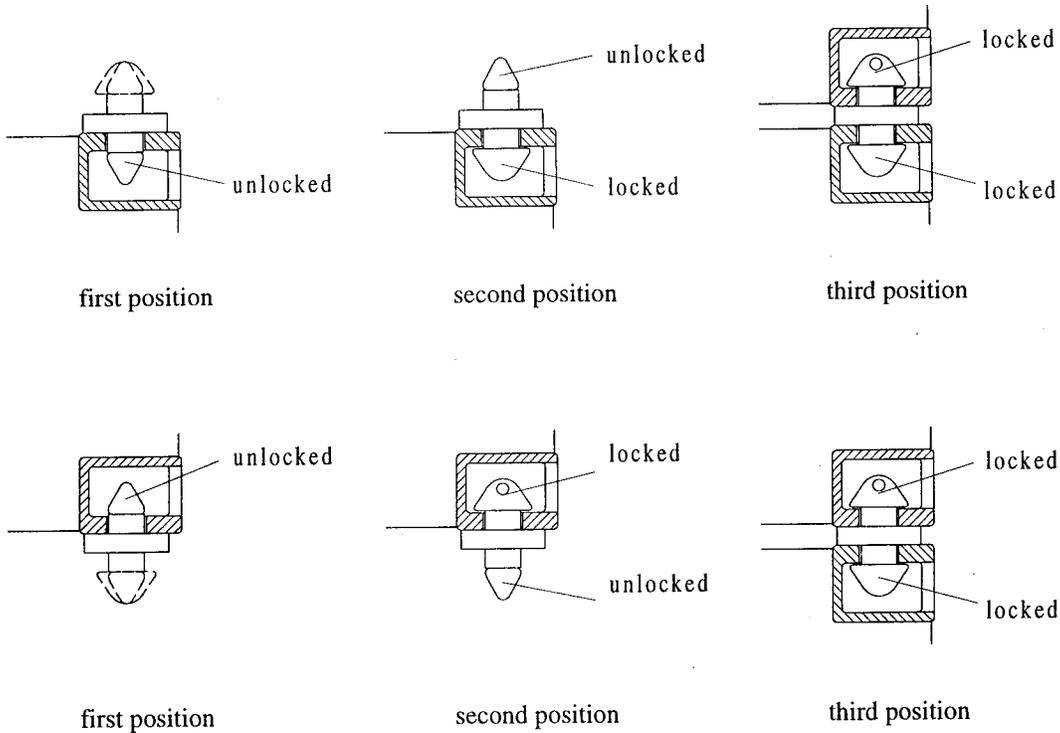




Container Lashing



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Container Lashing

CONTAINER LASHING

Abstract

The securing and lashing of containers on ship's decks is a difficult operation in terms of the work environment. There are great problems during loading and discharge of containers. The stevedores who carry out this work, known as riggers, have to work on container stacks which are often 13 meters high or more above the ship's deck. Safety arrangements are in some ports poor and the work frequently has to be performed in the dark, under windy and rainy and sometimes icy conditions.

The problems are to a large extent due to the lashing equipment. The immense diversity of the devices used gives rise to great problems.

Securing of containers is the responsibility of the ship's master (captain), which can mean that there are large differences in the manner in which the operation is effected between individual vessels and shipping companies.

Problems can also arise during sea transport and containers can be lost in the open sea.

Standardisation of this equipment is important, to avoid some of the problems. This standardisation must be carried out within the international standardisation organisation, ISO, in order to get the necessary international impact.

A standardisation project should comprise performance, design, construction, strength and use of all components used for securing of containers. Furthermore there should be clear instruction for their use.

This investigation presents commonly used equipment, proposes test methods and gives advice for dimensions, tolerances and strength requirements.

Keywords: container, cargo securing, lashing, twistlocks, turnbuckles, stacking cones, stackers, bridge fittings, lashing rods, buttresses

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TABLE OF CONTENTS

| | |
|--|-----------|
| FOREWORD | 6 |
| INTRODUCTION | 7 |
| HANDLING ROUTINES WHEN CONTAINERS ARE STACKED ON SHIP DECKS. | 7 |
| SURVEY OF PROBLEMS | 8 |
| FORCES ACTING IN THE LASHING SYSTEM DURING TRANSPORTATION AT SEA AND LOADING AND DISCHARGE IN PORTS | 9 |
| Compressive forces | 9 |
| Racking forces | 10 |
| Tensile forces | 11 |
| DIFFERENT EQUIPMENT USED FOR LASHING OF CONTAINERS | 12 |
| TWISTLOCKS | 13 |
| Manual twistlocks | 14 |
| Manual twistlocks, double-locks, two positions | 15 |
| Manual twistlocks with a fixed base and a single lock, two positions | 15 |
| Manual twistlocks, with double locks, three positions | 16 |
| Semi-automatic twistlocks | 16 |
| Latchlocks | 17 |
| Specific purpose locks | 18 |
| Dual purpose twistlocks | 19 |
| Dimensions of twistlocks | 20 |
| Intermediate plate | 20 |
| <i>Load carrying area intermediate plate</i> | 20 |
| <i>Thickness of the intermediate plate</i> | 21 |
| Top and bottom cones (locks) | 21 |
| <i>Load carrying area top and bottom cones</i> | 21 |
| <i>Height and width of top and bottom cone</i> | 23 |
| <i>Distance between top and bottom cone</i> | 24 |
| Handle | 24 |
| <i>Length of the handle</i> | 24 |
| <i>Length of the tail</i> | 25 |
| Collar | 25 |
| <i>Length of the collars</i> | 25 |
| <i>Width of the collars</i> | 26 |
| <i>Height of the collars</i> | 26 |
| Test methods for twistlocks | 27 |
| Tensile test | 27 |
| Compression test | 27 |
| <i>Compression strength of intermediate plate</i> | 27 |
| <i>Compression strength of cones (locks)</i> | 28 |
| Shear strength test | 28 |

| | |
|--|-----------|
| Test results for twistlocks and latchlocks | 28 |
| Compression test of intermediate plate and top or bottom cone. | 32 |
| <i>Compression test result</i> | 32 |
| Strength requirements of twistlocks | 35 |
| Tensile strength | 36 |
| Compression strength | 37 |
| <i>Compression strength of intermediate plate</i> | 37 |
| <i>Compression strength of cones</i> | 38 |
| Shear strength | 38 |
| | |
| STACKING CONES | 40 |
| Single stacking cone | 40 |
| Double stacking cone | 41 |
| Dimensions | 41 |
| Top and bottom collar cones | 41 |
| Intermediate plate | 41 |
| Collar cones | 41 |
| Distance between cones | 43 |
| Test methods of stacking fittings | 43 |
| Compression test | 43 |
| <i>Compression test of intermediate plate</i> | 43 |
| <i>Compression test of collar cones</i> | 44 |
| Shear strength test | 44 |
| Tensile and compression test, (Racking resistance test) | 44 |
| Test result | 45 |
| Strength requirements of stacking fittings | 45 |
| Compression strength | 45 |
| <i>Compression strength of intermediate plate</i> | 45 |
| <i>Compression strength of cones</i> | 45 |
| Shear strength | 45 |
| Tensile and compression strength of double stacking fitting | 46 |
| | |
| LASHING RODS | 47 |
| Dimensions of lashing rods | 48 |
| Top end of lashing rod or securing pad | 48 |
| Bottom end of lashing rod | 49 |
| Other parts of lashing rods | 49 |
| Test methods of lashing rods | 50 |
| Tensile test | 50 |
| Test result of lashing rods | 51 |
| Strength requirements of lashing rods | 51 |
| Tensile strength | 51 |
| | |
| TENSIONING DEVICE, TURNBUCKLES | 52 |
| Dimensions | 52 |
| Test methods | 52 |
| Tensile test of tensioning device | 52 |
| <i>Pre-tension ability</i> | 52 |
| <i>Tensile test</i> | 53 |
| Test results | 53 |
| Strength requirements | 53 |
| Tensile strength | 53 |
| Pretension ability | 54 |

| | |
|------------------------------|-----------|
| BRIDGE FITTINGS | 55 |
| Dimensions | 55 |
| Test methods | 55 |
| Tensile test | 55 |
| Compression test | 56 |
| Strength requirements | 56 |
| Tensile strength | 56 |
| | |
| BUTTRESSES | 57 |
| Dimensions | 57 |
| Test methods | 58 |
| Tensile and compression test | 58 |
| Strength requirements | 58 |
| | |
| MARKING | 59 |
| | |
| REFERENCES | 60 |
| | |
| APPENDIX 1 | 61 |

Foreword

This project was initiated by the Swedish Standards Institute **SMS** and is financially supported by the **Swedish Council For Work Life Research**, (formerly the Swedish Occupational Environment Found). Their support is gratefully acknowledged. The financial resources made available for this study have to a great extent contributed to increased safety in the future handling and securing of containers in both road and sea transport. International standards concerning safe lashing equipment and safe handling of it have been developed with this study as a base.

The members of the **ISO** standardisation working group ISO/TC 104/SC1/WG2 have been acting as a reference group for this report. The participants in the working group have been:

| | |
|--------------------|--|
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The support from the group has been of greatest importance and is gratefully acknowledged.

Introduction

Much cargo damage occurs because of substandard cargo securing methods and equipment. The ISO containers, which are in widespread use today, occasionally cannot meet the transportation stresses, because the securing means fail or are missing. This problem persists, despite that established practice for securing the containers has been developed during a long time. This also increases the risk for the workers in the ports. During loading and discharge unnecessary risks are taken because of inadequate securing equipment. Container losses in open sea can also mean very large environmental risks.

Initially this report presents a survey of existing lashing equipment and a summary of handling routines and problems. Equipment like for instance steel wires and chains are not included in this report. The reason for this is that according to the author's opinion, this type of equipment is insufficient for lashing of containers and should therefore not be used.

Existing knowledge of the forces acting in container stacks during sea transport is presented. Strength and functional requirements together with test methods are proposed. Results from tests and measurements carried out at the Swedish National Testing and Research Institute are reported.

Cell guides, lashing points on ship decks and similar fastening devices are parts of the ship's structure and are therefore not dealt with in this report.

Handling routines when containers are stacked on ship decks.

Combinations of lashing equipment are used to secure containers to ship decks. The equipment often consists of twistlocks used in combination with turnbuckles, rods, stacking cones and bridge fittings. How they are combined and used varies between ships, depending greatly on what procedures the ship's master prefers.

On a container ship deck, the containers are often stacked five tiers high and sometimes even higher. There are ships that stack seven tiers. The two or three lowest tiers are often positioned on stacking cones and secured to the deck by means of turnbuckles connected with diagonal lashing rods. In a case with five containers high the two or three top tiers are often secured only with twistlocks, sometimes supplemented with bridge fittings, see figure 1 and 2.

When loading containers on ship decks, the riggers place the first tier on stacking cones or twistlocks fitted into fittings in the deck of the ship. Before loading the next tier they place stacking cones or twistlocks into the top corner fittings of the containers in the first tier. This will then be repeated for each tier. The lashing equipment and the riggers are transported up onto the containers and when the crane lowers the next tier of containers, the riggers make sure that it is positioned correctly on top of the stacking cones or the twistlocks. By means of long rods the twistlocks are locked by turning their handles or other activating devices.

Semi-automatic twistlocks are today more and more used and they lock automatically when a container is lowered onto them.

The stack is finally secured by means of diagonal lashing rods with tensioning devices, normally turnbuckles. The lashing rods are often attached to the bottom corner fittings of the containers in the second and third tier, in the case of five in height, and the tensioning devices to lashing points in the ship deck, see figure 1 and 2. Other methods exist, for example parallel lashing where the lashing rods are attached to the top corner

fitting in one tier and the bottom corner fitting in the next. By use of the tensioning devices a pretension is set in the lashing rods, which holds the stack down and in contact with the ship's deck.

In some ports the twistlocks are fastened to the bottom corner fittings of the container to be loaded, before it is lifted onboard and stacked on top of another container. In other ports this can be banned because of the risk that a twistlock is dropped down during lifting. If the twistlocks are attached manually the riggers are standing under a hanging load which is not acceptable in some ports.

Conversely, when discharging, the riggers unlock the twistlocks and remove other lashing equipment before lifting of the containers can start. The spreader of the crane normally has guiding equipment, which allows lifting of the container in the top corner fittings without assistance from the riggers. The lashing equipment is usually brought down by the crane but it may occasionally be thrown down.

Bad weather conditions often prevail when containers are to be handled and secured. It must be taken into account that riggers often are exposed to risks, while working in rain, heavy wind and darkness.

Survey of problems

Some of the problems occurring in the ports during handling of containers are described in the SP Technical Report, Twistlocks 1989:53. The report is based on interviews with manufactures of lashing equipment, shipping companies, masters and port employees.

Problems with mixed equipment were highlighted, and especially twistlocks with different locking direction onboard a ship which can create danger. On such a ship, when riggers have locked all twistlocks, a crew member may afterwards hit all handles into the same direction, and thus unlock several twistlocks. During discharge of such a ship one of the twistlocks may be closed, when the crane is lifting a container. This can create a dangerous situation because the container corner fitting and the twistlock will be deformed, and the container will be hanging from the crane attached to the stack with the deformed twistlock, which will not open. Riggers must climb the stack and with tools or jet burners cut the twistlock.

If it is possible to place twistlocks upside down, they will lock in an opposite direction giving the same result as twistlocks with different locking directions.

If manual twistlocks lack a distinct stop in their different positions, they might still be "almost" locked when the handle indicates open position.

A problem related to semi-automatic twistlocks is if a container is unevenly put down and only gets one corner in place. The semi-automatic twistlock then locks, and the container is fixed. The crane becomes blocked, and the semi-automatic twistlock must be manually released.

If some semi-automatic twistlocks are unlocked by mistake, they can not be locked again without discharging the containers.

Low quality lashing equipment sometimes creates problems, because of bad tolerances and too small contact surfaces, which may damage the corner fittings.

Regarding the strength of the equipment used today most people are of the opinion that the strength is sufficient for the stresses that the equipment is subjected to at sea. It may, however, break during handling in ports. Also transport on larger ships with

higher stacks may increase the stresses. Equipment is sometimes thrown down onto the deck from the top of the stack, and this may result in deformations and pieces coming off.

Turnbuckles are used to apply a pre-tension force in the lashing rods. This resulting force depends on how long levers and how much manpower that are used. It is of interest to know the value of this force in order to avoid overtightening of the lashing system.

There is a need for a robust design of the lashing equipment but at the same time it must be of light weight because of the manual handling.

If equipment is properly applied and maintained onboard ships lots of problems would be solved. Container lashing manuals are recommended.

One thing asked for by several of the interviewed people was standardisation of all equipment used for securing of containers.

Forces acting in the lashing system during transportation at sea and loading and discharge in ports

Compressive forces

Compressive forces occur in the corner fittings as a consequence of stacking, plus the dynamic forces added during sea transportation as a result of roll, heave and pitch.

During loading in ports normally only the two or three upper tiers of the containers are secured by twistlocks only. This means that rather low forces are normally exerted on those twistlocks during loading. If a stacking fitting or a twistlock is used in the bottom of a stack, five high, the maximum load on it is $g \times 5 \times 30/4$ metric tons = 375 kN. If the container is warped, or when twistlocks with different thickness are used (which should be prevented) the load may be higher at single corners. If the container is loaded eccentrically the stresses increase. Dynamic inertia forces will be added during loading.

The dynamic effects of the sea transport must also be added to the 375 kN.

Looking at the strength of the container corner fittings as a guide for the compression forces one finds in the ISO 1161 standard "Corner Fittings - Specification" the design requirements for the corner fittings. The design load for the bottom corner fitting on the lowest container, resting on a flat support in a stack five high, is 810 kN. The next lowest container sits on the top corners of the lowest one, which means smaller surfaces if they are displaced relative to each other. The design load is here 680 kN on top corner fittings.

In ISO 1496 "Specification and Testing" it is required that a 40 foot container shall be loaded to a combined mass of $1.8 R = 54\ 864$ kg $\Rightarrow 13\ 716$ kg per corner fitting. The container is then submitted to a stacking force of $3\ 392$ kN = 848 kN per corner fitting. During this test the bottom corner fitting is submitted to a force of 980 kN and the top corner fitting is loaded with an offset load. The bottom corner fitting shall rest on a flat support.

The force, or resultant of any combination of forces, normally defined as racking forces, imparted on the aperture in the end of a corner fitting as a result of a lashing or securing device is in ISO 1161 assumed not to exceed the value 300 kN vertically and 150 kN horizontally.

There are today ships that stack containers, with twistlocks, seven high on deck. In the future containers will be stacked even higher in cell guides. This does not normally influence the twistlocks, but in combination ships built to carry different commodities, such as Container—Bulk, the containers are loaded internally in stacks locked by twistlocks and laterally supported by buttresses, see page 57. Here very high compressive forces may occur and if the twistlocks would be deformed the cargo could only be discharged with great difficulties, because the twistlocks can normally not be opened after deformation (compression). Those stacking/racking systems, which are not recommended by ISO, probably need special designing to keep the imposed forces within limits.

It should be discussed whether a twistlock shall be stronger than the ISO corner fitting or not, concerning compressive forces. According to the author's opinion they should be at least equally strong because of the difficulties that arise when the twistlocks are jammed between two container corner fittings.

At loading, inertia forces can (when containers are stacked on top of each other) give considerably higher dynamic short time factors than at sea movement.

A lot of investigation and calculations concerning forces acting in the lashing system have been carried out. The classification societies, American Bureau of Shipping, ABS, Bureau Veritas, BV, Det norske Veritas, DnV, Germanischer Lloyd, GL and Lloyd's Register of Shipping, LR, have long been investigating these issues. Their calculated values for permissible compressive forces are presented in table 1.

