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AIR CUSHION CRASH RESCUE VEHICLE (ACCRV) (PHASE 1)

Bell Aerospace Textron
P.O. Box 1
Buffalo, NY 14240

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This report defines the preferred concept for the USAF Air Cushion Crash Rescue Vehicle (ACCRV). It is the first of three principal technical reports to be prepared in the ACCRV preliminary design program. The second will report on the preliminary design to be developed from the chosen concept, The third will be a final report and will include preliminary results from check-out tests of a dynamic scale model, also part of this first phase report.

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1.0 INTRODUCTION AND SUMMARY

This report defines the preferred concept for the USAF Air Cushion Crash Rescue Vehicle (ACCRV). It is the first of three principal technical reports to be prepared in the ACCRV preliminary design program. The second will report on the preliminary design to be developed from the chosen concept. The third will be a final report and will include preliminary results from check-out tests of a dynamic scale model, also part of this first phase program.

Current aircraft fire and rescue vehicles, including the P-19, have limited capability to operate over rough and low strength ground surfaces especially soft, wet ground or marsh and snow, with no capability for overwater. In a wartime environment, fire fighting and rescue will be further restricted because of craters, debris or unexploded bombs.

Improved fire fighting vehicular mobility is needed to increase the probability of successfully rescuing crew and passengers. This will require a radical departure from current fire and rescue vehicle technology. The successful operation of ACV's over austere surfaces including swamps and water, suggests this ACV technology be used to develop an air cushion augmented fire/rescue vehicle, and this is the basis for the current effort. But the vehicle is to be able to effect a complete rescue from downed aircraft, not only able to respond immediately over all surfaces, but also incorporating a triage compartment, a high boom for access and a slide. Fire fighting equipment similar to the P-19 is to be carried but it is to be a complete rescue vehicle not simply a fire truck.

In the concept study now completed, Bell has considered many variations of layout subsystems and components. The ACCRV concept design which has been selected from these studies is illustrated in Figures 1-1, 1-2 and 1-3. It employs major components of the most up-to-date crash rescue trucks. It is similar in aspect to the P-19 'Rapid Intervention Vehicle' designed specifically for fire suppression but it is somewhat larger, especially longer, has a more powerful engine, and incorporates an air cushion system which can be immediately deployed to completely support the vehicle for off-runway or overwater operation, and a combined overwater/overland drive system. Its preliminary predicted performance meets or exceeds all aspects of the requirements.

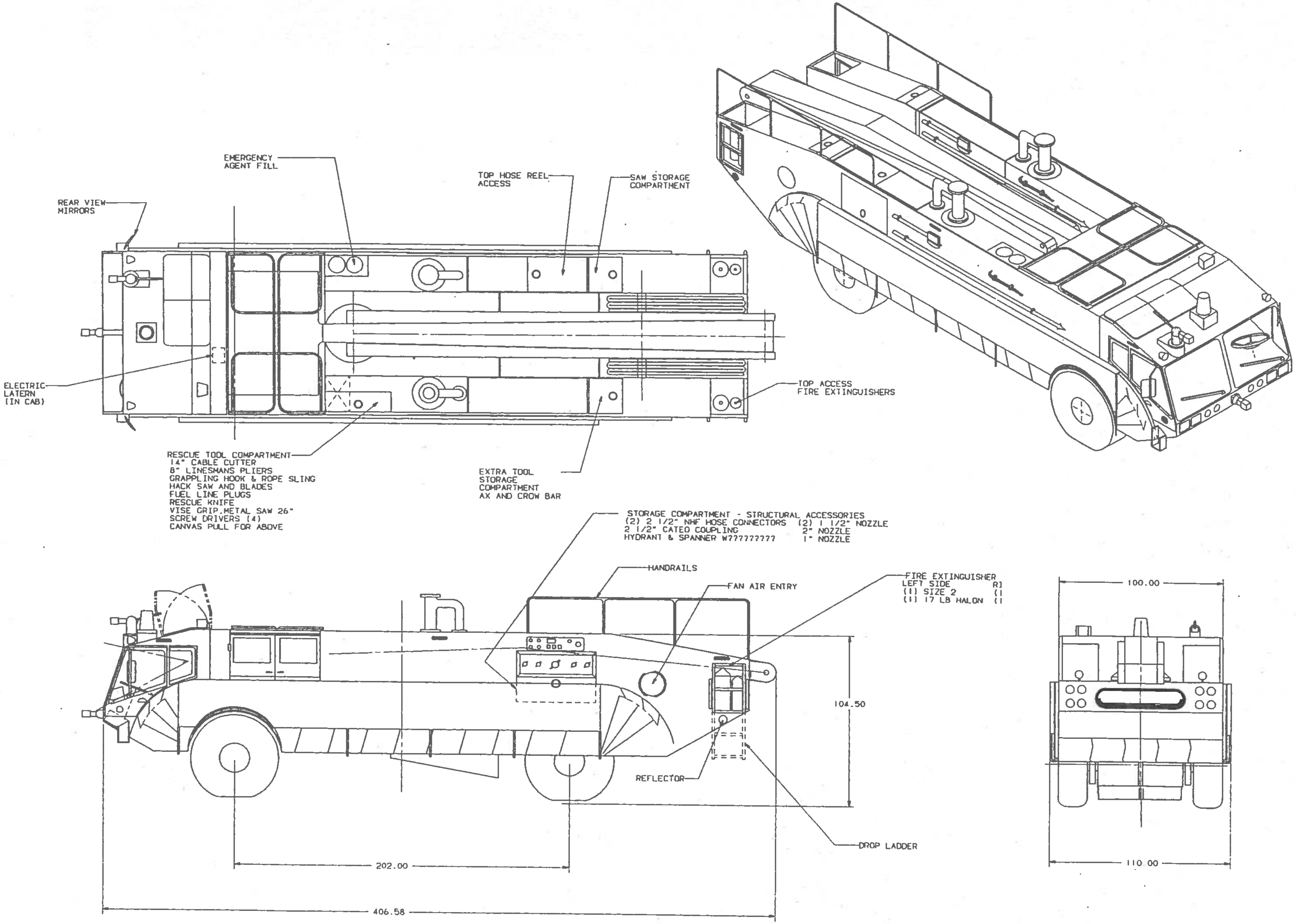


Figure 1-1. ACCRV Wheelborne

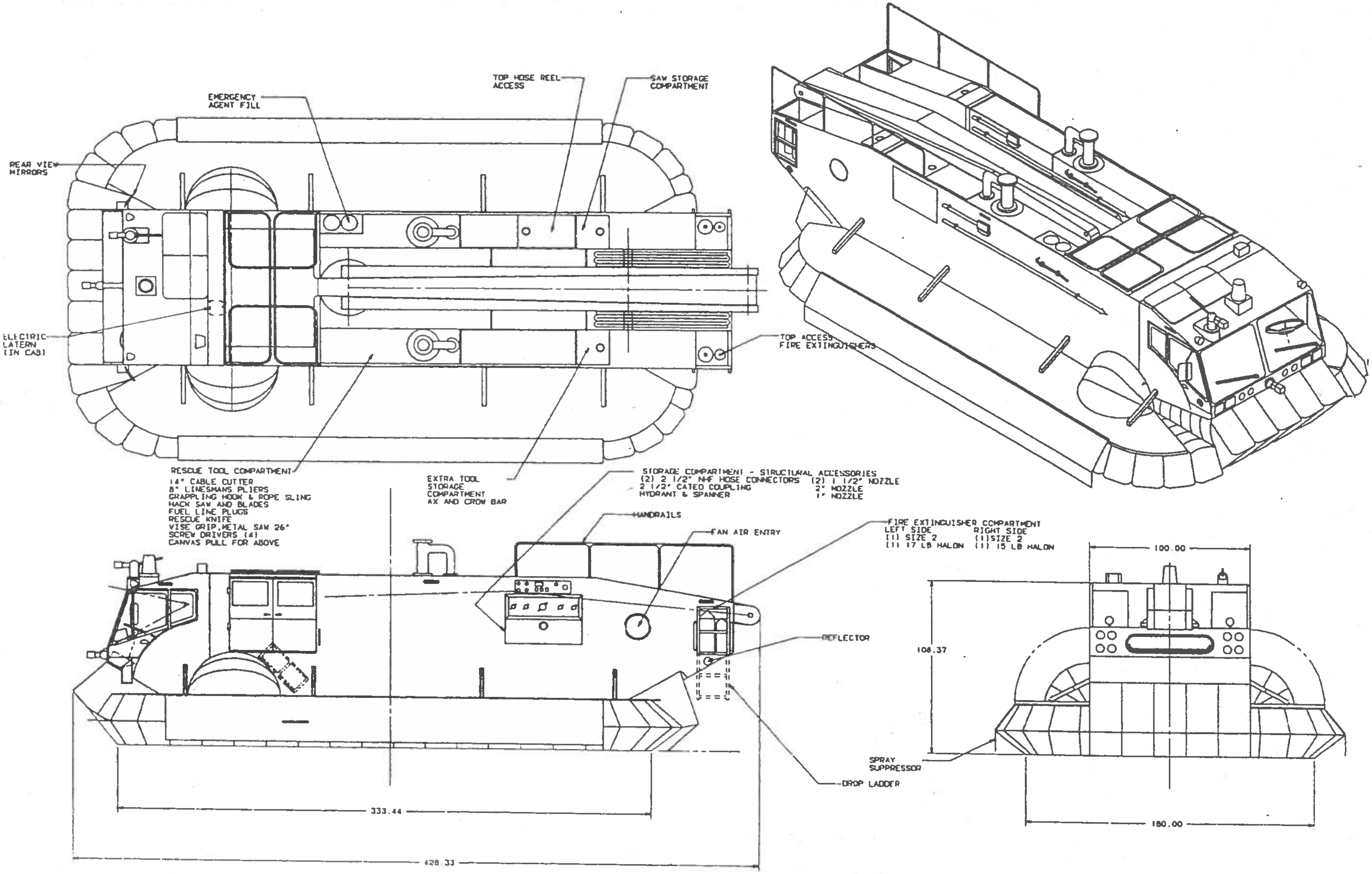


Figure 1-2. ACCRV Cushionborne

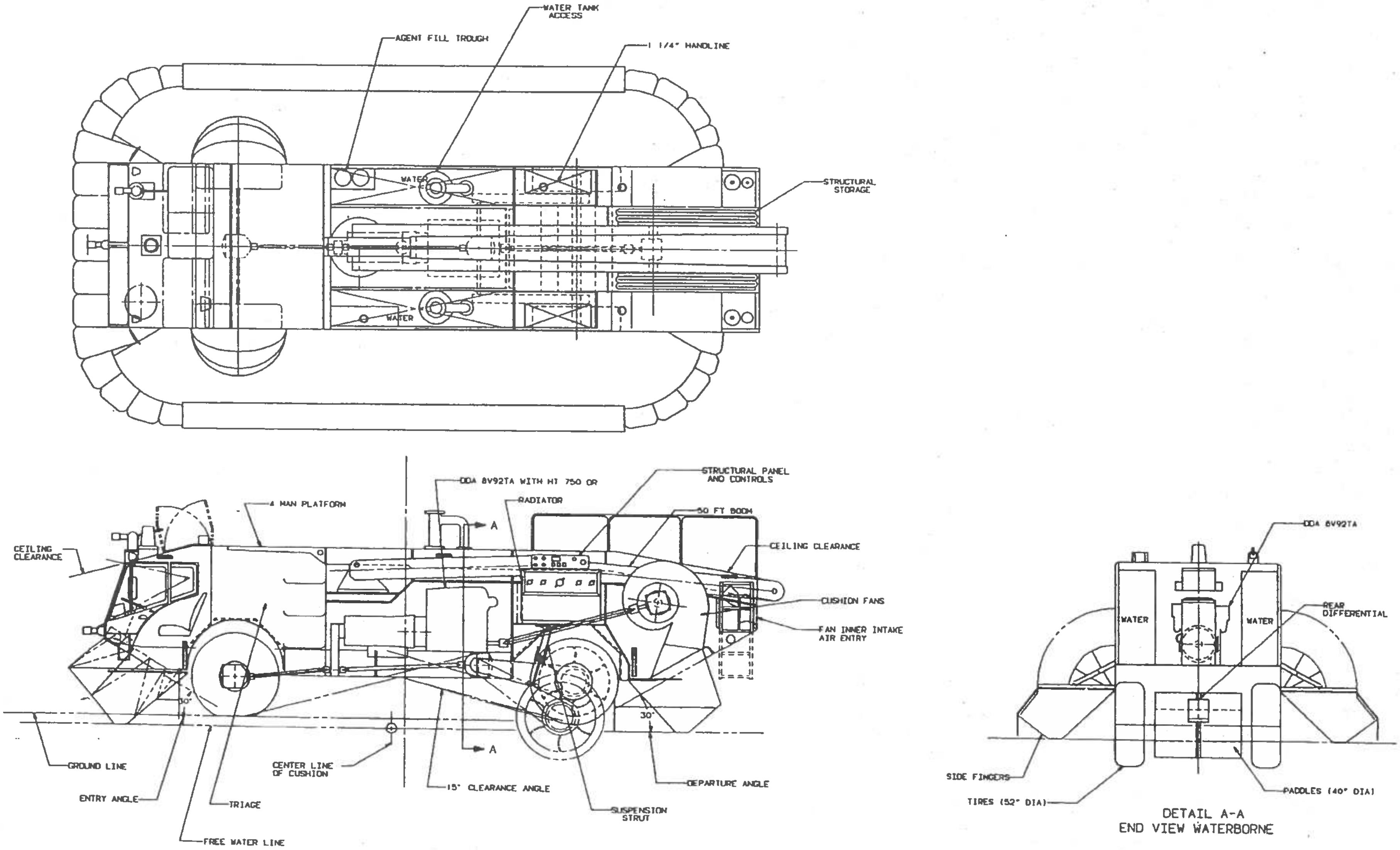


Figure 1-3. ACCRV Inboard Profile

2.0 CONFIGURATION CONSTRAINTS

The requirements to provide the performance of existing fire fighting vehicles including 65 mph roadway speed and 60% gradient capability besides other attributes, all suggest a conventional wheeled design for this mode. Tracks or half tracks were considered but were found to be more complicated and difficult to integrate into the air cushion design and combined land-water propulsion. Furthermore, the advantage of tracks over soft soils or snow is diminished in air cushion hybrid operation unless needed for generation of drawbar pull. Substantial reduction of tire load in this mode permits operation (with the large tires required for fully wheeled support in an off-road steep gradient situation) at much reduced pressure, hence increased contact area and traction.

The requirement for air transportability (and convenient roadway mobility) places limits on the wheel track such that if an air cushion system (adequate for 100% support and overwater operation) is restricted to the space bounded by the outside face of the wheels, it can not be made stable in roll. Furthermore, the cushion area will be too low and the cushion pressure, overwater wave drag and propulsion power required will be unnecessarily large. (These variables are analyzed in Section 3.2.1). Therefore, some means of extending the vehicle width for cushion operation must be adopted. A full length fold down structural panel along each side, carrying side skirts; with fore and aft skirts also, mounted beneath the vehicle's principal structure, is a straightforward solution and has been selected, combined with full depth finger skirts. The cushion surrounds the wheels and the fore and aft skirts are independently furled.

The third major subsystem configuration driver is the provision of an optimum, combined, all-surface land-water-marsh-mud-snow propulsion method. Air propulsion has usually been chosen for ACV's because air propellers produce the same thrust over any surface but in this case the air propeller is not attractive because it is not practical for the propeller disc to stay within the retracted head-on profile with reasonable power limitation. In any case the wheels must be driven to achieve the roadable performance. Thus a propulsion take-off from the same drive is desirable and a method which provides satisfactory water propulsion. Water propellers are a pre-eminent candidate for water drive but must be retracted overland. This is feasible as discussed in Section 3.3 but a major difficulty arises in transition to land, especially low CBR (e.g., swamp ground): first the wheels must be well below the propeller disc so that they can take over propelling while the propeller is still submerged and clear of the bottom (similarly to amphibians such as the Army's LARC-60); secondly, when cushionborne the propeller must be in the water, to all intents and purposes below the cushion skirts so that a considerable wheel extension both fore and aft must be provided or the transition from sand to dry land must be accomplished hullborne; and finally the propeller is a hindrance over swampy ground, snow, etc. and must be completely retracted.;

These difficulties lead to the rejection of the propeller in favor of a co-axial paddle between the rear wheels, driven with the wheels, if possible at all times. The paddle is used as a water drive; it is not retracted and contributes significantly to propulsion and flotation over very soft ground, clay, marsh, mud and deep snow. Sufficient thrust for adequate water propulsion could be achieved with the design shown in Figure 1-3. This paddle can be strongly built after the style of construction machinery to withstand land impacts. The aft paddle wheel/tire combination is augmented by the front wheel drive. A weight distribution control system, including en route tire pressure adjustment is incorporated to achieve the best balance between cushion support and wheel tractive effort. This is a combination which comes close to providing as consistent a drive over all surfaces as the air propeller does. However, recent detailed analyses of ventilation problems due to high loading required, puts this simple scheme in jeopardy as a high speed propulsor and it is doubtful whether sufficient thrust for the required 20 mph water speed is attainable. For above hump performance propellers are probably indispensable.

3.0 SUBSYSTEMS AND ALTERNATIVES CONSIDERED

3.1 Stress Analysis

3.1.1 Introduction

A preliminary structural evaluation of the ACCRV has been conducted to establish structural design criteria, establish primary load paths and develop a finite element model for analysis during the next phase. In establishing the structural criteria prime importance was placed upon personnel safety and vehicle integrity during rescue operation in adverse conditions.

3.1.2 Structural Description

In order to minimize weight the selected ACCRV structure is built from a standard off-the-shelf 5052 aluminum honeycomb sandwich panel with sufficient strength and stiffness to support structural loads. Typical mechanical property data for the sandwich panel are given in Figure 3.1-1. The ACCRV structural panels are assembled using various standard extruded shapes specifically designed to join and close-out the edges. The extrusions are bonded to the sandwich panels by a high performance room temperature cure epoxy adhesive. A typical fabrication using the honeycomb sandwich and joining extrusions is shown in Figure 3.1-2.

The ACCRV structural arrangement is displayed in Figure 3.1-3. This design makes maximum utilization of load carrying structure by using the structure for fuel, water and agent tank walls. In addition, the vehicle side walls serve as end closures for the fans. The boom turntable mounts on a panel which receives support on four sides, thus providing for adequate support and load distribution.

Towing/tie-down fittings are provided for securing the vehicle during shipment or towing when disabled. The fittings are an integral part of the ACCRV structure with two fittings forward and two aft. The fittings are positioned adjacent to lateral and longitudinal bulkheads in order to distribute the towing/tie-down loads to the vehicle structure. Added to the panels and bulkheads already discussed, the ACCRV has internal gussets, bulkheads, floors, fittings and stiffeners which complete the vehicle structure. These items accept the concentrated loads from the engine, transmission, suspension, etc., and distribute them to the structure.

3.1.3 Structural Design Criteria

Structural design criteria establish the guidelines for critical loading conditions, safety factors, etc., and are the foundation of structural analysis. The selected criteria cover all conditions that could be encountered in the vehicle operational spectrum including emergency conditions. A factor of safety is then applied to these loads to ensure that the vehicle structure does not fail under the derived design loads.

3.1.3.1 Operational Spectrum - The ACCRV shall have the capability of operating on pavement, adverse terrain and water.

a. Pavement

For highway operations the air cushion mechanism is stowed and the ACCRV operates like a conventional truck. Vehicle top speed is 65 mph on level ground.

PROPERTY	TEST	TEST VALUE
Panel Measurements	Thickness Weight	1.004 inch 0.92 psf
Flatwise Compressive @ R.T. ASTM C 365 3 x 3	Ultimate Stress Proportional Limit Modulus	330 psi 333 psi 163 ksi
Beam Flexure 20" Span 2" L x 24" W ASTM C 393	Ultimate Load Proportional Limit Deflection per 10 lbs	286 lbs 252 lbs 0.012 inch
2" W x 24" L	Ultimate Load Proportional Limit Deflection per 10 lbs	297 lbs 199 lbs 0.014 inch
Edgewise Compressive @ R.T. 2" W x 4" L ASTM C 364	Maximum Load Maximum Facing Stress	2523 lbs 31500 psi
2" L x 4" W	Maximum Load Maximum Facing Stress	2383 lbs 29800 psi
Edgewise Flexural 2" W x 12" L 8" Span	Ultimate Load Proportional Limit Deflection per 10 lbs	822 lbs 400 lbs .0005 inch
2" L x 12" W	Ultimate Load Proportional Limit Deflection per 10 lbs	780 lbs 367 lbs .0005 inch
Thermal Expansion 4" W x 30" L	After 2 hrs. @ 120°F After Cooling 2 hrs. @ R.T.	+ .0186" + .0008"

Figure 3.1-1. Mechanical Property Data 5052 Aluminum Honeycomb Sandwich

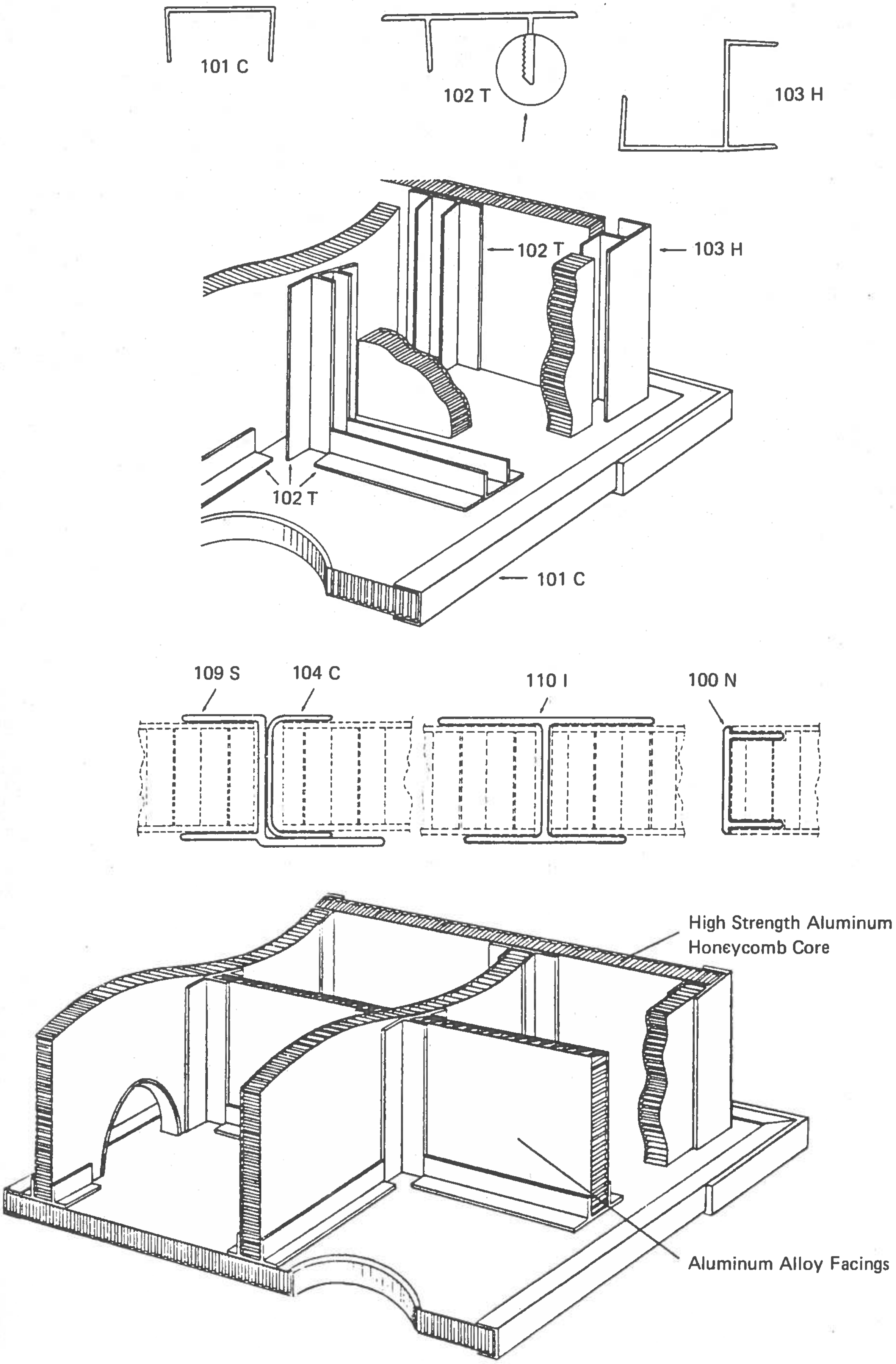


Figure 3.1-2. Typical Sandwich Assembly Technique

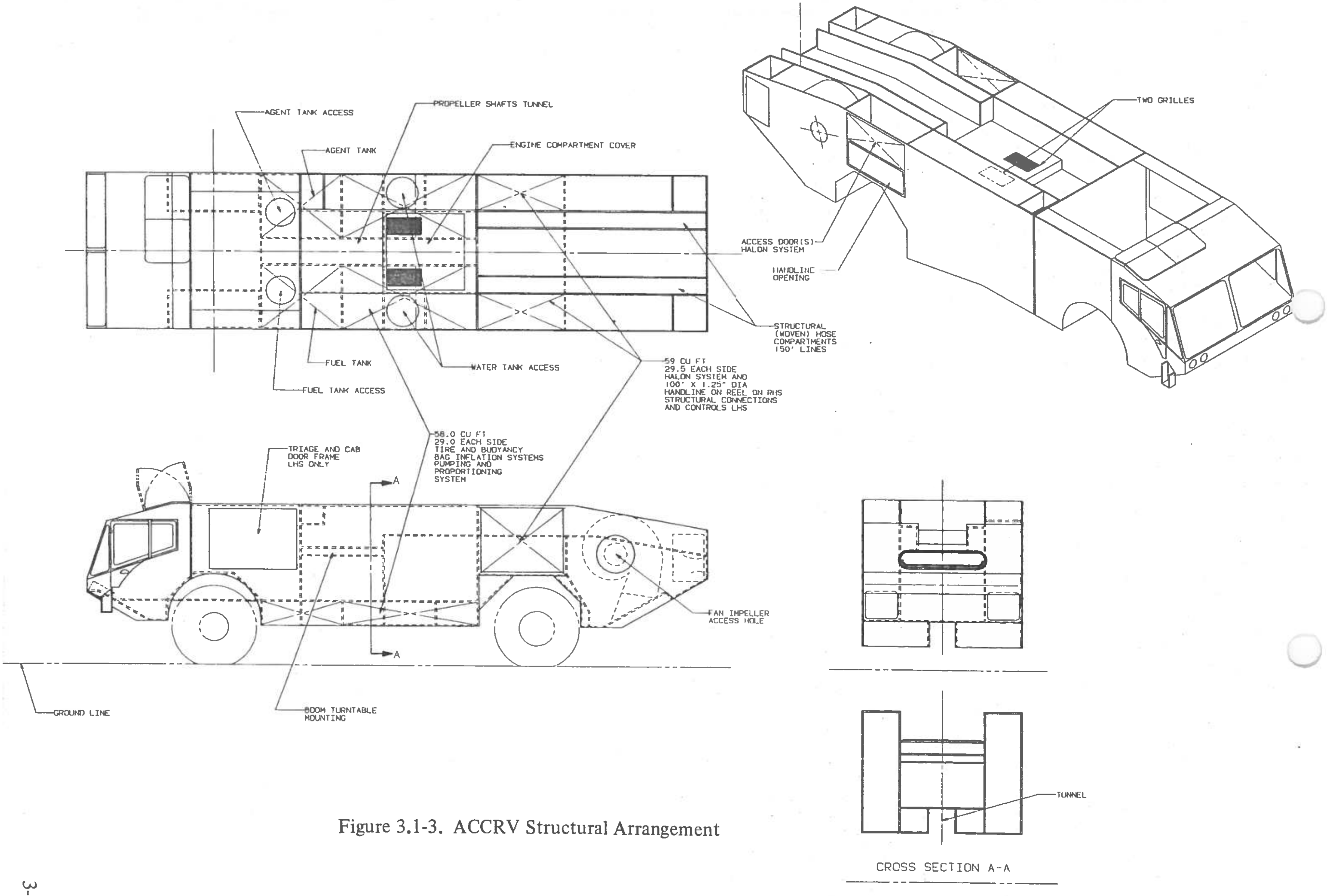


Figure 3.1-3. ACCRV Structural Arrangement

b. Adverse Terrain and Water

In adverse terrain the vehicle operates with air cushion augmentation, where the four wheels support 30% (maximum) of the vehicle weight. Adverse terrain is defined as any surface such as runway or soil; any soil or unprepared surface having a CBR of 3.0 or higher, any swamp, with or without water, rough terrain, and deep snow and/or ice covered surfaces. Vehicle operation in sheltered bodies of fresh water is limited to sea-state 1 with waves of 1.0 foot maximum. On level soft surfaces and water with the air cushion deployed, an operating speed of 20 mph shall be used. On rough terrain the vehicle shall be capable of traversing surfaces irregularities up to +/- 12.0 inches, 5% side slopes, and random obstacles up to 12 inches high.

3.1.3.2 General Criteria - The applied loads presented in this section are the maximum loads expected to be encountered in the operational life of the ACCRV. Under applied loads (limit) the structure shall not deform elastically or plastically so as to interfere with operation of the vehicle or require frequent replacement or repair. The limiting stress under applied loads corresponds to the 0.2 percent offset yield strength of the material. In addition, all applied loads are multiplied by a safety factor to obtain design loads (ultimate). The safety factor is generally 1.5. Special factors are used where necessary. The structure shall not fail under design loads.

Design Load = Applied Load x Safety Factor

The selected criteria and structural methods are based on government publications such as the automotive series handbooks and MIL-Handbooks/Specs, contractor manuals/experience and standard textbooks. Computer codes will be used to determine internal loads.

3.1.3.3 Hull Design Conditions - The critical design conditions for the hull are shown in Figures 3.1-4 and 3.1-5. With these parameters and the vehicle weight distribution the hull shear, moment and torsion along the vehicle length are obtained by computer code. Data are also shown for rotational and translational accelerations which are used to determine local load factors for hull mounted equipment.

The maximum externally applied loads for normal operation over highway and secondary unpaved roads, without air cushion augmentation, are shown in Figure 3.1-4.

In adverse terrain, the vehicle is mainly supported by an air cushion with the wheels (tires and paddles) supporting only sufficient weight to provide tractive effort and directional control. Adverse terrain covers operations off-road such as in rough terrain (12.0 in. high obstacles), swamps and overwater (sea-state). Maximum externally applied loads for adverse terrain operation are listed in Figure 3.1-5.

Operation overwater is limited to sea-state 1 where wave heights are no greater than 12.0 inches. No significant water impact loads on the hull are expected so the landborne design conditions will govern the design. The vehicle must be capable of hullborne operations at reduced speed and the hull and appendages must resist the associated hydrostatic pressures. Design pressure on hull due to flotation is equal to 3.0 times the hydrostatic pressure.

3.1.3.4 Crash Load Factors - Seat installations and the structural attachments for all items of equipment, failure of which could result in hazard to personnel or crew, shall be designed to withstand loads resulting from the following ultimate inertia load factors, applied separately.

DESIGN CONDITION	VERTICAL LOADS				HORIZONTAL LOADS			
	Z_{LF}	Z_{RF}	Z_{LR}	Z_{RR}	X_{LF}	X_{RF}	X_{LR}	X_{RR}
1.1 Braking - Front Wheels Only $n_z=1.0$, $n_x=.50$	.5W	.5W	0	0	.25W	.25W	0	0
1.2 Diagonal Wheels Loaded, with Front Wheel Obstruction $n_z=1.5$, $n_x=.50$	1.0W	0	0	.5W	.5W	0	0	0
1.3 Symmetrical Vertical Impact, $n_z=2.0$	.5W	.5W	.5W	.5W	0	0	0	0
1.4 Unsymmetrical Vertical Impact, $N_z=1.0$	1.0W	0	0	0	0	0	0	0

W = Vehicle Gross Weight

Figure 3.1-4. Wheel Loads Without Cushion Augmentation – Pavement and Unpaved Roads

DESIGN CONDITION	VERTICAL LOADS				HORIZONTAL LOADS			
	Z_{LF}	Z_{RF}	Z_{LR}	Z_{RR}	X_{LF}	X_{RF}	X_{LR}	X_{RR}
2.1 Wheels Equally Loaded $n_z=1.3$, $n_x=0$	.15W	.15W	.15W	.15W	0	0	0	0
2.2 Diagonal Wheels Loaded, with Front Wheel Obstruction $n_z=1.75$, $n_x=.50$	.75W	0	0	.30W	.5W	0	0	0
2.3 Unsymmetrical Vertical Impact, $n_z=1.3$	.60W	0	0	0	0	0	0	0
2.4 Rear Wheels Loaded Only, Tractive Effort $n_z=1.3$, $n_x=.50$	0	0	.30W	.30W	0	0	.25W	.25W

Add cushion loading to these conditions

Figure 3.1-5. Wheels Loads With Cushion Augmentation – Adverse Terrain

Downward	4.0	Upward	3.0
Forward	6.0	Aft	3.0
Laterally +/-	3.0		

Crash load factors shall in no way preclude the need for compliance with load factors derived from operational design conditions shown in Figures 3.1-4 and 3.1-5.

3.1.3.5 Skirt Loads

Skirt

The air cushion skirt shall be structurally capable of maintaining a cushion pressure 1.5 times the maximum dynamic operating pressure (P_{max}) at maximum payload and speed.

Applied Pressure = $1.5\ P_{max}$

Design Pressue = $2.25\ P_{max}$

Skirt Attachments

Design Pressure = $3.0\ P_{max}$

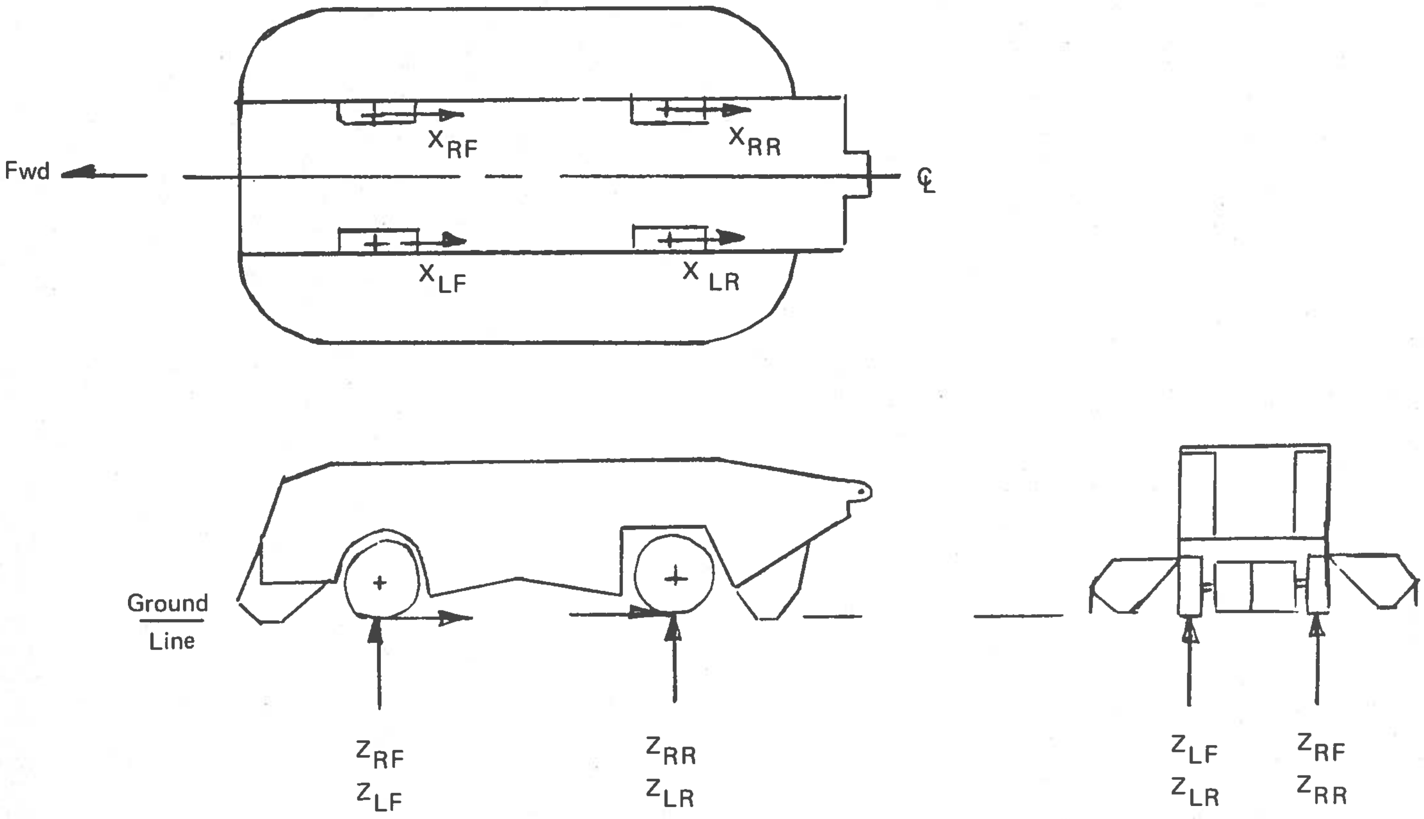
3.1.3.6 Wheel Loads - Maximum wheel loads encountered under dynamic loading conditions are shown below. See Figure 3.1-6 for wheel load nomenclature. These conditions cover sloped terrain, obstacle impact, braking and uneven terrain operations.

Maximum Wheel Loads

Design Condition	Applied Wheel Load
Fig. 3.1-4	$F_Z = 1.0W$ $F_Y = 0.50W$
Fig. 3.1-5	$F_Z = 1.0W$ $F_X = 0.50W$

Where W = Vehicle Design Weight = 30,000 lb

Design Loads = 2.0 Times Applied Loads



X = Longitudinal (Drag)

Z = Vertical

LF = Left Front

RF = Right Front

LR = Left Rear

RR = Right Rear

Figure 3.1-6. Wheel Load Nomenclature

3.1.3.7 Miscellaneous Criteria

Vehicle Design Gross Weight, W = 30,000 lb

Design Tow Loads: Maximum Apex Angle of Towing Bridle Equal to 60 Deg

Each Tow Fitting, $F_X = 0.50W$

$F_Y = 0.25W$

Paddlewheel Loads - TBD (Model Tests)

3.1.4 NASTRAN Finite Element Model

A structural analysis of the ACCRV hull and frame will be conducted as part of the next phase to ensure basic structural integrity under the imposed loads. The analysis will be conducted using the NASTRAN Release April 1984 general purpose computer program. The discussion below represents the status of the finite element model at the end of the current phase.

NASTRAN is a general purpose finite element computer program for structural analysis. Using this program, the entire hull/frame structure was modeled for subsequent analysis. The ACCRV finite element model is presented in Figure 3.1-7.

The finite element model was developed on CADAM from assembly drawings stored within the computer system. The outer shell, bulkheads and stiffeners are represented by quadrilateral and triangular plate elements in combination with beam and rod elements where appropriate. The model is described by 583 grid points, 46 bar, 149 triangular plate, and 391 quadrilateral plate elements for a total of 586 elements. There are 3498 unconstrained degrees of freedom. Loading from the suspension units are transferred to the flexible body by rigid elements at the suspension locations.

The NASTRAN program will be executed for the following loading conditions:

- Suspension system loads
- Critical hull torsion-bending
- Handling loads

Results of the finite element program will be used to verify basic hull/frame integrity, identify critically loaded areas, and evaluate overall vehicle stiffness.

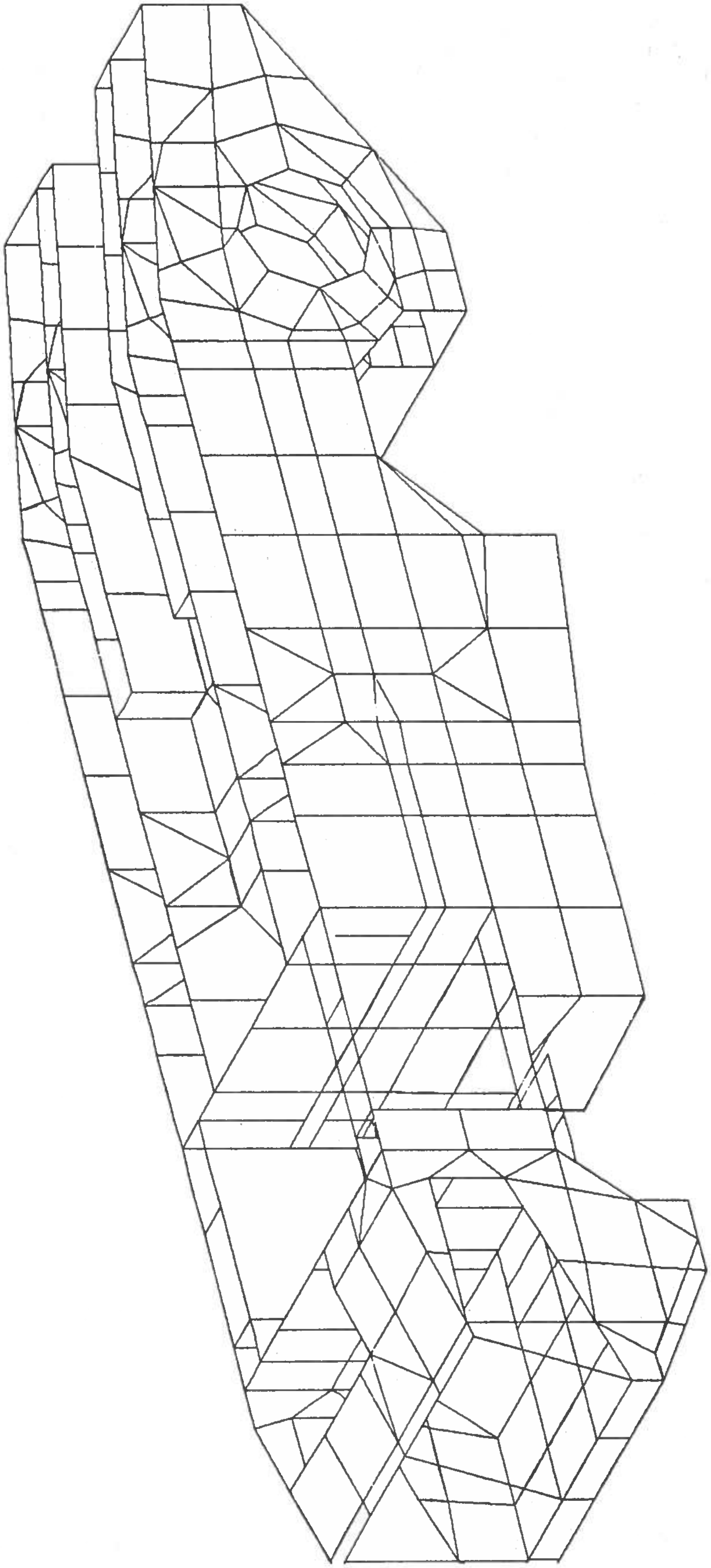


Figure 3.1-7. Finite Element Model

3.2 AIR CUSHION SUBSYSTEM

3.2.1 Skirts

A wide range of alternative skirt types have been used and are in use on many air cushion vehicles. They include plenum, lubricated bag, bag and finger variants. For the ACCRV the choice is constrained by the overall vehicle configuration, especially the need to avoid center keel members and to be compatible with the retractable side panels and method of air supply.

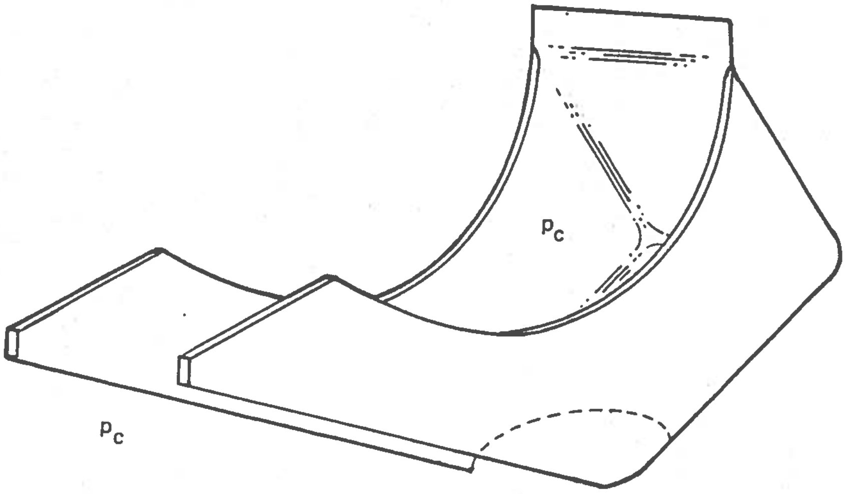
The skirt variations that have been considered in the concept design center on the use of a full finger design and have been particularly concerned with an initial definition of stability and trim requirements in the various phases of operation, especially acceleration through hump. In particular the following were studied:

a. Open or Closed Fingers. The 'closed' finger is illustrated and compared with the 'open' finger in the sketch, Figure 3.2-1. The significant difference is that the closed finger internal pressure is well above cushion pressure so that the finger itself is stiffer, provides for greater static stability and improves hump traverse by reducing drag. On the other hand it requires 20%-25% more horsepower for the same terrain performance, and is more complicated and higher in weight and cost than the open finger. The open finger was found to have acceptable stability and was therefore selected.

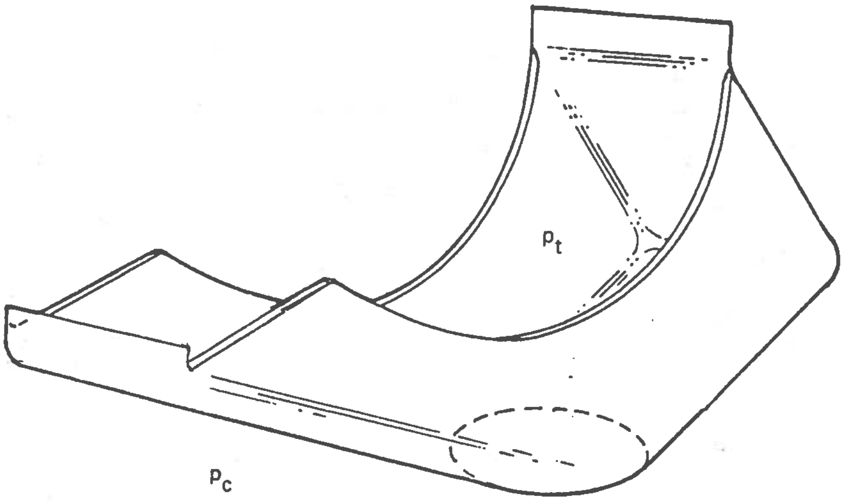
b. Detail finger geometry. The knee shaped finger operates to provide static stability without a center keel because of the area increase that results from inward taper of the shim. But selection of very flat taper for this reason brings down the outer break point or knee, which has an adverse effect on hump transition over water. This adverse effect can be overcome by enclosing the fingers behind a metal door which is deployable as a bow plate as shown in Figure 3.2- 2, but it is found that a compromise of inward taper can be accommodated which will allow a high enough outer knee while retaining satisfactory static stability. The alternatives are shown in this figure. Thus, the use of a bow plate has been avoided.

Finger storage and the need for spray suppression and the possibilities of using anti-spray skirts as a component of finger storage have also been studied. Obviously, the ACCRV will need to keep station more or less facing the crash. Cushionborne overwater (and possibly over powder snow for a limited time), visibility will be poor unless anti-spray skirts are used. Anti-spray skirts over the fingers can be designed to provide additional functions very conveniently, i.e., they can be used to strap in the retracted fingers and also as buoyancy bags. Given that flotation on the hull must be provided it is thought the technique most suitable for rescue overwater is to approach cushionborne and settle to hullborne close-in. The spray skirt would then only be needed for the slow final approach, but to operate hullborne at all, buoyancy bags for roll stability become essential and therefore must be included in the selected concept design. They then come free as strap-downs. It is also considered definitely necessary to strap in the side fingers to avoid a lot of loose flapping material in the normal roadable configuration and to allow loading for transport in a C-130 without snagging.

The side skirt retraction/deployment is accomplished by rotating a full length panel along each side from horizontal to vertical by means of hydraulic jacks (four each side), which operate folding elbow struts as shown in Figure 3.2-3. When stopped and



(a) Open



(b) Closed $P_t = 1\text{-}2 \times p_c$

Figure 3.2-1. ACCRV Comparison of Open – Closed Finger Skirt Designs

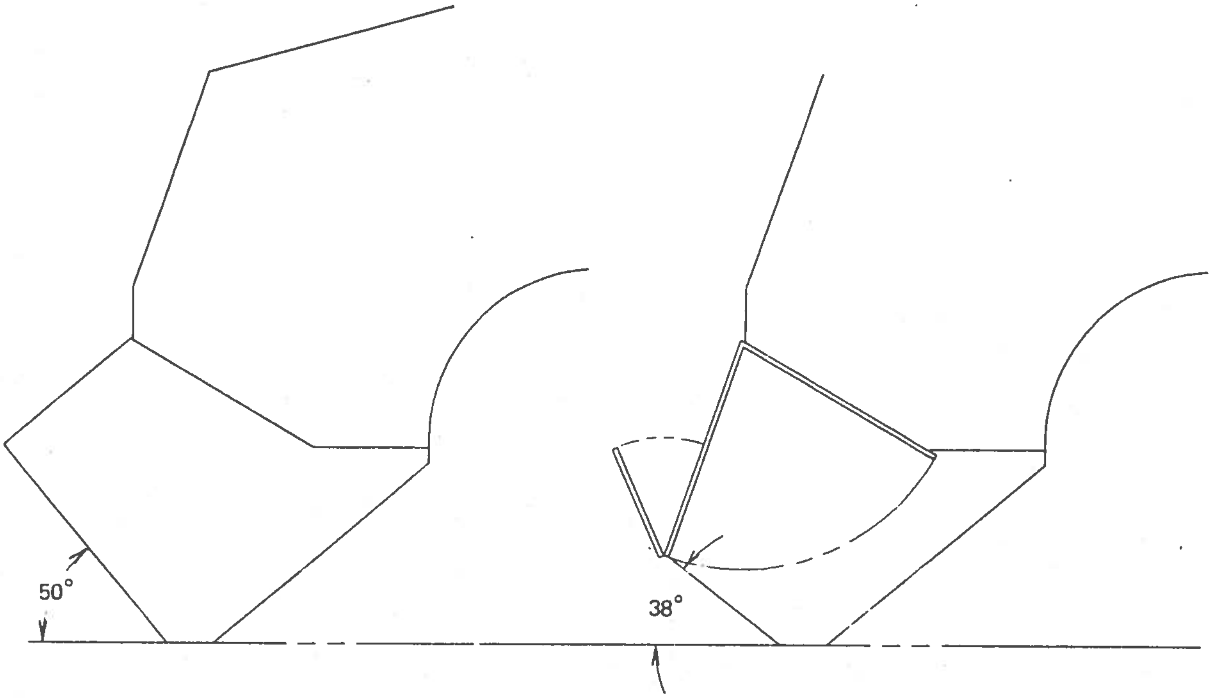


Figure 3.2-2. Bow Plate Option

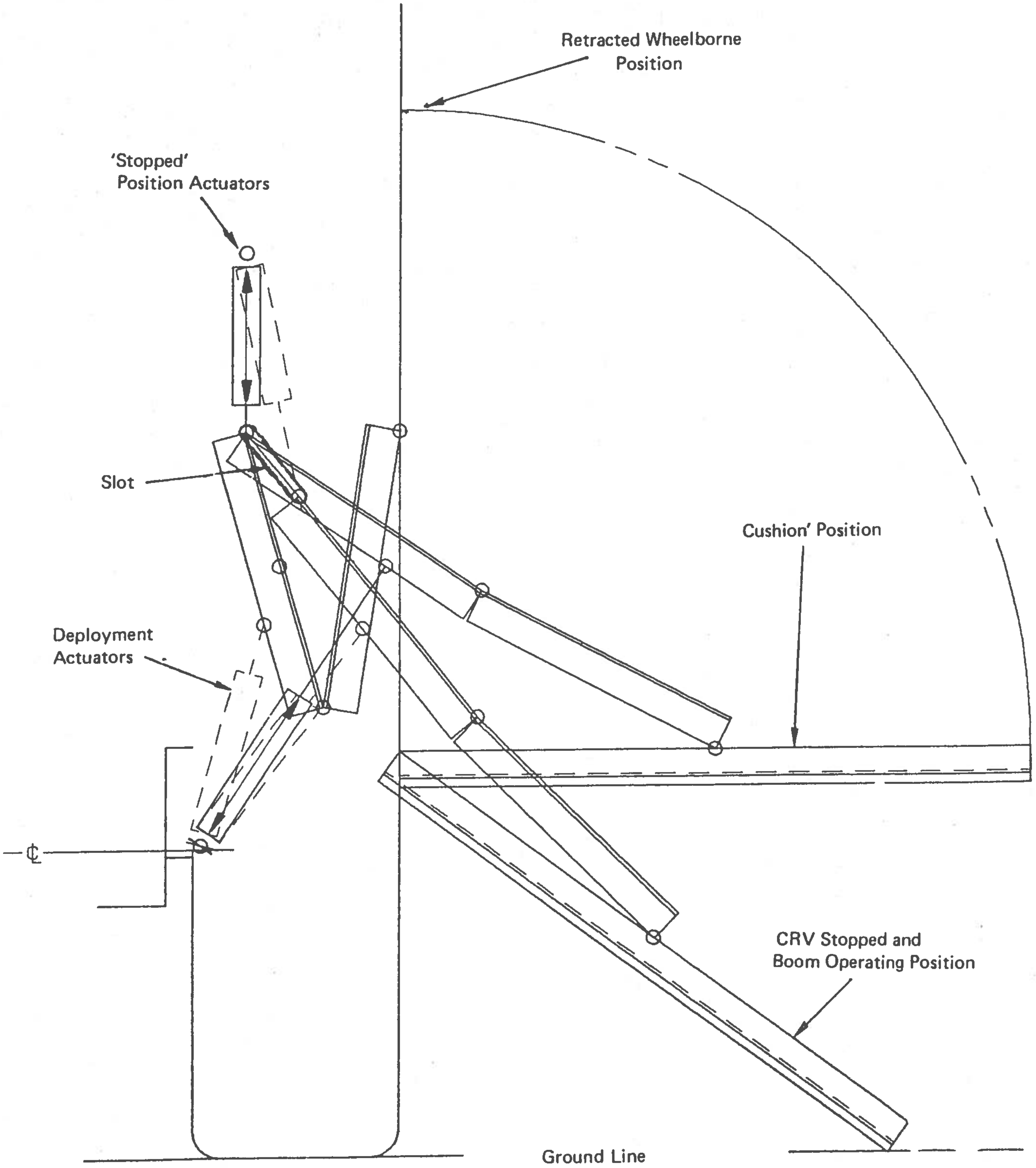


Figure 3.2-3. Panel Deployment

resting on the wheels these panels are further extended so that their edges reach the ground. This is accomplished by a second set of jacks as shown in the figure. The system can also incorporate differential control. The panel edges then become stabilizing outriggers for boom operation when stationary wheelborne and supports for the buoyancy bags when stationary hullborne. The differential operation may be used to balance support load on uneven ground or sideslope and to trim the craft level against the rolling moment of the boom in side-deployment hullborne (see Figure 3.2-4.

