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U. S. ARMY
TRANSPORTATION RESEARCH COMMAND
FORT EUSTIS, VIRGINIA

TCREC TECHNICAL REPORT 62-92

ARMY AIR LOGISTICAL SUPPORT STUDY

Task 1D643324D59806
(Formerly Task 9R87-14-007-06)

Contract DA 44-177-TC-754

December 1962

prepared by:

NORTHROP CORPORATION
Nortronics Division
Anaheim, California

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HEADQUARTERS
U. S. ARMY TRANSPORTATION RESEARCH COMMAND
Fort Eustis, Va

Sufficient economic and operational justifications are presented in the contractor's report to warrant follow-on research and development activities for cargo handling systems for Army aircraft. Because of considerations introduced subsequent to initiation of this study program, follow-on activities should include an initial analysis to determine the effects of the following on equipment and techniques:

1. The AC-2. Since the proposed cargo-compartment configuration of this aircraft closely resembles that of the HC-1, the AC-2 could provide a basis for:

   a. Closer dimensional compatibility both in unit loads and installed equipment and in terminal handling equipment for cargo to be moved by Army transport aircraft and the Air Force 463L-equipped aircraft.

   b. Major changes in recommended equipment concepts.

   c. A greater degree of system optimization and of standardization of equipment and techniques.

2. Combined Air-Landed and Aerial-Delivery Capabilities. The extent to which the Army plans to employ its aircraft in aerial delivery missions warrants a detailed analysis to determine the extent to which functions of the air-landed and aerial-delivery capabilities can be combined into a single equipment concept.

With reference to the contractor's recommendations on page 11, the following comments are submitted:

1. Concur with recommendations 1, 5, and 6.

2. Defer implementation of recommendations 2, 3, and 4, pending the additional analysis suggested in paragraphs 1a and 1b above.

3. Evaluate forward-area loading vehicles (see recommendation 4) being considered by the Air Force under Project 463L against the potential Army requirement for this type of vehicle.

FOR THE COMMANDER:

Kenneth B. Abel

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USATRECOM Project Engineer

Task 1D643324D59806
(Formerly Task 9R87-14-007-06)
Contract DA 44-177-TC-754
December 1962

ARMY AIR LOGISTICAL SUPPORT STUDY

NSS Report No. 2306

Prepared by:

Northrop Corporation
Nortronics Division
Anaheim, California

for
U.S. ARMY TRANSPORTATION RESEARCH COMMAND
FORT EUSTIS, VIRGINIA

FOREWORD

Under Contract DA 44-177-TC-754, the Transportation Research Command, United States Army, Fort Eustis, Virginia, authorized the Northrop Corporation to perform an engineering study and analysis of methods, procedures and equipment pertinent to a system for handling military cargo during transit from U.S. Air Force delivery points to U.S. Army receiving and distribution areas. The study was directed specifically to the HC-1 Chinook and AC-1 Caribou cargo aircraft. Consideration was given to the compatibility of the proposed systems to the USAF System "463L" cargo handling system.

The program was conducted in two phases by the Nortronics and Norair divisions of the Northrop Corporation under the technical direction of the Transportation Research Command. The Systems Support Department of the Nortronics Division had the responsibility for program management. Personnel assigned to the program included:

U.S. Army

Transportation Research Command

J. Vichness - Project Engineer

Northrop Corporation

Nortronics Division - Systems Support Department

W. N. Christensen - Project Engineer (Phase I)
J. M. Seman - Project Engineer (Phase II)
J. L. Fatz
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R. E. Krescanko
E. J. Partington

Norair Division

C. E. Elliott
R. Stewart

Submitted herein is the final project report, summarizing both phases of the project, which was initiated in June 1961 and concluded in August 1962.

Grateful acknowledgment is made for information and data furnished by all of the military services and commercial organizations contacted during the program.

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SECTION 1. SUMMARY

Presented in this report are the results of an engineering study of the methods, procedures, and equipment pertinent to a system for handling military cargo during air shipment from U.S. Air Force delivery points to U.S. Army receiving and distribution areas. The results compare the number of AC-1 Caribou and HC-1 Chinook aircraft, ground support equipment, and personnel required to accomplish a given logistic mission as a function of time for the following basic operational modes:

1. Manual loading and unloading of small modules of cargo.
2. Forklift loading of 2000-to 3000-pound palletized cargo units.
3. Special-purpose vehicle loading of 6000-to 7000-pound consolidated cargo loads moving over roller conveyors.
4. Special-purpose vehicle loading of 6000-to 7000-pound loads, consolidated on a mobile pallet moving over rails.

The resultant data are subsequently costed, and procurement and annual operating costs are presented. The normalized procurement costs of the basic modes in the order presented for a 5-hour mission time are \$1.00, \$0.81, \$0.82, and \$0.68. The normalized annual amortization, maintenance, and operating costs, including terminal support personnel, are \$1.00, \$0.74, \$0.75, and \$0.62 respectively.

Also presented in this report is a new cargo-handling system for aircraft. The system, based on a mobile pallet concept, is new in the manner in which a particular type of rolling assembly, the endless chain roller, is integrated into the system. The mobile pallet concept offers simplicity, reliability, economy of weight, and is particularly suited to the size and geometry of the AC-1 Caribou and HC-1 Chinook. The system lends itself to quick or automatic restraint of cargo and, as installed, will not degrade roll-on or roll-off capability. The use of the system forward of the Communication Zone is discussed because it provides an Army-Air Force compatible system to obtain a "through-put" capability.

Included in the report are several concepts of Universal cargo loaders for handling 10,000-pound palletized loads.

A loading analysis reveals that the U.S. Air Force's 463L System is not complementary to the U.S. Army's aerial resupply mission except during helicopter operations utilizing external loading.

SECTION 2. CONCLUSIONS

MATERIAL HANDLING SYSTEM 463L

Many factors of this study have shown that there is no compatability between the USAF 463L System and the U.S. Army air transport requirements. It is obvious from the physical sise of the aircraft that the 88-inch by 108-inch master pallet is not loadable into the AC-1 Caribou, nor does the 88-inch dimension provide adequate clearance in the 90-inch wide envelope of the HC-1 Chinook. The half-sized pallet, 54 inches by 88 inches is loadable into either carrier; however, as described in Section 8, Equipment Study and Design, an 88-inch long pallet is inefficient for loading Quartermaster pallets on the Army air carriers. Any attempt to obtain reasonable loading by double stacking STRAC containers on a 4-1/2-inch-thick 463L System half pallet, traversing a 2-1/2-inch roller conveyor, will fail or constitute a hazardous loading problem because of the limited vertical cabin clearance. As a result of the analyses in Section 8, it is concluded that internal use of either the 463L System master or half-sized pallets in Army carriers is not feasible. The use of either 463L pallet as a consolidating pallet for external slinging from the HC-1 Chinook is, however, both feasible and desirable. However, in this case, an efficient Army aerial supply system would relegate the helicopter to the forward area for short-haul missions over rough terrain, thus defeating the concept.

It is concluded, upon consideration of the foregoing factors, that there is no compatibility between the 463L System and any Army aerial cargo handling system that might evolve relative to the AC-1 Caribou and HC-1 Chinook as they are currently being produced.

CONCEPTS

A summary of the various operational concepts analyzed in this study and a tabulation of procurement and annual amortization and operating cost normalized to a manual operation is presented here.

Concept	Description	Initial Procurement Cost	Annual Amortization and Operating Cost
I	Manual loading and unloading and utilizing 8-g cargo restraining devices.	$1.00	$1.00
II-A	Forklift loading and unloading of palletized cargo and 8-g cargo restraining devices. Roller conveyors installed.	0.92	0.89
II-B	Same as II-A except 2-g restraint of cargo and a carrier-installed 8-g barrier net.	0.81	0.74
III-A	Special purpose vehicle loading and unloading of 7000-pound consolidated load and 2-g cargo restraint. Roller conveyors installed.	0.82	0.75
III-B	Same as III-A with the addition of bridging sections carried in the carrier to load or off-load to a platform or vehicle.	1.10	0.97
IV-A	Special purpose vehicle loading and unloading of 7000-pound consolidated load. Use of a mobile pallet and carrier-installed channel, restraining rails. 2-g cargo restraint.	0.68	0.62
IV-B	Same as IV-A with the addition of bridging sections carried in the carrier to load or off-load to a platform or vehicle.	0.71	0.63

Concept	Description	Initial Procurement Cost	Annual Amortization and Operating Cost
IV-C	Forklift loading and unloading of 7000-pound consolidated load. Use of mobile pallet and carrier-installed rails and ground rails. 2-g cargo restraint.	$0.68	$0.61
IV-D	No vehicles utilized for loading and unloading. Mobile pallet winched over rails. 2-g cargo restraint.	0.76	0.67

The most expedient innovation that can be effected to enhance the productivity of the AC-1 Caribou and the HC-1 Chinook is the installation of a barrier net. With a barrier net installed, the number of tiedowns is reduced; thus, the time required to restrain the cargo is shortened, and the tare weight is reduced. An extremely minor engineering analysis could provide the specifications for the barrier net and its installation. As shown in Concept II, a 15-percent reduction in system cost is realized when the barrier net is used.

Although the roller conveyor system of Concept III-A is attractive costwise, it requires that precision and extreme care be exercised by the loading crew, when loading consolidated loads over inclined ramps, to preclude damage to the carrier and possible personal injury. This eventuality results from the requirement to stack STRAC containers to obtain a full carrier load on the 11-foot consolidating pallet. To deviate from the stacked loads would require more consolidating pallets, and would result in greater loading and unloading time and in increased tare weight. To deviate from the single consolidated load would most likely render Concept II-B economically competitive or superior to Concept III-A.

Not only is the mobile pallet concept (Concept IV) of this study the most economical, but it also should be noted that the low-profile channel rails, as installed on the floor of the carrier, have the following advantages over roller or wheel conveyor assemblies similarly installed:

1. The low-profile channel rails (1 inch) will not have to be removed to obtain a roll-on/roll-off capability with vehicles of any tread width, and the rails present a minimum hazard to personnel who must work in the cargo compartment.

2. The presence of the rail on the carrier floor, properly secured, provides an infinite number of strong tie-down points for out-sized or aerial delivery cargo. The rails have the inherent strength to allow four-point tiedown of a full carrier load at 2-g flight load factors, thus eliminating much tiedown gear and time to effect tiedown.

3. The channel rails provide positive guidance during entry and exit for increased safety to personnel and the carrier.

4. The rails are extremely light as compared to the roller conveyor carrier floor sections and bridging sections.

5. To make use of the inherent structural strength of the channel rails, special skate-wheel roller conveyor sections could be built for insertion in the channel rails for aerial delivery.

Other advantages associated with the mobile pallet concept are the predictable, thus safe, behavior of the pallet during loading and unloading, and the absence of special devices and procedures when loading over inclined ramps. Utilization of a kneeling mobile pallet appears to provide a quick and convenient method of loading the aerial delivery pallets into the carriers. The kneeling pallet, with wheels located outside (widthwise), appears to be a reasonable and effective means of unloading the pallet without mechanical handling equipment and of recovering both the pallet and ground bridging rails. With the pallet kneeled to a 4-1/2-degree angle and a low-friction material on the pallet surface, very low forces would be required to arrest the load while the pallet is being winched back into the carrier.

The chief disadvantage that can be associated with the mobile pallet concept using the endless chain roller rolling assemblies is the effect of dirt or foreign matter in the rail. Rollers of approximately 1-inch diameter may have a tendency to jam when encountering debris in the rail. Although various brushes and sweeping devices attached to the endless chain roller assembly have been suggested for self-cleaning, a test and development effort would be required to reveal whether or not a problem exists and to specify a solution if problems should arise.

The advent of the consolidated pallet load into the Army's air logistic system will impose material handling requirements to service the AC-1 Caribou and HC-1 Chinook that are not known to exist in any present or proposed equipment. For maximum utility, a special purpose vehicle should be available which is capable of moving in under the tail of the HC-1 Chinook with the bottom of a consolidated load no higher than 12 inches off the ground. This single requirement suggests a cantilevered load which is unreasonable for the conventional forklift concept — 8000 pounds with a 5-1/2-foot load center.

Consideration should be given to providing the special-purpose vehicle with good mobility characteristics so that it could transport the consolidated load in a primitive airhead environment. Such a capability would possibly preclude or reduce the requirement to maintain large transport vehicles in the airhead environment and/or early break-bulk.

The lift height of special-purpose vehicles should be sufficient to load any Army vehicles that might be called upon to perform transport functions.

Not evaluated or examined in this study is the feasibility of extending the 11-foot mobile pallet concept to the C-130 aircraft, at least in the Communication Zone.

The advantages are:

1. Direct transferral of consolidated pallet loads from the C-130 to the Army carriers. This is in accord with the Quartermaster philosophy of increased amounts of "through-put" daily resupply.

2. Reduced cargo handling and transport, resulting in reduced vehicle and personnel requirements at the Joint Airfield.

3. Less sophisticated loading and unloading vehicles for the C-130 since the mobile pallet can traverse angular discontinuities resulting from inclined ramps and can engage restraining rails immediately upon reaching the aircraft floor in spite of the inclined ramp.

4. A good roll-on/roll-off capability at all times, including mixed loadings of rolling stock and palletized cargo.

Though an Army-Air Force compatible system as suggested here has not been analyzed, it appears that feasibility is predicated upon modification or revision to the length of the STRAC-A container and the mounting of the rolling assembly on the mobile pallet under the pallet. The concept envisioned provides two pair of channel rails installed on the floor of the C-130 to receive two rows of mobile pallets as shown in Figure 1. Since the width of the C-130 is only 123 inches, two 60-inch-wide pallets (specified for a 58-inch STRAC-A container plus tiedown space) do not allow sufficient clearance for aisle space. If aisle space is mandatory and 10 inches is acceptable, and 2-inch clearance at each side or between a pair of pallets and one side is required, the mobile pallet can be configured at 54-1/2 inches wide. This width is ideal for the Quartermaster wooden pallet and generous for the STRAC-B container (at 45 inches). The STRAC-A could only be loaded inefficiently, 33 inches on the 54-1/2-inch width, or be modified to 52 inches.

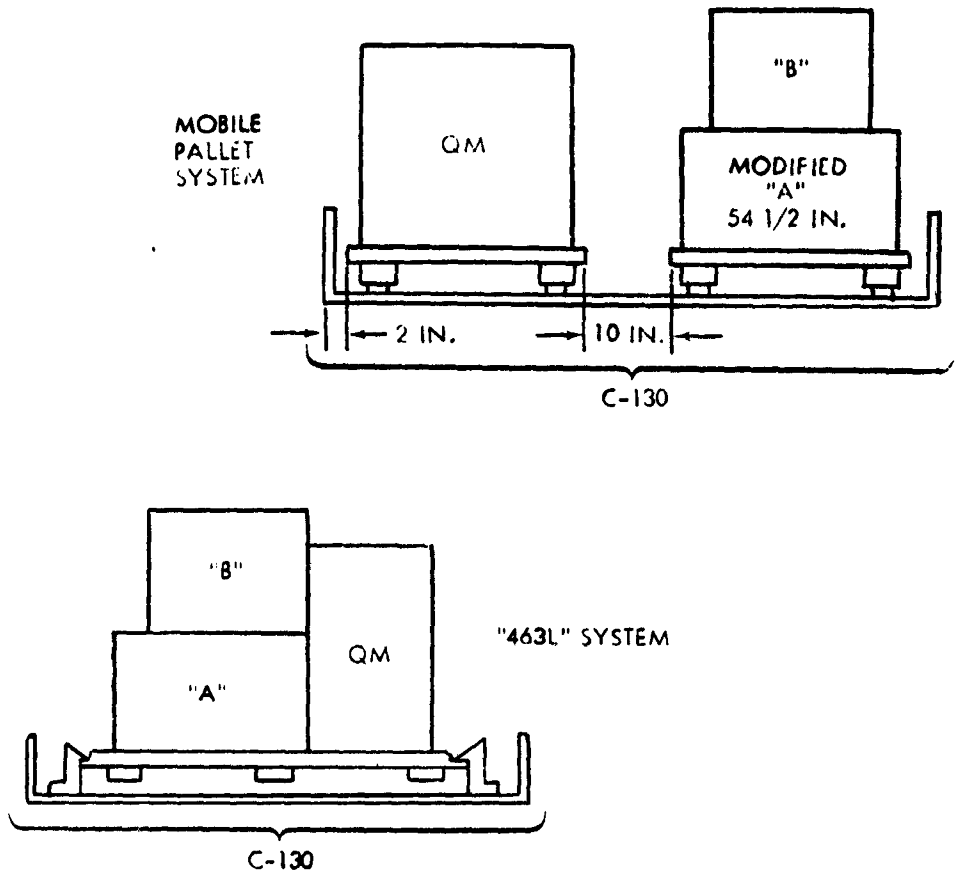
There remains one more significant advantage of the mobile pallet concept over the 463L System as installed in the C-130. It has been estimated that the 463L conveyor and tiedown system weighs approximately 3 pounds per inch and that the pallets weigh approximately 275 pounds each. The mobile pallet system rail and tiedown is estimated at 1 pound per inch and the pallets at 230 pounds each. Assuming four 463L pallets or six Army mobile pallets to gross-out the C-130, the 463L System tare weight is:

$$(3 \times 492) + (4 \times 275) = 2576 \text{ pounds}$$

and the mobile pallets system tare weight is:

$$(1 \times 492) + (6 \times 230) = 1872$$

The difference in tare weight is 704 pounds or approximately 2 percent of the C-130's lift capability.



	INSTL EQUIP	PALLETS	POUNDS
"463L"	(3 X 492 IN.) +	(4 X 275) =	2576
MOBILE PALLET	(1 X 492 IN.) +	(6 X 230) =	1872
DIFFERENCE			704

Figure 1. Possible Compatible System

EXTERNAL LOADING

Because of the simplicity of slinging and carrying cargo externally on the HC-1 Chinook and the existence of several military standard sling devices, no problems associated with the external loading could be discovered. A preliminary structural analysis of the consolidating pallet was performed which proved its capability of being sling-supported under 2-g flight load factors. In regard to productivity of external versus internal loading, insufficient data were obtained for a complete analysis or comparison with the proposed concepts. However, a brief analysis indicates that a reduction of aircraft velocity can be expected due to drag of the external load,and the increase in flight time will equal the reduction of loading time. Thus productivity will remain essentially the same for missions where flight time is the major factor. For short range missions this type of loading will show to advantage.

SECTION 3. RECOMMENDATIONS

Based on the findings of this study, it is recommended that consideration be given to initiating the following activities:

1. Engineering analysis for the installation and specification of barrier nets in the AC-1 Caribou and HC-1 Chinook.

2. Procurement of rough terrain forklift trucks of 3000- to 4000- pound lift capacity and compatible with approach to and loading of the AC-1 Caribou and HC-1 Chinook.

3. Engineering analysis and development of test programs to verify the feasibility of a mobile pallet concept.

4. Engineering and operations analysis to specify concepts and design requirements for forward-area loading vehicles of 7000- to 8000-pound load capacity.

5. Procurement of carrier-installed winches of increased speed-weight capacity to reduce loading time.

6. Determination of the feasibility of modifying the length of the STRAC-A container from 58 inches to 54 inches with the objective of realizing an Army-Air Force compatible system from at least the Communication Zone.

A final recommendation, based on the extreme importance of time, is that consideration be given to incorporating single-point refueling to minimize turn-around time.

SECTION 4. INTRODUCTION

OBJECTIVES

OVERALL

The ultimate program objective was to provide firm specific recommendations for a minimum family of cargo-handling devices to service air transported military cargo efficiently and effectively. The recommended devices are operationally compatible in all respects with the HC-1 Chinook and AC-1 Caribou Army cargo aircraft.

PHASE I

The object of the first phase of the program was to study, analyze, and compare existing cargo-handling and restraining mechanisms and problem areas in order or to evolve representative concepts to be utilized in solving the overall program problem. These concepts were presented to the U. S. Army Transportation Research Command (USA TRECOM) for evaluation and the selection of an optimum system to be developed more fully in the second phase of the program.

PHASE II

The object of the second phase of the program was to analyze further those concepts selected by TRECOM (Concepts II-B and IV) and to present concepts of the proposed cargo-handling equipment.

BACKGROUND

Because airborne logistics is an essential element of modern military tactics, it is imperative that the overall supply system, and each of its phases, function with maximum efficiency and economy. Within the general framework of airborne logistics, the Army has the specific responsibility for receiving materiel delivered to it by the Air Force at joint Army-Air Force terminals, and for transporting it to, and dispersing it from, Army airfields and airheads. To receive, transfer and distribute cargo in an efficient and economical manner, the Army requires materiel-handling equipment and devices which will:

1. Provide maximum utilization of available air transport by:

   a. Maximum payload per flight through efficient package sizing and minimum tare weight in airborne devices

   b. Minimum aircraft "turn-around" time through the use of efficient handling techniques;

2. Be compatible with:

   a. HC-1 (Chinook) helicopter and AC-1 (Caribou) aircraft

   b. USAF basic logistics aircraft and support systems

   c. All types of adverse terrain and climatic conditions

   d. Conventional and nuclear warfare tactics;

3. Be capable of consolidating large-volume, multipackage loads by use of pallets and containers;

4. Utilize compact, lightweight, aerially deliverable cargo handling equipment;

5. Incorporate existing commercial and military components wherever possible.

SCOPE

In order to satisfy the Army's need, the stated system requirements were viewed as individual problem areas, the sum of which represented the total system problem. Because of the magnitude of the problem, the solution could be achieved only through an integrated approach which considered each specific facet of the problem and evaluated it in the light of its relationship to the entire operation.

The overall program was divided into two phases:

Phase I Engineering Study

Phase II Comparative Analysis

Phase I was conducted under the following sub efforts:

1. Study and evaluation of present considerations including:

    a. Army organization

    b. Cargo aircraft characteristics

    c. Airfield considerations

    d. Unit loads

    e. Material Handling System 463L

2. Establishment of new concepts

3. Comparative analysis of evolved concepts

Phase II was conducted to complement the Phase I sub efforts to include:

1. Conceptual design and analysis of new proposed equipment

2. Cost effectiveness analysis of concepts.

SECTION 5. PRESENT CONSIDERATIONS

INTRODUCTION

In order to assess the problem properly, it was obviously necessary to analyze existing factors and conditions whose combined influences and constraints represented the total present Army air logistic situation. The study was directed to the following areas:

1. Army organization
2. Aircraft characteristics
3. Airfield considerations
4. Unit loads
5. Material-Handling System 463L

ARMY ORGANIZATION

To provide a familiarity with the Army organization as it affects this program, a brief study was conducted on the general military logistic chain, the future organization of units to be served by Army air supply, and the organization of aviation battalions which will be performing the supply function.

LOGISTIC CHAIN*

Theater Army Logistical Command (TALOG)

It is anticipated that TALOG will provide logistical support, with a few exceptions, to all U.S. Army Forces, Navy, and Air Force. The mission will be accomplished and the functions will be performed in part by

*Supply Segmentation and Unitization for Combat Support, QMB Project No. 23, Project 56-7, Quartermaster Board, U.S. Army, Ft. Lee, Va., June 1961.

Advanced Logistical Commands (ADLOG), and Area Commands within the communications zone. In addition, TALOG will be responsible for intersectional services for bulk POL, communications, and transportation. A Logistical Support Operations Center (LSOC) at TALOG headquarters coordinates, facilitates, and expedites the flow of logistical requirements and data through an ADP system.

Base Logistical Commands (BALOG)

Under the supervision and control of TALOG, the Base Logistical Command provides direct support to one or more Advance Logistical Commands. BALOG normally is the first point in the theater of operations to receive supplies from the ZI. The supplies are received by air or surface transport.

From the standpoint of off-loading, supplies will move to depots in BALOG for reconsignment to ADLOG depots or forward. In some cases, heavy tonnages of supplies (Classes I and V) will bypass BALOG depots and move as far forward as possible. These supplies will move forward primarily by surface means. Most aerial shipments for forward areas will originate in BALOG.

Advance Logistical Commands (ADLOG)

Under the supervision and control of TALOG, the Advance Logistical Command provides direct logistical support to the combat forces. These commands will be provided in numbers sufficient to meet the support requirements for any given situation. Depots will be required in ADLOG and they will be of a small, general type. These depots will receive supplies from BALOG by truck, rail, or air. The depots will maintain operating stocks of Classes II and IV and unslated Class III. Reserve stocks will be maintained for Classes I and V. It is expected that shipments of Classes I and V and possibly some packaged Class III can originate in BALOG, bypass ADLOG, and move directly as far forward as possible to supply installations in the Field Army area. Shipments originating at ADLOG will move, in the majority of cases, by surface means to support echelons in the Field Army.

The Field Army

General

Tactical concepts for the future, embodying rapid movement in any direction and wide dispersal of forces, rule out fixed supply installations with thousands of tons of supplies. Instead, relatively small installations, austerely stocked, with sufficient mobility to keep up with the Field Army movements, will be a necessity.

General Support Groups

The installations are expected to absorb the functions of the present Field Army depots. They will possess a higher degree of mobility than present Field Army depots and will be supported by BALOG and ADLOG depots. They will support the direct support groups, who are supporting the divisions, with reserve stocks only and will not be an echelon in day-to-day supply. Reserves of all classes of supply will be carried.

Direct Support Groups

These groups will be essentially supply points for the division and will possess 100-percent mobility. Classes I and V will be supplied directly from BALOG depots in the form of operating and reserve stocks. Classes II and IV and unslated Class III are supplied from ADLOG depots as operating and reserve stocks. Bulk Class III will be supplied from the Field Army POL systems. For the most part, supply to the division will be from the supply point. Unit distribution will be accomplished where practicable.

REORGANIZATION OBJECTIVE ARMY DIVISION - 1965 (ROAD 65)*

The reorganization of Army divisions is designed to meet the varying needs for a fast, mobile, flexible, and ready ground force. Since it is believed that the United States resources for deterrence of nuclear wars are adequate, this Army reorganization is to provide a readiness for nonnuclear combat. The reorganization develops a new degree of standardization in organization which will facilitate training as well as the tailoring of divisions to suit the mission and the terrain in which they will fight.

* "The New Army Divisions," *Armor*, Sept. - Oct. 1961, pp 22-23.

The proposed units will have the flexibility to accept new weapons and equipment as they become available; without major reorganisation or change in concept of employment. Also, the requirements for increased battlefield mobility and increased protection on today's battlefield indicate the desirability of creating a mechanised division which will be infantry-heavy and armor-protected.

The Infantry, Armored, and Mechanized Divisions are constructed by adding varying mixes of Combat Maneuver Battalions to a common Division Base. The fourth type of division, the Airborne, will be similarly constructed and will have the same degree of flexibility when finalized.

Division Base

The Division Base is common to all types of divisions and its strength can vary from 6000 to 7200 men. Each base will consist of:

1. A command and control element

2. A combat element

3. A combat support element

4. An administrative support element.

The command and control element of the Division Base includes three Brigade Headquarters, which are capable of controlling the tactical operations of several attached maneuver battalions, and appropriate combat support and administrative support elements.

Administrative support for the division is provided by a Division Support Command organized on a functional basis to provide supply, field maintenance, medical support, and administrative services to the division. The administrative complex permits the lower echelon commanders to devote maximum attention to tactical operations.

Combat Maneuver Battalion

The basic maneuver element of the ROAD divisions will be the tactically and administratively self-sufficient battalion. The Combat Maneuver Battalions — Infantry, Tank, Mechanized Infantry — which are added to the Division Base to construct the various types of divisions, are as similar in organization as possible, consistent with their individual roles. Thus the basic building blocks of the new divisions are the Division Base and the Combat Maneuver Battalions.

These battalions, with strengths of approximately 600 to 900 men, will be grouped in varying combinations under Brigade Headquarters to form Armored, Mechanized, Infantry, and Airborne divisions. All battalions are essentially of one combat arm, i.e., armor in the Tank Battalion, and infantry in the Mechanized and Infantry Battalions. This facilitates training.

Also, organization of the division is simplified by having battalions capable of giving up temporarily a company of another type. In addition to forming division-size units, the battalion structure used in the new concept facilitates the formation of task forces of brigades of lesser sizes.

Important equipment changes call for major increases in armored personnel carriers, artillery, recoilless rifles for assault fire, and aircraft for tactical mobility.

An Armored Division will be a division with approximately even numbers of Tank and Mechanized Infantry Battalions, while a Mechanized Division will have a greater proportion of Mechanized Infantry Battalions. An Infantry Division will be a division with predominantly Infantry Battalions, but with some Tank Battalions.

However, any type of division may have all types of battalions if the mission dictates this organization. There could be as many mixes of battalions as there are divisions, with the total number of Maneuver Battalions varying from 6 to 15, each division being tailored to the mission of the division and to its expected operational surroundings.

The strength of the typical division would be approximately 15,000 men with the Airborne Division approximately 14,000 men. Once organized for a particular strategic mission and operational environment, the composition of the division would remain relatively stable.

The new organization increases the compatibility for combined operations with the armed forces of allied nations. Implementation of the reorganization will begin gradually in 1962. There are indications that completion of the reorganization may precede 1965; thus it may become ROAD 63 or 64.

In summary the ROAD 65 Divisions will consist of the following:

	Strength
Division Base (common to all divisions)	6,000 - 7,200
Combat Maneuver Battalions	600 - 900
Battalions per Division	6 - 15
Typical Division	15,000
Airborne Division	14,000

AVIATION BATTALION

Aviation Battalions equipped with Caribou (AC-1) and Chinook (HC-1) aircraft will perform tactical support missions in combined arms combat operations including airdrop and airlanding of troops and equipment and combat resupply within the Field Army area and forward of the FEBA (forward edge of the battle area).

The greatly increased capabilities of such battalions equipped with AC-1 and HC-1 aircraft will result in increased capabilities in performance of tactical missions. The battalions will be employed in performing operations such as rapid repositioning of reserves laterally or forward; exploitation of the successes of ground elements by positioning and resupplying blocking forces; tactical resupply of engaged units such as armored spearheads and mechanized task forces; tactical reinforcement of isolated strong points; and limited airlanding or airdrop of troops or equipment in connection with plans of maneuver—in addition to administrative-type missions including aeromedical evacuation.

As more fixed-wing (light) transport aircraft of the Caribou class are obtained, they can be expected to become organic to organizations below corps level. It would thus appear that Caribou units may eventually be assigned to division level for tactical operations with subsequent support of, or attachment to, Brigade Combat Command or Battalion, as required in the division's plan for execution of its mission.

It appears doubtful that a Combat Maneuver Battalion engaged with the enemy would normally have a sphere of responsibility involving distances which would make practicable the normal attachment of a Caribou Company or a part of a company at that level. Thus, the support of a battalion in contact would be on a mission basis. However, if such a battalion's mission involves employment of the Caribou, a company of one or more platoons would be attached for that specific operation.

Under the present concept of aviation organization, it appears that light transport aircraft of the Caribou class will be grouped at a company level. Such a company can be expected to include three platoons of eight Caribous each. The company will be grouped with rotary-wing companies to comprise an Aviation Battalion. One such battalion will be organic to each Corps in the Field Army area, and one battalion will provide general support to the Field Army. A Fixed-Wing Aviation Battalion Headquarters may be provided at the Field Army level to expedite tactical utilization of the assigned aircraft. The aircraft would then be made available for attachment or support at Task Force, Battle Group-Battalion, Brigade, Combat Command, or Divisional level. The commander and staff of such a battalion will be trained in combined arms operations. They will thus have the capability to assist in planning and execution of tactical missions involving the employment of Caribou Companies in combined arms operations.

Normally, an aviation company will be attached to the unit to be supported. In this manner command, control, and tactical integrity can be maintained more effectively. This does not preclude the commitment of separate sections of the company on a mission basis.

Because of the size of the Caribou and the area necessary for tactical dispersal on the ground, the base airfield from which the Caribou Company operates should be located sufficiently to the rear to deny its engagement by enemy artillery. For tactical missions, the aircraft can utilize any suitable landing site in the forward area.

Aviation Company Data

The data presented here are based primarily on the "Caribou AC-1 Troop Test" conducted at Fort Benning, Georgia. They reflect the services required for a type field army of 12 divisions with a depth of 100 nautical miles. Army airlift requirements are established as approximately 1630 tons per day. It is assumed that the data for a Rotary-Wing Company would be very similar.

Aviation Company (FWLT) Fixed Wing Light Transport

(1) Strength

One company per corps (estimate three corps per Army)

One company per Field Army

Three flight platoons per company with eight aircraft each or 24 aircraft per company

(2) Mobility

50-percent mobility when using organic ground vehicles only

100-percent mobility when using organic ground vehicles plus one platoon of eight AC-1 aircraft

(3) Maximum Resupply Capability

200 tons in 24 hours at 150 nautical miles per company

217 tons at 16-18 hours per day with 61 sorties. This is equivalent to one-half of an Infantry Division's daily supply requirements.

(4) Real Estate Requirements

140 acres per company

90 acres per platoon on dispersed type operations

Base airfields should be beyond range of hostile divisional missile and conventional artillery capability.

(5) AC-1 Aircraft

Fuel Consumption

Fuel Consumption - average 114 gallons per hour (approximate)

Fuel consumption at 75-percent availability and 4 hours per day - 246,240 gallons per month (does not include spillage factor nor oil requirements)

Basic Load - AVGAS 20,160 gallons

Availability

Under normal combat conditions - 65 to 75 percent (70 percent attained during Troop Test)

TERMINAL SERVICE SUPPORT UNIT

To provide logistical support for Army Aviation Transport Companies, it appears that a Terminal Support unit of some type is required. The mission of such a unit would be load preparation, loading and unloading, documentation of airlanded cargo, and related functions for controlling and processing intransit storage of supplies being moved by air.

In order to preserve the tactical flexibility and mobility of Aviation Companies, it would appear necessary that the support unit not be organic to the aviation unit. Rather it would be attached to it, or placed in direct support of it, when it is to be operating primarily as in a logistical transport role. Since the Aviation Companies are within the Transportation Corps, it would appear logical that the support unit be responsible to the same technical service. In this manner, a direct line of command and control can be retained, training programs can be more effective, and operational responsibilitycan be clearly defined. Working directly with the aviation units, the support units can develop and maintain operational methods and doctrine fully compatible with the aviation requirements. The exact organization level at which the terminal support service unit would be assigned has not been established.

At this time, the organization location is much less important than the physical location of such a unit. It must be physically located at the operational base of the Aviation Company and may be required to provide a certain level of support in either manpower or equipment, or both, at the forward area landing sites during high flows of airlanded supplies. For this reason, the unit will require a high degree of mobility, including air mobility.

As a corollary to the above, it would also appear that consideration should be given to combining the functions of such an Aerial Terminal Support Unit with the functions of support units responsible for supporting air delivery units. Such a combination will conserve both man-power and equipment, in the support of Army Air Vehicles. For example, any specific aircraft or units of aircraft must either be engaged in airlanded or air delivery missions. Thus, whichever is the case, if dual support units are provided, one or the other will be idle most of the time. Also, a considerable degree of operational flexibility will be lost when the mission is changed from an airlanded mission to an aerial delivery mission, if different support units in different locations under different commands must be relied upon. In addition, when viewing the loading and unloading operations, the similarity in requirements is quite apparent. This is especially true when it is anticipated that most loads of airlanded supplies will be unitized in units too large to permit use of only manual techniques. Both operations then become concerned with mechanized aids for loading heavy unit loads, the primary difference being in the size of the load and the method of unloading at the delivery point. In addition, there is no equipment presently available to perform the mechanized operations efficiently. It follows that any equipment developed to fulfill functions for one operation should be capable of performing similar functions for the other mission without too great a compromise in design requirements. When such equipment has been developed and introduced, equipment duplication will be necessary in the same general geographic location to support the same aircraft if the separation of airlanded and air delivery functions continues.

AIRCRAFT CHARACTERISTICS

The following aircraft characteristics pertinent to this study were compiled:

HC-1 CHINOOK HELICOPTER

1. Description

   Multiturbine, twin-rotor helicopter. Rear loading.

   Three-man crew: pilot, copilot, flight engineer

2. Dimensions (feet)

Length (rotors open)	98.2
(fuselage)	51.0
Height	18.5
Disc Area	5468 square feet
Rotor Diameter	18.5
Cargo Compartment	
Length (inches)	362
Height (inches)	78
Width (inches)	90

3. Cargo Capacity — 6000 pounds

4. Combat Radius — 121 nautical miles

AC-1 CARIBOU AIRCRAFT

1. Description

Conventional, twin engine, cantilever high-wing monoplane

Rearloading. Two-man crew: pilot, copilot

2. Dimensions (feet)

Length	72.6
Height	31.7
Wing Span	96.1
Prop Ground Clearance (inches)	22

Cargo Compartment

Length (inches)	345
Width (floor) (inches)	73
(shoulder) (inches)	86
Height (inches)	75

3. Cargo Capacity — 7284 pounds

4. Combat Radius — 563 nautical miles

AIRFIELD CONSIDERATIONS

In considering operations involving both fixed- and rotary-wing aircraft, the fixed-wing airfield requirements will normally establish the operational limitations. Any airfield or strip suitable for fixed-wing operation should be more than adequate for helicopter operation. Under such a dual operation, it is desirable that rotary-wing landing areas be located so that their traffic pattern will not restrict fixed-wing usage of the primary runway(s). Once the airfield ground and air traffic requirements have been defined for the AC-1 Caribou, additional acreage requirements become a function of how many aircraft are to operate from the field and what level of in-transit storage must be provided for airlifted supplies. Both the latter also become a function of the effectiveness of the ground support units in loading, unloading, and processing of the airlifted material.

The 1961 Troop Test Operations of the AC-1 Caribou indicated that airfield requirements as now established in TM 5-251 are not valid for aircraft of this class. This is especially true of the clearance zone standards which are too restricted. The 28,500 pound AC-1 Caribou version was not used in the tests; thus exact requirements have not been established. Not only must the runway and clearance zone requirements be reviewed, but additional ground space must be allowed for loading zones, parking areas, dispersal areas, and company ground installations. As a guide, a field of approximately

140 acres is needed for an Aviation Company (FWLT) equipped with 24 aircraft, and a 90-acre area is required for a platoon of eight AC-1 aircraft.

In considering fixed-wing operations, there are four types of airfields which are applicable:

1. Base airfield

2. Dispersal airfield

3. Satellite airfield

4. Army airheads

All such fields will be within the Field Army area which is considered to be approximately 100 nautical miles in depth.

BASE AIRFIELD

The base airfield is defined as the primary field from which an Aviation Company would operate. Here it would have a full complement of ground support equipment and personnel, including both that organic to the company and that provided by the appropriate support units.

In the combat zone, base airfields will normally be located not closer than 25 miles to the FEBA (forward edge of the battle area).

In many instances, the base field may be jointly used by both Army and Air Force Aviation units. In other cases, it may be used solely by the Army, yet located near a larger Air Force airfield. Even in this case, Air Force intratheater aircraft may land on the Army airfield and discharge Army supplies for subsequent handling by the Army Transportation Corps by either ground or air. For ease of discussion in this report, any field serving both Army and Air Force aircraft is called a "Joint Field."

SATELLITE AIRFIELDS

A satellite field is a base of operation for an element of the Aviation Company to work from in the accomplishment of a specific mission or missions. The amount of maintenance, air traffic control and material-handling equipment provided at satellite fields will depend upon the duration of the mission and the amount of traffic expected. Traffic in this instance includes both air traffic and the volume of flow of material through the field.

Satellite fields can bc of the "hasty" category (see Construction) with modifications to lateral clearance of landing zone, overrun, approach zone, and length of runway compatible with AC-1 Caribou requirements. Other factors which must be considered in the selection of a satellite field are:

1. Drainage
2. Loading zones
3. Tactical parking areas.

DISPERSAL AIRFIELDS

Dispersal airfields are required to spread out the Aviation Company in order to reduce vulnerability. Dispersal airfields can be of the pioneer category (see Construction) with modification of strip length and lateral clearance corresponding to AC-1 Caribou requirements. Because of the size of the AC-1, consideration must be given to providing adequate tactical parking areas.

AIRHEAD

The airhead cannot actually be considered as an airfield but is included in this discussion because it represents the terminal point of the air logistic chain. By its very nature, it is extremely temporary, representing the absolute minimum requirements for aerial delivery of supplies vital to a tactical situation. At best, the airhead may meet the minimum standards of pioneer construction (see Construction). The life of an airhead will be limited to meet the immediate need.

CONSTRUCTION

Pioneer

A pioneer Army airfield represents the lowest standard of construction which can be utilized under favorable operating conditions. Safety factors are at, or close to, minimum requisites. The runway is usually limited to a soil surface, an existing road, or a natural sod surface, with operations frequently restricted almost entirely to favorable weather. For example, the airfield used by a division for brief periods would normally be of the pioneer type. Traffic is estimated on the basis that the total number of aircraft will be 95-percent operational, and each will make five flights per day. A selected area which will provide an unprepared site which does not meet all the design criteria contained in Army Technical Manual, TM 5-251, but which does allow safe operations, falls within the category of a pioneer airfield.

Hasty

A hasty Army airfield is one which is built to provide a substandard but operable margin of safety. This type of field allows reasonably safe and efficient operations, except in prolonged adverse weather. For example, the airfield used by a corps headquarters for varying periods up to approximately 6 months would be of the hasty type. Traffic is estimated on the basis that the total number of aircraft will be 75-percent operational, and each will make three flights per day. The choice of a finished runway will depend upon the soil conditions, the weather, the time of year, the availability of a particular kind of surfacing material, and the length of use of the field. Portable surfacing is normally used, although bituminous surfacing or emplaced sod may be utilized under appropriate circumstances.

Deliberate

A deliberate Army airfield is one which is constructed to established standards of safety and efficiency. Operations are practicable under adverse conditions. To be all-weather operable, the runway will have a well-graded, thoroughly compacted subgrade with a well-designed flexible or rigid pavement; it is built to specifications of instrument runways.

UNIT LOADS

ARMY UNIT LOAD CONCEPT

Recent Army studies on various aspects of unitization of logistic shipment seem to arrive at the same general conclusion that many benefits are obtainable through the application of the unitization concept. Some examples of unitization benefits have been cited as follows:

> Analyses of World War II logistics indicate that some 42 percent of the supplies and equipment consumed in that conflict could have been unitized on pallets or in shipping containers. *
>
> As much as 65 percent by weight of all future field army supply, exclusive of bulk POL, may be unitizable. Because of unpredictable consumption rates, only a small part of the unitized portion of the supply used in the forward area can be prepackaged at the origin (CONUS or COMZ) in directly usable (days of supply, unit consumption) load.
>
> The remainder of forward area supply will have to be drawn from theater stocks as required. This condition probably holds true for most field army supply. The advanced section (ADSEC) depot, or its future successor, will have to carry much of the burden of filling, packing, and shipping this portion of field army supply requirements.
>
> The ADSEC depot needs, therefore, simple tools for packing and consolidating supply requirements per consignee. From a supply standpoint CONEX inserts (STRAC Packs) and pallets appear best suited for this purpose. (Whether such loads can and should be moved beyond ADSEC in reusable containers will depend on the consignee's ability to handle cargo in that form.)**

Once the fact is accepted that it is desirable not only to utilize supplies, but also to retain load unitization through as many legs of the supply chain as practical, it then becomes important to determine the interaction of unit loads with Army airlift capabilities.

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*"Containerization and Roll-on/Roll-off," American Jet Power Co., May 1953.

**Determination of Requirements for Unitization of Cargo, Project CD 58-7, January 1960, U.S. Army Transportation Combat Development Group, Fort Eustis, Virginia.

ARMY STANDARD LOADS

For the purpose of this study three existing standardized loads were considered.

	QM Pallet	STRAC Pack A	STRAC Pack B
Dimensions Unloaded (inches)			
Length	48	58	45
Width	40	32-7/8	32
Height	54 (approx.)	33	33
Dimensions Max. Load (inches)			
Length	52	58	45
Width	43	32-7/8	32
Height	54 (approx.)	33	33
Average Payload (pounds)			
Class I, II, and IV	1550	1400	1000
Class III	2160		
Class V	3532		

Standard Quartermaster Pallet

The standard wooden Quartermaster pallet conforms to either specification MIL-P-15011D or MIL-P-3938B. Both permit four-way forklift access.

STRAC Containers

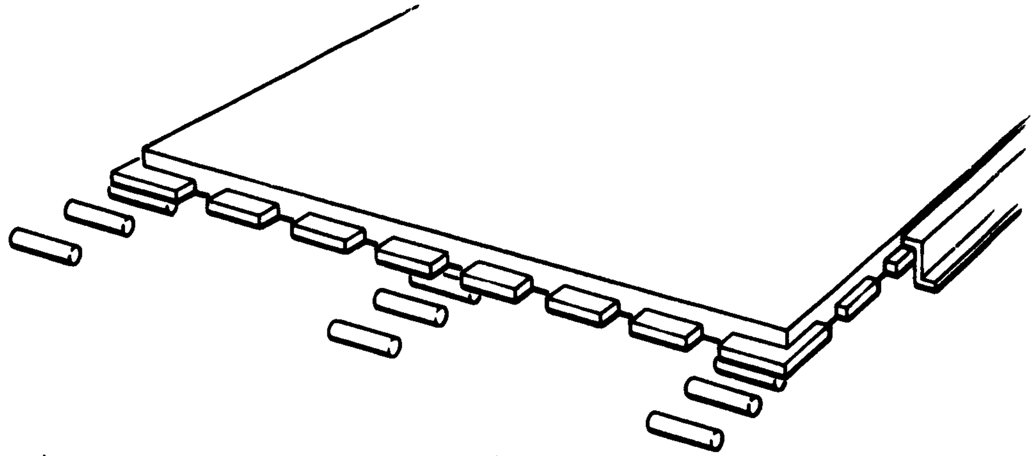
STRAC packs were designed as insert-type containers for the steel CONEX box. The purpose of inserts is to avoid break-bulk operations when loading and emptying CONEX boxes and to provide a pallet-size load of nominal weight better suited for air transportation than the CONEX box. Also, inserts can provide weather protection to supplies not processed for open storage or shipment on open top transportation equipment, and can be manhandled if necessary (by four to six men) or cut open and emptied while still in the larger container or on the carrier by themselves. For the purposes of this study, the STRAC packs will be considered to be shipped individually without the CONEX box.

MATERIALS HANDLING SYSTEM 463L

During the course of this study, the Air Force's 463L cargo and handling system was examined for compatibility with Army air carriers. The system is composed of special pallets, aircraft restraining rails, and roller conveyors, transport vehicles, and miscellaneous ancillary equipment.

The 463L system utilizes an 88-inch by 108-inch aluminum pallet, 2-1/2 inches thick, with a metal lip along its perimeter to engage a 5-inch high side guide and restraining rail. The pallet lip is notched every 10 inches to engage fore-and-aft restraints mounted 40 inches on center integral to the rail. The floor of the aircraft is equipped with a series of roller conveyor sections to support and transport the loaded pallet as illustrated in Figure 2. One rail and one set of rollers of this system are movable to receive the pallet on either its 88-inch or 108-inch dimension. A half-size pallet, 54 inches x 88 inches, of frame construction, 4-1/2 inches thick, is contemplated for the system. (Procurement status is unknown.)

The full-sized pallet is designed to carry a 10,000-pound load, corner supported, under 1.8 g loading. The half pallet is specified to carry 5000 pounds. The 463L System weight is conservatively estimated at 3 pounds per inch for the aircraft installed equipment and 275 pounds per pallet. The half-sized pallet is specified to weigh less than 200 pounds.



A/C INSTALLED EQUIPMENT	3 LB/IN.
MASTER PALLET (88 x 108)	275 LB
1/2 PALLET (54 x 88)	200 LB

Figure 2. USAF "463L" System

SECTION 6. LOGISTIC SYSTEM

INTRODUCTION

The capability of a nation's military logistic resources to deploy and resupply individual ground fighting units expeditiously in various political, geographical, and climatological environments of the world is as important as the weapons they command. However, by reasons of technological and economic factors, the characteristics of the logistic systems tend to limit both the development and use of modern weapons. Such limitations are manifest in the system or system elements in terms of quantity, loading envelopes, loading capacity, ability to gain access to difficult terrains, and ability to respond to urgent requests or capitalize on favorable tactical situations within a critical time. These limitations are generally so severe in today's military and political environment that weapon and organizational trends are striving desperately to be compatible with the logistic life line. Concurrently, the logistic systems are being enhanced by procurement of mechanized cargo handling systems, machine requisition and documentation control, and improved carrier and transport vehicles.

Perhaps the most recent and important contribution to military effectiveness, measured in terms of tactical mobility and flexibility, will result from the addition of the AC-1 Caribou and the HC-1 Chinook to the terminal logistic supply line. However, it is recognized that the mere addition of these two new carriers will not fully exploit the capabilities inherent in the new system. It is necessary to examine the requirements of the system in terms of incoming cargo and the facilities and personnel that are available to accomplish the necessary functions within the Army Air Logistic System (see Figure 3). Next, it is useful to compare quantitatively several likely operational concepts to accomplish a given mission in order to discover the significant factors that contribute to productivity and economy.

Within the scope of this study, the characteristics and performance of the Army air carriers are fixed, the nature of the cargo to be carried is specified, and the manner in which air cargo is introduced into the Army theater by the Air Force is yet to be determined. However, if the mission of the Quartermaster Corps can be considered essentially invariable, whether cargo moves through the system by surface or air, then a new and improved logistic capability designed around the AC-1 Caribou and HC-1 Chinook need only specify the carrier-installed systems, terminal-support facilities, and organizations required to implement a given system concept. To this end, the following discussions and evaluations are directed toward the establishment of a resupply model and the specification of several operational concepts that will demonstrate the effectiveness and economy of load consolidation and mechanization.

OPERATIONAL EVALUATION

In order to define the operational functions associated with air logistic operations, it is first necessary to examine the overall operation (Figure 3). Since this is primarily an operation involving priority-type shipments, much of the material to be transported via Army aircraft will have arrived by air and will be stocked in Army supply areas. However, a considerable portion of the task will also involve fulfilling urgent requirements by direct requisition to the communications zone (COMZ). Thus, in addition to the requirement for truck-to-aircraft transshipment, aircraft-to-aircraft transfer at the Joint Airfield would be desirable.

Shipments of bulk supplies will arrive at the Joint Airfield in Air Force 463L System transport aircraft on the pallets being used under the 463L system. Many such pallet loads can be expected to consist of shipments for different using units. In this case, the palletized load will have to be broken up and routed item by item.

As the flow of material through the air logistic system increases, it will become possible to consolidate master pallet-size loads at point of origin and move them through the system to the point where vehicle load restrictions require master pallet loads to be subdivided. Such restriction may result from either weight or space limitations. Ideally, it should be possible at this point simply to divide the master pallet load into halves or quarters without any need to completely break down the pallet load and reload it onto smaller pallets or containers. The solution of this problem is of primary concern to the Quartermaster Corps in reducing the time in the supply pipeline. To solve this

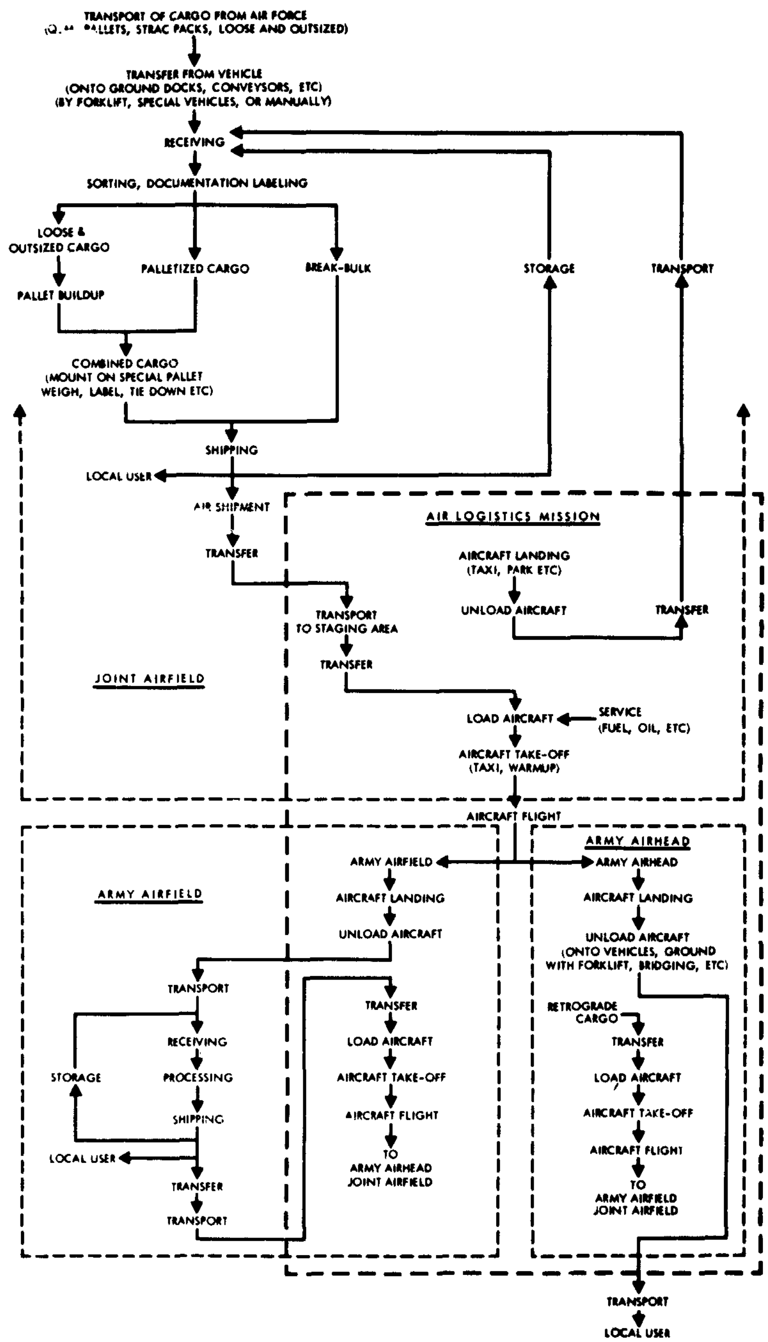


Figure 3. Operational Functions

problem, many other attendant requirements must be taken into consideration. These requirements are enumerated as follows:

1. Combining or consolidating multiple units of palletized and/or containerized cargo. (Cargo unit makeup.)

2. Mechanized handling and restraining of consolidated cargo within the aircraft.

3. Slinging consolidated cargo externally of the aircraft fuselage.

4. Positioning varying multiples of unitized cargo internally for inflight balance of the aircraft.

The stated requirements are directly related to aircraft operations and are of prime importance. However, in the design of equipment for fulfilling these requirements, it also must be borne in mind that the consolidated cargo will have to be removed and placed directly on the ground and will have to be loaded and unloaded from military ground vehicles of various types. Equipment designed without these additional requirements in mind may be severely limited in its usefulness and subsequently replaced with more versatile items.

SECTION 7. RESUPPLY MODEL

INTRODUCTION

In order to specify and cost the equipment and vehicles necessary to implement the Army Air Logistic system, it is useful to have a model that depicts both the geography of the mission and the work that must be accomplished by the system. Accordingly, a model was developed to assist in the determination of the system requirements.

With regard to the geographical or dimensional model, the philosophy behind the ROAD concept—a degree of autonomy at Brigade level—suggests at least three intermediate supply areas beyond the Joint airfield in reasonable proximity to the airheads. The intermediate supply areas or Army airfields would be expected to be as near to the FEBA as possible while remaining out of range of enemy artillery and/or below enemy radar surveillance. Approximately 25 nautical miles will satisfy both conditions. However, the width and depth of a ROAD or Airborne Division area will vary according to many factors. A 100-mile airlift radius—as measured from existing airfields, which could serve as the Joint airfield—provides reasonable coverage of two potential trouble areas. (See Figures 4 and 5.) The width of the front was arbitrarily established to be less than the depth but related to the number of air-landed cargo loads. It was estimated that 81 tons of resupply per day would reach the airheads by air. Eighty-one tons delivered in 3-ton units could service 27 airheads on a daily basis. Configuring the front so that a customer would be no farther than a mile and a half from an airhead, an 81-mile front results. Fewer airheads, of course, result in increased number of daily deliveries (see Figure 6).

ASSUMPTIONS

The amount and the manner in which the air cargo flows through the dimensional model was developed on the basis of the following assumptions:

1. Approximately 50 percent of the airheads are suitable for AC-1 Caribou landings.

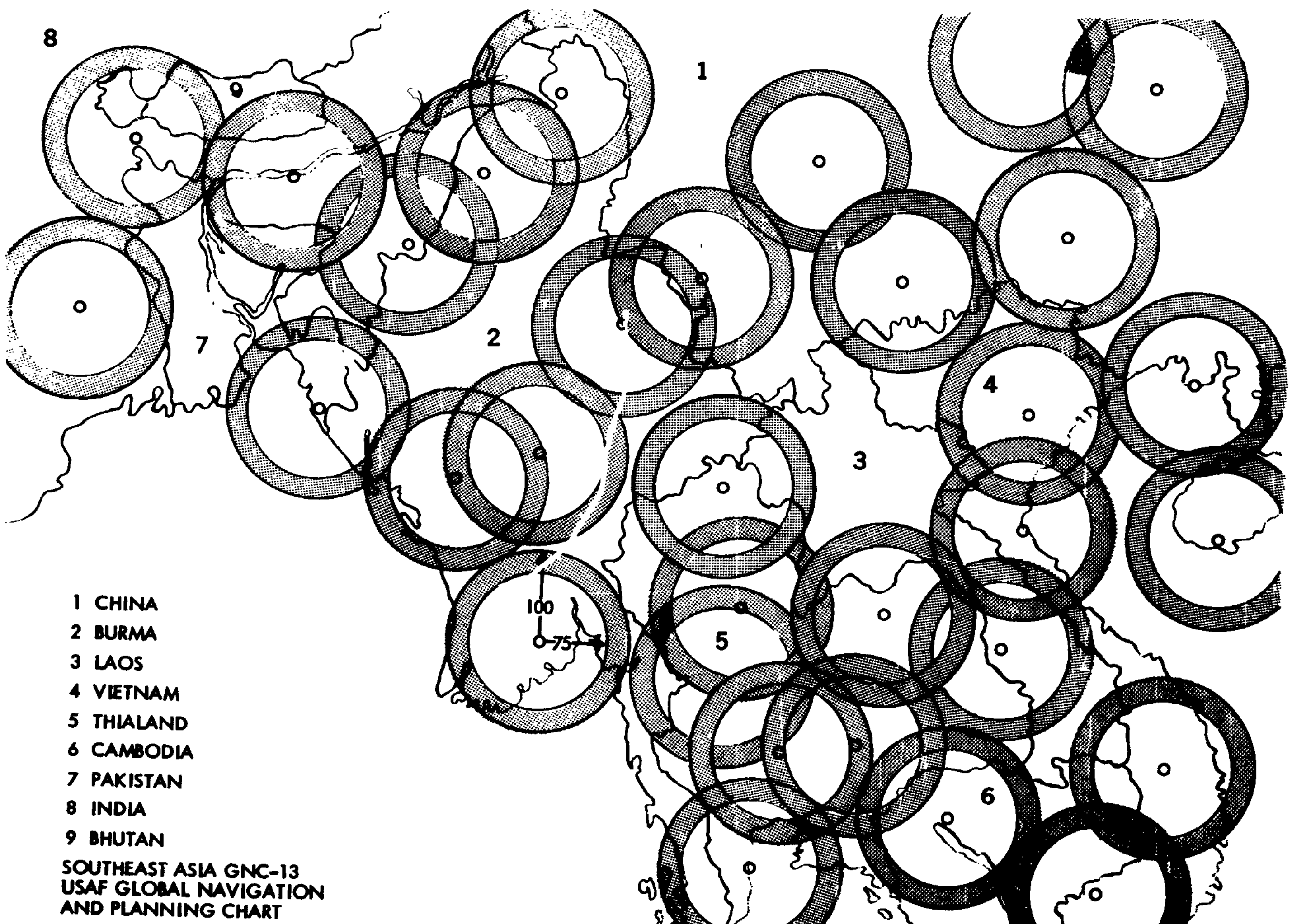


Figure 4. Southeast Asia

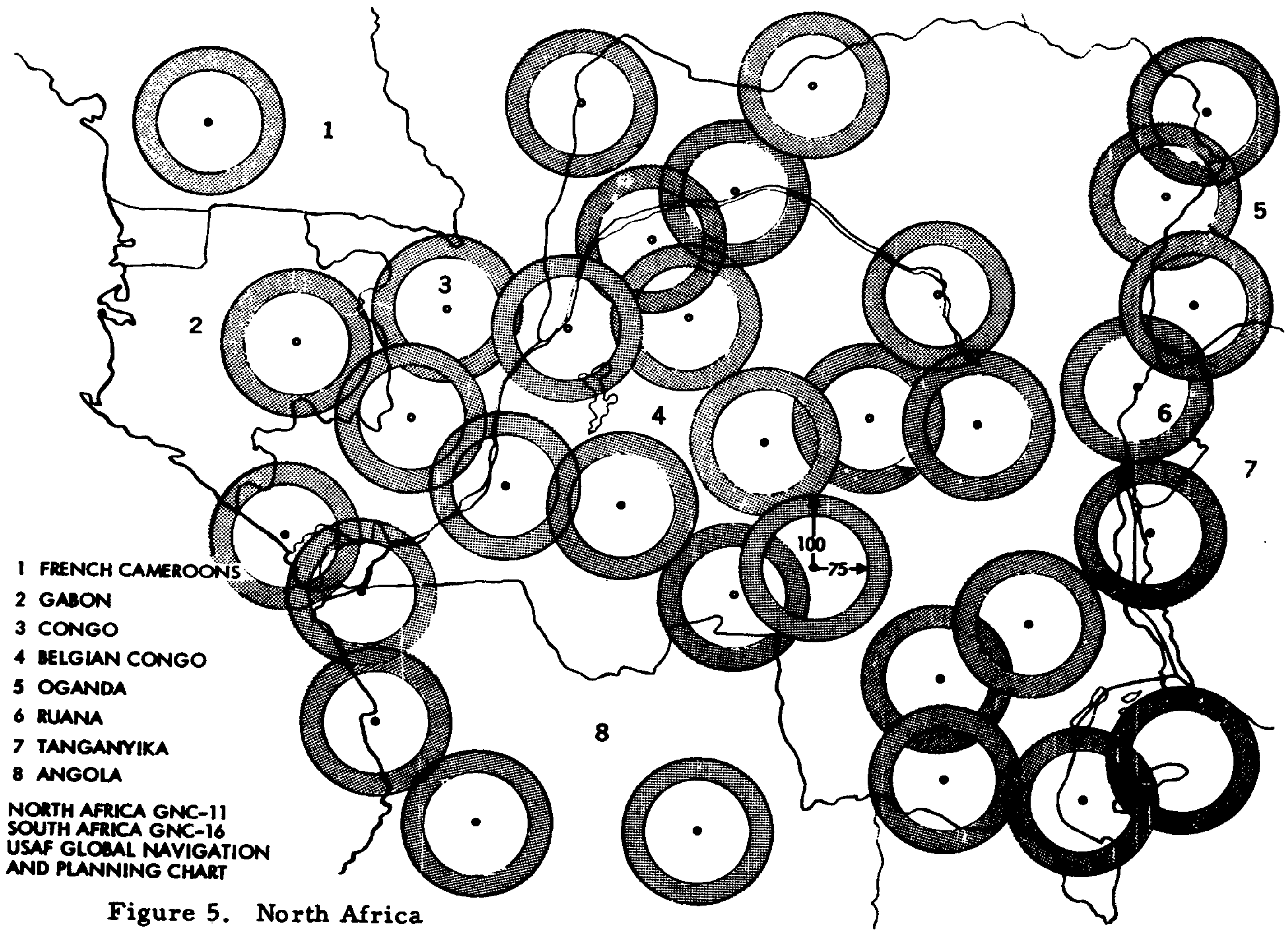


Figure 5. North Africa

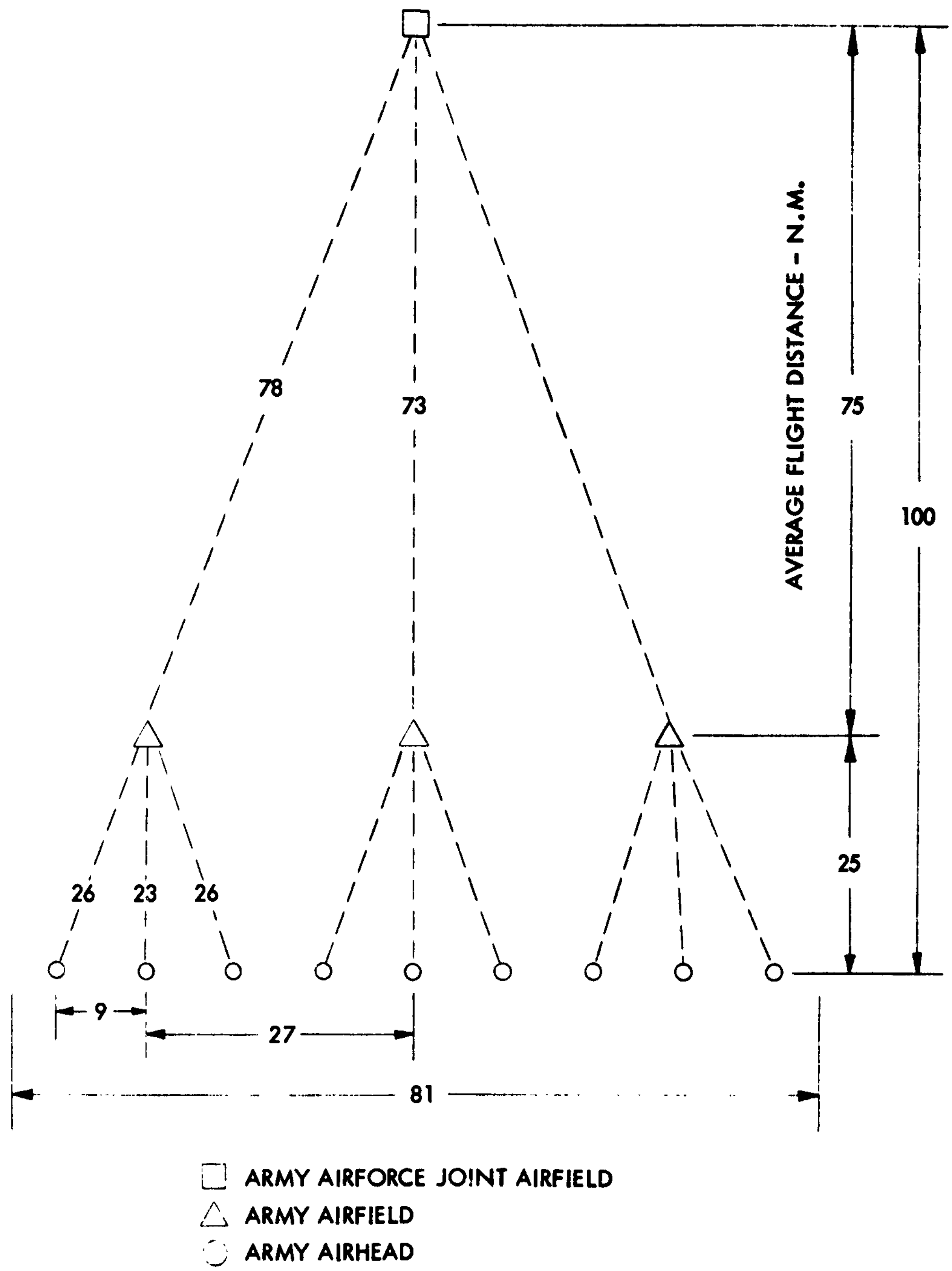


Figure 6. Dimensional Division or Theater Model

2. Approximately one-fifth of the air cargo (critical or urgently required resupply) would be consumed at the intermediate supply area, the Army airfield.

3. Approximately one-half of the resupply destined for the airhead would be routed through the intermediate supply area for the following reasons:

   a. To capitalize on the efficiency of the AC-1 Caribou when final delivery (25 nautical miles) is to be accomplished by HC-1 Chinook. (Approximately 80 percent of the cargo moving from the Army airfield to airhead is by HC-1 Chinook.);

   b. To preposition a vital load in closer proximity to the customer so that delivery could be effected on shorter notice as battle or weather conditions permit;

   c. To trade general cargo for a customer, tailor-made load.

4. Division resupply of 400 tons per day.

5. Twenty-five percent of the daily resupply to be moved by air. The resupply flow model that resulted from the foregoing assumptions is presented in Figure 7.

AIRCRAFT PRODUCTIVITY

The ratio of productivity or utilization of the AC-1 Caribou and HC-1 Chinook from the model developed is:

$$\frac{\text{AC-1 Caribou Productivity}}{\text{HC-1 Chinook Productivity}} = \frac{\Sigma\,(\text{ton-miles})}{\Sigma\,(\text{ton-miles})} = \frac{7850}{1670} = \frac{4.7}{1} \qquad (1)$$

Considering the average availability ratio of 6 hours to 4 hours, AC-1 Caribou to HC-1 Chinook, and the fuel consumption, which is approximately five times greater for the Chinook, the foregoing productivity ratio appears reasonable.

