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ISO 16049-1

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Air cargo equipment — Restraint straps —

Part 1: Design criteria and testing methods

Équipement pour le fret aérien — Sangles d'arrimage —

Partie 1: Critères de conception et méthodes d'essai

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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.

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. www.iso.org/directives

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

The committee responsible for this document is ISO/TC 20, *Aircraft and space vehicles,* Subcommittee SC 9, *Air cargo and ground equipment.*

This second edition cancels and replaces the first edition (ISO 16049-1:2001), which has been technically revised.

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

This part of ISO 16049 specifies the design criteria and testing methods applicable to air cargo restraint straps to be used for tie-down of unitized or non-unitized cargo on board civil transport aircraft.

Throughout this part of ISO 16049, 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 restraint straps. Deviation from recommended criteria should only occur after careful consideration, extensive testing, and thorough service evaluation have shown alternative methods to be satisfactory.

The requirements of this part of ISO 16049 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 1: Design criteria and testing methods

1 Scope

This part of ISO 16049 specifies the design criteria and testing methods adequate to guarantee the ultimate load and operational dependability of cargo restraint strap assemblies with a typical rated ultimate tension load capability of 22 250 N (5 000 lbf), as used by the airline industry in order to restrain 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, main deck or upper deck cargo systems and meeting the requirements of ISO 8097 (NAS 3610) or ISO/PAS 21100, or

b) 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.

The same restraint strap assemblies can also be used in other applications such as:

c) non-containerized (bulk loaded) baggage and cargo compartments,

d) to ensure cargo restraint inside an airworthiness approved air cargo container.

NOTE The ultimate loads allowable on the attachment points available in most aircraft bulk compartments and inside most air cargo containers are significantly lower than 22 250 N (5 000 lbf). This results in the restraint arrangement's ultimate load capability being dictated by the weakest element, i.e. the attachment points. Typical 22 250 N ultimate load restraint straps will therefore be in excess of the requirements for such applications.

Compliance with this part of ISO 16049 provides one means of cargo restraint straps airworthiness approval by Civil Aviation Authorities under TSO / ETSO C-172, in addition to the other requirements therein.

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 4117, *Air and air/land cargo pallets — Specification and testing*

ISO 4171, *Air cargo equipment — Interline pallets*

ISO 7166, *Aircraft — Rail and stud configuration for passenger equipment and cargo restraint*

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

ISO/TR 8647, *Environmental degradation of textiles used in air cargo restraint equipment*

ISO 9788, *Air cargo equipment — Cast components of double stud fitting assembly with a load capacity of 22 250 N (5 000 lbf), for aircraft cargo restraint*

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

1) Endorsement of NAS 3610.

ISO 12118, *Air cargo equipment — Identification of double-stud tie-down fittings having an omnidirectional rated load capacity of 22 250 N (5 000 lbf) or above*

ISO 16049-2, *Air cargo equipment — Restraint straps — Part 2: Utilization guidelines and lashing conditions*

ISO/PAS 21100, *Air cargo unit load devices — Performance requirements and testing parameters*

European Aviation Safety Agency CS-25, *Certification Specifications for Large Aeroplanes*[2)]

Japanese Airworthiness Standard Part 3 (Civil Aeronautics Law Article 10 § 4)[3)]

USA Code of Federal Regulations Title 14 CFR Part 25 — *Airworthiness Standards: Transport Category Airplanes*[4)]

European Technical Standard Order (ETSO) C-172, *Cargo Restraint Strap Assemblies*

Federal Aviation Administration Technical Standard Order (TSO) C-172, *Cargo Restraint Strap Assemblies*[3)]

NOTE Also see informative references in Bibliography.

3 Terms and definitions

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

3.1
restraint strap assembly
elementary tie-down unit consisting of flat woven textile webbing (one fixed length end and one adjustable end), one tensioning device and two end fittings, used for restraint of cargo on board civil transport aircraft

3.2
tie-down
fact of restraining cargo movements in relation to an aircraft's structure, throughout the range of relative accelerations resulting from the allowable flight envelope, by means of an appropriate use of a number of elementary tie-down devices against each direction of restraint

3.3
flat woven textile webbing
conventional or shuttleless woven narrow fabric made of continuous textile fibres, generally with multiple plies, and the prime function of which is load bearing

Note 1 to entry: A characteristic of webbing is its tight woven fabric selvedge.

3.4
tensioning device
mechanical device inducing a tensile force in the load restraint assembly

EXAMPLE Ratchets, winches, over-centre buckles; see examples in Figure 1, C1 and C6.

2) EASA CS-25 constitutes the European governments transport aircraft airworthiness approval Regulations, and it, as well as ETSO C-172, can be obtained from European Aviation Safety Agency (EASA), Otto Platz 1, Postfach 101253, D-50452 Cologne, Germany, or its web site at www.easa.europa.eu.

