C.5 RESTRAINING CARGO.

C.5.1 General.

All airlifted cargo must be restrained so it will not shift during any of the flight conditions that can normally be experienced by the aircraft. Dynamic forces caused by various flight conditions (air turbulence, rough landings, extreme flight attitudes, survivable crashes, etc.) tend to move the cargo in a forward, aft, side, or vertical direction or combinations of these directions. These forces are directly proportional to the cargo object's mass (weight) and to the rate of change in the aircraft's flight velocity. These forces are commonly expressed in units of gravitational force, signified herein by the letter "G". (See figure C-7)

These dynamic forces may be resisted by the application of restraining static loads to equal the dynamic loads. Except for vertically down, the restraining static load is achieved through the use of nets, straps, chains, etc. attached between the cargo object and the aircraft. The amount of restraint needed in each primary direction is equal to the weight of the object multiplied by the anticipated G loads.

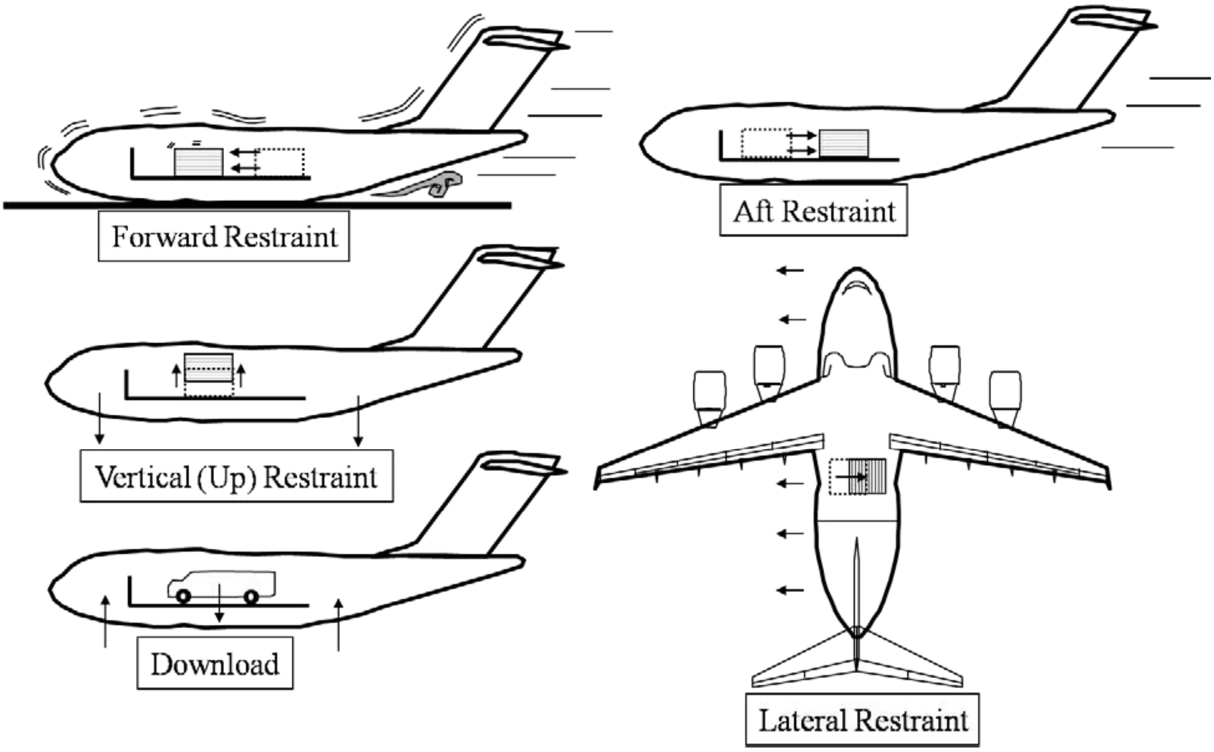

FIGURE C-7. Restraint for various situations.

C.5.2 Aircraft systems.

