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DESIGN NOTES ON AIR DELIVERY PLATFORMS

U S ARMY NATICK LABORATORIES
Natick Massachusetts

AIR DELIVERY
EQUIPMENT DIVISION

U.S. ARMY NATICK LABORATORIES

NATICK, MASSACHUSETTS

TECHNICAL MEMORANDUM
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DESIGN NOTES ON AIR DELIVERY PLATFORMS

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ABSTRACT

This memorandum discusses load environments to which an air delivery platform is subjected and relates the structural implications therefrom to accepted standards of performance and cost. Discussion is based on compatibility with the standard U.S. Air Force dual rail system used with the C-130 aircraft

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INTRODUCTION

The advent of dual rail systems in aircraft has placed increased demands on the role of air delivery platforms. The new air delivery platform can no longer be considered a simple skid as was the case with platforms used with the "first generation" skate wheel and bufferboard heavy air delivery systems. The platform now becomes an important structural link that binds the air delivery load to the aircraft system to form a more accurate and efficient air delivery system Because of the automatic restraint and release features of the dual rail system, the air delivery platform must provide an adequate structure to serve as a load path for distribution of forces which might be encountered while the rigged load is in the aircraft. This requirement plus the need for greater compatibility between aircraft system and the rigged load affects the design criteria of all the loading environments experienced by the air delivery platform.

DISCUSSION

Loadings

The type loadings to which a platform are subjected may be broken down into five categories. These are (1) ground handling, (2) in-flight restraint, (3) extraction, (4) recovery or parachute opening, and (5) ground impact. The characteristics of the ground handling and ground impact loadings are often nebulous but "average" conditions can be specified with acceptable accuracy for design purposes. The character of the other loadings, i.e., in-flight restraint, extraction, and parachute opening may be defined with much more precision. More detailed dicussion of these various loadings follows:

(1) Ground Handling.- Ground handling will be considered to include rigging and transporting-transferring the rigged load into the aircraft.

(a) Rigging.- A platform must be capable of withstanding loads incident to assembly and preparation for rigging by relatively unskilled troops with little or no materials handling equipment. During rigging it must be capable of enduring loads imposed on it by the lashings used to restrain the payload to it, and by the conveyors or uneven terrain on which it may rest. It must also be capable of withstanding loads which result from a rigged payload traversing conveyors.

(b) Transporting-Transferring into Aircraft.- A platform must be capable of withstanding all loads incident to transporting-transferring it, with its payload, from the rigging site into the aircraft. These loads occur during lifting or winching onto a transport vehicle, while transporting over rough terrain, and during the actual transfer into the aircraft. It is noteworthy that the surface of the transport-transfer vehicle(s) does not always lie in the same plane as that of the aircraft floor and therefore high localized reactions on the platform are often experienced during the transfer.

(2) In-Flight Restraint.- This category of loading includes restraint of the platform to the aircraft and payload to the platform to the following ultimate load factors (reference 1):

Forward	4.0
Aft	1.5
Up	2.0
Down	4.5
Side	1.5

It should be noted that the load factors listed above pertain to restraint during a "controlled-crash" condition. The ultimate down load factor specified for the C-130 for an in-flight gust condition is actually higher than that for the controlled-crash (5.1 vs. 4.5). This gust load factor can be expected to be more critical than the crash load factor for future higher speed aircraft as its magnitude is a function of airspeed (reference 2).

(3) Extraction.- The force of the extraction parachute is applied either to the platform or directly to the payload itself. When the extraction force is applied to the platform, localized platform structure of sufficient strength is required to withstand the extraction force. This case results in inertial forces due to the acceleration of the payload being applied to the platform through the cargo tiedowns. When the extraction force is applied to the payload, the forces applied to the platform by the tiedowns are opposite in direction and usually of much less magnitude than in the case of platform extraction because the only mass being accelerated through the tiedowns is that of the platform itself. The ratio of extraction force to extracted weight with the dual rail system is usually maintained between 0.7 and 1.5. The design load (ultimate) is taken as 1.5 times this ratio (reference 3). The applied force is appropriately treated as a static load because of the emergency situation where the system may malfunction resulting in the extraction parachute being towed for several seconds. In the normal case, the duration is also quite long (see typical trace, Figure 1) and is probably sufficient justification itself to design to the static load. However, devices which are used to transfer the extraction force from the platform to the recovery parachutes operate over a very short period of time and therefore should be designed and laboratory tested with the dynamic nature of their operation in mind.