3) Japanese Airworthiness Standard Part 3 (ISBN 4-89279-661-1) can be obtained from the Civil Aviation Bureau (CAB) of the Ministry of Land, Infrastructure and Transport, Tokyo, Japan, web site www.mlit.jp/en.

4) 14 CFR Part 25 constitutes the USA government transport aircraft airworthiness approval Regulations, and it, as well as TSO C-172, can be obtained from US Government Printing Office, Mail Stop SSOP, Washington DC 20402-9328, or its website at www.gpoaccess.gov/ecfr.

3.5
tension retaining device
metallic part connecting the webbing by clamping action and retaining the force induced in the tensioning device by hand

EXAMPLE Cam buckles, sliding bar buckles; see example in Figure 1, F.

3.6
end fitting
metallic device connecting the webbing or the tensioning device to the attachment point on the aircraft structure, the pallet edge rail or the load

Note 1 to entry: See examples in Figure 1, D1 to D6.

Note 2 to entry: The end fittings most commonly used on air cargo restraint straps include:

a) retainer equipped flat hook (see example in Figure 1, D1);

b) air cargo tie-down double stud (male) fitting conforming to ISO 9788 and ISO 12118, connected directly (sewn to the webbing; see example in Figure 1, D3) or by an intermediate ring;

c) piece of aircraft restraint (female) rail conforming to ISO 7166.

3.7
tension force indicator
device that indicates the tensile force applied to the restraint strap assembly by means of the tensioning device and movement of the load acting on the load restraint device

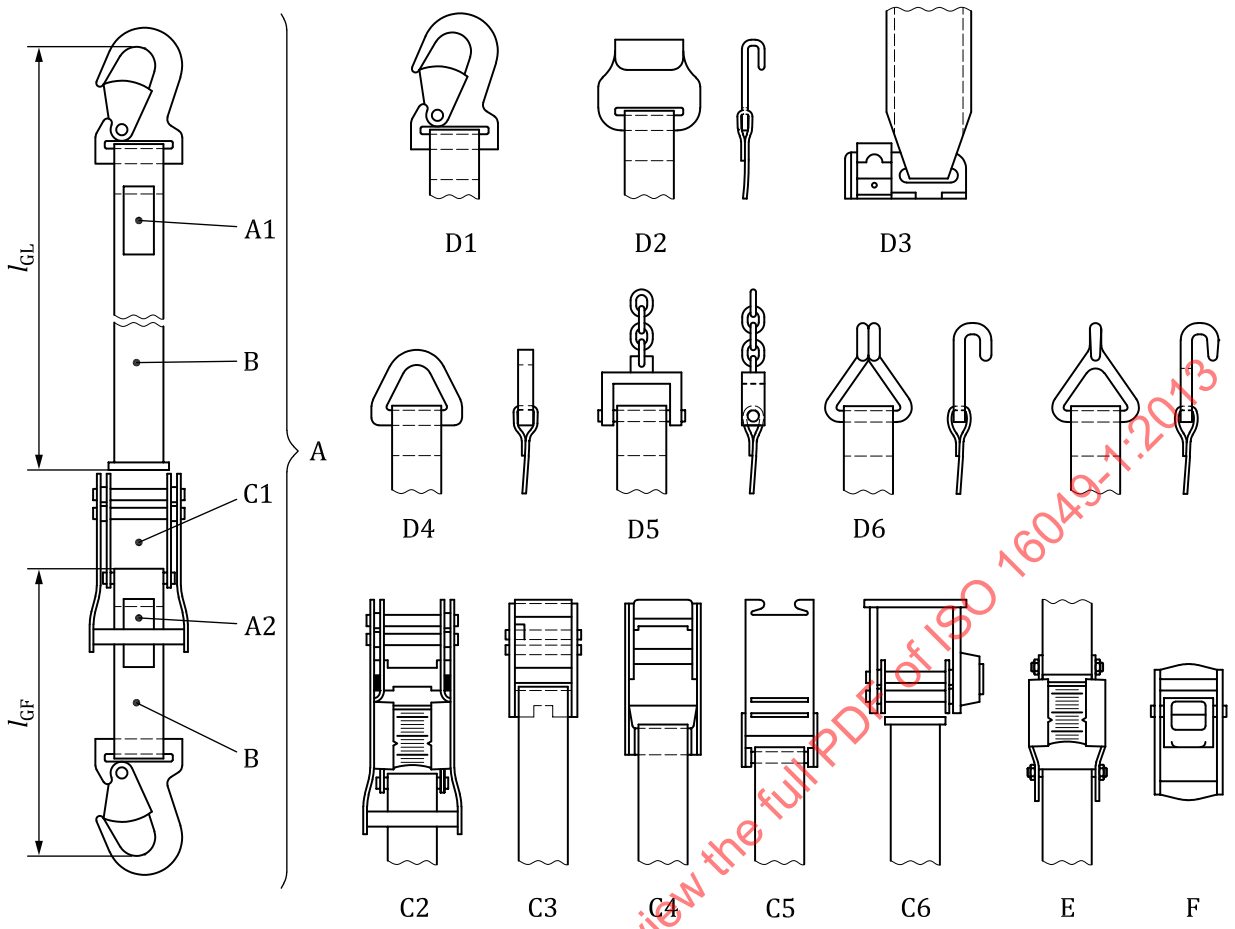
3.8
length of restraint strap assembly
3.8.1
fixed length
l_{GF}
length of a fixed end, measured from the force bearing point of the end fitting to the outer turning radius of the connection of the webbing to the tensioning device

