INTERNATIONAL STANDARD

ISO 16049-2

Third edition
2020-01

Air cargo equipment — Restraint straps —

Part 2:
Utilization requirements and recommendations and lashing calculations

Contents

Page

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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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

This third edition cancels and replaces the second edition (ISO 16049-2:2013), which has been technically revised. The main changes compared to the previous edition are as follows::

— new 4.14, Figure 3 and Table 1 regarding maximum number of tie-down locations on a pallet;

— deletion in 5.1, Basic methods, of Figure 4 former first drawing without lateral restraint dedicated straps;

— specification in 6.2, Calculation principles, of centreline angle and floor angle;

— deletion in 6.3, Practical calculation, and Bibliography of references to IATA AHM 311 and AHM 450;

— new 6.4, Calculation sheet.

A list of all parts in the ISO 16049 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document specifies utilization guidelines and the principles to be used in tie-down/lashing strength calculations for the use of air cargo restraint straps on board civil transport aircraft.

The civil aviation requirements referred to in the present document are those relating to operation of transport aircraft. They constitute the set of operation requirements internationally agreed in application of International Civil Aviation Organization (ICAO) Annex 6, Operation of aircraft, to the Convention on International Civil Aviation.

Throughout this document, the minimum essential criteria are identified by use of the key word "shall". Recommended criteria are identified by use of the key word "should" and, while not mandatory, are considered to be of primary importance in providing safe lashing arrangements. Deviation from recommended criteria should only occur after careful consideration and thorough service evaluation have shown the alternate methods ensure the same level of safety.

The requirements of this document are expressed in the applicable SI units, with approximate inch-pound units conversion between brackets for convenience in those countries using that system.

Air cargo equipment — Restraint straps —

Part 2:
Utilization requirements and recommendations and lashing calculations

1 Scope

This document aims at providing general utilization requirements and recommendations and calculation methods adequate to guarantee the effectiveness and ultimate load strength of tie-down/ lashing arrangements performed to restrain cargo on board civil transport aircraft during flight:

a) cargo loaded and tied down onto airworthiness approved air cargo pallets, themselves restrained into aircraft lower deck or main deck or upper deck cargo systems meeting the restraint requirements of air cargo pallets approved in accordance with ISO 8097 (NAS3610) or ISO 21100, or

b) additional tie-down on aircraft structure when necessitated by pallet maximum gross mass or centre of gravity limits, or

c) non-unitized individual pieces of cargo, or pieces of cargo placed onto an unrestrained ("floating") pallet into either lower deck, main deck or upper deck containerized cargo compartments of an aircraft, or

d) individual pieces of load loaded in non-containerized (bulk loaded) baggage or cargo compartments.

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

NOTE 1   Where tie-down is performed onto aircraft structure as per b) or c) above, additional restrictions can be stated in the aircraft's Authority approved Weight and Balance Manual.

NOTE 2   The use of chains, rods, or other rigid devices for tie-down onto civil transport aircraft floor tracks, which can generate excessive stress in the aircraft structure, is not part of the scope of this document. .

This document aims at providing industry recognized means of complying with Airworthiness Authorities general requirements applicable to load securing on board civil transport aircraft (see CCAR-25, JAS Part 3, 14 CFR Part 25 and EASA CS-25), and aircraft manufacturers Authority approved Weight and Balance Manuals for each aircraft type as specified therein. It is not the intent of this document to specify when restraint straps should be used, but how they should be used.

Meeting the methods requirements of this document is not alone sufficient to ensure flight safety: this document is based on the assumption that cargo tie-down will be designed, performed, and checked prior to aircraft departure in accordance with appropriate operating instructions conforming to the Weight and Balance Manual of the aircraft concerned, by competent, suitably trained, personnel as defined for example in ISO 9001:2015, 6.2.2 (see Clause 8).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 7166, *Aircraft — Rail and stud configuration for passenger equipment and cargo restraint*

ISO 8097:2001[1], *Aircraft — Minimum airworthiness requirements and test conditions for certified air cargo unit load devices*

ISO 9788, *Air cargo — Double stud tie-down fittings — Design and testing requirements*

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

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

ISO 21100, *Air cargo unit load devices — Performance requirements and test parameters*

3   Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
tie-down
lashing
fact of restraining cargo movements in relation to an aircraft's structure, throughout the range of relative accelerations resulting from the allowable flight envelope (3.3), 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* (3.1) 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> set of allowable 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
LL
maximum load to be expected in service as a result of the certified *flight envelope* (3.3) of the aircraft

Note 1 to entry: It is two thirds of the *ultimate load* (3.5).

