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AIR CARGO SUPPORT FACILITIES FOR ARMY AIRLIFT OPERATIONS

Charles S. Stahl

Army Construction Engineering Research Laboratory
Champaign, Illinois

May 1973

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AIR CARGO SUPPORT FACILITIES FOR ARMY AIRLIFT OPERATIONS

(STRATEGIC AIRLIFT GROUND SUPPORT FACILITIES)

by
Charles S. Stahl

May 1973

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13. ABSTRACT

This report analyzes cargo handling systems currently in use at air freight terminals. The study includes the conventional procedures which utilize conveyors or forklifts, pallets or containers, as well as an experimental towline-towcart Dortech system. Various operational areas within a terminal, such as the truck or aircraft loading and unloading docks, pallet buildup and breakdown stations, and the consolidation area are described in detail.

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FOREWORD

The investigation of air cargo support facilities for Army Airlift Operations was performed under RDT & E Project 4A664717D895, "Military Construction Systems Development," Task 04, "Military Airfield Facilities," Work Unit 001, "Strategic Airlift Ground Support Facilities." This work was performed under the direction of the Office of the Chief of Engineers, Directorate of Military Construction, Engineering Division Advanced Technology Branch. The OCE Technical Monitor was Mr. S. Gillespie, Advanced Technology Branch, Civil Engineering Section. The study was conducted under the general supervision of Dr. E.L. Murphree, then Acting Chief, Data Analysis Division, at the Construction Engineering Research Laboratory (CERL).

An acknowledgement is given to Mr. E.J. Worrel of the Data Analysis Division at the Construction Engineering Research Laboratory for his guidance and assistance as principal investigator of this project. Col. R.W. Reisacher is Director of CERL, Dr. L.R. Shaffer is Deputy Director.

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1 RESEARCH OBJECTIVES

To assist in the development of a computer simulation model for an air freight terminal, the present cargo handling systems must be clearly defined and characterized. The purpose of this investigation is to provide basic information about the functions of an air freight terminal. In particular, the information in this report is utilized in two CERL reports on computer simulation models of air freight terminals by L.P. McNamee[1] and by L.P. McNamee and C. Lee.[2]

Included in the characterization are detailed descriptions of cargo unitization by pallets or containers; the vehicular handling equipment, forklifts, K-loaders, and cranes; the conveyor and forklift systems; the towline-towcart Dortech system; truck and aircraft loading and unloading docks, interfacing bridges and swing bridge loading dock; and other operational areas, such as receiving, storage, consolidation, and palletizing areas.

2 CARGO UNITIZATION

The 463L System. The 463L system is the standard cargo handling system used at military installations in conjunction with intermodal transportation. This system, which derives its name from the 463L master pallet, consists of all materials handling equipment and terminal facilities including the building, cargo operational stations, ground/aircraft cargo handling equipment, and inter-terminal control facilities. The size and capabilities of all equipment and terminal facilities are dependent upon the characteristics of the 463L master pallet and its standard dimensions of 88 × 108 × 96 inches.

[1] L.P. McNamee, *Computer Simulation and Validation of the Travis Freight Terminal Facility*, (U.S. Army Construction Engineering Research Laboratory [CERL], March 1973).

[2] L.P. McNamee and C. Lee, *Development of a Standard Data Base and Computer Simulation Model for an Air Cargo Terminal*, Technical Report A-8 (CERL, January 1973).

In the 463L system, all unitizable cargo is packed into transportable modules as soon as possible. The two types of unitization modules that are used in conjunction with the 463L system are the air transportable pallet and the air transportable container. Cargo pieces are unitized according to one or a combination of the following characteristics:

1. Size – Cargo modules are loaded so that the module design specifications are not exceeded. Whenever possible, cargo of varying sizes is unitized in the same module to maximize the space used.
2. Weight – The packing of each module is planned in advance to also maximize the space used without exceeding the weight limitation of the module. Heavier cargo pieces are placed towards the bottom of the module to maintain a low center of gravity.
3. Type – Compatible cargo is unitized in the same module.
4. Destination – Cargo with the same destination is unitized together.

An analysis of the above factors indicated that the size of a cargo piece usually imposes the greatest limitation, since the cube limit of the module is usually reached prior to the weight limit. Also, odd-shaped freight often exceeds the boundary limits of the unitization module and prohibits cargo pieces from being packed efficiently.

Efficient cargo unitization at air terminals is a major goal because the transporting and storing of unitized modules results in reduced cargo handling and manpower requirements, rapid aircraft turnaround, and consequently savings in total system costs. Lower system costs also result when the cargo remains unitized for the duration of its shipment, or at least for extended periods of time. Whenever possible, the bulk freight should be unitized with other cargo pieces. It can then remain packaged until the final distribution and delivery process is completed. The continual build-up and breakdown of the same module during the shipment process usually results in extensive costs. As a result, it is not only important to unitize cargo as soon as possible in the shipment process, but precautions must be taken when choosing which cargo items to pack in the same unitization module.

Palletization. The air transportable pallet is the unitization module most often used at military installations. This 463L master pallet is the pallet size most extensively used; however, other sizes of pallets are used and are compatible with the 463L system. As illustrated in Table 1, the 463L master pallet can accommodate most of the cargo pieces processed through military air terminals. However, there is a need for both larger and smaller palletization modules to insure maximum cargo unitization efficiency.

The standard warehouse pallet, whose dimensions are 40 x 48 x 54 in., can be used to unitize small packages and lightweight cargo. (Limited utilization of this particular pallet is expected in the future.) As many as four standard warehouse pallets can be unitized onto one 463L master pallet. Warehouse pallets can be utilized at lower-volume terminals where the number of cargo pieces per payload is smaller when packed together according to cargo type or destination. Cargo with similar characteristics can be packed onto standard warehouse pallets; these, in turn, can be unitized onto a 463L master pallet with either three other warehouse pallets or a combination of loose cargo and warehouse pallets. If pallet breakdown is necessary before reaching the final destination, the 463L master pallet can be broken down 'nto smaller unitization modules rather than numerous loose cargo pieces.

In addition to the 463L master pallet and the standard warehouse pallet, pallet trains can be utilized. These provide from two to five pallet capability, and

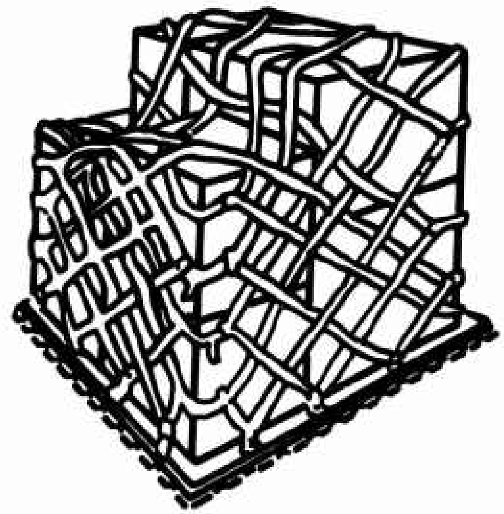

Figure 1. Cargo net securing 463L master pallet.

also provide larger than single pallet platforms for oversized cargo. Couplers to keep the pallets in line and properly spaced are used to connect 463L master pallets to form the pallet train. Since pallet trains are compatible with the 463L system, oversized cargo pieces (many are odd-shaped) can be more efficiently transported if they are packed onto pallet trains rather than handled loosely.

After the cargo has been placed onto the pallet, it is secured with pallet nets. These nets keep the pallet load from shifting and falling apart during cargo handling processes. Several pallet nets are usually needed to secure each pallet, and slip rings are provided on the pallet and the nets to allow for fast, easy application. Figure 1 shows cargo nets securing a typical load on a 463L master pallet.

Table 1
Unitization Module Cargo Fit*

Unitization Module	Average Load Weight (lbs)	Average Load Volume (cu ft)	Average Volume Utilization (%)	% of Total Sample Fitting on Module Pieces	Weight	Volume
Warehouse Pallet	1,060	50	71	7[illegible]	27	21
463L Master Pallet	6,780	390	80	94	80	73
Two-Pallet Train	13,210	840	83	98	92	88
Three-Pallet Train	21,200	1,315	86	99	96	93
Four-Pallet Train	30,770	1,720	84	99	97	96
Five-Pallet Train	33,500	2,260	88	99	98	97
Container (10 ft)	7,420	425	78	95	86	77
Container (20 ft)	15,700	945	84	98	93	87
Container (40 ft)	3,470	1,950	86	99	96	93

* Based on cargo survey of over 11,000 cargo pieces, conducted in 1966 at Travis AFB.

One disadvantage of the use of pallets as unitization modules is the lack of built-in protection from inclement weather. If open-air storage is used for palletized modules, either plastic or canvas covering must be placed over the cargo.

Containerization. Although used less extensively than pallets, the air transportable container can be used in support of higher-volume cargo terminal operations. Most containers used in conjunction with the 463L system have an 8 × 8 ft cross-section with lengths up to 40 ft. Containers are most often used to unitize oversized cargo. Figure 2 shows a typical 463L system container. Tables 1 and 2 list important dimensions and characteristics of unitization modules.

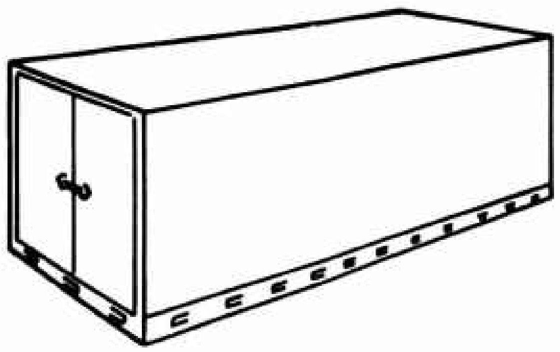

Figure 2. 463L system container.

Pallets versus Containers. Some of the advantages supporting palletization over containerization are the following:

1. The tare weight of pallets is approximately 10% less than the corresponding tare weight of containers for equivalent cargo weights and volumes.
2. When not in use, pallets may be stacked for storage requiring minimum space, whereas containers require the same amount of storage space no matter if they are loaded or not.
3. Pallets may be built up/broken down from all sides, but containers are only accessible from one side.
4. Maintenance, administration, and initial costs are lower for pallets.
5. The volume available for cargo is greater with pallets than with a similar size of container; the extra material needed for a container decreases its volume.

