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CR CLASSIFICATION SOCIETY

GUIDELINES FOR CERTIFICATION OF CONTAINER SECURING SYSTEMS

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GUIDELINES FOR CERTIFICATION OF CONTAINER SECURING SYSTEMS

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CHAPTER 1 GENERAL

1.1 General

This Guidelines sets forth requirements for the certification of the initial installation of container securing systems and lashing calculation computer software aboard vessels classed by CR. It is to be clearly understood that no representation is made as to the ability of any onboard container to withstand the loads allowed. The allowable loads have been derived from successful usage over a number of years and may exceed the design loads set forth in International Organization for Standardization (ISO) Standard 1496-1:2013 and the CR Rules for the Construction and Certification of Freight Containers (hereinafter referred to as the Rules for Freight Containers), and similar standards. It is the responsibility of the client, shipowner, or charterer to ascertain that the containers used in the system can withstand the loads applied to them.

It is also to be understood that no representation is made as to the absolute validity of the values for dynamic forces from roll, pitch, and heave, vessel vertical center of gravity, container spring constants, and lashing spring constants contained in this Guidelines. It is the responsibility of the client, shipowner, or charterer to establish the validity of the values for the above items used in the system.

A vessel classed by CR having an installed container securing system certified by CR may be distinguished by the additional notation **CSS** in the Record for unrestricted service.

A container securing program to calculate forces acting on the container securing arrangements and maximum permissible stack weights for unrestricted service may be installed onboard a vessel, see 8.2.5(d). An onboard container securing program installed on a vessel assigned the **CSP** notation shall be certified in accordance with Appendix 2 of this Guidelines and the vessel assigned the notation **CSP** for container securing program.

A vessel having an installed container securing system certified by CR for operation in specific voyage trade routes where reduced accelerations are used in the calculation of forces acting on the container securing system, see 5.2.4(c), shall have an onboard certified computer with container securing program, which is mandatory. Such operation may have a different maximum number and arrangement of containers than the unrestricted voyage trade. The suffix **RSS** shall be added to the container securing program notation, **CSP-RSS**, to signify the certification of the container securing program's capability to address both unrestricted service and specific voyage routes.

Typically, vessel stow planning is performed with an onboard container securing program that can calculate the maximum permissible stack weights for each individual stack based on the provided container lashing arrangements, and then the permissible stack weights are compared against the actual planned stack weights. Should an actual stack weight exceed the permissible, corrective action is to be taken by either reducing the stack weight or modifying the lashing arrangement accordingly.

Consideration regarding the use of the unrestricted lashing and stack weights or the voyage route-specific service lashing and stack weights rest with the vessel’s Master depending on the anticipated conditions to be encountered during the voyage.

The following table illustrates the general relationships between the **CSS**, **CSP** and **CSP-RSS** notations:

Container Securing Systems	**CSS**	
Container **S**ecuring **P**rogram	Unrestricted Service	Unresricted Service and Additional **R**oute **S**pecific **S**ervice
	CSP (mandatory if container securing program is installed)	**CSP-RSS** (mandatory for route specific service)

1.2 Submission of Plans and Design Data

1.2.1 General

Plans showing the arrangements and details of the container securing system are to be submitted for review. These plans are to clearly indicate the scantlings, materials, details, and rated strengths of the container securing system and the arrangements, dimensions, and weights of the containers.

1.2.2 Information to be Submitted

The following plans and supporting data(digital files or hard copies) are to be submitted to CR.

(a) Container stowage arrangement plans

(b) Cell guide arrangement and scantling plans

(c) Bridge strut or shoring system arrangement and scantling plans

(d) Buttress system arrangement and scantling plans

(e) Container lashing plans

(f) Details of securing fittings and lashing gear including certificates verifying breaking strength (i.e., type tests and product tests)

(g) Container loading conditions, to include as a minimum, the conditions with the maximum number of containers stowed above and below deck, and the contemplated container weights which result in the greatest metacentric height (GM). The assumed container weights and the location of the center of gravity of the container, if different from 45% of the container height above the base; as well as the vessel particulars including vertical center of gravity, center of flotation, transverse metacentric height, and draft are to be submitted.

(h) Detailed ship motion studies and calculations, if available

(i) Securing system calculations

(j) Container securing manual

1.3 Definitions and Symbols

Where directions, such as longitudinal, transverse, and vertical, are used in the Guidelines, they refer to motions, accelerations, or forces that are aligned with the principal axes of the vessel.

1.3.1 Definitions

The following definitions are given to provide a clearer understanding of terms that are used in this Guidelines.

(1) Base Sockets

Flush or raised sockets which are welded to the deck, hatch cover or container support foundation and which provide a means of securing the container to the base structure by means of a Lock Fitting or similar device. Other commonly used expressions or terms include: Deck Sockets or Twistlock Foundations.

(2) Bay

An athwartship block of containers associated with a hatch or hatch cover containing multiple stacks (or rows). Bays are numbered lengthwise from bow to stern with odd numbers for 20' containers and even numbers for 40' containers. The even number between two 20' containers is used to define 40' bays. See Fig. 1-1.

(3) Block Stowage

Stowage configuration where several adjacent stacks of containers are connected at one or more tiers. See also Container Block.

(4) Bridge Fitting

A device which connects the topmost corner fittings of two adjacent stacks of containers.

(5) Bridge Strut

An adjustable device connecting the outboard-most stack of a below deck block of containers to the vessel’s structure when cell guides are not used. Also referred to as Tension/Pressure fitting.

(6) Buttress

A deck mounted tower-like structure which provides horizontal restraint for stacks of deck stowed containers. Portable "locking frames" are sometimes used to connect the container corner fittings to the buttress.

(7) Cell Guides

A rigid securing system of vertical steel angles, spaced with some margin on container length and width that provides alignment and horizontal restraint for container stacks.

(8) Container Block

A number of container stacks interconnected by double stacking cones and/or bridge fittings. Also referred to as Block Stowage.

(9) Container Stack

A single vertical stack of containers which may be secured by lock fittings, lock fittings plus lashings, or cell guides.

(10) Corner Fitting

A fixture, typically a casting, consisting of standard apertures and faces, which provide a common interface for handling and securing containers. It is an integral part of the container end frame structure and is generally in compliance with ISO Standard 1161. A similar fitting can also be found at intermediate posts located some distance from the end frame structure (such as at the 40-ft location on a 45-ft container).

(11) Corner Posts

Reinforced vertical structure between the corner fittings at the ends of containers designed to take the compression and tension forces exerted by lifting, stacking, and securing. Some containers also have intermediate ‘corner’ posts located some distance in from their ends at a nominal 40-ft spacing.