3.5
ultimate load
UL
limit load (3.4) multiplied by a safety factor of 1,5

Note 1 to entry: See CCAR-25, JAS Part 3, 14 CFR Part 25 and CS-25, paragraph 25.303.

Note 2 to entry: It is used for calculation of cargo *tie-down arrangements* (3.2), based on the ultimate *load factors* (3.10) defined in the Airworthiness Authority approved *Weight and Balance Manual* (3.14), in each direction of restraint, throughout the certified *flight envelope* (3.3) of the aircraft type.

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1)   Endorsement of NAS 3610 revision 10, TSO/ETSO/CTSO/JTSO C-90c.

3.6
fore
direction of restraint, relative to the aircraft structure, determined parallel to the aircraft centreline towards the direction of flight

3.7
aft
directions of restraint, relative to the aircraft structure, determined parallel to the aircraft centreline opposite to the direction of flight

3.8
side
direction of restraint, relative to the aircraft structure, determined perpendicular to the aircraft centreline and parallel to its floor, left-hand or right-hand

3.9
upward
upward direction relative to the aircraft structure

3.10
load factor
acceleration, expressed as a multiple of the standard acceleration of gravity ("g" = 9,806 65 m.s^{-2}), in each direction of restraint (*fore* (3.6), *aft* (3.7), *sides* (3.8), *upward* (3.9)), that will result in limit or ultimate, as is the case, forces on the *tie-down arrangement* (3.2) proportional to the mass of the piece of cargo being restrained

Note 1 to entry: The load factors are provided by Airworthiness Authority approved *Weight and Balance Manual* (3.14) for aircraft type or sub-type.

Note 2 to entry: The load factors may be limit or ultimate.

3.11
restraint strap assembly
strap
basic *tie-down* (3.1) 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 1 to entry: See ISO 16049-1 for description, design criteria and testing requirements.

3.12
tie-down fitting
basic piece of hardware, either single stud (see ISO 7166) or double stud (see ISO 9788), with an omni-directional capability, allowing to attach (a) *strap(s)* (3.11) or other elementary *tie-down* (3.1) 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 to entry: 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).

3.13
floating
<air cargo pallet or equivalent flat support device> located onto an aircraft's cargo compartment rollerized conveyor but not restrained by the cargo system, the pallet and its load constituting "non-unitized" cargo and being restrained by a set of *straps* (3.11) attached to aircraft structural points

3.14
Weight and Balance Manual
WBM
manual, or sub-part of the Airplane Flight Manual, approved by the appropriate airworthiness Authorities as part of aircraft type certification

Note 1 to entry: It may be part of the Type Certificate (TC) of the aircraft type or sub-type concerned, or of a Supplemental Type Certificate (STC) for an aircraft type's conversion or its cargo loading system. A WBM Supplement, where provided, forms part of the approved WBM.

3.15
competent person
designated person, with suitable training, qualified by knowledge and practical experience and with the necessary operating instructions established

Note 1 to entry: A competent person can be suitably trained in accordance with, for example ISO 9001:2015, 6.2.2 or another equivalent quality management standard.

Note 2 to entry: See 4.1 for the operating instructions.

4   General requirements

4.1   Operating instructions shall be established by the aircraft operator, under control of his reporting Civil Aviation Authority. The operating instructions shall identify the general airworthiness requirements and the applicable aircraft Weight and Balance Manual, and should incorporate the requirements of this document, or an 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 (NAS 3610) or ISO 21100, operating instructions shall take into account the general requirements of the appropriate ISO 8097 (NAS 3610) or ISO 21100 configuration drawing(s) as to tie-down points locations and spacings.