In contrast, the following characteristics favor the use of containers for unitization purposes:

1. Containers provide a built-in protective storage environment to guard against rough handling, pilferage, and inclement weather. Therefore, containers can also be used as a temporary warehouse or to provide emergency shelter. The plastic net cover used for pallets provides minimal protection and is time-consuming to install.
2. Stacking loaded unitization modules on top of each other for increased storage and transportation efficiency is possible with containers. Odd-shaped and fragile cargo packed on pallets eliminates stacking possibilities.
3. The rigid construction of containers causes a lower attrition rate than that of pallets.

Table 2
Unitization Module Characteristics

Unitization Module	Module Size (L × W × H) (in.)	Tare Weight (lbs)	Nominal Gross Weight (lbs)	Internal Cube (cu ft)
463L Master Pallet	88 × 108 × 96	355	10,500	485
Two-Pallet Train	178 × 108 × 96	710	21,000	970
Three-Pallet Train	268 × 108 × 96	1,065	31,500	1,455
Four-Pallet Train	358 × 108 × 96	1,420	42,000	1,940
Five-Pallet Train	448 × 108 × 96	1,775	52,500	2 425
Container	(10 × 8 × 8)*	900	12,500	570
Container	(20 × 8 × 8)*	1,850	25,000	1,190
Container	(40 × 8 × 8)*	3,350	45,000	2,360

* Indicates measurement in feet.

3 VEHICULAR CARGO HANDLING EQUIPMENT

Vehicular materials handling equipment is an integral part of the 463L system. Since oversized and outsized cargo comprise a significant portion of a typical jumbo jet payload, vehicular materials handling equipment is necessary for loading/offloading processes and inter-terminal cargo transfer. In many situations, only pallets and palletizable cargo are placed on the inter-terminal cargo handling system at the truck and aircraft loading docks. Containers and pallet trains are usually taken directly to and from the loading docks via forklift truck or K-loader.

Forklifts. One forklift commonly used in support of air cargo terminal operations is the 10,000 lb capacity forklift. This truck is used to pick up, stack, transport, load, and unload cargo while servicing low and high floor aircraft. It is intended for handling 463L system unitization modules, specifically the 463L master pallet. This forklift is designed after the conventional forklift trucks. One difference is this truck has extra long forks (72 in.) and a triple stage mast for efficient loading and unloading of cargo. Important design features, characteristics, and common uses of the 10,000 lb forklift are the following:

1. Over level surfaces, this forklift can transport freight at a speed of 15 to 20 mph.
2. The 10K forklift has a maximum lift height of 150 n.
3. It can transport freight or unitization modules between operational stations, loading areas, and storage areas.
4. With its lifting mechanism, this forklift is used to load and unload loose cargo and unitization modules from platforms, conveyor systems, storage racks and bins, K-loaders, carts, and palletization pits.

At the truck loading area, sufficient space is required to allow for forklift maneuverability. As shown in Figure 3, the use of forklift trucks is one of the primary methods of loading and unloading trucks. In many cases, forklifts will take cargo directly from trucks and place it onto an inter-terminal cargo handling system such as towcarts or a conveyor.

Of the many inter-terminal uses of a forklift, one of the most important is the support it gives to the pallet buildup and breakdown operations. Although most unitization modules are built-up and broken down manually, forklifts are needed to move heavy cargo pieces and oversized cargo during the palletization process. Usually, one forklift is required for every two palletization areas.

K-loaders. K-loaders are used almost exclusively for loading and unloading aircraft and transporting these loads to and from the terminal. K-loaders are equipped with a lift mechanism which allows the cargo platform to be elevated. This lifting capability in conjunction with the roller conveyors on the cargo platform enables K-loaders to properly interface with both aircraft and inter-terminal cargo handling systems. Figure 4 shows a K-loader preparing to interface with another cargo handling system in order to transfer its load. At lower-volume freight terminals, K-loaders could provide the primary means of loading and unloading cargo aircraft. Using four 40K-loaders, a C-5A jumbo jet cargo carrier can be unloaded and loaded in one hour. At higher-volume cargo terminals, K loaders often provide support to more advanced cargo handling systems. For example, larger terminals might use swing loading docks to accommodate jumbo jet traffic. In this situation, K-loaders might be used for both loading/unloading smaller aircraft and to transport containers, pallet trains, oversized cargo, and outsized cargo between the terminal and the loading docks. Figure 5 shows K-loaders transporting containers to a swing loading dock to be loaded onto a jumbo jet cargo carrier. Also, when satellite storage is provided at freight terminals for special handling cargo such as explosives, K-loaders are frequently used for transporting this special handling cargo to and from the satellite storage area.

Table 3 lists the primary design characteristics of the 40K-loader. A 40K-loader can accommodate five 463L master pallets at one time on its cargo platform. Other frequently used K-loaders are the 25K and the

Table 3
Characteristics of the 40K-loader

Speed	15 mph
Payload	40,000 lbs
Length	43 ft
Width	10 ft
Height	40 in. to conveyor top
Cargo Platform	4 rows of roller conveyors
Platform Height Adjustment	50–156 in.

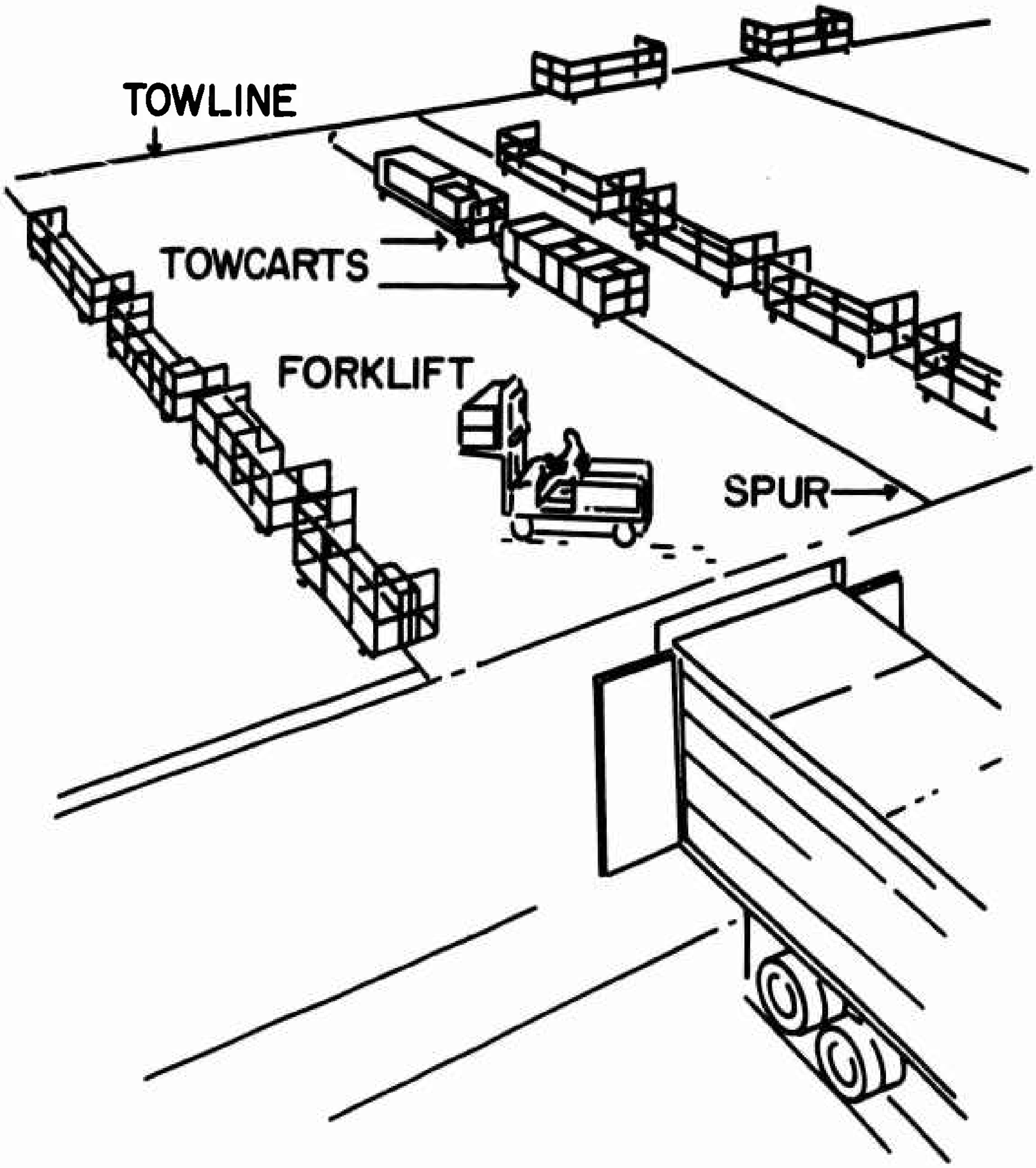

Figure 3. Forklift loading tow carts at truck dock.

55K-loader. Although these K-loaders have the same general characteristics as the 40K-loader, they can accommodate three and six 463L master pallets at one time, respectively, and can transport maximum payloads of 25,000 lbs and 55,000 lbs, respectively.

Other design features of K-loaders are the following:

1. A winching system is provided to move cargo and unitization modules on or off the cargo platform. (Maximum load/offload time for three 463L master pallets on most sizes of K-loaders is three minutes).
2. The cargo platform is equipped with guide rails and locking devices which control and secure cargo during loading and transporting operations.