(12) CSC Plate

Safety Approval Plate under the International Convention for Safe Containers (CSC), Appendix 3 [5], to be affixed to all freight containers for use at sea. Containers shall not be loaded to more than the maximum gross weight indicated on the CSC plate.

(13) Design Breaking Load

The design breaking load of a component as determined by test of a representative sample. The design breaking load is not to be more than the last load recorded during the test prior to failure. Also referred to as Minimum Breaking Strength (MBS).

(14) Flexible Securing System

System where the stiffness of the container and securing components affect the securing forces and forces developed in the end frame structure of the containers; for example, lashing systems.

(15) High-Cube Container

Container similar in structure to ISO standard containers, but taller. While a standard container has a maximum height of 2591 mm (8'-6"), a high-cube container is 2896 mm (9'-6") tall. Also referred to as hi-cube container.

(16) ISO Freight Container

Containers meeting the design dimensions and ratings of ISO container standards such as:

ISO 1496-1 – Series 1 freight containers, Appendix 3 [1]. This sets out the basic requirements for containers suitable for international conveyance by road, rail and sea.

ISO 668 – External dimensions and ratings, Appendix 3 [2]. This standard specifies only dimensions and maximum gross weight (R).

ISO 1161 – Corner fittings and specifications, Appendix 3 [3].

(17) Lashing Assembly

A tension element made-up of a rod, wire rope or chain, a tensioning device, and a lashing point; used to secure a stack of containers.

(18) Lashing Bridge

An athwartship, elevated platform between hatches on deck from which container stacks on the hatch covers or deck may be secured with lashing assemblies.

(19) Lashing Points (Eyes)

Fittings welded to the deck, hatch cover, or pedestal that connect the end of a lashing assembly to the vessel structure or hatch covers. These include "D"-rings, fixed or hinged lashing plates, pad eyes, etc.

(20) Linkage Plate

A plate that fits over twistlocks or single stacking cones and connects adjacent stacks of containers.

(21) Lock Fitting

A device inserted into a container corner fitting which can transmit tensile and shear loads associated with the separation forces in a stack of containers. Twistlocks or pin locks are common lock fittings.

(22) Minimum Breaking Strength (MBS)

The MBS is the minimum expected load at which the fitting will fail. Also referred to as Design Breaking Load.

(23) Proof Load (PL)

A test load applied to a container securing device during production testing. Generally, the proof load is the safe working load (SWL) of the device multiplied by a factor of 1.1. A representative unit of a series of container securing devices or fittings.

(24) Racking

Distortion of the structural shell of the container due to horizontal forces.

(25) Racking Force Load

Resultant horizontal force on a container end or side from the horizontal static and dynamic forces from ship motions, the securing forces from lashing or shoring, and the self-racking force of the container in question.

(26) Rigid Container Securing System

System where the racking stiffness of the containers does not materially affect the securing forces and forces developed in the end frame structure of the containers; for example, cell guides.

(27) Row (or Stack)

A single vertical stack of containers containing one or more tiers. Also referred to as a stack. See Fig. 1-2.

(28) Safe Working Load (SWL)

The design breaking load or minimum breaking strength (MBS) of a securing device divided by an appropriate safety factor. The maximum resultant load upon a component is not to exceed the SWL.

(29) Self-Racking Force

That portion of the container's own gross weight which contributes to the racking load on the container.

(30) Side Post

The vertical part of the container side between upper and lower container fittings that is reinforced to take stacking and lifting loads. These posts are usually provided on containers greater than 40-ft to facilitate standard lifting and stacking at a 40-ft spacing. See also Corner Post.

(31) Shoring

A pad, rail, brace, or framework which provides horizontal support for containers.

(32) Stacking Cone

A device inserted into a container corner fitting. Single stacking cone provides alignment and shear restraint in a stack of containers when cell guides are not used. Double stacking cone fits into container corner fittings and connect adjacent stacks of containers when cell guides are not used.

(33) Stack (or Row)

A single vertical stack of containers containing one or more tiers. Also referred to as a Row. See Fig. 1-2.

(34) Tensioning Device

An adjustable device used to tighten a lashing (i.e., turnbuckle). See 3.2.2(b).

(35) Tension/Pressure Fitting

An adjustable device connecting the outboard-most stack of a below deck block of containers to the vessel’s structure when cell guides are not used. Also referred to as Bridge Strut.

(36) Tier of Container

In a block of containers consisting of one or more stacks, those containers at the same vertical location in each stack would be considered to be in the same tier.

(37) Tier

An indication of the vertical position of a container in a stack. The first tier is the lowest or bottom-most position in the stack.

(38) Turnbuckle

A specific type of Tensioning Device. See 3.2.2(b).

(39) Twistlock

A fitting inserted into corner fittings and used to secure containers stacked on top of each other in tension, compression, and shear. This is a specific type of lock fitting.

Semi-automatic twistlock with a spring mechanism can automatically engage and secure the container above to the container below. However, this type of twistlock must be manually released or unlocked to discharge the container above. Fully automatic twistlock (FAT) engages the corner fittings of the lower container and does not require stevedores to lock or unlock the fitting when stowing or discharging containers. Special approval is required for certification of a fully automatic twistlock.

(40) Wind Exposed Container

Any container with more than one-third of its lateral area exposed to the wind, either above the top or beyond the ends of adjacent containers. If there is more than 5 m (nominally two-container stacks) transverse separation between the subject container and the adjacent container, the entire subject container is considered wind exposed.

1.3.2 Symbols

Symbols used in the Guidelines have the following definitions:

(a) Vessel Particulars

L	=	vessel’s length between perpendiculars, in m
B	=	vessel’s molded breadth, in m
D	=	vessel’s molded depth, in m

d = vessel's draft to the summer load line, in m

GM = transverse metacentric height, in m

(b) Motions and Accelerations

Symbols	Description	Reference
$\mathrm{T_R}, T_P, \theta, \phi$	Natural roll and pitch period and amplitude	5.2.3(b)
$\mathrm{k_1}, k_r, C$	Constants used in roll and pitch calculations	5.2.3(b)
$\mathrm{R_{CTR}}, P_{CTR}$	Roll and pitch center	5.2.3(b)
$\mathrm{x_C}, y_C, z_C$	Longitudinal, transverse, and vertical distance from vessel origin to center of gravity of container	5.2.4
$\mathrm{a_0}, k_C, k_3$	Constants used in acceleration calculations	5.2.4
$\mathrm{A_T}, A_{VMAX}, A_{VMIN}, A_L$	Accelerations at a point in the transverse, vertical (max and min), and longitudinal directions.	5.2.4(a) and 5.2.4(b)
$a_{\mathrm{GT}}, a_{RT}, a_{GRV}, a_{RV}, a_{GPV}, a_{PV}, a_{GL}, a_{PL}$	Acceleration components in the transverse, vertical, and longitudinal directions due to gravity, roll, and pitch	5.2.4(a) and 5.2.4(b)