4.3   Actual tie-down/lashing on pallets or aircraft in accordance with these instructions shall be performed and checked exclusively by competent, suitably trained, personnel. For example, the personnel trained in accordance with ISO 9001:2015, 6.2.2 or equivalent pertinent industry training and proficiency standards (see Clause 8) is advised.

4.4   Regardless of the tie-down method used (see Clause 5), all the following general rules shall be complied with.

4.5   Tie-down shall be performed using straps designed and tested in accordance with ISO 16049-1, onto tracks or receptacles meeting the requirements of ISO 7166, and using fittings meeting the requirements of either ISO 7166 (single stud) or ISO 9788 (double stud). It is presupposed that the tie-down is approved under TSO/ETSO/CTSO/JTSO C172a.

It is presupposed that the rated ultimate strength resulting from testing of the strap model used is used for calculation of the tie-down arrangement's strength (see Clause 6), using the safety factor of 1,5 prescribed by applicable regulations, e.g. CCAR-25, JAS Part 3, 14 CFR Part 25 and CS-25, paragraph 25.303. In the event of other straps or alternate tie-down equipment (e.g. ropes, cables) being used under the operator's responsibility, the following general rules 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 must 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 onto a pallet, but shall be attached to no more than one acting in any single direction of restraint (fore, aft, side or upward). When attaching more than one strap to a ring with hooks, the hooks shall fit in the ring and line up in the applicable directions of restraint.

NOTE   Attaching more than one strap to a given structural attachment point is not allowed at certain aircraft locations: see the applicable Weight and Balance Manual.

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 the rated ultimate load capacity of its weakest attachment point, under the requirement that the strap 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   The tie-down arrangement shall prevent cargo from overturning. 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 is used, they should be evenly distributed around the centre of gravity, and the straps should be distributed as far forward and aft as possible from the centre of gravity in order to withstand the overturning moment. At least half the straps for horizontal (forward, aft and side) restraint should contact or be attached to the cargo higher than its centre of gravity.

4.12   Each strap should make a minimum possible angle, not to exceed 30 °C with the direction of restraint for which it is accounted for (see Figure 1). In practical terms, to ensure angles a_1, a_2, a_3 in Figure 1 be no more than 30 °C in relation with, respectively, directions A, B and C, it should be checked that distances d_1, d_2 and d_3, respectively, are less than half of distances D_1, D_2 and D_3.