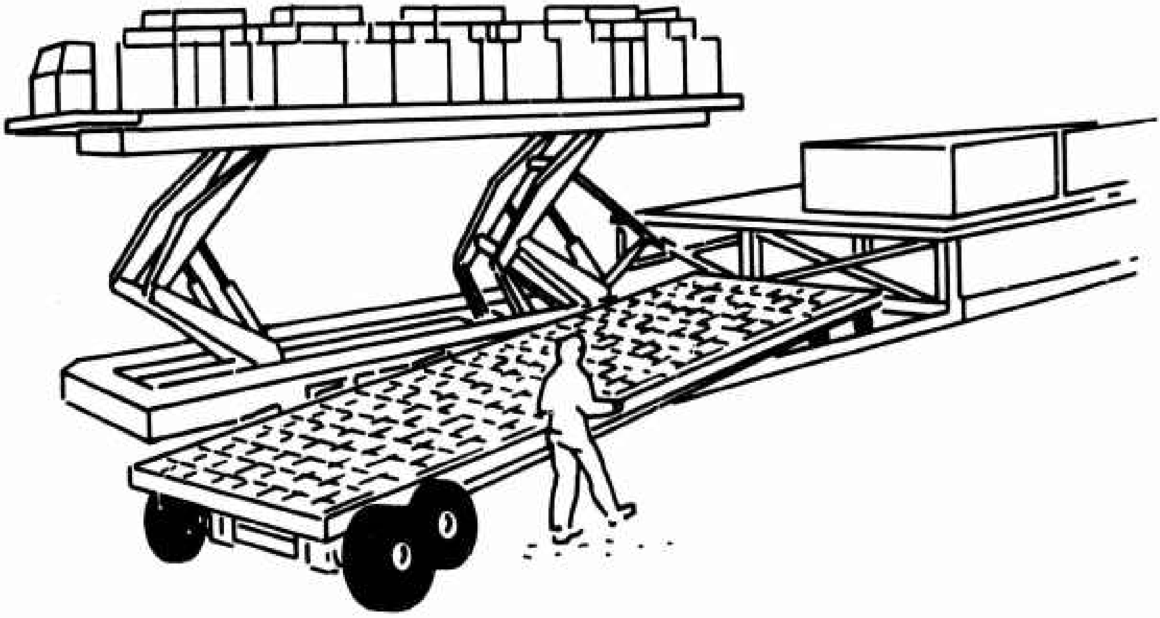

Figure 4. K-loader preparing to interface with another cargo handling system in order to transfer its load

3. An interfacing bridge, located on the forward edge of the cargo platform, can be used to span the gap and properly interface the cargo platform with the loading floor of an aircraft or another cargo handling system.

Cranes. Although not as extensively used as either forklifts or K-loaders, there are two types of cranes which could also be used in support of military cargo terminal operations – stacker cranes and bridge cranes.

Stacker cranes can be utilized in support of a towline cargo handling system. These cranes are used to store and retrieve towcarts and containers from the stacker bins in the storage area. (A more detailed description of the towline system is in Section 4.) As is shown in Figure 6, stacker cranes can move both vertically and laterally, and thus provide random access to the stacker bins. The crane shown in Figure 6 is transferring carts from the first row of stacker bins to the second row. By a similar process, stacker cranes in the other rows of the storage area can transfer the cargo to the desired storage bin. Shortly before the cargo is scheduled to be taken to the loading docks, the stacker cranes begin the transfer process of moving the cargo to the first row of stacker bins. The cargo is then transported from the storage area to the loading area via forklift, conveyor, or towline.

Bridge cranes are another type of crane which would be used in support of higher-volume cargo terminal operations. They could be used at the loading docks, at the pallet train and container storage areas, or at the pallet train and container buildup and breakdown stations. Bridge cranes are used primarily to place oversized cargo, outsized cargo, containers, and pallet trains onto other cargo handling systems such as conveyors and K-loaders and to assist in the unitization of heavy cargo pieces.

4 INTER-TERMINAL CARGO HANDLING SYSTEMS

Conventional Systems. An important function of the 463L system is to provide a means for actually supporting and moving the units of cargo from one position to another within the terminal complex. At lower-volume air freight terminals, forklift trucks could be utilized almost exclusively for this purpose. With the exception of some smaller and lighter weight cargo which could be transported manually or via handcart, forklifts could service the loading, storage, and operational areas.

Since 463L system pallets and containers are designed for lower surface roll-transfer operations for

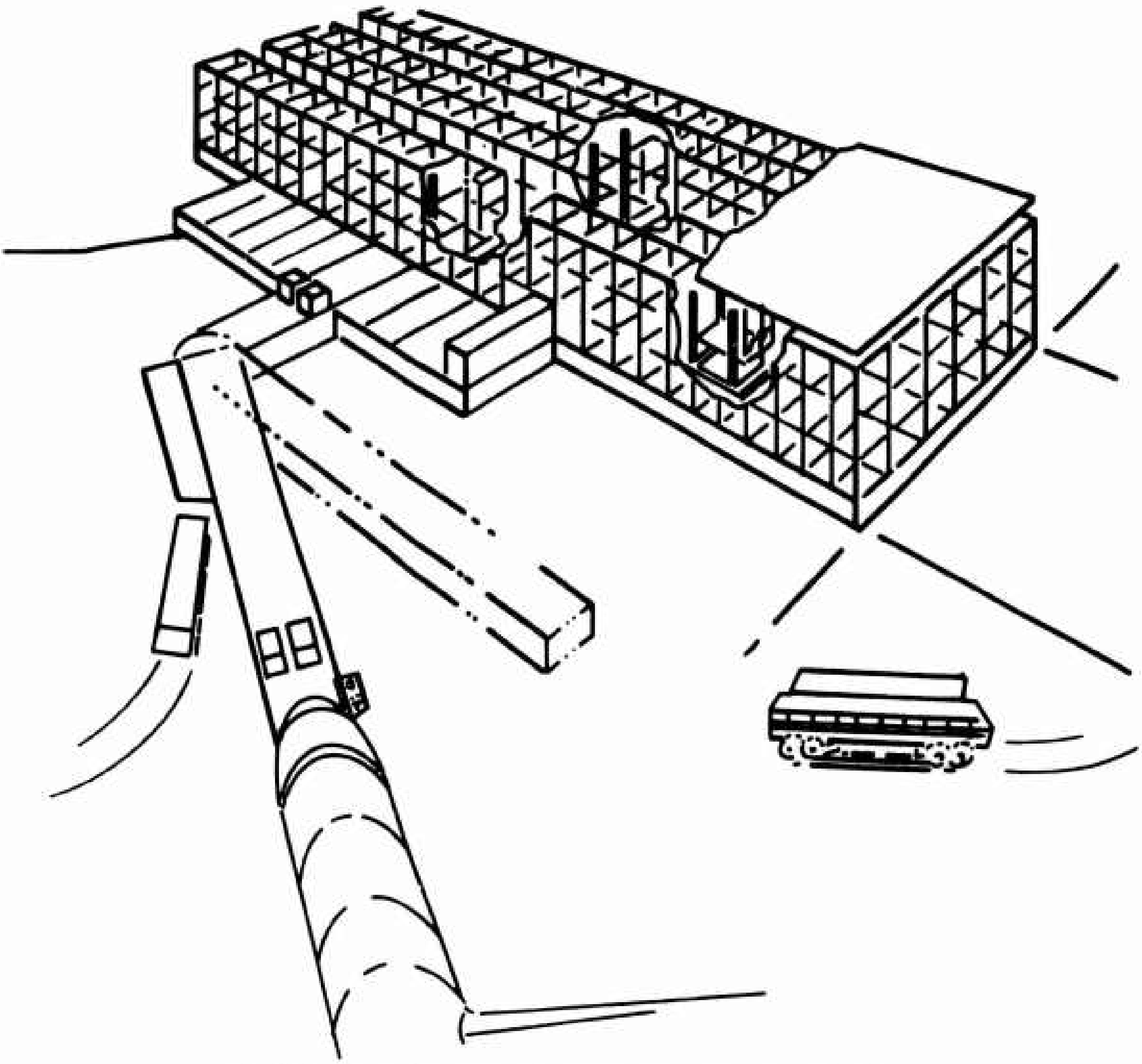

Figure 5. K-loaders carrying containers to swing loading dock.

moving and accessibility efficiency, powered ground roller conveyor systems are often used to support higher-volume terminal cargo movement. The roller conveyors are compatible with aircraft on-board loading systems. (Conveyor belts are usually not used for this purpose since it would be difficult for forklifts to insert or remove a single pallet or cargo piece at any location along the belt, and the entire system would become inoperative during times of power failure.) Long rollers with a large diameter are most commonly used for ground conveyor systems. A long roller, in contrast to three or four shorter rollers spanning the width of the conveyor, insures full roller contact with the lower surface of the cargo and reduces the number of parts in the conveyor system. Full roller contact with the cargo provides maximum control over the moving cargo.

For negotiating curves, either long tapered rollers, differentially rolling short rollers, or wheel conveyors are most commonly used. Figures 7, 8, and 9 show three alternatives for negotiating curves with a roller conveyor system. The wheels on the inner half of the wheel conveyor and the inside row of rollers on the differentially rolling short roller conveyor should be driven at differential speeds forcing the cargo to turn. To insure smooth, safe movement of cargo, all curves should be of a generous radius with strong continuous guide rails along each side (guide rails along the entire length of the conveyor system are recommended).