Table 1. Permissible compressive forces according to classification societies.

| ABS | BV | DnV | GL | LR |
|--------|--------|--------|----|--------|
| 810 kN | 810 kN | 810 kN | - | 810 kN |

If non-ISO containers tested to a higher strength standard is considered those values are increased.

Racking forces

Racking forces act in horizontal directions, because of wind, breaking green seas and ship movements, such as roll and sway.

It is therefore recommended that the holes of the corner top/bottom fittings are filled as much as possible by the collars of twistlocks or stacking fittings in order to prevent movement in the stacks in the horizontal direction. The collars must have dimensions that will fit into the corner fittings of all containers considering also the tolerances of containers described in ISO 668 Annex A, table A.1 and Figure A.1.

If the collars of the twistlocks fully fill the top and bottom holes of the corner fittings, they will withstand larger shear forces because small play gives less movement and therefore lower forces. Testing requirements can, in the view of the author, perhaps be regarded as unnecessary, provided that materials and dimensions of the collars are standardised with tolerances to the corner fitting. This would be preferable, because a shear (racking) test of this kind with high loads is very complicated to carry out. If common corner fittings are used for the testing, they may be deformed before the col-

lars. If harder materials in the corner fittings are chosen, a higher hole edge pressure will give an unrealistic test. A test load of only 300 kN is of course not very difficult to perform.

Racking forces (shear forces) occur in connection with tensile and compressive forces.

In ISO 1161 "Corner Fittings - Specification" and ISO 1496-1 "Specification and Testing part 1" it is stated that the bottom corner fittings shall withstand a design load (longitudinal restraint) of 300 kN.

In ISO 1496 "Specification and Testing" it is required that a container shall be subjected to and withstand a transverse rigidity test of 150 kN.

The calculated permissible forces, in both longitudinal and transverse direction, from the classification societies are presented in table 2 and 3.

Table 2. Permissible racking forces, longitudinal direction, according to classification societies.

| ABS | BV | DnV | GL | LR |
|--------|----|-----|--------|----|
| 300 kN | - | - | 300 kN | - |

Table 3. Permissible racking forces, transverse direction, according to classification societies.

| ABS | BV | DnV | GL | LR |
|--------|--------|--------|--------|--------|
| 350 kN | 400 kN | 350 kN | 400 kN | 500 kN |

If non-ISO containers tested to a higher strength standard are considered, these values are increased.

As is evident from above there are discrepancies between the test loads in the ISO standards and the rules from the classification societies.

Tensile forces

Tensile forces appear not only at lifting but also during roll and sway at sea, wind load and boarding green seas. Breaking green seas are supposed to give the largest stresses. One must consider whether the twistlocks must be able to withstand boarding breaking seas.

If containers, during sea transport, have been subjected to the stresses induced by breaking green seas, and if those impacts have created loads exceeding 400 kN, residual deformation would have been noticed more often on corner fittings of containers coming to port after stormy voyages. This conclusion is based on the fact that the ISO corner fittings used for the static tensile test of twistlocks have been proved to be very strong. They have started to deform at a load of about 400 kN in the twistlocks, if the twistlocks have had a sufficient load carrying area. Deformations of this kind have not been verified, according to the interviews carried out in an earlier investigation. Maybe the reason is that a boarding sea very rarely reaches the top tiers in a container ship with a deck load stacked four or five tiers high or that the forces are not so high as could be expected.

The design requirements in ISO 1161 "Corner Fittings - Specification" and ISO 1496 "Specification and Testing" is that the top corner fittings shall withstand a vertical load of 150 kN.

The calculated permissible tensile forces from the classification societies are presented in the following table.

Table 4. Permissible tensile forces according to classification societies.

| ABS | BV | DnV | GL | LR |
|--------|--------|--------|--------|--------|
| 200 kN |

If non ISO containers tested to a higher strength standard are considered, those values are increased to 250 kN.

Different equipment used for lashing of containers

In figure 1 typical examples of lashing equipment used on a small or medium sized container ship are shown. In figure 2 examples are given from a large container ship with lashing bridge on deck and cell guides in hold. The different types of equipment and their functions and locations are shown.

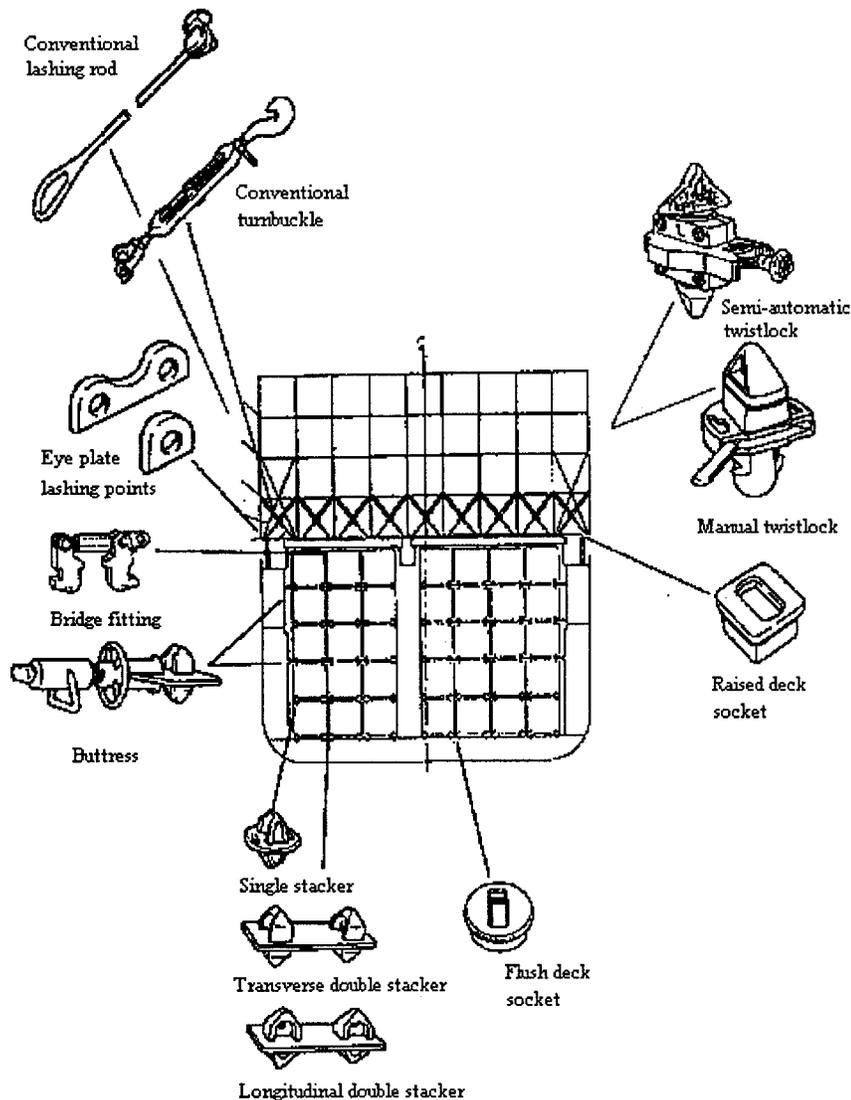


Figure 1. Typical examples of lashing equipment on a small or medium sized container ship

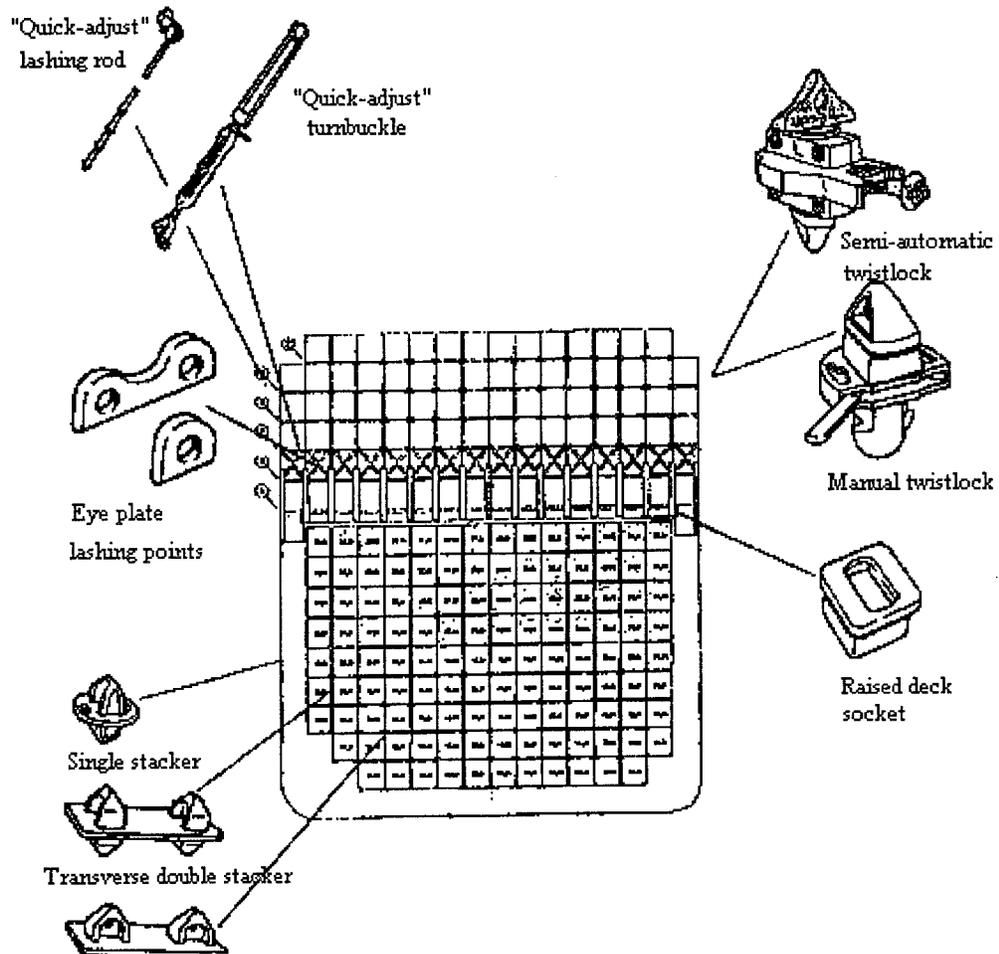


Figure 2. Typical examples of lashing equipment from a large container ship with lashing bridge on deck and cell guides in hold

Twistlocks

Twistlocks and latchlocks locate and secure containers either to each other, within a stack, or to the transport mode. They act through the container corner fittings. Twistlocks can be used together with other securing and lashing devices.

Latchlocks are another type but with similar function. The main difference is that latchlocks only lock on one side of the top/bottom aperture in the container corner fitting.

The top and bottom cones of the twistlock restrain connected containers against vertical movements and the collars restrain connected containers against horizontal movements.

There should be an eyehole in the top cone to identify the top cone and facilitate the handling of the twistlock. A practical solution can also be to let an up-bent tail of the handle, on a manual twistlock, identify the vertical orientation of the twistlock in a container stack.

The handle or the triggering device allows rotation of the shaft and therefore the locking and unlocking of the twistlock. The twistlock must have a positive locking mecha-

nism to ensure that it will not be accidentally dislodged out of the corner fitting, during loading and discharge of containers.

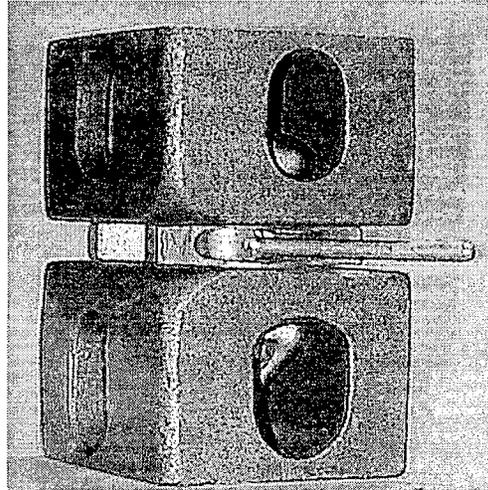


Figure 3. Twistlock fitted between top and bottom corner fittings.

In the text the following definitions are used:

collar: a part of a twistlock which fits into a corner fitting and restrains connected containers from horizontal movement

eyehole: a hole in the top cone of a twistlock

handle tail: an up-bent part of the handle

fixed base: a rigid part of a collar which allows manual pre-locking of the bottom part of a twistlock

triggering device: a hand-operated device which sets a twistlock

intermediate plate: a part of a twistlock that carries the compression force between stacked containers

single purpose twistlock: a twistlock of asymmetrical design complying with the standard orientation. It can be used only in one of the two following alternatives:

- only in the top corner fitting of the container on which another container will be stacked (alternative A).
- only in the bottom corner fitting of a container, which is going to be stacked on top of another container (alternative B)

double twistlock: a twistlock fitted with both top and bottom cone

dual purpose twistlock: a twistlock that, having the same orientation, can be pre-locked either in a top corner fitting or in a bottom corner fitting

single lock: a twistlock with locking function either in top or bottom cone only

double lock: a twistlock with locking function in both top and bottom cones

Manual twistlocks

A manual twistlock shall be oriented so that the cone with an eyehole is pointing upwards.

The handles shall always work in the horizontal plane and be fitted with a tail which shall be pointing upwards.

The unified direction of handle locking shall be *clockwise*, seen from above, to ensure safe locking.

All manual twistlocks with three defined positions shall have a positive locking mechanism which insures that the twistlock will not be dislodged out of the corner fitting during loading and unloading of containers.

The performance and reliability of twistlocks are functions of design and choice of material. Springs holding the handle in position shall be designed so that their function does not cease because of stress, corrosion and dirt. For safety reasons it is also important that there are distinct stop positions.

Manual twistlocks, double-locks, two positions

Manual twistlocks, double-locks, two positions, are regarded as an old type of equipment which gives an unsafe practice. They are still in use and are therefore presented here. They consist of:

- a top cone with an eyehole and a bottom cone rigidly connected together by a shaft.
- an intermediate plate with collars.
- a handle with a tail pointing upwards attached to the shaft.
- the handle travels in the horizontal plane and is limited by two end stops: fully closed or fully open, see figure 4.

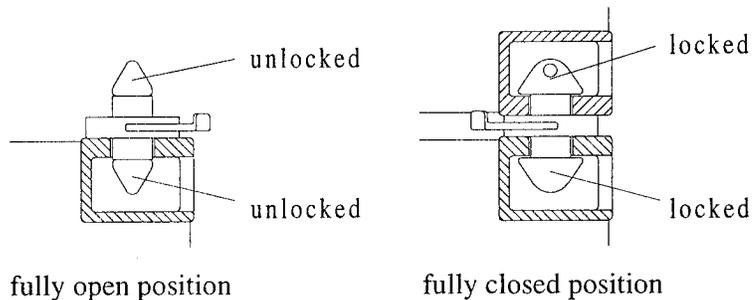


Figure 4. Manual twistlock, with double-locks, two positions

Manual twistlocks with a fixed base and a single lock, two positions

A manual twistlock with a fixed base consists of:

- a top cone with an eyehole which can be rotated in relation to a fixed base.
- an intermediate plate with collars and a fixed base.
- a handle with a tail pointing upwards, attached to the shaft.
- the handle moves in the horizontal plane and has two end positions: one end fully closed and one end fully open, see figure 5.

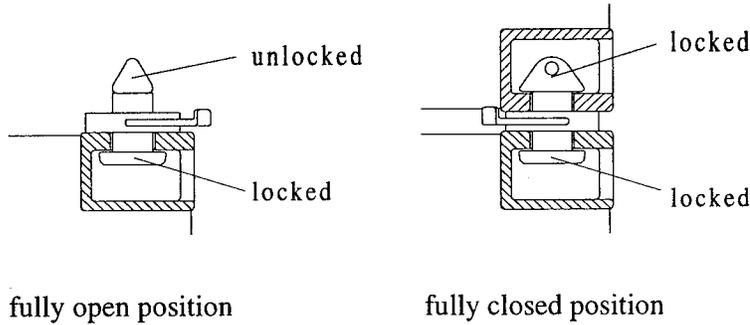


Figure 5. Manual twistlock with a fixed base and a single lock, two positions

Manual twistlocks, with double locks, three positions

A manual twistlock with double locks, three positions consists of:

- a top cone with an eyehole and a bottom cone rigidly connected together by a shaft.
- an intermediate plate with collars.
- a handle with a tail pointing upwards.
- the handle moves in the horizontal plane and has three positions;

first position: bottom cone fully open in order to engage the twistlock to the top corner fitting, see fig 6.

second position: top cone fully open and bottom cone closed in order to secure the twistlock to the top corner fitting and engage the twistlock to the bottom corner fitting of the next container, see fig 6.

third position; both top and bottom cones fully closed, see fig 6.

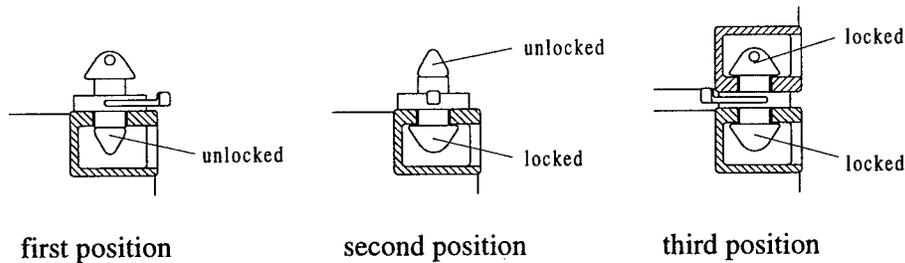


Figure 6 Manual twistlock with double locks, three positions, pre-mounted to the top corner fitting.

