
**Air cargo equipment — Restraint
straps —**

Part 2:
**Utilization guidelines and lashing
calculations**

Équipement de fret aérien — Sangles d'arrimage —

Partie 2: Lignes directrices pour l'utilisation et calculs d'arrimage

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 16049-2 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 9, *Air cargo and ground equipment*.

ISO 16049 consists of the following parts, under the general title *Air cargo equipment — Restraint straps*:

- *Part 1: Design criteria and testing methods*
- *Part 2: Utilization guidelines and lashing calculations*

Introduction

Throughout this part of ISO 16049, the minimum essential criteria are identified by the use of the imperative or the key word “shall”. Recommended criteria are identified by the use of the key word “should” and, while not mandatory, are considered to be of primary importance in providing safe lashing arrangements. Deviations from the recommended criteria may be made only after careful consideration, extensive testing and thorough service evaluation have shown an alternative method to be satisfactory.

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Air cargo equipment — Restraint straps —

Part 2: Utilization guidelines and lashing calculations

1 Scope

This part of ISO 16049 specifies utilization guidelines and principles to be used in strength calculation methods adequate to guarantee the effectiveness and ultimate load strength of tie-down/lashing arrangements used to restrain cargo on board civil transport aircraft during flight for either:

- a) cargo loaded and tied down onto airworthiness certified air cargo pallets, themselves restrained into aircraft lower deck or main deck cargo systems meeting the requirements of ISO 8097;
- b) additional tie down on aircraft structure when necessitated by pallet maximum gross mass or centre of gravity limits;
- c) non-unitized individual pieces of cargo, or pieces of cargo placed onto an unrestrained (“floating”) pallet into either lower deck or main deck containerized cargo compartments of an aircraft; or
- d) individual pieces of load loaded in non containerized (bulk loaded) baggage or cargo compartments.

This part of ISO 16049 is applicable to cargo tie-down/lashing arrangements using exclusively air cargo restraint straps conforming to ISO 16049-1. Its general recommendations may be used for tie-down arrangements using other means (e.g. steel cables, rope, chains, other types of straps), but under the user's responsibility as to their adequacy and the strength calculations required.

This part of ISO 16049 is not applicable to the use of chains or other rigid devices for tie-down onto civil transport aircraft floor tracks. These devices are generally not recommended for use due to the possibility of generating excessive stresses in the aircraft structure, except where explicitly approved in the manufacturer's Authority approved Weight and Balance Manual.

This part of ISO 16049 is intended to provide industry recognized means of complying with Airworthiness Authorities general regulations applicable to load-securing on board civil transport aircraft (see FAR/JAR Parts 25), and aircraft manufacturers Authority approved Weight and Balance Manuals for each aircraft type as specified therein. It is not the intent of this part of ISO 16049 to specify when restraint straps should be used, but how they should be used. It does not, under any circumstance, supersede the requirements of any of the above documents that take precedence at all times.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 8097, *Aircraft — Minimum airworthiness requirements and test conditions for certified air cargo unit load devices* ¹⁾

ISO 10254, *Air cargo and ground equipment — Vocabulary*

ISO 16049-1, *Air cargo equipment — Restraint straps — Part 1: Design criteria and testing methods*

Joint Aviation Regulations (JAR) OPS 1.035, *Quality system*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10254 and the following apply.

3.1 tie-down lashing
act of restraining cargo movements in relation to an aircraft's structure, throughout the range of relative accelerations resulting from the permissible flight envelope, by means of an appropriate use of a number of elementary tie-down devices against each direction of restraint

3.2 tie-down arrangement
geometric layout of an assembly of elementary tie-down devices affixed and tensioned around a piece of cargo in order to ensure its tie-down against each direction of restraint

3.3 flight envelope
for a given aircraft type or sub-type, the set of permissible values for accelerations which may be encountered during flight in the various directions relative to the aircraft's structure, as determined during the aircraft certification flight testing and certified by the Airworthiness Authority within the aircraft's type certificate

3.4 limit load
 L_L
maximum load to be expected in service as a result of the certified permissible flight envelope of the aircraft

NOTE See FAR/JAR Part 25, paragraph 25.301 (a). The limit load is two-thirds of the ultimate load (3.5).

3.5 ultimate load
 L_U
limit load multiplied by a safety factor of 1,5

NOTE See FAR/JAR Part 25, paragraph 25.303. The ultimate load is used for calculation of cargo tie-down arrangements, based on the ultimate load factors defined in the Airworthiness Authority approved Weight and Balance Manual, in each direction of restraint, throughout the certified flight envelope of the aircraft type.

1) Based on NAS 3610.

