C.5.3.5 Palletized cargo.

Restraint of palletized cargo is usually accomplished by restraining to pallet side rings. Large or heavy cargo may also be restrained to the aircraft floor.

C.5.3.5.1 Restraining cargo to the pallet.

Cargo is typically restrained to the pallet side rings as shown in A.4, figure A-10. Cargo may be covered by a cargo net or restrained directly to the side rings. A.4, figure A-8 shows the cargo net. The 463L pallet side rings are rated at 7500 pounds each, and the rings for Type V and Type VI (DRAS) platforms are rated at 10,000 pounds each.

C.5.3.5.2 Palletized cargo to aircraft floor.

Cargo may also attach directly to the aircraft tiedown rings if the pallet/platform cannot provide sufficient restraint to the item or if the pallet is only used as a means of transport in and out of the aircraft. Pallets oriented such that the width does not engage the aircraft rail system are also restrained to the cargo floor. The pallet/platform itself, if it is in the rail system, will usually engage the rail locks to restrain the pallet while the item is restrained to the floor (figure C-22).

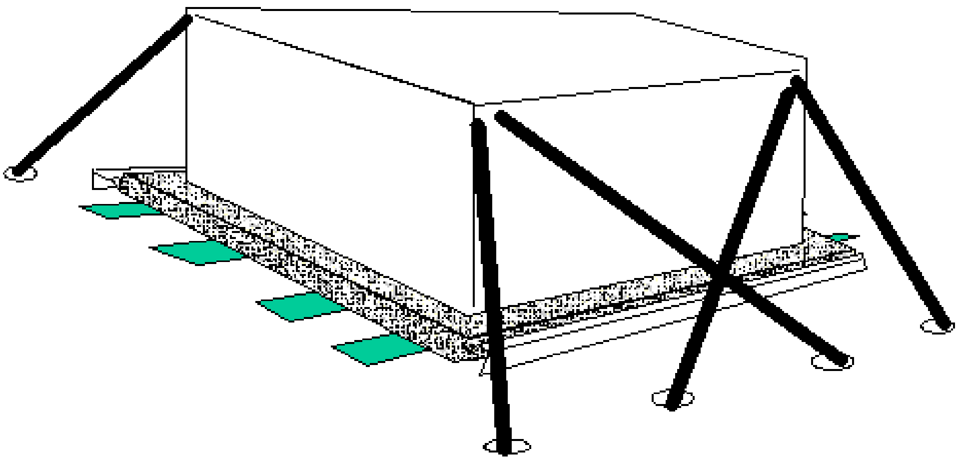


FIGURE C-22. Palletized cargo restrained to aircraft floor rings.

C.5.4 Analysis methods.

Effective and efficient use of available aircraft hardware requires certain considerations in the design and/or analysis of restraint methods.

C.5.4.1 Effect of angles.

Every tiedown device is capacity rated based on its ability to withstand a force exerted parallel to, and in the opposite direction of, its line of application (standard pull test). While it is possible to attach tiedowns to act in the same way, it is not efficient to do so since attachment in such a manner provides restraint against movement in only one direction. Separate-acting tiedowns would have to be applied to resist movement in the other directions to fully restrain the item. The total number of tiedowns needed to fully restrain a heavy object in this manner would be prohibitive.

By attaching a tiedown device at some angle to the direction of anticipated movement, it is possible to apply restraint in more than one direction, depending on the angle of pull. By varying the angle of pull, one tiedown device can provide simultaneous restraint in three directions.

Usually, attachment to the cargo is made at some point above the cargo floor. When attached as shown below, part of the rated capacity of the tiedown is available to prevent longitudinal movement of the item and part is available to provide restraint in the vertical (up) direction but no restraint is provided in the lateral direction.

The tiedown shown below will provide simultaneous restraint in all three directions (longitudinal, vertical, and lateral) and illustrates the most desirable and efficient configuration for each tiedown used. If only two of the three directions can be achieved, supplemental restraint will be required using separate tiedowns. Full restraint of the item below would be obtained by attaching tiedown devices symmetrically, in pairs, to the opposite corners/ends of the cargo item.