Semi-automatic twistlocks

Semi-automatic twistlocks consist of:

- a top cone with an eyehole and a bottom cone connected by a mechanism
- an intermediate plate with collars
- an internal mechanism automatically closing the cones when a container is landed either onto the twistlock, see fig 7, or fitted to the bottom corner fitting of a container, see fig 8
- a device for unlocking the twistlock

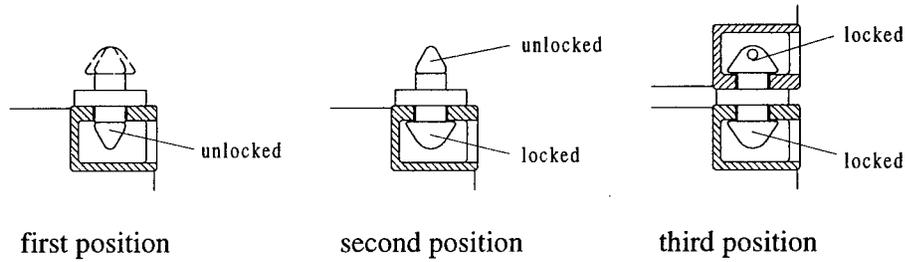


Figure 7 Semi-automatic twistlock, fitted to the upper corner fitting.

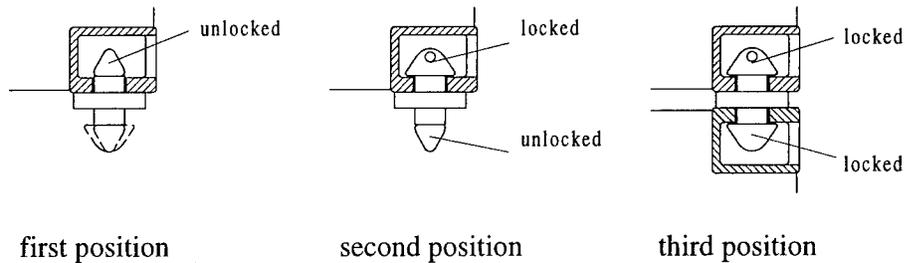


Figure 8. Semi-automatic twistlock, fitted to the bottom corner fitting.

Semi-automatic twistlocks (sometimes referred to as automatic twistlocks) shall be oriented so that the cone with an eyehole is pointing upwards. They shall be fitted with a device that clearly indicates the closing of both cones.

For semi-automatic twistlocks fitted with a handle, working in a horizontal plane, the handle shall be fitted with a tail pointing upwards and closing of the cones shall be indicated by the handle in its left position.

For semi-automatic twistlocks fitted with a pull wire, the closing of the cones shall be indicated by the full retraction of the wire.

For semi-automatic twistlocks fitted with other triggering devices the closing of the cones shall be shown by an indicator designed to ensure consistency with the requirements expressed above.

A semi-automatic twistlock shall have a positive locking mechanism which ensures that the twistlock will not be dislodged out of the corner fitting during loading and unloading of containers.

A semi-automatic twistlock is a twistlock that locks automatically when containers are loaded in a stack, but needs a manual operation to be fitted to either the top or bottom corner fitting of a container before stacking. A manual operation is also needed when unlocking semi-automatic twistlocks. They can be of either single or dual purpose.

Latchlocks

A latchlock is a type of semi automatic twistlock which consists of a top cone with an eyehole and a bottom cone. Between the cones is a mechanism, a latch, which locks container corner fittings together. Latchlocks shall have the same functional requirements as semi-automatic twistlocks described above. They can be equipped with a fixed base.

A latchlock can be of either single or dual purpose. It consists of:

- a top cone with an eyehole.
- an intermediate plate with collars.
- an internal mechanism, latch, automatically closing when a container is landed onto it, see fig 9 and 10.
- a device for unlocking the latchlock..

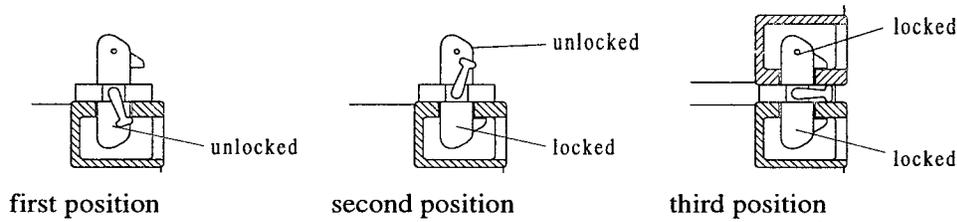


Figure 9. Latchlock.

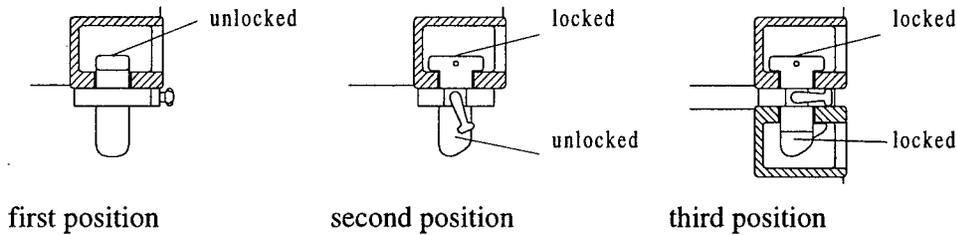


Figure 10. Latchlock with a fixed base.

Specific purpose locks

Specific purpose locks are always used together with other lashing and securing devices. They are normally located in the corner fittings in the end of a container where twistlocks can not be operated because of insufficient space. Normal use is to secure two 20-foot containers in a 40 foot container space. They are locked by twistlocks or latchlocks engaged in the opposite end of a container.

Specific purpose locks are not used together with other types of equipment engaged in the same corner fittings and there are therefore no dimensional restrictions concerning the cavity of the corner fitting.

A specific purpose lock can be of single purpose only. It consists of:

- a top cone with eyehole, and a bottom cone.
- an intermediate plate
- a geometry or an internal mechanism automatically locking when a container is placed in a horizontal position on top of it.

Specific locks are normally equipped with a fixed base.

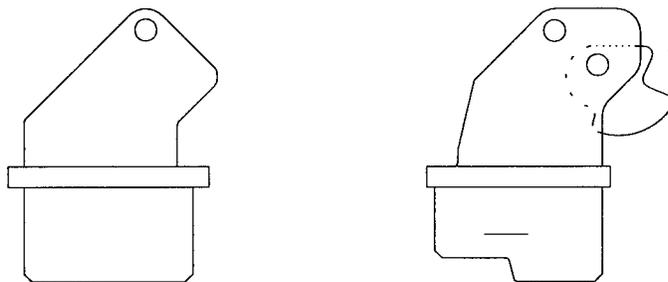


Figure 11. Examples of specific locks

Dual purpose twistlocks

Dual purpose twistlocks can be fitted either under a container, connected to a lifting equipment, or on top of a container in a container stack. *Dual purpose* is often designated as *dual function* in the literature.

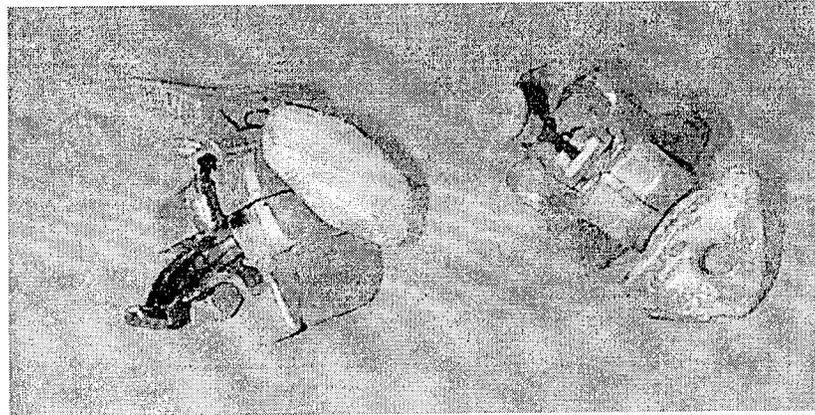


Figure 12. Examples of dual purpose twistlocks

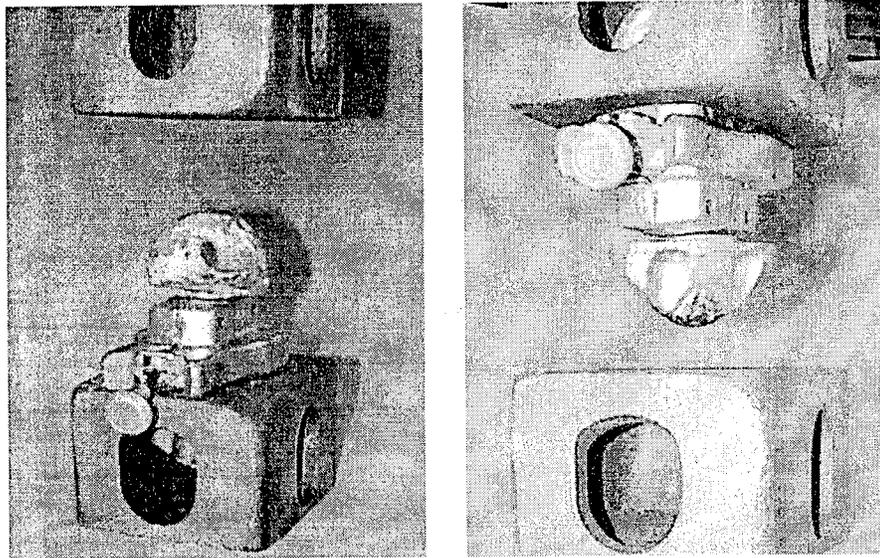


Figure 13. A semi automatic twistlock, dual purpose, fitted to the top and to the bottom corner fitting.

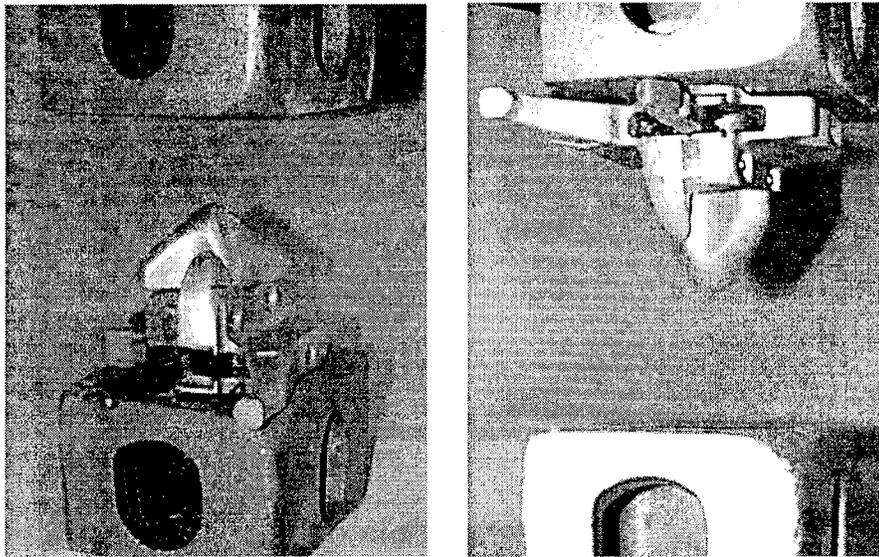


Figure 14. A semi automatic twistlock, dual purpose, fitted to the top and to the bottom corner fitting. This type is positioned upside down when fitted to the bottom corner fitting which consequently does not fully meet the proposed requirements.

Dimensions of twistlocks

The dimensions and tolerances of the twistlocks are essential if they shall be able to fit in the complex transport chain without creating problems. In this chapter the most critical dimensions are identified and dimensions and tolerances are proposed. In Appendix 1 measurements from 34 different twistlocks, available on the market, are presented.

Intermediate plate

Load carrying area intermediate plate

The compression load carrying area (flange surface bearing area) of the intermediate plate must distribute the compression forces over such a large area of the container corner fitting, that no permanent deformations occur when containers are stacked.

It is proposed that the load carrying area shall be at least 4 500 mm² and the twistlocks are to be designed so that they have the maximum load transfer area towards the closest vertical wall of the corner fittings, in order to prevent bending moments. The reason for this value is that compression tests on both top and bottom corner fittings were carried out with twistlocks, with a load carrying area of 4 300 mm², up to a load of 840 kN without any significant deformation of the corner fittings and only one out of sixteen twistlocks measured had smaller areas than 4 500 mm².

In diagram 1 measurements of the load carrying areas of the intermediate plate from 16 twistlocks are presented:

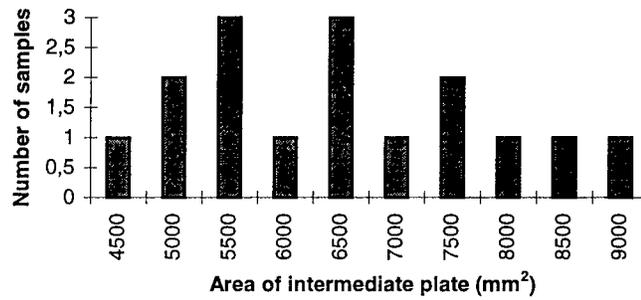


Diagram 1. Measurements of load carrying areas of the intermediate plate

Thickness of the intermediate plate

Differences in thickness of the intermediate plate can create problems in stacks if mixed twistlocks are in use. They might even damage the containers. It is therefore advisable to propose a dimension with tolerances to avoid such problems.

In diagram 2 measurements of the thickness of the intermediate plate from 34 twistlocks are presented:

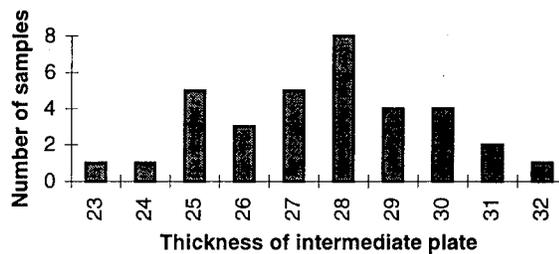
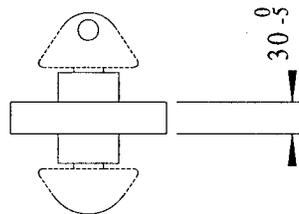


Diagram 2. Measurements of the thickness of the intermediate plate.

The thickness of the intermediate plate is proposed to be:



Dimensions in mm

Figure 15. Thickness of intermediate plate

Top and bottom cones (locks)

Load carrying area top and bottom cones

The top cone and bottom cone must be designed so that the load carrying area is large enough to carry the tensile forces without deforming the container corner fittings.

The minimum load carrying area (minimum bearing area) when lifting loaded containers is 800 mm². This area is given in International Standard ISO 1161, British standard BS 5237 and Swedish standard SS 842105. In the Japanese standard JIS Z 1617, there

is no requirement on load carrying area, but the twistlock itself has the same dimensions as those given in ISO 1161, BS 5237 and SS 842105.

In diagram 3 measurements of the load carrying areas of 32 cones from different twistlocks are presented:

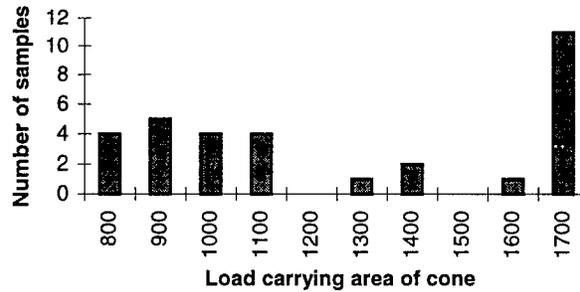


Diagram 3. Measurements of load carrying areas of top and bottom cone.

The presented measurements are all made on rather new products and all of them have areas larger than 800 mm². From earlier measurements several twistlocks are known to have smaller load carrying areas, but these twistlocks have damaged the container corner fittings in the tensile test. It is therefore proposed that the top and bottom cones shall be designed so that the load carrying area, in a fully locked position, in an ISO 1161 corner fitting, is larger than 800 mm², see figure 16.

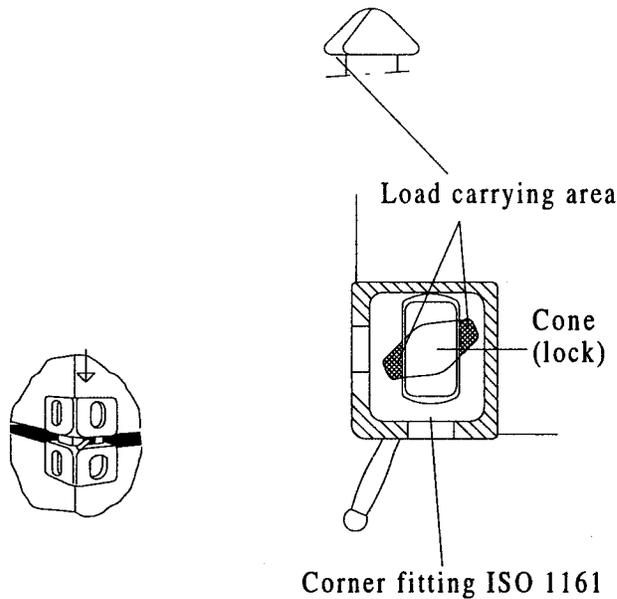


Figure 16. Load carrying area (minimum bearing area)

Height and width of top and bottom cone

The inside cavity of the corner fitting is limited and intended for use of other types of lashing equipment. It is therefore proposed that the top cone and bottom cone shall not protrude into the part of the corner fitting cavity, defined in figure 17, which is required for other lashing equipment.

