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Impact or Intermodal Containerization on USAF Cargo Airlift

Aeronautical Systems Division

AUGUST 1972

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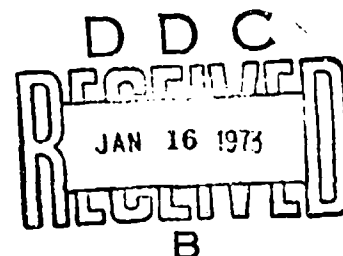
ASD-TR-72-76

IMPACT OF INTERMODAL CONTAINERIZATION ON USAF CARGO AIRLIFT

JOSEPH L. WEINGARTEN

TECHNICAL REPORT ASD-TR-72-76

AUGUST 1972



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Page 9 Last paragraph, second sentence - Add to end of sentence
, outside CONUS.

Page 13 Para B - Change 2700 to 7200

Page 19 Fig 5, C-130 4A - Change 13.62 to 14.15; 39.55 to 40.08

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Page 65 Para 1, line 1 - Change ca-go to cargo

Page 66 Line 2 - Change foller to roller

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Day, D., Engineering Report - Restraint and Loading
8 x 8 x 20 Foot Containers, ASD/SMD-TM-72-2, 6 Mar 72

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**IMPACT OF INTERMODAL CONTAINERIZATION
ON USAF CARGO AIRLIFT**

JOSEPH L. WEINGARTEN

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FOREWORD

This report was prepared by Mr Joseph L. Weingarten of the Equipment Development Branch, Directorate of Crew and AGE Subsystems Engineering, Deputy for Engineering of the Aeronautical Systems Division, to investigate the effects of the entry of intermodal containers into the airlift system.

The work was accomplished under Project 1244, "Advanced Air Cargo Handling," as an in-house study effort. The report was submitted by the author in August 1972.

This document has been reviewed and is approved.

Charles N. Moser

C. N. MOSER
Chief, Delivery and Retrieval Division
Deputy for Engineering
Aeronautical Systems Division

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ABSTRACT

This study was conducted to determine the impact of containerization on the airlift system. The report also provides background information on container construction and usage by other modes of transport.

The container is examined in relation to meeting, and being moved within, the framework of current air transportability, requirements. Concepts are also provided to develop techniques for efficient container movement in the near term and future.

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SECTION I

BACKGROUND

1. 463L SYSTEM

In 1957, the Air Force started the 463L Materials Handling System. The basic concepts behind this program form the backbone of today's military airlift/air cargo handling system.

The basic unit in the 463L system is a pallet 108 inches wide x 88 inches long made of a sandwich construction, aluminum over balsa wood, with a restraint lip shaped to fit aircraft guide rails and restraint mechanism. It is used in conjunction with side and top webbed restraint nets, which fasten to rings built into the pallet (Figure 1).

The two other portions of the system are the aircraft internal restraint system and the ground handling equipment.

The aircraft system consists of roller conveyors, external guide and locking rails, and tie-down rings (Figure 2). The conveyors and rails are for positioning pallet loads and to provide proper restraint for air movement. To move wheeled vehicles the restraint is achieved by chains or webbing straps from the vehicle to the

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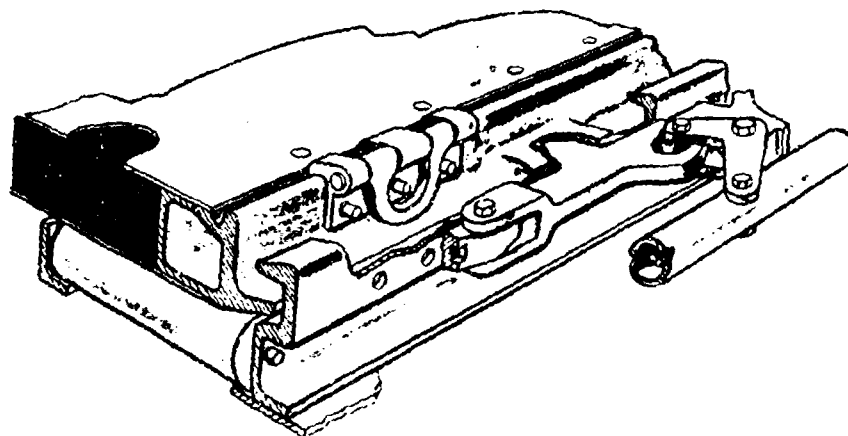
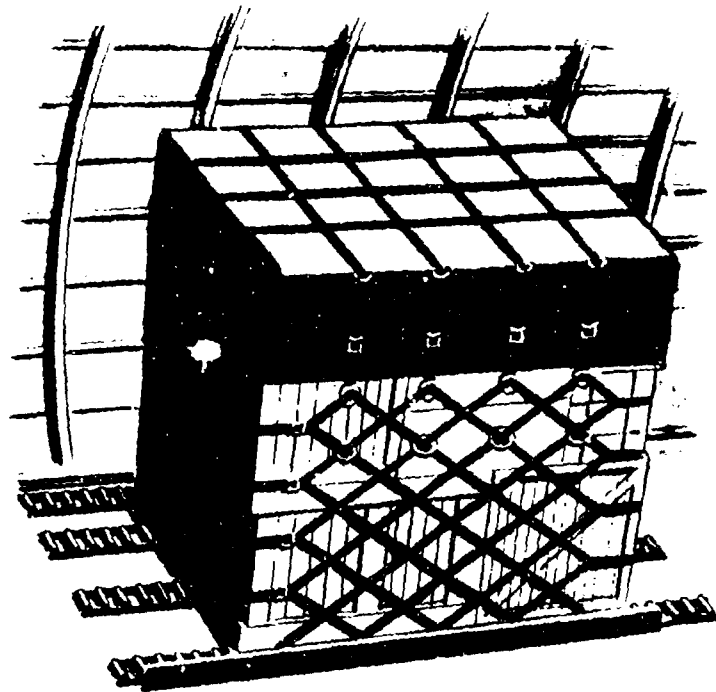


Figure 1. Aircraft Cargo System

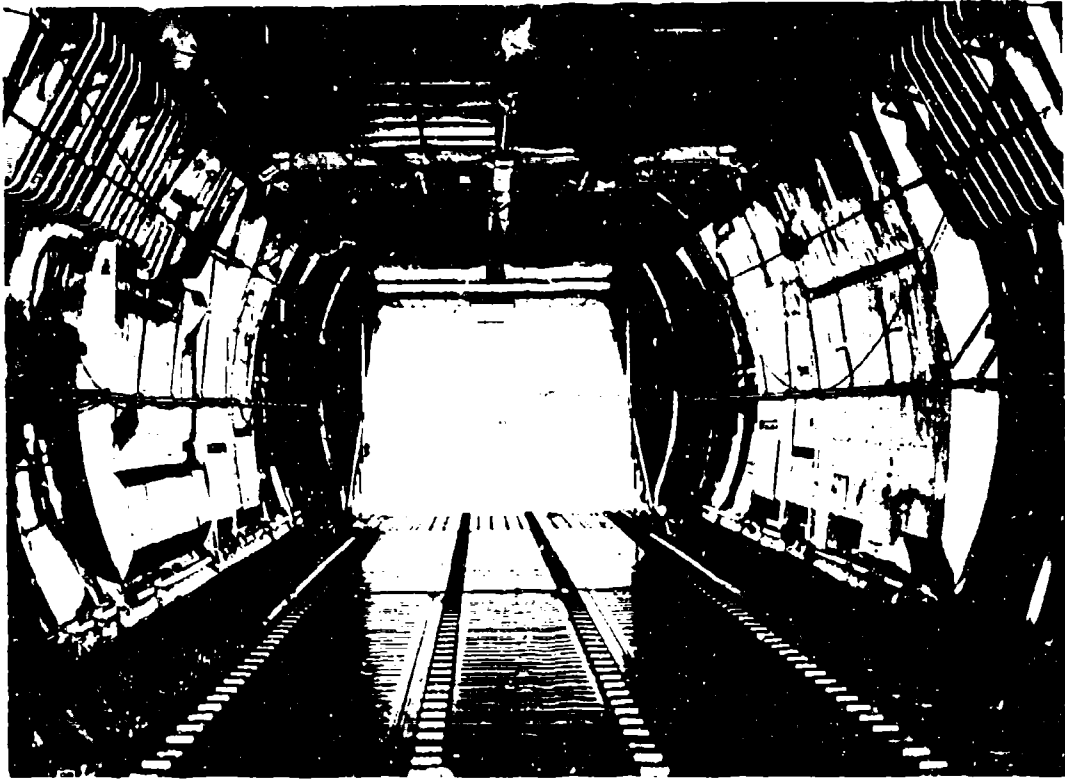


Figure 2. Interior C-141 Aircraft

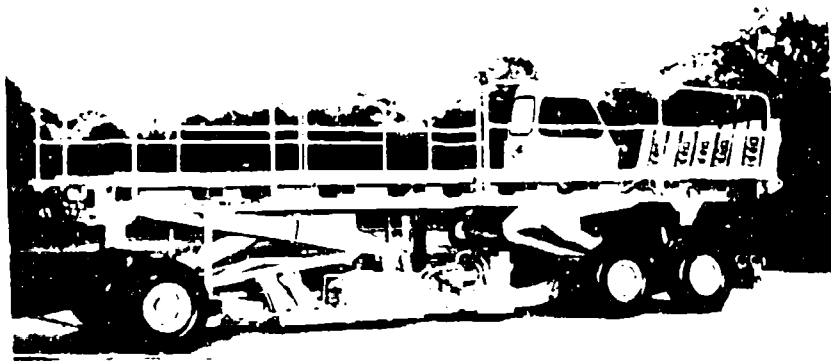


Figure 3. 463L-25K Loader

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aircraft tie-down rings.

After cargo is placed on a pallet it must be loaded and later unloaded from the aircraft. This bridge to the aircraft is performed by special ground handling equipment. The two types of 10,000-lb forklifts, a warehouse, a rough terrain, and 25,000 (Figure 3) and 40,000-lb flatbed loaders are the mainstay of this operation. Currently under development is a loader capable of operating in a forward area environment. All of this equipment revolves around the 463L pallet. In particular, the aircraft systems conform to specific requirements to handle the 108-inch width pallets. The usual length of a pallet is 88 inches; however, the rail system performs a secondary function of airdrop, where pallets up to 28 feet long have been placed in the aircraft.

2. START OF CONTAINERIZATION

In the same year the 463L started, a revolution began in the field of logistics. The era of true containerization began in October 1957 when the ship, Gateway City, crossed the Atlantic with a full complement of containers on board. Intermodal containerization is basically the unitization of cargoes by means of large reusable standardized boxes that could move in any mode of transport. The definition of an intermodal container could be traced back to the

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fiberboard box and wooden reusable pallets. One of the first enclosed general purpose containers can be traced to the US Army CONEX (Figure 4) containers, which were used in a variety of freight transport applications. The CONEX was introduced after World War II. It was used for example, extensively in Vietnam. Between 1966 and 1968, 156,287 units were moved across the Pacific.

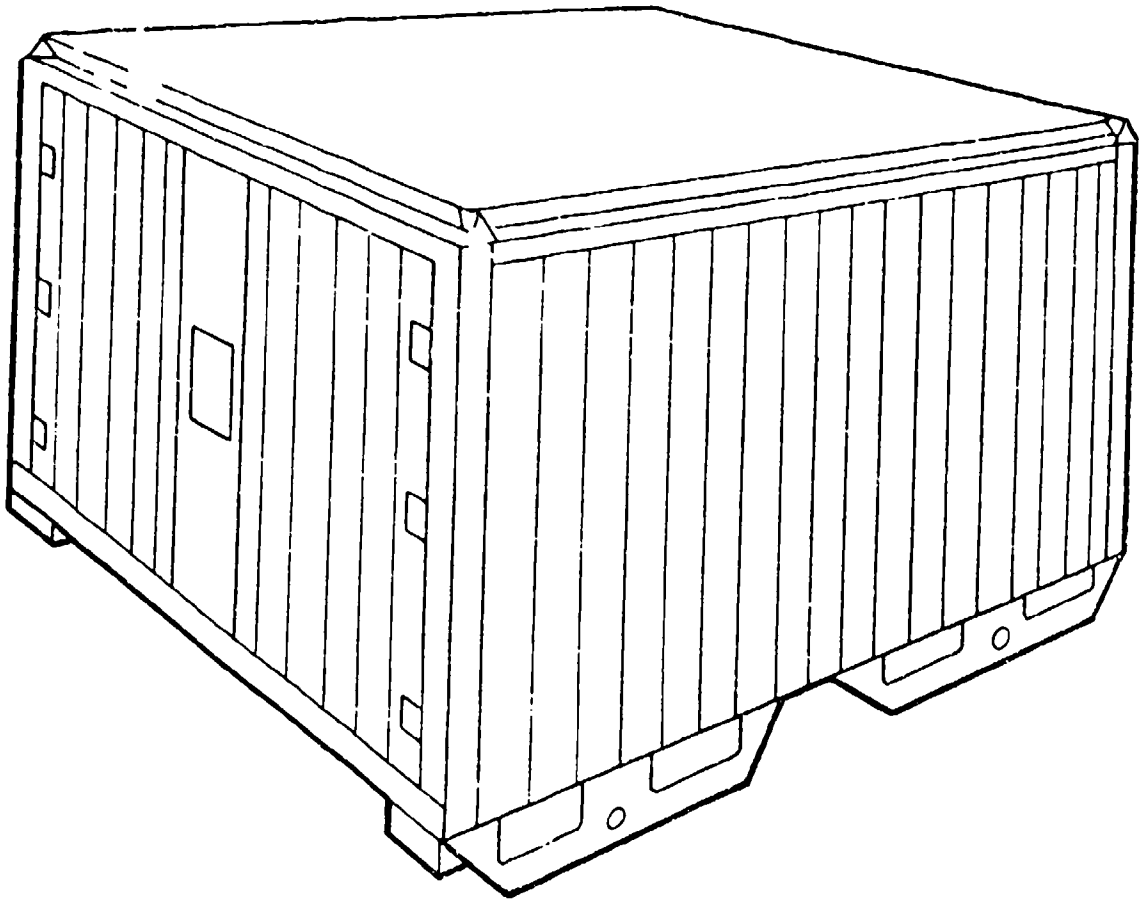


FIGURE 4. CONEX II CONTAINER

Although history shows that the roots of modern containerization lie with the military, it was the commercial steamship lines and their need to earn a profit that led to the spectacular growth in containers.

3. GROWTH OF CONTAINERS

It was found by Matson Steamship Lines in 1958 that, of ocean freight costs, 31% was accounted for by fleet operations and depreciation. Yet 43% was for loading and discharging costs. This was caused by increasing wages paid to longshoremen with little or no increase in productivity. It was apparent that the loading and discharging costs would have to be reduced. The obvious method was to increase productivity, and the solution was mechanization of loading large highway vans without wheels into the hold of a ship. This switch to containerized cargo resulted in increased capital costs for equipment, new ships, and loaders, and, therefore, increased interest and depreciation costs. Overall it is estimated that investment approximately doubled; however, the reduced manpower resulted in an overall savings of 10%. In port, time decreased considerably from 7 days for a break bulk ship to 22 hours for an equivalent containership. Other indirect costs included a reduction by 50% of breakage through containerization. Pilferage is negligible via container compared to an average 10 to 15% loss via conventional mode. The lower loss rates can be attributed to a reduction in handling of 2 to 8 times compared to break bulk shipments, depending on the origin and destination of the containers (Reference 1).

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The steamship lines recognized the need for fast transfer to inland areas by both truck and rail. This resulted in the basic designed box to meet both over the road requirements on a detachable buggy and placement on a railroad flatcar. Over the years one basic standard has evolved a box 8 x 8 x 10-20-30-40 feet long. By far the most common is the 20-foot-long box, accounting for 70% of an estimated 340,000 containers in the world today.

The increase of productivity in the transport industry, along with the reduction of in-transit loss and damage through the use of containers, can be viewed as a success by the wide acceptance throughout the world. Estimates have been made that in the next five years 500,000 container units will be built.

Within this report, details can be given on how containers are handled by the various transport modes; however, it is felt that this is not required here. It is apparent that the transport industry has found a very effective way to safely move cargo. The Department of Defense has only started to move toward containers from both commercial experience and limited use in Vietnam. The container also must enter one additional transport mode - that of air. As containers enter the DOD logistic network, the Air Force will be required to move them within the present airlift system.

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4. FUTURE DEVELOPMENTS

Future aircraft developments and possible mission changes could alter today's concepts in the movement of air cargo. But, of more immediate concern is the potential which exists for a major change in the landing phase of an aircraft. A joint USAF/Canadian Department of Industry, Trade, and Commerce Advanced Development Program is now in progress to demonstrate, by flight testing, the functional capabilities of an air cushion landing system (ACLS) for aircraft. The program is outlined for system application to an assault cargo aircraft using the CC-115/C-8 (Buffalo) aircraft as the test bed. The overall objective of this program is to give aircraft the capability of operating in rough fields or on soft soils, swamps, snow, and water. This type of landing system provides the opportunity to rework some major concepts of air cargo movement, both on-board the aircraft and in ground cargo handling, through air floatation techniques. This report presents concepts on how to provide the capability to move containers and general cargo within our present airlift system with evolution to future aircraft at the lowest possible cost and smallest change in operational concepts.

SECTION II

CARGO TRANSPORT OPERATIONS

The container has changed many of Industry's logistic concepts. Commercial utilization has grown overnight and its growth within the military system can be easily envisioned from past military supply needs.

1. CONTAINERS

The Department of Defense move to an all-voluntary force will result in a higher manpower cost. A problem similar to that which forced the steamship lines to change operating procedures in the late 1950's, and they along with other commercial transport industries moved decidedly in the direction of containers to increase productivity and efficiency. The Department of Defense is moving in the same direction to improve its logistics system.

The Department of Defense generates a great deal of cargo. Approximately 96% of it moves by sealift and the remainder by air. Table I provides a further breakdown of the service requiring a particular transport and shows the level of worldwide movement for both sea and airlift.

TABLE I
DOD WORLDWIDE CARGO MOVEMENT BY MODE OF TRANSPORT

<u>Year</u>	<u>% of Total Water (Sealift)</u>			<u>% of Total Airlift</u>		
	<u>Army</u>	<u>Navy</u>	<u>AF</u>	<u>Army</u>	<u>Navy</u>	<u>AF</u>
1965	59	21	20	25	14	61
1966	59	24	17	30	17	53
1967	64	19	17	40	21	39
1968	65	19	16	42	20	38

The Army is the dominant service with respect to cargo shipped on both water and in the air, and its future logistics concepts will have to play an important part in any Air Force air cargo movement and materials handling system.

During the Vietnam era containers have been utilized on a limited scale. The results are best stated in this manner: "Experience with large intermodal containers in Vietnam clearly indicates that full exploitation can have as revolutionary an impact on military shore-based logistics as it has had on commercial shipping" (Reference 2). The use of containers has grown within the Department of Defense. Of cargo that could be containerized, 28% was shipped in containers in FY 1968. This utilization factor grew to 64% in FY 1971 (Reference 2).