(c) Container Properties and Forces

Symbols	Description	Reference
$\mathrm{W_{(i)}}$	Gross container weight in tier (i)	5.2.7(a)
$\mathrm{L_{C(i)}}, H_{C(i)}$	Length and height of container in tier (i)	5/ 5.2.7(d)
$\mathrm{K_{CT}}, K_{CL}$	Container racking spring constants at ends for deflection in transverse direction and in sides for longitudinal deflection	2.4
$\mathrm{P_W}, F_{W(i)}$	Wind pressure and wind force at tier (i)	5.2.7(d)
$\mathrm{F_{H(i)}}, F_{L(i)}, F_{V(i)}$	Force components at tier (i) in the horizontal (transverse), longitudinal, and vertical directions.	5.2.7(a) to 5.2.7(c)
$\mathrm{Q_{(i)}}, R_{(i)}$	Transverse force acting at the top of container in tier (i) and the total racking force on tier (i)	5.3.2
$\mathrm{r_T}, r_W$	The portion of the horizontal force $\mathrm{F_{H(i)}}$ and wind force $F_{W(i)}$ acting on the container in tier (i)	5.3.2
$\mathrm{F_{CF(k)}}$	Design lashing force on container corner fitting in tier (k), taken in the direction of the lash	5.3.4
$\mathrm{C_{FH}}, C_{FV}$	Horizontal and vertical design lashing forces on container corner fitting	5.3.4
$\mathrm{C_{B(i)}}, C_{T(i)}$	Corner post compression into bottom/top of the container in tier (i)	5.3.5
$\mathrm{h_{C(i)}}, h_{W(i)}, h_{l(i)}$ $\mathrm{b_{CF}}, b_C, b_{l(i)}$	Vertical and transverse distances in a container stack used to calculated forces	5.3.5
$\mathrm{T_{B(i)}}, T_{T(i)}$	Corner post tension into bottom/top of the container in tier (i)	5.3.6

(d) Lashing Properties and Forces

Symbols	Description	Reference
E_l	Equivalent elastic modulus of the lashing assembly	Table 3-2
A_l	Cross sectional area of lash assembly tension element	Table 3-1
$\mathrm{L}_l, L_Z, L_Y, L_X$	Total length of lash assembly and its vertical (Z), transverse (Y), and longitudinal (X) projection	3.2.3(b) and 5.3.3(a)
β	Lash angle	5.3.3(a)
K_l, K_{lH}	Lashing spring constant and its horizontal component	5.3.3(a)

T_l, F_{lH}, F_{lV}	Total lash tension and its horizontal and vertical components	5.3.3(a)
$\Delta_{(i)}$	Horizontal displacement at top of container in tier (i)	5.3.3(b)

1.4 Descriptions of Container Stowage Locations

1.4.1 The following terms, used to describe container stowage locations (slot numbering system) onboard ship, are derived from Appendix 3 [4], ISO standard 9711-1:1990. The ISO Bay Plan Numbering Scheme is showed in Fig. 1-1 and Fig. 1-2.

(a) Bay or Bay Number

An athwartship row of containers associated with a hatch or hatch cover that identifies longitudinal location and container length (even numbers are used for 40-ft containers and odd numbers generally refer to 20-ft containers).

(b) Row or Row Number

A vertical stack of containers that identifies transverse location from centerline. Also referred to as Stack or Stack Number

(c) Tier or Tier Number

A horizontal group of containers that identifies the vertical location from a reference point – typically from the inner bottom below deck and from the weather deck or hatch cover on deck.

1.4.2 The ISO Bay Plan system utilizes a six digit number to uniquely describe each container slot location.

The first two digits indicate the bay number. The first 40-ft container bay starting at the bow is 02 and each 40-ft bay thereafter is numbered in increments of 4 (02, 06, 10, 14, 18,…). 20-ft container bays use the odd numbers preceding and following the 40-ft bay numbers.

The third and fourth digits indicate the row or stack number. For a stowage arrangement with an even number of bays in the hold or on deck, the odd numbered stacks are numbered sequentially (by 2’s) on the starboard side, beginning with 01 at the stack closest to centerline, and similarly for the even numbers on the port side. For an odd number of rows on deck, the centerline stack is numbered 00, the starboard stacks are numbered 01, 03, 05,…; and the port stacks are numbered 02, 04, 06,....

The fifth and sixth digits indicate the tier number. Below deck, the first tier just above the inner bottom is 02. Each tier above is numbered sequentially by 2’s (02, 04, 06, 08, 10,…). The first tier on deck is 82 and for each tier above, the number increases by 2 (82, 84, 86, 88, 90,…).