(4) Recovery.- As in the case of extraction, the forces exerted by recovery parachutes may be applied either to the platform or directly to the payload itself. Because of the magnitude of the forces associated with the opening of cargo parachutes and the vagaries of platform attitude relative to the direction of these forces, the case of parachute recovery forces applied to the platform entails a requirement for considerably more platform structure than where these forces are applied to the payload. In the latter case, the forces imposed on the platform through the cargo tiedowns are proportional only to the mass of the platform itself and whatever other materiel (such as energy dissipaters) is not directly attached to, or supported by, the payload. In the case of most large vehicles, the general practice is to take advantage of their inherent strength and suspend them directly from the parachutes. In keeping with this practice, the platform is suspended from the parachutes only when the payload is of such a nature that it cannot readily be suspended

itself. The magnitude of the limit load factor used for design is 3.0 times the weight of the suspended load. For design purposes the resultant forces are considered to be shared equally by any two of what are normally four suspension points, and are treated as static loads. As is the case for extraction, a factor of safety of 1.5 is used to obtain the ultimate loads. The typical trace (Figure 2) shows the long duration of the parachute opening shock. Credible data recently obtained from actual airdrops indicate that the criteria stated above err on the conservative side. Considerably more evidence will be required, however, to justify a reduction in these criteria under the critical design extremes of airspeed, platform attitude and parachute loading.

(5) Ground Impact.- The forces to which a platform is subjected at ground impact cover a wide range in nature and magnitude. The variables affecting these forces include:

(a) Vertical velocity

(b) Horizontal velocity

(c) Size and placement of payload and cushioning material

(d) Platform attitude

(e) Consistency of impact surface

(f) Irregularities in terrain

(g) Type and geometry of cargo tiedown lashings.

In actual practice, the forces imposed on the platform may be dependent on the inter-action of all the variables listed. Designing a platform to be reusable under the operational extremes of all these variables is simply not practical. However, a design condition reflecting certain of these variables can be selected which results in acceptable reuse. This condition may be expressed in practical terms simply as cantilever length L, applied force P, and direction of force (angle θ) as shown in Figure 3.

Performance

A platform or family of platforms must be capable of effective delivery of items ranging from small quantities of delicate items such as medical supplies to heavy equipment such as large combat vehicles. Specific design parameters are:

(1) Rigged Weights.- Unit gross weights range from 2,500 pounds to 35,000 pounds.

(2) Length.- Lengths range from 4 feet to 28 feet.

(3) Width.- Overall width is 108 inches for compatibility with the standard dual rail system.

Other features required in a platform are:

(1) Usable with standard paper honeycomb energy dissipater.

(2) Minimum thickness to allow for maximum height of payload and energy dissipater.

(3) Light-weight manhandleable components, to facilitate assembly and repair operations. Assembled weight should also be minimized.

(4) Capable of rapid assembly and repair by relatively unskilled personnel.

(5) Maximum reuse potential for training operations with minimum repair.

(6) Capable of being rapidly rigged and loaded into the aircraft with emphasis on use of unsophisticated materials handling equipment.

(7) Able to endure long-term storage under environmental extremes.

Cost

The cost of a platform should be as low as the performance requirements stated above will allow. In actual practice, an acceptable item has been produced at a cost of less than $32 per lineal foot of platform.

Design Philosophy

The most readily definable loadings to which a platform is subjected are those associated with in-flight restraint. Using these as a starting point, the strength of the local structure needed to restrain the platform load to the aircraft and also to restrain the load to the platform is readily established. Since the longitudinal edges of the platform mate directly with the aircraft dual rails, it follows that confining the restraint attachments and the cargo tiedown rings to these edges is an effective solution to minimizing the amount of platform structure needed. Even though tiedown points are thus not available on the lateral edges of the platforms, rigging ease and effectiveness can be assured by providing a large number of high capacity unit tiedown points along the longitudinal edges. Of the in-flight factors, the forward load factor has the most influence on platform design. (This is true at least with the conveyor configuration now standard in C-130 aircraft which provides intermediate supports across the lateral platform span and which thus greatly simplifies the problem of designing to the down load factors.) The aft load factor also requires consideration, though, because the standard dual rail system provides aft restraint only in the port restraint rail, resulting in an asymmetric loading on the platform. This load condition could be critical for some platform structure.