There are two restraint systems on the aircraft. Palletized loads generally use the rail system locks. Rolling stock and bulk loads generally use the floor tiedown rings along with aircraft provided tiedown devices (figure C-8). Tiedown rings are also used to restrain palletized or accompanying loads when the load-carrying system, such as a pallet or trailer, cannot fully restrain the item.

C.5.2.1 Aircraft tiedown ring.

On the C-27 and C-130 the majority of tiedown rings are rated at 10,000 lbs in any direction. The C-130 ramp rings are rated at 5,000 lbs. On the C-17 and C-5, the rings are rated at 25,000 lbs. Each aircraft comes equipped with tiedown devices, chains and straps, so that the item owner does not have to provide the tiedown material. The tiedown device and its associated chains or straps are stowed separately throughout the cargo compartment. See the appendices for each type of aircraft or the appropriate T.O. 1C-XXX-9 cargo loading manual for more detail.

C.5.2.2 Tiedown devices.

All aircraft are equipped with straps and chains and their associated tensioning devices to secure the item to the airplane.

The only tiedown devices currently approved for air transport use are those currently in USAF inventory, illustrated on figure C-9. Commercial restraint straps or chains, regardless of rating, are not approved at this time. Any nonstandard tiedown device shall be evaluated by ATTLA. Chains or metal tiedown devices shall have a minimum safety factor of 1.5 whereas fabric tiedown straps or devices such as webbing shall have a minimum safety factor of 2.