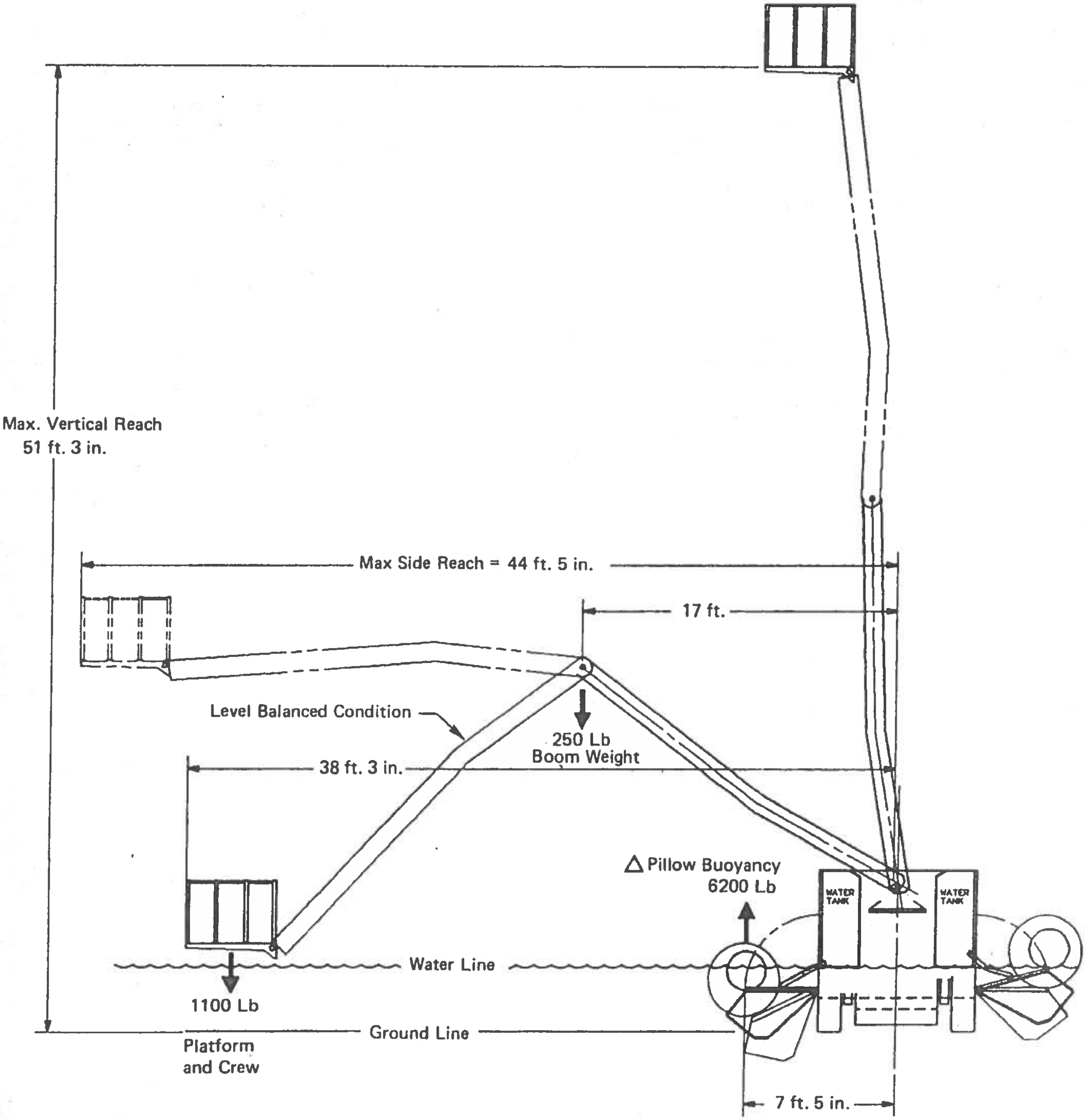


Figure 3.2-4. Boom Operation Hullborne

The retraction method and configuration is shown in Figure 3.2-5. A similar strap-down spray-suppression skirt was also considered for the front skirts to supplement this retraction method but it was considered an unessential adjunct and is therefore not included in the selected concept design.

The alternatives available for flotation are further discussed in the section on suspension.

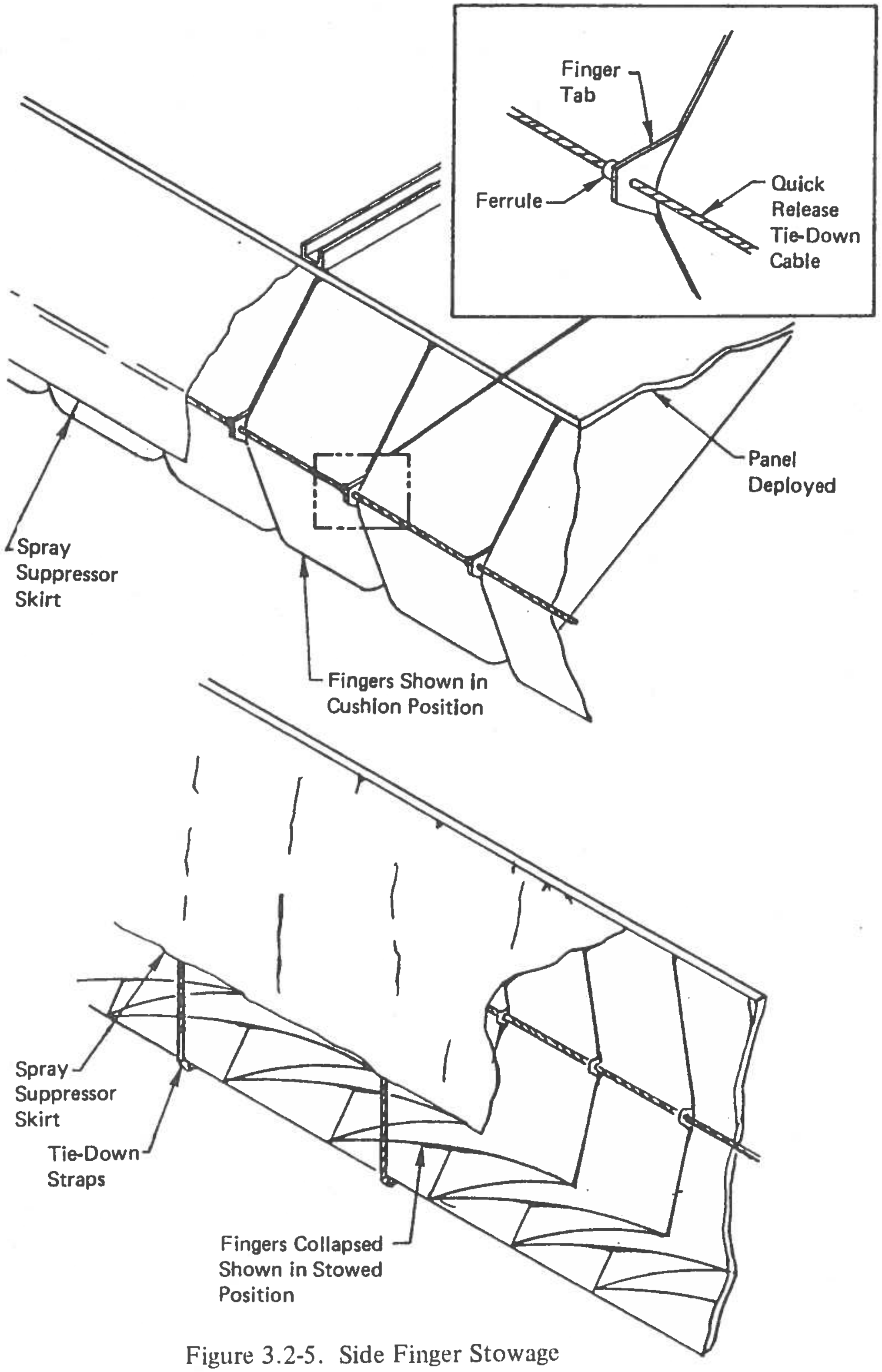


Figure 3.2-5. Side Finger Stowage

3.2.2 Air Cushion Fans and Cushion Powering

The selection of a lift fan involves the considerations shown in Figure 3.2-6. Numerous studies along these lines have been done in the past at Bell considering the whole range of possibilities, especially for the principal alternative types of axial and centrifugal. Figure 3.2-7 shows the important differences between these types.

PERFORMANCE:	Pressure, flow efficiency, horsepower, flow stability (fan curve slope)
INSTALLATION:	Size, shape, weight, drive, flow controls, bearings, arrangement, clutch
OPERATION:	Stresses, noise, vibration, erosion, operator controls
MANUFACTURING:	Materials, type of construction, repairability
COST:	Existing, modified or new design development, acquisition, support

Figure 3.2-6. Lift Fan Design Considerations

	Axial	Centrifugal
Pressure versus Flow Curve at Given rpm	Steep	Flat
Stall	Sharp	Gentle
Efficiency	80-89%	68-78%
Weight	Light	Moderate/Heavy Depending on Construction
Cost	Moderate	Moderate/Low Depending on Construction
Envelope	Small	Large

Figure 3.2-7. Characteristic Qualities of Fans

The desirable qualities of the axial fan of high efficiency, very lightweight and small volume are not essential for the ACCRV. Bearing in mind the need for a robust design and maximum assurance of avoiding heave stability problems, use of the centrifugal fan family, which has evolved over the years as most suitable for ACVs has been selected. Additional effort has been concentrated on detail optimization of the centrifugal approach.

The fan performance requirements are determined once weight and cushion areas are known, terrain tolerance defined and the skirt configuration set. Fan discharge pressure is determined by cushion pressure and skirt type. Flow requirement comes from operating conditions (i.e., terrain requirement, wave pumping, leakage, etc.).

Generally for ACVs it is found that flow requirements tend to fall into two categories, high speed and low speed with very low speed (sub-hump) designs using less flow and cushion power. Flow is defined by the air gap height, perimeter and cushion pressure. Power is the product of flow and pressure. Thus, if an air gap (otherwise called "daylight" clearance of "jet height" is decided, required power is known. Power required and performance (terrain capability) are proportional to this gap. In practice, it is found that larger ACVs tend to use larger gaps and can accept rougher conditions. Figure 3.2-8 is an empirical plot of air cushion jet height and cushion area. Bearing in mind the prescribed performance, an appropriate preliminary jet height has been selected for the ACCRV, as indicated. From this the design cushion power which is appropriate for the proposed craft is calculated. It is seen to be a function of size, cushion perimeter and is most strongly affected by cushion pressure, varying as $(p_c)^{3/2}$. This design power has been used for the selected concept design. It results in cushion requirements for flow and pressure of 900 cu ft/sec and 71.5 lb/sq ft, respectively. The effect of closed fingers is to reduce the overall efficiency factor η_o which includes pressure drop from fan outlet to cushion, thus for closed finger to cushion pressure ratio of 1.2 approximately 20% more power is required.

An estimated characteristic has been developed for the of centrifugal fan proposed (Figure 3.2-9). In selecting the design point a strong effort was made to provide a wide stall margin so that in case the engine rpm should need to fall, for example during selection of reverse gear cushionborne, the fan will still be capable of supplying enough pressure to maintain the cushion. Some sacrifice in fan efficiency at the design point is necessary.

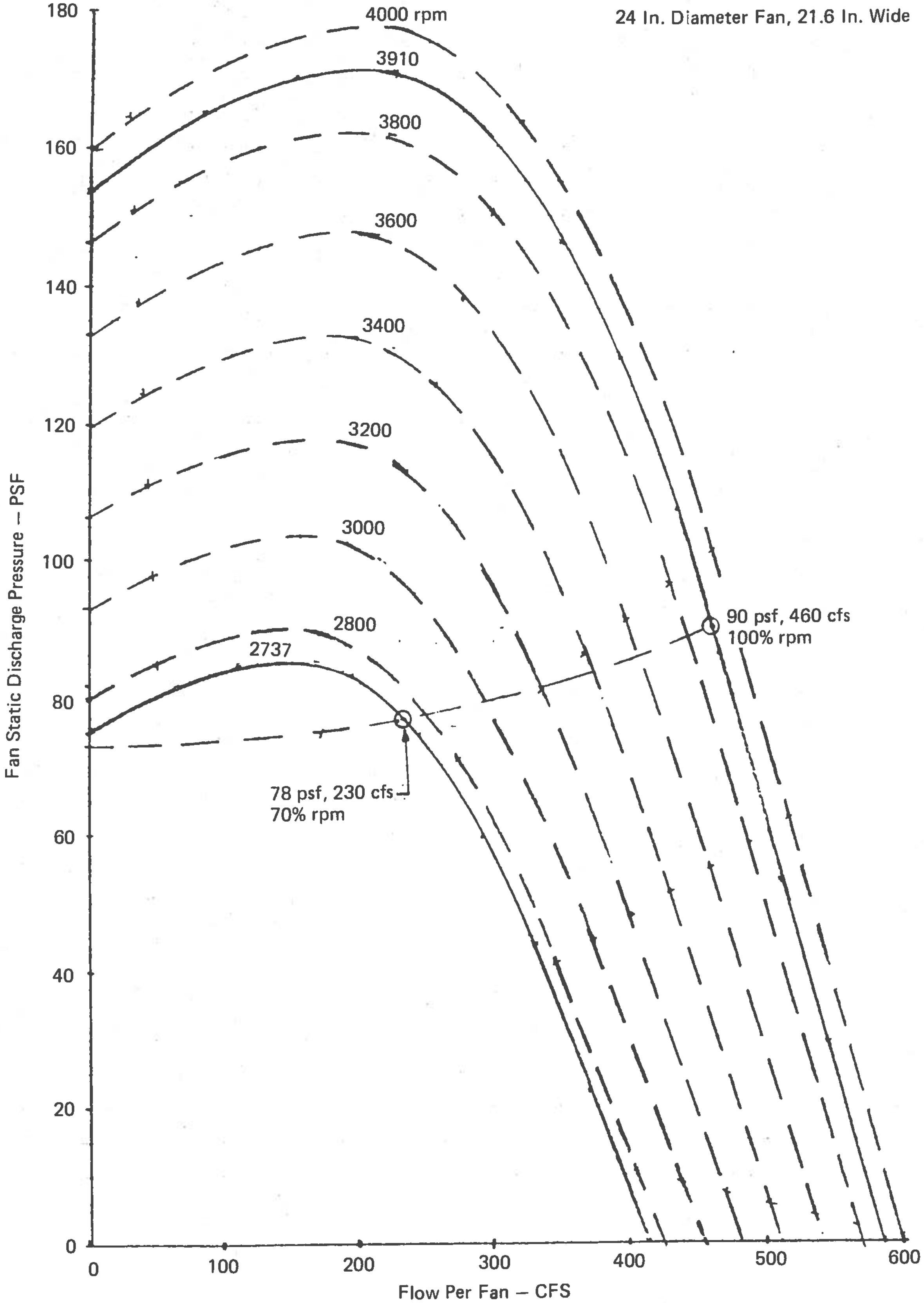


Figure 3.2-9. ACCRV Fan Characteristics

3.3 PROPULSION

This section is concerned with the reviews and trade-offs that have been made to arrive at the selected propulsion concept. The performance of the selected vehicle in its various environments is analyzed in Section 4.4.

Propulsion methods are considered for three modes - wheelborne, cushionborne and hybrid. Alternative surfaces are considered for each mode. For wheelborne the surfaces of interest are roads, rough terrain, firm ground, packed snow, ice and beach sand. On these surfaces the vehicle support will not usually need a cushionborne component and the skirts will be retracted. For cushionborne cases the surfaces of interest are water and marsh. Total support is provided by the air cushion. Hybrid operation on the other hand is appropriate to soft surfaces and may include rough terrain also, particularly on level ground. The surfaces of most interest are mud, marsh, soft sand and deep powdered snow, with the air cushion also providing smoother low-drag traverse of obstacle strewn surfaces.

3.3.1 Wheelborne

An approximate assessment of the road propulsion power requirement may be obtained from a review of the acceleration performance of existing firetrucks. In Figure 3.3-1 the relationship between lb of vehicle weight per horsepower to the acceleration time from 0-50 mph is shown for firetrucks in the 30K-100K weight class. The regression analysis equation for the line is

$$t(\text{sec}) = 0.9345\ (\text{lb/hp}) = 52.46$$

from which it is calculated that a 30,000 lb vehicle would require a 362 hp engine to achieve an acceleration of 0-50 mph in 25 seconds. Assuming accessory power requirements of 22 hp for the cooling fan, 13 hp for hydraulics and 5 hp for the alternator, and a typical mechanical driveline efficiency of 77%, results in approximately 250 hp at the wheels.

The vehicle maximum speed is to be at least 65 mph. Taking a frontal area 81 ft^2 (105 in. x 111 in. and a drag coefficient of 1.0, the aerodynamic drag is

$$D = 1/2\ \rho\ C_D\ A\ V^2\ \text{lb}$$

where V is the vehicle speed in ft/sec. The coefficient of rolling resistance on concrete is 0.02 (tires at maximum working pressure), making the rolling resistance = 600 lb. Thus, at 65 mph (95.3 ft/sec) the total resistance is 1475 lb.

Power required at the wheels is therefore:

HP = 1475 x 95.3/550 = 256 hp, in line with expectation from the foregoing comparison.

A further requirement is that of climbing a 40% grade at a speed up to at least one mph. This is to be achieved with the extinguishing agents being discharged at maximum rated capacity. The pumping power required is 190 hp. If the extinguisher nozzles are operating at 200 psi, and if all the fluids are discharged in the same direction that the vehicle is moving, they will create an additional resistance of 708 lb.

VEHCILE	GVW (LB)	HP	LB/HP	ACCELERATION PERFORMANCE
1) OTC P-19	33,600	400	84	0-25 MPH IN 25 SECONDS
2) OTC T-6	42,500	492	86	0-50 MPH IN 30 SECONDS
3) OTC M-12	93,470	984	96	0-50 MPH IN 35 SECONDS
4) OTC M-15	101,800	984	103	0-50 MPH IN 45 SECONDS

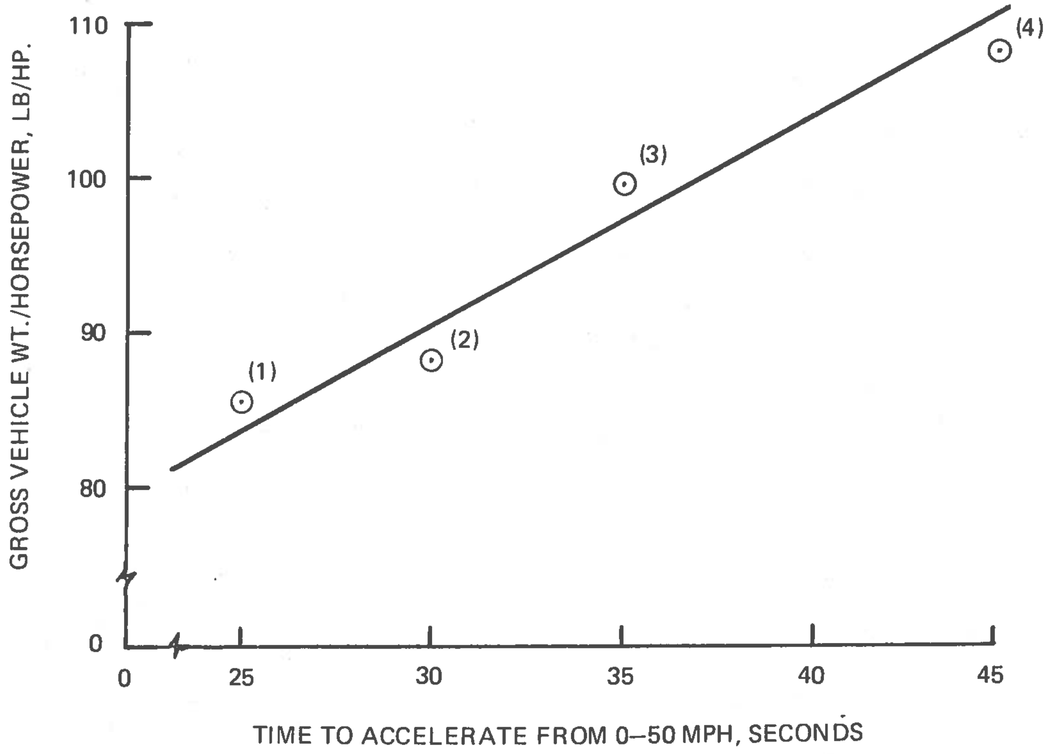


Figure 3.3-1. Acceleration Performance of Fire-Fighting Trucks

The total tractive effort required is therefore:

$$F = 708 + 600 + 30{,}000 \times 0.4 = 13{,}308 \text{ lb}$$

At 1 mph (1.47 ft/sec), this requires 35 hp at the wheels.

The results of this brief analysis show that the maximum speed requirement, the acceleration performance requirement will dictate the on-road horsepower, which is between 250 and 260 net hp.

3.3.2 Cushionborne

While over water, the ACCRV will be operating in the air cushion mode. Various types of propulsors may be considered for overwater propulsion, but if the water propulsor is to be used upon or even make a satisfactory transition to "soft surfaces" the selection becomes severely limited. Water propellers and waterjets are a hindrance on marshy ground and present special problems as described below. The remaining propulsive devices are air propellers, paddlewheels and paddletracks.

For a gross weight of 30,000 lb, the hump drag is 2800 lb at 12 mph.

To meet the design goal of 20 mph, hump drag plus 10% for acceleration over hump, should be used giving a required thrust of 3000 lb at 12.8 mph. Meeting this goal will result in a propulsor that will develop sufficient thrust to exceed the 20 mph requirement.

a. Water Propellers

If water propellers are used, they will be exclusively for water propulsion and if combined with wheels for "soft surface" traverse must have the wheels capable of providing sufficient traction before the propellers leave the water. On soggy, marshy surfaces, wet clay, mud and deep snow this may not be possible. In any event, the requirement is for the wheels to touch bottom while the propeller is immersed.

For effective propulsion at minimum depth the propellers should be outside the air cushion since in the displacement condition the water within the cushion cavity is some 15 in. lower. A feasible method of retraction with the propellers behind the craft is shown in Figure 3.3-2. Two long shafts penetrating between the individual fingers are visualized, with gearboxes on the rear wheel axle. Approaching a sloping beach cushionborne this propeller location is advantageous since they continue to operate in somewhat deeper water but departure is worsened. Transition from wheels to air cushion is made after the vehicle has entered the water to a depth of about 2 feet. The cushion can then be deployed. In addition, the wheels must operate unassisted over mud and marsh and snow unless still another system such as a retractable track between the wheels is added resulting in still more complexity, weight and cost. It is concluded that water propellers are not the most attractive propulsor in this application, but should be considered if possible.

b. Air Propellers

Air propellers provide consistent thrust over all surfaces and for this reason have been used on most ACVs. They are not considered suitable for the ACCRV because of size and storage limitations. A brief analysis to substantiate this conclusion

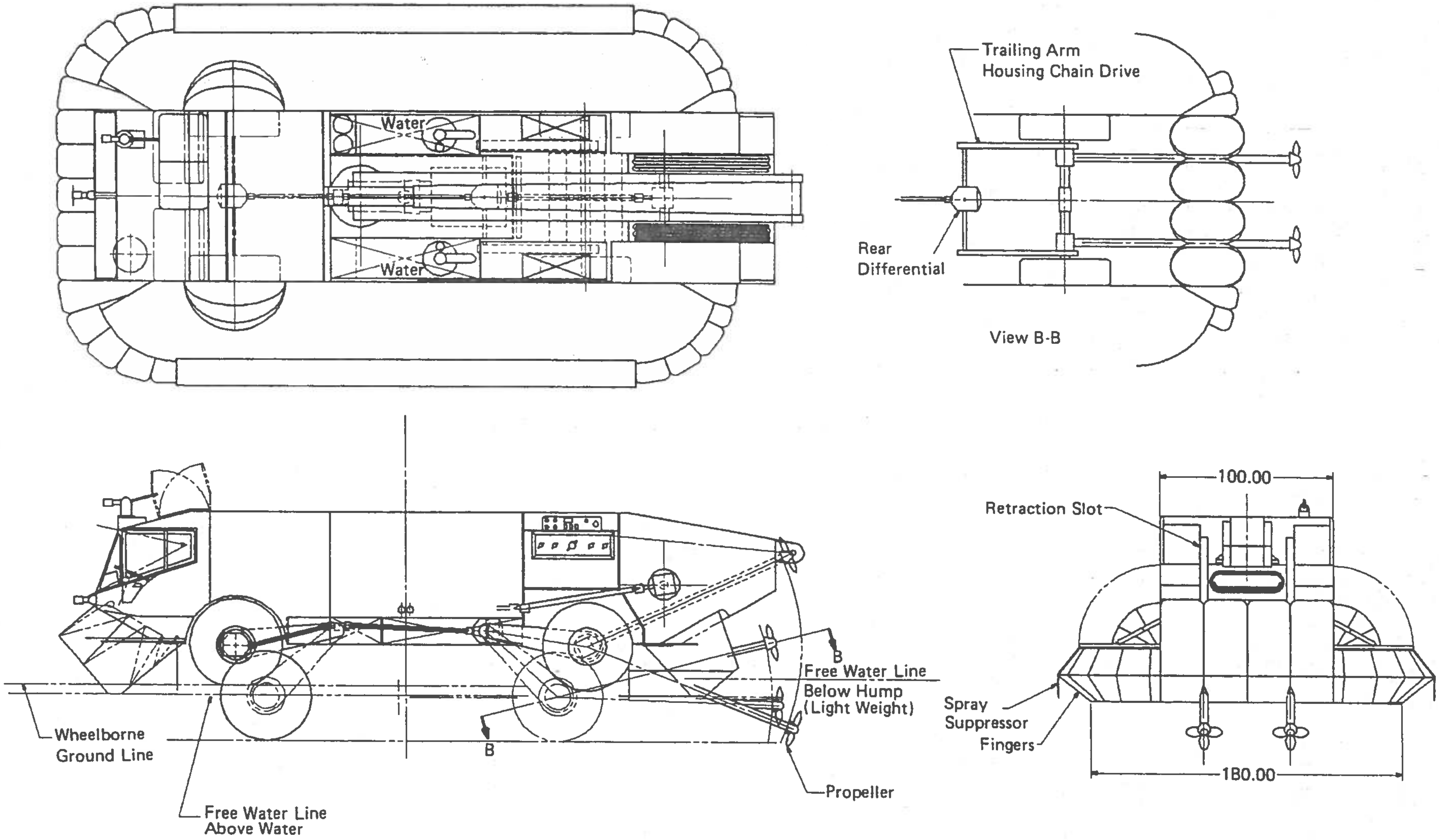


Figure 3.3-2. ACCRV Propeller Option

follows, based on the assumption that the largest diameter propeller that might be considered for ACCRV is 7 ft.

The power coefficient C_p is defined as (Ref. 2),

$$C_p = \frac{HP\ (\rho_o/\rho)}{2000\ (N/1000)^3 (D/10)^5} \qquad (1)$$

where

ρ_o/ρ is the ratio of air density to standard air density
N is the rpm
D is the propeller diameter in ft.

Therefore,

$$C_p = 2.975 \times 10^6\ HP/N^3 \qquad (2)$$

The propeller advance ratio J is

$$J = 60V/Nd \qquad (3)$$

where V is the vehicle speed in ft/sec.

$$\text{i.e., } J = 161/N \qquad (4)$$

The power required is given by

$$HP = \frac{TV}{550\ n_p} \qquad (5)$$

where T is the thrust in lb and n_p is the propeller efficiency

Therefore (6)

$$HP = 98.4/n_p$$

Substituting for HP in equation (2) yields

$$C_p = \frac{2.93 \times 10^8}{n_p\ N^3}$$

which, from equation (4) gives

$$C_p = 70.2\ J^3/n_p \qquad (7)$$

Values of J and n_p were selected, from which C_p was calculated. These were compared with the values obtained from the optimum efficiency chart for 4-bladed propellers given in Ref. 2. The maximum attainable efficiency was found to be 10%. It is seen from equation (6) that 1230 HP would be required to produce a thrust of 3600 lb at 12.5 mph. It is apparent that the power requirements of an acceptably sized air propeller are excessive for this type of vehicle. Even at the size used in this calculation a satisfactory configuration permitting drive on/off capability in a C-130 is a dubious proposition.

c. Paddlewheels

Use of paddlewheels for cushionborne propulsion is attractive because unlike water propellers, they will provide thrust in marsh conditions. A simple co-axial arrangement is conceived which will permit the vehicle to traverse smoothly from water to marsh to dryland and wheelborne or the reverse.

Considering sizing, diameter is first fixed as a compromise between land, snow and water propulsion. Thus, the wheels' loaded radius is 24.1 in. The outside paddle radius is 20 in. and blade depth 10 in. Available width is 50 in. Blade area is 500 sq. in/blade.

This size of wheel is tabulated to provide adequate thrust but due to the high blade speed ventilation is expected to limit thrust below a critical ventilation speed. This has been analyzed taking account of the time constant of the water response, the blade tip speed and the vehicle forward speed. The resisting thrust speed curve is shown in Figure 3.3-3. Better performance could be obtained from increased blade area. A retractable blade scheme was considered and is shown in Figure 3.3-4. This would also provide increased ground clearance in the wheelborne mode, but the added complexity was not considered acceptable. Increased clearance in the wheelborne inside plus improved soft surface traction could also be obtained by alternative variable geometry by which the paddle axle level relative to the wheel axle level would be changed. This was briefly examined and a retraction concept which does not involve reducing paddle width is shown in Figure 3.3-5. Again the increased complexity was considered marginally acceptable, and could only be recommended if other approaches failed.

d. Paddletracks

Paddletracks have equal validity for water propulsion and transition from water to marsh to wheelborne. Additionally, because of the increased contact area, better traction on soft surfaces, especially snow can be achieved. Bell conducted tests of paddle blade drag in a tow tank for various cleat depths, spacings, speeds, etc. Key data from these tests, which is unpublished, is shown in Figure 3.3-6.

Paddletrack propulsion for the AACRV is conceived as replacing the fixed steel paddle wheel blades with a rubberized track/cleat belt for use on snow and water. It must be declutched and retracted for normal overland conditions. To provide these functions allow support of the forward track idler and intermediate bogey, track width must be reduced below what is achievable with the paddle, introducing center and side arms as shown in Figure 3.3-7. Two tracks 20 in. wide can be accommodated, and they can be 60 in. long and retracted if the differential is moved forward and the length of the trailing arms increased.

Treating the data from the tests shown in Figure 3.3-6 as a 1/5 scale representation of the ACCRV and using 6.5 in. deep cleats at 15 in. spacing a gross area of 7.2 sq ft with four cleats submerged is obtained. Scaling the test data, which was obtained at speeds up to 20 ft/sec a thrust of 3600 lb is obtained at a relative cleat to

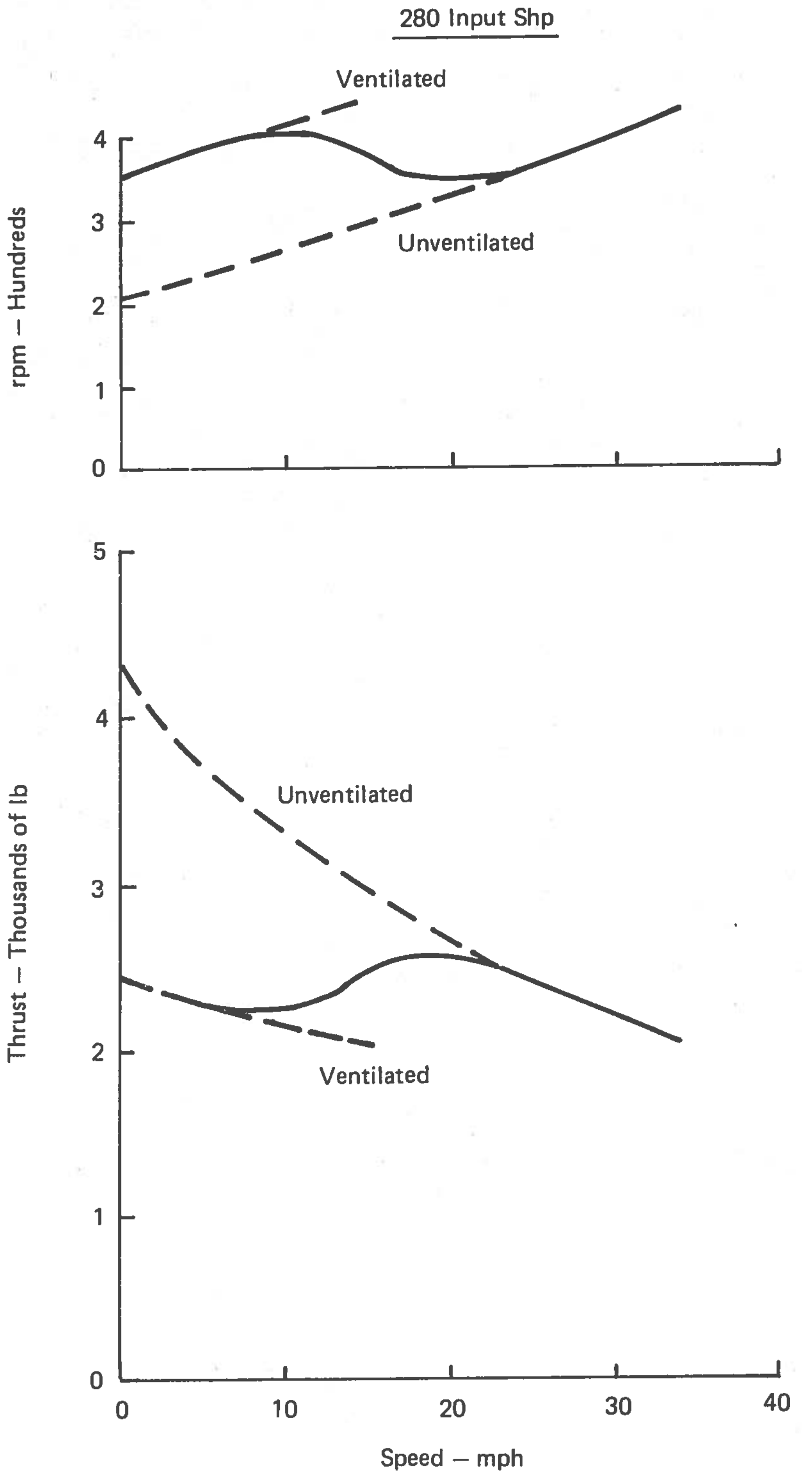


Figure 3.3-3. ACCRV Paddle Wheel Performance

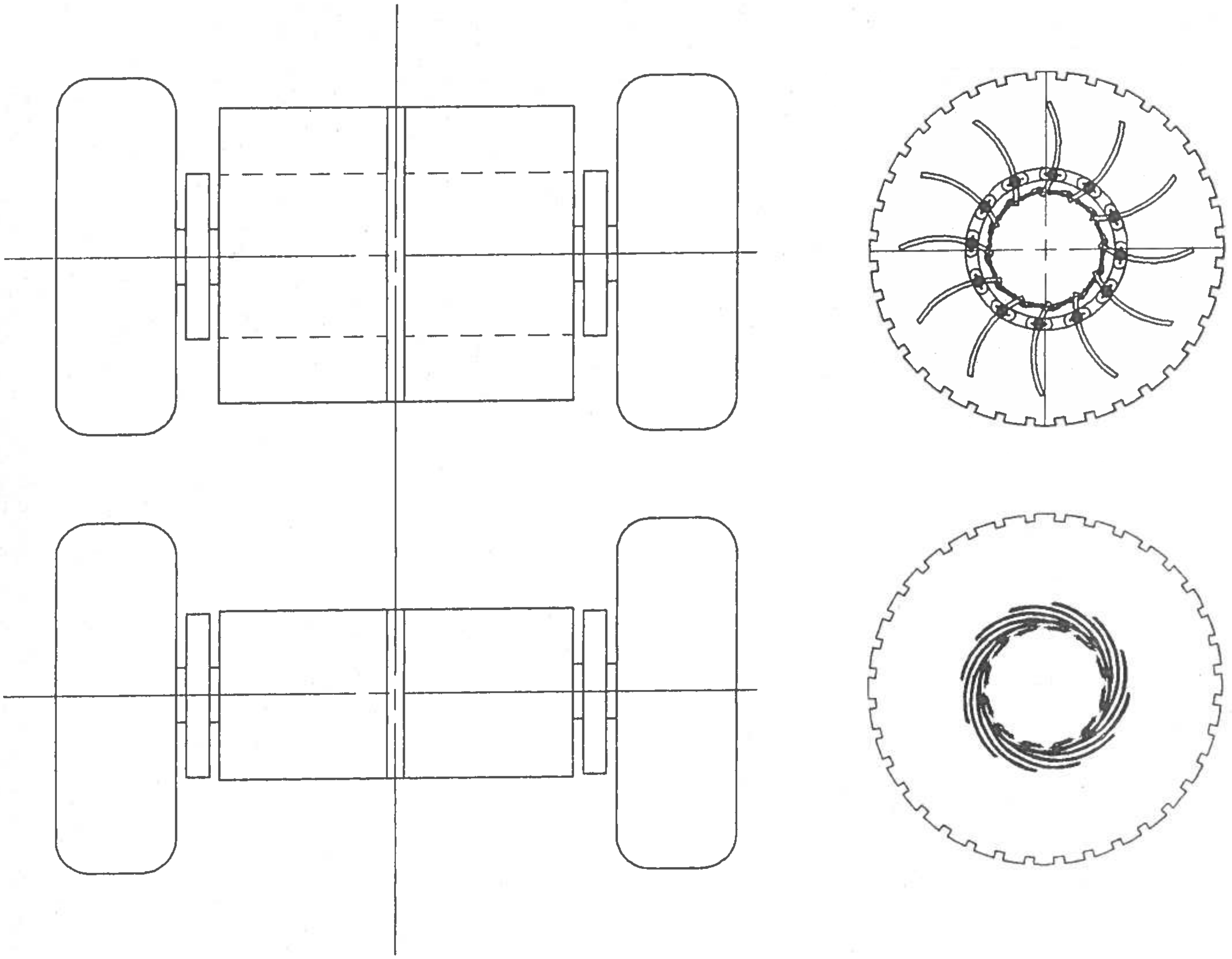


Figure 3.3-4. Retractable Blade Paddle Wheel

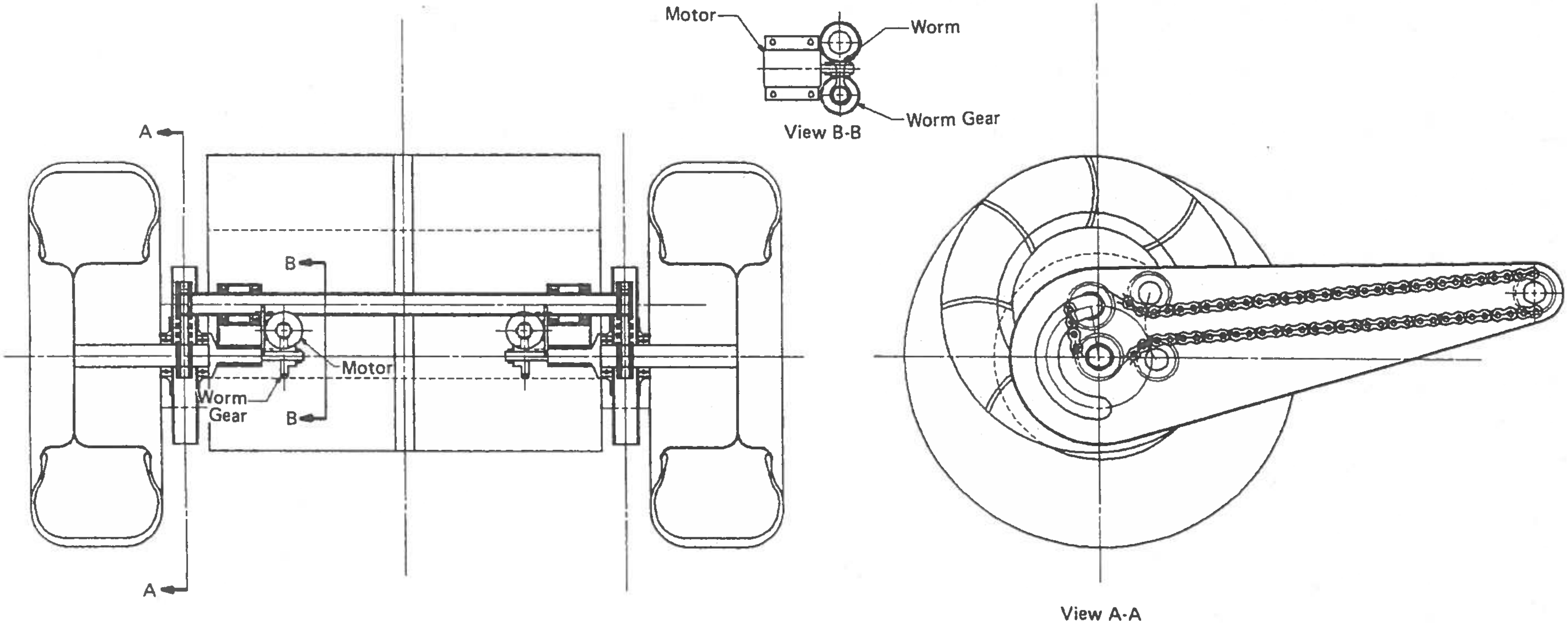


Figure 3.3-5. ACCRV Adjustable Height Paddle

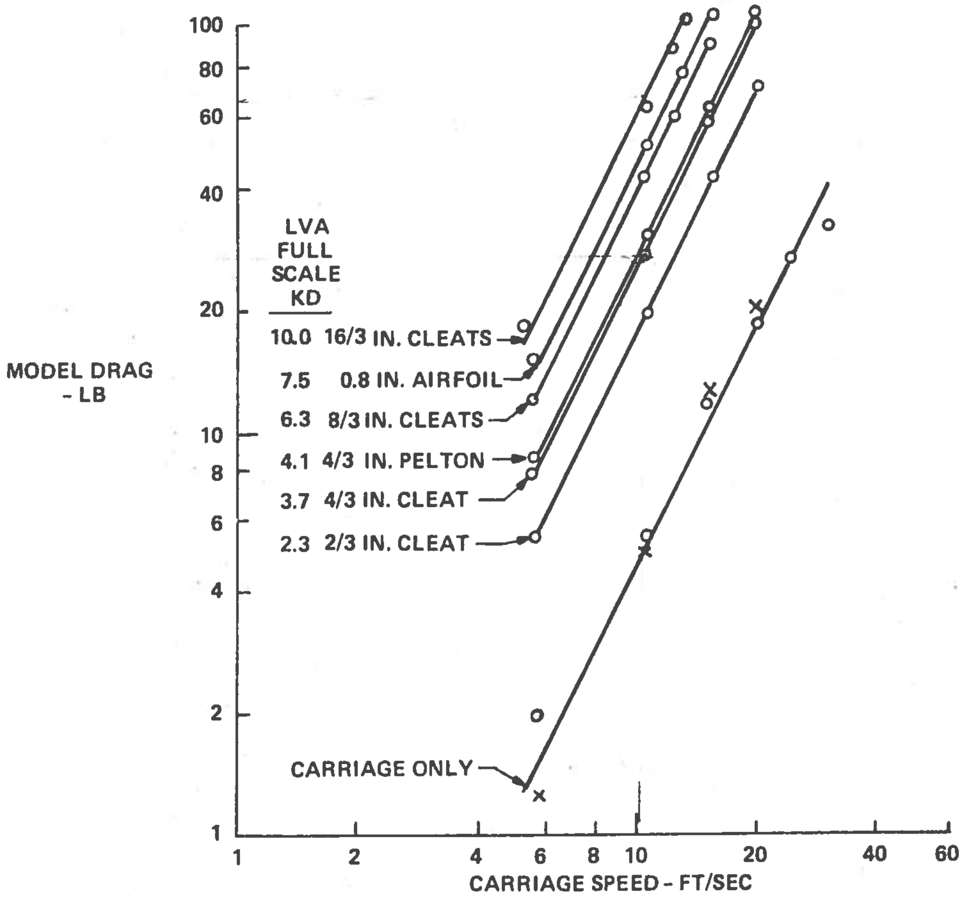


Figure 3.3-6. Tow Tank Model Test Data

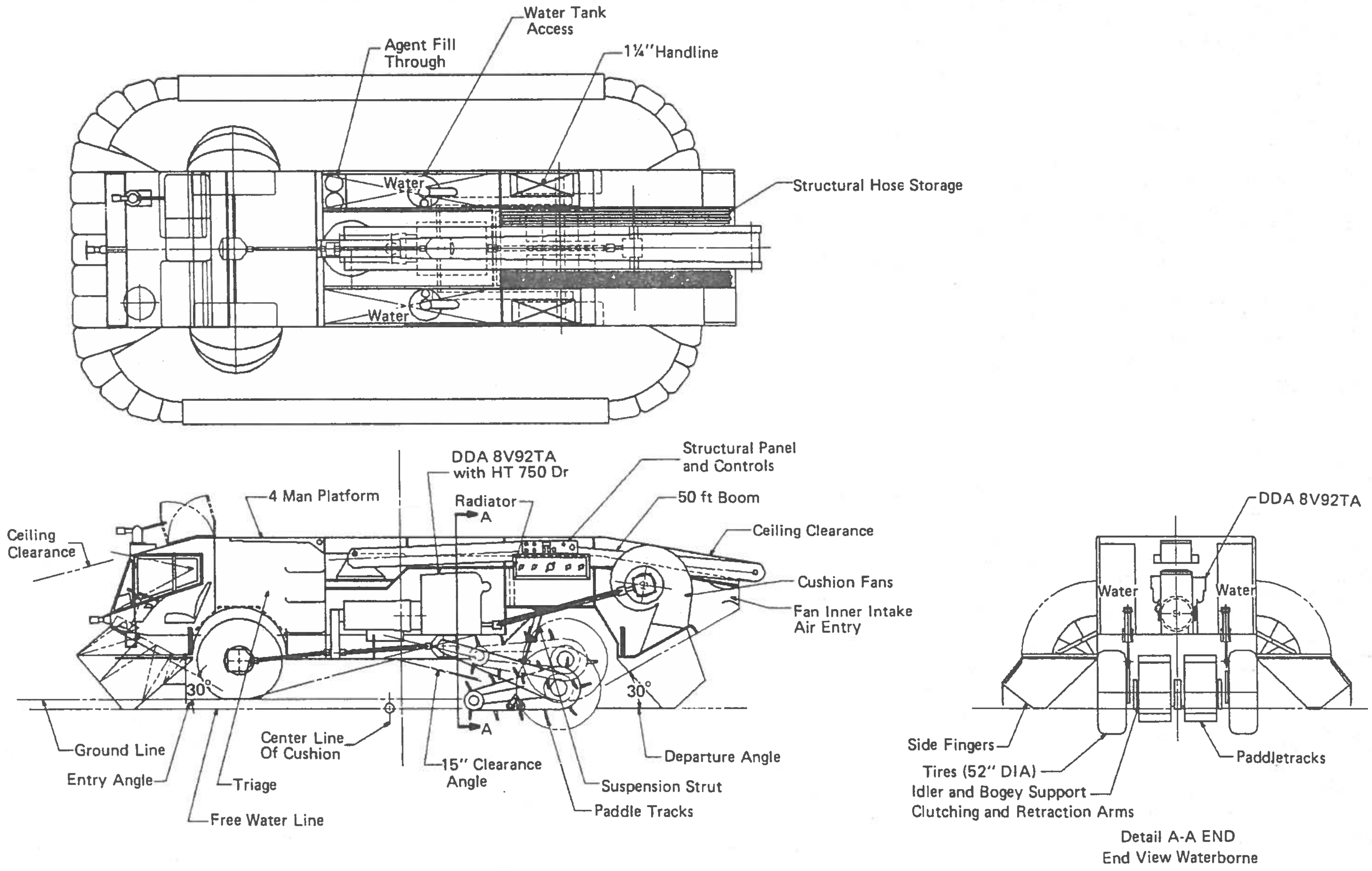


Figure 3.3-7. ACCRV Paddle Track Propulsion Scheme

water speed of 38 ft/sec. Adding 18 ft/sec for forward speed gives an rpm of 358 and power of 289 HP.

This rpm and power are still compatible with the wheel drive. Prima facie the paddletrack is a viable option but is susceptible to ventilation similarly to the paddlewheel. Its disadvantages are increased weight, complexity and cost. Its advantage is improved soft surface drive. But in the light of the air cushion's ability to offset floatation requirement without drag increase the simpler paddle wheel approach is preferred preferred for water drive. This hybrid operation is further discussed in the following paragraph. Finally, with regard to the water drive, it must be borne in mind that the difficult high hump thrust requirement is accompanied by a large wave for which the paddletrack may require attitude adjustment. It must also be noted that blade element velocities of both systems are high and model tests are needed to verify thrust estimates. This is not the case for water propellers.

3.3.3 Hybrid Operation

The air cushion assist will provide improved performance over certain very soft surfaces such as marsh, mud, loose soft sand and, especially, deep powdered snow. The criterion for hybrid operation is wheel sinkage. The wheels will sink further into a soft surface when the load is increased. The increased load will provide increased traction but the increased sinkage will provide increased resistance. On the above soft surfaces the resistance will increase faster than the tractive effort and at some load progress will be impossible.