Note 1 to entry: See Figure 2.

Note 2 to entry: This length can be zero, i.e. the end fitting directly attached to the tensioning device.

3.8.2
adjustable length
l_{GL}
length of an adjustable end, measured from the free end of the webbing to the force bearing point of the end fitting

Note 1 to entry: See Figure 2.

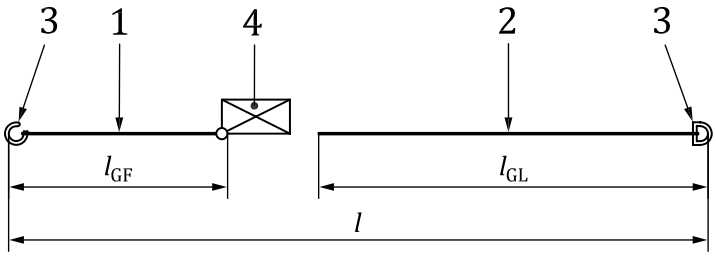


Key

A	restraint strap assembly (complete)	**D**	end fittings
A1, A2	space for marking (label)	**D1**	snap hook, flat, swivel or twisted, with retainer
B	webbing	**D2**	flat hook, with retainer
C	tensioning devices	**D3**	double stud tie-down fitting (directly sewn onto webbing)
C1	ratchet tensioner	**D4**	triangle, designed to engage with an anchorage
C2	ratchet tensioner with tension force indicator (see also E)	**D5**	connector to chain
C3	sliding bar buckle	**D6**	wire claw hook (single or double)
C4, C5	over-centre buckles	**E**	tension force indicator (see also C2)
C6	lashing winch	**F**	tension retaining device (cam buckle, sliding bar buckle)

Figure 1 — Examples of restraint strap equipment, including tensioning device C, end fitting D and tension force indicator E

3.8.3
total length
l
(l_{GF}) + (l_{GL}) + length of the tensioning device



Key

1	fixed end	3	end fitting
2	adjustable end	4	tensioning device or tension retaining device

Figure 2 — Two-piece restraint strap assembly

3.9
breaking force
BF
maximum force that the restraint strap assembly withstands when tested in a complete form, i.e. with tensioning device and end fittings, according to 5.5

3.10
hand force
HF
force applied to the handle of the tensioning device, which creates the tensile force in the restraint strap assembly

3.11
limit load
LL
maximum load to be expected in service

Note 1 to entry: See CS-25, JAS Part 3 or FAR Part 25, paragraph 25.301 (a).

Note 2 to entry: It is two thirds of the ultimate load (see hereafter), i.e. 14 827 N (3 333 lbf) for a typical rated ultimate load of 22 250 N (5 000 lbf).

3.12
ultimate load
UL
limit load multiplied by a safety factor of 1,5

Note 1 to entry: see CS-25, JAS Part 3 or FAR Part 25, paragraph 25.303.

Note 2 to entry: It is used for computation of cargo tie-down arrangements, based on the ultimate load factors defined in the Airworthiness Authorities approved Weight and Balance Manual, in each direction of restraint, throughout the certified flight envelope of the aircraft type. The restraint strap assembly's rated ultimate load is guaranteed not to exceed the measured breaking force (BF).

3.13
residual tension
tension force which can be measured in the webbing of a strap assembly attached between two fixed points, after its length was adjusted and its tension device was operated and latched with the reference hand force (HF), prior to application of any external load

3.14
competent person
designated person, with suitable training, qualified by knowledge and practical experience and with the necessary instructions to enable the required tests and examinations to be carried out

Note 1 to entry: A competent person can be suitably trained in accordance with ISO 9001:2008, 6.2.2.

3.15
traceability code
series of letters and/or numbers marked on a component or an assembly which enables its manufacturing and in-service history to be retraced, including webbing production batch identification

Note 1 to entry: See 7.2.