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It is clear that the DOD intends to utilize the container. The US Army has procured an initial buy of 6700, 8 x 8 x 20 foot containers and related hardware. This appears to be a large procurement, but if the total potential is viewed this number becomes rather small. Also under serious consideration is the tricon container. This is an 8 ft x 8 ft x 6 2/3 ft module that can be combined into three units to measure 8 ft x 8 ft x 20 ft. This type of container could well become the prime cargo mover in air transport. This size allows transport by helicopter to forward areas and, in essence, is a replacement for the CONEX within the sea-land system.

2. POTENTIAL LAND-SEA CONTAINER UTILIZATION

Container utilization prospects can be viewed in two parts - first as everyday resupply such as involved Europe in 1968, and second, as required with the conflict in Vietnam.

In 1968 a total of 22,000,000 tons was moved by sealoift in support of DOD operations worldwide. Of this total, 7-1/2 million tons moved to RVN. It was found that, if Vietnam operations had been fully containerized, a total of 82,100 containers would have been required to sustain cargo operations, with a total of 394,100 container movements per year. This is based on 80% of the cargo being containerized and a turn-around time of 75 days. Turn-around time

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to Europe is approximately one-half that of Asia, therefore requiring the same amount of containers for twice the cargo. A fully containerized logistic system in 1968 would have required 160,000 twenty foot units and approximately one million movements.

Actual container service to RVN in 1968 amounted to 20,830 loads, accounting for 828,600 measured tons.

A total of 160,000 containers appears to be rather staggering; however, the number can be lowered significantly by accelerating turn-around time. New high speed ships under construction and improved land handling of containers could reduce turn-around time to Europe to a conservative 28 days, and 65 days to Asia. This would, at a 1968 level, reduce container needs to 129,000 units, a reduction of 31,000 containers. At present container costs of approximately \$1200 a unit, this represents a cost avoidance of \$37,200,000.

3. CONTAINERIZED DEPLOYMENT

Assume that a one-half division force of approximately 15,000 men is deployed to a point 7200 nautical miles from CONUS. For this unit move a requirement exists for 89,000 measured tons for the first month and 37,000 measured tons of cargo for each month on station.

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A. Container Requirements

During a deployment it was found that approximately 67% of the cargo could be containerized, 28% could be driven on-board a ship, and 5% is non-containerizable. To move this equipment by ship, even under ideal emergency conditions, would require 1.5 days' loading, 11.5 days' sailing time, and 1.5 days' unloading. This would provide delivery of 14,000 tons per ship after 14.5 days. The first 15 days would be critical from an air supply phase. The object would be to provide maximum airlift support, while maintaining airlift capability to other areas on a skeleton basis. Of the 89,000 tons, 67% or 59,630 tons, would be containerized. A container loading level of 80% and airlift weight limit of approximately 30,000 pounds would require approximately 4,000 containers plus other roll-on, roll-off equipment to move the containers.

B. Airlift Support

If 50 C-5 and 150 C-141 aircraft are supplied for this effort, could this movement be accomplished? Turn-around time on both aircraft from CONUS to 2700 NM point and return to CONUS would be approximately three days. This would allow for loading and unloading. Capacity of the aircraft is seven containers for the C-5 and two for the C-141. Besides the 4,000 containers, it must be

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remembered that 30,000 tons of other equipment must be moved. If 15 C-5's and 50 C-141's are utilized for non-container cargo at a level of 100 tons for a C-5 and 25 tons for the C-141, the cargo movement shown in Table II could be accomplished in the first 15 days before sea delivery could be started.

TABLE II
Air Deployment

	Container Loads	Container Tonnage	Non-Container Tonnage	Total Tons
C-5	1225	18,375	7,000	25,375
C-141	1000	15,000	6,250	21,250
Totals	2225	33,375	13,250	46,625

A little over half the requirement could be supplied in the first 15 days. If deployment were to an inland area, nonaccessible by ship, it is possible to provide full support at the above rate for these 15,000 men. Of course, any increase above this level would require sea transport, at least to a closer intermediate point.

The above is only an analysis of moving a small strike force into an area, but it shows the possible amount of container movement involved. It is conceivable that the Air Force could be required to move 2,225 containers in a 15-day period. Due to the possibility of

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moving 30,000 pound containers at an everyday rate of approximately 55 units, and deployment rate of 150 units a day, equipment to handle containers will be required. As containers become more common and airlift support grows, the container capacity could increase to 100 units per day.

4. AIR FORCE CONTAINER UTILIZATION

The 463L System provides an extremely efficient method of unitizing cargo and movement between aerial ports. However, the 463L system accounts for only 10% of total Air Force tonnage moved. For example, in 1968 the Air Force shipped 3,520,000 tons of cargo by sea. A great deal of this cargo could have been containerized and, recently, containerization of Air Force sea cargo has been started.

SECTION III

PROBLEM AREAS

Although it is recognized that the 463L system is providing excellent service to the Air Force, it must be noted that this system is basically designed as an "aerial port to aerial port" concept. Containerization is moving us closer to the source-to-user concept, avoiding many of the in between steps. There is a potential within the Air Force to provide a very vital link in the movement of cargo under this concept, but as the mission changes to follow this concept, change within the Air Force will also be required.

1. CURRENT FRAMEWORK

The 463L system, as described in Section I, is built into many aircraft systems, yet on each aircraft the dimensions within the basic framework are different. If we view the three prime aircraft, the C-130, the C-141, and the C-5, and some ground equipment, this difference can easily be seen (Figure 5). This results in various design problems, and will affect any system built around the container.

Another problem with the rollers is moving wheeled vehicles on-

board the aircraft. The rollers on the C-130 must be completely removed, but those on the C-141 and C-5 are the flip-flop type and can just be turned over on the aircraft floor to provide a flat area. However, manpower must be expended each time.

Manpower must also be used to load and unload the aircraft. Powered systems, in the form of a winch, are available, but these require time to hook up. Of course, this grows in magnitude when viewing the C-5 with 36-pallet loads on board (Figure 6). Pallet rail design does not permit the building of couplers to attach the pallets to form a train that can be loaded in one try. Various attempts have been made to solve this problem area without success. It is very doubtful that a coupler could be built to accommodate the current pallet design. One area of continuing concern is that of cargo restraint. Under current criteria, the restraint load factors (Table III) vary from aircraft to aircraft with a safety range of 3 to 9, (out of a "full safety" possibility of 10) under various conditions. A change has been proposed to the air cargo restraint criteria (Reference 3) which would result in all cargo being restrained to a load factor of 3 on all aircraft, with a barrier net providing additional protection where needed. This will allow for a more effective interchange of cargo between aircraft and equipment designated "Air Transportable" to be built to a safety factor of 3 instead of the previous 9. This simple change will provide a safer

TABLE III

LOAD FACTOR (G) REQUIREMENTS RELATED TO AIR CARGO RESTRAINT

Cargo/Passenger Loading Configuration	Load Direction	Requirements Applicable To		
		Cargo System Airframe Attachments and Carry Through Structure MIL-A-008855 A (USAF) 31 Mar 71	Equipment to be Air Transported MIL-A-8421 (C) USAF 14 Aug 1969	Emergency Landing Loads
Cargo Poses Hazard to Crew & Passengers	Forward	Equal to Seat Installation Load Factor Minimum 9 G	② 3	④ 9
Cargo Poses No Hazard To Aircrew or Passengers	Forward	3		
	Aft	1.5	3	③ 9 or 2
Both Configurations I & II	Lateral	1.5	1.5	
	Vertical Up	2	3	
	Vertical Down	4.5	3	4.5

NOTES: 1 Equipment must operate after subsection to these loads.

2 In most cases 9 G ultimate will apply since it is not known in advance which cargo/personnel configuration will be involved.

3 When the loaded position in the A/C is fixed or specified for an item of equipment the 2 G applies.

4 May be 4 G if no passengers are on board.

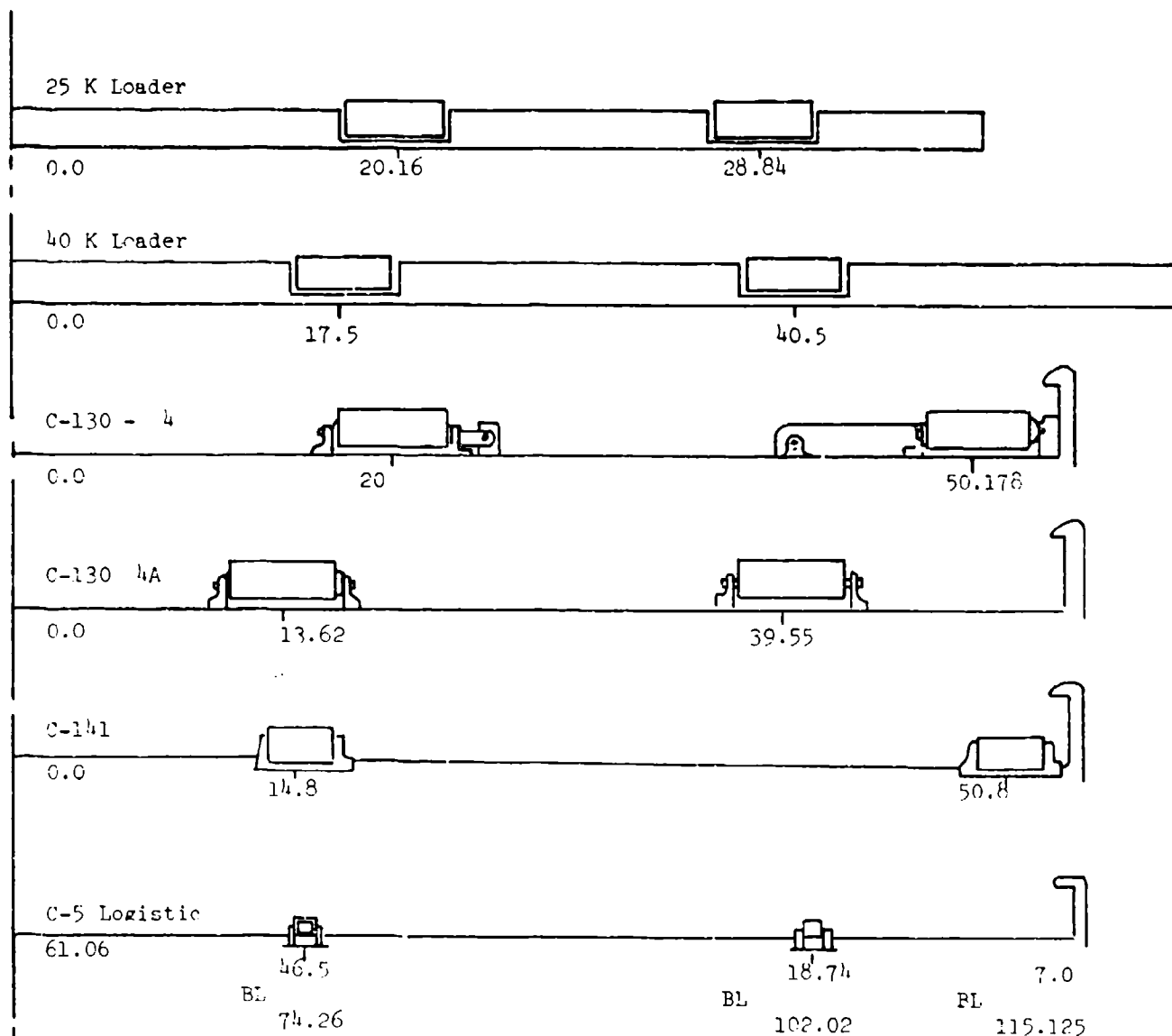


Figure 5. Aircraft and Loader Roller Locations



Figure 6. C-5 Aircraft With 36 Pallet Loads

system for passengers and crew and result in substantial cost savings to all military services.

Ground handling equipment has one major problem - that of age - along with procedures that need revision in today's world. Loading 22 pallets onto a C-5, and five pallets into the C-130 are both accomplished in the same manner. This results in wasted time and, with

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a capital expenditure of \$60 million per C-5, time on the ground is very expensive. Many minor problems exist with this equipment and the "lessons learned" concept should be used in the development of new equipment.

2. MISSION ASSIGNMENT

Air Force airlift is required to provide high speed movement of troops and supplies anywhere in the world. During peacetime the mission of hi-value or essential supplies becomes a prime mission. To accomplish this mission, the Air Force currently has three prime cargo aircraft - C-5, C-141, and C-130 - and three new aircraft which have been proposed for the late 1970's.

Although the Air Force mission will not change, some methods to accomplish it will. A possible change in mission accomplishment may concern any one type of aircraft. For example, the C-5 has been designed for forward area operations and combat airdrop. A more reasonable mission of this aircraft and the C-141 would be that of long range movement from major base to major base, and transfer of cargo to small aircraft for forward area or combat movement. Also, the establishment of major aerial ports could be accomplished in conjunction with the C-5 mission reorientation.

3. CONTAINER INTERFACE

The container was originally designed for movement by truck and ship. As the railroads developed special flatcars for container movement, a total surface system was completed. (Appendix I details container construction.) With the design of large aircraft, such as the C-5 and the Boeing 747F, the concept of a truly inter-modal, land-air-sea system became a reality. But, many problems will accompany the container's entry into the air mode. Container design did not take into account the unique problems of air transport. The result has been that present containers cannot be moved without auxiliary equipment.

At Wright-Patterson AFB, Ohio, a loading demonstration was conducted on three types of 8 ft x 8 ft x 20 ft containers on a C-141 aircraft. This demonstration has provided an insight into the various interface and operational constraints limiting container movement within the present system.

Details of the loadings are presented in Section IV and Appendix II. The loading shows that, from an operational standpoint, the container can be handled on today's military aircraft, but only with difficulty.

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The main factor is that the Air Force does not have the handling equipment for efficient movement of these large boxes. Equipment used for tie-down was not designed for container operations and, therefore, did not provide total adequate restraint. The loading clearly showed that hardware would be required for loading and air transport of containers on an everyday basis.

4. 463L/CONTAINER SYSTEM CONVERSION

The 463L system of today is a valuable asset to the Air Force and cannot just be junked or replaced, because containers are entering the system. The cost to do this would be prohibitive.

The subsequent sections of this report take an in-depth view of the container and provide an approach to incorporate the container into the airlift system with the smallest possible change to the 463L system.

SECTION IV
CONTAINER TEST LOADING

A test was conducted on 16 November 1971 of three containers to develop methods of moving a container immediately within the airlift system.

1. BACKGROUND

The use of containers had been growing rapidly in the movement of military sealift. It became apparent that a potential existed for the container to enter the airlift system. Direction had been issued by Secretary Packard on 8 May 1971, "to explore and develop new land-air-land systems innovations" and to support container-oriented logistic systems of the future. Air Force Systems Command directed that techniques be developed to transport containers within today's airlift environment. Two land-sea containers (Figure 7) were provided by the US Army and the third container, a prototype land-air-sea (Figure 8) manufactured by Dow Chemical Corporation, was transferred by Hq USAF from AFLC to ASD for these tests. During the course of the testing two additional items were tested. These were a 463L pallet coupler manufactured by Brooks and Perkins, and a spreader bar designed in-house and locally fabricated.

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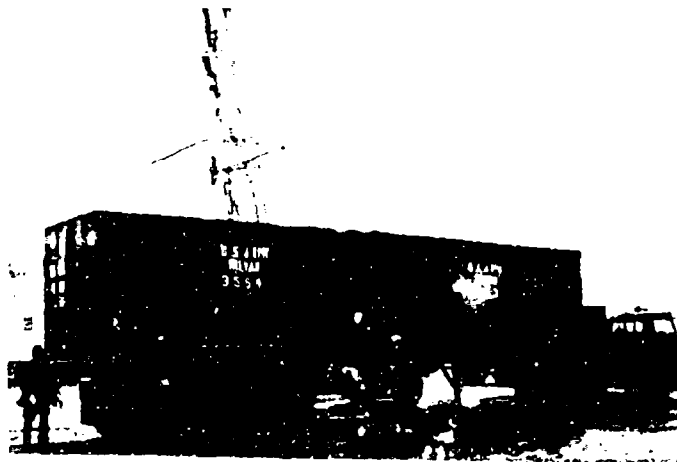


Figure 7. Two U. S. Army Mil Vans



Figure 8. Intermodal 20 Foot Container

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2. OBJECTIVE

To develop a method of transporting a sea-land container within today's airlift system without the need of new equipment.

3. LOAD CONFIGURATION

Three configurations were tested and are listed below:

(1) US Army ~~ammo~~ military van (5480 pounds) utilizing a 20-ft Dow airdrop platform (1590 pounds) for a slave pallet with a total tare weight of 7070 pounds.

(2) US Army military van used for general cargo (4600 pounds) was placed on three 463L pallets using Brooks and Perkins pallet couplers, with a total tare weight of 5500 pounds.

(3) A prototype intermodal container (3580 pounds) used a 20-ft A/E29H Metric ai-drop platform (1480 pounds). This resulted in a tare weight of 5060 pounds.

(4) Concrete building blocks were used to simulate a load in the containers. Each load had a total gross weight of 25,000 pounds.

4. RESTRAINT

The nature of air transport requires that cargo be securely fastened to the aircraft for both flight and crash loads as shown in Table II. In view of the small number of anticipated container moves, and current efforts to lower G restraint to 3 G's (Reference 3), it was determined that container restraint be made to meet a 3-4 G level in the forward condition. Basically, it is unknown how strong the container's walls are. Current Industry specifications range in the forward direction from 0.8 to 3 G, with even lower restraint in other directions. It must be realized that the air transportability requirements cannot be totally achieved in many cases (Reference 3), and the prime objective is to provide the best restraint possible. Procedures for tying down the container are detailed in Appendix II. Since the forward direction is the most critical, it was determined that a Van Zelm barrier net (HBU-B/A) designed for aircraft installation could be utilized to form an effective barrier across the forward container well. The barrier net can provide an effective restraint of approximately 105,000 pounds. Two basic tiedown configurations were developed for the tests, based on the pallet/platform combinations as described in paragraph IV.c. The Dow platform is an experimental replacement for the Metric platform and has the same tie-down positions; therefore it will be treated as a single type of platform in the following restraint analyses.