3.6**fore and aft**

directions of restraint, relative to the aircraft structure, determined parallel to the aircraft centerline towards the direction of flight, or opposed to it

3.7**side**

direction of restraint, relative to the aircraft structure, determined perpendicular to the aircraft centreline and parallel to its floor, lefthand or righthand

3.8**upward**

upward direction relative to the aircraft structure

3.9**load factors**

accelerations, expressed as multiples of the standard acceleration of free fall ($g_n = 9,806\ 65\ \text{m}\cdot\text{s}^{-2}$), in each direction of restraint (fore, aft, sides, upward), that will result in limit or ultimate, as is the case, forces on the tie-down arrangement proportional to the mass of the piece of cargo being restrained

cf. **ultimate load** (3.5) and **limit load** (3.4)

NOTE Load factors are provided by the Airworthiness Authority approved Weight and Balance Manual for the aircraft type or sub-type.

3.10**restraint strap assembly****strap**

elementary tie-down unit consisting of flat woven textile webbing (one fixed end and one adjustable end), one tensioning device and two end fittings, used for restraint of cargo on board civil transport aircraft

NOTE See ISO 16049-1 for the description, the design criteria and the testing requirements.

3.11**tie-down fitting**

basic piece of hardware, either single stud or double stud, with an omnidirectional capability, allowing to attach (a) strap(s) or other elementary tie-down unit(s) to the floor tracks or tie-down receptacles of an aircraft's structure or the edge tracks of an air cargo pallet

NOTE 1 See ISO 7166 for single stud hardware.

NOTE 2 See ISO 9788 and ISO 12118 for double stud hardware.

NOTE 3 Tie-down fittings most commonly include an attachment ring, but may also be directly sewn onto a strap as a permanent end fitting thereof (see ISO 16049-1).

3.12**floating**

air cargo pallet, or equivalent flat support device, located on an aircraft's cargo compartment rollerized conveyor but not restrained by the ISO 8097 compatible cargo system, the pallet and its load constituting "non unitized" cargo and being restrained by a set of straps attached to aircraft structural points

3.13**competent person**

designated person, suitably trained according to ISO 9000 or equivalent pertinent industry training and proficiency standards, qualified by knowledge and practical experience and with the necessary operating instructions established according to 4.1

4 General requirements

4.1 Operating instructions shall be established by the aircraft operator, under operating control of his reporting civil aviation authority. The operating instructions shall ensure compliance with the general airworthiness requirements and the applicable aircraft Weight and Balance Manual, and should incorporate the requirements of this part of ISO 16049, or equivalent industry standard (see Bibliography).

4.2 In addition, when restraint straps are attached to the edge rails of a certified air cargo pallet meeting the requirements of ISO 8097, operating instructions should take into account the general requirements of the appropriate ISO 8097 configuration drawing(s).

4.3 Actual tie-down/lashing on aircraft in accordance with these instructions shall be performed and checked exclusively by competent, suitably trained, personnel as defined in ISO 9000 or equivalent pertinent industry training and proficiency standards.

4.4 Regardless of the tie-down method used (see Clause 5), comply with the general rules given in 4.5 to 4.16.

4.5 Tie-down should be performed using straps designed and tested in accordance with ISO 16049-1, and the rated ultimate strength resulting from said testing of the strap model selected shall be used for calculation of the tie-down arrangement's strength (see Clause 6). In the event of other straps or alternate tie-down equipment (e.g. ropes, cables) being used under the operator's responsibility, the general rules given in 4.6 to 4.16 shall nevertheless apply and the minimum guaranteed ultimate strength of the specific equipment used shall be used for strength calculation.

4.6 If several elements (e.g. straps, fittings, structural attachment points) of different ultimate strengths are used together, the strength of the resulting total tie-down element shall be limited to the strength of the weakest item.

4.7 A total tie-down arrangement should be performed using exclusively straps of the same model, in order to ensure differences in elasticity will not result in unequal tension of the straps and premature failure of certain ones in the event of a major acceleration being encountered during flight. If different models are to be used, at least the straps material (e.g. polyamide, polyester, etc.) and rated ultimate strength shall be identical for any single direction of restraint.

4.8 Tie-down arrangements shall be symmetrical, i.e. performed using an equal number of tie-down attachment points (fittings or equivalent) on any two opposite sides of the piece of cargo, and the same number of straps, acting in the same direction(s) of restraint, onto any two symmetrically located attachment points. See Figure 1.

4.9 A single tie-down fitting may, subject to ring geometrical compatibility and any Weight and Balance Manual restrictions or limits as to load factors simultaneity, be attached to up to three straps acting in as many different directions, but shall be attached to no more than one acting in any single direction of restraint (fore, aft, side or upward).

4.10 A strap attached to fittings on opposite sides of the piece of cargo and passing over or around it is to be accounted for twice its rated ultimate load capacity. Under the requirement, it remains free to slide along the piece of cargo and not attached to it, so that the load is equally distributed between both ends of the strap. A strap attached to the piece of cargo may be accounted for only once.