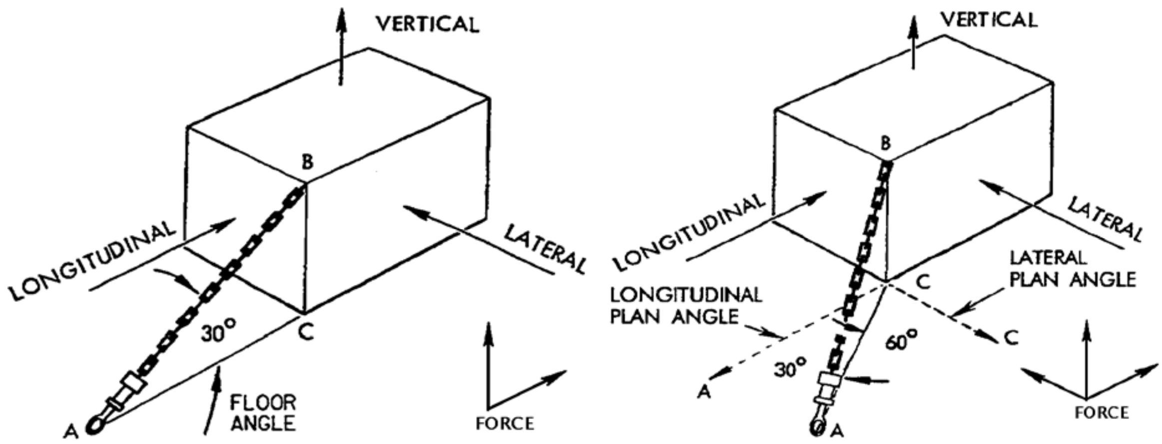


FIGURE C-23. Tiedown angles.

There are three angles formed by a tiedown chain that is attached to a load at a point above the cargo floor:

(1) The floor angle (sometimes called the vertical angle) is the angle between the chain and the floor.

(2) The longitudinal plan angle is the angle between the chain and a line that runs fore and aft in the cargo compartment through the attachment point on the load.

(3) The lateral plan angle is the angle between the chain and a line that runs laterally across the cargo compartment through the attachment point on the load.

Tiedown chains attached at floor and plan angles of 30 degrees provide the best compromise for adequate restraint of the cargo in all directions. Frequently, it will not be possible to use the 30-degree angles and other arrangements will be necessary.

Increasing the floor angle while keeping constant plan angles will provide a higher value of vertical restraint but will reduce the amount of longitudinal and lateral restraint. Keeping the same floor angle but increasing one of the plan angles (thus decreasing the other plan angle) will not affect the vertical restraint but will change the quantities of longitudinal and lateral restraint.

Assuming that the tiedown is the weakest link in the system and using the optimum 30 degree angles, a 5,000 pound capacity tiedown strap (CGU-1B) will provide 3,750 pounds of longitudinal restraint, 2,500 pounds of vertical restraint, and approximately 2,150 pounds of lateral restraint at attachment point B. Similarly, a 10,000-pound capacity (MB-1) chain will provide 7,500 pounds of longitudinal restraint, 5,000 pounds of vertical restraint, and approximately 4,300 pounds of lateral restraint. A 25,000 pound capacity (MB-2) chain will provide 18,750 pounds of longitudinal restraint, 12,500 pounds of vertical restraint, and approximately 10,800 pounds of lateral restraint when ideal angles can be achieved.

It is unlikely that the results above will be achieved in practice because it will not always be possible to achieve ideal chain angles. Tiedowns that are applied at other than the ideal angles will produce different (proportional) amounts of longitudinal, vertical, and lateral restraint. The amount of available restraint for such tiedowns should be calculated by using the tiedown angle ratio method (see C.5.4.3).

C.5.4.2 Calculating required tiedown.

An initial estimate of the number of tiedown chains or straps needed to restrain a unit of cargo should always be computed before a proposed tiedown configuration is attempted. A method that usually produces a good estimate is outlined below:

(1) Determine the gross shipping weight of the item as it will be loaded onto the aircraft (including any stowed gear).

(2) Multiply the weight in Step 1 by 3.0 to determine the forward restraint requirement (see 5.3.3.1).

(3) Divide the result in Step 2 by 7,500 if 10,000 pound capacity chains will be used or by 18,750 if 25,000 pound capacity chains will be used*.