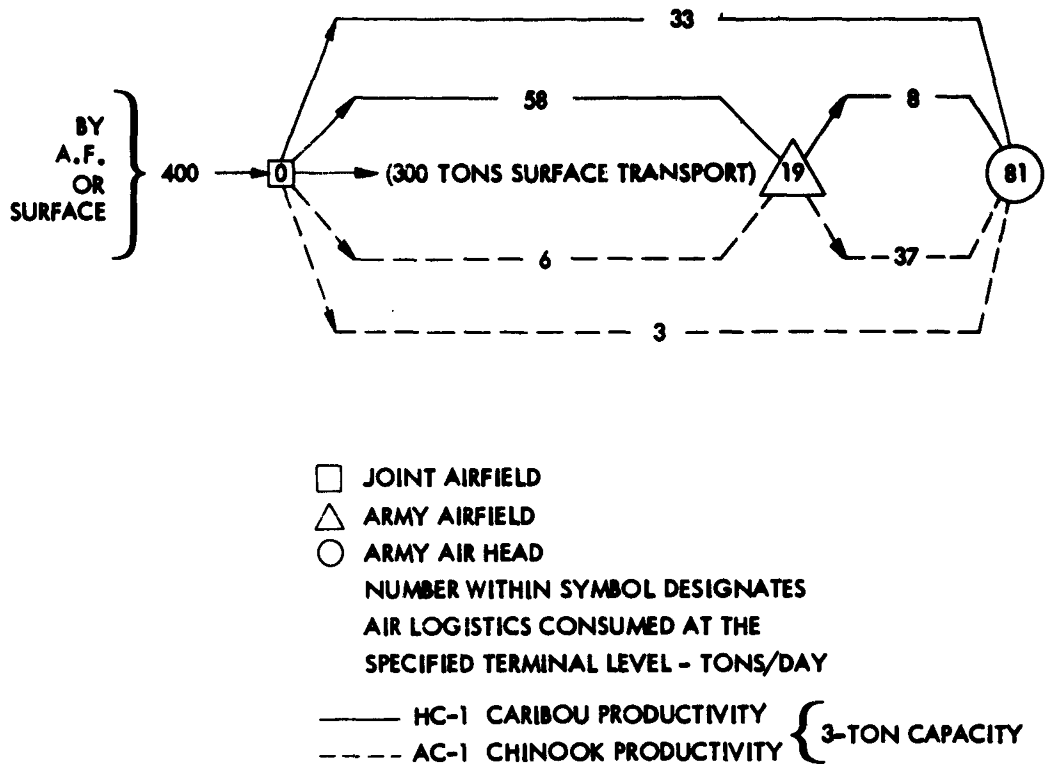


Figure 7. Tons Per Day in Army Air Logistic System

The approximate number of AC-1 Caribous and HC-1 Chinooks required to accomplish the daily transport of Figure 7 is determined as follows:

$$N = \frac{\Sigma \left[\frac{\text{Tons/Leg}}{3 \text{ Tons}} \left(\frac{2 \text{ x Radius}}{\text{Velocity}} + \text{Turn-around time} \right) \right]}{\text{Utilization}} \tag{2}$$

Where

Velocity = 130 knots

Turn-around time (not including loading & unloading) = 0.3 hour

HC-1 Chinook daily utilization = 4 hours

AC-1 Caribou daily utilization = 6 hours

The approximate number of AC-1 Caribous thus determined is 8.4 and the HC-1 Chinooks 3.3, or approximately 12 carriers total. No tare weight or waiting time are taken into account and this formula assumes all aircraft take off at the same time.

AIRCRAFT AVAILABILITY

The carriers flying at the rate specified above realize a ready, but not flying, availability of 50 percent or 12 hours a day (see Figure 8). However, to realize the full potential afforded by these new carriers in terms of rapid deployment, behind the line assault and shock movements, diversion, and retreat, 12 carriers with a coordinated 36-ton lift capability appear to be light to inadequate. Considering the smaller battalion size of the ROAD division, 600 men, at 240 pounds per troop, or its equivalent, is 72 tons and requires 24 carriers for a coordinated move. More realistically, the simultaneous movement of a battalion would probably result only under dire threat of annihilation in which case the troops might be presumed to be at something less than full battalion strength and equipped weight. Five-hundred men, at 200 pounds each, are 50 tons or approximately 17 carriers. More optimistically, an assault group such as a Rifle Company, Infantry Division Battle Group with equipment, vehicles, guns, and trailers amounts to 51.2 tons and can be lifted on a single mission by 17 carriers. If the available carriers were apportioned as determined previously, 8.4 AC-1 Caribous and 3.3 HC-1 Chinooks, at the utilization rate stipulated in FM 101-10, the average utilization rate, U, is

$$\text{U Average} = \frac{(8.4 \times 0.75) + (3.3 \times 0.66)}{8.4 + 3.3} = 0.725 \qquad (3)$$

The total carrier fleet is thus

$$\text{N Carriers} = \frac{17}{0.725} = 23.5 \text{ or } 24 \qquad (4)$$

The number of Caribous is

$$\text{N AC-1 Caribous} = \frac{8.4}{8.4 + 3.3} \times 24 = 17 \qquad (5)$$

F + R + M = 1

F = FLYING RATE

R = READY TO FLY WHEN NOT FLYING

M = MAINTENANCE RATE

A = F + R

A = AVAILABILITY RATE

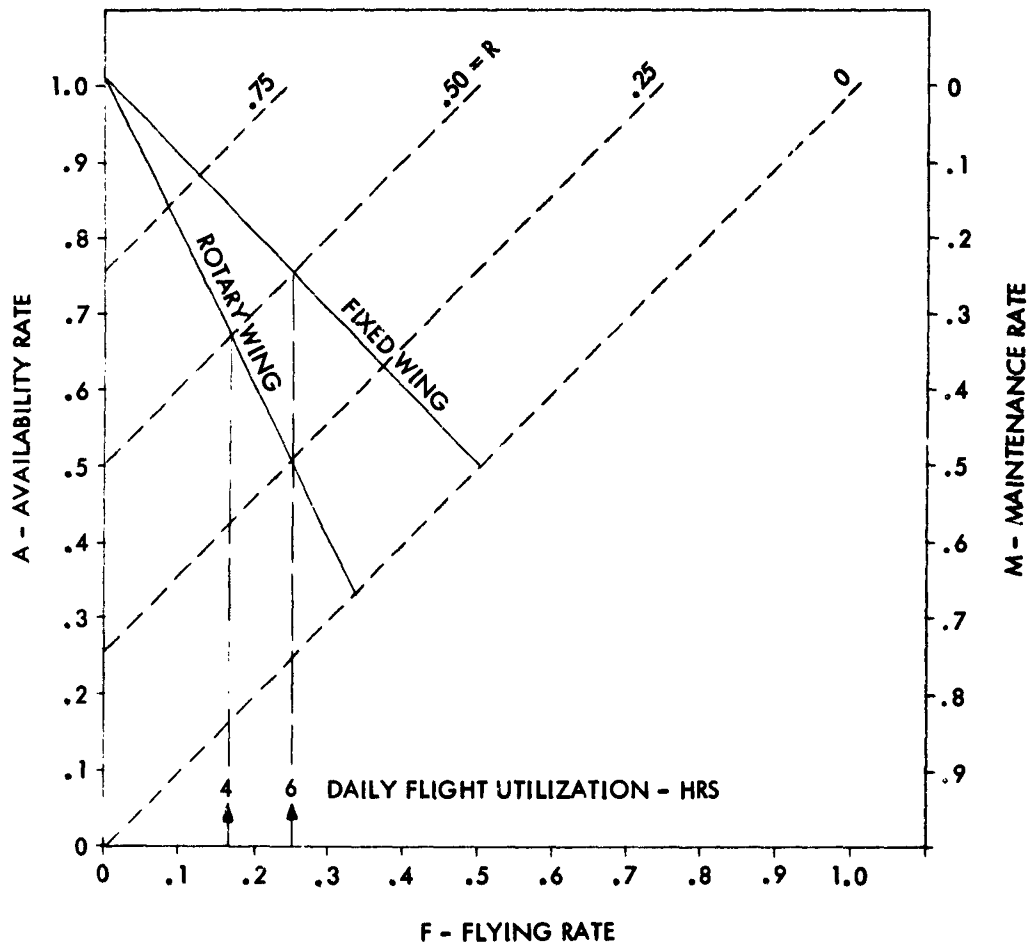


Figure 8. Availability Versus Flying Rate

and the number of Chinooks is

$$\text{N HC-1 Chinooks} = \frac{3.3}{8.4 + 3.3} \times 24 = 7 \quad (6)$$

SERVICE RATE

Utilizing the dimensional model, Figure 6 and the cargo flow model, Figure 7, it is possible to determine the required service rate of carriers at the various terminals. This information will be useful in establishing the amount and performance of material handling equipment required at the various terminals.

The cycle time per leg flown in the dimensional model is:

$$t_{cycle} = \frac{2\,\text{Radius}}{\text{Velocity}} + (\text{Turn-around time} + \text{Loading} + \text{Unloading time}) \quad (7)$$

Also, the total flight time per leg to move the cargo specified in the cargo model is given by:

$$t_{total} = \frac{\text{Tons/leg}}{3} \times t_{cycle} \quad (8)$$

Assuming a velocity of 130 knots and the sum of turn-around, loading, and unloading time to be 30 minutes, the computations of cycle time and total carrier time per leg are presented in Figure 9. The average frequency of arrival at the various terminals is a function of both the number of carriers available and employed in the logistic mission and the demand for material or resupply at any point in time. From Figure 9, the total time to accomplish the resupply mission as a function of the number of carriers participating has been computed and is presented in Figure 10. The conditions of Figure 10 are that a sufficient number of carriers are exclusively assigned to a given leg to accomplish the cargo flow in that leg in the time specified on the abscissa.

The measure of worth and effectiveness of a military supply system, in addition to its ability to perform the routine mission, is its capability to rise to the emergency or critical situations. In that light, all components of the logistic system should be configured to realize

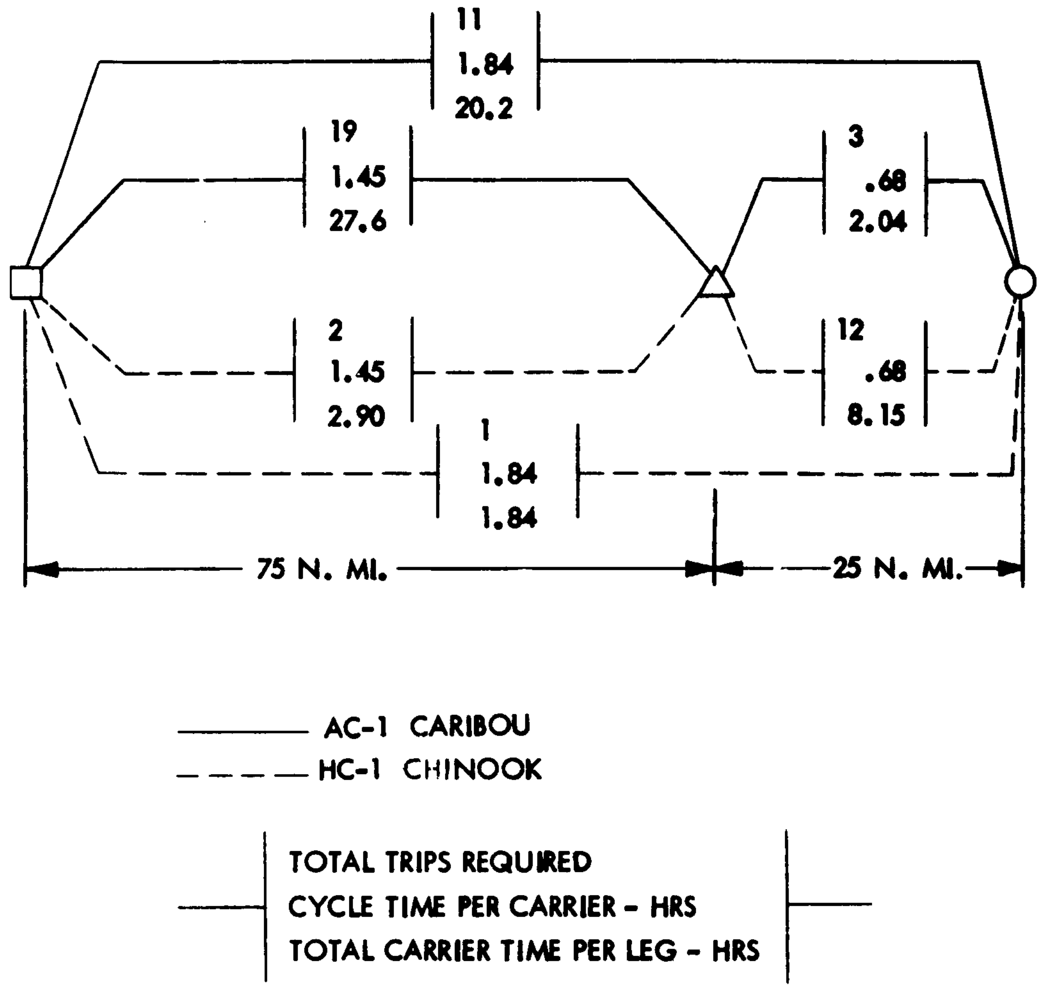


Figure 9. Time and Number of Missions Associated with the Resupply Mission

the maximum productivity attainable with the carriers to meet emergency situations. Thus, for the purpose of creating a high service rate requirement on the material handling system, it is assumed that 20 of the 24 carriers are available and enlisted to perform the assumed resupply mission in as short a time as possible. This requirement on the system could possibly result from

- Critical circumstances in the combat area;
- Need to quickly effect the resupply mission in order to prepare and mount an aerial assault mission a short time later;

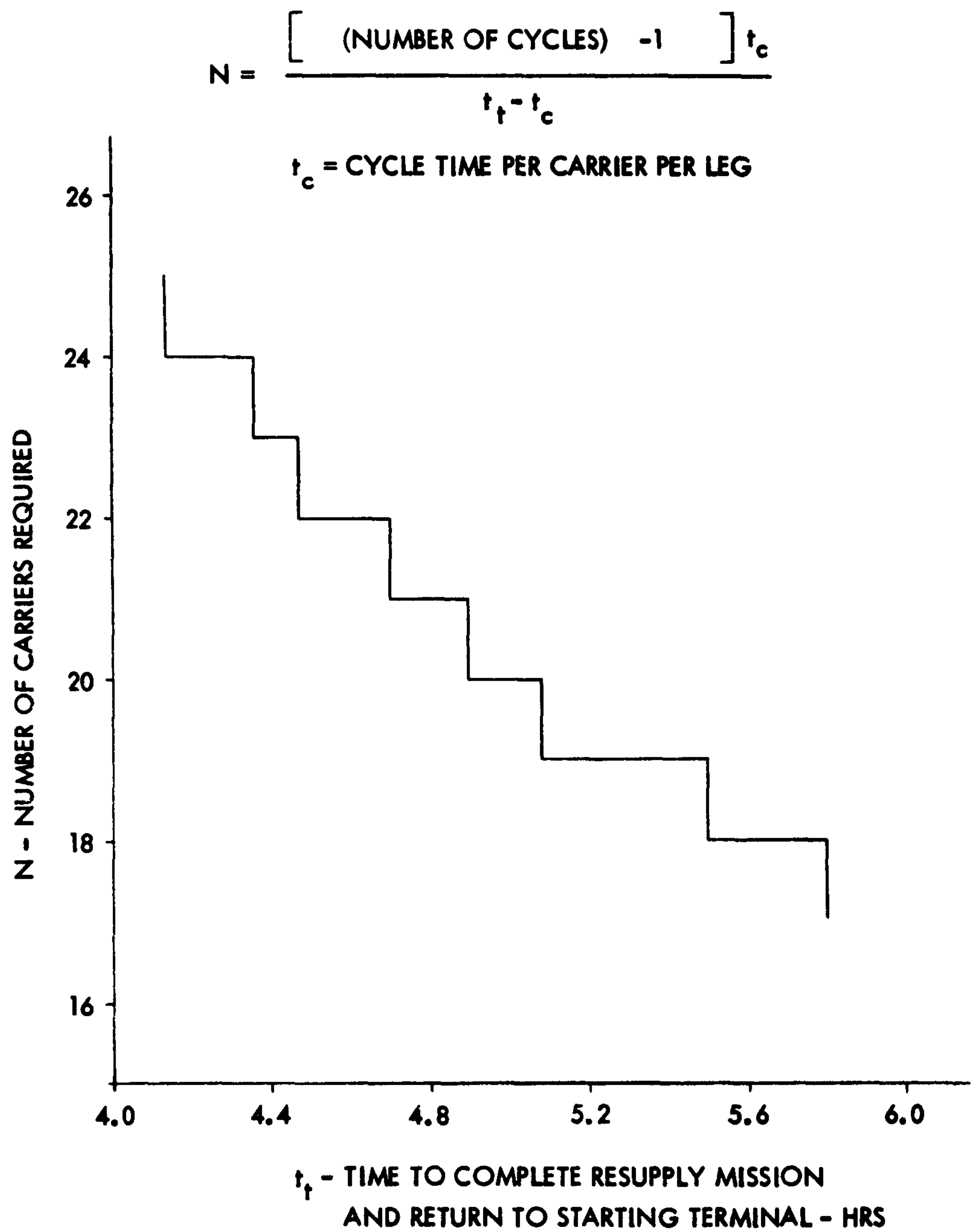


Figure 10. Number of Carriers Required to Accomplish Daily Resupply Mission as a Function of Time

3. Short time, limited access to the customer as a result of weather, hostile action, or tactical interference.

From Figure 10, it is observed that 20 carriers can effect the logistic mission and return to their starting terminal in 4.9 hours. The average arrival rate, λ, resulting at the terminals is

$$\lambda = \frac{\text{(No. of turn-arounds per terminal level/No. of terminals) - 1}}{\text{4.9 - (One cycle time)}} \tag{9}$$

Thus, the arrival rate, λ, at the:

Joint Airfield (for loading)

$$= \frac{33 - 1}{4.9 - 1.45} = \frac{9.3 \text{ carriers}}{\text{hour}} = \frac{\text{carrier}}{6.45 \text{ minutes}}$$

Army Airfield (for unloading)

$$= \frac{(21/3) - 1}{4.9 - 1.45} = \frac{1.74 \text{ carriers}}{\text{hour}} = \frac{\text{carrier}}{34.5 \text{ minutes}}$$

Army Airfield (for loading)

$$= \frac{(15/3) - 1}{4.9 - 0.68} = \frac{0.95 \text{ carriers}}{\text{hour}} = \frac{\text{carrier}}{63 \text{ minutes}}$$

$$= \frac{\text{carrier}}{22.3 \text{ minutes}}$$

Airhead (for unloading)

$$= \frac{(27/9) - 1}{4.9 - 0.68} = \frac{0.47 \text{ carriers}}{\text{hour}} = \frac{\text{carrier}}{128 \text{ minutes}}$$

Since, by Queueing Theory, the waiting line tends to infinity when the service rate, μ, and arrival rate, λ, are equal for single service station, the service rate must be greater than the arrival rate in order to realize the system efficiency desired. If the service rate cannot be increased to an acceptable degree greater than the arrival rate, then consideration must be given to utilization of multiple service stations to reduce waiting time.

The foregoing analyses of cycle time and aircraft requirements are typical but general. In Section 10, Concept Evaluation, each concept to be considered is analyzed discretely in the determination of cycle time, service station requirements, and aircraft requirements as a function of total time to complete the resupply mission.

SECTION 8. EQUIPMENT STUDY AND DESIGN

CONSOLIDATING PALLET DETERMINATION

WIDTH

The specification of a pallet upon which a consolidated load can be composed for the AC-1 Caribou and HC-1 Chinook must take into account weight, cube, and geometry. Considering first the physical plan form dimensions that are required to contain a consolidated load for the Army carriers, the various dimensions of the pallets and the loading width of the AC-1 Caribou (73 inches) leave little alternative but to load the wooden pallets along their width. Loading in this manner results in a 60-inch wide consolidating pallet - the STRAC A at 58 inches plus 2 inches for tiedown fittings.

LENGTH

The length of the consolidated pallet was determined by a compromise of several factors. All the possible combinations of the QM pallets and STRAC containers that would constitute a consolidated load of between 5250 and 7400 pounds were tabulated. The assumption was made that the STRAC containers would be stacked in two layers where possible. An average width of 33 inches also was assumed for the STRAC A (32-7/8 inches) and STRAC B (32 inches) containers.

The six possible pallet configurations have been reduced to five by assuming an average weight of 1550 pounds for the QM pallets transporting Class I (1575 pounds) and Classes II and IV (1528 pounds) materiel as follows:

		Weight (pounds)	Width (inches)
QM	Classes I, II, & IV	1550	43 (loaded)
	Class III	2160	
	Class V	3532	
STRAC	A	1400	33
	B	1000	33

All the possible combinations of the foregoing have been tabulated and presented in Table 1. Also included is a summary and listing of those combinations containing only QM pallets or STRAC containers (pure loads). The cumulative distribution is plotted in Figure 11.

The tabulated data shows justification for the selection of 132 inches as the consolidating pallet length for two reasons. First, 90 percent of the two important loadings of the consolidated pallet, a pure load of STRAC's or QM pallets, occurs at 132 inches (actually 128 and 129 inches, respectively). Second, 73 percent of all the combinations can be accommodated within the 132-inch dimension. This 132-inch dimension allows satisfactory loading into the Army air carriers as will be shown in subsequent analysis. A longer pallet to accommodate additional combinations cannot be justified because of the handling problems involved. It was felt that the pure loads would occur more frequently in the logistic system than the mixed combination. However, no attempt was made to weight the data in this direction.

No attempt was made in this analysis to determine the loading capacity of the 463L full pallet (88 by 108 inches) because its size precludes its use in the Army air carriers.

HALF PALLET

For the purpose of determining the feasibility of the use of a half pallet transporting a half Army carrier load, Table 2 has been prepared to show the combinations to make a load of between 2800 and 3600 pounds. A cumulative distribution of the combinations in Table 2 is presented in Figure 12.

The data shows that the 463L 88-inch-length half pallet will accommodate 100 percent of the combinations. This suggests the use of two consolidating pallets of 88 inches in length for loading the Army pallets. However, there are several drawbacks which preclude the use of half-size pallet and illustrate the noncompatibility of the 463L system with the Army logistic system.

1. Of the 10 possible combinations for a half load, four include combinations of STRAC A containers (32-7/8 by 58 inches) which will not fit on the 463L half pallet (54 by 88). The half pallet should be increased to 60 inches wide or reduce the length of the STRAC A container to 52 inches to become useful.

TABLE 1
POSSIBLE LOAD MAKEUPS FOR LOADS BETWEEN 5250 AND 7400 POUNDS
(LOAD LIMITS APPROXIMATE CAPACITY OF ARMY AIR CARRIERS)

UNIT LOAD MAKEUP							
	QM Pallets		STRAC Containers		Total Weight	Consolidated Load Length	No. of Combination for Given Length
1550	2160	3532	1000	1400	(lb)	(in.)	
4	-	-	1	-	7200	205	1
3	1	-	-	-	6810	172	
4	-	-	-	-	6200	172	2*
1	2	-	-	1	7270	162	
2	1	-	2	-	7160	162	
3	-	-	1	1	7050	162	
1	2	-	1	-	6870	162	8
2	1	-	-	1	6660	162	
3	-	-	2	-	6650	162	
2	1	-	1	-	6160	162	
3	-	-	-	1	6050	162	
1	1	-	2	1	7110	152	
1	1	-	3	-	6710	152	4
2	-	-	2	1	6500	152	
2	-	-	3	-	6100	152	
1	-	-	3	2	7350	142	
-	1	-	5	-	7160	142	4
1	-	-	4	1	6950	142	
1	-	-	5	-	6550	142	
-	-	-	7	-	7000	132	1*
1	1	1	-	-	7242	129	
2	-	1	-	-	6632	129	
-	3	-	-	-	6480	129	5*
1	2	-	-	-	5870	129	
2	1	-	-	-	5260	129	
-	2	-	-	2	7120	119	
-	1	1	-	1	7092	119	
1	-	1	-	2	7082	119	
-	2	-	1	1	6720	119	
-	1	1	1	-	6692	119	

1	2	-	1	-	6870	162	8
2	1	-	-	1	6660	162	
3	-	-	2	-	6650	162	
2	1	-	1	-	6160	162	
3	-	-	-	1	6050	162	
1	1	-	2	1	7110	152	
1	1	-	3	-	6710	152	4
2	-	-	2	1	6500	152	
2	-	-	3	-	6100	152	
1	-	-	3	2	7350	142	
-	1	-	5	-	7160	142	4
1	-	-	4	1	6950	142	
1	-	-	5	-	6550	142	
-	-	-	7	-	7000	132	1*
1	1	1	-	-	7242	129	
2	-	1	-	-	6632	129	
-	3	-	-	-	6480	129	5*
1	2	-	-	-	5870	129	
2	1	-	-	-	5260	129	
-	2	-	-	2	7120	119	
-	1	1	-	1	7092	119	
1	-	1	-	2	7082	119	
-	2	-	1	1	6720	119	
-	1	1	1	-	6692	119	
1	1	-	-	2	6510	119	
1	-	1	-	1	6482	119	15
-	2	-	2	-	6320	119	
1	1	-	1	1	6110	119	
1	-	1	1	-	6082	119	
2	-	-	-	2	5900	119	
-	2	-	-	1	5720	119	
1	1	-	2	-	5710	119	
2	-	-	1	1	5500	119	
-	2	-	1	-	5320	119	
-	-	1	1	2	7332	109	
1	-	-	-	4	7150	109	
-	1	-	2	2	6960	109	
-	-	1	2	1	6932	109	
1	-	-	1	3	6750	109	
-	1	-	3	1	6560	109	
-	-	1	3	-	6532	109	
-	1	-	-	3	6360	109	
1	-	-	2	2	6350	109	
-	1	-	4	-	6160	109	16
-	1	-	1	2	5960	109	
1	-	-	3	1	5950	109	
1	-	-	3	-	5750	109	
-	1	-	2	1	5560	109	
1	-	-	4	-	5550	109	
1	-	-	1	2	5350	109	
-	-	-	3	3	7200	99	
-	-	-	4	2	6800	99	
-	-	-	1	4	6600	99	
-	-	-	5	1	6400	99	
-	-	-	2	3	6200	99	8*
-	-	-	6	-	6000	99	
-	-	-	3	2	5800	99	
-	-	-	4	1	5400	99	
-	-	2	-	-	7064	86	
-	1	1	-	-	5692	86	2*
-	-	1	1	1	5932	76	
-	-	1	-	2	6332	76	3
-	-	1	2	-	5532	76	
-	-	-	-	4	5600	66	1*

-	-	1	3	-	6532	109	
-	1	-	-	3	6360	109	
1	-	-	2	2	6350	109	
-	1	-	4	-	6160	109	16
-	1	-	1	2	5960	109	
1	-	-	3	1	5950	109	
1	-	-	3	-	5750	109	
-	1	-	2	1	5560	109	
1	-	-	4	-	5550	109	
1	-	-	1	2	5350	109	
-	-	-	3	3	7200	99	
-	-	-	4	2	6800	99	
-	-	-	1	4	6600	99	
-	-	-	5	1	6400	99	
-	-	-	2	3	6200	99	8 *
-	-	-	6	-	6000	99	
-	-	-	3	2	5800	99	
-	-	-	4	1	5400	99	
-	-	2	-	-	7064	86	
-	1	1	-	-	5692	86	2 *
-	-	1	1	1	5932	76	
-	-	1	-	2	6332	76	3
-	-	1	2	-	5532	76	
-	-	-	-	4	5600	66	1 *

NOTE: QM pallets loaded on 43-inch dimension, STRAC containers loaded on
average 33-inch dimension
QM pallets single-layer
STRAC containers double stacked.

* Denotes pure loads of QM pallets or STRAC containers.

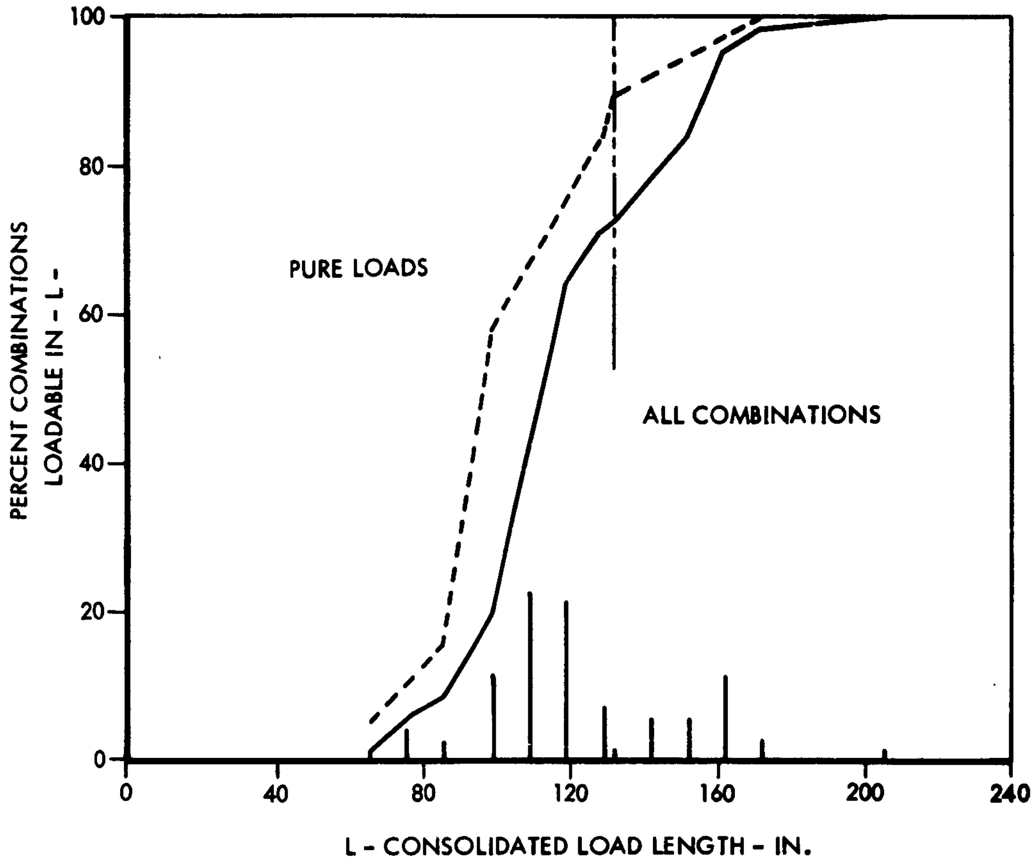
SUMMARY

Load Length	Number of Combinations	Cumulative Distribution
66	1	1.43
76	3	5.72
86	2	8.58
99	8	20.01
109	16	42.87
119	15	64.30
129	5	71.44
132	1	72.87
142	4	78.58
152	4	84.29
162	8	95.72
172	2	98.58
205	1	100.00

PURE LOADS OF QM'S OR STRACS

66	1	5.26
86	2	15.79
99	8	57.89
129	5	84.21
132	1	89.47
172	2	100.00

3



	WIDTH	WEIGHTS
QM'S	43 IN.	1550, 2160, 3532
STRAC'S	33 IN.	1000, 1400

Figure 11. Unit Load Length for a Full Carrier Load 5250 to 7400 Pounds

2. It will be shown in a later section of this report that the 4-inch-thick 463L half-pallet double stacked with STRAC containers presents a loading limitation in the AC-1 Caribou aircraft.

3. Even with the use of two half-pallets to give a full load limit, the number of possible combinations is limited to 10 as opposed to a possible 51 combinations available when using a consolidating pallet of 132 inches. This will impose a serious problem during the consolidating operation, a problem which will increase in complexity when the weight of the load decreases with longer range operations.

From the foregoing discussions it is concluded that:

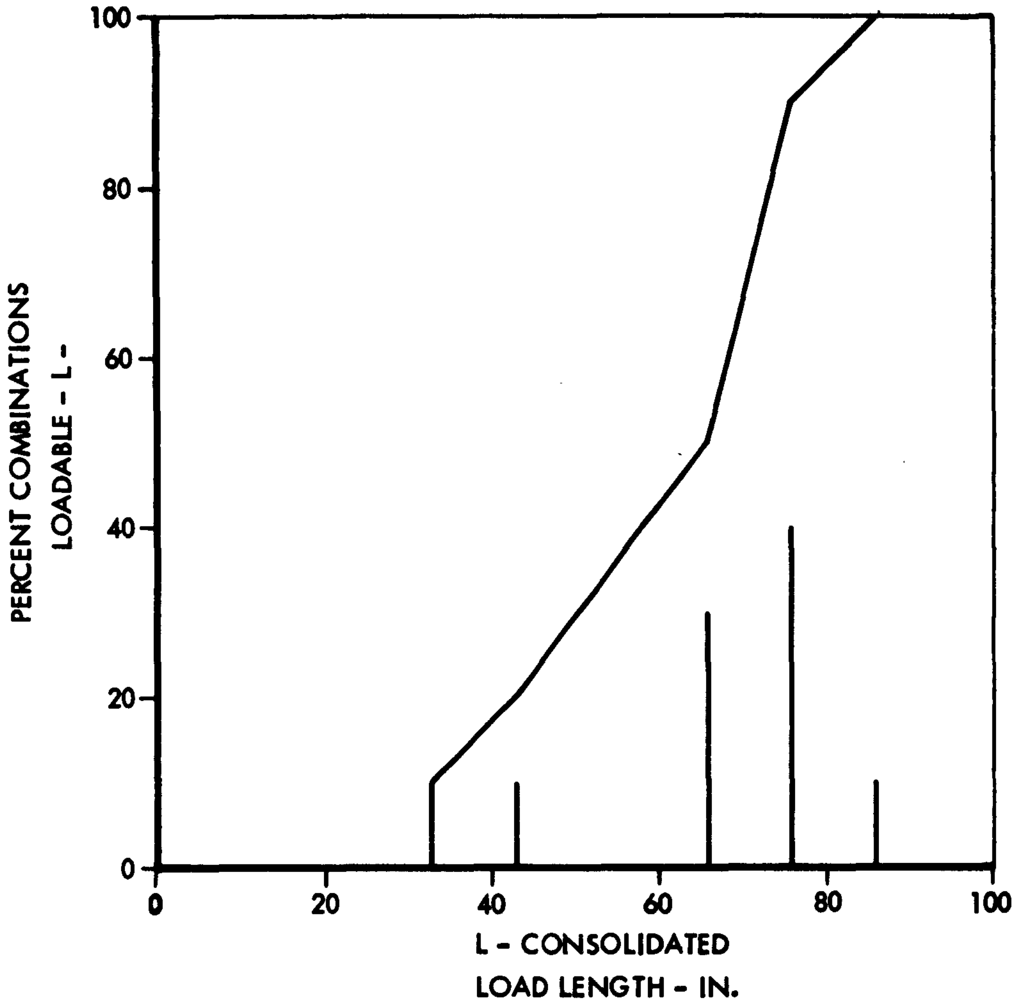
1. A half-load, consolidated pallet configuration for the Army carriers is not practicable.

2. There is no interaction and little compatibility between the Air Force's 463L system and the Army's requirements within the scope of this study.

3. The optimum consolidating pallet size for the Army's carriers is 5 by 11 feet.

TABLE 2
POSSIBLE LOAD MAKEUPS FOR LOADS BETWEEN 2800 AND 3600 POUNDS (LOAD LIMITS APPROXIMATE ONE-HALF CAPACITY OF ARMY AIR CARRIERS)

UNIT LOAD MAKEUP QM. Pallets			STRAC Containers		Total Weight	Consolidated Load Length	No. of Combination for given length
1550	2160	3532	1000	1400	(lb)	(in.)	
2					3100	86	1
	1			1	3560	76	
1			2		3550	76	4
	1		1		3160	76	
1				1	2950	76	
			2	1	3400	66	
			3		3000	66	3
			1	2	2900	66	
		1			3532	43	1
				2	2800	33	1



	WIDTH	WEIGHTS
QM'S	43 IN.	1550, 2160, 3532
STRAC'S	33 IN.	1000, 1400

Figure 12. Unit Load Length for a Half Carrier Load 2800 to 3600 Pounds

PALLET LOADING IN ARMY AIRCRAFT

ROLLER CONVEYOR SYSTEM

[redacted]

The most popular pallet and loading concepts today embody thin sheet, frame, honeycomb, or foam-filled pallets loaded over wheel or roller conveyor bridging devices that are precisely aligned with the plane of the aircraft floor. These systems leave little to be desired when operating on hard level terrain, when servicing aircraft whose floors are approximately parallel to the ground, and when servicing aircraft whose loading envelopes are clear and free when viewed from directly astern. Unfortunately, neither of the Army carriers of this study can expect to enjoy the luxury of hard, level ramps upon which to work, nor does either have a clear loading envelope as viewed from astern. Only the AC-1 Caribou possesses a floor parallel to the ground (see Figure 13).

Alternatives to direct, level bridging, when the overhanging tail presents the obstruction, are to:

1. Move a dolly or forklift carrying the load in under the tail section of the aircraft and elevate the load for transfer.

2. Move the load along an inclined ramp that is attached to the aft end of the aircraft floor until the load is clear of the obstruction or reaches the juncture of ramp and floor, then elevate the opposite end of the ramp to the plane of the aircraft floor or allow gravity to pivot the pallet.

Both of the foregoing methods encounter a common difficulty on each carrier when assuming use of the 11-foot pallet and stacked load previously determined. The difficulty is simply one of overhead clearance for the cargo. Two STRAC containers measure 66 inches when stacked. Two stacked STRAC containers loaded on a 2-1/2-inch pallet which is sitting on a 2-1/2-inch wheel or roller conveyor occupy 71 inches of vertical height.

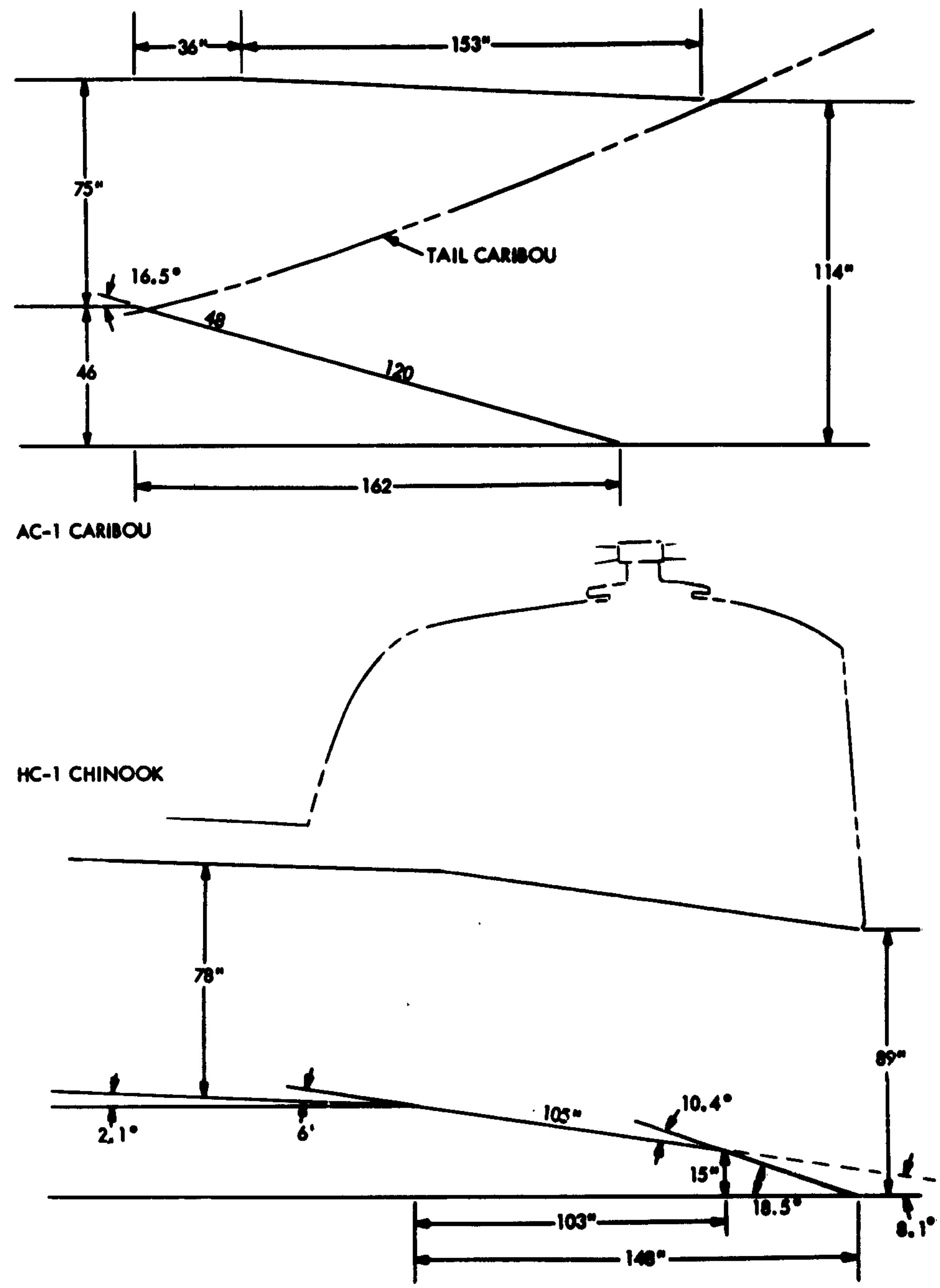


Figure 13. Loading Envelopes

Assuming that the ramps of the two carriers are elevated to be parallel to the plane of the cargo floor, Figure 14 depicts the allowable load heights that can be loaded on to the ramps for straight-in loading. As shown in Figure 14, the allowable load heights are 68 and 64 inches for the AC-1 Caribou and the HC-1 Chinook, respectively. Assuming that the ramps are removed to permit the loads to be passed under the obstructing empennage and elevated immediately adjacent to the cargo floor, Figure 15 shows that the allowable load height is 71 and 65 inches

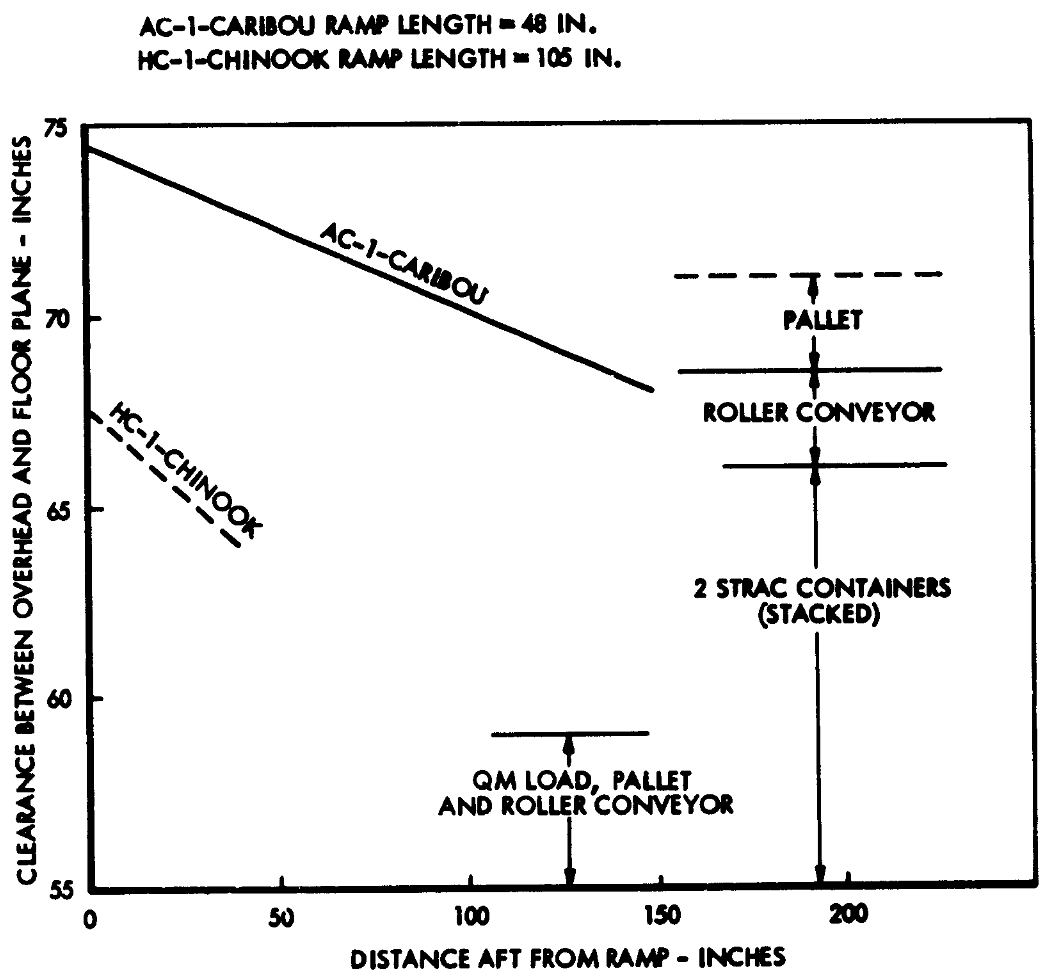


Figure 14. Allowable Load Height for Straight-in Loading to Carrier Ramp

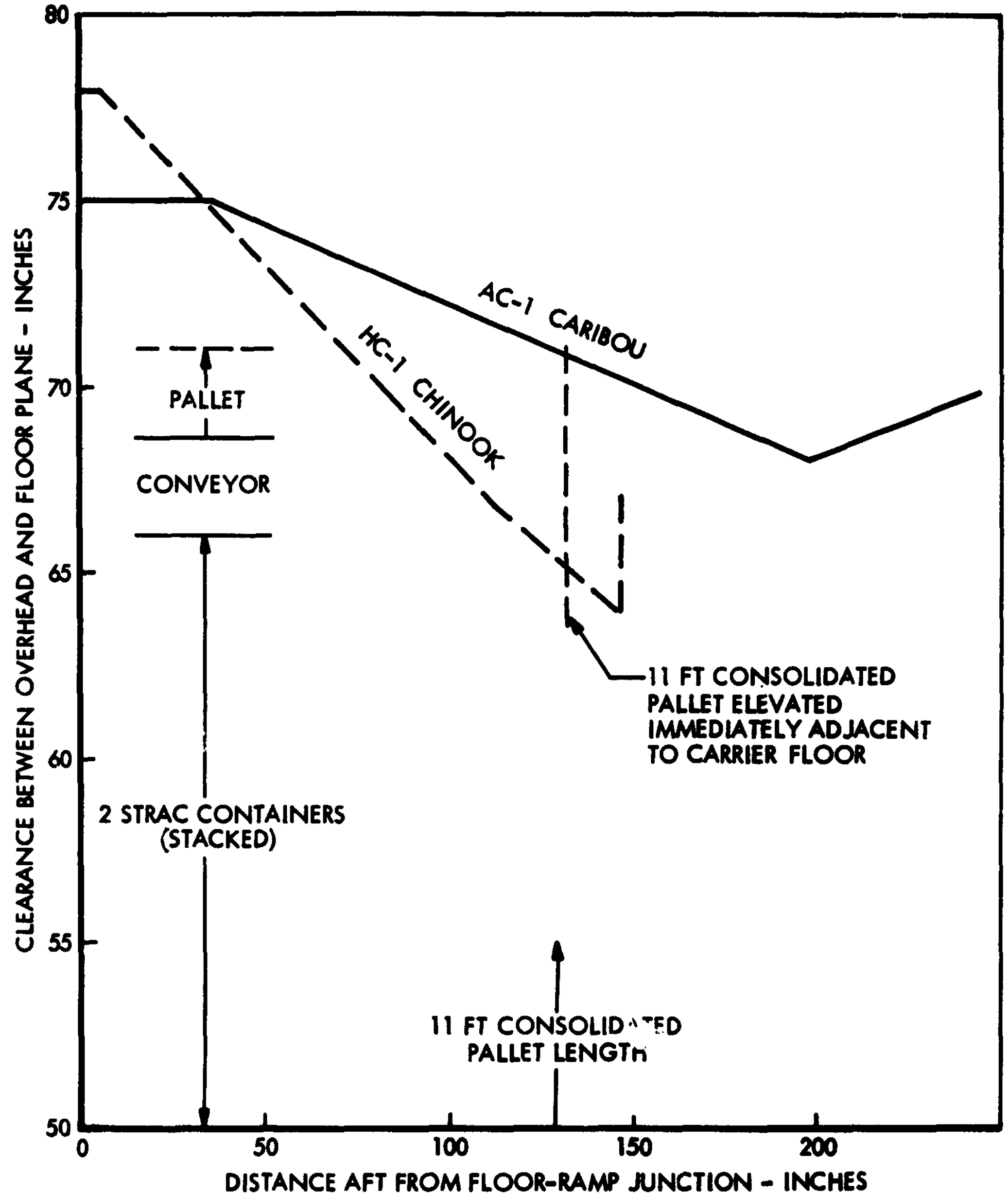


Figure 15. Allowable Load Height for Straight-In Loading to Carrier Floor

for the AC-1 Caribou and HC-1 Chinook, respectively. In either case, the clearance is not adequate to load stacked STRAC containers; however, QM pallets at 59 inches (54-inch load plus 2-1/2-inch roller conveyor plus 2-1/2-inch consolidating pallet) can be straight-in loaded in both cases.

[redacted]

Since straight-in loading is not feasible for the 66-inch load height, the feasibility of loading over inclined ramps in order to clear the empennage is the next most logical consideration. This loading technique must consider:

1. Height of the truck bed or loading vehicle to mate with the ramp for the desired ramp angle.

2. Overhead clearance of an inclined load entering the fuselage.

3. Overhead clearance at the empennage when the load rotates or pivots to rest on the cargo floor.

4. Devices and pallet structure to carry concentrated loads at the point where the load rotates from the ramp to the plane of the cargo compartment floor.

5. Devices, pallet design, or cargo loader characteristics that first permit movement of the consolidating pallet as it bridges from the loading vehicle to the ramp and, secondly, preclude destruction of the rollers when and if they end-support the consolidating pallet.

The allowable load height, as a function of ramp angle and truck bed height, is presented in Figure 16. Figure 16 again shows that the 71-inch load cannot be loaded straight-in, zero angle between the cargo compartment floor and the ramp. Specifically Figure 16 is presented to show the angles which a load must traverse as a function of the height of the vehicle transferring the load to the carriers. Included in Appendix I is a summary of typical military trucks for illustration of bed height. As can be noted, the allowable load height in the vicinity of empennage increases as the ramp angle increases; however, the opposite is true as the load enters the cargo compartment. A load entering the cargo compartment at an

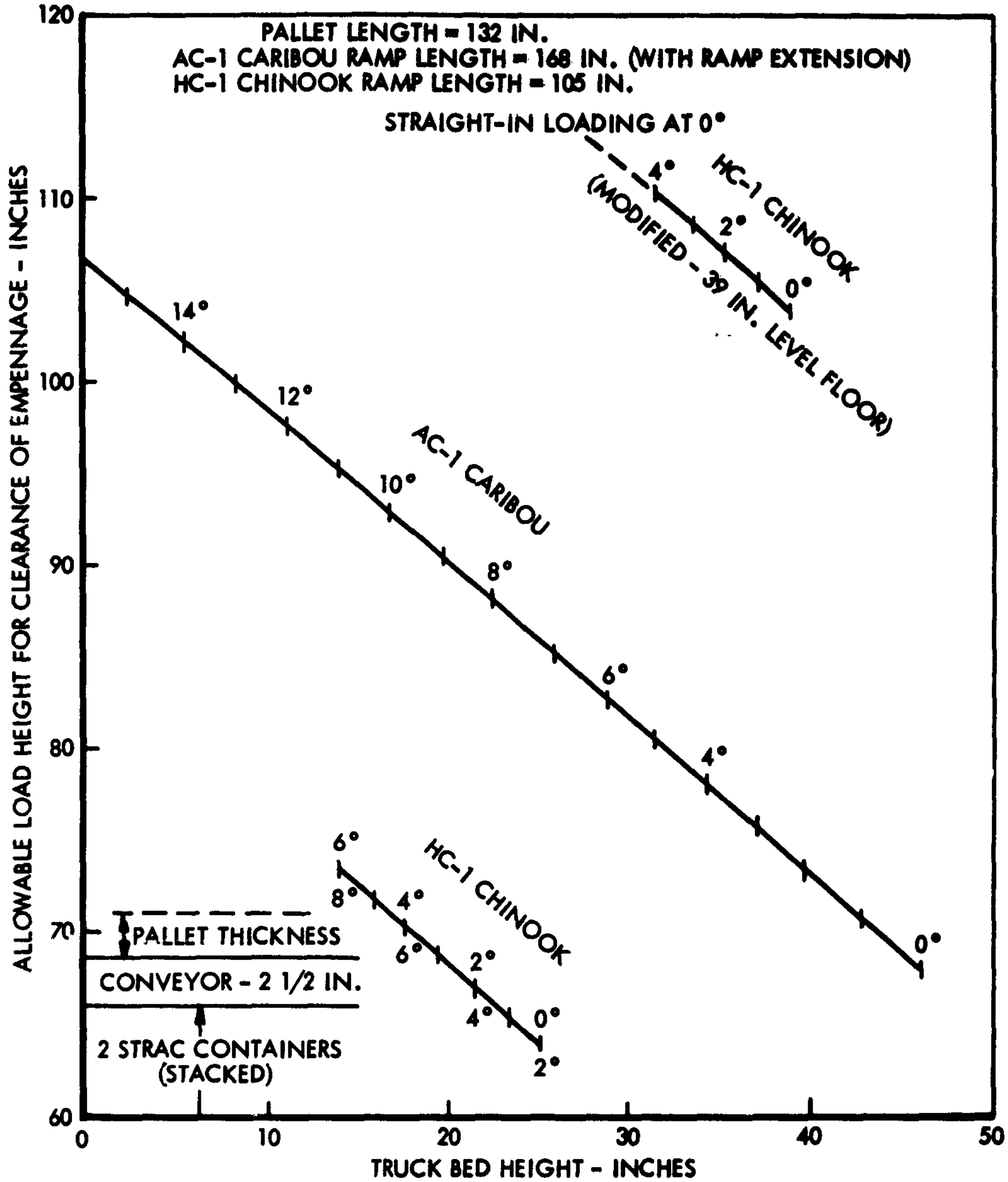


Figure 16. Allowable Load Height and Ramp Angle as a Function of Truck Bed Height for Direct Bridging

angle with the floor plane loses allowable load height as a function of load length and load center of gravity position. Figures 17 and 18 are presented to show the relationship between allowable load height and ramp angle for two load lengths and the center of gravity 5 percent (6-1/2 inches) of the load length fore and aft of the pallet center. By cross plotting the data on Figures 16, 17 and 18, the optimum ramp angle for maximum load height can be determined. Figure 19 presents optimum ramp angles for the AC-1 Caribou, 2-1/2 degrees, and the HC-1 Chinook, 6-1/2 degrees.

From Figure 19, it is concluded that direct bridging to a roller conveyor cargo handling system in the AC-1 Caribou and the HC-1 Chinook is feasible for the loading and unloading of QM pallet loads at 54 inch height under a variety of conditions including direct bridging with the ramp elevated to the plane of the cargo compartment floor. It is further concluded that consolidated, stacked STRAC containers can be loaded and unloaded over a roller conveyor system in the carriers with the following requirements and provisioning:

1. That the total depth of roller conveyor section and pallet thickness is not to exceed 5 inches;

2. That aircraft as parked for loading or unloading be on level terrain or that the plane of the terrain in the loading area immediately aft of the carrier be below the plane supporting the carrier's flotation gear. An alternative or safeguard would include consideration of a slight depression for the nose wheel to insure adequate clearances and geometry;

3. That both carriers, AC-1 Caribou and HC-1 Chinook, be provided with ramp angle measuring devices and/or detents to insure the proper ramp position prior to loading and unloading;

4. That only two STRAC containers be stacked on top of the first tier of STRAC's and that they be positioned reasonably well over the center of the consolidating pallet;

5. That reasonable precautions be made to locate the center of gravity of the composite load at the center of the consolidating pallet;

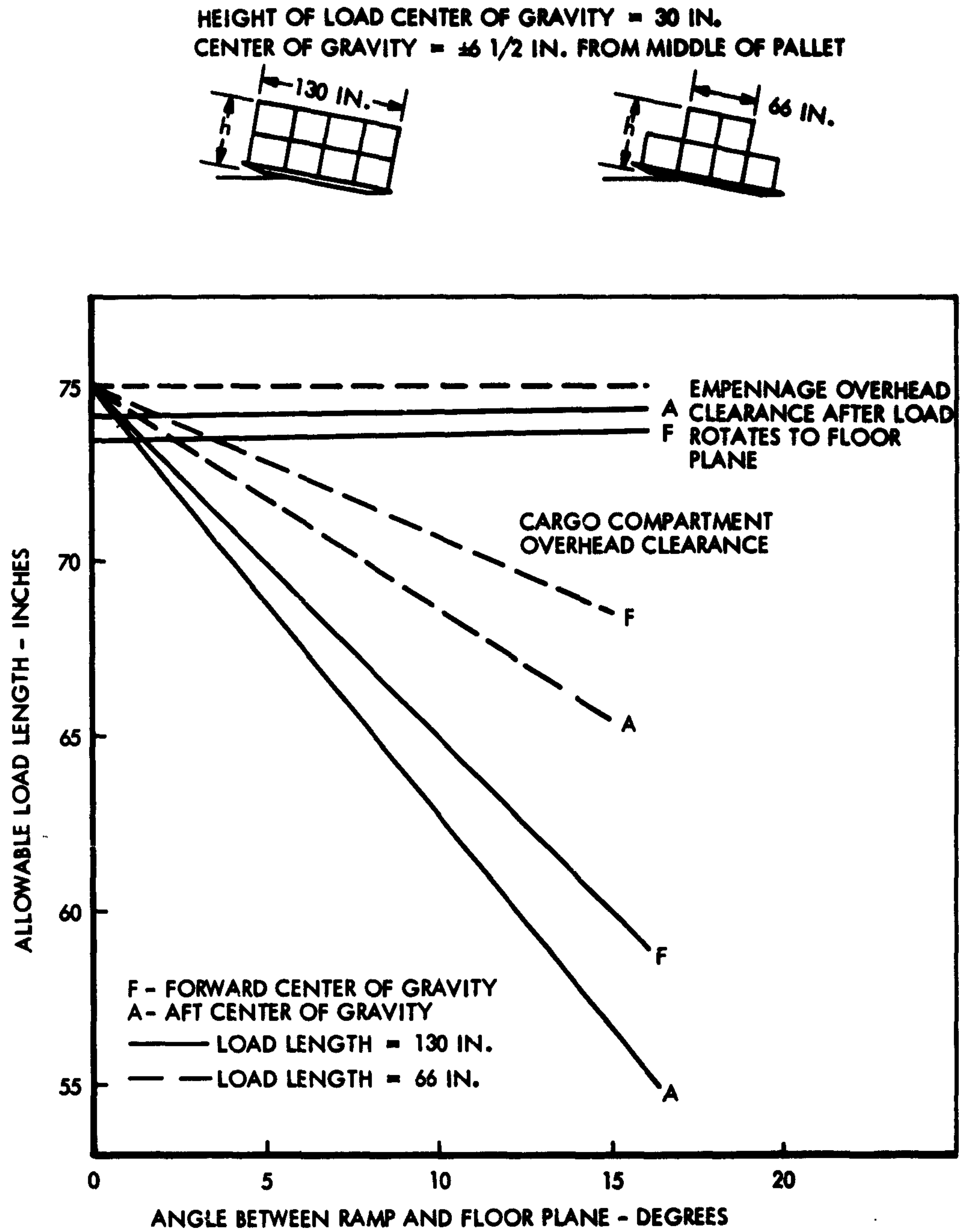


Figure 17. Allowable Load Height for Inclined Ramp Loading and Gravity Rotation (AC-1 Caribou)

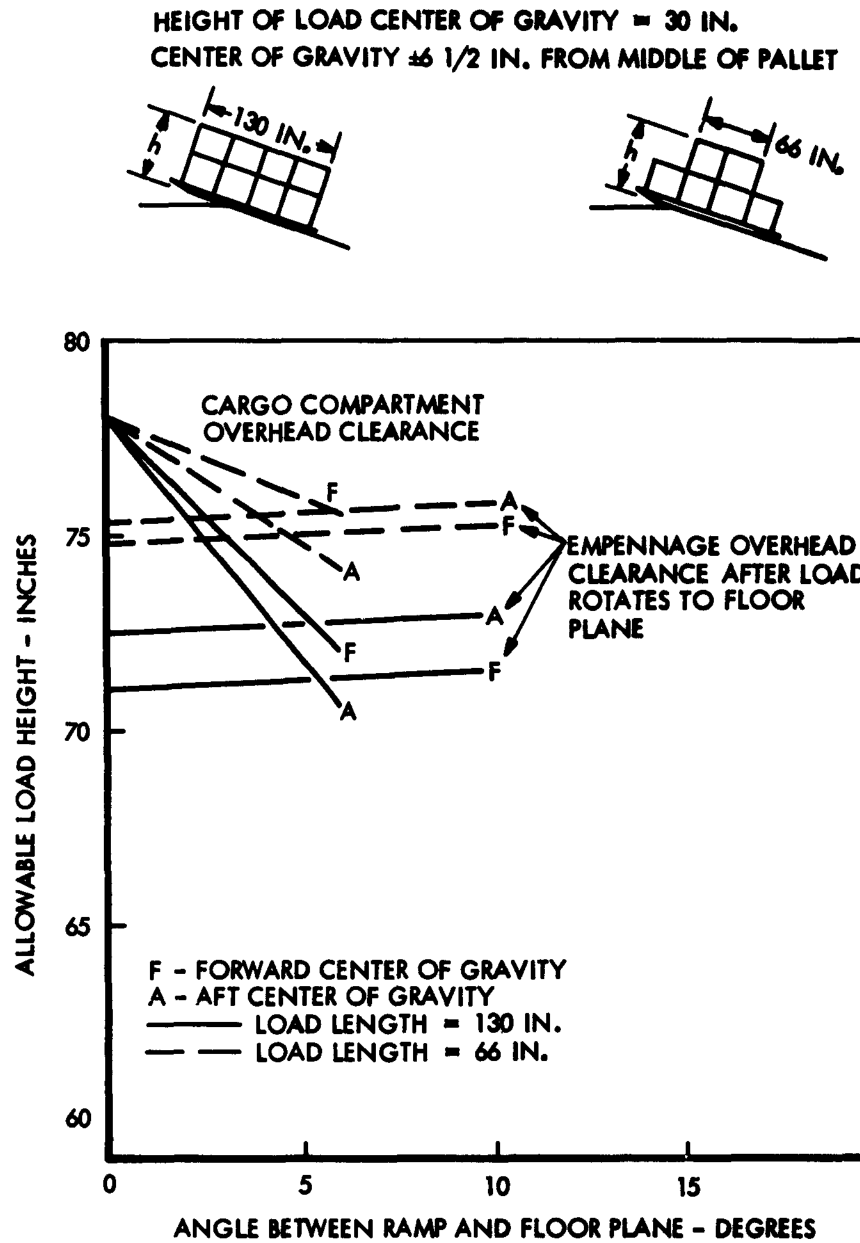


Figure 18. Allowable Load Height for Inclined Ramp Loading and Gravity Rotation (HC-1 Chinook)

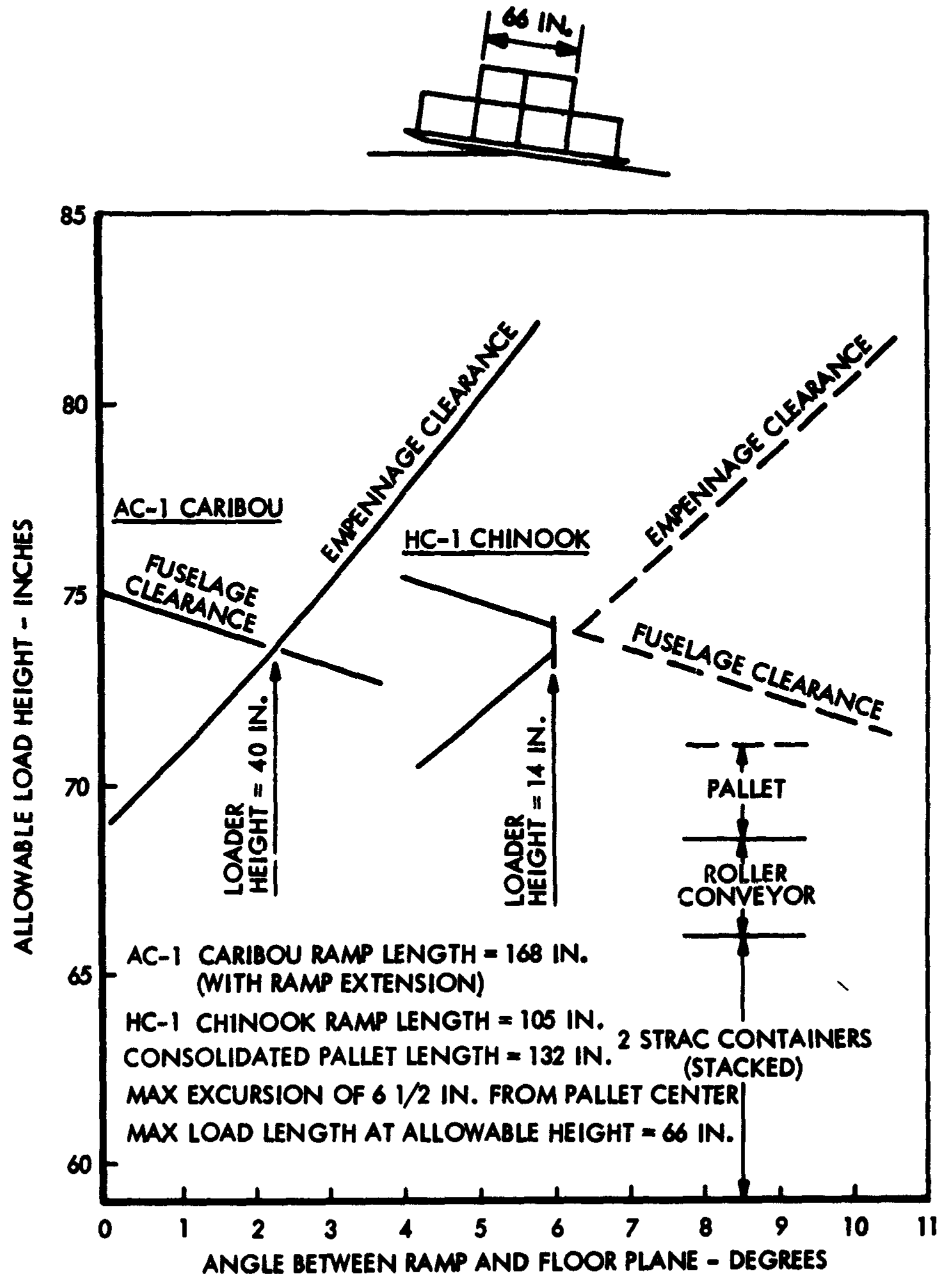


Figure 19. Optimum Ramp Angle Determination for Direct Bridging to Carriers Equipped with Roller Conveyor System

6. That a teeter-totter or pivoting device or its functional equivalent be provided at the junction of ramp and fuselage to distribute the loads over the bottom of the consolidating pallet to preclude destruction of the conveyor rollers (see Teetering Bridge Device); or

7. That a pivoting, double-shoe or skid device (see Consolidated Pallet Design) or its functional equivalent be provided at each corner of the consolidating pallet to distribute roller loads when bridging from the ground or a loading vehicle to the ramp;

8. That a loader or adjustable bed height vehicle be provided to accomplish bridging and mating to ramp of the carriers. Vertical height adjustment range should be from 12 inches for the HC-1 Chinook to 50 inches for direct level bridging to the AC-1 Caribou.

SUMMARY

If all the foregoing requirements and provisioning are satisfied, six STRAC containers on a consolidating pallet can be loaded and unloaded from both carriers over a roller conveyor system with reasonable safety and facility. Without all conditions satisfied, it is advisable to limit the loading of the consolidating pallet to a single layer of four STRAC containers.

By provisioning pivoting and skid devices, a single layer, consolidated load of four STRAC containers can be bridged directly to the ground from either carrier or directly to 72-inch truckbed height from the AC-1 Caribou or a 43-inch truckbed from the HC-1 Chinook.

Assuming a consolidated load of QM pallets 59 inches high (54-inch load plus 2-1/2-inch roller section plus 2-1/2-inch pallet), the AC-1 Caribou ramp with ramp extension is too short for direct bridging to the ground. The limiting ramp angle for safe entry or exit of the load in the fuselage is 13 degrees (see Figure 20), and the ramp and extension should be 205 inches long. The pure QM load can be directly bridged, over its 168-inch ramp and extension, to truck beds or platforms between 8 inches and 53 inches only. The HC-1 Chinook can load or discharge 132-inch consolidated pallet loads of QM's to platforms from ground level to 29 inches high (see Figures 20 and 21).