Once provision has been made for the high local loads associated with platform-to-aircraft and payload-to-platform restraint, consideration of the other loading conditions included herein indicates selection of a sandwich construction for the platform to be a wise and possibly inescapable choice. The favorable strength-to-weight and strength-to-cost ratios which can be obtained with a properly designed sandwich construction are the primary reasons for such a choice.

The next most significant type loading affecting the platform design is ground handling. Although selection of a specific design condition must be a matter of judgment based on experience, a condition can be chosen which strikes an acceptable balance between performance and the resulting structural penalty. Of course, with any such compromise, there will occur an occasional extreme instance such as when the entire rigged weight of a load may teeter on the edge of a single roller, thus exceeding the selected design condition and resulting in platform damage. A useful design condition is shown in Figure 4, the variables being the force P, the length and diameter of the rollers, and the pitch between rollers. The configuration of the aircraft roller conveyors, the load distribution on the platform and the pertinent load factor determine the values of these variables. For sandwich construction the structural details directly influenced by the ground handling design condition are principally facing thickness and material and core compressive strength. Also under the category of ground handling is a design requirement for a measure of stiffness far in excess of that needed for in-flight restraint.

Large deflections during rigging due to high tensions in lashings can compound the difficulties in traversing roller conveyors with or without platform damage and can make it impossible to properly engage the aircraft dual rail restraints.

When the in-flight restraint and ground handling design conditions have been satisfied, experience indicates that with attention to a few localized areas, quite acceptable reuse can generally be obtained. High localized stresses at ground impact are often induced at the intersections of platform lateral and longitudinal frame members and in the fastening of the facings to the peripheral frame members in sandwich construction. Simple reinforcements at these locations contribute measurably to platform reuse.

The application of the design philosophy of simple replacement or repair of damaged components, together with the design considerations discussed above, very effectively minimizes the cost per use for air delivery platforms.

After ground impact, in-flight restraint, and ground handling loading conditions have been satisfied, it soon becomes apparent that the platform which has evolved has a substantial inherent structural capability to cope with parachute extraction and opening forces. The platform structure used to withstand high localized cargo tiedown forces both for the in-flight restraint and for the ground impact conditions can readily be adapted to withstand the localized parachute forces associated with extraction and suspension. Also, the bending strength which results from meeting ground handling requirements i.e., the combination of puncture resistance and ability to withstand high lashing tensions without large deflections, is usually sufficient to cope with a parachute opening shock while delivering a substantial payload. The chart, Figure 5, summarize the influence of the various categories of loadings on the design of specific components of the standard Army modular platform.

These loading conditions will also apply to the design of most air delivery platforms which are compatible with the standard dual rail system and fulfill the user requirements.

As a final thought, environmental requirements should be borne in mind throughout the design. Not only must a platform maintain structural integrity during long-term exposure to extremes of temperature, humidity and to harmful bacteria or vermin, but it must also maintain dimensional stability within fairly close limits because of the nature of the aircraft dual rail system. These considerations are likely to dictate the final selection of materials and methods of manufacture.

REFERENCES

1. Military Specification MIL-A-8865(ASG) Airplane Strength and Rigidity - Miscellaneous Loads, dated 18 May 1960

2. Military Specification MIL-A-8861(ASG) Airplane Strength and Rigidity - Flight Loads, dated 18 May 1960.

3. Military Standard MIL-STD-814, Requirements for Tiedown, Suspension and Extraction Provisions on Military Materiel for Air Delivery, dated 19 January 1962.