The angles a_1, a_2, a_3 shall not be confused with a strap's floor angle and centreline angle. The floor angle and centreline angle of a strap are to be used to calculate a strap's restraint capability in each direction: see 6.2.2.
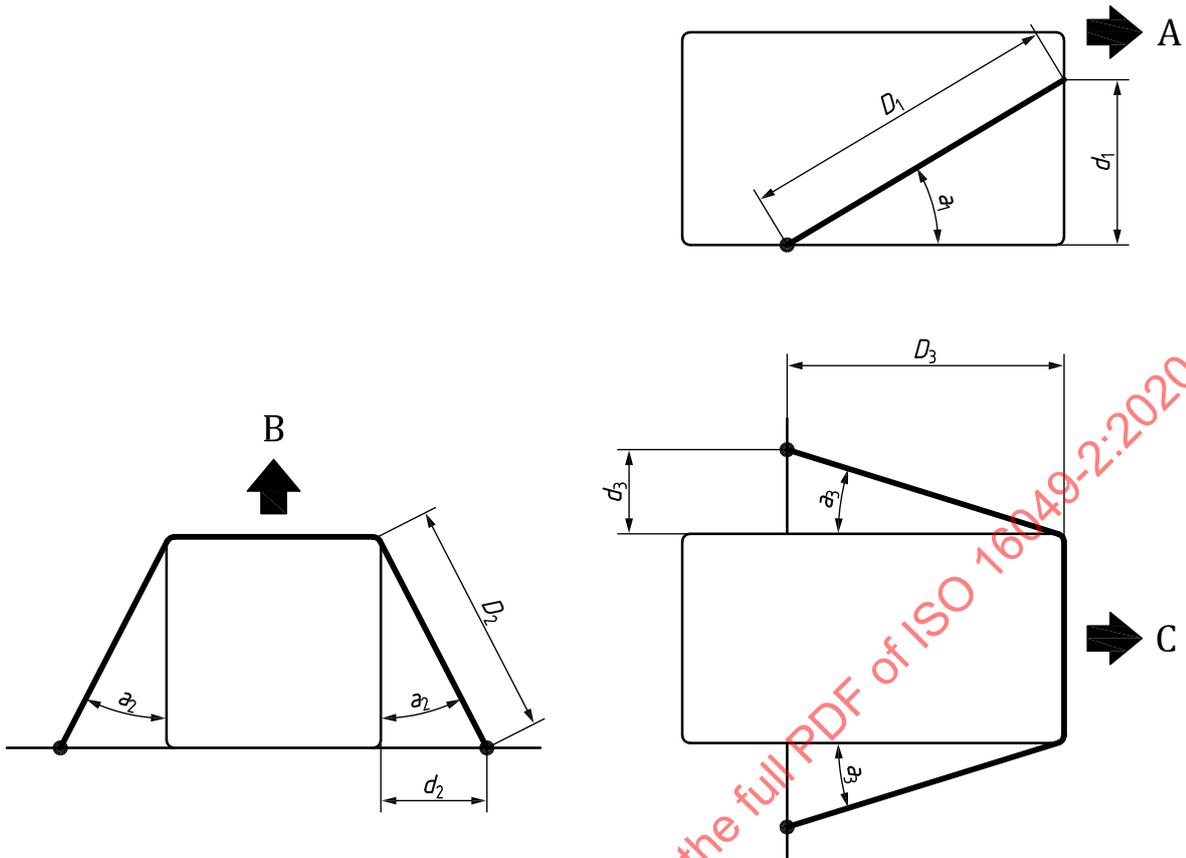
Figure 1 — Angles

4.13 A minimum distance of 0,5 m (20 in) shall be maintained on a pallet between any two tie-down attachment points (fittings) bearing straps ensuring restraint in the same direction (see examples in Figure 2).
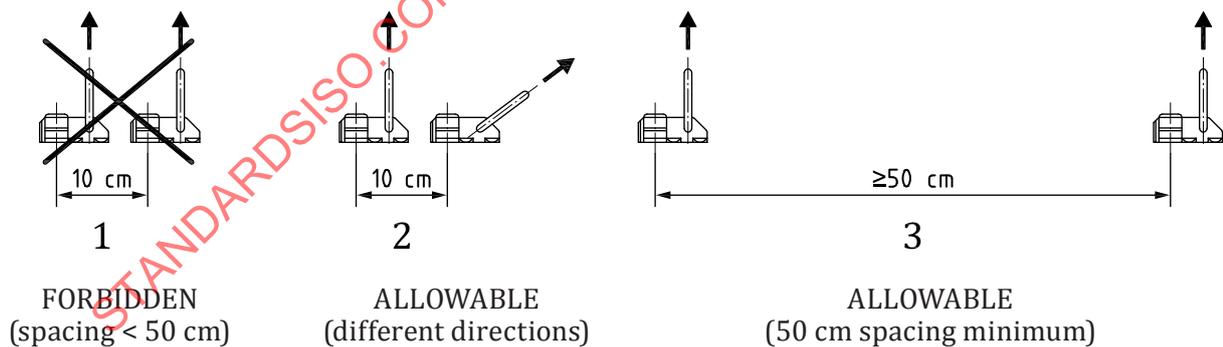
Figure 2 — Minimum distances

For this purpose, a strap shall be considered as acting in one direction if it makes a minimum possible angle, not to exceed 30 °C, with this direction. The load vector components in the other directions, resulting from this angle, may be neglected if the loads in these other directions are taken up by other dedicated straps, themselves forming a minimum angle with the direction concerned.

