SAE Aerospace
An SAE International Group

AEROSPACE RECOMMENDED PRACTICE

SAE ARP5595

Issued 2003-03

Cargo Restraint Straps - Utilization Guidelines

FOREWORD

This SAE Aerospace Recommended Practice (ARP) specifies utilization guidelines and the principles to be used in tie-down strength calculations for the use of air cargo restraint straps to perform cargo tie-down on board civil transport aircraft. It identifies the various concerns to be taken into consideration to ensure flight safety, and provides recognized industry standard methods to achieve it. It is intended as a guide toward standard practice, and is subject to change to keep pace with experience and technical advances.

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 cargo tie-down arrangements. Deviation from recommended criteria should only occur after careful consideration and thorough service evaluation have shown alternate methods to provide an equivalent level of safety.

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1. SCOPE:

1.1 Purpose:

1.1.1 This SAE Aerospace Recommended Practice (ARP) aims at providing general utilization guidelines 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 certified air cargo pallets, themselves restrained into aircraft lower deck, main deck or upper deck cargo systems meeting the requirements of NAS 3610, or

b. additional tie-down on aircraft structure when necessitated by pallet maximum gross mass or CG, or

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.

1.1.2 This document aims at providing industry recognized means of complying with Airworthiness Authorities general regulations applicable to load securing on board civil transport aircraft (see FAR Parts 25 and 121, in 2.1, Applicable Documents), 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. It shall not, under any circumstance, supersede the requirements of any of these documents, which shall take precedence at all times.

1.1.3 This document, therefore, provides recommended practical means of compliance with flight safety objectives, intended to be available as a common base for carriers as well as their airport handling agents when establishing their own in-house publications and staff training programs.

1.1.4 This document is not intended to apply to cargo restraint on board military transport aircraft, and does not take into account any specific criteria for military aircraft. Nothing, however, precludes it being used for guidelines in this case, it pertaining to the military operator to identify and implement any additional applicable criteria.

1.2 Field of Application:

1.2.1 This International Standard applies to cargo tie-down/lashing arrangements using exclusively air cargo restraint straps conforming to AS5385, Cargo Restraint Straps - Design Criteria and Testing Methods. 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.

NOTE 1: The use of chains or other rigid devices for tie-down onto civil transport aircraft floor tracks is generally not recommended, 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. Any Weight and Balance Manual restrictions shall be strictly complied with.

1.2.2 In addition, when restraint straps are attached to the edge rails of a certified air cargo pallet meeting the requirements of NAS 3610, operating instructions should take into account the general requirements of the appropriate NAS 3610 configuration drawing(s).

1.2.3 Operating instructions shall be established by the aircraft operator, under operating control of his reporting 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 the present document, or equivalent industry standard (see 2.2, Reference Documents).

1.2.4 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 9002, clause 4.18, or equivalent pertinent industry training and proficiency standards.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale PA 15096-0001.

AS5385	Cargo Restraint Straps - Design Criteria and Testing Methods
ARP5486	Air Cargo Pallets - Utilization Guidelines
AS33601	Track and Stud Fitting for Cargo Transport Aircraft, Standard Dimensions for
AS36100	Air Cargo ULDs - Performance Requirements and Test Parameters [in preparation]

2.1.2 Government Regulations: Available from U.S. Government Printg Office, M/S SSOP, Washington DC 20402.

14 CFR Part 25	Airworthiness Standards: Transport category airplanes (FAR Part 25)
14 CFR Part 121	Air carriers certification and operation (FAR Part 121)
FAA AC 120-59	Air carriers internal evaluation program