4.11 For upward restraint, a minimum of two straps, regardless of the mass to be restrained, shall be used over the top of the piece of cargo, one on each side of its centre of gravity. When a higher number of upward straps are used, they should be evenly distributed around the centre of gravity.

4.12 Each strap should make a minimum possible angle, not to exceed 30°, with the direction of restraint for which it is accounted (see Figure 1). In practical terms, to ensure angles α_1 , α_2 , α_3 in Figure 1 be no more than 30° in relation to, respectively, directions A, B and C, check that distances d_1 , d_2 and d_3 , respectively, are less than half of distances D_1 , D_2 and D_3 .

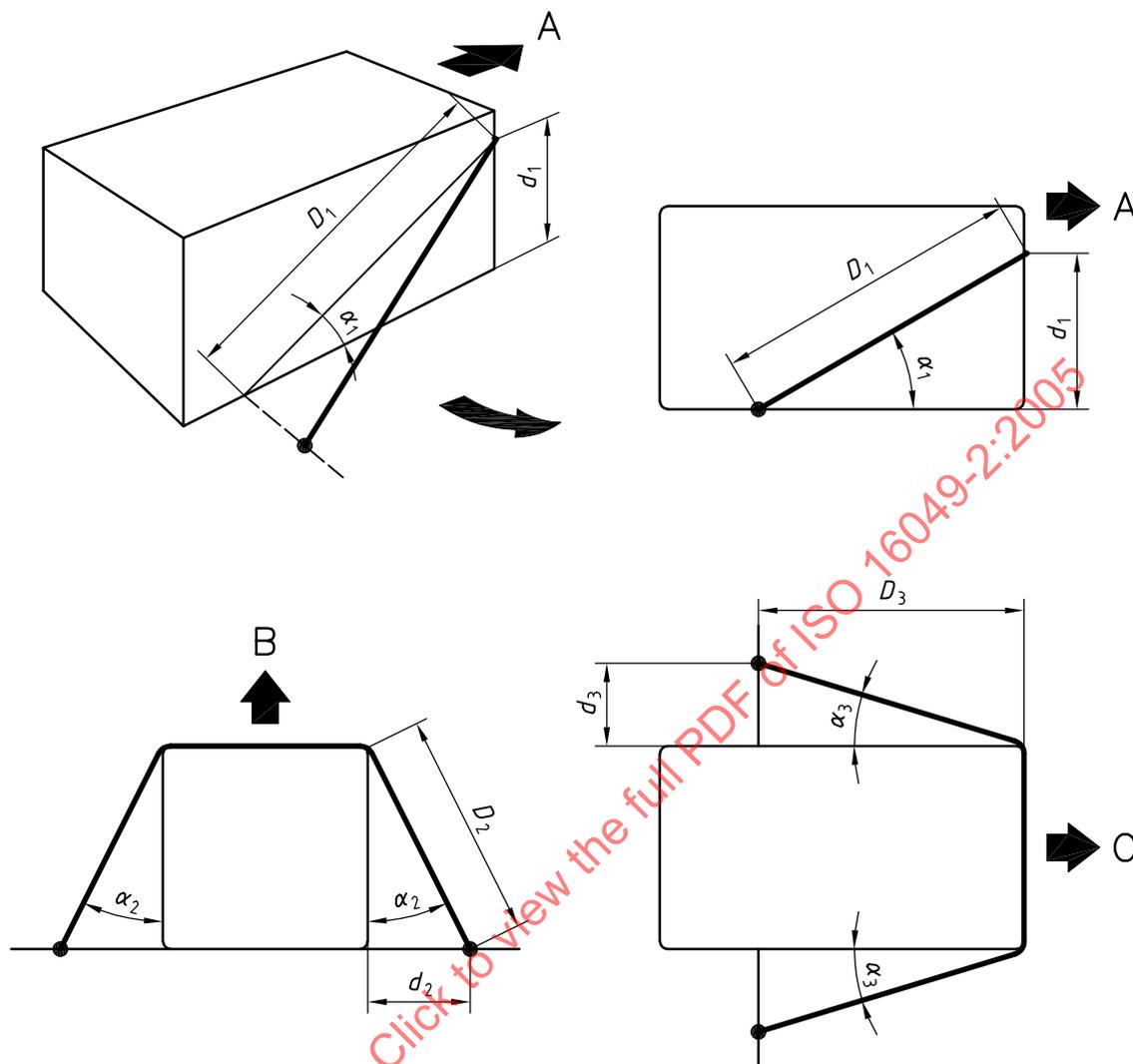


Figure 1 — Examples of strapping position angles with respect to restraints in directions A, B and C

4.13 A minimum distance of 50 cm (20 in) shall be maintained between any two tie-down attachment points (fittings) bearing straps ensuring restraint in the same direction (see examples in Figure 2).