4 Design criteria

4.1 General

4.1.1 This part of ISO 16049 specifies the design criteria for individual restraint strap assemblies, but does not intend to specify, in any manner, the way they are to be used onboard aircraft to ensure proper restraint throughout the certified flight envelope. Tie-down arrangements shall meet all the applicable requirements of the Airworthiness Authorities approved Weight and Balance Manual for the aircraft type or sub-type concerned, particularly as regards, but not necessarily limited to, ultimate load factors to be taken into account to determine the number of straps to be used in each direction of restraint, maximum angles to be observed with the direction of restraint, minimum spacing of attachment points, etc.

4.1.2 When restraint strap assemblies are attached to the edge rails of a certified air cargo pallet meeting the requirements of ISO 8097 (NAS 3610) or ISO/PAS 21100, operating instructions should duly take into account the restraint net attachment point locations on the pallet edge rail and other requirements defined by the appropriate ISO 8097 (NAS 3610) or ISO/PAS 21100 configuration drawing(s).

4.1.3 The use of reliable and guaranteed restraint strap assemblies is necessary but not sufficient to ensure flight safety; this part of ISO 16049 is based on the assumption that straps will be used and tie-down will be performed in accordance with operating instructions established by the aircraft manufacturer, by competent, suitably trained, personnel, for example as defined in ISO 9001:2008, 6.2.2 (see Reference[4] in the Bibliography).

4.1.4 Subject to proper operating instructions as per 4.1.1 and 4.1.2 being defined and complied with, using restraint strap assemblies manufactured to an adequate design and a tested ultimate load capability is nevertheless deemed necessary in order to ensure flight safety. General utilization guidelines and calculation methods adequate to guarantee the effectiveness and ultimate load strength of the tie-down arrangements performed to restrain cargo on board civil transport aircraft can be found in ISO 16049-2.

4.1.5 The restraint strap assembly shall be designed to be used on and compatible with:

a) the edge rails of air cargo pallets meeting the requirements of ISO 4117 or ISO 4171 [airworthiness approved according to ISO 8097 (NAS 3610) or ISO/PAS 21100],

b) aircraft seat tracks or structural attachment points meeting the requirements of ISO 7166,

either directly, or using intermediate attachment hardware such as ISO 9788 double stud tie-down fittings.

4.2 Ultimate load

The breaking force (BF) of the restraint strap assembly, when tested in accordance with 5.5, shall guarantee a rated minimum ultimate tensile load to be specified at purchasing as well as through operating instructions.

The rated minimum ultimate load most commonly specified in the airline industry is 22 250 N (5 000 lbf). This is compatible with the best omni-directional performance obtainable from structural attachment points and intermediary hardware. In the interest of overall economy and world-wide standardization, users are encouraged to use this value.

NOTE An example of justified deviation is where dedicated restraint straps are designed for use with ISO 7166 single stud tie-down fittings. Then, the rated ultimate load consistent with the fitting's is 8 900 N (2 000 lbf).

4.3 Elongation

4.3.1 Care shall be taken in selecting the materials and design most appropriate for minimizing the restraint strap assembly elongation under load, in order to improve its restraint capability.

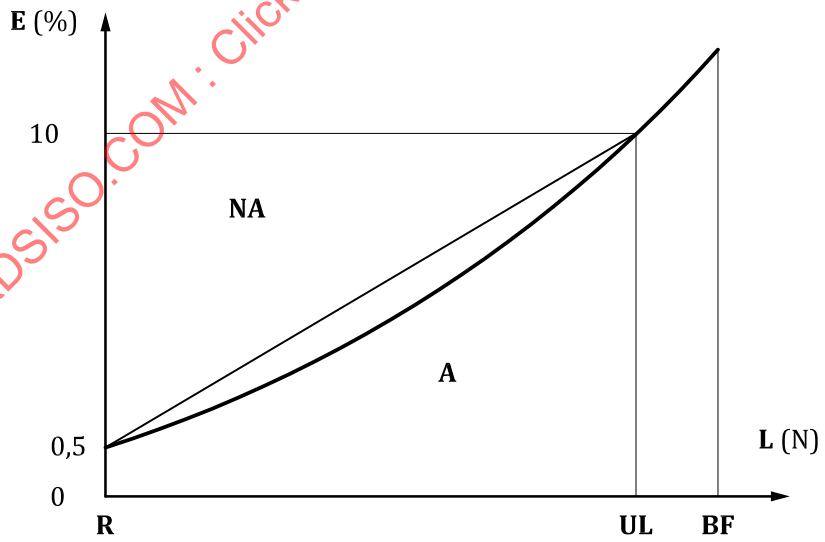
4.3.2 The total elongation of the complete restraint strap assembly under load, as measured between the force bearing point of the end fittings, i.e. the sum of webbing elongation and any longitudinal deformation of the hardware (tensioning device or end fitting), shall not exceed 10 % when submitted to the rated ultimate load (UL).