4.14 A minimum distance of 0,4 m (16 inch) shall be maintained between any tie-down attachment point (fitting) and an adjacent pallet corner's edge. Together with the minimum spacings specified

in 4.13, this results in limiting the maximum number of fittings which can be attached to a pallet. See Figure 3 and Table 1.
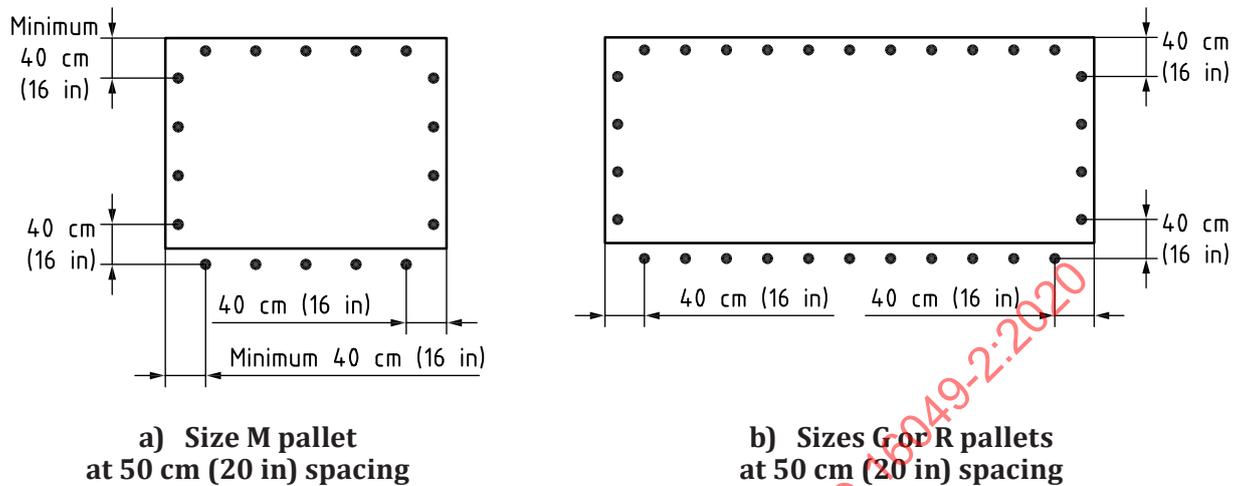

a) Size M pallet
at 50 cm (20 in) spacing

b) Sizes G or R pallets
at 50 cm (20 in) spacing

Figure 3 — Maximum pallet tie-down locations

Table 1 — Maximum pallet tie-downs number

ISO 21100 Pallet size	Small side		Long side		Total maximum fittings number
	mm (inch)	maximum fittings number	mm (inch)	maximum fittings number	
A	2 235 mm (88 inch)	4	3 175 mm (125 inch)	5	18
B	2 235 mm (88 inch)	4	2 743 mm (108 inch)	5	18
M	2 438 mm (96 inch)	4	3 175 mm (125 inch)	5	18
G	2 438 mm (96 inch)	4	6 058 mm (238.5 inch)	11	30
R	2 438 mm (96 inch)	4	4 978 mm (196 inch)	9	26

Table 1 shall not be used to determine the maximum allowable weight of cargo on a pallet based on straps ultimate restraint capability. This is determined by the detailed restraint calculations (see Clause 6), based on the aircraft's Weight and Balance Manual maximum allowable loads and limited to the maximum gross weight allowed on the pallet position concerned.

NOTE   4.13 and 4.14 apply to restraint to pallet edge track, and do not apply to direct restraint on aircraft structure: then the requirements of the Weight and Balance Manual, Weight and Balance Manual Supplement, or Cargo Loading Manual usually vary according to the attachment points concerned.

4.15   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 to all straps the residual tension defined in ISO 16049-1 usually results in complying with these requirements.

Tension can be checked by pulling across the strap; it shall not move by more than a hand's width.