4.14 All straps bearing in the same direction of restraint shall be equally tensioned inasmuch as feasible in order to ensure they equally bear the restraint forces in the event of an in-flight load. Straps should be tensioned without any slack, but without excess. Particularly when using an aluminium sheet pallet, care should be taken not to bend the pallet's edge rail upward. Applying the residual tension defined in ISO 16049-1 to all straps usually results in complying with these requirements.

4.15 Care should be taken that any straps passing over or around the piece(s) of cargo cannot come into contact with sharp or cutting edges capable of cutting the strap's webbing, or, if unavoidable, to provide padding adequate to protect it.

4.16 Care should be taken to provide positive protection against the risk of downward sliding of any straps bearing in an horizontal direction of restraint, by either tightening them immediately over an adequate protrusion of the load (e.g. horizontal batten), or comparable protrusion in a wooden crate's wall, etc. or, if not available, attaching them with a security rope over the load, capable of maintaining their location.

Dimensions in centimetres

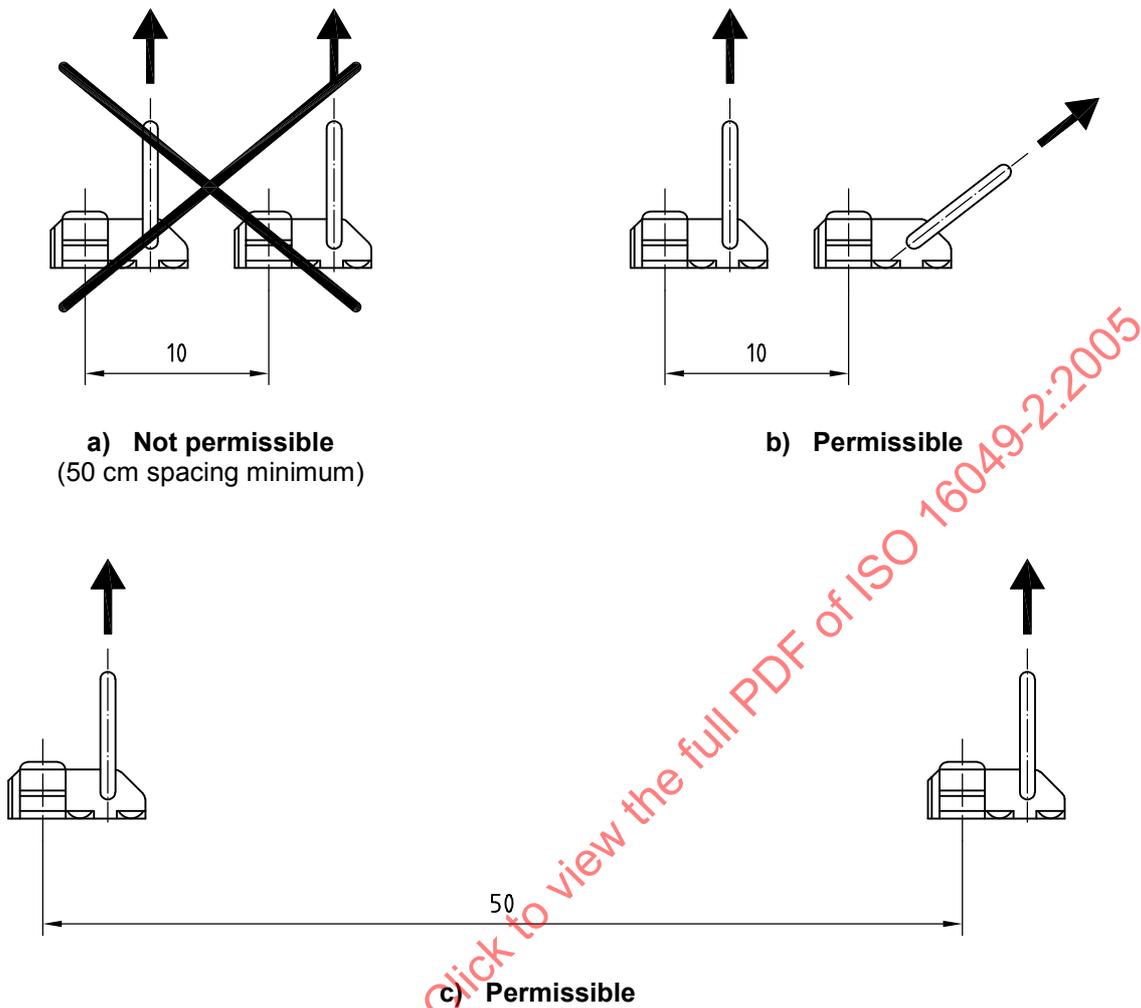


Figure 2 — Examples of distances between two tie-down attachment points

5 Tie-down methods

5.1 General

There are several acceptable general methods for tying down a rectangular or similar shape type of cargo, as described in 5.2 to 5.5 (see Clause 7 for additional precautions applying to different special shapes of cargo).