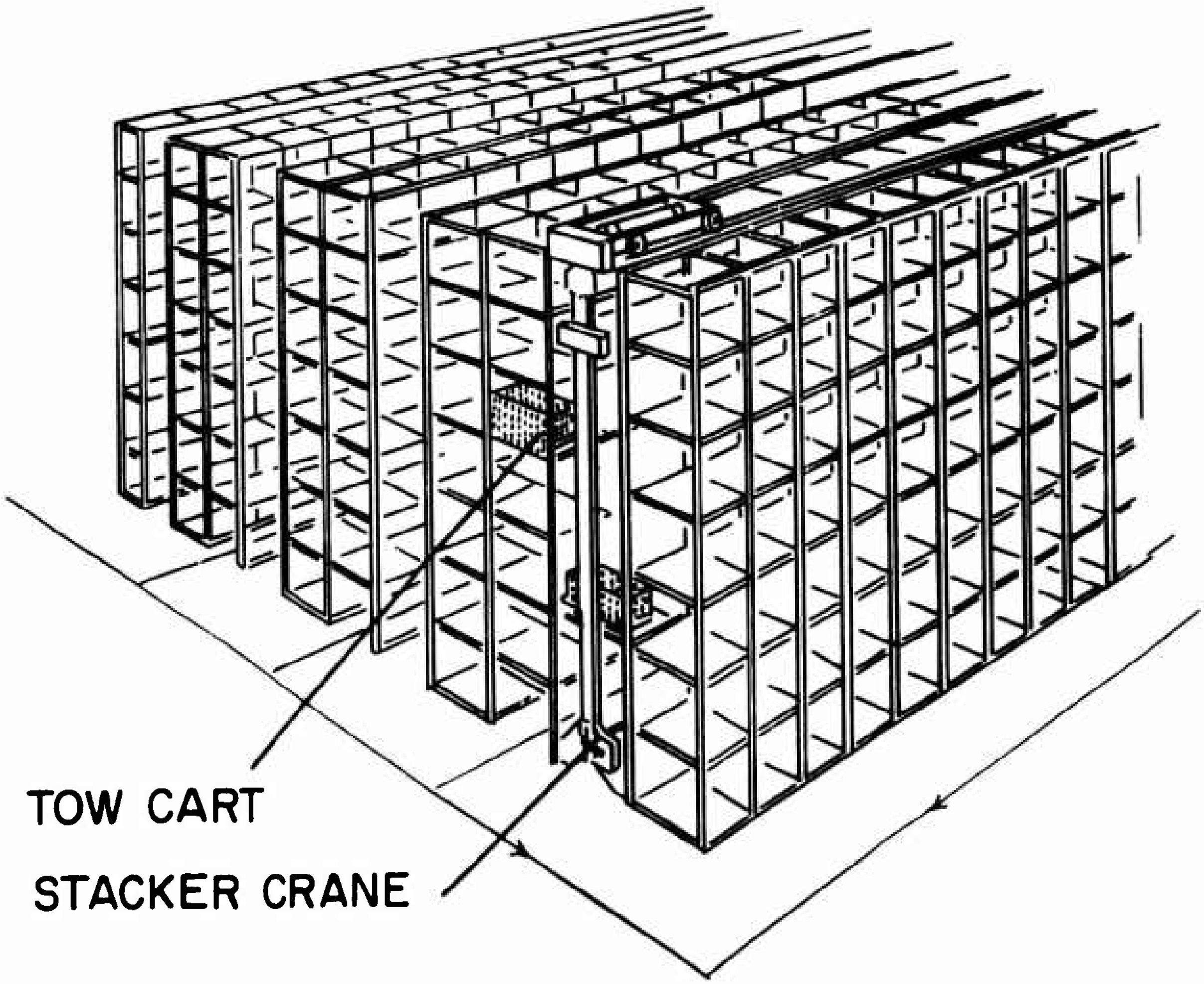

Figure 6. Stacker crane and bins supporting towline cargo handling system.

Maximum flexibility of the system is provided by two-directional powered rollers. By installing trays of short, two-directional powered rollers at right angles among the long rollers of a basic two-directional roller conveyor, four-directional movement can be obtained. A synchronized up/down type mechanism is needed to raise the shorter rollers above the longer rollers and thus move the cargo at right angles to its original flow. Four-directional systems are usually implemented at the aircraft loading docks so that pallets and containers can be properly positioned prior to the loading process. (This is discussed in more detail in Section 5.) Figure 10 shows the position of the roller trays among the basic roller system.

The volume of cargo transported by a conveyor system is dependent upon the length and width of the conveyor, and the speed at which it is operated. A wider conveyor system increases the percentage of cargo capable of being moved without bypassing the conveyor system. However, as conveyor width is increased, the average utilization of conveyor width is reduced.

To fully evaluate the cost and effectiveness of increasing the width of conveyors requires consideration of the costs of the air cargo terminal floor areas used for the conveyor system as opposed to a cargo bypass system (forklifts provide one such bypass system for cargo which is too large for the conveyor system). Again referring to the cargo measurement survey conducted at Travis AFB in 1966, Tables 4 and 5 show the cargo handling characteristics of various conveyor

Table 4
Cargo Handling Characteristics of Various Conveyor Widths for Palletizable Cargo

Conveyor Width (ft)	Cumulative % of Total Cargo			% Area Utilization
	Pieces	Weight	Volume	
2	64	20	16	78
4	95	78	78	64
5	98	90	93	58
6	99	91	94	54
7	99	96	97	47
8	99	99	99	44

Table 5
Cargo Handling Characteristics of Various Conveyor Widths for Oversize Cargo

Conveyor Width (ft)	Cumulative % of Total Cargo			% Area Utilization
	Pieces	Weight	Volume	
2	50	20	12	73
4	85	50	47	71
5	92	70	57	67
6	95	80	65	69
7	98	87	81	70
8	98	91	87	70
9	99	97	95	70

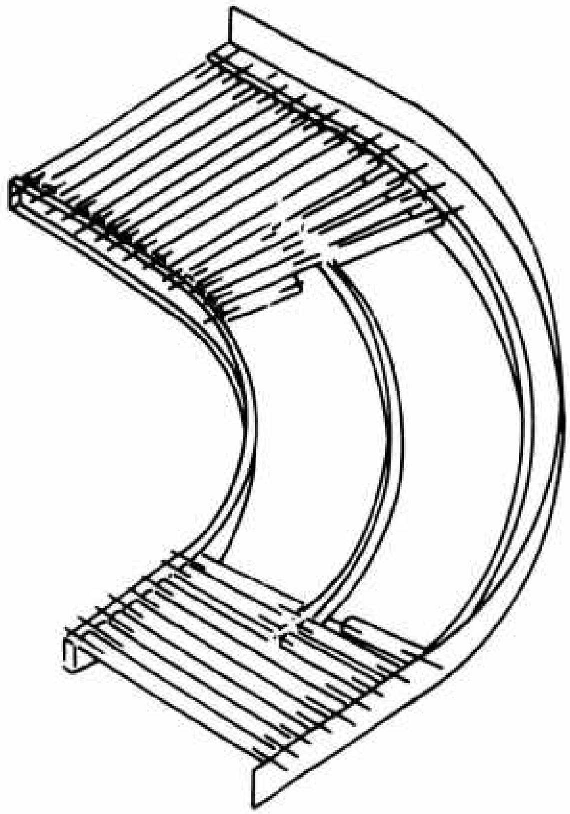

Figure 7. Roller conveyor curve using differentially rolling short rollers.

widths for palletizable and oversize cargo respectively. (A significant portion of the cargo that was too big for the 463L master pallet in this survey was long and narrow). For example, Table 4 shows that a conveyor 2 ft wide was able to accommodate 64% of the total number of cargo pieces, 20% of the total cargo weight, and 16% of the total cargo volume of palletizable cargo in this particular survey.

An Experimental System. In 1968, Dortech Incorporated introduced a new approach to air terminal cargo handling. This towline-towcart system is presently in the experimental state. When implemented, a towline system could be used in conjunction with a conveyor system for transporting bulk freight within the terminal. Prior to the palletization process, towcarts could be used for moving loose cargo. A towcart is a four-wheeled cart which is 8 ft long, 4 ft wide, and 5 ft high, and is capable of carrying an average load of 1200 lbs. The towcart must be designed to prevent cargo from protruding over its boundaries so that the storage and maneuverability of the cart is not limited; removable sides are available to keep odd-shaped cargo within the limits.

A towline is used to pull the towcarts throughout the terminal. The towline is a length of chain located in a slotted trench in the floor and continually running in a pulley-like fashion. A retractable towpin is attached to the bottom of the towcart so that the cart can be connected to the towline. The towpin is connected to "pusher dogs," which are attachments located at regular intervals along the towline. After a towcart has been loaded, either manually or by forklift, with cargo of the same inter-terminal destination (storage, unitization area, loading dock, etc.), it is coded and placed

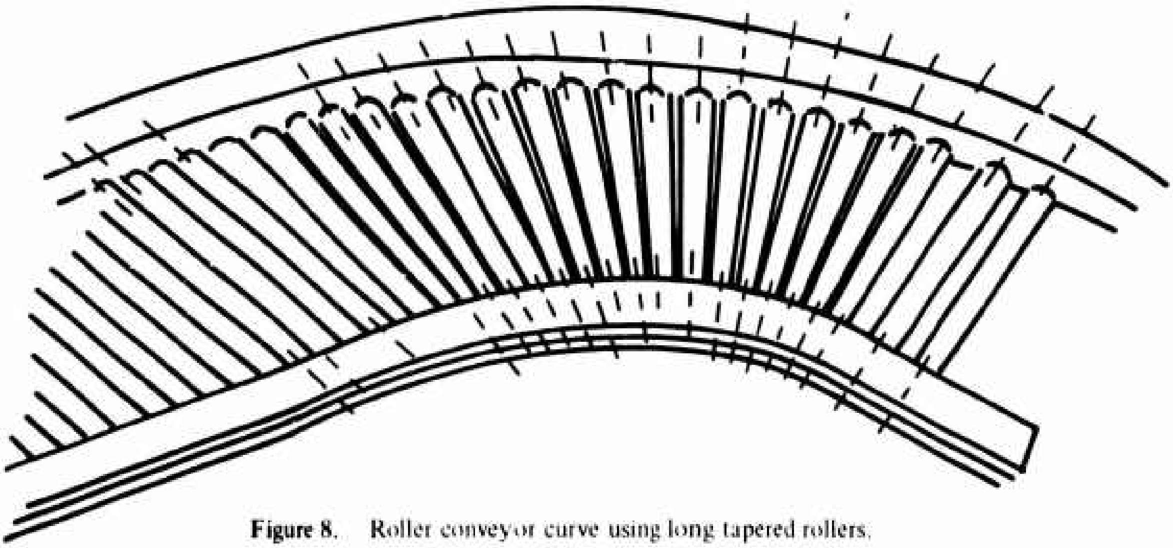

Figure 8. Roller conveyor curve using long tapered rollers.

into a corresponding slot on the towline to be pulled to its next station. According to the slot in which the towpin was placed, a switching device in the towline will pull the cart onto a side spur away from the main flow of the towline system and toward its destined handling station. When the carts are no longer needed at a particular station, they can be either temporarily stored in an area adjacent to that station or recoded for its next destination and placed back onto the towline system. For example, empty carts might be sent back to the loading docks; whereas, a loaded cart might be coded for the stacker bin storage area.

The towline system is usually most efficient and safe if it is operated along the outside walls of the terminal. In this manner, the interference of the moving carts to the rest of the terminal's operations will be kept minimal. However, a number of successive "pusher dogs" should be removed from the towline at regular intervals to create traffic gaps. This enables forklifts to move with a minimum of interruption.