4.3.3 Webbing slippage through the tensioning device (see 4.7.5) is allowed only during pretension (i.e. while the tensioning device is being actuated and latched), and if:

a) it does not exceed 0,5 % of the maximum total length of the complete restraint strap assembly, when submitted to the residual tension force resulting from release of the tensioning device handle in the closed position, and

b) it no longer occurs under any load between zero and the rated ultimate load (UL), after the tensioning device handle has been latched.

4.3.4 The total elongation when submitted to intermediate loads shall not exceed the linear relationship between the maximum values stated in 4.3.2 and 4.3.3 (see Figure 3).



Key

E Elongation
F Tensile force
R Residual load at tension
UL Ultimate load
A Allowable area

Figure 3 — Allowable elongation range

4.4 Flammability

The webbing, as used in the restraint strap assembly, i.e. including sewing and any treatment, shall meet the flammability test criteria of CS-25, JAS Part 3 or FAR Part 25 Appendix F, Part I, paragraph (a)(1)(v); it may not have a burn rate greater than 100 mm (4,0 in) per minute when tested horizontally with the apparatus and test procedures required in Appendix F, Part I, paragraph (b)(5).

4.5 Environmental degradation

4.5.1 The available data concerning degradation of woven textile fibre performance when exposed to environment factors, as provided in ISO/TR 8647, shall be taken into account for webbing and thread selection and treatment, commensurate with the expected storage and service life of the restraint strap assembly.

4.5.2 An expiry date after which the rated performance may not be expected to be maintained shall be provided to the purchaser at or before the time of delivery of each production batch, and shall be marked on each strap as part of the required traceability code (see 7.2). The expiry date may take into account the expected storage duration, providing the strap assemblies are delivered and stored in an ultraviolet protective packaging, and any storage conditions requirements which might affect performance degradation are specified.

4.5.3 For environmental degradation assessment, it should be assumed that the restraint strap assemblies will be operated throughout temperature ranges of −40 °C (−40 °F) to 60 °C (140 °F) with relative humidity between 20 % and 85 %, including ice, snow and occasional soaking in water.

4.5.4 In addition, the strap assembly components and materials should be selected in order to allow separate recycling of the non-textile and webbing parts when the unit is out of use or after its expiry date. Instructions for recycling should be provided by the manufacturer.

4.6 Dimensions

4.6.1 **Length**: the length of the fixed end (l_{GF}) and the adjustable end (l_{GL}) shall be specified by the purchaser.

NOTE The length of the fixed end (l_{GF}) can be zero (end fitting attached directly to the tensioning device, or forming an integral part thereof). However, the use of such restraint strap assemblies is not recommended on air-land pallets meeting the requirements of ISO 4117, when equipped with vertical mounted edge rail tie-down slots, due to the risk of interference with aircraft restraint systems or an adjacent pallet during handling.

4.6.2 **Width**: the nominal width of the webbing, measured between the outer faces of selvedges, should preferably be 51 ± 1 mm (2,00 ± 0,04 in) for a strap with a 22 250 N (5 000 lbf) ultimate load rating. Width between 38 mm (1,5 in) and 63 mm (2,5 in) is acceptable for the same load rating.

4.7 Tensioning device

4.7.1 The type of tensioning or tension retaining device is to be selected on agreement between the manufacturer and the purchaser. The types most commonly used in the air cargo industry are:

a) continuous tension devices (ratchet buckles), or

b) “flat” one stroke tension devices (over-centre, sliding bar buckles).

Unless otherwise mentioned, the design criteria hereafter apply regardless of the type of device concerned.

4.7.2 The thickness of the device when in its latched position shall be kept to a minimum consistent with its design principle. The following recommended maximum thicknesses should be considered:

a) 50 mm (2,0 in) for ratchet buckles,

b) 40 mm (1,6 in) for one stroke devices.

4.7.3 The loose end of the adjustable webbing shall be protected against fraying, and positive means shall be provided to prevent it from getting free from the tension device at maximum length.

4.7.4 Tensioning devices of the "flat" one stroke types should provide, when actuated, a minimum 50 mm (2 in) tensioning length on the webbing.

4.7.5 Tensioning devices design shall aim to maximize friction coefficients in order to obtain self-blocking capability and eliminate any risk of slippage of the webbing against the device once latched, including when the webbing was soaked in water, or when submitted in flight to repeated slack (zero load)/tight cycles.

If some initial slippage is unavoidable during pretension (i.e. while the tensioning device is being actuated and latched):

a) it shall not exceed 0,5 % of the maximum total length of the complete restraint strap assembly, when submitted to the residual tension force resulting from latching the device handle in the closed position (see 4.3.3), and

b) it shall maintain the minimum tensioning length on the webbing when the device is being actuated, as per 4.7.4, and

c) no measurable slippage is allowable under any load between zero and the rated ultimate load (UL), after the tensioning device handle has been latched.