*Note: If the attachment points on the cargo item or the floor tiedown rings on the aircraft are weaker than the capacity of the chain that is being used, divide the result in Step 2 by the weakest capacity.

(4) Round up the result from Step 3 to the next EVEN whole number (chains should always be attached in pairs). The result will be an estimate of the number of chains that will be needed to restrain the cargo item to 3.0 G's forward.

(5) Example: A 30,000-pound vehicle is to be airlifted on a C-17. An additional 2,375 pounds of crew gear will be stowed inside the vehicle prior to loading. There are 2 attachment points on each end of the vehicle, plus 2 additional points down each side of the vehicle, for a total of 8 points, each rated at 65,000 pounds capacity.

Step 1: 30,000 + 2,375 = 32,375 lb. (gross shipping weight)

Step 2: 32,375 x 3.0 G = 97,125 lb. (restrain to 3.0 G forward)

Step 3: 97,125 ÷ 18,750 = 5.2

Step 4: Rounding up to the next even number gives a total of 6 (3 pairs) 25,000-pound capacity chains that will be required for forward restraint.
Note: If 10,000-pound capacity chains will be used, the results would be: 97,125 ÷ 7,500 = 12.95. In this case, a total of 14 (7 pairs) 10,000-pound capacity chains would be required for forward restraint.

(6) Repeat the process for aft, vertical, and lateral (left and right) directions. Generally, the total number of chains required to achieve forward and aft restraint will also provide enough vertical and lateral restraint; if not, additional chains should be added in pairs until the required amount of vertical and lateral restraint is achieved.

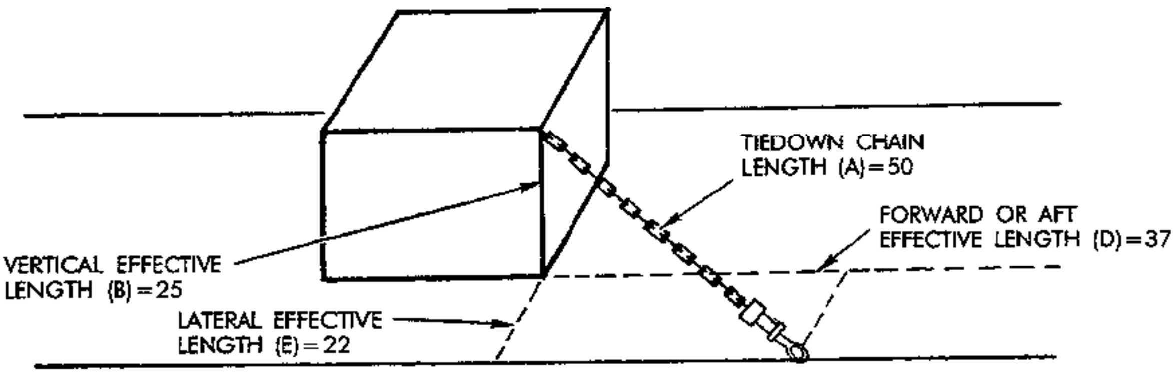
Use the initial estimate to determine a proposed tiedown configuration. The tiedown angle ratio method (see C.5.4.3 and figure C-24) should then be used to calculate the exact amount of restraint that is available from each device in the proposed configuration. Results should be checked against the restraint requirements of C.5.2.3 to ensure that the item has been properly restrained to requirements.

C.5.4.3 Calculating available tiedown.

The tiedown angle ratio method, illustrated by the example problem shown on figure C-24, is used to calculate the actual amount of restraint available from any given tiedown. The method shown is the same method used by USAF loadmasters when they restrain cargo aboard the aircraft.

When calculating the amount of restraint that is available for any given tiedown, consideration shall be given to the weakest component in the tiedown loop, i.e. the chain, device, floor ring, pallet ring, or cargo item attachment point that has the smallest capacity rating. For example, an MB-1 (10,000 pound capacity) chain and device attached to a 463L pallet ring is limited by the 7,500 pound capacity of the pallet ring. Similarly, if an MB-2 (25,000-pound capacity) chain and device were attached to a cargo item attachment point that has a rated capacity of 15,000 pounds, the maximum amount of restraint available to the MB-2 chain and device would be limited to the 15,000 pound capacity of the attachment point. (This assumes the floor ring attachment point is rated at more than 15,000 pounds capacity. If the floor ring attachment point were rated at less than 15,000 pounds capacity, then the floor ring attachment point would become the limiting factor.)