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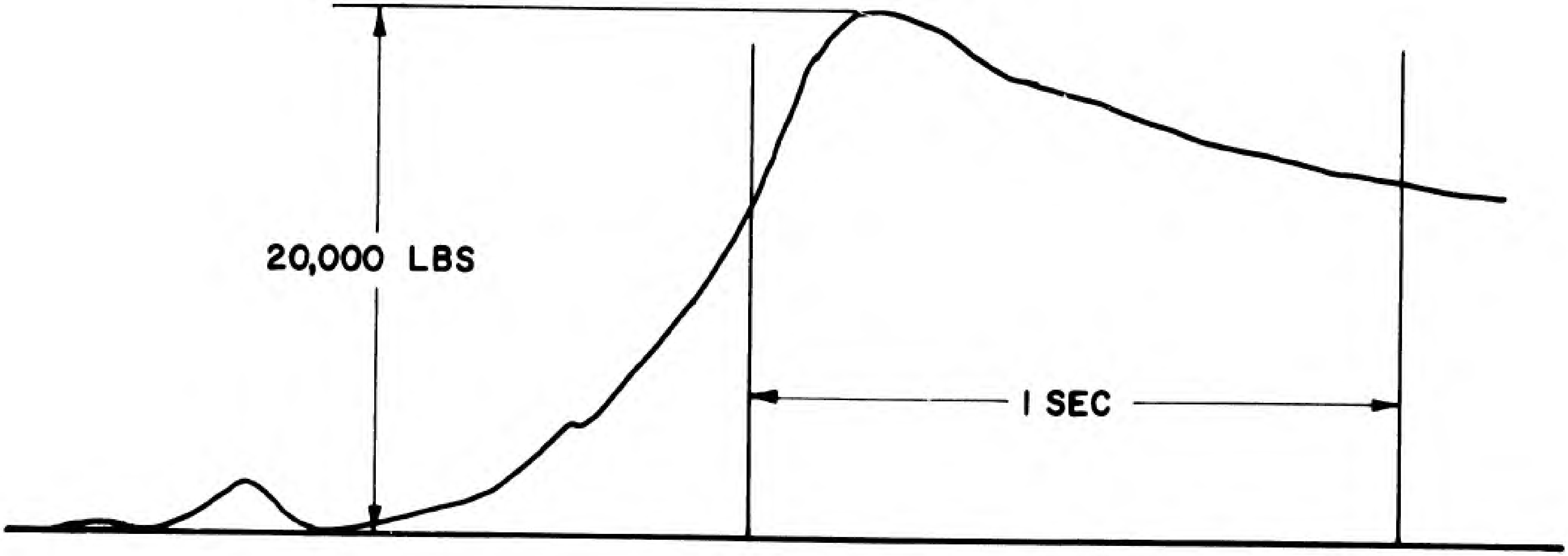
TYPICAL TRACE* OF EXTRACTION FORCE vs TIME FOR