5.2 Over-top method

This method consists in ensuring cargo restraint by placing a set of straps in vertical planes, passing over-top of the load, and forming a net-like arrangement to provide multi-directional restraint. See Figure 3.

This may involve a risk of unrestrained cargo movement between the boundaries defined by tie-down fittings, which may constitute a hazard to the aircraft. See 7.2 for preventive action.

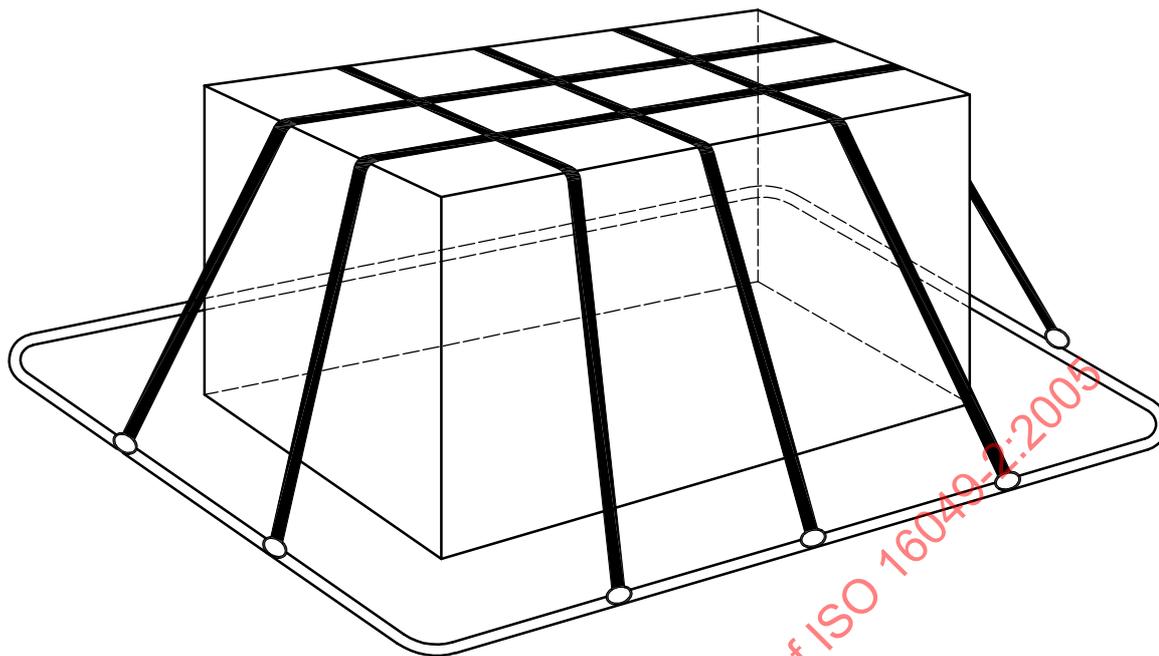


Figure 3 — Example of “over-top” tie-down arrangement

5.3 Directional method

This method consists in ensuring cargo restraint by placing a dedicated set of straps in a given set of directions of restraint. See Figure 4.

Where the number of straps is different in the different horizontal directions, the load may only be loaded in the correct orientation within the aircraft. Appropriate loading instructions shall be given and maintained in the event of a trans-shipment. See 6.1.2.