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5. ANALYSIS OF CONTAINER RESTRAINED TO 20-FT AIRDROP PLATFORM

Forward Restraint

$$1/2(FR) = \underline{10,000 \cos 31^\circ} + \underline{10,000 \cos 33^\circ} + \underline{10,000 \cos 35^\circ}$$

$$\begin{array}{ccc} \emptyset - 28 & N - 23 & L - 18 \\ + \underline{10,000 \cos 32^\circ} & + \underline{10,000 \cos 28^\circ} & + \underline{10,000 \cos 20^\circ} \\ J-15 & G-10 & D-7 \end{array}$$

$$= 51,840$$

$$FR = 103,680 \text{ lb}$$

Aft Restraint

$$1/2 AR = (\underline{5000 (\cos 36^\circ)}) + (\underline{5000 \cos 0^\circ}) \quad 3$$

19 - top aft corner 30, 33, and 38 around aft end

$$AR = 10,000 (.809) + 30,000$$

$$AR = 38,100 \text{ lb}$$

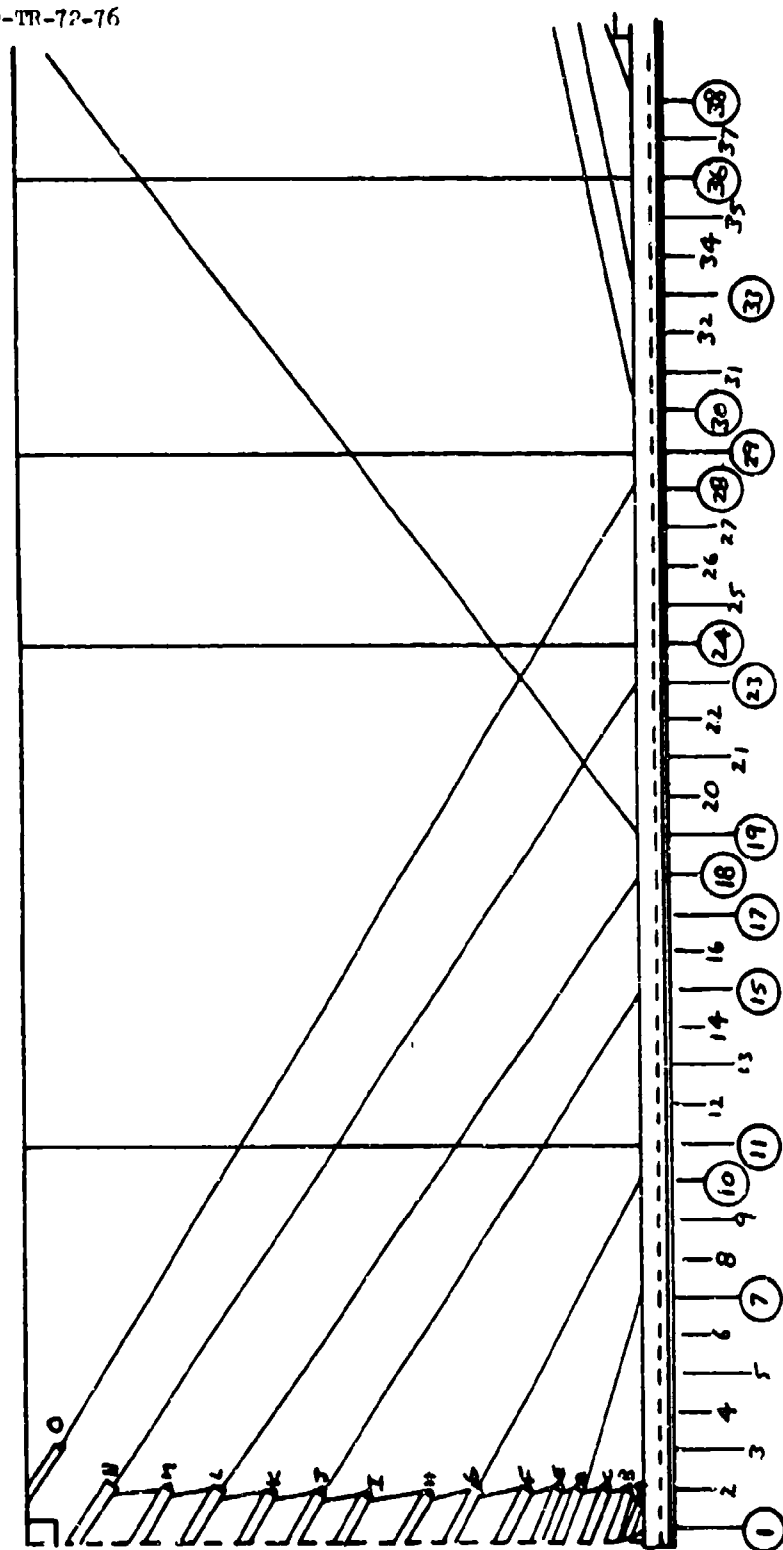
Vertical Restraint

$$1/2 VR = \underline{5000 (\cos 0^\circ)} \quad 4 + \underline{5000 \cos 54^\circ}$$

11, 24, 29, and 36 over top 19 - top aft corner

$$+ \underline{10,000}$$

1 - bottom of net



RESTRAINTS

Forward	=	103,680 lb
Aft	=	38,100 lb
Vertical	=	55,880 lb
Lateral	=	40,000 lb

Figure 9. Container Restrained to a 20-ft Airdrop Platform

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$$VR = 55,880 \text{ lb}$$

Lateral Restraint

$$1/2 \text{ LR} = \underline{5000 (4)}$$

11, 24, 29, + 36 over top

$$\text{LR} = 40,000 \text{ lb}$$

6. ANALYSIS OF CONTAINER RESTRAINED TO THREE 463L PALLETS

Forward Restraint

$$1/2 \text{ FR} = (7500) (\cos 26^\circ) (6)$$

Ø-13, L-8, J-7, H-5, F-4 and C-3

$$+ \underline{5000 (\cos 26^\circ)} + \underline{5000}$$

N-10

2 around front

$$\text{FR} = 100,000$$

Aft Restraint

$$1/2 \text{ AR} = \underline{5000 (\cos 23^\circ)} + \underline{5000 (\cos 37^\circ)}$$

2 - top aft corner 7 - top aft corner

$$+ 2(5000) (\cos 0^\circ)$$

12 and 13 around aft end

$$\text{AR} = 37,188 \text{ lb}$$

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Vertical Restraint

$$1/2 \text{ VR} = (\underline{5000}) (\underline{4}) (\underline{\cos 0^\circ}) + \underline{5000} (\underline{\cos 0^\circ})$$

6, 9, 11 and 12 over top 1 - bottom of net

$$+ \underline{5000} (\underline{\sin 23^\circ}) + \underline{5000} (\underline{\sin 37^\circ})$$

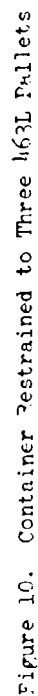
2 - top aft corner 7 - top aft corner

$$\text{VR} = 59,910 \text{ lb}$$

Lateral Restraint

$$1/2 \text{ LR} = 5000 (4)$$

$$\text{LR} = 40,000 \text{ lb}$$



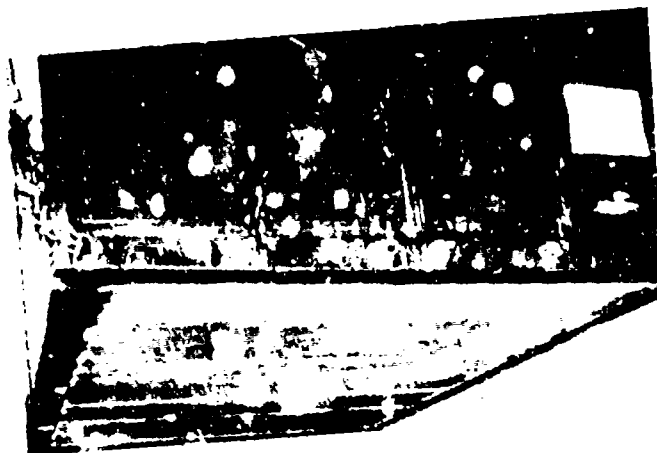


Figure 11. Flatbottom Intermodal Container

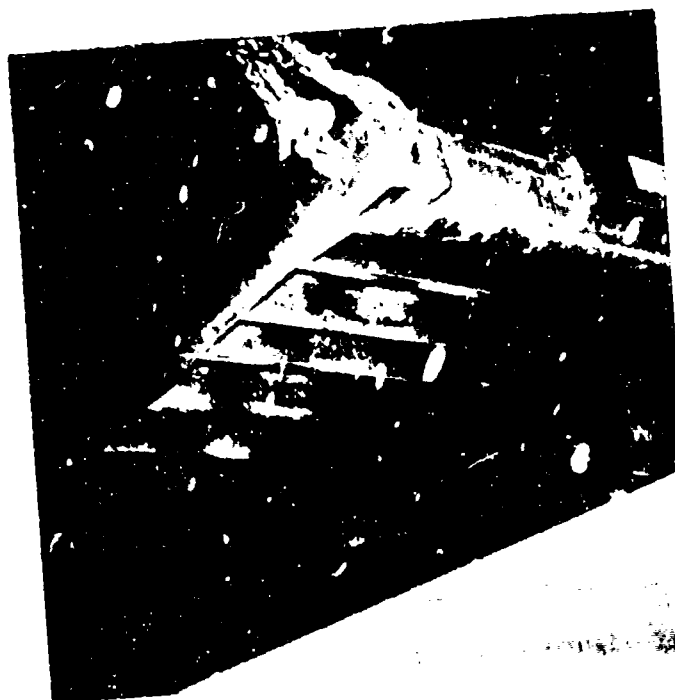


Figure 12. Bottom Land-sea (Milvan) Container.

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7. PLATFORM/CONTAINER INTERFACE

The Dow container has a flat bottom, as shown in Figure 11. However, this is an exception rather than the rule. Almost all container bottoms are built as shown in Figure 12 of the military van container. In viewing the bottom, it can be seen that the corner fitting (Appendix I) protrudes 1/4 inch below the bottom surface. If this container were placed on a 463L pallet for example, the pallet would be damaged and the result could be aircraft floor overloading. To prevent this damage or load concentration, four 2 ft x 8 ft x 1 in. plywood spacing sheets were placed under the container to avoid corner fitting contact with the platform, as shown in Figure 13.

An additional problem exists with the use of 463L pallets as slave pallets. Three pallets must be combined to carry a container, as shown in Figure 14. Various methods have been attempted over the years to develop an effective coupler to tie these pallets together. It was found during the actual loading that some of the locks on the aircraft would not engage the pallets. A close examination of Figure 15 can provide an insight into the problems encountered. Two pallets in the figure are not made by the same manufacturer as evidenced by the different tie-down rings, a

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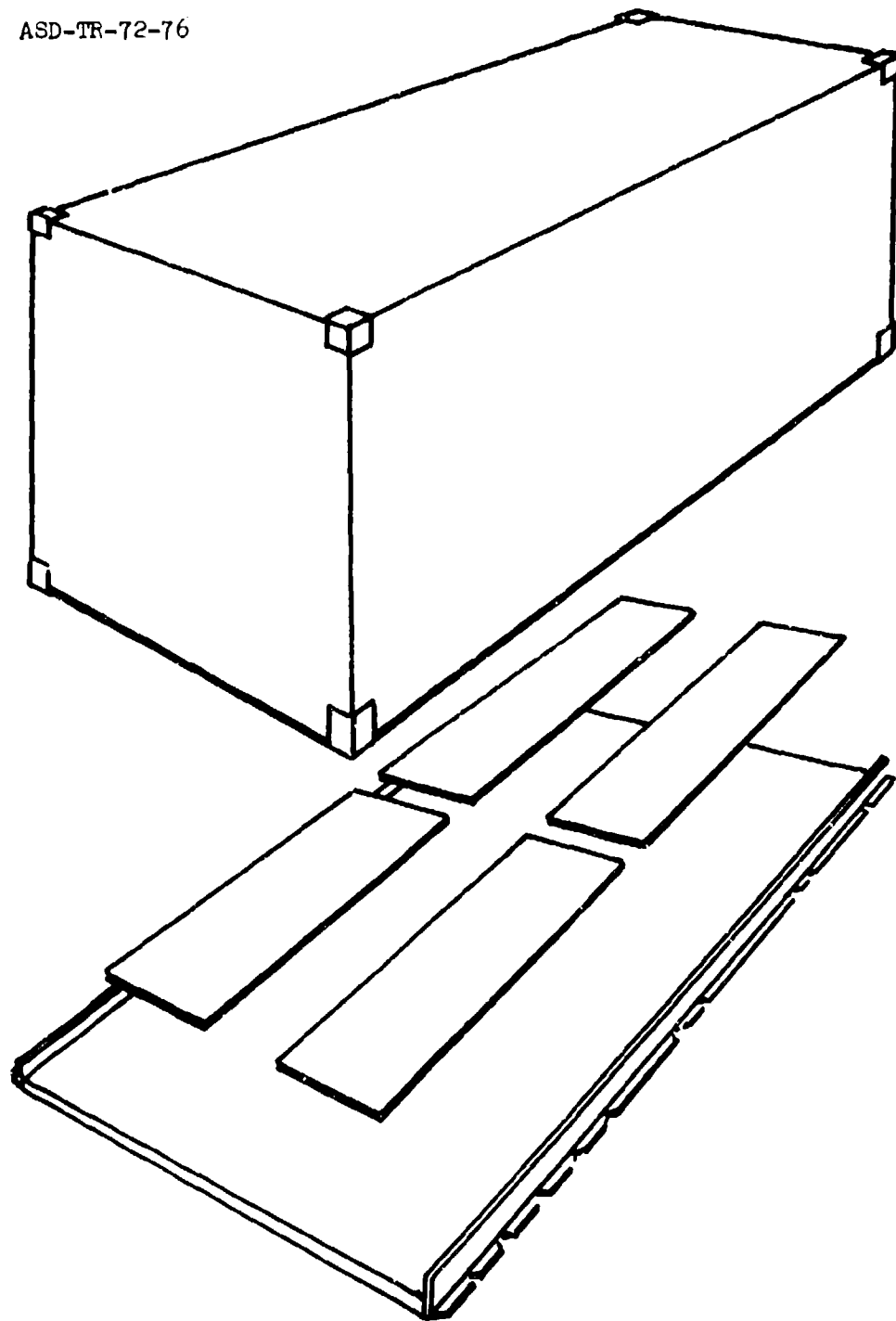


Figure 13. Spacing Between Container and Pallet

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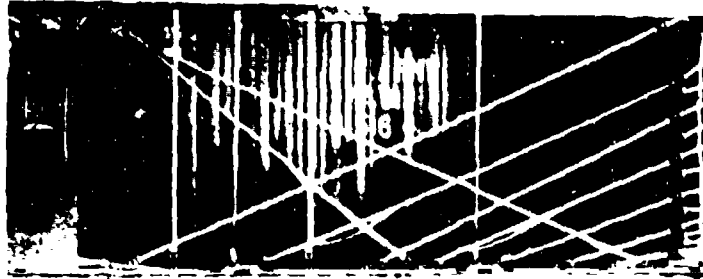


Figure 14. Milvan Restrained On 463L Pallets

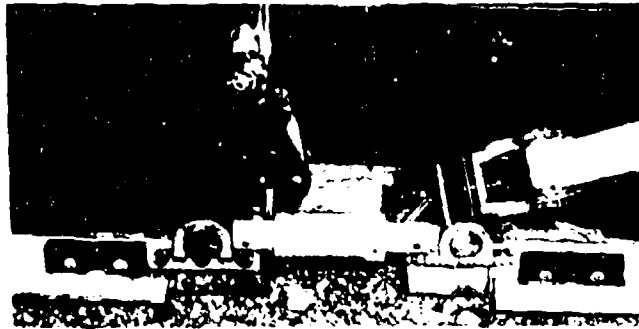


Figure 15. Pallet Coupler

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situation common in the airlift system. It can also be noted that the coupler has some play in the connection to the tie-down ring which, in this case, causes an interval of up to 5/8-inch. Individual pallets in many similar cases could be rocked back and forth in a train until the locks engage. This cannot be done with a heavy load spanning three pallets.

8. CARGO HANDLING EQUIPMENT INTERFACE

As stated in the objective, the required use of new equipment was to be avoided. However, within the 463L system no provisions was made for a crane or lifting sling to handle the container. The crane utilized during tests had a capacity of 20 tons and was available through base motor pool. The spreader bar was designed in-house and procured locally for under \$4-0.00. The sling consists of two 100-inch spacers (Figure 16) to prevent rubbing of cables against the sides of the container. To lift the container, chains were looped through the bottom corner fittings and a hook from the spreader bar was attached to the chain loop. Another spreader bar that was tested was the Army fixed-top lifting unit. Some problems were encountered in the use of this item (Figure 17). The position of the net over the forward corners inte-fered with the sling as it was lowered

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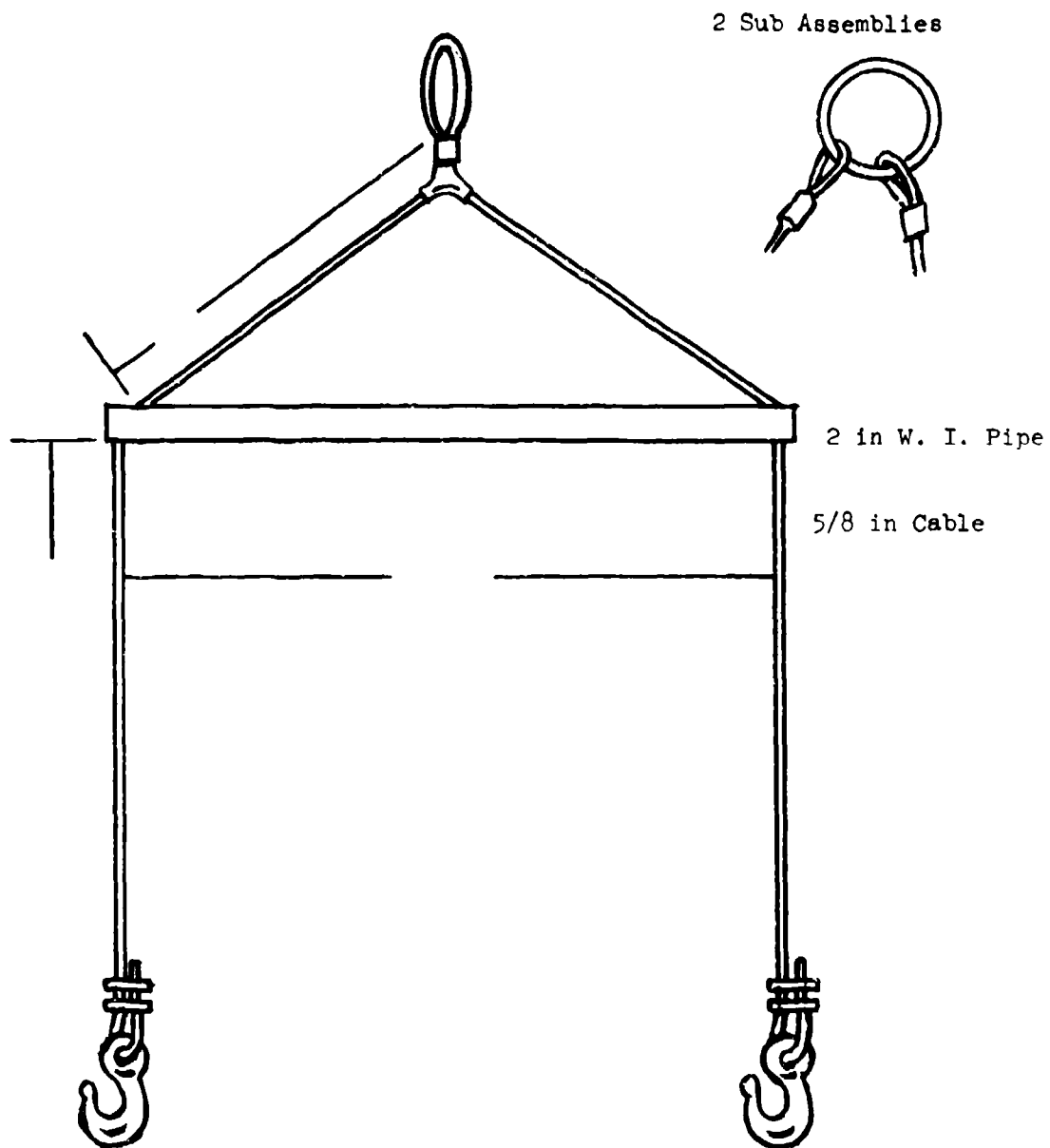


Figure 16. Sling/Spreader Bar

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into the place. The webbing had to be moved to permit locking of the sling, as shown in the close-up insert in Figure 17. The webbing was covering the locking hole.