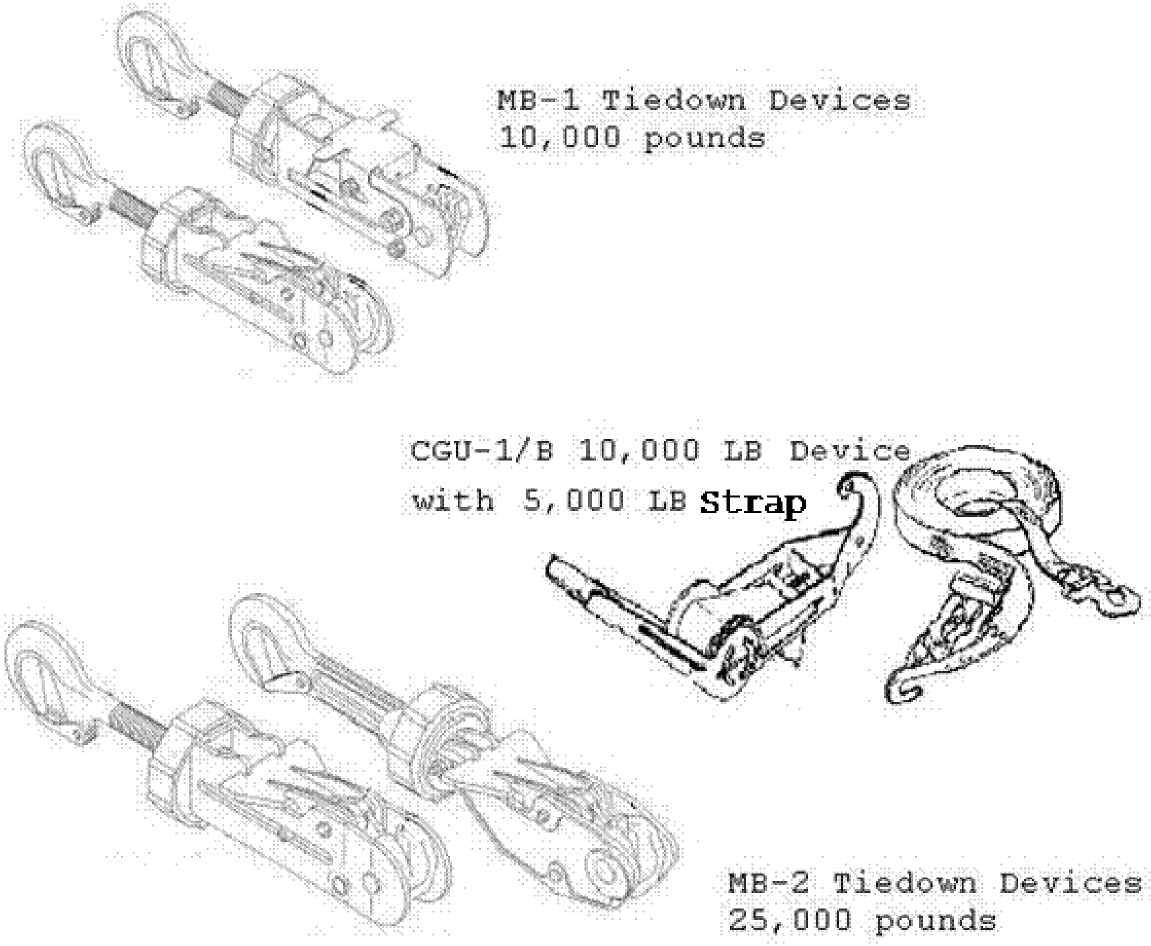

FIGURE C-8. Tiedown devices.

C.5.2.3 Restraint levels.

All cargo must be restrained to prevent movement during normal flight conditions, extreme flight conditions, and hard landings. The published limits are summarized in table C-II. The limits for tanker aircraft (KC-135 and KC-10) are different and the KC-10 limits are in accordance with FAA rules.

If there are personnel in front of cargo the cargo item must be restrained to 9Gs forward. Lateral and vertical restraint requirements are greater for KC-135 and KC-10 aircraft. For further details on calculations see C.5.3.

TABLE C-II. Summary restraint levels for cargo.

Direction	Load Factor	Input Condition
Forward	3G & 10 ft/sec	Hard Landing or sudden deceleration
Aft	1.5G & 5 ft/sec	Sudden acceleration
Lateral	1.5G & 5 ft/sec	Skidding
Up	2G & 10 ft/sec	Extreme turbulence
Down [1]	4.5G & 11.5 ft/sec	Hard landing
[1] Primary cargo restrained by cargo floor. Secondary cargo must be restrained by primary cargo.		

C.5.3 Principles.

Certain fundamental principles must be observed when restraining cargo for flight. Although the details of tying down each unit of cargo vary with its bulk, weight, configuration, and position in the airplane, these basic principles of restraint are always applicable. If the principles are observed, satisfactory restraint of cargo movement can be achieved.

C.5.3.1 Basis of analysis.

To develop sufficient strength in a tiedown, the strap, chain, or tension member must lead off in the general direction of the load to be restrained. The closer the tiedown can lie to the direction of the load, the more efficient the tiedown will be. This important point is illustrated below:

Consider a weight that is suspended by a pair of 10,000-pound capacity chains that are hanging perfectly vertical. The maximum amount of weight that can be suspended from the two chains is 20,000 pounds:

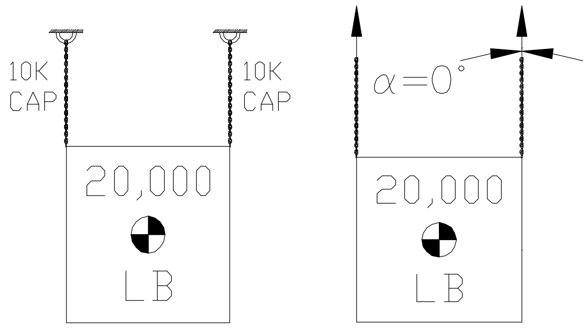

FIGURE C-9. Chain angle 1.

The drawings below illustrate that the amount of weight that can be suspended by the 10,000 pound capacity chains is dependent upon the angle ("α") formed with the direction of required force:

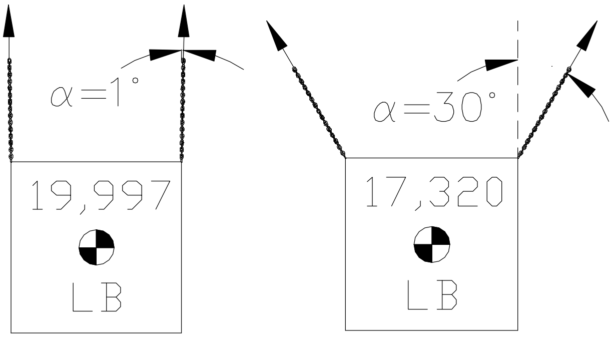

FIGURE C-10. Chain angle 2.