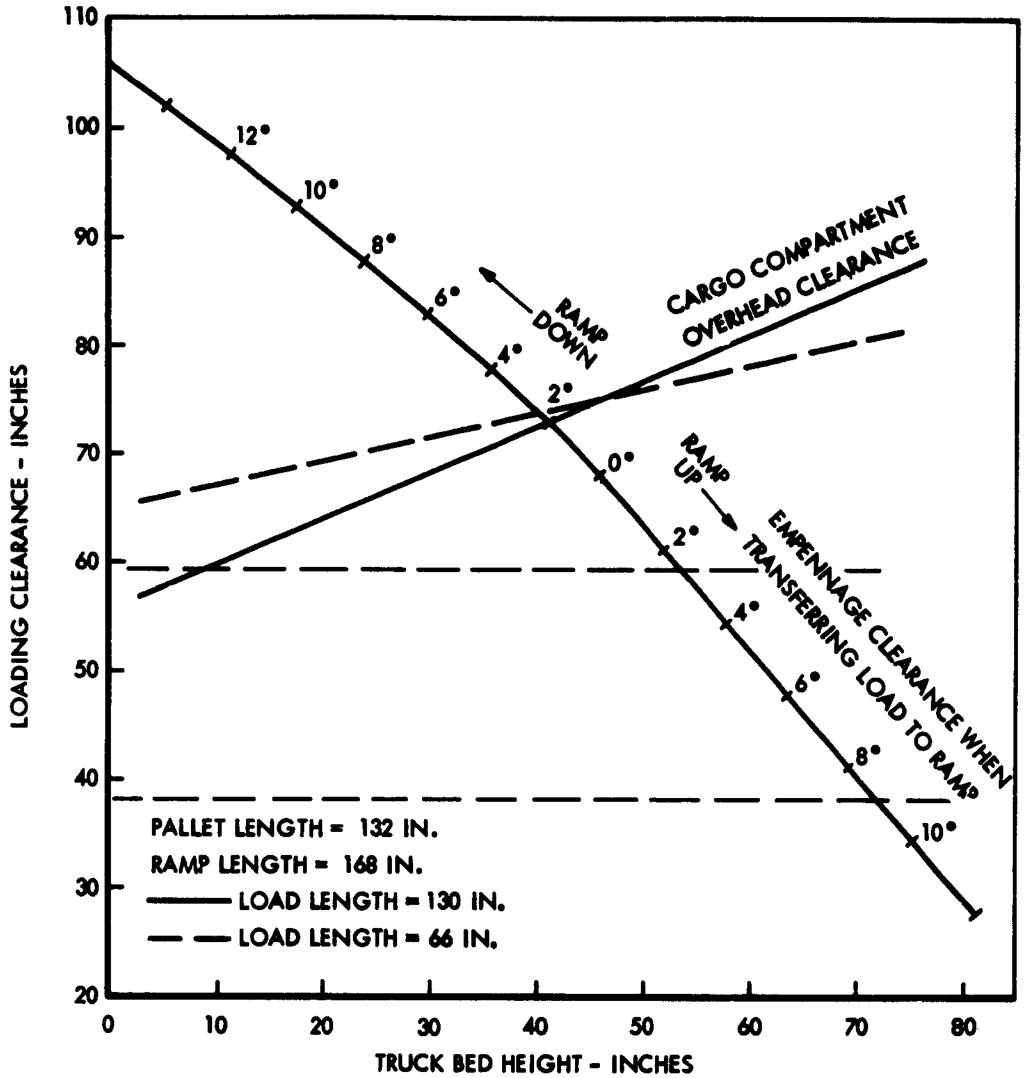


Figure 20. AC-1 Caribou Loading Summary - Roller Conveyor System

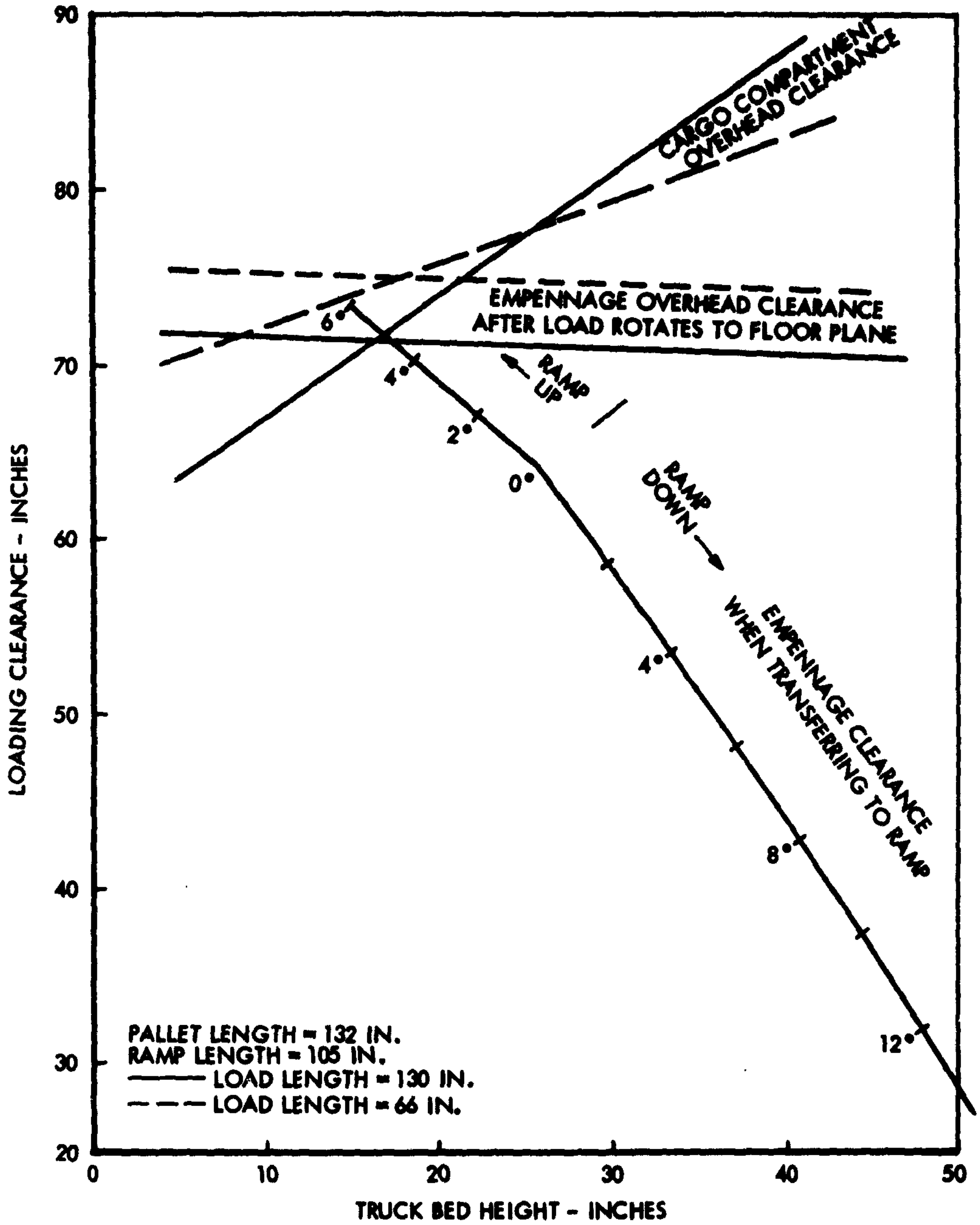


Figure 21. HC-1 Chinook Loading Summary - Roller Conveyor System

CONSOLIDATING PALLET DESIGN

PALLET REQUIREMENTS

The maximum loads capable of being transported by the AC-1 Caribou and HC-1 Chinook are approximately 7000 pounds. To be compatible with the aircraft, the consolidating pallet must be designed to withstand dynamic flight loads of 2.0 g down, 1.5 up and aft, 1.0 g side and 2.0 g forward when loaded to 7000 pounds.

Another necessary consideration of pallet design is the manner in which it would be handled and used in the system. Listed below are the loading configurations regarded as most critical.

1. Teeter - A pallet is in a position of teetering when it has a single support at its center. This occurs during transfer from the ramp of the aircraft to the cargo floor.

2. Forklift - Lifting the pallet by forklift distributes the pallet weight on two supports spaced approximately 20 inches apart and near the pallet center.

3. Cable Lift - When airlifted by helicopter or crane, the pallet must be supported by cables or slings.

4. Loading - The pallet must be capable of supporting the required load combinations as compiled in Table 1 when the center of gravity of the load is within 6-1/2 inches of the center of the pallet.

BASIC PALLET

During the early phases of this study, the advantages of a consolidating pallet became apparent, and subsequent analysis indicated a 5-foot by 11-foot pallet to be optimum.

Of the various types and constructions of consolidating pallets investigated in this study—all wood, aluminum frame, aluminum honeycomb, and polyurethane foam and aluminum—all except the aluminum polyurethane pallet were eliminated by reason of weight, cost, or thickness. The basic pallet, as designed, is composed of a sheet aluminum skin riveted to a basic framework of aluminum channel. The pallet interior is filled with expanded polyurethane. Tie-down fittings for restraining cargo nets are provided along the pallet edges (see Figure 22). The pallet configuration evolved has a smooth unobstructed surface and is suitable for palletized loads as well as for miscellaneous and outsized cargo.

This basic pallet would be utilized for straight-in loading over level roller conveyors.

CONSOLIDATING PALLET CONFIGURATION

When loading or unloading a basic pallet over a nonparallel roller conveyor ramp the roller capacities are inadequate to end-support the pallet and specialized devices are required to distribute the loads. The Bridging Load Assembly presented in Figure 23 is a concept of such a device.

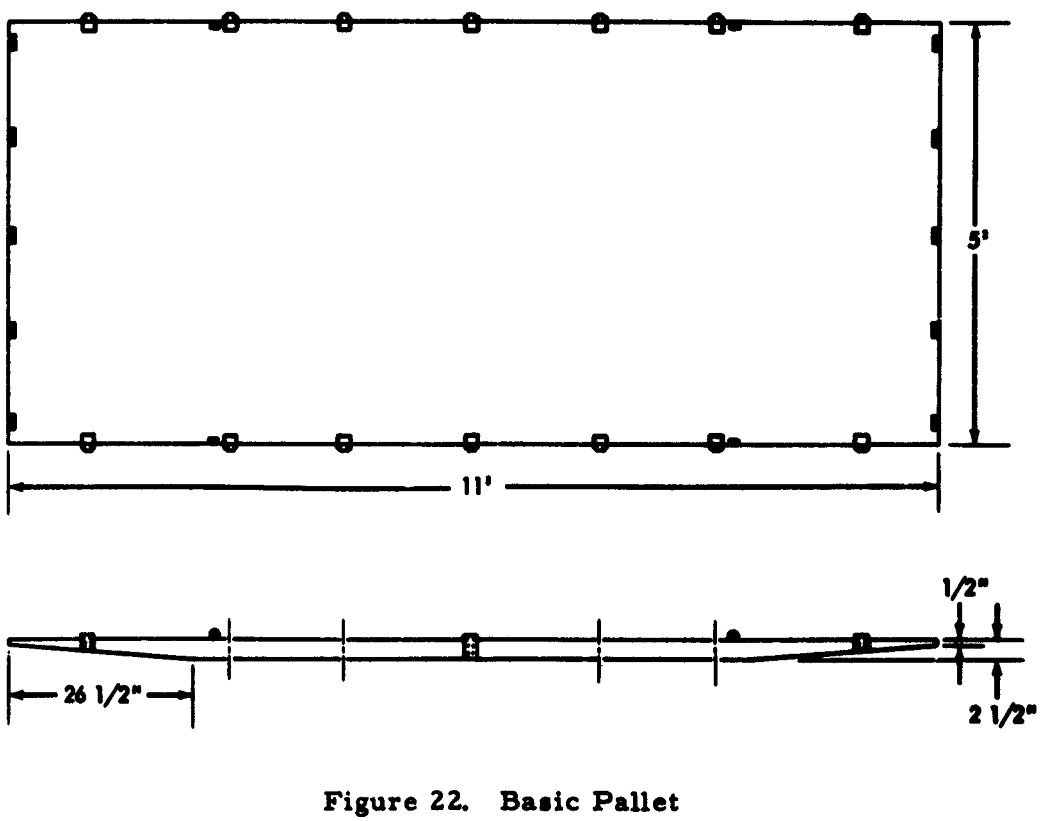


Figure 22. Basic Pallet

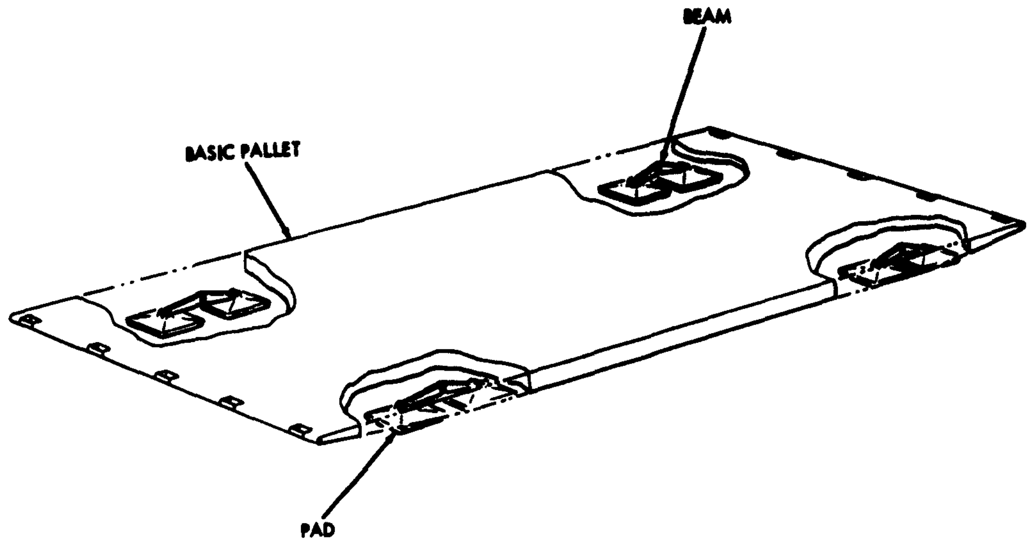


Figure 23. Consolidating Pallet

It consists of two pads pivoted at each end of a connecting beam. The connecting beam is fastened to the basic pallet. There are four sets of bridging load assemblies per pallet. The pivoting action of the pads and the connecting beam distribute the pallet weight to conform to the changes in angle in the conveyor system, thus preventing damage to the rollers or the pallets due to highly localized overstressing as the pallet moves between two nonparallel planes.

TEETERING BRIDGE DEVICE

Another such concept is the Teetering Bridge Device which is provided in the aircraft at the junction of the floor and ramp to preclude damage to the rollers and the consolidating pallet that would result from concentrated loads, (see Figure 24). The Teetering Bridge Device consists of an assembly mounted on an articulated base which is fastened to the floor and ramp of the aircraft. The teeter assembly is composed of two endless chain conveyors mounted on a basic framework. There is a Teetering Bridge Device for each line of

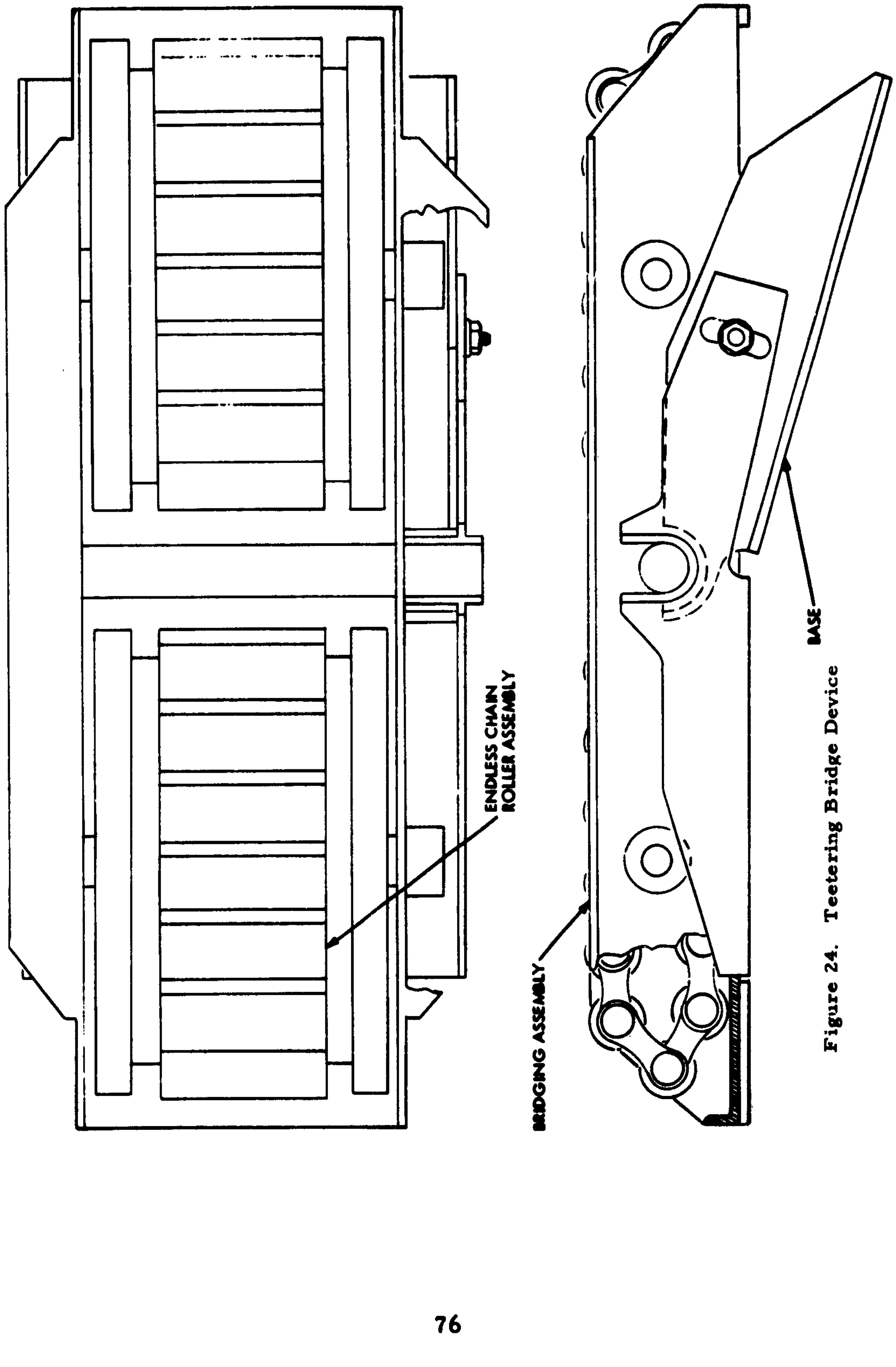


Figure 24. Teetering Bridge Device

roller conveyors. In operation, the articulated base pivots to match the angle made by the lowered ramp and the aircraft floor. The teetering bridge is manually set in the horizontal, or inclined position, for unloading or loading operations respectively. As the center of gravity of the pallet passes over the pivot point of the teeter assembly, the entire assembly tips to conform to the plane of the next roller section.

MOBILE PALLET DESIGN

INTRODUCTION

The mobile pallet concept (Figure 25) was evolved to alleviate some of the overhead clearance problems, reduce the human control and monitoring function, bridge angular discontinuities easily and safely, provide quick tiedown, and provide a means of quickly disposing of cargo on the ground or loading the customer's vehicle at the Airhead. The mobile pallet, instead of being moved over wheel or roller conveyor assemblies, moves on its own rolling assembly in rails provided to distribute contact loads that are excessive for the aircraft floor structure or the natural terrain.

DESCRIPTION

The mobile pallet consists of the essentials of the basic consolidating pallet modified to mount a retractable rolling assembly and is as depicted in Figure 26. It was designed to conform to the design parameter presented in Figure 27 in order to navigate the angular discontinuities that result when bridging from the ground.

The pallet proper is similar to the basic pallet previously described. The framework is constructed of formed 0.025-inch aluminum "C" section and extends around the periphery of the pallet. Two 3/4- by 0.049-inch wall tubes are placed through the frame to serve as guides and supports for the pivoting axles of the rolling assemblies. Two 1/2-inch diameter tubes are placed at the ends of the pallet as a tiedown fitting. Also incorporated in the frame is a pair of hand cranked detent devices for maintaining the pallet elevated on the rolling assemblies. Holes for eyebolts are provided for attachment of hoisting slings.

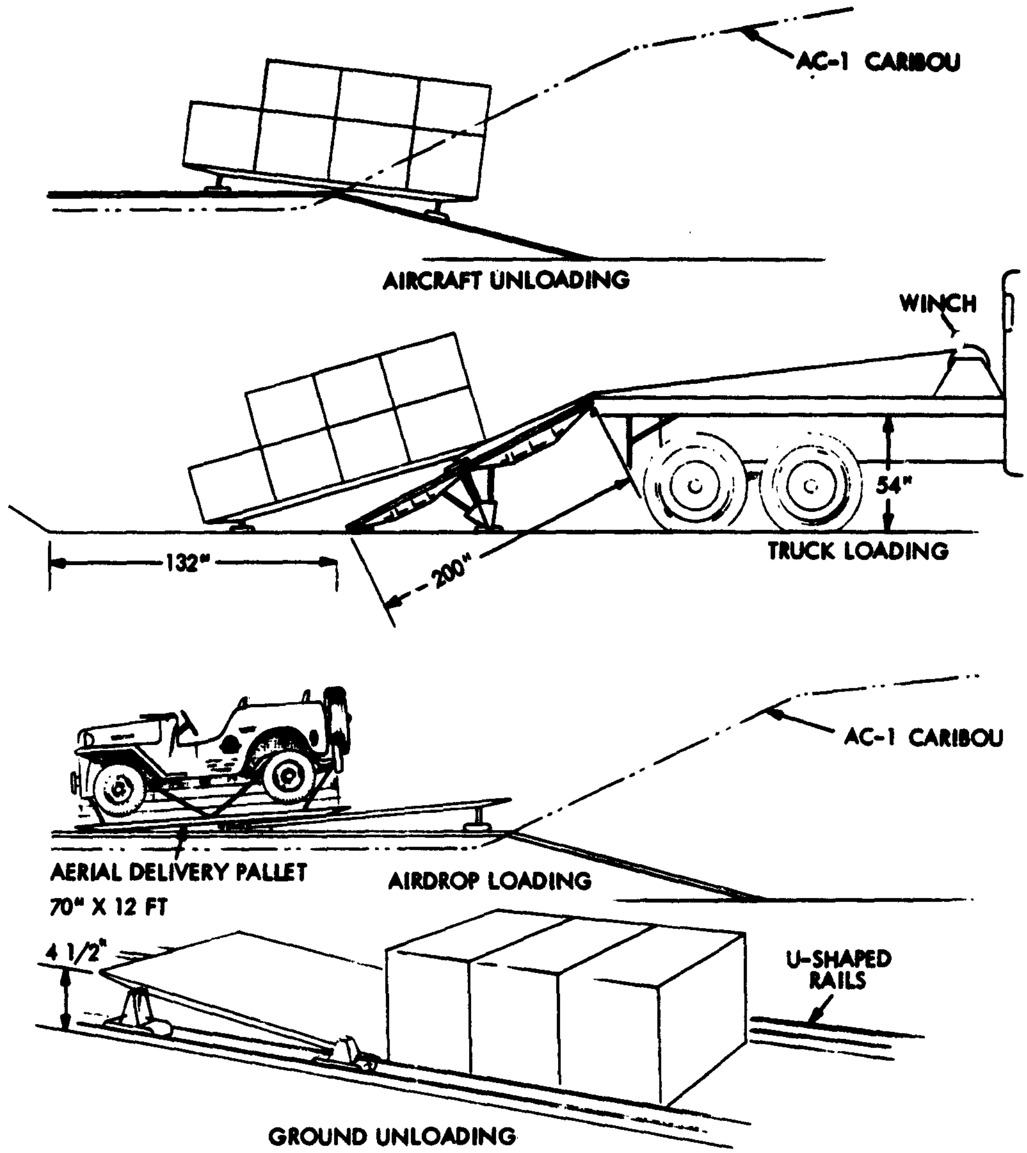
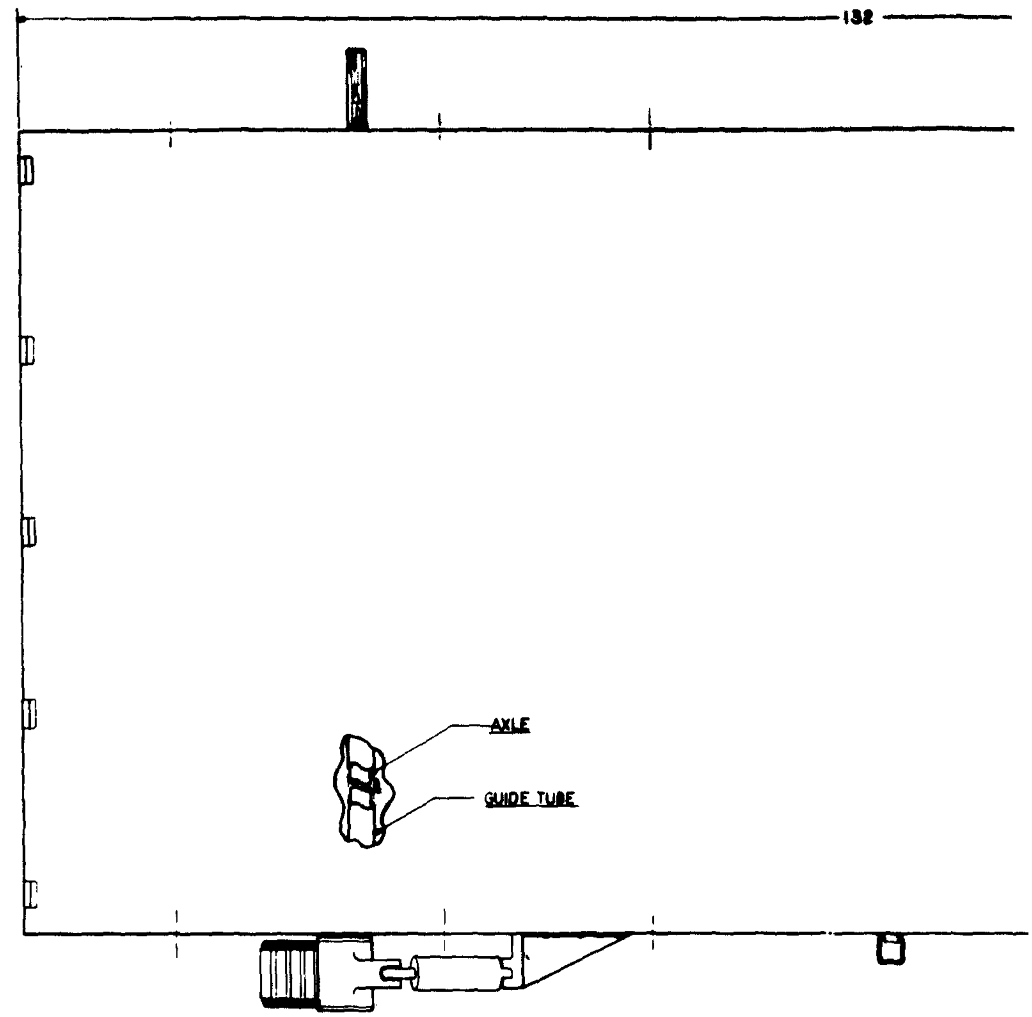
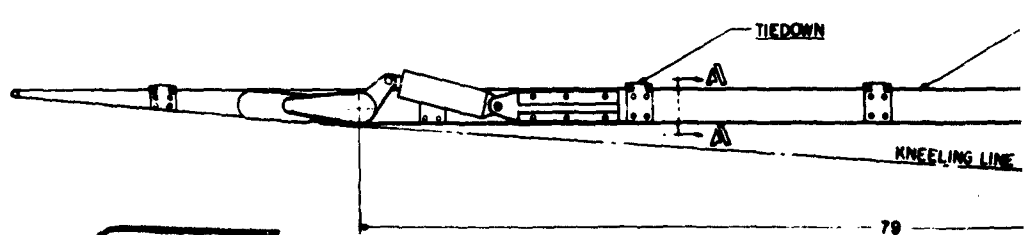


Figure 25. Mobile Pallet Concept





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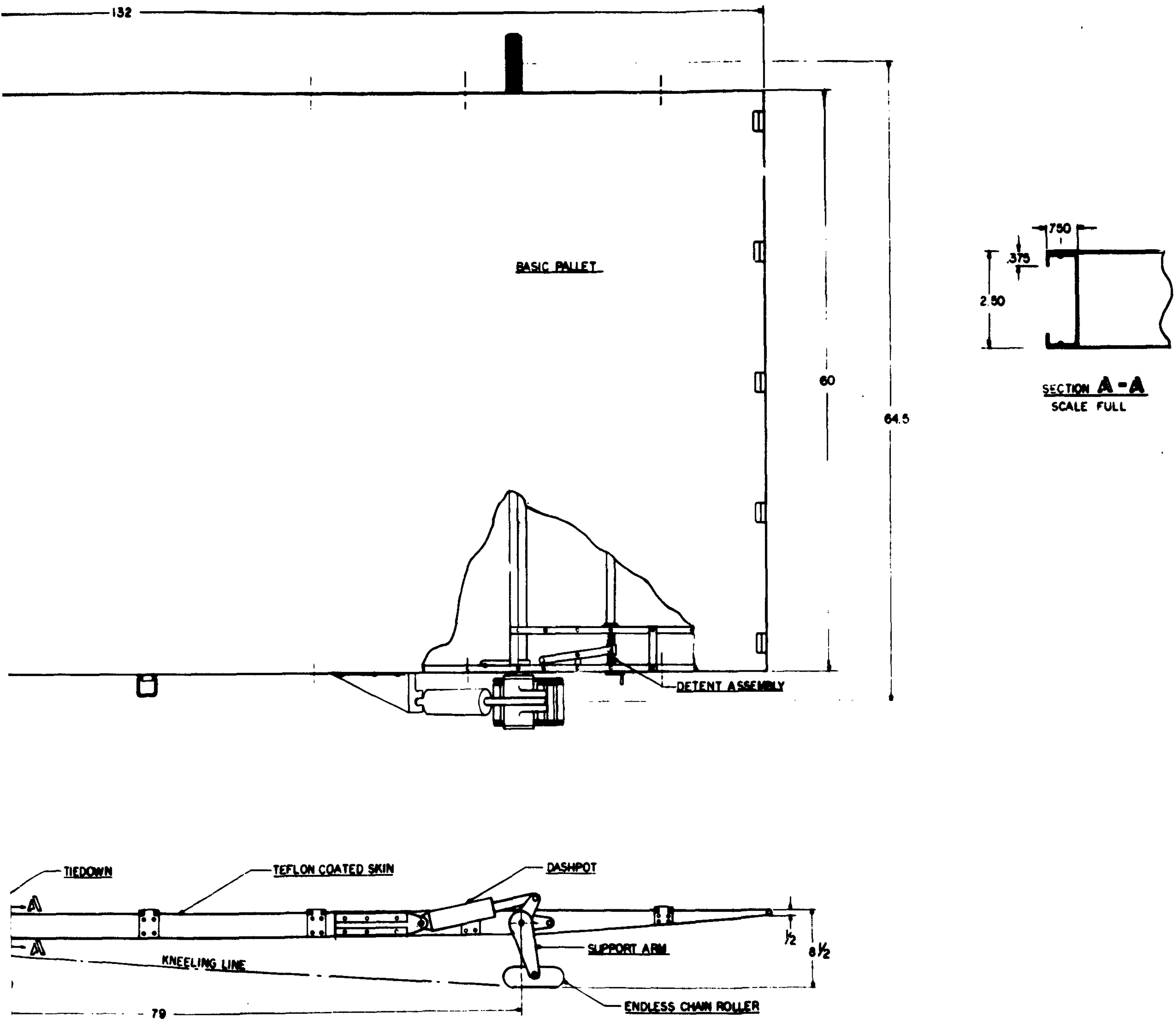
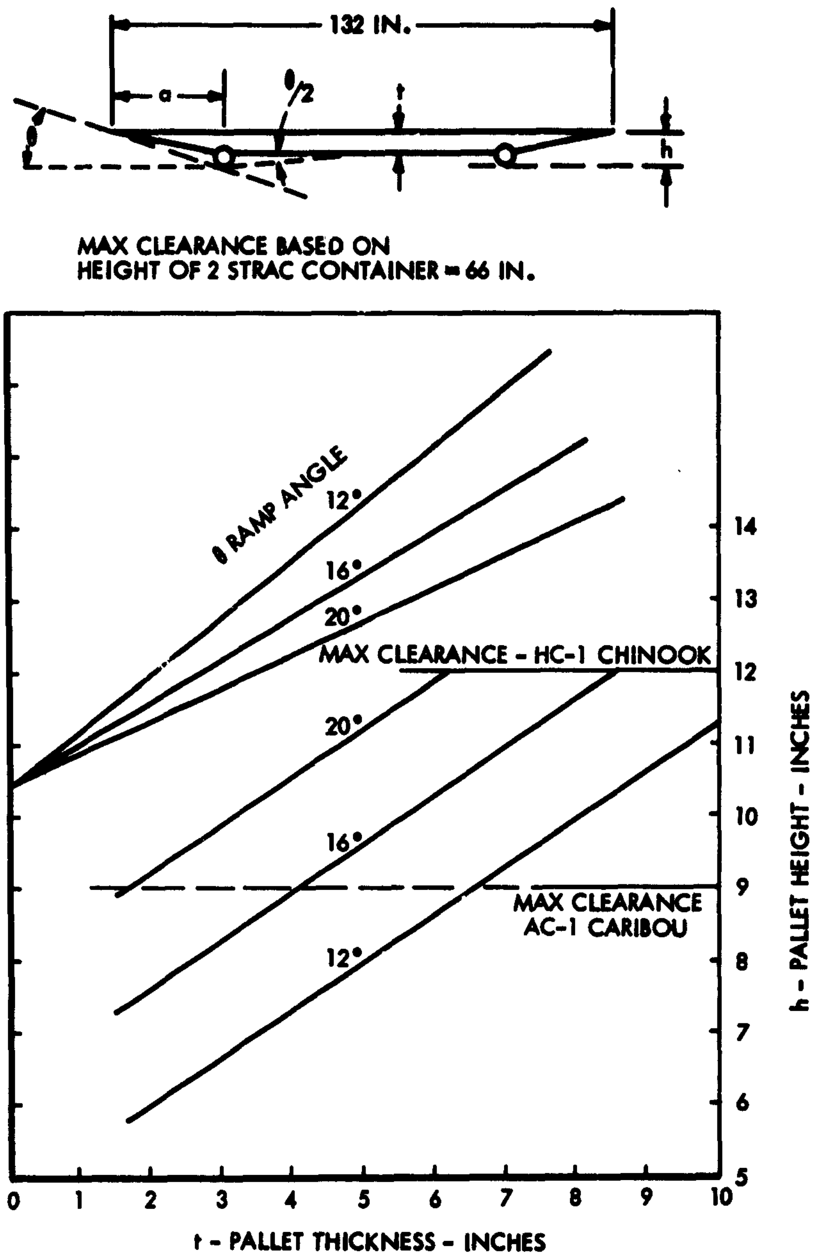


Figure 26. Mobile Pallet



NOTE:
1 DEGREE OF RAMP ANGLE = 0.8 IN. OVERHEAD CLEARANCE OR 1.25 IN. PALLET THICKNESS.

Figure 27. Mobile Pallet Design Parameters for Ramp Clearance

The skin of the pallet is 0.025-inch aluminum sheet and is riveted to the frame. The interior is filled with polyurethane foamed in place. The upper surface of the skin is coated with teflon to reduce friction and to allow the cargo to be unloaded without the use of forklift trucks.

ENDLESS CHAIN ROLLER (ECR)

A special feature of the mobile pallet design is the rolling assembly. Because of the difficulty of locating wheels of reasonable diameter with sufficient capacity to carry the required loads, the endless-chain roller (ECR) was substituted for wheels, (see Figure 28).

The endless-chain roller assembly is composed of a continuous chain of rollers mounted on a supporting hub (Figure 29). The hub is shaped to serve as a center platen and exterior guide rails for the roller assembly. Flanges on the lower outside edges of the hub retain the entire assembly within the aircraft cargo floor rail.

The loaded pallet moves by the caterpillar action of the roller track around the center platen. The entire load is carried on the roller between the frame and the floor. The loaded pallet moves easily because of the absence of axle and journal friction.

The ECR assembly is attached to the pallet by a supporting arm with pivots at the ECR and at the pallet, thus permitting the pallet to be raised, lowered, or canted as desired. Each pallet is equipped with four ECR assemblies.

PALLET SUSPENSION

The ability to retract all of the rolling assemblies allows the loaded pallet to be transported with less hazard of rolling off the transport vehicle. The added ability to retract the fore or aft pair of rolling assemblies individually provides an enhanced unloading capability. With the top of the pallet coated with teflon and the pallet in a kneeled position, the cargo will either move or be near incipient slip. The ability to kneel the pallet provides the capability to unload the pallet easily at a primitive airhead environment without material handling equipment or to discharge an aerial-delivery pallet onto the floor of the aircraft as shown in Figure 25.

Three methods of suspending and retracting the rolling assemblies from the pallet have been considered in this concept - fixed, hydraulic, and manual release and retract.

[redacted]

The fixed rolling assembly essentially provides a dolly with limited capabilities and utility. This type of suspension will be the lightest in weight.

[redacted]

The second rolling assembly suspension system includes a manually actuated hydraulic system. The system would include a three-position selector valve—front, rear, both—and a pump handle incorporating a turn-to-lock-or-meter valve and hand pump. This configuration could be lowered, elevated, and kneeled by a single operator as desired or required.

Ma[redacted]

The third method of suspending the rolling assemblies provides a manual crank release of the axle with the pallet settling against dash pots to preclude damage to pallet and/or cargo. Extension of the rolling assemblies is effected only by physically elevating the pallet and allowing the rolling assembly to move to the down, detent position under action of a return spring.

Of the three mobile pallet suspension configurations, the manual release configuration is regarded as the most practical and reliable. Since the pallet height is sufficient for proper loading and the support arms are sufficient even under flight loads, there appears to be little reason to retract the rolling assemblies except for unloading. When the pallet is unloaded, it can be lifted manually to extend the rolling assemblies.

The manual method is the one utilized in the design presented in this report. The ECR's are maintained in position by the support arms. Each arm has a detent lug and dashpot lug fashioned on it. The arm is mounted on an axle placed through the pallet. A hydraulic dashpot connects between the pallet side and the dashpot lug of the arm.

In operation, when it is desired to lower the pallet for unloading, the detent crank is rotated to withdraw the detent pins from the support arms. When the arms are freed, the pallet slowly lowers itself, the speed being regulated by the flow of oil through an orifice in the dashpot. The ECR's never fully retract to the lower surface of the pallet but remain slightly extended to allow the pallet to roll rather than be skidded.

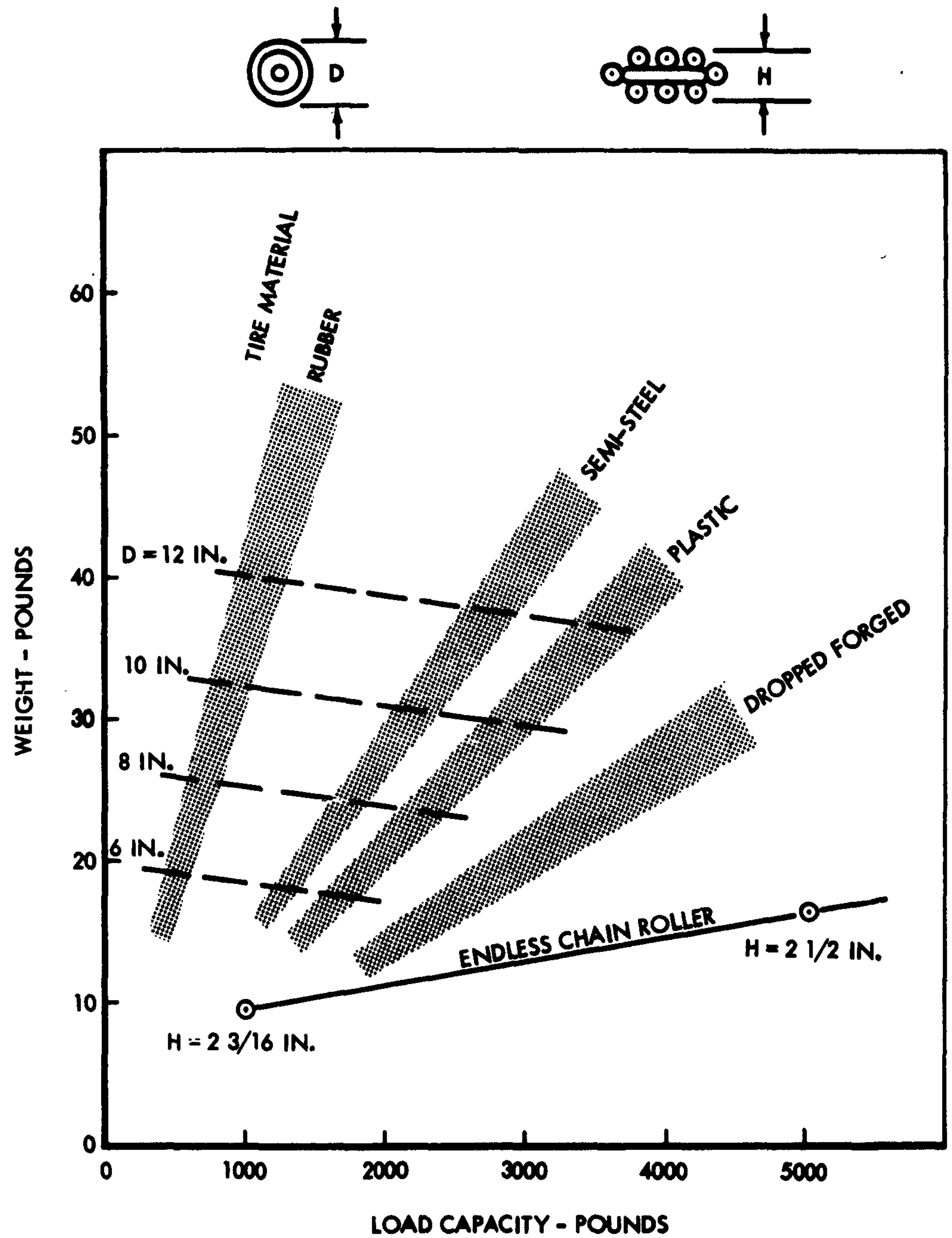
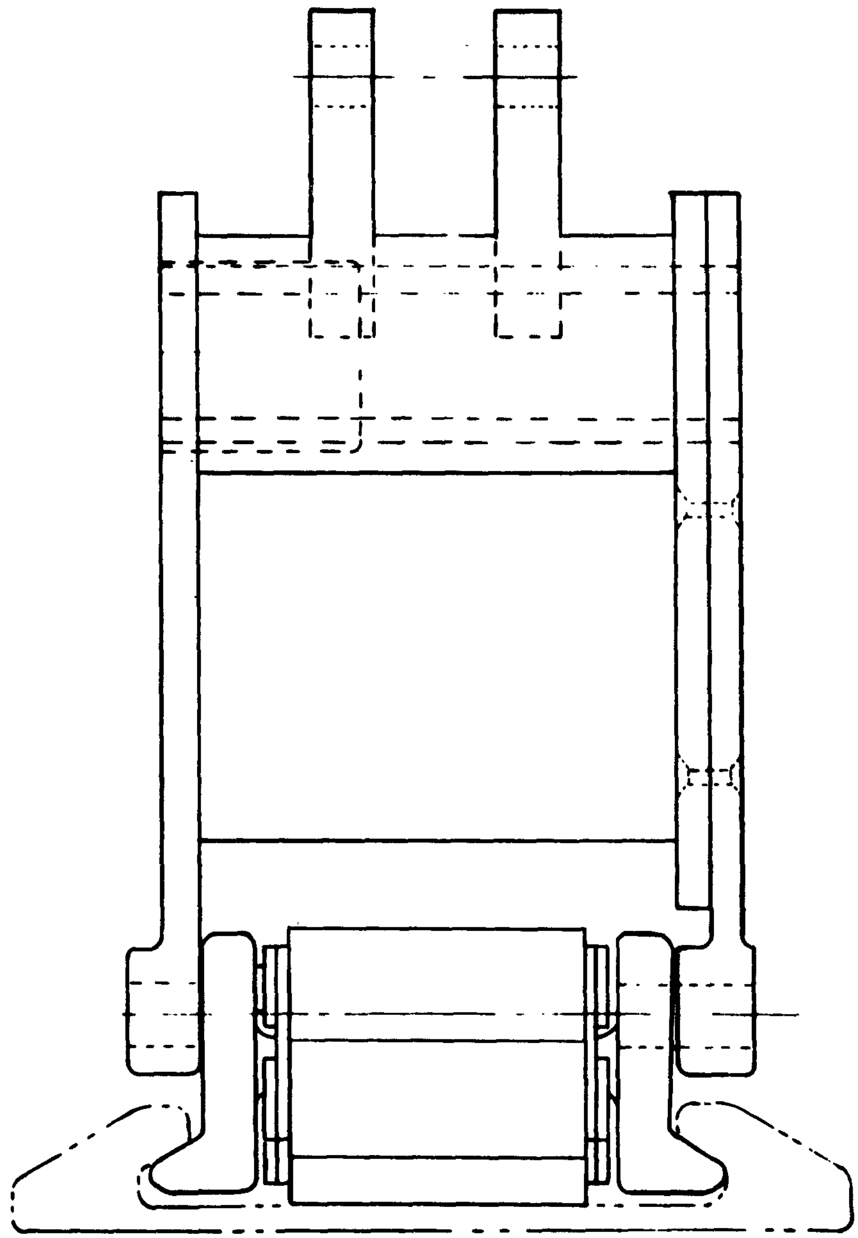


Figure 28. Comparison of Wheels and Endless-Chain Roller Characteristics



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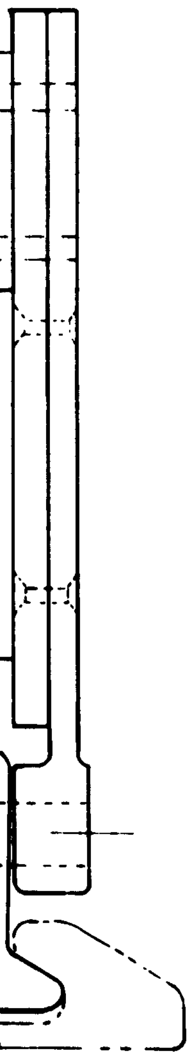


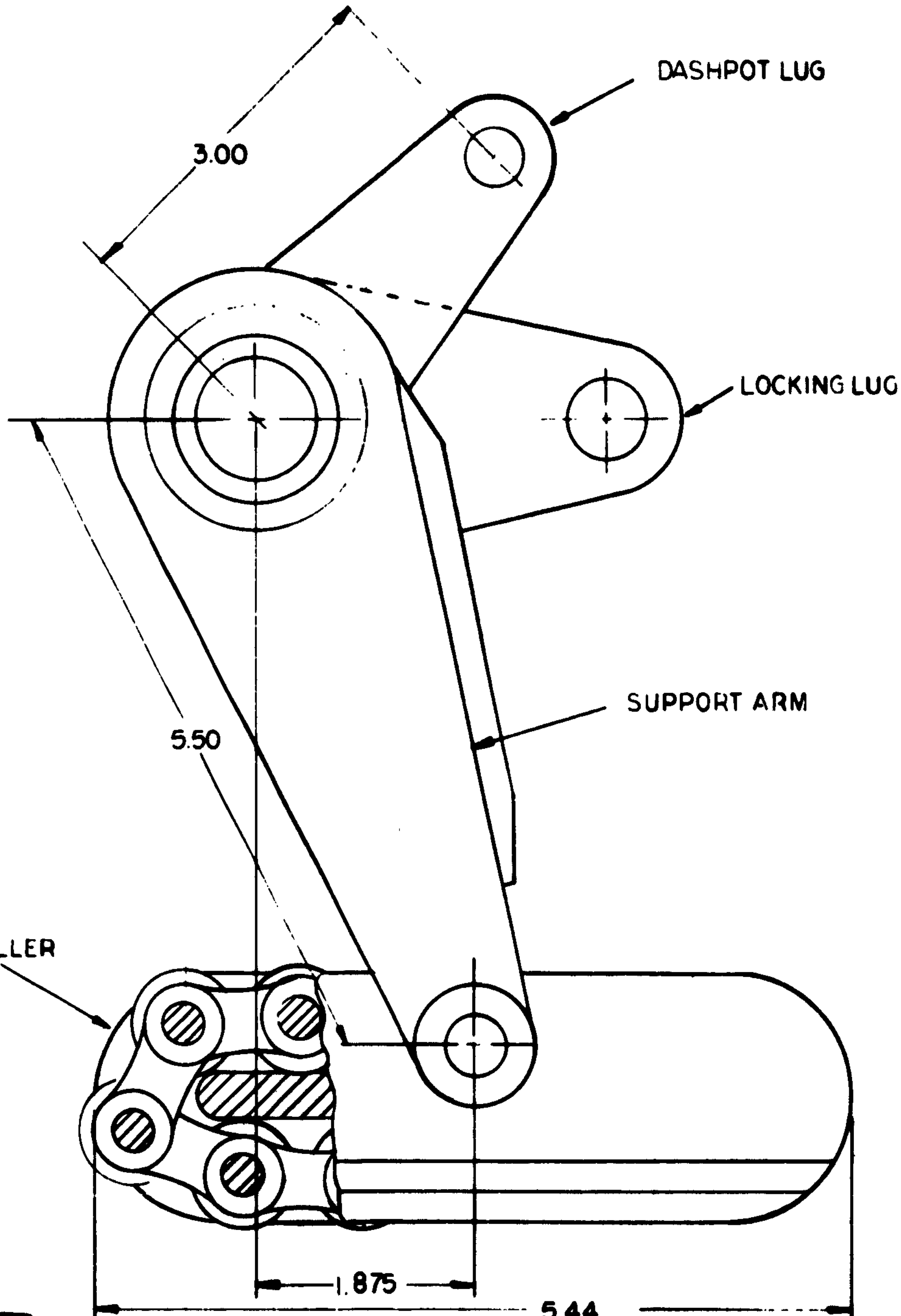


Figure 29. Endless-Chain Roller Assembly

To erect the pallet, the edge of the unloaded pallet is lifted manually and the ECR rolling assemblies snap down into place. A second man is required to crank the supporting detent pin into place.

RAIL DESIGN

In conjunction with the ECR device, rails or ramps are required to distribute the load of the mobile pallet over a larger area than is inherent in the ECR (see Appendix III). These rails are also necessary for movement of the pallet from one level to another.

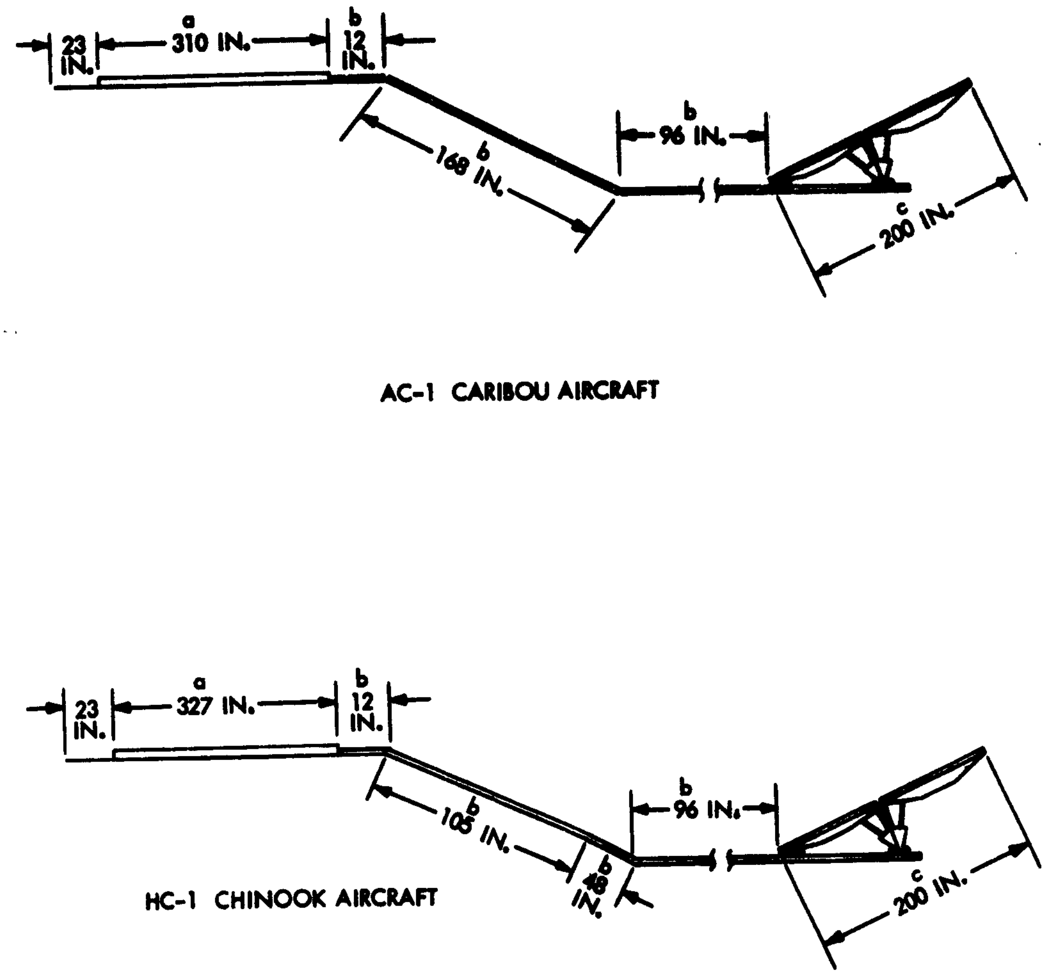
Three individual sets of rails are required. Each set consists of two rails braced together to provide lateral stability and proper spacing. The rail system consists of the following:

AIRCRAFT CARGO FLOOR RAIL

This rail is fastened to the aircraft cargo compartment floor and serves not only to spread the load and guide the mobile pallet but also acts to restrain the pallet under 2-g lateral and vertical accelerations. The length of the cargo compartment floor rail depends upon the particular aircraft. The rail extends within 12 inches of the ramp and 23 inches of the cabin bulkhead. A 12-inch channel section at the ramp end provides guidance and easy engagement of the ECR to the restraining rail section. The rail is formed with saw teeth on the interior of the side to complement a locking device. The rail and ramp section lengths are presented in Figure 30.

GROUND RAIL

The ground rail is used on the ground outside the aircraft and is capable of supporting the fully loaded mobile pallet with a ground pressure as low as 10 psi. A section of the ground rail is secured on the ramp of the aircraft and a length of 1 foot is used on the aircraft floor for guiding the pallet into the aircraft cargo floor rail. It also serves as a base for the vehicle ramp assembly. If ground pressures of lower than 10 psi are expected such as snow or mud, wood planking may be carried in the aircraft



LEGEND

(a) AIRCRAFT CARGO FLOOR RAIL

(b) GROUND RAIL

(c) VEHICLE RAMP ASSEMBLY

Figure 30. Rail Configuration

and used to spread the load. Too great a weight penalty would be incurred to design for lower ground pressures since they occur the lesser proportion of the time.

VEHICLE RAMP ASSEMBLY

The vehicle ramp assembly serves to traverse the mobile pallet between the ground rail and a vehicle bed or loading dock. It must accommodate the various vehicle bed heights encountered and adjust for the normal deflection of the truck bed due to the cargo loads. The length of the guide channel is dependent upon the maximum angle of loading and the vehicle bed height. A 16-degree angle was selected as the maximum angle encountered in loading the two Army aircraft (see Figure 30). The total ramp length was selected as 200 inches (see Figure 31) to accommodate a truck or loading dock height of 55 inches which encompasses the standard 1/2-, 1-, 2-, 2-1/2-, and 5-ton cargo trucks.

Each side of the vehicle ramp assembly was divided into two separate beams of half the span length and connected only at the ECR assembly for portability. The top end of the ramps hook to the vehicle. This method of construction allows for fore and aft excursion during truck bed deflection under load.

The lower section has a set of ECR's as the base to allow for normal motion during loading of the vehicle.

A system of cross bracing is employed to provide stability between the two ramp assemblies. This bracing may be quickly installed and automatically spaces the ramp assemblies at the proper track distance.

PALLET CHOCKS

The ECR configuration lends itself readily to rail restraint. The hub containing the roller chain is provided with a flange that is restrained by an overhanging lip on the aircraft rail, thus providing restraint of the ECR assembly in both side and vertical loads. Longitudinal restraint can be effected by conventional tiedown devices, pins, or shear devices between the tracks and the ECR, or quick locking pallet chocks placed in the track in front of and behind the ECR.

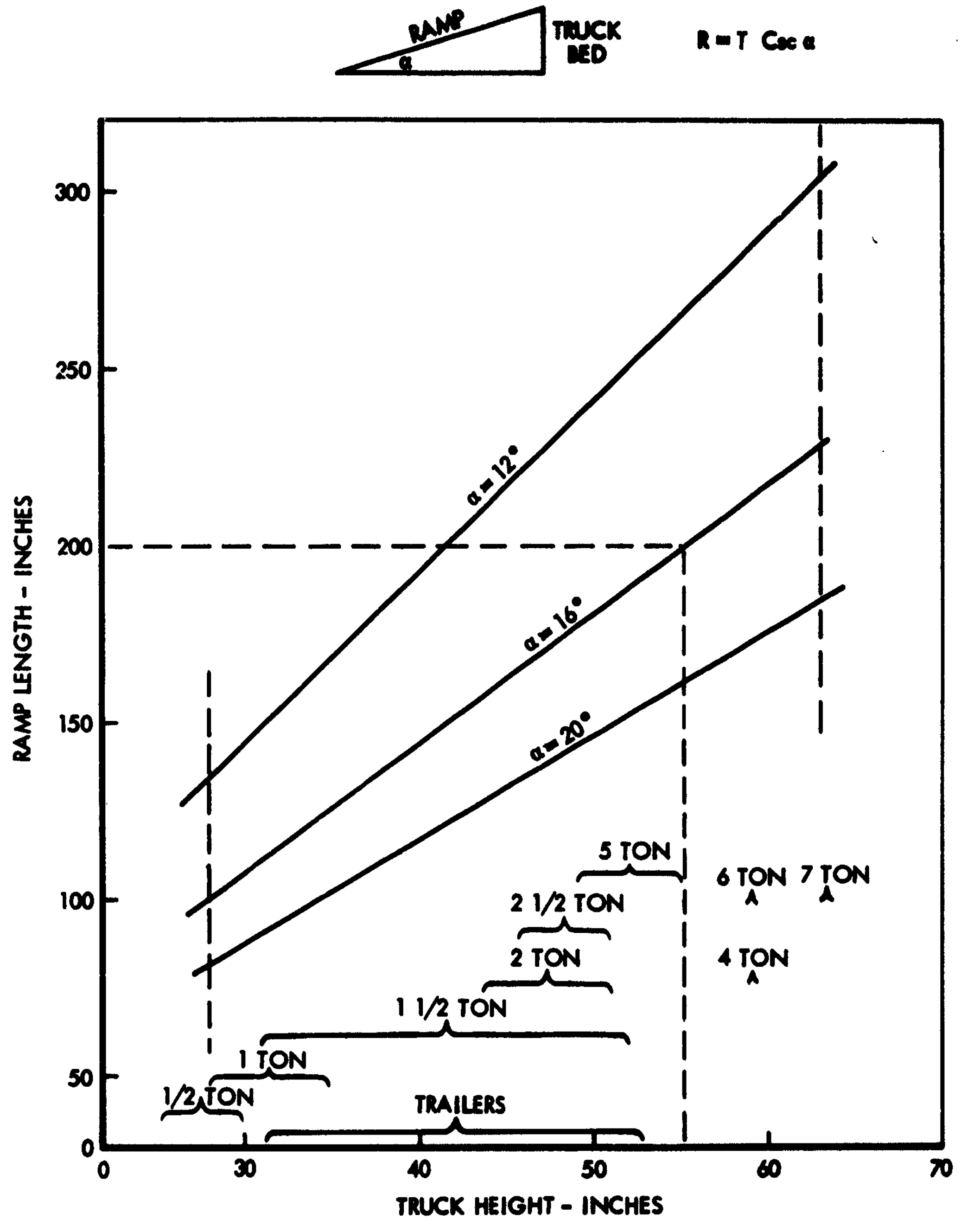
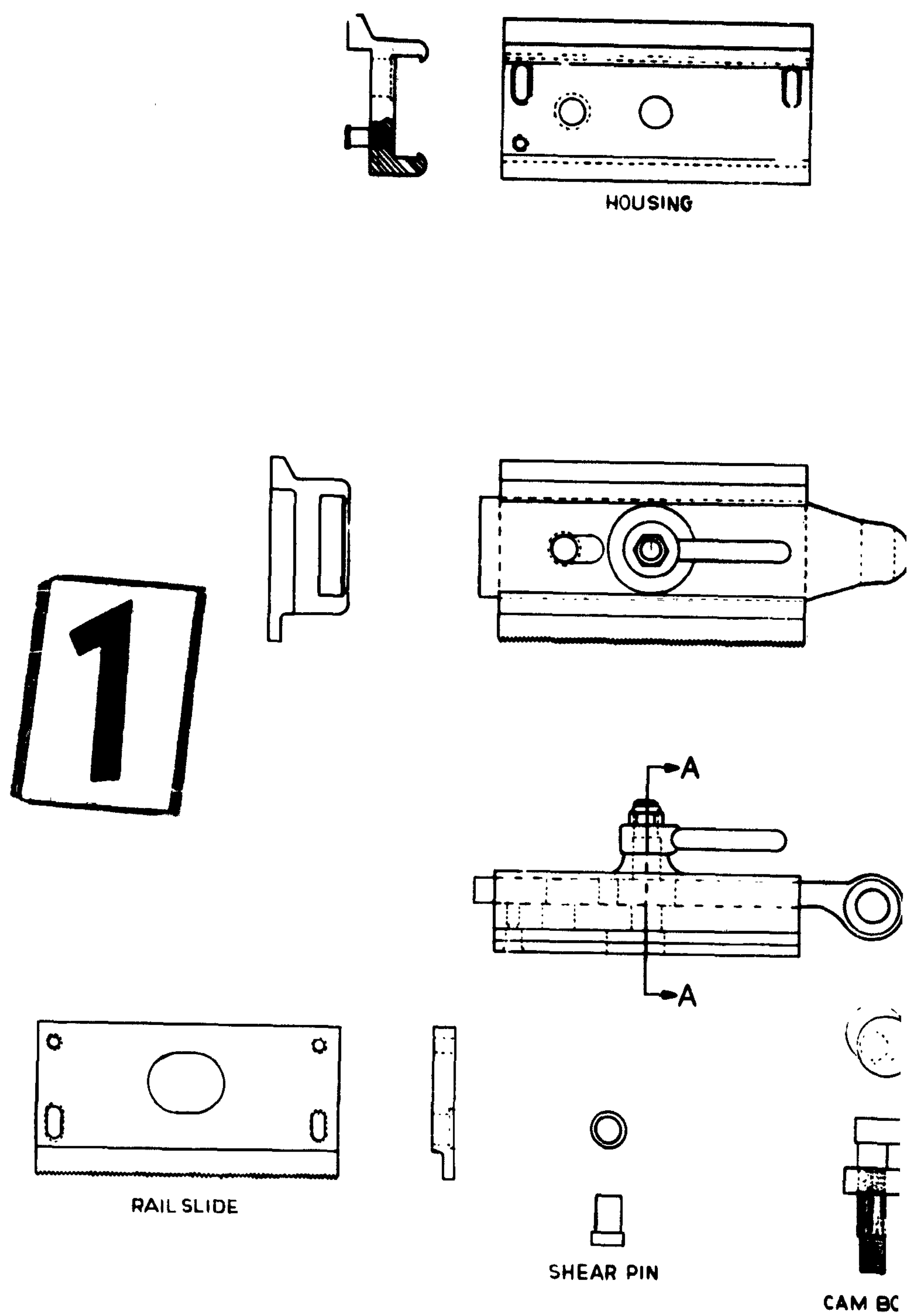


Figure 31. Ramp Length Versus Truck Bed Height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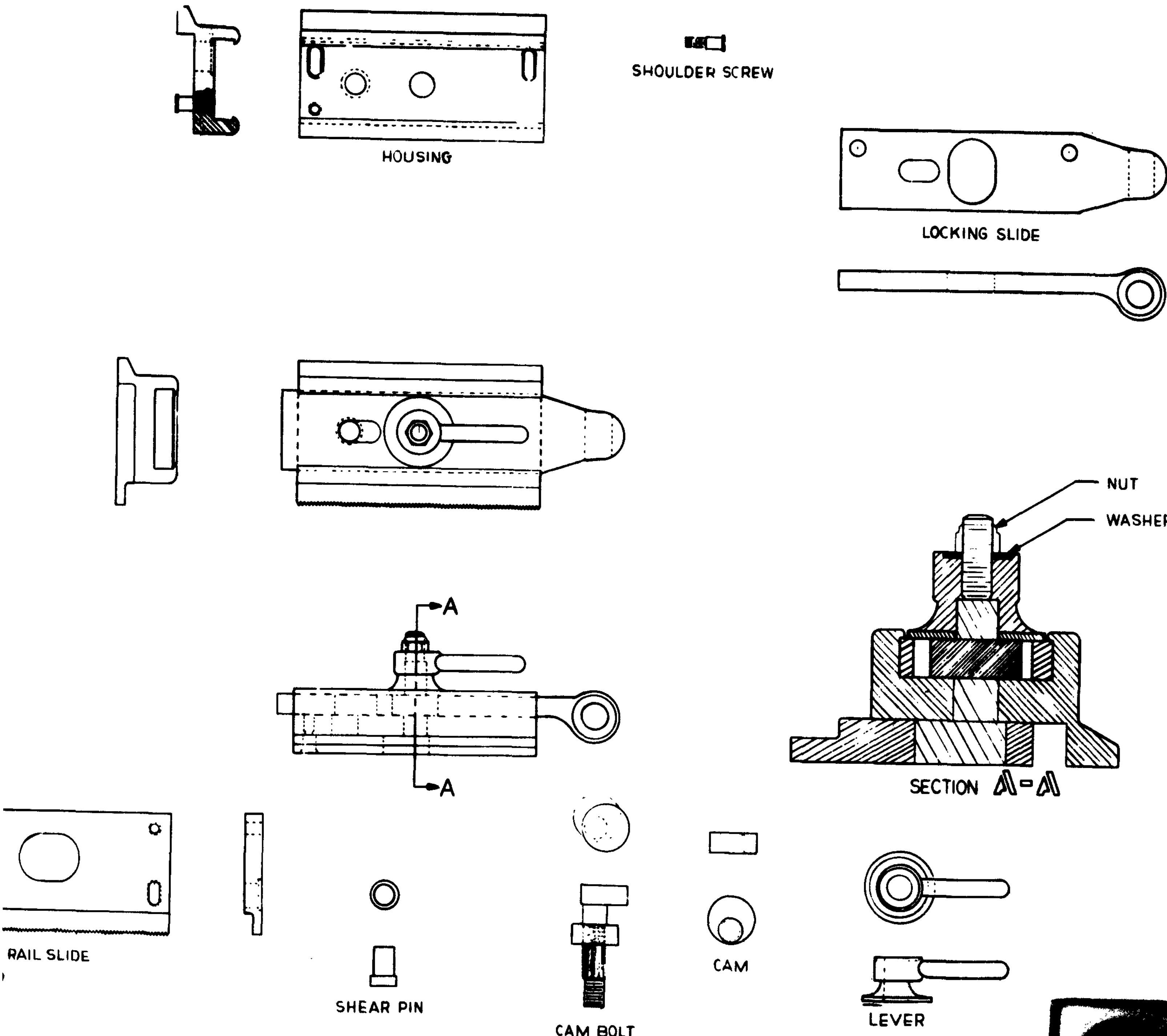
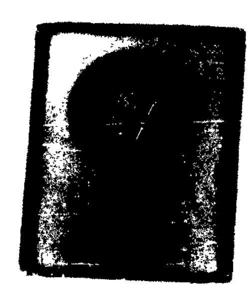


Figure 32. Pallet Chock



One such unit features an over-center locking device actuating an overlapping rail slide which is extended by manually operating a cam bringing the slide in contact with the inside of the rails (Figure 32). The slide on one side and the housing are serrated and mate with a like serration in the rail. Once extended, the slide may be manually locked in position to restrain the pallets. When retracted, the slide clears the inside lip of the rails and the device may be removed for loading and unloading the pallets. The ECR, equipped with rail or track restraint, provides the unique capability of entering or engaging the restraining rail immediately after traversing the floor-ramp junction in spite of the angle that exists. This capability is not inherent in the roller conveyor, rail restraint of the 463L system having a full length pallet lip that must be guided into the rail. Straight-in loading is required in this instance.

AERIAL DELIVERY

Although not primarily intended for aerial delivery, the mobile pallet, because of its rolling assembly and rail configuration, is capable of aerial delivery. The pallet retention system, however, will require modification as shown in Figure 33. A pallet chock with tiedown ring is locked in the track forward of the pallet. A standard tiedown is utilized to restrain the pallet from moving aft. At drop time, the tiedown device is removed and the pallet is free to move down the rail and out of the aircraft.

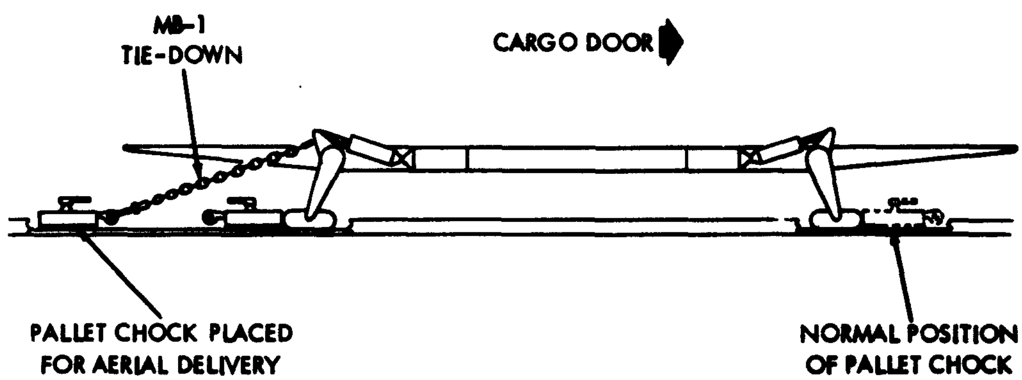


Figure 33. Aerial Delivery Tiedown

It is doubtful, however, that the mobile pallet should be utilised for aerial delivery. It is a manufactured item costing many times more than standard aerial delivery platforms. The salvage value after drop is questionable.

BASE PLATE PALLET SUPPORT

Although currently the major portion of Army supplies is unitised on QM or STRAC pallets, the designs of these pallets do not lend themselves to flexible use of the roller conveyor. In developing a system for the three pallets of this study, the spacing of the lower boards on the various size pallets was found to differ to an extent necessitating excess roller length to accommodate mixed pallet loads. Any other pallets introduced into the system would have a similar effect. Thus, it would be necessary to use an undesirable number of roller conveyor sections to insure proper support, and restrictions would still exist as to the direction in which pallets could be moved. Thus, in order to accommodate the wooden pallets of this study to a minimum roller conveyor system, a pallet support plate of some type would be desirable.

The most austere loading system would involve only lightweight roller conveyor sections on the aircraft floor and the addition of detachable flat base plates to each pallet to move via Army air. Such a plate would consist of a sheet of plywood with the same area as the pallet served. In considering only the QM and STRAC pallets, two sizes of base plate should suffice.

Base plate thickness could be standardized, but such a determination is directly related to the size and spacing of the rollers provided.

In order to keep the base plate aligned under the pallet, flush mounted, spring-loaded clips could be used. Both the plywood sheets used as base plates and clips used to retain them in place should be reuseable to a limited extent, but specifications and procurement should be on an expendable basis.

NETS

CARGO NETS

The cargo net is composed of nylon webbing woven diagonally in an open diamond pattern. The nets are used to secure cargo to the floor of the aircraft or to the consolidating pallets. They are equipped with metal hooks, delta rings or similar fastenings. The standard nets now in service are satisfactory for this purpose. An analysis of costs and weights for use in this study are presented in Appendix IV.

BARRIER NETS

Barrier nets are used in cargo aircraft to restrain cargo which may break loose and travel forward to the pilot's compartment in the event of a crash landing. Barrier nets reduce the strength required of the cargo nets and permit the use of a lighter cargo net with fewer tiedown devices.

The net is fabricated of nylon web straps sewn in a cobweb pattern, and end straps with rings are provided to restrain it in the aircraft. The nets should be designed to fit a particular aircraft, with tiedown points located for maximum efficiency. Unfortunately, neither the AC-1 Caribou nor the HC-1 Chinook have tiedown points located above floor level for restraining the upper portion of the net. Installation of tiedown points in these aircraft would require serious modification to the structural members, and this would be impractical.

Figure 34 illustrates a method of barrier net installation using only the tiedown points available in the floor. Shock cord of sufficient capacity is strung in the aircraft between the net tiedown straps and the floor tiedown points. These cords are tied to the side of the aircraft with light lines.

In use, as the load moves forward, it engages the net. The light tie lines break, directing the load from the net to the tiedown points. The shock cord stretches, absorbing some of the load, and when taut, completely stops the load.