For ratchet type tensioning devices (see C1 or C2 in ISO 16049-1:2020, Figure 1), there shall be a minimum of two full webbing wraps around the mandrel, cylinder, spool or equivalent once the strap is fully tensioned.

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

NOTE   Some strap types have movable sleeves of an abrasion resistant flexible material, which can slide along the webbing to be located at its points of interference with the restrained load.

4.17 Care should be taken to provide positive protection against the risk of downward sliding of any straps bearing in an horizontal direction of restraint, either by 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.

5   Tie-down method

5.1   Basic method

Cargo restraint shall be ensured by a dedicated set of straps in a given set of directions of restraint. See Figure 4.
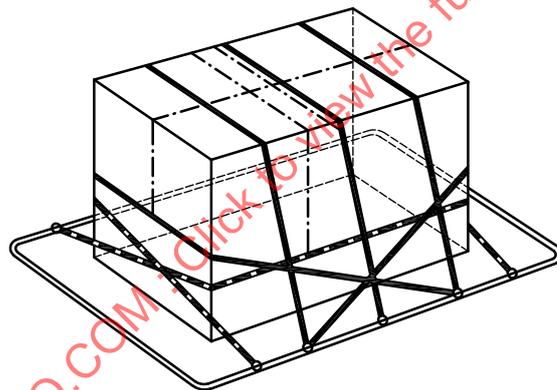
Key

—··—··—   security rope (see 4.17)

Figure 4 — Example of tie-down arrangements (see 5.2)

Where the number of straps is different in the different horizontal directions, the pallet 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.

NOTE   See Clause 7 for additional precautions applying to different special shapes of cargo.

5.2   Directions of restraint

5.2.1   Whatever method is used, restraint in each of the four required horizontal directions (forward, aft, both sides) may be ensured by either a dedicated set of straps for an individual direction, or the general effect of the straps assembly forming a tie-down arrangement, equivalent, though less deformable, to a certified pallet net, to provide multidirectional restraint. See Figure 4.

5.2.2 Upward restraint shall be ensured by a dedicated set of straps. Upward restraint straps shall be equally set on each side of the piece of cargo's centre of gravity, and distributed as far away from it as possible in order to minimise any overturning moment. See 4.11.

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 gravity ("g" = 9,806 65 m.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 $L_x = L_f$ is to 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, e.g. at cargo warehouse, 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 most current international civil transport aircraft, and may be used to perform advance tie-down:

— L_f = 1,5 g,

— L_a = 1,5 g,

— L_y = 1,5 g,

— L_z = 3,0 g.

At loading on aircraft, the actual load factors shall then be checked with the operator or crew, and additional tie-down performed if required.

The forward ultimate load factor L_f to be used shall be 9,0 g in a cabin or main deck compartment where there is no certified 9g barrier net or equivalently stressed bulkhead installed between the load and passenger(s) or crew, in order to cater for emergency landing conditions (see CCAR-25, JAS Part 3, 14 CFR Part 25 and CS-25, paragraphs 25.561 and 25.787). It pertains to operators of such aircraft to provide and implement specific 9,0 g tie-down instructions.

The upward ultimate load factor L_z to be used particularly requires check by each individual operator in establishing his tie-down operating instructions, according to the aircraft fleet he operates: some aircraft types may have certified upward load factors at certain locations up to 4,0 g.

6.2 Calculation principles

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

— the strap's own rated ultimate load (see ISO 16049-1 for determination and testing), or;

— the aircraft or pallet attachment point's rated ultimate load in the direction concerned, or;

— 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.

NOTE   Pallet track attachment points load capability with an ISO 9788 double stud tie-down fitting is 22,25 kN (5 000 lbf) when tracks testing was performed on the pallet type to demonstrate the tie-down capability requirement in ISO 21100:2017, 4.10.3.5.