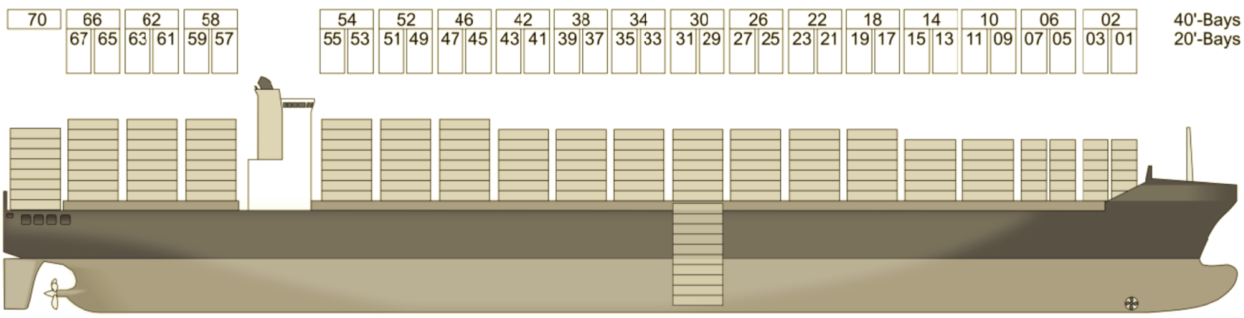


Fig.1-1
ISO Bay Numbering Scheme

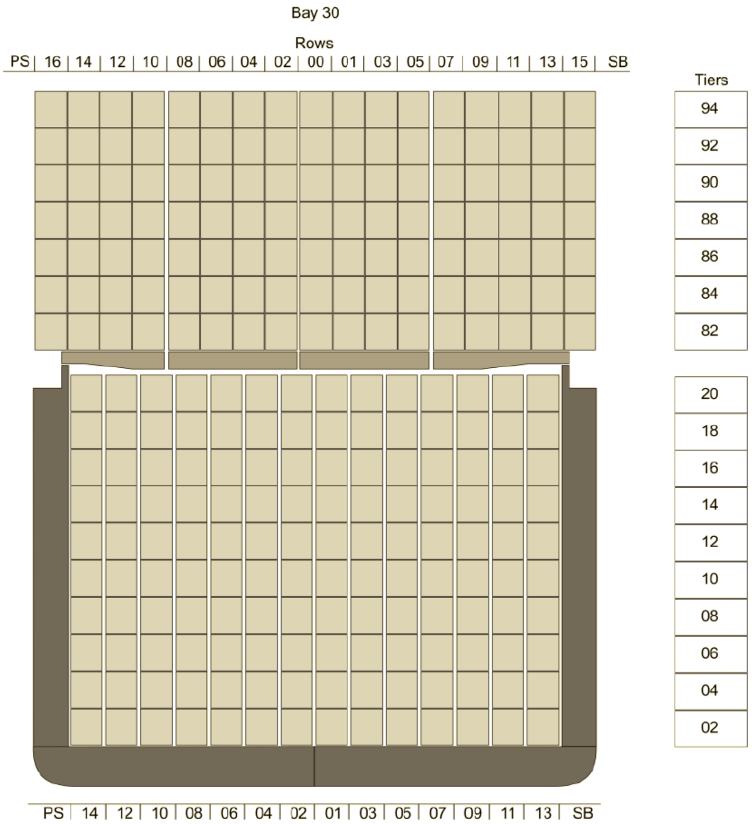


Fig. 1-2
ISO Stack/Row and Tier Numbering Scheme

CHAPTER 2 CONTAINER CHARACTERISTICS

2.1 General

All cargo containers used for ocean transport are to have a proper CSC Approval Plate affixed (as defined in the IMO International Convention for Safe Containers 1972, Appendix [5]) and should meet the minimum strength and load requirements of ISO 1496-1:2013, Appendix [1]. Where special containers are used for unique cargoes that have reduced or increased load capacities, these limitations shall be considered when stowing them onboard ship and also when determining permissible tier and container stack weights.

2.2 Dimensions

The premise of this Guidelines is that the dimensions of the containers and characteristics of the corner fittings or castings are in agreement with the international standards given in ISO 668:2013 and ISO 1161:1984. Even so, there are some ocean transport containers that are not defined by these references, and Table 2-1 and Table 2-2 are offered as a brief summary of the dimensions for standard ISO containers and for some additional commonly used container sizes.

Table 2-1
External Container Dimensions and Tolerances

Nominal Size	Gross Mass	External Dimensions					
		Length	Tolerance	Width	Tolerance	Height	Tolerance
	kg	mm	mm	mm	mm	mm	mm
10 ft ISO 668	10,160	2991	＋0/－5	2438	＋0/－5	2438	＋0/－5
20 ft ISO 668	30,480	6058	＋0/－6	2438	＋0/－5	2438	＋0/－5
						2591	＋0/－5
30 ft ISO 668	30,480	9125	＋0/－10	2438	＋0/－5	2591	＋0/－5
						2896	＋0/－5
40 ft ISO 668	30,480	12192	＋0/－10	2438	＋0/－5	2591	＋0/－5
						2896	＋0/－5
45 ft	30,480	13716	＋0/－10	2438	＋0/－5	2896	＋0/－5
48 ft	30,480	14630	＋0/－10	2591	＋0/－5	2908	＋0/－5
53 ft	30,480	16154	＋0/－10	2591	＋0/－5	2908	＋0/－5

Table 2-2
Container Corner Fitting Dimensions and Tolerances

Nominal Size	Gross Mass	Dimensions Center to Center of Corner Fittings			
		Length	Tolerance	Width	Tolerance
	kg	mm	mm	mm	mm
10 ft ISO 668	10,160	2787	＋3/－5	2259	＋0/－5
20 ft ISO 668	30,480	5853	＋3/－5	2259	＋0/－5
30 ft ISO 668	30,480	8918	＋4/－6	2259	＋0/－5
40 ft ISO 668	30,480	11985	＋4/－6	2259	＋0/－5
45 ft	30,480	11985	＋4/－6	2259	＋0/－5
		13509	＋4/－6		
48 ft	30,480	11985	＋4/－6	2259	＋0/－5
		14422	＋4/－6		
53 ft	30,480	11985	＋4/－6	2259	＋0/－5
		15947	＋4/－6		

When containers with other dimensions are to be used, they should be addressed in the documents submitted for approval.

2.3 Permissible Container Loads and Strength Ratings

The combined static, dynamic, and securing loads imposed on the container structure are not to exceed those given in Table 2-3 for standard 20-ft and 40-ft containers. These limits are derived, in part, from ISO1496-1:2013.

The allowable loads for standard 45-ft containers are to be assumed equivalent to those for 40-ft containers given in Table 2-3 when the 45-ft containers are supported and loaded at the end walls or at the 40-ft points.

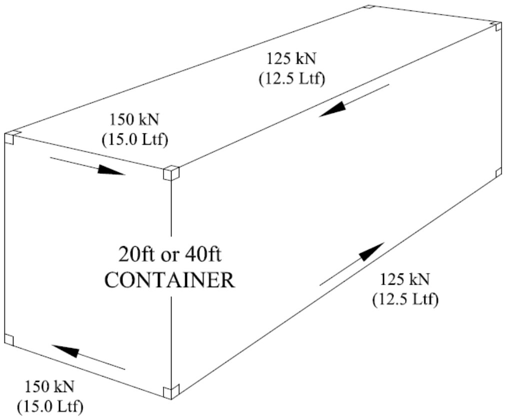
48-ft and 53-ft containers are not commonly used in many services, and an industry standard for strength ratings has yet to be developed. If no specific container strength test data is available for these containers, the strength ratings for 40-ft containers given in Table 2-3 may be used for the design of the securing system if the 48-ft containers and 53-ft containers are supported and loaded only at the end walls. If additional sets of stacking posts are used, see 2.3.2.

The design container loads given in Table 2-3 are illustrated in Fig. 2-1.