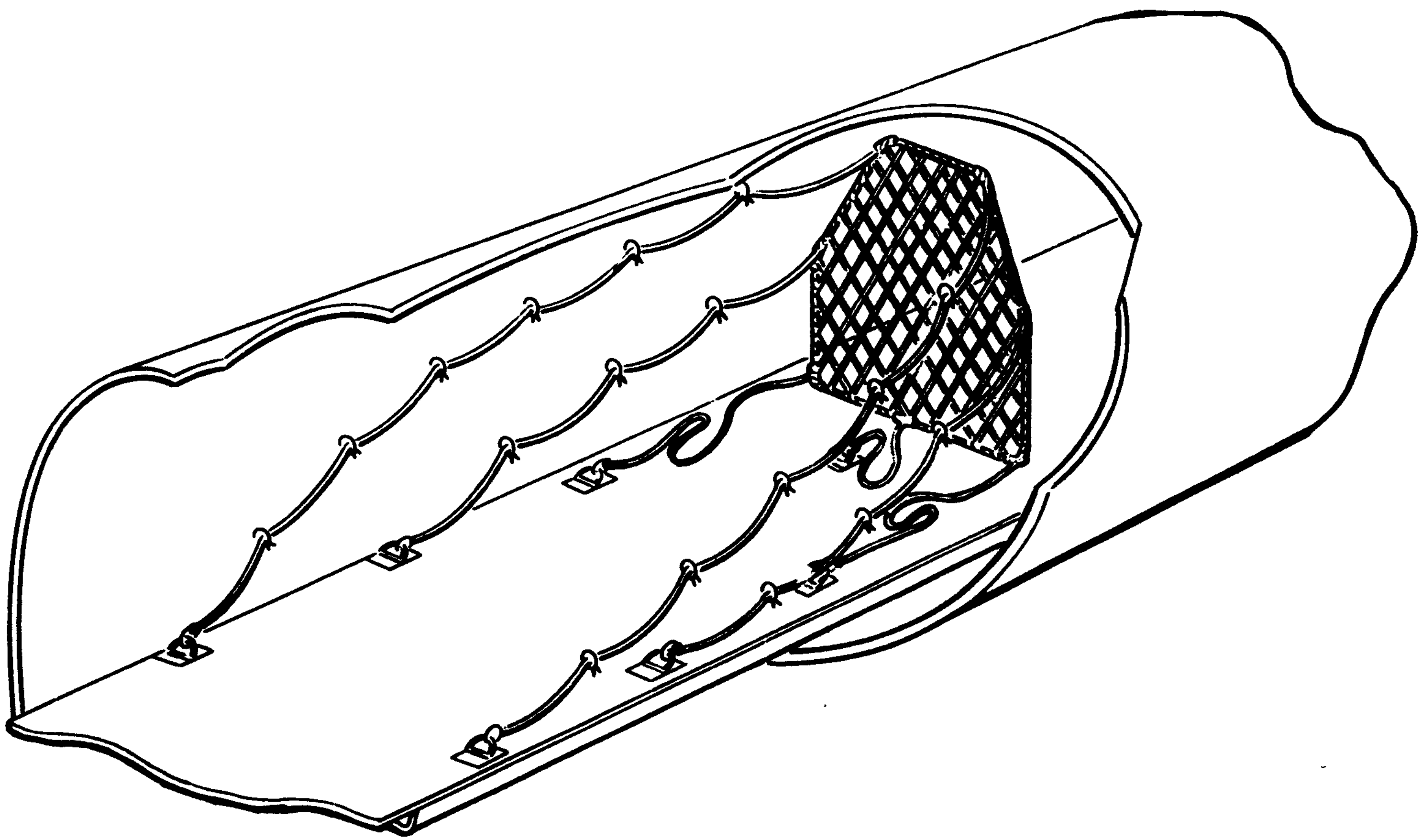
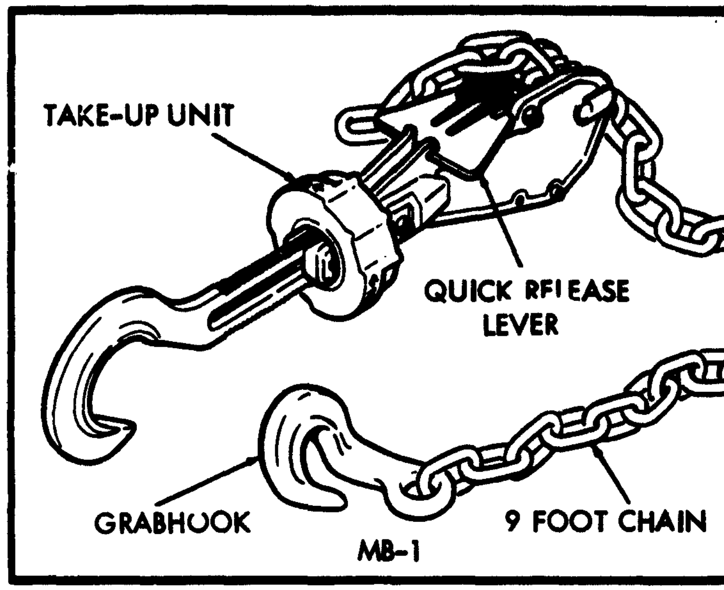


Figure 34. Barrier Net Installation

TIEDOWN DEVICES

Two tiedown devices, the MC-1 and MB-1, standard equipment in the AC-1 Caribou aircraft, were investigated. The device MC-1 as shown in Figure 35 consists of a webbing strap with two metal hooks, one stationary and one movable. The movable hook has a pretension lever which enables final tensioning of the strap. In use, the stationary hook on the end of the strap is hooked to a tiedown fitting. The strap is then passed over the load, and the movable hook is inserted in another tiedown fitting. The strap is tightened by pulling its free end through the movable hook, which automatically locks in place. Final tensioning is done by closing the pretension lever, which engages with a spring loaded retainer bar. To remove the device, tension on the strap is released by moving the spring-loaded restrainer bar against the spring and then raising the pretension lever. The device MC-1 has an ultimate strength of 5000 pounds.

Device MB-1 consists of a 9-foot steel chain with a grab hook attached to one end. The other end of the chain passes through a hooked device which locks the chain when in tension. A quick-release lever makes it possible to detach the two components instantly, regardless of the tension on the chain. A takeup unit allows final tensioning of the chain. In use, the grab-hook end of the chain is passed around part of the load and the hook is engaged with a link of the chain. The hook of the device is then engaged with a tiedown fitting. The MB-1 device has an ultimate strength of 10,000 pounds.



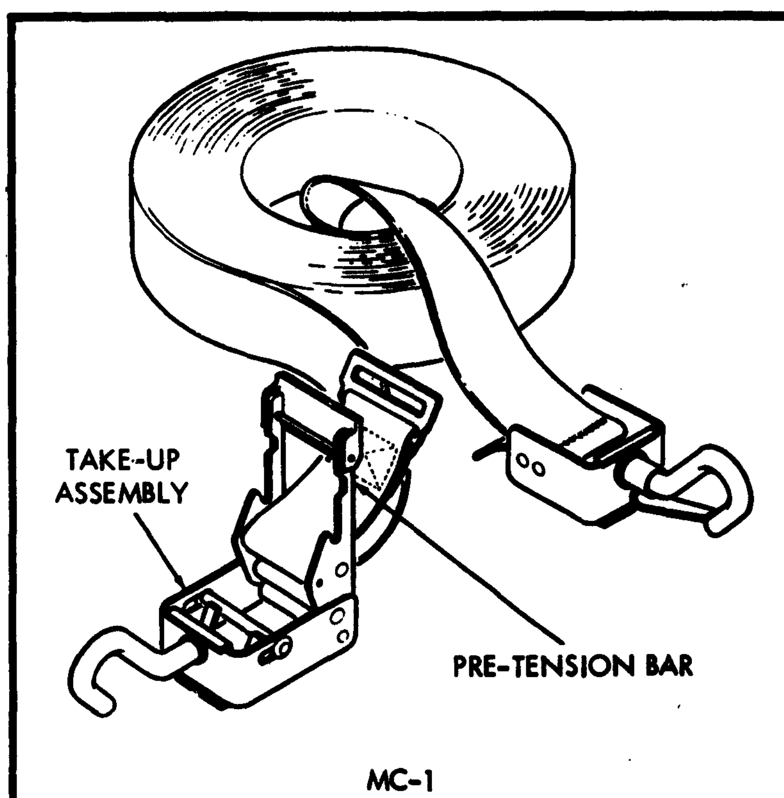


Figure 35. Tiedown Devices

SECTION 9. SYSTEM CONCEPTS

INTRODUCTION

When seeking improved concepts and systems, it is useful to compare new concepts with the existing systems. In this regard, the study has been expanded to cover operational modes as they exist today and modes that could be implemented in a short time with minimum development for comparison with the simple ultimate system. Whereas the ultimate system is envisioned to encompass consolidated cargo loading, present concepts embody a substantial amount of manual bulk loading. The present trend toward palletized cargo necessitates the use of mechanical material-handling equipment, as would an ultimate system, but an air logistic system could be quickly implemented ~~with off-the-shelf~~ equipment to handle pallet loads of 3000 to 4000 pounds or less.

CONCEPT DESCRIPTION

Four major concepts have been developed during this study. The essential characteristics of the four concepts are as follows:

Concept I — Manual loading and unloading at all terminals of small packages and the use of conventional tiedown and restraint of cargo.

Concept II — Forklift loading and unloading of 1000- to 3000-pound palletized modules at all air terminals and the use of conventional tiedown and restraint of cargo. Interior aircraft movement of the cargo is on roller conveyors.

- II-A Use of an 8-g cargo net
- II-B Use of a 2-g cargo net with an 8-g carrier-installed barrier net.

Concept III		Gravity conveyor loading and unloading of 6000- to 7000-pound consolidated loads at all terminals. The cargo is consolidated for 2-g flight loads prior to loading aboard the carrier. An 8-g barrier net is installed in the aircraft.
	III-A	Gravity roller conveyor system installed on carrier floor and ramp for cargo movement within the carrier. Conventional tiedown devices and techniques utilized to restrain cargo. Special purpose vehicles required at all terminals for loading and unloading.
	III-B	Similar to III-A with the exception that special purpose cargo handling vehicles are not required at the airhead. Additional roller conveyor sections required to bridge along the ground then to standard Army vehicle at the airhead. The additional conveyor sections are carried in aircraft at all times.
Concept IV		Channel rails used for loading and unloading of 6000- to 7000-pound consolidated loads on the mobile pallet. The cargo is consolidated for 2-g flight loads prior to loading aboard the carrier. An 8.0-g barrier net is installed in the aircraft. Quick-locking pallet restraint mechanism use is assumed.
	IV-A	Cargo loaders available to load and unload at all terminals. The loader envisioned has the capability of mating directly to the cargo floor or ramps of the aircraft.
	IV-B	Cargo loaders available at the Joint and Army airfields only. Unloading of the customer's vehicle at the airhead will be accomplished by bridging devices and winches.
	IV-C	Same as "B" except that the Telefork 62, rough terrain forklift truck, is substituted for the cargo loader. The cargo is placed on and picked up from the ground rails.

Concept IV-D This mode employs no lift trucks or cargo loaders but assumes that loading and unloading is accomplished entirely with bridging devices and winched to and from the transport vehicles.

The total bridging assembly applicable to this analysis is shown in Figure 30.

SYSTEM CONCEPT I - MANUALLY LOADED BULK CARGO

In order to establish a basis for comparison, this operational mode of manually loading small modules of cargo has been included in the evaluation. It has been assumed that no material handling equipment will be available for loading or unloading. Personnel will be provided to move cargo prepositioned on the ground 50 feet from the aircraft for loading and a transport vehicle will be positioned adjacent to the carrier at a distance of approximately 10 feet for unloading. Transport vehicles, 3-ton capacity, will be provided to move cargo to and from the Joint and Army airfields. Personnel for loading, transport drivers, and vehicles at the Joint and Army airfields will comprise the ground support for this concept. No personnel or vehicles are provided at the airhead.

SYSTEM CONCEPT II - PALLETIZED CARGO LOADS

Concept II represents an operational mode that could be implemented on very short notice with off-the-shelf equipment and vehicles. The air carriers are merely equipped with wheel or roller conveyor assemblies to permit easy movement of 1000-to 3000-pound palletized cargo modules within the carrier. In addition, conventional rough terrain forklift trucks are provided to handle the palletized cargo. Although the forklift trucks are not specified in this study, two candidates can be identified. The Sandpiper (see Appendix I) under development by the Quartermaster Corps is an excellent candidate but could only be carried externally on the HC-1 Chinook. The ART-30 (see Appendix I), a Marine Corps development, built essentially of M38-A 1 (Jeep) components, is also an attractive candidate. The ART-30 can be transported internally or externally in the HC-1 Chinook. The Quartermaster Corps Telefork series lift trucks are too large to load pallets directly onto the cargo floor of the AC-1 Caribou or HC-1 Chinook.

The evaluation of Concept II includes forklift trucks at all terminals, including the airheads. Terminal personnel and transport vehicles are provisioned as in Concept I. No personnel other than forklift truck drivers are provisioned at the airhead. Tiedown and restraint of cargo is accomplished with conventional nylon-web nets and tensioning devices to the floor of carrier. The following variations of Concept II are evaluated to show the effect on system cost.

II-A Use of an 8-g net and tiedown procedure in restraint of cargo.

II-B An 8-g barrier net installed aft of the pilot's compartment for protection of crew and 2-g cargo net and tiedown procedure.

Concept No. II encompasses several techniques for handling unit loads with the very minimum of extraneous equipment based upon the combined use of barrier nets, lightweight roller conveyors, and the simple pallet support plates.

SYSTEM CONCEPT III - CONSOLIDATED CARGO LOAD (ROLLER CONVEYOR)

Concept III utilizes the consolidating pallet (Figure 23) which is assumed to be consolidated with a full carrier load prior to the arrival of the carrier in the supply area. The consolidation of the cargo on the pallet is accomplished with standard nets and devices to withstand 2-g flight loads. The consolidating pallet is restrained within the carrier by conventional tiedown devices. Loading and unloading of the pallet is accomplished over roller conveyor assemblies installed on the carrier ramps and floors.

The carrier installed roller conveyor assemblies are of a conventional nature with the following exception: roller spacing on the ramp is 2-1/2 inches and roller capacity is 400 pounds to withstand concentrated loads imposed by the ends of the pallet when bridging from the ground or a vehicle to the inclined ramp. Teetering bridging devices are used at the junction of the aircraft ramp and carrier floor.

Concept III is divided into two operational modes as follows:

III-A Special purpose vehicles are provisioned at all terminals, including the airheads, to perform the function of loading and unloading directly from the carrier floor or ramp.

III-B Special purpose vehicles are provisioned at the Joint and Army airfields only. Unloading onto the Army vehicle at the airhead is accomplished with bridging conveyor sections to the ground, thence to the vehicle. These additional bridging sections are assumed to be permanently assigned and carried by the aircraft at all times. The use of a winch on the Army vehicle to pull the load out of the carrier and on to the vehicle is also assumed.

Personnel are provided for loading, unloading, cargo restraining and release, and vehicle drivers are provided at the Joint and Army airfields. Special purpose loaders and drivers are provided at the airhead for Concept III-A only. Sufficient pallets are provided for Concept III to permit trading a loaded for an unloaded pallet at all terminals, including the airheads.

SYSTEM CONCEPT IV - CONSOLIDATED CARGO LOAD (MOBILE PALLET)

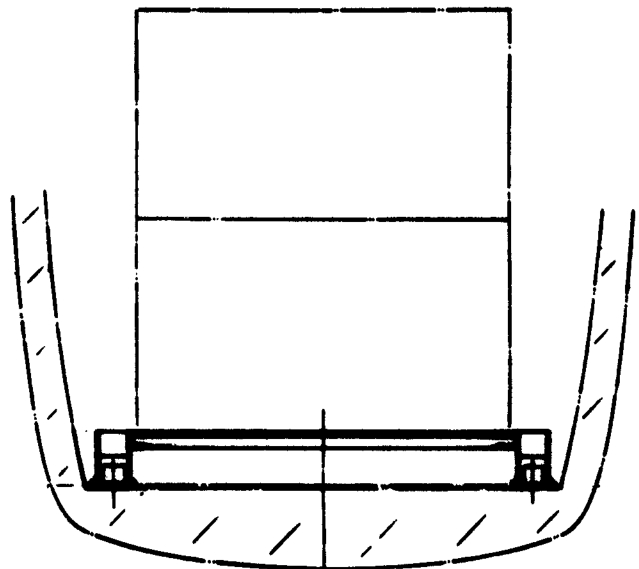
Concept IV utilizes the mobile pallet (Figure 26) consolidated in the supply area. As in Concept III, consolidating nets and pallets and sufficient spares are provided throughout the system to maintain a continuous cargo flow. Also, personnel and vehicles are provided at the Joint and Army airfields to accomplish all loading and unloading operations. Concept IV differs from Concept III primarily in the manner in which the pallet is given mobility. Concept IV embodies a pallet with an attached rolling assembly. The rolling assembly, consisting of endless chain roller devices, utilizes channel rails for load distribution which also provides a quick, convenient, simple, and lightweight means of cargo restraint. The mobile pallet requires no special equipment to bridge the angular discontinuities attendant on the inclined ramp.

The simplicity, reliability, flexibility, and safety of loading and unloading of the mobile pallet concept are outstanding. First, the mobile pallet running in a channel track section is under positive lateral control at all times as can be seen in Figure 36. By observing a single loading limitation only, that of not stacking STRAC containers ahead of the forward rolling assembly, the consolidated load cannot sweep or exceed its maximum loaded height dimension when entering or leaving the fuselage irrespective of the ramp angle. This limitation is not severe nor difficult to accommodate. Seven STRAC containers can be loaded easily within this limitation -- the second tier of three STRAC's must not come nearer than 26 inches to the front edge of the mobile pallet. As a result of the dimensions and geometry of the two carriers and position of the rolling assembly on the mobile pallet, the aft end of the mobile pallet can accommodate the double stacked STRAC containers without threat of damage to the aft fuselage section as the load rotates upward to the floor plane.

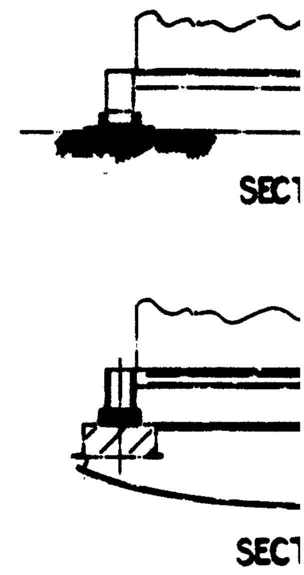
Although the mobile pallet requires a rather appreciable total height to traverse the various angles attendant on the carriers of this study, the manner and consistency in which it rotates and its insensitivity to c.g. position will permit safe loading with extremely close tolerances. For the purpose of this study the pallet design parameters as taken from Figure 27 are for a 2-inch pallet to traverse a 16-degree ramp angle. Since Figure 27 specified design parameters for a sharp ended pallet, the thickness is arbitrarily increased to approximately 2-1/2 inches to provide structure for tiedown at the end of the pallet. This pallet thus has a total height of approximately 8 inches. Adding to the pallet height a quarter of an inch for track thickness, the mobile pallet assembly consumes approximately 8-1/4 inches of the available clearance at the empennage and in the fuselage.

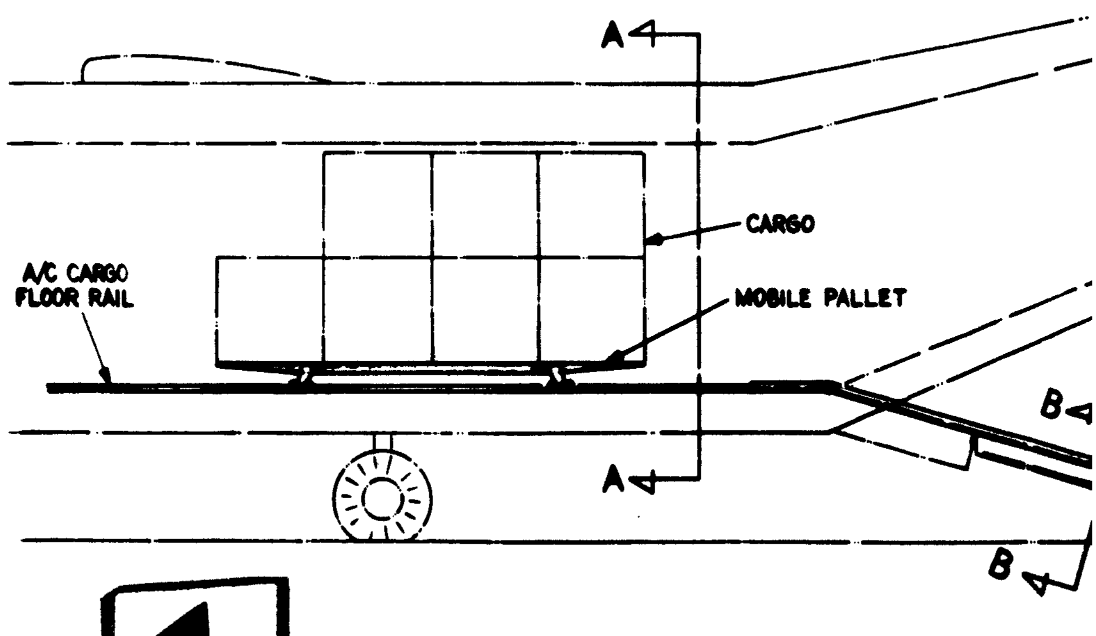
Where the roller conveyor system was assumed to occupy 71 inches of vertical height for a stacked STRAC load, the mobile pallet occupies 74-1/4 inches of vertical height. This leaves approximately three quarters of an inch clearance for the stacked load in the Caribou. Again, because of the positive and consistent action of the mobile pallet with its load, three quarters of an inch overhead clearance is considered adequate.

A loading summary for the mobile pallet is presented in Figure 37. The loading clearances of the mobile pallet versus truckbed height have the same characteristics as the roller conveyor system except for steep, down-ramp angles. The mobile pallet does not lose loading clearance when entering or leaving the cargo compartment if a single STRAC container is deleted from the second tier at the front of the



SECTION A-A





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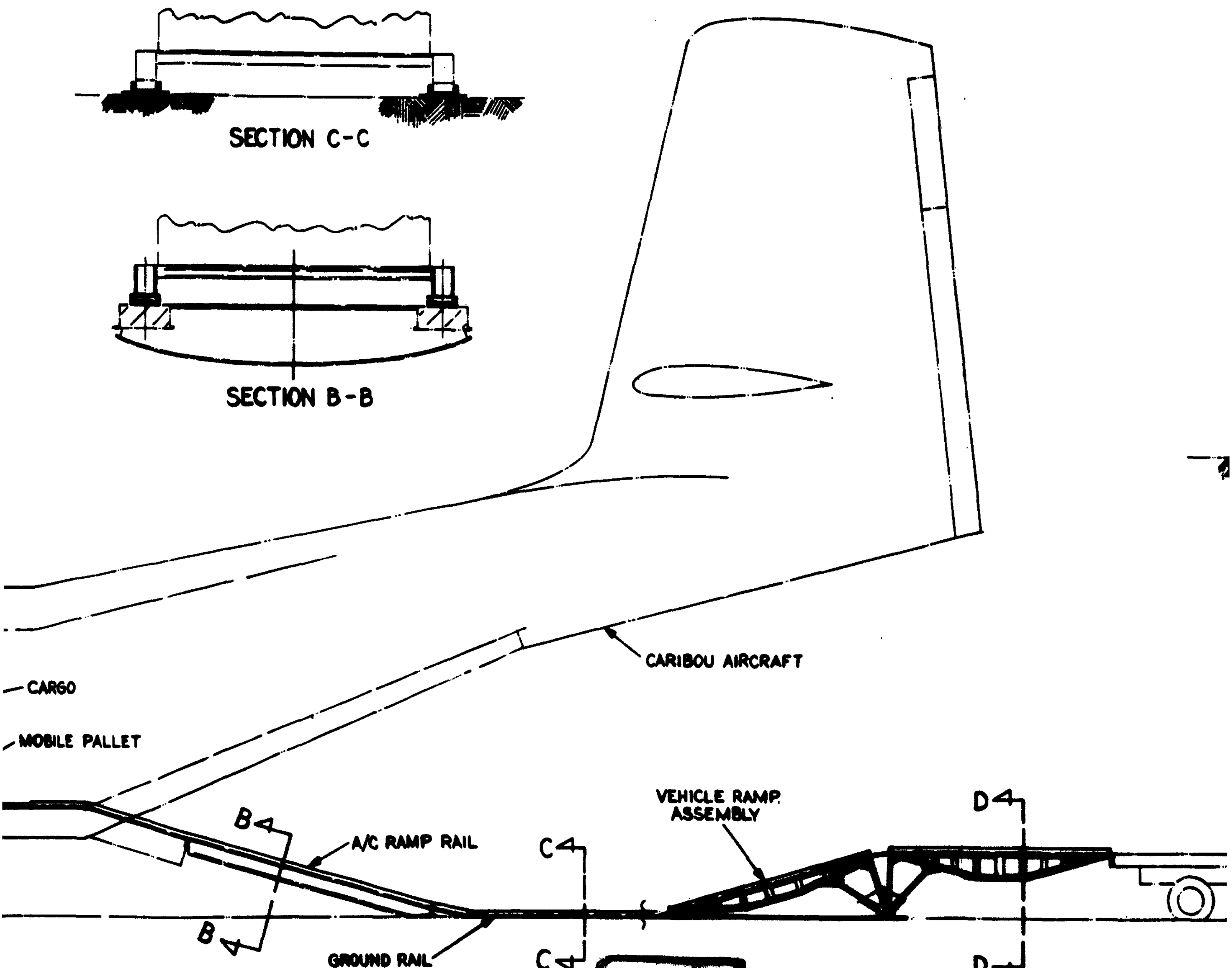


Figure 36. Concept IV Co

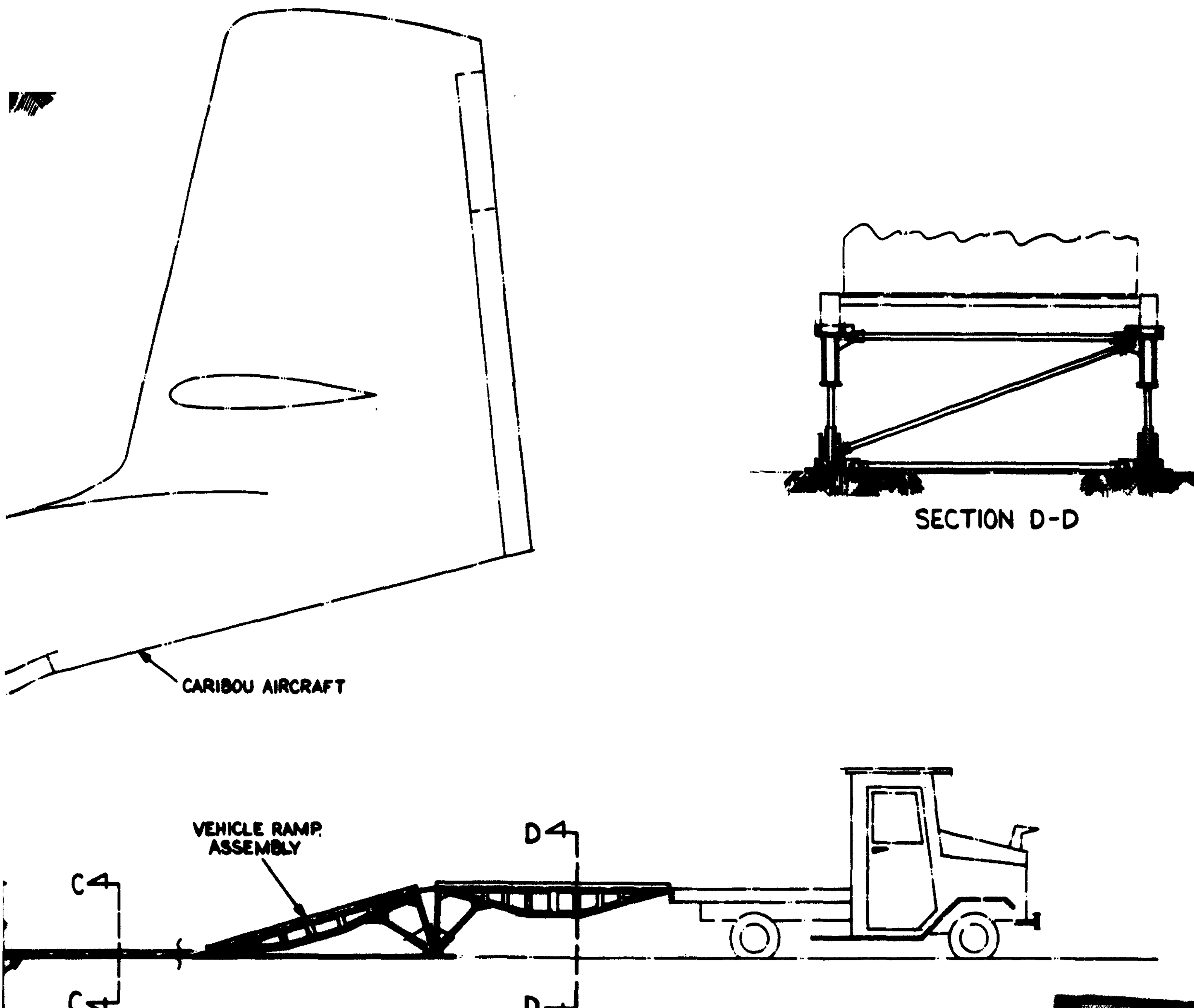


Figure 36. Concept IV Configuration

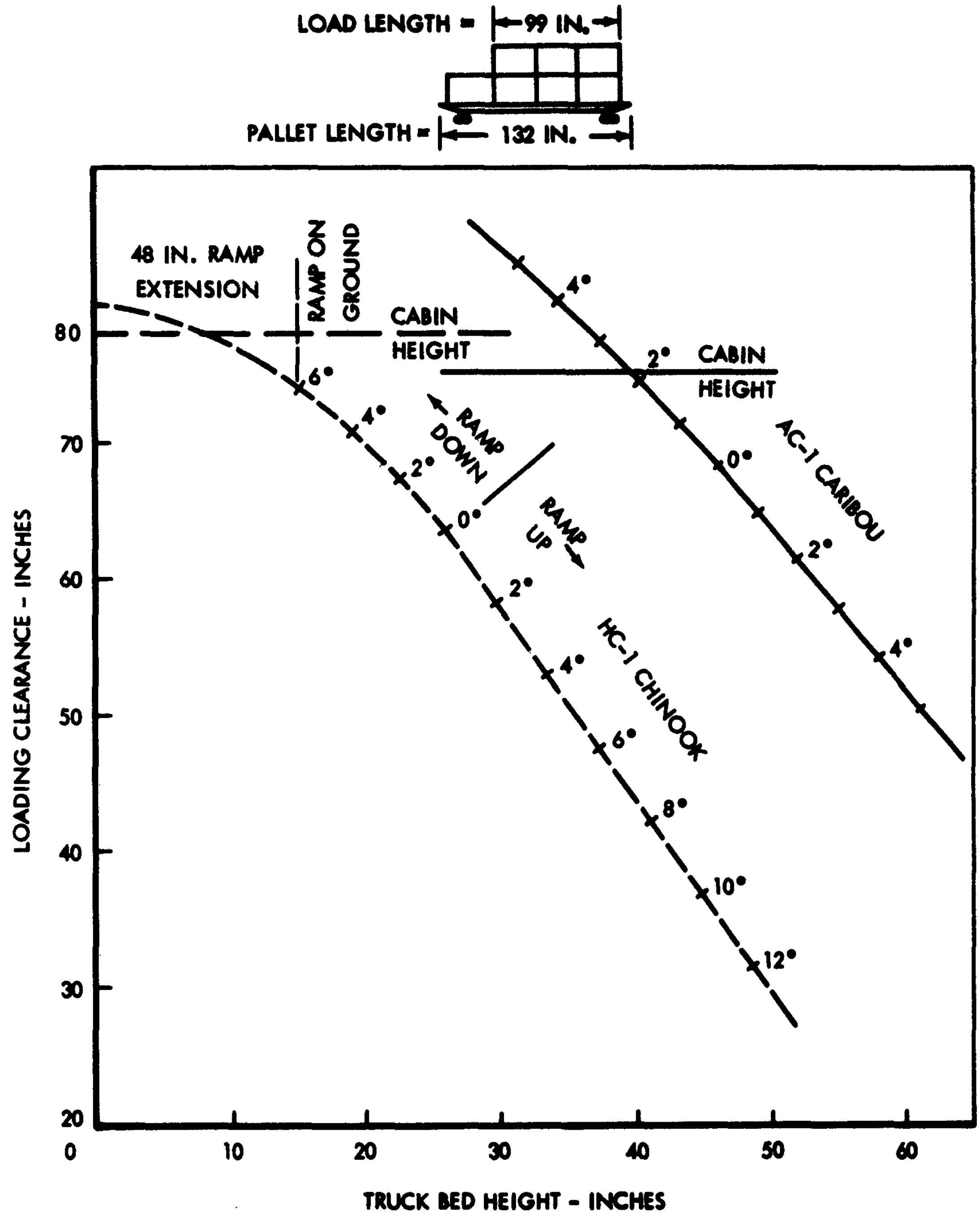


Figure 37. Mobile Pallet Loading Summary

pallet. Thus, Figure 37 shows that the mobile pallet can on- or off-load a Caribou with a unit of 7 STRAC containers to platforms of 39 inches high down to ground level and 3 QM pallet loads from 51 inches down to ground level. Similarly, the mobile pallet can on- or off-load the Chinook of a STRAC load from 13 inches to ground level and a QM load from 27 inches to ground level.

In addition, it should be noted that the rolling assembly and the track in which the pallets move are located outside (width-wise) the pallet and its load. This feature permits retrieval of the tracks after the pallet is unloaded.

Concept IV is divided into four operational modes as follows:

IV-A Universal cargo loaders are provided at all terminals for loading and unloading, directly from the carrier ramp or floor. One loader and driver are provided at each airhead. The loaders are equipped with rails to guide the mobile pallet, as well as a winch for movement.

IV-B In mode B, the loading and unloading operations at the Joint and Army airfields are identical with those of mode A. Universal cargo loaders are provided at the Joint and Army airfields only. The carriers are provided with additional channel rail sections, a section to bridge 96 inches along the ground and 200 inches upward to a vehicle. No personnel or equipment are allocated to the airhead. It is assumed that the Army will provide its own transport vehicle equipped with winch to pull the unit pallet load onto its transporter. Concept IV could do with fewer pallets in the system than Concept III because of a kneeling feature included in the pallet concept but for comparison purposes this feature was not utilized in the cost analysis. The ability to retract the wheels on one end of the pallet allows the pallet to be drawn easily from under the load and the pallet to be retained with the carrier. It is assumed that 20 percent of the unloadings at the airhead will, as a result of various circumstances, necessitate temporary abandonment of the pallet.

Concept IV-C Mode C employs the same unloading procedure at an airhead as in "B". However, the Telefork 62 forklift truck is employed at the Joint and Army airfields.

This mode assumes use of the ramp extension and ground rails since the Telefork 62 cannot handle a consolidated (6000- to 7000-pound) pallet lengthwise for load insertion. The Telefork 62 must engage the pallet (5 by 11 feet) from the side and place it in the ground rails extending aft from the carrier to be winched aboard. This concept is not limited to the Telefork 62 but only to those forklift trucks with the load capability.

IV-D In this mode, it is assumed that no material handling vehicles are used or available to handle the consolidating loads. All loading and unloading operations at all terminals are accomplished over the ground rails and ramp sections between the air carrier and a conventional surface transport vehicle.

Mode D requires loading teams be provided at the Joint and Army airfields. At the airhead, the customer is assumed to provide the required personnel to accomplish unloading.

In all the concepts described, the pilot and/or copilot should be relieved of any loading responsibility at the Joint and Army airfields in order that they may concern themselves with flight planning and aircraft maintenance. At the airhead environment, when using customer personnel, it would appear desirable for either the pilot or copilot to oversee the operations in the interests of both expediency and safety to the aircraft.

SECTION 10. CONCEPT EVALUATION

INTRODUCTION

The four basic concepts were evaluated to determine the total system requirements in terms of men, material, and carriers to accomplish the logistic mission postulated in the Resupply Model, Section 7 (page 41). The study also included the determination of the effects of time to accomplish the logistic mission on system requirements and cost.

The operational model employed in the evaluation observed the following considerations and constraints:

1. All air cargo (100-tons) originating at the Joint airfield, is moved 3000 feet from the supply area via surface transport to the airstrip. It is assumed that the incoming cargo, by Air Force carriers, is landed on or near the strip being utilized by the Army carriers so that the surface transports included in this evaluation could move the incoming cargo to the Army supply area. No equipment has been included in this study to off-load the Air Force carriers or load the Army surface transporters at the Air Force's unloading position. No cost assessments are made for material-handling equipment or personnel in the supply area.

2. All cargo arriving at the Army airfield is moved 3000 feet via surface transport to a supply and makeup area. All cargo moving forward from the Army airfield is again moved 3000 feet to the airstrip via surface transport for loading aboard the carrier.

3. All concepts except Concept I provide equipment for loading the customer's vehicle at the airhead. Concept I assumes that the customer provides personnel to off-load the carrier and load his own vehicles. Concepts III-B and IV-B provide bridging devices and use of a winch on the Army's vehicles to move the consolidated pallet on to the vehicle; otherwise the load is deposited on the ground. Concepts III-A and

IV-A provide special-purpose vehicles to load the vehicle at the airhead. The provision of special-purpose vehicles at the airheads appears to be extravagant because of the infrequent arrivals of cargo carriers at the airheads. However, the advent of 6000- to 7000-pound consolidated cargo loads could pose a serious handling problem without the special-purpose vehicles. The infrequent arrival rate at the airhead would allow the special-purpose vehicle to perform a limited transport service, thus reducing the personnel and vehicular requirements at the FEBA.

4. The evaluation herein includes the personnel and equipment required for loading and unloading Army carriers at both the Joint and Army airfield. Also included are the transport vehicles and drivers required between the airstrip and supply or makeup area. Vehicles for loading or unloading and drivers only are provided at the airhead. Equipment and personnel required to load the transporters in the supply area are not included in this study. It is assumed that existing organizations will continue to provide the necessary services of packaging, unitization, documentation, cargo makeup, and loading within the supply areas.

5. Transport vehicles travel at an average velocity of 20 miles per hour. Details as to number of personnel per loading and unloading station, carrier-installed equipment weight and cost, vehicle cost and capabilities, etc., are either presented in this section or appear in Appendices I and IV.

6. Where the major portion of cargo in a leg of the resupply model is transported by one type of aircraft, this aircraft is considered to carry all of the cargo in that leg. This assigns the task of cargo transport between the Joint airfield and Army airfield and the Joint airfield and airhead to the AC-1 Caribou. The HC-1 Chinook is assumed to carry all the cargo from the Army airfield to the airhead.

EFFECTIVENESS EVALUATION

In this discussion, the effectiveness of the concepts developed to accomplish the resupply mission are compared. The effectiveness criteria used is essentially productivity in tons per hour. The evaluation of productivity assumes each carrier at constant takeoff gross weight, thus ignoring maximum cargo or maximum landing weight cut-offs on the cargo-radius curves (See Figure 38). Productivity in tons per hour can be written:

$$\text{Tons per hour} = \frac{\text{Cargo (tons)}}{\text{Cycle time (hours)}} \tag{10}$$

The cargo that can be carried is a function of both radius and payload lost to installed system weight. The cycle time must include flight time, takeoff and landing time, ground maneuvering and taxi time, loading time, unloading time, and time spent waiting to be loaded or unloaded. In order to simplify the analysis, it is convenient to group those flight activities which are generally invariable and consume time over and above that computed from cruise velocity as maneuver time, t_m, thus:

	Time (Seconds)	
	AC-1 Caribou	HC-1 Chinook
(1) Locate landing area, turn and maneuver for landing interval	20	20
(2) Decelerate from cruise speed to approach speed	40	40
(3) Landing ground run or time to decelerate from approach speed to zero speed	15	15
(4) Time to taxi 1000 feet at 20 feet/sec	50	0
(5) Time to take off or attain climb-out speed	15	15
(6) Time to accelerate from climb-out speed to cruise speed	40	40
Total time per terminal — sec	180	130
Total time per cycle — min	6	4.33
Total time per cycle — hours	0.1	0.072

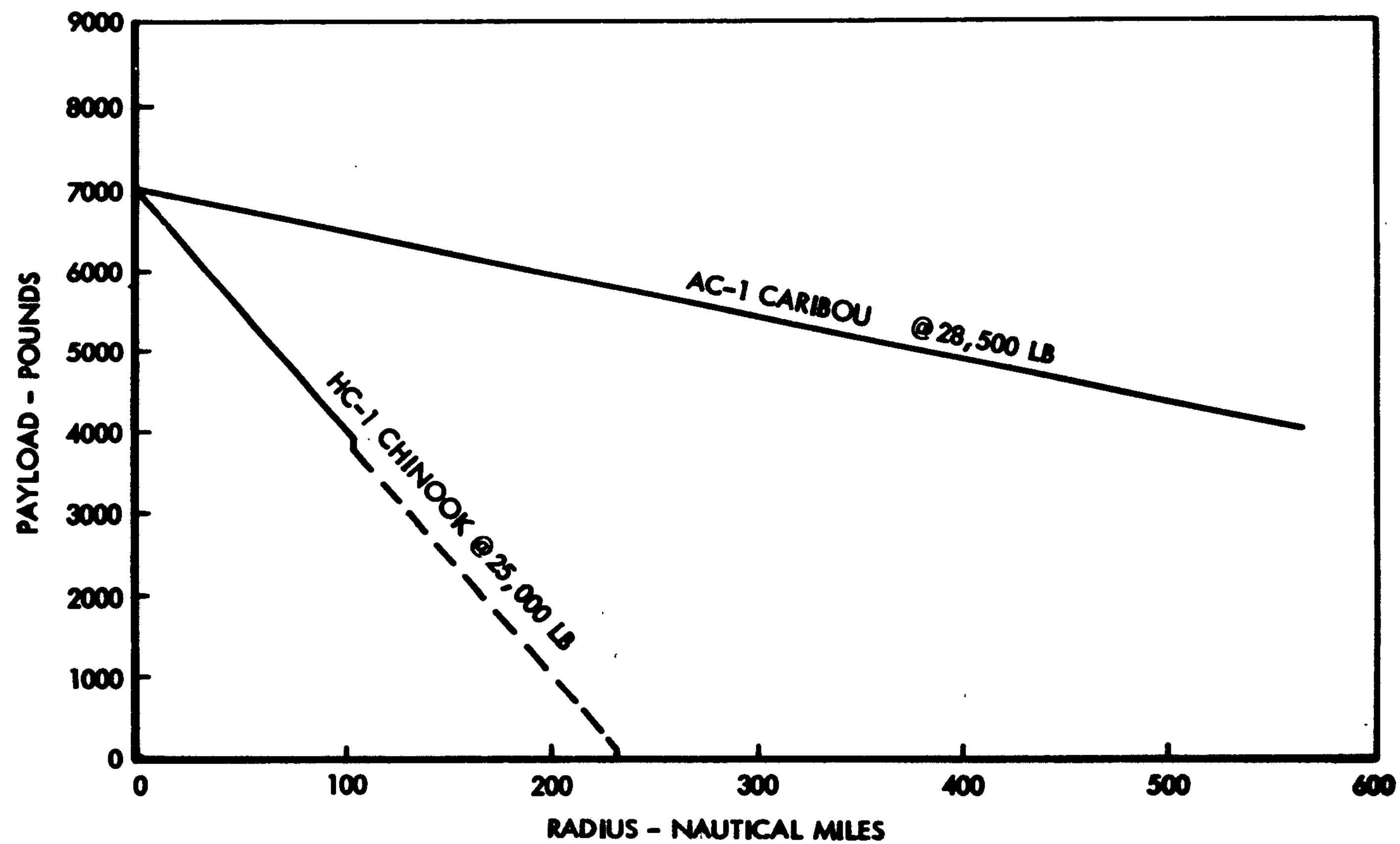


Figure 38. Payload Versus Radius Performance

Expressions for productivity of the two carriers at a cruise velocity of 130 knots are:

$$\text{(Tons/hour) AC-1 Caribou} = \frac{8000 - 7R - W_T}{\left(\frac{2R}{130} + 0.1 + \frac{\ell + u + w}{60}\right) 2000} \quad (11)$$

$$\text{(Tons/hour) HC-1 Chinook} = \frac{8000 - 33R - W_T}{\left(\frac{2R}{130} + 0.072 + \frac{\ell + u + w}{60}\right) 2000} \quad (12)$$

where

R = Radius in nautical miles

W_T = Tare weight of carrier installed equipment (pounds)

ℓ = Loading time (minutes)

u = Unloading time (minutes)

w = Waiting time (minutes)

Tare weight of installed equipment and loading and unloading times have been determined in Appendix IV and are presented in Table 3 for the nine operational modes. Productivity of the nine modes as determined from Equations (11) and (12), with zero waiting time, is presented in Figures 39 and 40 for the AC-1 Caribou and HC-1 Chinook.

Although productivity as presented in Figures 39 and 40 provides a convenient comparison of the various operational modes, it reveals little in the way of ground support facilities required to attain a given productivity. An operational mode that is capable of high productivity will fall far short of its capability if excessive time is spent waiting to be loaded or unloaded as a result of inadequate ground service facilities. The determination of waiting time involves consideration of arrival rate, service rate, and the number of service stations at a given terminal. However, arrival rate is in turn a

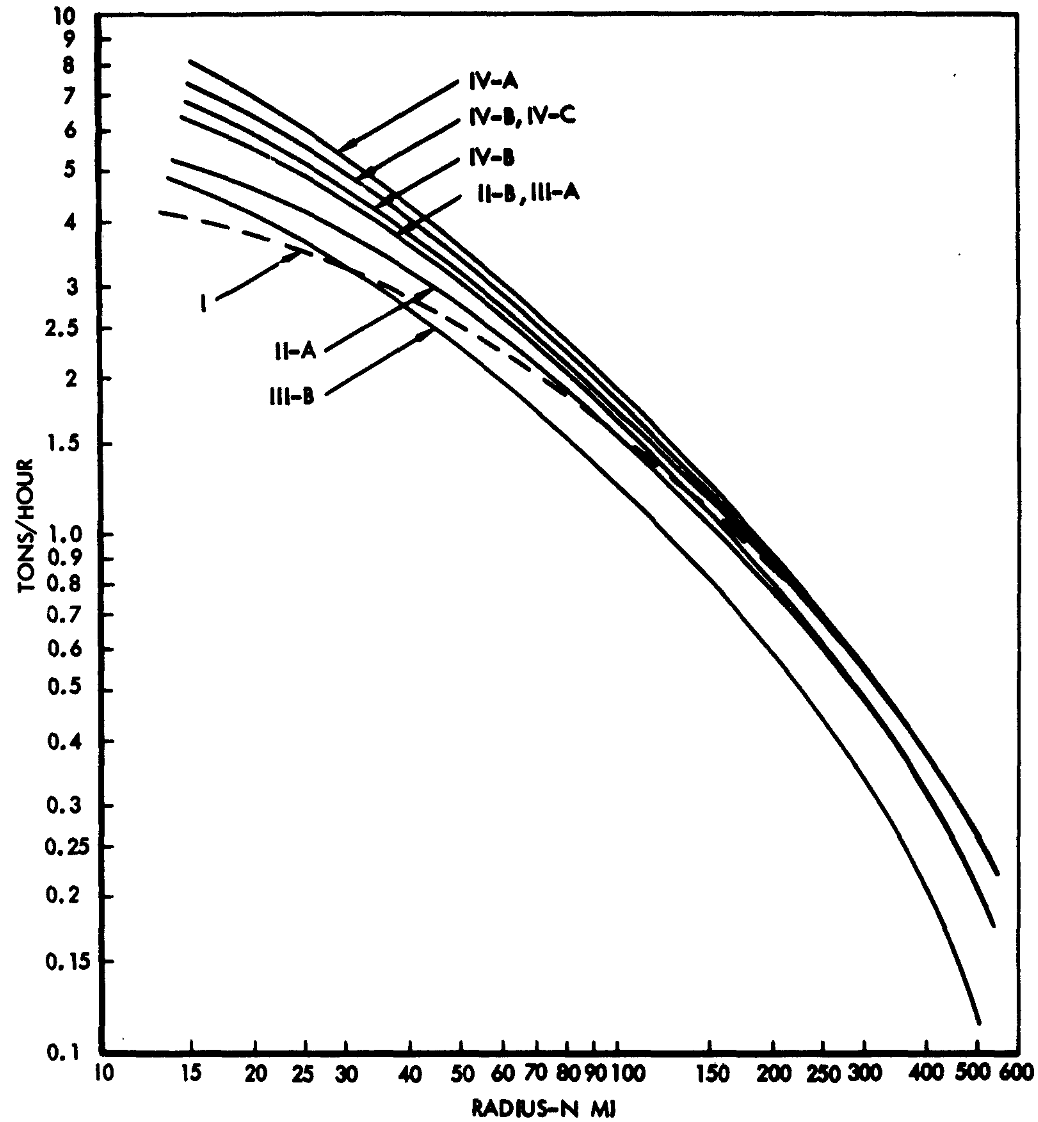


Figure 39. AC-1 Caribou Productivity - Zero Waiting Time

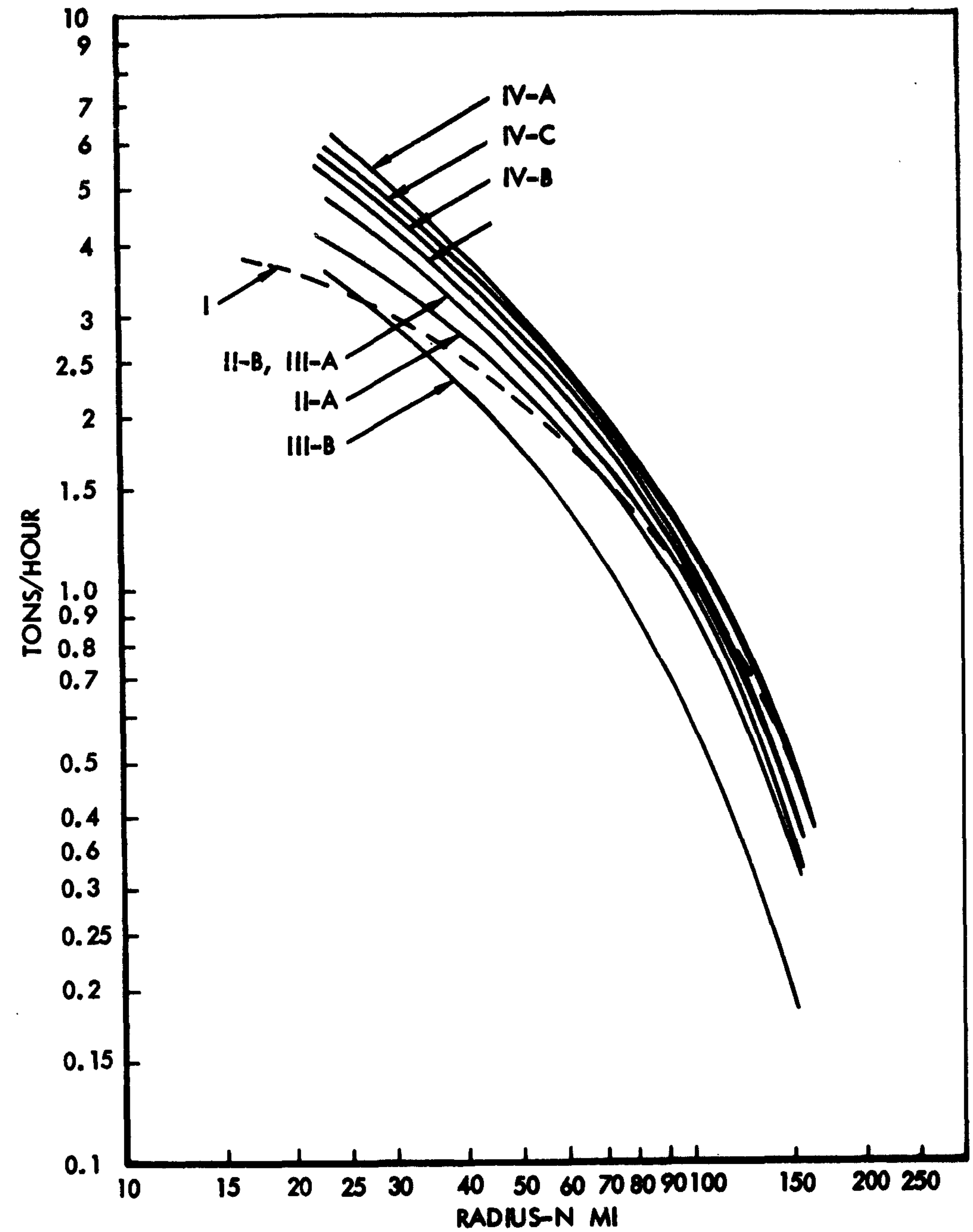


Figure 40. HC-1 Chinook Productivity - Zero Waiting Time

TABLE 3
CARRIER TARE WEIGHTS, LOADING AND UNLOADING TIMES
FOR VARIOUS OPERATIONAL CONCEPTS

		Palletized Cargo		Consolidated Cargo					
	Bulk Cargo	8-g Tiedown	8-g Barrier 2-g Tiedown	Roller Conveyor		Mobile Pallet — Rails and Ramps			
Operational Mode	I	II-A	II-B	III-A	III-B	IV-A	IV-B	IV-C	IV-D
Loading Time (min) Joint A/F / Army A/F	27.2	12.0	8.0	4.5	4.5	3.1	3.1	3.0	5.5
Unloading Time (min) Army A/F	9.3	6.75	3.75	5.0	5.0	3.5	3.5	3.4	5.5
Unloading Time (min) Air Head					9.0		5.5	5.5	
Tare Weight (lb)									
Caribou	134	1191	1168	1318	2605	2056	3191	2191	3191
Chinook	134	1159	1136	1346	2633	2052	3187	2187	3187

function of waiting time as it contributes to the cycle time of a carrier between two terminals as follows:

$$t_{cyc} = \frac{2R}{130} + t_m + \ell + w_\ell + u + w_u \tag{13}$$

where

w_ℓ = waiting time to load

w_u = waiting time to unload

and

$$w = \frac{\bar{\ell}}{\lambda} = \frac{\mu(\lambda/\mu)^k}{(k-1)!\,(k\mu - \lambda)^2} P_O \tag{14}$$

where

$\bar{\ell}$ = average queue length

λ = arrival rate

μ = service rate (loading or unloading time)$^{-1}$

k = number of service stations

and P_O the probability that there are zero units in the system is

$$P_O = \frac{1}{\sum_{i=0}^{k-1} \frac{1}{i!}\left(\frac{\lambda}{\mu}\right)^i + \frac{1}{k!}\left(\frac{\lambda}{\mu}\right)^k \frac{k\mu}{k\mu - \lambda}} \tag{15}$$

The relationship derived in Appendix V of arrival rate and cycle time is:

$$\lambda_t = \frac{n-1}{t_t - t_{cyc}} \tag{16}$$

where

t_t = total time to complete the resupply mission

t_{cyc} = cycle time per leg

n = number of trips required per leg

and

$$n = \frac{2000C}{8000 - W_T - 7R} \tag{17}$$

where

C = total cargo to be moved through a leg (tons).

The total number of carriers per leg, N, is given by:

$$N = \frac{n - 1}{\frac{t_t}{t_{cyc}} - 1} = \lambda t_{cyc} \tag{18}$$

The total cargo flow, in tons, in the system from Figure 7 is:

Between Joint airfield and 9 airheads -- 36 tons

Between Joint airfield and 3 airfields -- 64 tons

Between 3 airfields and 9 airheads -- 45 tons

From Equation (17), the number of trips per leg is determined. Assuming a total mission time, t_t, and varying waiting time in Equation (13), arrival rate of Equation (16) is plotted as a function of waiting time for each leg in Figure 41. The total arrival rate at the Joint airfield is the summation of the arrival rate of carriers working between the Joint airfield and the Army airfield and between the Joint airfield and the airhead.

Superimposed on Figure 41 is the number of service stations that yield the waiting time on the abscissa for the arrival rate on the ordinate. This cross plot for service stations was determined from the relationship of Equation (14) and Figure 42. The determination of waiting

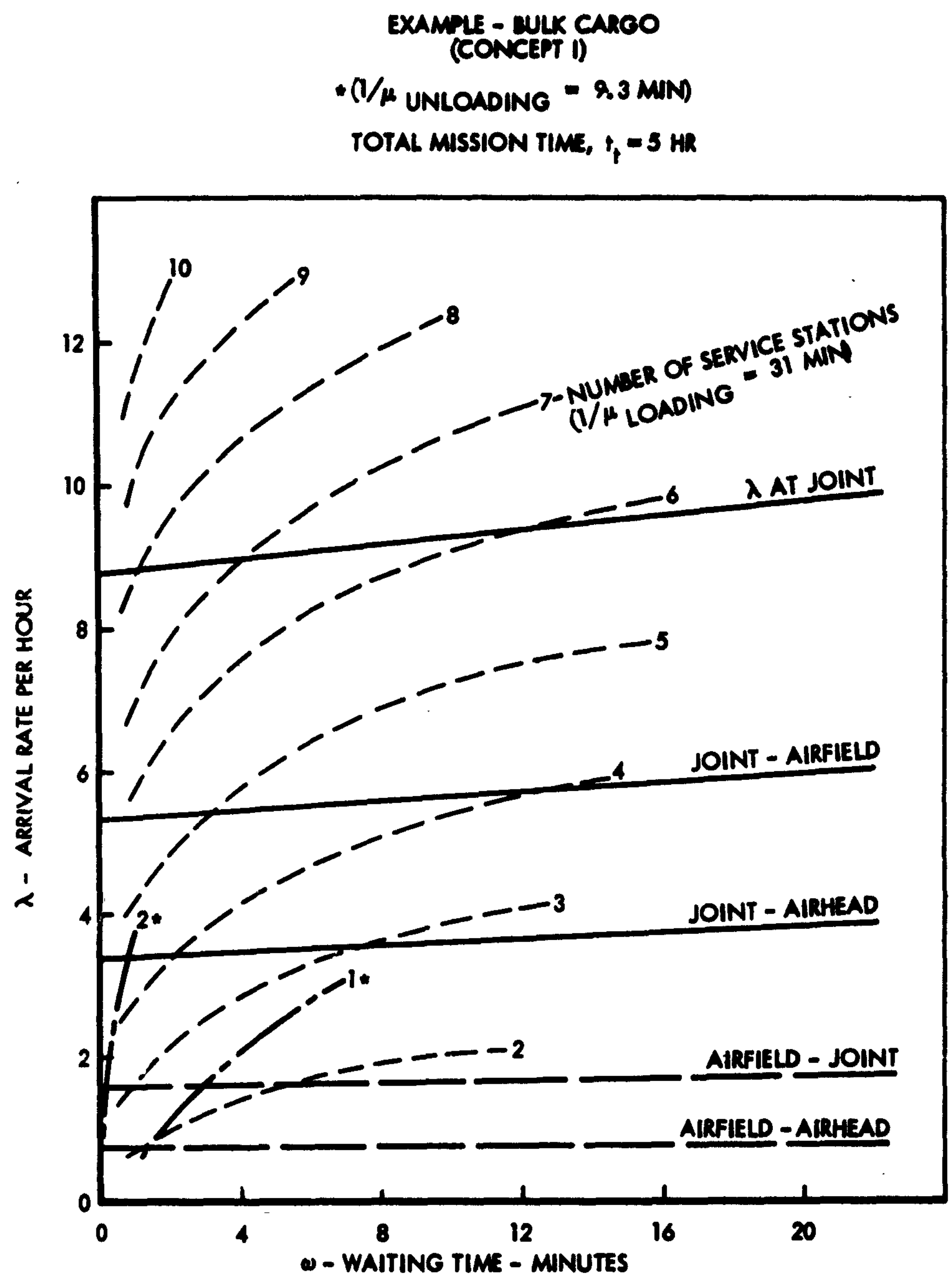


Figure 41. Waiting Time Determination

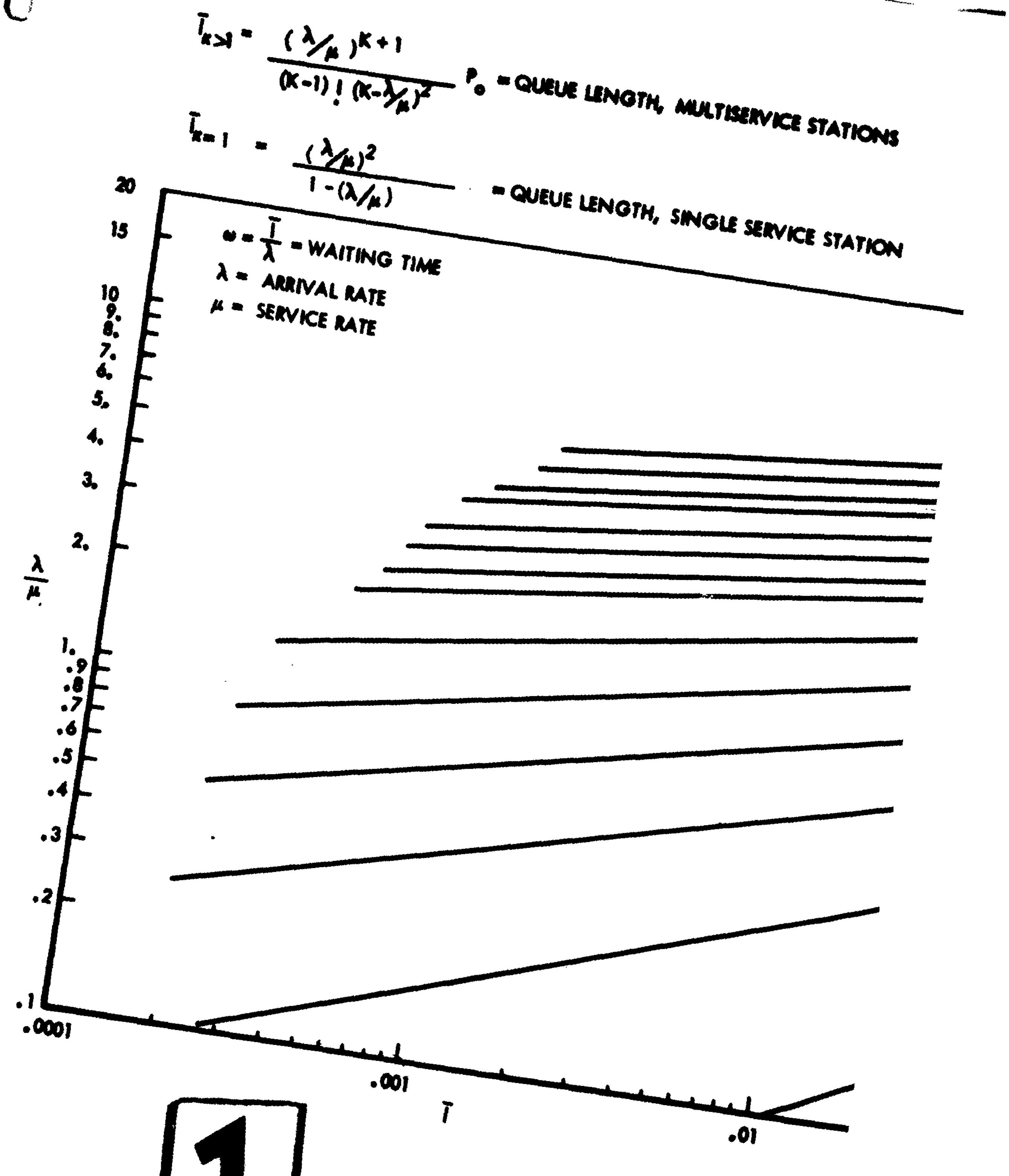
time, w, for the leg between the Joint and Army airfield can now be read directly from Figure 41. For example, seven loading stations at the Joint airfield result in 4 minutes of waiting per cycle and two unloading stations at the Army airfield result in 0.2 minute of waiting per cycle. An average of 4.2 minutes per cycle is thus spent waiting to load or unload in the cycle between the Joint airfield and the Army airfields.

Similarly, for the cycle between an Army airfield and three airheads, two loading stations result in 1 minute of waiting time. For the example shown, four service stations are required at each Army airfield. No waiting time will be assessed against airheads because of the low arrival rates.

A tradeoff exists between number of carriers, N, and number of service stations, K, as a function of waiting time, i.e., as waiting time increases, the number of required carriers increases, while the number of service stations decreases. There is obviously an optimum waiting time which results in a minimum system cost. Due to the complexity of the expression relating waiting time to required service stations, a closed form analytical solution cannot be obtained. Therefore, a value of waiting time was selected for the cost comparison which appeared to minimize the cost. This was done by plotting required carriers as a function of waiting time and selecting the "knee" of the curves.

COST ANALYSIS

Cost comparison of the various operational modes can be accomplished on the basis of initial procurement and annual operation and amortization. (See Appendix IV.) For a cost comparison, it would be convenient to estimate the cost on the basis of a 24-carrier company; however, the previous analysis has demonstrated that the various operational concepts manifest appreciably different capabilities. On the basis that the Army will procure carriers and equipment and establish organizations to attain a performance capability in terms of time, the cost comparison will follow the previous analysis and present costs of the system to accomplish the resupply mission as a function of time.


$\bar{l}_{K>1} = \frac{(\lambda/\mu)^{K+1}}{(K-1)!\,(K-\lambda/\mu)^2} P_0$ = QUEUE LENGTH, MULTISERVICE STATIONS
$\bar{l}_{K=1} = \frac{(\lambda/\mu)^2}{1-(\lambda/\mu)}$ = QUEUE LENGTH, SINGLE SERVICE STATION
$\omega = \frac{\bar{l}}{\lambda}$ = WAITING TIME
λ = ARRIVAL RATE
μ = SERVICE RATE
$\frac{\lambda}{\mu}$
20
15
10
9.
8.
7.
6.
5.
4.
3.
2.
1.
.9
.8
.7
.6
.5
.4
.3
.2
.1
.0001
.001
.01
$\bar{l}$

1

ERVICE STATIONS

LE SERVICE STATION

$$P_0 = \frac{1}{\left[\sum_{i=0}^{K-1} \frac{1}{i!}\left(\frac{\lambda}{\mu}\right)^i\right] + \frac{1}{K!}\left(\frac{\lambda}{\mu}\right)^K \frac{K\mu}{K\mu - \lambda}}$$

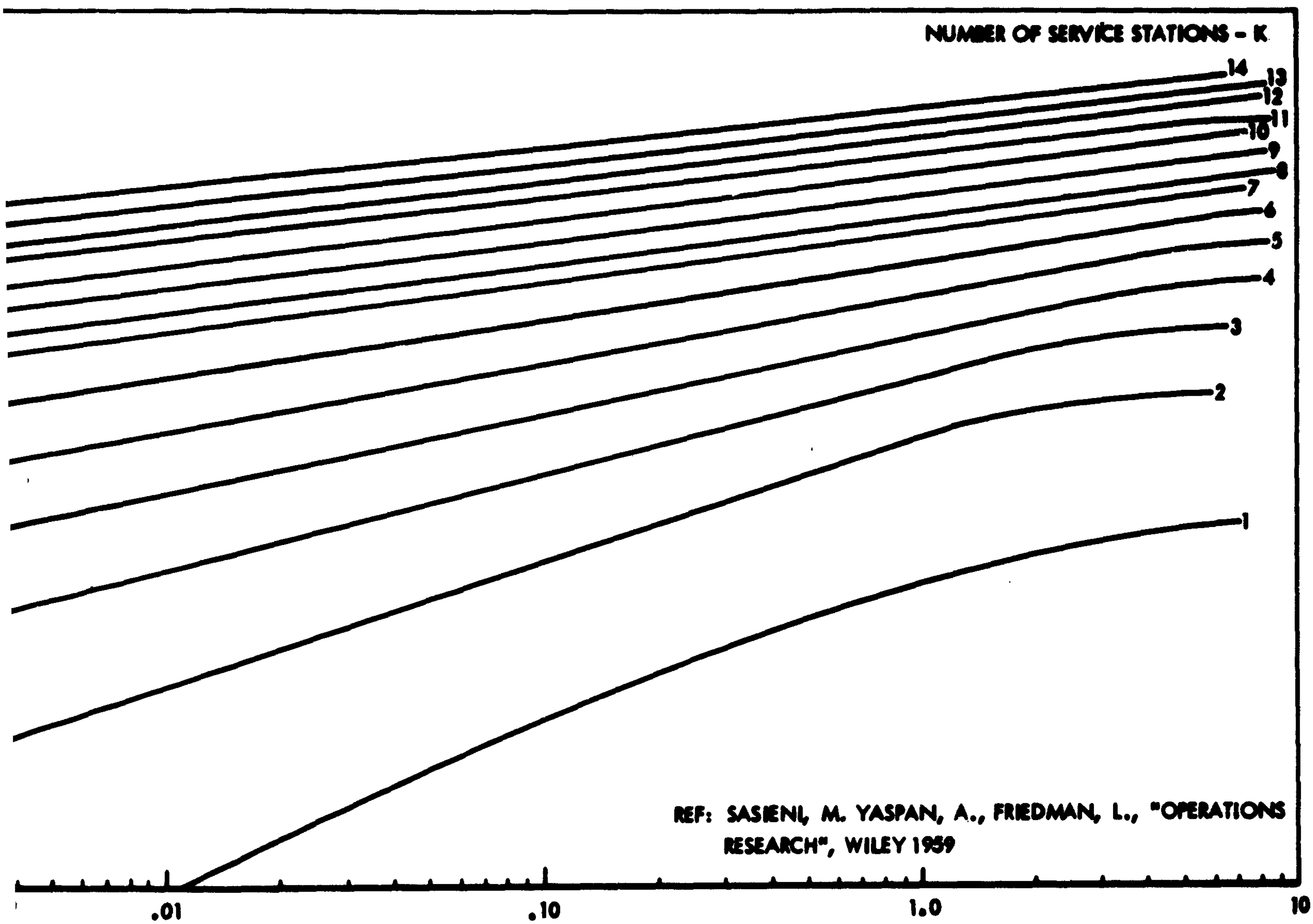


Figure 42. Queue Length. Waiting Time Determination

The costing factors to be used in the comparison are as follows:

PROCUREMENT AND ACTIVATION COSTS

Carrier

The AC-1 Caribou costs will be assumed to be \$500,000 each and the HC-1 Chinook, \$1,000,000 each.