As the angle "α" increases, the vertical component of the chain strength decreases, as does the amount of weight that can be supported:

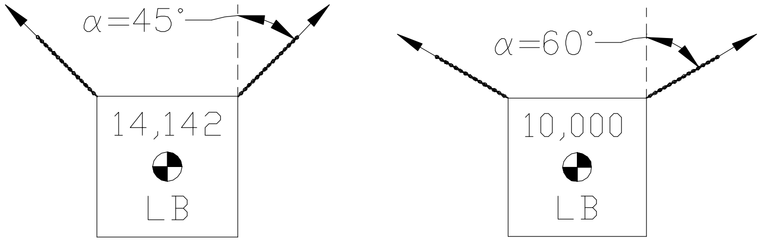

FIGURE C-11. Chain angle 3.

As "α" approaches 90 degrees, the amount of weight that can be supported approaches zero:

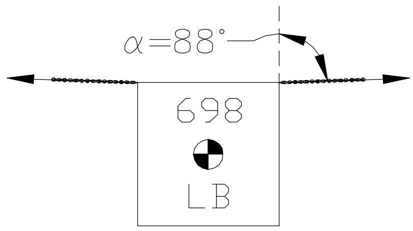

FIGURE C-12. Chain angle 4.

The above illustrations can also be visualized as a birds-eye view of a cargo item resting on the aircraft floor. The item weight would then be analogous to the restraint capability of the chain configuration used.

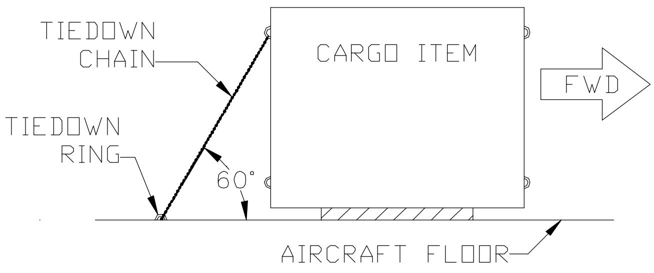

FIGURE C-13. Cargo item chain angle 1.

Assume the tiedown ring and chain hardware on figure C-13 has a working load limit of 10,000 pounds. If the chain is applied at a floor angle of 60 degrees, the strength available for restraint in the forward direction will be 5,000 pounds:

If the tiedown chain is adjusted to a shallower attachment angle, the strength available for restraint in the forward direction will increase proportionally with the decrease in floor angle. For example, if the tiedown chain is attached at a floor angle of 30 degrees as shown below, the strength available for restraint in the forward direction will increase to 8,660 pounds:

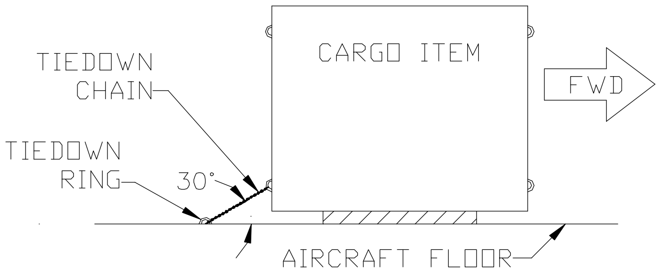

FIGURE C-14. Cargo item chain angle 2.

C.5.3.2 Usage rules.

Determining types and quantities of tiedown devices to be used in restraining cargo should be based on the following:

(1) Always secure cargo for the required amount of restraint with the minimum number of tiedown devices.

(2) The maximum available restraint for any tiedown is determined by using the lesser rating of the following: the tiedown (floor) fittings used, the tiedown attachment points on the cargo item, or the effective strength of the tiedown device used.