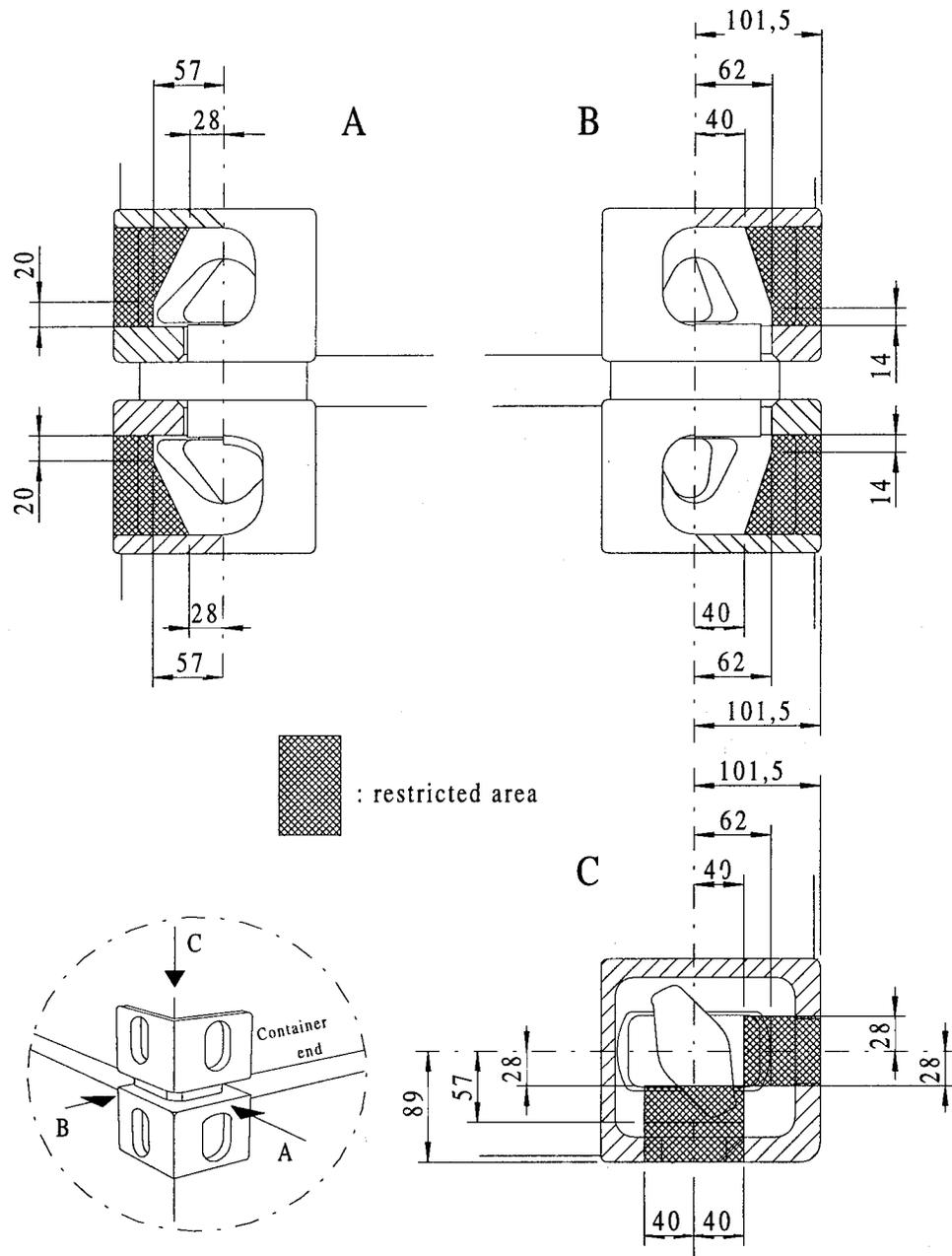


Figure 17. Restricted part of corner fitting cavity.

Distance between top and bottom cone

The twistlocks must be possible to use also in situations when the container corner fittings are filled with earth and other dirt. There must therefore be a play between the cones and the inside of the corner fitting. The thickness of the corner fittings is according to ISO 1161 = $28.5_{-1.5}^0$ mm. As the intermediate plate can have a dimension between 25 and 30 mm the distance between the locks (cones) must vary with this thickness if the play in the corner fittings of stacked containers shall remain the same.

In diagram 4 measurements of the distance between top and bottom cones, exclusive of the thickness of the intermediate plate, from 16 twistlocks are presented:

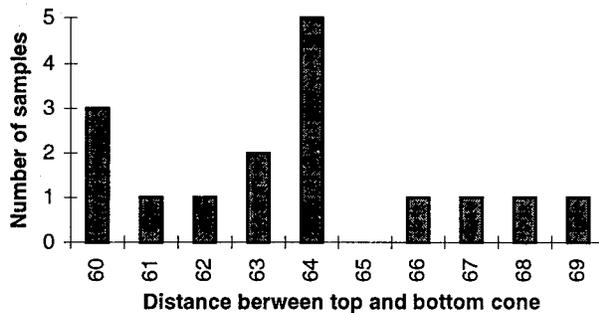
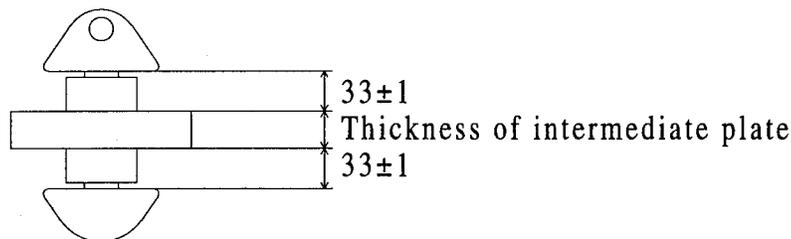


Diagram 4. Measurements of the distance between top and bottom cones exclusive of the thickness of the intermediate plate.

The distance between top and bottom locks is proposed to be the actual thickness of the intermediate plate plus $2 \times (33 \text{ mm} \pm 1 \text{ mm})$, see figure 18.



Dimensions in mm

Figure 18. Distance between top and bottom lock.

Handle

If the twistlock is equipped with a handle it shall be possible to manoeuvre it from the end of the container.

Length of the handle

The maximum length of the handle, if equipped, is derived from the distance between two 20 foot containers placed in a 40 foot container area. The minimum value is derived from the dimensions of a corner fitting and making it possible to get hold of the handle.. It should be observed that "Russian stowage" is not acceptable according to ISO 3874.

The length of the handle measured from the centre line of the locks to the end shall be 170_{-5}^0 mm, see figure 19.

Length of the tail

The bent-up tail of the handle shall have a length of 25 ± 2 mm, see figure 19.

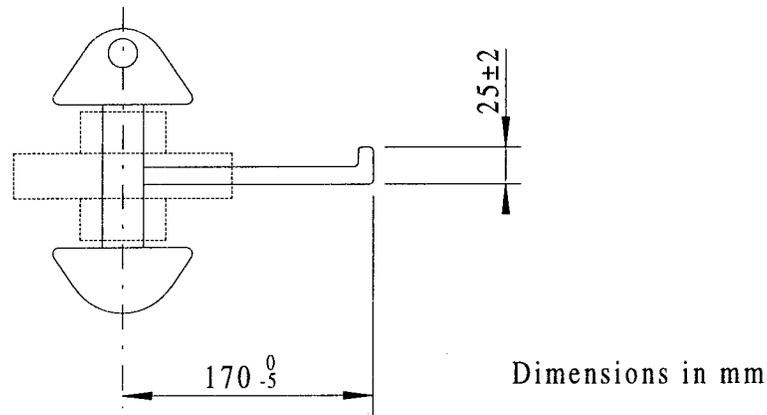


Figure 19. Length of the handle and tail.

Collar

The collars are to fit into the ISO top and bottom corner fitting apertures. The dimensions and tolerances are chosen in order to get a small play and still not have problems during operation. This has been done in order to take into consideration the dimensional tolerances of the corner fitting location as described in ISO 668. Annex A.1 "Corner fittings" and Figure A.1 "Corner fitting location", to ensure that any containers, within the extreme tolerance values, will be possible to secure to each other.

Length of the collars

In diagram 5 measurements of the length of the collars from 16 twistlocks are presented:

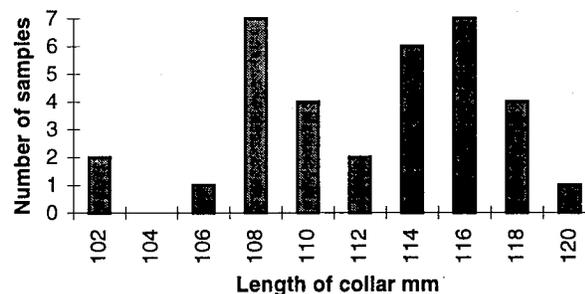


Diagram 5. Measurements of the length of the collars

Taking into consideration the dimensional tolerances of the corner fitting location as described in ISO 668 and reinsuring that any container, within the extreme tolerance values, will be possible to secure to each other, it is proposed that the length shall be $107.5_{-1.5}^{+0}$ mm, see figure 20. This length is calculated from the tolerances in ISO 668.

Width of the collars

In diagram 6 measurements of the width of the collars from 16 twistlocks are presented:

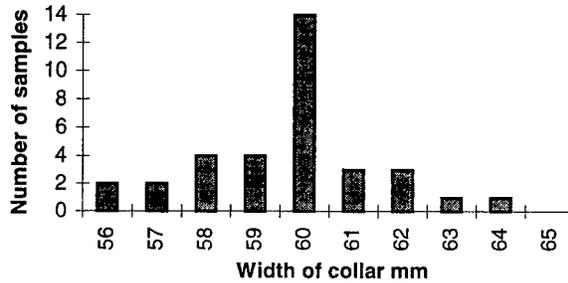


Diagram 6. Measurements of the width of the collars

Taking into consideration the dimensional tolerances of the corner fitting location, as described in ISO 668, and ensuring that any container, within the extreme tolerance values, will be possible to secure to each other, it is proposed that the width shall be $59.5^{+0}_{-1.5}$ mm, see figure 20. This width is calculated from the tolerances in ISO 668.

Height of the collars

In diagram 7 measurements of the height of the collars from 16 twistlocks are presented:

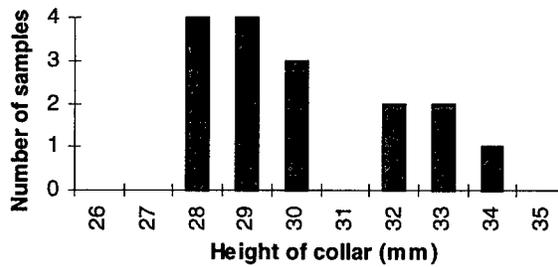


Diagram 7. Measurements of the height of the collars

Taking into consideration the dimensional tolerances of the distance between the locking cones it is proposed that the height shall be 30 mm, see figure 20.

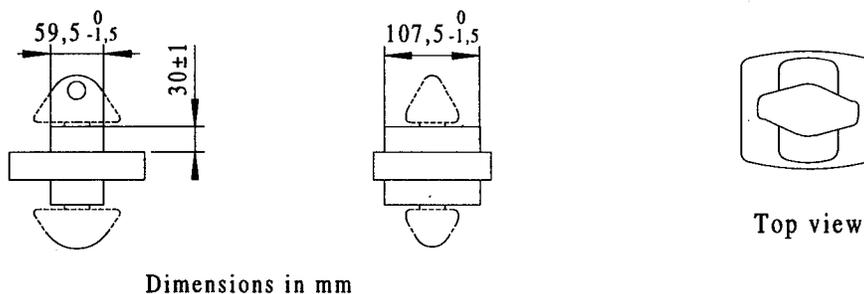


Figure 20. Dimensions of collar

Test methods for twistlocks

Tensile test

In the tensile test the force shall be applied to the twistlock by means of a tensile test machine and two fittings with dimensions equivalent to the ISO 1161 corner fittings. See figure 21. The test force shall be maintained for 5 min.

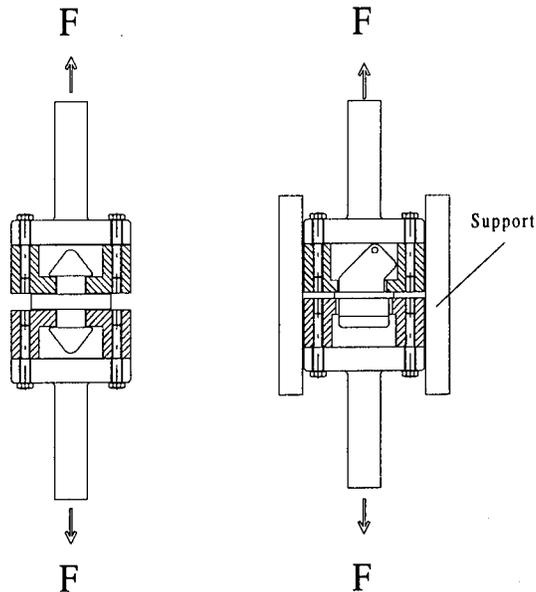


Figure 21. Tensile test of twistlock and latchlock (left) and specific locks (right).

Compression test

Compression strength of intermediate plate

When performing the compression test the intermediate plate shall be compressed in a testing machine by two steel plates with holes equivalent to ISO 1161 corner fittings. See figure 22. The test load shall be applied for 5 minutes.

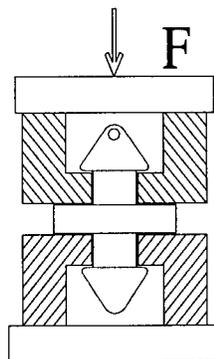


Figure 22. Compression test of intermediate plate.

Compression strength of cones (locks)

When performing the compression test on the top cone or the bottom cone, the cones shall be compressed in a testing machine by a flat steel plate and a steel plate with a hole equivalent to ISO 1161 corner fittings, see figure 23. The test load shall be applied for 5 minutes.

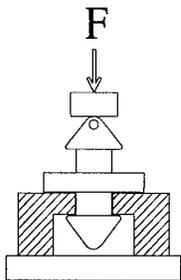


Figure 23. Compression test of top or bottom cone.

Shear strength test

For the shear strength test the twistlock shall be placed in its locked position in a test rig equivalent to ISO 1161 corner fittings, see figure 24. The twistlock shall be tested both in the longitudinal and the transverse directions. The shear test load shall be applied for 5 minutes.

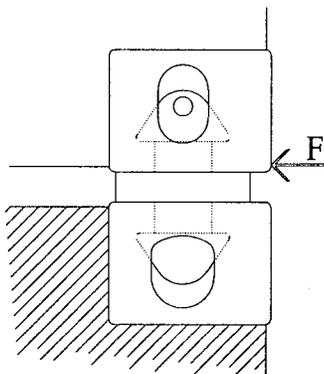


Figure 24. Shear test.

Test results for twistlocks and latchlocks

Samples have been sent to the Swedish National Testing and Research Institute, from different countries, for testing in accordance with the test methods described in this report. The test methods have been judged by the institute to be reproducible and not too complicated to perform. Test rigs have been constructed and used during the tests and they have served their purpose without problems. Initially some of the test rigs had to be modified but the last generation has been successful.

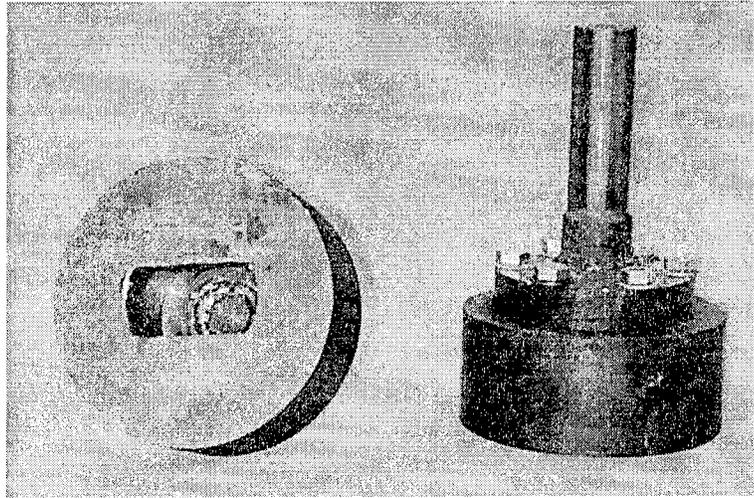


Figure 25. Tensile test apertures.

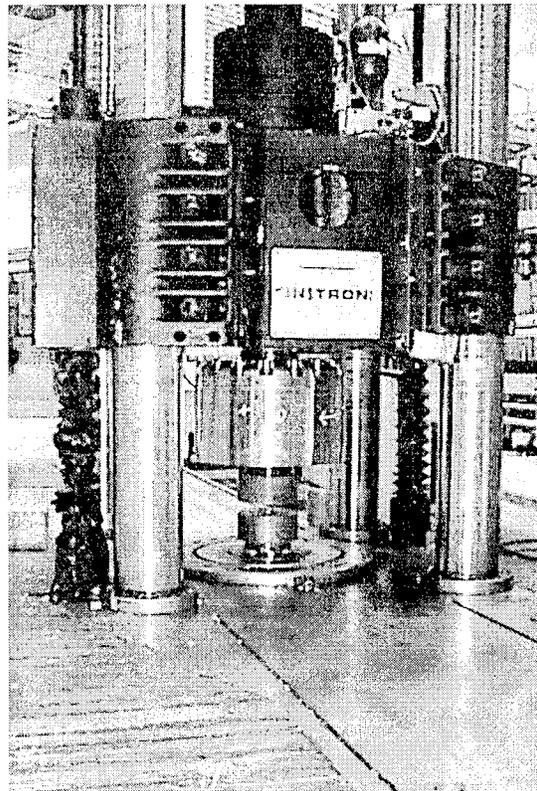


Figure 26. Testing machine with tensile test fixture.