System Auxiliary Equipment

These items of equipment include nets, tiedown devices, pallets, conveyors, tracks, etc. (Appendix IV). All equipment items in Concepts I and II are procured and assigned to the carriers on a one-to-one basis. All equipment items of Concept III, except consolidating pallets and nets, are similarly procured and assigned. Consolidating pallets and nets are procured in sufficient quantities to permit trading loaded for empty pallets at each terminal (or vice versa), plus allowances for pallets in the ground system between the airstrip and the supply area. The number of consolidating pallets and nets required is computed as follows:

$$N_{pallets} = \left\{ N_{A/C} + K_J + \lambda_J \left[\left(\frac{2R_T}{V_T} + \ell_p \right) \right] + N_{A/F}K_{A/F} + N_{A/F}\,\lambda_{A/F} \left[\frac{2R_T}{V_T} + \frac{p + \mu_p}{2} \right] + aN_{A/H} \right\} (1 + \text{percent spares}) \tag{19}$$

where

K = number of service stations per terminal

λ = arrival rate

R_T = radius of transport between supply or pallet makeup area and the airstrip (assumed to be 3000 feet)

V_T = velocity of ground transport (assumed to be 20 miles per hour)

ℓ_p = time to load and consolidate a pallet (approximately 6 minutes)

μ_p = time to unload a consolidating pallet (approximately 5 minutes)

a = percentage of pallets reaching the airhead that is temporarily abandoned or traded (assumed to be 20 percent for mobile pallet with the semi-self-unloading capability and 100 percent for pallets in the gravity roller conveyor system.)

Spares are computed at 25 percent.

Subscripts are:

A/C = Aircraft

A/F = Army airfields

A/H = Army airheads

J = Joint airfield

Terminal Support Vehicles

Terminal support vehicles include transport and lift vehicles and are presented in Appendix I. In general, transport vehicles will weigh approximately twice their carrying capacity and cost 80 to 90 cents a pound. Assuming the transporters will be carrying approximately 3 tons, the cost of a transport vehicle will be assumed to be $10,000.

Rough-terrain lift trucks only will be assumed in this study. Again, cost factors are presented in Appendix I. The cost of the rough terrain lift trucks is approximately $2.50 times the lift capacity in pounds.

Special-purpose vehicles, those required to handle and load the 6000- to 7000-pound consolidated loads, are estimated to cost $2.50 per pound of capacity. Lift trucks are procured for each terminal (including the A/H) on the basis of one lift truck per three service stations, but not less than one. Transport vehicles are procured according to the following relationship:

$$N_T = \left(\lambda_J + 3\lambda_{A/F}\right)\left(\frac{2R_T}{V_T} + \ell_T + u_T\right) \qquad (20)$$

where ℓ_T and u_T are the time to load and unload the transport vehicle.

Special-purpose loaders are procured for all terminals; one each for Concepts III-A and IV-A, but for the Joint and Army airfields only in Concepts III-B and IV-B.

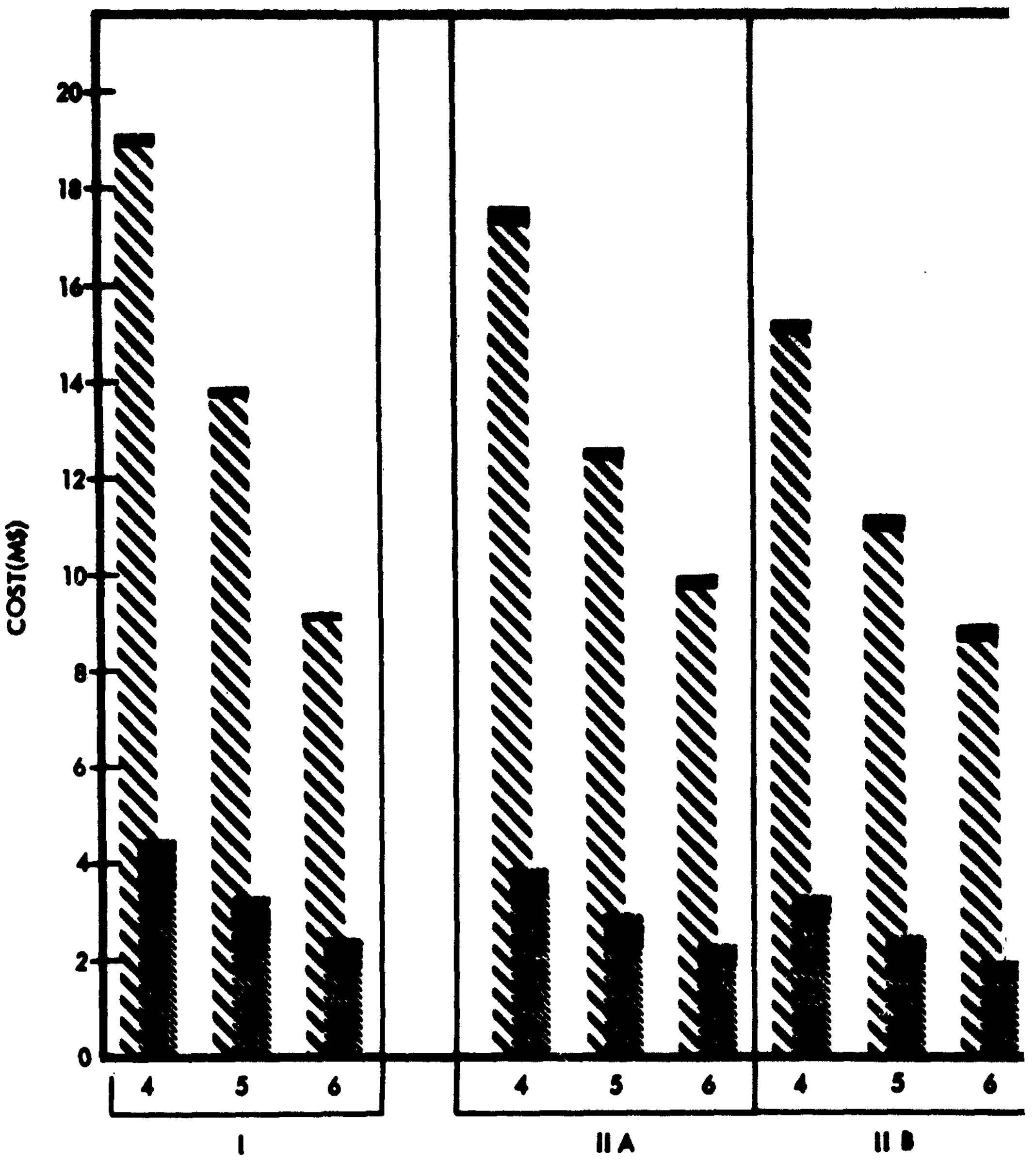
All procurement and activation costs are increased 25 percent to include spares and miscellaneous tools, and support equipment.

Annual Amortization and Operating Costs

Because the various operational concepts postulated in this study utilize varying amounts of manpower, the procurement and activation costs inadequately reflect the true cost of the concepts presented. It is both necessary and more realistic to examine the annual expenditure including personnel cost required to obtain a given capability. Accordingly the annual amortization and operation costs have been estimated as follows: The amortization period for procurement and activation items is assumed to be 10 years. Terminal support personnel are assumed to receive average pay and allowances amounting to $4000 per year plus 75 percent indirect cost, amounting to $7000 per year.* Aircraft crew costs are assumed to be $25,000 per year for a crew of three (includes one plane captain in the case of the AC-1 Caribou). It is further assumed that crews will be available or procured at the rate of 1.2 per carrier. The AC-1 Caribou flying costs including POL and maintenance are estimated at $80 per flying hour and twice that, or $160 per flying hour, for the Chinook. Ground support vehicles are estimated at $1.50 per operating hour. On a peace-time training and readiness basis, it is assumed each concept will be exercised at an average rate of 1 hour per day.

A cost comparison of the various operational concepts as determined from the foregoing criteria is presented in Figure 43 and Tables 4 and 5.

*Army Military Training and Personnel Costs Guide Lines and Assumptions, Statistics Div., ODPSR, OCA, April 1959.



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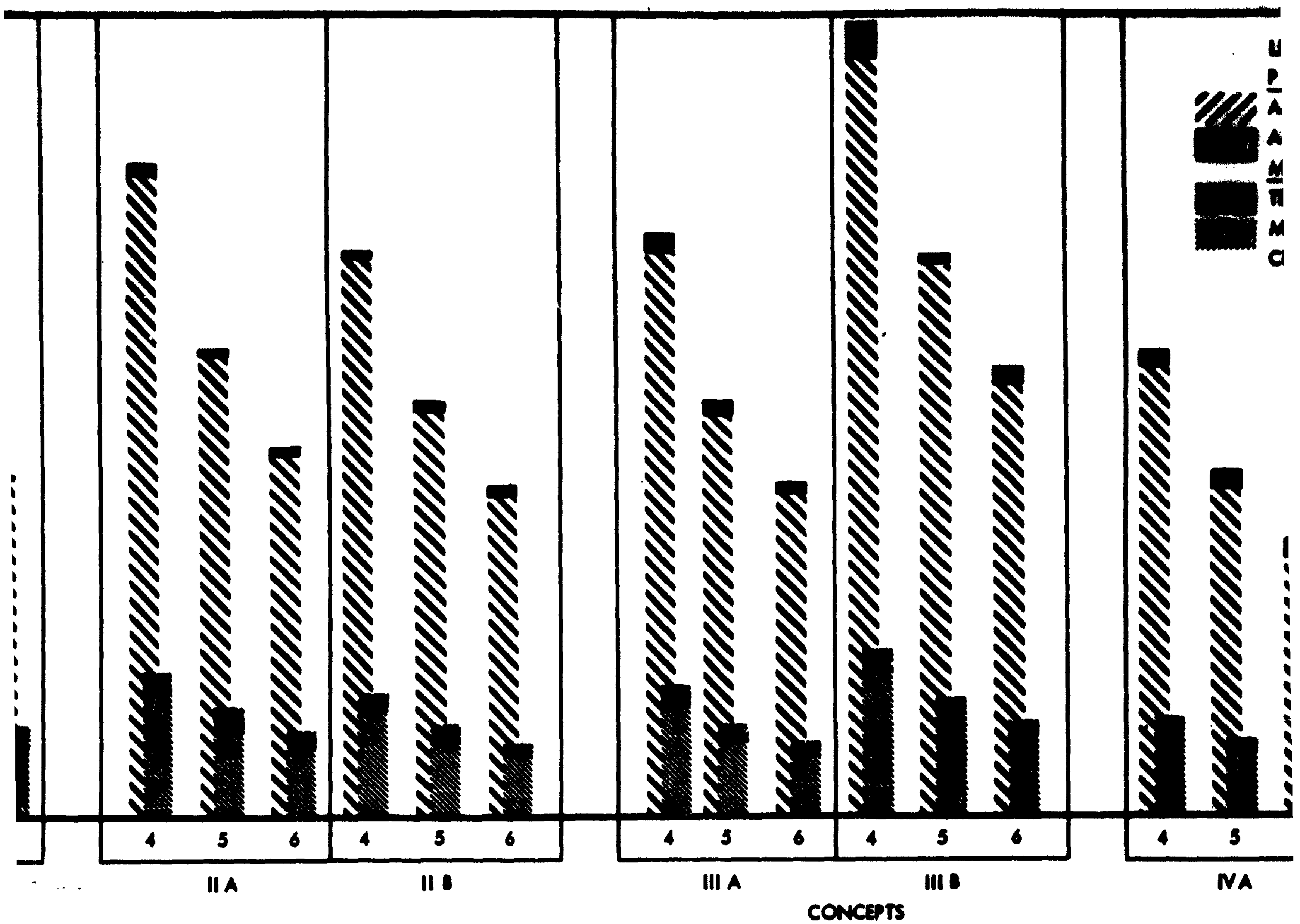

TOTAL TO COMPLETE RESUPPLY MISSION HRS.

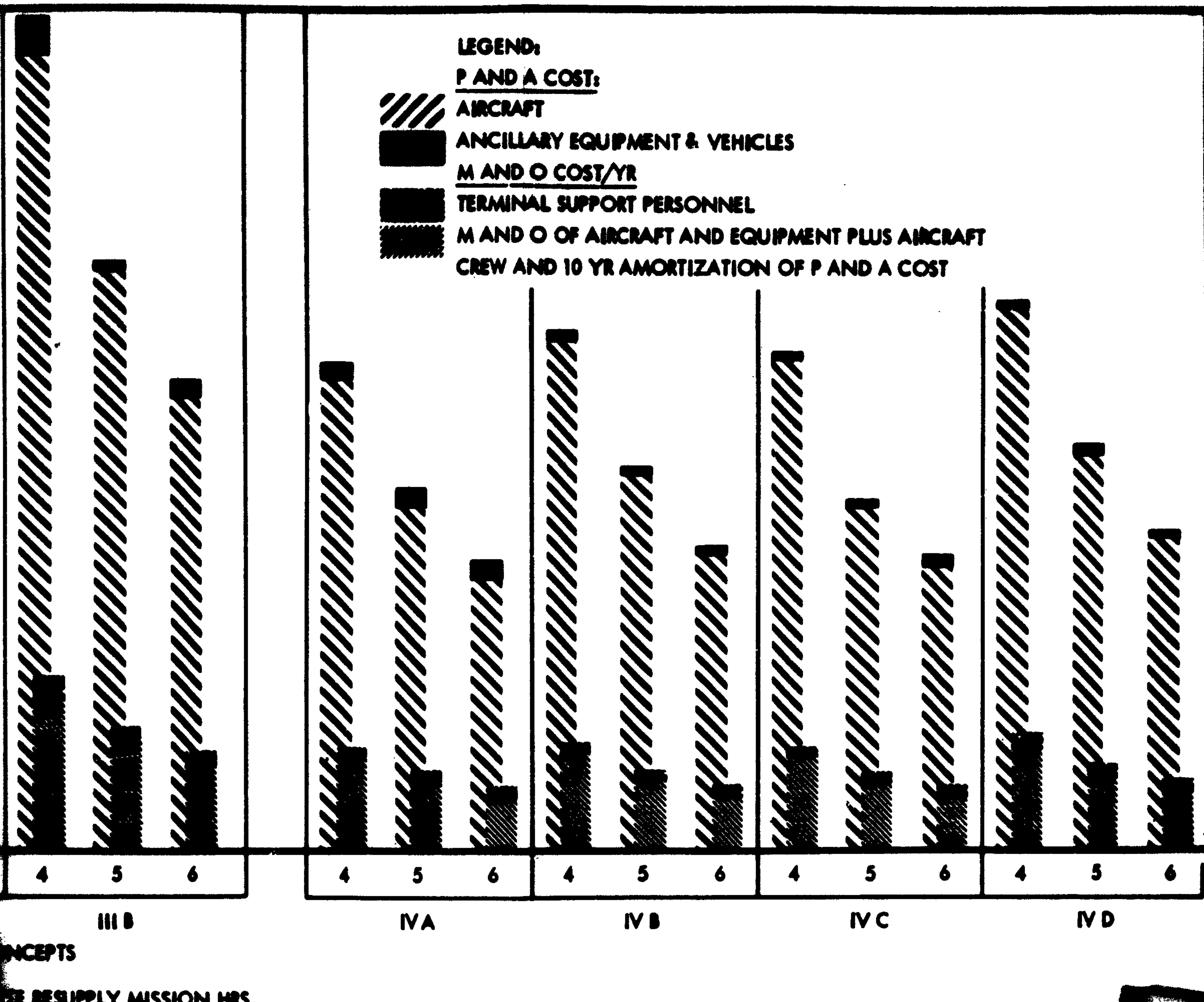

Figure 43. Procurement and Activation Cost and Annual Amortization Maintenance and Operation Cost

	Concept I			Concept I[illegible]			
				A			
Total Mission Time (Hours)	4	5	6	4	5	6	4
Number of Aircraft	26.52	19.19	14.66	24.77	17.61	13.76	21.6
Caribou	22.90	16.44	12.43	21.84	15.32	11.87	19.2
Chinook	3.62	2.75	2.23	2.93	2.29	1.89	2.3
Number of Stations - Joint Airfield	10	7	5	6	6	4	4
Number of Personnel/Station	6	6	6	5	5	5	5
Total Personnel	60	42	30	30	30	20	20
Drivers, Forklifts and/or Transport and/or Special Vehicles	2	1	1	3	3	3	3
Total Personnel Joint Airfield (one)	62	43	31	33	33	23	23
Number of Stations - 3 Army Airfields	9	6	6	6	6	6	6
Number of Personnel/Station	9	9	9	5	5	5	5
Total Personnel	81	54	54	30	30	30	30
Drivers, Forklifts and/or Transport and/or Special Vehicles	3	3	3	6	6	6	6
Total Personnel Army Airfields (Three)	84	57	57	36	36	36	36
Drivers, Transports and/or Special Vehicles at Airheads (Nine)	–	–	–	9	9	9	9
Grand Total Personnel	146	100	88	78	78	68	68
Cost of Personnel/Yr @ $7000 each (M $)	$1.022	$ .700	$ .616	$ .546	$ .546	.476	.4[illegible]
10 Years Amortization of P&A Cost (M $)	1.908	1.377	.923	1.751	1.263	.997	1.5[illegible]
Cost of A/C Crew/Yr @ $25,000/Yr (M $)	.796	.576	.440	.743	.528	.413	.6[illegible]
Cost of A/C Maint & P.O.L./Yr (M $)	.868	.632	.486	.798	.573	.451	.6[illegible]
Cost of Vehicle Maint & P.O.L./Yr (M $)	.003	.002	.002	.010	.010	.010	.0[illegible]
Total M&O Cost/yr (M $)	$4.597	$3.287	$2.467	3.848	2.920	2.347	3.3[illegible]

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TABLE 4
M&O COST SUMMARY

Concept I			Concept II						Concept III								
			A			B			A			B			A		
4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	
26.52	19.19	14.66	24.77	17.61	13.76	21.67	15.64	12.33	22.15	15.51	12.26	29.21	21.09	16.64	17.63	12.86	:
22.90	16.44	12.43	21.84	15.32	11.87	19.28	13.75	10.75	19.83	13.66	10.71	25.66	18.28	14.30	15.82	11.41	
3.62	2.75	2.23	2.93	2.29	1.89	2.39	1.89	1.58	2.32	1.85	1.55	3.55	2.81	2.34	1.81	1.45	
10	7	5	6	6	4	4	3	2	3	2	2	3	3	2	2	2	
6	6	6	5	5	5	5	5	5	7	7	7	7	7	7	5	5	
60	42	30	30	30	20	20	15	10	21	14	14	21	21	14	10	10	
2	1	1	3	3	3	3	2	2	2	2	2	2	2	2	2	2	
62	43	31	33	33	23	23	17	12	23	16	16	23	23	16	12	12	
9	6	6	6	6	6	6	3	3	6	3	3	6	3	3	3	3	
9	9	9	5	5	5	5	5	5	7	7	7	7	7	7	5	5	
81	54	54	30	30	30	30	15	15	42	21	21	42	21	21	15	15	1
3	3	3	6	6	6	6	6	6	6	6	6	6	6	6	6	6	
84	57	57	36	36	36	36	21	21	48	27	27	48	27	27	21	21	2
—	—	—	9	9	9	9	9	9	9	9	9	—	—	—	9	9	
146	100	88	78	78	68	68	47	42	80	52	52	71	50	43	42	42	3
$1.022	$ .700	$ .616	$ .546	$ .546	.476	.476	.329	.294	.560	.364	.364	.497	.350	.301	.294	.294	
1.908	1.377	.923	1.751	1.263	.997	1.524	1.114	.888	1.570	1.124	.901	2.151	1.515	1.207	1.256	.934	
.796	.576	.440	.743	.528	.413	.650	.469	.370	.665	.465	.368	.876	.633	.499	.529	.386	
.868	.632	.486	.798	.573	.451	.693	.505	.401	.705	.500	.398	.943	.688	.547	.560	.412	
.003	.002	.002	.010	.010	.010	.010	.009	.009	.009	.009	.009	.004	.004	.004	.009	.009	
$4.597	$3.287	$2.467	3.848	2.920	2.347	3.353	2.426	1.962	3.509	2.462	2.040	4.471	3.190	2.558	2.648	2.035	:

ABLE 4
ST SUMMARY

Concept III					Concept IV											
A		B			A			B			C			D		
5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
15.51	12.26	29.21	21.09	16.64	17.63	12.86	10.19	18.94	13.78	10.92	18.71	13.21	10.47	20.15	14.71	11.46
13.66	10.71	25.66	18.28	14.30	15.82	11.41	8.97	16.89	12.15	9.55	16.22	11.66	9.17	17.95	12.96	9.99
1.85	1.55	3.55	2.81	2.34	1.81	1.45	1.22	2.05	1.63	1.37	1.95	1.55	1.30	2.20	1.75	1.47
2	2	3	3	2	2	2	1	2	2	1	2	2	1	3	2	2
7	7	7	7	7	5	5	5	5	5	5	5	5	5	6	6	6
14	14	21	21	14	10	10	5	10	10	5	10	10	5	18	12	12
2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1
16	16	23	23	16	12	12	7	12	12	7	12	12	7	19	13	13
3	3	6	3	3	3	3	3	3	3	3	3	3	3	6	3	3
7	7	7	7	7	5	5	5	5	5	5	5	5	5	6	6	3
21	21	42	21	21	15	15	15	15	15	15	15	15	15	36	18	9
6	6	6	6	6	6	6	6	6	6	6	6	6	6	3	3	3
27	27	48	27	27	21	21	21	21	21	21	21	21	21	39	21	21
9	9	–	–	–	9	9	9	–	–	–	–	–	–	–	–	–
52	52	71	50	43	42	42	37	33	33	28	33	33	28	58	34	25
.364	.364	.497	.350	.301	.294	.294	.259	.231	.231	.196	$ .231	$ .231	$ .196	$ .406	$ .238	$ .175
1.124	.901	2.151	1.515	1.207	1.256	.934	.751	1.336	.985	.788	1.274	.937	.749	1.414	1.042	.820
.465	.368	.876	.633	.499	.529	.386	.306	.568	.413	.328	.545	.396	.314	.605	.441	.344
.500	.398	.943	.688	.547	.560	.412	.329	.605	.444	.354	.579	.425	.339	.644	.474	.372
.009	.009	.004	.004	.004	.009	.009	.009	.004	.004	.004	.004	.004	.004	.002	.002	.002
2.462	2.040	4.471	3.190	2.558	2.648	2.035	1.654	2.744	2.077	1.670	$2.633	$1.993	$1.602	$3.07[illegible]	$2.197	$1.713

		Concept I					
						A	
Total Mission Time		4	5	6	4	5	
Number of Aircraft	AC-1 Caribou	22.90	16.44	12.43	21.84	15.32	1
	HC-1 Chinook	3.62	2.75	2.23	2.93	2.29	
Cost System Ancillary Equip/A/C Except Pallets & Nets - AC-1 Caribou		$347*	$347*	$347*	$684*	$684*	$
	HC-1 Chinook	-	-	-	675*	675*	
Cost System Ancillary Equip Except Pallets & Nets - AC-1 Caribou (M$)		-	-	-	-	-	
	HC-1 Chinook (M$)	-	-	-	-	-	
Cost of Pallets and Nets Per Set		-	-	-	-	-	
Number of Pallet and Net Sets Required		-	-	-	-	-	
Cost of Pallets and Nets (M$)		-	-	-	-	-	
Total Cost of Ancillary Equipment (M$)		.0092	.0067	.0051	.0169	.0120	
Total Cost of Ancillary Equipment with 25% Spares (M$)		.0115	.0084	.0064	.0211	.0150	
Aircraft Cost							
Total Cost of Aircraft - AC-1 Caribou @ $500,000 each (M$)		11.450	8.220	6.215	10.920	7.660	[illegible]
- HC-1 Chinook @ $1,000,000 each (M$)		3.670	2.750	1.120	2.930	2.290	[illegible]
Total Cost of Aircraft with 25% Spares (M$)		18.900	13.713	9.169	17.312	12.438	[illegible]
Total Number Stations Required at Airfields							
Joint (one Base)		10	7	5	6	6	4
Army (Three Bases)		9	6	6	6	6	6
Airhead (Nine Bases)		9	9	9	9	9	9
Forklifts required (1 per 3 stations per field)							
Joint Airfield		-	-	-	2	2	2
Army Airfield		-	-	-	3	3	3
Army Airhead		-	-	-	9	9	9
	Total	-	-	-	14	14	14
Special Vehicles Required (1 per 3 stations per field)							
Joint Airfield		-	-	-	-	-	-
Army Airfield		-	-	-	-	-	-
Army Airhead		-	-	-	-	-	-
	Total	-	-	-	-	-	-
Total Cost Forklifts (Cost = W lift x $2.50/lb) (M$)		-	-	-	.105	.105	
Total Cost Special Vehicles (Cost = W lift x $2.50/lb) (M$)		-	-	-	-	-	-
Total Cost Forklifts/Spec. Vehicles with 25% Spares (M$)		-	-	-	.131	.131	
Total Transport Vehicles Required		5	4	4	4	4	4
Total Cost Transport Vehicles ($10,000 each) (M$)		.050	.040	.040	.040	.040	
Total Cost Transport Vehicles with 25% Spares (M$)		.063	.050	.050	.050	.050	
Cost Summary P & A (M$)							
Ancillary Equipment		.0115	.0084	.0064	.0211	.0150	.
Aircraft		18.9000	13.7130	9.1690	17.3120	12.4380	9.
Forklifts		-	-	-	.1310	.1310	.
Special Vehicles		-	-	-	-	-	-
Transport Vehicles		.0630	.0500	.0500	.0500	.0500	.
	Total P & A Cost (M$)	19.078	13.771	9.225	17.514	12.634	9.

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TABLE 5

P&A COST SUMMARY

	Concept I			Concept II						Concept III							
				A			B			A			B			A	
	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5
	22.90	16.44	12.43	21.84	15.32	11.87	19.28	13.75	10.75	19.83	13.66	10.71	25.66	18.28	14.30	15.82	11.41
	3.62	2.75	2.23	2.93	2.29	1.89	2.39	1.89	1.58	2.32	1.85	1.55	3.55	2.81	2.34	1.81	1.45
lete - AC-1 Caribou	$347*	$347*	$347*	$684*	$684*	$684*	$702*	$702*	$702*	$574.04	$574.04	$574.04	$ 963.08	$ 963.08	$ 963.08	$773.20	$773.
HC-1 Chinook	-	-	-	675*	675*	675*	694*	694*	694*	625.78	625.78	625.78	1014.82	1014.82	1014.82	769.19	769.
AC-1 Caribou (M$)	-	-	-	-	-	-	-	-	-	.0114	.0078	.0061	.0247	.0176	.0138	.0122	.00
HC-1 Chinook (M$)	-	-	-	-	-	-	-	-	-	.0015	.0012	.0010	.0036	.0029	.0024	.0014	.00
	-	-	-	-	-	-	-	-	-	877.85	877.85	877.85	877.85	877.85	877.85	1282.85	1282.
	-	-	-	-	-	-	-	-	-	54.5	40.0	35.3	64.8	49.3	41.6	34.2	27.
	-	-	-	-	-	-	-	-	-	.0478	.0351	.0310	.0569	.0432	.0365	.0438	.035
	.0092	.0067	.0051	.0169	.0120	.0094	.0152	.0110	.0086	.0607	.0441	.0381	.0852	.0637	.0527	.0574	.044
$)	.0115	.0084	.0064	.0211	.0150	.0117	.0190	.0138	.0108	.0759	.0551	.0476	.1065	.0796	.0659	.0718	.056
each (M$)	11.450	8.220	6.215	10.920	7.660	5.935	9.640	6.875	5.375	9.915	6.830	5.355	12.830	9.140	7.150	7.910	5.705
0 each (M$)	3.670	2.750	1.120	2.930	2.290	1.890	2.390	1.890	1.580	2.320	1.850	1.550	3.550	2.810	2.340	1.810	1.450
	18.900	13.713	9.169	17.312	12.438	9.781	15.038	10.956	8.694	15.294	10.850	8.631	20.475	14.938	11.863	12.150	8.944
	10	7	5	6	6	4	4	3	2	3	2	2	3	3	2	2	2
	9	6	6	6	6	6	6	3	3	6	3	3	6	3	3	3	3
	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
	-	-	-	2	2	2	2	1	1	-	-	-	-	-	-	-	-
	-	-	-	3	3	3	3	3	3	-	-	-	-	-	-	-	-
	-	-	-	9	9	9	9	9	9	-	-	-	-	-	-	-	-
Total	-	-	-	14	14	14	14	13	13	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	1	1	1	1	1	1	1	1
	-	-	-	-	-	-	-	-	-	3	3	3	3	3	3	3	3
	-	-	-	-	-	-	-	-	-	9	9	9	-	-	-	9	9
Total	-	-	-	-	-	-	-	-	-	13	13	13	4	4	4	13	13
	-	-	-	.105	.105	.105	.105	.0975	.0975	-	-	-	-	-	-	-	-
(M$)	-	-	-	-	-	-	-	-	-	.2275	.2275	.2275	.0700	.0700	.0700	.2275	.2275
M$)	-	-	-	.131	.131	.131	.131	.121	.121	.2844	.2844	.2844	.0875	.0875	.0875	.2844	.2844
	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	.050	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040
	.063	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050
	.0115	.0084	.0064	.0211	.0150	.0117	.0190	.0138	.0108	.0759	.0551	.0476	.1065	.0796	.0659	.0718	.0561
	18.9000	13.7130	9.1690	17.3120	12.4380	9.7810	15.0380	10.9560	8.6940	15.2940	10.8500	8.6310	20.4750	14.9380	11.8630	12.1500	8.9440
	-	-	-	.1310	.1310	.1310	.1310	.1210	.1210	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	.2844	.2844	.2844	.0875	.0875	.0875	.2844	.2844
	.0630	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500
Cost (M$)	19.078	13.771	9.225	17.514	12.634	9.974	15.238	11.141	8.876	15.704	11.240	9.013	21.507	15.155	12.066	12.556	9.335

TABLE 5
P&A COST SUMMARY

	Concept III						Concept IV												
	A			B			A			B			C			D		
	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
	19.83	13.66	10.71	25.66	18.28	14.30	15.82	11.41	8.97	16.89	12.15	9 55	16.22	11.66	9.17	17.95	12.96	9.99
	2.32	1.85	1.55	3.55	2.81	2.34	1.81	1.45	1.22	2.05	1.63	1.37	1.95	1.55	1.30	2.20	1.75	1.47
	$574.04	$574.04	$574.04	$ 963.08	$ 963.08	$ 963.08	$773.20	$773.20	$773.20	$1908.20	$1908.20	$1908.20	$908.20	$908.20	$908.20	$1908.20	$1908.20	$1908.20
	625.78	625.78	625.78	1014.82	1014.82	1014.82	769.19	769.19	769.19	1904.19	1904.19	1904.19	904.19	904.19	904.19	1904.19	1904.19	1904.19
	.0114	.0078	.0061	.0247	.0176	.0138	.0122	.0088	.0069	.0322	.0232	.0182	.0147	.0106	.0083	.0342	.0247	.0190
	.0015	.0012	.0010	.0036	.0029	.0024	.0014	.0011	.0009	.0039	.0031	.0026	.0018	.0014	.0012	.0042	.0033	.0028
	877.85	877.85	877.85	877.85	877.85	877.85	1282.85	1282.85	1282.85	1282.85	1282.85	1282.85	1282.85	1282.85	1282.85	1282.85	1282.85	1282.85
	54.5	40.0	35.3	64.8	49.3	41.6	34.2	27.3	22.1	36.1	28.6	23.1	36.2	27.7	22.5	42.8	29.8	25.1
	.0478	.0351	.0310	.0569	.0432	.0365	.0438	.0350	.0284	.0463	.0367	.0297	.0464	.0355	.0289	.0594	.0382	.0322
	.0607	.0441	.0381	.0852	.0637	.0527	.0574	.0449	.0362	.0824	.0630	.0505	.0629	.0475	.0384	.0933	.0662	.0540
	.0759	.0551	.0476	.1065	.0796	.0659	.0718	.0561	.0453	.1030	.0788	.0631	.0786	.0594	.0480	.1166	.0828	.0675
	9.915	6.830	5.355	12.830	9.140	7.150	7.910	5.705	4.485	8.445	6.075	4.775	8.110	5.830	4.585	8.975	6.480	4.995
	2.320	1.850	1.550	3.550	2.810	2.340	1.810	1.450	1.220	2.050	1.630	1.370	1.950	1.550	1.300	2.200	1.750	1.470
	15.294	10.850	8.631	20.475	14.938	11.863	12.150	8.944	7.131	13.119	9.631	7.681	12.575	9.225	7.356	13.969	10.288	8.081
	3	2	2	3	3	2	2	2	1	2	2	1	2	2	1	3	2	2
	6	3	3	6	3	3	3	3	3	3	3	3	3	3	3	6	3	3
	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	3	3	3	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	4	4	4	-	-	-
	1	1	1	1	1	1	1	1	1	1	1	1	-	-	-	-	-	-
	3	3	3	3	3	3	3	3	3	3	3	3	-	-	-	-	-	-
	9	9	9	-	-	-	9	9	9	-	-	-	-	-	-	-	-	-
	13	13	13	4	4	4	13	13	13	4	4	4	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	.0300	.0300	.0300	-	-	-
	.2275	.2275	.2275	.0700	.0700	.0700	.2275	.2275	.2275	.0700	.0700	.0700	-	-	-	-	-	-
	.2844	.2844	.2844	.0875	.0875	.0875	.2844	.2844	.2844	.0875	.0875	.0875	.0375	.0375	.0375	-	-	-
	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040	.040
	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050	.050
	.0759	.0551	.0476	.1065	.0796	.0659	.0718	.0561	.0453	.1030	.0788	.0631	.0786	.0594	.0480	.1166	.0828	.0675
	15.2940	10.8500	8.6310	20.4750	14.9380	11.8630	12.1500	8.9440	7.1310	13.1190	9.6310	7.6810	12.5750	9.2250	7.3560	13.9690	10.2880	8.0810
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	.2844	.2844	.2844	.0875	.0875	.0875	.2844	.2844	.2844	.0875	.0875	.0875	-	-	-	-	-	-
	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500	.0500
	15.704	11.240	9.013	21.507	15.155	12.066	12.556	9.335	7.511	13.360	9.847	7.882	12.741	9.372	7.492	14.136	10.421	8.199

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TM 9-2800-1	Military Vehicles
TM 10-500	Aerial Delivery of Supplies and Equipment, General
TM 10-1600	Organizational Preventive Maintenance Services and Technical Inspections of Materials Handling Equipment
TM 10-1602	Truck, Fork Lift Gasoline (Clark "Carloader")
TM 10-1602	Truck, Fork Lift, Gasoline (Clark "Planeloader")
TM 38-230	Preservation Packaging, and Packing of Military Supplies and Equipment
TM 57-210	Air Movement of Troops and Equipment
TM 743-200	Storage and Materials Handling
FM 1-5	Army Aviation Organizations and Employment
FM 1-100	Army Aviation
FM 10-13	Quartermaster Reference Data

FM 10-17	Quartermaster Organisation and Service in Army and Corps
FM 10-40	Quartermaster Aerial Supply Company
FM 10-64	Quartermaster Class II and IV Supply in Theatre of Operations
FM 38-1	Logistics Supply Management
FM 55-4	Transportation Movements in Theaters of Operations
FM 55-52	Transportation Terminal Battalion and Terminal Service Company
FM 57-35	Airmobile Operations
FM 57-100	The Airborne Division
FM 101-10	Staff Officers' Field Manual Organizational, Technical and Logistical Data
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TO 00-25-30	Unit Costs of Aircraft, Guided Missiles, and Engines
TO 1C-124A-9	Technical Manual Loading Instructions, USAF Series C-124 Aircraft
TO 1C-130A-9	USAF Series C-130A, RC-130A, C-130D, C-130B Aircraft; USCG Series SC-130B Aircraft
TO 1C-133A-9	Technical Manual Loading Instructions USAF Series C-133A and C-133B Aircraft

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MIL-STD-129	Marking for Shipment and Storage

MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-137	Materials Handling Equipment
MIL-STD-147	Palletized Unit Loads (40" x 48" 4-Way Partial and 4-Way Pallets)
JAN-N-262	Nets, Cargo (Wire Rope)
MIL-S-3112	Sling, Bagged Cargo, Duck, 9- By 3-Foot
MIL-S-3905	Sling, Pallet
MIL-P-3938	Pallet, Material Handling Hardwood, Stringer Construction, 4-Way (Partial)
MIL-C-4751	Casters, Rigid and Swivel, Precision Heavy Duty, and Shock Absorbing
MIL-P-4894	Pallet Materials Handling, Box Type, Wood (Light Duty)
MIL-C-5041	Castings, Tire and Tubeless Tires; Aircraft Pneumatic
MIL-S-5944	Slings, Aircraft, General Specification For
MIL-H-6261	Handbooks, Condensed; Operation, Service and Repair Instructions (For Various Ground Equipment Items)
MIL-T-6480	Tie Down, Cargo, Aircraft, Type C-2
MIL-P-6640	Pneumatic Bag, Aircraft, Lifting, 12-Ton Capacity, Type F-2
MIL-T-7181	Tie Down, Cargo, Aircraft, Type A-1A
MIL-O-7262	Chain, D-1 Aircraft Cargo Tie Down
MIL-T-7270	Tie Down, Cargo, Aircraft, Type D-1
MIL-P-7936	Parts and Equipment, Aeronautical, Preparation for Delivery

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MIL-C-11218	Conveyors, Roller and Wheel, Gravity and Conveyor Supports
MIL-B-11886	Box, Metal, Shipping, Reusable, (Transporter)
MIL-S-13443	Limited Coordination Military Specification Sling, Cotton Duck (12 feet by 12 feet)
MIL-C-14510	Conveyors, Drag, Coal, Truck Loader, Self-Propelled, Power-Driven
MIL-P-15011	Pallets, Material Handling, Hardwood, Post Construction
MIL-T-15442	Trucks, Lift, Fork, Gasoline, Pneumatic Rubber Tires

MIL-T-15445	Trucks, Lift, Fork, Gasoline, Solid Rubber Tires
MIL-T-15636	Truck, Lift, Fork, Electric, Solid Rubber Tires
MIL-T-15830	Tractors, Wheeled, Warehouse, Gasoline 4-Wheel Pneumatic Rubber Tires
MIL-T-1610	Trucks, Straddle-Carry, Gasoline, Pneumatic Rubber Tires
MIL-N-16626	Net, Sling, Cargo (Fiber Rope)
MIL-T-17480	Trailers, Platform, Warehouse, Caster Steer, 4000 and 6000 Pounds Capacity, Solid Rubber Tires
MIL-S-18313	Slings, Cargo, Net, Nylon Webbing
MIL-C-18431	Cargo Shoring Set, Wire Net
MIL-C-19201	Conveyor, Roller, Gravity, Accordion
MIL-P-19243	Pallet, Personnel, Safety, 2000-Pound Capacity
MIL-C-19436	Conveyor, Roller, Gravity, Car Door, Telescopic Frame
MIL-T-20698	Trucks, Forklift, Self-Side Loading, Gasoline
MIL-B-21560	Box, Metal, Shipping: Reusable, Transporter, Steel, Type 1, Capacity 135 Cubic Feet, Max. Load 9000 Pounds
MIL-T-21855	Trucks, Forklift, Gasoline, Pneumatic-Tired Rough Terrain 6000- and 10,000-Pound Capacity at 24-Inch Load Center
MIL-D-21857	Dunnage Mattress, Pneumatic, Cargo Shoring
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MIL-C-22137	Cranes, Overhead Traveling
MIL-P-22562	Pallet, Material Handling

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MIL-T-25960	Tiedown, Cargo, Aircraft, Type MB-2, 25,000-Pound Capacity
MIL-C-26080	Conveyor, Drag, Wheel Mounted, Gasoline-Engine-Powered
MIL-P-26342	Pallet Box, Fiberboard, Expendable, For Air Shipment
MIL-T-26780	Tiedown, Cargo Aircraft, Nylon Web Net
MIL-P-26966	Pallet, Material Handling, Lightweight, Air Cargo
MIL-T-27260	Tiedown, Cargo, Aircraft CGU-1/B
MIL-P-27443	Pallet, Cargo, Aircraft HCU-6/E
MIL-N-27444	Net, Cargo Tiedown, Pallet HCU-7/E
MIL-C-40027	Conveyor, Roller, Gravity, With Connector Roller; Bridge Erection Aid
MIL-S-52159	Sling, Multiple Leg: 5/8-Inch by 6-Foot Chain; With Special Hooks and Ring

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APPENDIX I. LOADING AND TRANSPORT VEHICLES

INTRODUCTION

In the discussion of the various concepts (Section 9), two classes of material-handling vehicles were considered: forklift trucks and special-purpose loaders. In Concept II, a 3000-to 4000-pound palletized load on the QM pallets can be managed satisfactorily with forklift trucks. The only rough terrain lift truck currently in production is the Quartermaster Telefork series of vehicles. Unfortunately, these vehicles are too large to be used for inserting loads into the Army air carriers. Two other rough terrain lift trucks, the QM Sandpiper and the Marine Corps ART-30, are currently under development and were expected to be in production before the AC-1 Caribou and the HC-1 Chinook were available in large quantities. Both the Sandpiper and the ART-30 are suitable for loading the air carriers.

The second class of material-handling vehicles considered in this study is the special-purpose vehicle required to handle the 6000- to 7000-pound consolidated load of Concepts III and IV. The dimensions of the consolidated load pallet defined in this study (5 by 11 feet), and the manner in which the pallet must be loaded (lengthwise), rendered the conventional lift truck concept inappropriate. The special-purpose loader must be able to transverse the empennage overhang with a 7000-pound, 66-inch high, 11-foot long consolidated load. In loading the AC-1 Chinook, this load must not exceed 12 inches from the ground. Since forklift-type vehicles with a 7000-pound, 5-1/2-foot load center capability are not considered practicable, special-purpose vehicles will be required. However, considering that the Air Force will be delivering maximum loads of 10,000 pounds on the 463L pallet (88 by 108 inches), the special-purpose vehicles should be able to handle both load configurations. Several concepts of special loaders have been considered and are presented in this appendix.

A third class of special-purpose vehicle, not included in any of the concepts of this study, evolved from the possible requirement for handling material in a primitive airhead environment. Conventional, high-utility material-handling equipment carried on such a mission would consume most or all of the carrier's cargo capacity. Rough terrain vehicles either currently available or under development would not fit in the AC-1 Caribou. Thus, a preliminary analysis was performed which evolved a small, minimum-weight, track-laying vehicle capable of lifting and transporting the 7000-pound unit load as well as fitting in the Caribou. The vehicle that resulted is estimated to weigh 1200 pounds and was called a "Lift-Tug." It is presented in a latter section of this appendix.

This section also encompasses a survey of transport trucks, both military and commercial. The special movable-bed vehicles may prove to be a solution to the direct loading of the Army aircraft.

COMMERCIAL FORKLIFT TRUCKS

A literature survey of standard, gasoline-powered, pneumatic-tired forklift trucks was included in the vehicle investigation, and the information contained therein was studied and analyzed. Specifications and cost information on forklifts with various capacities were compiled in Table 6.

MILITARY FORKLIFT TRUCKS

TELEFORK

The Telefork series of multipurpose vehicles have the capabilities of a forklift, crane, and tractor, and are designed to be used on most types of terrain and under extreme climatic conditions.

This series consists of the following:

1. 6000-pound capacity at 24-inch load center (Telefork 62)
2. 10,000-pound capacity at 24-inch load center (Telefork 102)
3. 15,000-pound capacity at 36-inch load center (Telefork 153)

Prototypes of these vehicles have been tested, and Teleforks 62 (Figure 44) and 102 have been classified as standard.

GAS POWERE

				Dimensions			
Model	Max. Rated Capacity	Service Wt(lb)	Cost	Length Truck-Fork	O.A. Width	O. A. Height Forks Lowered	M He
CY-150	7 1/2T	20,490	$13,590 13,795*	169-48	96"	112-157	120-
CYF-150	7 1/2T	20,060	12,070 12,345*	-	-	-	-
CFY-165	8 1/4T	21,200	12,450 12,725*	169-48	96"	112-157	120-
CY-165	8 1/4T	21,600	13,900 14,175*	-	-	-	-
Y-100	5 T	14,365	10,315 10,585*	133 3/4-48	76"	81-150	84-21
Y8024	4 T	12,850	9,075 9,345*	132 1/8-48	77"	81-150	84-21
YL-6024	3 T	9,424	7,915 8,059*	115 1/2-42	56 5/8"	72 3/8-116 3/8	84"-1
YL-6024	3 T	9,650	8,130 8,274*	113 1/2-42	68"	71-85	84"-1
CY-40	2 T	7,050	6,877 7,021*	96-40	42"	55-125	70-20
CY-20	1 T	4,600	4,871 4,943*	80 1/2-32	36"	55-112	70-17
A-15	7 1/2T	21,650	13,000	168-48	96"	110-155	120-2
680P	3 T	11,000	8,100	110 7/8-42	53 7/8"	68"-98	86 1/
501P	2 T	8,000	$6,400	85 1/2-36	45 1/2"	73"-92"	107 3

Note: Price of Clark forklifts dependent on fork height.
Above prices F. O. B. Factory
0 denotes specifications not given
- denotes specifications identical
Price on YL-6024 for single and dual drive wheels

*Increase in price for extra cost of special drive and transmission system.

1

TABLE 6
(Sheet 1 of 2)
GAS POWERED, PNEUMATIC TIRED, FORKLIFT TRUCKS

			Dimensions					Clearances				
d acity	Service Wt(lb)	Cost	Length Truck-Fork	O.A. Width	O. A. Height Forks Lowered	Max. Fork Height	O. A. Height Forks Raised	At Upright	Drive Axle	Steer Axle	Center Frame	Counter Wt.
/2T	20,490	$13,590 13,795*	169-48	96"	112-157	120-210	169-259	9"	10 1/2"	14"	16 1/4"	12
/2T	20,060	12,070 12,345*	-	-	-	-	-	-	-	-	-	-
4T	21,200	12,450 12,725*	169-48	96"	112-157	120-210	193-283	9"	10 1/2"	14"	16 1/4"	12
4T	21,600	13,900 14,175*	-	-	-	-	-	-	-	-	-	-
	14,365	10,315 10,585*	133 3/4-48	76"	81-150	84-210	117-249	4 1/4"	9"	7"	9 3/4"	6"
	12,850	9,075 9,345*	132 1/8-48	77"	81-150	84-210	117-249	7 1/2"	8 1/2"	7"	8 3/4"	6 1/2"
	9,424	7,915 8,059*	115 1/2-42	56 5/8"	72 3/8-116 3/8	84"-168	111 5/8-195 5/8	6"	7 3/4"	7"	10 1/4"	7 3/4"
	9,650	8,130 8,274*	113 1/2-42	68"	71-85	84"-168	110 1/4-194 1/4	4 5/8"	6 3/8"	7"	8 7/8"	6 3/8"
	7,050	6,877 7,021*	96-40	42"	55-125	70-202	91-223	5"	6 1/2"	8 3/4"	8 1/4"	10 7/8"
	4,600	4,871 4,943*	80 1/2-32	36"	55-112	70-178	91 1/2-199 3/4	5"	7 1/4"	7 1/8"	7"	10"
2T	21,650	13,000	168-48	96"	110-155	120-220	186-276	0	0	0	12"	0
	11,000	8,100	110 7/8-42	53 7/8"	68"-98	86 1/4-116 1/4	109 3/8-169 3/8	0	0	0	10 3/8"	0
	8,000	$6,400	85 1/2-36	45 1/2"	73"-92"	107 3/4-145 3/4	126 1/2-164 1/2	0	0	0	9 7/8"	0

Clark forklifts dependent on fork height.
ices F.O.B. Factory
specifications not given
specifications identical
YL-6024 for single and dual drive wheels

ce for extra cost of special drive and transmission system.

TABLE 6
(Sheet 1 of 2)
GAS POWERED, PNEUMATIC TIRED, FORKLIFT TRUCKS

Dimensions			Clearances					Vehicle Speed & Grades Loaded		
O. A. Height Forks Lowered	Max. Fork Height	O. A. Height Forks Raised	At Upright	Drive Axle	Steer Axle	Center Frame	Counter Wt.	Forward	Reverse	Max. Grade
112-157	120-210	169-259	9"	10 1/2"	14"	16 1/4"	12	19 MPH	19 MPH	36% at Counter Wt.
-	-	-	-	-	-	-	-	22 MPH	22 MPH	30%
112-157	120-210	193-283	9"	10 1/2"	14"	16 1/4"	12	17.5 MPH	18 MPH	30% at Counter Wt.
-	-	-	-	-	-	-	-	22 MPH	22 MPH	-
81-150	84-210	117-249	4 1/4"	9"	7"	9 3/4"	6"	18" approx	18" approx	16%
81-150	84-210	117-249	7 1/2"	8 1/2"	7"	8 3/4"	6 1/2"	16 1/2 MPH	16 MPH	43%
72 3/8-116 3/8	84"-168	111 5/8-195 5/8	6"	7 3/4"	7"	10 1/4"	7 3/4"	12.0 MPH	12.2 MPH	55%
71-85	84"-168	110 1/4-194 1/4	4 5/8"	6 3/8"	7"	8 7/8"	6 3/8"	11.2 MPH	11.4 MPH	39%
55-125	70-202	91-223	5"	6 1/2"	8 3/4"	8 1/4"	10 7/8"	11 MPH	7.4 MPH	62%
55-112	70-178	91 1/2-199 3/4	5"	7 1/4"	7 1/8"	7"	10"	11 MPH	11 MPH	61%
110-155	120-220	186-276	0	0	0	12"	0	23 MPH	23 MPH	25%
68"-98	86 1/4-116 1/4	109 3/8-169 3/8	0	0	0	10 3/8"	0	11.5 MPH	11.5 MPH	0
73"-92"	107 3/4-145 3/4	126 1/2-164 1/2	0	0	0	9 7/8"	0	10 MPH	10 MPH	0

on system.

3

TABLE
(Sheet 2
GAS POWERED, PNEUMATIC

		Forks						
		Lift Speed (FPM)		Dimensions			Rated Load Capacity	Load
Model	Max. Rated Capacity	Empty	Loaded	Spread	Max. Width	Max. Height	24"	36"
CY-150	7-1/2T	55	50	80"	7	3"	15,000#	12,000#
CYF-150	7-1/2T	-	-	-	-	-	-	-
CFY-165	8-1/4T	40	36	80"	7	2 1/2"	16,500#	13,170#
CY-165	8-1/4T	-	-	-	-	-	-	-
Y-100	5 T	32.1	26.8	68"	8	2	10,000#	7,650#
Y8024	4 T	48	42	68"	6	2	8,000#	6,200#
YL-6024	3 T	44	38	48"	6	2	6,000#	4,590#
YL-6024	3 T	44	38	60"	6	2	6,000#	4,550#
CY-40	2 T	58	50	40"	5	1 3/4	4,000#	4,400 @ 20"
CY-20	1 T	62	55	30"	4	1 1/4	2,000#	2,200# @ 20"
A-15	7-1/2T	105	75	66"	6	2 1/2	15,000#	11,800#
680P	3 T	0	50	44"	5	1 1/2	6,000#	0
501P	2 T	0	70	39"	4	1 1/2	4,000#	0

1

TABLE 6
(Sheet 2 of 2)
GAS POWERED, PNEUMATIC TIRED, FORKLIFT TRUCKS

Forks										
(FPM)	Dimensions			Rated Load Capacity Load Centers					Lift Tilt	
›oaded	Spread	Max. Width	Max. Height	24"	36"	48"	Tires	Power Steering Brakes	Backward	Forward
50	80"	7	3"	15,000#	12,000#	9,900#	9:00 X 20 OPT. 10:00 X 20	Yes	10°	6°
-	-	-	-	-	-	-	-	-	-	-
36	80"	7	2 1/2"	16,500#	13,170#	10,880#	-	Yes	10°	6°
-	-	-	-	-	-	-	-	-	-	-
26.8	68"	8	2	10,000#	7,650#	6,100#	Fwd 8.25 X 18 Rear 7.50 X 15	Yes	12°	4°
42	68"	6	2	8,000#	6,200#	5,240 @ 45"	Fwd 8.25 X 18-12 Rear 7.50 X 15-10	Yes	12°	4°
38	48"	6	2	6,000#	4,590#	6,500 @ 15"	Fwd 8.25 X 15-12 Rear 7.50 X 10-10	Steering Only	10°	3°
38	60"	6	2	6,000#	4,550#	6,500# @15"	Fwd 750:15-10 Rear 750 X 10-10	Steering Only	10°	3°
50	40"	5	1 3/4	4,000#	4,400 @ 20"	3,400# @30"	Fwd 7:00 X 12-12 Rear 7:00 X 12-12	Steering Only	15°	6°
55	30"	4	1 1/4	2,000#	2,200# @ 20"	1,680# @30"	Fwd 6:50 X 10 Rear 6:50 X 10	No	15°	6°
75	66"	6	2 1/2	15,000#	11,800#	10,000#	9:00 X 20	Yes	12°	6°
50	44"	5	1 1/2	6,000#	0	0	Fwd 8:25 X 15 Rear 7:50 X 10	No	10°	5°
70	39"	4	1 1/2	4,000#	0	0	Fwd 7:00 X 12 Rear 6:50 X 10	No	10°	5°

TABLE 6
(Sheet 2 of 2)
POWERED, PNEUMATIC TIRED, FORKLIFT TRUCKS

Rated Load Capacity Load Centers					Lift Tilt		Max. Grades Loaded	
24"	36"	48"	Tires	Power Steering Brakes	Backward	Forward	Low Gear	High Gear
15,000#	12,000#	9,900#	9:00 X 20 OPT. 10:00 X 20	Yes	10°	6°	36%	0
-	-	-	-	-	-	-	0	0
16,500#	13,170#	10,880#	-	Yes	10°	6°	26.5%	0
-	-	-	-	-	-	-	27%	0
10,000#	7,650#	6,100#	Fwd 8.25 X 18 Rear 7.50 X 15	Yes	12°	4°	17.5%	0
8,000#	6,200#	5,240 @ 45"	Fwd 8.25 X 18-12 Rear 7.50 X 15-10	Yes	12°	4°	0	0
6,000#	4,590#	6,500 @ 15"	Fwd 8.25 X 15-12 Rear 7.50 X 10-10	Steering Only	10°	3°	23%	7%
6,000#	4,550#	6,500# @ 15"	Fwd 750:15-10 Rear 750 X 10-10	Steering Only	10°	3°	24%	7.4%
4,000#	4,400 @ 20"	3,400# @ 30"	Fwd 7:00 X 12-12 Rear 7:00 X 12-12	Steering Only	15°	6°	26%	0
2,000#	2,200# @ 20"	1,680# @ 30"	Fwd 6:50 X 10 Rear 6:50 X 10	No	15°	6°	0	0
[illegible],000#	11,800#	10,000#	9:00 X 20	Yes	12°	6°	25%	0
[illegible],000#	0	0	Fwd 8:25 X 15 Rear 7:50 X 10	No	10°	5°	0	0
4,000#	0	0	Fwd 7:00 X 12 Rear 6:50 X 10	No	10°	5°	0	0

3

Figure 44. Telefork 62

The Telefork series can be equipped to operate in temperatures of -65° F by installing personnel cab, personnel heater, and powerplant heater. Seals, hoses, and lubricants will withstand temperatures of -65° F. The specifications of these vehicles are presented in Table 7.

ART-30

The ART-30 (Figure 45) is a rough terrain forklift truck capable of lifting a 3000-pound load and of being towed at speeds up to 45 miles per hour. It is presently under development by the United States Marine Corps.

High-strength aluminum plates, sheet and extrusions, and alloy steel, are utilized in an effort to achieve structural strength, rigidity and

Figure 45. ART-30

light weight. The vehicle incorporates the engine, transmission and axles of the M38-1 "Jeep." Specifications of the ART-30 are also listed in Table 7.

SANDPIPER L-42

The Sandpiper is a lightweight, 4000-pound capacity, rough terrain forklift developed by the Quartermaster Corps (Figure 46). For comparison purposes, its specifications too are included in Table 7.

The Sandpiper is made up of three major assemblies: the front pod, the center section, and the rear pod.

The front pod is a rigid frame upon which is mounted the lift mechanism and the pivoting front wheel mounts, with related hydraulic actuating cylinders for both. The usual forklift practice is to pick up and carry a load with its center of gravity forward of the front axle. This results in an unbalanced condition so that approximately 85 percent of the gross load is supported by the front wheels with 15 percent

TABLE
MILITARY FORK

Vehicle	Load Capacity (lb)	Load Center	Height Max. (in.)	Length (in.)	Width (in.)	Service Weight (lb)
Telefork 62	6,000	24"	91 W/O O. H. Guard	204	86	17,000
Telefork 102	10,000	24"	100 W/O O. H. Guard	240	103	27,400
Telefork 153	10,500 15,000	51" 36"	103 W/O O. H. Guard	316	106	37,500
Model ART-30	3,000	24"	60	162	78	3,100
Sandpiper Model L-42	4,000	24"	81	156	95	5,000

1

TABLE 7

MILITARY FORKLIFT TRUCKS

ngth .)	Width (in.)	Service Weight (lb)	Fork Length (in.)	Ground Clearance Min. (in.)	Grade-ability (slope)	Speed Max. (MPH)	Lift Height (in.)	No. of Wheels	No. of Wheel Drive	Ground Bearing Pressure	Cost
204	86	17,000	48	16	45%	25	144	4	4	20 psi	$14,240
240	103	27,400	60	16	45%	25	144	4	4	20 psi	21,920
316	106	37,500	72	16	45%	25	144	4	4	20 psi	30,000
162	78	3,100	40	9	80%	25	70	4	4	——	6,800
156	95	5,000	40	14	30%	25	84	4	2 rear	——	10,000

Figure 46. Sandpiper L-42

remaining on the rear wheels — which results in an extremely unstable condition especially over rough terrain. The pivoting wheel-mounted arms, which can be retracted for picking up the load, result in an equal weight distribution on all wheels (Figure 47).

If the vehicle's rear wheels, which provide the driving force, were both slipping and the front wheels were on dry land, the front wheel mounts could be pivoted fully forward and the service brakes set, then by retracting these wheels the vehicle would move forward through the entire stroke (approximately 3 feet). This procedure could be repeated until the rear wheels develop sufficient traction to move the vehicle.

If all four wheels of the vehicle should become mired, the rear wheels could be steered (fifth-wheel steering) to the maximum angle and the lead wheel chocked. The axle could then be steered to the maximum angle in the other direction. This will result in moving

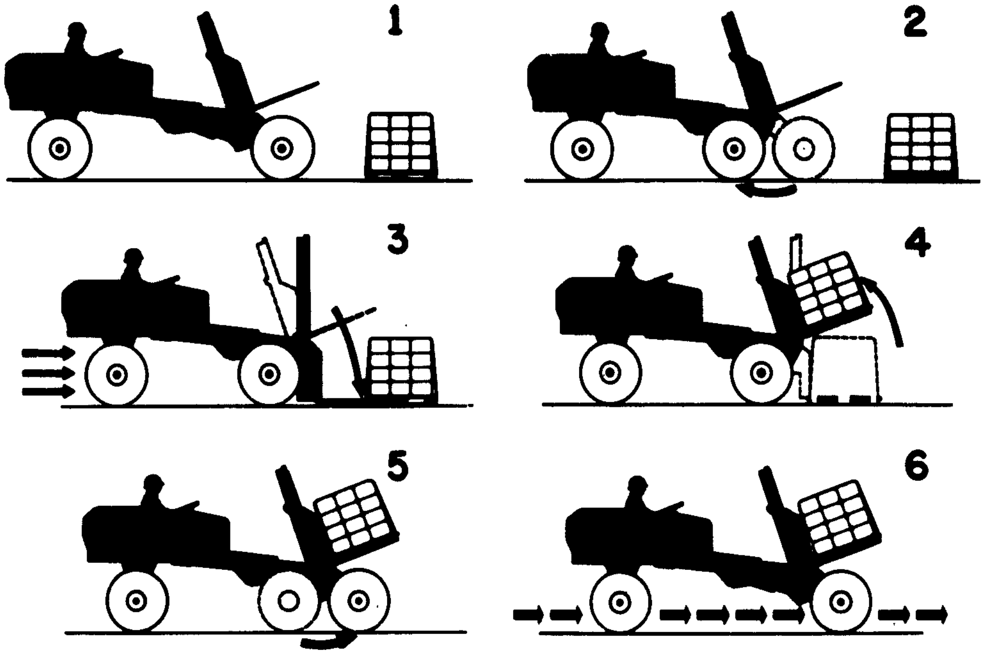


Figure 47. Sandpiper Loading

the vehicle forward by approximately 5 feet. This procedure could be repeated until the driving wheels develop sufficient traction to propel the vehicle. In effect, this results in "walking" the truck with the rear axle and wheels.

The center section consists of a torsion bar, which is attached to the front and rear pods allowing sufficient radial movement between the front and rear pods to enable one wheel to be displaced 14 inches up or down while the other three wheels remain on the ground.

The rear pod consists of the power package, the operator's cockpit, and the steering mechanism.

As can be seen, the vehicle comprises three separate sections which can be assembled and disassembled in the field. The rear pod is the self-contained drive unit, and can be coupled to various types of front working pods.

FORKLIFT TRUCK COST ANALYSIS

Initial cost information was included in Tables 6 and 7 along with the specifications. These cost figures were plotted against lift capacity in Figure 48. To determine an initial cost estimate for the costing purposes in this study, a line was drawn on the graph through the low lift capacity points of the standard trucks and the Teleforks. This line gave an approximation of $2.50 per pound of lift capacity. Verification of this figure was obtained by plotting the cost of the ART-30 and Sandpiper L-42.

NORTRONICS' FORKLIFT CONCEPT

The "Lift-Tug Material-Handling Vehicle" (Figure 49) is a small, self-propelled, track-laying vehicle designed as a utility lift and transport vehicle. It is capable of lifting and transporting 3000-pound loads and of transporting 6000-pound loads when used in combination with a consolidated pallet. This vehicle weighs approximately 1200 pounds, and would be of a size to be readily transportable in the AC-1 Caribou and HC-1 Chinook aircraft.

Its specific capabilities are:

1. By surrounding the load, the vehicle can lift and transport on or off the road a 6000-pound load, 43 by 52 inches, having a 26-inch load center The 6000-pound load can be lifted to a height of 24 inches. A 3000-pound load of the same dimensions can be lifted 43 inches.

2. By lifting one end of a 5-by 11-foot consolidated pallet loaded to 7000 pounds, the vehicle can transport this load on the road with pallet ECR's extended or off the road by towing the skidded (ECR retracted) pallet.

3. The vehicle can lift and transport outsized loads (greater than 52 inches in length) of 1500 pounds with a 17-inch load center.

Transport of the above loads can be accomplished off the road at a speed of 5 feet per second or on the road at 20 feet per second.

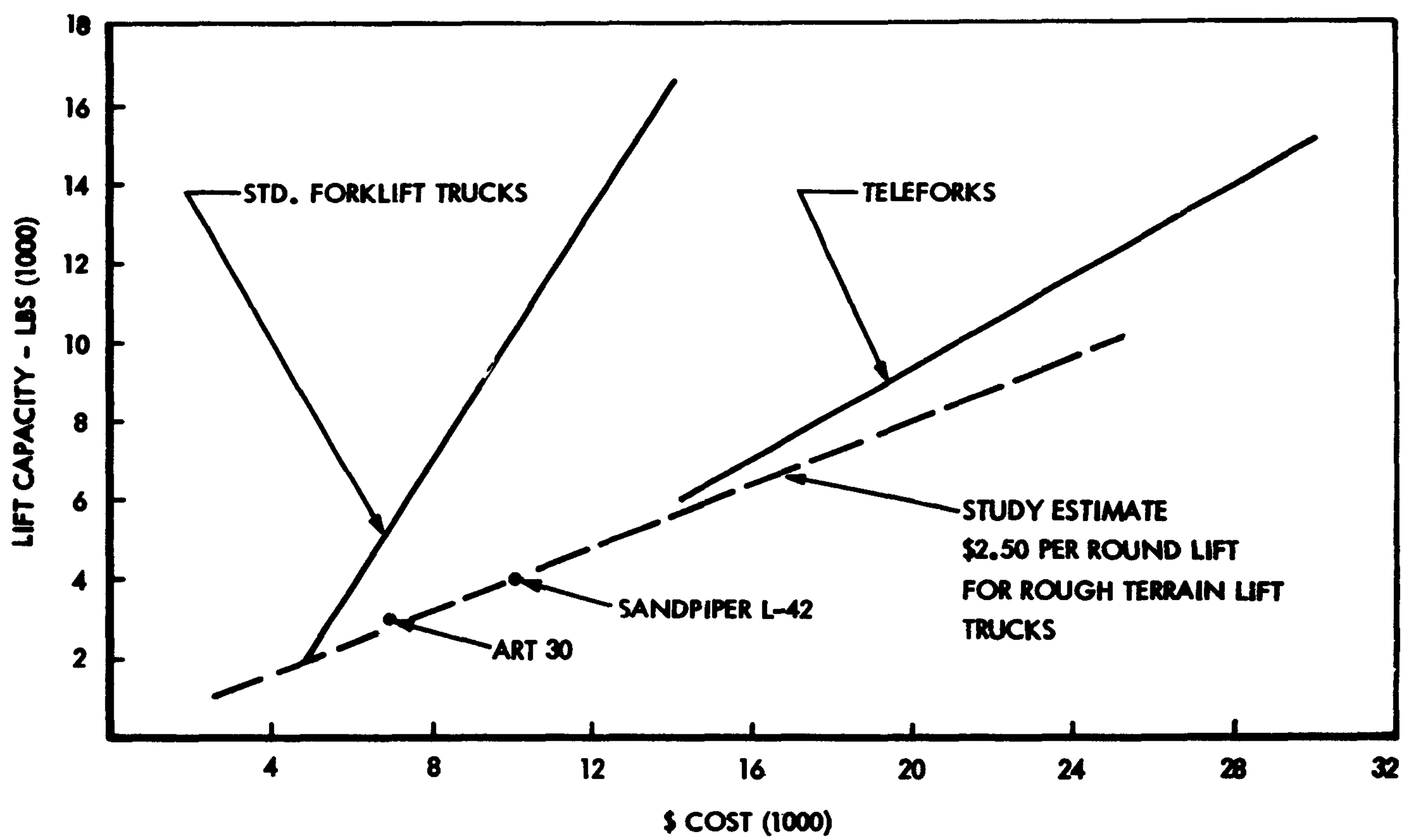


Figure 48. Mobile Material Handling Equipment Lift Capacity Versus Cost

Figure 49. Nortronics' Lift Tug Material-Handling Vehicle

The vehicle chassis is arranged so that it surrounds the heavier loads avoiding the need for counterweighting. The chassis is a U-shaped section with engine, transmission, differential axle, and operator's platform at the base of the "U." The legs of the "U" support the track drive and road wheels. The vehicle has high mobility due to the short wheelbase and the same speed characteristics in either travel direction.

The chassis supports a lift fork mounted on a fore and aft traversing mechanism. The lift fork is arranged so that it may swivel with respect to the chassis, thereby increasing mobility when towing or skidding the large consolidating pallet.

The traversing mechanism supports the lift actuator and is capable of a maximum traverse of 30 inches. The mechanism consists of a pin-ended beam supported at each track support housing by rollered fittings. A double-acting, two-stage actuator is fixed between the traverse beam and the vehicle chassis to provide the traversing motion and to stabilize the beam.

The lift actuator is a single-acting, two-stage unit capable of a maximum lift height of 43 inches from the ground line. It lifts 6000 pounds through the first stage lift of 24 inches and 3000 pounds through the second stage lift of 19 inches. The fork and outer jacket form an integral unit which is swivelled about the actuator axis. The outer jacket and telescoping sleeves are splined together so that by locking the inner sleeve to the traversing beam, a swivel lockout is accomplished. The actuating cylinder is internal to the inner splined sleeve and its rods serve as the fluid transfer system.

The vehicle controls are mounted in a swinging pedestal and on a fixed console. The pedestal swings so that the operator may face forward and have the primary controls in front of him regardless of vehicle travel direction The pedestal may also be positioned so that the vehicle can be operated from the ground. The pedestal contains the differential steering levers, throttle, lift and traverse controls, and a runaway switch which will act to stop and lock in position all phases of motion of the vehicle.

The console contains the starting controls, the direction and speed shift controls, and the hydraulic, electrical, fuel, and engine systems gaging.

SPECIAL TRUCK TRANSPORTS

HI-LO TRANSPORT TRUCKS

The HI-LO Truck Corporation of San Leandro, California, manufactures trucks and trailers whose beds are capable of being raised or lowered to match dock level (Figure 50). These vehicles have front wheel drive only, and can be tilted to the rear or front.

This vehicle was considered in the loading and unloading of the Army aircraft because the tilting bed can be aligned to match the aircraft cargo floor.