For a typical tire, as the load is increased, it is necessary to increase the pressure such that the tire footprint (on a hard surface) is maintained approximately constant. This is mandated by the manufacturer to prevent carcass slipping on the rim or being damaged by excessive deflection. Some increase may be permitted at low pressure and very low speed (Figure 3.3-8), but essentially the tractive effort (friction and shear) tends to be proportional to this fixed footprint area. Thus, the only way to improve soft surface wheeled propulsion is to increase the total footprint area (by having larger wheels or more wheels) until the vehicle can be sustained on the given soft surface with acceptably low sinkage.

The given wheeled tractive effort available on a given soft surface can be applied to propel the vehicle, using a low wheel load to avoid excessive sinkage and wheel resistance, if the air cushion is used to support the appropriate proportion of the weight since the air cushion itself offers no significant resistance to forward motion, as will normally be the case.

With special reference to snow, it is common experience that a four-wheel drive vehicle using moderate tire pressure with limited differential provides satisfactory performance on packed or shallow snow. Over this type surface the ACCRV will operate better on the wheels alone than with the cushion deployed and better still when the wheel sinkage causes the paddle blades to become effective as cleats.

The provision of additional area by adding wheels pays a poor dividend in terms of space requirement since only a low percentage of the tire planform area is realized as footprint. The proportion is maximized by making the tire as wide as possible hence it is found that terratires, etc. are exceptionally wide. Wider tires than those now in use on the P=19 were considered for the AACRV, going to 21.5 in. width instead of 17.5 in. Such tires are poor performers on roads on cornering, etc. The wider tire (Goodyear 22/65 R25) instead of 17.5 R25 is 55% heavier, and 50% more expensive and the

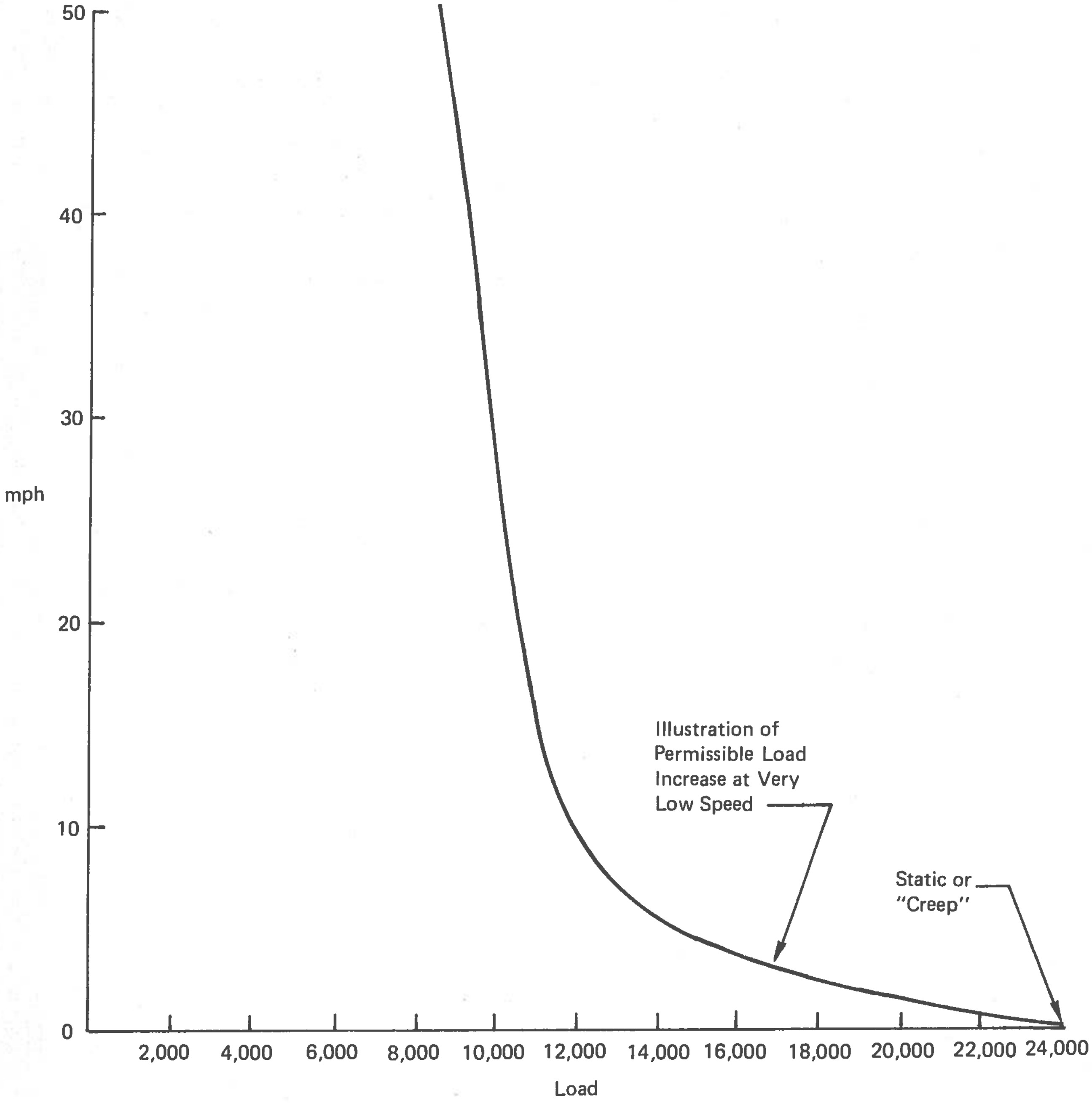


Figure 3.3-8. Michelin Mobile Crane Tire Lowest Pressure Quoted = 72 psi

increased wheel diameter required encroaches on the triage area and reduces paddle width unacceptably. For these reasons and because of the available cushionborne assist, propulsion capability of the paddle and commonality with the P-19K the tires used on that vehicle were adopted for the ACCRV as the primary configuration pending model tests.

Earlier the poor dividend in contact area resulting from adding wheels was discussed. When tracks are used they pay a maximum dividend in this respect and in most cases will be found to give the best traction on soft surfaces within a given envelope. Tracks were considered as a variant of the rear paddle on the ACCRV. They were conceived as rubberized belts with deep cleats for water propulsion extending forward as shown in Figure 3.3-7. No scheme could be devised which did not involve not only retraction and extension similar to the paddle scheme, (applied to the whole track) but also declutching the track from the wheels. The additional complexity combined with doubts as to the propulsive efficiency on water (blades one behind the other) make the co-axial paddle a more attractive option, although the tracks are expected to give better propulsion on snow.

The mechanism for traction on soft snow involves compaction at the front of the wheel or track increasing the shear strength of the snow, permitting a tread or cleat to react enough force. For any given system (wheel, track, paddle, etc.) the permissible contact pressure is a function of the particular snow condition. In the hybrid mode in this design concept the wheel/paddles can be extended until satisfactory pressure is achieved, further rear wheel sinkage being controlled by compaction beneath the paddle drum.

In the hybrid mode in this design concept the wheel/paddles can be extended until satisfactory pressure is achieved, further rear wheel sinkage being controlled by compaction beneath the paddle drum.

SUMMARY

Considering all modes and surfaces the simplest most effective propulsion method is though to be the coaxial rigid paddle combined with four wheel drive. The thrust predictions must however be confirmed by test, but it is not likely that the paddle size that can be accommodated will permit the required 20 mph to be achieved, at least not at full gross weight and without water jet boost at hump. The most feasible alternative is the use of retractable water propellers with entry/exit from the water wheel/hullborne and has marsh type soft surface capability.

Bell is conducting a program of model testing to generally explore the probability of paddle propulsion for ACVs. Preliminary data is expected to be available early in 1986. The final selection of propulsion method will be made in the light of this data.

3.4 POWERING AND TRANSMISSION

3.4.1 Engine Selection

The Detroit Diesel 8V92TA engine was selected as the most suitable power plant to provide the total power for individual and combined ACCRV system operation.

Power levels shown in Figure 3.4-1 were computed for achieving the performance levels specified in the statement of work and in NFPA-414 for Class 1 fire fighting equipment. The power levels are for individually driven subsystems and for groups of subsystems driven simultaneously. All power estimates are based on standard day conditions and a vehicle gross weight of 30,000 lb.

To ensure that no suitable engine for ACCRV is overlooked, Bell conducted a survey of all available engines in the 300 to 800 hp range, foreign and domestic, in-inventory and underdevelopment. Figure 3.4-2 is an all inclusive listing of the engines

Mode	Condition		hp
Wheeled	65 mph top speed (incl drag)		338
	0-50 mph in 25 sec.		324
	1 mph on 40% grade		35
	50 mph level ground (incl drag)		197
Air Cushion	Paddle Wheel Operation		425
	Lift power		252
Pumping	990 gpm		190
	Momentum drag		708 lb
Boom Operation Accessories and Losses	Alternator	5	55
	Hydraulic Pump	13	
	Cooling Fan	22	
	Intake/Exhaust	15	

Combined System Operation

1.	Pump at 990 gpm while on cushion and station keep with paddlewheel (35 hp) operating all accessories.	(190 Pump + 252 Fan + 35 stationkeep + 55 accessories) = 532 hp
2.	Ascent 40% grade at 1 mph, pumping + all accessories.	(35 grade + 190 pump + 3 momentum + 55 accessories) = 273 hp
3.	Various Subsystems.	As noted
4.	20 mph in water on cushion + accessories.	(425 wat. prop + 252 fan + 55 accessories) = 732 hp

Figure 3.4-1. Power Requirements (30,000 lb. GVW)

Manufacturer	Engine	hp(1)	Dry Wt (lb)	Size (in.) LXWXH	Engine Cost Per Vehicle 1985 $	Remarks	
Caterpiller	CAT3208*	350	1450	37 x 36 x 35	20,000	In AF Inventory 5-7000 hr MTBO	Insufficient Pwr
Caterpiller	CAT3508	800	9600	86 x 67 x 68		In Inventory – Off the Road Application	Heavy Weight
Cummins	VTA-903-T	600	2450	55 x 33 x 37	23,008	In Military Inventory Uprating to 600 hp in Progress	Power Level Marginal
*Detroit Diesel	8V-92TA	736	2250	43 x 35 x 41	28,000	Two Engines Completed NATO 400 hr Test at 736 hp. 90% of Parts in Mil. Inventory.	Medium Weight Reasonable Cost
Detroit Diesel	8V-71TA	600	2090	41 x 37 x 41	22,000	Uprated Engine, has completed NATO 400 hr Test at 550 hp	Power Level Marginal
Detroit Disel	6V-53T*	350	1360	37 x 36 x 38	20,000	In Military Inventory - Completed NATO 400 hr Test	Insufficient Power
Garrett	GT601	540	2170	56 x 41 x 38	123,000	Excessively High Cost and Low Power at 100°F Development Engine	Extremely High Cost
John Deere	Score 350	750	1500	40 x 30 x 30	70,000	Extensive Development Required – Partially Funded by USN	Development Engine – Risk
*MTU	MTU880-V6	750	1760	39 x 37 x 30	56,800	Over 400 hrs on V-12 - V-6 Not Tested. Some Dev. Cost to be Amortized on First 7 Engines, Foreign Engine – GM Has Liscense to Build in US	High Cost Low Weight
*Rolls Royce	CV8-750A	750	3050	41 x 41 x 38	38,500	In Production, Foreign Engine But Can Be Licensed	Heavy Weight

(1) 59°F; Sea Level; No Intake/Exhaust Losses
* Viable Candidates

Figure 3.4-2. Engine Comparison – Initial Screening considered for ACCRV. Nine candidates were examined including one rotary (RC2-350), one turbine (6T601) (light weight alternatives) and seven diesels. The rotary engine is under development by John Deere. A two rotor configuration has adequate horsepower for the ACCRV. Its development is partially funded by the U.S. Navy but the schedule for a qualified engine is not firm. The weight advantage offered is negated by schedule, cost and development risk. The Garret 6T601 turbine engine was rejected primarily on the basis of cost, being nearly twice as expensive as the next highest cost engine. The DD 6V53 and CAT 3208 engines were eliminated because of inadequate power with a single engine installation.

The Cummins VTA 903-T and the Detroit Diesel 8V71TA are marginal on power; both are rated at 600 hp at standard conditions. There is not sufficient power to account for hot day operation, power output degradation over life of the engine or for design margins.

The three remaining engines are viable candidates. They are the Rolls Royce CV 8, the MTU 880 V6, and the Detroit Diesel 8V92TA. The manufacturers of these engines were contacted for detailed physical and performance data, availability and cost verification.

The trade studies to date have shown these engines to be suitable power plants for ACCRV which provide acceptable (but not equal) levels of performance. As further information was compiled on each engine, supportability criteria, the DD8V92TA emerged as the preferred engine for ACCRV. It is an available engine of reasonable weight, produces the required horsepower level and is the lowest cost alternative of all engines considered. Figure 3.4-3 summarizes the principal dimensions and characteristic curves of the performance of the DD8V92TA engine, and lists the standard equipment.

3.4.2 Transmission

The HT-750DR-5 speed automatic transmission was selected and coupled to the DD8V92TA engine to meet the acceleration, graceability and top speed requirements of the ACCRV.

Available transmissions for the ACCRV are listed in Figure 3.4-4.

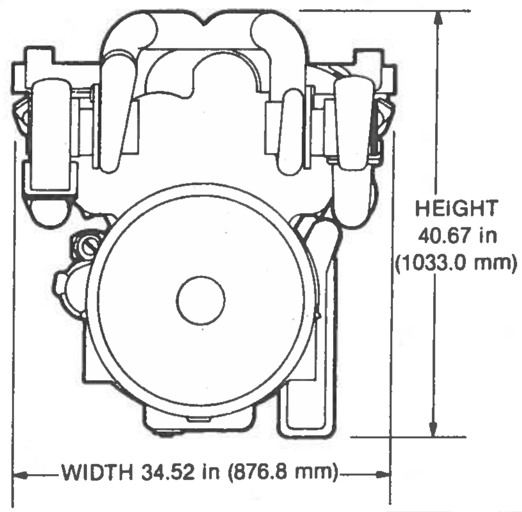
They include six automatic and six semiautomatic transmissions. Of these, ten incorporate a torque converter, a feature deemed to be essential in the ACCRV drive train. Principal characteristics of the HT750DR transmission are given in Figure 3.4-5, Specifications.

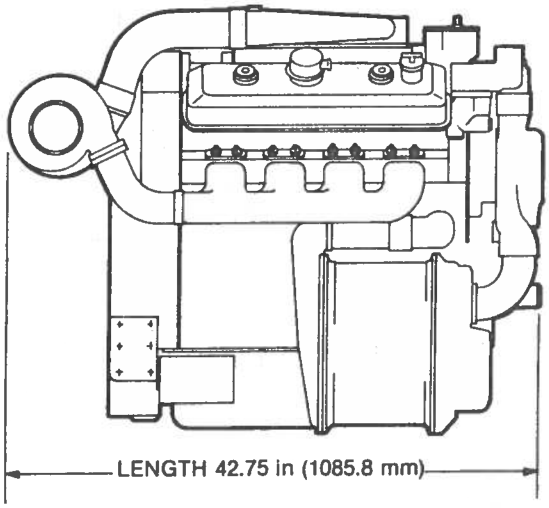
3.4.3 Power Distribution

The requirement for a single diesel engine to supply all the power on the air cushion crash rescue vehicle demands a power distribution system capable of simultaneously accommodating all subsystem demands for varying power levels and speeds, while at the same time limiting power to some components under various operating conditions. To achieve this with minimum complexity and weight the power distribution system shown in Figure 3.4-6 was selected.

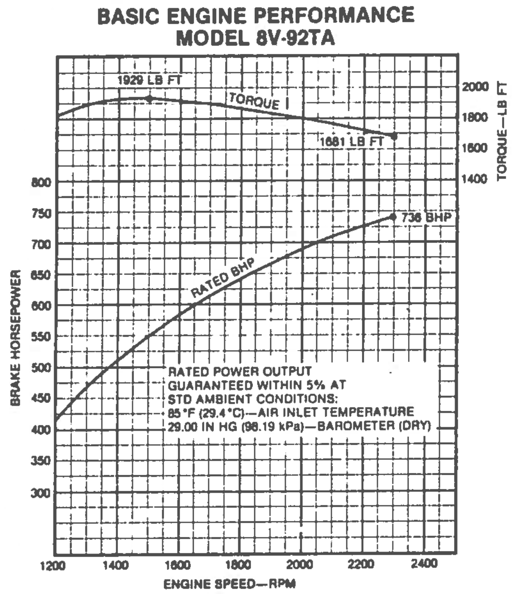
Perhaps the best way to describe the functional characteristics of this system is by addressing its operation in the various operating modes.

principal dimensions





performance



standard equipment

Aftercooler

Block—Cast Iron

Flywheel

Flywheel Housing

Governor—Limiting Speed

Oil Pan—Capable of 70% grade operation

Starting Equipment—24 volt

Turbocharger—Two turbochargers.
Location determined by installation requirements.

Electronic Control System

specifications

Engine Type	Two Cycle
Number of Cylinders	8
Bore and Stroke	4.84 in x 5 in (123 mm x 127 mm)
Displacement	736 cu in (12.1 liters)
Rated Gross Power: 85 °F (29.4 °C)—Air Inlet Temperature and 29.00 in Hg (98.19 kPa) Barometer (Dry)	736 BHP (549 kW) @ 2300 RPM
Torque: 85 °F (29.4 °C)—Air Inlet Temperature and 29.00 in Hg (98.19 kPa) Barometer (Dry)	1929 lb ft (2615 N•m) @ 1500 RPM
Compression Ratio	17 to 1
Fuel Capability	Diesel #2 through CITE
Fuel Consumption at Idle	4.4 lbs/h (2.0 kg/h)

Figure 3.4-3. Engine Characteristics

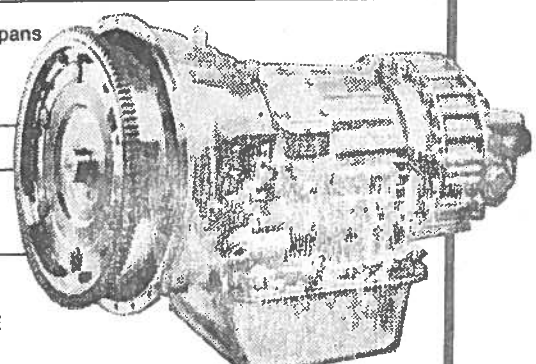
Manufacturer	Model	Type	Max hp	Input Torque	Dry Wt.(lb)	L X W X H (in)
Allison	CLBT 750	TC Drive Automatic	425	1300	1174	48x25x26.1
	HT-740	TC Drive Automatic	400	1100	800	37.4x22.5x25.6
	HT-754CR	TC Drive Automatic	425	1300	940	41x22.5x25.6
Selected →	HT-750DR	TC Drive Automatic	425	1300	940	41x22.5x25.6
	HT-750DR(DB)	TC Drive Automatic	425	1300	1490	49x22.5x37.7
	CLBT 5860	TC Drive Semiautomatic	475	1196	2185	58.9x29.4x34.8
	CLTB 5960	TC Drive Semiautomatic	525	1350	2165	56.0x29.4x34.8
	CLBT 6061	TC Drive Semiautomatic	675	1800	2446	56.9x29.4x34.8
Clark	CL8000	TC Drive Semiautomatic	525	1250	3800	
Twin Disk	2000	TC Drive Semiautomatic	500	1250	2100	46.5x27.8x35
Caterpillar	7155	Clutch Drive Semiautomatic	460	1350	1090	32.8x23x26.1
Eaton Co.	TS 1312	Clutch Drive Semiautomatic	550	1300	725	33x22x22

Figure 3.4-4. Available Transmissions

3.4.3.1 Mode 1 - Drive Mode - This mode is used on paved, gravel or dirt roads suitable for normal vehicular traffic, or when operating off road on suitably supportive surfaces. The vehicle is operated in the same manner as a nonaugmented crash fire rescue vehicle, and power distribution is accomplished in the conventional manner.

Power from the engine is transmitted through the power divider to the Allison HT750DR. The HT750DR in turn provides power to the drop box which directs power to the front and rear axles. All ranges of the HT750DR are usable with engine and transmission output speeds related as shown in Figure 3.4-6 adjusted for 2300 input rpm. Under this condition, however, the electronic control system governor on the engine limits the engine power curve so that at no time does the maximum engine net torque

		HT 754CR
rating +	Net input power	445 hp (332 kW) (max)
	Input speed	2400 rpm (max); 1900 rpm (min)
	Net input torque	1300 lb ft (1763 N•m) (max)
	Vehicle weight	Up to 80,000 lbs (36,280 kg) GVW
mounting	Direct	SAE 1 flywheel housing with flex plate drive
	Remote	Converter housing side pads, and rear housing top pad
torque converter	Type	Single-stage, 3-element, polyphase
	Stall torque ratios	TC 470-3.04; TC 495-2.21; TC 496-1.83; TC 497-2.70; TC 499-2.09
	Automatic lockup clutch	Effective in all forward ranges
input hydraulic retarder (optional)	Type	
	Capacity (horsepower absorption)	
gearing	Type: Constant mesh, spur type, planetary—standard & second gear start	
	Range	Ratios*
	First	7.973
	Second	3.188
	Third	2.021
	Fourth	1.383
	Fifth	1.000
	Reverse	4.716 (reverse with second gear start)
power takeoff**	Converter driven (one)	
	Location	Top, left side at 10 o'clock position (as viewed from rear)
	Size of opening	SAE 6-bolt
	Ratio	1.00 x turbine speed (all ranges)
	Rating	Intermittent—400 lb ft (543 N•m) Continuous—300 lb ft (407 N•m)
	Engine driven (two) (optional)	
	Location	Converter housing: one o'clock position and eight o'clock position (as viewed from rear)
	Size of opening	SAE 8-bolt
	Ratio	One o'clock—1.35 x engine speed—eight o'clock—.844 x engine speed
	Rating	Intermittent—260 hp (194 kW) Continuous—200 hp (149 kW)
oil system — **Transmission**	Oil type	Dexron®, Dexron II®, or C-3
	Capacity (less external lines) (approx.)	7.5 US gal (28.4 litres) 6″ or 7″ pans
	Sump	Integral
	Filter**	External. Remote mounted
drop box	Capacity	
	Oil type	
drop box disconnects	(optional)	
size	Length	41.0 in (1041 mm)
	Width	21.75 in (552.4 mm)
	Height (6″ pan)	25.6 in (650 mm)
	Weight (dry)	940 lbs (426 kg) (approx)



TYPICAL HT 750DR
AUTOMATIC SHIFT POINT SCHEDULE

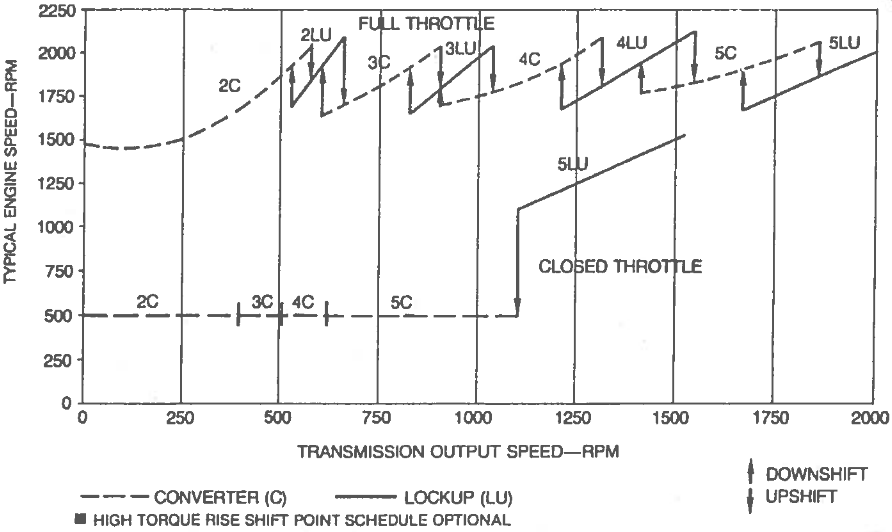


Figure 3.4-5. Specifications

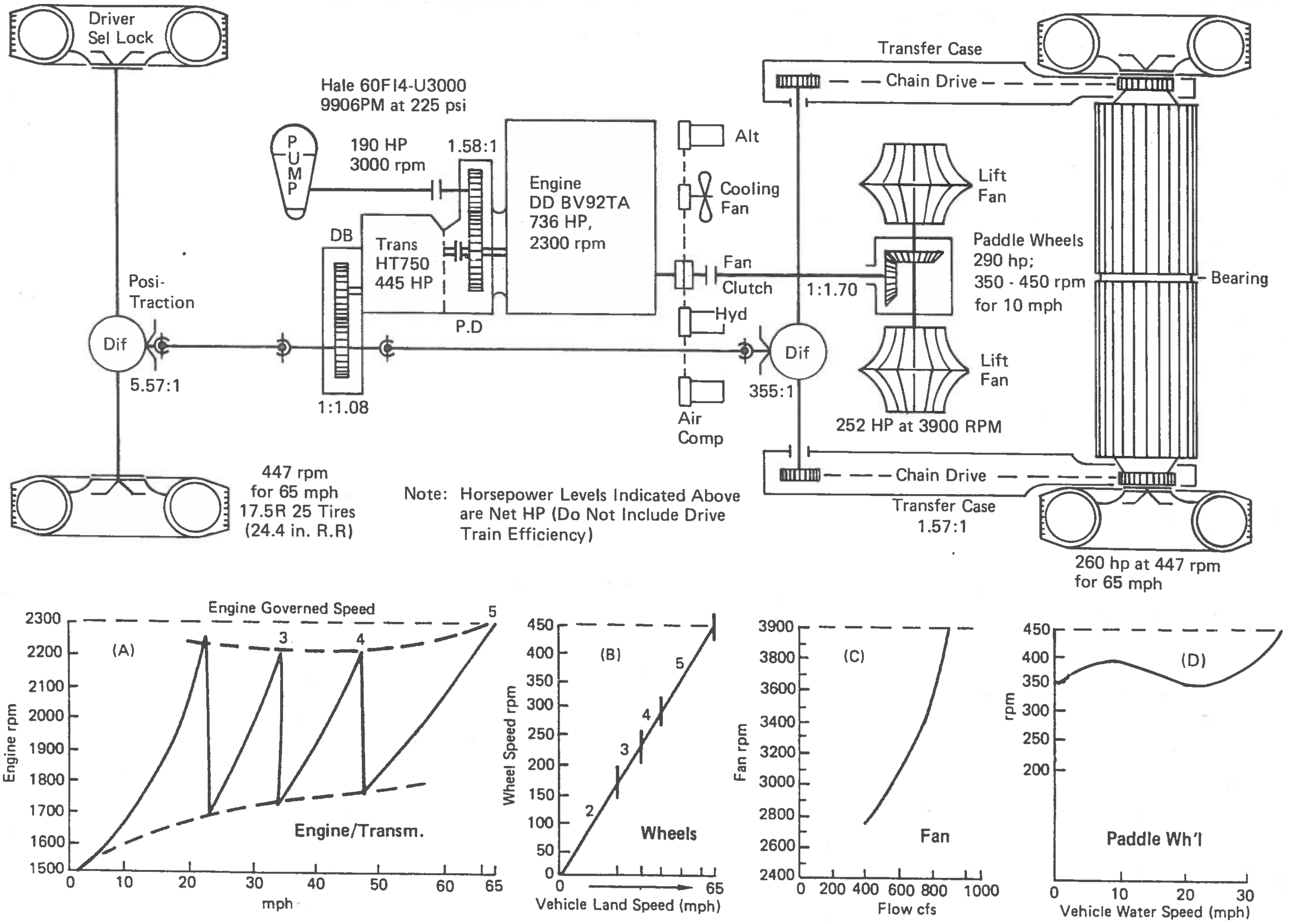
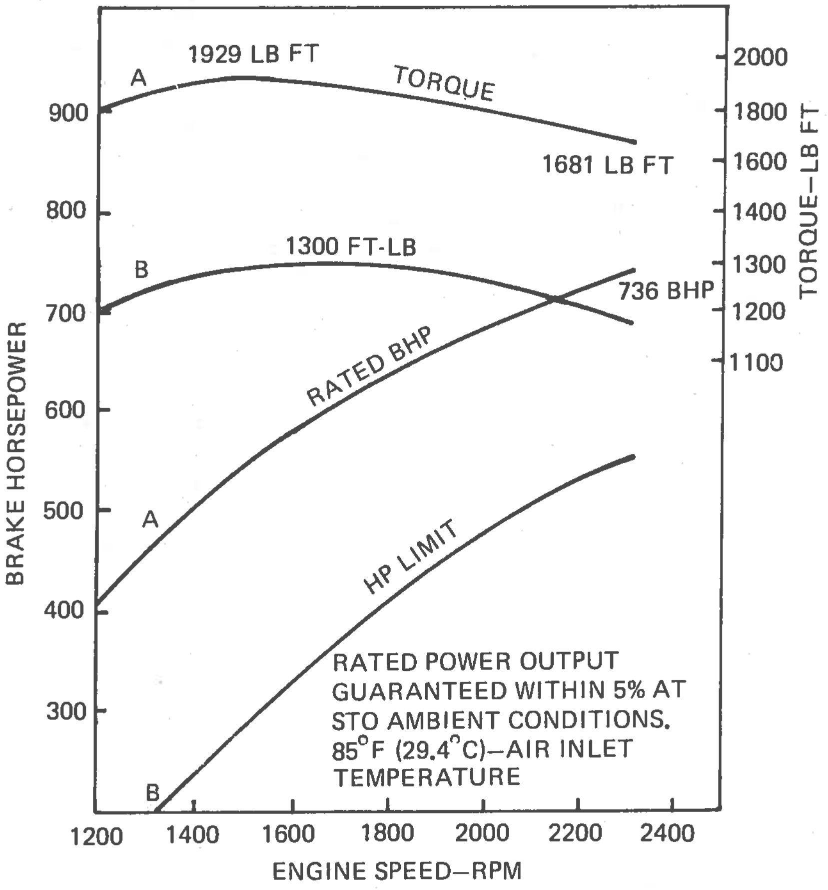


Figure 3.4-6. Power Distribution System

exceed the allowable 1300 ft-lb, or intermittent 500 hp that can be sustained by the transmission and power divider. Analysis indicates that all mobility requirements in the wheel drive only mode can be met or exceeded with only 338 hp delivered to the transmission, which is considerably less than the power available under the action of the electronic governor. See Figure 3.4-7.



Curves A used only when left fans are operating.
Curves B used in all modes except when left fans are operating.

Figure 3.4-7. Performance of Model 8V92TA Engine Basic and with Torque Limiter

The power train after the HT750DR is conventional in concept although of a customized configuration. The output from the transmission passes through a drop box which is rigidly attached to the transmission housing. The function of the drop box is threefold:

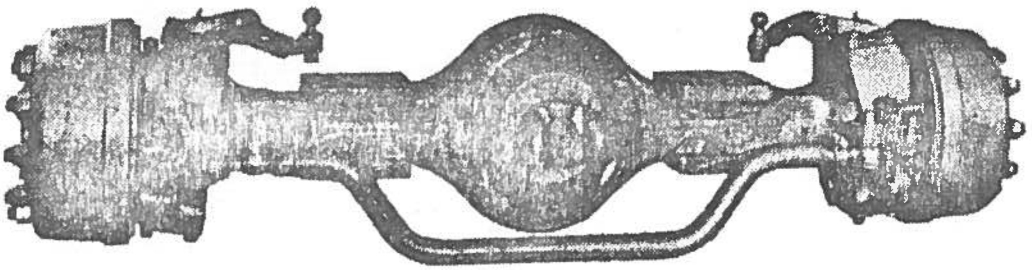
1. It provides the required offset between the transmission output shaft and drive shaft.
2. Splits the power output to the forward and rear differentials.
3. It adjusts the transmission output rpm to achieve 65 mph top speed with the tires inflated to 40 psi (24.4 in. rolling radius).

The drop box increases the output shaft speed by a ratio of 1.08:1.

Drive Shaft and Universal Joints - A floating shaft with universal joints at either end is used to transmit torque to the front axle. The shaft is installed at a nominal angle of 7 degrees between flanges. In wheel supported operations, the shaft can transmit full power. In the hybrid mode when the front wheels are lowered to come in contact with the ground, the shaft angle increases to 11 degrees but the torque transmitted at this steeper angle is limited by traction to only 30% of full output.

The shaft extending aft to the rear axle is also couples with universal joints at either end. Unlike the forward shaft, however, neither end is required to accommodate angular deflections as both the drop box and the rear axle are mounted to the chassis. The bias angle on the rear shaft will be 5 degrees or less.

Differentials - The forward differential provides a 5.57:1 ratio in a single reduction hypoid gear, housed in an aluminum case. The differential incorporates a lock mechanism, a feature which is driver activated for positive wheel drive. The forged case Figure 3.4-8 has provisions for mounting suspension brackets, yokes, brakes and drums. In addition, the front axle includes the king pins and steering arms for attaching steering drag links.



- **MAXIMUM ADAPTABILITY TO MOST VEHICLE DESIGN**
- **35° or 28° MAXIMUM TURNING ANGLE**
- **STOPMASTER BRAKES — AIR OR HYDRAULIC**
- **DISC OR CAST SPOKE WHEELS**
- **LARGE RATIO SELECTION**
- **RH OR LH SINGLE REDUCTION OR DOUBLE REDUCTION CARRIER**
- **HYPOID GEARING**
- **5° 30″ KING PIN INCLINATION**
- **BUILT-IN 2° CASTER AND 1/4° CAMBER**
- **COMPATIBLE WITH SSHD REAR TANDEM DRIVES**
- **OPTIONAL HYD. CYL. POWER ASSIST ARM ON KNUCKLE**

Figure 3.4-8. FDS 1600 Front Driving Axle

The real axle is modified to accept a chain drive transfer case which comprises the trailing link that supports the rear wheels and paddles. A heavy series Morse 8-140-H chain (1 in. wide, 1-1/2 in. pitch, 42,000 lb. tensile) is used to transmit power from the axle to the rear wheels.

The rear differential uses a 3.55 reduction. This ratio is combined with the 1.57 reduction of the chain drive to match the 5.57 single reduction rates of the forward axle differential. The 3.55 ratio is the lowest commercially available ratio for this series of axles. The 1.57 chain drive ratio is needed in order to facilitate physical attachment of the chair sprocket to the real wheels/paddles at a suitable diameter.

3.4.3.2 Mode 2 - Pump and Drive Operation - This mode is used when it is necessary to use the fire fighting system and at the same time maneuver the vehicle around the fire. This is accomplished through the use of a power divider, which contains the following active elements:

1. An oil cooled multiplate power transmission clutch mounted to the engine flywheel. It transmits power to the HT750DR transmission torque convecter when engaged.
2. A water pump engage/disengage clutch which transmits power from the engine flywheel directly to the water pump when engaged.
3. A control system to:
   - engage/disengage the pump clutch
   - modulate the engagement of the main power transmission clutch.

For pump and drive operations, the power transmission clutch is disengaged, the pump clutch engaged, and the engine brought up to the speed necessary for fire pump operation, approximately 1900 rpm. Movement of the vehicle is accomplished by selecting a desired drive range on the HT750, usually 1st, 2nd, or reverse, and then progressively engaging the power transmission clutch until the desired speed or distance is reached. Modulation of the power transmission clutch is placed under the control of the driver's accelerator pedal. Power out of the HT750 is directed to the wheels as in Mode 1.

3.4.3.3 Mode 3 - Augmented Drive Operation - The purpose of this mode is to get the vehicle to the desired destination over surfaces which cannot be traversed by wheeled vehicles, such as water and fluid soil conditions. This is accomplished by using air cushion support augmentation and either of two propulsion methods.

The first propulsion method is used when capability to traverse marginal terrain (marsh, snow, crudely filled bomb craters, or soft soil) is required. The air cushion is deployed, the fans are engaged and all wheels are lowered to the ground. The maximum weight carried by the suspension is 30% of the gross vehicle weight, sufficient ground pressure to utilize the tractive capabilities of the surface without sinking in and become immobilized. Power for locomotion is provided through the drive train as in Mode-1.

The second propulsion method, used mostly on water is similar to the first except motion is accomplished through the use of paddlewheels, attached to the rear wheels. The front axle remains retracted making little or no contact with the water to reduce drag. All vehicle weight is supported by the cushion except for 700 lb. flotation provided by the partially immersed rear wheels.

Each of the two paddle wheels installed between the rear wheels of the vehicle is rigidly bolted to the axle of the rear wheel. It rotates with the rear wheel and is driven by the chain drive through the rear differential. Most suitable operation in the water is achieved with the transmission in the fourth gear range, which gives a paddlewheel speed of up to 450 rpm (insets A and C of Figure 3.4-6) Since the paddle wheel is driven through the transmission and rear axle differential complete flexibility exists for forward speed control, reverse, and steering.

The fans used to supply air to the augmenting cushion require additional horsepower over that used in Modes 1 and 2. Therefore, the electronic engine control unit is returned to the higher power curve A in Figure 3.4-7, after engagement of the cushion fans.

Lift power is provided by engaging the fan clutch coupled to the forward end of the engine crankshaft. This is, a centrifugal Sprague type clutch which drives the lift fans through a step-up angle gearbox. Its ability to freewheel in the reverse direction prevents the lift fans from back driving the engine during the transmission shift sequence. The maximum power tapped from this end of the engine is 252 hp. It is limited by the engine governed speed (2300 rpm) which corresponds to a maximum fan speed of 3900 rpm.

Engagement of the cushion fans causes two additional events to occur: 1) the power transmission clutch in the power divider is disengaged, and 2) the engine governed speed is automatically set to 2300 rpm. Conditions are now set for making the transition from wheel supporting surfaces to those requiring augmentation. The fans, being at max rpm, provide the greatest lift clearance, and the power divider can be modulated to provide forward or reverse motion through the wheels or paddle wheels, or both, depending on terrain requirements.

After transition, forward motion is best achieved by selecting the transmission range desired, and fully engaging the power divider main power transmission clutch; maximum acceleration and top speed will be achieved as the transmission automatically progesses through the gears. Under these conditions, the lift fans do not operate at constant speed. Being directly coupled to the engine, their speed will vary between 3900 and 2700 rpm as engine variations in speed are demanded by the transmission gear setting and automatic shift point controls. Nevertheless, suitable air cushion lift heights will be maintained.

Vehicle speed control is accomplished as in Mode 2. Releasing the accelerator pedal disengages the power divider power transmission clutch; applying the brakes slows or stops the paddle wheels. Limited forward speeds can be achieved by using lower transmission gear ranges and for power divider clutch modulation.

Overwater steering is achieved by braking one paddle wheel. This is implemented through the steering wheel with a linkage whose braking force is proportional to steering wheel displacement. The sense is same as for steering the vehicle on land. Turning the wheel to the right applies the brake to the right paddle wheel causing the vehicle to turn to the right. This is readily implemented with a dual zone diagonal (front left/rear right) braking system. The front wheels are totally inactive in the water mode of operation. Section 4.3 describes the yaw rates achievable by this system.

3.4.3.4 Pump and Drive Augmented Mode - This mode is identical to the augmented drive mode except that the water pump clutch is engaged. Turning the water pump clutch on has only one effect on the power distribution system and that is to turn engine speed control over to the water pump pressure governor, which varies engine speed to maintain 225 psi in the fire fighting system. Engine speed will vary between 1750 and 1900 rpm as the demand for water discharge goes from 0 to 845 gpm. This corresponds to a fan rpm of 2970 to 3200 rpm.

The fan rpm and flow corresponding to this range of engine speeds is shown in inset (C) of Figure 3.4-6. Here it is seen that the flow varies between 500 and 700 cfs. This simply varies the gap of the cushion, which remains quite adequate for stationkeepup/creep operation.

Sufficient flow is always available and the fraction of vehicle weight carried by the cushion does not change since fan pressure over this entire range of flows remains essentially constant. Best cushion performance will be obtained at high from rpm/high flow. Thus the operator will open the throttle to increased fan speeds to suit desired conditions. Speed control and steering functions are identical to Mode 3.

3.4.3.5 Auxiliary Systems Drives - The fire system water pump is engine driven. The power divider installed between the engine and the transmission provides a convenient power take-off point, while it simultaneously steps up the engine rpm to the level required to develop full pump output. A short shaft couples the pump to the power divider. The power divider uses two sets of spurgears, coupled through a hydraulic clutch, with an output/input ratio of 1.60. For efficient pump operation, it is necessary to run the engine at 1750 to 1900 rpm.

The Detroit Diesel 8V92TA rear housing is equipped with power take-off pads for accessory drive; the selection of a suitable turbochange arrangement allows most of the pads to be accessed. The following accessories will be direct driven and mounted to the rear housing:

- Steering/lift platform hydraulic pump
- Power divider hydraulic control pump
- Air compressor
- Alternator

3.5 SUSPENSION AND FLOTATION

3.5.1 Introduction

The all-terrain and all-weather operation required coupled with the weight and space constraints due to transport in a C-130 impose rather stringent requirements on the land suspension and water flotation systems.

For land operation on firm surfaces, the ACCRV must first be able to operate on runways and highways at high speed with the air cushions stowed. Secondly, operation off road and on snow or ice is also required. A conventional 4-wheel drive springing and damped system, coupled with a variable tire inflation pressure system will be used to provide good traction over a broad range of terrain and weather conditions. For operation in swamps and on open water the cushion drive will be deployed. This introduces a need for adjustable wheel/paddle distance from the hull bottom. The variable height suspension system permits lowering of the rear wheel/paddle centerline to provide waterborne propulsion, and easy transition from water to land.

For land operation on soft surfaces and also to provide improved obstacle negotiation crossing craters, ditches or other rough terrain features can not be achieved with the wheel/spring/damper system alone, the cushion will be deployed and the wheel paddle drive used for traction. This requires that the wheel suspension provides a controlled load on the wheels, and the normal position will now be six inches below the fully wheelborne case with the suspension springs fully extended.

Over-water operation requires the capability to float safely in the event of engine or other major system malfunction. Therefore, hullborne flotation is required during the rescue portion of the mission. Firefighting can be accomplished while on-cushion or hullborne but the waterborne on-cushion stability is too low to permit boom extension. The suspension and flotation system concepts and trades to provide this mission flexibility are discussed in this section.

3.5.2 Front Suspension

A conventional truck type single beam front axle with coil springs and hydropneumatic dampers was selected as the baseline suspension system. The other concepts evaluated used independent front axle designs. Some improvement in ride quality would result from independent front wheel suspension but the weights would increase by at least 25% and cost a similar amount. Since the air cushion system can be used to reduce off-road wheel loads, the use of independent front wheel axles was eliminated from further consideration. A single axle also simplifies the interface with the 4-wheel drive system described in Section 3.4.2.

The ACCRV suspension was designed to permit 100% of the load on either pair of diagonally opposite wheels and traversing obstacles up to 12 inches in height. This, plus the need for vertical adjustment to adapt the system to waterborne or landborne operation led to utilizing the same type of trailing arm, concentric coil spring/hydropneumatic strut system used on the rear suspension. Figure 3.5-1 illustrates the selected concept. The total wheel travel required is less at the front than the rear units since the front wheels are retracted in waterborne operation to minimize drag. The trailing arms will be attached to pivots forward of the wheels and through a soft attachment to the spring pads on top of the axle. The coil spring/strut units will be mounted to structure above and to the same axle pads but without the stroke amplification needed at the rear wheels. The combined set of trailing arm suspension and axle systems will accommodate the range of land and waterborne positions required.

Figure 3.5-2 illustrates the hydro pneumatic shock strut required, which will be th same unit for both front and rear suspensions.

In use, the oleo element functions to retract the wheel compressing the spring for waterborne operation and to provide damping for wheelborne or hybrid operation. The pneumatic element functions to maintain the wheel load in hybrid operation. The spring element functions for wheelborne operation only. Specially designed struts are required for this application, but they do not involve any new technology.

The front suspension system includes provisions for hydraulic power steering assist. Steering mechanisms and brake systems are also integral with the selected axle providing proper toe-in and camber for turning operations. The axle selection and description is included in Section 3.4.3, Power Distribution. The wheels and tires selected are the same as those used on the P-19 vehicle. During the preliminary design phase the rim selection will be reviewed for compatibility with the operation at low inflation pressures. The wheel has an unrestrained diameter of 52.8 inches, and a width of 17.5 inches across the tire. Various tread designs are available for improved traction in off-the-road operation.

3.5.3 Rear Suspension

The rear suspension system configuration is similar to the forward system in that the wheels are mounted on trailing arms and the same coaxial coil spring/damper

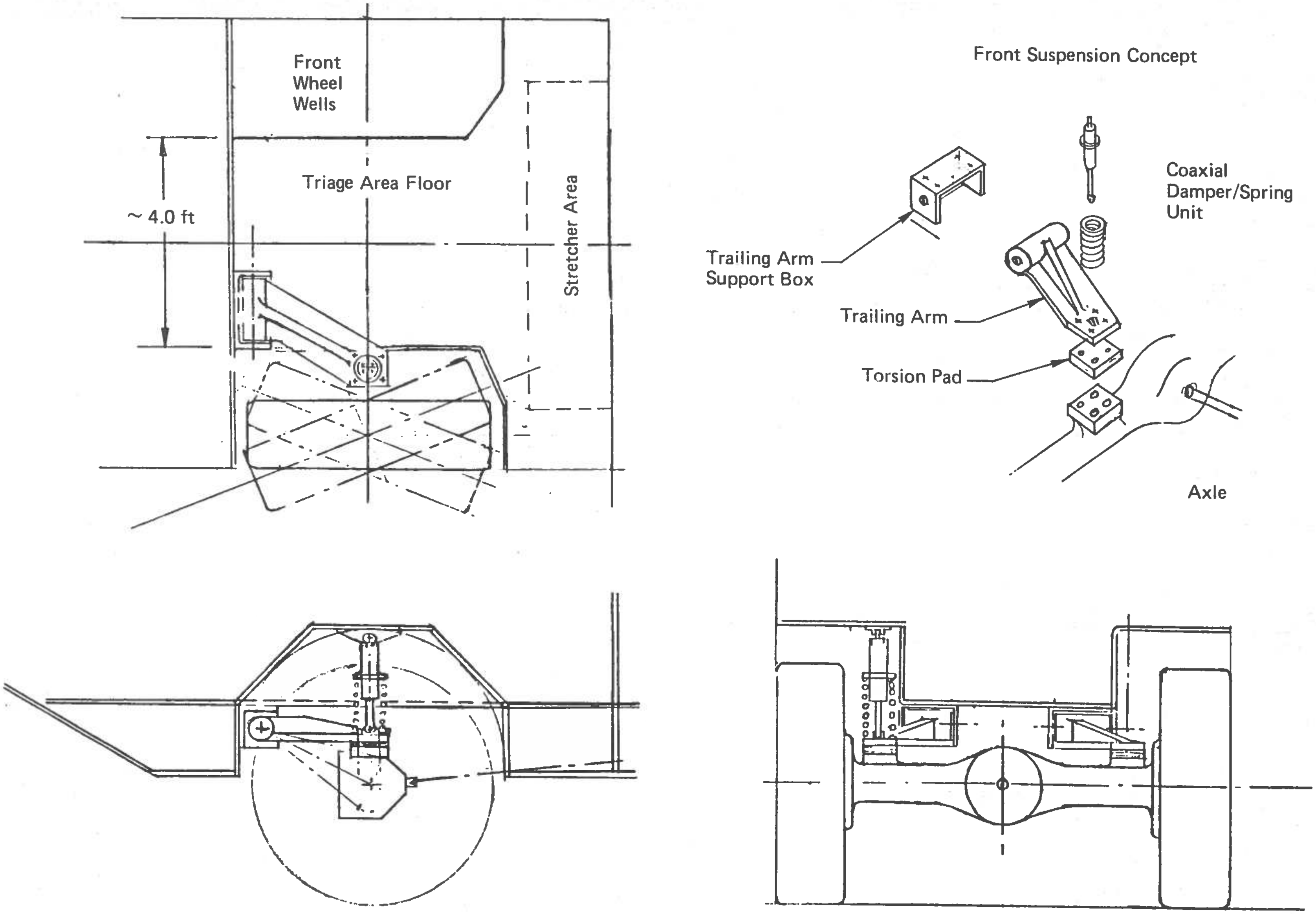


Figure 3.5-1. Front Suspension Concept

unit is used for prepositioning and load control. The trailing arms for the rear suspension have a dual function. The first is to transfer impact loads on the wheels to the vehicle structure and also provide rigidity against sway and side loads just as the forward units do. The second is to serve as a transfer case housing the chain drive to the rear wheels and paddles. These transfer case trailing arms transfer the wheel loads to the structure through the spring/damper unit similar to the front; but whereas the forward suspension uses thick elastomeric pads between the axle and the spring/damper to compensate for the axle cant angle, the rear system uses a spherical bearing at the drive sprocket end. A sway strut introduced to take out side load. The transfer boxes remain in the plane of the wheel/paddle when the wheel axle cants. The straight through wheel axle stabilizes the wheel axle combination and avoids the large torque loads which would result from independent suspension, involving cantilevered wheels/paddles. The small difference in length resulting from the axle cant is allowed for by using a tube over bar central connection, which also permits differential rotation. The system is illustrated in Figure 3.5-3.