To move the container from one location to another, low profile flatbed trucks were utilized. Within the vicinity of the aircraft, and for aircraft loading, a standard 25K, 463L load was used.

9. CONTAINER LOADING OPERATIONS

The containers arrived at Wright-Patterson AFB empty and at a point approximately 10 miles from the flight line. The containers

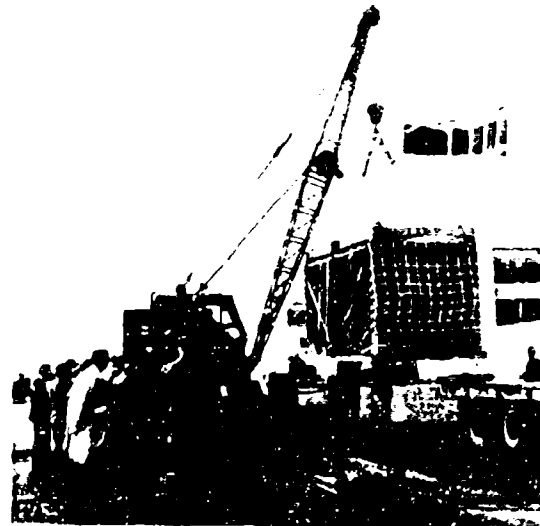


Figure 17. U. S. Army Fixed Spreader Bar

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were filled with dummy loads and transferred to the flight line. For the purpose of this report, it is assumed that loaded containers arrived in the vicinity of the flight line on a truck chassis. The first operation was to prepare the container for airlift. This was accomplished by lifting the containers off the truck chassis.

Placement on platforms and tying down to proper restraint levels was then accomplished. Appendix II has complete step by step details for rigging a container to a platform. Three methods can then be employed to bring the container to the aircraft. All use a common link, i.e., a crane to lift the container to a rollerized surface and a 25 x 40 K loader. The rigged container could be lifted directly onto the loader (Figure 18), as in this test, or rolled onto the loader from a vehicle such as a flatbed truck with added rollers (Figure 19). Another approach is the storage of a rigged container on a rollerized dock for transfer to loader.

Once the container has been placed onto the loader, the remaining operations are similar to normal aircraft loading procedures. Because of height and length of the unit, extra care

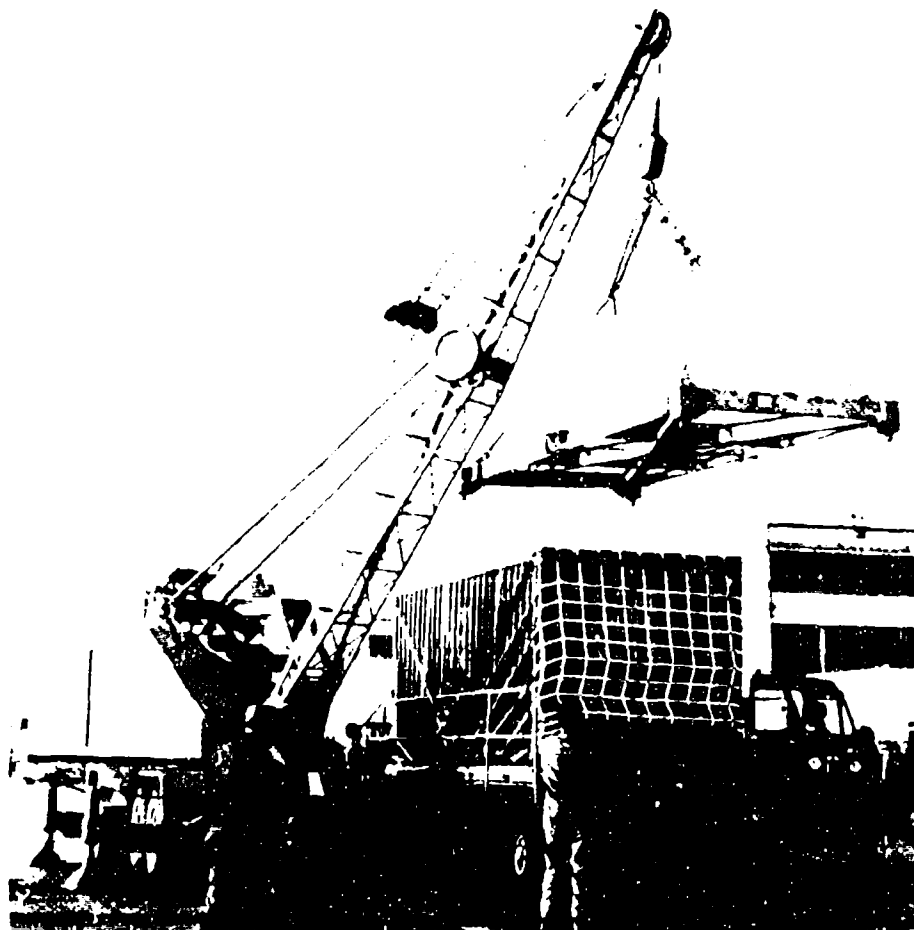


Figure 18. Positioning Army Fixed Spreader Bar.

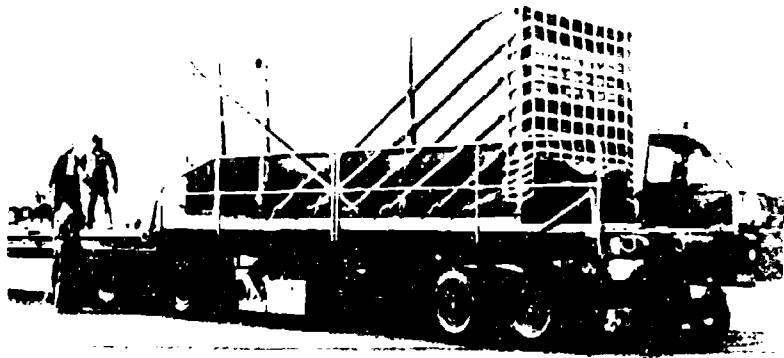


Figure 19. Transfer Rigged Container to 25 K Loader

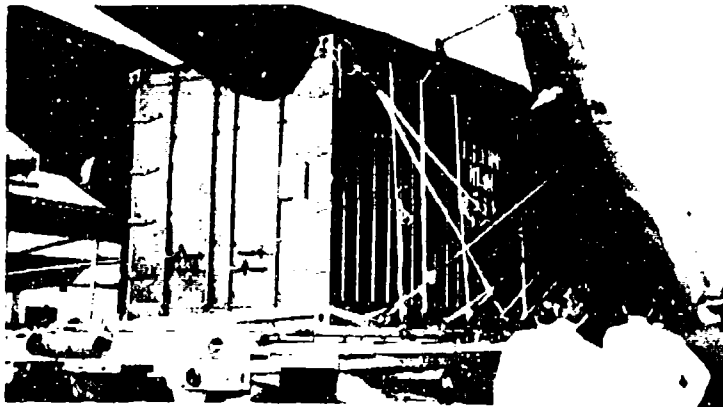


Figure 20. Positioning Loader in C-141 Loading Bay.

must be taken to line up the load to match the aircraft rail system and maintain height clearance. The loader should be in low profile position as it proceeds to the aircraft and is positioned within the loading area (Figure 20). The loader is then raised to be level with the aircraft floor. This provides

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a clearance of approximately 6 inches (Figure 21). After proper alignment has been completed, the aircraft winch is then used to pull the container on board (Figure 22) until the container is locked into the rail system. Under normal conditions this procedure takes approximately 10 minutes per container on-board (Figure 22) until the container is locked into the rail system. Under normal conditions this procedure takes approximately 10 minutes per container as shown in Table IV. The same basic procedure is used in reverse to unload the container.

TABLE IV
CONTAINER LOADING TIME

Test Load	Time (min)	
	Loading	Unloading
3-463L Pallets/Mil Van 3564	9	9
Dow Platform/Mil Van 6010	7	30*
Metric Platform Dow Cont	8	14*

*Problem was encountered with chain linkage jamming under platform.

This was due to lack of proper equipment kit for use with the K-loader.

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Figure 21. Loading Clearance

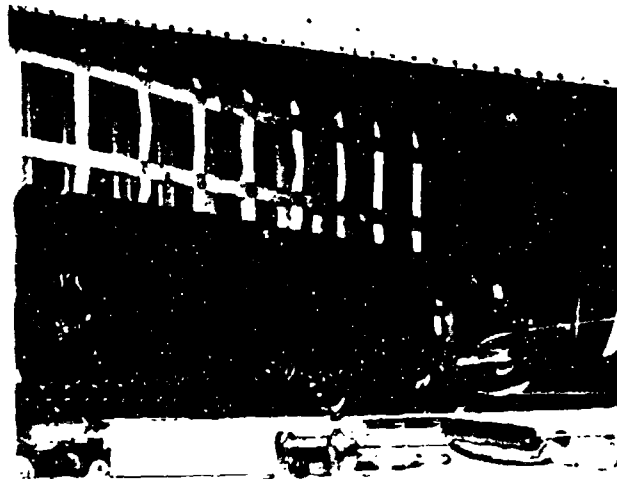


Figure 22. Winching Container Load in Aircraft

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10. IN-FLIGHT PROBLEM AREAS

Three basic problem areas exist that affect the movement of the container which have not been previously discussed. These are listed here with possible solutions to the problems being discussed in Section V.

- (1) Internal cargo restraint
- (2) Explosive decompression
- (3) Location of center of gravity and actual container weight

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SECTION V
IMMEDIATE AND NEAR TERM NEEDS

Containers are now entering the airlift system but in very limited numbers. The degree to which they will enter the system in the future is not known. A need will exist to effectively handle these new loads. The system developed for this purpose should be simple and have the ability to expand as container airlift grows.

1. MISSION NEED

Within all transportation systems there has always been a dream to fulfill a source-to-user concept. Under this concept, material is placed in a container at the factory and shipped directly to the ultimate user. The sea-land container was the largest major step toward this concept. Of course, the military services want to move as close as possible to source-to-user concept.

To accomplish a DOD container program, two basic box sizes are being considered - one the 8 x 8 x 20 ft container and the other a tricon container which is made up of three smaller units 6 2/3 ft long x 8 x 8 that connect to form the larger unit.

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2. AIR VERSUS STANDARD CONTAINER

Two fundamental approaches can be taken by the Department of Defense. First, a single container system standardized to one size box. The alternative would be a family of containers built to meet various mission needs. The systems concept must also consider intermodal combinations.

A determination must be made as to which type of system - land-air-land, land-air-sea, or land-sea-land with air capability - would best suit the interests of the Department of Defense.

Table V shows the cost and weight estimates for the various types of containers.

TABLE V
WEIGHT AND COST OF VARIOUS CONTAINER TYPES

	Land-Air-Land	Land-Air-Sea	Mil Van/Standard Commercial
Weight Pounds	3350	3500	4800
Cost 1971 \$	3260	3600	1200

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A quick comparison shows that a multi-use land-air-sea container could not be used economically within the system, if only a 4% air utilization were encompassed. However, the question remains: should a special air mode container be built or should the military van/standard container be used in the air system? Considering the container usage data computed for 1968 (in Section II), a comparison can be made. To move 1968 tonnage, by sea, 160,000 containers would be required. At the current 4% level of air movement, 6,400 containers would be assigned to air; however, because of faster turn-a-round time this number could be reduced to 2900 containers. One additional factor is required, that of cost and number of adaptors required for movement of the standard land-sea containers. To handle 40,000 movements per year, or 100 a day, would require approximately 300 adaptor units. This would allow for 100 units in transit and 100 at each end for load preparation. An adaptor unit discussed later in this section would have a tare weight of 1000 pounds and cost of \$1500 (excluding development costs).

The cost to move the two types of containers has computed at the current airlift service industrial funding of 12.15¢ per ton-mile. Distance used was a 3000-mile movement across the Atlantic and 7500 over the Pacific.

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Cost = CM x W x M x TMC

CM = number of container movements

W = three weight (tons)

M = miles

TMC = ton mile cost

The above data has been compiled into Table VI for comparison. It should be noted that these computations did not assume entry of sea-land containers into the dual container system, which will happen, nor is the amount of containers capable of sustaining a contingency deployment as described in Section II. An adaptor capability will still be required if a dual container system is adopted by the Air Force.

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TABLE VI
COSTS OF CONTAINER SYSTEMS

	Standard Container System	Dual Container System
Sea-Land Containers	187,800,000	184,320,000
Air-Land Containers		9,454,000
Adaptors	4,500,000	
Air Costs to Europe	25,369,200	14,260,000
Air Costs to Asia	42,282,000	23,765,400
Total	259,951,200	231,799,450

All Dollars

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A close look at Table VI presents another possibility. Equipment costs of the dual system are higher, yet a higher tare weight for the standard container results in higher transport costs. The solution could be a single lightweight container built for land-sea mode. For example, the advantage would be that any container could fit into the Air Force system and would result in lower transportation costs on all modes.

Another factor that tends to equalize the cost variances is that the need will still exist for a system to move the standard container. Also, logistics costs will have to be viewed in maintaining the two systems.

3. IMMEDIATE MOVEMENT

Both the procedures and container tie-down as outlined in Section IV and Appendix II can be used for immediate transport of containers. It must be recognized that certain limitations must be accepted. For example, the restraint provided is not adequate in the side; up and aft directions and new hardware would be required to solve this problem, nor is internal restraint truly provided.

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4. NEAR TERM

Before equipment needs can be reviewed, a determination must be made as to how to handle containers in the Air Force pipeline. Here a great deal can be learned from the other transport industries. For example, ships as well as aircraft require a place to land. Just as certain docks are designated container ports, so should major USAF installations, both in CONUS and overseas, be designated aerial container ports. This would require Army and Navy Trans-Shipments through those ports just as rail and trucks now move through container seaports. Of course, other bases should be able to handle containers, but on a limited scale. This two-prong approach will make a difference in equipment procurement for various bases and will allow for expansion at a lower overall cost. Equipment needs fall into three categories: equipment required for aerial container ports, smaller bases, and interface with aircraft and 463L. The first two are basically concerned with handling equipment, while the last would be needed at both types of bases.

A. Operations

At the present time, movement of a container would basically be an emergency situation. This type of an operation would, under

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an aerial container port concept, require an East and West coast port only. Likely bases to perform the function of container port would be Travis AFB, Cal., and McGuire AFB, N.J. Currently, two or three overseas ports could handle the container flow. This could be expanded to other major aerial ports.

B. Equipment

With time, additional ports could be established as required. Only one item of basic hardware would be required in addition to a container adaptor -- a vehicle capable of efficiently off-loading a container from a truck or railroad car onto the truck. The possible flow of container to aircraft is shown below:

Truck						Storage		
Rail Car	Vehicle	Storage	Adaptor	Vehicle	Rollers	Loader	A/C	

Container Flow Chart

Figure 23

In determining the exact vehicle for container operations, the overhang of six inches for the adaptor must be taken into account, as well as the deck space of the loaders. A weight and center of gravity device built into the vehicle would be extremely useful. Another possibility is the use of a portable weighing system developed by the Air Force originally to measure aircraft weight (may be used in this case). The main ports would have this heavy duty equipment, but many smaller bases would require development of the capability to load the container. The technique described in the use of a base crane and sling/spreader bar could be adopted at these locations. This would require procurement of a sling/spreader bar and an agreement with Base Civil Engineers for use of a crane. It is recommended that any sling/spreader bar procured be provided with a commercial container corner fitting hook to negate the need to use unsafe procedures such as chain loops (Figure 42). If container traffic increases at any particular base, one of the vehicles developed for the container port could be moved in.

An adaptor restraint system to the container is the common link of all systems. Although an airdrop platform and nylon straps can be used in the immediate case, a better, less costly system can be developed. The adaptor could be of an open framework design and the container would rest on this pallet. The pallet could be built to 10-ft interlocking lengths, and thereby be able to accommodate

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containers up to 40 ft long. The container locking system used on other modes of transport could also be added to the pallet with a resultant increase in restraint available through the container framework as an integral part of the pallet. A net would be attached to the pallet and cover the entire container to provide an adequate external restraint system. The net design would be made to avoid any conflict with top corner fittings and ground handling equipment. It is possible that this pallet could utilize some common parts of other Air Force platforms, but be both lighter and able to provide a cost effective final product.

Internal restraint may, in some cases, be nonexistent or impossible to provide. It has been shown that a cargo aircraft with cargo on-board has an accident once every 500,000 flights (Reference 3). If cargo in the container were restrained for over-the-road truck movement, and adequate external restraint provided, loss or damage to this cargo under these risk factors may be acceptable.

C. Other Problem Areas

Two additional areas will require investigation, explosive decompression and maximum allowable gross weight. Explosive decompression is a problem associated only with air transport and, therefore, none of the current containers are required to provide a solution to this emergency situation. A container that is full of

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cargo does not present a problem, nor does an empty one where the door can be left open allowing free movement of air. A container that has a small amount of cargo in it presents the largest problem. Three solutions are possible - one is a requirement that blow-out panels be provided with every container. This again would be a limiting factor on types of containers allowable for airlift, and should be avoided. The second possibility is to open the latches on a rear door in conjunction with slave/net assembly with adaptor to hold the door in place, but not open the door or break any seals. In case of decompression the door would pop open without causing additional damage. The rubber seal along the door can also be viewed as a weak link in the container construction. A test has been proposed to determine if this seal would rupture during decompression. Should this test be successful it would greatly simplify container air mode operations. The maximum gross weight allowable is presently set at 25,000 pounds gross weight for air transport. This limit was established by industry and adopted by the Air Force. Over an equivalent floor space, 463L pallets carry 27,300 pounds of cargo and, therefore, the container gross weight can be raised to this level. It may be possible to increase this load factor. To determine the upper limit, tests can be conducted at the airdrop load test facility, US

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Army Natick Laboratory. These tests will provide data on aircraft floor loading. This information could be used in design of the adaptor pallet to better distribute loads, resulting in a higher load capability.

5. SUMMARY

Methods developed over the years by land and sea modes of transport can provide the background, concepts, operations, and equipment ideas for effective air operations. The effects of the intermodal container on the airlift system can be minimized by building a pipeline and equipment around the current container and 463L system.

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SECTION VI
FUTURE DEVELOPMENT

The ability to move a limited amount of containers today is provided by the near term solution. However, the true problems within the Air Force are to find the most practical means of moving large numbers of containers, should the requirement arise.

1. SYSTEM CONVERSION

Basically, four different methods have been proposed by Lockheed-Georgia Company in a study for Military Airlift Command (Reference 4) for movement of containers in the airlift system. Two systems involve modifications to the aircraft, and the others to adaptors for interface between the container and the 463L rail system.