(3) Straps and chains shall not be mixed to restrain cargo in the same direction (due to different elongation characteristics). However, 10,000 and 25,000 pound rated devices with the appropriate chains may be used for a given direction of restraint.

(4) Units of general cargo may be grouped and effectively restrained by cargo nets. Concentrated cargo units within such groupings must rest on the cargo floor or on pallets and be individually restrained by appropriate tiedown devices.

(5) Tiedowns should be attached in a symmetrical pattern by using corresponding fittings on each side of the cargo floor centerline.

(6) Use nylon tiedown devices on crates, boxes, or items that might crush easily. Nylon devices that are under tension loads can be easily cut; therefore, do not use nylon tiedown devices over sharp edges.

(7) Use steel tiedown devices on heavy objects that have attachment lugs or a hard surface for the chains to wrap around.

When tiedown devices are attached to cargo, the lines of action for the tiedown devices should, if possible, intersect above the cargo center of gravity as shown below. Such a tiedown configuration reduces the tendency of cargo to overturn when subjected to combined upward and side loads.

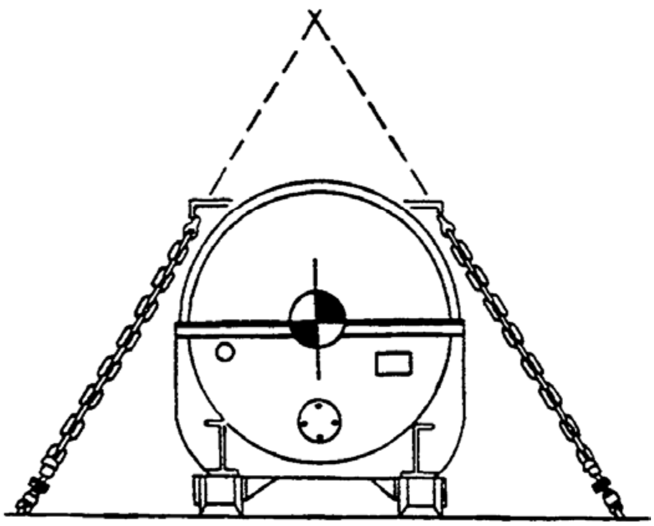

FIGURE C-15. CG location for effective restraint.

The point of attachment of a tiedown device to a cargo unit must be substantial enough to withstand the loads for which the cargo unit is being restrained. A tiedown device cannot be secured to any convenient protrusion on a cargo unit without due consideration of the protrusion's strength.

Although all materials stretch in direct proportion to the applied load, materials have varying rates of stretch. Under tension, nylon devices stretch more readily than steel and permit the steel device to assume the majority of the load. Therefore, when two or more tiedown devices are used in the same direction, the devices shall be of similar material and equally tensioned to ensure the load is evenly distributed.

Restraint straps or chains that are simply passed over or around a unit of cargo (instead of being attached directly to it) can provide double the strength of a single restraint, provided the capacity of the fittings is equal to or greater than the strap or chain capacity. Commonly called a strap or chain gate, this type of tiedown configuration can only provide restraint in a single direction. To increase the utility of this concept, a chain bridle may be used to obtain restraint in more than one direction:

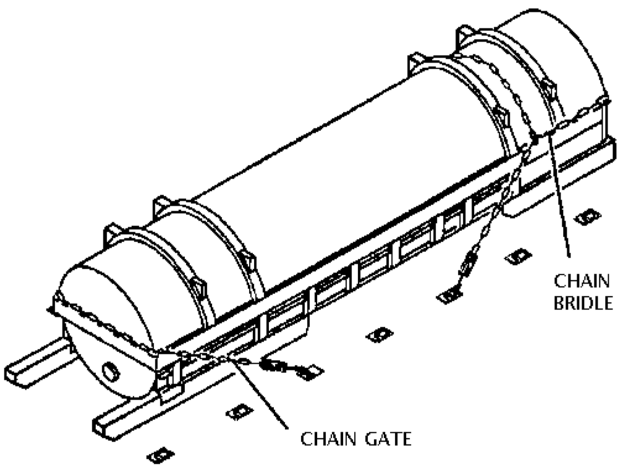

FIGURE C-16. Chain gate and chain bridle.