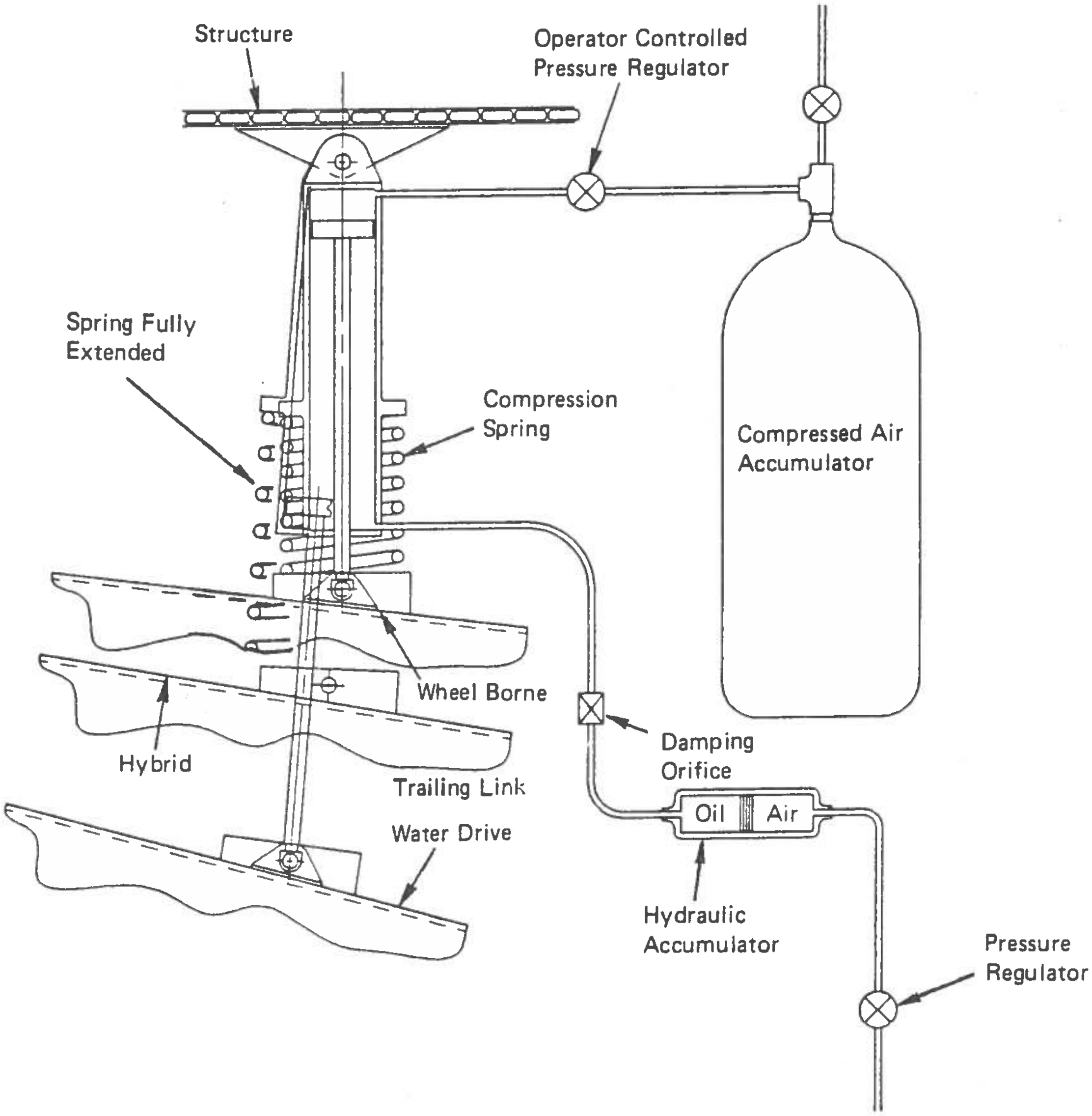


Figure 3.5-2. Oleo-Pneumatic Spring Strut

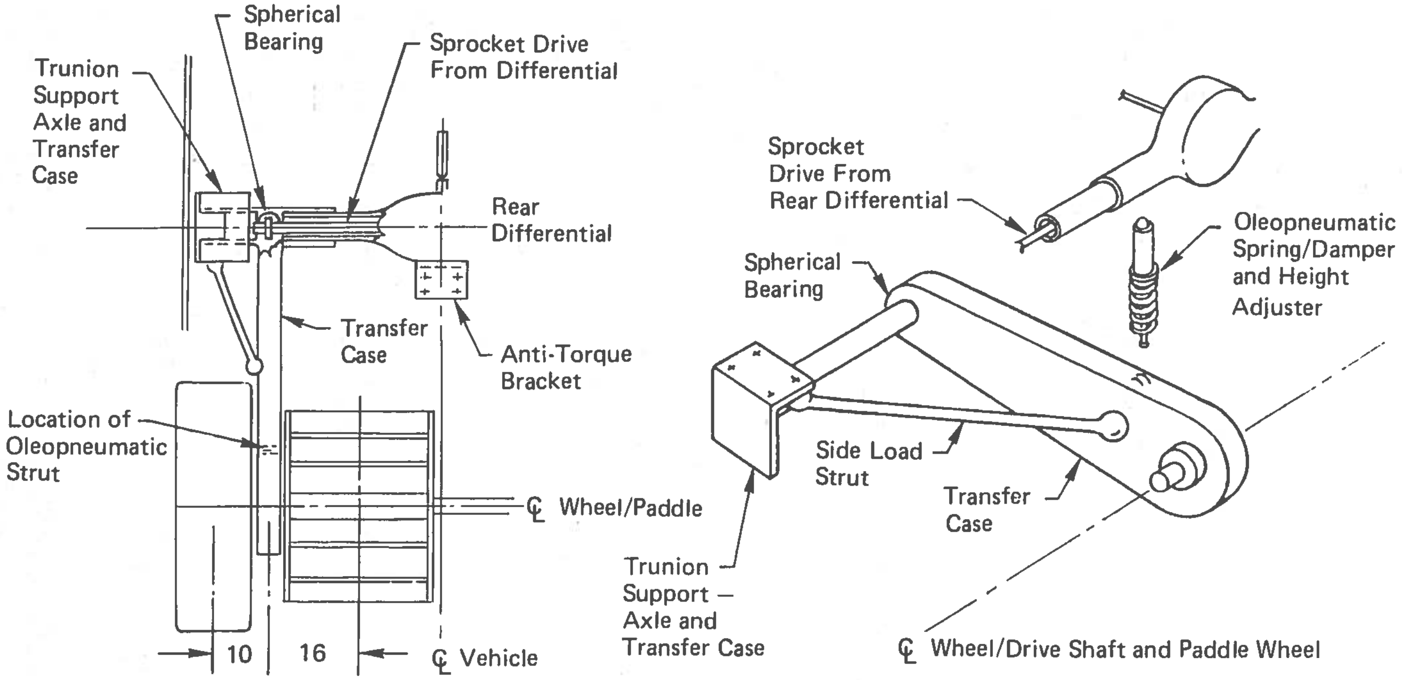


Figure 3.5-3. Rear Suspension Concept

The spring/damper system shown in Figure 3.5-2 provides the initial adjustment of vertical wheel position by changing the pressure balance between the gas and liquid sides of the piston. The strut will adjust the transfer case to a new static position. In the dynamic mode the jounce force works against the spring and the gas pressure and the spring drive the wheel/transfer case down against the damping action of the oil being transferred to the hydraulic accumulator through the damping orifice. During waterborne operation while on cushion, the wheel/paddle system is extended down into the water to a centerline consistent with good paddle wheel performance. Adjustment of the strut load to a constant value supporting the wheel weight is achieved by regulating the oil pressure. If this support is reduced to an appropriate value the wheel buoyancy may be used to control paddle immersion for optimum performance. In any event the lowest permissible position will be set by a full strut extension. For hullborne operations in the water the paddlewheels would be retracted to the region of normal land operation where good paddle wheel performance would result. Initial dynamic studies indicated good ride qualities using a spring rate of 1000 lb/inch and a damping factor of 0.5.

3.5.4 Flotation

Since the ACCRV must operate over water its flotation capability must be examined for both cushionborne and for off cushion operation. The requirement for the latter is to provide safety for the crew/rescued personnel in the event of an engine malfunction. Since this provision is required, operation in the hullborne mode for close-in maneuvering can be used and may be preferable. Maneuvering adjacent to a downed craft including full extension of the rescue boom is possible hullborne, since adequate lateral stability is introduced by providing for increased flotation. Extending the boom sideways from the ACCRV during rescue operations on water becomes feasible.

The ACCRV structure will be watertight, providing inherent flotation in an emergency without use of the air cushion. The basic hull box has a volume of about 900 cu. ft. Considered by itself, the craft would float with a waterline about 3 ft above the bottom of the hull, including the buoyancy of the wheels, tires and other submerged drive train components. Bilge pumps will be provided to scavenge water entering through door seals and other hull penetrations. By this means the craft could be kept afloat in an emergency engine-out condition for a time possibly limited by bilge pump capacity and battery power. For reliable emergency protection, additional flotation must be added to stabilize the craft for hullborne rescue operation. This is achieved with very little weight penalty by designing the spray skirt as an inflatable bag, and is adopted as a necessary option.

Figure 3.5-4 illustrates the spray skirt in the inflated configuration displaying the waterline condition for the selected 4 foot diameter inflated bag. For hullborne rescue operation, the panels will be extended down, the spray skirt inflated and the lift fans declutched. From the spray skirt geometry, the inflated but not stretched diameter would be about 2.2 feet. Using a conservatively designed one-way stretch reinforced elastomer for the spray skirt, the diameter is increased to four feet providing about 580 cu ft. This is sufficient to raise the craft so that its waterline is below the centerline of the paddle wheel with the wheel retracted to the land mode position. At this level there is more than sufficient buoyancy margin to stabilize the craft in pitch and roll for 360 deg operation of the rescue boom. Figure 3.5-5 displays the sensitivity of the inflated diameter spray skirt to lateral boom extension for two variations in the spray skirt reserve buoyancy and notes the recommended design point. This figure also shows the maximum roll angle of the vehicle which would result from 1100 lb boom load over the range of boom extensions. Figure 3.5-6 notes the percent of total load (30,000 lb) which would be borne by the hull versus selected spray skirt inflated dia, and the resulting hull immersion depth. By varying the angle at which the panels are extended, the spray skirt inflated diameter, and the boom load/extension limits, this flotation concept provides excellent flexibility. The 4 ft diameter recommended point design provides good vehicle stability without limiting the boom extension distance, and permits a load on the platform equivalent to a 4 man crew/rescued personnel. At this diameter the two inflated spray skirts provide sufficient buoyancy to float the entire ACCRV weight even if the hull were flooded. The waterline in this flooded but floating condition would be less than two feet above the bottom of the hull, with the panels in the full down position, and 20% buoyancy remaining.

3.5.5 Auxiliary Systems

The auxiliary systems related to suspension/flotation include the following:

- Hydraulics to operate the brakes, power steering and the hydropneumatic struts
- Pressurization for the gas side of the hydropneumatic struts
- Pressurization for inflating the spray skirts when hullborne flotation is required
- Tire inflation system

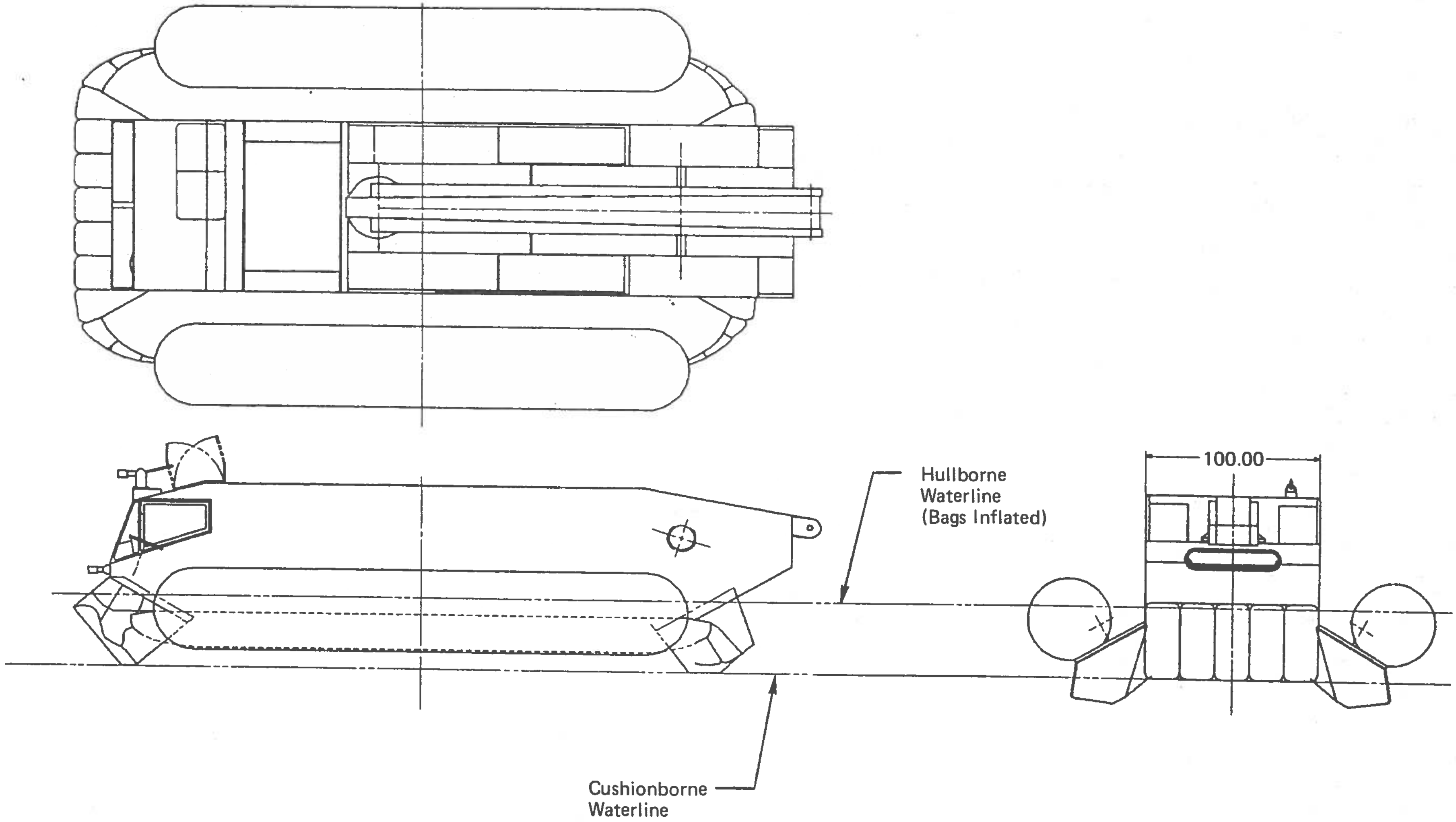


Figure 3.5-4. Hullborne Flotation Concept

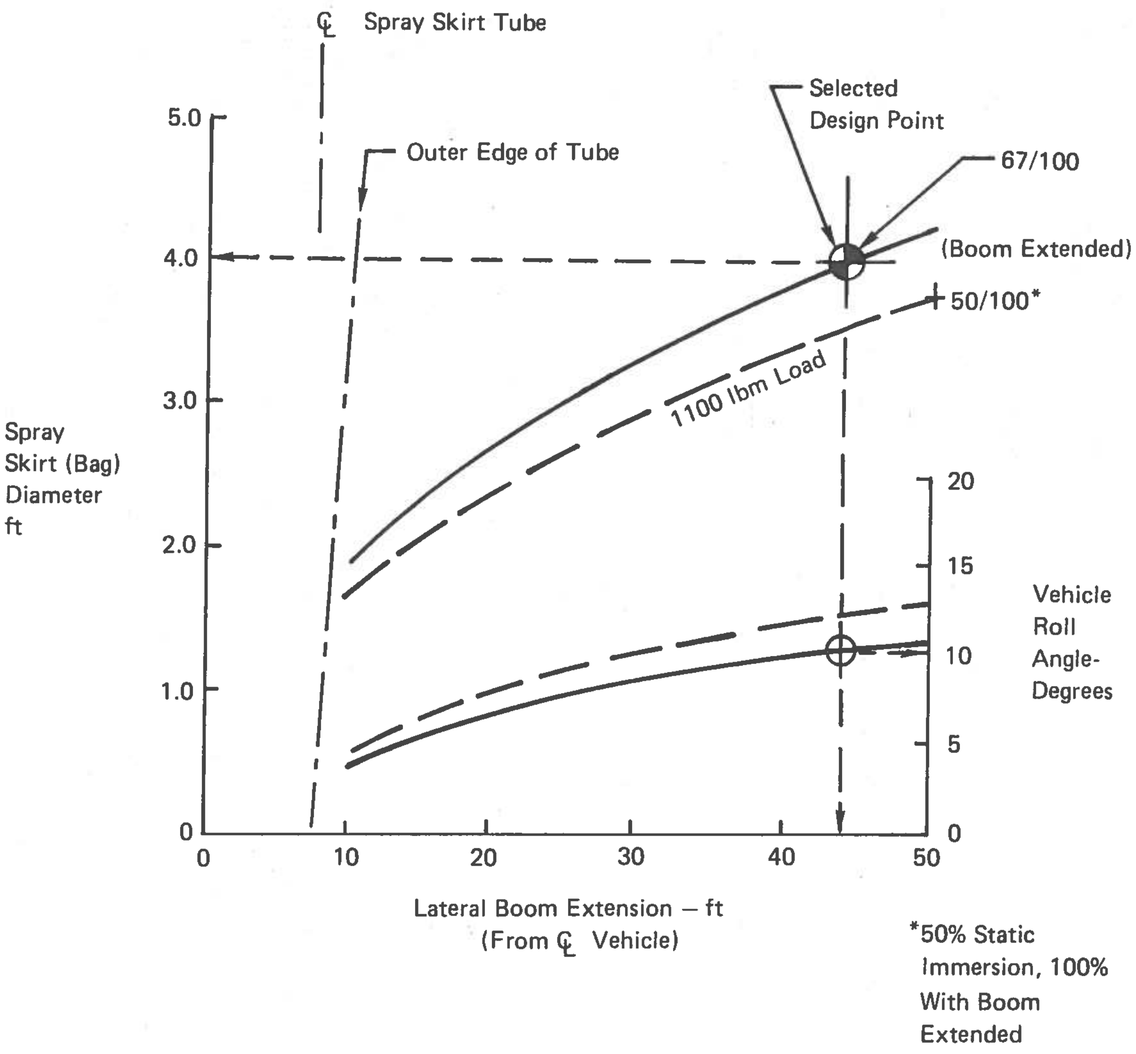


Figure 3.5-5. Spray Skirt Diameter Needed versus Permissible Boom Reach

Hydraulics

The brake hydraulic system is a standard configuration, self-contained, with a compartmented master cylinder. Flexible hydraulic lines are used at all wheel locations. A schematic of the brake system is shown in Figure 3.5-7. One feature, somewhat unique to the waterborne operation is that the two zone system brakes diagonally opposite wheels. Selecting this concept for braking instead of front and rear pairs meets the land safety requirement and provides steering on water. Turning the steering wheel brakes one paddlewheel while the other is still powered through the differential, offsetting the thrust vector to provide a steering command.

The basic hydropneumatic circuit for wheel positioning and damping was shown in Figure 3.5-2. Both sides are regulated down from a nominal 3000 psi to a working pressure of 2000 psi for operation of the strut. The gas side accumulator prevents large increases in pressure during normal damper operation. Adjusting the gas pressure setting will automatically rebalance the system to a new nominal wheel height. On the rebound stroke, oil will be displaced for a rate controlled force by a damping orifice to decrease the remaining stored energy in the moving wheel system.

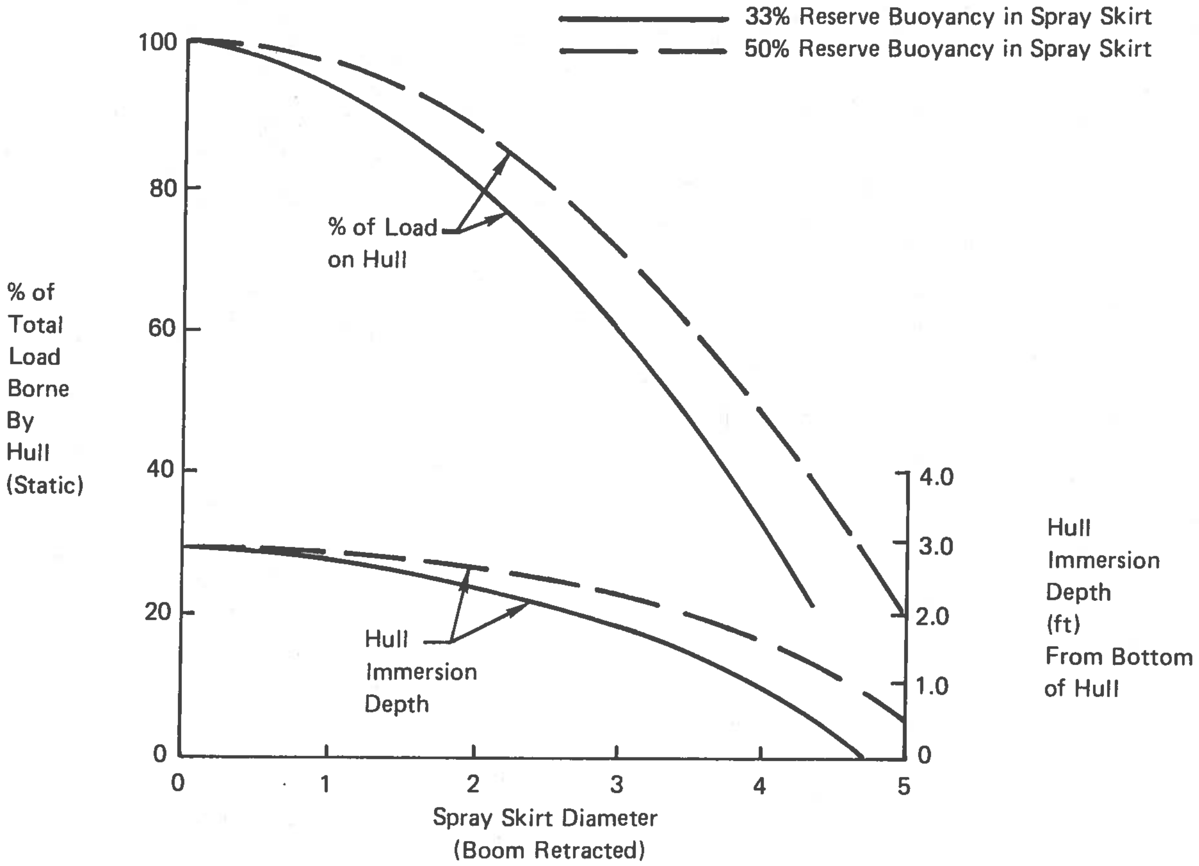


Figure 3.5-6. Hull Flotation Share

Spray Skirt Inflation

The selected flotation volume is provided by two four-foot diameter inflated spray skirts. An internal pressure of approximately 2.0 psig will be needed to keep these nearly circular while displacing water. Each spray skirt is 23 feet long. The volume of gas needed for each inflation is approximately 580 ft^3 at standard conditions. Some margin is added to this to allow for the range of temperature variations, leakage and for multiple inflations per mission if required. A reasonable criterion would be to allow for one inflation hydroborne while performing the actual rescue, and one inflation for contingency in the event of an engine out emergency on the return leg of the overwater mission. The total requirement then becomes 1140 scf if a passive on-board stored gas system is utilized. If a compressor and air is used, it should have multiple energy sources (e.g., engine and battery or an APU) so that failure of one source will not prevent operation of the flotation system.

The 1140 scf for the stored gas system, will require about 15 ft^3 of storage space on the vehicle if the gas is stored at 2200 psia and would add considerably more weight to the craft (~ 400 lb). This system would provide higher filling rate capability than the compressor concept if it were needed. Since the basic craft has some flotation, a rapid inflation rate does not appear to be needed. A conversion from air cushion to full flotation hullborne in two minutes would require a blower which delivers 285 scfm. It can be initiated as the ACCRV is approaching the downed aircraft. A regenerative type blower (high flow low pressure) supplied by Rotron is selected.

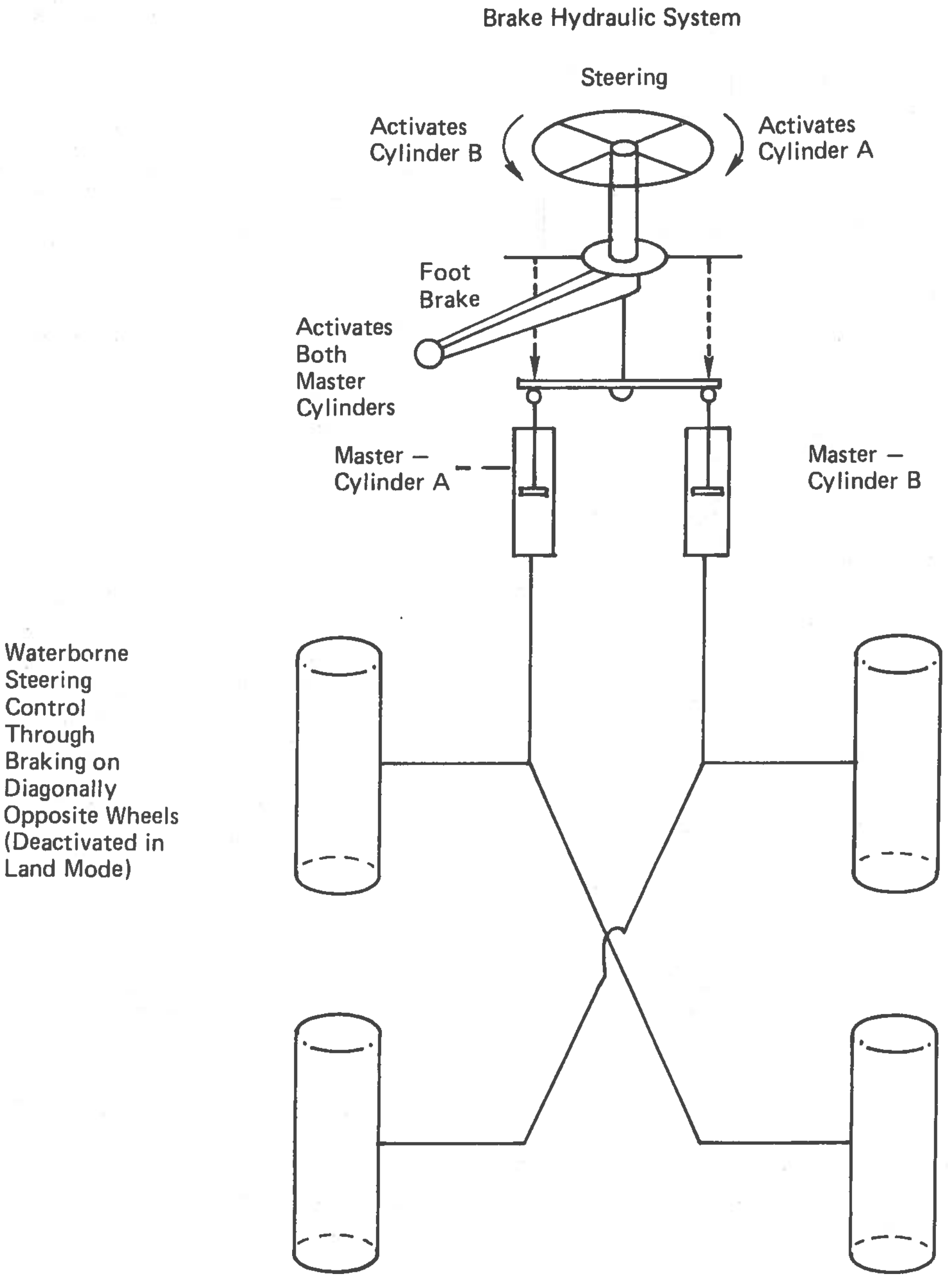


Figure 3.5-7. Braking/Water Steering System Schematic

Tire Pressure Control System

The tire inflation/deflation system operates on demand to maintain the prescribed pressure. Consequently tire pressure can be held constant at all speeds and temperature conditions. The driver also has the option of reducing tire pressure to maintain a large tire footprint for operation in snow, on rough ice and on very soft soils.

An existing central tire inflation system will be adapted for the ACCRV using developed components and methods. Current systems in use have been developed by the Eaton Corp and the Labinal Co in France. Detail selection will be made in the next phase. For typical performance available, the AM General system characteristics for the M939 truck application are given in Figure 3.5-8.

3.6 EQUIPMENT

3.6.1 Fire Fighting System

The selected ACCRV configuration leaves intact all of the crash rescue and structural fire fighting capabilities of the P-19. Although the components are reorganized to make use of available space, they are standard components as used in current production type CFR vehicles.

Primary power for the system is taken from the engine flywheel through a power divider which allows pump-and-propel modes of operation for both land and water operations. A highly efficient and reliable around the pump type water/agent delivery system provides the superior performance needed for the ACCRV to accomplish its mission of controlling and extinguishing aircraft fires. A structural control panel with discharge and suction connections equip the vehicle to perform as a structural fire fighting unit.

The components and systems are described in the following paragraphs:

3.6.1.1 Water Tanks - Weight, space, and structural considerations have resulted in the selection of construction methods which integrate the hull and tank structures.

Because the hull is of monocoque construction, and inherently stiffer than a conventional CFR vehicle, the usual distortions which might be transferred to the tanks are eliminated, along with the usual protective tank mounting schemes and their inherent complexity and weight. Thus any tank, separate or integral, can be hard mounted to the hull.

The double wall panels used to construct the hull are ideal for tank construction as well; this type of construction has been used by Bell in many applications where the main loads applied resulted from fluid pressures. Sensibly then, the hull and tank structures are integrated into a single unit. Integrity of design is insured by the NASTRAN modeling as discussed in Section 3.1.

Each of the twin tanks is provided with a removable, sealed inspection cover and access opening, 20 in. in diameter. See Figure 3.6-1. A Victaulic snap-on type coupling is used to connect/disconnect the vent/overflow loop from the inspection cover and vent/overflow pipe, when it is necessary to enter the tank or transport the vehicle by air. A four-inch vent/overflow pipe passes through the tank and directs excess water toward the vehicle centerline. The 5 inch vent/overflow loop has a 5 inch cap on one of the vertical legs, allowing it to be used as an emergency fill opening for a 2-1/2 in.

	M939 5-TON SERIES
TIRES	Single Radials 14.00 X R 20 Tubeless High-floatation
BEADLOCKS	Rubber reinforced with Kevlar—17.9% bead compression
WHEELS	10-hole bolt circle—10-inch rims 2-piece take-apart design with bolt on lock ring for easy beadlock installation
AIR COMPRESSOR	16 cfm (average) .46m^3/min. 2-cylinder water cooled
DIFFERENTIALS	Fully automatic locking differentials on all axles
TIRE PRESSURE SETTINGS	Highway (HWY)—75 psi (5,2 bars) Cross Country (C/C)—30 psi (2,1 bars) Mud, Sand, Snow—20 psi (1,4 bars) Emergency—10 psi (0,7 bars)
TIRE DEFLATION TIMES	HWY to C/C—2 min. 36 sec. C/C to Mud, Sand, Snow—54 sec. Mud, Sand, Snow to Emergency—1 min. 42 sec.
TIRE INFLATION TIMES	Emergency to Mud, Sand, Snow—55 sec. Mud, Sand, Snow to C/C—2 min. 10 sec. C/C to HWY—10 min. 30 sec.
RECOMMENDED VEHICLE SPEEDS (MAXIMUM)	HWY—50mph(80 km/h) C/C—30mph(50 km/h) Mud, Sand, Snow—10 mph (15 km/h) Emergency—6 mph(10 km/h)

EMS SYSTEM FEATURES

- Four (4) preset tire pressure selections corresponding to terrain (Highway; Cross Country; Mud, Sand, Snow; and Emergency).
- Actuated with dashboard mounted control.
- Uniformly inflates or deflates radial tires to the selected pressure while the vehicle is moving or at a standstill.
- Automatically maintains the selected tire pressure. In the event of a leaking tire, pressure is maintained up to the full capacity of the vehicles' air compressor.
- Actual tire pressure can be monitored at all times on a dash mounted air pressure gauge.
- Tubeless radial tires:
  - Simple to repair
  - Larger punctures more repairable than bias tires
  - Slower air loss when punctured
  - Decrease tire/rim slippage
  - Run cooler
  - Lighter weight
- Adequate brake system pressure is insured with a priority valve.
- Hub mounted valves allow individual shut-off of tires.
- Integral drilled air passages for tactical environments.
- High strength steel and fiber braided external air lines for durability.
- Tires can be changed without draining others of air.
- Long-term storage without pressure loss.

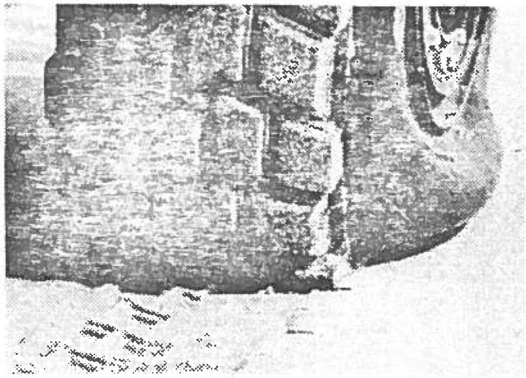


Figure 3.5-8. M939 Truck System Characteristics

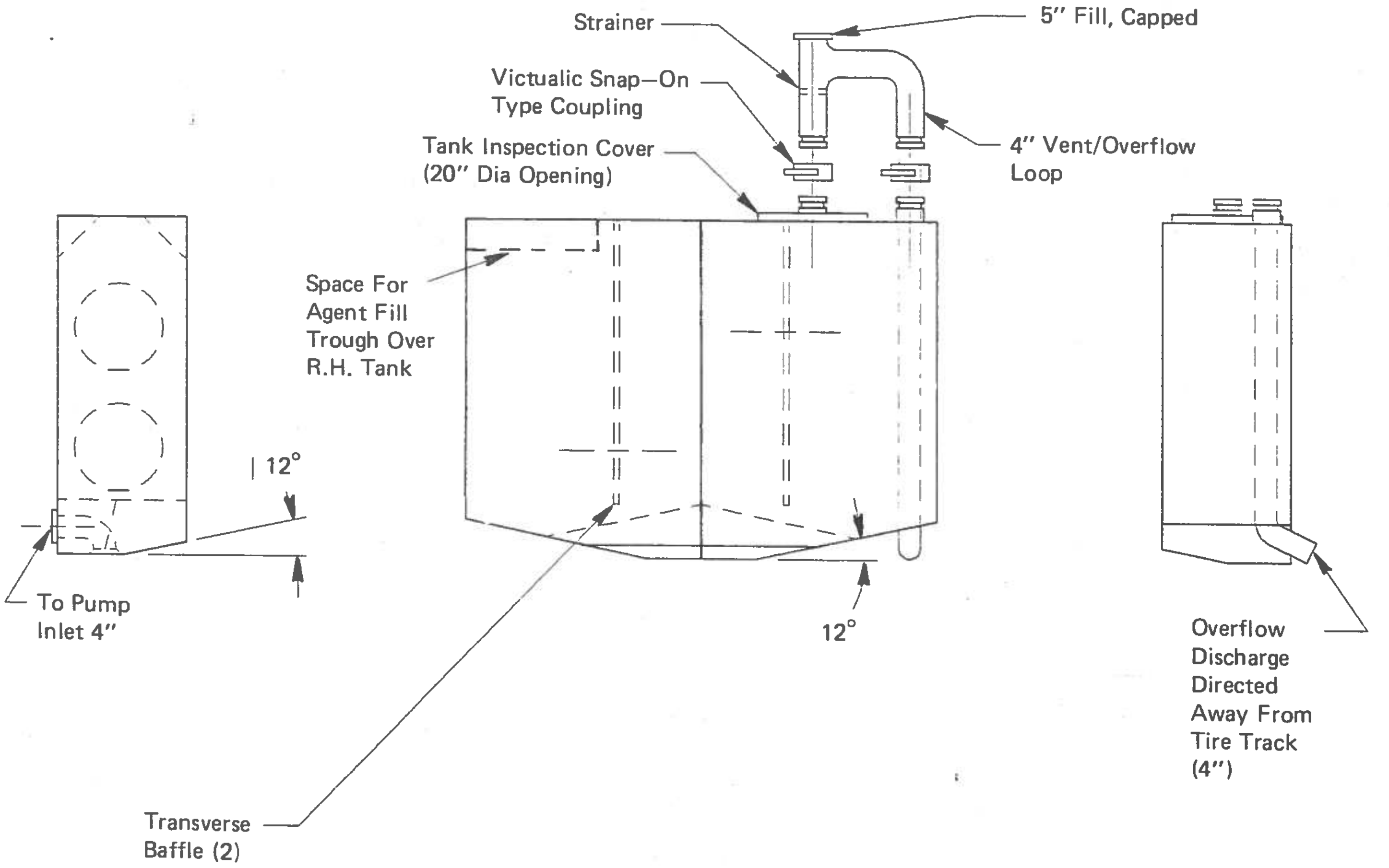


Figure 3.6-1. Water Tank Design

hose. Both right and left tanks are identical and symmetrically equipped, having a net capacity of 500 gallons each. Fill, vent, overflow, and access functions have been combined to allow for top mounted storage compartments and the agent fill trough over the tanks.

Transverse baffles not more than 3 ft apart are used to limit rapid shifting of the water; the narrow design width of the tank eliminates the need for longitudinal baffles. Twelve degree bottom surfaces are used to allow pumping at rated capacities while on 20% slopes. The completed tank, including the seals, will withstand an internal static pressure of 1 psig at the top of the tank without leaking. The double wall extruded panel sections used to construct the hull insure the tanks ability to withstand an internal tank pressure of 8 psig at the tank bottom.

To prevent corrosion and eliminate leakage due to bonding or weld faults, or structural cracking due to vehicle damage, the water tanks are fully lined with a rubber bladder, similar to those used for aircraft fuel tanks. The bladder is field replaceable for ease of repair or maintenance.

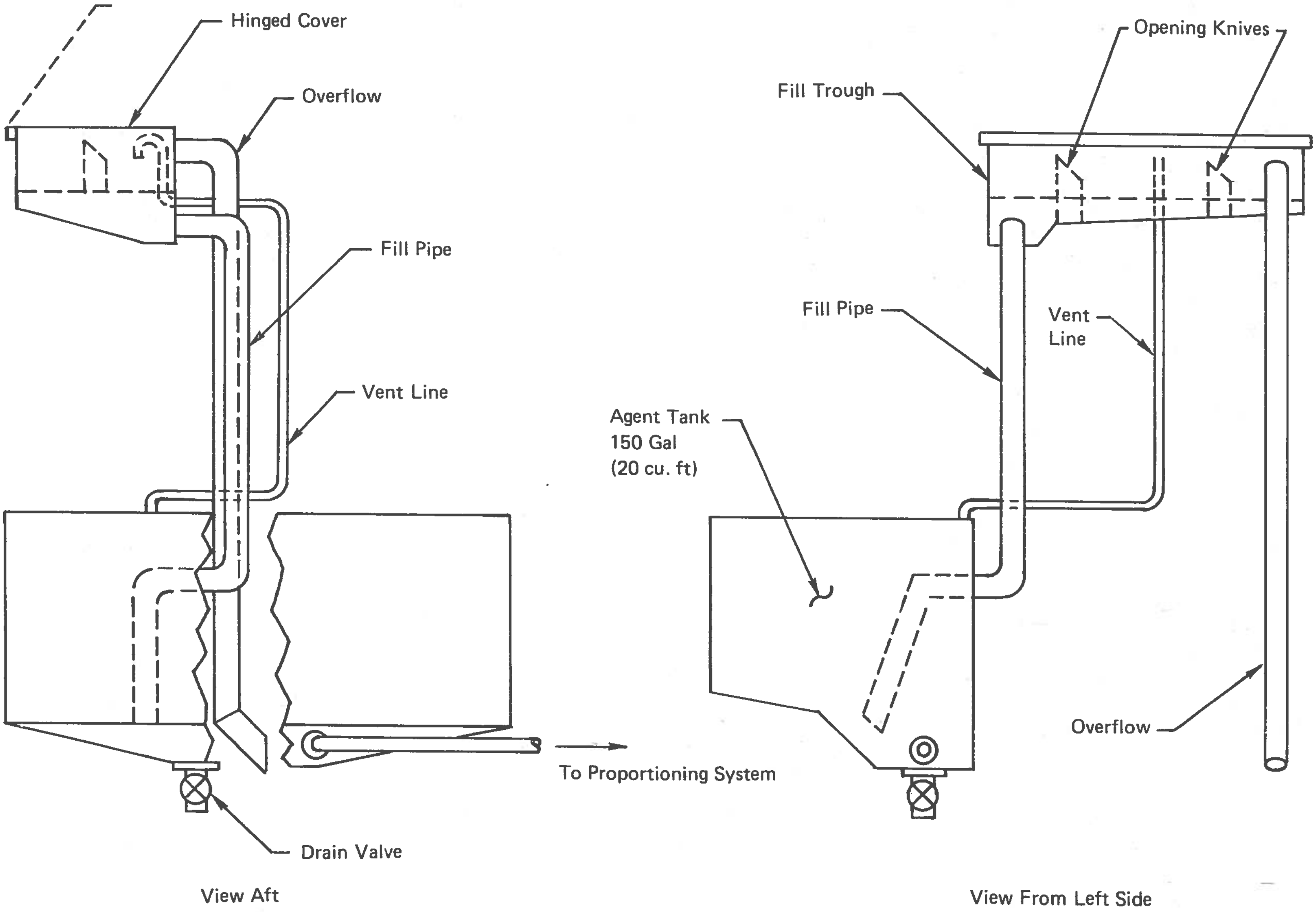
3.6.1.2 **Agent Tank** - The fire fighting liquid concentrate tank has a working capacity of 150 gallons which is sufficient to accommodate the discharge of 4850 gallons of water at a 3% agent concentration. A tank fill, vent, and overflow system is provided. Tank outlets are provided at the bottom of the tank for drainage and supply to the proportioning system. The location of the tank under the triage deck is ideally close to the pumping and proportioning system, minimizing agent loss upon shutdown. Access to the 20 in. diameter inspection cover is attained through the triage deck. Refer to figure 3.6-2.

The fill trough, located behind the triage and over the water tank on the right side of the vehicle, has a hinged cover held closed by a quick release latching mechanism, and includes a 10 mesh stainless steel screen to prevent entry of foreign matter into the system. Knives, rigidly mounted to the trough, permit opening of the sides or bottoms of two five-gallon agent containers simultaneously. The screen and knife assembly is rigidly constructed and readily removable. The fill and vent pipes, leading from the trough to the agent tank are routed along side the right hand integral water tank. The fill pipe is led through a bulkhead fitting and discharges near the bottom of the agent tank to minimize frothing. A vent tube leading from the top of the agent tank returns froth to the fill trough for recovery; excessive overflow is led to the ground through the use of an overflow pipe.

The agent tank also makes use of structural panels in the hull, and is bladder lined for the same reasons and in the same manner as the water tank.

3.6.1.3 **Pumps** - A HALE 60FJ4-U3000 single stage water pump will be provided for the fire fighting system. The pump is located and accessed from within the 48 inch wide engine compartment. The centerline of the pump inlet is approximately 16 in. above the centerline of the water tank outlets, a design feature employed satisfactorily in many commercial CFR vehicles. Power to the pump is from the engine flywheel, through a hydraulic clutch which may be engaged at any vehicle speed, and a drive shaft.

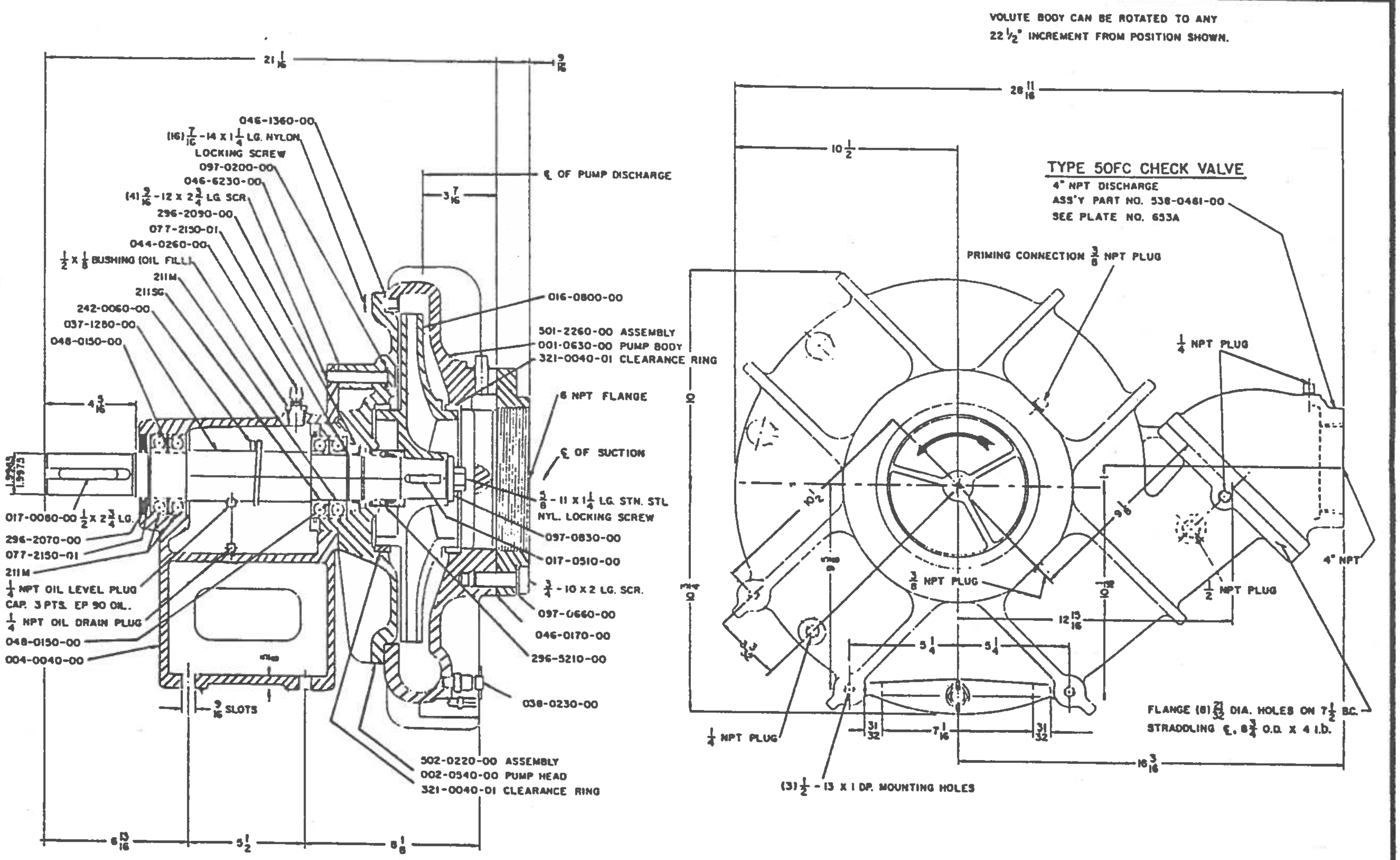
Capability of the pump in the application will be rated at 990 gpm at 225 psi with an impeller speed of 3000 rpm. Power consumption will be 187 horsepower in this condition. This pump was selected because of its simplicity of design and minimum number of components. A performance curve and outline drawing is included in Figures 3.6-3 and 3.6-4. The standard impeller for this pump is cast iron, and will be supplied for prototype units. However, Hale will supply bronze impellers for production vehicles.



View Aft

View From Left Side

Figure 3.6-2. Agent Fill Trough and Tank



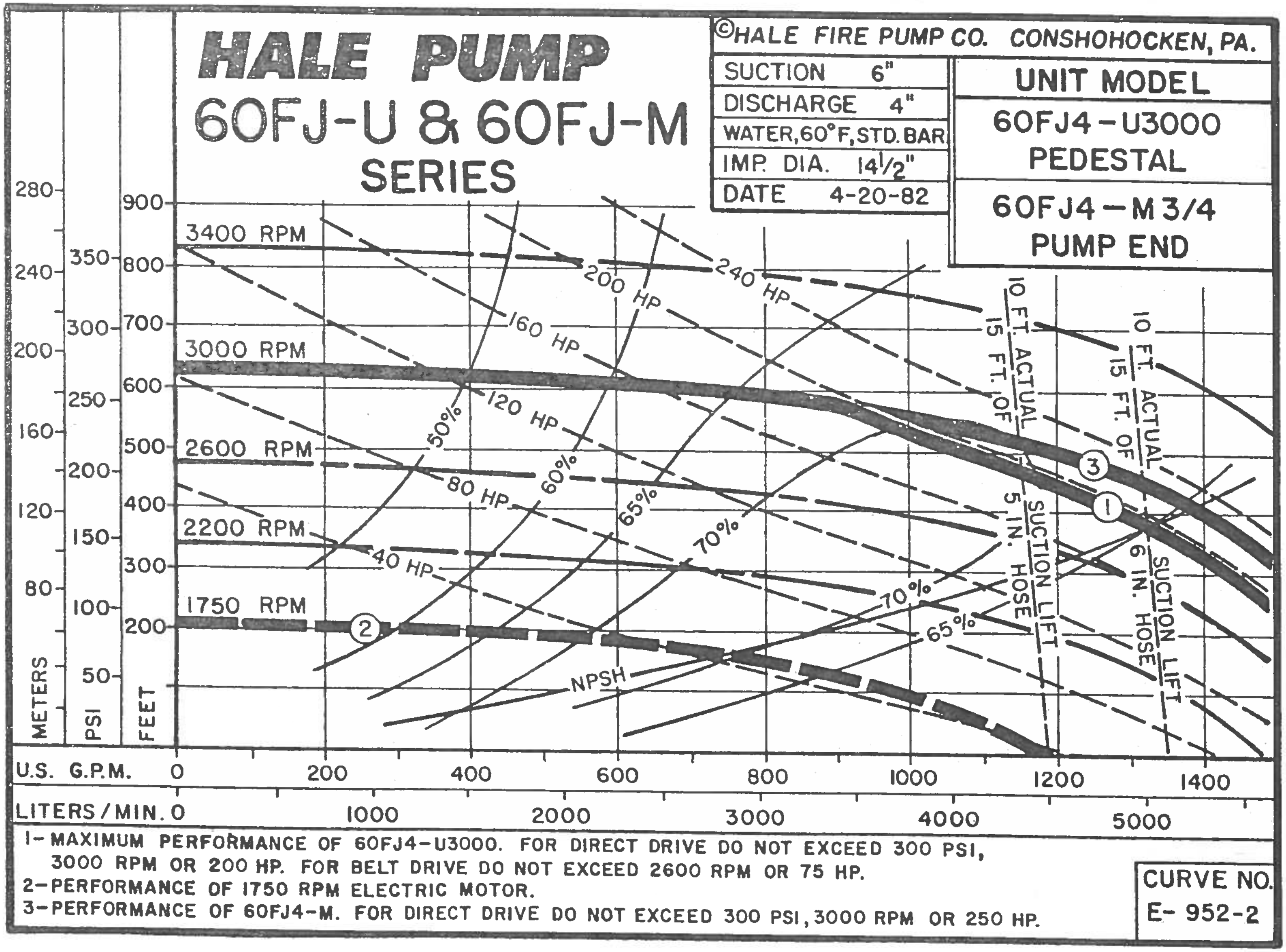
HALE TYPE
60FJ-U SERIES PEDESTAL MOUNT PUMPS

PLATE NO. 685

© HALE FIRE PUMP CO.
CONSHOHOCKEN, PA.

12-20-83 PW

Figure 3.6-3.



1- MAXIMUM PERFORMANCE OF 60FJ4-U3000. FOR DIRECT DRIVE DO NOT EXCEED 300 PSI, 3000 RPM OR 200 HP. FOR BELT DRIVE DO NOT EXCEED 2600 RPM OR 75 HP.
2- PERFORMANCE OF 1750 RPM ELECTRIC MOTOR.
3- PERFORMANCE OF 60FJ4-M. FOR DIRECT DRIVE DO NOT EXCEED 300 PSI, 3000 RPM OR 250 HP.

Figure 3.6-4.

A priming pump will be provided, mounted beneath the main deck behind the cab, controlled from a combination switch and priming valve mounted on the outer control panel. The motor and pump, or the motor by itself can be easily disconnected, serviced, or removed through an access door. An oil reservoir of at least 6 quarts is provided to lubricate the pump; a drainage means shall be provided.

Because of the closed hull design, a bilge pump, electrically driven, is installed in the pumping and proportioning compartment. The pump will be float actuated, and capable of keeping the hull free of water caused by minor fire system leaks, condensation, air conditioner drainage, and incidental water from top side.

3.6.1.4 Proportioning System - Reference is made to Figure 3.6-5 for the following discussion.

Water for the fire pump is drawn from the two water tanks through 4 inch combination shut-off and check valves into a 5 inch main feed line. Twin valves are used to limit water shifting from one side of the vehicle to the other under flotation or side slope operations. These valves also prevent contamination of the water tank with agent concentrate or agent/water mixtures should other system malfunctions occur. Water supplied to the pump is raised to 225 psi for CRF operations, of 100 to 300 psi for structural work.

The fire pump discharge is divided among four separate circuits as appropriate, (a) pressure relief, (b) discharge from the ACCRV to the fire, (c) to the water tanks and (d) to the around-the-pump proportioning system.

The pressure relief and bypass circuit (a) returns excess flow to the pump suction when system pressure exceeds 240 psi for crash rescue operations, and any other preset pressure for structural operations. The relief valve control is mounted to the structural panel. The compact plumbing system, the around the pump proportioning system, and the pressure relief valve eliminate the need for other types of surge controls.

Discharge from the ACCRV (circuit (b)) to the fire is through three devices, a 500 (+50, -0) gpm turret, a 250 (+25,-0) gpm bumper turret and a 95 (+5, -0) gpm handline, which may be used in any combination.

The roof turret is located on the right hand side of the vehicle on a hinge-down panel. The hinge down feature is used when vehicle height must be reduced for air transportability, a procedure requiring less than 15 minutes. Operation of the turret is from above the cab roof. The operator stands on a step up panel hinged on the cab/triage bulkhead and lowered forward over the top of the fold down seat back in the cab. He operates the turret through the roof hatch. Cab operation is preferred to keep the fire fighters out of the triage. The side location is chosen to avoid the operator blocking the door from the cab to the triage. A hinge up panel in the cab roof provides the necessary operator working clearance. Turret depression is 15°, elevation 45°, with rotation of at least 100° each side of center, these motions requiring no more than 200 in.-lb of torque. The turret discharge pattern is infinitely variable from straight stream to fully dispersed through the use of a manual control handle. The control for the turret discharge valve is located on top of the cab within easy reach of the turret operator.