When necessary, loaded carts can be stored in a stacker bin. As shown in Figure 6, stacker cranes provide random accessibility to the stacker bin storage area. Stacker bins can also be used to store empty carts when they are not needed.

As mentioned previously, a towline system could operate in conjunction with a ground roller conveyor system. Many cargo pieces are not cartable; the unitized loads on the 463L master pallet or larger module are one example. These loads would need to be moved via conveyor or forklift. However, the towline system could be used for moving bulk freight from the truck loading docks to inter-terminal stations prior to the unitization process.

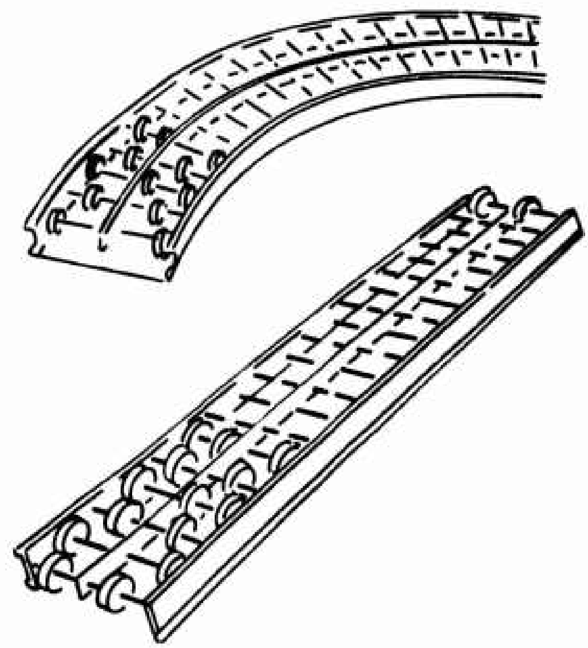

Figure 9. Curved and straight wheel conveyors.

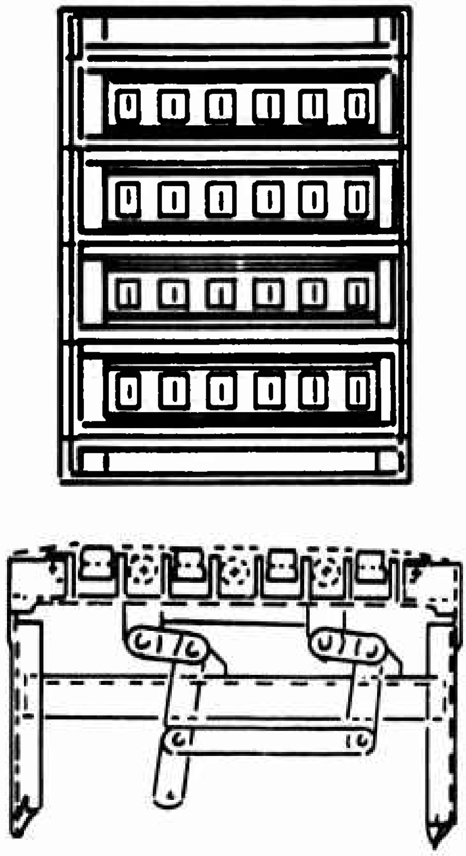

Figure 10. Four-directional movement is obtained by installing short two-directional powered rollers at right angles to original long two-directional rollers.

5 LOADING AND UNLOADING AREAS

Truck Docks. Trucks are loaded and unloaded both manually and by forklift. Occasionally, larger materials handling equipment such as cranes are needed to load/offload heavier cargo pieces. Incoming cargo is usually taken from the truck and placed on an inter-terminal cargo handling system. For example, loose cargo pieces and pre-unitized cargo could be taken directly from the truck and placed on a ground roller conveyor finger which reaches out to the truck docks. Therefore, with a minimum amount of handling, cargo can be unloaded and moved by conveyor into the terminal. Another alternative is to place the unloaded cargo onto an awaiting towcart. As shown in Figure 3, spurs from the main towline system extend out to the truck docks.

Table 6
Minimum Truck Dock Requirements

Terminal Capacity (tons/day)	Number of Truck Docks Required
200	10
400	10
600	10
1000	10
1500	12
2000	16
3000	25
4500	37
6000	49

Cargo which cannot be sent by cart or conveyor could be taken directly into the terminal via forklift. Also, forklifts could transport cargo which is not going into the terminal, but is destined for a special handling area or outside storage (for example ammunition and pre-unitized loads).

In most cases, a 20 ft × 20 ft area is needed for each truck dock.[3] Table 6 lists the number of truck docks required for various terminal capacities.[4] This table gives a general idea of truck dock requirements. It is based upon the underlying assumptions used by Dortech in developing the towline system. The main assumptions made by Dortech applicable to truck docks are:

1. The average truck load is 15 tons.
2. The minimum stripping rate is 5 tons/hr (7 tons/hr is the minimum standard for New York Longshoremen).[5]
3. All terminals will have a minimum of 10 truck docks.

[3] *Air Logistics Studies 1970's, Phase II, Air Cargo Terminals and Materials Handling System, Annex C (Permanent Air Terminals)* Technical Report AD825 867 (Deputy Chief of Staff Systems and Logistics, May 1967).

[4] Dortech Incorporated, *Air Freight Terminal Complex Concept Development Report*, Vol II (Department of the Air Force, Headquarters 375th Air Base Group, Scott AFB, Illinois, November 1968).

[5] Douglas Aircraft Co., Inc., *Post 1971 Materials Handling Study Final Report*, Vol IV (Engineering Analyses), Part 1, Preferred System and Summary, Technical Report ASD-TR-67-5/AD820 718.

Aircraft Loading Docks and Interfacing Bridges. There are many alternative methods for loading and unloading jumbo jet aircraft involving vehicular materials handling equipment and fixed loading dock systems. Although vehicular equipment offers a more mobile and flexible alternative than a fixed loading dock system, loading docks are probably easier to maintain and less costly when projected over expected equipment lifetimes.[6]

As mentioned earlier, using a team of four 40K-loaders, a C-5A jumbo jet cargo carrier can be unloaded and loaded again in less than one hour. This presents a highly flexible system because it would no longer be necessary to taxi the aircraft to the terminal complex and park it in a limited loading space to achieve proper interfacing with terminal cargo handling systems. K-loaders can effectively turn around a jumbo jet while it is parked in a maintenance area.

However, as jumbo jet traffic increases, more permanent loading systems will be needed. For loading/offloading processes, as an example, an interfacing bridge or loading dock could be used to span the gap between the terminal and the loading door of the aircraft. This would provide a continuous flow of cargo between the respective cargo handling systems. An interfacing bridge should be able to receive an entire aircraft load on its center section and move it to one side of its platform using four-directional powered rollers. Then the center section would be available to receive the outgoing load from the terminal's cargo handling system. The new load could then be transferred to the aircraft's cargo handling system via the powered rollers of the interfacing bridge. Consequently, the jumbo jet could be turned around before the terminal's system handles the incoming load.

A 45–60 minute turnaround time for the C-5A and other jet traffic is dependent upon the design of the interfacing bridge. The following criteria outline the Military Airlift Command's basic requirements for a loading dock system.[7]

1. A winching system to aid in the loading/offloading of pallet trains and containers is necessary. For example, two winches capable of 8,000 lb pull each could be located on either side of the bridge along the centerline of the pallet lane.
2. The bridge should be able to accommodate two rows of 18 pallets each for a total of thirty six 463L pallets at one time.
3. The loading system must be able to position containers with lengths up to 40 ft for removal by 463L cargo handling equipment. An interfacing section for vehicular material handling equipment (forklifts, K-loaders, etc.) should be provided for loading/offloading single pallets, pallet trains, and containers. This section should be located along one side of the interfacing bridge so that any loading/offloading processes involving vehicular equipment will not interfere with the normal flow of cargo to and from the aircraft.
4. The platform on the interfacing bridge must be able to move cargo both forward and aft, with a manual means of moving cargo in case of power failure. Four-directional movement is desirable at certain sections of the bridge to aid in the positioning of oversize cargo and containers or to move a load to an outside lane of the bridge. Powered roller conveyor systems are most commonly used since they are compatible with in-terminal, aircraft, and 463L systems.
5. Sufficient clearance between the terminal and the aircraft loading area should be provided so that taxi-in/taxi-out operations are not hindered. Towing equipment is necessary when there is not enough area for the aircraft to maneuver under its own power during taxiing operations.
6. The cargo and interfacing bridge must be protected from aircraft exhaust velocity and temperature. Therefore, either the terminal's loading dock will need to be moved away from the aircraft loading area during taxi-in/taxi-out operations, or the aircraft will need to be towed after it comes within a certain distance of the terminal.
7. Minimum tolerances should be placed on aircraft positioning methods even if towing equipment is used. The interfacing bridge needs sufficient tilting and elevating capabilities in order to properly interface with the aircraft.

[6] *Terminal Facilities 1973, Annex B, Phase II (Cargo Terminal Planning)*, AD 843 894 (Military Airlift Command, August 1968).

[7] *Terminal Facilities 1973, Annex B, Phase II (Cargo Terminal Planning)*, AD 843 894 (Military Airlift Command, August 1968).

8. The interfacing bridge should be equipped with guide rails and flipper arms to provide added control over cargo movement. The width between the guide rails along the cargo lanes will need to be adjustable in order to accommodate various sizes of unitization modules and oversize cargo. Flipper arms along the conveyor lanes can be used to position and move cargo when alignment problems occur, while guide rails provide boundary constraints to the cargo flow.

Swing Bridge Loading Dock. A swing bridge loading dock[8] provides one of the most efficient means of loading/offloading jumbo jet cargo aircraft. A swing bridge has two major assemblies. First, it has a 150 ft long, self-powered moving section which pivots about a 66 in. diameter turntable. This swinging portion of the bridge allows planes to taxi in/taxi out under their own power. After an aircraft is parked, the swing bridge travels through approximately a 75-degree arc until it reaches its operating position which is in line with the centerline of the aircraft. The second assembly of the swing bridge is a fixed bridge which spans the distance between the turntable and the terminal entrance. Figure 11 shows a C-5A interfaced with a swing bridge loading dock. Figure 12 shows a swing bridge at its turntable or pivot point where its two main assemblies are connected.

