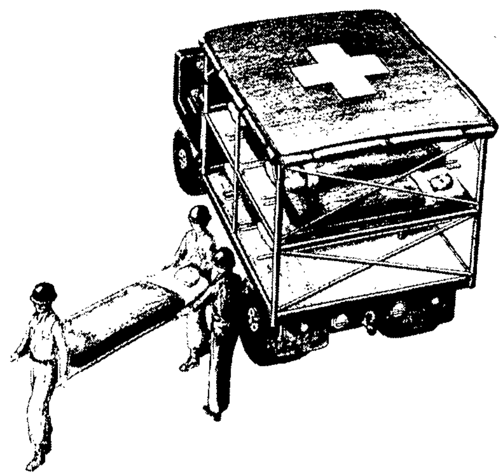


Fig. 18 - Little carrier (on flat bed body)

sible development of new techniques for handling materials. Modification to the prototype will be performed as testing progresses.

User test models are now being fabricated and tested, with eventual classification of the item as a rough terrain fork lift truck for aerial recovery operations and for other uses where rapid delivery of the item by conventional equipment precludes using present, standard, heavier types of fork lift trucks.

Fifth, what is its long-range future? Based on the testing to be performed on the present prototype Sandpiper, it is contemplated that this truck design can be used in designing similar vehicles up to 10,000 lb capacity.

Because it can be easily sectionalized, the Sandpiper lends itself to a greater flexibility than could be obtained by any known vehicle. The versatility of the basic, detachable power pod is shown in the artist's concepts (Figs. 14-18).

Utilization by the Armed Forces - Sixth, what does its success mean to the Armed Forces? The full utilization of the Sandpiper will provide the Army with a versatile and rugged item that will be inexpensive to purchase and easy to maintain. This will result in lower maintenance costs and proportionately small spare parts stocks.

The item will be the first of its kind to be developed with the specific intention of being fully compatible with the Army's concept of dispersing depot storage in advance areas. Because of its novel design (three assembly type), it is believed that the Sandpiper will be the first all-purpose vehicle, within its power and capacity class, to become available to the Army.