The bumper turret, located on the centerline of the ACCRV below the windshield line, will be controlled from a console positioned beside the driver and near

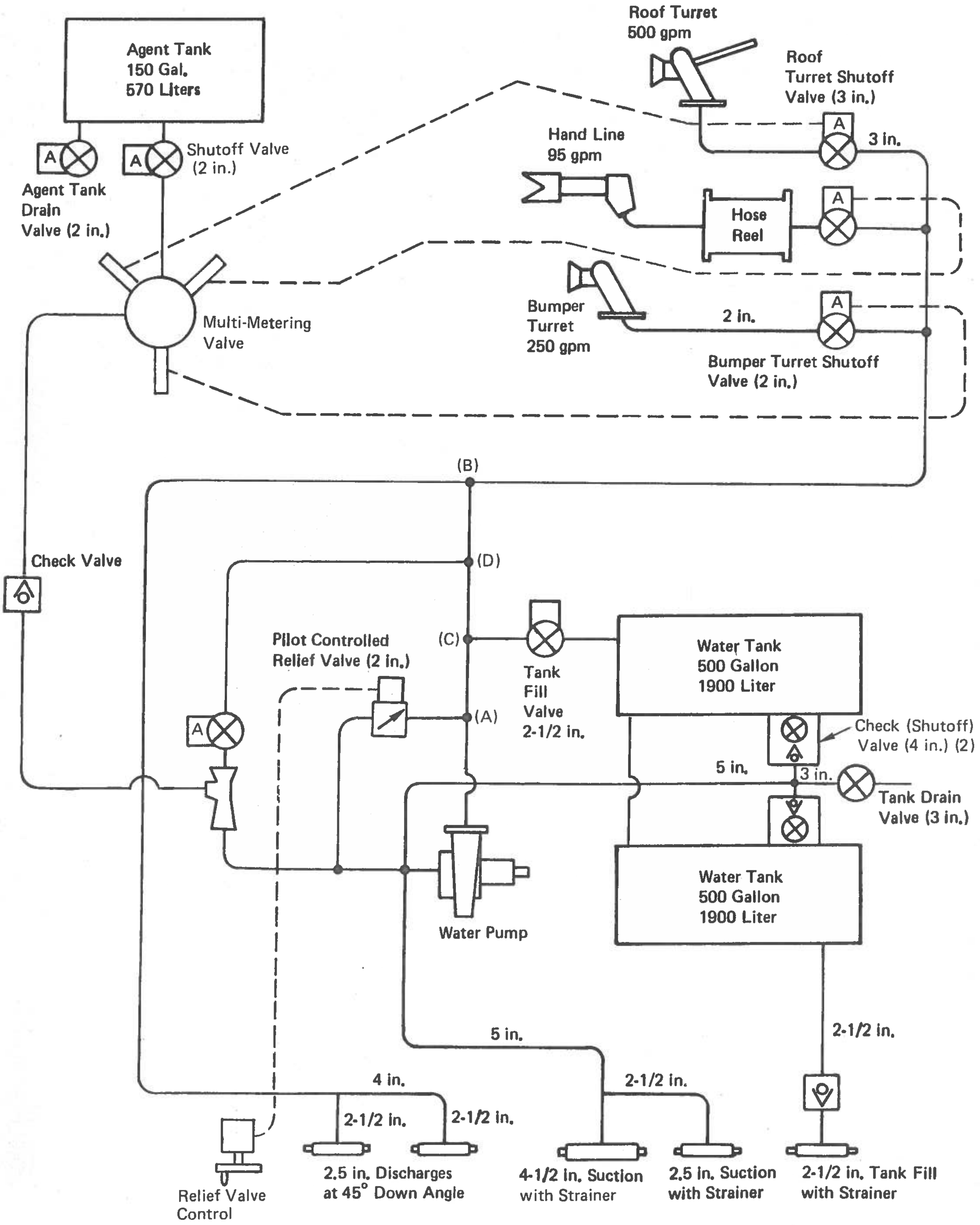


Figure 3.6-5. Pumping and Proportioning System Schematic

the front of the cab. The turret will have two modes of control: (1) Joystick Control - each individual turret motion is controlled by the operator by means of a power assisted directional control lever, (2) Automatic Control - turret oscillates back and forth automatically.

An on/off push bottom switch will be provided to activate the automatic oscillation control mode. The rate of oscillation can be set anywhere between 15° per second to 30° per second, the width of the sweep anywhere between 20° and 90°. The centerline of the oscillation pattern is adjustable anywhere within the range of rotation of the turret. The nozzle pattern and nozzle elevation are adjustable without interruption of the automatic oscillation movement. The turret can be depressed at least 20°, elevated at least 45° and rotated 90° to either side of the straight ahead position. The pattern control will allow infinitely variable pattern settings from straight stream to fully dispersed.

The hose reel located directly over the right rear tire can be used from the right side of the vehicle or the top. The reel, with its bracket for the handline nozzle and guide rollers is mounted on a vertical pivot. Facing the side of the ACCRV, the handline may be deployed through the side door for ground use; facing the front of the ACCRV, the handline may be deployed through a deck access door and used on the rescue platform.

A reel with 100 ft, 1-1/4 in. hose capacity will be supplied. The design of the hose reel assembly will prevent dragging, snarling, and overrunning of the reel. Horizontal and vertical rollers will be provided to reduce chafing and friction of the hose or catching of the couplings when the hose is being withdrawn. An electric rewind motor will allow the hose to be rewound at a rate of 85 fpm. A manual rewind with features to minimize rewind motor drag will also be provided. The electric rewind control switch will be positioned to allow one person to activate and wind the hose onto the reel. The switch will be located to protect it from interference from the hose. An air actuated 1/4 turn valve will be provided to open or shut off the discharge flow. An air purge system control will be provided to purge any water or foam solution downstream of the discharge valve from the piping, hose, and nozzle to prevent freezing in low temperature conditions. The air purge system will include a check valve to prevent water from entering the vehicles air system. The hose will have a non-aspiring type nozzle attached which will be capable of discharging water or foam solution at a rate of 95 gpm (+5, -0 gpm) and will have a straight stream effective reach of at least 60 feet. It will not be necessary to clean the hose or nozzle after use at the scene of an emergency in order to accomplish rewind operations and storage. Lubrication fittings as required will be in accordance with MS 15003.

A provision is made to fill the water tanks of the ACCRV directly from an external suction connection. The tank shut-off valves are closed, the pump primed, and the tank fill valve opened, (circuit (c)) filling the tanks. A check valve in the agent tank supply line presents accidental contamination of the agent tank.

The proportioning system (circuit (d)) consists of three fixed orifices with shutoff valves piped in a parallel arrangement, around the pump water piping, and an agent eductor returning pressurized water to the pump inlet. The three fixed orifices piped in paralelled are all contained in a single housing and called out as a multi-metering valve in Figure 3.6-5. (This is a standard component available from Feecon Corp.)

Water flowing through the eductor (venturi) draws agent into the flow which is subsequently mixed with the pump discharge water, most of which is expelled to the fire. The amount of agent drawn into the flow depends on the number of fixed orifices brought into play (1 to 3). One orifice/shutoff valve is dedicated to provide the proper amount of agent to the roof turret, one orifice/shutoff valve supplies the bumper turret, and one supplies the hand line. Each valve is controlled by an air signal when the corresponding discharge nozzle shutoff valve is actuated. When the roof turret is opened, the valve in the roof turret agent orifice line also opens. This logic also applies to the bumper turret and handline. Thus, agent supply is called for on demand, keeping the proper mix ratio. The system will provide agent concentrate ratios of 2.8% to 3.5% for 3% concentrate or 5.5% to 7% for 6% concentrate for the range of flows used in CFR operation, 60 to 845 gpm. In both cases, the orifice devices can be removed and exchanged to provide for the use of 3% or 6% agent concentrate.

Discharge and proportioning equipment will be provided by Feecon or Akron with preference given to those items currently in USAF inventory.

3.6.1.5 Piping, Connections and Controls - The unique configuration of the ACCRV concentrates and centrally locates all of the fire fighting system components except the structural outlets and control. Adjacent to the pump and proportioning compartment are: 1) cab with bumper and roof turret to the front, 2) agent tank to the right and, water tanks to the rear, and discharges and suctions to the left. This configuration decreases the lengths of wetted piping after tank shutoff valves, and pressure piping from the pump to the discharge, compared to standard CFR vehicles.

The compact pumping and proportioning configurations, coupled with the closed hull design, has several benefits. The amount of agent concentrate lost during system purge is minimized, winterization of the pumping system is easily accomplished, and pressure surges due to water inertia are substantially mitigated.

Piping material will be 304L stainless steel, schedule 10 minimum, with efficient radiused turns to prevent pressure loss. Although the ACCRV hull provides a stiff platform for the fire fighting system, extensive use of Victaulic type couplings will be made to enhance maintainability and reduce corrosion rates by separating different types of materials.

In addition to the automatic drain valves on the bumper and roof turrets, a separate manually operated low point drain valve is provided for all piping, pumps, and wetted control lines. Careful attention will be paid to the installation of control lines to prevent "traps" or horizontal installations which will not drain within the allowable 4 minutes. Discharge of the drain valve will be beneath the ACCRV.

Structural connections and the control panel will be provided on the left side of the ACCRV above the left rear wheel. If an air cushion failure occurs, or if the vehicle is deliberately put in the hullborne mode both the structural panel and connections will be above the water line. Use of the structural panel requires that the side sections of the air cushion be deployed, and that the operator use the cushion top deck as platform, placing all controls and connections within easy reach. Controls are mounted behind the panel, with full access to the back of the panel for service.

The structural control panel includes:

- a digital readout display for total flow
- flowmeters for both side discharges

- water pump relief valve control
- CFR or structural select switch
- priming pump control
- engine tachometer
- engine throttle control, air type
- engine oil pressure gage
- engine coolant temperature
- panel light controls
- tank shutoff valve control

The structural connection panel includes:

- two 2-1/2 in. discharges with caps and chains
- one 4-1/2 in. suction with long handle cap and strainer
- one 2-1/2 in. suction with cap and strainer
- one 2-1/2 in. tank fill with cap and chain

Operation of the ACCRV for crash fire rescue operations requires that the following cab controls and indicators be available to the driver:

- tank level gauges for agent and water
- autopump on/off
- agent tank on/off
- air cushion fan on/off
- transmission shift lever
- accelerator pedal
- bumper turret control panel (to be detailed at time of design)
- brake pedal
- air cushion panel attitude control
- buoyancy pillow inflate/deflate switch
- steering system

Operation of these controls is described in other sections of this report.

3.6.1.6 Winterization - The winterization system will permit satisfactory operation of the ACCRV and fire fighting systems and provide required heating in ambient temperatures as low as -40°F. The winterization system will be powered by an auxiliary power unit or the ACCRV electrical system and shall be designed to provide the required performance during all phases of vehicle and fire fighting operations regardless of engine speed. The system design and installation will include the necessary coolant flow shutoff features to permit the removal and reinstallation of the major components of the system without loss of coolant in excess of the capacity of the component being removed. The winterization system will be so installed and the vehicle so insulated that, after stabilization of operative temperatures, the system when operating in temperatures as low as -40°F (with the winterization kit in operation), can be shutdown for a period of at least 2 hours without requiring the draining of the agent system and without freeze damage to the ACCRV and its components. Incorporation of the winterization features will not detract from the performance of the ACCRV or fire fighting systems in normal or high ambient temperatures up to 125°F. The winterization system will include but not be limited to the following features:

a. Two coolant circulating pumps, one independent of the booster heater.
b. Diesel fueled booster heater.
c. Cab and compartment heating and ventilating system.

d. Fire system heat exchangers.
e. Water recirculating pump.
f. Engine heating system.
g. Control system.
h. Diesel fueled auxiliary power unit.

The winterization system provides for forced flow of coolant solution through a closed circuit with an electrically driven coolant pump. The booster heater transfers heat from its boiler to the coolant as it is being circulated. The coolant, through heat exchangers, distributes this heat to the cab heater and defroster, the pumping and proportioning compartment, the hose reel and battery compartments, the engine cooling system and oil pan, agent tank, and water tanks. The coolant distribution system has an expansion tank with filler opening and drain readily accessible for inspection and servicing. The capacity of the expansion tank is adequate to assure that all coolant lines will remain full if the coolant system is allowed to cool at a temperature of -40°F. Reference is made to Figure 3.6-6.

A 24 vdc centrifugal type coolant pump is used to circulate the coolant through the booster heater circuit. The pump size assures the proper temperature differential between the input and output temperatures as recommended by the booster heater manufacturer when using winter coolants. The coolant circulating pump is equipped with ball bearings to assure a long life expectancy, and satisfactory operation at -40°F. A flow switch is incorporated in the coolant system to monitor the flow of the coolant pumped; in event of a pump failure, an impulse will be sent to a relay which in turn will blow the vehicle's horn.

A booster heater using diesel fuel and operating on 24 volts dc, conforming to MIL-H-4697 requirements will be supplied. The heating capacity supplied will result from a study of the ACCRV in its final configuration. The heater will be located in the hull behind the rear axle in a partitioned compartment also housing the battery boxes and the APU. Access to the heater is from the top deck and/or beneath the vehicle. Acceptable heaters are manufactured by Janitrol, Webasto, Espar, and Benmar; final selection will be made during the design stage.

All necessary controls for the operation of the booster heater will be provided. The booster heater can be activated from the cab. Circuits integral with the booster heater include thermostatic control of the boiler heat and overheat/shutdown protection. Automatic switches will be provided to shut down the booster heater in event of an overheat problem or an ignition failure. If these types of failures occur, a signal would be sent to a relay which in turn would blow the vehicle's horn.

The booster heater's exhaust is directed up and towards the air cushion fan intakes to prevent damage to equipment due to radiation or conduction of heat. The location of the booster heater on the vehicle precludes the possibility of exhaust fumes entering the cab or reverse drafts from entering the heater exhaust pipe and causing a malfunction. Drain lines connected to the water jacket of the booster heater allow draining of the coolant to the outside of the vehicle.

The heating and defrosting systems are adequate for four persons in the cab and four in the triage compartment. The fresh air intake, capable of 120 cfm and normally located low on the cab, will be located near the roofline to avoid taking in water in the event of an air cushion failure or hullborne operation.

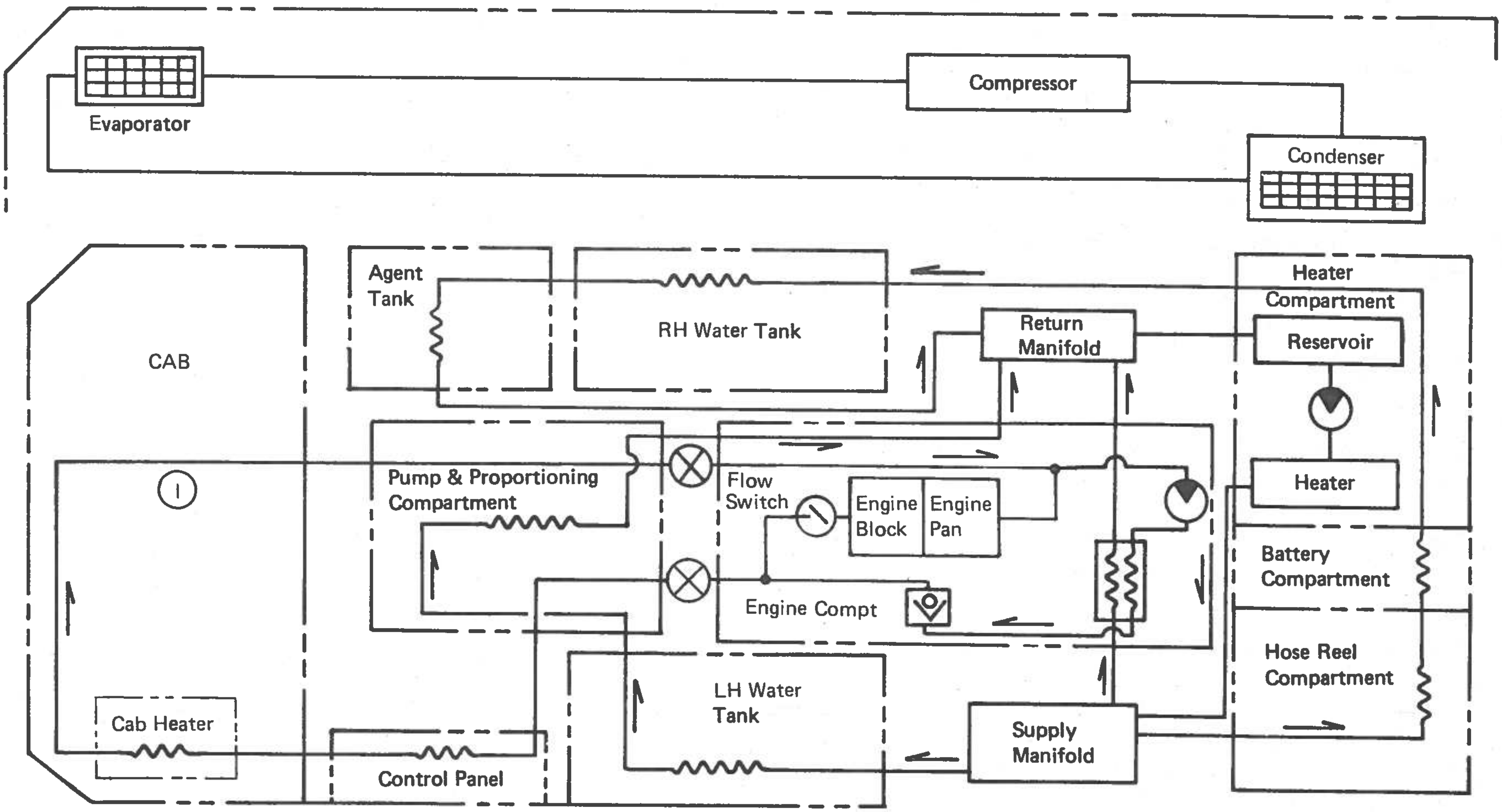


Figure 3.6-6. Winterization Schematic

The cab and triage compartment heater will contain a heater core, dampers, and damper controls to allow mixing of the inside with outside air to any degree desired ranging from total air recirculation to total fresh air ingestion. The electric blower motor driven blower mounted inside the heater housing will blow the inducted air over the heater core and through the defroster ducting to distribute it evenly over the transparent glass areas in the cab and through ducting to controllable registers near the floor in the partition between cab and triage area on each side of the door. A multispeed motor control will be provided to control the velocity of the air flow. Adequate heating capacity will be provided to maintain a cab floor temperature of +40°F and a clear glass area of 75% of the total surface, when the cab and triage compartment are occupied by eight people and the outside temperature is -40°F.

Tube and fin heat exchangers are used in two compartments, the pumping and proportioning compartment, and the partitioned heater, battery, APU, and hose reel compartment. The exchangers will be sized to maintain 40°F at the compartment floors.

All of the fire system discharge piping not automatically drained on shutdown is located in the heated pumping and proportioning compartment, eliminating the need to recirculate heated water through all wetted piping. A recirculating water pump is provided for the water tanks, taking water from the bottom of the tanks and returning it to the tank tops. This circulation is separate from a auxiliary heater flow, which is through heat exchangers located in the bottom of the water tanks.

A separate coolant circuit is provided to transfer engine heat to the structural control panel and vehicle cab, as shown diagrammatically on Figure 3.6-6. Two features are added to the conventional arrangement to allow heating of the circuit without the engine running. First, an electrically operated coolant pump instead of the engine coolant pump, circulates the coolant and second, a heat exchanger is added to transfer heat from the booster heater circuit into the isolated circuit.

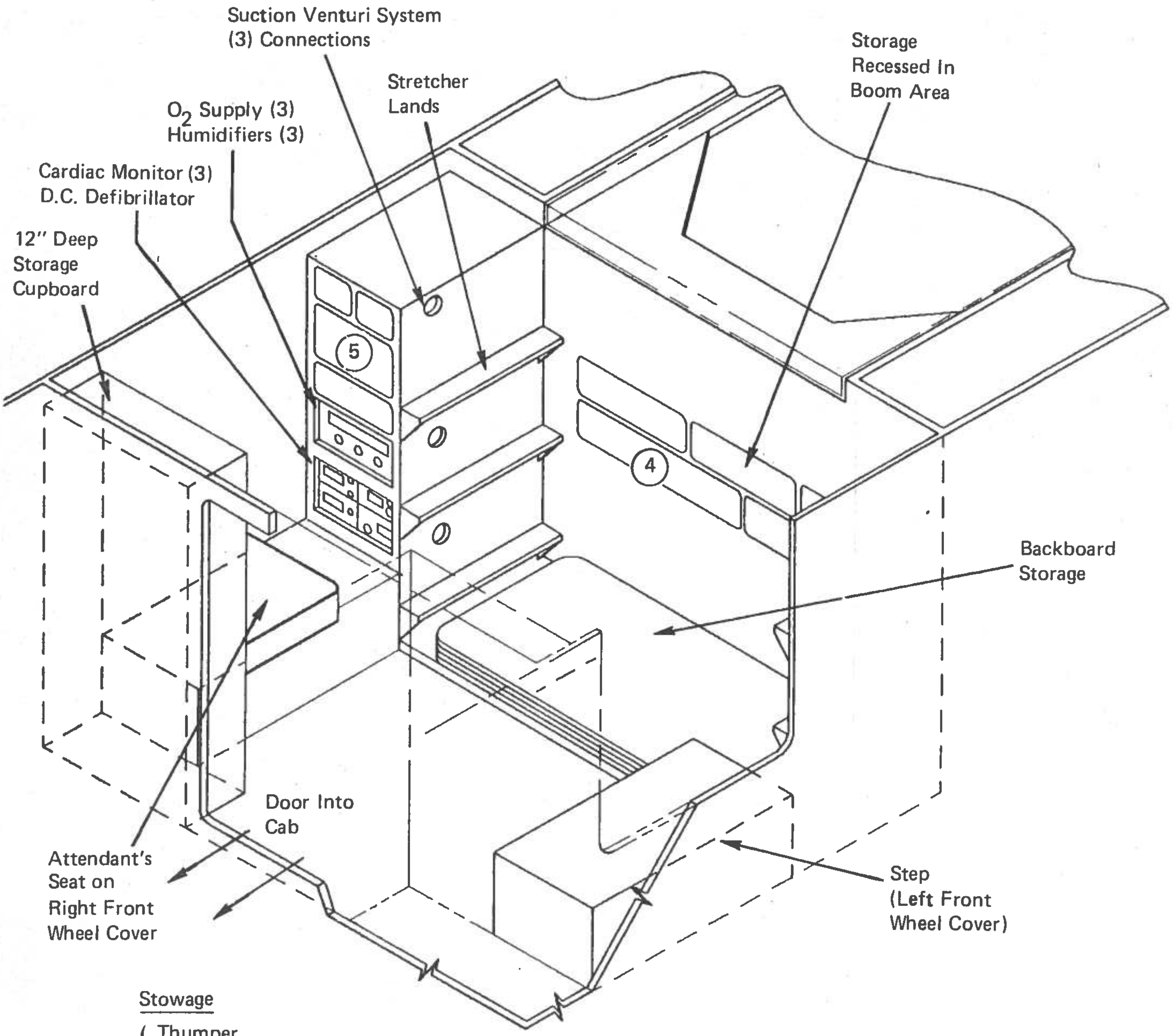
When using the booster heater, the engine and cab/control panel are in parallel circuits appropriately balanced to heat the cab and engine to required temperatures. When operating the main engine, the cab circuit is in series with the engine, and the auxiliary circulating pump is shut down by the flow switch on the engine to heater output port, avoiding inadvertent overheating of the engine. This design will assure the standby and starting performance specified without affecting the engine's normal cooling and lubricating systems. The heating system will be adequate to maintain engine temperatures required to assure engine starting within 15 seconds in temperatures as low as -40°F.

Cab controls for the winterization system shall be as follows:

- start/stop switch for booster heater
- fan control and heat regulator for cab heater
- water tank recirculating pump switch
- red indicator light to signal booster heater failure

3.6.2 Triage Area

3.6.2.1 Configuration - The triage area is located directly behind the cab, over the agent tank and pump and proportioning compartment, and extends from the left to the right side of the vehicle (see Figure 3.6-7 and 3.6-8); access doors are provided on the left side. This location provides excellent access to the cab and communications



Stowage

④ Thumper
Airway Kit
I.V. Kit
O_2 Cylinders

⑤ I.V. Pump
B.P. Cuffs
Cervical Collar

Figure 3.6-7. Triage Layout and Stowage

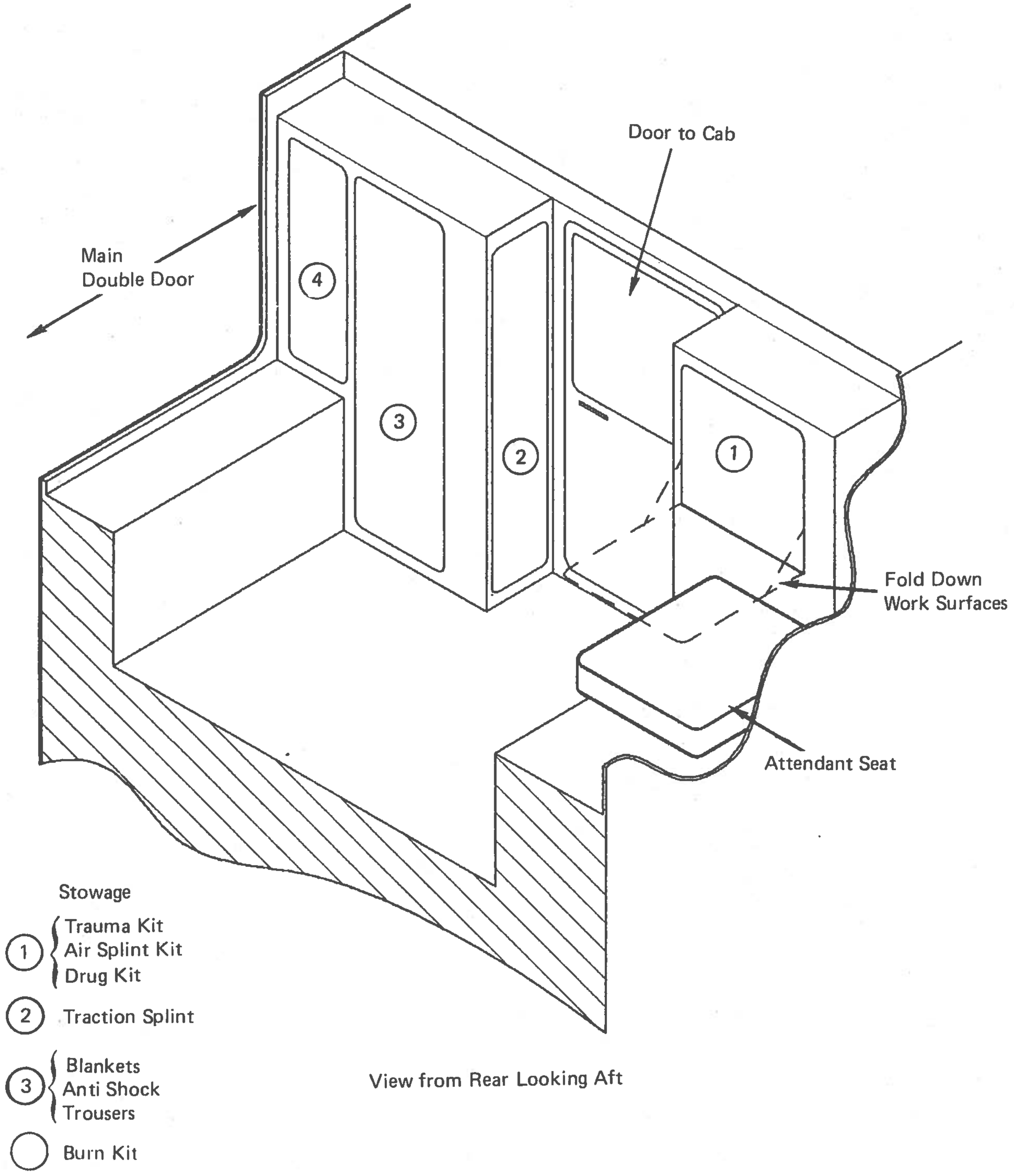


Figure 3.6-8. Triage Layout and Stowage

equipment, assuring optimum coordination of medical and rescue operations; it is also located away from the engine and lift fans, keeping noise interference to a minimum.

The working deck in the triage area is approximately five feet below the ACCRV top deck, and offers some protection to the injured and crew. When not in use, the rescue boom platform can cover the triage compartment for added protection. Equipment storage cabinets are provided for medical supplies. The right hand compartment door in Figure 3.6-8 is bottom hinged and serves as a work surface when opened. It is anticipated that the medical attendant will use the seat over the right hand wheel well, thereby being close to the Cardiac Monitors, and in a position to observe the injured personnel.

3.6.2.2 Emergency Medical Equipment The list of medical equipment that follows is typical of that carried on an ambulance, and will be provided.

Qty	Description	Wt (lb)	H x L x W (in.)	Comments
3	Cardiac Monitors	9.55 ea	3.8 x 13.3 x 5.7	Battery Included
1	DC Defibrillator	11.90	3.8 x 13.3 x 9.2	Battery Included
1	I.V. Infusion Pump	2.75	7.2 x 4.3 x 5.0	Battery Included
3	Electronic B.P. Cuffs	1.75 ea	2.7 x 5.6 x 5.5	Battery Included
1	CPR Thumper	25.3	6.0 x 30.5 x 26.0	
2	Alum. D-Size 0_2 Cylinders with Yoke	7.35 ea	4.0 x 30	For use with Thumper
1	Drug Kit	13.65	22.5 x 8.5 x 18.0	Soft-pack
1	Airway Kit	10.50	18.0 x 10.0 x 16.5	Soft-pack
1	I.V. Kit	16.50	18.0 x 10.0 x 16.5	Soft-pack
1	Trauma Kit	12.75	22.5 x 8.5 x 18.0	Soft-pack
3	Medical Anti-Shock Trousers with Single Gauge	6.65 ea	8.5 x 9.60 x 16.0	Size when folded into soft-pack
3	Traction Splints	3.60 ea	3.5 x 50.25 x 10.5	
3	Burn Packs	3.35 ea	6.0 x 10.5 x 14.0	Soft-pack
1	Air Splint Kit	2.85	4.0 x 18.75 x 19.5	Soft-pack
3	Medium Cervical Collars	0.35 ea	8.0 x 5.0 x 6.0	
3	Large Cervical Collars	0.40 ea	8.5 x 5.5 x 6.5	

Qty	Description	Wt (lb)	H x L x W (in.)	Comments
3	Blankets	1.00 ea	6.0 x 4.0 x 10.0	Folded
1	Installed Suction Venturi System	-		
1	Installed 0_2 "H" Cylinder Aluminum	37.5	9 x 48	Can be placed outside of compartment
3	Cardboard Backboards	0.75 ea	0.35 x 78 x 20	Disposable
3	0_2 Humidifiers	1.05	5.0 x 3.5 x 3.5	
	Total Weight	234 lb		

NOTE: Installed 0_2 system will have 3 outlets with humidifier, one at the head of each patient.

In addition to the above, three stretchers of 6 ft 6 in. length can be stowed on the stretcher mounts. The oxygen cylinder, size H, will be secured as weight and space requirements dictate.

3.6.3 Rescue Boom, Slide and Equipment

3.6.3.1 Rescue Boom - The selection of a rescue boom type and location is based on these perceived needs: 1) to reach any cockpit emergency exit of all aircraft in the USAF inventory on land or water, 2) to allow quick access to the triage deck for injured personnel, 3) to be able to perform a rescue at the water surface. Weight and space constrictions require the lightest and most compact arrangement available.

The rescue boom selected is of the articulated arm type, primarily because it can reach over the front of the vehicle, and be reasonably extended away from the hull.

The boom is mounted amidships directly behind the triage area and over the transmission. This position was selected to allow for two platform positions: either even with the top deck and over the triage area or adjacent to the triage area over the top deck. Access to the platform for rescue personnel is from the cab through the triage area or directly through the second roof hatch, when the platform is in the forward position. Transfer of injured personnel from the platform to the triage area is readily accomplished with the platform in its aft position.

The length of the articulated boom which can be stowed within the profile constraints gives an overall extended length of 41 ft. An upper boom telescoping section increases this reach to 44.5 ft. With the boom extended over the front of the cab and the centerline of the platform directly over the front face of the cab, platform height will be approximately 51 ft from hard ground. The platform can also be placed at the water surface with the front edge of the platform up to 30 ft 9 in. from the front of the cab or 44 ft to the rear (see Figure 3.6-9).

The rescue boom may be used on firm surfaces with the side panels deployed to the ground, or over water in the hullborne mode with side panels deployed and the spray skirts inflated to the buoyancy pillow configuration. Under these conditions, the full range of the rescue boom may be used. Operation of the boom in the cushionborne mode could lead to instability under some conditions and is therefore not allowable.

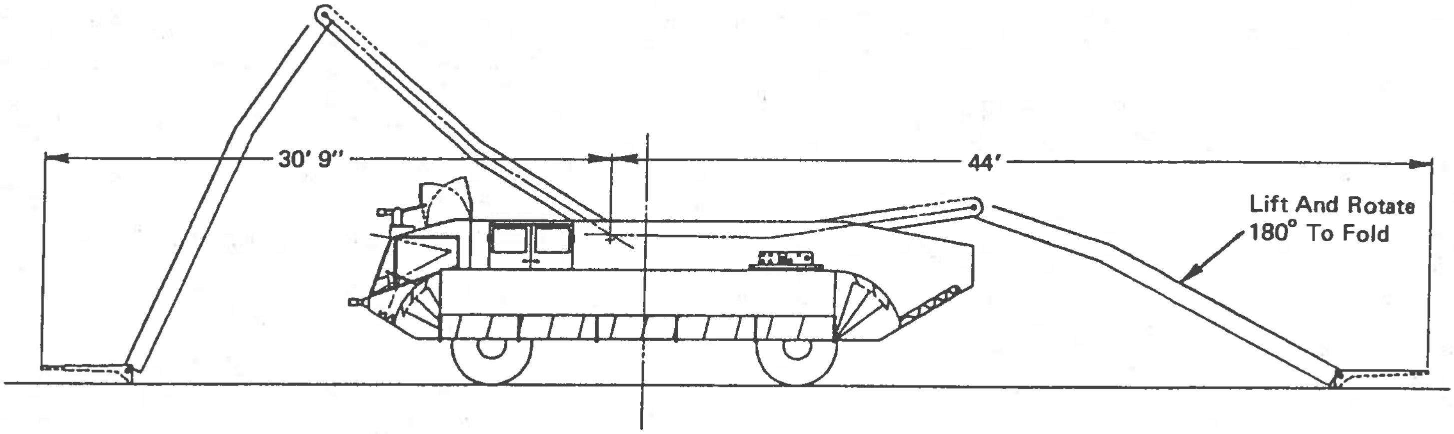


Figure 3.6-9. Fore and Aft Boom Reach

The rescue platform will be equipped with appropriate handrails which can be removed and stowed on the triage deck for air transport. The rail design will recognize that it may be necessary to move unconscious personnel off the front of the platform directly to the triage area or to the ground. A boom control panel can be attached to a hand rail for use, and is demountable for transport. Provisions are made to lower the boom using controls located near the triage area in the event of control malfunction or an inability of the rescue crew to use the platform mounted control.

A standard boom configuration meeting current weight and configuration requirement has not been located. In the design phase, it will be necessary to work with a boom manufacturer, to use the hull work with structure in lieu of the normal universal base mounts, substitute advanced composite materials for parts made of conventional materials, and possibly use electro/hydraulic articulation controls in lieu of all-mechanical controls. The selected design may also modify the extension/retraction capabilities of the upper boom to bring the stowed length within the vehicle profile.

Relative motion between the waterborne ACCRV-rescue boom and the aircraft is inevitable. It is necessary that rescue personnel be able to secure the rescue platform to the aircraft, and that the boom not become a rigid link between the aircraft and the ACCRV. Therefore, provisions are made in the boom control system to "float" the boom such that linking forces are kept within the boom's structural capability, and restoring forces are such that the ACCRV hull and the rescue platform tend to remain in the same relative positions. Relative position holding is also necessary for rescue slide use.

3.6.3.2 Slide - The slide unit, being a restricted-use item, (only platform positions or aircraft exit opportunities sufficiently elevated allow its use), is not integrated into the boom mechanism but packed separately. Anchor points are provided on the rear of the boom platform, and on the top deck to allow attachment. Separate attaching means are provided to attach the slide directly to the aircraft if necessary.

The slide consists of separately inflatable sections of approximately 2 ft in length allowing incremental deployment to the required length. In order to attach the slide flexibly to the ACCRV, and allow it to move as the relative position of the ACCRV and aircraft change (in waterborne operations), two three part block sets, using bungee cord as the line and equipped with quick release jam cleats, may be used to secure the lower end of the slide to the deck. See Figure 3.6-10.

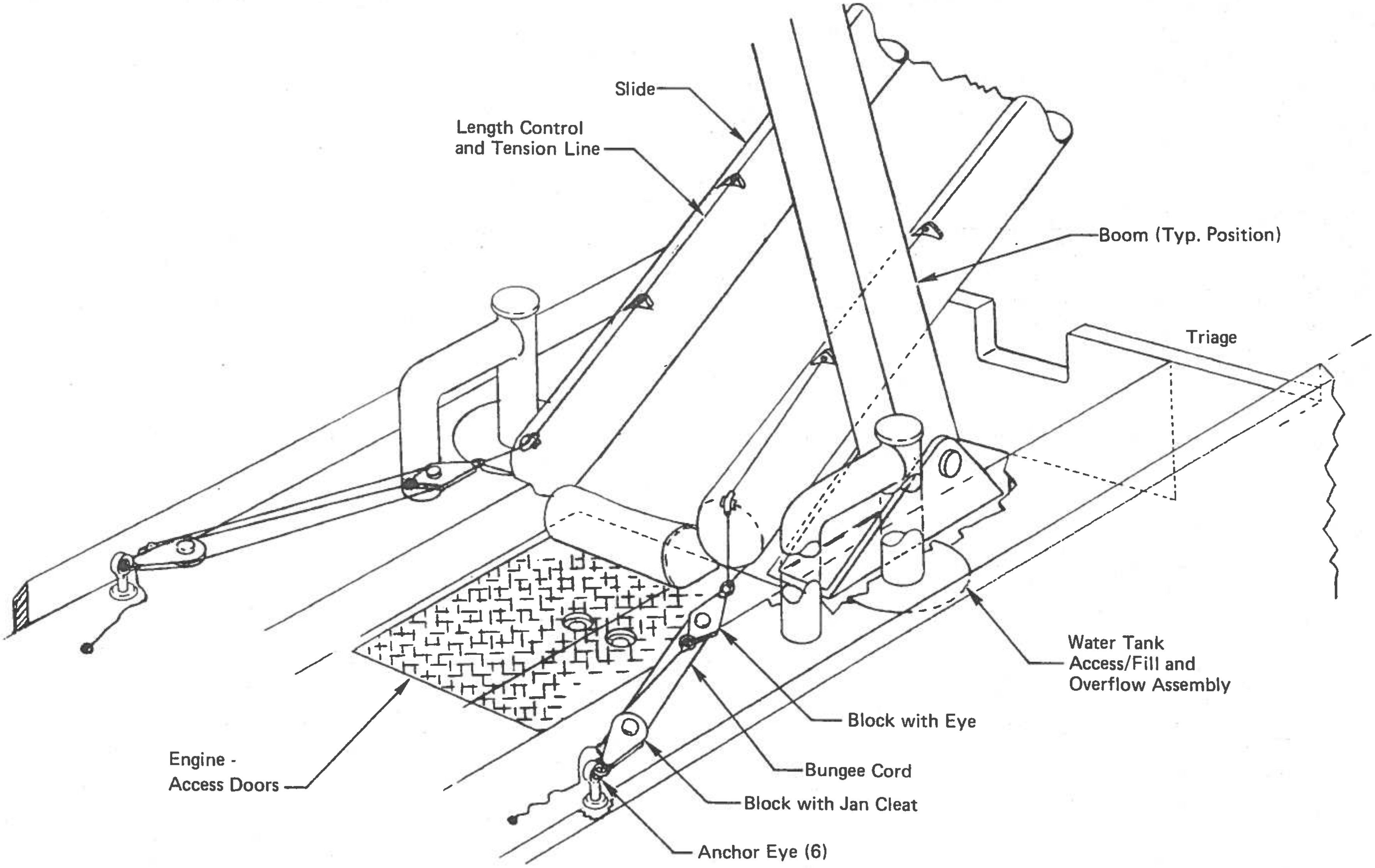


Figure 3.6-10. Slide Attachment

Deployment of the slide is from the aircraft or platform end. Individual sections are inflated, pulling length control lines thru ears on the remaining uninflated sections. The lines are used to guide the slide to the ACCRV deck, perhaps in coordination with a lead line to the deck from the inflated end of the slide. When the desired length is reached, the length control lines are fastened to the aircraft attachment device(s) or boom platform as required, thereby securing the upper end. Tensioning of the deck lines makes the slide ready for use.

The use of the slide is similar to aircraft slides commonly in use, except that the length control lines are also employed as hand rails for controlled descent.

3.6.3.3 Auxiliary Equipment - Stowage for the rescue tool kit FSN 4210-00-900-8557, with components as listed below, will be provided in the top tool compartment located on top of the left water tank, conveniently accessible to crewmen going onto the boom platform.

a. Aircraft cable cutter, 14-inch, capacity to 1/4 inch.
b. Lineman's pliers, heavy duty, 8-inch long.
c. Grappling hook and rope sling, 40 inches long.
d. Hack saw frame, adjustable 8 to 12 in.
e. Six fuel line plugs; 3 hardwood, 3 neoprene.
f. Rescue knife with "V" blade and serrated-edge axe.
g. Vise grip wrench, 10 in. long.
h. Three hack saw blades, 10 in. steel.
i. Metal cutting saw, 20 in. blade.
j. Two slot screwdrivers (4 and 6 in. with No. 2 tip).
k. Two Phillip screwdrivers (4 and 6 in. with No. 2 tip)
l. Heavy canvas roll, treated for storing all of the above items.

An auxiliary generator is provided, located in the same compartment area as the diesel fired auxiliary heater. Power capability will be at least 2500 watts at 120 vac, 60 Hz. Two twist lock receptacles will be provided in locations to be specified. Fuel will be provided from the main vehicle tank using a separate in-tank electric pump. Provisions will be made for operating the winterization equipment, and vehicle horn at 24 vdc. As an option, a 14 vdc battery charger can be added for charging the batteries in an isolated non-series state.

The auxiliary equipment listed below is stored in compartments at the rear of the ACCRV on either side of the rescue boom.

a. One axe conforming to GGG-A-926, type II.

b. Two 2-1/2 in. NH straight double, female hose connectors conforming to MIL-C-52404, Class A, Type XVIII.

c. One gated coupling 2-1/2 in. NH internal by 2-1/2 in. NH external, conforming to MIL-C-52404, Type XVIII, Class C.

d. One crowbar per GGG-B-101, Type II, Class I, size 4.

e. One claw-type door opener conforming to GGG-B-101, Type V, Class 1, Style B.

f. Two adjustable hydrant and spanner wrenches per GGG-W-665, Type IV.

g. One circular blade metal cutting saw.

h. One bolt cutter per GGG-C-740, Type II, Class 3, 5/8 in. rod.

i. One 1 in. nozzle.

j. Two 1-1/2 in. nozzles.

k. One 2 in. nozzle.

Two fire extinguishers, size 2, conforming to MIL-E-24091B are mounted inside the rear side compartments.

An electric lantern conforming to MIL-L-26598, Class 2, is mounted in the cab, on the cab rear wall to the left of the turret operator, where it can be reached from the cab door.

The pike pole per MIL-P-43116, Type III, style A, size 1 is mounted on the top deck.

The 17 lb Halon 1211 2A.60BC extinguisher and the 15 lb Halon 1211 10BC extinguisher are mounted in separate compartments over the cushion fans, and are accessible from the top deck.

These auxiliary equipment placements are illustrated in the form-view Figure 1-1. Final equipment mountings will be determined at the time of design.

4.0 SELECTED CONCEPT CHARACTERISTICS

4.1 LEADING PARTICULARS AND DIMENSIONS

The summary of leading particulars included in this section describe the physical and functional characteristics of the selected ACCRV shown in Figures 4.1-1 and 4.1-2. These are the products of analyses and designs conducted during the Concept Definition phase of the ACCRV program.

4.1.1 General

Weight	Gross	-	30,502	lb
	Empty	-	19,017	lb
Load Capacity	Water	-	1000	gal
	Agent	-	150	gal
	Fuel	-	75	gal
	Crew	-	4	
	Passengers	-	4	
Dimensions	Wheeled	-	407L	x 110W x 105H
	Hybrid	-	428L	x 218 x 108H
Wheelbase		-	202	in.
Approach/Departure Angle		-	30°	
Turning Diameter		-	100	ft (Wall to Wall)
Air Transportability		-	C130	(Roll-on, Roll-off)

4.1.2 Performance

Gross HP to Weight Ratio		-	49	(installed)
Land	(Wheeled)	-	65	mph max
		-	50	mph crusing
Water	(Cushion-borne	-	10	mph (SS-1)*
Marginal Terrain	(Hybrid)	-	Terrain Dependent	
Gradiability	(Wheeled)	-	60%	(Traction Limit)
	(Hybrid)	-	5%	
Pump & Drive	(Wheeled)	-	40%	@ 1 mph

4.1.3

Engine	-	DD8V92%A
Type	-	2 cycle, 8 cycle diesel, turbo charged
Bore	-	4.84 inches
Stroke	-	5.0 in.
Displacement	-	736 cu in.
Compression Rates	-	17:1
Fuel	-	DF1, DF2, JP5 to JP8
Rated HP	-	736 (80° Day)
Control	-	Electronic with torque shaping/limiting option

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* 40 mph with propellers.

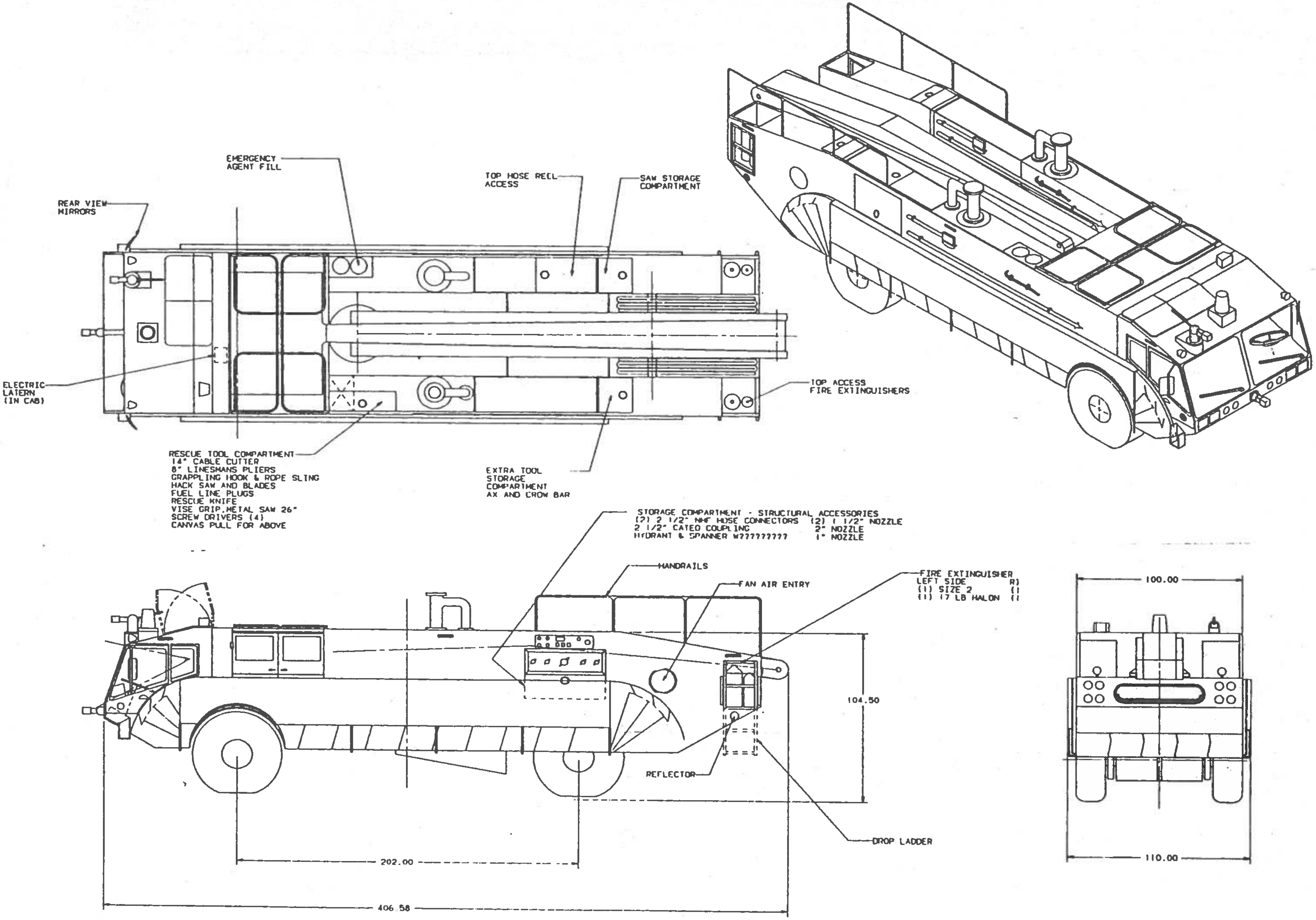

Figure 4.1-1. ACCRV Wheelborne

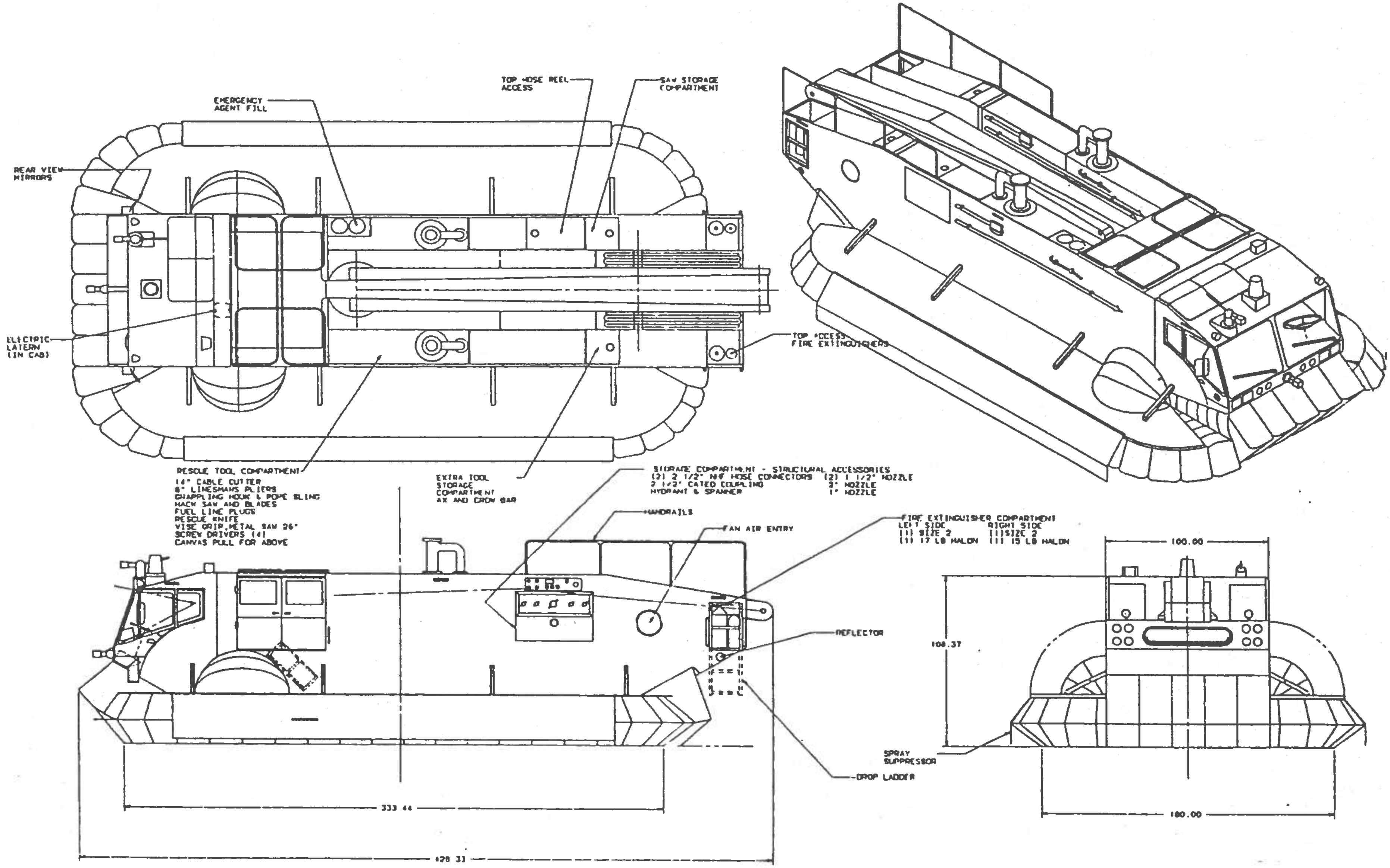

Figure 4.1-2. ACCRV Cushionborne

4.1.4 Power Train

	Transmission	Automatic Allesor HT750 DR with TC 499 Torque Converter
	Rates	1st - 7.97:1 4th - 1.40:1 2nd - 3.19:1 5th - 1:00:1 3rd - 2.07:1 Rev - 4.47:1
	Drop Box	1:1.08 ratio with drive to front and rear axle; integral bidirectional overrunning clutch
	Front Axle	Rockwell FDS 1600 single reduction hypoid gear with differential lock; 5.57:1 reduction, integral king pin and power assist arm
	Rear Axle	Eaton 16121 series single speed level gear with driver selected lockup differential. 3.55:1 reduction
	Transfer Case	Chain drive 1.57:1 reduction
	Power Divider	Multi disc oil cooled clutch with modulator to engage the main power transmission clutch
4.1.5	Suspension	Rigid Axle
	Front	Coil springs/damper, cross axle
	Rear	Tube over-bar axle, coil springs/damper - adjustable load, extendable
	Tires	Tubular radial 17.5 R25
4.1.6	Service Brakes	Internal shoe 17 x 5 in. hydraulic with power assist
4.1.7	Frame	Integral Alum. hollow core/honeycomb construction
4.1.8	Lift System	Single plenium, full depth finger configuration with retractable side panels
	Cushion Area	420 ft^2
	Cushion Press	71.5 psi
	Cushion Flow	980 cfs
	Fan	Dual double-entry centrifugal
	Fan drive	Bevel gear splitter box eith integral centrifugal clutch

4.1.9	Flotation System	-	4 ft dia x 23 ft long inflatable spray skirt
4.1.10	Water, snow and soft surface propulsion	-	Dual paddlewheels directly coupled to the rear vehicle wheels - each 40 in. dia x 24 in. wide
4.1.11	**Fire Fighting System**		
	Water Tank	-	1000 gal capacity integral, bladder lined
	Agent Tank	-	150 gal capacity integral, bladder lined
	Water Pump Rating	-	Single Stage Hale 60FJ4-U3000
		-	990 gpm at 225 psi at 3000 rpm
	Discharge	-	500 gpm turret - manual
		-	250 gpm bumper turret-automatic and manual
		-	Hose reel, 95 gpm nozzle, 100 ft hose
	Proportioning System	-	Around-the-pump type
	Structural Connections	-	(1) $4\frac{1}{2}$ in. and (1) $2\frac{1}{2}$ in. sections
		-	(2) $2\frac{1}{2}$ in. discharge
		-	(1) $2\frac{1}{2}$ in. tans fill
		-	(2) $2\frac{1}{2}$ in. emergency tank fill
	Pump Drive	-	Direct flywheel PTO
	Fire Extinguishers	-	(2) Size 2, per MIL-E-24091B
		-	(1) 17 lb HALON 1211 2A.60 BC
		-	(1) 15 LB HALON 1211 10 BC
	Winterization	-	(1) Diesel fueled booster heater with distribution system
4.1.12	**Rescue**		
	Boom/Platform	-	4 man capacity 45 ft max. reach
	Slide	-	inflatable
	Triage Area	-	3 injured personnel plus 1 attendant
		-	Standard Complement of medical equipment/supplies
	Auxiliary Equipment	-	2500 watt generator
		-	Tool kit FSN-4210-00-900-8557

4.2 MASS PROPERTIES ANALYSIS AND CONTROL

4.2.1 Introduction

To meet the ACCRV operational land and water performance requirements, vehicle weight, c.g. location, and moments are being carefully controlled. This has been factored into all subsystem selection and location trade-offs, along with the placement of variable loads (passengers, fuel, water, and aqueous foam).