NORTRONICS' AIRCRAFT CARGO HANDLING VEHICLE CONCEPTS

REQUIREMENTS

The Nortronics - Systems Support cargo-handling vehicle concepts were based on providing vehicles capable of unloading, loading, and transporting palletized cargo at the joint Air Force-Army air facility and Army airheads. As such, they must be air transportable; be compatible with Air Force-Army logistic equipment; and be capable of performing cargo handling operations from rough, unprepared areas under extreme climatic conditions. To meet these requirements, the Nortronics vehicles have the following characteristics:

1. Self-propelled - do not require prime moving equipment
2. Off-road capabilities - can traverse most rugged operational terrain or operate in mud, sand, snow
3. Gasoline engine powered - uses most common military fuel
4. Lightweight and compact - air deliverable
5. Performs entire handling operation - can load, unload, and transport cargo to other aircraft or using forces; helicopter can lift loads directly from the deck. Can unload transport aircraft without entering cargo compartment

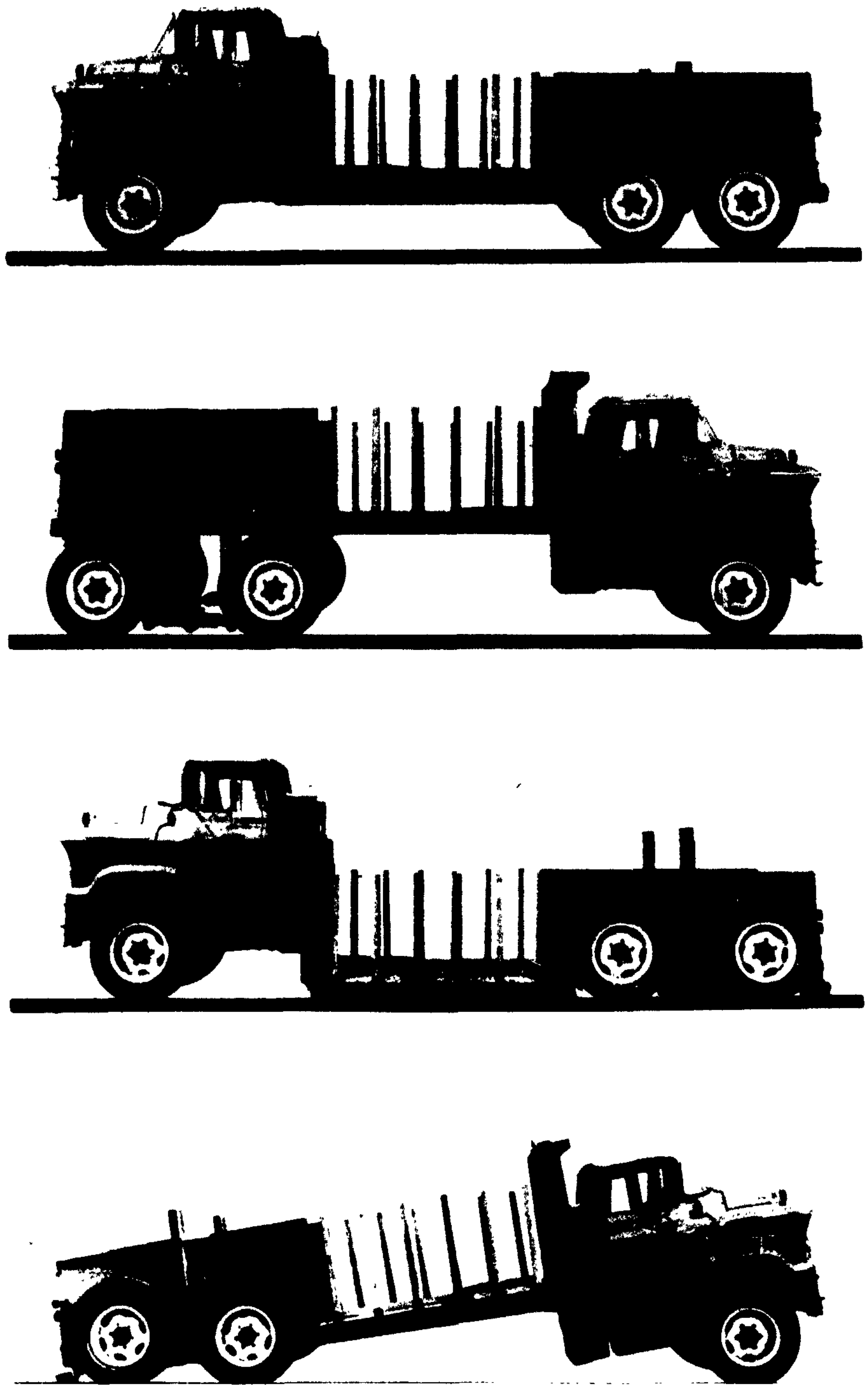


Figure 50. Hi-Lo Truck

6. Mobile - can serve as cargo carriers over long distances if required

7. Compatible with Air Force-Army transport aircraft and logistic equipment, and the 463L System

8. Capable of handling single or multiple packages

9. Capable of loading pallets from the ground

10. Utilizes winch to load or unload aircraft

11. Cargo platform can be elevated, tilted, or rotated

12. Incorporates existing, available, service-proven components and materiel.

TRACKED CARGO HANDLING VEHICLE

Description

The tracked cargo loader is a lightweight, self-propelled vehicle designed to load, unload, and transport palletized cargo rapidly to and from aircraft and storage facilities (Figures 51 and 52).

The loader is compatible with the 463L Materials Handling System, military cargo aircraft, and Army logistic equipment. In the design of this vehicle maximum use is made of standard components, or modifications of existing components to minimize development time and expense.

Full-tracked, the loader is capable of operating over any kind of terrain or in any kind of climatic condition. Lightweight and compact, the vehicle may be air transported or air dropped by parachute. The vehicle is powered by a six-cylinder gasoline engine and has three forward speeds and one reverse. Directional control is accomplished by brake levers actuating a controlled steering differential which slows one track and speeds the other. The cargo platform, equipped with conveyor rollers, can accommodate one 108 by 88 inch or two 54 by 88 inch 463L logistics pallets. The vehicle can

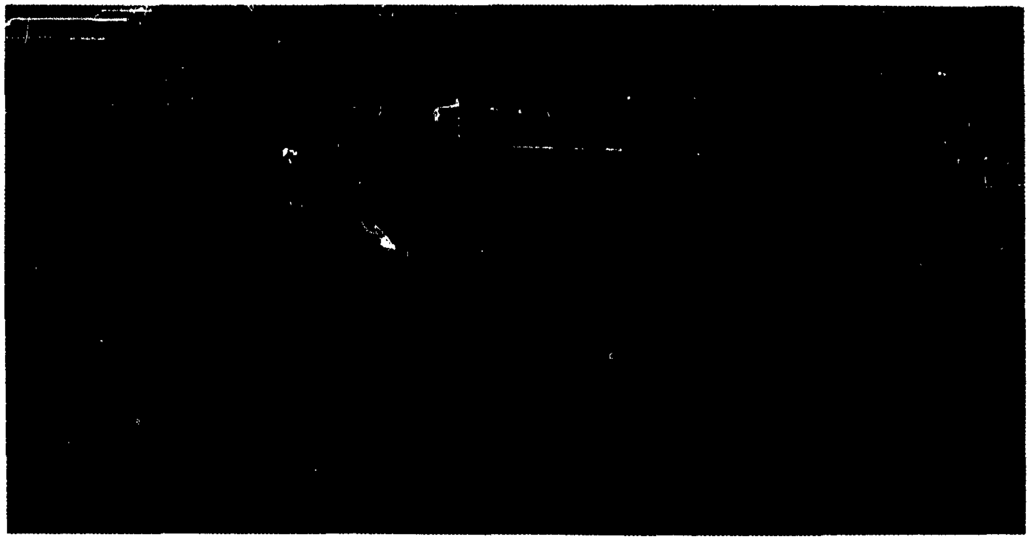


Figure 51. Nortronics' Tracked Cargo-Handling Vehicle

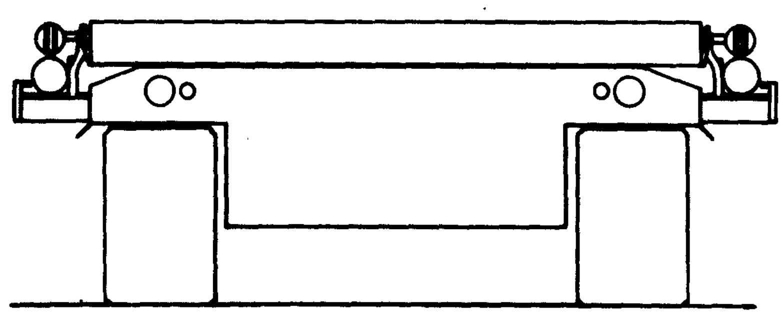
transport a 10,000 pound payload. Maximum speed is approximately 20 miles per hour. The vehicle can negotiate 30 percent side slope and a 45 percent grade.

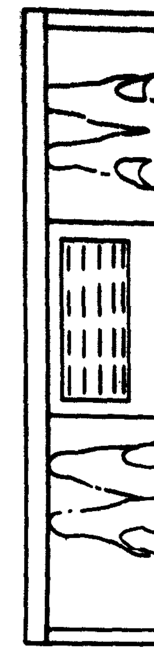
The concept features a tiltable, extendable cargo platform that is rotatable through 5 degrees. A boom arrangement with stabilizing outriggers is used to lift cargo on to or off of the cargo deck. In addition, the rollers in the cargo deck are automatically extended to provide a low-friction surface when the cargo deck is elevated. A cargo winch is incorporated in the design. The cargo boom and platform elevating system is removable for air transport.

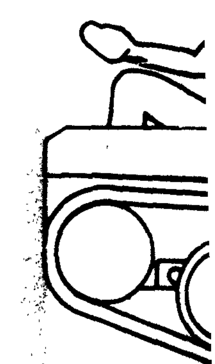
<u>Specifications</u>

Dimensions (Inches)

Length	150
Width	110
Reducible to	88







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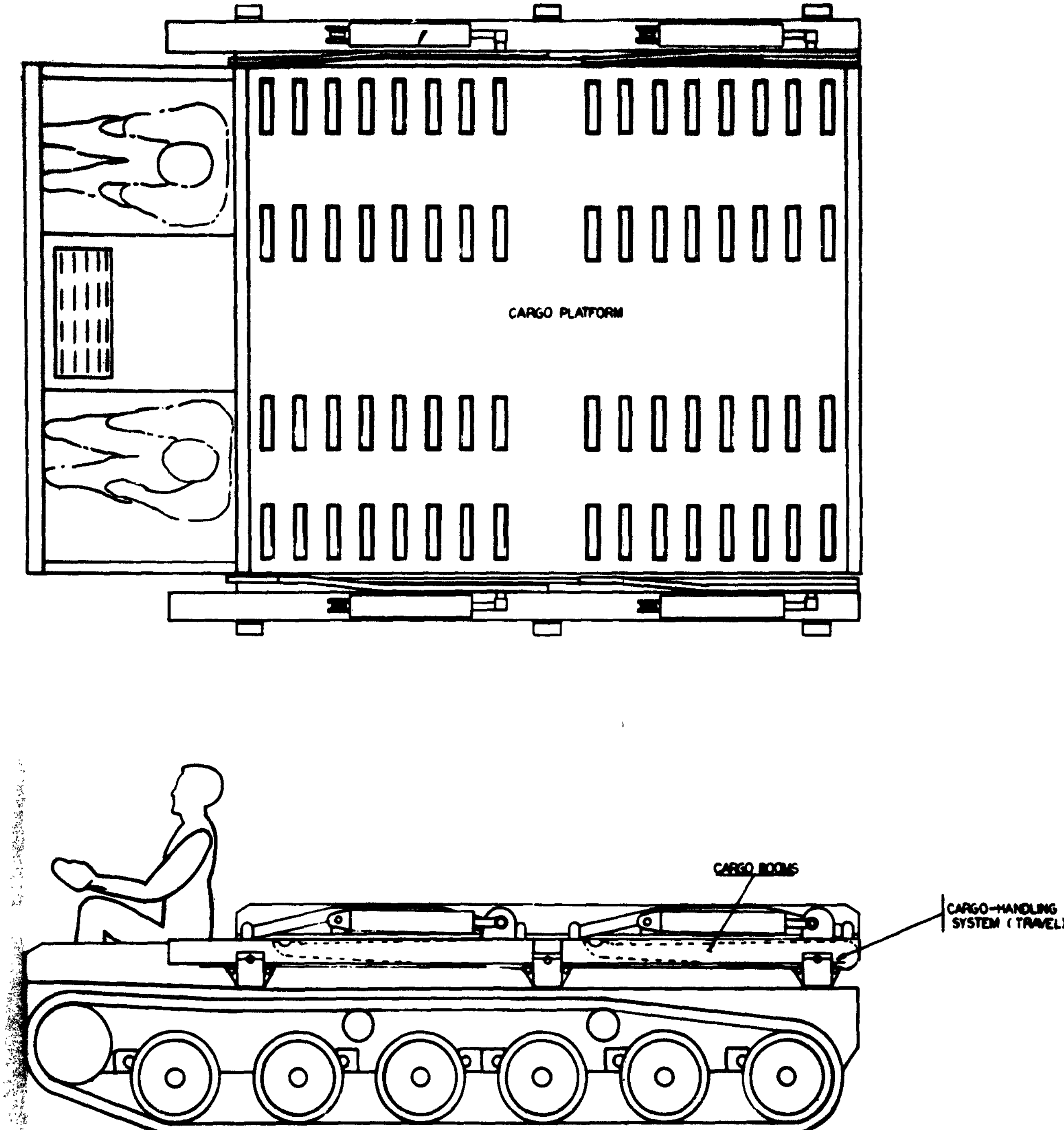


Figure 52. Nortronics'Tracked Cargo-Handling Vehicle

Specifications (Cont.)

Height (Top of Platform)	
Minimum operational	Ground
Maximum operational	60
Weight (Pounds)	
Curb	8000
Gross	18,000
Power Package	
Engine	Six cylinder gasoline, maximum gross horsepower 119 bhp at 3600 rpm
Transmission	Four-speed automatic with torque converter
Steering	Controlled steering differential
Tracks	16 inch, band type
Suspension	Transverse torsion bar

Operation

The cargo-handling system is based on two sets of hydraulically actuated booms sliding on rails mounted externally on the basic vehicle frame. When the booms are made to slide forward on the rails, detents in the booms engage the cargo platform and allow the platform to be raised, tilted, or rolled, depending on the combination of booms actuated. Elevating the boom also automatically extends the cargo rollers from the cargo deck, providing a low-friction surface. When the platform descends, the rollers retract, providing a safe low-friction surface for cargo transportation. The rollers may also be locked in the extended or retracted position if desired. When the booms are made to slide to the rear of the rails, they disengage from the cargo platform and serve as cargo handling booms capable of lifting cargo off the ground on to the cargo platform or from the platform to the ground. The booms may be adjusted laterally to handle any size pallets from 88 inches to 110 inches wide. Telescoping side rails are built into the sides of the cargo platform to extend the platform width from 88 inches to 110 inches if necessary.

WHEELED CARGO-HANDLING VEHICLE

Description

Like the tracked cargo vehicle previously discussed, the wheeled cargo loader is a self-propelled vehicle designed to load, unload, and transport palletized cargo rapidly to and from aircraft and storage facilities (Figures 53, 54, and 55). The loader is compatible with the 463L Materials Handling System, military cargo aircraft, and army logistic equipment. In the design of this unit, maximum use is made of standard components, or modifications of existing components to minimize development time and expense.

Large, off-the-road, low-pressure tires and four-wheel drive, with the option of independent power supply to either rear wheel, permit the vehicle to operate over any type of terrain and in any kind of climatic conditions. The vehicle may be air delivered by military cargo aircraft, such as the C-130.

The vehicle is powered by a four-cylinder gasoline engine, and has four forward speeds and one reverse speed. Power is provided to the front wheels mechanically and to the rear wheels hydraulically. Independent, hydraulic, proportional, power steering is provided for both front and rear wheels. This steering arrangement permits a minimum turn radius of 23-1/2 feet and a maximum sidewise crab of 20 degrees (Figure 56). The loader may be operated from the cab or remotely by the driver walking alongside the vehicle. The 88 by 158 inch dimension of the cargo platform can accommodate the 463L and Quartermaster pallets and various STRAC container combinations. The vehicle can transport a 10,000 pound payload at a maximum highway speed of 25 miles per hour. Fully loaded, the vehicle can negotiate a 30 percent slope and a 40 percent grade.

This concept features a tiltable cargo platform which may be either retracted or elevated. In addition, the platform may be rotated

Figure 53. Nortronics' Wheeled Cargo-Handling Vehicle

Figure 54. Nortronics' Wheeled Cargo-Handling Vehicle

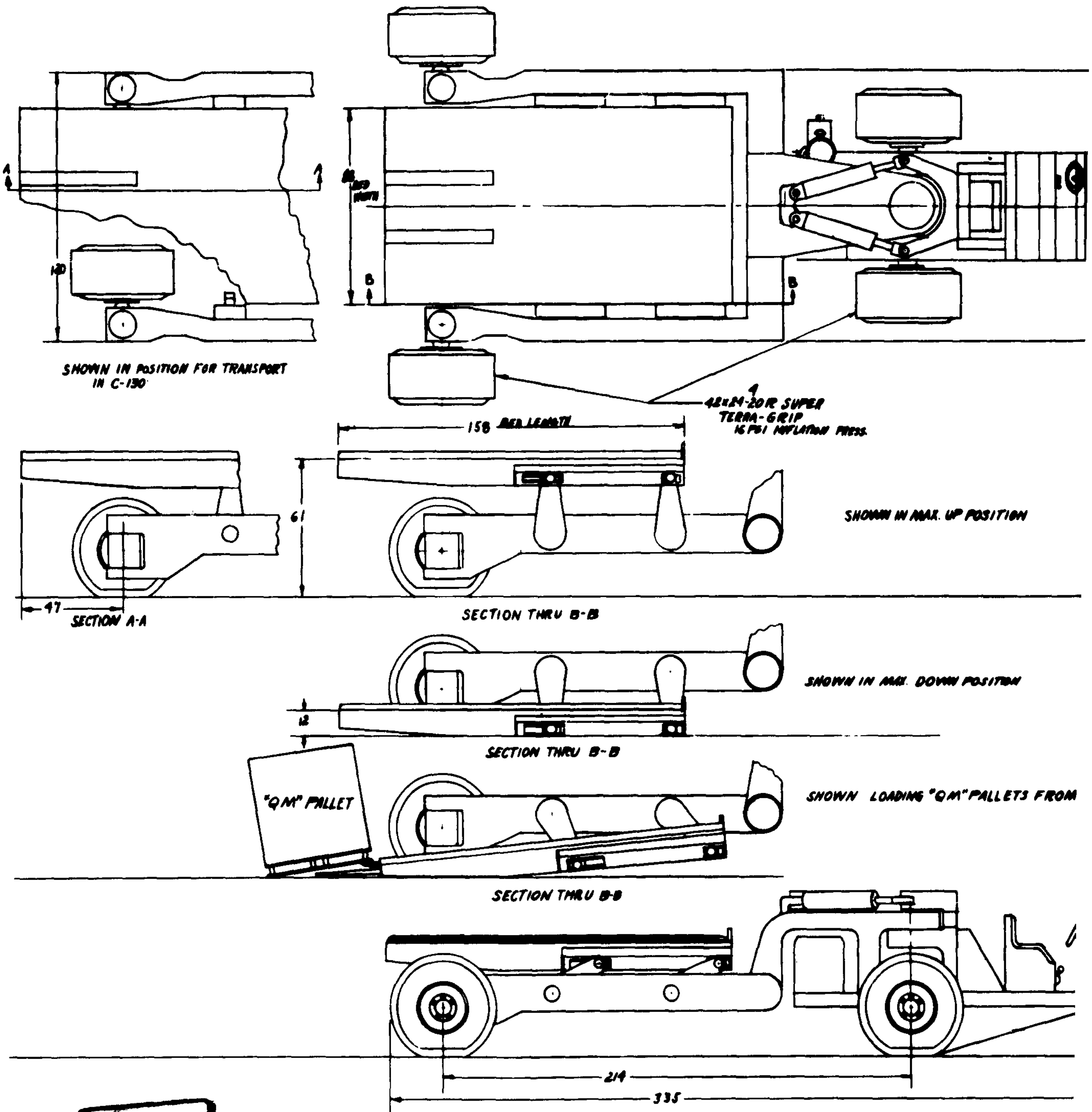


Figure 55. Nortro
Vehicl

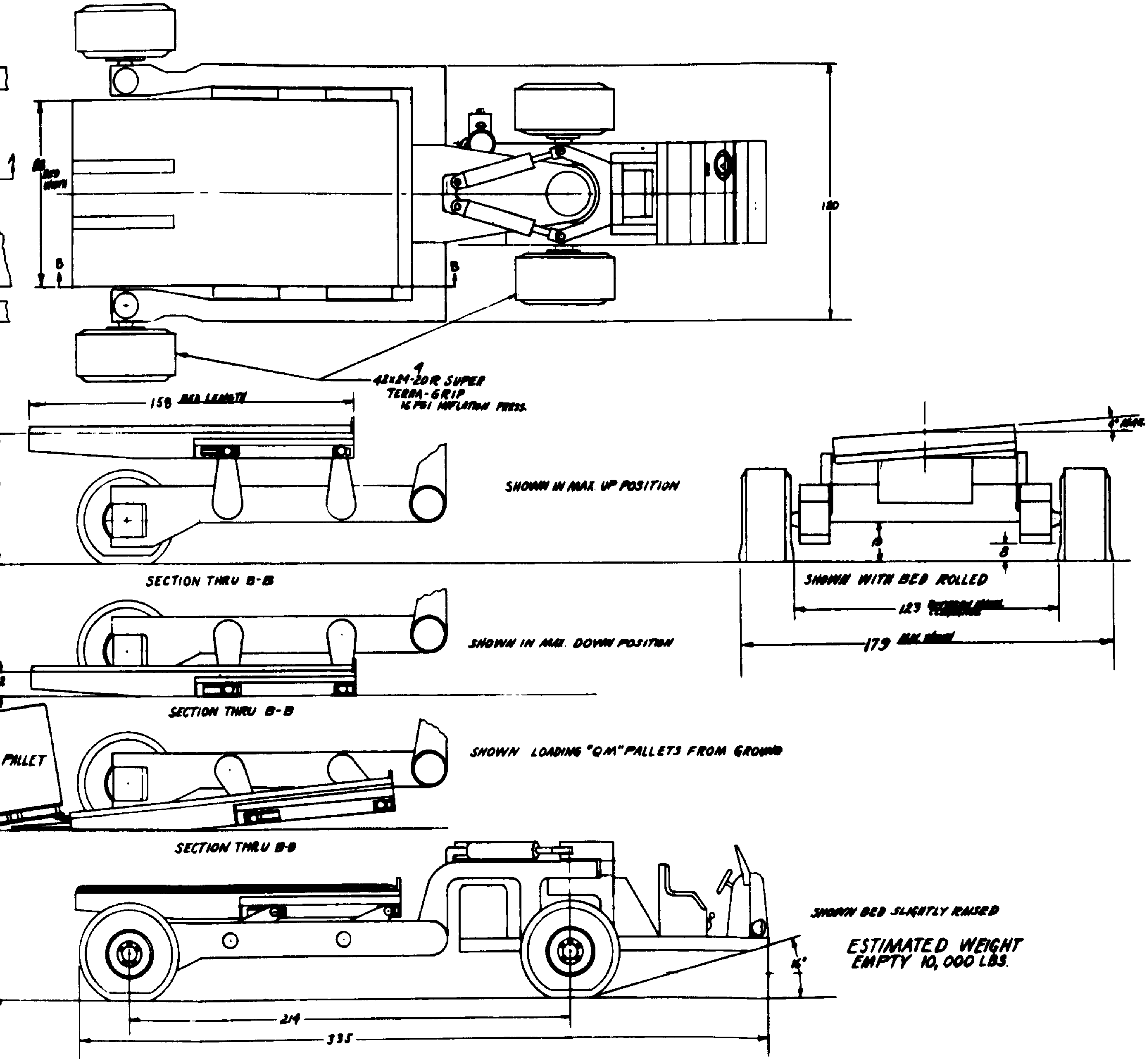


Figure 55. Nortronics' Wheeled-Cargo Handling Vehicle Bed Configurations

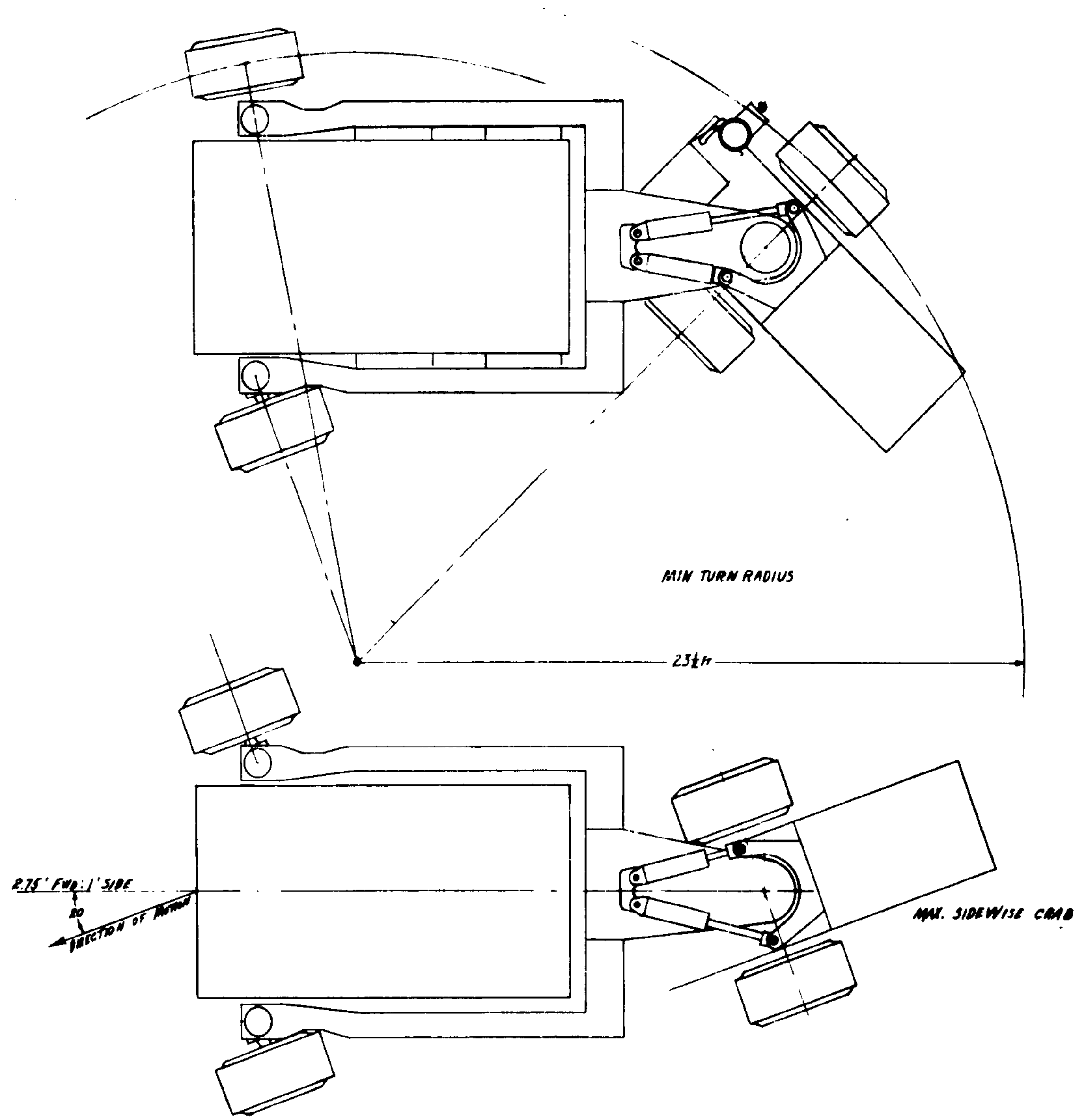


Figure 56. Nortronics' Wheeled Cargo-Handling Vehicle Maneuvering Configurations

through 4 degrees. A winch and a powered conveyor belt system on the platform are provided for cargo on-and-off loading.

Specifications

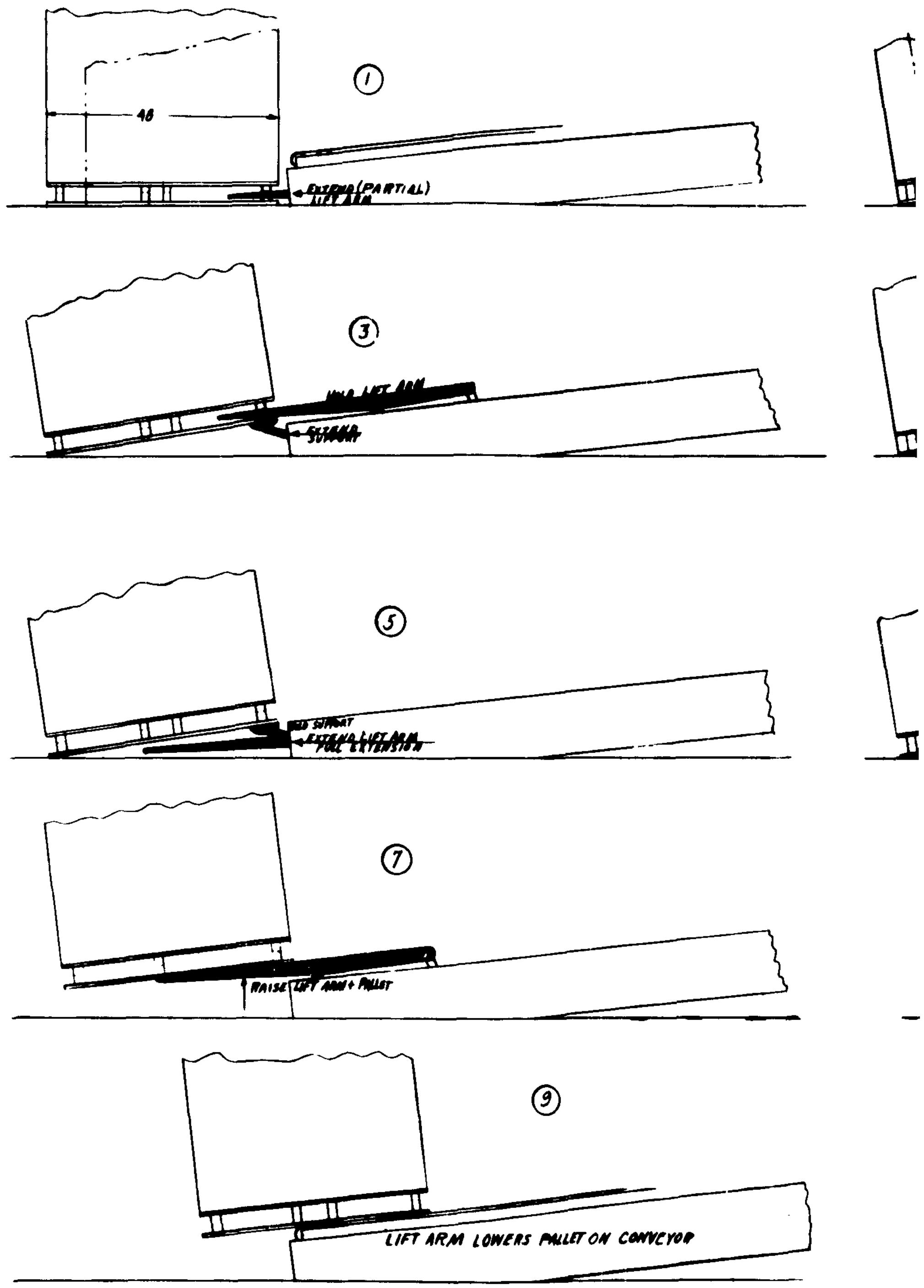
Dimensions (Inches)	
Length	335
Width	179
Reducible to	120
Height (Top of Platform)	
Minimum operational	12
Maximum operational	61
Weight (Pounds)	
Curb	10,000
Gross	20,000
Power Package	
Engine	M-151 1/4-ton Tactical Utility Truck; 4 cylinder; gasoline; water cooled; 73 bhp at 4200 rpm (max. gross); 124.5-lb-ft torque at 1800 rpm (max)
Power Train	
Standard transmission	M-151 1/4 ton
Four-speed manual shift	M-151 Tactical Utility Truck
Suspension	Unsprung. Four tires: 42 x 42-20R Super Terra-Gripp; 16 psi.

Operation

Basically, the vehicle is loaded from the rear, utilizing extendable lift arms, positionable cargo platform, independently operated conveyor belts, and a vehicle-mounted winch. The loading operation may be conducted either from the cab or remotely from the rear alongside of the vehicle. The following discussion presents two loading modes to be used for Quartermaster and 463L system pallets respectively.

Quartermaster Pallet Loading Sequence (Figure 57).

Step	Action
1.	a. Lower platform to position parallel to and in proximity with ground.
	b. Back vehicle to within approximately 6 inches of pallet.
	c. Drop rear of platform to ground and extend pallet lift arms to enter pallet openings, approximately 10 inches.
2.	Raise pallet lift arms and pallet end approximately 12 inches.
3.	Extend pallet support to position below pallet lower face.
4.	Lower pallet lift arms, allowing pallet to rest on pallet support.
5.	Retract pallet lift arms; lower arms to lowest position; re-extend lift arm to maximum extension.
6.	Retract pallet support.
7.	Raise lift arms to maximum height raising supported pallet.
8.	Retract lift arms and lift pallet.
9.	Lower lift arms placing pallet on conveyor rollers; lower lift arm to initial position.
10.	Actuate conveyor roller and move pallet aboard.
11.	Continue similar procedure with other pallets.


48
1
EXTEND (PARTIAL) LIFT ARM
3
HOLD LIFT ARM
EXTEND SUPPORT
5
EXTEND LIFT ARM FULL EXTENSION
7
RAISE LIFT ARM + PALLET
9
LIFT ARM LOWERS PALLET ON CONVEYOR

1

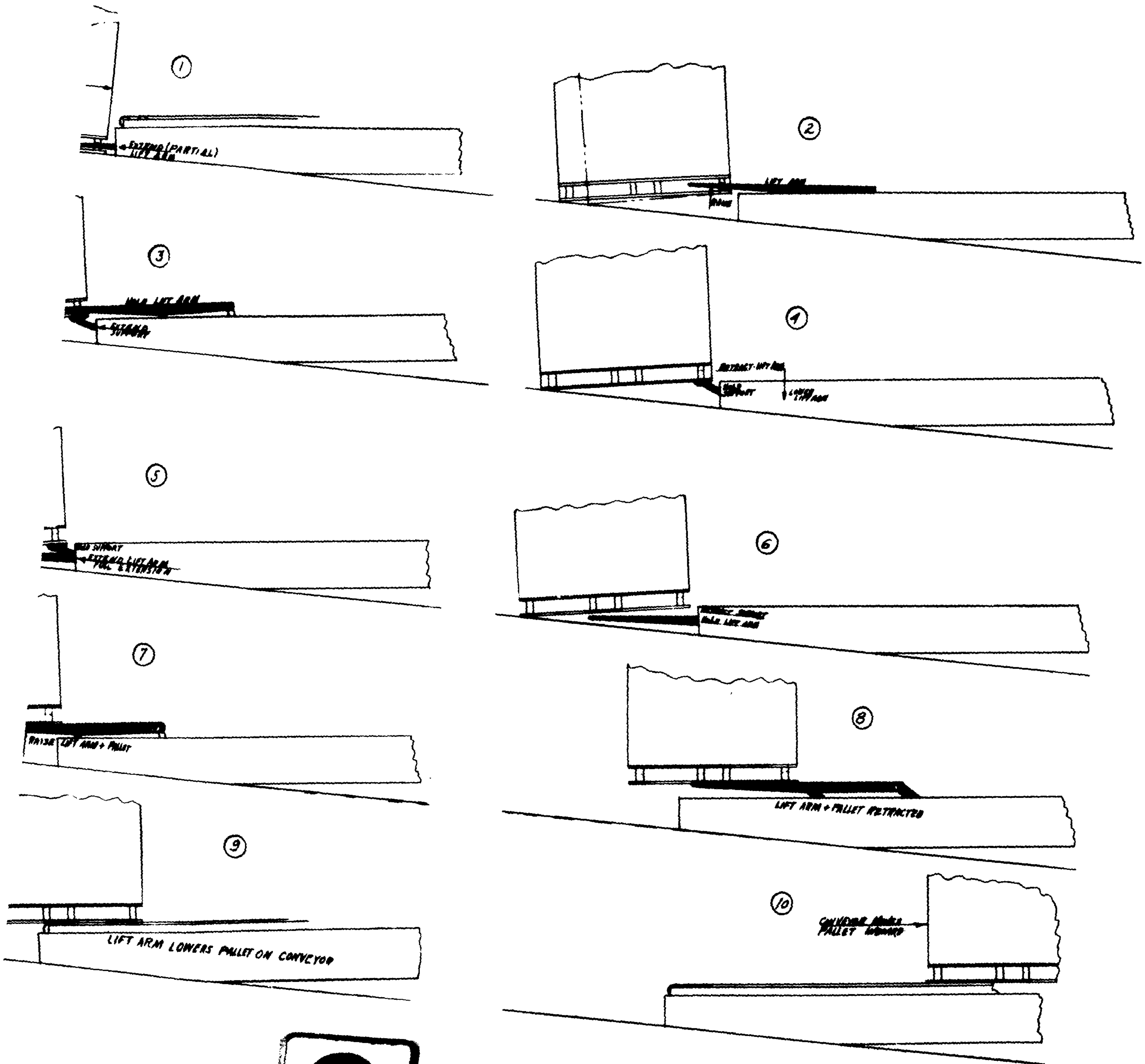


Figure 57. Nortronics' Wheeled Cargo-Handling Vehicle Quartermaster Pallet Loading Sequence

463L System Pallet Loading Sequence (Figure 58).

Step		Action
1.	a.	Drop rear of platform; raise front of platform.
	b.	Elevate front of platform to increase the platform-to-ground angle.
2.		Extend pallet lift arms so that they burrow under pallet edge. If pallet is on a hard surface, such as concrete, attach the vehicle winch cable to the load and winch onto the arms.
3.		Raise pallet end about 10 inches by raising lift arms.
4.		By carefully inching vehicle toward pallet and simultaneously slowly retracting lift arms, the pallet end may be placed on vehicle bed.
5.		Using winch cable and winch, pallet mav be winched aboard.

STANDARD MILITARY TRUCK TRANSPORTS

As background information for the establishment of the characteristics of the mobile pallet and the bridging concepts, a summary of typical military trucks was compiled (Table 8). Only those trucks which might be utilized in forward areas were included.

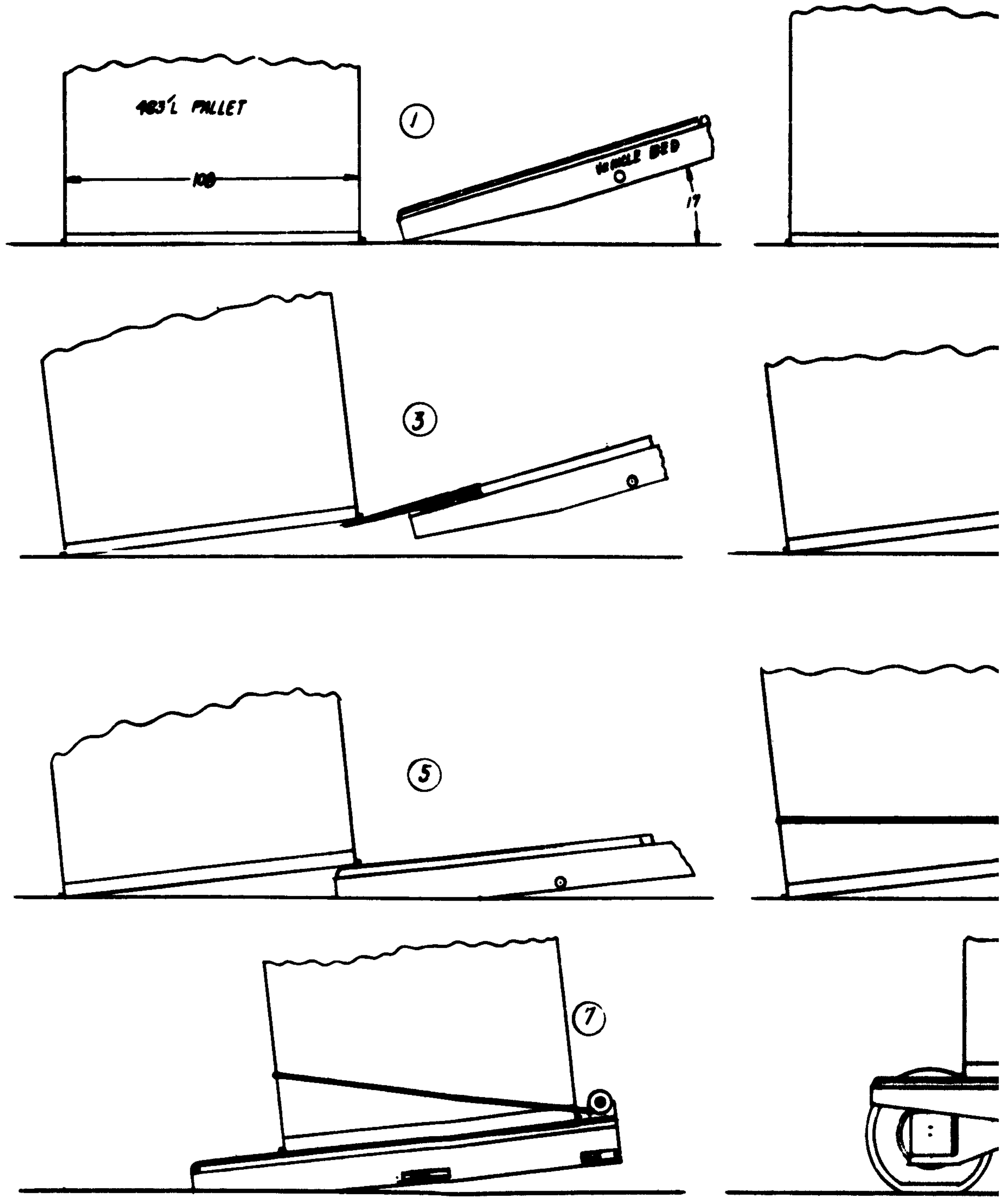


Figure 58.

1

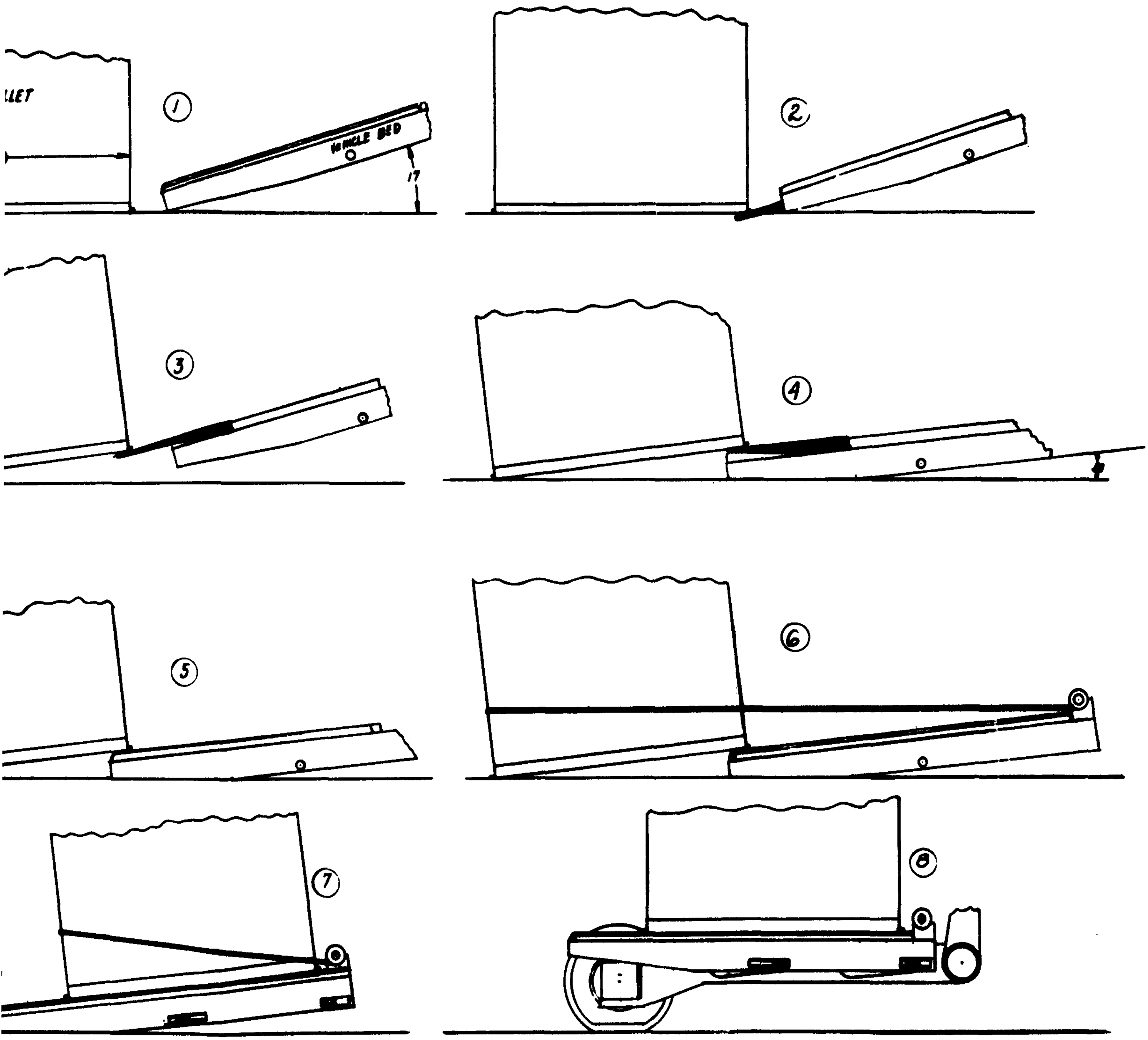


Figure 58. Nortronics' Wheeled Cargo-Handling 463L System Pallet Loading Sequence

1

TABLE 8
MILITARY VEHICLES

Vehicles	Loading Height Empty (Inches)	Winch Frt.	Winch Mid Section	Bed & Cab Height	Cargo Bed Size Length (Inches)	Cargo Bed Size Width (Inches)	Cargo Bed Size Height (Inches)
7-1/2 Ton, Truck, Prime Mover	63-1/4	X	X	124-1/4	132	96	58
6 Ton, Truck, Prime Mover and Cargo	58-3/4	-	X	114	90	92	43-1/4
6 Ton, Truck, Prime Mover	57-1/2	-	X	120	132	93	60
6 Ton, Truck, Cargo	58	-	X	119	132	88	59
5 Ton, Truck, Cargo	48-7/8	-	-	111-1/8-88	168	92	60
*5 Ton, Truck, Cargo	54-7/8	X	-	116	168	88	60
4 Ton, Truck, Ponton	58-1/2	X	-	119-84	147	88	59
4 Ton, Truck, Cargo	58-1/2	X	-	119-84	147	88	59
4 Ton, Truck, Cargo	58-5/16	X	X	118-1/2-84	132	88	59
4 Ton, Truck, Cargo	58-5/16	X	-	118-1/2-84	132	88	59
4 Ton, Truck, Cargo	58-5/16	-	-	118-1/2	132	88	59
*2-1/2 Ton, Truck, Cargo and Dump	49-1/2	X	-	110	120	81-1/2	64
*2-1/2 Ton, Truck, Cargo	45	X	-	105-80	147	80	60
*2-1/2 Ton, Truck, Cargo	51-1/16	X	-	124-1/2	204	88	60
*2-1/2 Ton, Truck, Cargo	51	X	-	111	147	88	60
*2-1/2 Ton, Truck, Cargo	43-1/2	X	-	104-5/8-82	147	80	60
2-1/2 Ton, Truck, Cargo	49-1/2	-	-	106-84	200	80	59
*2-1/2 Ton, Truck, Cargo	48-1/2	X	-	93	144	81-1/2	64
*2-1/2 Ton, Truck, Cargo	48-1/2	X	-	93-76	120	81-1/2	64
*2-1/2 Ton, Truck, Cargo	51-1/8	X	-	112-1/8	147	88	-
2-1/2 Ton, Truck, Cargo	49-1/2	-	-	106-84	176	80	59
2-1/2 Ton, Truck, Cargo.	48-1/2	-	-	93	144	81-1/2	64
2-1/2 Ton, Truck, Stake and Platform	45-1/2	-	-	91-1/4	168	84	42
2-1/2 Ton, Truck, Stake and Platform	46-7/8	-	-	88-7/8	192-3/4	90	42
*1-1/2 Ton, Truck, Personnel and Cargo	31	X	-	87-67-1/2	120	48-1/4	54
1-1/2 Ton, Truck, Stake and Platform	52	-	-	99	193	89-1/2	42
1-1/2 Ton, Truck, Cargo	47	X	-	104-1/2-87	108	70	59-14
1-1/2 Ton, Truck, Cargo	47	-	-	106-87	180	70	59
1-1/2 Ton, Truck, Cargo	46	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

7-1/2 Ton, Truck, Prime Mover	63-1/4	X	X	124-1/4	132	96	58
6 Ton, Truck, Prime Mover and Cargo	58-3/4	-	X	114	90	92	43-1/4
6 Ton, Truck, Prime Mover	57-1/2	-	X	120	132	93	60
6 Ton, Truck, Cargo	58	-	X	119	132	88	59
5 Ton, Truck, Cargo	48-7/8	-	-	111-1/8-88	168	92	60
*5 Ton, Truck, Cargo	54-7/8	X	-	116	168	88	60
4 Ton, Truck, Ponton	58-1/2	X	-	119-84	147	88	59
4 Ton, Truck, Cargo	58-1/2	X	-	119-84	147	88	59
4 Ton, Truck, Cargo	58-5/16	X	X	118-1/2-84	132	88	59
4 Ton, Truck, Cargo	58-5/16	X	-	118-1/2-84	132	88	59
4 Ton, Truck, Cargo	58-5/16	-	-	118-1/2	132	88	59
*2-1/2 Ton, Truck, Cargo and Dump	49-1/2	X	-	110	120	81-1/2	64
*2-1/2 Ton, Truck, Cargo	45	X	-	105-80	147	80	60
*2-1/2 Ton, Truck, Cargo	51-1/16	X	-	124-1/2	204	88	60
*2-1/2 Ton, Truck, Cargo	51	X	-	111	147	88	60
*2-1/2 Ton, Truck, Cargo	43-1/2	X	-	104-5/8-82	147	80	60
2-1/2 Ton, Truck, Cargo	49-1/2	-	-	106-84	200	80	59
*2-1/2 Ton, Truck, Cargo	48-1/2	X	-	93	144	81-1/2	64
*2-1/2 Ton, Truck, Cargo	48-1/2	X	-	93-76	120	81-1/2	64
*2-1/2 Ton, Truck, Cargo	51-1/8	X	-	112-1/8	147	88	-
2-1/2 Ton, Truck, Cargo	49-1/2	-	-	106-84	176	80	59
2-1/2 Ton, Truck, Cargo.	48-1/2	-	-	93	144	81-1/2	64
2-1/2 Ton, Truck, Stake and Platform	45-1/2	-	-	91-1/4	168	84	42
2-1/2 Ton, Truck, Stake and Platform	46-7/8	-	-	88-7/8	192-3/4	90	42
*1-1/2 Ton, Truck, Personnel and Cargo	31	X	-	87-67-1/2	120	48-1/4	54
1-1/2 Ton, Truck, Stake and Platform	52	-	-	99	193	89-1/2	42
1-1/2 Ton, Truck, Cargo	47	X	-	104-1/2-87	108	70	59-14
1-1/2 Ton, Truck, Cargo	47	-	-	106-87	180	70	59
1-1/2 Ton, Truck, Cargo	46	-	-	106-87	108	70	59
1-1/2 Ton, Truck, Stake and Platform	46-5/16	-	-	90-1/2	140	80	42
1-1/2 Ton, Truck, Stake and Platform	43-7/8	-	-	83	142	82	57
1-1/2 Ton, Truck, Stake and Platform	43-7/8	-	-	82-1/4	106	82-1/16	57
1-1/2 Ton, Truck, Stake and Platform	46	-	-	99	140-1/2	82	57
1-1/2 Ton, Truck, Stake and Platform	44	-	-	86	140-1/2	82	42
1-1/2 Ton, Truck, Stake and Platform	49	-	-	88	141-1/2	80-3/4	38-1/2
1-1/2 Ton, Truck, Cargo	46	-	-	107	140-1/2	82	58
1-1/2 Ton, Truck, Cargo	43-7/8	-	-	105	142	82	57
1 Ton, Van	28-3/8	-	-	74-1/4	73-3/4	48-1/2	57
1 Ton Pickup	28-3/8	-	-	74-1/4	78-5/8	48-1/2	44-1/2
1 Ton Pickup	29	-	-	77-3/4	96-1/16	54	22-7/16
1 Ton Carryall	35	-	-	81-1/4	84-1/2	53-3/4	50-3/4
1 Ton Panel	34	-	-	85	108-5/8	62-7/8	51-5/8
3/4 Ton Truck Command	33	-	-	89-3/4	78	64	53-3/4
3/4 Ton Truck Carryall	29	-	-	80-7/32	-	-	-
*3/4 Ton Truck Cargo	29-3/4	X	-	89-1/2-63-1/2	78	64	55-3/4
3/4 Ton Truck Pickup	31-1/8	-	-	75-3/4	90	48-1/4	42-1/2
3/4 Ton Truck Pickup	30-3/4	-	-	79-3/4	90	54	47
3/4 Ton Truck Pickup	32	-	-	78	87	50	16-1/4
1/2 Ton Truck Pickup	27	-	-	74-3/4	78-3/4	49	50
1/2 Ton Truck Pickup	27	-	-	76	78	49	20
1/2 Ton Truck Pickup	25-3/4	-	-	74-1/16	78	48-1/2	56
1/2 Ton Truck Pickup	29	-	-	79-1/4	78-1/8	49	48
1/2 Ton Truck Pickup	29	-	-	79-73-1/2	78	48-1/2	56
1/2 Ton Truck Pickup	30	-	-	76	78	50	16-1/4
1/2 Ton Truck Panel	28-1/2	-	-	83	-	-	-
1/2 Ton Truck Panel	28-1/2	-	-	84	77-5/8	61-13/16	51-1/8
1/2 Ton Truck Carryall	27-1/2	-	-	80	91-1/2	61-3/4	50-3/4
1/2 Ton Truck Carryall	27-1/2	-	-	80	91-1/2	61-13/16	50-3/4
20 Ton Trailer Cargo, Tracked	53	-	-	132	216	106	72
8 Ton Trailer Ammo	34	-	-	83	140	-	-
6 Ton Trailer Tracked	52	-	-	134	132	80	72
6 Ton Trailer Tracked	40	-	-	80	120	72	27
4 Ton Trailer Ammo, 2-Wheel	35	-	-	75	-	-	-
1-1/2 Ton Trailer Cargo, 2-Wheel	40	-	-	99-1/8	110	74	60
1 Ton Trailer Cargo, 2-Wheel	31-1/4	-	-	73	96	46-1/4	-
3/4 Ton Trailer Cargo, 2-Wheel	35	-	-	83	96	65-1/2	48
9 Ton Tractor, Cargo	57-3/4	-	-	120	157	114-1/2	62-1/4
2.6 Tons, Carrier Half-Track	-	X	-	106	85	80	-
2.7 Tons, Carrier Half-Track	-	X	-	89	85	75	-
2.5 Tons, Car Half-Track	-	X	-	100-87-1/2	85	87-1/2	-

*2-1/2 Ton, Truck, Cargo	48-1/2	X	-	93-76	120	81-1/2	64
*2-1/2 Ton, Truck, Cargo	51-1/8	X	-	112-1/8	147	88	-
2-1/2 Ton, Truck, Cargo	49-1/2	-	-	106-84	176	80	59
2-1/2 Ton, Truck, Cargo.	48-1/2	-	-	93	144	81-1/2	64
2-1/2 Ton, Truck, Stake and Platform	45-1/2	-	-	91-1/4	168	84	42
2-1/2 Ton, Truck, Stake and Platform	46-7/8	-	-	88-7/8	192-3/4	90	42
*1-1/2 Ton, Truck, Personnel and Cargo	31	X	-	87-67-1/2	120	48-1/4	54
1-1/2 Ton, Truck, Stake and Platform	52	-	-	99	193	89-1/2	42
1-1/2 Ton, Truck, Cargo	47	X	-	104-1/2-87	108	70	59-14
1-1/2 Ton, Truck, Cargo	47	-	-	106-87	180	70	59
1-1/2 Ton, Truck, Cargo	46	-	-	106-87	108	70	59
1-1/2 Ton, Truck, Stake and Platform	46-5/16	-	-	90-1/2	140	80	42
1-1/2 Ton, Truck, Stake and Platform	43-7/8	-	-	83	142	82	57
1-1/2 Ton, Truck, Stake and Platform	43-7/8	-	-	82-1/4	106	82-1/16	57
1-1/2 Ton, Truck, Stake and Platform	46	-	-	99	140-1/2	82	57
1-1/2 Ton, Truck, Stake and Platform	44	-	-	86	140-1/2	82	42
1-1/2 Ton, Truck, Stake and Platform	49	-	-	88	141-1/2	80-3/4	38-1/2
1-1/2 Ton, Truck, Cargo	46	-	-	107	140-1/2	82	58
1-1/2 Ton, Truck, Cargo	43-7/8	-	-	105	142	82	57
1 Ton, Van	28-3/8	-	-	74-1/4	73-3/4	48-1/2	57
1 Ton Pickup	28-3/8	-	-	74-1/4	78-5/8	48-1/2	44-1/2
1 Ton Pickup	29	-	-	77-3/4	96-1/16	54	22-7/16
1 Ton Carryall	35	-	-	81-1/4	84-1/2	53-3/4	50-3/4
1 Ton Panel	34	-	-	85	108-5/8	62-7/8	51-5/8
3/4 Ton Truck Command	33	-	-	89-3/4	78	64	53-3/4
3/4 Ton Truck Carryall	29	-	-	80-7/32	-	-	-
*3/4 Ton Truck Cargo	29-3/4	X	-	89-1/2-63-1/2	78	64	55-3/4
3/4 Ton Truck Pickup	31-1/8	-	-	75-3/4	90	48-1/4	42-1/2
3/4 Ton Truck Pickup	30-3/4	-	-	79-3/4	90	54	47
3/4 Ton Truck Pickup	32	-	-	78	87	50	16-1/4
1/2 Ton Truck Pickup	27	-	-	74-3/4	78-3/4	49	50
1/2 Ton Truck Pickup	27	-	-	76	78	49	20
1/2 Ton Truck Pickup	25-3/4	-	-	74-1/16	78	48-1/2	56
1/2 Ton Truck Pickup	29	-	-	79-1/4	78-1/8	49	48
1/2 Ton Truck Pickup	29	-	-	79-73-1/2	78	48-1/2	56
1/2 Ton Truck Pickup	30	-	-	76	78	50	16-1/4
1/2 Ton Truck Panel	28-1/2	-	-	83	-	-	-
1/2 Ton Truck Panel	28-1/2	-	-	84	77-5/8	61-13/16	51-1/8
1/2 Ton Truck Carryall	27-1/2	-	-	80	91-1/2	61-3/4	50-3/4
1/2 Ton Truck Carryall	27-1/2	-	-	80	91-1/2	61-13/16	50-3/4
20 Ton Trailer Cargo, Tracked	53	-	-	132	216	106	72
8 Ton Trailer Ammo	34	-	-	83	140	-	-
6 Ton Trailer Tracked	52	-	-	134	132	80	72
6 Ton Trailer Tracked	40	-	-	80	120	72	27
4 Ton Trailer Ammo, 2-Wheel	35	-	-	75	-	-	-
1-1/2 Ton Trailer Cargo, 2-Wheel	40	-	-	99-1/8	110	74	60
1 Ton Trailer Cargo, 2-Wheel	31-1/4	-	-	73	96	46-1/4	-
3/4 Ton Trailer Cargo, 2-Wheel	35	-	-	83	96	65-1/2	48
9 Ton Tractor, Cargo	57-3/4	-	-	120	157	114-1/2	62-1/4
2.6 Tons, Carrier Half-Track	-	X	-	106	85	80	-
2.7 Tons, Carrier Half-Track	-	X	-	89	85	75	-
2.5 Tons, Car Half-Track	-	X	-	100-87-1/2	85	87-1/2	-

*Reference TM 9-2800
TO 19-75A-89

APPENDIX II. MOBILE PALLET DESIGN ANALYSIS

PALLET REQUIREMENTS

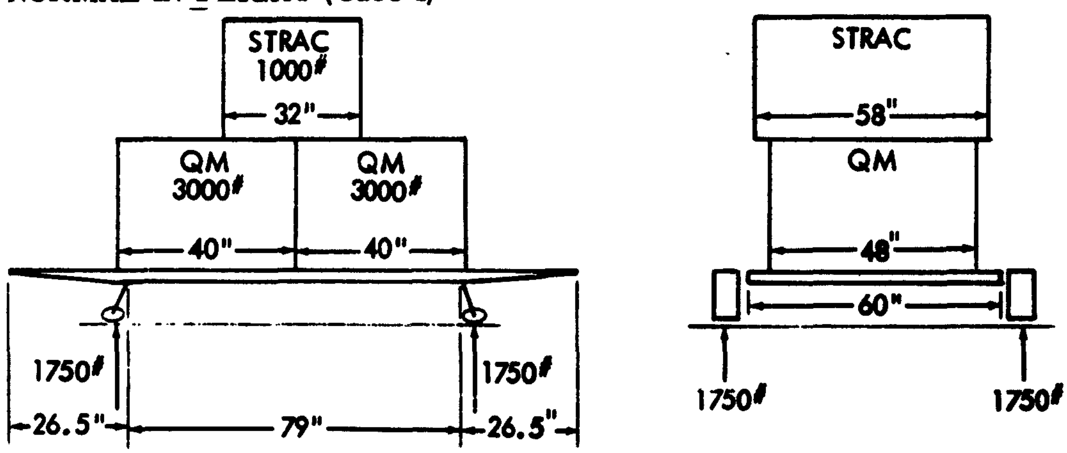
In the design of the mobile consolidating pallet, certain factors, which are dependent upon the extreme operating condition, must be established. These factors are:

Pallet load	- 7000 pounds maximum
Load factor	- 2.0 g maximum
Size: length	- 132 inches
Width	- 60 inches
Height	- 8 inches
Thickness	- 2.5 inches
Load conditions	- Helicopter lifting
	- In-flight attitude
	- Forklifted

PALLET LOADING

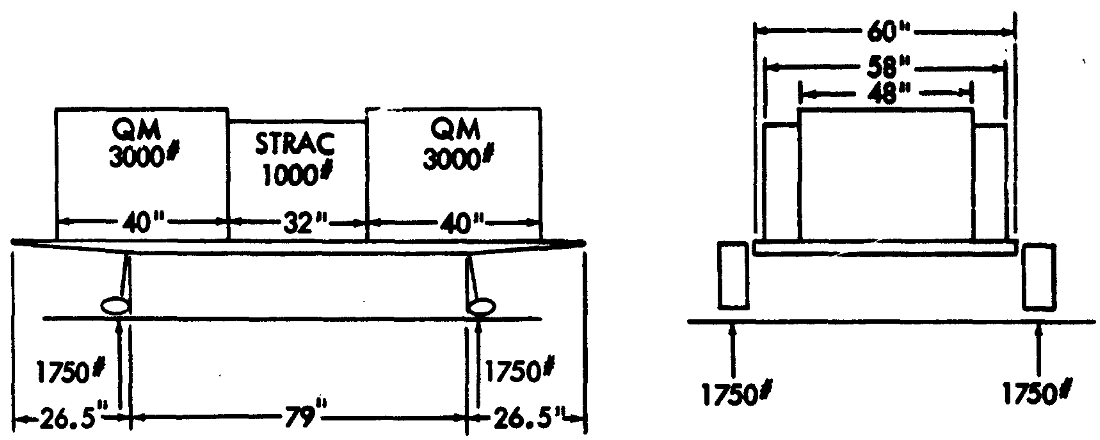
There are a possible 51 combinations of unit aircraft loadings in the 132 inch pallet. By study and elimination, this number was reduced to the few presented herein which give the most critical loading conditions.

NORMAL IN FLIGHT (Case I)



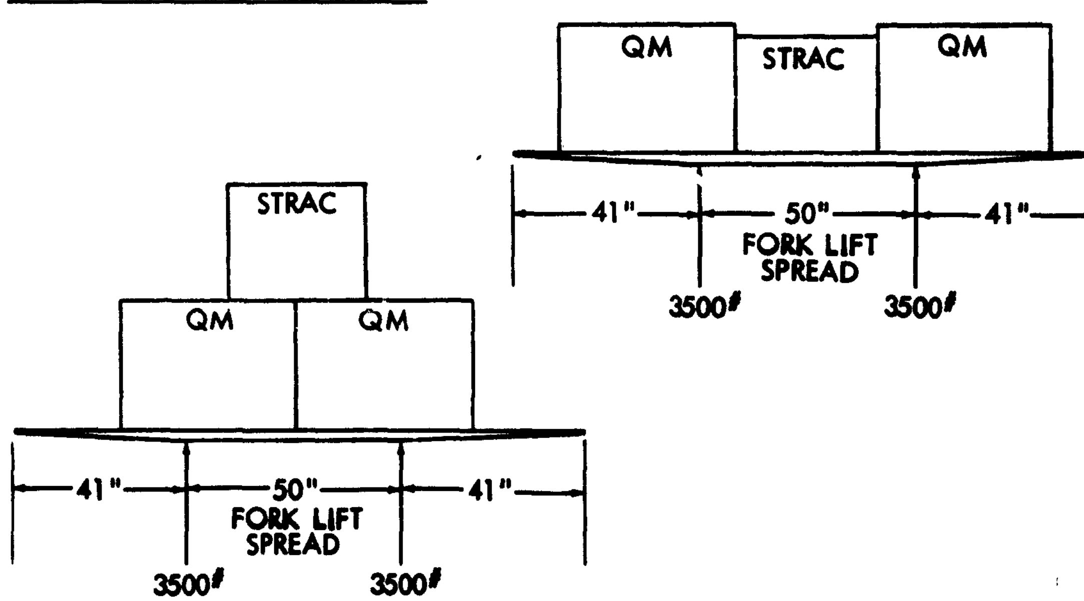
NOTE: **Although stacking STRAC containers on QM pallets is not possible due to the height limitations of the aircraft, this configuration gave a conservative assumption of a critical design loading condition.**

HELICOPTER EXTERNAL LOAD (Case II)



With the helicopter external load lifting points located at the ECR positions, the loading of the two above cases is identical.

FORK LIFT LOAD (Case III)



MAXIMUM MOMENT DETERMINATION

Although the unit aircraft loads tend to distribute themselves along the length of the consolidating pallet, should the deflection of the large pallet be greater than that of the unit loads, concentrated rather than equally distributed loads will occur. By testing both conditions for maximum moment, the greatest, and thus the most conservative value, will be obtained.

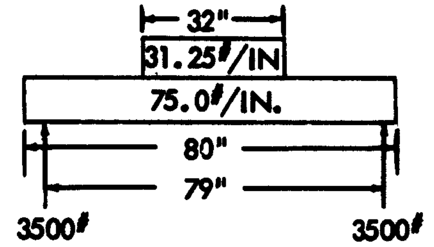
NORMAL IN FLIGHT

Distributed load (Case I)

M_{max} @ Center

$= (3500)(39.5) - (75 \times 40^2 \times .5) - (31.25 \times 16^2 \times .5)$

$= 38{,}000$ in. lb

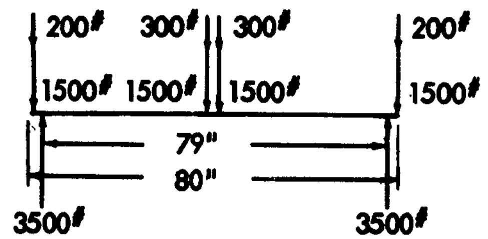


Concentrated load (Case I)

M_{max} @ Center

$= (3500)(39.5) - (1700)(40)$

$= 70{,}000$ in. lb



Distributed load (Case II)

M_{max} @ Center

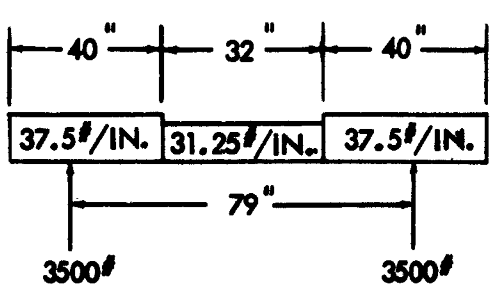
$= (3500)(39.5) - (37.5 \times 40 \times 36) - (31.25 \times 16 \times 8)$

$= 44{,}300$ in. lb

M @ ECR

$= 37.5 \times 17^2 \times 0.5$

$= 5410$ in. lb



Concentrated load (Case II)

M_{max} @ Center

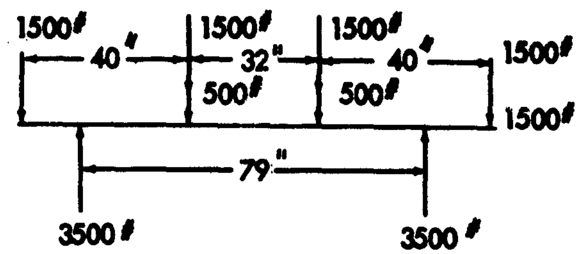
$= (3500 \times 39.5) - (37.5 \times 40 \times 36) - (31.25 \times 16 \times 8)$

$= 44{,}300$ in. lb

M @ ECR

$= -1500 \times 17$

$= -25{,}500$ in. lb



Distributed load (Case III)

$$P_F = \frac{(2800 \times 87.5) + (2000 \times 55.5) + (2000 \times 23.5) - (1000 \times 8.5)}{79}$$

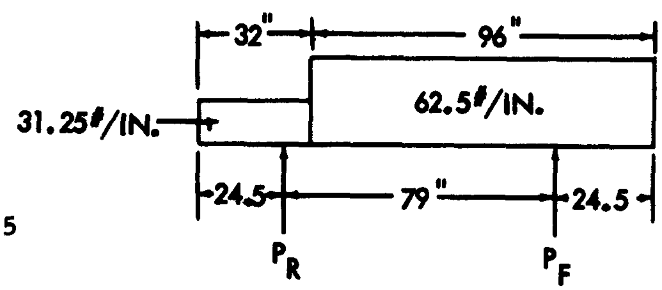
$= 4{,}094.9$ lb

$P_R = 7000 - 4094.9$

$= 2905.1$ lb

$M_{PF} = 62.5 \times 24.5^2 \times .05$

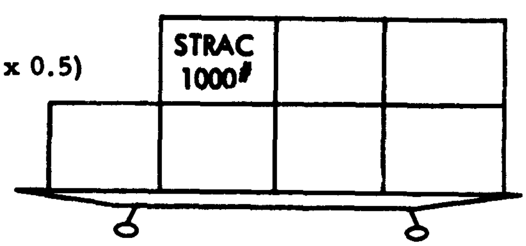
$= 18{,}758$ in. lb



M_{max} @ Center (approx)

$= (4094.9 \times 37.9) - (62.5 \times 62.5^2 \times 0.5)$

$= 33{,}516$ in. lb



Concentrated load (Case III)

M @ P_f

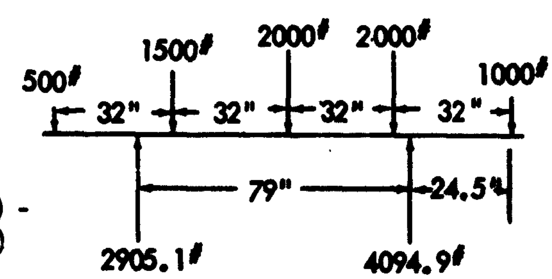
$= 1000 \times 2415$

$= 24{,}500$ in. lb

M_{max} @ Center

$= (4094.9 \times 39.5) - (1000 \times 64) -$
(2000×32)

$= 64{,}813$ in. lb



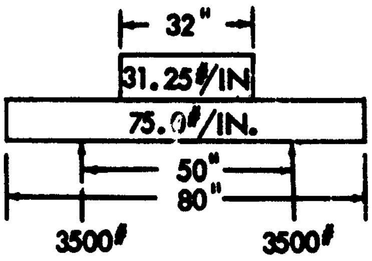
FORKLIFT LOADING

Distributed load (Case I)

M_{max} @ Center

$= (3500 \times 25) - (75 \times 40^2 \times 0.5) - (31.25 \times 16^2 \times 0.5)$

$= -12,500$ in. lb



M @ Fork

$= -75.0 \times 15^2 \times 0.5$

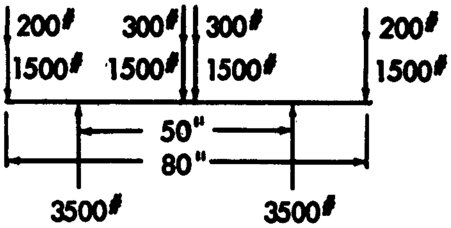
$= -8,438$ in. lb

Concentrated load (Case I)

M_{max} @ Center

$= (3500 \times 25) - (1700 \times 40)$

$= -19,500$ in. lb



M @ Fork

$= -1700 \times 15$

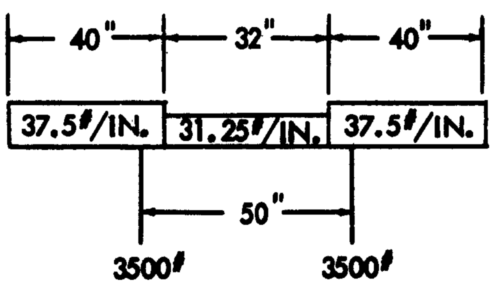
$= -25,500$ in. lb

Distributed load (Case II)

M_{max} @ Center

$= (3500 \times 25) - (37.5 \times 40 \times 36) + (31.25 \times 16 \times 8)$

$= -6,700$ in. lb



M @ Fork

$= -37.5 \times 31$

$= -1162.5$ in. lb

Concentrated load (Case II)

M_{max} @ Center

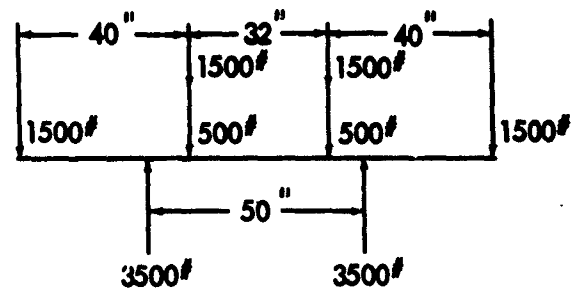
= (3500 x 25) - (1500 x 56) - (2000 x 16)

= 28,500 in. lb

M @ Fork

= -1500 x 31

= -46,000 in. lb



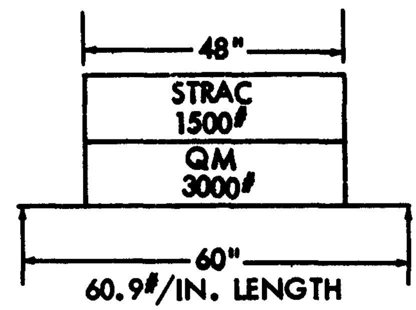
SUMMARY

Normal Inflight Loading	
Distributed load (Case I)	38,000 in. lb
Concentrated load (Case I)	*70,000 in. lb
Distributed load (Case II)	44,300 in. lb
Concentrated load (Case II)	44,300 in. lb
Distributed load (Case III)	33,516 in. lb
Concentrated load (Case III)	64,813 in. lb
Forklift Loading	
Distributed load (Case I)	12,500 in. lb
Concentrated load (Case I)	19,500 in. lb
Distributed load (Case II)	6,700 in. lb
Concentrated load (Case II)	28,500 in. lb

*Maximum moment to be used for stress analysis.