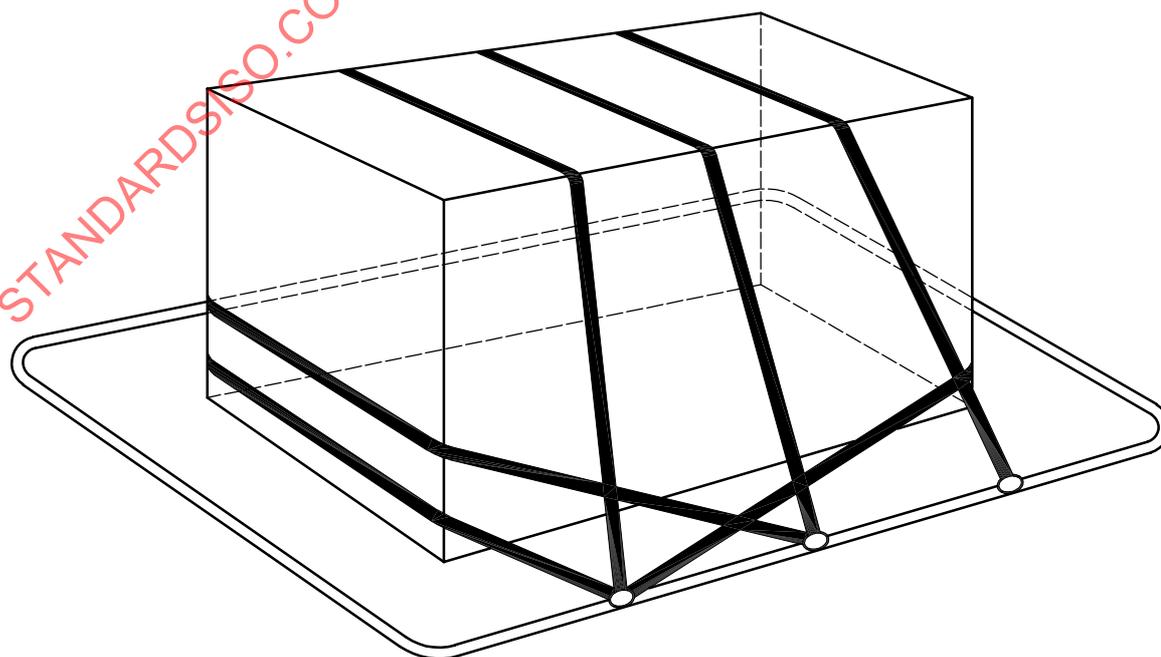


Figure 4 — Example of “directional” tie-down arrangement

5.4 Other methods

Most of the other methods are combinations of the two previous methods, as illustrated in Figure 5.

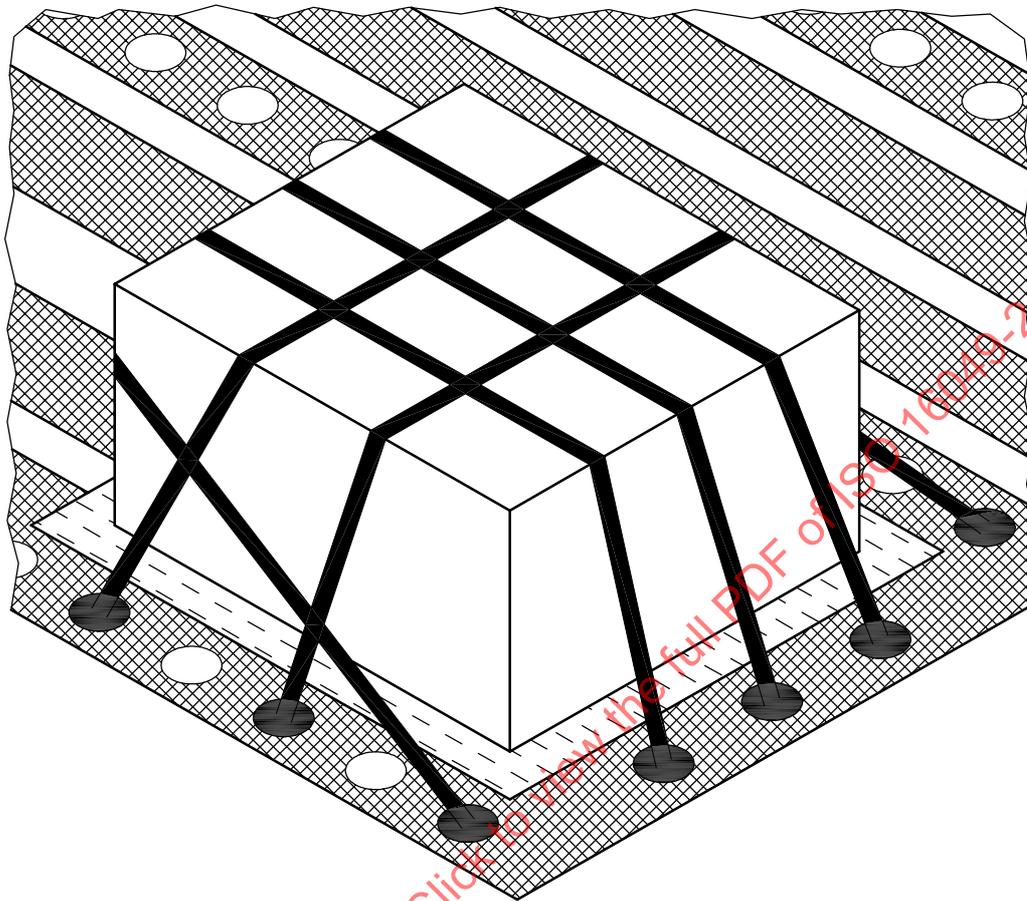


Figure 5 — Example of combination tie-down arrangement

5.5 Directions of restraint

Whatever method or combination is used, restraint in each of the five required directions (forward, aft, both sides, upward) may be ensured by either a dedicated set of straps for an individual direction or the general effect of the straps assembly forming a net like tie-down arrangement, equivalent, though less deformable, to a certified pallet net, to provide multi-directional restraint. See Figures 3, 4 and 5.