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 subclause 6.2.1 above) according to the angles it forms with the reference directions of restraint. Since two angles only are necessary, for standardization of practices it is recommended to use the centreline angle (α) and floor angle (β) as defined in Figure 5.
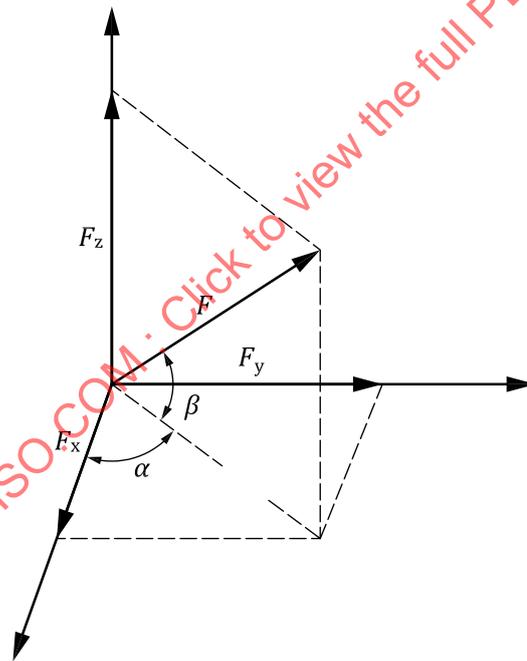
Key

F_z up component

F_y side component

F_x forward or aft component

α centreline angle

β floor angle

Figure 5 — Load components

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

— Forward or aft load: $F_x = F \times \cos(\beta) \times \cos(\alpha)$

— Side load: $F_y = F \times \cos(\beta) \times \sin(\alpha)$

— Up load: $F_z = F \times \sin(\beta)$

with $[F_x^2 + F_y^2 + F_z^2 = F^2]$

6.2.4 A strap attached between a tie-down fitting and a point of the piece of cargo shall be accounted 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 individual straps components in the direction concerned, and shall be equal to or greater than the applied ultimate load, with:

$\Omega = L \times m_T$

where

Ω is the applied ultimate load;

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

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

6.3 Practical calculation

6.3.1 Since in field practice it can be difficult 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 of:

— preformatted calculation sheets or charts, or;

— graphs or abacus methods, or;

— pre-computed tables based on general assumptions to be complied with and to be used by excess, or;

— any other method deemed appropriate, e.g. computer software.

avoiding 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. Each method shall specify the conditions and verifications (including angles measurement or evaluation) required for its use.

6.3.3 It is essential in order to avoid mistakes that any operating instructions and related charts, graphs, etc. clearly state in bold characters whether the mass figures are expressed in pounds or kilograms (kg are preferred for international application in order to further minimize the risk of mistakes). No mixing of inch-pound and metric units is allowable.

6.4 Calculation sheet

6.4.1 A tie-down calculation sheet shall be prepared when straps are used for primary restraint of cargo to a pallet or to aircraft structure. It is recommended to prepare a pre-computed tie-down

calculation sheet (see 6.3.1) that can be used by excess so that a new tie-down calculation sheet does not need to be prepared every time the same or a similar type of cargo is built up and loaded on an aircraft. A standard tie-down arrangement should be documented in a revision-controlled drawing and specify the range of cargo features (e.g., weight and dimensions) and a range of strap floor and centreline angles and tie-down locations that conform to the standard tie-down arrangement.

6.4.2   The tie-down calculation sheet can be both carrier and aircraft type specific, with pre-printed aircraft load factors. If not, the applicable load factors shall be entered from the carrier's (operator's) operating instructions, reflecting the aircraft's Weight and Balance Manual. It is recommended it includes a total tie-down arrangement schematic to allow easy identification of each strap and to show the estimated angles.

6.4.3   Distinct tie-down calculation sheet models are required for respectively:

— ensuring primary restraint onto a pallet, itself restrained in the aircraft's cargo loading system (CLS), or

— ensuring primary restraint on the aircraft structural points of a non-CLS-restrained ("floating") pallet. In this case, the sheet shall be both carrier and aircraft type specific per 6.4.2, and include schematics to allow easy identification of the aircraft structural attachment points used and their limitations.