Table 5. Tensile test results of twistlocks and latchlocks

Twistlocks

| Marking | Type | Tensile test load 300 kN | Tensile strength Breaking load kN |
|---|-----------------|-----------------------------|--------------------------------------|
| All Set Marin Pull-Wire | Semi-automatic | No damage | 477.0 |
| Tayo Seiki Kogyo Japan N1 TL2 | Manual 2-pos | No damage | 516.2 |
| Tayo Seiki Kogyo Japan N1 TL2 | Manual 2-pos | No damage | 472.3 |
| Asia Marine Co. LTE SK-24 261 NYK | Semi-automatic | No damage | 797.1 |
| Asia Marine Co. LTE SK-24 261 NYK | Semi-automatic | No damage | 743.6 |
| Taio Seiki Kogyo KK Osaka Japan | Manual 3-pos | No damage | 745.2 |
| MitsuiO.S.KKogyo Kaisha LTD Tokyo BL 50 T Japan | Semi-automatic | No damage | 726.5 |
| TWIH 5802 WW 20 | Manual 2-pos | No damage | 467.7 |
| 14910 -1 3966 | Fixed base | Slightly jammed | 384.9 |
| ANCRA AC 3,2 | Manual 3-pos | No damage | 821.8 |
| Inter cie 5krr2 GL | Manual 3-pos | No damage | 538.6 |
| Inter 021601 | Manual 3-pos | No damage | 393.2 |
| RS 021601 18/87 | Manual 3-pos | No damage | 661.5 |
| Peck & Hale 476 | Fixed base | No damage | 451.8 |
| Span set C50-3 | Fixed base | No damage | 585.9 |
| CS MK | Manual 3-pos | No damage | 690.5 |

Latchlocks

| | | | |
|-------------|----------------|-----------|-------|
| Taiyo NA-12 | Semi automatic | No damage | 539.4 |
| Taio NA 7 E | Fixed base | No damage | 503.0 |

Note: The latchlocks apply an eccentric load to the test rig, which results in a bending moment of the whole test rig. According to C R Cushings report "Pull test of twistlock/corner casting combinations", June 1996, the tests performed indicate that at a load of 200 kN the latchlocks start to deform the container corner fittings. This load is in that case higher than 150 kN, see ISO 1161.

An earlier tensile test of twistlocks, which was performed at the Swedish National Testing and Research Institute, was carried out with normal container corner fittings instead of the test rig described earlier. The result shows that the corner fittings used in this test were much stronger than the required strength, 150 kN, given in ISO 1161 and ISO 1496 series. However, there may be weaker corner fittings on the market still corresponding with ISO 1161..

These tests also indicated the necessity of load carrying areas of sufficient size. If the load carrying areas were too small, the corner fittings were deformed at low force values in the test. The results from the investigation are shown in the following table. The full results are given in SP Technical Report 1989:53.

Table 6. Twistlocks tested between normal container corner fittings

| <i>Twistlock type</i> | <i>Breaking load kN</i> | <i>Cause of failure</i> |
|--------------------------|-------------------------|---|
| Double lock 2-position | 150 | Corner fitting deformed due to too small load carrying area |
| Double lock 2-position | 578 | Bottom lock |
| Double lock 3-position | 403 | Bottom lock |
| Double lock 3-position | 440 | Bottom lock |
| Double lock 3-position | 578 | Top lock |
| Double lock 3-position | 413 | Top lock |
| Double lock 3-position | 503 | Shaft |
| Double lock 3-position | 510 | Top lock |
| Double lock 3-position | 382 | Shaft |
| Double lock 3-position | 433 | Bottom lock |
| Double lock 3-position | 347 | Bottom lock |
| Double lock 3-position | 471 | Bottom lock |
| Double lock 3-position | 463 | Bottom lock |
| Fixed base | 401 | Fixed base |
| Fixed base | 304 | Intermediate part |
| Fixed base | 384 | Intermediate part |
| Fixed base | 327 | Fixed base |
| Fixed base | > 500 | Test interrupted |
| Fixed base | 343 | Fixed base |
| Fixed base + bottom cone | 343 | Fixed base |
| Fixed base + bottom cone | 187 | Corner fitting deformed due to too small load carrying area |

Compression test of intermediate plate and top or bottom cone.

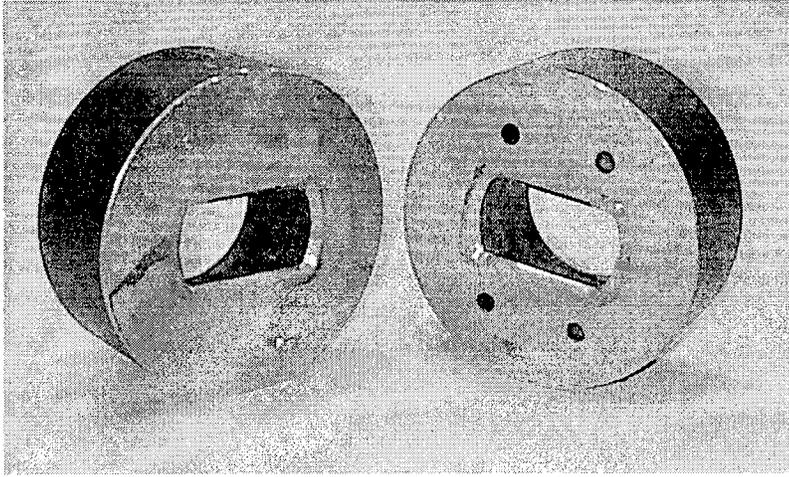


Figure 27. Compression test rig

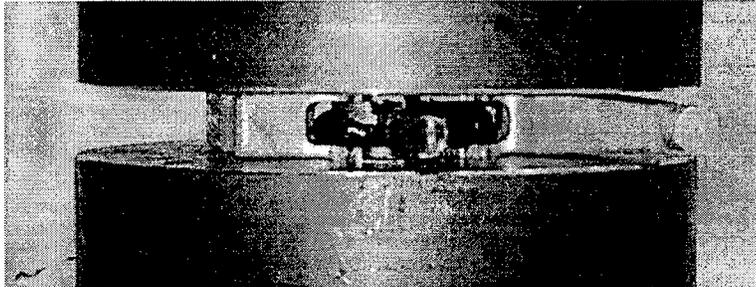


Figure 28. Compression test rig and mounted twistlock

Compression test result

When performing the compression test of the intermediate plate the test load was increased in steps of 250 kN up to 1000 kN. All twistlocks and latchlocks could withstand a test load of 1000 kN without adversities. The test load was finally increased to 1350 kN with the following result:

Table 7. Compression test results of twistlocks and latchlocks

Twistlocks

| <i>Marking</i> | <i>Type</i> | <i>Compression test load, Intermediate plate: 1350 kN</i> | <i>Compression test load, Top or bottom cone: 300 kN</i> |
|---|----------------|---|--|
| All Set Marin Pull-Wire | Semi-automatic | No damage | No damage |
| Taiyo Seiki Kogyo Japan | Manual 2-pos | No damage | Hole in cone deformed |
| Asia Marine Co. LTE SK-24 261 NYK | Semi-automatic | No damage | No damage |
| Taiyo Seiki Kogyo KK Osaka Japan | Manual 3-pos | No damage | No damage |
| MitsuiO.S.KKogyo Kaisha LTD Tokyo BL 50 T Japan | Semi-automatic | No damage | No damage |
| 5802 WW 20 | Manual 2-pos | No damage | Hole in cone deformed |
| 3966 | Fixed base | No damage | No damage |
| AC 3,2 | Manual 3-pos | No damage | No damage |
| Inter cie 5krr2 | Manual 3-pos | No damage | No damage |
| Inter 021601 | Manual 3-pos | No damage | No damage |
| 18/87 | Manual 3-pos | No damage | No damage |
| Peck & Hale 476 | Fixed base | No damage | No damage |
| C5D-3 | Fixed base | No damage | No damage |
| CS MK | Manual 3-pos | No damage | No damage |

Latchlocks

| | | | |
|--------------|---------------|-----------|-----------|
| Taiyo NA-12 | one side lock | No damage | No damage |
| Taiyo NA 7 E | one side lock | No damage | No damage |

Table 8. Shear strength test of twistlocks and latchlocks

Twistlocks

| <i>Marking</i> | <i>Type</i> | <i>Shear strength longitudinally and transversely</i> <i>Test load 300 kN</i> |
|---|----------------|--|
| All Set Marin Pull-Wire | Semi-automatic | No damage |
| Taiyo Seiki Kogyo Japan | Manual 2-pos | No damage |
| Asia Marine Co. LTE SK-24 261 NYK | Semi-automatic | No damage |
| Taiyo Seiki Kogyo KK Osaka Japan | Manual 3-pos | No damage |
| Mitsui O.S.K Kogyo Kaisha LTD Tokyo BL 50 T Japan | Semi-automatic | No damage |
| 5802 WW 20 | Manual 2-pos | No damage |
| 3966 | Fixed base | No damage |
| AC 3,2 | Manual 3-pos | No damage |
| Inter cie 5krr2 | Manual 3-pos | No damage |
| Inter 021601 | Manual 3-pos | No damage |
| 18/87 | Manual 3-pos | No damage |
| Peck & Hale 476 | Fixed base | No damage |
| C5D-3 | Fixed base | No damage |
| CS MK | Manual 3-pos | No damage |

Latchlocks

| | | |
|--------------|---------------|-----------|
| Taiyo NA-12 | one side lock | No damage |
| Taiyo NA 7 E | one side lock | No damage |

Strength requirements of twistlocks

Strength requirements may be imposed on the twistlocks regarding

- tension
- compression
- shear
- fatigue
- performance safety

The interviews and studies performed so far indicate that the strength of the twistlocks existing today is more than sufficient. Practically no indications of damage at sea have been observed. The most usual damages are that the handles break or bend. These damages occur when the twistlocks are thrown onto the ship deck from a large height. Another cause of damage is that twistlocks are pulled apart by harbour cranes. This is due to right or left locking twistlocks, or that the handle has no distinct stop position in neutral but can be moved across this position and thus lock backwards.

Concerning tensile fatigue fracture in the shaft, only a negligible small number have been recorded. One case was observed where the shaft had a fatigue fracture, because a strong handle had been shrunk on in the middle of the shaft. In the second case a fatigue fracture had occurred as a consequence of a handle having been welded onto the shaft and thereby initiated a crack propagation. Both twistlocks were however of an older and obsolete type.

That this type of damage occurs so rarely is because, except at lifting, there are high tensile stresses in the twistlocks only in extreme conditions, for example at very rough sea sometimes together with wind load and breaking boarding sea.

Concerning tensile fatigue strength, it would not imply large costs if there were defined requirements for a number of load cycles at a certain load to verify that there are no built in factors in the design, which severely reduce the fatigue strength of the twistlocks. It is however worth reminding that tensile forces normally do not occur in the twistlocks during sea transport.

The intermediate plate must not be deformed at compressive loading between containers and thereby lock the twistlock. This case is extremely troublesome, since it probably occurs in the bottom of the container stack and normally would require a jet burner to be solved.

The compressive strength of the corner fittings should be taken into account when discussing the compressive strength of the twistlock. The intermediate plate of the twistlocks must have such a large area that the corner fittings of the container are not damaged at high compressive loads.

The collars of the twistlock restrain the containers from horizontal movements and should therefore be able to withstand shear forces. A separate shear test under realistic conditions is complicated to perform. It would be possible to verify the shear strength in a tensile test.

The strength requirements on twistlocks would in such case only comprise tensile and compressive strength.

Finally it can be discussed whether the strength of the container corner fittings should influence the twistlocks to the extent that they should be equally strong. It is not unusual that the harbour crane pulls the twistlocks apart. If the corner fitting and the twistlock are equally strong, the corner fitting may be so deformed that the container

can not be lifted. Those deformations often lead to the container being scrapped. Therefore it may be preferable that the twistlock breaks before the corner fitting starts to deform. The tensile requirement on a corner fitting at lifting in the top corner fitting is 150 kN according to ISO 1161. This requirement is very low and the present investigation indicates that the strength of the twistlock, used today, lies by large amounts above this requirement. That the strength of the corner fittings also is much higher than the requirement 150 kN implies that this load level can be increased dramatically in the existing standards and this would consequently lead to a required maximum tensile strength of the twistlock lower than this value.

On the other hand it is the opinion of the author that it would be an advantage if the twistlocks were stronger than the corner fittings concerning compressive forces. The reason for this is that when a twistlock is jammed in the bottom of a stack, it is very difficult to release it.

It is a tradition in container standardisation that strength requirements are never related to breaking loads but rather to proof loads. During testing the proof-loads are normally held for 5 minutes, not allowing any deformations or other abnormalities.

Tensile strength

According to ISO 1161 and ISO 1496 the required "tensile" strength of the ISO corner fittings is minimum 150 kN without permanent deformations. If the requirements of twistlocks shall be consistent with the corner fittings they shall also withstand a minimum tensile force of 150 kN. Tensile tests show however that the corner fittings are much stronger than that. Tests on twistlocks have been conducted with standard corner fittings up to 578 kN and the corner fittings have only been slightly deformed on the inside by this load. The external dimensions of the corner fittings have not been affected very much provided that the load bearing area of the twistlock has been large enough.

Consideration can be given to the fact that a damaged corner fitting normally leads to scrapping of container and that it therefore is better if the twistlock breaks before the corner fitting.

The classification societies have higher requirements for breaking strength, of lashing equipment, than ISO, for corner fittings: American Bureau of Shipping, ABS, Bureau Veritas, BV, Det norske Veritas, DnV, Germanischer Lloyd, GL, and Lloyds Register of Shipping, LR, have specified SWL (safe working load), PL (proof load) and BL (minimum breaking load) for twistlocks as described in table 9.

Table 9. Tensile strength requirements for twistlocks by the classification societies.

| | ABS | BV | DnV | GL | LR |
|--------|-----|-----|-----|-----|-----|
| SWL kN | 200 | 200 | 200 | 200 | 200 |
| PL kN | 220 | 260 | 220 | 250 | 300 |
| BL kN | 335 | 400 | 400 | 400 | 400 |

It must be taken into account that the corner fittings and twistlocks in use today are much stronger than what is required in ISO 1161, cf. the test results, and that there is no practical experience of twistlocks with a breaking strength of just above 150 kN. The calculations made by the classification societies, see chapter "Forces acting in the lashing system", indicate that the tensile forces can be as high as 200 kN during sea

transport. The magnitude of forces, induced in the lashing system by, a breaking green sea hitting a container stack is difficult to foresee.

As can be seen in the test results the tested twistlocks and latchlocks were all much stronger than 150 kN, with a few exceptions where the twistlocks did not break, but due to a very small contact area they cut through the corner fitting.

The author would recommend a tensile test load of 250 kN, maintained for 5 minutes, without any permanent deformation and other abnormalities which render it unsuitable for use, and a minimum breaking load of 400 kN.

To verify the tensile strength requirement the twistlock can be tested according to proposed methods. The force shall act between the locking cones or the top locking cone and the fixed base.

The tensile force shall be applied by means of two corner fittings in accordance with ISO 1161, see figure 21, page 27.

Compression strength

The twistlocks must withstand the compression forces without any permanent deformations and the function of the twistlock must not be affected by the test.

A compression test with the top cone housed in a bottom corner fitting and the load applied directly on the top cone to simulate misalignment is proposed. This probably occurs often in real life and the twistlock must withstand these compression forces.

Compression strength of intermediate plate

It is obvious that the twistlock must withstand a compression force of at least 848 kN, see ISO 1496 test no 1 stacking, without any permanent deformation or loss of function. It could be of a great advantage if the twistlocks are even stronger, because the stacks are becoming higher (and some containers in a stack may not be conforming with ISO 1496 series 1 and can have higher mass ratings). Jammed twistlocks because of compression forces must be avoided. If the twistlock is jammed in the bottom of a stack it can be very difficult to free the container (especially if the stack is located inside a hull).

The compression forces acting in a stack come from the weight of the stack plus the vertical accelerations occurring during sea transport. The pre-tension forces induced by the turnbuckles shall be added to the compression force.

Regarding the strength of the container corner fittings against compression forces there is some guidance in the ISO 1161 standard "Corner Fittings - Specification" giving the design requirements for the corner fittings. The design load for the bottom corner fitting resting on a flat support is 810 kN. The next lowest container sits on the top corners of the lowest one, which means smaller surfaces if they are displaced relative to each other. The design load is 680 kN on top corner fittings.

In ISO 1496 "Specification and Testing" it is required that a 40-foot container shall be loaded to a combined mass of $1.8 R = 54\,864 \text{ kg} = 13\,716 \text{ kg}$ per corner fitting. The container is then submitted to a stacking force of $3\,392 \text{ kN} = 848 \text{ kN/corner fitting}$. During this test the bottom corner fitting is submitted to a force of 980 kN and the top corner fitting is loaded with an offset load. The bottom corner fitting rests on a flat support.

The force, or resultant of any combination of forces, applied to the aperture in the end of a corner fitting as a result of a lashing or securing device, is in ISO 1161 assumed not to exceed the value 300 kN vertically and 150 horizontally.

As can be seen in the test results for the compression test, 14 different types of twistlocks and 2 latchlocks were tested with a compression force of 1000 kN without being affected by this test load. The compression force was then increased to 1350 kN and only one of the twistlocks was affected, but it was still possible to open this twistlock by hand. The result indicates that twistlocks in use today are much stronger concerning compression strength because of the manufacturers' awareness of the problems that can occur. It is the opinion of the author that it would be an advantage if the twistlocks were stronger than the corner fittings with regard to compressive forces.