Unsymmetrical tiedowns permit load distributions that may ultimately result in tiedown device failure. Such a failure would result from the different load-deflection rates of dissimilar materials or of identical materials of different length. Any material subjected to a tension load will stretch. A longer length tiedown has more stretch potential than a shorter length tiedown. If two tiedowns of the same type and capacity are used to restrain a load in a given direction and one is longer than the other, the longer tiedown, with its greater stretch potential, will permit the shorter tiedown to assume the majority of any load that may develop. If the shorter tiedown becomes overstressed and fails, the longer tiedown would then be subjected to the full load and it, too, would likely fail. Therefore, symmetrical tiedowns should be as close to the same length as possible.

Tiedown device attachment generally follows similar patterns because of cargo floor tiedown ring layout and symmetrical restraint requirements. The following procedures shall be used when attaching tiedown devices to the cargo and to the tiedown rings on the compartment floor: (All references are to figure C-18)

(1) Always compute the number of tiedown chains required. Apply aft restraint (tiedowns 1, 2, 5, and 6) in the opposite direction but at the same angle as the forward restraint (tiedowns 3, 4, 7, and 8). Use the same attachment point (points A, B, C, or D) on the cargo for attaching a forward and aft restraint chain if possible.

(2) Apply restraint in a symmetrical pattern around the cargo unit being restrained. Always attach an even number of tiedowns (4 chains, or 6 chains, etc.) in pairs (1 and 2, 3 and 4, 5 and 6, 7 and 8, etc.) for forward or for aft restraint. The tiedown chains should be attached in a symmetrical pattern by connecting to opposite fittings (A opposite B, C opposite D, E opposite F) across the cargo floor centerline.

(3) If the center of gravity is not located at the geometric center of the load--when possible--add an additional tiedown (tiedowns 9 and 10) on each side of the load to place the center of gravity equal distance between a pair of tiedowns.

(4) Tiedown chains are normally attached to the cargo unit. Tensioning devices are attached first to the floor rings and then to the tiedown chains. Slack in the chains is removed by adjusting the tensioning device.

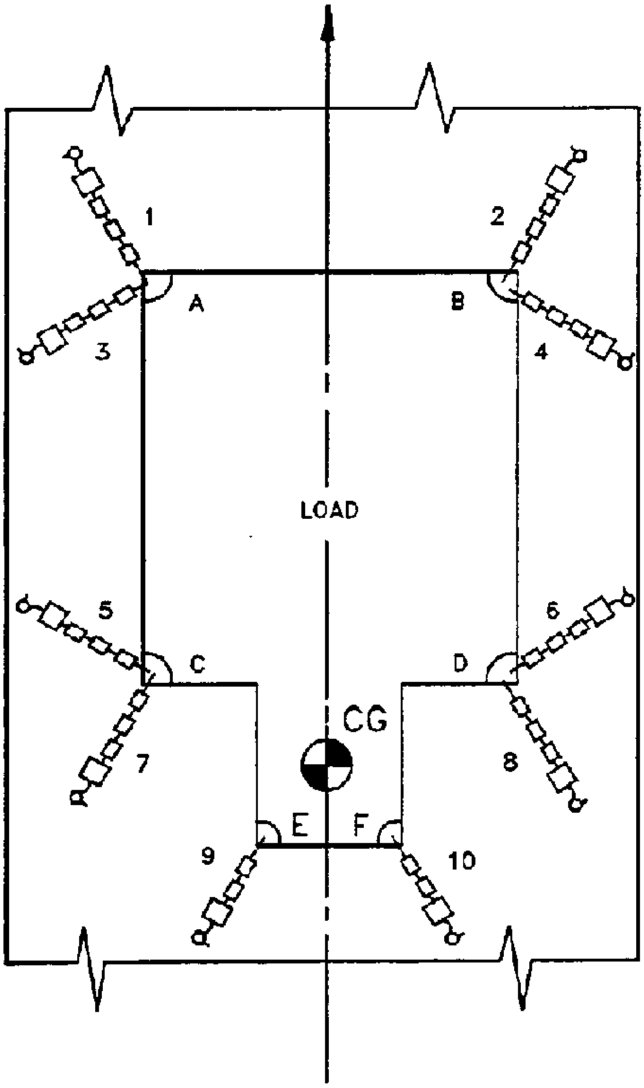

FIGURE C-17. Sample tiedown pattern.