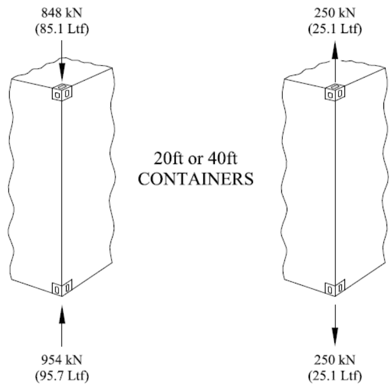
Table 2-3
Design Loads on Containers and Container Fittings

		Nominal Container Size:	20-ft Container	40-ft Container
		Maximum Gross Weight:	30.48 tons	30.48 tons
		Units:	kN	kN
End Wall Racking			150	150
Side Wall Racking			125	125
Corner Post Compression			848	848
Transverse Securing Force on Corner Fitting:	Top Corner	Tension	250	250
		Compression	250	250
	Bottom Corner	Tension	350	350
		Compression	350	350
Longitudinal Securing Force on Corner Fitting	Top Corner	Tension	100	100
		Compression	50	50
	Bottom Corner	Tension	200	300
		Compression	200	300
Lashing Force on Top and Bottom Corner Fitting		Vertical	300	300
		Horizontal	150	150
Vertical Tension on Top Corner Fitting			250	250
Vertical Tension on Bottom Corner Fitting			250	250

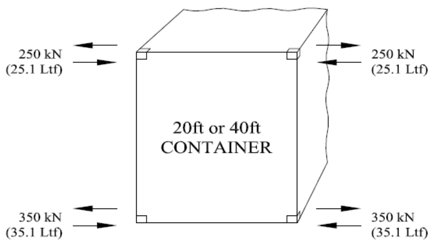
For containers which cannot support the above loads due to the container construction standards, the loads are to be properly reduced. See 1.1.



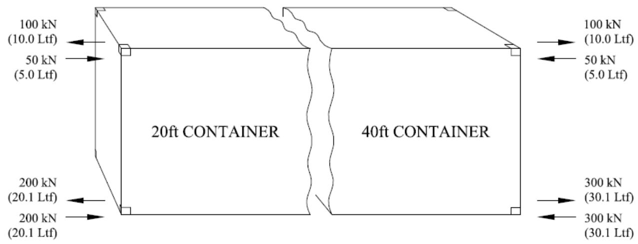
Racking Loads



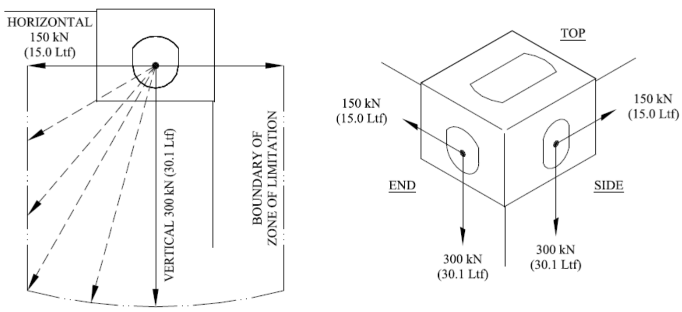
Compression and Tension Loads



Transverse Securing Forces



Longitudinal Securing Forces



Lashing Forces on Corner Fittings

Fig. 2-1
Design Loads for ISO 20-ft and 40-ft Containers

2.3.1 Permissible Forces on Corner Fittings

The permissible horizontal securing and shoring forces on 20-ft and 40-ft containers listed in Table 2-3 are illustrated in Fig. 2-1. Note that the bearing area for all securing fittings must be evaluated to ensure that the local shear force in the sides of the corner fitting does not exceed 34% of yield for the maximum design load.

The design vertical and horizontal lashing loads that may act on the upper and lower container corner fittings in either vertical plane are given in Table 2-3 and illustrated in Fig. 2-1.

2.3.2 Containers with Stacking Posts Offset from the End Walls

Most containers greater than 40-ft in length have stacking posts at locations offset from the end walls that match the spacing of the corner posts on 40-ft containers. This facilitates the stowage of these longer containers over the top of 40-ft containers (or any containers with stacking posts at 40-ft spacing) or at hatch locations with 40-ft base sockets. Over-wide containers (48-ft containers and 53-ft containers) also typically have special fittings at the top and bottom of the stacking posts that have apertures with a transverse separation that matches the standard width container.

These longer containers with the 40-ft stacking posts permit a wide variety of mixed length stack configurations. There are limitations based on the ability to operate twistlocks and apply lashings, but considerable variability still exists where the containers are supported from below and loaded from above (a function on where twistlocks are placed and lashings applied).

When designing the securing system, the location of support at the bottom of the container and application of load at the top of the container becomes critical for these longer containers. The capacity of these containers to support vertical loads (compression from containers above or lashing loads) can be limited if the support is at a stacking post while the load is applied at the end wall (or vice versa). The compressive strength rating of a container in such a situation can be much less than that of the strength of the end wall corner posts. The stacking posts are also usually less robust than the corner posts and can support less compression even when loaded and supported at the same post. Because the stacking posts in the side wall do not provide a direct load path to the aperture at the standard spacing, there is a moment induced in the bottom fitting unless a special extra-wide twistlock is used.

2.4 Racking Spring Constants

In the absence of container test data or container specifications, the values given in Table 2-4 shall be used for standard ISO containers ranging in height from 2438 mm to 2908 mm (8' to 9'-6.5").

Table 2-4
Racking Spring Constant, K_C and K_{CL}

Panel Location	Container Racking Spring Constant (kN/mm)
Container Door End, K_C	3.73
Container Closed End, K_C	15.69
Container Side, K_{CL}	5.79

For non ISO containers, the racking spring constants are to be determined based on container test data.

2.4.1 Specialty Containers

Containers used for the transport of unique cargo with unusual or non-standard dimensions and structure and with reduced racking strength or racking spring characteristics shall be evaluated separately and shall be clearly defined in general stowage operations. It is good practice to stow containers with reduced racking strength within cell guides or in the uppermost tiers on deck where racking loads are not severe.

2.4.2 Container Strength Tests

Containers that have one or both doors removed for the transport of special cargoes shall be assumed to have reduced racking strength and shall similarly be stowed within cell guides or in the uppermost tiers on deck.

2.5 Container Strength Tests

Tests shall be conducted on prototypes of unusual containers to establish the permissible values for the strength parameter listed in Table 2-3. Such testing shall follow the procedures and requirements described in the Rules for Freight Containers.

CHAPTER 3 SECURING DEVICES

3.1 General

All devices and other elements used to secure containers onboard a vessel, whether they are fixed to the hull structure or loose fittings, are to meet the minimum strength requirements described in this Chapter. Determination of the forces imposed on each device or element is discussed in Chapter 5. The selection, arrangement, and use, of the devices shall also be in accordance with the guidance given in Chapter 4.