To verify the compression strength requirement the twistlock can be tested according to the proposed test method. The function of the twistlock must not be affected by the test. The compression force shall be applied in a testing machine via two steel plates with holes equivalent to ISO 1161 corner fittings, see figure 22 (page 27). The author would recommend a compression test load of 1000 kN maintained for 5 minutes without any permanent deformation or other abnormalities which render it unsuitable for use.

Compression strength of cones

During handling containers sometimes hit twistlocks on their cones, while the other end of the twistlock is engaged to a corner fitting. The twistlock must withstand these impacts without damage to avoid stops and difficulties during handling. The forces that a container creates when it is lowered down onto a twistlock are moderate and it is estimated that the force will not exceed 150 kN.

To verify the compression strength requirement the compression force shall be applied to the top or bottom cone in a testing machine by one flat steel plate and another steel plate with a hole equivalent to ISO 1161 corner fittings, see figure 23 (page 28).

The classification societies have no requirements for the compression strength of a cone.

As can be seen in the compression test results, two of the 16 tested twistlocks and latchlocks were affected by this test.

If the cone is hit from the side it will be bent, but it is probably impossible to make it so strong that it can withstand impacts of this sort.

It is proposed that the twistlock shall withstand a compression force of 150 kN, maintained for 5 minutes, without any permanent deformation or other abnormalities which render it unsuitable for use. The function of the twistlock shall not be affected by the test.

Shear strength

During transport at sea the longitudinal accelerations are low but when a container is loaded on a railway wagon or a lorry the longitudinal accelerations are considerably higher. According to ISO 3874 they may reach 2 g in railway traffic. In the CEN standardisation work they are set to 1 g under the condition that hump shunting of railway cars is prohibited.

Transversely, transport at sea gives the highest accelerations, 0.6 - 0.7 g, while rail and road only give 0.3 - 0.5 g.

The effect of impacts from breaking green seas in both the longitudinal and transverse directions is unknown to the author.

The lashing equipment presented in this report is normally only used in sea transport and therefore only forces occurring during sea transport should be considered.

Account must be taken of the fact that normally only two of the four corner fittings take up the force when a container is submitted to racking.

In ISO 1161 "Corner Fittings - Specification" and ISO 1496-1 "Specification and Testing, Part 1" it is stated that the bottom corner fittings shall withstand a design load (longitudinal restraint) of 300 kN.

In ISO 1496 "Specification and Testing" it is required that a container shall be subjected to and withstand a transverse rigidity test of 150 kN.

The test results indicate that all twistlocks can withstand very high shearing forces. Their design normally demands much material in the collars to fulfil the dimensional requirements, and this makes them very strong. Testing is however difficult to perform, depending on inadequacies of test rigs in combination with the high forces. At the Swedish National Testing and Research Institute tests have been performed with only moderate forces induced by corner fittings purchased on the open market. As can be seen in the shear test results the twistlocks and the latchlocks were not affected at all by a test load of 300 kN in both directions.

The calculated permissible forces from the classification societies were presented above in table 2 (page 11).

The classification societies also have recommended values for shearing strength and specifies SWL (safe working load), PL (proof load) and BL (minimum breaking load) for twistlocks as described in table 10.

Table 10. Shear strength requirements for twistlocks by the classification societies.

| | ABS | BV | DnV | GL | LR |
|--------|-----|-----|-----|-----|-----|
| SWL kN | 150 | 150 | 150 | 210 | 150 |
| PL kN | 165 | 195 | 165 | 263 | 225 |
| BL kN | 250 | 300 | 300 | 420 | 300 |

As is evident from above there are discrepancies between the SWL-loads, concerning shearing strength, and the calculated permissible forces concerning corner fittings in the regulations from the classification societies.

The collars of the twistlock are proposed to withstand a shearing test load of 300 kN transversely and longitudinally, maintained for 5 minutes, without any permanent deformation or other abnormalities which render them unsuitable for use.

The force shall be applied in a testing machine via two steel plates with holes equivalent to ISO 1161 corner fittings, see figure 24 (page 28).

Stacking cones

Stacking cones or stacking fittings, or stackers, locate and secure containers either to each other, within a stack, or to the transport mode. They act through the container corner fittings. Stacking fittings are always used together with other lashing and securing devices.

The top and bottom cones restrain connected containers against horizontal movements.

A double cone can only be used when the top corner fittings of the container layers are on the same level. The intermediate plate secures the two corner fittings in separate stacks to each other.

The performance and reliability of stacking fittings are functions of design and choice of material. They shall be designed so that their function does not cease because of stress, corrosion and dirt.

For the purpose of this text, the following definitions apply to stacking fittings:

cone: a part of a stacking fitting which fits into a corner fitting and restrains connected containers from horizontal movements.

Single stacking cone

A single stacking cone consists of two cones opposite to each other, attached to an intermediate plate. See figure 29.

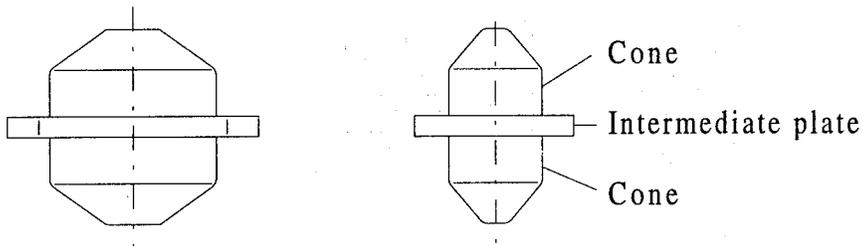


Figure 29. Single stacking cone

intermediate plate: a part of a stacking fitting that carries the compression force between stacked containers. See figure 29.

pin lock: a device, consisting of a cone and a pin, which is used to locate and secure containers on the deck or to each others also in a vertical direction. See figure 30.

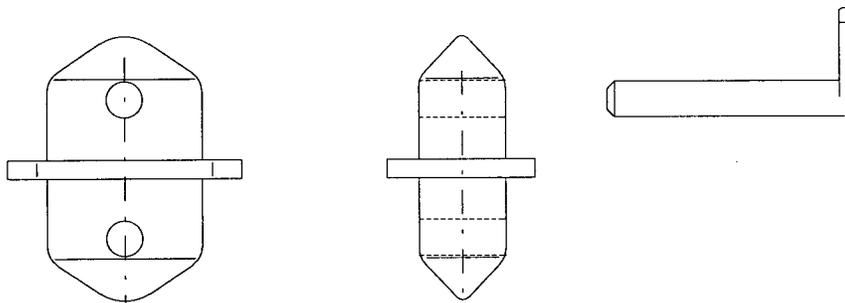


Figure 30. Pin lock

Double stacking cone

A double cone stacking fitting consists of two cones opposite to each other, attached to the ends of an intermediate plate. They are supposed to connect and secure containers to each other and can be of transverse or longitudinal type. When fixed into position, they form a solid block from several separate container stacks, absorbing horizontal forces. The transverse type secures containers standing with their long sides against each other and the longitudinal type secures containers with the ends against each other. See figure 31.

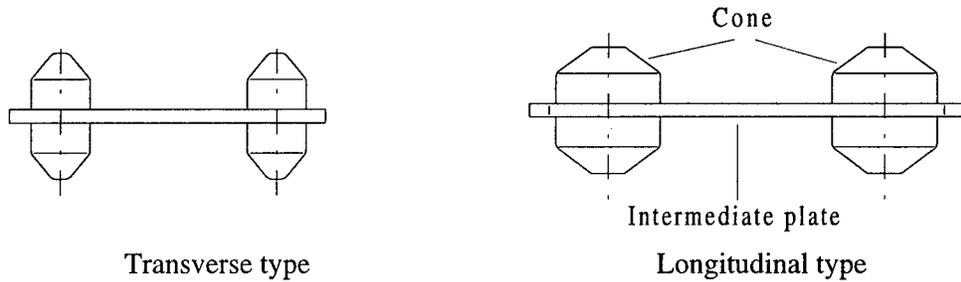


Figure 31. Double cone stacking fittings

Dimensions

Top and bottom collar cones

The top and bottom cone shall be designed so that they do not protrude into the area of the corner fitting, which is required for other lashing equipment, see figure 32, where the restricted area is specified.

Intermediate plate

The thickness of the intermediate plate is recommended to be 12 ± 3 mm. See figure 26. The thickness shall always be kept equal among all the intermediate plates in the same stacking layer.

The compression load carrying area (flange surface bearing area) of the intermediate plate shall be at least $4\,500 \text{ mm}^2$. The intermediate plate shall be so designed as to have the maximum load transfer area towards the walls of the corner fittings.

Collar cones

The cones shall fit into the ISO top and bottom corner fitting apertures and shall have the dimensions as in figure 33, see also the section on collars page 25 - 26.

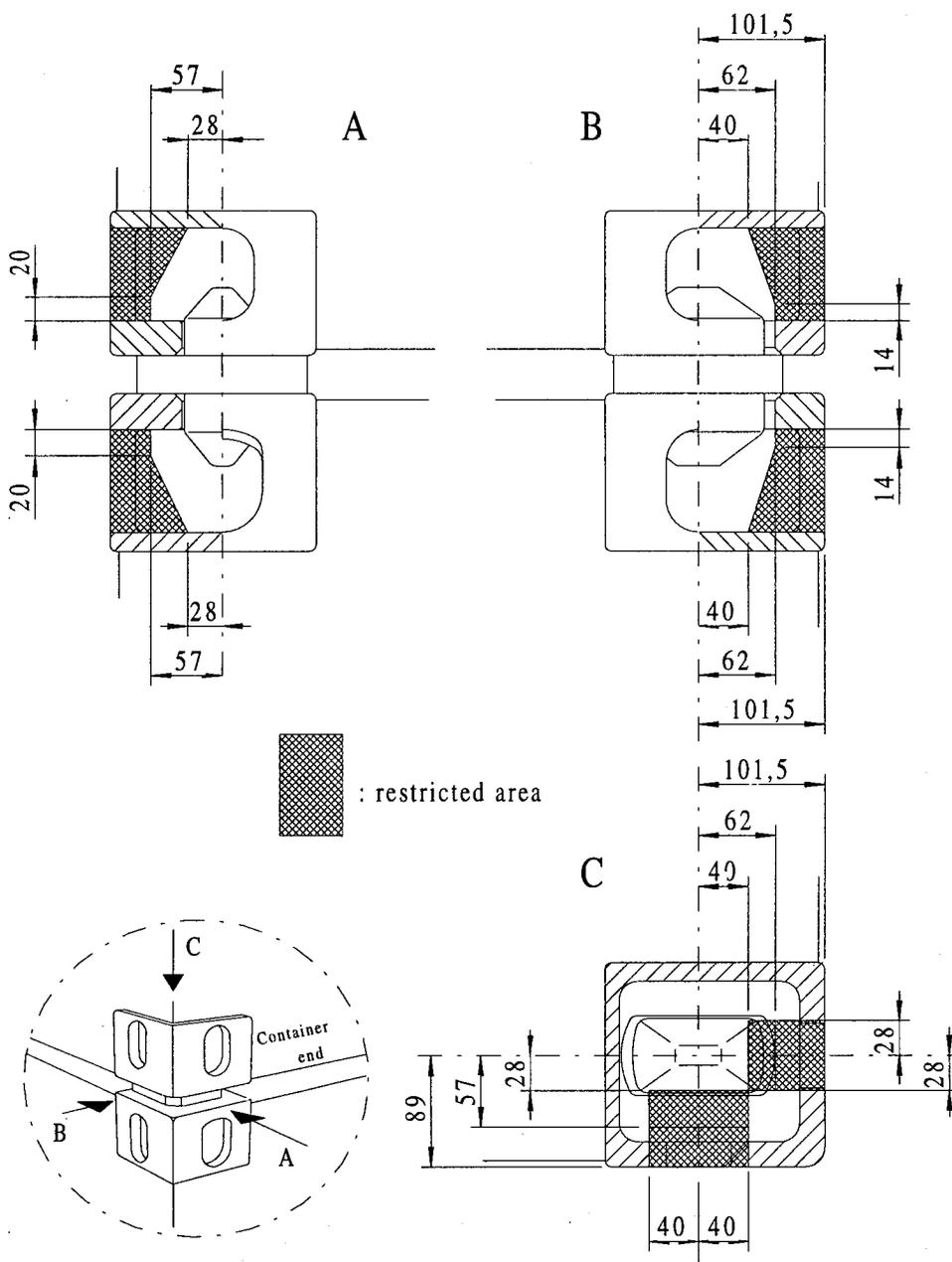


Figure 32. Restricted part of cavity.

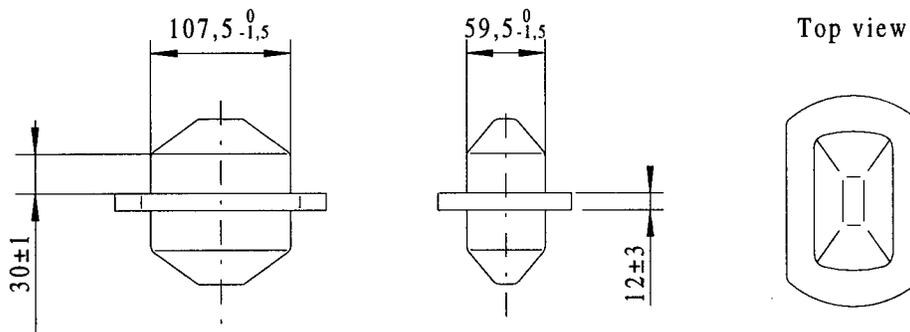


Figure 33. Dimensions of cone.

Distance between cones

The distance between the cones in a transverse double cone shall be in accordance with the container spacing of the ship where it is used.

The distance between the cones in a double cone of longitudinal type (derived from the space between two 20 foot containers placed in a 40 foot container space) shall be 280 ± 5 mm, see fig. 34.

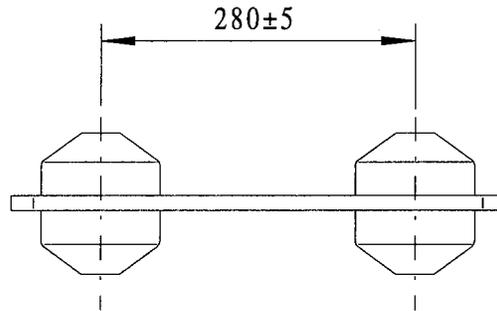


Figure 34. Distance between the cones

Test methods of stacking fittings

Compression test

Compression test of intermediate plate

When performing the compression test the intermediate plate shall be compressed in a testing machine by two steel plates with holes equivalent to ISO 1161 corner fittings. See figure 35. The test load shall be applied for 5 minutes.

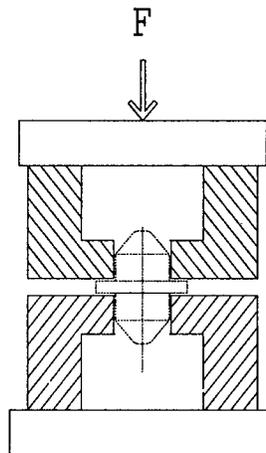


Figure 35. Compression test of intermediate plate.

Compression test of collar cones

When performing the compression test to the top cone, it shall be compressed in a testing machine via a flat steel plate and a steel plate with a hole equivalent to ISO 1161 corner fittings, see figure 36. The test load shall be applied for 5 minutes.

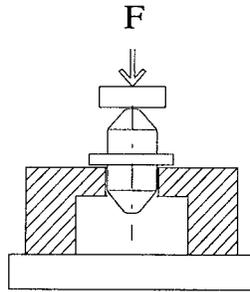


Figure 36. Compression test of top or bottom cone.

Shear strength test

For the shear strength test the stacking fitting shall be placed in a test rig equivalent to ISO 1161 corner fittings, see figure 37.

The stacking fitting shall be tested both in the longitudinal and transverse directions.

The shearing test load shall be maintained for 5 minutes.

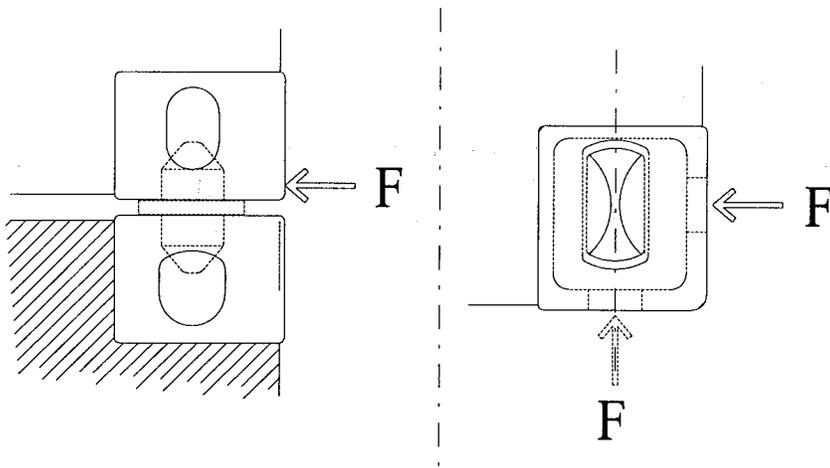


Figure 37. Shear test.

Tensile and compression test, (Racking resistance test)

The force shall be applied to the double stacking fitting in a tensile test machine by four fittings in dimensions equivalent to the ISO 1161 corner fittings. See figure 38. The test load shall be maintained for 5 minutes in each direction.