The length of the swing bridge should remain constant so that the platform can accommodate an entire C-5A payload at one time, no matter if the load consists entirely of pallets or a combination of pallets, oversize and outsize cargo. However, the size and shape of the conveyor and fixed dock portions of the swing bridge might change depending upon the demands of the terminal being serviced.

An interfacing bridge section should be connected to the end of the swing bridge to insure proper alignment and interfacing with the aircraft. This interfacing section would correct any pitch, roll, or elevation differences created between the end of the swing bridge and the cargo loading doors on the aircraft.

Other design features of a swing bridge loading dock are the following:

1. Sheltering partitions can be positioned over the bridge to permit all-weather operations.
2. Hydraulic jacks are used to lift the bridge upward so that its tires are not in contact with the pavement. This operation is used to level and stabilize the bridge prior to the cargo transfer process.
3. The operator's cab is located to the side of the swing bridge allowing the operator unobstructed view of the aircraft's cargo compartment and the two assemblies of the swing bridge.
4. A walkway is provided around the outside of the bridge to make access to the platform of the bridge easier for operating and maintenance personnel.
5. Only 463L master pallets are moved over the entire length of the bridge. Containers and pallet trains are loaded/offloaded at a K-loader dock located on the side of the swing bridge, as shown in Figure 13. Skid-mounted cargo and vehicles can be loaded/offloaded directly from the C-5A to the ground after the swing bridge is moved away; forklifts carrying the skids and the vehicles can be driven off of the C-5A to the ground via the fore-loading ramp.
6. The fixed or staging dock has five conveyor lanes for positioning incoming and outgoing payloads on the same dock at one time. Figure 14 shows the fixed position of the swing bridge. Outgoing cargo received from the terminal is temporarily stored in lanes 4 and 5 while incoming cargo is offloaded, moved down lane 1, and transferred to lanes 2 and 3. After the offloading process is complete, the cargo in lanes 4 and 5 is transferred to lane 1 and loaded onto the aircraft. During the loading/offloading process described above, incoming containers and pallet trains are moved directly from the interfacing bridge to the K-loader dock. Outgoing containers and pallet trains are transported via K-loader or forklift from the terminal to the K-loader dock at which time they are combined with the flow of pallets moving toward the aircraft via conveyor lane 1.
7. Other design features of the swing bridge loading dock are winches, four-directional powered rollers, and guide rails.

[8] J.M. Hansford, et al, *A Design Study of a C-5 Airlift Cargo Loading System for Major Permanent Terminals*, Technical Report ASD-TR-70-1/AD 865 683 (Lockheed Georgia Company, January 1970).

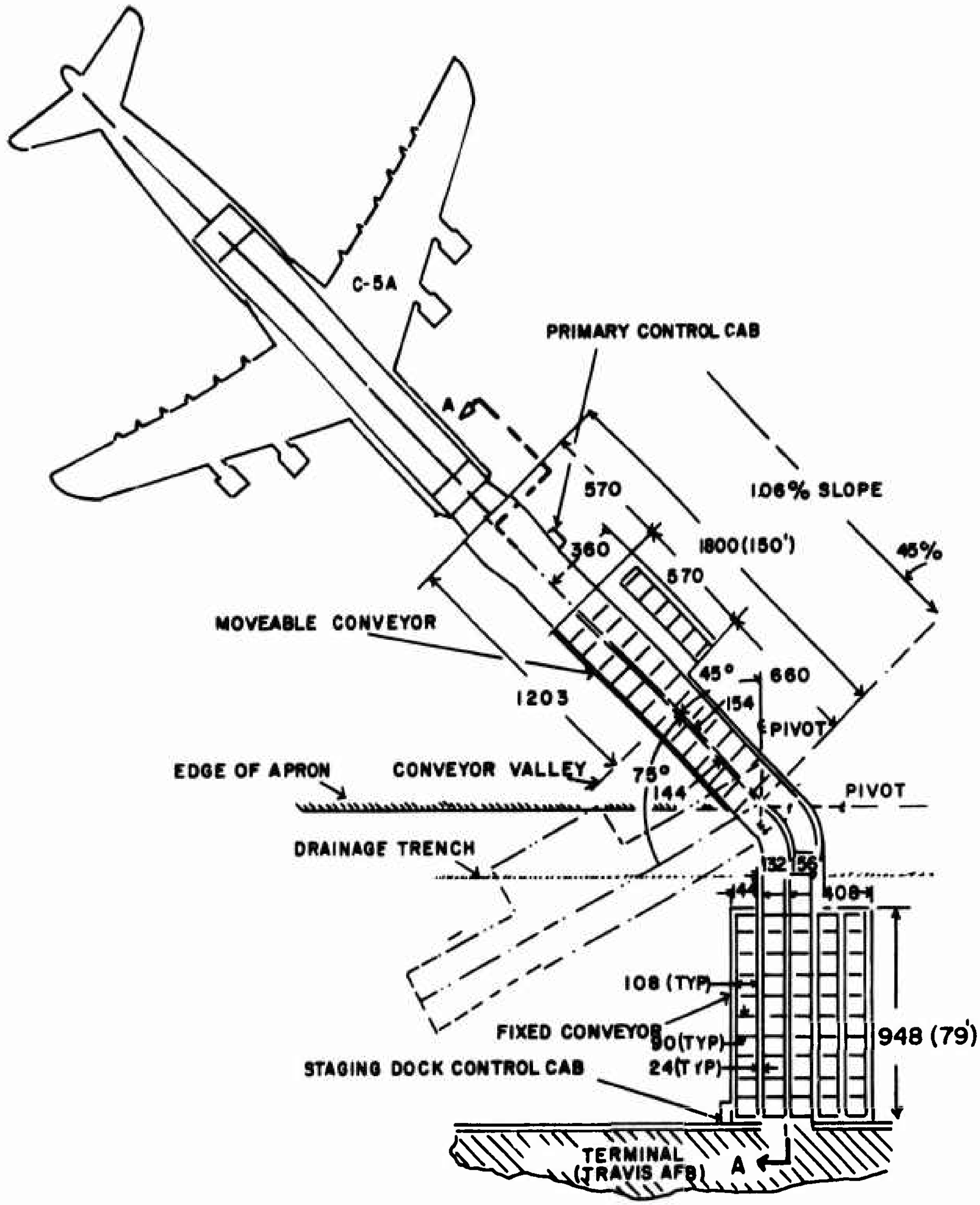

Figure 11. C-5A interfaced with swing bridge loading dock.

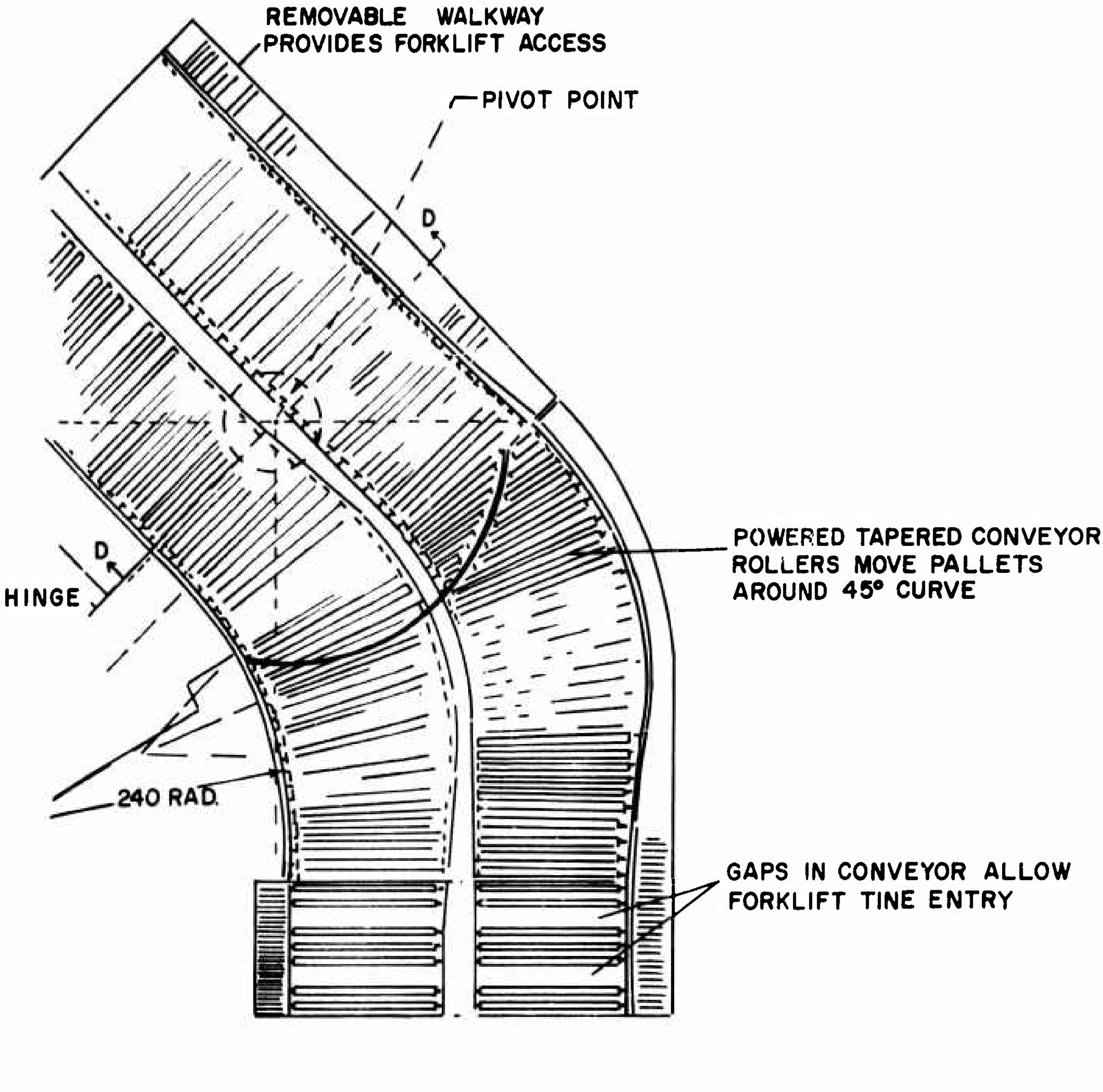

Figure 12. Pivot point of swing bridge loading dock.