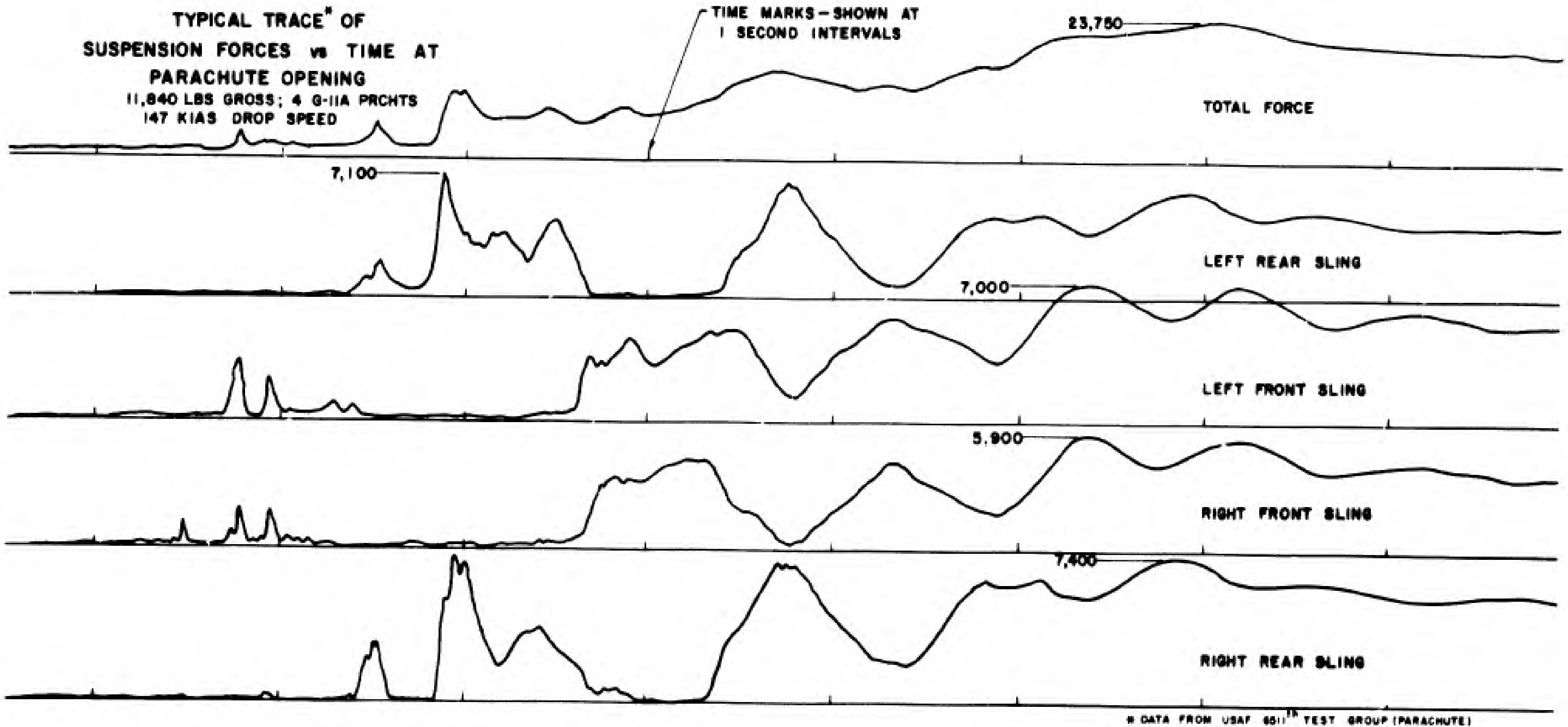
28 FT. DIA. RINGSLOT PARACHUTE

AT 130 KIAS 25,150 LBS GROSS



* DATA FROM USAF 6511th TEST GROUP (PARACHUTE)
PROJECT FTL-249 DROP NR. 0526F-62

FIGURE 1


TYPICAL TRACE* OF
SUSPENSION FORCES vs TIME AT
PARACHUTE OPENING
11,840 LBS GROSS; 4 G-11A PRCHTS
147 KIAS DROP SPEED

* DATA FROM USAF 6511th TEST GROUP (PARACHUTE)
PROJECT FTL-249, DROP NR 0415F-62

FIGURE 2

DESIGN CONDITION FOR GROUND IMPACT

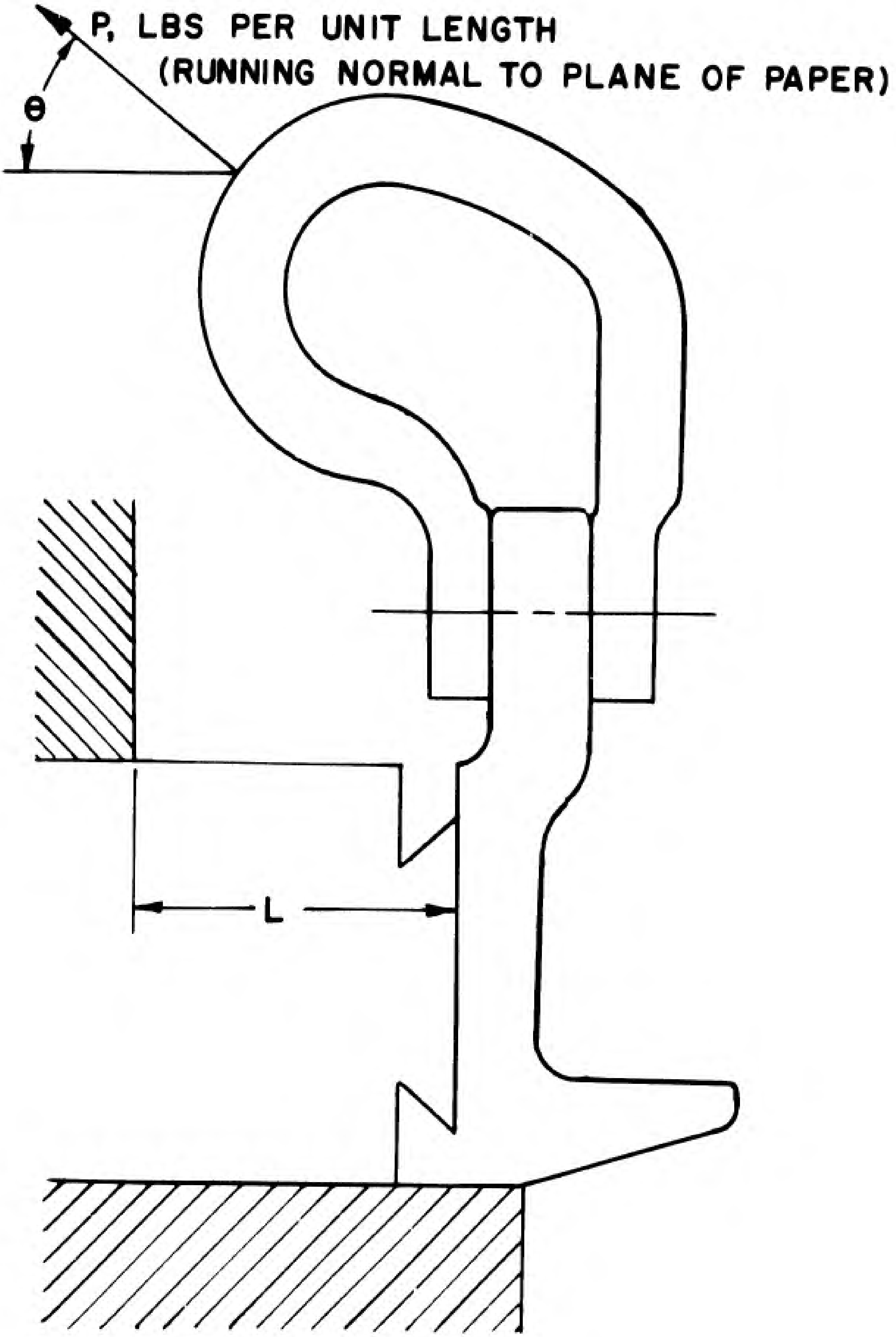


FIGURE 3