2.1.3 AIA Publications: Available from AIA, 1725 De Sales Street NW, Washington DC 20036.

NAS 3610	Cargo Unit Load Devices, Specification for

2.1.4 Airplane Manuals: Available from the relevant aircraft manufacturer(s).

Weight and Balance Manual(s) for the aircraft type(s)/sub-type(s) concerned

2.2 Reference Documents:

2.2.1 ISO Publications: Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

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 (endorsement of NAS 3610)
ISO 9002	Quality systems - Model for quality assurance in production, installation and servicing
ISO 9788	Air cargo equipment - Cast component of double stud tie-down fittings having an omnidirectional rated load capacity of 22 500 N (5 000 lbf) or above
ISO 12118	Air cargo equipment - Identification of double stud tie-down fittings having an omni-directional rated load capacity of 22 500 N (5 000 lbf) or above
ISO 16049-1	Air cargo equipment - Restraint straps - Part 1: Design criteria and testing methods
ISO 16049-2	Air cargo equipment - Restraint straps - Part 2: Utilization guidelines and lashing calculations

2.2.2 IATA Publications: Available from International Air Transport Association, 800 place Victoria, P.O. Box 113, Montreal Quebec H4Z 1M1, Canada.

ULD Technical Manual:

UTM 60/2	Cargo restraint straps

Airport Handling Manual:

AHM 670	Standardization of gravity forces against which load must be restrained
AHM 671	Securing of load
AHM 692	Ramp handling and loading procedures, training and qualifications

2.2.2 (Continued):

Other publications:

Principles of Aircraft Handling (incorporating: ULD Handling guide)

2.3 Definitions:

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.

LASHING: Equivalent to "tie-down".

TIE-DOWN ARRANGEMENT: 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. The geometric layout of such an assembly.

FLIGHT ENVELOPE: For a given aircraft type or sub-type, the 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.

LIMIT LOAD (LL): The maximum load to be expected in service as a result of the certified allowable flight envelope. See FAR Part 25, paragraph 25.301(a). It is two thirds of the ultimate load (see hereafter).

ULTIMATE LOAD (UL): The limit load multiplied by a safety factor of 1,5. See FAR Part 25, paragraph 25.303. It shall be 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.

FORE AND AFT: The directions of restraint, relative to the aircraft structure, determined parallel to the aircraft centerline towards the direction of flight, or opposed to it.

SIDES: The directions of restraint, relative to the aircraft structure, determined perpendicular to the aircraft centerline and parallel to its floor, left hand or right hand.

UPWARD: The upward direction relative to the aircraft structure.

LOAD FACTORS (limit - or ultimate -): The accelerations, expressed as multiples of the standard acceleration of gravity ("g" = 9.8065 m/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. They are provided by the Airworthiness Authority approved Weight and Balance Manual for the aircraft type or sub-type.

2.3 (Continued):

RESTRAINT STRAP ASSEMBLY: Basic 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. See AS5385 for design criteria and testing requirements.

STRAP: For the purpose of the present document, equivalent to “Restraint strap assembly”.

FITTING (tie-down -): Basic piece of hardware, either single stud (see AS33601 and ISO 7166) or double stud (see ISO 9788 and 12118), 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. 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 AS5385).

FLOATING PALLET: An air cargo pallet, or equivalent flat support device, located onto an aircraft’s cargo compartment rollerized conveyor but not restrained by the NAS 3610 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.

COMPETENT PERSON: Designated person, suitably trained according to ISO 9002 clause 4.18 or equivalent pertinent industry training and proficiency standards, qualified by knowledge and practical experience and with the necessary operating instructions established according to 1.2.3.

3. GENERAL REQUIREMENTS:

Regardless of the tie-down method used (see Section 4 hereafter), the following general rules shall be complied with:

3.1 Tie-down should be performed using straps designed and tested in accordance with AS5385, and the rated ultimate strength resulting from said testing of the strap model used shall be used for calculation of the tie-down arrangement’s strength (see Section 5 hereafter). 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.

3.2 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.

3.3 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.

3.4 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.

3.5 A single tie-down fitting may, subject to ring compatibility, be attached to up to three straps acting in different directions, but shall be attached to no more than one acting in any single direction of restraint (fore, aft, side or upward). See Figure 2.

3.6 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 is not attached to it. A strap attached to the piece of cargo may be accounted for only once.