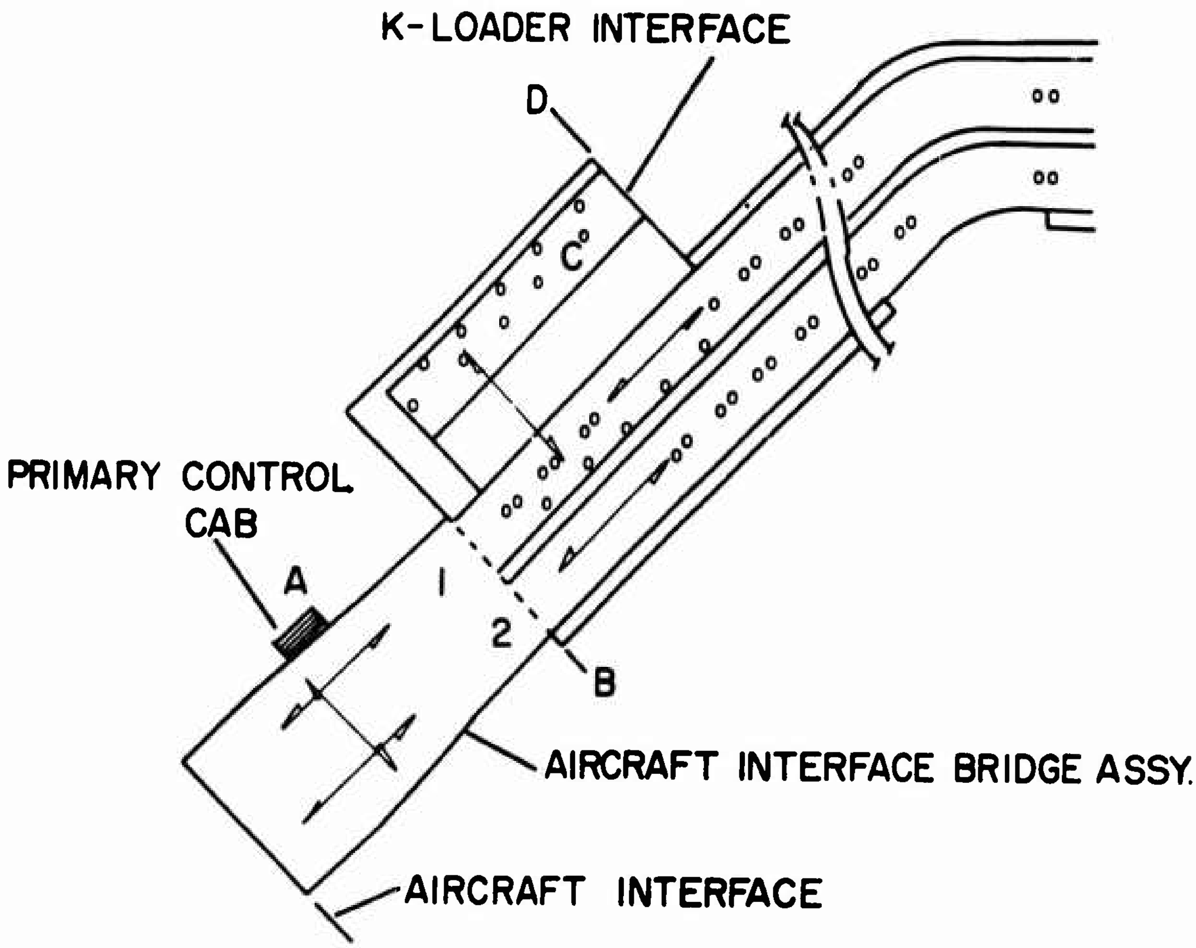

Figure 13. K-loader interfaced at side of swing bridge loading dock.

Cargo unloaded from an aircraft via a loading dock system can be placed directly onto an inter-terminal cargo handling system. Conveyor fingers or towline spurs reach out to the loading docks to accommodate unitized modules and loose cargo pieces. Cargo which is outsized to these inter-terminal systems is transported by forklift. Unloaded cargo which is not routed into the terminal (special handling cargo, outsized cargo, pre-unitized cargo) is unloaded by K-loader or forklift and taken to its destination.

6 OPERATIONAL AREAS

The major functions of a freight terminal are the following:

1. Receive cargo arriving via land transportation, sort it according to destination and cargo type, unitize bulk freight whenever possible, and then transfer the cargo to the aircraft side of the terminal.
2. Load/offload aircraft.

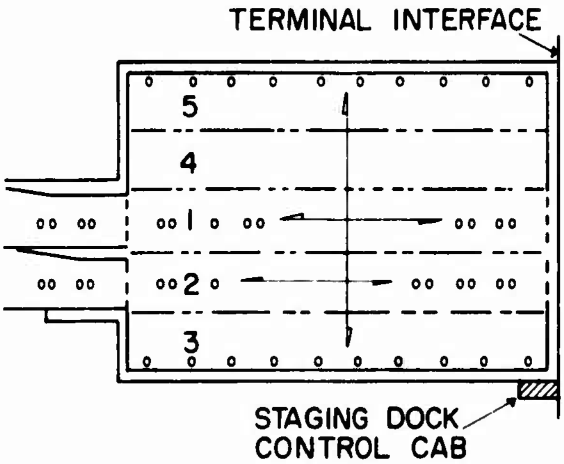

Figure 14. Fixed part of swing bridge loading dock interfaced with terminal.

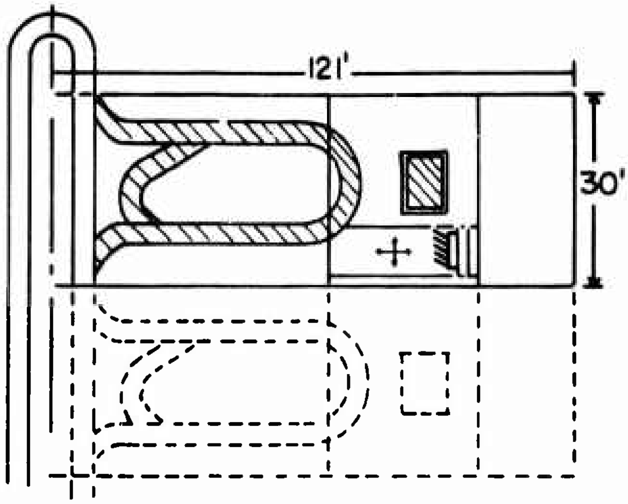

Figure 15. General layout of palletization area.

3. Receive cargo arriving via aircraft, sort it according to destination and cargo type, break down unitized loads when necessary, and then transfer the cargo to either the land transportation side of the terminal or to another aircraft.

4. Store cargo prior to sorting or transfer.

The land transportation side of the terminal consists primarily of truck loading docks, although a railroad spur should be provided when needed. Truck and rail docks connect this side of the building to the surrounding loading and parking areas for trucks. The parking, servicing, and loading aprons for aircraft are connected to the aircraft side of the terminal by loading docks and bridges and cargo staging areas.

Receiving and Documentation. As all cargo enters or leaves the terminal, it should be checked-in or checked-out. This enables terminal personnel to know what cargo is being handled and stored within the terminal at all times. Cargo pieces and modules should also be tagged so that the content of each module or package is known. Dangerous, special handling, high priority, and regular cargo pieces will be easily identifiable. As the status of each cargo piece changes (for example, loose cargo becomes unitized or unitized loads are stored) within the terminal, the data sheet on that particular cargo piece should be up-dated. When the cargo leaves the terminal, a copy of the data sheet in the form of a shipping list can be forwarded to the next destination. This allows each terminal to compare their shipping lists against the cargo they actually receive to check for pilferage and damaged cargo.

Pallet Buildup and Breakdown Stations. As discussed in Section 2, it is beneficial from a cost and time savings standpoint to unitize cargo loads as early in the transportation process as possible. Therefore, most cargo received at the truck docks is taken to a pallet buildup station since this cargo is usually in the form of bulk freight.

Bulk freight is taken to a pallet buildup/breakdown station from either the loading docks or a storage area via forklift, conveyor, or towline. The towline spur or conveyor lane feeding the pallet buildup/breakdown station should have sufficient cargo so that the men building up a pallet can be selective as to which pieces are unitized together; this allows for optimal cube utilization. In conjunction with a conveyor system, an accumulation conveyor at the palletization area is utilized. Unless high priority cargo is being handled which cannot be delayed, cargo pieces for two pallets are allowed to build-up on the accumulation conveyor prior to the palletization process. After enough cargo has accumulated, it is moved to a circular area conveyor in the palletization area. If a 5 ft wide conveyor is used, approximately 3630 sq ft of floor area per palletization station would be needed. Figure 15 shows the general layout of a palletization area.