6 Calculation methods

6.1 Load factors

6.1.1 The ultimate loads restraint capability of any tie-down arrangement shall be calculated based on the mass of the piece(s) of cargo to be retained and the following in-flight ultimate load factors, expressed in multiples or fractions of the standard acceleration of free fall g_n ($g_n = 9,806\ 65\ \text{m}\cdot\text{s}^{-2}$):

- L_f = load factor in the forward direction of restraint,
- L_a = load factor in the aft direction of restraint,
- L_Y = load factor in either side direction of restraint,
- L_Z = load factor in the upward direction of restraint.

A single longitudinal load factor $L_X = L_f$ may be used instead of separate fore and aft load factors, whenever there may exist an uncertainty as to the actual direction in which a pallet will be loaded into the aircraft. See 6.1.2.

6.1.2 The load factors shall be those certified for the aircraft type concerned in its manufacturer's Authority approved Weight and Balance Manual, to be contained in the operator's operating instructions. Where they differ according to location or orientation in the aircraft, the load factors certified for the actual location or orientation on board of the piece(s) of cargo concerned may be used. Whenever tie-down is to be performed while the actual location and orientation on board are still undetermined (e.g. advance palletization), the highest aircraft load factor shall be used in each restraint direction.

6.1.3 When tie-down is to be performed while the aircraft type concerned is still undetermined, or when, exceptionally, no load factors data is readily available on the aircraft type, the following ultimate load factors were determined to be higher than or equal to those applicable for current international civil transport aircraft, and may safely be used to perform advance tie-down:

- $L_f = 1,5 g_n$
- $L_a = 1,5 g_n$
- $L_Y = 1,5 g_n$
- $L_Z = 3,0 g_n$

The forward ultimate load factor L_f to be used shall be $9,0 g_n$ in a cabin or main deck compartment where there is no certified $9,0 g_n$ barrier net or equivalently stressed bulkhead installed between the load and passenger(s) or crew, in order to cater for emergency landing conditions (see FAR/JAR 25, paragraphs 25.561 and 25.787). It pertains to operators of such aircraft to provide and implement specific $9,0 g_n$ tie-down instructions.

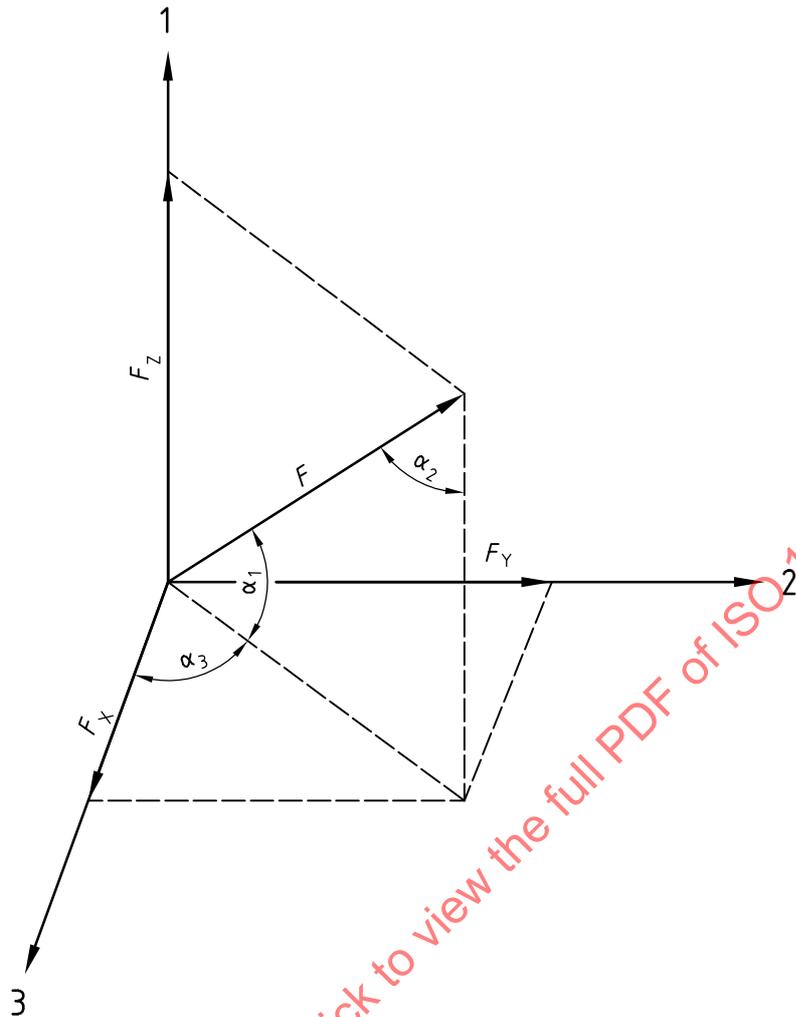
The upward ultimate load factor L_Z to be used requires checking by each individual operator in establishing his/her tie-down operating instructions according to the aircraft fleet he/she operates. Due to differences with aircraft size, i.e. smaller (narrow body) aircraft may have certified upward load factors of up to $4,0 g_n$ at certain locations, while very large capacity aircraft seldom exceed $2,1 g_n$. It is the responsibility of operators of aircraft presenting upward load factors higher than the $3,0 g_n$ common industry practice to provide and implement specific tie-down instructions.