When multiple tiedowns are attached to floor rings that are in the same lateral row (i.e. pulling on the same floor bulkhead), the amount of vertical restraint may be limited. Example: four MB-1 devices attached to floor fittings in the same lateral row may each provide forward and aft restraint to their maximum capacity but the amount of vertical restraint available per floor ring may be limited. The vertical restraint reduction varies depending on the aircraft, and depending on the number of other devices attached to the same lateral tiedown row. Consult the respective aircraft loading manual (T.O. 1C-XXX-9) to determine the extent to which vertical restraint is reduced when multiple tiedowns are attached to the same lateral row of floor rings.



This figure illustrates a method of determining restraint provided by a cargo tiedown. As illustrated, tiedown ratios can be determined by dividing the directional distance in which restraint is required by the chain (or strap) length. This ratio is then multiplied by the strength of the tiedown, device, or attachment point on the cargo, whichever is less, to find the effective restraint received from the tiedown pattern used.

FIGURE C-24. Tiedown angle ratio method - sheet 1 of 2.

EXAMPLE (Note: Quantities used are from the figure example above)

1) First, measure the tiedown chain length (A) from the attachment point on the cargo to the tiedown fitting on the cargo floor (50 inches). You will use this measurement in each calculation.

2) **<u>CALCULATING THE VERTICAL RESTRAINT</u>:**

a) For determining vertical restraint, measure the vertical dimension (B) from the attachment point on the cargo to a point directly beneath it on the cargo floor (25 inches).

b) Divide the vertical dimension (B) by the tiedown chain length (A) to determine a ratio:

$$\frac{25}{50} = 0.50 RATIO$$

c) Multiply this ratio by the rated strength of the tiedown chain or the rated strength of the tiedown fitting on the cargo or the rated strength of the tiedown floor fitting, *<u>whichever is less</u>*:

$$0.50 \times 10{,}000^{*} = 5{,}000 POUNDS$$ **VERTICAL RESTRAINT RECEIVED FROM TIEDOWN**

3) **<u>CALCULATING THE FORWARD OR AFT RESTRAINT</u>:**

a) For determining forward or aft restraint, obtain a forward or aft dimension (D) by measuring from a point directly beneath the attachment point on the cargo along a longitudinal axis to a point lateral to the tiedown fitting being used on the cargo floor (37 inches).

b) Divide the forward or aft dimension (D) by the tiedown chain length (A) to determine a ratio:

$$\frac{37}{50} = 0.74 RATIO$$

c) Multiply this ratio by the rated strength of the tiedown chain or the rated strength of the tiedown fitting on the cargo or the rated strength of the tiedown floor fitting, whichever is less:

$$0.74 \times 10{,}000^{*} = 7{,}400 POUNDS$$ **FWD OR AFT RESTRAINT RECEIVED FROM TIEDOWN**

4) **<u>CALCULATING THE LATERAL RESTRAINT</u>:**

a) For determining lateral restraint, obtain a lateral dimension (E) by measuring from a point directly beneath the attachment point on the cargo, along the cargo floor, to the row of tiedown fittings being used (22 inches).

b) Divide the lateral dimension (E) by the tiedown chain length (A) to determine a ratio:

$$\frac{22}{50} = 0.44 RATIO$$

c) Multiply this ratio by the rated strength of the tiedown chain or the rated strength of the tiedown fitting on the cargo or the rated strength of the tiedown floor fitting, whichever is less:

$$0.44 \times 10{,}000^{*} = 4{,}400 POUNDS$$ **LATERAL RESTRAINT RECEIVED FROM TIEDOWN**

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* Note: This quantity should always represent the weakest link in the system. If the rated strength of the chain or either attachment point being used is less than 10,000 pounds, the ratio should be multiplied by the weakest rated strength.

FIGURE C-24. Tiedown angle ratio method – sheet 2 of 2 continued.