Instructions for proper installation, use, inspection, maintenance, and lubrication of securing components are to be included in the Container Securing Manual (refer to Chapter 8). It is important to note that in a seaway, the changing direction of the accelerations acting on the containers and the gaps in most fittings securing the containers create a system where components do slide on one another. This can result in significant abrasion and wear. It is recommended that all loose components be inspected and inventoried regularly. If any loose components are found defective they shall be marked and removed from service. Fixed securing devices are to be visually inspected regularly for damage such as cracking or deformation that would make them inoperable or incapable of transmitting load to the hull structure.

3.2 Loose Fittings

Securing devices that are not permanently attached to the hull structure and that can be removed for storage or maintenance are "loose fittings." These include fittings that pass loads between containers, and fittings that pass loads from containers to the hull structure.

3.2.1 Twistlocks, Stackers, and Other Container Connectors

These fittings are designed to fit the openings in the container corner castings and connect the container to another container or to fixed securing fittings. They are to be designed to pass compression and shear loads and when designed with a locking mechanism, tensile loads.

(a) Stackers or Stacking Cones

These pass compression and shear loads only. They are used with containers where corner post tension restraint is not required. Double stackers connect two container stacks and can provide some translational restraint for the stack.

The cones on these fittings are sized slightly smaller than the openings in the container corner castings. This allows some sliding to occur before the cones engage the container and restrain horizontal movement.

Fig. 3-1
Sample of Stacker

(b) Lock Fittings

Lock fittings are similar to stackers but have the capability to pass tension loads. They are commonly called twistlocks and come in manual, semi-automatic, and fully automatic types. The manual twistlocks require an operator to lock and unlock the fitting. Semi-automatic twistlocks can be locked automatically when the containers are set in place, but must be manually unlocked. The fully automatic twistlocks do not require manual locking or unlocking, relying instead on slight tipping/rotation of the container above to disengage the fitting.

As is the case for stacking cones, lock fittings allow containers to slide horizontally before the fittings engage and restrain horizontal movement. Likewise, there are gaps between the tension elements and the corner castings that allow some vertical separation of containers to occur before the tension is restrained.

(c) Bridge Fitting, Bridge Strut

Bridge fittings are designed to connect the topmost containers in a stack with an adjacent stack of exactly the same height. They can support tensile or compressive loads in a horizontal direction and are used to connect independent stacks of containers into a block that may better resist overturning moments. Often bridge fittings are used in conjunction with bridge struts to pass transverse loads from connected stacks to the hull structure.

Bridge fittings and struts are typically adjusted with a threaded element that forms a tight connection in tension, or both tension and compression, with little tolerance for sliding or movement. However, in a seaway, other elements of the stack can slide and may loosen the bridge and strut fittings. The affect of clearances that can develop in service are to be taken into account during the assessment of the container securing arrangement.

3.2.2 Lashing Assemblies

Lashing assemblies are utilized to resist the overturning moment of a free standing stack of containers. Some of the ways that they can be applied are described in Chapter 4. Typically, they consist of a tension element (for example, steel rod, chain or wire rope), a tensioning device (for example, a turnbuckle), and a lashing point. The lashing point is a fixed securing device and is discussed in 3.3 of this Chapter. Modern container lashing assemblies typically use a steel rod as the tension element.

The upper end of the lashing rod is are designed to fit the openings in the container corner castings and to engage or secure the rod to the corner casting when rotated to the intended angle of application. As noted, they are commonly designed to only support tensile loads, not compressive loads. Slack is removed, and the assembly is tightened with a threaded element in the tensioning device. Repetitive container stack movements that occur in a seaway can cause the lashing assembly to alternate between slack and taut conditions. This may cause the tensioning device to loosen if not fitted with a locking device to prevent the threaded portion from backing off. The stiffness of the lashing assembly is an important factor in the load sharing between the lashings and containers.

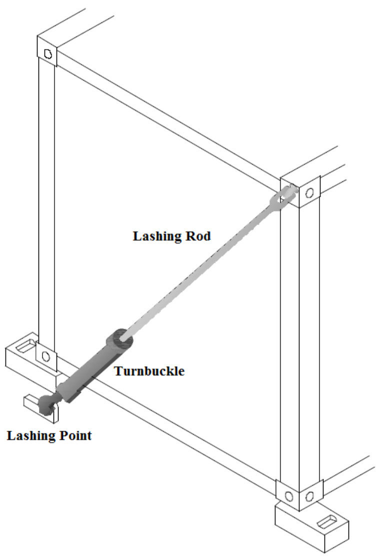


Fig. 3-2
Examples of Lashing Assemblies

(a) Tension Elements: Lashing Rods, Chain, Wire

Normally, high tensile steel is used to create rods that have the appropriate strength and length while remaining light enough for one person to handle. The end fittings must be easily installed in a corner casting several meters above the access platform and also mate with the tensioning device. Flexibility to handle containers of different heights (standard and hi-cube containers) can be provided with additional links or attachment points on the rod.

Chain and wire rope are not typically used on pure containerships because they are more difficult to install and maintain. They can, however, be useful for non-standardized cargo stowage arrangements.

(b) Tensioning Devices (Turnbuckles)

Tensioning devices usually require an additional rod or tool to turn the barrel or body of the turnbuckle as it is tightened or loosened. It is important that it also be fitted with a locking mechanism to reduce the likelihood that lashing assemblies will slacken in a seaway due to the cyclical loading and unloading associated with the vessel's motions.

The maximum range of operation (minimum to maximum working length) is one of the primary factors determining the working length of the entire lashing assembly.

Fig. 3-3
Sample of Turnbuckles

3.2.2 Stiffness of Loose Fittings

For the flexible securing devices (lashing assemblies and some bridge struts) the actual stiffness is critical to the proper analysis of the container securing system. The stiffness can be determined by properly designed and conducted tests, and in some cases, by calculation.

(a) Stiffness Measurements

It is best to determine the spring constant (K_L) of the entire securing assembly by testing. For lashing assemblies, the test shall include the fixed lashing point, tensioning device, and tension component assembled as it will be in service. The assembly shall be loaded up to its Safe Working Load (SWL) and measurements of strain taken at discrete points of load application (zero to the SWL). The lashing assembly spring constant will be the average slope of the load/strain curve.