6.2 Calculation principles

6.2.1 The ultimate restraint capability of each individual strap (F) shall be accounted as the lowest of one of the following:

- the strap's own rated ultimate load (see ISO 16049-1 for determination and testing);
- the aircraft or pallet attachment point's rated ultimate load in the direction concerned;
- the rated strength of the piece of cargo's attachment point, if the strap is attached to cargo at one end (not applicable if the strap passes around or over the piece of cargo and attached at both ends to aircraft structure or pallet track); or
- the rated ultimate load of any intermediate hardware (e.g. tie-down fitting) used.

6.2.2 The ultimate restraint capability of the total tie-down arrangement is the sum of the three components (F_X forward or aft, F_Y side, and F_Z upward) of each individual strap's ultimate strength (F , as defined in 6.2.1) according to the angles ($\alpha_1, \alpha_2, \alpha_3$ as defined in Figure 1) it forms with the reference directions of restraint. See Figure 6.



Keys

- 1 upward component
- 2 side component
- 3 forward or aft

Figure 6 — Components of the ultimate strength F for an individual strap

6.2.3 The respective components for any individual strap in each direction of restraint are:

— forward or aft load: $F_X = F \times \cos \alpha_1 \times \cos \alpha_3$

— side load: $F_Y = F \times \cos \alpha_1 \times \sin \alpha_3$

— up load: $F_Z = F \times \cos \alpha_2$

and

$$F_X^2 + F_Y^2 + F_Z^2 = F^2$$

6.2.4 A strap attached between a tie-down fitting and a point of the piece of cargo shall be accounted for once. Where a strap is attached to two fittings on opposite sides of the piece of cargo and passing over or around it, it shall be accounted as two separate straps, using the most critical angles of either end of the strap (see 4.10).

6.2.5 The ultimate restraint capability provided by the total tie-down arrangement in each of the five directions of restraint is the sum of the individual strap's components in the direction concerned and shall be equal to or greater than the applied ultimate load (L_U), F_{LU} , calculated as follows:

$$F_{LU} = L \times m_C$$

where

L is the applicable load factor as defined for each direction in 6.1;

m_C is the total mass of cargo to be tied down.

6.3 Practical calculation

6.3.1 Since in field practice it may be almost impossible and prone to error to actually measure the angles for each individual strap and perform in detail the corresponding component forces calculation, each aircraft operator shall establish simplified operating instructions to be used by field staff (e.g. in cargo warehouses or when actually loading aircraft cargo compartments) in order to determine tie-down/lashing arrangements ultimate restraint capability.

6.3.2 Such operating instructions may consist in either:

- preformatted calculation sheets or charts,
- graphs or abacus methods,
- precomputed tables based on general assumptions with which to comply, or
- any other method deemed appropriate,

thus avoiding the necessity to perform detailed calculations for each individual package tie-down, providing the applicable assumptions, if any, are clearly stated and checked, and the results of the method used conform to the calculation principles set in 6.2.

The most commonly used method of providing operating instructions for tie-down calculations is described in IATA Airport Handling Manual AHM 671, *Securing of load* [8]. For international applications, it is recommended this method be preferentially used in order to ensure uniformity of procedures between operators and handling agencies, and thereby enhance flight safety through uniform training and methods consistency.

6.3.3 To avoid making mistakes, it is essential that any operating instructions and related charts, graphs, etc. clearly state in bold characters whether the mass figures are expressed in pounds or kilograms (kilograms are preferred for international application in order to further minimize the risk of mistakes).

7 Specific requirements

7.1 General

There are specific circumstances when the general principles of tie-down as specified in Clauses 4, 5 and 6 (essentially applicable for rectangular shaped packages of a convenient size), may be insufficient in ensuring proper cargo restraint and flight safety. The resulting specific requirements for some of the commonest cases are specified in 7.2 to 7.4, but there are many other potential ones (e.g. the commonest specific cases are overhanging loads, "tall" loads, pipes and other long loads, reels/drums/spools, automobiles, aircraft engines, stacked pallets, marine containers). It remains the operator's responsibility to interpret the requirements specified in 7.2 to 7.4 in the operating instructions, as well as to identify and adequately handle any other specific situations, which might render general requirements inappropriate or insufficient.