TRANSVERSE LOADING

A conservative analysis would occur by assuming the loading shown below.



The loading on a strip 1 inch wide

$$= \frac{3000}{40} + \frac{1500}{32}$$

$$= 121.9 \text{ lb/in. length}$$

Reaction at end supports

$$= 121.9 \times 0.5$$

$$= 60.9 \text{ lb/in.}$$

M_{max} @ Center

$$= (60.9 \times 30) - \frac{121.9}{48} \times 24^2 \times 0.5$$

$$= 1091 \text{ in. lb/in.}$$

DESIGN MOMENT

The design moment is the combination of the maximum longitudinal moment and the transverse moment.

$$M_{max} \text{ @ Center} = \left[\left(\frac{70,000}{60}\right)^2 + (1091)^2\right]^{1/2}$$

$$= 1600 \text{ in. lb}$$

With 2.0 g load factor and 1.5 safety factor

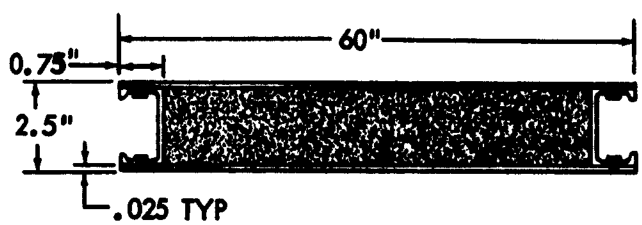
$$M_{design} = 1600 \times 2 \times 1.5 = 4800 \text{ in. lb}$$

This is a very conservative figure as it combines the maximum condition of each axis without regard to the type of loading or the bridging effect of the pallet on pallet combination (concentrated loads which are less critical).

PALLET DESIGN ANALYSIS

The pallet is a honeycomb structure consisting of 7075-T6 aluminum "C" section side rails, a skin of 0.025-inch thick 7075-T6 aluminum core,with a polyurethane core foamed in place.

SECTION AT PALLET CENTER



$$Z = \frac{I}{C} = \frac{bh^3}{12C}$$

$$= \frac{1.0 \times (2.5^3 - 2.45^3)}{12 \times 1.25}$$

$$= 0.077 \text{ in.}^3$$

where Z = section modulas
I = moment of inertia
C = centroid distance
b = base length
h = height

$$f_b = \frac{M_{max}}{Z}$$ where fb = bending stress

m = design moment (4800 in.lb)

$$= \frac{4800}{0.077}$$

$$= 62{,}300 \text{ lb/in.}^2$$

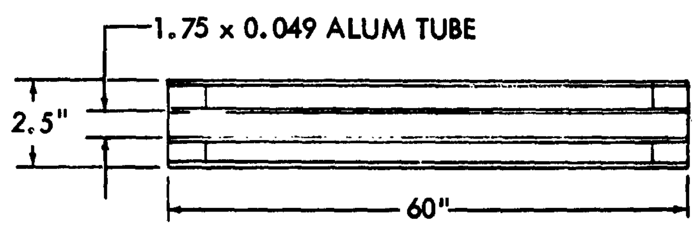
$$ms = \frac{F_{tu}}{f_b} - 1$$ where ms = margin of safety

F_{tu} = allowable stress

$$= \frac{78{,}000}{62{,}300} - 1$$

$$= 0.251$$

SECTION THROUGH ECR'S



$$Z = \frac{bh^3}{12C} = \frac{1.0(2.5^3 - 2.45^3 + 1.75^3 - 1.652^3)}{12 \times 1.25}$$

$$= .1475 \text{ in.}^3$$

Since the moment will be smaller and the section modulas is greater than the center section, this section is not critical.

BENDING OF END RAILS

The transverse bending is resisted by the rails at the ends of the pallet. The running load produces bending between the ECR's. The maximum bending will occur where a 1000 pound STRAC container is mounted on two QM pallets (Case I) since load is distributed on four ECR's.

$$M_{max} \text{ @ Center} = \frac{38{,}000}{2}$$

$$= 19{,}000 \text{ in. lb}$$

The section modulas was found to be

$$Z = 0.25$$

$$\therefore f_b = \frac{m}{Z} = \frac{19{,}000}{0.25} = 76{,}000 \text{ lb/in.}^2$$

$$ms = \frac{F_{tu}}{f_b} = \frac{78{,}000}{76{,}000} - 1 = 0.025$$

The margin of safety is extremely low but the loading condition was designed to give an extreme that cannot occur in operation.

MAXIMUM SHEAR CONDITION

It is quite possible to eccentrically load the pallet for a maximum shear condition of 1500 pounds when the unit aircraft load is near but not at the mobile pallet support. An analysis was made and it was found that shear was not a critical design factor. The margin of safety was in the order of 8.8.

TIEDOWN LOAD CONDITION

The mobile pallet is equipped with tie-down rings on the sides and a tube on the ends to serve the same purpose and yet maintain a smooth surface to allow the cargo to slide off.

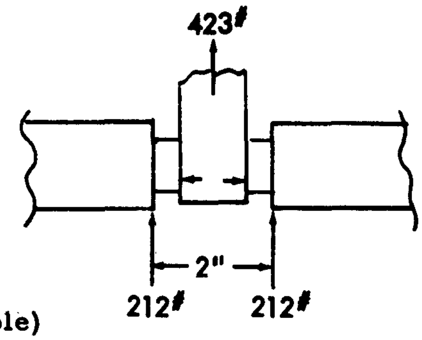
Maximum up-load = 7000 lb (with 2.0 g)
Number of tie-down points = 24

$$\text{Load per point} = \frac{7000}{24} = 282 \text{ lb}$$

Design load = load per point by safety factor
= 282 x 1.5'
= 423 lb

This load on the side tie-down points is negligible.

The end tiedown rail consists of a 1/2 x 0.120 aluminum alloy tube as shown.



$$Z = 0.01138 \text{ in.}^3 \text{ (tube)}$$

$$M_{max} = 212 \times 0.5 = 106 \text{ in. lb}$$

$$f_b = \frac{m}{Z} = \frac{160}{.00138} = 9{,}340 \text{ lb/in.}^2$$

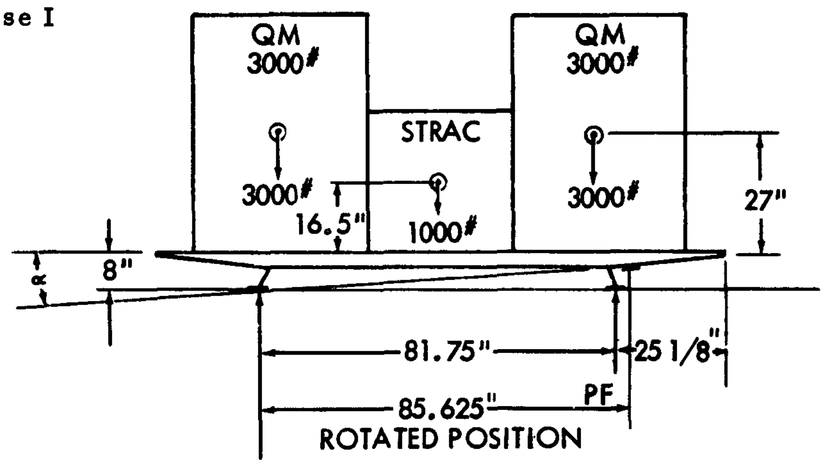
$$F_{tu} = 38{,}000 \times 1.5 = 9{,}340 \text{ lb/in.}$$

$$ms = \frac{F_{tu}}{f_b} - 1 = \frac{57{,}000}{9{,}346} - 1 = 5.1 \text{ (ample)}$$

ECR SUPPORT ANALYSIS

Load due to lowering of pallet

Case I



Location of Vertical C. G.

$$= \frac{(W_{QM}\, H_{QM})^2 + (W_{STRAC}\, H_{STRAC})}{\text{TOTAL W}}$$

$$= \frac{(3000 \times 2 \times 27) + (1000 \times 16.5)}{2(3000) + 1000}$$

= 25.5 inches above surface of pallet

$= 33.5$ inches above ground level

$$P_F = \frac{Wl/z}{1} = \frac{7000}{2} = 3500 \text{ lb (1750 lb per side)}$$

$$\alpha = \text{arc tan} \frac{8}{26.5 + 79 + 1.94} = 0.07474$$

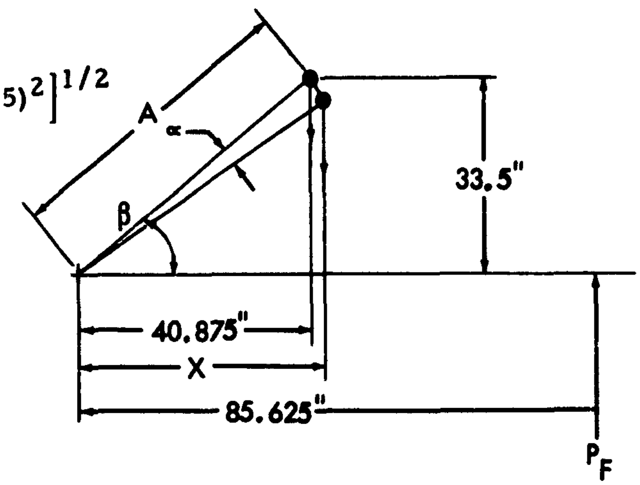
$$\alpha = 4.3°$$

$$\text{Sin } \alpha = 0.075$$

$$\text{Cos } \alpha = 0.9972$$

When the pallet is in the kneeled position (one set of ECR's retracted), the center of gravity of the load shifts and the reaction of the kneeled ECR (P_F) increases in proportion to the shift.

Original position of C. G.



$$A = \left[(40.875)^2 + (33.5)^2\right]^{1/2}$$

$$= 52.85 \text{ in.}$$

$$H = 33.5 \text{ in.}$$

$$L = 40.875 \text{ in.}$$

$$\beta = \text{arc tan} \frac{33.5}{40.875}$$

$$= 39.3°$$

$$\beta - \alpha = 39.3 - 4.3 = 35°$$

$$x = A \cos (\beta - \alpha)$$

$$= (52.85)(0.8192)$$

$$= 43.29$$

$$\text{New } P_F = \frac{3500 \times 43.29}{85.625}$$

$$= 3539 \text{ lb (1770 lb per side)}$$

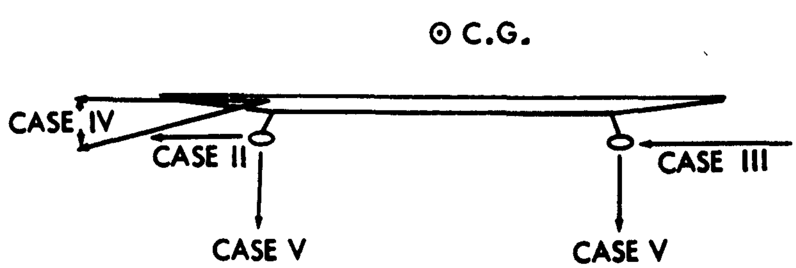
Similar analyses were performed on the pallet in flight. The results are summarized in the table below which includes the following factors:

1. Design loads = Normal load + load factor + safety factor

2. Load factor-lowering = 1.0 g
   Load factor-flight = 2.0 g
   Safety factor = 1.5

TABLE 9
SUMMARY OF ECR LOADS

	Description	Direction of Load	Normal Load Front/Side lb	Normal Load Rear/Side lb	Design Load Front/Side lb	Design Load Rear/Side lb
I	Pallet lowering (example)	Down- Down	-1750 -1750	-1750 Not Critical	-2625 -2625	-2625 —
II	Flight-Tension to rear ECR	Down Forward Result	-4618 —	-1118 -7000	-6927 —	-1677 -9500 -9600
III	Flight-Compression to rear ECR	Down Forward Result	-4618 -7000	-118 —	-6927 -10,000 -12,247	-1677 —
IV	Flight-Tension to rear of pallet at ECR	Down	-3966	-2798	-5949	-4197
V	Flight-Vertical loads	Down Up	-3500 +1750	-3500 -1750	-5250 -2625	-5250 -2625



ECR CONNECTING TUBE ANALYSIS

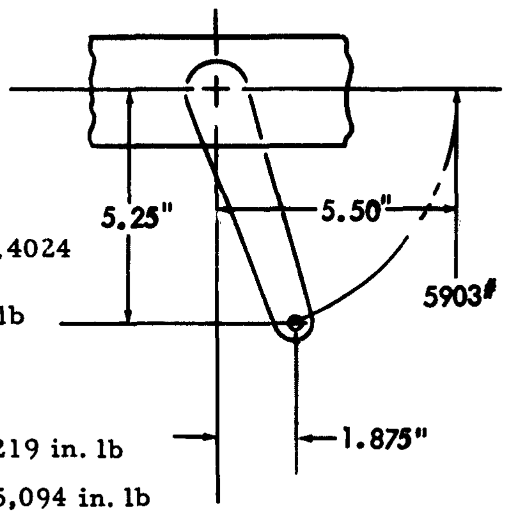
During lowering of the mobile pallet only one end kneels. The ECR's on each side operate independently. However, to insure uniform lowering, a connecting axle is utilized to join both sides. This tube is subject to torsion. The connecting tube as previously stated is 1.5 x 5/32 inch wall 7075-T6 aluminum alloy.

Allowable stress, $F_s = 40{,}000 \text{ lb/in.}^2$

Polar section modulas, $Z_p = 0.4024 \text{ in.}^3$

$\frac{\text{Length}}{\text{Diameter}} \text{ ratio} = \frac{60}{1.5} = 40$

$\frac{\text{Diameter}}{\text{Wall}} \text{ ratio} = \frac{1.5}{.156} = 9.6$



Allowable moment, $T = 40{,}000 \times 0.4024$

$= 16{,}096$ in. lb

During kneeling

M @ Start $= 2625 \times 1.875 = 4219$ in. lb

M @ Finish $= 2625 \times 5.750 = 15{,}094$ in. lb

The torsional deflection of the shaft at failure would be

$$\theta = \frac{TL}{EI_p}$$

where L = length
E = modulus of elasticity
I_p = polar moment of inertia

$$= \frac{16{,}096 \times 60}{10 \times 10^6 \times .4024}$$

$$= 15°$$

The axle seems adequate to adjust for unbalance load provided the torsional deflection does not exceed 15 degrees, which is a factor controlled in the design by the dashpots.

SPLINE ANALYSIS

Affixed to the ends of the aluminum connecting tube is a steel-splined tube. It serves to mount the ECR support arms and has the following characteristics.

Diametrical pitch, DP,	0.50
Pitch diameter	1.200
Root	flat
Pressure angle	30°
Outside diameter - male	1.440 in.
Outside diameter - female	1.379 in.
Material	3140 steel heat treated
F_{su}	95,000 psi

Shear area = πPD x DP x 6

= π 1.2 x 0.5 x 3.00

= 5.652 in.^{2}

M_{max} = (12,247 x 5.75) + (8,606 x 1.875)

= 86,556 in./lb

$$fs = \frac{86,556}{5,652} \qquad ms = \frac{95,000}{15,310}$$

= 15,310 psi = 5.2 (ample)

SHEARING OF DETENT PIN

Pin diameter = 0.625 in.

Area = .3066 in.^{2}

Moment Case I & II = 86,556 in. lb

Case III = 11,154 in. lb

Pin moment arm = 3.0 inches

$$\text{Shear} = \frac{M}{L} = \frac{86,556}{3.0} = 28,852 \text{ lb}$$

$$\text{Shear stress, } f_s, = \frac{28,852}{.3066} = 94,103 \text{ psi}$$

Allowable, $f_s = F_{su}$ = 95,000 psi (4130 steel heat treated)

$$\text{Margin of safety} = \frac{95{,}000}{94{,}103} - 1 = 0.01$$

The bearing of the detent pins was not analyzed fully, but was found to be noncritical.

ECR ROLLERS

There will be a maximum of 6 x 4 = 24 rollers in contact with the track or a minimum of 5 x 4 = 20 rollers. Each roller is 2.375 inches long.

The maximum load is 7000 pounds with a load factor of 2.0 g making 14,000.

The load per roller is therefore $\frac{14{,}000}{20}$ = 700 pounds.

The rollers roll under a hardened steel platen and on the aluminum track. The aluminum track, then, is more critical in design than the steel platen.

MOBILE PALLET WEIGHT SUMMARY

The pieces composing the pallet were analyzed to determine their weight and a summing is presented below.

Item	Weight Each	No.	Total Weight (lb)
1. Basic Pallet		1	134.39
2. ECR's	11.18	4	44.72
3. Arms	2.15	4	8.60
4. ECR lowering equipment	1.66	4	6.64
5. Guide tube	3.36	4	13.44
6. Connecting tube and spline	1.76	4	7.04
7. Detent pin equipment	1.55	4	6.20
8. Tiedown equipment (rings and bolts)			2.06
9. Dashpot and equipment	2.1	4	8.40

APPENDIX III. RAIL AND RAMP DESIGN ANALYSIS

INTRODUCTION

In conjunction with the endless chain roller (ECR) tractive device on the mobile pallet, rails or ramps are required to guide the pallet and to distribute the load over a larger area than is inherent in the ECR. These rails or ramps are also necessary to provide a bearing and bridging surface for movement of the mobile pallet.

Three individual sets of rails are required, and are described in Section 8. Equipment Study and Design. The scope of this appendix involves the loading criteria which impose critical stresses in the various components under conditions of flight and pallet movement, and definition of the structure required to resist the imposed loadings.

In general, a factor of safety of 2.0 was considered adequate for this application. Unless otherwise indicated, a load factor of 1.5 is used to define the effect of shock encountered when the pallet is in motion. Figure 36 describes the overall configuration.

LOAD CHARACTERISTICS

The maximum pallet loading situation occurs with a load of seven STRAC containers or similar cargo to cause the following load conditions:

1. Maximum cargo of 7000 pounds
2. Maximum tare weight of 350 pounds
3. Maximum center of gravity excursion due to an unsymmetrical cargo load of 12 inches in diameter

The vertical center of gravity of the cargo is assumed to be located 40 inches above the cargo floor, the pallet center of gravity being 7.5 inches above the floor.

The design flight load conditions will be critical for the aircraft cargo floor rail only, since the other rails and ramps are used only during loading and unloading operations. The design flight load criteria used in the analysis are as follows.

1. 2.0 g acting forward and aft, with 1.0 g down

2. 2.0 g acting vertically down or 1.0 g acting up

3. 2.0-g side load acting left or right with 1.0 g down.

The preceding loading conditions are resisted by the cargo floor rails and by the aircraft floor structure. The 8-g forward condition existing during crash conditions is reacted by a barrier net as described in Section 8, and is not considered in this analysis.

AIRCRAFT CARGO FLOOR RAILS

CRITICAL LOAD CONDITIONS

The critical down load exerted by the ECR assembly on the floor rail occurs during the side load condition as a reactive couple due to the overturning moment resulting from the side load condition combined with the 1-g load due to gravity, with additional load due to the unsymmetrically loaded cargo, resulting in a net down force of 7280 pounds. (2-g sideload condition plus 1-g vertical down).

$$M_{max} = 7000\,(2)(40) + 350\,(2)(7.5)$$

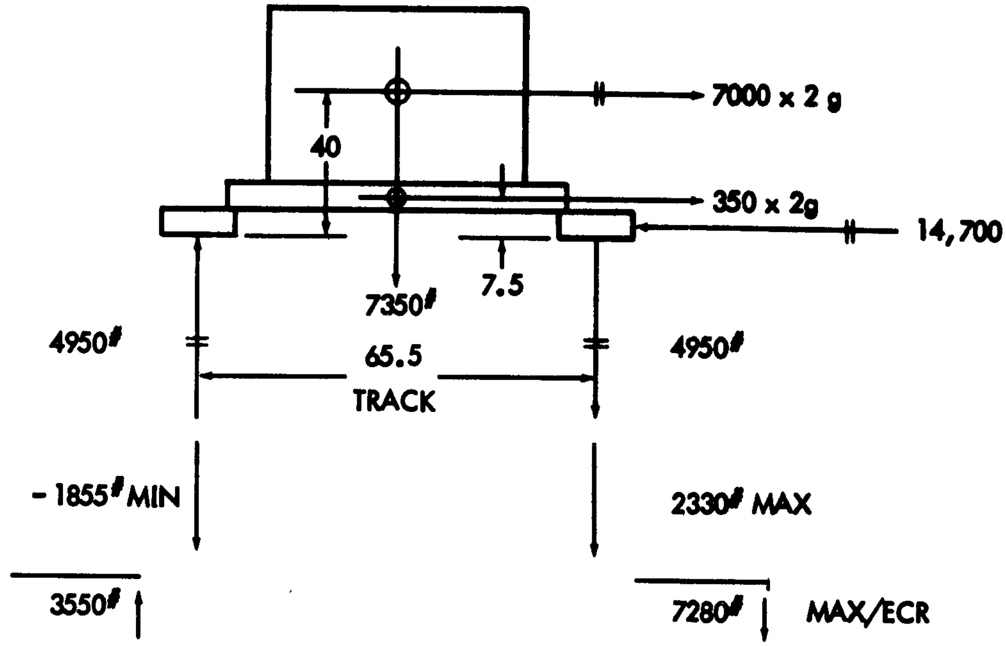
$$= 560{,}000 + 5250$$

$$= 565{,}250 \text{ in.-lb}$$

$$\text{Reactive Couple Load} = \frac{565{,}250}{65.5}\left(\frac{46.88}{81.75}\right) = 4950 \text{ lb}$$

$$\frac{\text{Max. Down Load}}{\text{One ECR}} = 4950 + 2330 = 7280 \text{ lb Max. ECR Down}$$

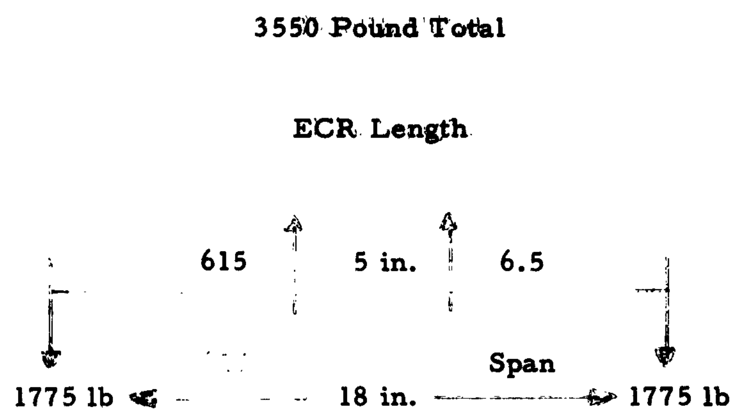
$$\frac{\text{Max. Up Load}}{\text{One ECR}} = 4950 - 1400 = 3550 \text{ lb Max. ECR Up}$$



With five rollers, 2.375 inches long, considered to act simultaneously, a maximum compressive stress of 60,500 psi will occur. This represents a rather low factor of safety on yield, which could, under the right conditions, cause some brinelling under the rollers. However, this situation is not critical since the stress tends to decrease under load as the exposed area increases. The amount of permanent set that could conceivably occur under very maximum conditions would still not hamper the normal operation of the rollers, since they will have the capability of skimming over small discontinuities of this nature. The cargo floor rail is thus considered adequate for the worst down load case, as long as the cargo floor itself has sufficient structural integrity to support the 7280 pound load, exerted by five rollers, and diffused through the rail base, which is 0.188 inch thick.

The maximum up-load situation on the cargo floor rails also occurs during a side loading condition, where the maximum overturning reactive couple load due to the side inertia is partially relieved by the minimal 1-g load down on the ECR assembly, causing a net up force of 3550 pounds. This up load is resisted by attach bolts into the cargo floor support structure, and causes critical bending in the floor rail. The rail section, as shown in Figure 59, has an area moment of inertia of 0.211 in.^{4}, a minimal section modulus of 0.316 in.^{3}, and a centroid located 0.332 inch from the base of the section. This section, without additional support, is capable of supporting the maximum up-load bending over a span of 18 inches between holddown bolts with a 2.0 factor of safety on ultimate.

<u>18-Inch Span</u>



NOTE: Simple supports possible when holddown bolts are loose.

$$M_{max} = 1775\ (6.5)$$

$$\sigma_t = \frac{1775(6.5)(0.668)}{0.211} = 36{,}500 \text{ psi}$$

$$F.S. = 2.0$$

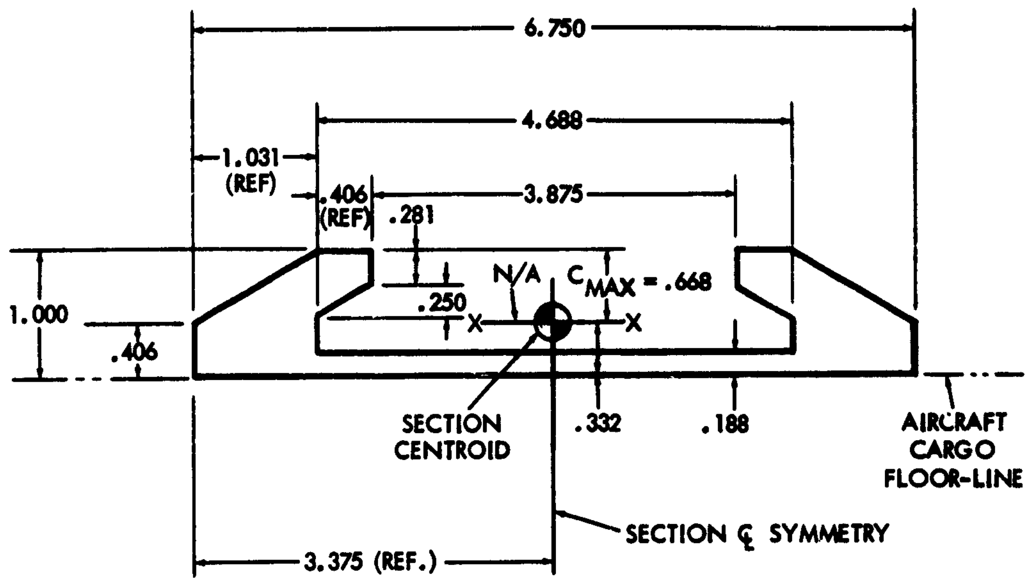
<u>24-Inch Span</u>

$$M_{max} = 1775(12)$$

$$\sigma_t = \frac{1775(9.5)(0.668)}{0.211} = 53{,}400 \text{ psi}$$

$$F_1S_1 = 1.4$$

If the factor of safety were reduced to 1.4, the section would support a span of 24 inches without modification.



MAT'L - 7075 - ST ALUMINUM EXTRUSION

AREA = 2.66 IN^2 WEIGHT = 3.22 LB/FT

MOMENT OF INERTIA = .211 IN^4 } X-X AXIS

SECTION MODULUS = .316 IN^3 } X-X AXIS

Figure 59. Aircraft Cargo Floor Rail

The section as shown is designed functionally to restrain and guide the roller assembly along the aircraft cargo floor, and is considered satisfactory for this application.

GROUND AND RAMP RAILS

As the rolling pallet is winched aft in the aircraft to the ramp area, the rail section is changed to a channel shape, designed primarily to guide and support the ECR assemblies and not capture them. Several channel sections were investigated, and a standard AN shape chosen for the task (Figure 60). A 6 inch by 2.128 pounds per foot section is commercially available, and is sufficient for the load conditions.

The ground and ramp rails were found to be critical for local brinnelling under the rollers. The magnitude of the brinnelling effect depends upon the load factor during winching, which should be nominal, and the number of rollers in contact when the load factor is experienced. Assuming contact with the end two rollers only and a load factor of 1.5 g due to the dynamic condition, it is theoretically possible to develop a compressive stress of 81,000 psi, which of course exceeds the elastic limit of the 7075 ST material.

$$\text{Max. } p = \frac{7280}{5\,(2.375)} = 6.3 \text{ lb/in.}$$

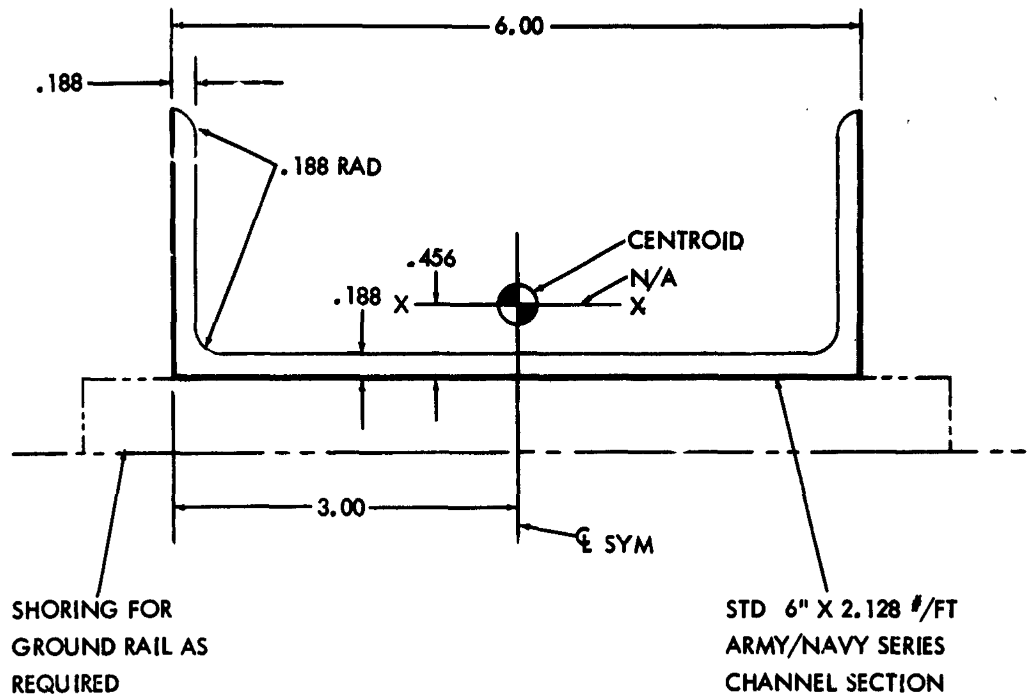
where

minimum number of rollers = 5

roller length = 2.375

$$\text{Max. } S_c = 0.798 \left[\frac{p}{D}\left(\frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2}\right)\right]^{1/2}$$

$$\left.\begin{array}{l} \left(\dfrac{1-\nu_1^2}{E_1}\right) = 3.105 \times 10^{-8} \text{ (Steel)} \\[2ex] \left(\dfrac{1-\nu_2^2}{E_2}\right) = 8.30 \times 10^{-8} \text{ (Alum.)} \end{array}\right\} E = 11.405 \times 10^{-8}$$



MAT'L - 7075 - ST ALUMINUM ALLOY EXTRUSION
AREA = 1.809 IN^2 ; WEIGHT = 2.28 LB/FT
MOMENT OF INERTIA = 9.01 IN^4 } XX - AXIS
SECTION MODULUS = 3.00 IN^3 }

Figure 60. Aircraft Ramp Rail and Ground Rail Section

$$\text{Max. } S_c = 0.798 \sqrt{\frac{6.3 \times 10^8}{0.938(11.+05)}} = 0.798 \sqrt{57.4 \times 10^4}$$

$$\text{Max. } S_c = \underline{60{,}500 \text{ psi}}$$ Note assumes all (5) rollers working - Unconservative

Dynamic Case

$$\text{Max. } S_c = 54{,}000 \text{ lb}$$

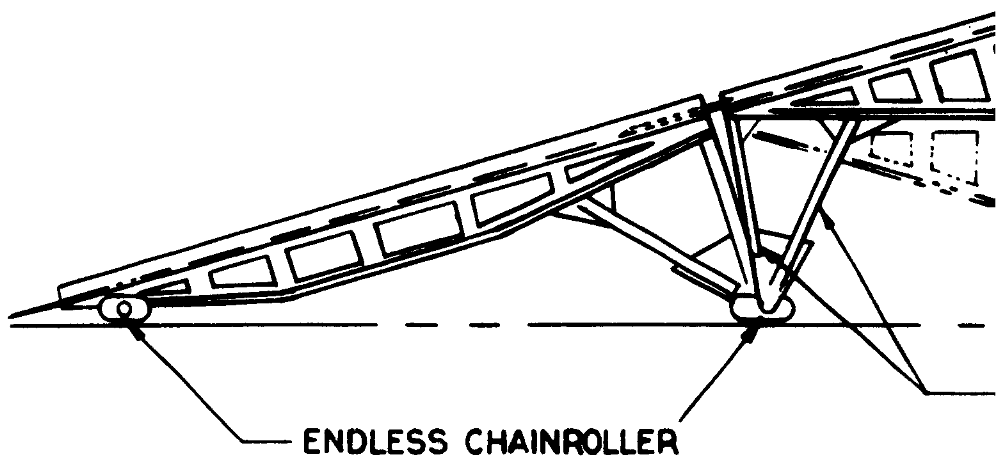
$$L_1F_1 = 1.5 \qquad \underline{S_c = 81{,}000 \text{ psi}}$$

Here again is the situation of the stress being relieved as the exposed area is increased due to brinnelling. The ECR assemblies should have the ability to pass over this small depression.

The ground rail will also be critical for bending when loaded by the passing roller assembly and supported by the ground. It is virtually impossible to design this rail in anticipation of all soil, rock, ice, and other ground conditions in the use area, without incurring a severe weight penalty; failure could even then occur due to torsional or lateral instability and buckling. Accordingly, the rail is assumed to receive adequate support from auxiliary wood shoring and planking to suit the existing soil support conditions. In most situations, very little if any additional support is indicated, although it was impossible to be completely definitive on this point during the scope of this study.

VEHICLE RAMP ASSEMBLY

This rail system (Figure 61), must provide the bridge from the ground rail to the delivery vehicle, accommodate the various bed heights encountered, and adjust for the normal deflection of the truck bed due to the cargo loads. The bed height may vary from 28 to 54 inches above the average ground line. In addition, the pallet geometry can tolerate an angular change in the ramp and rail system of only 16 degrees, without interference or auxiliary lifting. Because of this limitation, the bridging rail must be 200 inches long to accommodate the 55-inch truck bed, and not exceed the 16-degree angular change. Beams of this length/width ratio become critical for lateral buckling of the compressive flange, or a



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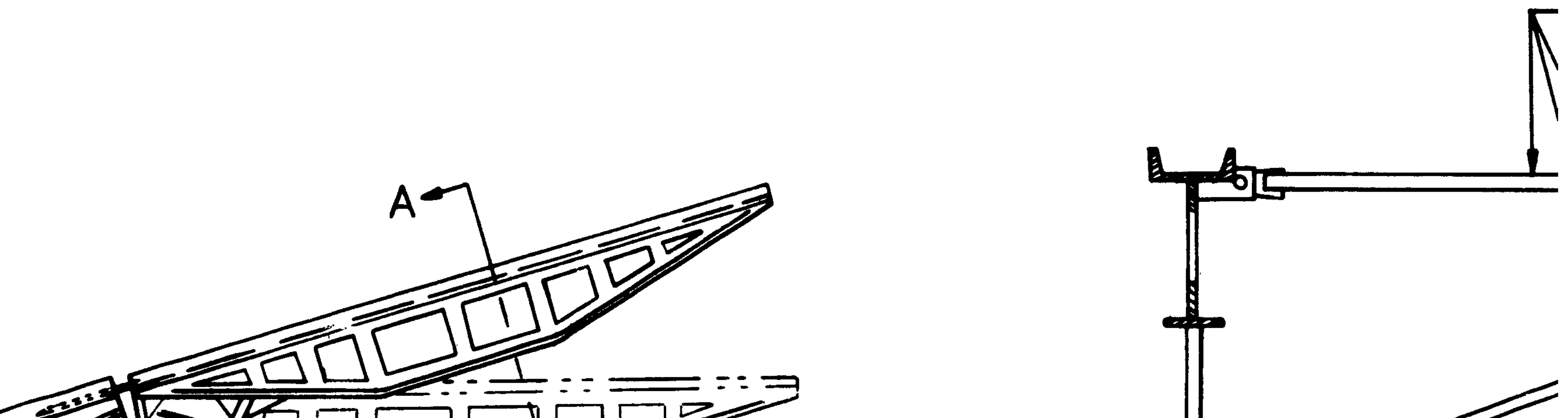

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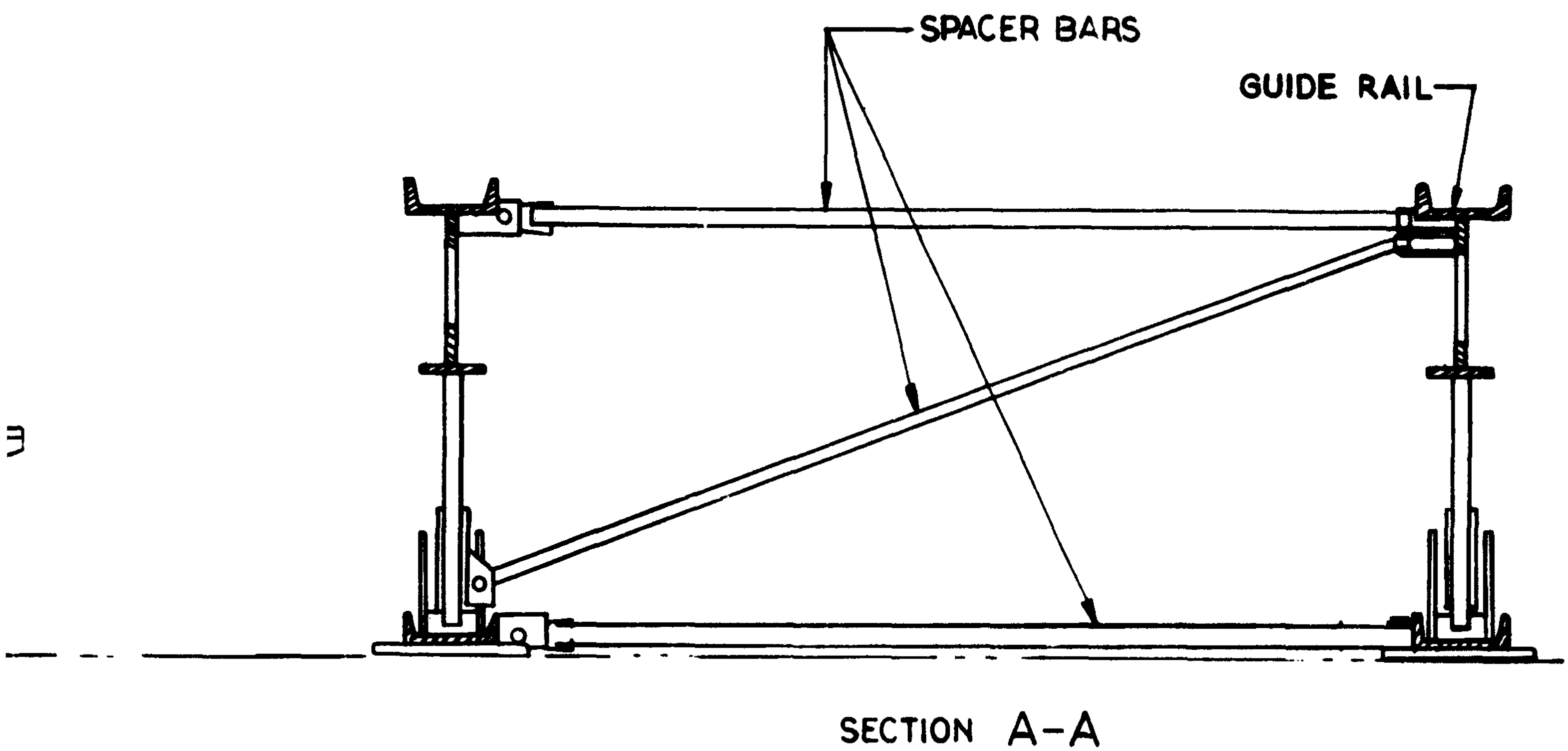


Figure 61. Vehicle Ramp Assembly

torsional instability. For this reason, the bridging rail was divided into two separate beams of half the span length. The top ends are to be hooked to the vehicle, while the bottom ends are supported by roller assemblies in the ground rail, which allows for a fore and aft excursion during truck bed deflection under load. The rail is arranged in two sections, to facilitate storage and handling, and to provide an unsupported span of 100 inches. The lower section has a set of roller assemblies for a base to allow for normal motion during loading of the vehicle. The upper section, which is attached to the loading vehicle, is pin-jointed to the lower rail, to allow some rotation of the joint. The two rail assemblies are of course doubled, one in each of the pallet tracks, and are the extension of the ground rails. A system of cross bracing is employed at the central joint of the bridging rail to provide stability between the two rail tracks. This bracing may be quickly installed and taken down, and automatically spaces the rail assemblies at the proper track distance.

The bridging rail section (Figure 62), in the area of maximum bending moment, is approximated by an I-beam section, whose top flange is the 6-inch AN channel previously described. The section is to be welded from 6061 aluminum alloy, since the beam is not stress critical. The moment of inertia of the section is 88.9 in.^{4}, and is capable of supporting a critical buckling stress of 6420 psi without instability. Assuming a load factor of 1.5 g, a factor of safety of 1.54 exists when the pallet is situated to produce maximum bending moment in the rail.

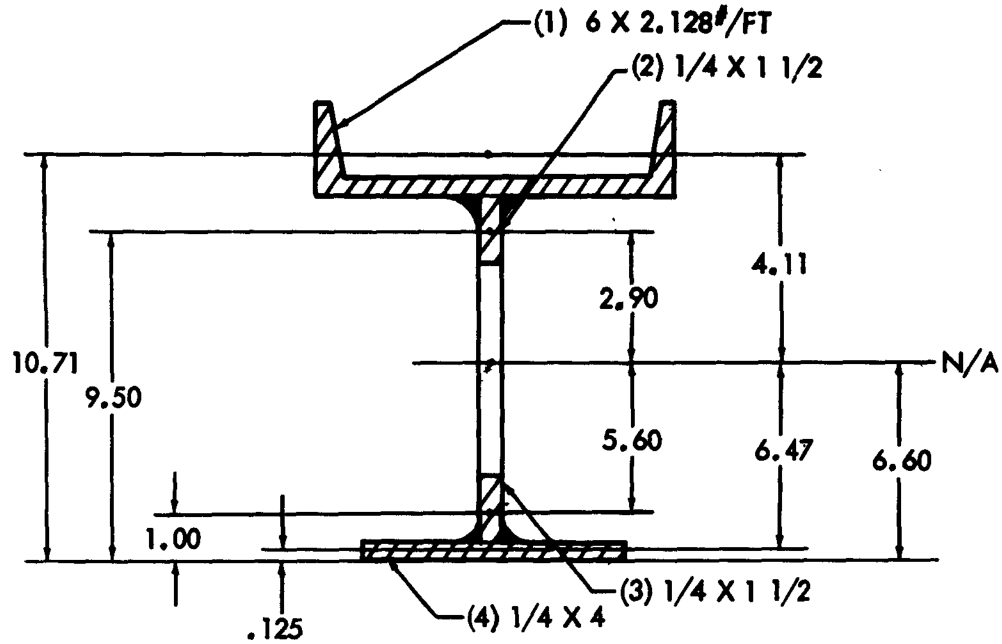


Figure 62. Vehicle Ramp Assembly Rail Section

From Figure 62

Section	Area	Y_o	A_oY_o	d	d^2	Ad^2	$\bar{I}_o$
1	1.81	10.71	19.40	4.11	16.85	30.50	0.58
2	0.375	9.50	3.56	2.90	8.40	3.15	0.07
3	0.375	1.00	0.38	5.60	31.3	11.74	0.07
4	1.00	0.13	0.13	6.47	42.8	42.80	0.01
E	3.560		23.47			88.19	0.73

$\bar{y} = \frac{23.47}{3.56} = 6.60$ $\bar{I} = 0.73 + 88.19 = 88.92$ in.^{4}

Assume previous support condition and maximum bending moments

$$\sigma \text{ max} \quad x = 32.4 \text{ (for 100 in. span)}$$

$$M_{max} = 38.650 \text{ in. lb/beam}$$

$$\text{Ratio } \frac{Ld}{bt} = 976 \text{ as before}$$

$$S_{C_R} = 6420 \text{ psi}$$

$$\sigma \text{ comp} = \frac{(4.34 \times 10^4)(5.65)}{8.798} = 2790 \text{ psi}$$

Load Factor - 1.5, F.S. = 1.54

The following summarizes the approximate weights of the various rails:

1. The cargo floor rail will weigh 3.22 pounds per foot for each side, or a total of 6.44 pounds per foot for the aircraft.

2. The ramping rail and ground rail will weigh 2.128 pounds per foot per side, and will total 4.256 pounds per foot of rail distance.

3. The bridging rail assemblies will weigh approximately 200 pounds total for both sides, and will accommodate all vehicles from 28 to 54 inches in bed height.

APPENDIX IV. EQUIPMENT AND HANDLING ANALYSIS

CARGO RESTRAINING

NET ANALYSIS

An analysis was made of cargo and barrier nets. Barrier nets were studied for the feasibility of being installed permanently in the aircraft to withstand the crash restraint of an 8-g factor forward, thus permitting the use of 2-g factor cargo nets for restraining the cargo inside the aircraft.

Cargo nets, used to secure palletized cargo or small items stacked together, are available in various capacity ratings and sizes. The particular assigned rating is the loading the net will withstand without failure of any part or section.

Barrier nets are used commercially in cargo aircraft to withstand the large restraint g factor in the forward direction resulting from a crash landing. They preclude the use of heavier cargo nets that would be required for the cargo, thus increasing the capacity of the aircraft and reducing the time and cost for the loading and unloading operations.

Table 10, Net Analysis, shows several cargo and barrier nets for various restraint factors, weights, and required restraint, with cost and weight per square foot for each. From this information and analysis, weight and cost curves were developed.

NET CURVES

Figure 63, Net Cost and Weight versus Required Restraints, shows cargo and barrier net cost and weight for various required restraints developed from the net study and analysis.

RESTRAINING DEVICES

Table 11 compares two types of restraining devices, the MC-1 and MB-2, by weight, cost and tensile capacity of each. A comparison of weight, cost, and time to install or remove in an

TABLE 10
NET ANALYSIS

Type of Net	Restraint Factors (g's)	Cargo Weight (lb)	Required Restraint (lb)	Weight Per Sq Ft (lb)	Cost Per Sq Ft
Cargo Net	8	15,000	120,000	0.406	$1.11
Cargo Net	8	10,000	80,000	0.317	0.94
Cargo Net	4	7,000	28,000	0.167	0.70
Cargo Net	3	7,000	21,000	0.122	0.56
Cargo Net	2	7,000	14,000	0.122	0.56
Barrier Net	6	40,000	240,000	1.040	2.89
Barrier Net	8	6,000	48,000	0.740	2.08

aircraft was made between an aircraft with barrier net permanently installed and utilizing a 2-g cargo net and an aircraft without barrier nets thus requiring 8-g cargo nets. Other necessary variables are as follows:

1. Angle of tie (forward and aft)

2. Number of restraining devices required for 2-g factor at 7000-pound weight

3. Number of restraining devices required for 8-g factor at 7000-pound weight

4. Restraining devices cost and weight for 2-g factor at 7000-pound weight

5. Restraining devices cost and weight for 8-g factor at 7000-pound weight

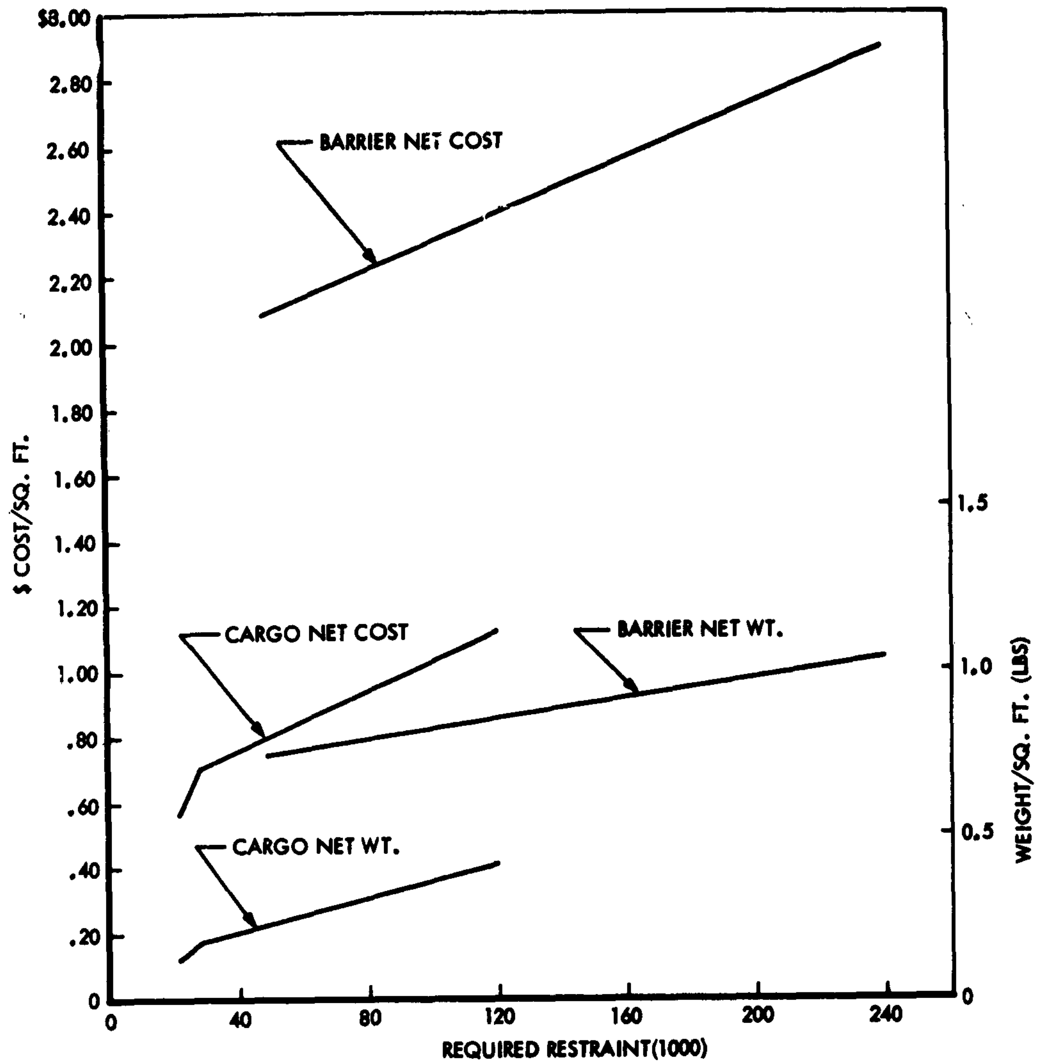


Figure 63. Net Cost and Weight Versus Required Restraint

TABLE 11

RESTRAINING DEVICES ANALYSIS

Restraint Device	Weight (lb) Cost	Angle of Tie		No. of Devices - 2g's*		No. of Devices - 8g's*		Weight & Cost for 2g's*		Weight & Cost for 8g's*	
		Fwd	Aft	Fwd/Aft	Total	Fwd/Aft	Total	Weight (lb)	Cost	Weight (lb)	Cost
MC-1 (5000 lb)	3.47/ $6.50	45°/45°	45°/45°	2/6	8	0/6	6	27.76	$52.00	20.82	$ 39.00
		30°/30°				11/0	11			38.17	71.50
MB-1 (10,000 lb)	10.03/ $23.50	45°/45°	45°/45°	2/0	2			20.06	$47.00		
		30°/30°				2/0	2			20.06	$ 47.00
		TOTALS			10		19	47.82	$99.00	79.05	$157.50

* At 7000-pound load.

In computation of number of restraint devices required for both restraint factors, 2-g and 8-g, at 7000-pound weight, the most desirable angle of ties permitting minimum number of restraining devices was used.

Because of the location of the four 10,000-pound capacity tiedown rings in the AC-1 Caribou aircraft, it was assumed that only two 10,000-pound rings would be accessible for use in restraining the load in the forward direction.

Restraint criteria for the Caribou aircraft are as follows:

Direction	Restraint Factor (g's)
Forward	8
Aft	2
Vertical	up 2
Sideward	1.5

As noted from the analysis, 8 MC-1 and 2 MB-1, making a total of 10, restraining devices are required for a 2-g restraint factor at 7000-pound weight, while a total of 19 restraining devices — 17 MC-1's and 2 MB-1's — are required for 8-g restraint factor at 7000-pound weight.

CARGO NET AND BARRIER NET ANALYSIS

The size of cargo nets required for restraining STRAC, Quartermaster, and consolidating pallets will be approximately 5 feet wide, 11 feet long by 65 inches high, for an area of 228.3 square feet. The size of the barrier net for restraining the 8-g factor in the AC-1 Caribou aircraft would be approximately 75 inches by 80 inches for an area of 41.67 square feet.

The cost and weight per square foot, as shown in Table 12, for the required restraint on 2-g and 8-g cargo nets and 8-g barrier nets at 7000-pound weight each, were taken from Figure 63, permitting the computation of total cost and weight of these items.

TABLE 12

CARGO NET AND BARRIER NET ANALYSIS

Description	Dimensions	Area Sq Ft	Weight Per Sq Ft	Cost Per Sq Ft	Total Weight	Total Cost
8-g Cargo Net at 7000-lb Weight	5' x 11' x 65"	228.3	0.24 lbs	$0.83	54.79 lbs	$189.49
2-g Cargo Net at 7000-lb Weight	5' x 11' x 65"	228.3	0.12 lbs	0.56	25.11 lbs	127.85
8-g Barrier Net at 7000-lb Weight	75" x 80"	41.67	0.66 lbs	2.12	**37.50 lbs	*138.34

* Includes cost of installing barrier net in aircraft ($50.00)

** Includes weight barrier net installation in aircraft (10 pounds)

TABLE 13

SUMMARY, COST AND WEIGHT OF CARGO NETS, BARRIER NETS AND RESTRAINING DEVICES

	8-g, 7000-lb Barrier Net		8-g, 7000-lb Cargo Net		2-g, 7000-lb Cargo Net		Tiedown Devices		Total	
	Weight	Cost	Weight	Cost	Weight	Cost	Weight	Cost	Weight	Cost
Aircraft with Barrier Net	37.50 lbs	$138.34			25.11 lbs	$127.85	47.82 lbs	$ 99.00	110.43 lbs	$365.19
Aircraft without Barrier Net			54.79 lbs	$189.49			79.00 lbs	$157.50	133.79 lbs	$346.99

NOTE: Above total and weight for one aircraft only.

SUMMARY - COST AND WEIGHT

Table 13 shows the total cost and weight of cargo and barrier nets and restraining devices, for an aircraft with barrier nets permanently installed and for an aircraft without barrier nets. A cargo net of 2g's was used with the aircraft containing the barrier net, while in the aircraft without the barrier net, an 8-g cargo net would be required.

A saving of 3.36 pounds is realized on aircraft with installed barrier nets over those without barrier nets, although an additional initial investment of $18.20 would be required which would be offset as shown in the discussion that follows.

SPARES - CARGO NETS

Figure 64 includes the cost of the 8-g barrier net (75 inches by 80 inches) and cost of installing it permanently in the aircraft ($50 estimate), with the initial investment cost of one 5-foot by 11-foot by 65-inch size 2-g cargo net.

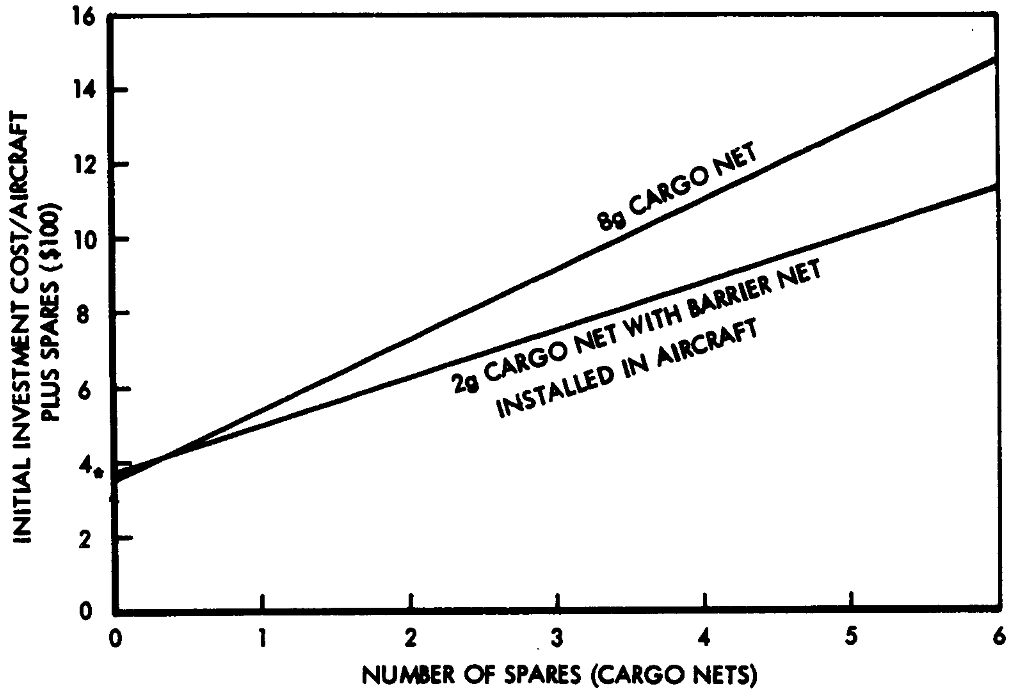
The initial investment costs of restraining devices for each type cargo net, 2g's and 8g's, also are included. It is assumed no spares will be required for restraining devices and the barrier net, since the barrier net permanently installed in the aircraft will not be subject to hard use or handling.

As shown in Figure 64, the initial investment cost of the 2-g cargo net with barrier net is greater than the 8-g cargo net, but is considerably cheaper as spare requirements of cargo nets increase.

WEIGHT - RESTRAINING DEVICES AND NETS

An important factor to be considered in using aircraft with barrier nets permanently installed in the aircraft to withstand the 8-g crash restraint factor is the increased cargo capacity of the aircraft. As shown in Table 13, a saving of 23 pounds is realized when using the barrier net rather than the 8-g restraining net.

If $500,000.00 (AC-1 Caribou cost) is spent to attain a 6000-pound lift capability, then each pound of lift is worth approximately $83, and 23 pounds represents a $1909 investment. The annual cost for carrying this excess weight can be computed as follows. Assuming



*INITIAL INVESTMENT OF RESTRAINING DEVICES & NETS/AIRCRAFT

Figure 64. Initial Investment, Nets and Restraining Devices

the carrier cost to be \$500,000 plus 25 percent for activation and spares, and amortizing over 10 years, the yearly carrier cost is \$62,500 per year. When \$25,000 per year is added for the crew, the daily amortization cost is approximately \$244. If fuel and maintenance per flight hour is \$80, then the cost per flight hour as a function of daily flight utilization, F, is:

$$\frac{\text{Dollars}}{\text{Flight Hr.}} = \frac{244 + 80F}{F} \tag{21}$$

and the cost per ton-nautical-mile for a 130-knot, 3-ton carrier is

$$\frac{\text{Dollars}}{\text{Ton N. Mi.}} = \frac{244 + 80F}{F(3 \times 130)} = \frac{0.625}{F} + 0.205 \tag{22}$$

The annual cost as a function of flight utilization and excess weight in pounds, W_E, is:

$$\text{Caribou Annual Cost} = \frac{0.625}{F} + 0.205 \; \frac{W_E}{2000} \; F \times 130 \times 360$$

$$= (14.6 + 4.8F)\, W_E \tag{23}$$

By the same type of analysis:

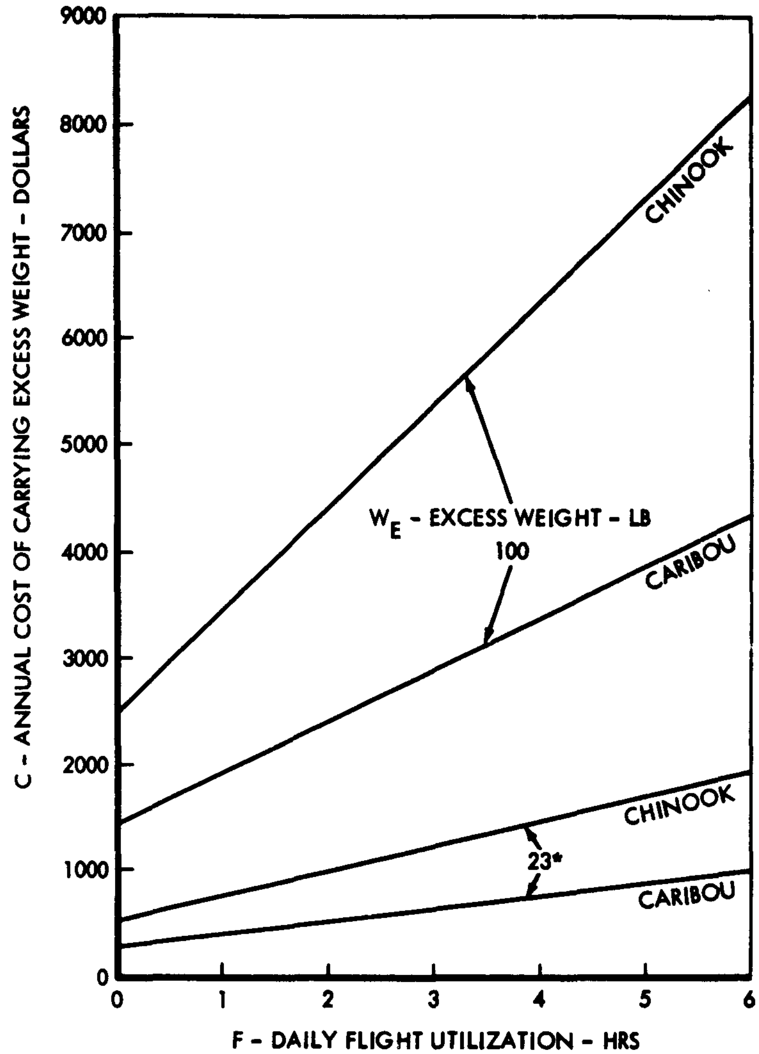
$$\text{Chinook Annual Cost} = (25.00 + 9.59F)\, W_E \tag{24}$$

Figure 64 shows the annual cost for excess weight. The 23 pounds representing the differences in cargo-restraining concepts amounts to \$1000 per year per aircraft at a 6-hour daily flight utilization rate for the Caribou, and \$1900 per year for the Chinook.

TIME - LOADING OR UNLOADING

At airheads where time required to load or unload the aircraft is of prime importance, an aircraft with barrier nets installed, using 2-g cargo nets having a total of only 10 tiedown devices, would be more desirable than an aircraft with 8-g cargo net with 19 tiedown devices.

If a carrier has been procured to generate productivity in tons per hour, then each minute lost to loading and unloading is a loss of



*THE WEIGHT SAVED
WITH A 2-g CARGO NET AND BARRIER
NET OVER AN 8-g CARGO NET-
INCLUDING TIEDOWN DEVICES

Figure 65. Annual Cost of Carrying Excess Weight

productivity and must be replaced by the procurement of additional carriers. The cost of replacement is computed as follows: The percent productivity, P, lost to some increment of time, Δt, is:

$$\text{Percent Productivity Cost} = \frac{P - P_{\Delta t}}{P} = 1 - \frac{P_{\Delta t}}{P}$$

$$= 1 - \frac{C/t}{C/(t + \Delta t)} = 1 - \frac{t + \Delta t}{t} = \frac{\Delta t}{t} \qquad (25)$$

Where C = Cargo

t = Carrier cycle time

$$= \frac{2 \text{ Radius}}{\text{Velocity}} + \text{Turnaround} + \text{Loading} + \text{Unloading}$$

Assuming 6 minutes or 0.1 hour for turnaround at two terminals, a nominal 10 minutes of time to load and unload, a cruise velocity of 130 knots, and a Caribou cost of \$500,000 plus 25 percent activation and spares, the additional procurement cost to recover productivity lost to 1 minute of loading and unloading time is

$$\Delta \text{ Procurement Cost} = \frac{\$625{,}000}{\frac{2R}{130}\, 60 + 6 + 10} \qquad (26)$$

The above relationship is presented in Figure 66.

GRAVITY ROLLER CONVEYOR EVALUATION

ROLLER CONVEYOR ANALYSIS

Table 14, Roller Conveyor Analysis, is a compilation of standard 5-foot roller conveyor sections with various roller capacities, and frame and roller materials and gauges. Various roller lengths and roller spacings with conveyor capacity, weight, and cost per 5-foot conveyor section for the various configurations are shown. The conveyor capacity for a 10-foot section, included as the ratio from a 5-foot section for a 10-foot section, is not a 1:1 ratio as in the case of the figures in the conveyor weight and conveyor cost columns.