(b) Stiffness Calculation for Lashing Assemblies

When testing is not possible, the lashing assembly spring constant may be determined from the stiffness of the tension element (e.g., rod, chain, or wire).

$$\mathrm{K}_l = \frac{A_l E_l}{L_l} = \text{lashing spring constant, in kN/mm}$$

where

A_l = cross-sectional area of a lashing assembly tension element, in mm^2

E_l = equivalent elastic modulus of the lashing, in kN/mm^2

L_l = overall length of the lashing assembly measured from the securing point to the container corner casting attachment point (no deduction for tensioning device), in mm. This length is to include the longitudinal separation of the lashing point and face of the container stack, unless this longitudinal separation is less than 400 *mm*.

In the absence of submitted lashing test data, the values given in Tables 3-1 and Table 3-2 may be used in the above expression.

Table 3-1
Area of Lashing Component, A_l

Lashing Element	A_l
Steel Wire Rope	Nominal area
Steel Rod	Actual area
Steel Chain	One side of link

Table 3-2
Equivalent Elastic Modulus, E_l

Lashing Element	E_l (*kN/mm^2*)
Steel Wire Rope	88.3
Steel Rod in lashing assembly with $L_l \leq 5000$ mm (for lashings extending up ~1 tier)	97.1
Steel Rod in lashing assembly with $L_l > 5000$ mm (for lashings extending up ~2 tiers)	176.6
Steel Chain	98.1

Lashing elements made of materials other than steel will be specially considered. Each wire rope lashing element is to be pre-stretched to remove its construction stretch by loading to 50% of its rated breaking strength before being placed in service.

(c) Stiffness Calculation for Bridge Strut and Shoring

The spring constant of the bridge strut or shoring is expressed by the following equation.

$$K_S = \frac{T'}{\Delta_S} = \text{strut or shoring spring constant, in kN/mm}$$

where

T' = bridge strut or shoring force applied, in kN

Δ_S = displacement of the bridge strut or shoring under load, T', in mm

3.3 Fixed Fittings

Securing devices that are permanently attached to the hull structure (including fittings attached to hatch covers) and that can not be removed for storage or maintenance are "fixed fittings". In some cases, loose fittings (for example, lashing assemblies) are used between containers and the fixed fittings such as lashing plates. In other cases, fixed fittings provide support directly to containers, as is the arrangement with doubler plate foundations.

3.3.1 Foundations and Base Plates

These fittings are used under the corner castings and stacking posts of the containers. They support the entire compressive load from the stack and transfer it to the hull structure. In cargo holds with cell guides, these foundations can be simple doubler plates since they do not support any tension or shear load. Where there are no cell guides, but the stacks are restrained from tipping by bridge fittings and/or shoring fittings, the foundations will typically have centering cones or transverse guides between container stacks to take the shear or transverse load at the bottom of the stack. This keeps the bottom of the stack from sliding horizontally. In some cases (for example between 20-ft containers in a 40-ft cell), guide plates or "shear chocks" are used to restrain the free ends of the 20-ft containers from transverse movement as the vessel rolls.

3.3.2 Twistlock Foundations (Deck Sockets or Base Sockets)

When stacks are secured with flexible lashing assemblies and the container corners are to be restrained in tension as well as compression, twistlock foundations or "base sockets" are used. These fixed fittings have apertures designed for use with a twistlock that are similar to the apertures in the bottom of a container corner casting. Once the twistlock is engaged, the base socket can transmit the full allowable corner post tensile load into the hull's structure. It is important that the top plate of the base socket be capable of taking the full MBS rating in tension through the small contact area of the ears of the twistlock that provide the restraint.

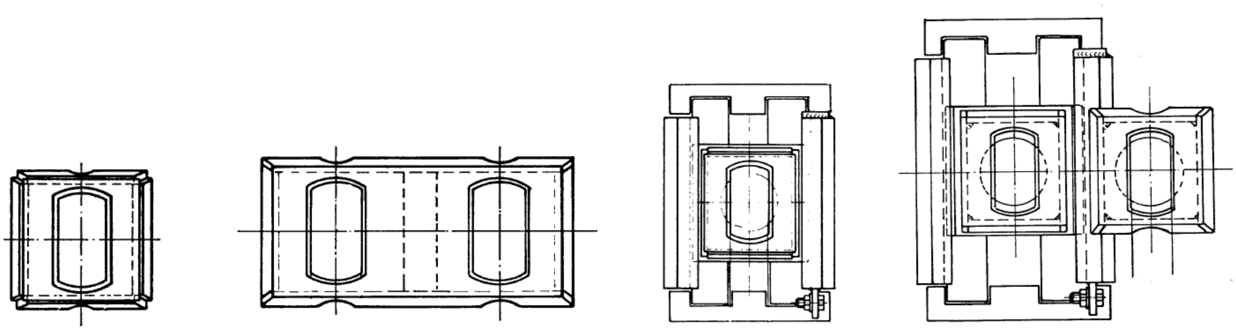


Fig. 3-4
Sample of Twistlock Foundations or Base Sockets

As seen from Fig. 3-4, base sockets are manufactured in single and double configurations. For locations where the containers must span hatch covers, or are supported partly on hatch covers and partly on pedestals, sliding base sockets are often used. These allow relative movement in the underlying hull structure while still providing tension, transverse shear, and compression restraints.

Dimensional tolerances during installation shall ensure center-to-center distances as defined in Appendix 3 [2] do not differ by more than the following:

Longitudinal	＋0/－5 mm	for 10-ft containers
	＋0/－6 mm	for 20-ft containers
	＋0/－10 mm	for 30, 40, 45, 48, and 53-ft containers
Transverse	＋0/－5 mm	
Difference in diagonals	<13 mm	for 20-ft containers
	<19 mm	for 40, 45, 48, and 53-ft containers

Regarding the flatness of the base plane of a stack of containers created by four foundations, no point shall deviate from the plane of the other three by more than:

± 3 mm for 20-ft containers

± 6 mm for 40, 45, 48, and 53-ft containers

3.3.3 Lashing Plates and D-Rings

Lashing plates and D-rings are the connecting points for lashing assemblies to the hull structure. These fittings are welded to the deck, pedestals, lashing bridges, or hatch covers. The lashing plates and D-rings are to typically have a strength rating equivalent to or greater than the MBS of the lashing assembly and be aligned with the direction of the load. Some lashing plates have swivels to accommodate different stack configurations. D-rings offer the option of a low profile when not in use and are most common on open decks or in holds, where taller obstructions would be a problem.

3.4 Strength Ratings and Factors of Safety

Each container securing device, whether loose or fixed, has an allowable strength rating referred to as the Safe Working Load (SWL). The calculated load in a container securing device subject to the accelerations and forces defined in Chapter 5 is not to exceed the safe working load (SWL). The SWL is defined as a function of the Minimum Breaking Strength (MBS) and a Safety Factor (SF) as discussed in 3.4.1 and 3.4.2.