The Lockheed-Georgia study was based on two aircraft, the C-141 and the C-5, and the analysis methods are described as follows:

(1) The container restraint rail design consisting of adding another restraint rail inside the present 463L restraint rail system to accommodate the 96-inch-wide container.

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(2) The combination restraint rail design consists of replacing or modifying the existing 463L restraint/rail system to accommodate both pallets and containers.

(3) The bottom adaptor design consists of securing the container to a pallet, thereby making the combined unit compatible with the existing 463L system.

(4) The side adaptor design consists of securing a side adaptor to the container, thereby making the combined unit compatible with the existing 463L system.

Cost factors were also determined as shown in Table VII for the above system on a cost/ton-mile over a 5-year period during peacetime.

TABLE VII
SYSTEM COST TON-MILE

System	C-141	C-5
Container Rail	.054¢	.045¢
Combined Rail	.051¢	.041¢
Bottom Adaptor	.029¢	.030¢
Side Adaptor	.021¢	.020¢

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Although the study shows that a side adaptor is the best cost solution, it assumes a container with a flat bottom and side indents. Unfortunately, in the real world this container exists only as a test item. The bottom adaptor, as outlined in Section V, in a real sense is, from the standpoint of cost effectiveness, the preferred method.

Douglas Aircraft Company in a 1967 (Reference 5) study for the Air Force noted that containers would inject a penalty to the airlift system by their use. However, they concluded that "the Air Force should take action necessary to move USASI* type containers as designed by various customers" and recommended "design and procure the necessary adaptors and barrier nets to permit moving of USASI* type containers in the military aircraft system." *(USASI type containers are presently designated NASI - MH5.1-1971 and are those discussed throughout this report as standard containers).

The system proposed as a near term solution can also provide the answer for the future on the C-141 and C-5. Both the Lockheed and Douglas documents substantiate this procedure of action.

2. FUTURE AIRCRAFT

Cargo can be broken down into four categories: wheeled vehicles, 463L pallets, containers, and out-sized cargo. Ideally, a system with the capability to handle all of the above is desired. This can be accomplished within today's state-of-the-art, but following the pattern of current systems it would be far from ideal. A review must be made of some new system concepts now being developed in other areas for possible utilization in cargo handling. Although the following is conceptual, it can be made to operate inside an aircraft for loading and unloading.

Currently under development is a new type of landing gear that allows an aircraft to land on a cushion of air (Figure 24). The system consists of a trunk around the aircraft's lower structure (Figure 25), with numerous nozzles through which air is pumped. This creates floatation for the aircraft and results in a smooth landing on almost any flat surface. This system has been successfully flown on an LA-4 aircraft and is now being installed on a Canadian Buffalo C-8 aircraft (Figure 24). The technology now being developed could provide the basis for a future air cargo handling system. If the aircraft can land on any surface, the ground handling (Figure 26) and load-unloading equipment may also

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require this capability.

The actual system details are presented in Appendix III and basically would consist of an inverted trunk on the aircraft cargo floor. This would provide lift to float the cargo over the floor. The system would be built in sections, so that air would not be pumped to all parts of the aircraft at the same time. This air cushion floor would be utilization of an air source not in use on the ground. It could also be used in flight for airdrop of cargo. As the system is now designed it can accommodate wheeled

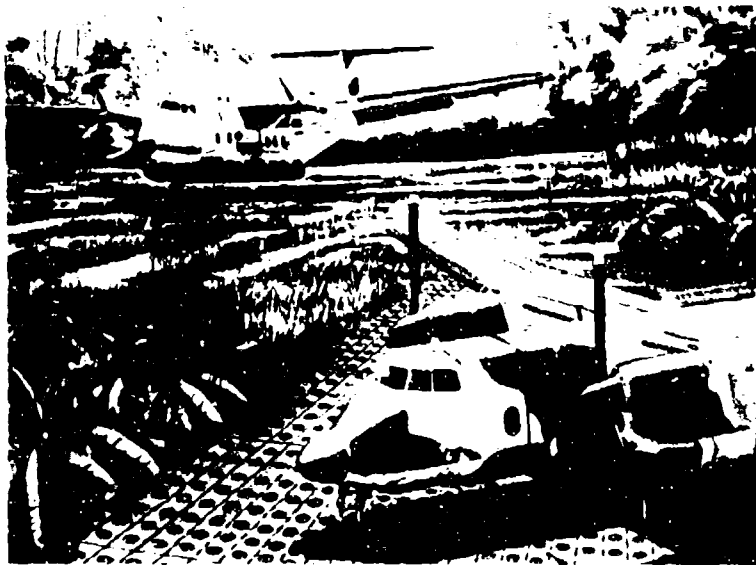


Figure 24. C-8 Air Cushion Landing System

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vehicles as the floatation trunk folds flat when not in use. Of special interest is its use in container handling. A container without a flat bottom has a rib construction. This design allows entrapment of air and pressure buildup, allowing the container to float. Thus, air cushion techniques could provide a single cargo handling system.

3. TERMINALS

If container usage continues to grow, under the proposed aerial container port concept, the Air Force terminal areas may begin to look more like seaports. In essence, these would be cargo parking

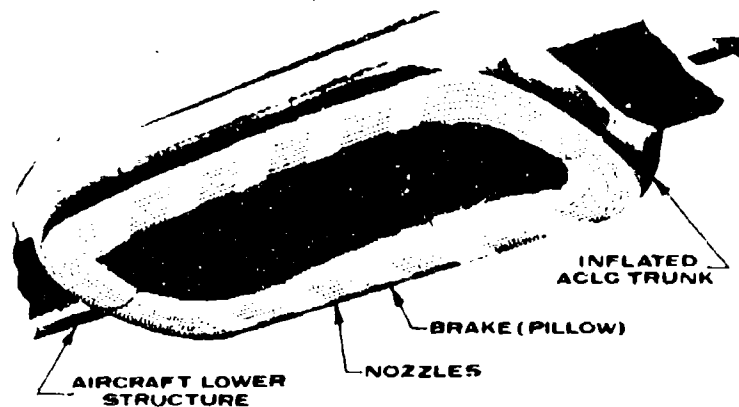


Figure 25. Air Cushion Landing Trunk

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lots for containers with doors built to the aircraft floor height for unloading and loading. This could be similar to the current C-5 mobile door but of a permanent installation. Through shipment of containers will reduce the need for consolidation of cargo at the aerial port and reduce costs associated with handling cargo.

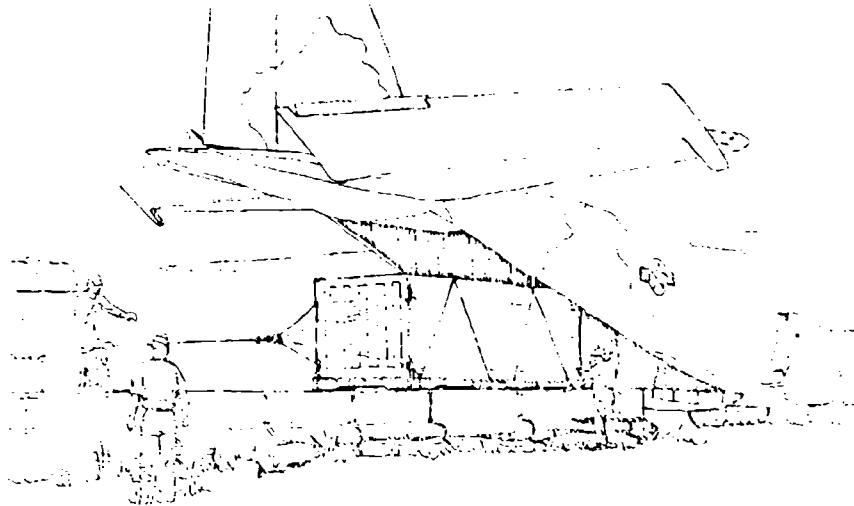


Figure 26. Air Cushion Loading Dock

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SECTION VII

SUMMARY

It is apparent that containerization of military cargo will play an important role in future airlift operations. However, certain factors must be recognized that will have a bearing on any Air Force system. Container design has been set by international agreement and cannot be changed to meet Air Force requirements.

Although it may prove to be cost effective to build a special container for a closed-loop air system, a capability will also have to move the standard land-sea units. The Air Force may also have to consider new operational concepts as the aerial container port, yet, at the same time provide this new capability through an integration with the current 463L system.

The impact of containerization on 463L and airlift system is not known. It can be safely assumed that containers will not flood the airlift system overnight. Careful planning and development now of various components such as adaptor slave pallet/net combination, and sling/spreader bar, can assure an easy transition

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from a pure pallet system to a pallet/container system. Certain investigations such as the foller and decompression tests should be accomplished now. Looking to the near future, a systems analysis should be conducted to determine container handling equipment needs within the airlift system.

If container movements become large the system would allow expansion. It may also become necessary to build a new system in future aircraft. However, any new system should attempt to provide full system capability.

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APPENDIX I

CONTAINERS

The container within an airlift system may be of two different types: first, the standard sea-land container as shown in Figure 27; and second, a container built for intermodal transport. The basic difference is that the true intermodal container has extra provisions for air transport such as a flat bottom, special intents for locking, higher strength walls, and decompression panels. The container has an 8 ft x 8 ft cross section and comes in incremental lengths starting at 10 ft minimum to 40 ft maximum.

The actual design and construction of the container varies within the manufacturing industry. No one specification is available; however, various standards have been developed in an attempt to provide a single guide line. Although these standards do differ, two factors have remained constant, overall dimensions and corner fittings (Figure 28). Although the variances could be slight, they also can vary by as much as a factor of 2: the air mode container of the MHS standard requires a forward load restraint

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factor of 3, and the load factor of the SAF 832 standard is 1-1/2.

1. STRUCTURAL FEATURES OF A TYPICAL CONTAINER

With the above in mind, a closer look can be made of a typical container as shown in Figure 27.

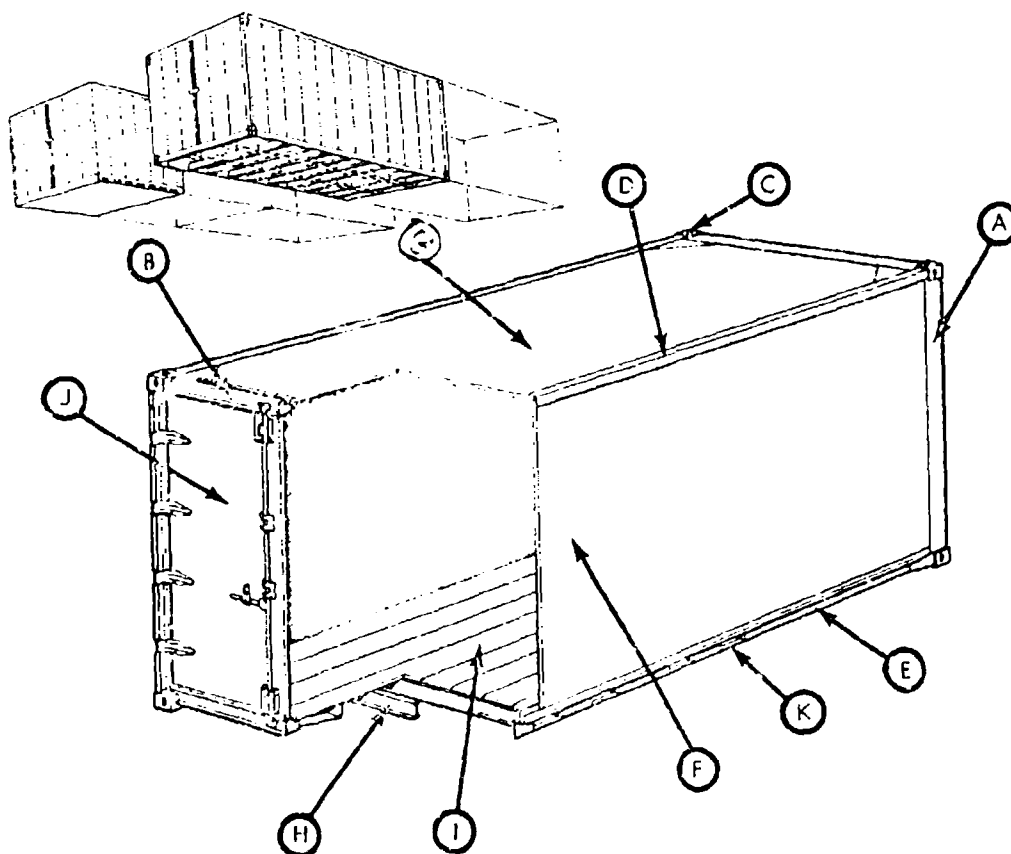
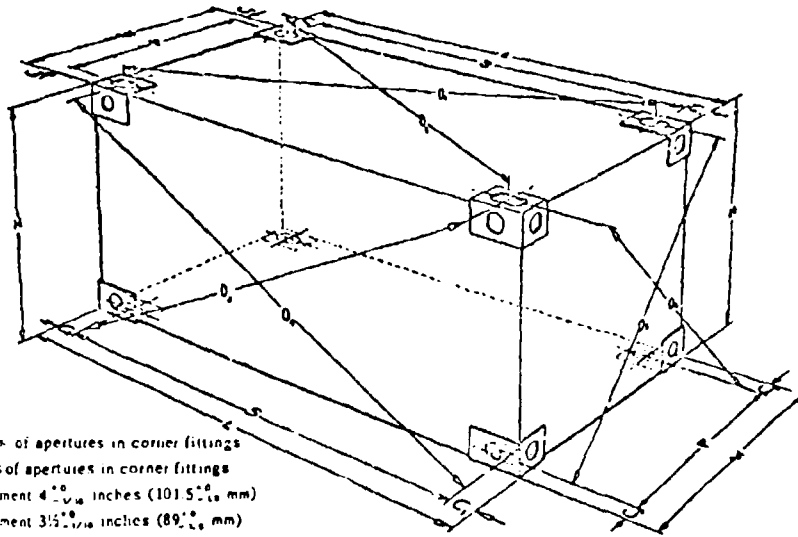


Figure 27. Container Structural Features



- S = Length between centers of apertures in corner fittings
 P = Width between centers of apertures in corner fittings
 C_1 = Corner fitting measurement $4 \frac{1}{8} \pm \frac{1}{16}$ inches (101.5 ± 1.3 mm)
 C_2 = Corner fitting measurement $3 \frac{1}{2} \pm \frac{1}{16}$ inches (89 ± 1.3 mm)
 L = External length of container
 W = External width of container
 D = Distance between centers of apertures of diagonally opposite corner fittings resulting in 6 measurements, D_1, D_2, D_3, D_4, D_5 and D_6
 K_1 = Difference between D_1 and D_2 or between D_3 and D_4 , i.e., $K_1 = D_1 - D_2$ or $K_1 = D_3 - D_4$ or $K_1 = D_5 - D_6$ or $K_1 = D_6 - D_5$
 K_2 = Difference between D_1 and D_3 , i.e., $K_2 = D_1 - D_3$ or $K_2 = D_2 - D_4$
 H = Overall height

Nominal Length Feet	Length Overall (L)		S		P		K ₁ Max.		K ₂ Max.	
	mm	Ft.-In	mm	Ft.-In	mm	Ft.-In	mm	In	mm	In
40	12190 $\begin{smallmatrix} +2 \\ -8 \end{smallmatrix}$	40 0 $\begin{smallmatrix} 0 \\ -3/8 \end{smallmatrix}$	11985	39 1/4	2259	7 4 31/32	19	3/4	10	3/8
30	9125 $\begin{smallmatrix} +0 \\ -10 \end{smallmatrix}$	29 11-1/4 $\begin{smallmatrix} +0 \\ -3/8 \end{smallmatrix}$	8918	29 1/2	2259	7 4 31/32	16	5/8	10	3/8
20	6055 $\begin{smallmatrix} +3 \\ -3 \end{smallmatrix}$	19 10-1/2 $\begin{smallmatrix} +0 \\ -1/4 \end{smallmatrix}$	5653	18 1/2	2259	7 4 31/32	13	1/2	10	3/8
10	2990 $\begin{smallmatrix} +1 \\ -4 \end{smallmatrix}$	9 9-3/4 $\begin{smallmatrix} +0 \\ -3/16 \end{smallmatrix}$	2781	9 1/4	2259	7 4 31/32	10	2/8	10	3/8

Width Overall (W): 8 Ft. 0 $\pm \frac{9}{16}$ in., 2435 $\pm \frac{7}{8}$ mm

Height Overall (H): 8 Ft. 0 $\pm \frac{9}{16}$ in., 2435 $\pm \frac{7}{8}$ mm or 8 Ft. 6-1/2 $\pm \frac{9}{4}$ in., 2600 $\pm \frac{7}{8}$ mm

NOTE: Dimensions S and P are reference dimensions only. The tolerances to be applied to S and P are governed by the tolerances shown for the overall length (L) and overall width (W)

Figure 28. Assembled Corner Fitting - Diagonal Tolerances

A. End Frames

End frames are provided at both the front (a) and rear (b).

These usually are welded assemblies of steel members with cast

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corner fittings (c) with a standardized pattern of handling sockets. For use on-board ship, the containers must meet a six-high stacking requirement and racking on deck. This leads to the use of 1/4-inch material formed into a box section as a common-design solution. Figure 29 shows additional details.

B. Side Rails

Side rails (D, E) running longitudinally along the top and bottom of the container join the end frames together and mount the side panels (F). These members are usually aluminum; however, steel is also used. Most of the rail-to-frame joints are bolted. Figure 29 shows details of a typical extruded aluminum rail.

C. Side Panels

The end frames and rails provide a support for the attachment of panels (F), basically sheet material. In the case of aluminum side panels, sheet-post construction is used, with the posts being of a hat-section type as shown in Figure 29. Posts are spaced, between one and two feet apart, and may be either exterior or interior, depending on where the operator desires to have the flush surface. Sheet material thickness of 0.062-inch is

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common, with the weight being 0.89 lb/sq ft. The weight of stiffeners is quite variable, but a value of 0.92 lb/running ft has been computed for a representative extruded section. With posts spaced two feet apart, the weight of panel material is 1.8 lb/

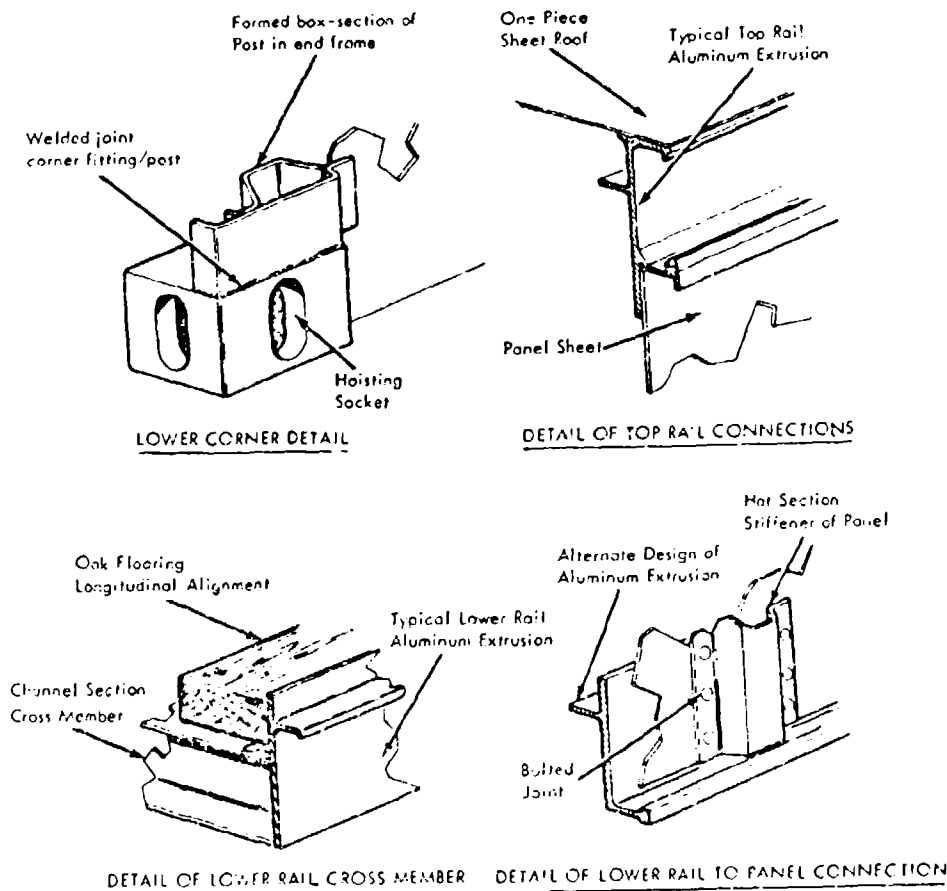


Figure 29. Container Design Details

sq ft. Aluminum panels are often augmented by a plywood interior liner (Figure 30) which may be either half or full-height. With a

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half-height liner, the average panel weight is approximately 2.2 lb/sq ft.