4.2.2 Mass Properties Analysis

A comprehensive mass properties analysis of the ACCRV conceptual design was conducted for various operating conditions between weight empty and gross weight. Weights, center-of-gravity location and vehicle moments of inertia were estimated using drawing analyses and information resident in a Bell data base acquired on previous air cushion vehicle hardware and vehicle study programs.

The current empty weight of the ACCRV is 19,037 lb. Addition of 4 crew (680 lb), 4 passengers (680 lb), 100% fuel load (525 lb), water (8330 lb) and aqueous foam (1250 lb) to the empty vehicle weight results in a loaded weight of 30502 pounds. Complete mass properties estimates for the empty and fully loaded ACCRV are summarized in Figure 4.2-1. Figure 4.2-2 depicts the vehicle reference axis. Based on previous experience on similar programs at Bell, a weight control margin of 3% of the ACCRV empty weight is included in the weight statements. This margin compensates for weight uncertainties inherent in a conceptual design phase.

Eighteen operating weight conditions were examined with various expenditures of on-board disposable loads such as fuel, water, aqueous foam and varying the number of passengers. Figure 4.2-3 lists the cases analyzed and shows the summarized results. These data used to develop an operating longitudinal c.g. envelope of possible vehicle configurations as presented in Figure 4.2-4. Varying disposable loads causes a maximum dispersion of the vertical center-of-gravity (c.g.) position of 10.5 inches. Lateral c.g. location variance is small, the maximum difference being 0.7 inch. The maximum variation in the longitudinal position is 7.1 inch. Weight estimates for the fully loaded condition are based on layout analysis (17.0% of weight), procurement sources (19.9%), customer data and equipment lists (35.9%), empirical analysis (4.8%), performance analysis requirements (1.7%) and statistical methods (20.6%). Areas where these techniques were applied are identified in Figure 4.2-5. This table presents the estimating rationale in terms of vehicle subsystems, empty and gross weights, and appropriate percentages.

4.3 STABILITY AND CONTROL

4.3.1 Wheelborne

4.3.1.1 Wheelborne Stability - Stability in the wheelborne mode is provided by the wheel/suspension system characteristics and proper wheel base and wheel tread. A combined tire/suspension stiffness of 12,000 lb/ft per wheel or 48,000 lb/ft total has been selected for the design. This stiffness results in an undamped natural heave frequency of 1.14 and 1.47 hertz at the loaded and empty weights, respectively. The wheel dampers have been sized to provide a damping coefficient of 1668 lb/fps per wheel or 6672 lb/fps total. This provides a damping ratio of 0.5 and 0.65 at the loaded and empty weights, respectively. These frequencies and damping ratios are typical for vehicles that must operate both on and off road and were selected based on BAT's experience with wheeled and tracked armored vehicles.

ACCRV WEIGHT, CENTER OF GRAVITY LOCATION AND MOMENTS OF INERTIA

WBS	DESCRIPTION	WT(LB)	X(IN)	Y(IN)	Z(IN)	WT*X	WT*Y	WT*Z	WT*X^2	WT*Y^2	WT*Z^2	ISELFxx	ISELFyy	ISELFzz	LX	LY	LZ
1.01.01	HULL, STRUCTURAL FRAME	2112.0	226.0	0.0	40.0	4.773E+05	0.000E+00	8.448E+04	1.079E+08	0.000E+00	3.379E+06	2.804E+06	1.484E+07	1.556E+07	280.0	100.0	77.0
1.01.02	CAB AND EQUIPMENT COMPARTMENTS	1082.0	40.0	0.0	30.0	4.328E+04	0.000E+00	3.246E+04	1.731E+06	0.000E+00	9.738E+05	1.343E+06	7.146E+05	1.174E+06	55.0	100.0	70.0
1.01.03	PLATFORM AND PLATFORM STRUCTURE	129.0	110.0	0.0	75.0	1.419E+04	0.000E+00	9.675E+03	1.561E+06	0.000E+00	7.256E+05	8.725E+04	3.634E+04	1.232E+05	58.0	90.0	4.0
1.01.04	CREW AND PASSENGER ACCOMODATIONS	232.0	50.0	0.0	40.0	1.160E+04	0.000E+00	9.280E+03	5.800E+05	0.000E+00	3.712E+05	6.187E+04	1.005E+05	1.005E+05	60.0	40.0	40.0
1.01.05	APPENDAGES	113.0	174.0	0.0	40.0	1.966E+04	0.000E+00	4.520E+03	3.421E+06	0.000E+00	1.808E+05	7.533E+04	6.516E+05	6.968E+05	260.0	80.0	40.0
1.01.06	FUEL TANK BLADDER	23.0	149.0	-28.0	5.0	3.427E+03	-6.440E+02	1.150E+02	5.106E+05	1.803E+04	5.750E+02	3.534E+03	6.356E+03	8.357E+03	54.0	38.0	20.0
1.01.07	INTEGRATION AND ASSEMBLY	258.0	174.0	0.0	40.0	4.489E+04	0.000E+00	1.032E+04	7.811E+06	0.000E+00	4.128E+05	1.570E+05	1.473E+06	1.591E+06	260.0	80.0	30.0
1.01.00	HULL AND FRAME	WT(LB)	XCG(IN)	YCG(IN)	ZCG(IN)	WT*X	WT*Y	WT*Z	WT*X^2	WT*Y^2	WT*Z^2	ISELFxx	ISELFyy	ISELFzz	LX	LY	LZ
	SUBTOTAL	3949.0	155.6	-0.2	38.2	6.144E+05	-6.440E+02	1.509E+05	1.235E+08	1.803E+04	6.044E+06	4.532E+06	1.782E+07	1.925E+07			
1.02.01	SPRING SYSTEM	412.0	178.0	0.0	10.0	7.334E+04	0.000E+00	4.120E+03	1.305E+07	0.000E+00	4.120E+04	1.991E+05	1.350E+06	1.487E+06	196.0	70.0	30.0
1.02.02	FRONT AXLE (INCL. DIFFERENTIAL, STEERING, BRAKE DRUMS)	1133.0	80.0	0.0	0.0	9.064E+04	0.000E+00	0.000E+00	7.251E+06	0.000E+00	0.000E+00	5.004E+05	7.553E+04	5.004E+05	20.0	70.0	20.0
1.02.03	REAR AXLE (INCL. DIFFERENTIAL, BRAKES, DRUMS, YOKES)	799.0	276.0	0.0	-20.0	2.202E+05	0.000E+00	-1.596E+04	6.079E+07	0.000E+00	3.192E+05	3.525E+05	5.320E+04	3.525E+05	20.0	70.0	20.0
1.02.04	WHEELS (4)	1170.0	178.0	0.0	-10.0	2.083E+05	0.000E+00	-1.170E+04	3.707E+07	0.000E+00	1.170E+05	5.387E+05	3.806E+06	4.223E+06	196.0	70.0	25.0
1.02.05	TIRES (4)	1339.0	178.0	0.0	-10.0	2.383E+05	0.000E+00	-1.339E+04	4.242E+07	0.000E+00	1.339E+05	7.727E+05	4.513E+06	4.833E+06	196.0	70.0	45.0
1.02.06	WEIGHT DISTRIBUTION SYSTEM (STRUTS)	232.0	258.0	0.0	20.0	5.986E+04	0.000E+00	4.640E+03	1.544E+07	0.000E+00	9.280E+04	1.184E+05	2.803E+04	9.908E+04	15.0	70.0	35.0
1.02.07	CONTROLS	36.0	20.0	0.0	40.0	7.200E+02	0.000E+00	1.440E+03	1.440E+04	0.000E+00	5.760E+04	1.275E+03	3.750E+02	1.500E+03	10.0	20.0	5.0
1.02.08	TIRE AIR PRESSURE SYSTEM	62.0	178.0	0.0	30.0	1.104E+04	0.000E+00	1.860E+03	1.964E+06	0.000E+00	5.580E+04	1.033E+03	1.033E+03	1.033E+03	10.0	10.0	10.0
1.02.09	INTEGRATION AND ASSEMBLY	15.0	178.0	0.0	30.0	2.670E+03	0.000E+00	4.500E+02	4.753E+05	0.000E+00	1.350E+04	6.156E+03	4.805E+04	5.415E+04	196.0	70.0	5.0
1.02.00	SUSPENSION	WT(LB)	XCG(IN)	YCG(IN)	ZCG(IN)	WT*X	WT*Y	WT*Z	WT*X^2	WT*Y^2	WT*Z^2	ISELFxx	ISELFyy	ISELFzz	LX	LY	LZ
	SUBTOTAL	5197.0	174.2	0.0	-5.5	9.051E+05	0.000E+00	-2.854E+04	1.785E+08	0.000E+00	8.310E+05	2.490E+06	9.875E+06	1.155E+07			