NOTE The requirement in 4.7.5 c) also applies to the length adjustment device on the adjustable length of the restraint strap assembly.

4.7.6 The tensioning device shall be equipped with a positive, self-engaging, locking system in the closed/tensioned position in order to prevent any risk of self or inadvertent release, whether or not under tension.

The design shall provide an immediate visual indication as to whether this lock is in the open or closed position.

Disengagement of the locking system shall be possible only by a deliberate hand action, without the use of tool(s), up to a strap tension of at least 20 % of the rated ultimate load. Design should aim at minimizing spring effect creating a hazard to the operator (see 4.10.4).

4.7.7 The tensioning device shall be designed so that the locking system can be engaged and a residual tension of at least 4 % and at most 10 % of the rated ultimate load can be obtained with a reference hand force (H_F) not exceeding 500 N (110 lbf) exerted onto the handle.

4.7.8 The tensioning device shall be designed so that, in the absence of any tension, it is possible by intentional action only to continuously slide the adjustable end of the webbing through it in order to lengthen or shorten the restraint strap assembly's total length (see the note to 4.7.5 in the absence of positive action).

4.8 End fittings

4.8.1 The type(s) of end fittings, which may be different at each end of the restraint strap assembly, is (are) to be selected on agreement between the manufacturer and the purchaser. See the note to 3.6 as regards the types most commonly used.

Unless otherwise mentioned, the design criteria hereafter apply regardless of the type of fitting concerned.

4.8.2 The thickness of end fittings shall be kept to a minimum consistent with their type, in order to minimize the risk of interference with aircraft cargo systems or an adjacent pallet during handling. A maximum thickness of 19 mm (0,75 in) should be considered, based on consistency with intermediate double stud tie-down fittings.

4.8.3 Flat hooks shall be equipped with a retainer preventing any risk of self or inadvertent disengagement, whether or not under tension.

Disengagement of the retainer shall be possible only by a deliberate hand action, without the use of tool(s). It may be possible to disengage the retainer only after full tension release on the restraint strap assembly.

4.8.4 Wire hooks, D rings, or equivalent shall be duly welded in order to prevent any risk of self-opening under load.

4.8.5 Two different end fittings may, at the purchaser's option, be provided on one same end of the assembly, in order to increase attachment flexibility. In this case, testing as per 5.5 shall be performed twice, using each of the fittings as the attachment point.

4.9 Webbing and sewing

4.9.1 The materials and any treatment such as heat stabilization, flame resistance, dye, anti-abrasion, stiffening, etc., used for webbing and threads shall be identified in the manufacturer's documentation for each restraint strap assembly model, together with a summary of the tested characteristics of the yarn and the woven product.

NOTE Materials mostly used in the air cargo industry include:

— polyamide (PA)

— polyester (PES)

— polypropylene (PP)

high tenacity continuous multifilament fibres. See ISO 2076 for material definition. If necessary, the contents of the constituent materials can be determined by chemical analysis according to ISO 1833.

4.9.2 All seams shall be made from thread of a Young modulus not exceeding that of the webbing and shall be made with a locking stitch. Cross-stitching or equivalent shall be used for webbing seams likely to incur all or part of the tension load.

NOTE The sewing thread can be of a different colour from that of the webbing, in order to facilitate visual inspection.

4.9.3 Consideration should be given to anti-abrasion treatment of the webbing, commensurate with the expected service life of the restraint strap assembly. See 5.10 for optional abrasion testing.

4.10 Detailed design

4.10.1 All parts or inner or outer edges of the tensioning device and the end fittings that can come into contact with the webbing under load shall be suitably rounded in order to prevent the risk of cutting. A minimum radius of 3,2 mm (0,125 in) for unmoving parts (in relation to the webbing) or 6,4 mm (0,25 in) for moving parts (in relation to which the webbing can slide) should be considered.

4.10.2 All metal parts shall be coated. Consideration should be given to anti-corrosion treatment, commensurate with the expected storage and service life of the restraint strap assembly.

4.10.3 There shall be no sharp edges, corners or protrusions which may come into contact with the webbing or the operator's hands. All such items shall be suitably chamfered.

4.10.4 The tensioning device, tension retaining device if any, and the end fittings shall be designed so as to prevent any risk of pinching, crushing or shearing which might result in the operator's hands being injured. Particular attention should be paid to preventing the risk of a spring effect when releasing the tensioning device handle to the open position under load.

5 Testing methods

5.1 Tests

The following tests shall be conducted in order to ensure that the integrity and function of the restraint strap assembly are maintained throughout the rated load range. Equivalent alternative methods (see Bibliography) may be used providing that the details of the method used are duly recorded together with the test results.