3.7 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 center of gravity. When a higher number of upward straps is used, they shall be evenly distributed around the center of gravity.

3.8 Each strap should make a minimum possible angle, not to exceed 30°, 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 on the figure be no more than 30° 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.

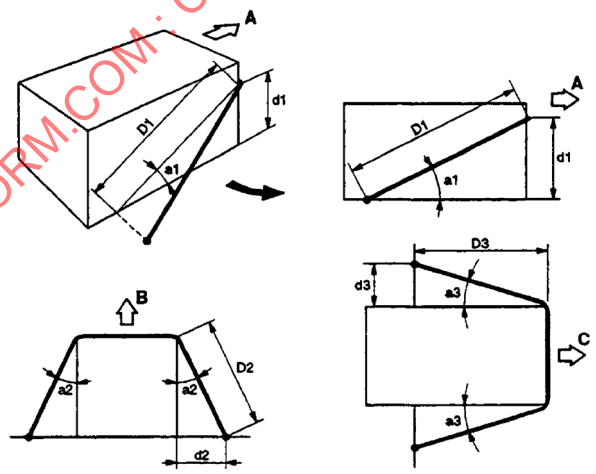
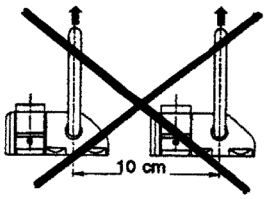
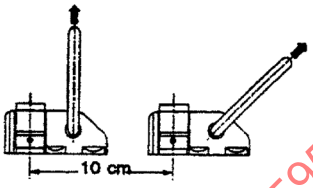


FIGURE 1

3.9 A minimum distance of 0.5 m (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).



FORBIDDEN
(50 cm / 20 in spacing **minimum**
for two straps in the same direction)



UP strap FWD strap

ALLOWABLE
(**exclusively** for straps in
different directions of restraint)

FIGURE 2

For this purpose, a strap shall be considered as acting in one direction if it makes a minimum possible angle, not to exceed 30°, 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.

3.10 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 AS5385 usually results in complying with these requirements.

3.11 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.

3.12 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.

4. TIE-DOWN METHODS:

There are several general methods for tying down a rectangular or similar shape type of cargo, as described hereafter (see Section 6 hereafter for additional precautions applying to different special shapes of cargo).

4.1 Over Top Method:

It consists in ensuring cargo restraint by a set of straps located in vertical planes, passing over the top of the load, and forming a net like arrangement to provide multidirectional restraint. See Figure 3.

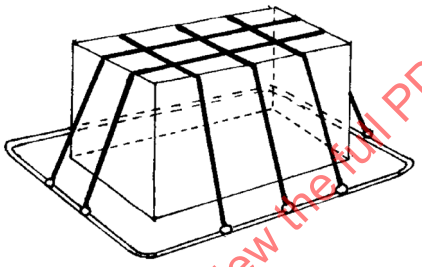


FIGURE 3 - Example of "Over Top" Tie-Down Arrangement

NOTE 2: 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 6.2 hereafter for preventive action.

4.2 Directional Method:

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

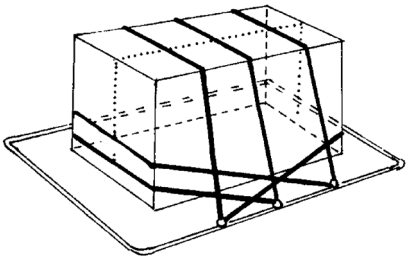


FIGURE 4 - Example of "Directional" Tie-down Arrangement

4.2 (Continued):

Requires knowledge of pallet's location in aircraft to define the forward direction. If unknown at the time of build-up, all sides shall be tied down for "forward".