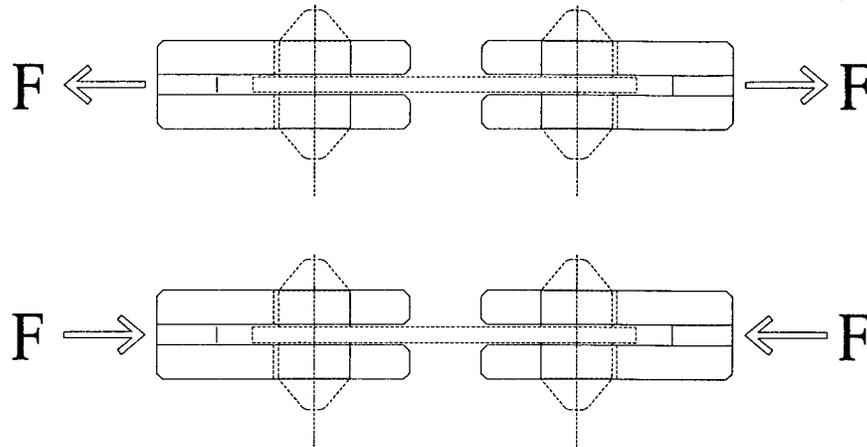


Figure 38. Tensile and compression test.

Test result

No samples have been available for testing.

Strength requirements of stacking fittings

Compression strength

Compression strength of intermediate plate

Compression forces influence stacking fittings in the same way as twistlocks, and we refer to the twistlock chapter above (page 37).

The stacking fitting shall, according to ISO 1496, withstand a compression force of at least 850 kN without any permanent deformation or other abnormalities which renders it unsuitable for use.

To verify the compression strength requirement the stacking fitting can be tested according to the proposed test method. The compression force is applied in the same way as when testing twistlocks.

Compression strength of cones

Compression forces on cones apply to stacking fittings as to twistlocks, see page 38. It is believed necessary to mention that a stacking fitting most probably will be struck out of the corner fitting if a container hits it.

The stacking fitting shall withstand a compression force of 150 kN without any permanent deformation or other abnormalities, which render it unsuitable for use.

The compression force shall be applied to the top cone in a testing machine via one flat steel plate and one steel plate with a hole equivalent to ISO 1161 corner fittings.

To verify the compression strength requirement the stacking fitting shall be tested according to the proposed test method

Shear strength

Shearing forces apply to stacking fittings as to twistlocks, see twistlock shearing forces on page 38.

The stacking fitting shall withstand a shearing test load of 300 kN longitudinally and transversely, held for 5 minutes, without any permanent deformation or other abnormalities which renders it unsuitable for use.

The force shall be applied in a testing machine via two steel plates with holes equivalent to ISO 1161 corner fittings.

To verify the shear strength requirements the stacking fitting shall be tested according to the proposed test method.

Tensile and compression strength of double stacking fitting

The double stacking fittings are subjected to large forces because of their location as connections between stacks. The stacks probably move at the same time and in the same direction, but differences in play can cause very high compression or tensile forces in the connecting plate between the four cones.

In the standardisation work it is proposed that the double stacking fitting shall withstand a tensile and a compressive force (horizontal) of 300 kN, both in the longitudinal and the transverse direction, without any permanent deformation or other abnormalities which render it unsuitable for use.

The classification societies have requirements for shearing strength and specify SWL (safe working load), PL (proof load) and BL (minimum breaking load) for double stacking fittings as described in the following table:

Table 10. Strength requirements by the classification societies

| | ABS | BV | DnV | GL | LR |
|--------|-----|-----|-----|-----|-----|
| SWL kN | 450 | 400 | 400 | 560 | 400 |
| PL kN | 585 | 520 | 440 | 620 | 600 |
| BL kN | 750 | 800 | 800 | 730 | 800 |

There are great discrepancies in the opinion between the ISO standardisation committee and the classification societies.

According to the opinion of the author, very high forces occur between the columns in the stacks, and it is therefore proposed that the collars and intermediate plate of the double stacking fittings shall withstand a tension and compression force of 600 kN, maintained for 5 minutes, in each direction, without any permanent deformation or other abnormalities which render it unsuitable for use, as well as a minimum breaking load of 800 kN.

To verify the strength requirement the stacking fitting can be tested according to the proposed test method. The force shall act between the cones, see figure 38, and shall be applied by means of a device simulating four corner fittings, in accordance with ISO 1161.

Whether fatigue is a problem with this type of equipment is not known by the author. It would not be difficult to perform such a test, but as there are no documented failures of this type, a static test is considered sufficient.

Lashing rods

Lashing rods together with tensioning devices secure a layer of containers, within a stack, to the transport mode. They act from the container bottom corner fittings to anchor points on the transport mode, via tensioning devices, see figure 39. They are always used together with other securing devices such as stacking fittings and twistlocks.

They shall have a sufficient length so that it together with the tensioning device fits between the corner fittings and the transport mode. See figure 1, 2 and 39. In figure 40, 41 and 42 three types of lashing rods are shown.

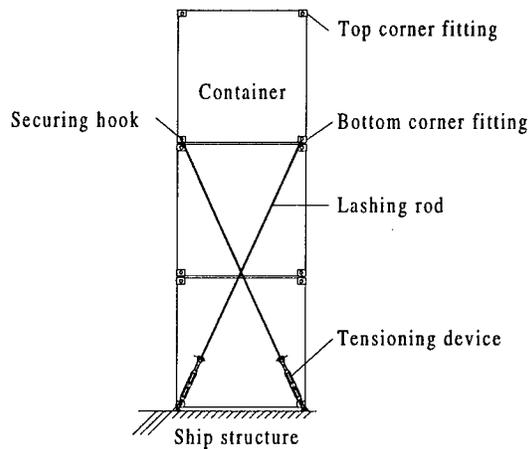


Figure 39. Lashing rod system.

The following definitions apply to lashing rods:

securing pad: a securing fitting (hook) which fits into a corner fitting and to which a lashing rod can be attached, see figure 40.

plug hook: a fixed part of a lashing rod which fits into a corner fitting, see figure 41.

hinge hook: an articulated part of a lashing rod which fits into a corner fitting, see figure 42.

lashing rod: a rod with a top which fits into a corner fitting or to a connecting part, which in turn fits into a corner fitting, and a bottom part, which fits into a tensioning device, e. g. a turnbuckle.

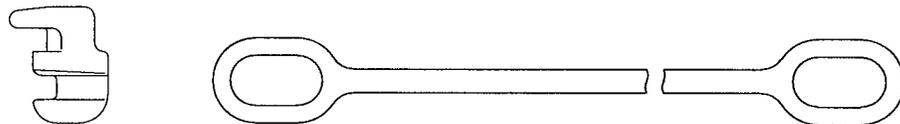


Figure 40. Securing pad and lashing rod

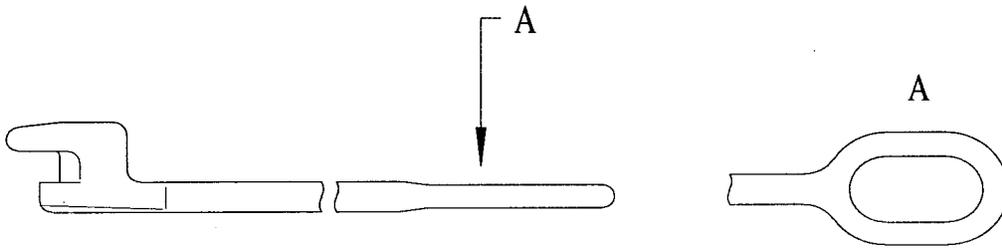


Figure 41. Lashing rod, plug hook.

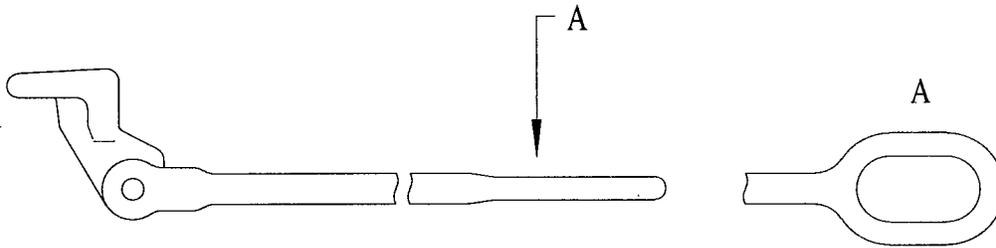


Figure 42. Lashing rod, hinged hook.

Dimensions of lashing rods

Top end of lashing rod or securing pad

The top end of a rod or a securing fitting shall be designed so that it fits into the end hole of the ISO 1161 - corner fitting and not protrude into the part of the corner fitting cavity, which is required for other lashing equipment such as twistlocks and stacking fittings, see figure 43.

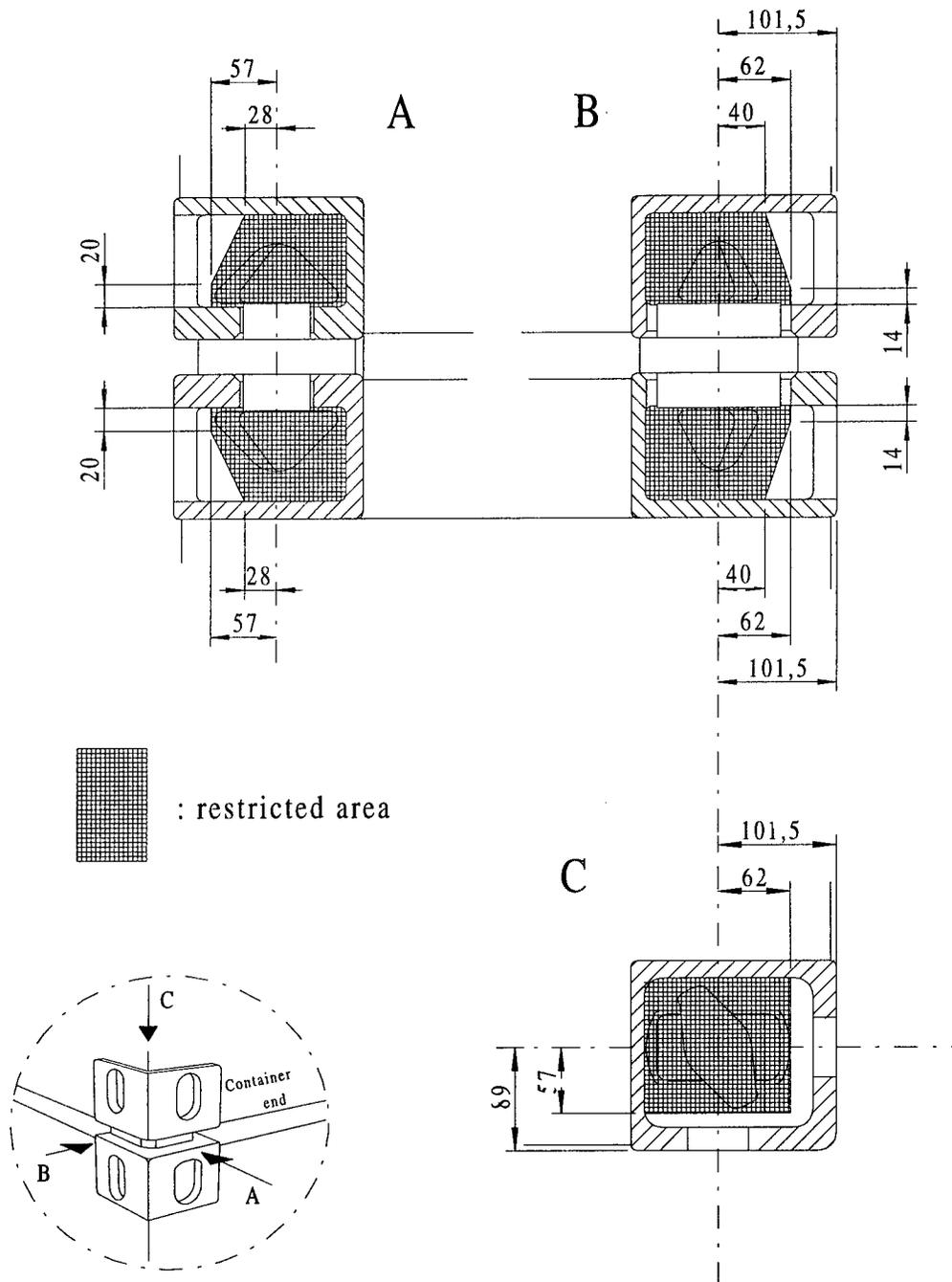


Figure 43. Restricted part of cavity. Dimensions in mm.

Bottom end of lashing rod

The bottom end of a rod shall be designed so that it fits to a tensioning device.

Other parts of lashing rods

Those parts shall be designed so that they fit together or to the transport mode.

Test methods of lashing rods

Tensile test

The lashing rod is proposed to be subjected to a tensile test load for 5 min, without permanent deformation, and the force shall then be increased until failure occurs. The breaking force shall be recorded. See figure 44.

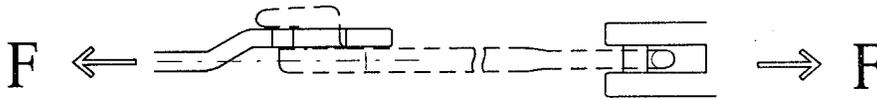


Figure 44. Tensile test of lashing rod.

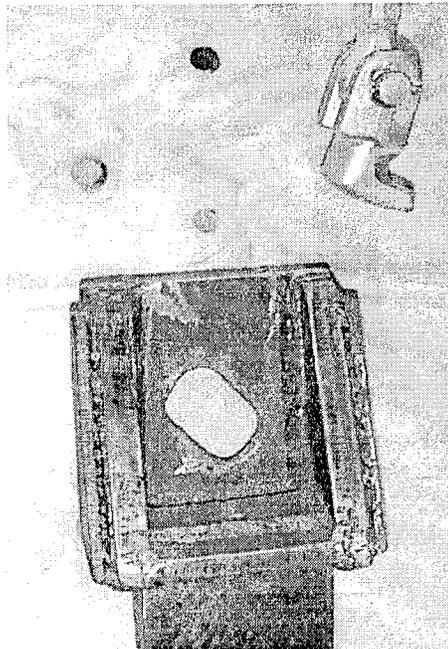


Figure 45. Test fixture

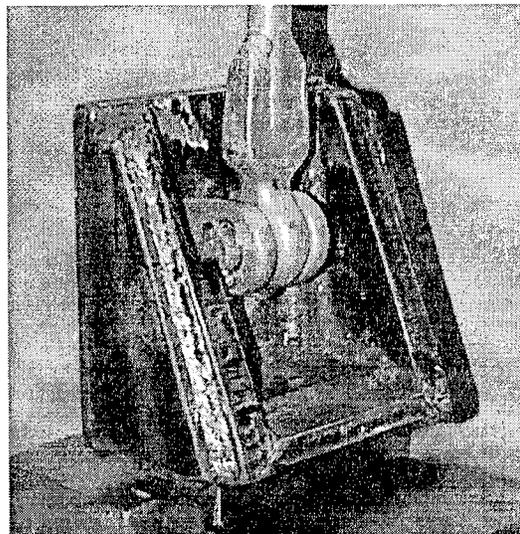


Figure 46. Tensile test of hinged lashing rod engaged in the test fixture

Test result of lashing rods

Table 11. Tensile test of lashing rods

| Marking | Test load 270 kN | Breaking load kN |
|---|------------------|------------------|
| Koei R 25 | No remark | 491.6 |
| Koei R 25 | No remark | 481.8 |
| Conver OSR GLR | No remark | 460.9 |
| Conver OSR (hinged) | No remark | 491.6 |
| M/V IBN Bajjah Conver OSR GL Nedlloyd Fast rod | No remark | 517.9 |
| LB 11-50 5055 mm | No remark | 536.3 |

Strength requirements of lashing rods

Tensile strength

The forces acting on a lashing rod during sea transport are results of the ship's rolling, and added to that is the pre-tension, which has been applied to the rod by a tensioning device, normally a turnbuckle. It can therefore be of interest to know the elongation properties of the lashing rods.

The classification societies have specified SWL (safe working load), PL (proof load) and BL (minimum breaking load) for lashing rods as described in following table.

Table 12. Tensile strength requirements for rods by the classification societies.

| | ABS | BV | DnV | GL | LR |
|--------|-----|-----|-----|-----|-----|
| SWL kN | 293 | 245 | 245 | 245 | 245 |
| PL kN | 322 | 319 | 270 | 306 | 367 |
| BL kN | 490 | 490 | 490 | 490 | 490 |

In the test results above the tested lashing rods could all withstand a proof load of 270 kN and four out of six samples tested had a breaking strength exceeding 490 kN.

In the standardisation work it is proposed that lashing rods shall withstand a tensile force of 270 kN without any permanent deformation and no requirement concerning breaking load. This value 270 kN is derived from ISO 1161, Figure 3 "Limits of load due to lashing and securing", and is the maximum force the corner fitting is designed for in the direction in which the rods normally are oriented.

To verify the tensile strength requirement the rods can be tested in accordance with the proposed test method. The force shall act between a device simulating the corner fitting and a connection similar to what the tensioning device is equipped with. If the lashing rod is designed to be connected to a corner fitting by a securing pad, this securing pad shall be a part of the tensile test.

Tensioning device, Turnbuckles

A tensioning device is a device which in one end fits to the bottom part of a lashing rod and in the other end to the structure of the transport mode, see figure 47 and 48.

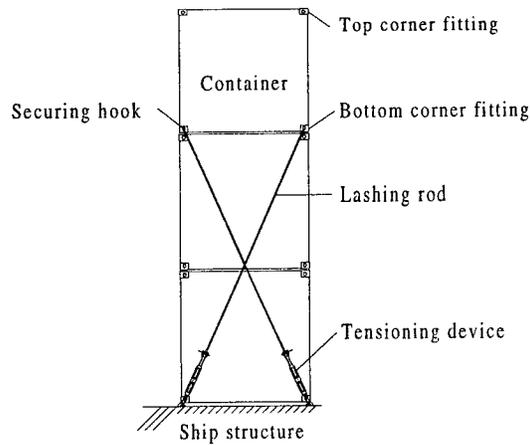


Figure 47. Lashing rod system.