DESIGN CONDITION FOR GROUND HANDLING

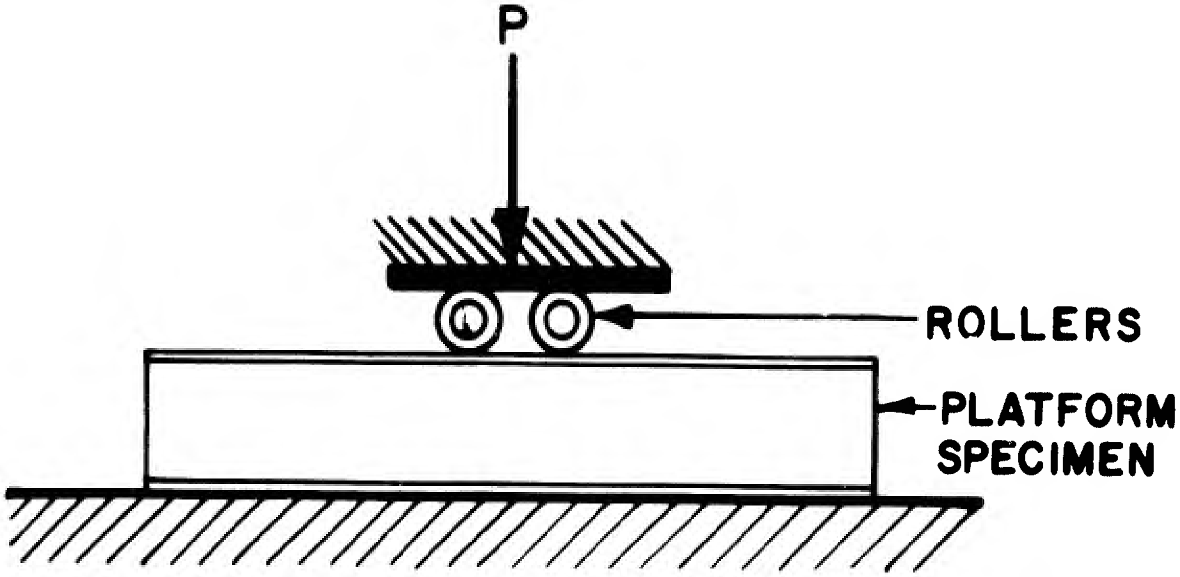


FIGURE 4

INFLUENCE OF THE VARIOUS CATEGORIES OF LOADINGS
ON DESIGN OF SPECIFIC COMPONENTS OF THE ARMY MODULAR AIR DELIVERY PLATFORM

X - Primary Influence
Y - Secondary Influence

LOADING CATEGORIES	Restraint Fitting	Side Rail	Panel	Tiedown Clevis	NOTES
GROUND HANDLING			X		
IN-FLIGHT RESTRAINT	X	X		X	
EXTRACTION		Y		Y	When platform extraction is used
RECOVERY		Y	Y	Y	When platform suspension is used
GROUND IMPACT			X		

Figure 5