Figure 4.2-1. ACCRV Mass Properties Analysis (Sheet 1 of 4)

```
1.03.01  ENGINE                          2318.0   214.0     0.0    35.0  4.961E+05  0.000E+00  8.113E+04  1.062E+08  0.000E+00  2.840E+06  3.574E+05  4.105E+05  2.946E+05   30.0   25.0   35.0

1.03.02  INDUCTION/EXHAUST                129.0   214.0     0.0    35.0  2.761E+04  0.000E+00  4.515E+03  5.908E+06  0.000E+00  1.580E+05  5.375E+03  1.075E+04  1.398E+04   30.0   20.0   10.0

1.03.03  COOLING/RADIATOR                 219.0   244.0     0.0    45.0  5.344E+04  0.000E+00  9.855E+03  1.304E+07  0.000E+00  4.435E+05  5.439E+04  1.250E+04  4.221E+04    3.0   48.0   26.0

1.03.04  ENGINE CONTROLS                   26.0   214.0     0.0    35.0  5.564E+03  0.000E+00  9.100E+02  1.191E+06  0.000E+00  3.185E+04  1.083E+03  1.083E+03  1.733E+03   20.0   20.0   10.0

1.03.05  POWER TAKE-OFFS (INCL. 1.03.01)

1.03.06  ENGINE ELECTRICAL (INCL. 1.03.01)

1.03.07  INTEGRATION AND ASSEMBLY          26.0   278.0     0.0     0.0  7.228E+03  0.000E+00  0.000E+00  2.009E+06  0.000E+00  0.000E+00  9.208E+02  9.208E+02  1.733E+03   20.0   20.0    5.0
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
1.03.00  PROPULSION                    WT(LB)  XCG(IN) YCG(IN) ZCG(IN)    WT*X       WT*Y       WT*Z     WT*X^2     WT*Y^2     WT*Z^2    ISELFxx    ISELFyy    ISELFzz       LX     LY     LZ
         SUBTOTAL                        2718.0   217.0     0.0    35.5  5.899E+05  0.000E+00  9.641E+04  1.283E+08  0.000E+00  3.473E+06  4.191E+05  4.357E+05  3.542E+05
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

1.04.01  TRANSMISSION, WET               1082.0   164.0     0.0    26.0  1.774E+05  0.000E+00  2.813E+04  2.910E+07  0.000E+00  7.314E+05  6.528E+04  1.735E+05  1.803E+05   40.0   20.0   18.0

1.04.02  TRANSFER CASE (DROP BOX)         103.0   140.0     0.0    16.0  1.442E+04  0.000E+00  1.648E+03  2.019E+06  0.000E+00  2.637E+04  5.493E+03  5.253E+03  8.583E+02    6.0    8.0   24.0

1.04.03  POWER DIVIDER                    480.0   190.0     0.0    27.4  9.120E+04  0.000E+00  1.315E+04  1.733E+07  0.000E+00  3.604E+05  2.592E+04  1.492E+04  1.492E+04    7.0   18.0   18.0

1.04.04  SHAFTS AND COUPLINGS             170.0   178.0     0.0     8.0  3.026E+04  0.000E+00  1.360E+03  5.386E+06  0.000E+00  1.088E+04  4.817E+02  2.044E+05  2.041E+05  120.0    3.0    5.0

1.04.05  DISK BRAKES AND CONTROLS
         (INCL.IN 102.02; 102.03)
1.04.06  STEERING CONTROLS                160.0    60.0     0.0    10.0  9.600E+03  0.000E+00  1.600E+03  5.760E+05  0.000E+00  1.600E+04  2.267E+04  3.333E+04  1.333E+04   30.0   10.0   40.0

1.04.07  THROTTLE/REVERSE/FUEL CONTROLS    26.0   178.0     0.0     0.0  4.628E+03  0.000E+00  0.000E+00  8.238E+05  0.000E+00  0.000E+00  4.333E+02  1.083E+03  1.083E+03   20.0   10.0   10.0

1.04.08  CLUTCHES/COUPLINGS               185.0   178.0     0.0    28.0  3.293E+04  0.000E+00  5.180E+03  5.862E+06  0.000E+00  1.450E+05  1.233E+04  7.708E+03  7.708E+03   10.0   20.0   20.0

1.04.09  REAR AXLE DRIVE  CHAIN & BOX     252.0   267.0     0.0    -8.0  6.728E+04  0.000E+00 -2.016E+03  1.796E+07  0.000E+00  1.613E+04  9.710E+04  7.400E+04  1.281E+05   50.0   60.0   32.0

1.04.10  PADDLE WHEELS (2)                453.0   261.0     0.0   -22.0  1.182E+05  0.000E+00 -9.966E+03  3.086E+07  0.000E+00  2.193E+05  1.625E+05  1.208E+05  1.625E+05   40.0   52.0   40.0

1.04.11  INTEGRATION AND ASSEMBLY          26.0   178.0     0.0    30.0  4.628E+03  0.000E+00  7.800E+02  8.238E+05  0.000E+00  2.340E+04  5.633E+03  2.188E+04  2.708E+04  100.0   50.0   10.0
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
1.04.00  AUTOMOTIVE/MARINE DRIVE TRAIN WT(LB)  XCG(IN) YCG(IN) ZCG(IN)    WT*X       WT*Y       WT*Z     WT*X^2     WT*Y^2     WT*Z^2    ISELFxx    ISELFyy    ISELFzz       LX     LY     LZ
         SUBTOTAL                        2937.0   187.5     0.0    13.6  5.506E+05  0.000E+00  3.987E+04  1.107E+08  0.000E+00  1.549E+06  3.978E+05  6.568E+05  7.400E+05
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

1.05.01  FOLD-DOWN PANELS AND HARDWARE    659.0   174.0     0.0     1.0  1.147E+05  0.000E+00  6.590E+02  1.995E+07  0.000E+00  6.590E+02  1.780E+06  4.964E+04  1.829E+06   30.0  180.0    2.0

1.05.02  FINGERS AND ATTACHMENTS          536.0   186.0     0.0   -10.0  9.970E+04  0.000E+00 -5.360E+03  1.854E+07  0.000E+00  5.360E+04  1.750E+06  5.064E+06  6.711E+06  335.0  195.0   34.0

1.05.03  RETRACTION SYSTEM                155.0   182.0     0.0    10.0  2.821E+04  0.000E+00  1.550E+03  5.134E+06  0.000E+00  1.550E+04  1.596E+05  8.765E+05  1.029E+06  260.0  110.0   16.0
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
1.05.00  SKIRT SYSTEM                  WT(LB)  XCG(IN) YCG(IN) ZCG(IN)    WT*X       WT*Y       WT*Z     WT*X^2     WT*Y^2     WT*Z^2    ISELFxx    ISELFyy    ISELFzz       LX     LY     LZ
         SUBTOTAL                        1350.0   179.7     0.0    -2.3  2.426E+05  0.000E+00 -3.151E+03  4.363E+07  0.000E+00  6.976E+04  3.689E+06  5.990E+06  9.569E+06
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
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Figure 4.2-1. ACCRV Mass Properties Analysis (Sheet 2 of 4)

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1.06.01  FAN ASSEMBLIES (2)                 335.0    330.0     0.0    36.0  1.106E+05  0.000E+00  1.206E+04  3.648E+07  0.000E+00  4.342E+05  2.268E+05  1.703E+05  2.575E+05   60.0   75.0   50.0

1.06.02  DRIVE SHAFTS/COUPLINGS             129.0    278.0     0.0    30.0  3.586E+04  0.000E+00  3.870E+03  9.970E+06  0.000E+00  1.161E+05  1.247E+03  5.375E+04  5.285E+04   70.0    4.0   10.0

1.06.03  SHAFT AND GEARBOX                  187.0    326.0     0.0    35.0  6.096E+04  0.000E+00  6.545E+03  1.987E+07  0.000E+00  2.291E+05  8.477E+03  5.750E+03  9.740E+03   15.0   20.0   12.0

1.06.04  FAN CONTROLS                        20.0    330.0     0.0    36.0  6.600E+03  0.000E+00  7.200E+02  2.178E+06  0.000E+00  2.592E+04  3.333E+02  8.333E+02  8.333E+02   20.0   10.0   10.0

1.06.05  INTEGRATION AND ASSEMBLY            20.0    330.0     0.0    36.0  6.600E+03  0.000E+00  7.200E+02  2.178E+06  0.000E+00  2.592E+04  3.333E+02  6.167E+03  6.167E+03   60.0   10.0   10.0
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
1.06.00  LIFT SYSTEM                      WT(LB)  XCG(IN) YCG(IN) ZCG(IN)       WT*X       WT*Y       WT*Z    WT*X^2    WT*Y^2    WT*Z^2   ISELFxx    ISELFyy    ISELFzz         LX     LY     LZ
         SUBTOTAL                          691.0    319.2     0.0    34.6  2.206E+05  0.000E+00  2.392E+04  7.068E+07  0.000E+00  8.312E+05  2.372E+05  2.368E+05  3.271E+05
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

1.07.01  VEHICLE ELECTRICAL SYSTEM          438.0    210.0     0.0    35.0  9.198E+04  0.000E+00  1.533E+04  1.932E+07  0.000E+00  5.366E+05  6.570E+04  6.570E+04  6.570E+04   30.0   30.0   30.0

1.07.02  VEHICLE HYDRAULIC SYSTEM            82.0    178.0     0.0    10.0  1.460E+04  0.000E+00  8.200E+02  2.598E+06  0.000E+00  8.200E+03  5.467E+03  5.467E+03  5.467E+03   20.0   20.0   20.0

1.07.03  BOOM SYSTEM                        695.0    230.0     0.0    62.0  1.599E+05  0.000E+00  4.309E+04  3.677E+07  0.000E+00  2.672E+06  5.375E+04  3.628E+06  3.665E+06  250.0   28.0   12.0

1.07.04  BILGE SYSTEM                        31.0    178.0     0.0    10.0  5.518E+03  0.000E+00  3.100E+02  9.822E+05  0.000E+00  3.100E+03  5.167E+02  5.167E+02  5.167E+02   10.0   10.0   10.0

1.07.05  ENVIRONMENTAL CONTROL (A/C, HEAT)  206.0     65.0     0.0    40.0  1.339E+04  0.000E+00  8.240E+03  8.704E+05  0.000E+00  3.296E+05  3.090E+04  3.090E+04  3.090E+04   30.0   30.0   30.0

1.07.06  AUXILIARY EQUIPMENT (HOSES, REELS) 361.0    276.0     0.0    60.0  9.964E+04  0.000E+00  2.166E+04  2.750E+07  0.000E+00  1.300E+06  2.407E+05  1.564E+05  3.008E+05   60.0   80.0   40.0

1.07.07  FUEL SYSTEM                         67.0    130.0   -30.0    10.0  8.710E+03 -2.010E+03  6.700E+02  1.132E+06  6.030E+04  6.700E+03  1.117E+03  2.792E+03  2.792E+03   20.0   10.0   10.0

1.07.08  COMPRESSED AIR SYSTEM               93.0    178.0     0.0    20.0  1.655E+04  0.000E+00  1.860E+03  2.947E+06  0.000E+00  3.720E+04  6.200E+03  6.200E+03  6.200E+03   20.0   20.0   20.0

1.07.09  PUMPING SYSTEMS                    196.0    190.0     0.0    35.0  3.724E+04  0.000E+00  6.860E+03  7.076E+06  0.000E+00  2.401E+05  1.307E+04  1.307E+04  1.307E+04   20.0   20.0   20.0

1.07.10  INTEGRATION AND ASSEMBLY            26.0    178.0     0.0    40.0  4.628E+03  0.000E+00  1.040E+03  8.238E+05  0.000E+00  4.160E+04  5.471E+03  5.471E+03  1.083E+04   50.0   50.0    5.0
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
1.07.00  AUXILIARY SYSTEMS                WT(LB)  XCG(IN) YCG(IN) ZCG(IN)       WT*X       WT*Y       WT*Z    WT*X^2    WT*Y^2    WT*Z^2   ISELFxx    ISELFyy    ISELFzz         LX     LY     LZ
         SUBTOTAL                         2195.0    206.0    -0.9    45.5  4.521E+05 -2.010E+03  9.988E+04  1.000E+08  6.030E+04  5.174E+06  4.229E+05  3.915E+06  4.102E+06
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------


         EMPTY CONDITION                  WT(LB)  XCG(IN) YCG(IN) ZCG(IN)       WT*X       WT*Y       WT*Z    WT*X^2    WT*Y^2    WT*Z^2   ISELFxx    ISELFyy    ISELFzz
         TOTAL                           19037.0    187.8    -0.1    19.9  3.575E+06 -2.654E+03  3.792E+05  7.553E+08  7.833E+04  1.797E+07  1.219E+07  3.893E+07  4.590E+07


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Figure 4.2-1. ACCRV Mass Properties Analysis (Sheet 3 of 4)

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1.08.01  FUEL (75 GAL.)          525.0   142.0   -28.0    4.0  7.455E+04 -1.470E+04 2.100E+03 1.059E+07 4.116E+05 8.400E+03 6.755E+04 1.320E+05 1.908E+05  54.0  38.0  10.0

1.08.02  WATER (1000 GAL.)      8330.0   189.0     0.0   55.0  1.566E+06  0.000E+00 4.582E+05 2.944E+08 0.000E+00 2.520E+07 8.653E+06 9.763E+06 1.391E+07 104.0  96.9  57.0

1.08.03  AGENT (150 GAL.)       1250.0   188.0    28.0   10.0  2.350E+05  3.500E+04 1.250E+04 4.418E+07 9.800E+05 1.250E+05 1.771E+05 4.017E+05 5.254E+05  60.0  38.0  16.0

1.08.04  CREW (4)                680.0    50.0     0.0   60.0  3.400E+04  0.000E+00 4.080E+04 1.700E+06 0.000E+00 2.448E+06 5.553E+05 3.683E+05 3.683E+05  40.0  70.0  70.0

1.08.05  PASSENGERS (4)          680.0   100.0     0.0   60.0  6.800E+04  0.000E+00 4.080E+04 6.800E+06 0.000E+00 2.448E+06 5.553E+05 3.683E+05 3.683E+05  40.0  70.0  70.0
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
1.08.00  LOAD                    WT(LB) XCG(IN) YCG(IN) ZCG(IN)    WT*X       WT*Y      WT*Z     WT*X^2    WT*Y^2    WT*Z^2   ISELFxx   ISELFyy   ISELFzz    60.0   4.0  12.0
         SUBTOTAL               11465.0   172.5     1.8   48.4  1.978E+06  2.030E+04 5.544E+05 3.577E+08 1.392E+06 3.023E+07 1.001E+07 1.103E+07 1.536E+07
-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------


         LOADED CONDITION        WT(LB) XCG(IN) YCG(IN) ZCG(IN)    WT*X       WT*Y      WT*Z     WT*X^2    WT*Y^2    WT*Z^2   ISELFxx   ISELFyy   ISELFzz
         TOTAL                  30502.0   182.0     0.6   30.6  5.553E+06  1.765E+04 9.336E+05 1.113E+09 1.470E+06 4.820E+07 2.220E+07 4.997E+07 6.126E+07


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                                          ACCRV MASS PROPERTIES ANALYSIS SUMMARY


                                                C.G. LOCATION                 MOMENTS OF INERTIA (ABOUT C.G. AXIS)


             EMPTY CONDITION:

                        WEIGHT =  19037.0 LB.         XCG =    187.8 IN.             Ixx =   2.268E+07 LB-IN^2
                                                      YCG =     -0.1 IN.             Iyy =   1.332E+08 LB-IN^2
                                                      ZCG =     19.9 IN.             Izz =   1.299E+08 LB-IN^2


             LOADED CONDITION:

                        WEIGHT =  30502.0 LB.         XCG =    182.0 IN.             Ixx =   4.328E+07 LB-IN^2
                                                      YCG =      0.6 IN.             Iyy =   1.717E+08 LB-IN^2
                                                      ZCG =     30.6 IN.             Izz =   1.649E+08 LB-IN^2


      NOTE:  THE ORIGIN OF THE COORDINATE SYSTEM IS LOCATED AT
             THE VEHICLE FRONT CENTER, IN PLANE WITH THE LOWEST
             HORIZONTAL SURFACE.
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Figure 4.2-1. ACCRV Mass Properties Analysis (Sheet 4 of 4)

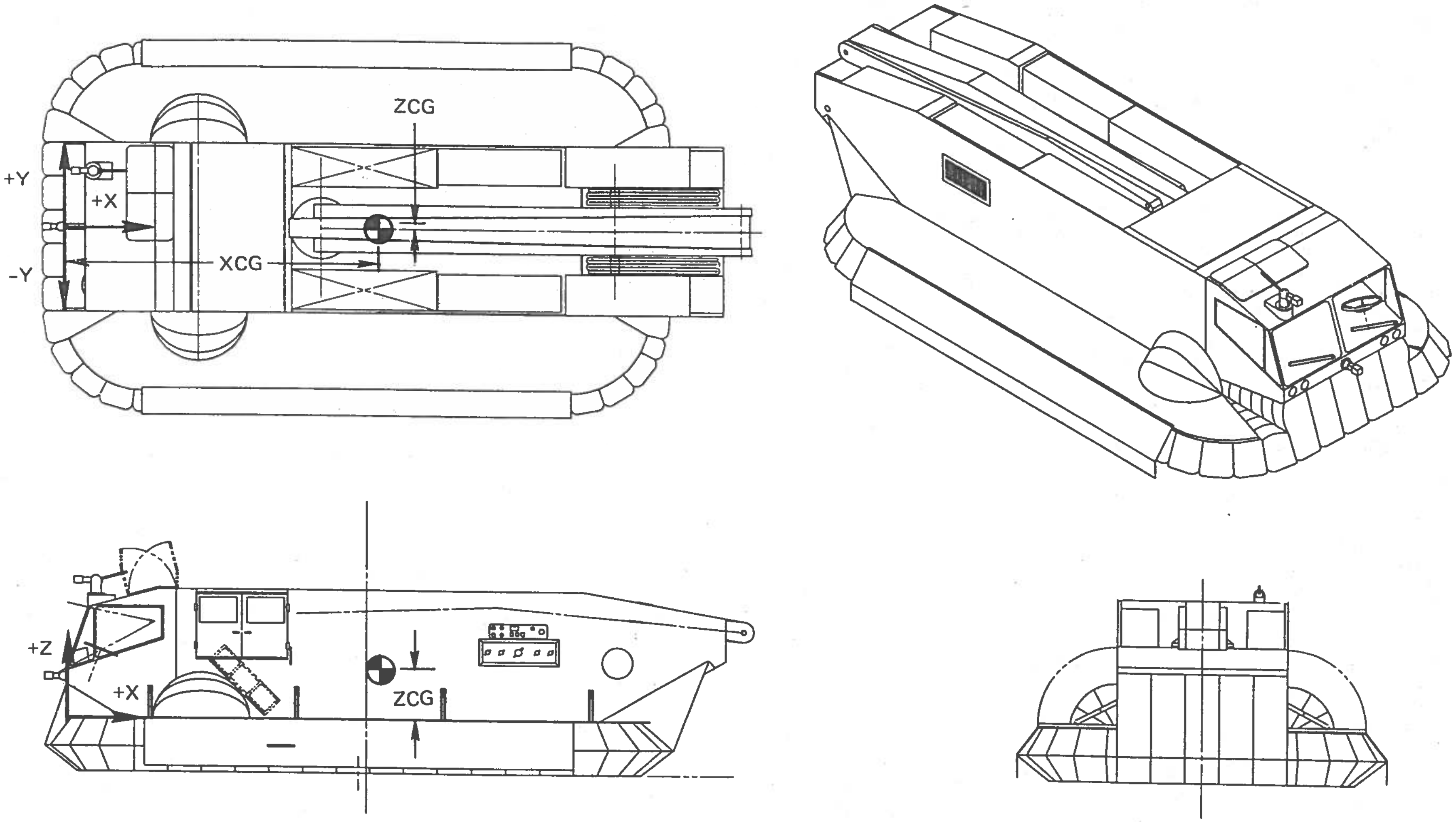
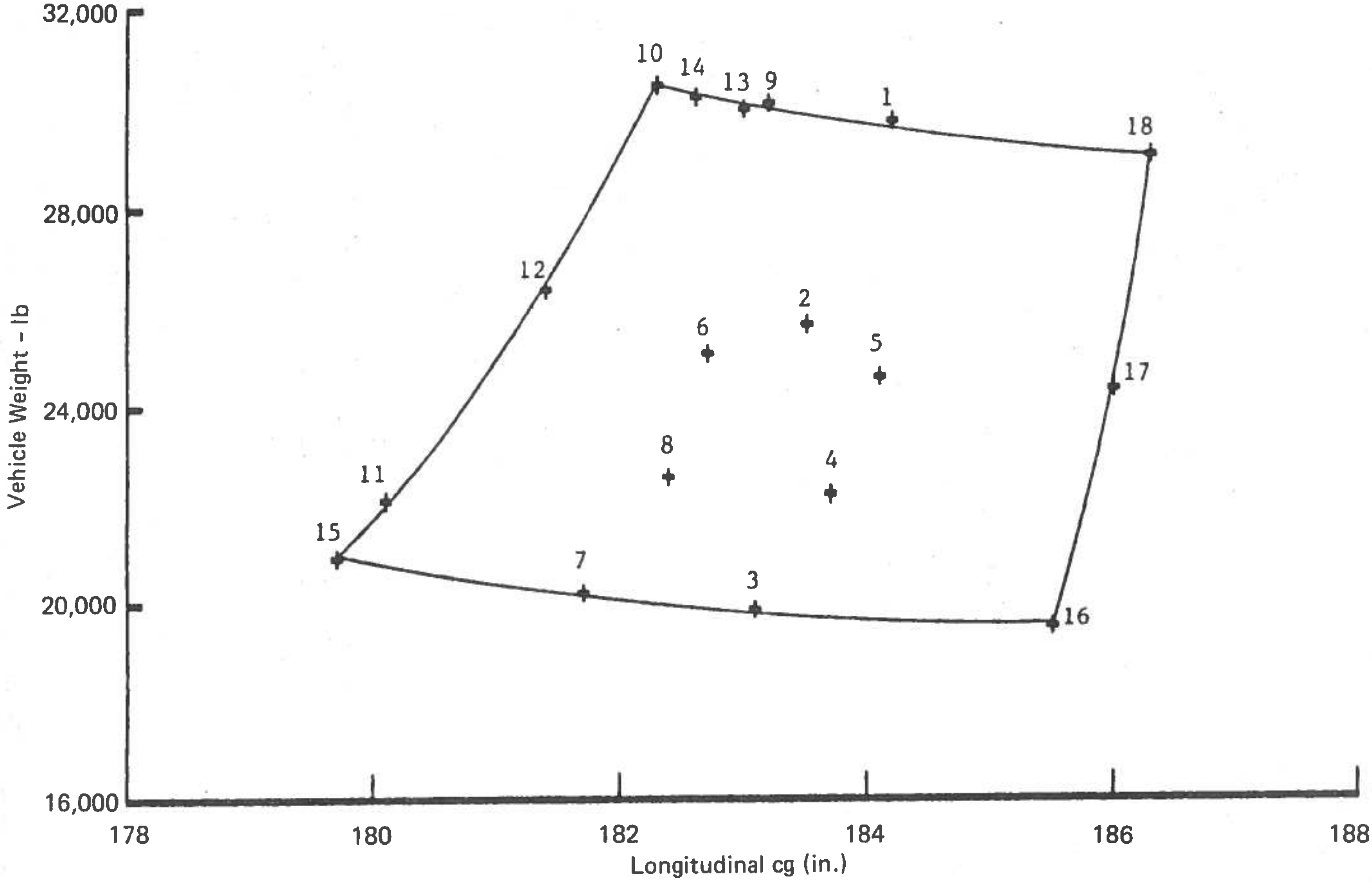


Figure 4.2-2. ACCRV Moment Reference Axes



Note: Numbers Correspond to Condition #'s on Table 4.2-2.

Figure 4.2-3. Longitudinal cg Envelope

CONDITION #	# PASSENGERS	# CREW	% FUEL	% WATER	% FOAM	GROSS VEHICLE WEIGHT LB	CENTER OF GRAVITY (IN.)			MOMENTS OF INERTIA LB-IN^2		
							X	Y	Z	Ixx	Iyy	Izz
1	0	4	100	100	100	29822.0	184.2	0.6	30.0	4.218E+07	1.684E+08	1.621E+08
2	0	4	100	50	100	25657.0	183.5	0.7	23.7	3.125E+07	1.569E+08	1.551E+08
3	0	4	25	0	0	19848.3	183.1	-0.3	21.3	2.457E+07	1.498E+08	1.454E+08
4	0	4	25	25	25	22243.3	183.7	0.1	22.2	2.688E+07	1.523E+08	1.493E+08
5	0	4	25	50	50	24638.3	184.1	0.5	24.2	3.012E+07	1.557E+08	1.532E+08
6	2	4	50	50	50	25109.5	182.7	0.3	24.6	3.102E+07	1.589E+08	1.561E+08
7	2	4	25	0	0	20188.3	181.7	-0.3	22.0	2.534E+07	1.528E+08	1.479E+08
8	2	4	25	25	25	22583.3	182.4	0.1	22.8	2.763E+07	1.553E+08	1.518E+08
9	2	4	100	100	100	30162.0	183.2	0.6	30.4	4.276E+07	1.712E+08	1.647E+08
10	4	4	100	100	100	30502.0	182.3	0.6	30.7	4.333E+07	1.741E+08	1.672E+08
11	4	4	100	0	100	22172.0	180.1	0.8	21.6	2.791E+07	1.572E+08	1.529E+08
12	4	4	100	50	100	26337.0	181.4	0.7	24.6	3.268E+07	1.627E+08	1.601E+08
13	4	4	0	100	100	29977.0	183.0	1.1	31.2	4.244E+07	1.727E+08	1.657E+08
14	4	4	50	100	100	30239.5	182.6	0.8	30.9	4.293E+07	1.734E+08	1.665E+08
15	4	4	100	0	0	20922.0	179.7	-0.8	22.3	2.657E+07	1.565E+08	1.513E+08
16	0	2	25	0	0	19508.3	185.5	-0.3	20.6	2.377E+07	1.430E+08	1.391E+08
17	0	2	25	50	50	24298.3	186.0	0.5	23.7	2.940E+07	1.488E+08	1.468E+08
18	0	2	25	100	100	29088.3	186.3	1.0	30.0	4.097E+07	1.606E+08	1.545E+08

Figure 4.2-4. ACCRV Operating Weight Conditions

DESCRIPTION	CONFIG. ESTIMATE	BASIS					
		LAYOUT ANALYSIS	PROCUREMENT SOURCE	CUSTOMER DATA AND EQUIPMENT LISTS	EMPIRICAL ANALYSIS	PERFORMANCE ANALYSIS REQUIREMENT	OTHER STATISTICS ETC. (1)
HULL AND FRAME	3949	3194					755
SUSPENSION	5197		1900				3297
PROPULSION	2818		2318		300		200
AUTO./MARINE DRIVE	2725	500	1215				1010
SKIRT SYSTEM	1350	750			600		
LIFT SYSTEM	751	751					
AUXILIARY SYSTEMS	2247		650		570		1027
EMPTY CONDITION	19037 (100%)	5195 (27.3%)	6083 (32.0%)	- (0%)	1470 (7.7%)	- (0%)	6289 (33.0%)
CREW AND PASSENGERS	1360			1360			
FUEL	525					525	
WATER AND AGENT	9850			9850			
GROSS VEHICLE	30502 (100%)	5195 (17.0%)	6083 (19.9%)	10940 (35.9%)	1470 (4.8%)	525 (1.7%)	6289 (20.6%)

(1) INCLUDES A DATA BASE OF PRIOR BELL PROGRAMS SES-100B, JEFF(B), LACV(30) WITH SCALING

Figure 4.2-5. ACCRV Conceptual Weight Estimating Rationale

With a wheelbase of 202 inches, the vertical suspension stiffness provides a pitch stiffness of 54,900 and 56,300 ft lb/deg at the loaded and empty conditions. At upward end wheel lift off, this results in maximlum restoring moment of 240,900 and 146,300 ft lb at the loaded and empty weights, respectively. With a wheel tread of 85 inches, the roll stiffness is 7900 and 9200 at the loaded and empty weights and the maximum restoring roll moment is 79,900 and 55,200 ft lb at the loaded and empty condition. The maximum restoring moments at loaded weight provide adequate margin for boom operation at full extension in all quadrants. At empty weight, they provide adequate margin in pitch for full fore/aft boom extension but are somewhat marginal in roll for full side boom extension. Because of this, the baseline design calls for extending and using the air cushion skirt side panels as but outriggers when using the boom.

For operation on side slopes, the ACCRV roll stiffness provides static stability on slopes with up to a 52% grade at the loaded weight and to a 74% grade at the empty weight condition.

4.3.1.2 Wheelborne Control - Steering control in the wheelborne mode is provided through front wheel steering. Independent suspension on a common front axle that acts as an "I" beam and proper selection of castor and camber angle insures high speed steering and cornering stability. Tight turns can be negotiated at low speeds yielding a wall to wall turning diameter of 1200 inches or 2.9 vehicle lengths, as shown in Figure 4.3-1.

4.3.2 Waterborne

4.3.2.1 Cushionborne Mode Stability

Heave Stability - The heave dynamics of an air cushion suspension system are represented by a third order characteristic equation instead of the second order equation that is typical for wheeled suspension system. The additional dynamic order for an ACV is due to the compressibility of the air in the cushion. This results in a lag in the air cylinder type damping from the cushion. The damping phase shift due to this lag is destabilizing and becomes more significant as the lag increases and/or as the heave stiffness increases. Bell and others have shown that the air cushion system becomes unstable whenever the compressibility lag time constant exceeds the characteristic stiffness time constant. This has led to the development of a heave stability index for ACV's of the form,

$$\mathrm{HSI} = \frac{\gamma \bar{P}_c h_{gap}}{h_c Q} \left[\frac{Q}{2P_c} - \frac{\partial Q}{\partial P}\,\mathrm{fan}\right] \geq 1 \text{ for stability}$$

where h_c = cushion depth

h_{gap} = gap height under cushion

P_c = gage cushion pressure

$\bar{P}_c$ = absolute cushion pressure

Q = cushion flow

$\frac{\partial Q}{\partial P}$ fan = fan slope

γ = process exponent (approximately 1.2 over water, based on tests)

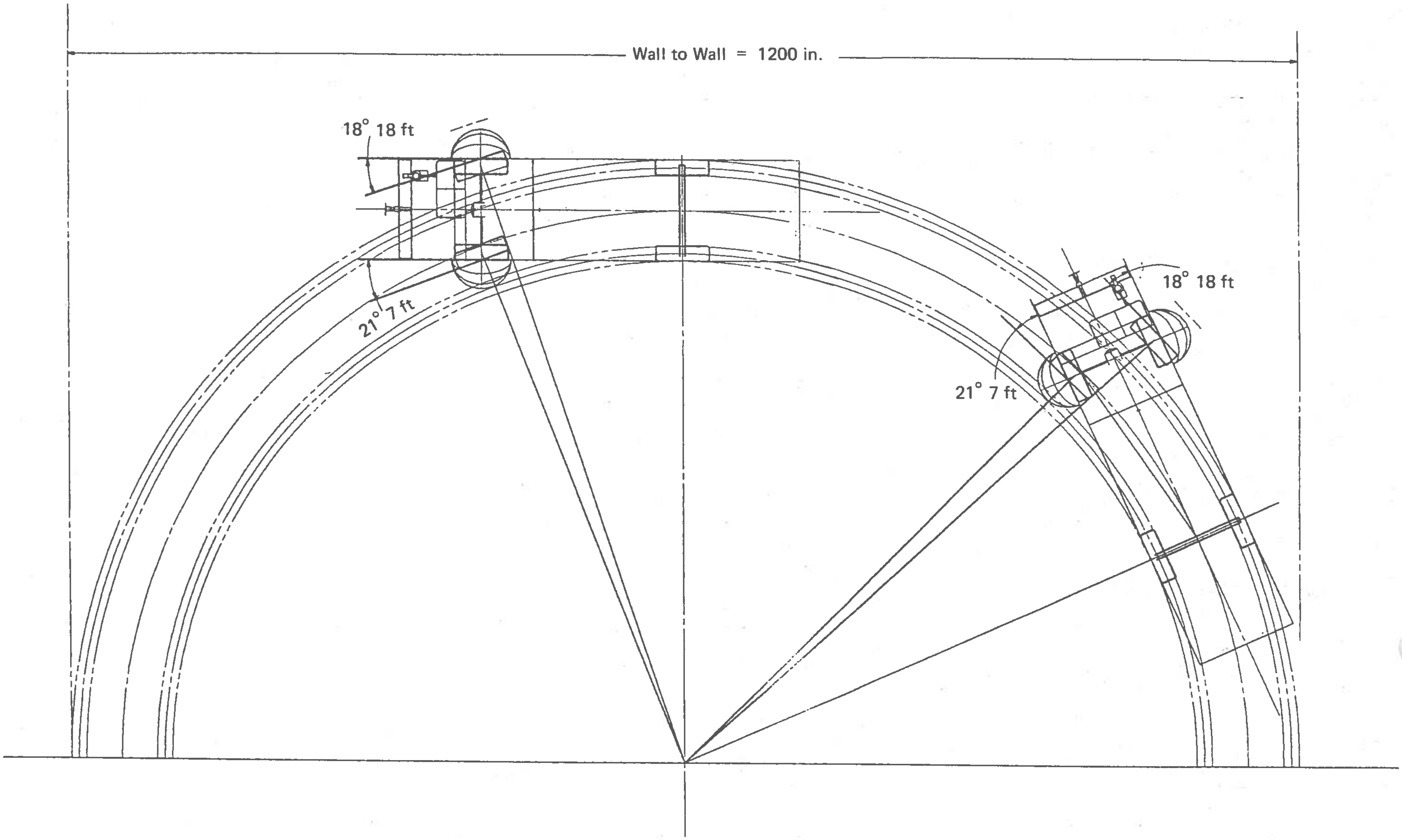


Figure 4.3-1. The turning diameter of the ACCRV at low speeds is less than 3 vehicle lengths.

Analysis of the ACCRV with this index shows that a conventional open finger seal with a uniform gap height could result in heave instabilities when operating the vehicle over a smooth, flat surface. The heave stability index in this case is 0.55 for 100% fan rpm and 0.75 for 70% fan rpm. To avoid this possibility over smooth water, the effective gap height on the ACCRV has been increased significantly by incorporating a series of air lube holes near the lower tips of the open fingers. By spacing these holes over a finger depth of about six inches and sizing them to nominally pass the 100% rpm cushion flow, the ACCRV must move down 6 inches to shut off the cushion flow rather than just the air gap height of only 0.75 inches. This makes the effective air gap look like 6 inches and reduces the vertical stiffness by the ratio of 6 over 0.75 or by a factor of 8.

The heave stability of the ACCRV with th;is finger design is 3.9 at 100% fan rpm and 5.3 at 70% fan rpm. Bell experience has hsown that there is more freedom to modify the effective gap height than any of the other ACV design parameters that influence stability. Modifying the gap height with finger lube holes was tested on the full scale Bell Air Cushion Equipment Transporter (ACET) and found radically improve heave stability without any significant adverse effects on drag.

Static Attitude Stability - Static attitude stability of the ACCRV is provided by the large inward taper of the bottom or skin face of the knee-shaped open fingers. High inward taper is obtained without sacrificing cushion area by the use of these knee type open fingers that cant outward at the top and then inward at the bottom. This results in a large increase in finger contact area and outward cushion center of pressure (CP) shift on the fingers that move downward as a result of any attitude change. As an example, right hand side down roll of the ACCRV results in a large increase in the contact area on the right hand skirt fingers and a restoring shift in cushion CP to the right. The predicted static pitch and roll stability with these fingers is shown in Figure 4.3-2 and 4.3-3, respectively. As shown in these figures, the stiffness increases more slowly at first. This is because an ACV initially rotates about the cg until an air gap is created on the upward side that is large enough to pass the cushion flow. After this, an ACV tends to rotate about the upward side and the stiffness increases more rapidly. This continues until the finger is immersed to the knee at which point the stiffness starts to decrease rapidly. For the ACCRV, this occurs at about 3.5 deg. in pitch and 5.5 deg. in roll. The maximum ACCRV pitch stiffness at this attitude is more than adequate for dynamic pitch stability. As shown, the ACCRV pitch stiffness results in static pitch trims of 1.8 and 2.5 degrees for the loaded and empty conditions respectively, both of which have longitudinal cg's aft of the cushion cp. This provides more than ample margin for dynamic plow in stability through hump speed but may result in higher than desired drag at top speeds. While the roll stiffness of the single cushion, open finger ACCRV is somewhat lower than that for most existing ACV's with multiple cushion compartments and/or closed fingers, analysis indicates that it is more than adequate for the relatively low speed, low wave height operating environment for the ACCRV. Neither the pitch or roll stiffness of the ACCRV on cushion, however, is adequate for operation of the rescue boom. For this operation, the ACCRV must go into a displacement mode to provide adequate stability.

Stability Against Plow In - Providing adequate stability against plow in is a key concern in the design of ACV's. Plow in can result from swamping by the cushion generated bow wave at speed below hump or from excessive seal drag and cp shifts at high speeds above hump. For the speed range of interest for the ACCRV, plow in at

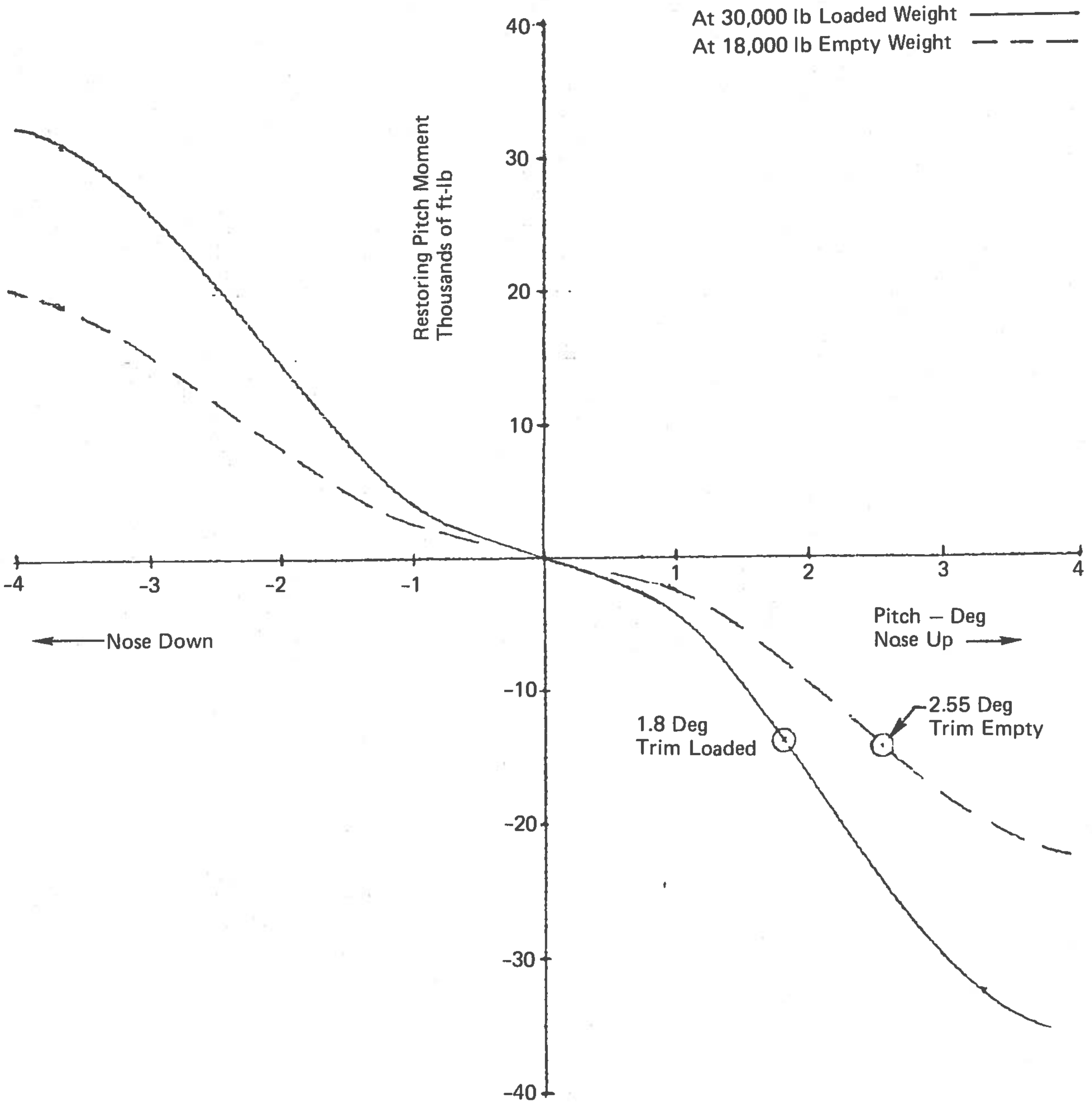


Figure 4.3-2. Static Pitch Stability – Overwater Cushionborne Mode

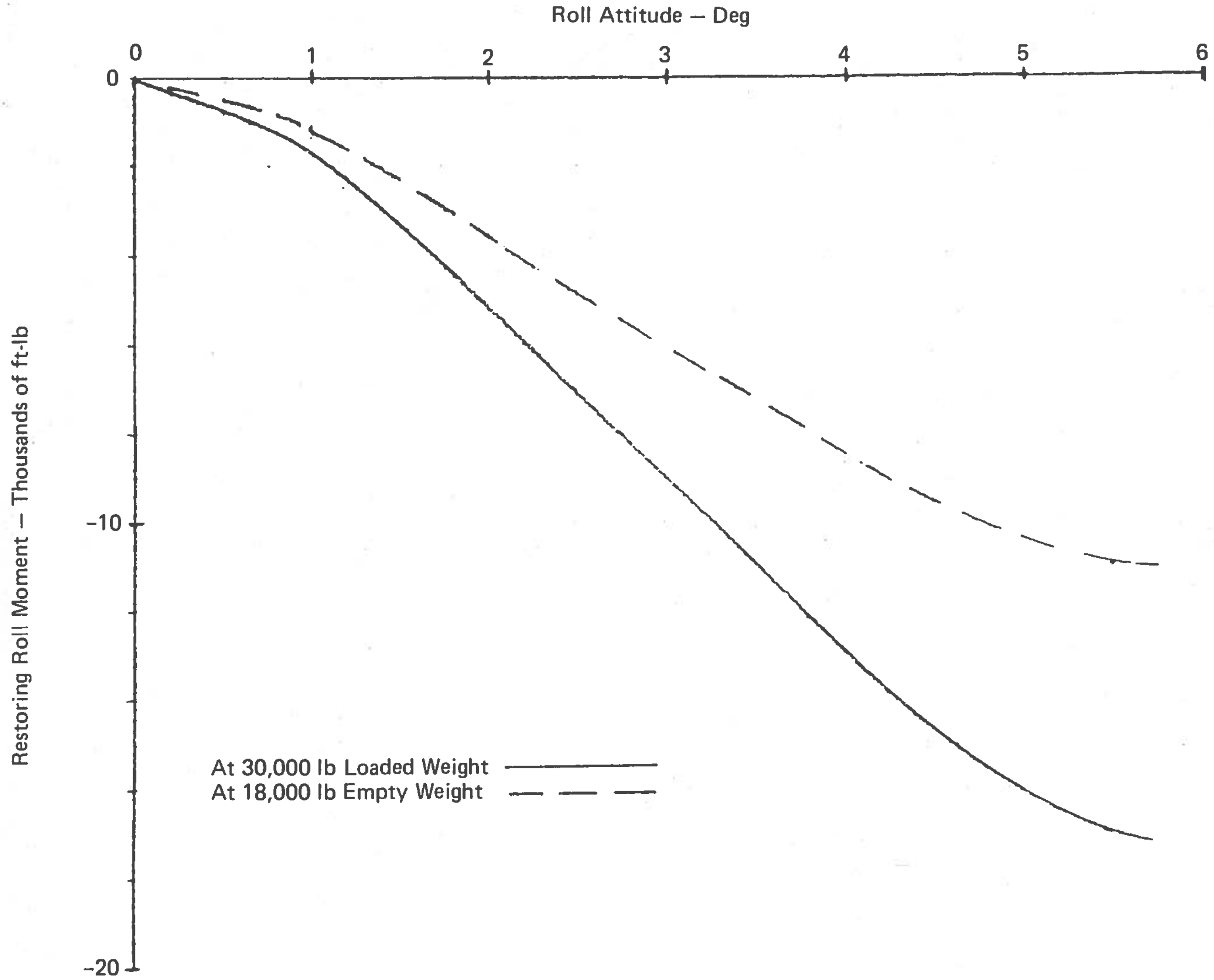


Figure 4.3-3. Static Roll Stability – Overwater Cushionborne Mode

speeds below hump is of primary concern. BAT experience with a wide range of ACV's has shown that the most severe plow in situation in this case results when the cushion generated wave has a wavelength that is approximately equal to the craft cushion length as illustrated in Figure 4.3-4. It occurs at about 60 to 70% of hump speed. The wave is quite large at this condition (height on the order of 22 inches for the ACCRV) and has a large trough near the center of the cushion. The creates a large air gap near the wave trough and the vehicle must settle rather deeply into the water to prevent excessive leakage through this gap and resulting loss of cushion pressure. The settling of the vehicle into the water can result in swamping of the fore seal fingers above the knee line by the fore crest of the wave if sufficient knee-line freeboard is not provided. Once this happens, the fore fingers collapse from green water pile up over the knee line and a plow in situation results. ACCRV stability against this condition is provided by a good static nose up pitch trim plus a high knee line on the fore fingers. Destabilizing nose down moments from the front wheels are eliminated by retracting them above the water line in this mode. Additional dynamic nose up trim is provided from the paddle wheel thrust. If excessive, it can be adjusted by changing the paddle wheel blade angle relative to the hub.

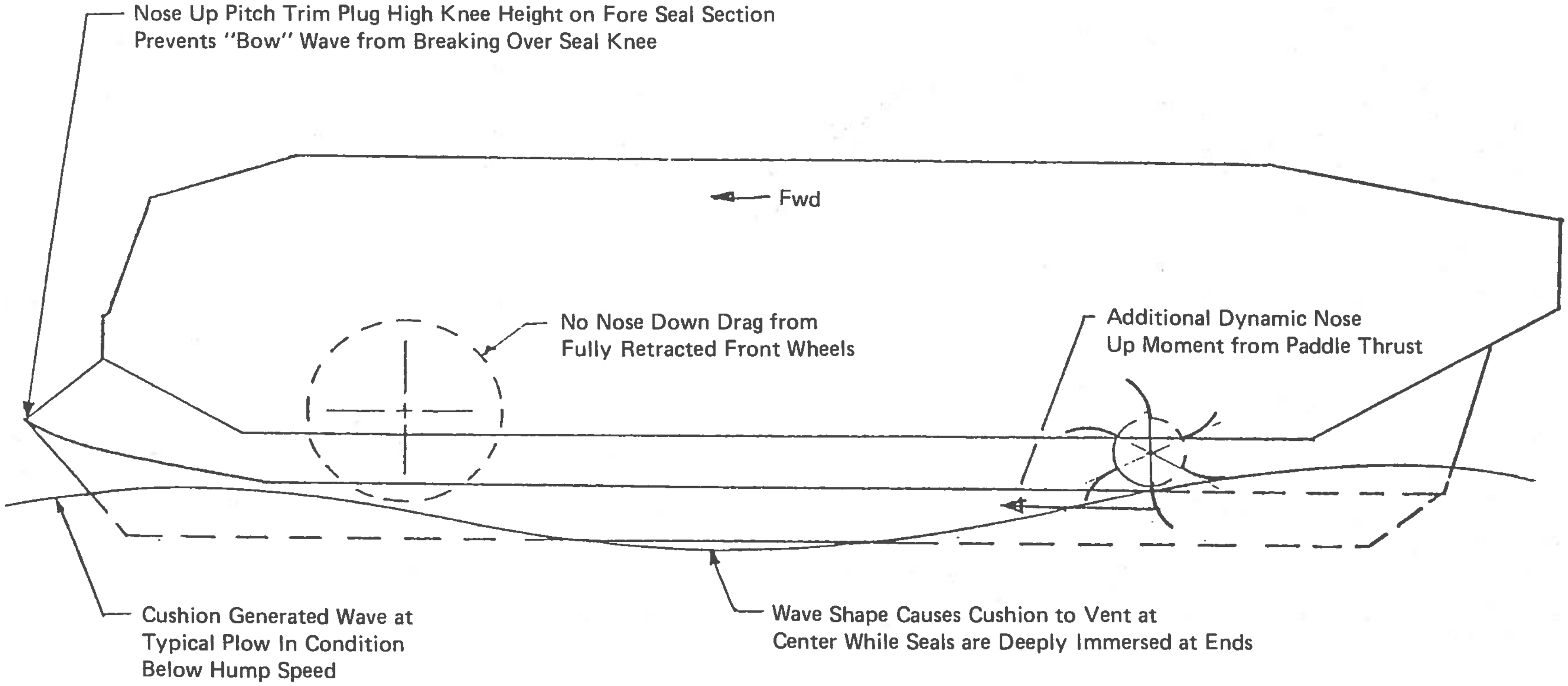


Figure 4.3-4. ACCRV Stability Against Low Speed Plow In

4.3.2.2 Displacement Mode Stability - Stability of the ACCRV in the displacement mode is provided by the body or hull and by 23 ft long spray skirt bags on the side panels. In the displacement mode, the bags are inflated to a 4 ft diameter and the panels are lowered to a position where the bags carry 2/3 or 20,000 lb of the 30,000 lb loaded ACCRV weight, while the hull carries the remaining 10,000 lb. Each bag is capable of displacing a maximum weight of 15,700 lb which provides a 38% reserve buoyancy with the bags alone and a reserve buoyancy in excess of 5% in the event that the craft interior should become flooded. The predicted static attitude stability with this design is compared with the tipping moments for full 44 ft 5 inches horizontal boom extension in Figure 4.3-5. As shown, the side bags provide most of the restoring stiffness in roll for boom operation to the side. For fore and aft boom operation, the bags are only about half as effective in providing pitch stiffness but the hull pitch stiffness tends to make up the majority of the loss. As shown, this results in a total restoring stiffness that is adequate for boom operation in all quadrants. The minimum reserve restoring stiffness is 36% for pitch up with aft boom operation. The static attitude for boom operation in all quadrants is shown in Figure 4.3-6 along with the attitudes for maximum restoring moment.

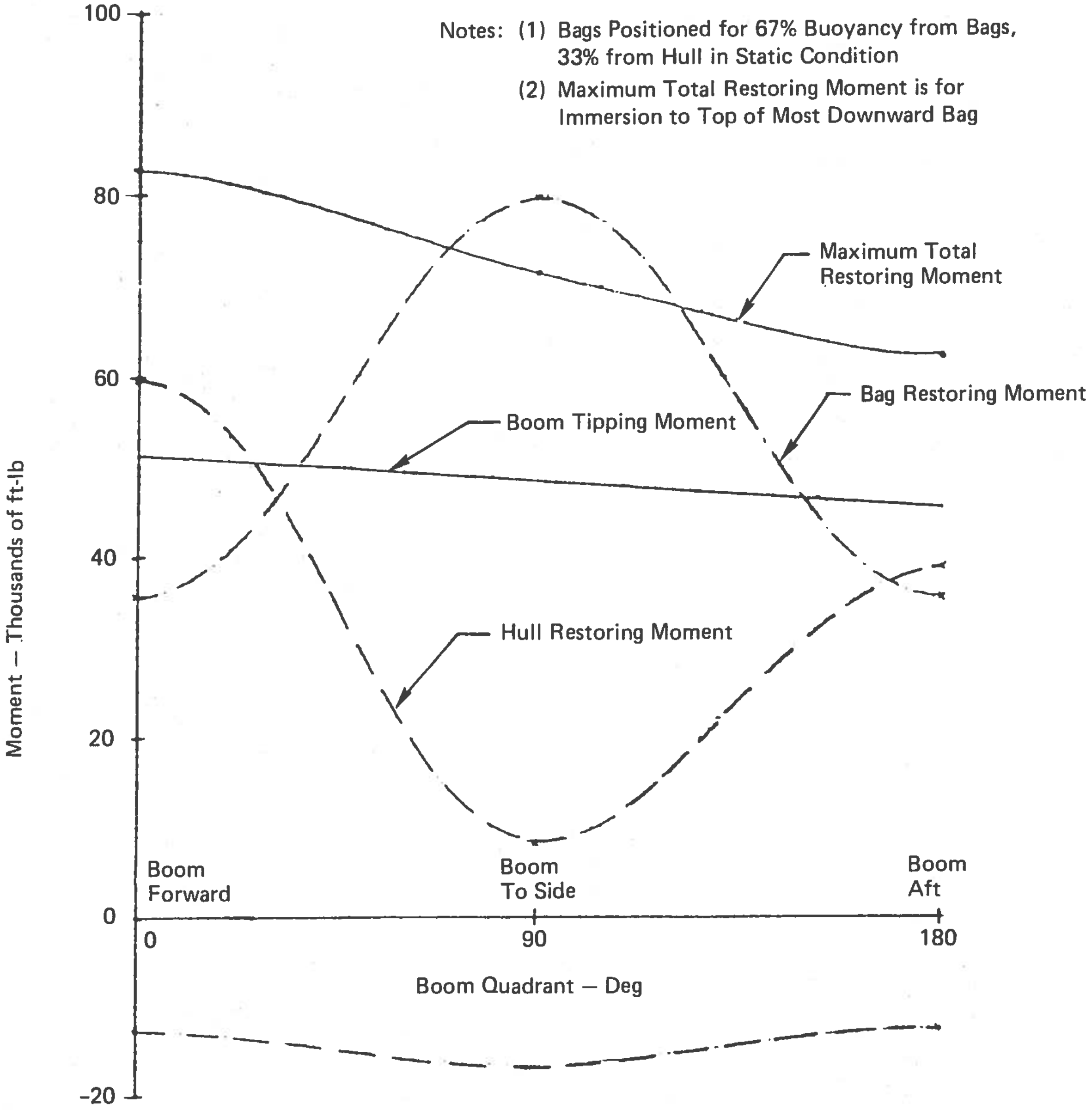


Figure 4.3-5. Static Attitude Stability – Overwater Displacement Mode

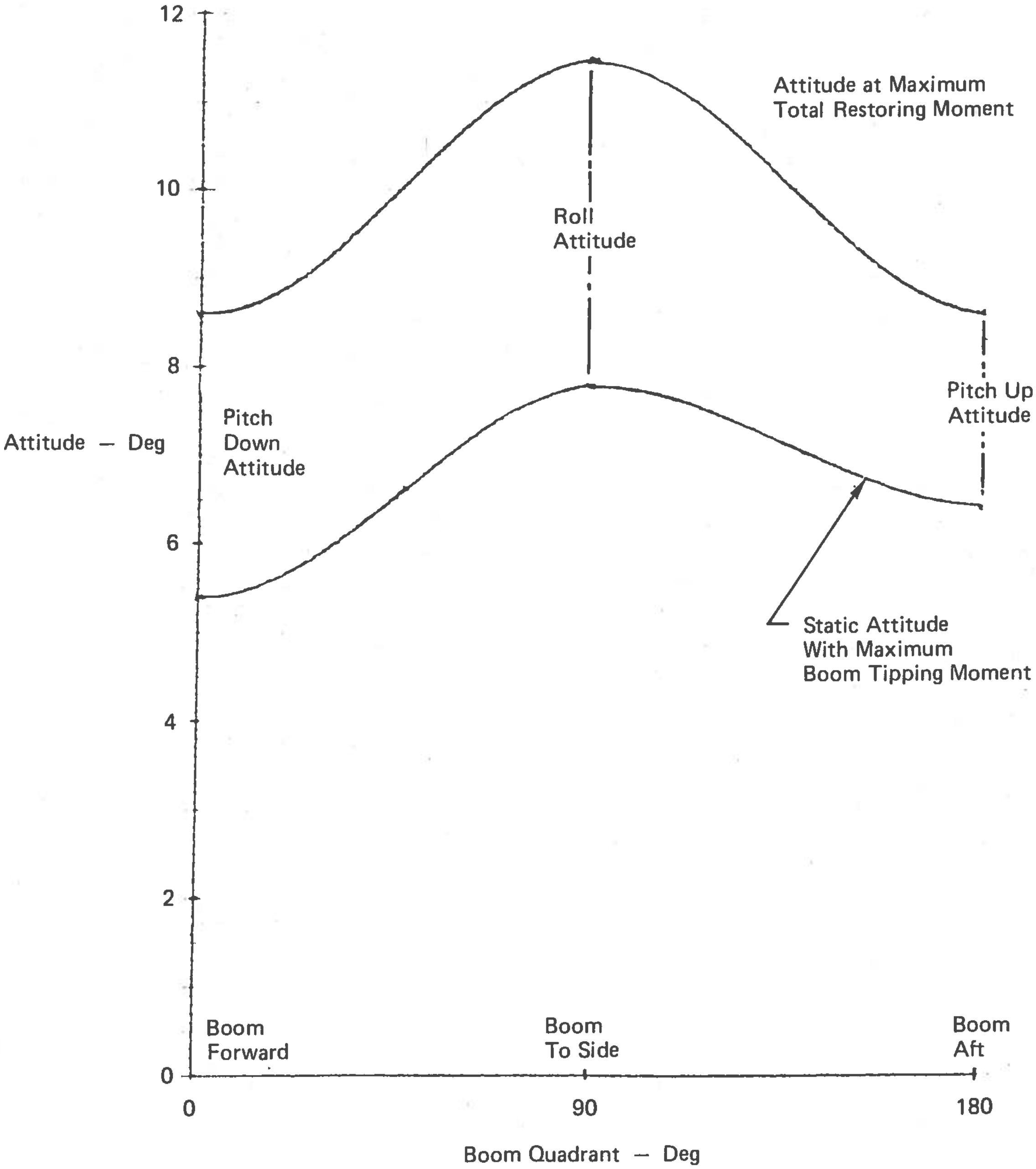


Figure 4.3-6. Static Attitudes — Overwater Displacement Mode

4.3.2.3 Waterborne Control - Waterborne steering control of the ACCRV in both the cushionborne and displacement modes is provided by using the independent aft wheel brakes to brake the wheel/paddle wheel on the side in the direction of the desired turn. This causes the braked paddle wheel to slow down and produce less thrust and the unbraked paddle wheel to speed up and produce more thrust. The differential thrust produces a yawing moment that turns the vehicle in the desired direction. Maximum control power is obtained by braking one paddle wheel to a stop. This causes the other paddle wheel to speed up as required to absorb the horsepower available. Except for some change in efficiency with speed, the thrust produced with the speeded up paddle wheel is essentially the same as that for both unbraked paddle wheels at the same horsepower. Thus, the maximum yaw control power available is roughly equal to the thrust times the lateral distance from the cg to the paddlewheel centers. The variation in on cushion yaw control power with speed is shown in Figure 4.3-7 for the maximum and cruise thrust conditions. As shown, the ACCRV has good control power at the on cushion cruise thrust above hump. At lower speeds, good control power levels can be obtained by temporarily increasing the thrust level towards maximum thrust during control maneuvers. This also applies to the low speed displacement mode.

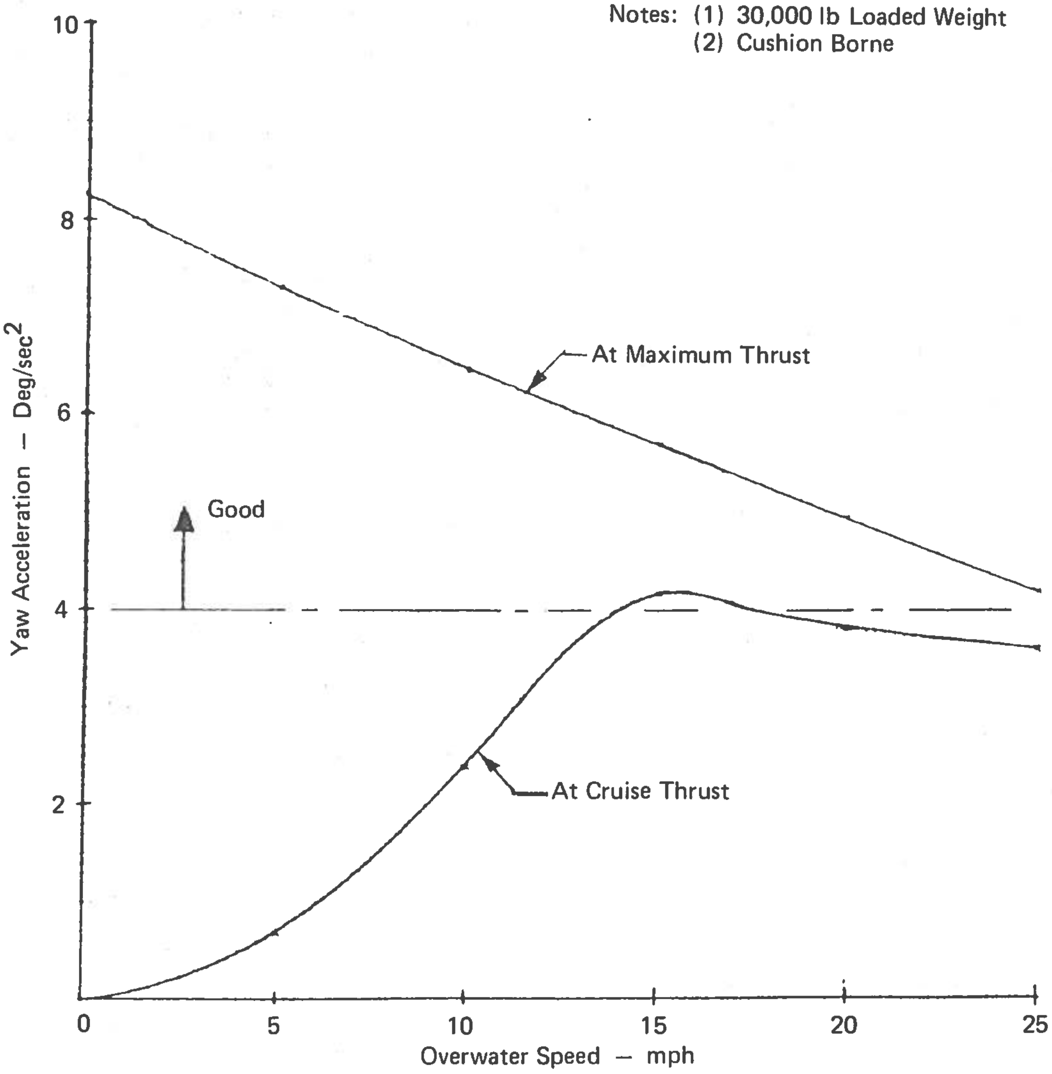


Figure 4.3-7. Overwater Control Power

Since the front wheels of the ACCRV are driven and steerable, it may be possible to obtain some additional low speed control power at the front end of the craft by proper selection of a tire design/tread that produces some thrust in water.

4.3.3 Hybrid

4.3.3.1 Hybrid Stability

Heave Stability - ACCRV stability in the hybrid mode was studied using the hybrid suspension model illustrated in Figure 4.3-8. Linearized root locus analysis of this model indicates that both the air cushion and wheel suspension contribute to provide stable operation over the full range of hybrid conditions of interest. This is shown in the root locus plots in Figure 4.3-9 for wheels that are actively controlled to carry a constant percentage of the vehicle weight without wheel springs and dampers active and for wheels that also have active springs and dampers for the nominal hybrid wheel load case of 30%. The pair of imaginary roots that lie above and below the seal axis in this figure are associated with the conventional second order rigid body suspension dynamics mode. They result primarily from the combined stiffness and damping of the air cushion and wheel suspension systems. The fact that they are off the real axis indicates that this mode is less than critically damped. In this case, the damping ratio is proportional to the inclination (from the horizontal) of a radial line from the original to the root. The root on the real axis results from air cushion compressibility dynamics. As shown, the hybrid system is quite stable with all roots well removed from the unstable right hand plane. The air cushion alone (0% weight on wheels) is stable and carrying increasing percentage of vehicle weight on the wheels (without suspension stiffness and damping) further improves the stability by moving all roots further away from the unstable right hand plane. It also improves the damping of the system as indicated by the movement of the pair of imaginary roots closer to the real axis.

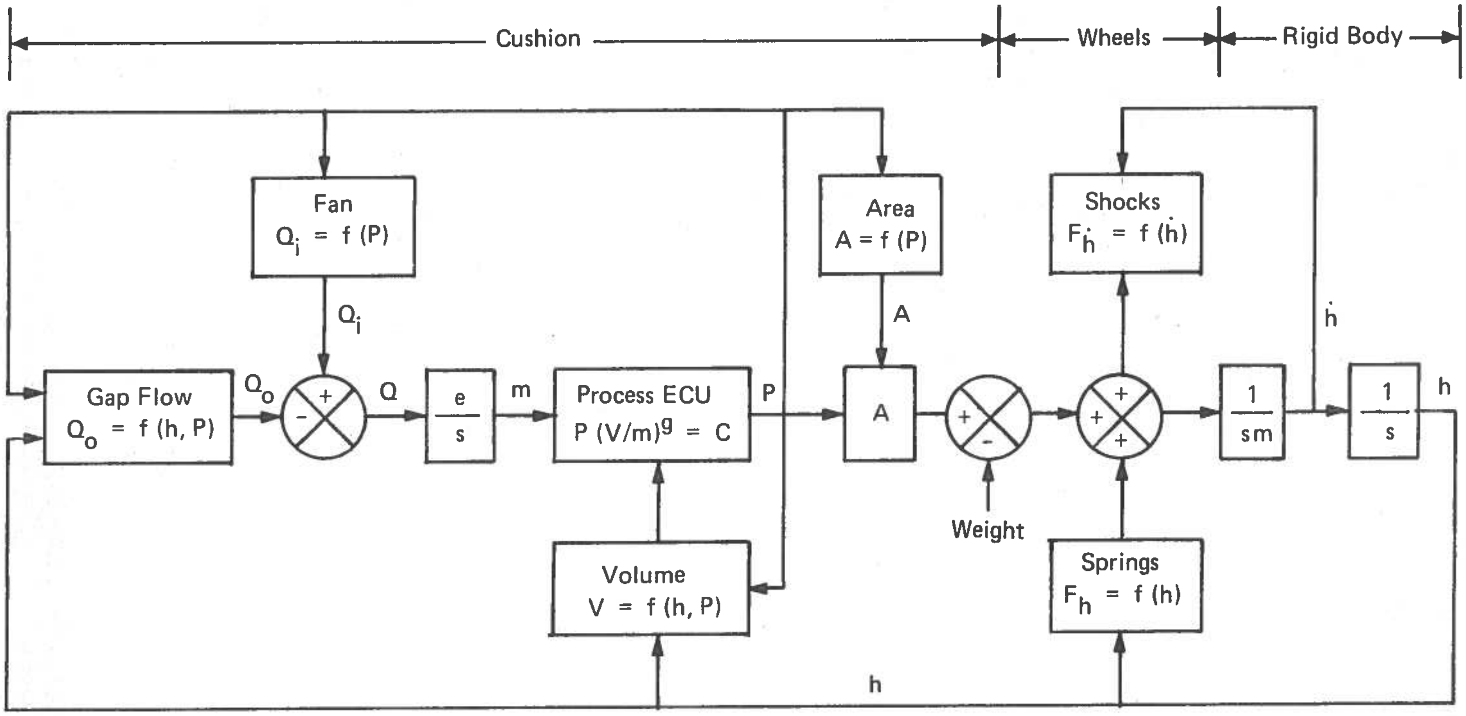


Figure 4.3-8. Hybrid Vehicle Model

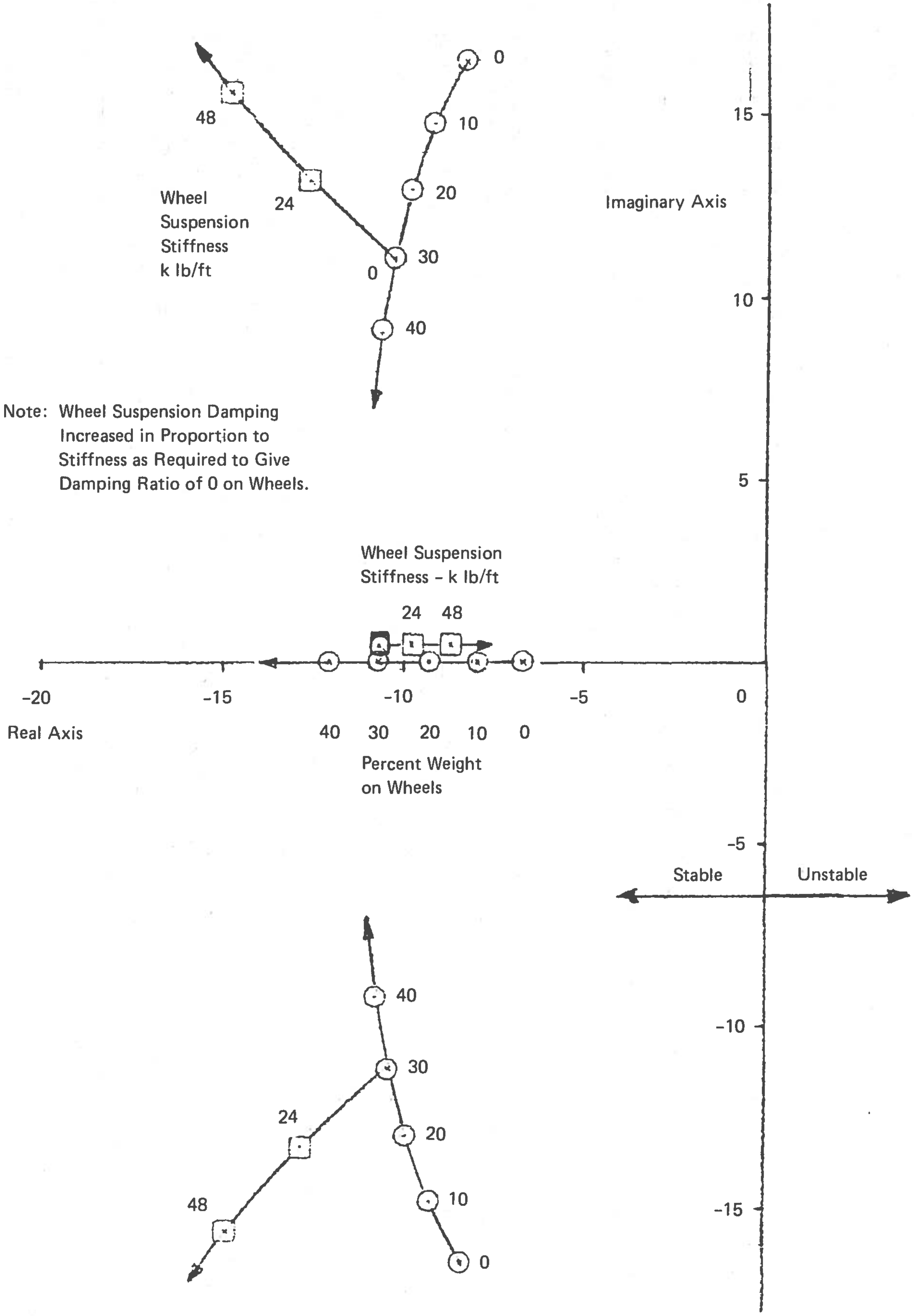


Figure 4.3-9. ACCRV Heave Stability in Hybrid Mode

Studies on the influence of adding wheel stiffness and damping independently have shown that adding wheel stiffness alone results in a significant decrease in damping but only a small decrease in stability margin. Adding wheel damping alone results in significant improvements in both stability margin and damping. Adding wheel stiffness and damping together as required to keep the wheelborne heave damping ratio constant results in a significant increase in stability of the second order rigid body suspension mode and a slight decrease in the stability of the cushion compressibility mode. Damping of the rigid body mode is essentially unchanged because the roots tend to move out on a radial line from the origin. The roots at a wheel suspension stiffness of 48,000 lb/ft are representeative of operation at normal wheel extension. Those at a stiffness approaching zero are large enough to go beyond the normal rebound range of the wheel springs. This could happen during operation in deep snow and during ditch crossing.

Attitude Stability - The static attitude stiffness in the hybrid mode can vary significantly depending on the wheel loading. At very low wheel loadings, it approaches the cushion only stiffness. At low wheel loadings, it is dominated by the wheel stiffness which is much higher than the cushion stiffness. The maximum cushion contribution in this case varies from 15% in pitch to 30% in roll. At the moderate wheel loadings of interest (30% weight on wheels), the high wheel stiffness results in excessive venting of the cushion with pitch and roll and loss of the cushion contribution unless the wheel position is actively controlled to maintain a constant combined loading on all four wheels as the ACCRV is pitching and rolling. Thus, for the range of hybrid wheel loading operating of interest (=10 to 30% weight on wheels), it can be assumed that the static hybrid pitch and roll stiffness will be approximately equal to the wheel pitch and roll stiffness for the wheelborne mode. However, since the amount of weight that is carried on the wheels is much less than in the wheelborne mode, the maximum restoring moment at upward wheel lift off is much less than for the wheelborne mode. The maximum restoring moment is equal to the sum of the cushion and wheel load fractions times the respective maximum cushion and wheel restoring moments. The maximum pitch and roll moments are shown in Figure 4.3-10 as a function of weight on the wheels. As shown, roll stability in the hybrid mode does not provide sufficient margin for operation of the boom at full extension. Pitch stability provides adequate margin for full extension of the boom for 15% or greater weight on the wheels but would require shorter boom extensions to prevent tipping for less than 10% weight on the wheels. Rather than restrict boom extension and/or quadrant of operation, it is planned to go to the wheelborne mode and extend the side panels until they come in contact with the pound before commencing boom operations.

4.3.3.2 Hybrid Control - Steering control in the hybrid mode is provided through front wheel steering. While not considered essential, additional steering control power is available by using the independent aft wheel brakes to brake the wheel on the ride in the direction of the desired turn, as is done on the water mode of operation.

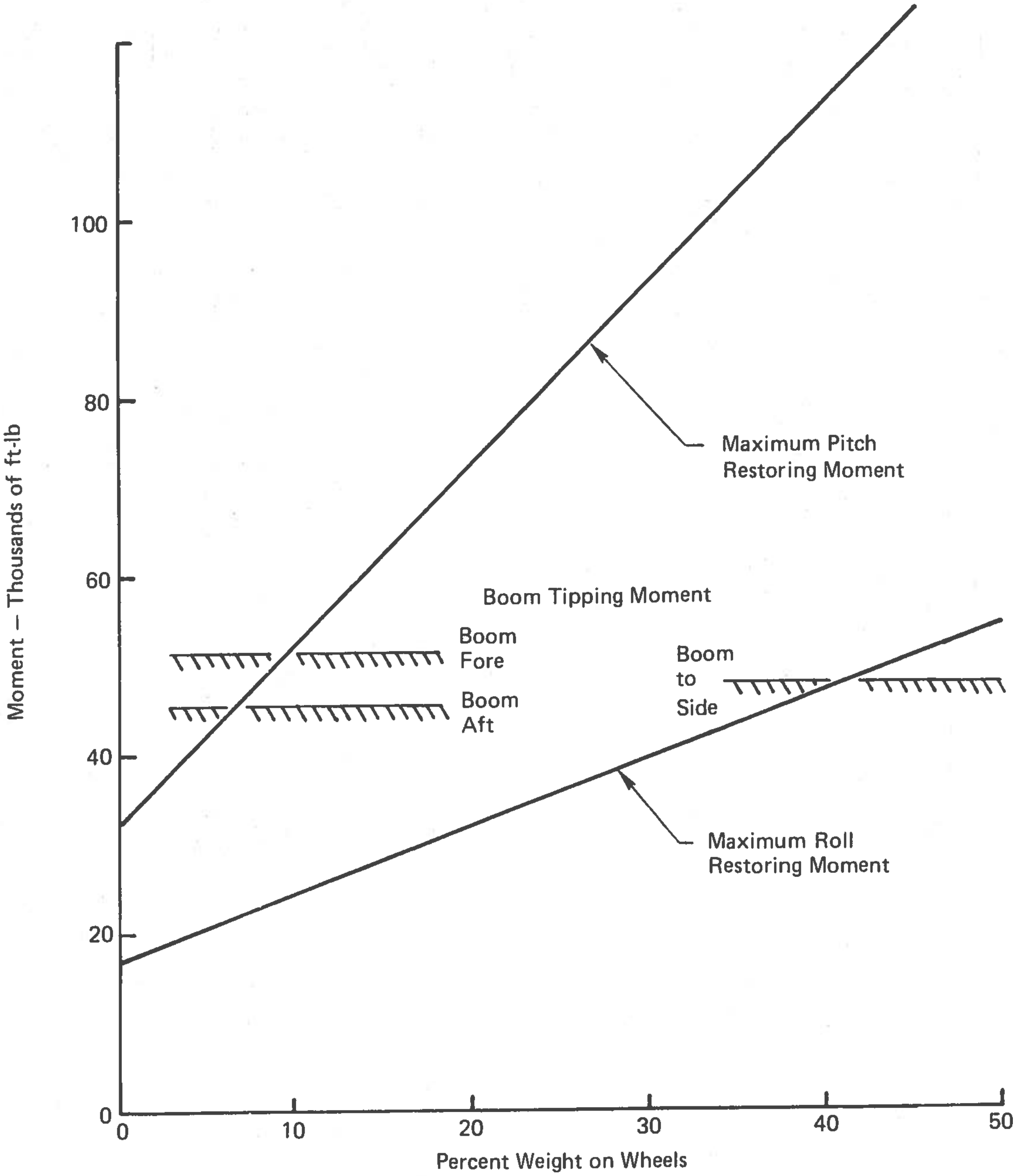


Figure 4.3-10. Static Attitude Stability – Hybrid Mode

4.4 PERFORMANCE

Performance of the selected concept design is analyzed for the three modes of operation - wheelborne, cushionborne and hybrid.

4.4.1 Wheelborne

Road performance has been calculated using the Detroit Diesel Allison's "System Computerized Applications Analysis" known as the SCAAN computer code. This program takes detailed account of the particular transmission and drive losses, tire characteristics, etc., and is generally accepted in the automotive truck business.

Inputs are gross weight, wheel rpm/mile, vehicle height and width, engine power, torque and acceleration characteristics, etc., and external power required for accessories. Cases were run for the ACCRV design at both 30,000 and 34,000 lb gross weight with alternative power deduction for accessories.

Specific printouts are included as Appendix A. Key figures have been underlined and the following summaries result:

	30,000		34,000	
Accessory Power	40 hp	190 hp	40 hp	190 hp
Maximum Speed mph	68	64	68	67
Time to Accelerate to 50 mph Level Concrete (secs)	16	24	14	21.5
Maximum Gradient at 2.00 mph %	INFIN	134	INFIN	218

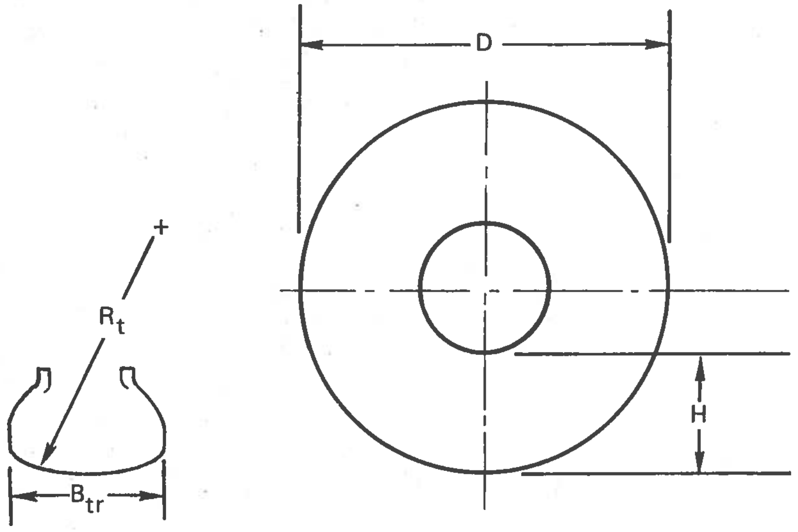
The SCAAN printouts show up the fact that the grade climbing requirement of the 40% slope at no less than one mph is very handsomely exceeded on dry concrete. This requirement is one of traction rather than power. The proposed scheme of controlling both the wheel load and the tire pressure ensures maximum traction under all operating conditions.

The ability to traverse surfaces which are typically found off the road in various parts of the world was examined using Bell generated computer codes.

The 17.5R25 tire characteristics listed in Figure 4.4-1 were modelled with tire pressures of 10 to 40 psi, and axle loadings representing 100% and 30% of the gross vehicle weight.

Soils are modelled by means of constants which are used in the Bekker mobility equations. The properties of a wide variety of soils from many parts of the world are given in Figure 4.4-1.

Drawbar pull developed by each wheel is shown in Figure 4.4-2. This shows that the ACCRV can traverse most soils, including rice paddies (Thailand clay) in the wheeled mode (7500 lb/wheel). Tire pressure control is beneficial in some soils but not



Tire Characteristics

D = 52.8 In.
H = 13.9 In.
B_{tr} = 17.5 In.
R_t = 50 In. (Est.)

Infl Press = 10 psi to 40 psi
Carcass Press = 8 psi

W_1 = 7500 Lb = 100%
W_2 = 2250 Lb = 30%

Soil Properties

	Terrain	Moisture Content (%)	n	k_c		k_ϕ		c		ϕ
				lb/in.$^{n+1}$	kN/m^{n+1}	lb/in.$^{n+2}$	kN/m^{n+2}	lb/in.^{2}	kPa	
1.	Dry Sand (Land Locomotion Lab., LLL)	0	1.1	0.1	0.95	3.9	1528.43	0.15	1.04	28°
2.1	Sandy Loam	15	0.7	2.3	5.27	16.8	1515.04	0.25	1.72	29°
2.2	(LLL)	22	0.2	7	2.56	3	43.12	0.2	1.38	38°
3.1	Sandy Loam	11	0.9	11	52.53	6	1127.97	0.7	4.83	20°
3.2	Michigan (Strong, Buchele)	23	0.4	15	11.42	27	808.96	1.4	9.65	35°
4.1	Sandy Loam	26	0.3	5.3	2.79	6.8	141.11	2.0	13.79	22°
4.2	(Hanamoto)	32	0.5	0.7	0.77	1.2	51.91	0.75	5.17	11°
5.1	Clayey soil	38	0.5	12	13.19	16	692.15	0.6	4.14	13°
5.2	(Thailand)	55	0.7	7	16.03	14	1262.53	0.3	2.07	10°
6.1	Heavy Clay	25	0.13	45	12.70	140	1555.95	10	68.95	34°
6.2	(Waterways Experiment Stn., WES)	40	0.11	7	1.84	10	103.27	3	20.69	6°
7.1	Lean Clay	22	0.2	45	16.43	120	1724.69	10	68.95	20°
7.2	(WES)	32	0.15	5	1.52	10	119.61	2	13.79	11°
8.1	Snow		1.6	0.07	4.37	0.08	196.72	0.15	1.03	19.7°
8.2	(Harrison)		1.6	0.04	2.49	0.10	245.90	0.09	0.62	23.2°

Figure 4.4-1. Tire and Soil Properties

Soil	Load on Wheel (lb)	Inflation Pressure (psi)	Tire Deflection (in.)	Sinkage (in.)	Drawbar Pull Per Wheel (lb)	Comments
Sand (Dry) (1.1)	7500	40	-0-	7.26	1337	
		30	0.16	6.37	1934	
		20	1.90	4.41	2849	
		10	13.80	2.35	2435	Tire Flat
	2250	40	-0-	3.42	713	
		30	-0-	3.42	713	
		20	-0-	3.42	713	
		10	0.38	2.35	863	
Sandy Loam (3.1)	7500	40	0.47	0.31	2638	
		30	0.22	4.79	1177	
		20	2.01	3.37	1855	
		10	14.10	1.57	1575	
	2250	40	-0-	2.51	479	
		30	-0-	2.51	479	
		20	-0-	2.51	479	
		10	0.47	1.50	656	
Clay (Rice Paddy) (5.1)	7500	40	-0-	4.20	-250	Bog Down
		30	0.28	3.02	392	
		20	2.35	1.42	1229	
		10	14.7	0.35	585	Flat Tire
	2250	40	-0-	1.21	346	
		30	-0-	1.21	346	
		20	0.05	0.64	381	
		10	0.68	0.35	533	
Lean Clay (Hard) (7.1)	7500	40	0.54	0.00	4152	
		30	1.22	0.00	4918	
		20	2.84	0.00	6034	
		10	15.0	0.00	8550	Flat Tire
	2250	40	0.04	0.00	1110	
		30	0.08	0.00	1316	
		20	0.19	0.00	1684	
		10	0.79	0.00	2708	
Snow Fluffy (8.2)	7500	40	-0-	29.8	-5790	Bog Down
		30	-0-	29.8	-5790	
		20	0.32	26.8	-3257	
		10				
	2250	40	-0-	16.8	-1522	
		30	-0-	16.8	-1522	
		20	-0-	16.8	-1522	
		10	0.01	13.3	-432	
	1225	10	-0-	12.5	-797	
		5	0.01	11.0	-409	
	612	10	-0-	9.0	-391	
		5	-0-	9.0	-391	

Figure 4.4-2. Wheel Operation on Various Soils

really required except in Thailand clay (rice paddies) where the vehicle bogs down when tire pressures above 30 psi are used. It also shows that 20 psi is the optimum tire pressure for operations in rice paddy type soil.

Not shown by the above results is the influence of forward speed on power requirement, ride quality and other imponderables. The positive drawbar pulls available in all cases with wheel load reduced to 30% and associated reduced sinkage indicate the probability that a cushion augmented hybrid operation may be practical on most of these surfaces, and preferable because of increased speed and smoother operation.

The results for soft snow clearly show that putting the full weight on the wheels presents progress, whereas sufficient reduction of load provides a positive DBP, which may be increased by considering the paddle wheels.

In hybrid operations, the cushion supports 70% of the weight reducing the load on the wheels to 2250 pounds. As might be expected, this reduces the drawbar pull but, resistance to motion is also reduced to approximately 1% of the gross vehicle weight. In any case, while hybrid operation is feasible with the off-loaded wheels providing the propulsive force, there appears to be no advantage to operate in hybrid rather than wheeled mode in these soils.

In deep snow of homogeneous properties however, neither tire pressure nor axle loading can produce sufficient drawbar pull for vehicle propulsion. This is evident by the negative drawbar pull in Figure 4.4-2.

Analyzing mobility on snow is more complex than indicated, in that snow of any significant depth is not homogeneous. In addition to the significant effect of water content, the temperature, age, crust formation and wind (packing) significantly alter its properties. Therefore, deep snow can be better negotiated in the cushionborne mode, if an effective propulsion can be developed.

4.4.2 Cushionborne

Overwater performance to reach 20 mph is specified, and wave height is to be 1 ft maximum, but in other respects the requirements are not specific. Performance is therefore shown for a number of different conditions.

Parameters which affect cushionborne overwater speed, particularly the ability to overcome the high drag peak occurring at the critical wave making speed, include the following:

Vehicle weight
Headwind
Wave conditions
Water depth

The goal for vehicle fully laden gross weight is 30,000 lb. This may be exceeded but in some circumstances operation at lighter weight may be feasible. For example, for a specifically overwater mission it may be reasonable to jettison some water if conditions are such that fast speed cannot otherwise be attained. Drag has therefore been calculated for a range of weights from 20,000 to 35,000 lb. Conventionally for ACV's drag is also calculated as a function of required sea state or wave conditions and it has been the practice to combine the headwind associated with the production of that sea state into the calculation. Drag will be somewhat less in calm water as also shown in Figure 4.4-3. Peak drag is plotted against weight in Figure 4.4-4.

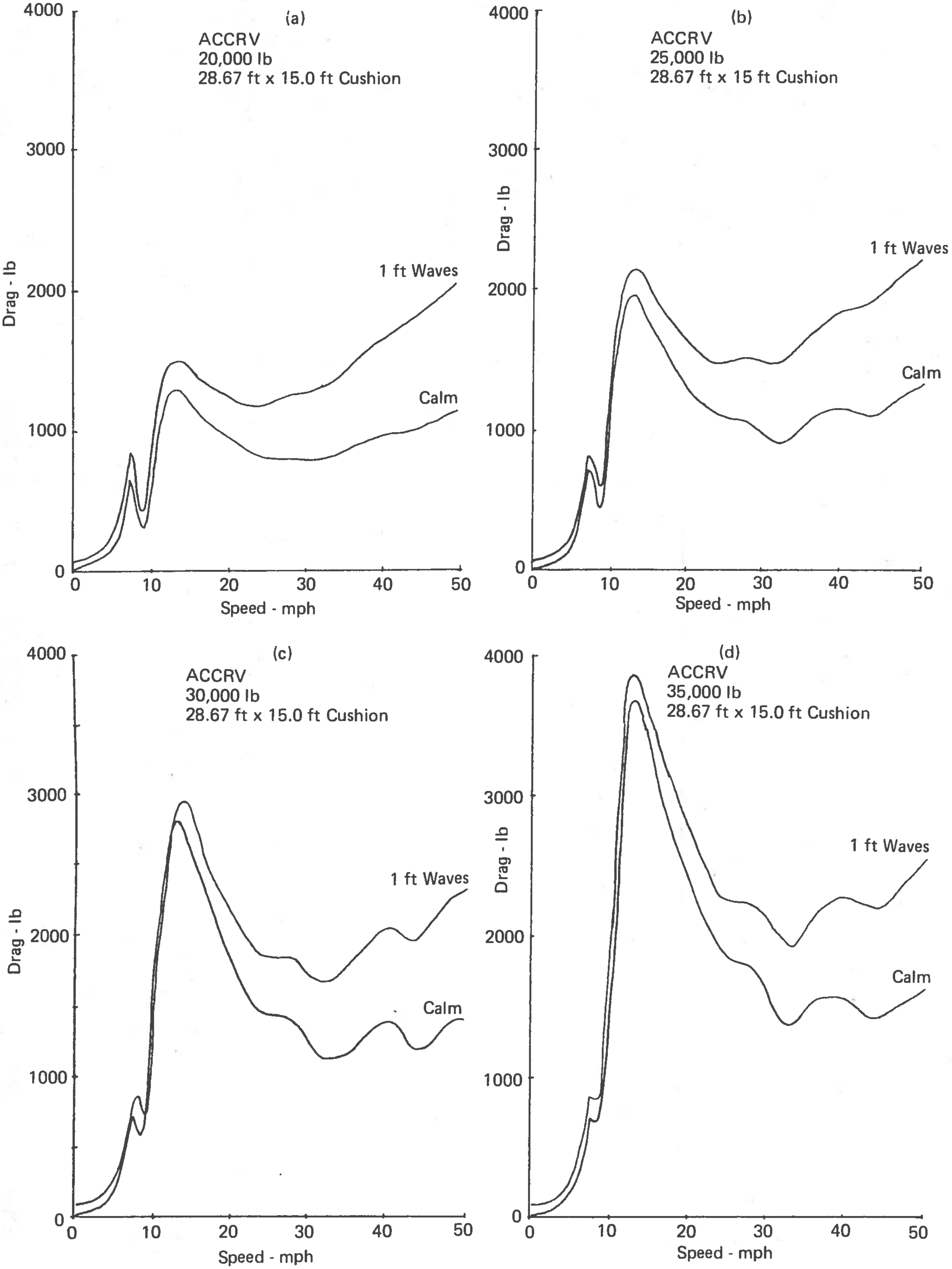


Figure 4.4-3. Total Deep Water Drag

Water depth can have a very pronounced effect. In some cases deep water drag is doubled in the critical water depth. This is of importance if an acceleration is required over a stretch of water of uniform critical depth - an unlikely case but one that should be considered. Figure 4.4-5 shows drag for several water depths.

Finally, it should be noted that drag is very strongly dependent on cushion length. The wave drag is given by:

$$D_W = \frac{4\ C_W\ W/S \cdot W}{\rho l}$$

Where

D_W = Peak wave drag - lb

C_W = A coefficient depending on aspect ratio l/b. For aspect ratios below 3

$$C_W = \frac{2.75}{2.75 + l/b}$$

W = Gross vehicle weight, - lb

W/S = Cushion pressure, lb/sq ft

ρ = Water density = 62.5, lb/cu ft

l = Cushion length, ft

b = Cushion beam, ft

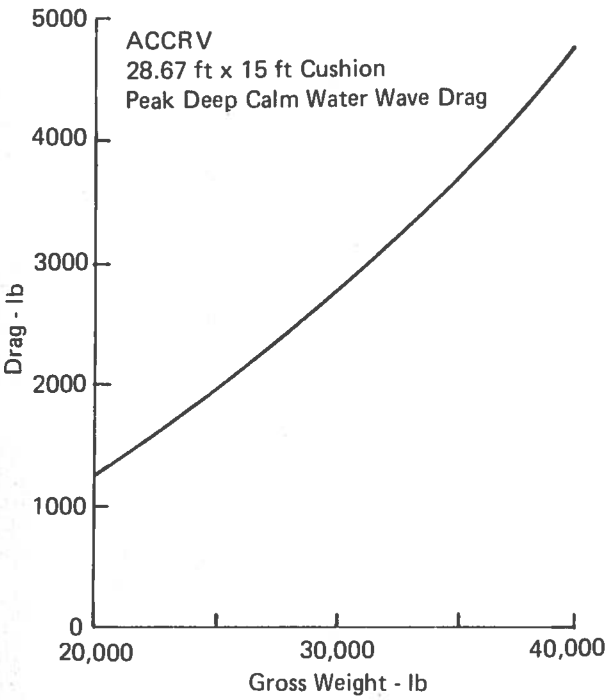


Figure 4.4-4. Variation of Hump Drag with Gross Vehicle Weight

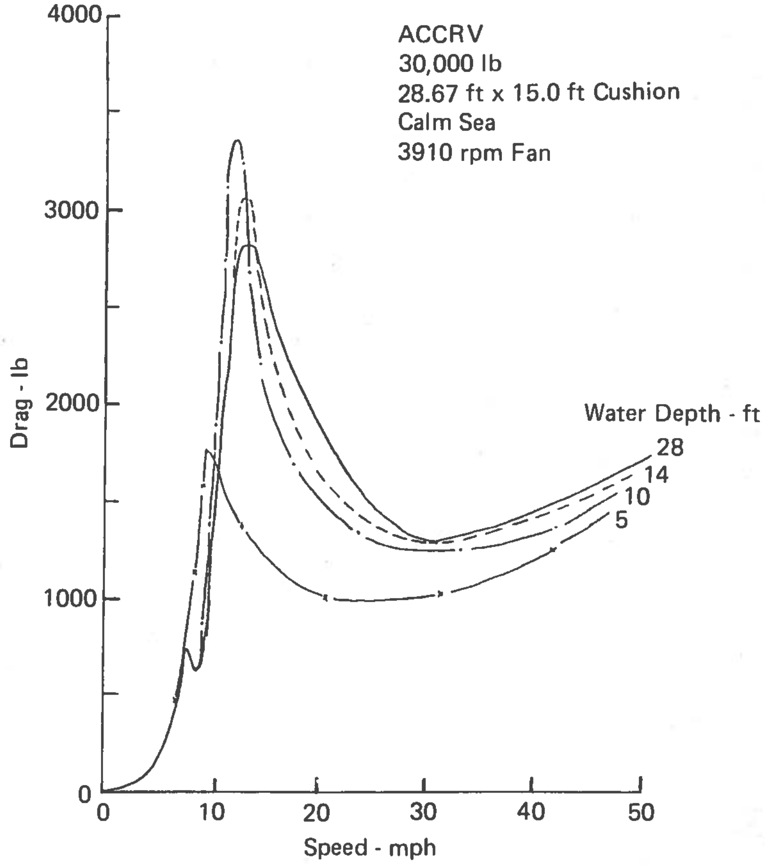


Figure 4.4-5. Effect of Water Depth on Total Drag

Since cushion pressure is proportional to length, drag is seen to vary as C_w/l^2. The coefficient C_w is a function of aspect ratio l/b and becomes smaller as l/b increases, i.e., with increasing l, accentuating the length advantage. The variation of peak deep water drag to cushion length for several weights is shown in Figure 4.4-6. This is important because adjustments of this kind are likely to occur in the preliminary design phase. It is estimated that the cushion length can be increased to at least 34 ft without violating the maximum transportable dimension of 420 in. but this will also require a longer wheelbase accompanied by a further aft cg (such as will result from increasing the length of the triage compartment) and will result in overall weight increases. The best detail compromise will emerge from the analyses to be conducted in Phase II.

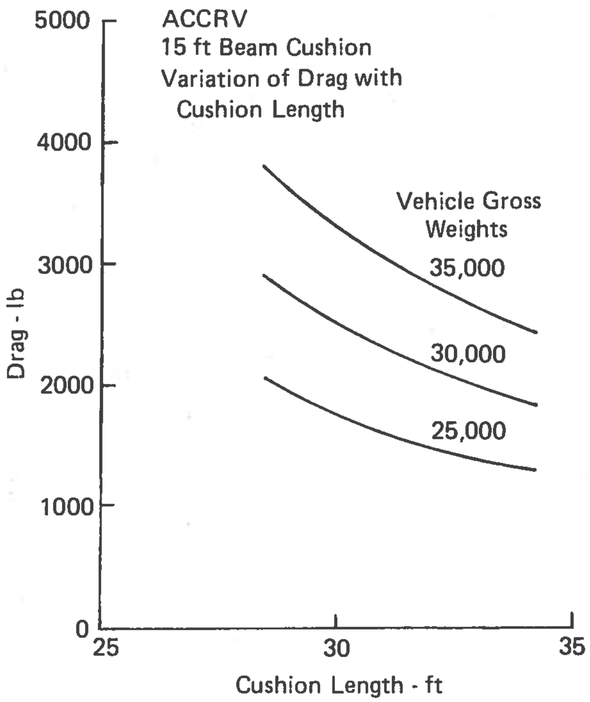


Figure 4.4-6. Variation of Drag with Cushion Length

Paddle thrust is a function of paddle diameter, blade area, rotational speed and applied power. For the selected paddle, which is coaxial with the wheel, the diameter is limited to 40 in. If the retractable option illustrated in Figure 3.3-6 were adopted a larger diameter could be used. Blade width cannot be increased but depth or chord is a compromise for good soft surface performance. Increasing rpm and power to obtain more thrust is limited by ventilation boundaries which occur at higher forward speed when rotational speed is increased.

Propeller thrust is similarly a function of disc area and power with thrust per horsepower dependent on disc loading. A comparison of propeller produced thrust and paddlewheel thrust vs vehicle speed in shown in Figure 4.4-7. Ventilation point for the paddle has been calculated from the natural frequency of the disturbed water depth. The two curves show available thrust from the two methods with the same 325 hp applied.

A 700 lb water jet increment is also available for short duration. The possibility of jettisoning some water for hump traverse was mentioned earlier. Use of the on-board pump and roof turret with the jet directed aft for this purpose will provide

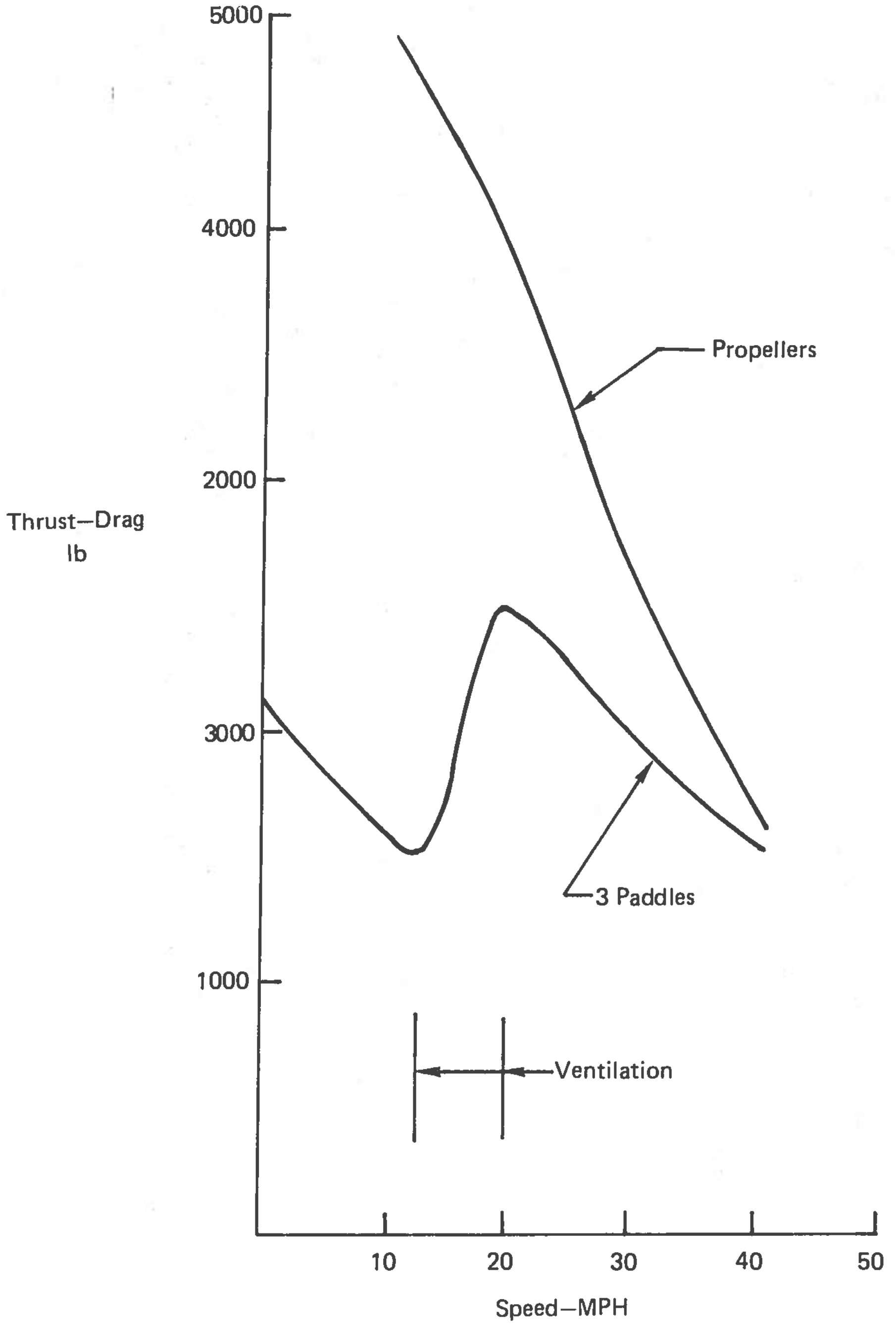


Figure 4.4-7. ACCRV Thrust Comparison

this 700 lb additional thrust. Since the acceleration time needed to go through hump is in the order of 15 sec and it is a peak condition only and since a crewman can stand in the second roof hatch and control the turret for additional steering in this mode, it seems negligent not to make use of it, if needed for a transient such as a high weight shallow water condition.

Finally, Figure 4.4-8 superimposes thrust on drag for two cases which example range of germane valves of these parameters.

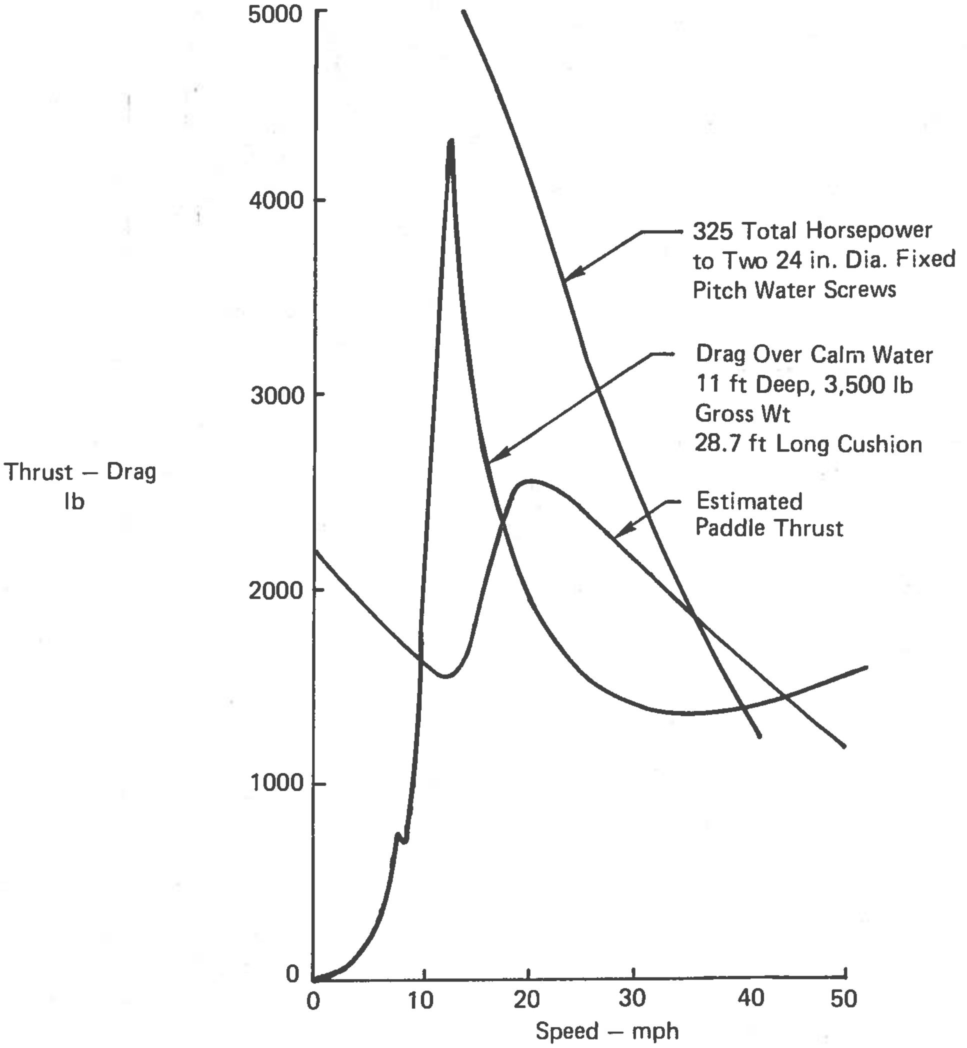


Figure 4.4-8(a). ACCRV Worst Condition Overweight Drag – Maximum Propeller Thrust

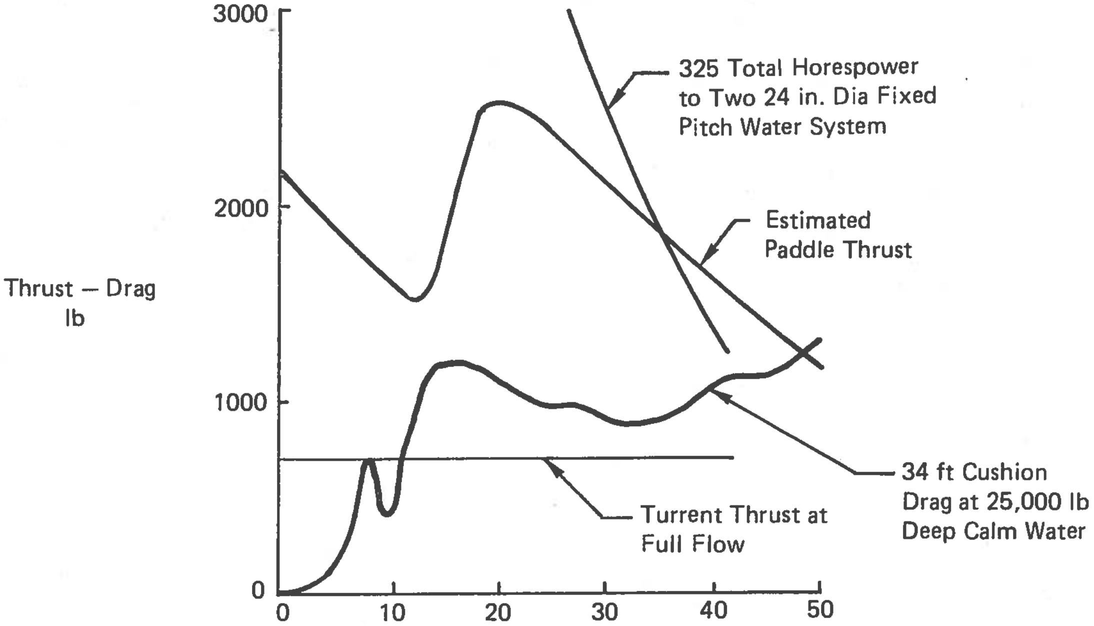


Figure 4.4-8(b). ACCRV Light Weight Condition Extended Cushion – Drag Maximum Paddle Thrust

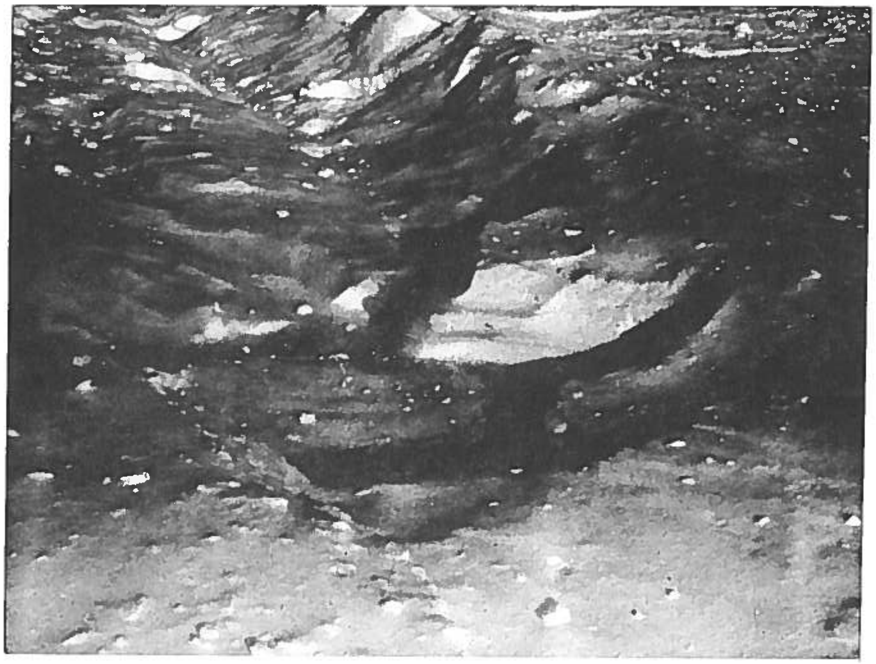
4.4.3 Hybrid

There is little doubt that an air cushion vehicle operating at a cushion pressure on the order of 1/2 psi can provide sufficient flotation in deep snow. Figure 4.4-9 shows typical footprints of ACVs in stratified snow of various depths hovering for periods up to 5 minutes. Vehicle speed decreases surface deformation as shown in Figure 4.4-10. The issue is whether the traction device, wheel, wheel/paddle or track can develop sufficient thrust (drawbar pull) to overcome the resistance of the cushionborne vehicle, which typically ranges between 1/2% and 1% of the vehicle weight i.e. 150 to 300 lb on level ground.

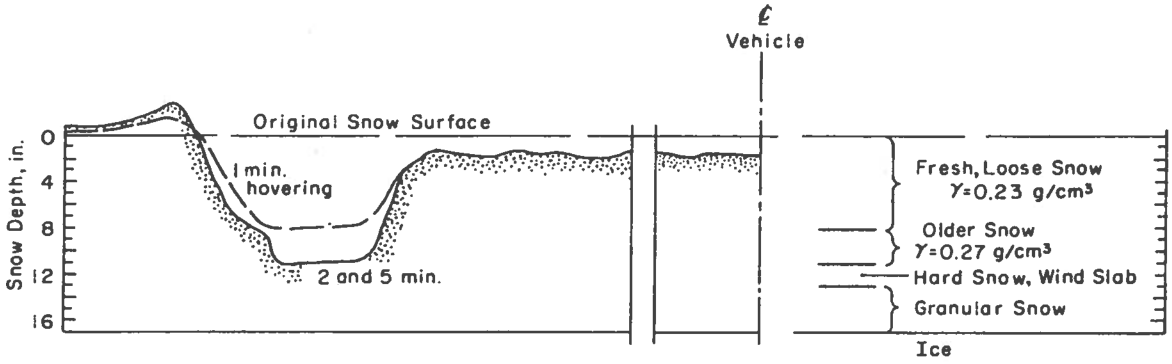
It was shown in Figure 4.4-2 that wheels by themselves can not propel the vehicle on deep soft snow. The paddle wheel may but is not amendable to analysis using existing computer codes.

A simple 1/5 scale model of the wheel/paddle wheel combination is being fabricated by Bell. It will be used to determine the drawbar pull developed by this device on snow. Preliminary results are expected early in Phase II which will be used to determine whether to continue with the paddlewheel or revert to a lightweight track for snow operation.

Figure 4.4-11 shows that a 60 inch long 20 week wide track can produce sufficient drawbar pull to propel the vehicle in the same type of snow (8.2 on Figure 4.4-1) in which wheels were immobilized at any axle load/tire pressure combination.



Erosion of soft snow surface at rear bag, hovering time 5 minutes.



Cross Section of Snow Surface Erosion During Hovering

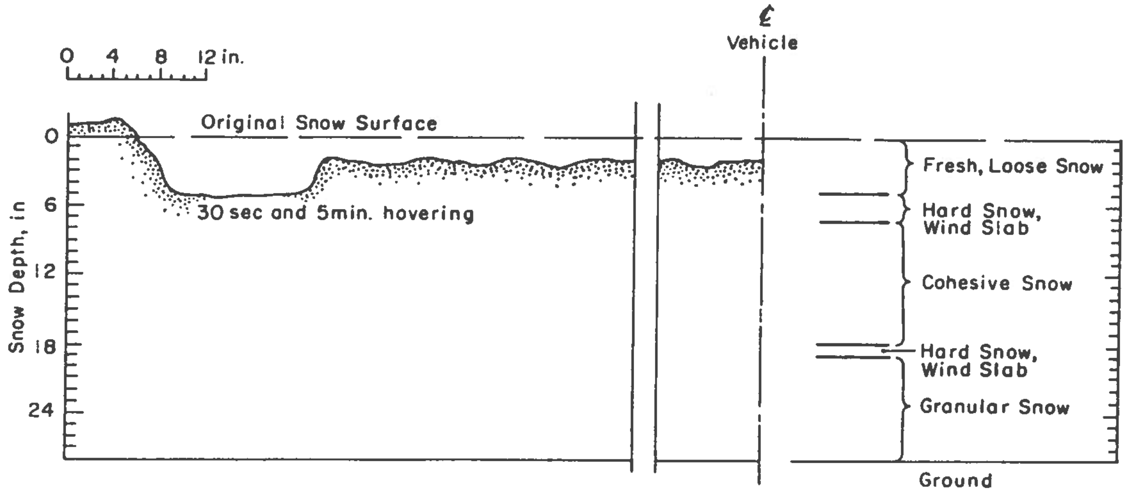


Figure 4.4-9. ACV Operation on Snow

Snow characteristics may be visualized by considering sinkage of observer's foot prints.

Abrasion of windswept snow surface, vehicle speed 10 – 15 mph.

Vehicle speed decreases surface deformation in deep snow.

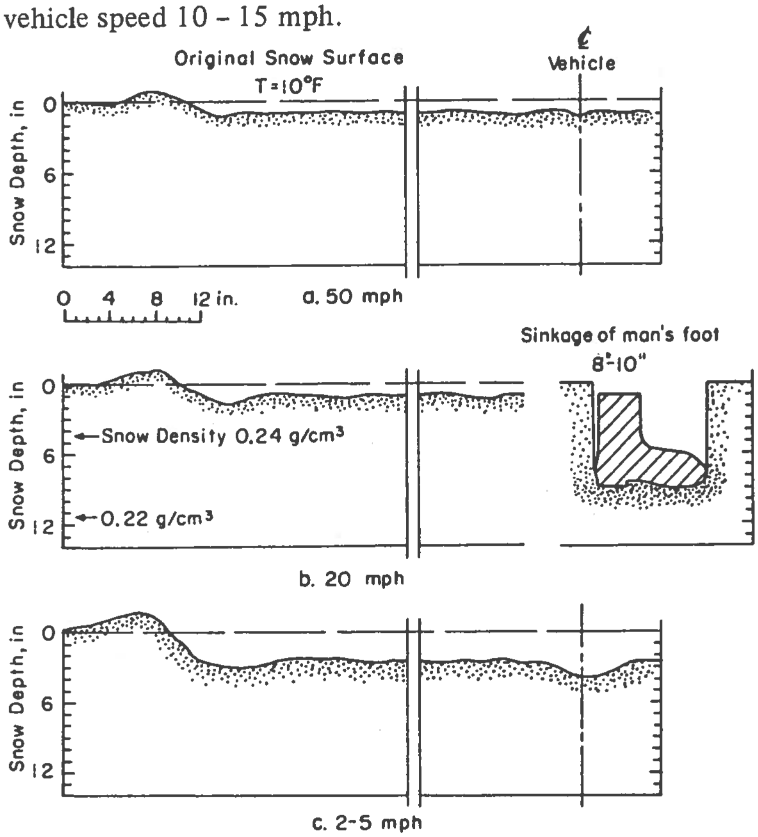


Figure 4.4-10. Deformation of soft snow surface, various vehicle speeds.

Load on Track W	Track Sinkage Z	DP
100	0.57	378.7
500	1.563	575.0
1000	2.41	814.0
2000	3.72	1273.2
3000	4.79	1713.9
4000	5.73	2138.5
5000	6.59	2548.6

Figure 4.4-11. Drawbar Pull Developed

5.0 CONCEPT OPERATIONAL CONSIDERATION AND CONCLUSION

1. An air cushion assisted crash rescue vehicle can provide significant improvement in obstacle negotiation and off-the-road mobility. Road performance equals or exceeds that of the P-19.

   1.1 A 50 mph cruising speed, 65 mph top speed and 0 to 50 mph in 25 sec are readily achievable.

   1.2 Water speed with paddlewheel propulsion at full weight is limited to 10 mph. Water propellers are required for overhump operation - a maximum speed of 40 mph can then be achieved.

   1.3 No analytical models exist which can quantify performance of paddlewheels on snow. Subscale model tests are required.

   1.4 A 60 inch long dual track can produce sufficient drawbar pull to propel a cushionborne vehicle on deep fluffy snow.

2. Fire fighting operations can be conducted in the wheeled, cushionborne and hybrid modes of operation.

3. Pump and drive is possible in all modes of operation. Pump and drive on a 40% grade is limited to the wheeled mode only.

4. Rescue operations requiring maximum extension of the boom in any direction can be performed:

   1. In the wheeled mode, using the side panels as outriggers.

   2. In the displacement mode using flotation bags for stability augment. Maximum heel angle with the boom fully loaded (4 men on the platform) is less than 11 degrees.

ADDITIONAL FEATURES

- Extended side panels provide a platform for improved access to the upper part of the vehicle sides.

- In the cushionborne mode, the side panels function as decks for rescuees, especially from an overwater or marsh crash site.

- Up to 25 people could be carried ashore, with the vehicle cushionborne after all fluids are expended.

APPENDIX A

DETROIT DIESEL ENGINE AND SCAAN PRINTOUT

30,000
– 40 H.P.