FRP/plywood panels consist of a plywood core with a fiberglass reinforced plastic overlay on each face of the panel. Most often, the fibers are in a woven roving form, i.e., untwisted in a fabric, within a polyester matrix. The common thickness of plywood stock is 3/4 inch. Total panel thickness is usually in the range of 0.84 to 0.88-inch. The weight of such a sandwich panel is in the range of 3.0 to 3.2 lb/sq ft, depending on the proportion of glass fiber in the overlay and the thickness. The panels are joined to the frame by riveting.

Steel panels are also used primarily on containers from foreign sources. Steel container sheet material is usually rigidized by corrugation, and separate posts are not added. Welding is used as the joining means. A typical design employs 18-gauge (0.49-inch) sheet stock with corrugations of about 1.5 inches depth. Such a panel fabrication weighs about 2.6 lbs/sq ft.

D. Roofs

The roof (C) is generally of the same material and construction as the side panels, with only a few exceptions. Roof bows of aluminum units are often joined with adhesives. One-piece sheet

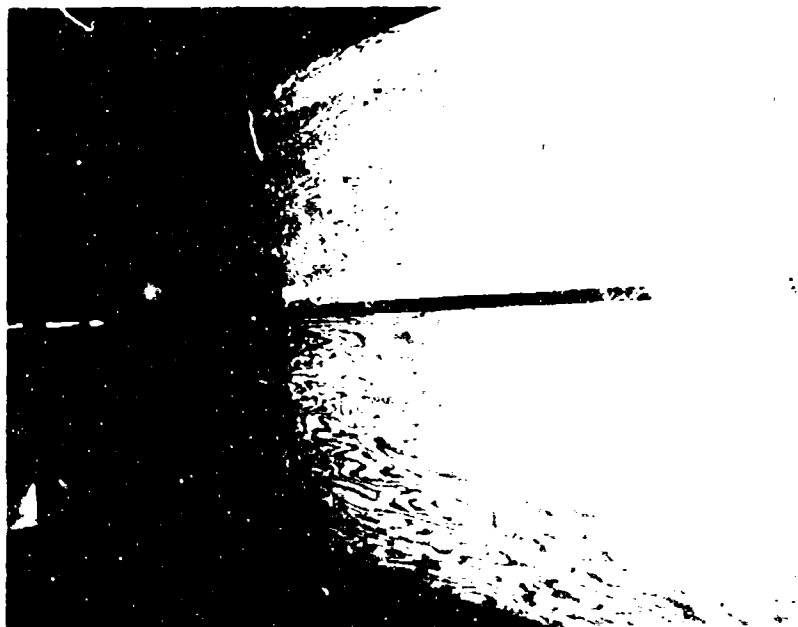


Figure 30. Container Side-Wall Interior

material is preferred in order to maximize resistance to water entry from above.

E. Bottom Structure

The understructure and flooring transfer loads induced by dead weight and inertial reactions of the contents to the side rails. The cross members (H) are formed channels or extruded shapes with a depth on the order of 5 inches and a thickness of about 0.188 inch, of aluminum. Steel is also used for these members, generally when the side rails are of steel. The deck surface (I) is usually of oak or softwood floorboard, shiplap



Figure 31. Container Underside

jointed, and between 1-1/8 and 1-3/8 inches thick. Plywood is also used for flooring, in which case an RFP overlay with a silica sand finish may be applied. Figures 29 and 31 show typical floor detail. Within the airlift, the bottom presents the largest single problem: by not being a flat smooth surface, the container cannot be moved in the present world of air cargo. All air cargo systems are based on roller conveyors. A few containers have been built with flat bottoms but even these present problems. The corner fittings (C) are hard in comparison to the container bottom, and result in damage to the roller conveyor during movement from soft to hard corner. The standard container corner is 1/4 inch lower than the

bottom level. When a container is stacked, the bottom will deflect. This 1/4 inch prevents the container from applying any pressure on another container other than through the corner posts.

F. Doors

Doors (J) are most frequently of heavy plywood clad with metal faces, referred to as plymetal. The thickness of the composite is in the range of 0.75 to 1.0 inch, with the face material being about 22 gauge (0.031 inch) if steel, and 0.040 inch if aluminum. Sandwich fabrications for doors may also have an aluminum exterior and a steel interior, where the steel is not exposed to a highly corrosive atmosphere and at the same time resists the forces and abrasion of cargo impacting the end wall. Doors are generously proportioned for the further reason that when firmly engaged to the end frame, they significantly contribute to the container's resistance to racking forces. Thus, locking bars, either one or two per door half, are securely anchored in keepers on the door and in camming locks on the end frame. In so-called anti-rack hardware these locks restrain the bar end from play in all directions. Hinges complete the assembly.

G. Handling Provisions

Standardized corner fittings (C) have elongated sockets on top to which are engaged connecting fittings of the spreader of a

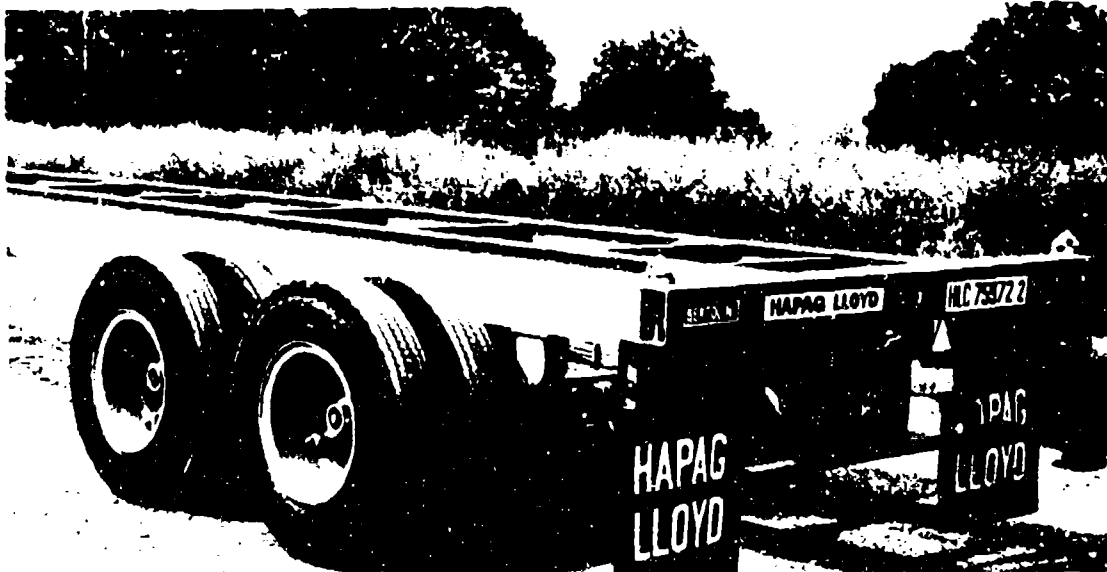


Figure 32. Land Transporter

crane or mobile handling unit. It may be noted in the detail in Figure 29 that there are protective plates in proximity to the top corner handling fittings to guard against damage when spreader drops on a container top misaligned with the fittings. Similar sockets are on the under surface of the bottom corner fittings to provide restraint when containers are on deck or on a land vehicle (Figure 32). Locking is performed by twisting the male element either manually or by remote actuation (Figure 33). The container's corner fittings also have openings on their sides to enable hoisting by hooks and slings (Figure 3b) at both the top and bottom corners. Additionally, forklift pockets (K) are provided

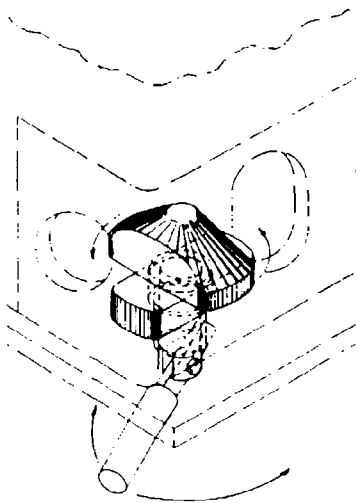


Figure 33. Container Bottom Securing Fitting

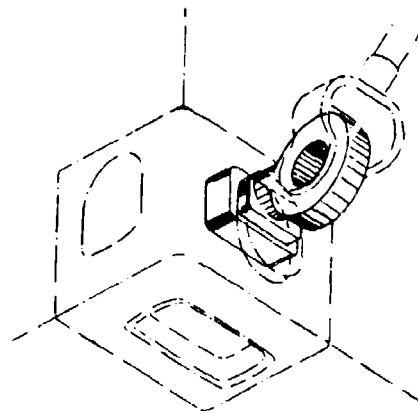


Figure 34. Hoist/Sling Attachment

to permit handling from the bottom by the tines of lift trucks. This mode of handling is losing favor, and, as a consequence, pockets in the understructure of containers are becoming relatively rare. Note on Figure 27 that four pockets are shown in the typical design. Usually the outer pockets are aligned with the forklift tines of a high-capacity lift truck capable of handling a loaded container. The two inner pockets are used by lift trucks capable of handling only an empty container.

2. CURRENT HANDLING EQUIPMENT

Most equipment within industry is designed for high speed turn around of a ship (Figure 35) moving containers between containerports.

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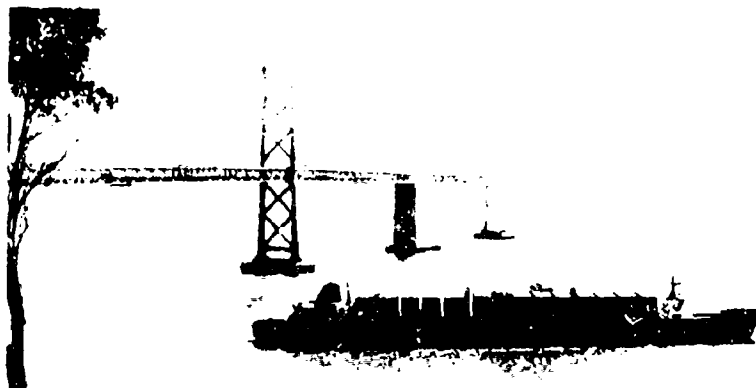


Figure 35. Container Ship

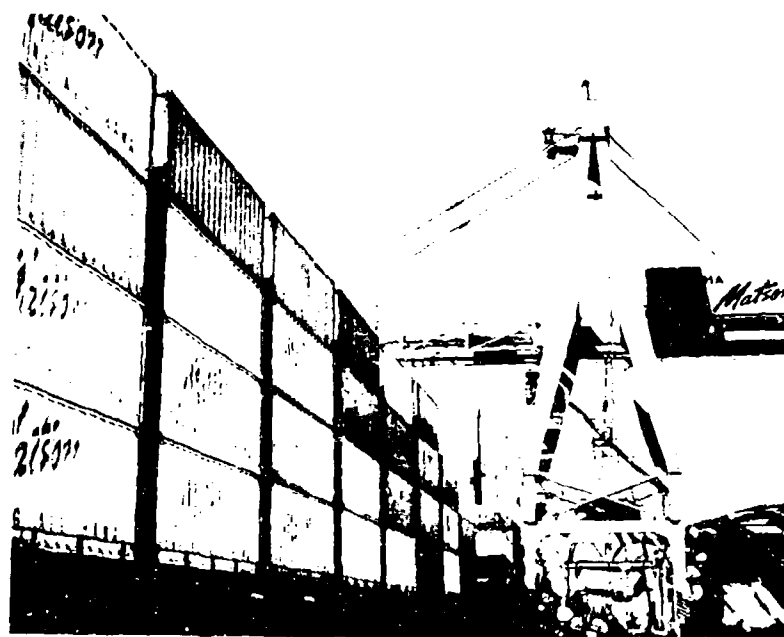


Figure 36. Shoreside Container Crane

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Transfer between ship and door is performed by shore-side gantry crane (Figure 36) and in some cases able to operate up to 60 transfers per hour. Figure 37 shows a container being positioned by the gantry for on-deck shipment. Commercial type cranes are also employed at ports not intended as container movements such as stacking, transfer to or from a truck chassis and rail car. Straddle loader and various forklifts are the most predominate vehicles used in this operation (Figure 38). The straddle lift can vary in size to a very large and not too mobile vehicle as shown in Figure 39. The forklifts shown lift the container from the top; however, forklifts with conventional tines are also used. These lifts should be avoided because they are used to lift containers without forklift pockets and, in many cases, they damage the container. Forklifts are available to handle containers with a gross weight of 67,200 pounds.

3. INTERMODAL CONTAINER

Only a few of the intermodal containers have been built. The major limiting factor is cost relationship. A standard cost is approximately \$1200, an intermodal unit cost is about \$3500 for a 20-ft container. When a ship is being procured, an Industry standard procedure is to also obtain containers in a ratio of 2.5 to 3.0 in relation to ship capacity. Ships are now under construction which

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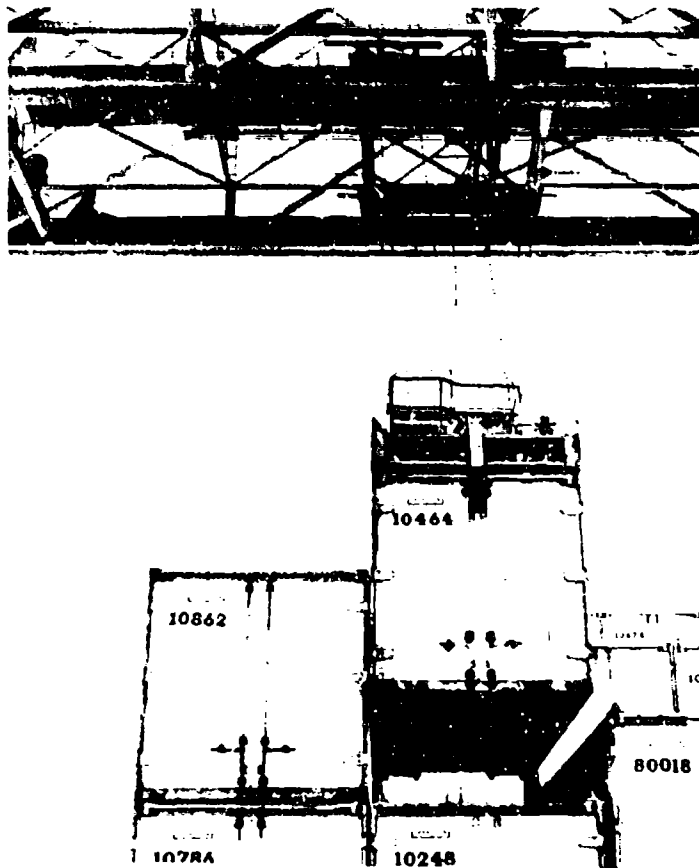


Figure 37. Positioning Container on Board Ship

are able to carry in excess of 2000 containers, which would lead to a rather large cost increase to provide containers that can be interchangeable in all modes. This cost variance is not justified in relation to air movement of containers. Only one aircraft has been built to specifically carry the intermodal container, and although the container will fit in other aircraft, they are not equipped to restrain the container. The intermodal container has

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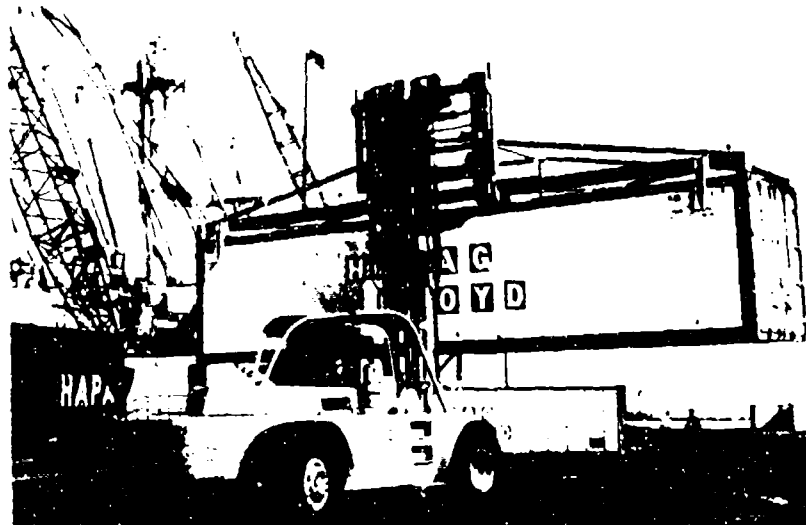


Figure 38. 40 Foot Container and Forklift

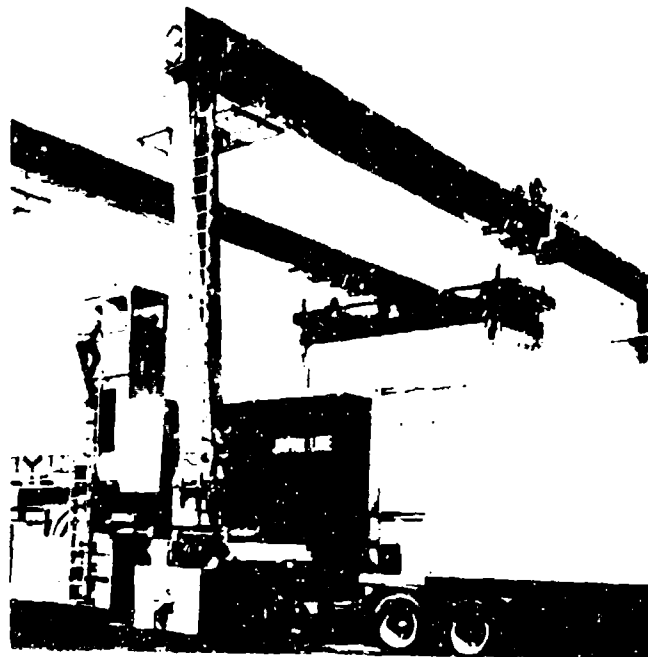


Figure 39. Stradle Lift

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three basic differences, one, it increases overall strength of the container and two, it indents on twenty 1/8-inch centers along the sides to match an aircraft locking system. (The Air Force locking system is built to 10 inches on center). The third difference is a flat bottom; but, indications are that Industry will adopt a slave pallet concept in the near future.