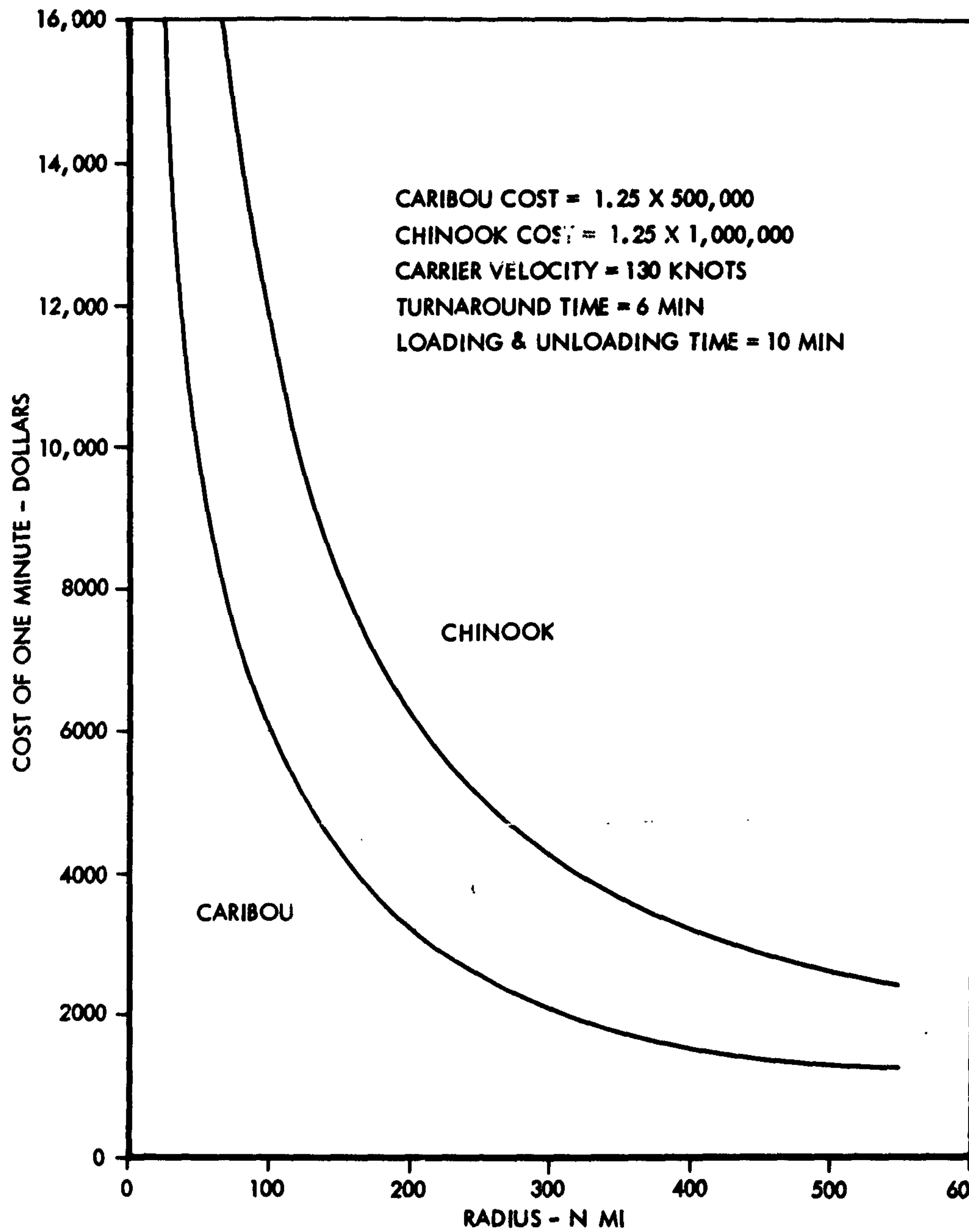


Figure 66. Equipment Cost of One Minute of Carrier Cycle Time for Constant Productivity

RO

Capacity Roller	Frame Size (Rollers High)	Material & Gauge Frame	Material & Gauge Rollers	Roller Diameter 1.75"	Roller Diameter 1.9"	Roller Length 9"	Roller Length 15"	Roller Spacing (In.) 2	Roller Spacing (In.) 2-1/4	Roller Spacing (In.) 3	Roller Spacing (In.) 4
50#	2-1/2"	S-12	S-16	X	-	X	-	X	-	X	X
				-	-	-	X	X	-	X	X
250#	3-1/2"	S-13	S-13	-	X	X	-	-	X	X	X
				-	-	-	X	-	X	X	X
150#	3-1/2"	S-16	S-16	-	X	X	-	-	X	X	X
				-	-	-	X	-	X	X	X
40#	2-1/2"	A-16	A-16	X	-	X	-	X	-	X	X
				-	-	-	X	X	-	X	X
80#	3-1/2"	A-16	A-16	-	X	X	-	-	X	X	X
				-	-	-	X	-	X	X	X

Note: Above prices are f. o. b. List — Approximately 30% discount on quantity or
2-1/2" aluminum frame 50524-38, Rollers 6663-T832

1

TABLE 14
ROLLER CONVEYOR ANALYSIS

Material & Gauge		Roller Diameter		Roller Length		Roller Spacing (In.)				10 Ft. Section Conveyor Capacity (lb) for Various Spacings				5 Ft. Section Conveyor Capacity (lb) for Various Spacings				5 Ft. Section Conveyor Wt/Secti for Various Spacin			
Frame	Rollers	1.75"	1.9"	9"	15"	2	2-1/4	3	4	2"	2-1/4"	3"	4"	2"	2-1/4"	3"	4"	2"	2-1/4"	3"	4
S-12	S-16	X	-	X	-	X	-	X	X	800	-	800	800	1500	-	1000	750	56	-	43	3
		-	-	-	X	X	-	X	X	800	-	800	800	1500	-	1000	750	80	-	60	5
S-13	S-13	-	X	X	-	-	X	X	X	-	1200	1225	1250	-	2675	2700	2700	-	93	78	6
		-	-	-	X	-	X	X	X	-	1150	1200	1225	-	2650	2675	2675	-	129	106	8
S-16	S-16	-	X	X	-	-	X	X	X	-	1225	1250	1275	-	2700	2700	2250	-	75	64	5
		-	-	-	X	-	X	X	X	-	1175	1200	1225	-	2675	2700	2250	-	103	86	7
A-16	A-16	X	-	X	-	X	-	X	X	475	-	480	485	1000	-	800	600	29	-	23	1
		-	-	-	X	X	-	X	X	450	-	460	470	1000	-	800	600	38	-	29	24
A-16	A-16	-	X	X	-	-	X	X	X	-	675	690	705	-	1470	1480	1200	-	43	36	2
		-	-	-	X	-	X	X	X	-	645	670	685	-	1455	1465	1200	-	57	47	3

e f. o. b. List — Approximately 30% discount on quantity orders — Steel Rollers Galvanized with Plated Bearings
n frame 50524-38, Rollers 6663-T832

2

TABLE 14
ROLLER CONVEYOR ANALYSIS

Roller Spacing (In.)				10 Ft. Section Conveyor Capacity (lb) for Various Spacings				5 Ft. Section Conveyor Capacity (lb) for Various Spacings				5 Ft. Section Conveyor Wt/Section for Various Spacings				5 Ft. Section Conveyor Cost/Section for Various Spacings				
2	2-1/4	3	4	2"	2-1/4"	3"	4"	2"	2-1/4"	3"	4"	2"	2-1/4"	3"	4"	2"	2-1/4"	3"	4"	6"
X	-	X	X	800	-	800	800	1500	-	1000	750	56	-	43	37	$33.35	$ -	$21.60	$17.75	$14.0
X	-	X	X	800	-	800	800	1500	-	1000	750	80	-	60	51	39.00	-	25.25	20.70	16.5
-	X	X	X	-	1200	1225	1250	-	2675	2700	2700	-	93	78	66	-	40.95	31.80	25.85	
-	X	X	X	-	1150	1200	1225	-	2650	2675	2675	-	129	106	88	-	49.65	38.50	31.00	
-	X	X	X	-	1225	1250	1275	-	2700	2700	2250	-	75	64	55	-	36.85	28.70	23.55	
-	X	X	X	-	1175	1200	1225	-	2675	2700	2250	-	103	86	72	-	42.85	33.35	27.15	
X	-	X	X	475	-	480	485	1000	-	800	600	29	-	23	19	42.45	-	31.60	26.40	
X	-	X	X	450	-	460	470	1000	-	800	600	38	-	29	24	52.50	-	38.55	32.15	
-	X	X	X	-	675	690	705	-	1470	1480	1200	-	43	36	29	-	47.75	36.55	29.80	
-	X	X	X	-	645	670	685	-	1455	1465	1200	-	57	47	39	-	58.15	44.75	36.15	

:ount on quantity orders — Steel Rollers Galvanized with Plated Bearings

3

From the foregoing information roller conveyor cost and weight factors, listed below, were developed for establishing weight and cost the roller conveyor systems required for each suggested pallet concept.

ROLLER CONVEYOR - COST AND WEIGHT FACTORS

$$W_{5'S} = (16 + 0.06C) = \frac{8.15 \quad 66 + C}{S} \quad \frac{D(0.46 + 0.06L)}{1.9} \tag{27}$$

$$W_{5'A} = 0.52\ W_{5'S}$$

$$C_{5'S} = \left[7 + \frac{3100 + 10C}{S}\right] \frac{D}{1.9} \left[0.685 + 0.035L\right] \tag{28}$$

$$C_{5'A} = 1.4\ C_{5'S}$$

where

$W_{5'S}$ = weight of 5-foot steel roller section

$W_{5'A}$ = weight of 5-foot aluminum roller section

$C_{5'S}$ = cost of 5-foot steel roller section

$C_{5'A}$ = cost of 5-foot aluminum roller section

C = capacity of roller

D = diameter of roller

L = length of roller

S = roller spacings

Roller Conveyor Weight and Cost Factors for Various Pallet Concepts

By using the above cost and weight factors, cost and weight data were compiled as shown in Table 15.

TABLE 15
ROLLER CONVEYOR WEIGHT AND COST FACTORS

	Wooden Pallets QM & STRAC Move in Either Direction*	Wooden Pallets QM & STRAC Move Length-wise Only*	Basic Pallet 5' x 11'	Consolidating Pallet 5' x 11'
Roller Capacity (lb)	375	190	190	400
Roller Spacings (Inches)	2-3/4	6	6	2-1/2
Roller Diameter (Inches)	1.9	1.9	1.9	1.9
Roller Length (Inches)	9	9	6	6
Weight/Foot (Steel) (lb)	19.79	9.09	8.13	22.2
Weight/Foot (Aluminum) (lb)	10.29	4.73	4.33	11.54
Cost/Foot (Steel)	$5.40	$3.76	$3.37	$8.50
Cost/Foot (Aluminum)	$7.56	$5.26	$4.72	$11.90

NOTE: Above Cost f.o.b. list price. Approximately 30-percent discount can be applied to these prices.

* Low-height loads only with straight in loading.

GRAVITY WHEEL CONVEYOR EVALUATION

A study was made of gravity wheel conveyors consisting of the following specifications:

CONVEYOR FRAME

Steel

Galvanized steel, 12 gauge, formed channels 2-1/2 inches wide with 1-inch flanges. Two 14-gauge galvanized steel center bands in 12-inch and 18-inch widths and three in 24-inch widths. Wheels project 3/8 inch above frame.

Aluminum

Aluminum frames, 2-1/2-inch and 3-1/2-inch deep channels of 5052-H36 aluminum, 1/8-inch thick, with steel wheels. General construction is the same as steel frames.

CONVEYOR WHEELS

1. Smooth, free running
2. Seven 1/4-inch lifetime grease-packed ball bearings
3. Zinc plated, with final irridite dip to reduce oxidization
4. Baffle cove constructed to keep grease in and dirt out
5. 5/8-inch face, 1/4-inch bore, 15/16-inch hub, 2-inch diameter
6. Weight - 4 ounces
7. Wheel capacity - 25 pounds for steel and 12 pounds for aluminum

CONVEYOR WHEEL AXLES

~~Unplated~~ steel 1/4-inch hex-head axles with self-locking nuts, power wrench tightened. Conveyor widths of 12 inches and 18 inches, 4 axles per foot; 24-inch width, 6 axles per foot.

Table 16, Gravity Wheel Conveyor Analysis, lists all the variations of the listed conveyors showing overall widths, wheels per foot, frame sizes, materials and gauges, and wheel capacities. Five-foot conveyor capacity, weight, and cost for the various widths and wheels per foot also are shown.

From data contained in Table 16, the following gravity wheel conveyor cost and weight factors were developed for establishing weights and costs of modified versions of gravity wheel conveyors suitable for the various suggested concepts of cargo handling.

GRAVITY WHEEL CONVEYORS - COST AND WEIGHT FACTORS

$$(\mathrm{Wt/Ft})_{\substack{\mathrm{S\text{-}W}\\ \mathrm{S\text{-}F}}} = \frac{\text{No. wheels/ft}}{4} + \frac{\text{No. axles/ft x width (in.)}}{48} + 4 \tag{29}$$

$$(\mathrm{Wt/Ft})_{\substack{\mathrm{S\text{-}W}\\ \mathrm{A\text{-}F}}} = \frac{\text{No. wheels/ft}}{4} + \frac{\text{No. axles/ft x width (in.)}}{48} + 2 \tag{30}$$

$$(\mathrm{Wt/Ft})_{\substack{\mathrm{S\text{-}W}\\ \mathrm{A\text{-}F_M}}} = \frac{\text{No. wheels/ft}}{4} + \frac{\text{No. axles/ft x width (in.)}}{48} + 0.47 \tag{31}$$

$$(\mathrm{Cost/Ft})_{\substack{\mathrm{S\text{-}W}\\ \mathrm{S\text{-}F}}} = \$0.50\ (\mathrm{Wt/ft}) \tag{32}$$

$$(\mathrm{Cost/Ft})_{\substack{\mathrm{S\text{-}W}\\ \mathrm{A\text{-}F}}} = \$1.00\ (\mathrm{Wt/ft}) \tag{33}$$

$$(\mathrm{Cost/Ft})_{\substack{\mathrm{S\text{-}W}\\ \mathrm{A\text{-}F}}} = \$0.50 \left(\frac{\text{No. wheels/ft}}{4} + \frac{\text{No. axles/ft x width (in.)}}{48}\right) + (1.50 \times 0.47) \tag{34}$$

$$\text{Capacity Lb/Ft} = 25\left(\frac{\text{Number wheel}}{\text{Ft}}\right) \tag{35}$$

GRAVITY W

Overall Width (Inches)	Wheels Per Foot	Frame Size Wheels High	Material & Gauge Frame Wheels	Wheel Capacity (lb)	Conveyor Capacity (lb) For Va						
					6	8	10	12	14	16	1
12	6	2-1/2"	Galvanized Steel	25	750						
	8	2-1/2"	Galvanized Steel	25		1000					
	10	2-1/2"	Galvanized Steel	25			1250				
	12	2-1/2"	Galvanized Steel	25				1500			
	16	2-1/2"	Galvanized Steel	25						1600	
18	10	2-1/2"	Galvanized Steel	25			1250				
	12	2-1/2"	Galvanized Steel	25				1500			
	14	2-1/2"	Galvanized Steel	25					1600		
	16	2-1/2"	Galvanized Steel	25						1600	
	18	2-1/2"	Galvanized Steel	25							16(
	20	2-1/2"	Galvanized Steel	25							
24	16	2-1/2"	Galvanized Steel	25						1600	
	18	2-1/2"	Galvanized Steel	25							16(
	20	2-1/2"	Galvanized Steel	25							
	24	2-1/2"	Galvanized Steel	25							
	28	2-1/2"	Galvanized Steel	25							
12	6	2-1/2"	Alum. Steel	25	750						
	8	2-1/2"	Alum. Steel	25		1000					
	10	2-1/2"	Alum. Steel	25			1050				
	12	2-1/2"	Alum. Steel	25				1050			
	16	2-1/2"	Alum. Steel	25						1050	
18	12	2-1/2"	Alum. Steel	25				1050			
	14	2-1/2"	Alum. Steel	25					1050		
	16	2-1/2"	Alum. Steel	25						1050	
	18	2-1/2"	Alum. Steel	25							105
24	16	2-1/2"	Alum. Steel	25						1050	
	18	2-1/2"	Alum. Steel	25							105
	20	2-1/2"	Alum. Steel	25							
	24	2-1/2"	Alum. Steel	25							
	28	2-1/2"	Alum. Steel	25							
12	6	3-1/2"	Alum. Steel	25	750						
	8	3-1/2"	Alum. Steel	25		1000					
	10	3-1/2"	Alum. Steel	25			1250				
	12	3-1/2"	Alum. Steel	25				1470			
	16	3-1/2"	Alum. Steel	25						1470	
18	12	3-1/2"	Alum. Steel	25				1470			
	14	3-1/2"	Alum. Steel	25					1470		
	16	3-1/2"	Alum. Steel	25						1470	
	18	3-1/2"	Alum. Steel	25							147
24	16	3-1/2"	Alum. Steel	25						1470	
	18	3-1/2"	Alum. Steel	25							147
	20	3-1/2"	Alum. Steel	25							
	24	3-1/2"	Alum. Steel	25							
	28	3-1/2"	Alum. Steel	25							

1

TABLE 16
GRAVITY WHEEL CONVEYOR ANALYSIS

Frame Size Wheels High	Material & Gauge Frame Wheels	Wheel Capacity (lb)	Conveyor Capacity (lb) For Various Wheels/Ft. 6	8	10	12	14	16	18	20	24	28	Conveyor Weight (lb) For Various Wheels/Ft. 6	8	10	12	14	16	18	20	24	28	Conveyor Cost/: 6	8	10	1
													Five (5) Foot Section (Steel)													
2-1/2"	Galvanized Steel	25	750										33										16.35			
2-1/2"	Galvanized Steel	25		1000										35										17.90		
2-1/2"	Galvanized Steel	25			1250										37										19.50	
2-1/2"	Galvanized Steel	25				1500										40										21
2-1/2"	Galvanized Steel	25						1600										45								
2-1/2"	Galvanized Steel	25			1250										40										21.70	
2-1/2"	Galvanized Steel	25				1500										42										23.
2-1/2"	Galvanized Steel	25					1600										45									
2-1/2"	Galvanized Steel	25						1600										47								
2-1/2"	Galvanized Steel	25							1600										49							
2-1/2"	Galvanized Steel	25								1600										53						
2-1/2"	Galvanized Steel	25						1600										59								
2-1/2"	Galvanized Steel	25							1600										61							
2-1/2"	Galvanized Steel	25								1600										63						
2-1/2"	Galvanized Steel	25									1600										67					
2-1/2"	Galvanized Steel	25										1600										71				
													Five (5) Foot Section (Aluminum Frame Steel Whee													
2-1/2"	Alum. Steel	25	750										21										22.10			
2-1/2"	Alum. Steel	25		1000										23										23.35		
2-1/2"	Alum. Steel	25			1050										25										25.25	
2-1/2"	Alum. Steel	25				1050										27										27.
2-1/2"	Alum. Steel	25						1050										30								
2-1/2"	Alum. Steel	25				1050										28										29.
2-1/2"	Alum. Steel	25					1050										31									
2-1/2"	Alum. Steel	25						1050										34								
2-1/2"	Alum. Steel	25							1050										37							
2-1/2"	Alum. Steel	25						1050										39								
2-1/2"	Alum. Steel	25							1050										41							
2-1/2"	Alum. Steel	25								1050										43						
2-1/2"	Alum. Steel	25									1050										47					
2-1/2"	Alum. Steel	25										1050										51				
													Five (5) Foot Section (Aluminum Frame, Steel Whee													
3-1/2"	Alum. Steel	25	750										22										23.85			
3-1/2"	Alum. Steel	25		1000										24										25.10		
3-1/2"	Alum. Steel	25			1250										26										27.00	
3-1/2"	Alum. Steel	25				1470										28										28.7
3-1/2"	Alum. Steel	25						1470										31								
3-1/2"	Alum. Steel	25				1470										29										31.4
3-1/2"	Alum. Steel	25					1470										31									
3-1/2"	Alum. Steel	25						1470										35								
3-1/2"	Alum. Steel	25							1470										38							
3-1/2"	Alum. Steel	25						1470										40								
3-1/2"	Alum. Steel	25							1470										42							
3-1/2"	Alum. Steel	25								1470										44						
3-1/2"	Alum. Steel	25									1470										48					
3-1/2"	Alum. Steel	25										1470										52				

TABLE 16
GRAVITY WHEEL CONVEYOR ANALYSIS

	or Capacity (lb) For Various Wheels/Ft.								Conveyor Weight (lb) For Various Wheels/Ft.										Conveyor Cost/Section For Various Wheels/Ft.									
	10	12	14	16	18	20	24	28	6	8	10	12	14	16	18	20	24	28	6	8	10	12	14	16	18	20	24	28
Five (5) Foot Section (Steel)																												
									33										16.35									
0										35										17.90								
	1250										37										19.50							
		1500										40										21.35						
				1600										45										24.80				
	1250										40										21.70							
		1500										42										23.50						
			1600										45										25.30					
				1600										47										26.50				
					1600										49										28.30			
						1600										53										30.50		
				1600										59										31.85				
					1600										61										33.40			
						1600										63										34.90		
							1600										67										37.95	
								1600										71										41.05
Five (5) Foot Section (Aluminum Frame Steel Wheels)																												
									21										22.10									
0										23										23.35								
	1050										25										25.25							
		1050										27										27.00						
				1050										30										30.55				
		1050										28										29.70						
			1050										31										31.00					
				1050										34										32.25				
					1050										37										39.95			
				1050										39										39.65				
					1050										41										41.15			
						1050										43										42.65		
							1050										47										45.65	
								1050										51										48.65
Five (5) Foot Section (Aluminum Frame, Steel Wheels)																												
									22										23.85									
0										24										25.10								
	1250										26										27.00							
		1470										28										28.75						
				1470										31										32.30				
		1470										29										31.45						
			1470										31										32.75					
				1470										35										34.00				
					1470										38										35.70			
				1470										40										41.40				
					1470										42										42.90			
						1470										44										44.40		
							1470										48										47.40	
								1470										52										50.40

3

where:

$(Wt/Ft)_{S-W \atop S-F}$ = Weight/foot of conveyor with steel wheels and frame

$(Wt/Ft)_{S-W \atop A-F}$ = Weight/foot of conveyor with steel wheels and aluminum frame

$(Wt/Ft)_{S-W \atop A-F_M}$ = Weight/foot of conveyor with steel wheels - aluminum frame modified

$(Cost/Ft)_{S-W \atop S-F}$ = Cost/foot of conveyor with steel wheels and frame

$(Cost/Ft)_{S-W \atop A-F}$ = Cost/foot of conveyor with steel wheels and aluminum frame

$(Cost/Ft)_{S-W \atop A-F_M}$ = Cost/foot of conveyor with steel wheels and aluminum frame modified

ON-AND-OFF LOADING

In order to attain the maximum efficiency and utilization of available aircraft, several on-and-off loading concepts were studied and analyzed. In making these comparison analyses, certain assumptions were made as listed below:

1. In the loading operations, the cargo was assumed to be 50 feet from the aircraft.

2. In the unloading operations, the cargo transporter was assumed to be 10 feet from the aircraft.

3. Personnel, unencumbered by load travel at the rate of 4 feet per second.

4. When carrying loads, personnel travel at 3 feet per second.

5. Time required for a man to stoop or bend to perform an operation at floor level and return to an upright position is 3 seconds.

6. To change levels, personnel require 3 seconds to climb from ground to carrier level and 1 second to jump from carrier to ground level.

7. Empty pallets are carried manually at 3 feet per second (see 4).

8. Loaded pallets move by winch at rate of 1/3 foot per second.

9. Loaded QM and STRAC pallets moved manually at 4 feet per second on roller conveyors.

10. Tiedown devices are placed in 14 seconds each and removed in 10 seconds. Pallet chocks can be placed in rails in 10 seconds and removed in 5 seconds.

11. Cargo loaders and forklift trucks move at the rate of 7 feet per second when not in the vicinity of aircraft; at 1 foot per second under the aircraft.

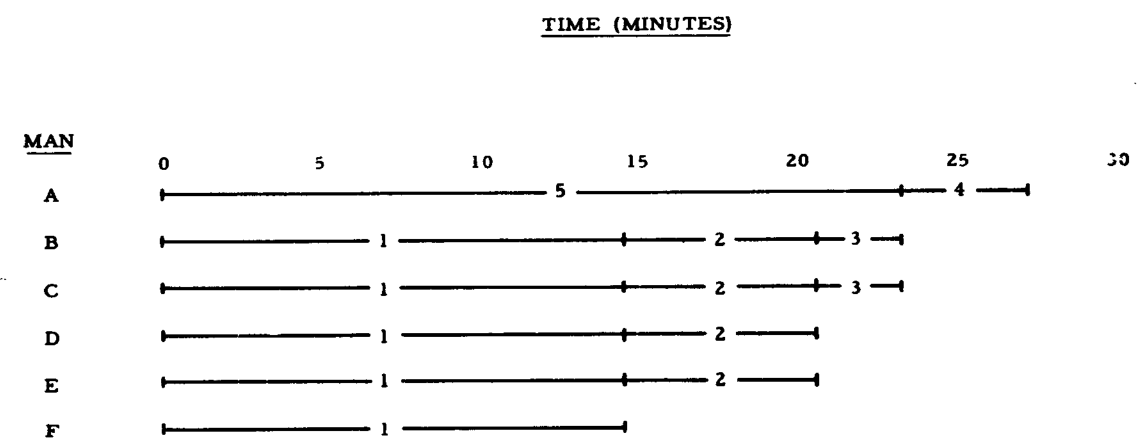
12. Empty pallets are loaded and returned in Concepts III and IV.

Utilizing the above time factors and those which are peculiar to an operation, loading and unloading analysis of each concept and mode was accomplished and presented in Figures 67 through 81. The charts developed the manpower and time required for each operation, as well as the cycle time, man minutes, idle time and material handling equipment required. A sample computation, Concept IV A, is shown in Table 17.

MATERIAL HANDLING EQUIPMENT WEIGHT AND COST

A cost and weight summary for the material handling equipment discussed in this report was prepared, Table 18, and from this a loading concept tare weight and cost summary was tabulated in Table 19.

LOAD 100-60 LB PACKAGES BULK CARGO INTO AIRCRAFT



TOTAL TIME 27.2 Minutes

MAN-MINUTES 129.1

TASKS

1. Cargo Loading
2. Cargo Net Placement
3. Tiedown Placement
4. Inspection
5. Supervision

EQUIPMENT

MATERIAL HANDLING

None

NETS

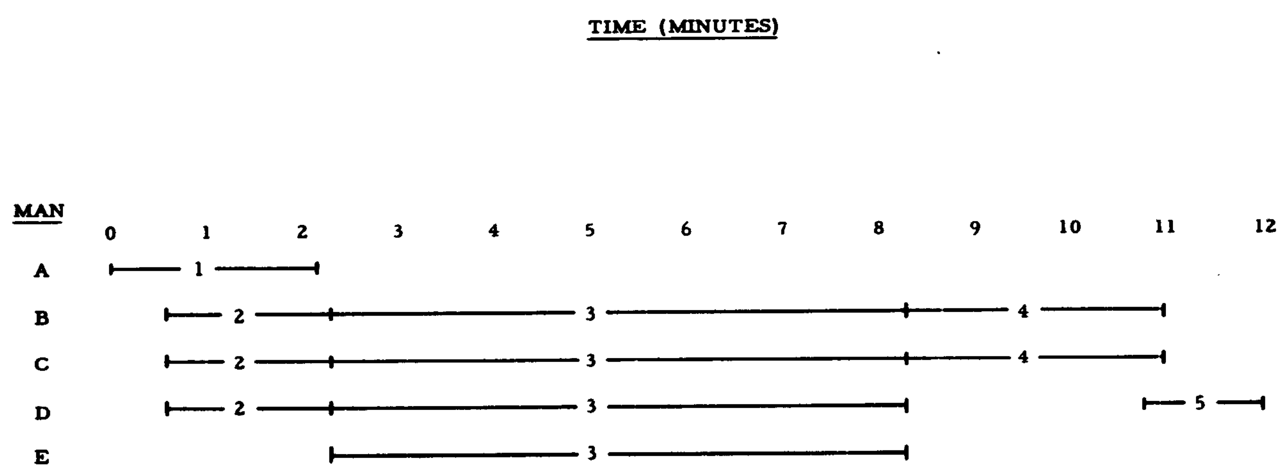
8.0-G Cargo

TIEDOWNS

19 Conventional

Figure 67. Concept I All Terminals (Loading Time)

LOAD THREE 2000 LB WOOD PALLETS INTO AIRCRAFT



TOTAL TIME 12.0 Minutes

MAN-MINUTES 38

TASKS

1. Forklift Truck
2. Aircraft Loading
3. Cargo Net Placement
4. Tiedown Placement
5. Inspection

EQUIPMENT

MATERIAL HANDLING

Forklift Truck

Aircraft Roller Conveyor

NETS

8.0-G Cargo

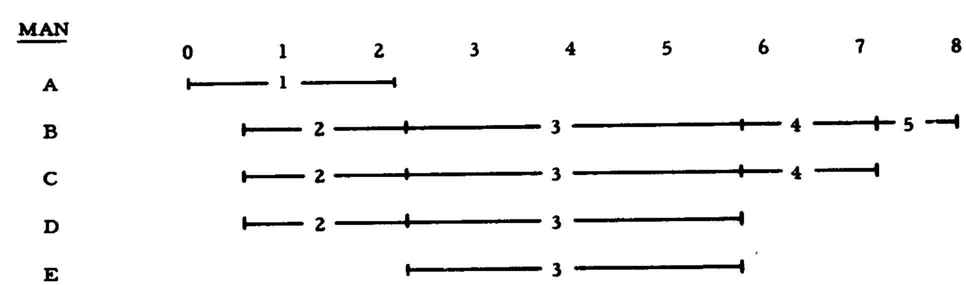
TIEDOWNS

19 Conventional

Figure 68. Concept II-A All Terminals (Loading Time)

LOAD THREE 2000 LB WOOD PALLETS INTO AIRCRAFT

TIME (MINUTES)



TOTAL TIME 8 Minutes

MAN-MINUTES 25

TASKS

1. Forklift Truck
2. Aircraft Loading
3. Cargo Net Placement
4. Tiedown Placement
5. Inspection

EQUIPMENT

MATERIAL HANDLING

Forklift Truck
Aircraft Roller Conveyor

NETS

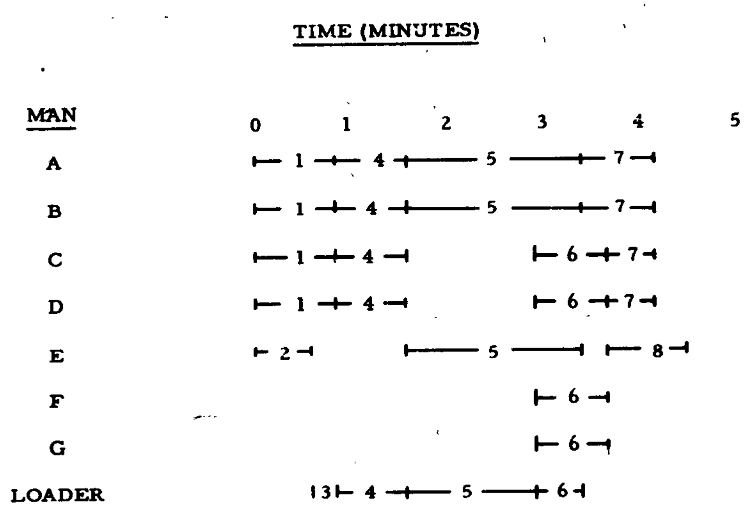
2.0-G Cargo in A/C
8.0-G Barrier in A/C

TIEDOWNS

10 Conventional

Figure 69. Concept II-B All Terminals (Loading Time)

LOAD ONE 6000 LB CONSOLIDATED PALLET



TOTAL TIME 4.5 Minutes

MAN-MINUTES 18.75

TASKS

1. Empty Pallet Removal
2. Winch Cable Preparation
3. Loader Movement
4. A/C Ramp Conveyor Placement
5. Cargo Loading
6. A/C Ramp Conveyor Removal
7. Tiedown Placement
8. Inspection

EQUIPMENT

MATERIAL HANDLING
- Universal Cargo Loader
- Consolidating Pallet
- Aircraft Roller Conveyor
- Aircraft Ramp Roller Conveyor
- Teetering Bridging Devices

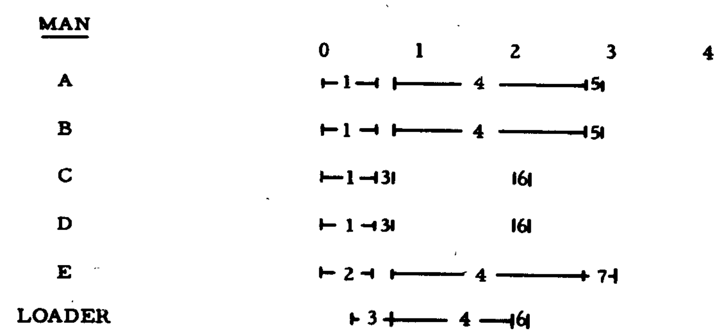
NETS
- 2.0-G Cargo
- 8.0-G Barrier

TIEDOWNS
- 10 Conventional

Figure 70. Concept III-A and-B All Terminals (Loading Time)

LOAD ONE MOBILE PALLET FROM CARGO LOADER

TIME (MINUTES)



TOTAL TIME 3.1 Minutes

MAN-MINUTES 10.2

TASKS

1. Empty Pallet Removal
2. Winch Cable Preparation
3. Loader Movement
4. Cargo Loading
5. Pallet Restraining
6. Ramp Removal
7. Inspection

EQUIPMENT

MATERIAL HANDLING

Universal Cargo Loader
Mobile Pallet
A/C Cargo Floor Rails
A/C Ramp Rail

NETS

2.0-G Cargo
8.0-G Barrier

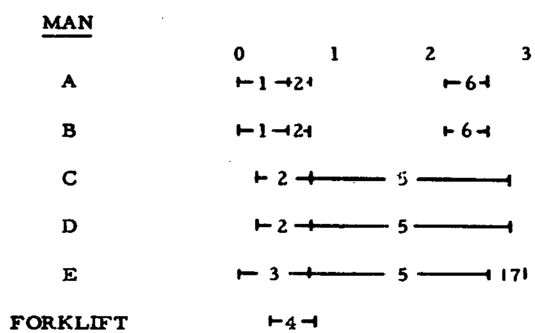
TIEDOWNS

4 Pallet Chocks

Figure 71. Concept IV-A and-B All Terminals (Loading Time)

LOAD ONE 6000 LB MOBILE PALLET FROM GROUND RAIL

TIME (M UTES)



TOTAL TIME 3.0 Minutes

MAN-MINUTES 10.6

TASKS

1. Ground Rail Placement
2. Empty Pallet Removal
3. Winch Cable Preparation
4. Forklift Movement
5. Cargo Loading
6. Ground Rail Removal
7. Inspection

EQUIPMENT

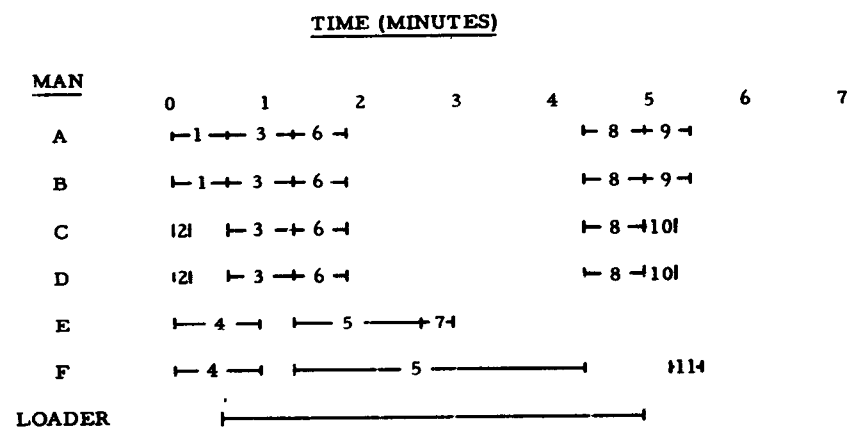
MATERIAL HANDLING
- Forklift Truck
- Mobile Pallet
- A/C Cargo Floor Rails
- A/C Ramp Rails
- Ground Rails

NETS
- 2.0-G Cargo
- 8.0-G Barrier

TIEDOWN
- 4 Pallet Chocks

Fig‿re 72. Concept IV-C All Terminals (Loading Time)

LOAD ONE 6000 LB MOBILE PALLET



TOTAL TIME 5.5 Minutes

MAN-MINUTES 17.4

TASKS

1. Ground Rail Placement
2. Restraint Removal
3. Vehicle Ramp Assembly Replacement
4. Winch Cable Preparation
5. Cargo Loading
6. Empty Pallet Removal
7. Loader Winch Cable Retraction
8. Vehicle Ramp Assembly Removal
9. Ground Rail Removal
10. Pallet Restraining
11. Inspection

EQUIPMENT

MATERIAL HANDLING
- Standard Transporter
- Mobile Pallet
- A/C Cargo Floor Rails
- A/C Ramp Rails
- Ground Rails
- Vehicle Ramp Assembly

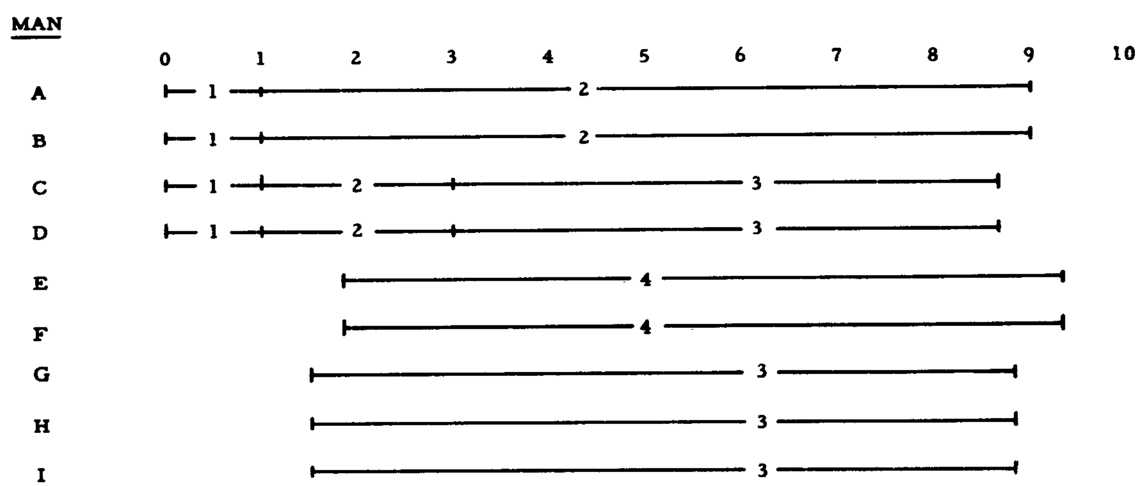
NETS
- 2.0-G Cargo
- 8.0-G Barrier

TIEDOWN
- 4 Pallet Chocks

Figure 73. Concept IV-D All Terminals (Loading Time)

UNLOAD 100-60 LB PACKAGES, BULK CARGO FROM AIRCRAFT

TIME (MINUTES)



TOTAL TIME 9.3 Minutes

MAN-MINUTES 72.3

TASKS

1. Tiedown Removal
2. Cargo Net Removal
3. Cargo Unloading
4. Transporter Loading

EQUIPMENT

MATERIAL HANDLING
Truck Transporter

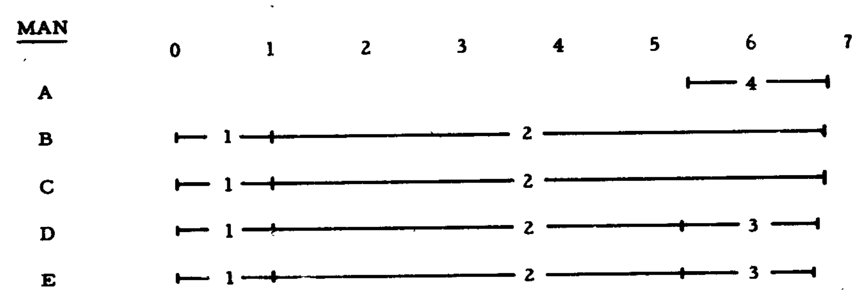
NETS
8.0-G Cargo

TIEDOWNS
19 Conventional

Figure 74. Concept I All Terminals (Unloading Time)

UNLOAD THREE 2000 LB WOOD PALLETS FROM AIRCRAFT

TIME (MINUTES)



TOTAL TIME 6.75 Minutes

MAN-MINUTES 28.3

TASKS

1. Tiedown Removal
2. Cargo Net Removal
3. Cargo Unloading
4. Forklift Truck

EQUIPMENT

MATERIAL HANDLING

Forklift Truck
Aircraft Roller Conveyor

NETS

8.0-G Cargo

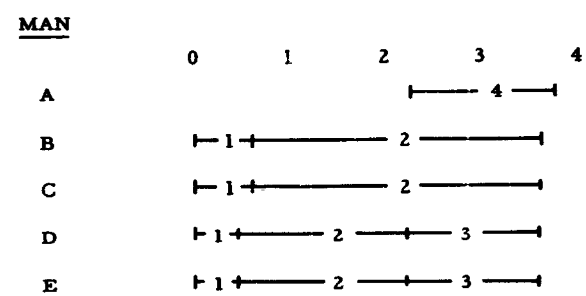
TIEDOWNS

19 Conventional

Figure 75. Concept II-A All Terminals (Unloading Time)

UNLOAD THREE 2000 LB WOOD PALLET FROM AIRCRAFT

TIME (MINUTES)



TOTAL TIME 3.75 Minutes

MAN-MINUTES 15.9

TASKS

1. Tiedown Removal
2. Cargo Net Removal
3. Cargo Unloading
4. Forklift Truck

EQUIPMENT

MATERIAL HANDLING

Forklift Truck
Aircraft Roller Conveyor

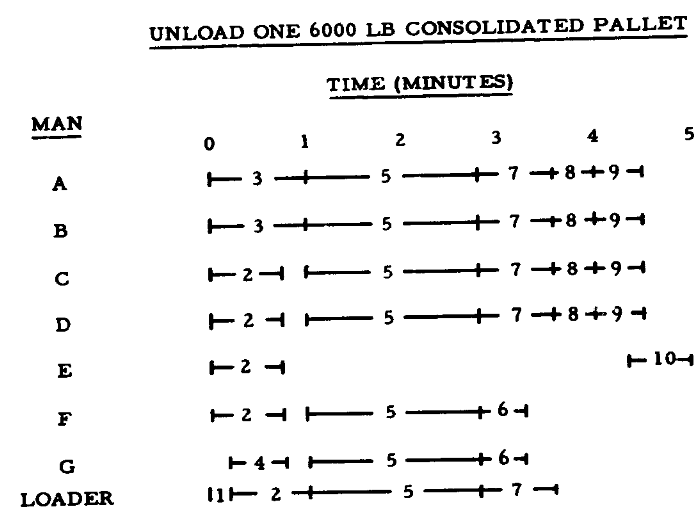
NETS

2.0-G Cargo in A/C
8.0-G Barrier in A/C

TIEDOWNS

10 Conventional

Figure 76. Concept II-B All Terminals (Unloading Time)



TOTAL TIME 5.0 Minutes

MAN-MINUTES 24.8

TASKS

1. Loader Movement
2. A/C Ramp Conveyor Placement
3. Tiedown Removal
4. Winch Cable Preparation
5. Cargo Unloading
6. Winch Cable Retraction
7. A/C Ramp Conveyor Removal
8. Empty Pallet Loading
9. Tiedown Placement
10. Inspection

EQUIPMENT

MATERIAL HANDLING

Universal Cargo Loader
Consolidating Pallet
Aircraft Roller Conveyor
Aircraft Ramp Roller Conveyor

NETS

2.0-G Cargo on Pallet
8.0-G Barrier

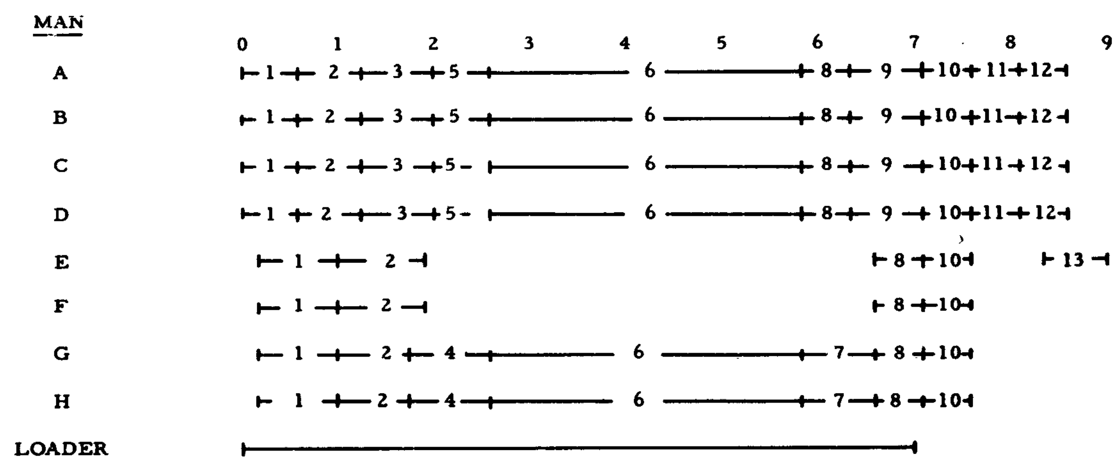
TIEDOWNS

10 Conventional

Figure 77. Concept III-A All Terminals III-B Army Airfield (Unloading Time)

UNLOAD ONE 6000 LB CONSOLIDATED PALLET AT AIRHEAD

TIME (MINUTES)



TOTAL TIME 9.0 Minutes

MAN-MINUTES 48.0

TASKS

1. Ground Roller Conveyor Placement
2. Vehicle Ramp Roller Conveyor Placement
3. Aircraft Ramp Conveyor Placement
4. Winch Cable Preparation
5. Tiedown Removal
6. Cargo Unloading
7. Winch Cable Retraction
8. Vehicle Ramp Roller Conveyor Removal
9. Aircraft Ramp Conveyor Removal
10. Ground Roller Conveyor Removal
11. Empty Pallet Loading
12. Tiedown Placement
13. Inspection

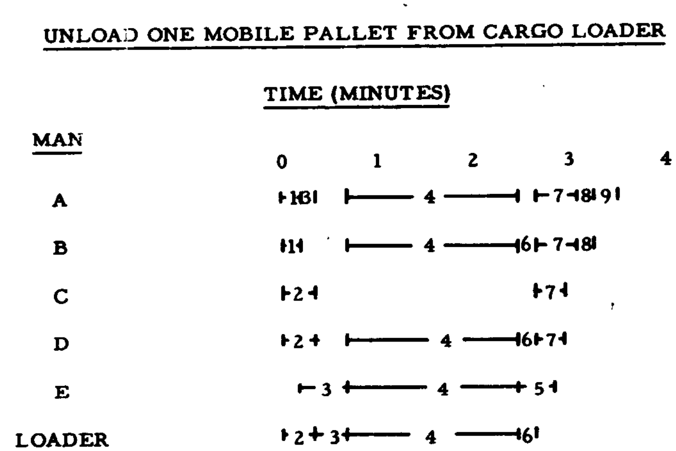
EQUIPMENT

MATERIAL HANDLING
- Cargo Loader
- Consolidating Pallet
- A/C Roller Conveyor
- A/C Ramp Roller Conveyor
- Ground Roller Conveyor
- Vehicle Ramp Roller Conveyor

NETS
- 2.0-G Cargo on Pallet
- 8.0-G Barrier

TIEDOWN
- 10 Conventional

Figure 78. Concept III-B Airhead (Unloading Time)



TOTAL TIME 3.5 Minutes

MAN-MINUTES 11.7

TASKS

1. Restraint Removal
2. Loader Movement
3. Winch Cable Preparation
4. Cargo Unloading
5. Winch Cable Retraction
6. Ramp Removal
7. Empty Pallet Loading
8. Empty Pallet Restraining
9. Inspection

EQUIPMENT

MATERIAL HANDLING

Universal Cargo Loader
Mobile Pallet
A/C Cargo Floor Rail
A/C Ramp Rail

NETS

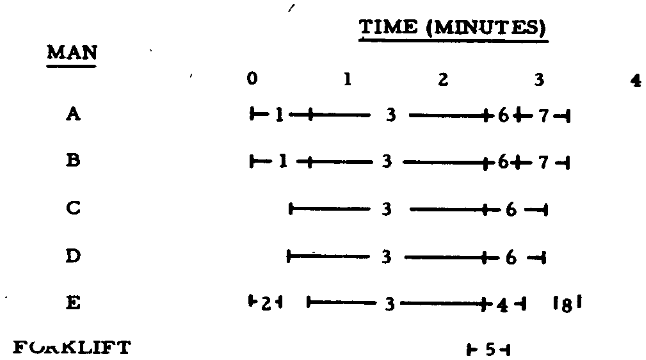
2.0-G Cargo
8.0-G Barrier

TIEDOWN

4 Pallet Chocks

Figure 79. Concept IV-A All Terminals IV-B Army Airfield (Unloading Time)

UNLOAD ONE 6000 LB MOBILE PALLET



TOTAL TIME 3.4 Minutes

MAN-MINUTES 14.7

TASKS

1. Ground Rail Placement
2. Winch Cable Preparation
3. Cargo Unloading
4. Winch Cable Retraction
5. Forklift Movement
6. Empty Pallet Loading
7. Ground Rail Removal
8. Inspection

EQUIPMENT

MATERIAL HANDLING

Forklift Truck
Mobile Pallet
A/C Cargo Floor Rails
A/C Ramp Rails
Ground Rails

NETS

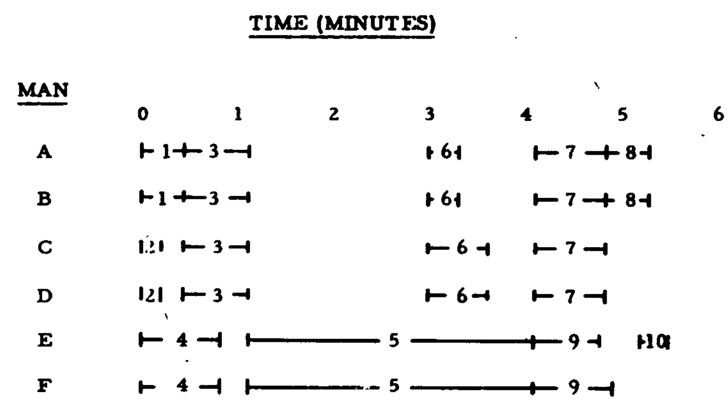
2.0-G Cargo
8.0-G Barrier

TIEDOWN

4 Pallet Chocks

Figure 80. Concept IV-C Army Airfield (Unloading Time)

UNLOAD ONE MOBILE PALLET AT AIRHEAD



TOTAL TIME 5.5 Minutes

MAN-MINUTES 19.1

TASKS

1. Ground Rail Placement
2. Restraint Removal
3. Vehicle Ramp Assembly Placement
4. Winch Cable Preparation
5. Cargo Unloading
6. Empty Pallet Loading
7. Vehicle Ramp Assembly Removal
8. Ground Rail Removal
9. Winch Cable Retraction
10. Inspection

EQUIPMENT

MATERIAL HANDLING

Standard Transporter
Mobile Pallet
A/C Cargo Floor Rails
A/C Ramp Rails
Ground Rails
Vehicle Ramp Assembly

NETS

2.0-G Cargo
8.0-G Barrier

TIEDOWN

4 Pallet Chocks

Figure 81. Concept IV-B and-C Airhead IV-D All Terminals (Unloading Time)

TABLE 17

CONCEPT IV A&B (LOADING TIME)

CONDITIONS

1. Loading vehicle - universal cargo loader used for transport of mobile pallet load.
2. Load location - loader is 50 feet from aircraft.
3. Cargo restraints - cargo is restrained to pallet with 2.0-g cargo net. Pallet restrained in aircraft by rails and 4 pallet chocks. 8.0-g barrier net erected in aircraft.
4. Aircraft parked, ramps, down in position to mate with loader bed.
5. Aircraft equipped with cargo floor rail and ramp rail.

TASK I EMPTY PALLET REMOVAL	Seconds	Minutes	Man-Minutes
4 men enter a/c	3.0		
Walk 16 ft to empty pallet at 4 ft/sec	4.0		
Remove aft pallet chocks at 5 sec each	5.0		
Push pallet aft 16 ft at 2 ft/sec	8.0		
Bend and pick up pallet	3.0		
Walk down ramp 14 ft and 10 ft away from a/c at 3 ft/sec	8.0		
Return 10 ft to a/c at 4 ft/sec	2.5		
Total removal time	33.5	0.57	2.27
TASK 2 WINCH CABLE PREPARATION			
1 man enters a/c	3.0		
Walks average 28 ft to winch at 4 ft/sec	7.0		
Operates controls and clutch release	3.0		
Pulls winch cable average 28 ft to a/c door at 2 ft/sec	14.0		
Returns 28 ft to winch at 4 ft/sec	7.0		
Total preparation time	34.0	0.57	0.27

TABLE 17 (Cont'd)

CONCEPT IV A&B (LOADING TIME)

TASK 3 LOADER MOVEMENT	Seconds	Minutes	Man-Minutes
Cargo loader moves 42 ft at 7 ft/sec	6.0		
Moves 8 ft to a/c ramp at 1 ft/sec	8.0		
A/C ramp positioned and clamped by 2 men	10.0		
Total movement time	24.0		0.33
TASK 4 CARGO LOADING			
2 men mount loader	3.0		
Winch cable pulled 14 ft from a/c door to pallet at 2 ft/sec	7.0		
Winch cable attached to pallet	2.0		
Mobile pallet moves 5 ft on loader, 14 ft on a/c ramp and 16 ft to forward pallet chocks in a/c at 1/3 ft/sec (1 man operates winch 2 guide and restrain)	108.0		
Total movement time	120.0	2.0	6.0
TASK 5 PALLET RESTRAINING			
2 men place 2 pallet chocks at 10 sec each	10	0.17	0.33
TASK 6 RAMP REMOVAL			
When pallet clears ramp 2 men unclamp and raise ramp allowing loader to depart	10.0	0.17	0.33

TABLE 17 (Cont'd)

CONCEPT IV A&B (LOADING TIME)

TASK 7 INSPECTION	Seconds	Minutes	Man-Minutes
Winch operator walks 12 ft to pallet at 4 ft/sec	3.0		
Inspects pallet	12.0		
Walks 16 ft to cargo door at 4 ft/sec	4.0		
Jumps to ground and departs	1.0		
Total inspection time	20.0	0.33	0.33
Total man-minutes			10.16

TABLE 18

MATERIAL HANDLING EQUIPMENT WEIGHT AND COST ANALYSIS SUMMARY

Item No.	Description	Dimensions	Weight Each (lb)	Cost Each	Total Weight (lb)	Total Cost
1	Basic Pallet for Consolidating Load	60" x 132" x 2-1/2"			136.4	$ 682.00
2	Bridging Load Assembly		3.5	$17.50	14.0	70.00
3	Consolidating Pallet				150.0	750.00
4	Mobile Pallet				231.0	1155.00
5	A/C Cargo Floor Rail - Caribou	2 @ 25.85'	3.22/ft	5.80/ft	166.0	299.86
	Chinook	2 @ 27.25'	3.22/ft	5.80/ft	176.0	316.10
6	A/C Ramp Rail - Caribou	2 @ 15'	2.2/ft	4.50/ft	66.0	135.00
	Chinook	2 @ 12.75'	2.2/ft	4.50/ft	56.0	114.75
7	Ground Rail	2 @ 15'	2.2/ft	4.50/ft	66.0	135.00
8	Vehicle Ramp Assembly				200.0	900.00
9	Connecting Devices for Ramps and Tracks		2.50	12.50	20.0	100.00
10	Teetering Bridging Device		30.00	30.00	120.0	120.00
11	A/C Roller Conveyor 190# capacity of rollers 6" spacing 6" width of roller 1.9" diameter					
	Caribou	2 @ 25.85'	8.13/ft	2.36/ft	420.0	122.00
	Chinook	2 @ 27.25'	8.13/ft	2.36/ft	443.0	128.62
12	A/C Ramp Roller Conveyor (Same as above) Caribou	2 @ 13'	22.2/ft	5.95/ft	577.0	154.70

	Chinook	2 @ 27.25'	3.22/ft	5.80/ft	176.0	316.10
6	A/C Ramp Rail - Caribou	2 @ 15'	2.2/ft	4.50/ft	66.0	135.00
	Chinook	2 @ 12.75'	2.2/ft	4.50/ft	56.0	114.75
7	Ground Rail	2 @ 15'	2.2/ft	4.50/ft	66.0	135.00
8	Vehicle Ramp Assembly				200.0	900.00
9	Connecting Devices for Ramps and Tracks		2.50	12.50	20.0	100.00
10	Teetering Bridging Device		30.00	30.00	120.0	120.00
11	A/C Roller Conveyor 190# capacity of rollers 6" spacing 6" width of roller 1.9" diameter					
	Caribou	2 @ 25.85'	8.13/ft	2.36/ft	420.0	122.00
	Chinook	2 @ 27.25'	8.13/ft	2.36/ft	443.0	128.62
12	A/C Ramp Roller Conveyor (Same as above) Caribou	2 @ 13'	22.2/ft	5.95/ft	577.0	154.70
	Chinook	2 @ 11.75'	22.2/ft	5.95/ft	522.0	139.82
13	Ground Roller Conveyor (Same as above)	2 @ 12'	22.2/ft	5.95/ft	532.8	142.80
14	Vehicle Ramp Roller Conveyor (Same as above)	2 @ 15.65'	22.2/ft	5.95/ft	695.0	186.24
15	8g Cargo Net for 56,000 lb. Required Restraining Weight Factor	5' x 11' x 65"	0.24/sq ft	0.83/sq ft	54.8	189.49
16	8g Aircraft Barrier Net for 56,000 lb. Required Restraining Weight Factor	75" x 80"	0.66/sq ft	2.12/sq ft	37.5	138.34
17	2g Cargo Net for 14,000 lb. Required Restraining Weight Factor	5' x 11' x 65"	0.12/sq ft	0.56/sq ft	25.1	127.85
18	Pallet Chock Locking Device		7.50	50.00	30.0	200.00
19	MC-1 Tiedown Devices					
	For A/C with 8g Barrier Net & 2g Cargo Net		3.47	6.50	27.8	52.00
	For A/C with 8g Cargo Net		3.47	6.50	59.0	110.50
20	MB-1 Tiedown Devices					
	For A/C with 8g Net & 2g Cargo Net		10.03	23.50	20.1	47.00
	For A/C with 8g Cargo Net		10.03	23.50	20.1	47.00
21	Aerial Delivery Rollers					
	Caribou	52.7'	5.04/ft	5.12/ft	265.6	269.82
	Chinook	55.5'	5.04/ft	5.12/ft	279.7	284.18
22	Universal Cargo Loader			2.50/lb of Capacity		15,000.00

TABLE 19

LOADING CONCEPT TARE WEIGHT AND COST SUMMARY

Concept	Material Handling Equipment Required: Item No.	Description	Carrier	Weight (lb.)	Cost ($)	Total Weight (lb.)	Total Cost ($)
I	15	8.0 g Cargo Net		54.8	189.49		
	19	MC-1 Tiedown Devices		59.0	110.50		
	20	MB-1 Tiedown Devices		20.1	47.00	133.9	$346.99
II-A	15	8.0 g Cargo Net		54.8	189.49		
	19	MC-1 Tiedown Devices		59.0	110.50		
	20	MB-1 Tiedown Devices		20.1	47.00		
	11	Aircraft Roller Conveyor	Caribou	420.0	122.00		
			Chinook	443.0	128.62		
	12	Aircraft Ramp Roller Conveyor (carried but not used)	Caribou	577.0	154.70		
			Chinook	522.0	139.82		
	10	Teetering Bridging Device (carried but not used)		60.0	60.00		
		Fork Lift Truck					
			Caribou			1190.9	$683.69
			Chinook			1158.9	675.43
II-B	16	8.0 g Barrier Net		37.5	138.34		

II-A	15	8.0 g Cargo Net		54.8	189.49		
	19	MC-1 Tiedown Devices		59.0	110.50		
	20	MB-1 Tiedown Devices		20.1	47.00		
	11	Aircraft Roller Conveyor	Caribou	420.0	122.00		
			Chinook	443.0	128.62		
	12	Aircraft Ramp Roller Conveyor (carried but not used)	Caribou	577.0	154.70		
			Chinook	522.0	139.82		
	10	Teetering Bridging Device (carried but not used)		60.0	60.00		
		Fork Lift Truck					
			Caribou			1190.9	$683.69
			Chinook			1158.9	675.43
II-B	16	8.0 g Barrier Net		37.5	138.34		
	17	2.0 g Cargo Net		25.1	127.85		
	19	MC-1 Tiedown Devices		27.8	52.00		
	20	MB-1 Tiedown Devices		20.1	47.00		
	11	Aircraft Roller Conveyor	Caribou	420.0	122.00		
			Chinook	443.0	128.62		
	12	Aircraft Ramp Roller Conveyor (carried but not used)	Caribou	577.0	154.70		
			Chinook	522.0	139.82		
	10	Teetering Bridging Device (carried but not used)		60.0	60.00		
		Fork Lift Truck					
			Caribou			1167.5	$701.89
			Chinook			1135.5	693.63
III-A	16	8.0 g Barrier Net		37.5	138.34		
	17	2.0 g Cargo Net		25.1	127.85		
	19	MC-1 Tiedown Devices		27.8	52.00		
	20	MB-1 Tiedown Devices		20.1	47.00		
	3	Consolidating Pallet		150.0	750.00		
	11	Aircraft Roller Conveyor	Caribou	420.0	122.00		

		Fork Lift Truck					
			Caribou			1190.9	$683.69
			Chinook			1158.9	675.43
II-B	16	8.0 g Barrier Net		37.5	138.34		
	17	2.0 g Cargo Net		25.1	127.85		
	19	MC-1 Tiedown Devices		27.8	52.00		
	20	MB-1 Tiedown Devices		20.1	47.00		
	11	Aircraft Roller Conveyor	Caribou	420.0	122.00		
			Chinook	443.0	128.62		
	12	Aircraft Ramp Roller Conveyor (carried but not used)	Caribou	577.0	154.70		
			Chinook	522.0	139.82		
	10	Teetering Bridging Device (carried but not used)		60.0	60.00		
		Fork Lift Truck					
			Caribou			1167.5	$701.89
			Chinook			1135.5	693.63
III-A	16	8.0 g Barrier Net		37.5	138.34		
	17	2.0 g Cargo Net		25.1	127.85		
	19	MC-1 Tiedown Devices		27.8	52.00		
	20	MB-1 Tiedown Devices		20.1	47.00		
	3	Consolidating Pallet		150.0	750.00		
	11	Aircraft Roller Conveyor	Caribou	420.0	122.00		
			Chinook	443.0	128.62		
	12	Aircraft Ramp Roller Conveyor	Caribou	577.0	154.70		
			Chinook	522.0	139.82		
	10	Teetering Bridging Devices	Caribou	60.0	60.00		
			Chinook	120.0	120.00		
	22	Universal Cargo Loader					
			Caribou			1317.5	$1451.89
			Chinook			1345.5	1503.63

TABLE 19

LOADING CONCEPT TARE WEIGHT AND COST SUMMARY

Concept	Material Handling Equipment Required: Item No.	Description	Carrier	Weight (lb.)	Cost ($)	Total Weight (lb.)	Total Cost ($)
III-B	16	8.0 g Barrier Net		37.5	138.34		
	17	2.0 g Cargo Net		25.1	127.85		
	19	MC-1 Tiedown Devices		27.8	52.00		
	20	MB-1 Tiedown Devices		20.1	47.00		
	3	Consolidating Pallet		150.0	750.00		
	11	Aircraft Roller Conveyor	Caribou	420.0	122.00		
			Chinook	443.0	128.62		
	12	Aircraft Ramp Roller Conveyor	Caribou	577.0	154.70		
			Chinook	522.0	139.82		
	13	Ground Roller Conveyor		532.8	142.80		
	14	Vehicle Ramp Roller Conveyor		695.0	186.24		
	10	Teetering Bridging Devices	Caribou	120.0	120.00		
			Chinook	180.0	180.00		
			Caribou			2605.3	$1840.93
			Chinook			2633.3	1892.67
IV-A	16	8.0 g Barrier Net		37.5	138.34		
	17	2.0 g Cargo Net		25.1	127.85		
	18	Pallet Chocks		30.0	200.00		

	11	Aircraft Roller Conveyor	Caribou	420.0	122.00		
			Chinook	443.0	128.62		
	12	Aircraft Ramp Roller Conveyor	Caribou	577.0	154.70		
			Chinook	522.0	139.82		
	13	Ground Roller Conveyor		532.8	142.80		
	14	Vehicle Ramp Roller Conveyor		695.0	186.24		
	10	Teetering Bridging Devices	Caribou	120.0	120.00		
			Chinook	180.0	180.00		
			Caribou			2605.3	$1840.93
			Chinook			2633.3	1892.67
IV-A	16	8.0 g Barrier Net		37.5	138.34		
	17	2.0 g Cargo Net		25.1	127.85		
	18	Pallet Chocks		30.0	200.00		
	4	Mobile Pallet		231.0	1155.00		
	5	Aircraft Cargo Floor Rail	Caribou	166.0	299.86		
			Chinook	176.0	316.10		
	6	Aircraft Ramp Rail	Caribou	66.0	135.00		
			Chinook	56.0	114.75		
	22	Universal Cargo Loader					
			Caribou			555.6	$2056.05
			Chinook			555.6	2052.04
IV-B	16	8.0 g Barrier Net		37.5	138.34		
	17	2.0 g Cargo Net		25.1	127.85		
	18	Pallet Chocks		30.0	200.00		
	4	Mobile Pallet		231.0	1155.00		
	5	Aircraft Cargo Floor Rail	Caribou	166.0	299.86		
			Chinook	176.0	316.10		
	6	Aircraft Ramp Rail	Caribou	66.0	135.00		
			Chinook	56.0	114.75		
	7	Ground Rail		66.0	135.00		
	8	Vehicle Ramp Assembly		200.0	900.00		
	9	Connecting Devices		20.0	100.00		
	22	Universal Cargo Loader					
			Caribou			841.6	$3191.05
			Chinook			841.6	3187.04
IV-C	16	8.0 g Barrier Net		37.5	138.34		
	17	2.0 g Cargo Net		25.1	127.85		

	4	Mobile Pallet		231.0	1155.00		
	5	Aircraft Cargo Floor Rail	Caribou	166.0	299.86		
			Chinook	176.0	316.10		
	6	Aircraft Ramp Rail	Caribou	66.0	135.00		
			Chinook	56.0	114.75		
	22	Universal Cargo Loader					
			Caribou			555.6	$2056.05
			Chinook			555.6	2052.04
IV-B	16	8.0 g Barrier Net		37.5	138.34		
	17	2.0 g Cargo Net		25.1	127.85		
	18	Pallet Chocks		30.0	200.00		
	4	Mobile Pallet		231.0	1155.00		
	5	Aircraft Cargo Floor Rail	Caribou	166.0	299.86		
			Chinook	176.0	316.10		
	6	Aircraft Ramp Rail	Caribou	66.0	135.00		
			Chinook	56.0	114.75		
	7	Ground Rail		66.0	135.00		
	8	Vehicle Ramp Assembly		200.0	900.00		
	9	Connecting Devices		20.0	100.00		
	22	Universal Cargo Loader					
			Caribou			841.6	$3191.05
			Chinook			841.6	3187.04
IV-C	16	8.0 g Barrier Net		37.5	138.34		
	17	2.0 g Cargo Net		25.1	127.85		
	18	Pallet Chocks		30.0	200.00		
	4	Mobile Pallet		231.0	1155.00		
	5	Aircraft Cargo Floor Rails	Caribou	166.0	299.86		
			Chinook	176.0	316.10		
	6	Aircraft Ramp Rails	Caribou	66.0	135.00		
			Chinook	56.0	114.75		
	7	Ground Rails		66.0	135.00		
		Fork Lift Truck					
			Caribou			621.6	$2191.05
			Chinook			621.6	2187.04
IV-D		Same as IV-B (no universal cargo loader.)					

3

APPENDIX V. QUEUEING THEORY

In order to use Erlang's analysis to determine service station requirements, it is necessary to determine an average arrival rate. The assumption is made that all the carriers arrive back at the starting terminal at the conclusion of the mission. The carriers are loaded at the starting terminal and unloaded at the intermediate terminal. At time zero, the first carrier enters the loading cycle. To an observer standing on the loading dock, the interval between the departure of the 1st carrier and the departure of the last carrier is

$$\ell = t_t - t_c \tag{36}$$

where

ℓ = total loading time

t_t = total mission time

t_c = time for one carrier to complete one full cycle

The interval to an observer at the intermediate airfield is the same as equation (36), i. e. .

$$u = t_t - xt_c - (1 - x)t_c$$

$$= t_t - t_c$$

where x is the fractional part of the cycle that occurs between the carrier's departure from the loading dock and its departure from the unloading dock and u is the total unloading time.

The total number of arrivals at either dock is represented by n, so that the number of time intervals, Δt, between arrivals is n - 1. The average time interval is

$$\Delta t = \frac{t_t - t_c}{n - 1} \tag{37}$$

The average arrival rate, λ, is the reciprocal of the average time interval, or

$$\lambda = \frac{1}{\Delta t} = \frac{n - 1}{t_t - t_c} \tag{38}$$

When the total number of carriers (N) to be used has entered the cycle, then

$$N(\Delta t) = t_c \tag{39}$$

or

$$\frac{N}{\lambda} = t_c \tag{40}$$

The average rate at which the carriers are serviced at the loading or unloading docks is the reciprocal of the average loading or unloading time per carrier, respectively, i.e.

$$\mu_{\ell} = 1/t_{\ell}, \text{ and} \tag{41}$$

$$\mu_u = 1/t_u \tag{42}$$

Erlang's analysis relates the average time which would be spent in a queue waiting for service as a function of the average arrival rate, λ; the average servicing rate, μ; and the number of stations, K, available to service the arrivals. The relationship between the number of units waiting for service, $\overline{1}$, and the average waiting time, w, is

$$\overline{1} = w\lambda \tag{43}$$

The queue length for a single service station is

$$\overline{1}_{K = 1} = \frac{(\lambda/\mu)^2}{(1 - \lambda/\mu)} \tag{44}$$

and for a multi-service station installation is

$$\overline{1}_{K > 1} = \frac{\lambda \quad (\lambda/\mu)^{K + 1}}{(K - 1)\,!\,(K - \lambda/\mu)^2} \quad P_o \tag{45}$$

where P_o is

$$P_o = \frac{1}{\sum_{i=o}^{k-1} (1/i!)\,(\lambda/\mu)^i + \frac{1}{K!}\left(\frac{\lambda}{\mu}\right)^k \frac{K\mu}{K\mu - \lambda}} \tag{46}$$

Equations (44), (45), and (46) are developed in Chapter 14 of "Introduction to Operations Analysis" (C. West Churchman, Russell L. Ackoff, and E. Leonard Arnoff; John Wiley & Sons, Inc., 1958). Because the waiting time for a single service station includes the servicing time, it was necessary to subtract the service time, shown in equation 12 of that publication, to arrive at equation (44).

The above equations assume that the service rate, μ, is a constant; that the arrival rate, λ, is randomly distributed with time; and that the units are serviced in order of arrival.

DISTRIBUTION

USCONARC	3
USACGSC	1
USAWC	1
USAAVNBD	1
USATMC(FTZAT), ATO	1
DCSLOG	2
OCRD, DA	1
TO, USAAVNC	2
USAAVNS, CDO	1
DCSOPS	1
USATCDA	1
USATMC	2
USATC&FE	4
USATSCH	3
USATRECOM	17
TCLO, USAAVNS	1
USA LN Det, WPAFB	3
ASTIA	10
USAMOCOM	3
USAMC	2
USSTRICOM	1
Nortronics	12

AD

Northrop Corp., Nortronics Div.,
Anaheim, California
ARMY AIR LOGISTICAL SUPPORT STUDY
by W. N. Christensen & J. M. Seman
December 1962, 269 p. incl. illus.
and tables (Final Report)
(NSS 2306) (TCREC 62-92)
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The results of an engineering study of methods, procedures and equipment pertinent to a system for handling military cargo

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2. Air Transportation
3. Cargo

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