5.2 Objective

The objective of the tests is to measure the performance of the complete restraint strap assembly under load. The rated ultimate load (UL) shall not exceed the lowest recorded breaking force (BF). Additional tests for measuring the performance of the isolated webbing are optional.

5.3 Test specimens

The restraint strap assemblies shall be pre-conditioned for at least 24 h at normal room ambient temperature and humidity (approximately 20 ± 2°C and 65 ± 5 % RH) prior to conducting the tests. Three test specimens randomly selected from the same production batch shall be used for each test, and the test results recorded for each specimen.

5.4 Testing apparatus

5.4.1 Use a certified and calibrated tensile testing machine with a load measuring accuracy of 1 % or better, and a load capacity at least 25 % higher than the restraint strap assembly's rated ultimate load.

The test apparatus shall be selected in order to test a complete restraint strap assembly, including end fittings and all appurtenances, with a minimum length of l_{GF} plus length of the tensioning device plus l_{GL} of 0,5 m (20 in). Where two end fittings exist at a same end of the assembly, separate tests shall be conducted with each fitting.

5.4.2 Ensure that the machine is equipped with a load recording system (calibrated chart, dial, scale), such that the load exerted at rupture of the specimen (BF) shall remain indicated after the rupture.

5.4.3 In order to provide comparable results, the pulling clamps should have a uniform speed of 75 ± 25 mm (3,0 ± 1,0 in) per minute per 1 m (40 in) total length of the specimen being tested (see 5.7.3 for cyclic load test speed).

5.4.4 Ensure that the machine is equipped prior to the test with pulling attachments compatible with the tested restraint strap assembly's end fitting types:

a) for hook type end fittings, use 8 mm (0,3 in) maximum diameter steel wire (based on typical rings of air cargo tie-down fittings);

b) for double stud (male) fitting type, use a segment of steel track conforming to ISO 7166. The arrangement shall be such that the track can be oriented 90°, 45° or 0° to the direction of pulling;

c) for fittings consisting of a piece of aircraft restraint (female) track, use two steel studs conforming to ISO 9788, located at 25,4 mm (1 in) centres parallel to the direction of pulling.

5.5 Ultimate load test

5.5.1 Step 1: adjust the total length of the restraint strap assembly till no slack exists, action the tensioning device and latch it with an approximate reference hand force of 500 N (110 lbf) at the handle. Record the residual tension force in the strap assembly after latching the handle.

5.5.2 Step 2: start applying tension and observe the tensioning device to determine if slippage of the webbing occurs. If this is the case:

a) if slippage is measurable at any tension load on at least two of the tested specimens, the restraint strap assembly is inadequate and shall be rejected;

b) if slippage is measurable at any tension load on only one of the tested specimens (possibly defective), eliminate this one and substitute it with a new one.

5.5.3 Step 3: Increase tension to the rated limit load (LL) and hold for at least 3 s. Observe the condition of the complete restraint strap assembly.

No permanent deformation of non-textile parts or sewing rupture is allowed.

5.5.4 Step 4: Increase tension to the rated ultimate load (UL) and hold for at least 3 s. Observe the condition of the complete restraint strap assembly.

Permanent deformation of non-textile parts is allowed, unless it results in disengagement. Partial seam rupture is allowed, unless it results in more than 25 % of a given seam becoming loose.

Notwithstanding allowable partial damage, the restraint strap assembly shall keep the tension load fully for at least 3 s.

5.5.5 Step 5: Increase tension to rupture of the restraint strap assembly. Record the measured breaking force (BF) and the part(s) of the assembly which failed.

5.5.6 Testing is deemed successful if rupture occurred at a load higher than the rated ultimate load (UL), and any damage observed under the ultimate load did not exceed the allowances in 5.5.4.

5.5.7 Repeat the test for the two other specimens. Record the results. Should one of the specimens fail, i.e. exhibit a breaking force (BF) lower than the rated ultimate load (UL), then:

a) either the batch of restraint strap assemblies shall be rejected;

b) or it shall be de-rated, if acceptable to the purchaser, to an ultimate load (UL) lower than the lowest recorded breaking force.

5.5.8 If the tested restraint strap assembly includes double stud fitting type end fittings, the test procedure from 5.5.1 through 5.5.7 shall be repeated three times, reorienting the segment of steel track as per 5.4.4 b):

a) with the tension load normal (90°) to the track surface;

b) with the tension load 45° to the track surface;

c) with the tension load parallel (0°) to the track surface.

Testing in this case shall therefore require 9 specimens. Alternatively, only the 90° load test may be performed, providing the model of double stud fitting used was separately tested at 45° and 0° angles under the same ultimate load. Appreciation of test results shall be as per 5.5.7.