APPENDIX II

CONTAINER TIE-DOWN FOR AIP TRANSPORT

This appendix presents details on container tie-down using a 20-ft airdrop platform. Both the Metric A/E29H and the US Army Type II airdrop platform in a 20-ft configuration can be used as a slave pallet for air transport of any 8 x 8 x 20 ft container. To ensure proper tie-down, the following sequence of events should be followed.

Cut four strips of 1-inch plywood to a size of 2 x 8 ft.

These strips shall be positioned as shown below on the platform.

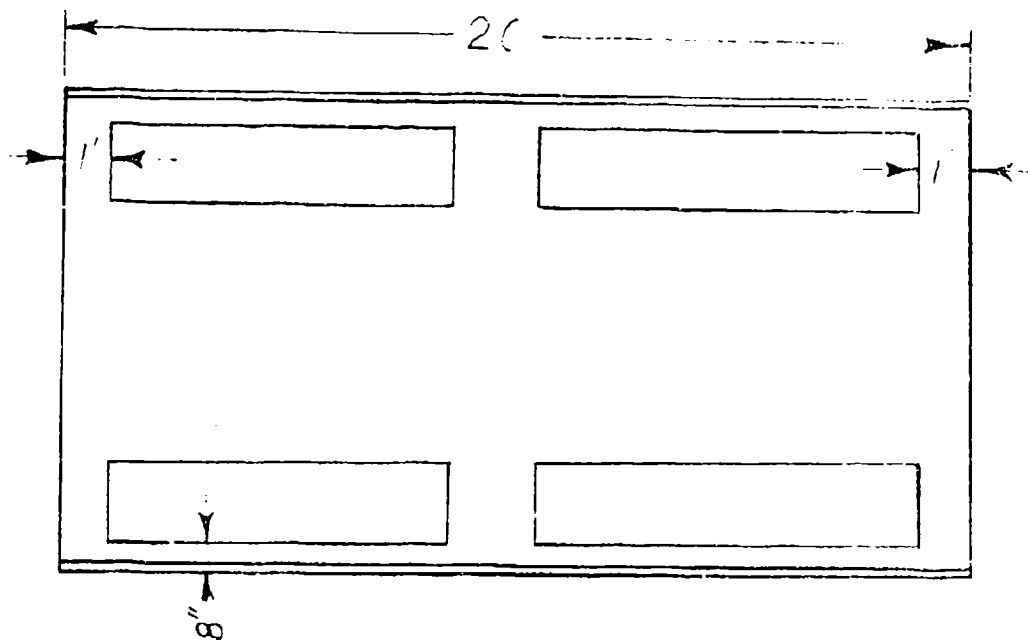


Figure 40. Position of Spacing

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Position the container on the platform with equal spacing on the sides and forward end of the container at forward edge of the platform (forward end of container is opposite the doors). Place the lumber spacer between restraint fail and container side as described below. The spacer must cover a distance of 16 ft in length; for example, two containers, 2 in. x 4 in. x 8 ft on each side, can be used.

Place 15 clevises, Figure 41, tie-down, air delivery, type II, MS70085, on each side of the airdrop platforms in accordance with Figure 9 (circled numbers).

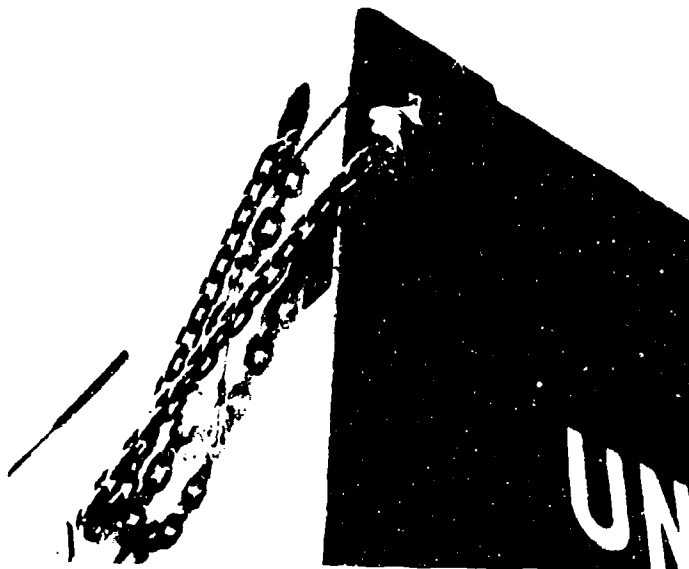


Figure 41. Corner Chain Tie-Down

Arrange tie-down components (Position symbols shown in Figure 9) as follows:

- (1) Place MB1 tie-down chain in each upper aft corner fitting. (Figure 42)
- (2) Attach CGU-1/B webbing strap from point 19 to each upper aft corner fitting chain loop; two straps required.
- (3) Place a CGU-1/B strap from the following points around the rear of the container to the same point on the other side: 30, 33, and 38. Three straps are required.



Figure 42. Golf Club Clevis

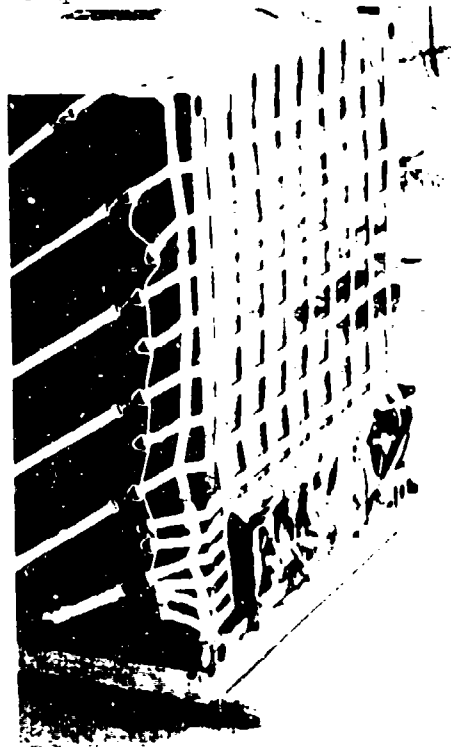


Figure 43. Barrier Net

- (4) Connect four sets of two CGU-1/B straps together. Eight straps are required. Attach one clamp of each set to the following

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points: 11, 24, 29, 36 and place over the top of the container to the same tie-down point on the other side.

(5) Place the HBU-8/A barrier net over the forward wall of the container. The top two horizontal strips of webbing must be on top of the container as shown in Figure 43. Tie-down of the barrier net should be accomplished by placing a CGU-1/B strap between the following points in the order listed on both sides. Do not tighten straps until all are in place = 28 - Ø

1 - A

23 - N

18 - L

15 - J

10 - G

7 - D

(6) Tighten all straps and tape loose ends.

APPENDIX III

ON-BOARD AIR-CUSHION CARGO HANDLING SYSTEM

To develop a system that can do everything is an ideal every engineer can hope to achieve. Since it is improbable that this can be accomplished, a system is described here in an attempt to provide a futuristic on-board air cargo handling system.

1. REQUIREMENTS

What, in addition to the current system, should a future system be able to accomplish? To meet the ideal, it should handle all types of cargo without the need to change any one part of the system. For example, as described in Sections I and III, the aircraft rail system must be removed to accommodate wheeled vehicles. An ideal system should be able to move any of the following items without change to the system or manpower:

- a. 463L pallets
- b. Wheeled vehicles
- c. Containers (sea-land, 10, 30, or 40 ft, as described in Appendix I, without flat bottom).
- d. Outsize cargo

Of course, it is improbable that such a system can be built; but how close can a new system come to achieving the ideal? Limiting

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factors such as aircraft size and weight capacity are the first step. If it is assumed that this has been determined, can an air cargo handling system be designed to achieve minimum loading time of all types of air cargo?

2. SYSTEM CONCEPT

Air has been used extensively to move heavy loads such as vehicle movement. This is usually accomplished by means of an air pad, as shown in Figure 44. The pads direct air down and form a pressure layer between the object and ground. Vehicles use a similar approach, using a skirt on the vehicle perimeter, which forms the air pressure area (Figure 45). The air-cushion landing system uses a different technique of an expandable trunk (Figure 25) with distributed jets all around the trunk (Figure 46). The trunk acts both as a tire, air pad, and skirt. It appears that a version of the trunk concept is best suited for on-board aircraft use. It is obvious that a pure skirt design would just fill the aircraft with air and be hard to control. Air pads could supply air just over one area and could be located throughout the aircraft; this would probably require extensive plumbing. Such an arrangement would allow a load to hit the floor between pad, or a pad on the floor facing up; however, this could easily cause damage and result in difficult loading problems.

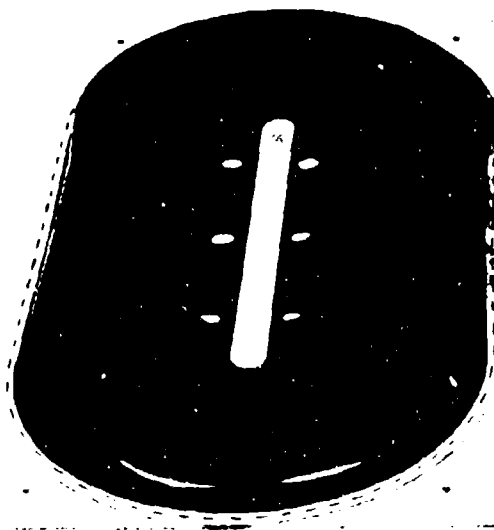


Figure 44. Air Pad

The trunk design offers advantages which, with modification from a landing system, could very effectively be inverted and placed into the aircraft. The system would be based (Figure 47) on two trunks running fore and aft in the aircraft, with a lateral barrier to prevent loss of air pressure. The barrier would act as a skirt and be fabricated of an elastic material; it would also contain a sensor to activate air into the next section of the trunk. This system would also allow any one section to be "on" or "off" through a control for cargo movement. Figure 48 shows a close-up of the trunk and barrier. Figure 49 shows the overall system in a simplified version. The cargo load floats on the air pressure, which is held in

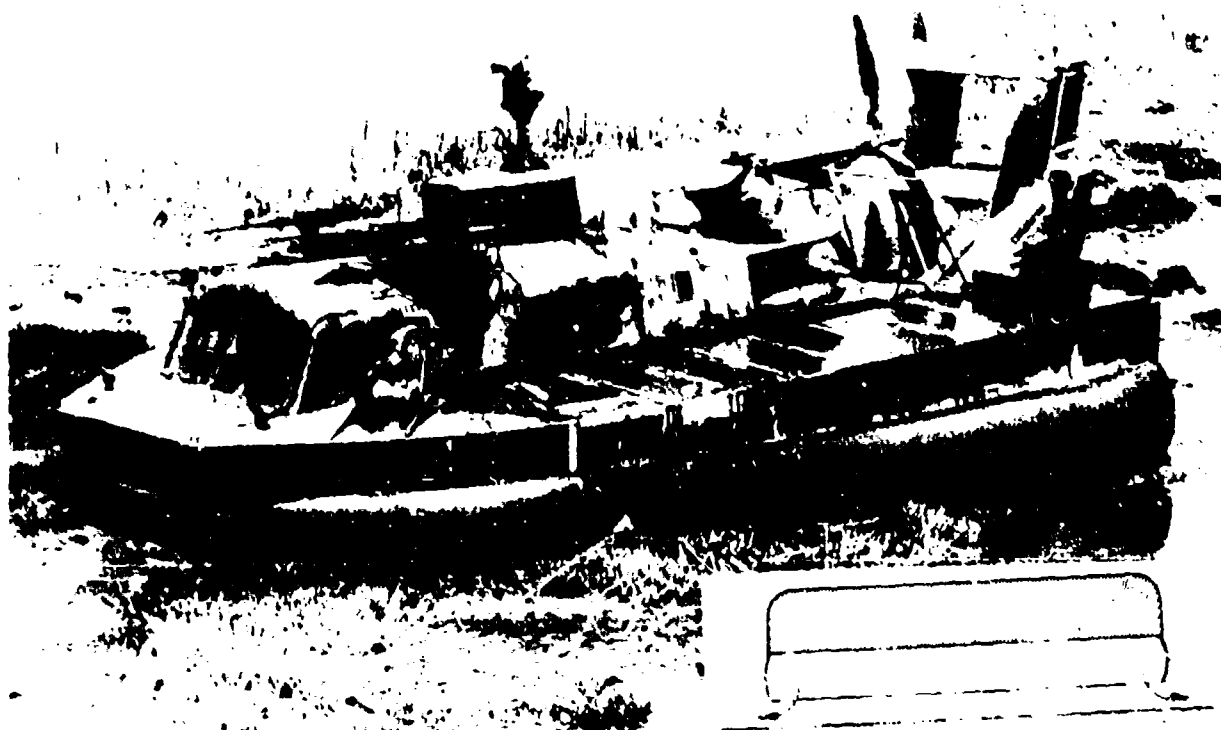


Figure 45. ACV Using Simple Skirt

place by an inverted skirt effect. An extremely heavy load could overcome the air pressure and rest on the trunk as shown in Figure 50. This would provide pressure, making movement of the load still relatively simple. For this case, and to further protect the trunk, a bar of Teflon or similar material could be attached to the top of the trunk. Various trunk designs would have to be tried to determine optimum conditions and some possibilities are shown in Figure 51.

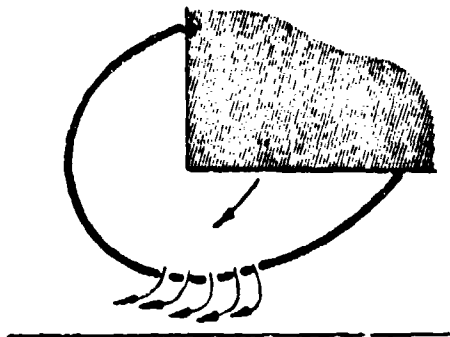


Figure 46. Distributed Jet

3. AIRCRAFT INTERFACE

Actual power systems would be installed on an aircraft as part of the landing gear. The air supply would then be used for the cargo handling system. The trunk would be attached to the aircraft floor as shown in Figure 52 and would be made of an upper and lower sheet. The system shown allows for easy removal of the trunk for repair and maintenance, and at the same time in a deflated state would provide a flat surface. The lower sheet also acts as a protective backing for the deflated condition, and permits wheeled vehicles to be driven on the aircraft without any change. Damage tests conducted on the landing gear trunk have shown that a ripped trunk would still function within this system.

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4. CONTAINER INTERFACE

Because of the flexibility of the trunk, even land-sea containers without flat bottoms could be loaded in the aircraft. In viewing Figures 51 and 53 it can be seen that the container construction could be considered as a series of skirts and, as they are filled with air, floatation takes place. Because of the flexible nature of the trunk, the container can be moved over it, whereas it could not be moved over an air pad system.