4.3 Other Methods:

Most of them are combinations of the two previous methods, as illustrated in Figure 5 typical example:

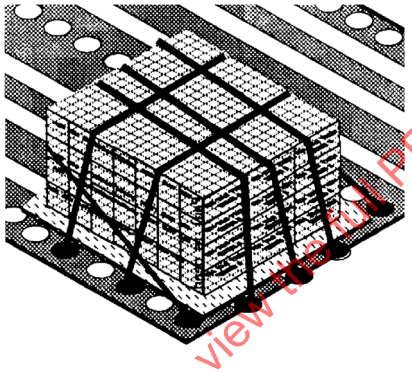


FIGURE 5 - Example of "Combination" Tie-Down Arrangement

4.4 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 multidirectional restraint: see Figures 3, 4, and 5.

5. CALCULATION METHODS:

5.1 Load Factors:

5.1.1 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" = 9.8065 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.

NOTE 3: 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 5.1.2 hereafter.

5.1.2 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 in the aircraft, the load factors certified for the actual location on board of the piece(s) of cargo concerned may be used; whenever tie-down is to be performed while the actual location on board is still undetermined (e.g., advance palletization), the highest aircraft load factor shall be used in each restraint direction.

5.1.3 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 (see NOTE 4)
- L_a = 1.5 g
- L_y = 1.5 g
- L_z = 3.0 g (see NOTE 5)

NOTE 4: The forward ultimate load factor L_f to be used shall be 9 g in a cabin or main deck compartment where there is no certified 9 g 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 25, paragraphs 25.561 and 25.787).

NOTE 5: The upward ultimate load factor L_z to be used requires check by each individual operator in establishing his tie-down operating instructions, according to the aircraft fleet he operates, due to differences with aircraft size: smaller (narrow body) aircraft may have certified upward load factors at certain locations up to 4 g, while very large capacity aircraft seldom exceed 2.1 g.

5.2 Calculation Principles:

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

- the strap's own rated ultimate load (see AS5385 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 is 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.

5.2.2 The ultimate restraint capability of the total tie-down arrangement shall be 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 5.2.1) according to the angles (a_1, a_2, a_3 as defined in Figure 1) it forms with the reference directions of restraint.

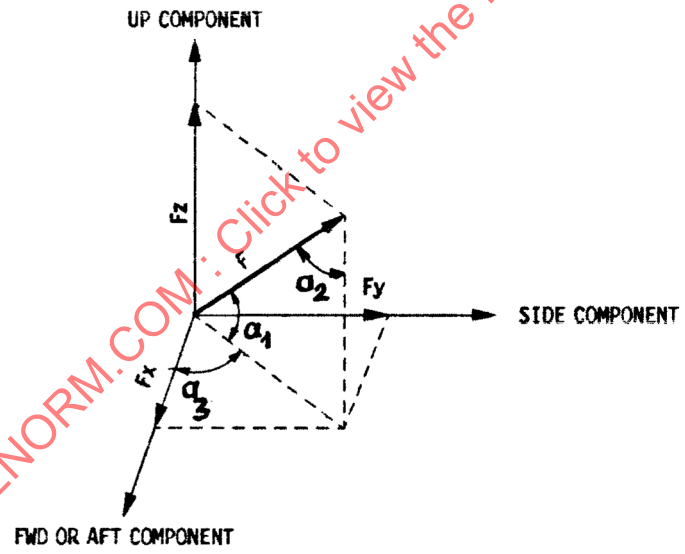


FIGURE 6

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

- Forward or aft load: $F_x = F \times \cos a_1 \times \cos a_3$
- Side load: $F_y = F \times \cos a_1 \times \sin a_3$
- Up load: $F_z = F \times \cos a_2$

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

5.2.4 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.

5.2.5 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:

[Applied ultimate load (UL) = applicable load factor (L) x total mass of cargo to be tied down],

using the ultimate load factors (L) defined for each direction in 5.1.

5.3 Practical Calculation:

5.3.1 Since in field practice it may be exceedingly difficult, lengthy 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.

5.3.2 Such operating instructions may consist in either of:

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

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 5.2.

NOTE 6: 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 (see 2.2, Reference Documents). 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.

5.3.3 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).