5.6 Elongation test

5.6.1 The elongation test shall be performed on the same specimens simultaneously with the load test.

5.6.2 After step 1, two markers shall be taken on the specimen's webbing, as far apart from each other as possible, one on each side of the tensioning device. Neither mark shall be closer than 38 mm (1,5 in) from an end fitting. The distance (L_1) between marks shall be measured with an accuracy of ± 1 mm (±0,04 in) or better.

Apply step 2.

5.6.3 Apply step 3. Measure the new distance (L_3) between marks. (L_3-L_1) provides a measurement of the elongation (i.e. sum of elastic deformations), or the actual displacement to be expected in operation.

5.6.4 Apply step 4. Measure the new distance (L_4) between marks.

5.6.5 The measured elongation (E) at step n, expressed in percentage, is provided by the equation:

$$E_n = \frac{(L_n - L_1)\times 100}{L_1}$$

5.6.6 Repeat the test for the two other specimens. Record the results. Average the values obtained for the three specimens, and round up the results to the nearest 1 %. The resulting value of E_4, shall not exceed 10 % (see 4.3.2).

5.6.7 If the tested restraint strap assembly includes double stud fitting type end fittings, thus requiring three tests at different angles, the elongation test needs only to be conducted once on each specimen, e.g. with the tension load normal (90 °) to the track surface.

5.7 Cyclic load test

5.7.1 A cyclic load test shall be performed to simulate the recurrent load cycles resulting from movements of the aircraft during flight (e.g. gust loads).

5.7.2 The test apparatus (see 5.4.1) is to apply to the complete restraint strap assembly a tension load varying between zero (slack condition) and 0,4 times the limit load (0,4 × LL), and release it. This constitutes one cycle.

5.7.3 The restraint strap assembly specimen shall be:

a) installed on the testing apparatus,

b) adjusted in length, ensuring the webbing has sufficient take-up within the tensioning device so that there is at least one full wrap of the mandrel, cylinder, spool or equivalent prior to tension device actuation and latching,

c) then initially pre-tensioned by actuating and latching the tension device to ensure proper seating of the webbing,

d) then tension shall be adjusted through the testing apparatus, to take up any webbing slippage during pre-tension of the restraint device [see 4.7.5.a)] and set the same design residual tension in accordance with 4.7.7 for all tested specimens.

For ratchet type tensioning devices, there shall be no more than two full webbing wraps of the mandrel, cylinder, spool or equivalent in the tensioned test specimen.

e) then the overall length of the pre-tensioned strap assembly shall be measured between the force bearing points of the end fittings, with an accuracy of ± 1 mm (±0,04 in),

f) then the webbing's position within the tensioning device shall be recorded by a fine ink mark measured on the tensioned adjustable part 25 mm (1,0 in) to 38 mm (1,5 in) from the edge of the tensioning device.

5.7.4 The assembly shall then be submitted to 100 cycles as defined in 5.7.2 at a frequency of 1,2 ± 0,2 Hz, ending at the same design residual tension as measured at the beginning of the test [see 5.7.3 d)].

5.7.5 After the test, the tensioned restraint strap assembly shall be retained in the test apparatus and inspected for defects. There shall be no permanent deformation or abnormal wear on non-textile components. There shall be no evidence of broken or otherwise weakened webbing strand or sewing stitches. The overall strap assembly's length, measured between the force bearing points of the end fittings with an accuracy to the nearest integer percentile, shall not have increased by more than 3 % of the length submitted to the test.

No slippage through the tensioning device shall have been recorded at any moment of the test. This shall be verified by measuring the distance between the mark performed in accordance with 5.7.3 f) and the edge of the tensioning device has not changed by more than 13 mm (0,5 in), to allow for device settling.

5.7.6 Repeat the test for the two other specimens, assuring the same webbing position mark dimension and residual tension are applied in each test. Record the results. Should one of the three test specimens fail (see 5.7.5), then the batch of restraint strap assemblies shall be rejected.

5.8 Flammability test

5.8.1 The webbing in its production condition, after any treatment, shall be tested for flammability performance in accordance with CS-25, JAS Part 3 or FAR Part 25 Appendix F, Part I, paragraph (a)(1)(v). See 4.4 for minimum performance requirements.

5.8.2 The flammability test shall be performed on a minimum of three webbing specimens, and the results averaged. The results shall be recorded in a test report to be provided to the purchaser at or before time of delivery of each production batch.

5.9 Webbing elongation test (optional)

5.9.1 In addition to the elongation test of the complete restraint strap assembly as per 5.6, a test may be conducted to measure the elongation under load of the isolated webbing.

5.9.2 The test tension loads to be used should be those specified in steps 3 to 5 of 5.5.

5.9.3 The US Federal Test Method 4108 (see Reference[13] in Bibliography) may be used for the webbing elongation test.

5.10 Webbing abrasion test (optional)

5.10.1 A webbing abrasion test may be performed, commensurate with the expected service life of the restraint strap assembly (see 4.9.3).