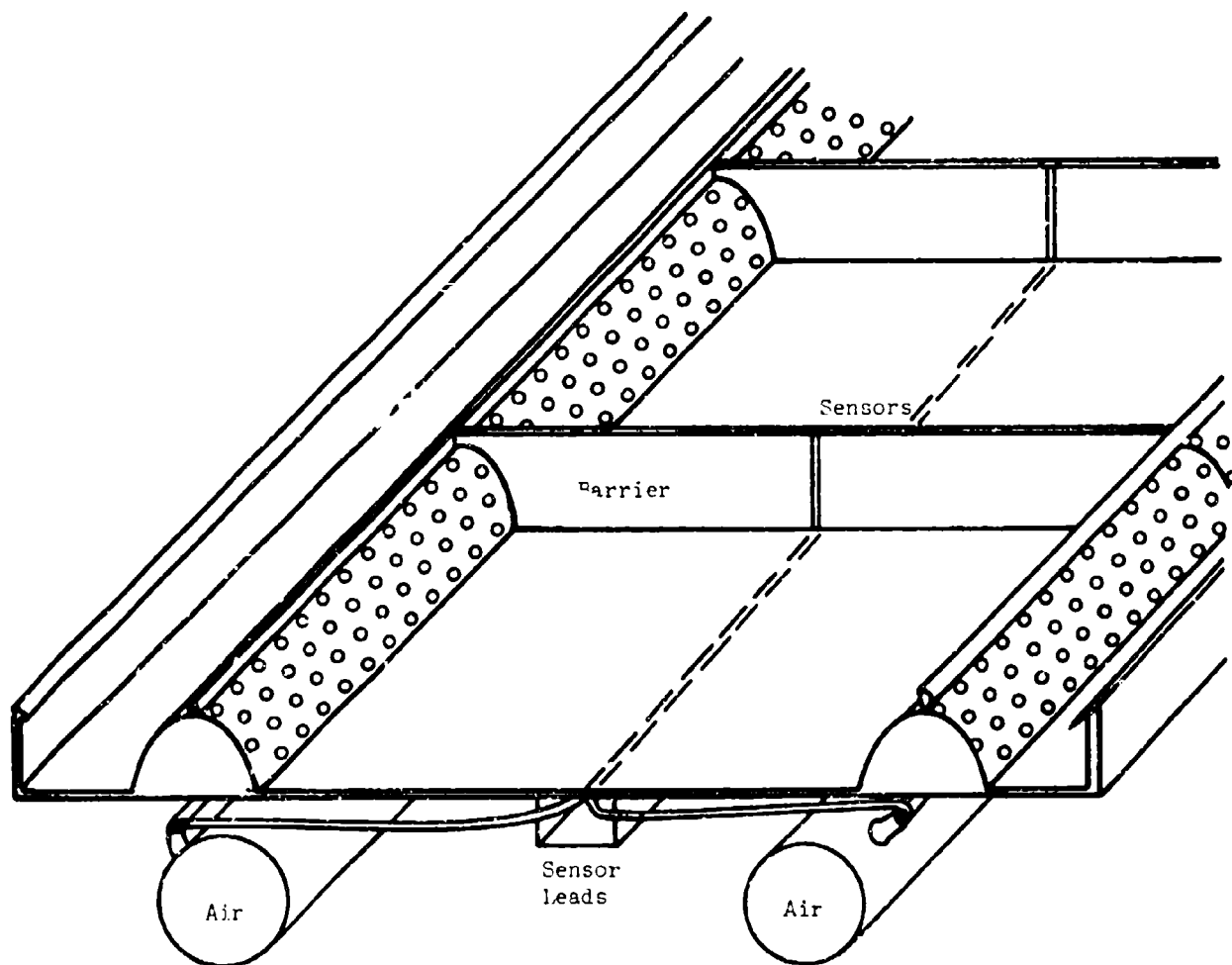


Figure 47. AirTrunk /Air Cargo Handling System

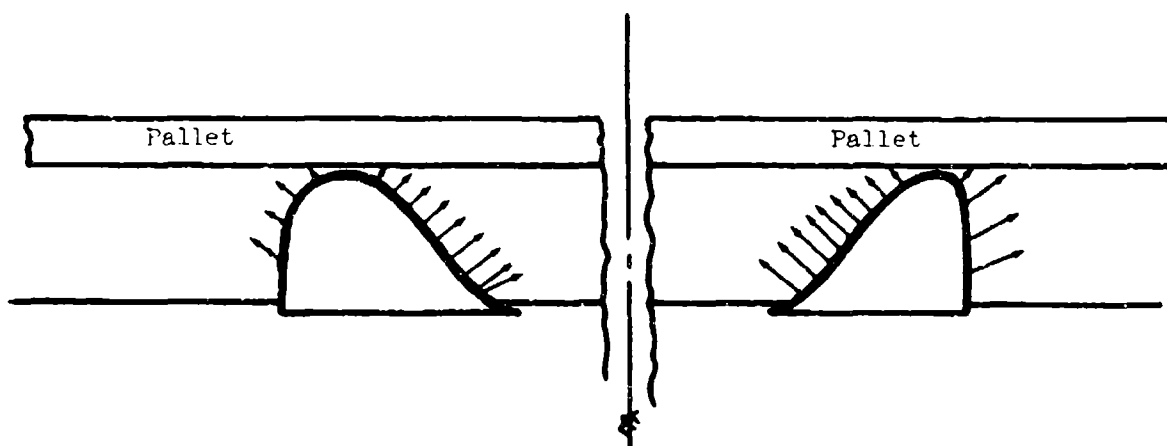
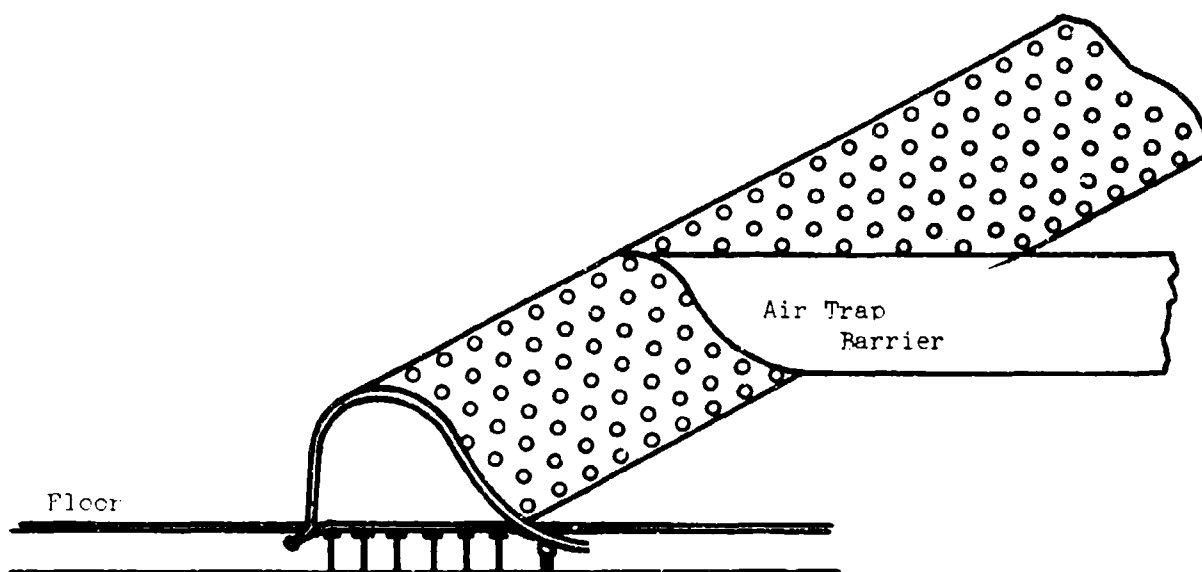


Figure 48. Air Trunk Pressure Principle

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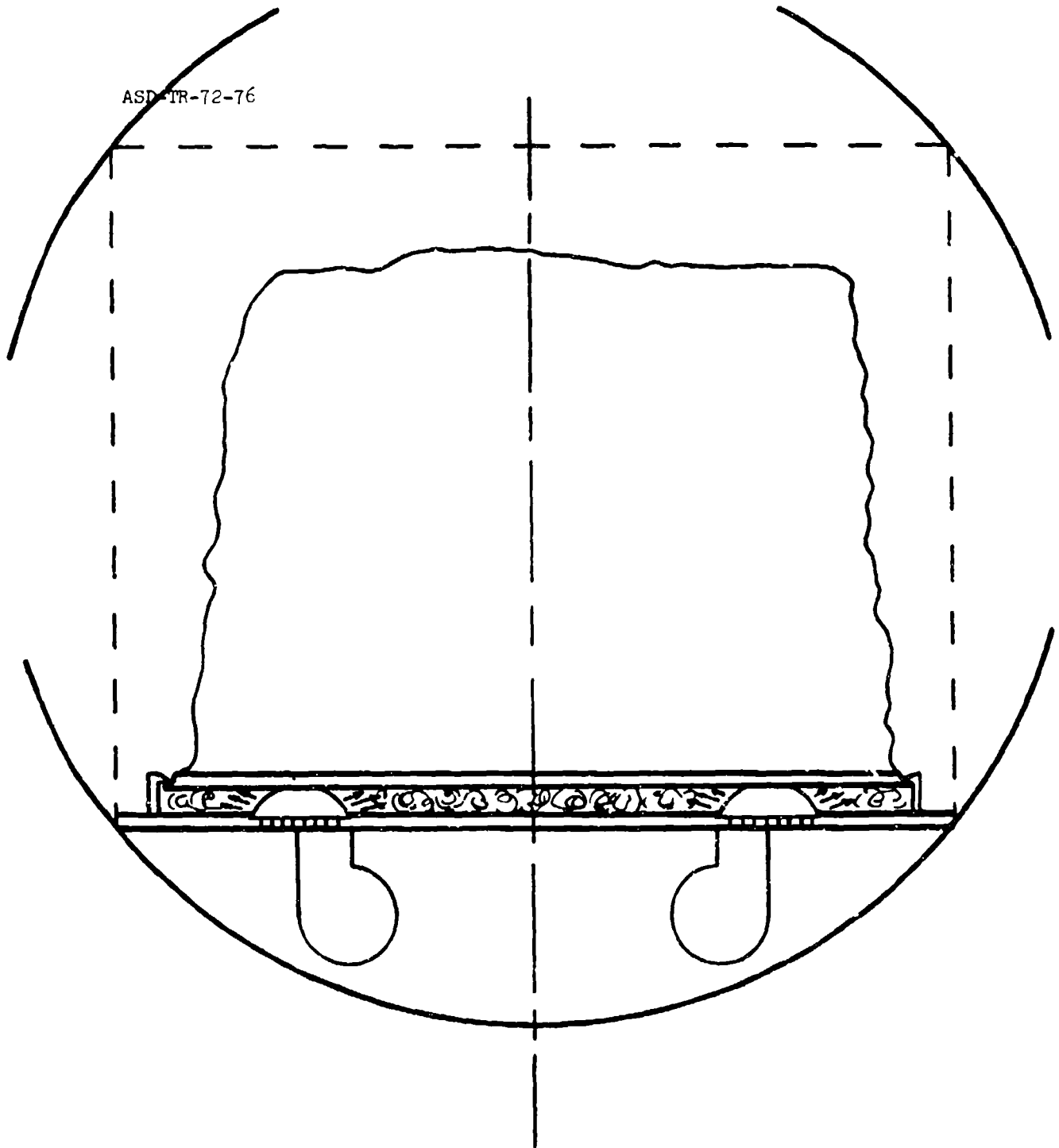


Figure 49. Aircraft Cross Section.

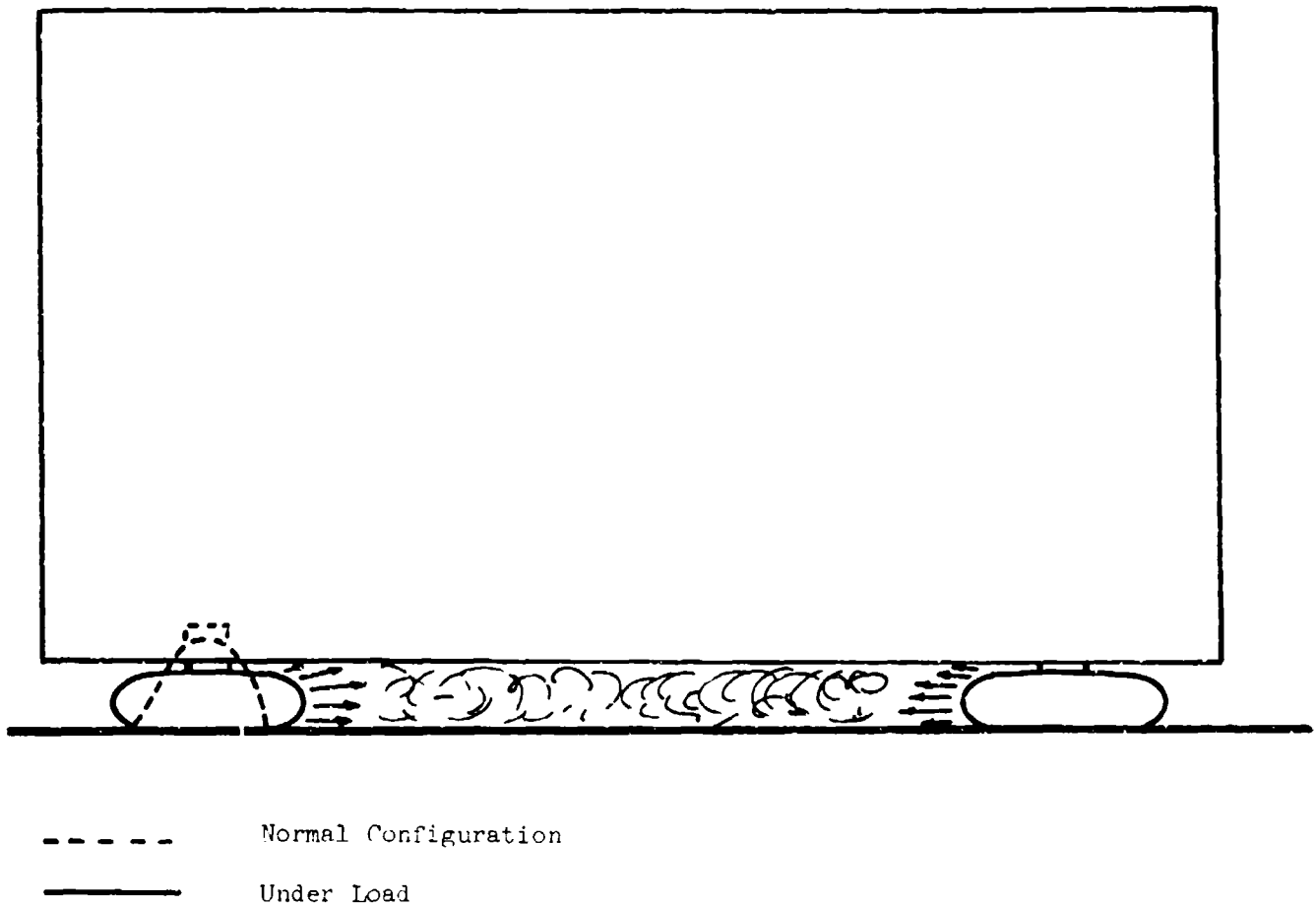


Figure 50. Heavy Load Movement

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Flat Sheet Inflates to
Semi-Circle



Shaped Trunk



Flat Sheet Inflates to
Semi-Circle with Air Trap
Flap. Can be Used on Any Shape



Any Shape With a Frictional
Surface Attach to Top of
Trunk or Coated on Trunk.

Air outlets in trunks can vary to direct air as required.
If air is needed in one location more holes are added to
the trunk.

Figure 51. Various Trunk Configurations.

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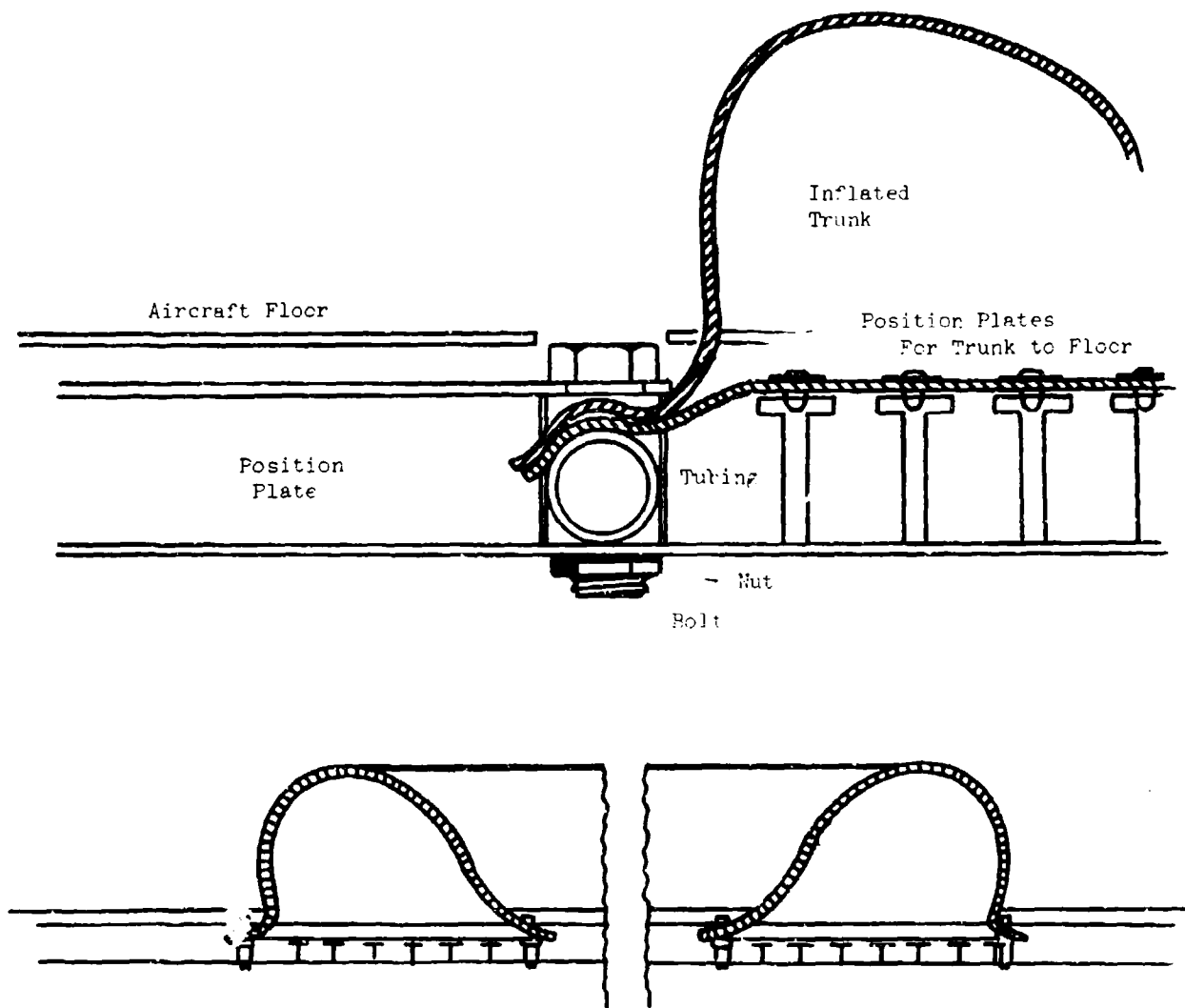


Figure 52. Trunk/Floor Attachment

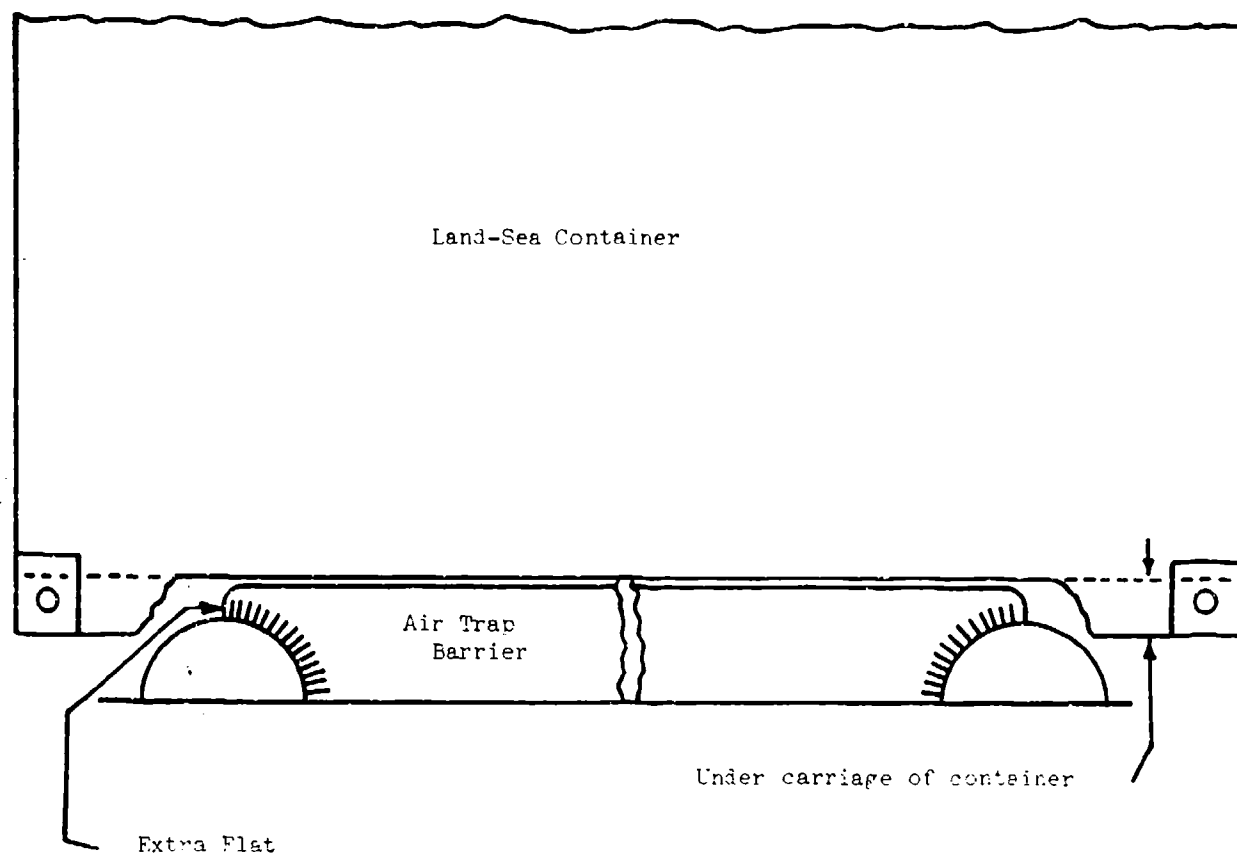


Figure 53. Container Movement Over Trunk

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