6.4.4   The following rounded up values in Table 2 for angles sines and cosines can be used for simplification and industry standardization in pre-formatted calculation sheets:

Table 2

Strap floor angle or centreline angle	0°	15°	30°	45°	60°	75°	90°
Angle cosine	1,00	0,95	0,85	0,70	0,50	0,25	0
Angle sine	0	0,25	0,50	0,70	0,85	0,95	1,00

6.4.5   The calculation sheet shall clearly specify the force unit used, i.e. either daN or lbf (pound force). See 6.3.3. Different units shall never be used for calculations on the same flight. In order to avoid errors, it is further recommended that only one unit be used at any given airport location.

6.4.6   The tie-down calculation sheet shall be signed by the agent which prepared it and checked the numbers, then by the responsible loading supervisor who verified performance of actual tie-down, then transmitted to Load Control to be added to the flight's file.

7   Specific requirements

7.1   General

There are specific circumstances when the general principles of tie-down as laid out in Clause 4, Clause 5 and Clause 6, essentially applicable for rectangular shaped packages of a convenient size, may not be sufficient to ensure proper cargo restraint and flight safety. The resulting specific requirements for some of the commonest cases are laid out in 7.2 to 7.4 (also see ISO 16412), but there are many other potential ones: 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 these in the operating instructions, as well as identify and adequately handle any other specific situations which might render general requirements inappropriate or insufficient.

7.2 Risk of cargo slippage

7.2.1   Whenever the plan-view shape of the piece(s) of cargo to be tied down is significantly smaller than the spacing of available tie-down receptacles, there is a possibility that cargo shifts or slides during flight, within the boundaries defined by tie-down fittings. Tie-down straps used in the direction of possible shifting may not entirely guarantee against such a hazard, due to straps elasticity under load.

7.2.2   Where such shifting/slippage potential may in some respect jeopardize flight safety (e.g. take a part of the cargo out of the allowable pallet contour and bring it to interfere with the aircraft's structure, or other damaging consequence), additional steps should be taken to prevent any such damageable occurrence.

7.2.3   Such preventive steps may consist in:

— providing chocks or equivalent to increase friction in the direction concerned (see NOTE), or;

— blocking with other cargo to fill in the empty horizontal space, or;

— providing additional, well tightened, straps in excess of the minimum calculated number for the ultimate load in the direction of restraint concerned, or;

— other equivalent method or combination.

NOTE   In view of the limited static and dynamic friction factors usually achieved between cargo base area and the pallet surface, reliance on unaided friction alone is not acceptable to prevent potentially damageable consequences for the aircraft.

7.3 Risk of cargo tilting

7.3.1   Certain pieces of cargo, particularly "tall" ones the height of which is significantly more than their width, or those with a high located centre of gravity, present a significant risk of tilting down or overturning as a result of horizontal accelerations. A standard tie-down arrangement, particularly where straps are passing around or over the piece of cargo and attached on opposite sides of it, may not fully guarantee against this hazard, due to straps slippage and elasticity under load.

7.3.2   Whenever the centre of gravity height of a piece of cargo is significantly higher than its bearing base is wide, additional steps should be taken to prevent the risk of tilting or overturning.

7.3.3   Such preventive steps may consist in:

— blocking with sufficiently strong and high other cargo on all sides liable to tilting. The height of blocking cargo shall be higher than the unstable piece of cargo's centre of gravity height, or;

— providing a diagonally braced supporting stand widening the piece's bearing width to increase stability prior to tie-down, or;

— providing additional, well tightened, straps over the minimum calculated number in the directions of restraint concerned. Such straps shall bear onto the unstable piece higher than its centre of gravity, and should preferably be attached to the piece of cargo itself. If passing around it, particular care shall be taken to ensure they cannot slip down lower than this height (see 4.16), or;

— other equivalent method or combination.

7.4 Long and narrow items

7.4.1   Long items with a narrow cross-section, whether or not overhanging from the pallet, may present a tie-down hazard due to the peculiar difficulty in effectively attaching fore and aft restraint straps: e.g., (a) piece(s) of pipe should not be restrained by just inserting the strap's hook(s) into its (their) open end,