C.5.3.3 Bulk cargo.

Cargo shall be tied down in such a manner that the load will be prevented from moving or changing shape. In the case of non-rigid cargo such as stacked boxes, it is important that the stack be prevented from collapsing or shifting. Inadvertent shifting of a single box within the load could loosen all the tiedowns. In the following example, tiedown is satisfactory for upward restraint, but not for sideward or forward/aft restraint.

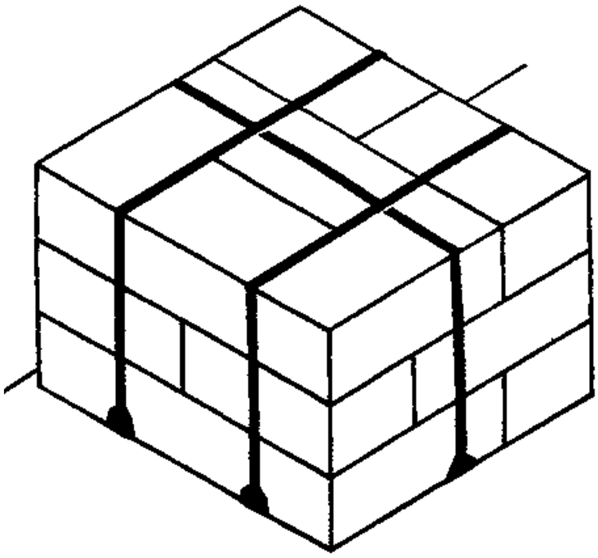

FIGURE C-18. Unsatisfactory bulk cargo restraint.

If the tiedowns are very long across the top of the load, a severe upward force will permit the cargo to move as shown below. Hence, the length of ties across the top of a load should be kept as short as possible. Alternatively, such cargo is commonly stacked in an “igloo” shape to begin with.

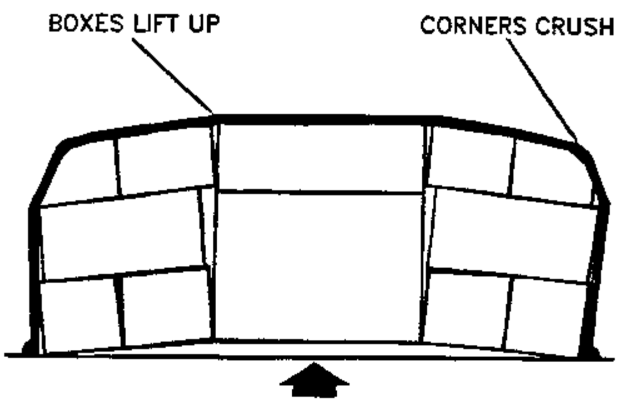

FIGURE C-19. Vertical cargo shift.

For forward or aft restraint, the type of tiedown shown below will not prevent the cargo shifting except for the friction forces introduced. Neglecting friction, the tiedown cannot begin to restrain the load until it has shifted so that the tiedowns begin to go in the same direction as the force.

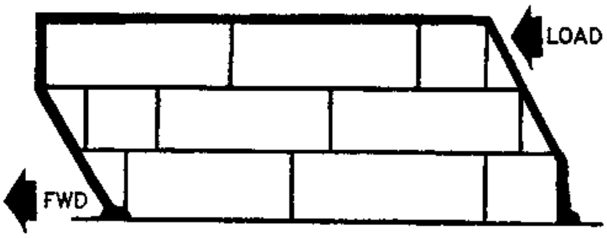

FIGURE C-20. Longitudinal/Lateral cargo shift.