The 463L master pallet can be built up or broken

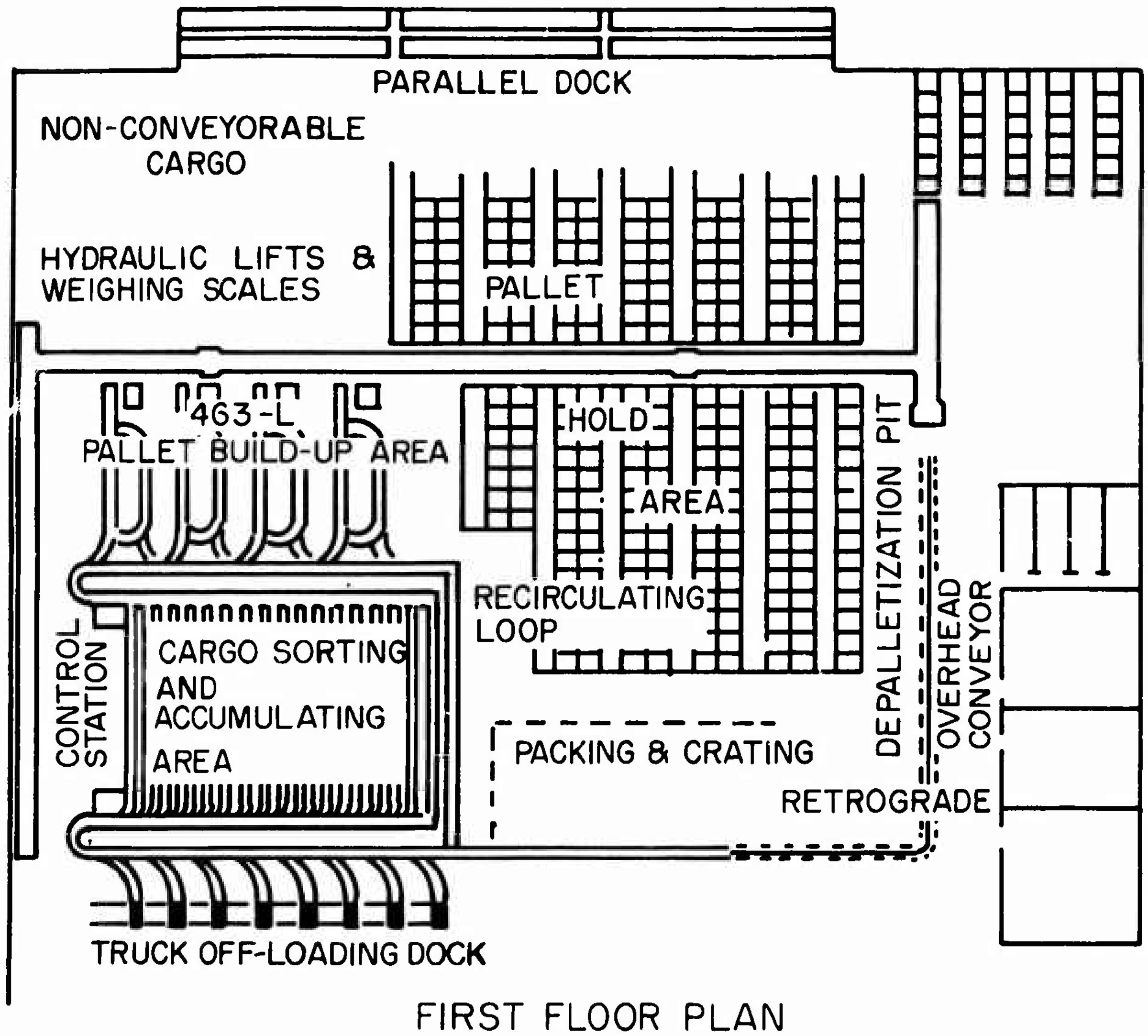

Figure 16. Typical terminal layout.

down manually, although forklifts are used to handle the larger, heavier pieces. During buildup/breakdown operations, the pallets sit on platforms. These platforms are equipped with powered roller conveyors to allow for the transfer of the built-up pallet from the platform to another powered roller conveyor to take the pallet to the loading docks or to a storage area. Each platform retracts into a pit in the floor to aid personnel in the buildup/breakdown process. A continuous weighing capability adjusts weights so that the platform is kept at a working level height at all times. Templates showing the permissible stack heights for each type of aircraft handled are needed at all unitization areas so that the stack height limit will not be exceeded. It takes two men about 45–60 minutes to build up or break down one 463L master pallet. After the buildup process is completed the platform can be returned to its original height in order to interface properly with the conveyor system. The location of the pit in relation to the circular conveyor is shown in Figure 15. It is important that sufficient space be provided in the palletization area to accommodate forklift traffic.

If a towline system is used to transfer cargo to the palletization area, a conveyor line will be needed near the retractable pit since most unitization modules are not cartable. Figure 16 shows a typical terminal layout.

Table 7
Number of Pallet Buildup/Breakdown Stations Required for Various Terminal Capacities*

Terminal Capacity (tons/day)	Number of BuildJup/Breakdown Stations Required: Single Pallet Stations	Container & Pallet Train Stations
200	4	2
1000	15	5
3000	45	12
6000	90	20

* Dortech Incorporated, *Air Freight Terminal Complex Concept Development Report*, Vol II (Department of the Air Force, Headquarters 375th Air Base Group, Scott AFB, Illinois, November 1968).

A minimum amount of cargo handling can be accomplished if the cargo sorting, accumulation, and unitization areas are close to the truck loading docks.

The pallet breakdown process is just the reverse of the buildup process. Although the palletization areas are identical for both operations, usually each station is utilized solely for one or the other of the two functions.

Container and Pallet Train Buildup and Breakdown Stations. Container and pallet train buildup/breakdown stations are similar to single pallet buildup/breakdown stations except that more oversize cargo is handled, and therefore less of the loading is done manually. The amount of manual loading that can be used for building up or breaking down these unitization modules will depend upon the cargo type and volume. For heavy loading, forklifts, bridge cranes, and hoists are used. To maximize the space utilized, smaller cargo pieces with a similar destination are used as filler in the larger unitization modules. Therefore, communication between the sorting and accumulation area and the oversize cargo unitization area is necessary so that filler cargo with the same destination as the oversized cargo pieces will be unitized with the larger cargo and channelled away from the single pallet unitization area.

High-line docks[9], as shown in Figure 17, are also used for the unitization of oversized cargo. These docks are located either inside or outside the terminal complex. Each dock has six pallet positions so that an entire pallet train can be built up. Total square footage necessary for a high-line dock is 5130 sq ft. This allows for a structure which is 10 ft wide, 46 ft long, and 40 in. high. There is clearance space of 14 ft on each side and at one end, plus 75 ft at the other end to allow for crane, forklift, and K-loader maneuverability. The high-line dock platform can be equipped with roller conveyors so that loaded modules can be easily transferred to materials handling equipment.

Table 7 shows the approximate number of single pallet and container and pallet train buildup/breakdown stations required for various terminal capacities. These numbers are only a guide since the actual number of stations will depend on the type of cargo handled at each installation.

Consolidation Area. The consolidation area is a temporary storage area used for accumulating loose cargo pieces. In terminals of lower volume, the consolidation area might consist of a few storage racks located near the main storage area. Cargo which does not have either a high priority or the same destination or cargo features as other palletizable cargo, can be temporarily stored in the consolidation area until enough bulk freight of similar characteristics can be palletized together. Cargo that stays in the consolidation area for more than two or three days is usually unitized in a module with other miscellaneous cargo or else shipped on as loose cargo. The purpose of the consolidation area is to encourage maximum unitization of cargo in order to eliminate, as much as possible, the costly handling of individual cargo pieces.

[9] *Terminal Facilities 1973, Annex B, Phase II (Cargo Terminal Planning)*, AD 843 894 (Military Airlift Command, August 1968).

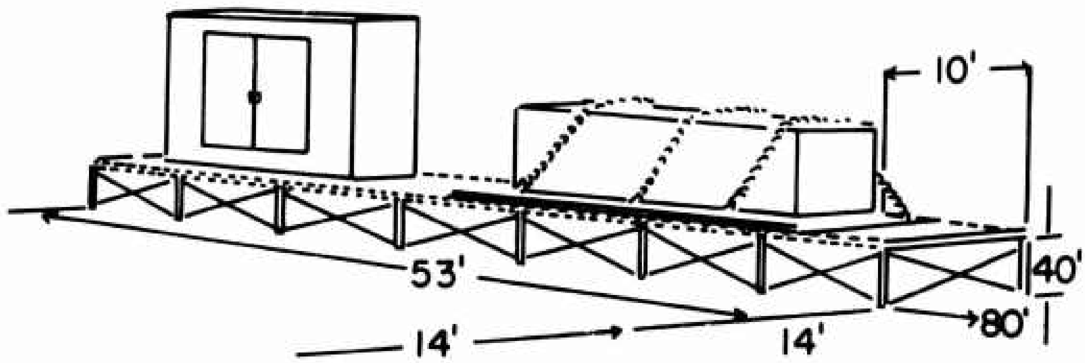

Figure 17. High-line dock for unitization of oversized cargo.

7 SUMMARY AND CONCLUSIONS

During this investigation of cargo handling systems currently in use at air freight terminals, some interesting facets emerged that have a direct bearing on the consideration of different methods of cargo transfer. In particular, in an open-port air freight terminal, where cargo processing is accomplished continually, no temporary storage of cargo is required prior to pallet aggregation. The Dortech system calls for such temporary storage of cargo in a multi-story structure with a vertical and horizontal crane used for storage and retrieval. If temporary storage is unnecessary, then an expensive capital investment could be saved.

Another difficulty associated with the towline-towcart approach is the congestion that might occur at the truck docks. One cart for each pallet buildup station would be needed at each truck dock position. This could mean 10 or more carts at each truck dock position, prohibiting forklifts from moving about freely. Conversely, the towline cannot function properly while forklifts are transferring cargo over the same area. Crashes could occur, resulting in damaged cargo or equipment, or bodily injury to terminal personnel. The towline system of the Pan American Air Cargo Terminal at J.F. Kennedy Airport in New York City operates under the "stop for forklift" rule and is idle 40% of the time due to the large amount of heavy cargo traffic.

An even greater incompatibility occurs between conveyors and forklifts. Conveyor systems must be disassembled to allow forklifts to operate over the same area. The towlines are under the floor, however, allowing the forklifts to pass over — if gaps exist between towcarts.

Whenever one cargo handling system forces another cargo system to function improperly, then inefficiency must result. Means must be provided to minimize the inefficiency. However, heavy cargo still has to be palletized and is usually transported by forklifts to and from the palletization areas. Consequently, modifications must be made in utilizing either a conveyor system or a towline system simultaneously with forklifts. This report provides background information for reports by L.P. McNamee and C. Lee[10] and by L.P. McNamee,[11] which present a computer simulation model of an air freight terminal. The simulation model can be utilized to compare changes in operation procedures, cargo capacities, and alternate methods of cargo transfer in varying degrees.

[10] L.P. McNamee and C. Lee, *Development of a Standard Data Base and Computer Simulation Model for an Air Cargo Terminal*, Technical Report A-8 (Construction Engineering Research Laboratory [CERL], January 1973).

[11] L.P. McNamee, *Computer Simulation and Validation of the Travis Freight Terminal Facility*, (CERL, March 1973).

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