It shall have a sufficient length so that it together with the lashing rod fits between the corner fittings and the transport mode. See figure 47.

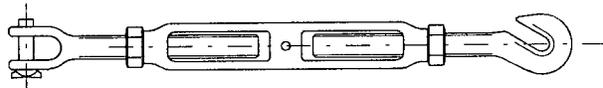


Figure 48. Tensioning device, turnbuckle.

It shall be able to induce a pre-tension to the lashing rods and keep this pre-tension during the transport.

Dimensions

The ends of a tensioning device shall be designed so that they fit together with a lashing rod in one end and to the transport mode in the other. They shall have a length which is adjusted to the length of the lashing rod together with which it is designed to be used.

Test methods

Tensile test of tensioning device

Pre-tension ability

With a force of 0,5 kN applied to the handle (length 1 m, if it is not fixed to the tensioning device) of the tensioning device the resulting tightening force is measured in a tensile test machine.

Tensile test

The force is increased to the test load and held there for 5 min. The force is then increased until failure occurs and the breaking force shall be recorded. The force shall be applied through suitable fittings. See figure 49.

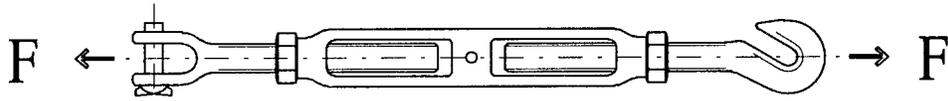


Figure 49. Tensile test of tensioning device.

Test results

Table 13. Tensile test of tensioning devices

| Marking | Generated force, kN | Test load 270 kN | Breaking load kN |
|--|---------------------|------------------|------------------|
| Taiyo 1 ¼ | 60.3 | No damage | 430.3 |
| Taiyo 1 ¼ | 65.6 | No damage | 417.2 |
| Koei R T5 | 77.4 | No damage | 510.1 |
| Koei R T5 | 71.4 | No damage | 517.8 |
| M/V IBN Bajjah Nedlloyd | 71.3 | No damage | 548.3 |
| NL American 14-9-95 Spanschroet TNO test TAV J Veensta | 47.3 | No damage | 502.3 |

Strength requirements

Tensile strength

The tensile force shall act between an anchor point and a connection similar to the one with which the lashing rod is equipped.

The classification societies have specified SWL (safe working load), PL (proof load) and BL (minimum breaking load) for tensioning devices as is described in the following table.

Table 14. Tensile strength requirements by the classification societies.

| | ABS | BV | DnV | GL | LR |
|--------|-----|-----|-----|-----|-----|
| SWL kN | 293 | 245 | 245 | 245 | 245 |
| PL kN | 322 | 319 | 270 | 306 | 367 |
| BL kN | 490 | 490 | 490 | 490 | 490 |

As is evident from the test results, all tested turnbuckles could withstand 270 kN, without any deformation, and four out of six turnbuckles could withstand 4 900 kN without breaking.

In the standardisation work it is proposed that tensioning device shall withstand a tensile force of 270 kN without any permanent deformation and no requirement concerning breaking load. This value 270 kN is derived from ISO 1161, Figure 3 "Limits of load due to lashing and securing", and is the maximum force the corner fitting is designed for in the direction which the rods normally are oriented.

All of the tested turnbuckles fulfil this requirement.

To verify the tensile strength requirement the tensioning device can be tested according to the proposed method. The force shall act between the connecting devices. The test load shall be maintained for 5 minutes, and the tensioning devices shall withstand the test load without any permanent deformation or other abnormalities which render it unsuitable for use.

Pretension ability

With a force of 0.5 kN applied to the handle of the tensioning device the resulting tightening force shall be determined in a tensile test machine. If any lever can be used the force shall be applied at a distance of 1 m from the rotating centre of the turnbuckle. As can be seen in the test result above, most of the tensioning devices (turnbuckles) generated a pre-tension force between 60 kN and 70 kN with a lever 1 m in length and 0.5 kN applied.

The generated force is of such importance that it, according to the author's opinion, should be marked on the product.

If there shall be a requirement for pre-tension, this requirement is recommended to be 60 kN.

Bridge fittings

Bridge fittings, see figure 50, sometimes referred to as top fittings, are used to locate and secure the top layer of containers in a stack. They act through the top corner fittings and are used together with other lashing equipment in both the longitudinal and transverse direction.

They can only be used when the top corner fittings of the container layers are on the same level, and they are used to secure two corner fittings in separate stacks to each other, see figure 50. Some can be used to absorb both tension and compression forces in the horizontal plane, some only tension forces.

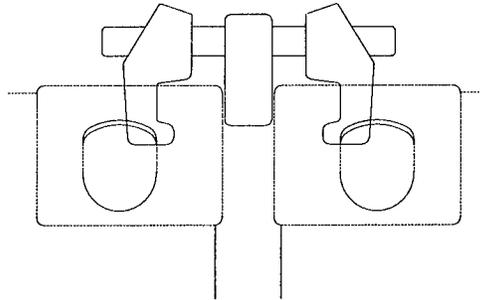


Figure 50. Bridge fitting mounted between two container stacks

Dimensions

Bridge fittings shall be designed so that they fit into the top corner fittings of a container. There are no dimensional restrictions in the top corner fitting cavity because the corner fittings engaged by the bridge fittings are not intended for any use of other lashing equipment.

The distance between the locks (hooks) of the bridge fittings must be adjustable in order to be able to be mounted into the corner fittings.

If the bridge fittings are intended to absorb compression forces, the space element, which is normally used between the outer sides of the corner fittings, must have a length in accordance with the container spacing of the ship where it is used.

Test methods

Tensile test

In the tensile test the force shall be applied to the bridge fitting by a tensile test machine and a device simulating the top hole of two top corner fittings equivalent to the ISO 1161, see figure 51. The test force shall be maintained for five minutes.

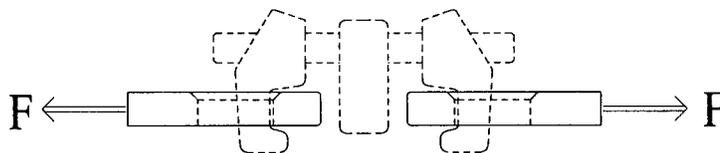


Figure 51. Tensile test of bridge fitting

Compression test

The compression force shall be applied to the bridge fitting by two flat and parallel steel plates simulating the top hole of two top corner fittings equivalent to the ISO 1161, see figure 52.

The test force shall be maintained for five minutes.

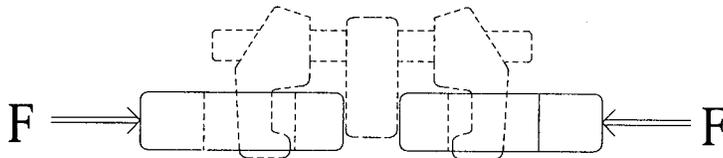


Figure 52. Compression test of bridge fitting

Strength requirements

Tensile strength

According to ISO 1161 and 1496 series the required racking (tensile and compressive) strength of the ISO corner fittings is minimum 150 kN without permanent deformation.

The classification societies have specified SWL (safe working load), PL (proof load) and BL (minimum breaking load) for bridge fittings as described in following table. As far as the author can understand the values given in the following table are valid for both tensile and compression forces.

Table 15. Tensile and compressive strength requirements by the classification societies.

| | ABS | BV | DnV | GL | LR |
|--------|-----|-----|-----|------|-----|
| SWL kN | 50 | 50 | 50 | 50 | 50 |
| PL kN | 55 | 65 | 55 | 62.5 | 75 |
| BL kN | 85 | 100 | 100 | - | 100 |

All societies seem to agree about the levels, and it is therefore proposed to set a requirement for both tensile and compression test at 65 kN, without any permanent deformation or other abnormalities which render the equipment unsuitable for use. This requirement would in that case be lower than the required 150 kN for corner fittings in ISO 1161.

If there shall be a requirement for breaking strength it should in that case be set to 100 kN.

Buttresses

Buttresses are lateral supports acting between the container stacks and the ship structure, normally inside the hold. They act through the container corner fittings and are at one end fitted with a single cone stacking fitting, which fits between the top corner fitting of a container and the bottom corner fitting of another container placed above the first one. The other end of the buttress is fitted to the ship structure, see figure 53.

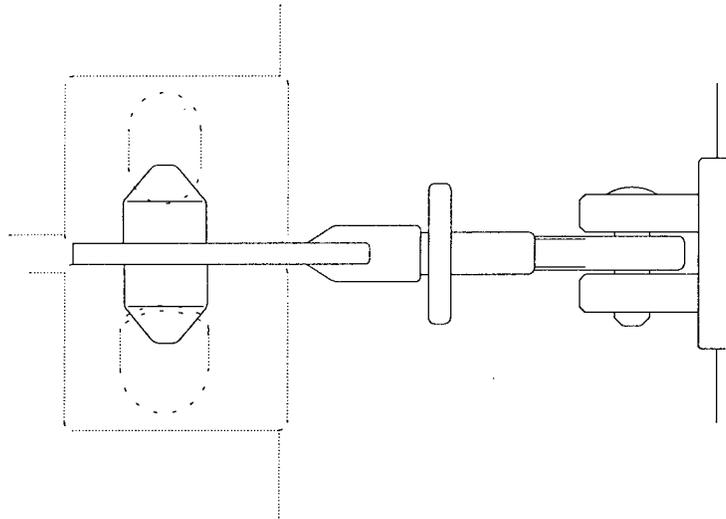


Figure 53. Buttress

Buttresses restrain horizontal movements in stacks of containers.

The top and bottom cone of the buttresses restrain connected containers against horizontal movements.

Buttresses can be of different types. Some only absorb tensile or compression forces while others absorb both.

Dimensions

Buttresses shall be designed so that they, at one end, fit into the top and bottom corner fittings of two containers placed on top of each other.

The other end shall fit to the ship structure.

There are no dimensional restrictions in the corner fitting cavities because the corner fittings that are engaged by the buttresses are not intended for any use of other lashing equipment.

The distance between the single cone stacking fitting of the buttress and the other end is normally adjustable and dependent on the ship's structure.

The thickness of the intermediate plate of the single cone in the end of the buttress shall have the same thickness as the intermediate plate of the stacking cones or twistlocks that are used in the other corner fittings of the containers.

The collar dimensions of the single cone shall be in accordance with what is required for twistlocks and stacking fittings, see Fig. 20.

Test methods

Tests of buttresses have been performed at the Swedish National Testing and Research Institute but the results from these tests are not available. The proposed method has however proved to be satisfactory.

Tensile and compression test

The force shall be applied to the buttress in a tensile test machine. The force shall be applied to the end with the stacking cone by two fittings in dimensions equivalent to the ISO 1161 corner fitting and the other end with a device similar to what is used in the ship, see figure 54. The test force shall be maintained for five minutes in each direction.

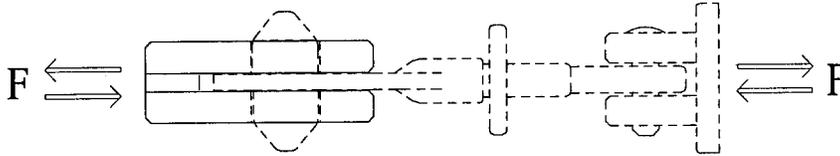


Figure 54. Tensile and compression test of buttress

Strength requirements

The buttresses have to withstand very high horizontal (shoring) forces in the transverse direction during sea transport.

The classification societies have calculated these forces in the transverse direction. In the following table the results from their calculations of permissible forces are presented.

Table 16. Permissible forces in transverse direction supporting a stack at an intermediate level.

| ABS | BV | DnV | GL | LR |
|--------|--------|--------|--------|--------|
| 600 kN | 700 kN | 600 kN | 650 kN | 840 kN |

The classification societies have also specified SWL (safe working load), PL (proof load) and BL (minimum breaking load) for buttresses as described in following table. Given values are valid for both tensile and compression forces.

Table 17. Tensile and compressive strength requirements, by the classification societies.

| | ABS | BV | DnV | GL | LR |
|--------|-----|-----|-----|-----|-----|
| SWL kN | 500 | 420 | 420 | 650 | 440 |
| PL kN | 550 | 545 | 462 | 715 | 640 |
| BL kN | 835 | 840 | 840 | 850 | 840 |

Calculated forces and requirements seem confusing but all societies agree about the levels, and it is therefore proposed to set a requirement for both tensile and compression tests of 600 kN without any permanent deformation or other abnormalities which render the equipment unsuitable for use.

If there shall be a requirement for breaking strength it is proposed to follow the classification societies' recommendations and set it to 850 kN.

Marking

It would be an advantage if all lashing equipment intended for lashing of containers were marked with the maximum force it is designed to withstand. The well known SWL (Safe Working Load) is probably not so good because of the risk of confusion with lifting equipment, which is marked like this.

According to IMO "Code of Safe Practise for Cargo Stowage and Securing" the marking shall be MSL (Maximum Securing Load).

In Europe, lashing equipment intended for road transport will be marked with LC (Lashing Capacity) in the future.

If the container lashing equipment conforms with the requirements in an international ISO standard and also is marked to show this, it would be of great importance for the safety of the users. The marking should, as mentioned before, also include the maximum force or load allowed on the equipment.

Furthermore tensioning devices should be marked with their generated pre-tension force, as this is valuable information for the user of this type of equipment. There should also be user's instructions giving guidance how to reach the pre-tension force.

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- Twistlocks. SP Technical Report 1989

Appendix 1

In the following table different measurements from 34 different twistlocks are presented.

| Marking | Type | Thickness Intermediate Plate mm | Area Inter. Plate mm ² | Length Collar mm | Width Collar mm | Height Collar mm | Distance Top-bottom lock mm | Area Top and bottom lock mm ² |
|--|------------------|--|--|------------------------|-----------------------|------------------------|--------------------------------------|---|
| All Set Marin | Semi-automatic | 30.5 | 6600 | 118 | 60 | 28 | 100 | 1350 top 990 bot |
| Taiyo Seiki Kogyo Japan | Manual 2-pos | 28 | 5500 | 108 | 58 | 30 | 92 | 940 top 940 bot |
| Asia Marine Co. LTE SK-24 261 NYK | Semi-automatic | 30 | 8400 | 118 | 60 | 29 | 93 | 830 top 830 bot |
| Taiyo Seiki Kogyo KK Osaka Japan | Manual 3-pos | 25 | 5500 | 108 | 60 | 29 | 86 | 1250 top 850 bot |
| MitsuiO.S.KK ogyo Kaisha LTD Tokyo BL 50 T Japan | Semi-automatic | 28 | 9300 | 118 | 60 | 29 | 88 | 780 top 950 bot |
| 5802 WW 20 | Manual 2-pos | 28 | 6300 | 110 | 60 | 28 | 90 | 1850 top 1080 bot |
| 3966 | Fixed base | 28 | 5500 | 111 | 60 | 30 | 88 | 1940 top 820 bot |
| Taiyo NA-12 | one side lock | 26 | 7700 | 116 | 59 | 32 | 90 | 1870 top 1870 bot |
| Taiyo NA 7 E | one side lock | 26 | 4900 | 110 | 60 | 32 | 90 | 1560 top 1120 bot |
| AC 3,2 | Manual 3-pos | 29 | 7650 | 110 | 60 | 28 | 92 | 1700 övre 1110 undre |
| Inter cie 5krr2 | Manual 3-pos | 29 | 4330 | 108 | 58 | 30 | 93 | 930 top 1995 bot |
| Inter 021601 | Manual 3-pos | 30 | 5720 | 118 | 62 | 29 | 92 | 1890 top 1030 bot |
| 18/87 | Manual 3-pos | 30 | 4800 | 114 | 59 | 28 | 90 | 1800 top 2120 bot |
| Peck & Hale 476 | Fixed base | 27 | 6720 | 115 | 60 | 34 | 95 | 1700 top 960 bot |
| C5D-3 | Fixed base | 25 | 8010 | 114 | 60 | 33 | 91 | 1060 top 850 bot |
| CS MK | Manual 3-pos | 25 | 6990 | 95 | 56 | 33 | 93 | 1940 top 1400 bot |
| | Manual 2-pos | 30 | | 110.5 | 57 | | | |
| | Manual 2-pos | 23 | | 120 | 60 | | | |
| | Manual 2-pos | 28 | | 108 | 60 | | | |
| | Manual 2-pos | 26 | | 116 | 61 | | | |
| | Manual 2-pos | 31 | | 106 | 57 | | | |

| | | | | | | |
|-----------------|----|--|-------|------|--|--|
| Manual 2-pos | 25 | | 102 | 59 | | |
| Manual 2-pos | 29 | | 108 | 58 | | |
| Manual 2-pos | 29 | | 108 | 60 | | |
| Manual 2-pos | 25 | | 108 | 61 | | |
| Manual 2-pos | 28 | | 112 | 62 | | |
| Manual 2-pos | 27 | | 113 | 61 | | |
| Fixed base | 27 | | 116 | 58 | | |
| Fixed base | 27 | | 116.5 | 62.5 | | |
| Fixed base | 28 | | 113 | 60 | | |
| Fixed base | 24 | | 115 | 56 | | |
| Fixed base | 27 | | 113 | 62 | | |
| Fixed base | 32 | | 113 | 59 | | |
| Fixed base | 28 | | 116.5 | 63.5 | | |