```
SCAAN No 123668
date:  6/25/85,  1:31pm edt
tm001118, MONETTE
REJECTED APPLICATION

             DETROIT DIESEL ALLISON
          SCAAN Application Information
          =============================

VEHICLE:  CRASH TRUCK -BELL AEROSPACE AIR CUSHION CRASH TRUCK
   3900  vocation library file number
  30000. lbs. gross vehicle weight
  30000. lbs. weight on drive wheels (100.0 percent)
  25.594 in. radius, wheel-  bias tires (DDA rolling resist)
  394.00 wheel rev/mile
      4  total tires in contact with road
   5.390 driveline reduction ratio, total
          driveline: propeller shaft, all wheel drive
   94.15 % driveline efficiency
  227.47 lb.ft.sec.2 driveline equivalent inertia
   0.600 traction limit coefficient
  1.0000 road surface factor (smooth concrete)
   8.70 x  9.20 ft. vehicle height x width
  0.8000 air resistance coefficient
DIESEL ENGINE:  D.D.A. 8V-92T 9200
 (NOTE:  ENGINE RATING/VOCATION COMPATIBILITY
  SUBJECT TO D.D.A. REVIEW)
   736.0 in3 engine displacement
 10457   engine library file number
  540.0  gross horsepower @ 2300. rpm (SAE, 85 deg F, 500 ft. alt)
 deductions- (hp. at 2300. rpm)
   22.0# hp fan
    5.0# hp alternator/generator
    0.0# hp air compressor
   13.0# hp steer pump
       # (deduction value responsibility: MONETTE)
  500.0 net horsepower @ 2300. rpm  (SAE, 85 deg F, 500 ft. alt)
   eng rpm      1200. 1300. 1400. 1600. 1800. 2000. 2200. 2300. 2500.
   gross hp     302.5 333.9 363.9 421.9 471.2 510.3 534.1 540.0   0.0
   net hp       287.6 317.6 346.0 400.5 445.5 479.5 497.4 500.0 -47.4
   net torque   1259. 1283. 1298. 1315. 1300. 1259. 1187. 1142. -100.
   friction hp   40.0  44.9  50.3  62.8  78.0  95.9 115.5 125.0 145.5
(max. net   engine torque of 1314.6 lb ft occurs at 1606. rpm)
(max. gross engine torque of 1385.0 lb ft occurs at 1600. rpm)
  2.818 lb.ft.sec.2 engine inertia


THIS SCAAN INFORMATION SUBJECT TO THE
DISCLAIMER SET FORTH IN  PIM 436 OR  PUB 35


REJECTED APPLICATION
```

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SCAAN No 123668
date:  6/25/85,  1:31pm edt
tm001118, MONETTE
REJECTED APPLICATION

                DETROIT DIESEL ALLISON
        SCAAN Application Information (cont)
        ====================================

VEHICLE:  CRASH TRUCK -BELL AEROSPACE AIR CUSHION CRASH TRUCK
CONVERTER: ALLISON TC-496 REF. TC-18771,11-22-77
TRANSMISSION: ALLISON HT-750 DR (GENERAL CALIB.)
  18145. lb.ft.  max transm output torque, 1st range conv stall
  10572. lb.ft.  max transm output torque, rev range conv stall
TRANSM. APPLICATION- HT-750 DR CRASH TRUCK,CRANE CARRIER
  13514   transm application library file number
   Shift Calibration: 2300. rpm, HT-750DR CONVENTIONAL
     upshift      mph     downshift    mph
      1C-1L       6.56     1L-1C       2.13
      1L-2C       8.15     2C-1L       5.32
      2C-2L      16.40#    2L-2C        --
      2L-3C      20.34     3C-2L      19.07
      3C-3L      25.87#    3L-3C        --
      3L-4C      32.07     4C-3L      28.54
      4C-4L      37.80#    4L-4C        --
      4L-5C      47.65#    5C-4L        --
      5C-5L      52.26#    5L-5C        --
     #  Indicates shift speed in excess of optimum (cross-over)
        point; value modified to give shift at optimum point
   1406   SCAAN Adaptation Parts List Number

THIS SCAAN INFORMATION SUBJECT TO THE
DISCLAIMER SET FORTH IN  PIM 436 OR  PUB 35

REJECTED APPLICATION
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```
SCAAN No 123668
date:  6/25/85,  1:31pm edt
tm001118, MONETTE

          DETROIT DIESEL ALLISON
     SCAAN Summary-  REJECTED Application
     ===================================
Vehicle        CRASH TRUCK -BELL AEROSPACE AIR CUSHION CRASH TRUCK
Engine         D.D.A. 8V-92T 9200
Transmission   ALLISON HT-750 DR (GENERAL CALIB.)
Converter      ALLISON TC-496 REF. TC-18771,11-22-77

                                       recommendation      appli-
                                         or rating         cation  status
 ==========================================================================
  ENGINE:
--->ENGINE RATING/VOCATION COMPATIBILITY                            <-----
---> SUBJECT TO D.D.A. REVIEW                                       <-----

  CONVERTER:
--->Stall turbine torque, lb.ft.          2300.max          2327. <-(XXX)
    Engine rpm, conv. stall               (-----)           1847.
    Converter stall torque ratio          (-----)           1.830
    Engine peak torque rpm vs min. rpm    1606.min          1803.  O.K.
    Conv. SR at 2300. gov rpm           0.800/1.000         0.870  O.K.

  TRANSMISSION:
    Input horsepower                       500.max           500.  O.K.
    Input torque, lb.ft. (lockup)         1575.max          1315.  O.K.
    Input rpm (gov.)                    1900./2400.         2300.  O.K.

  VEHICLE/DRIVELINE:
    GVW lbs for  64.98 geared mph       80000.max          30000.  O.K.
    1st gear conv. stall gradeability   55.00%min          (inf.)  O.K.
    2nd gear conv. stall gradeability    (-----)            70.45%
    1st conv. 70% eff. gradeability      (-----)           (inf.)
    1st conv. 80% eff. gradeability      (-----)           (inf.)
    1st conv. 70% eff. transm BTU/min (at 1837. eng rpm)   6312.
    1st conv. 80% eff. transm BTU/min (at 1887. eng rpm)   4642.
    Geared top speed, mph (gov. rpm)     (-----)            64.98
    DOT Specification AC 150/5220-10, 26 May 72 (crash truck):
     Mph on  1.50% grade                  50.00min          67.37  O.K.
     Gradeability at 50.00 mph            1.50%min           8.15% O.K.
     Gradeability at  2.50 mph           50.00%min         (inf.)  O.K.
     Acceleration, 0% grade, 0-50 mph,sec.
      Start in range 1, 7.973 ratio       60.00max          14.18  O.K.
      Start in range 2, 3.188 ratio       60.00max          14.35  O.K.
     Acceleration, 8.0% grade (start in range 1, 7.973 ratio)
      Dist,ft (max) to reach mph (min) 1320./20.00      64./20.00 O.K.
     Acceleration, 8.0% grade (start in range 2, 3.188 ratio)
      Dist,ft (max) to reach mph (min) 1320./20.00      66./20.00 O.K.

  ALL TRANSMISSION APPLICATIONS require submittal of
    A & I Form SA 0003A, SCAAN Summary and
    SCAAN Application Information

  NOTE:   Symbols indicate:
--->Not within TRANSMISSION RATINGS        <-(XXX)
     SCAAN Summary-  REJECTED Application
     ===================================
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SCAAN No 123668
date:  6/25/85,  1:31pm edt
tm001118, MONETTE
REJECTED APPLICATION

           DETROIT DIESEL ALLISON
      Vehicle Full Throttle Performance
      ==================================


  veh engine   tr   drawbar wheel   net % tran ht
  mph   rpm  effort   pull    hp   grade BTU/min
 =====================================================

Reverse 1, ratio= -4.716 -start, converter operation
  0.00  1847  25154  24964*   0.0 150.04  19283
 -2.00  1804  23663  23469* 126.2 125.59  13244
 -4.00  1814  21436  21237* 228.7 100.22   8717
 -5.39  1837  19610  19404* 281.9  84.81   6499  70% Conv. Efficiency
 -6.00  1854  18906  18701* 302.5  79.72   5711
 -6.79  1887  18090  17883* 327.3  74.24   4846  80% Conv. Efficiency
 -8.00  1953  16855  16642  359.6  66.67   3847
-10.00  2100  14687  14465  391.7  55.04   3168
-11.99  2300  12519  12287  400.2  44.89   3176

Forward 1, ratio= 7.973 -low range start, converter operation
  0.00  1847  43172  42982*   0.0  infin  19283
  2.00  1808  38082  37887* 203.1  infin   9817
  3.19  1837  33640  33443* 286.1  infin   6312  70% Conv. Efficiency
  4.00  1886  31051  30851* 331.2  infin   4664
  4.01  1887  31010  30811* 331.9  infin   4642  80% Conv. Efficiency
  6.00  2112  24822  24616* 397.2 143.56   2964
  6.56  2199  23044  22836* 402.8 117.38   2948
auto lockup shift
  6.56  1850  23044  22836* 402.8 117.38   1157
  8.00  2258  20520  20307* 437.8  91.96   1462
  8.15  2300  20133  19919* 437.6  88.79   1494

Forward 2, ratio= 3.188 -drive range start, converter operation
  0.00  1847  17469  17278    0.0  70.45  19283
  2.00  1810  16899  16704   90.1  67.03  14926
  4.00  1803  15909  15710  169.7  61.47  11279
  6.00  1815  14839  14633  237.4  55.87   8328
  7.98  1837  13620  13405  289.7  49.95   6149  70% Conv. Efficiency
  8.00  1837  13604  13390  290.2  49.88   6128
 10.00  1886  12584  12362  335.6  45.23   4465
 10.04  1887  12570  12344  336.4  45.15   4439  80% Conv. Efficiency
 12.00  1960  11622  11390  371.9  41.04   3341
 14.00  2058  10619  10376  396.4  36.86   2775
 16.00  2173   9580   9325  408.7  32.70   2625
 16.40  2199   9377   9119  410.0  31.91   2625
auto lockup shift
 16.40  1850   9377   9119  410.0  31.91    835
 18.00  2031   9048   8779  434.3  30.60    936
 20.00  2256   8371   8087  446.4  27.99   1070
 20.34  2295   8230   7944  446.4  27.46   1094


REJECTED APPLICATION
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SCAAN No 123668
REJECTED APPLICATION

 veh engine   tr   drawbar wheel  net % tran ht
 mph   rpm  effort  pull    hp   grade BTU/min
=================================================

Forward 3, ratio= 2.021 -auto upshift, converter operation
 20.34  2003   7080   6794  384.1  23.25   3050
 22.00  2055   6752   6452  396.1  22.02   2778
 24.00  2124   6333   6016  405.3  20.47   2638
 25.87  2199   5949   5615  410.3  19.05   2609
auto lockup shift
 25.87  1850   5949   5615  410.3  19.05    819
 26.00  1859   5941   5605  411.9  19.02    824
 28.00  2003   5782   5427  431.7  18.39    903
 30.00  2146   5545   5169  443.6  17.49    981
 32.00  2289   5240   4841  447.1  16.35   1061
 32.07  2293   5228   4829  447.1  16.31   1064

Forward 4, ratio= 1.383 -auto upshift, converter operation
 32.07  2053   4677   4278  400.0  14.41   2595
 34.00  2098   4487   4065  406.8  13.68   2475
 36.00  2148   4291   3844  411.9  12.92   2419
 37.80  2199   4116   3646  414.9  12.25   2405
auto lockup shift
 37.80  1850   4116   3646  414.9  12.25    615
 38.00  1860   4110   3638  416.5  12.22    619
 40.00  1958   4039   3540  430.9  11.88    667
 42.00  2055   3945   3418  441.9  11.47    716
 44.00  2153   3826   3269  448.9  10.96    765
 46.00  2251   3685   3097  452.0  10.38    814
 47.00  2300   3608   3004  452.1  10.06    838
 47.65  2332   3209   2595  407.7   8.68    846

Forward 5, ratio= 1.000 -auto upshift, converter operation
 47.65  2108   3209   2595  407.7   8.68   2475
 48.00  2115   3191   2571  408.4   8.60   2467
 50.00  2153   3088   2436  411.8   8.15   2436
 52.00  2194   2986   2299  414.1   7.69   2429
 52.26  2199   2973   2281  414.3   7.63   2429
auto lockup shift
 52.26  1850   2973   2281  414.3   7.63    639
 54.00  1911   2944   2221  423.9   7.42    669
 56.00  1982   2903   2143  433.4   7.16    705
 58.00  2053   2852   2054  441.1   6.86    740
 60.00  2124   2791   1954  446.6   6.53    777
 62.00  2194   2721   1844  449.9   6.16    818
 64.00  2265   2644   1725  451.3   5.76    861
 64.98  2300   2604   1663  451.2   5.55    882
 66.00  2336   2248   1256  395.6   4.29    905
 68.00  2407   1081     74  195.9   0.25    950
 68.13  2411   1009      0  183.4   0.00    953

  Note:    * exceeds vehicle traction limit


REJECTED APPLICATION
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```
SCAAN No 123668
date:  6/25/85,  1:31pm edt
tm001118, MONETTE
REJECTED APPLICATION

          DETROIT DIESEL ALLISON
      Vehicle Engine Braking Performance
      ==================================

  engine braking- (hp  at 2300. rpm)
   125.0 engine friction
    22.0 fan
     5.0 alternator/generator
    13.0 steer pump

  veh engine equilib  transm wheel
  mph   rpm  % grade BTU/min   hp
 =================================
Forward 1, ratio= 7.973, conv. operation
  2.28   644   -0.97     132     0.6
  4.00   668   -7.07     529    20.4
  6.11   712  -18.23    2279    84.3
lockup operation
  2.28   644   -0.97     132     0.6
  2.57   725  -19.82     189    38.6
  4.00  1129  -20.88     369    63.3
  8.00  2258  -33.46    1158   198.5
  8.15  2300  -34.01    1201   205.3
  8.50  2400  -35.38    1299   222.0
Forward 2, ratio= 3.188, conv. operation
  5.70   644   -0.81     133     0.6
  8.00   656   -2.06     249     8.6
 12.00   682   -4.62     939    36.9
 15.29   712   -7.50    2158    81.3
lockup operation
  5.70   644   -0.81     133     0.6
  6.43   725   -8.14     171    38.2
  8.00   903   -8.21     230    47.8
 12.00  1354   -9.09     431    79.5
 16.00  1805  -10.86     662   127.2
 20.00  2256  -13.09     924   192.5
 20.39  2300  -13.29     959   199.3
 21.27  2400  -13.77    1038   215.5
Forward 3, ratio= 2.021, conv. operation
  9.00   644   -0.81     134     0.6
 12.00   654   -1.50     215     6.9
 16.00   668   -2.44     511    20.4
 20.00   687   -3.67    1107    43.6
 24.00   711   -5.18    2080    79.0
 24.12   712   -5.23    2115    80.2
lockup operation
  9.00   644   -0.81     134     0.6
 10.14   725   -5.46     174    38.2


 REJECTED APPLICATION
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SCAAN No 123668
REJECTED APPLICATION

 veh engine equilib  transm wheel
 mph   rpm  % grade BTU/min   hp
=================================
12.00   858   -5.50     215   45.3
16.00  1144   -5.77     318   62.9
20.00  1430   -6.31     443   85.6
24.00  1716   -7.08     575  115.3
28.00  2003   -8.05     733  153.1
32.00  2289   -9.03     895  196.1
32.16  2300   -9.06     904  197.9
33.56  2400   -9.40     977  214.0
Forward 4, ratio= 1.383, conv. operation
13.15   644   -0.85     134    0.6
16.00   651   -1.19     171    4.4
20.00   660   -1.65     299   11.3
24.00   670   -2.19     536   21.7
28.00   683   -2.82     910   36.7
32.00   698   -3.58    1464   57.6
35.25   712   -4.24    2044   78.4
lockup operation
13.15   644   -0.85     134    0.6
14.82   725   -4.03     161   37.9
16.00   783   -4.05     177   40.9
20.00   979   -4.18     232   51.7
24.00  1175   -4.40     293   64.1
28.00  1370   -4.71     359   78.9
32.00  1566   -5.12     433   96.9
36.00  1762   -5.62     511  118.6
40.00  1958   -6.18     611  144.3
44.00  2153   -6.78     697  172.9
47.00  2300   -7.21     782  194.8
48.00  2349   -7.36     812  202.5
49.04  2400   -7.51     844  210.7
Forward 5, ratio= 1.000, conv. operation
18.18   644   -0.94     133    0.6
20.00   647   -1.08     145    2.2
24.00   654   -1.40     210    6.6
28.00   660   -1.72     322   12.1
32.00   668   -2.10     499   19.8
36.00   676   -2.52     747   29.6
40.00   686   -2.99    1084   42.5
44.00   698   -3.52    1509   58.4
48.00   710   -4.07    2023   76.8
48.74   712   -4.18    2128   80.5
lockup operation
18.18   644   -0.94     133    0.6
20.00   708   -2.77     151   29.2
20.49   725   -3.26     156   37.8
24.00   849   -3.37     193   44.4
28.00   991   -3.53     242   52.5


REJECTED APPLICATION
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SCAAN No 123668
REJECTED APPLICATION

 veh engine equilib  transm wheel
 mph    rpm  % grade BTU/min    hp
==================================
32.00  1133    -3.74     297   61.7
36.00  1274    -4.00     361   72.2
40.00  1416    -4.30     431   84.2
44.00  1557    -4.64     497   97.7
48.00  1699    -5.02     563  113.1
52.00  1841    -5.44     634  130.6
56.00  1982    -5.89     709  149.9
60.00  2124    -6.36     769  170.7
64.00  2265    -6.83     856  192.0
64.98  2300    -6.95     882  197.3
67.81  2400    -7.29     955  213.4


REJECTED APPLICATION
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```
SCAAN No 123668
date:  6/25/85,  1:31pm edt
tm001118, MONETTE
REJECTED APPLICATION

             DETROIT DIESEL ALLISON
      Vehicle Full Throttle Acceleration
      ==================================

      (on   0.00 percent grade)


speed    time    dist   accel    eng    gear
 mph      sec     ft  mph/sec   rpm   range
=========================================
          start in range  1
  1.00    0.08      0 13.021* 1806   1C
  2.00    0.15      0 13.020* 1808   1C
  3.00    0.23      1 13.019* 1830   1C
  4.00    0.31      1 13.018* 1886   1C
  5.00    0.38      1 13.017* 1984   1C
  6.00    0.46      2 13.016* 2112   1C
  6.56    0.50      2 13.015  2199   1C- 1L
  7.00    0.54      3 13.015* 1975   1L
  8.00    0.61      4 13.013* 2258   1L
  8.15    0.63      4 13.013  2300   1L- 2C
  9.00    0.73      5  8.061  1857   2C
 10.00    0.86      7  7.613  1886   2C
 12.00    1.13     11  6.835  1960   2C
 14.00    1.45     17  6.116  2058   2C
 16.00    1.80     25  5.344  2173   2C
 16.40    1.87     27  5.165  2199   2C- 2L
 18.00    2.22     36  4.531  2031   2L
 20.00    2.68     48  4.184  2256   2L
 20.34    2.77     51  4.094  2295   2L- 3C
 22.00    3.15     63  4.197  2055   3C
 24.00    3.65     80  3.891  2124   3C
 25.67    4.15     98  3.583  2199   3C- 3L
 26.00    4.19    100  3.422  1859   3L
 28.00    4.78    123  3.318  2003   3L
 30.00    5.40    149  3.164  2146   3L
 32.00    6.06    179  2.967  2289   3L
 32.07    6.08    180  2.950  2293   3L- 4C
 34.00    6.77    214  2.732  2098   4C
 36.00    7.53    253  2.575  2148   4C
 37.80    8.25    292  2.427  2199   4C- 4L
 38.00    8.33    296  2.372  1860   4L
 40.00    9.19    345  2.310  1958   4L
 42.00   10.07    398  2.231  2055   4L
 44.00   10.99    456  2.135  2153   4L
 46.00   11.95    520  2.024  2251   4L
 47.65   12.81    578  1.748  2332   4L- 5C
 48.00   13.00    592  1.750  2115   5C
 50.00   14.18    677  1.655  2153   5C
 52.00   15.43    771  1.560  2194   5C
 52.26   15.60    784  1.542  2199   5C- 5L
 54.00   16.76    873  1.487  1911   5L


REJECTED APPLICATION
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```
speed    time    dist   accel    eng    gear
 mph      sec     ft  mph/sec   rpm    range
=======================================
56.00    18.13    984  1.436   1982    5L
58.00    19.55   1103  1.377   2053    5L
60.00    21.05   1232  1.311   2124    5L
62.00    22.62   1373  1.237   2194    5L
64.00    24.30   1528  1.158   2265    5L
66.00    26.16   1706  0.911   2336    5L
68.00    33.01   2383  0.099   2407    5L
68.13 = maximum speed                  5L
       (on   0.00 percent grade)

 note:    * indicates acceleration limited by wheel slip



speed    time    dist   accel    eng    gear
 mph      sec     ft  mph/sec   rpm    range
=======================================
            start in range  2
  1.00     0.08      0 11.883  1825    2C
  2.00     0.17      0 11.452  1810    2C
  3.00     0.26      1 10.911  1804    2C
  4.00     0.35      1 10.415  1803    2C
  5.00     0.45      2  9.962  1808    2C
  6.00     0.55      3  9.539  1815    2C
  7.00     0.66      4  9.075  1825    2C
  8.00     0.78      5  8.585  1837    2C
  9.00     0.90      6  8.061  1857    2C
 10.00     1.02      8  7.613  1886    2C
 12.00     1.30     13  6.835  1960    2C
 14.00     1.61     19  6.116  2058    2C
 16.00     1.97     26  5.344  2173    2C
 16.40     2.04     28  5.165  2199    2C- 2L
 18.00     2.39     37  4.531  2031    2L
 20.00     2.85     50  4.184  2256    2L
 20.34     2.93     52  4.094  2295    2L- 3C
 22.00     3.32     64  4.197  2055    3C
 24.00     3.82     81  3.891  2124    3C
 25.87     4.32     99  3.583  2199    3C- 3L
 26.00     4.36    101  3.422  1859    3L
 28.00     4.95    124  3.318  2003    3L
 30.00     5.57    151  3.164  2146    3L
 32.00     6.22    180  2.967  2289    3L
 32.07     6.25    181  2.950  2293    3L- 4C
 34.00     6.94    215  2.732  2098    4C
 36.00     7.69    254  2.575  2148    4C
 37.80     8.42    293  2.427  2199    4C- 4L
 38.00     8.50    298  2.372  1860    4L
 40.00     9.36    347  2.310  1958    4L
 42.00    10.24    400  2.231  2055    4L
 44.00    11.16    457  2.135  2153    4L
```

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SCAAN No 123668
REJECTED APPLICATION


speed    time    dist  accel    eng    gear
 mph      sec     ft  mph/sec   rpm   range
=======================================
46.00    12.12    521  2.024   2251    4L
47.65    12.97    580  1.748   2332    4L- 5C
48.00    13.17    594  1.750   2115    5C
50.00    14.35    678  1.655   2153    5C
52.00    15.60    772  1.560   2194    5C
52.26    15.77    785  1.542   2199    5C- 5L
54.00    16.92    875  1.487   1911    5L
56.00    18.30    985  1.436   1982    5L
58.00    19.72   1105  1.377   2053    5L
60.00    21.21   1234  1.311   2124    5L
62.00    22.79   1375  1.237   2194    5L
64.00    24.47   1530  1.158   2265    5L
66.00    26.33   1708  0.911   2336    5L
68.00    33.17   2384  0.099   2407    5L
68.13 = maximum speed                  5L
       (on   0.00 percent grade)


REJECTED APPLICATION
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```
SCAAN No 123668
date:  6/25/85,  1:31pm edt
tm001118, MONETTE
REJECTED APPLICATION

          DETROIT DIESEL ALLISON
          Engine-Converter Match
          ======================


 speed    .engine..    ....turbine....  heat rej
 ratio    rpm torque  hp      rpm torque BTU/min
==============================================
0.0000  1847  1293    0.0       0  2327  19283
0.1000  1815  1298   78.5     182  2273  15694
0.2000  1803  1300  149.2     361  2173  12595
0.3000  1807  1299  213.7     542  2070   9894
0.4000  1819  1297  269.6     728  1946   7621
0.4900  1837  1294  312.3     900  1822   5956 70 % eff
0.5000  1839  1294  316.5     919  1808   5795
0.5500  1859  1291  340.1    1022  1748   4947
0.6000  1887  1285  363.5    1132  1686   4175 80 % eff
0.6500  1921  1278  386.3    1248  1625   3447
0.7000  1971  1267  406.8    1380  1548   2913
0.7500  2033  1249  425.6    1525  1466   2463
0.8000  2109  1224  439.5    1687  1369   2202
0.8500  2225  1177  448.9    1891  1247   2101
0.8602  2262  1159  450.0    1946  1215   2092
0.8700  2300  1142  450.5    2001  1182   2100 gov. rpm
0.8851  2317  1075  427.4    2051  1095   1995
0.9000  2334  1009  402.6    2100  1007   1942
0.9250  2358   840  336.9    2181   811   1710 coupling
0.9500  2388   629  259.8    2269   601   1109
0.9750  2427   368  154.8    2366   344    650

 Lockup Operation
  eng   ...turb...
 speed torque  hp
====================
  1200  1238  282.8
  1300  1262  312.4
  1400  1277  340.4
  1600  1294  394.1
  1800  1279  438.3
  1850  1271  447.8 conv-lockup intersection
  2000  1238  471.5
  2200  1166  488.6
  2300  1121  490.8 gov. rpm
  2320  1087  480.0
  2365   768  345.8
  2410   461  211.4
  2455   165   77.1


REJECTED APPLICATION
```