The design strength limit for the attachment welds for fixed securing devices is covered in 3.4.3. For all container supporting elements, such as cell guides, lashing platforms, shoring, and buttresses, as well as related hull structure, the design limits are given in 5.4.4 and 5.4.5

3.4.1 Safety Factors for Securing Devices

In order to account for such unpredictable factors as deterioration of securing devices, deterioration of containers, manufacturing imperfections, extreme ship motions, and variations in container and lashing spring constants, a safety factor is used to reduce the minimum breaking strength (MBS) of a device to an acceptable safe working load (SWL). The SWL is obtained by dividing the minimum breaking strength (MBS) of the element by the specified safety factor (SF).

$$\mathrm{SWL} = \frac{\mathrm{MBS}}{\mathrm{SF}}$$

The safety factors shown in Table 3-3 are to be used for all container securing devices.

Table 3-3
Safety Factors for Securing Fittings

Lashing Element	Material	Safety Factor (SF)
Steel Wire Rope	---	2.0
Steel Rod	MS HTS	2.0 1.67
Steel Chain	---	2.0
Other Steel Fittings and Securing Devices	MS HTS	2.0 1.67
Nodular Iron Fittings	---	2.0

MS = ordinary strength steel
HTS = higher strength steel with $f_y \geq 315\ \mathrm{N/mm^2}$

3.4.2 Strength Ratings for Securing Devices

All securing devices are subject to factory testing to confirm the minimum breaking strength (MBS). This testing is described in Chapter 7. The manufacturer shall provide with each delivered order of fittings an test reports which confirms the MBS and SWL and is issued by recognized organization. The certified SWL is to be used to design the container securing system. Table 3-4 shows nominal design values of mean breaking strength and safe working load that are in common use and is provided for reference.

3.4.3 Strength of Weldments for Fixed Securing Devices

The strength of weldments for lashing plates (padeyes), base sockets, and other fixed securing devices is governed by the permissible stress given below. The applicable load is the SWL of the device.

$$q = 0.53f_y$$

where

q = nominal permissible shear stress, in *kN/cm*^{2}

f_y = minimum specified yield point of the weld filler material, in *kN/cm*^{2}

For higher strength filler material, f_y is not to be taken as greater than 72% of the specified minimum tensile strength. Note that the strength of the weld filler material is not to be taken greater than the strength of the lowest strength base material to which the weld is attached.

The structure supporting any securing device shall meet the design requirements of the hull structure. See also 5.4.5.

Table 3-4
Typical Design Load for Container Securing Fittings

Lashing Element	Min. Breaking Strength (MBS) *kN*	Safe Working Load (SWL) *kN*
Tension Element (Lashing Rod)	490	293
Tensioning Device (Turnbuckle)	490	293
Lock Fitting(Twistlock)	500	299
Lashing Point (Lashing Plate)	490	293
Lashing Point (D-Ring)	460	275
Twistlock Foundation (Base Socket)	500	299
TP Bridge Fitting	400	200

CHAPTER 4 CONTAINER SECURING ARRANGEMENTS

4.1 General

Containers are generally to be stowed above and below deck with their sides or longest dimension oriented in the fore-and-aft direction. Stowage in the athwartship direction is to be considered separately. Containers shall not be stowed in locations above and below deck that preclude access for inspection and maintenance of equipment or systems required for safe operation of the vessel. In general, containers shall not be stowed on deck beyond the sides of the vessel. Container stacks may be secured with systems employing fixed and flexible restraints or combinations of both. A brief overview of typical container securing arrangements is given in this Chpater. Maximum securing loads shall take into consideration the limits of the supporting vessel structure. Permissible loads and ratings for securing systems are dependent on the strength and flexibility of the securing components and the containers. The design principles and guidance for evaluating these systems is presented in Chapter 5.

4.2 Stacks Secured Only with Lock Fittings

Container stacks may be secured using only lock fittings (twistlocks) at all four corners between tiers and between the base sockets and the bottom corner castings. This system may be used for securing stacks with one or more containers depending on the location, accelerations, and the wind load (if located above the weather deck). Restraint against tipping is provided by locking devices at the base of each tier. Permissible stack weights are based on the vertical strength of the lock fittings and container corner posts, in tension and compression, and by the end wall racking strength of the containers.

4.3 Flexible Securing Systems (Lashings)

Container stacks may be secured using flexible lashing assemblies that are connected to fixed points at the deck, hatch cover, or elevated lashing platform and the openings in the container corner castings. The lashing assemblies may be used to provide vertical and/or lateral restraint. Lock fittings are also typically required in stacks secured with flexible lashing assemblies. This type of securing system is generally used for container stacks on the weather deck.

4.3.1 Typical Lashing Arrangements

Securing systems for deck stowage of containers are generally designed so that each stack is independent and may be loaded or unloaded without impact to the adjacent stack. The following Subparagraphs describe several common lashing arrangements.

(a) Cross Lash

A cross lash system utilizes two lashing assemblies per end wall that lead across the end panels of the container stack in both directions. The lower end of a lashing assembly starts at a fixed securing point, such as a lashing plate, on one side and typically extends to the bottom corner casting of the second or third tier container above the lashing point at the opposite side. An example of a double cross lashed stack with both an upper and a lower cross lash is shown in Fig. 4-1. Although both the upper and lower lashing assemblies provide lateral restraint, note that the steeper angle of the upper lash renders the lash less effective, while the vertical component of the restraining force contributes to the overall corner post compression load in the containers below. The upper cross lash rod, because of the length, is more awkward to handle and install.

(b) Paired Lash

A paired cross lash arrangement is a double cross lash in which the lashing assemblies run to the bottom corner casting of the upper tier and to the top corner casting of the lower tier. This arrangement is stiffer than a single cross lash system and provides some measure of redundancy. A paired lash system typically utilizes rods that are generally the same length.

(c) Vertical Lash

A vertical lashing assembly is used to resist the tipping moment and in particular, the vertical uplift load (corner post tension) on the uphill side of an inclined stack. These lashing assemblies are typically used at outboard wind loaded stacks. An example is shown in Fig. 4-2.

(d) Side Lash

A side lash is similar to a cross lash except that it leads away from the container stack instead of across the end face of the stack. Refer to Fig. 4-3. In addition to the lateral restraint provided, the vertical component of the restraining force from a side lash helps to reduce corner post tension. However, it can not be applied to both sides of an outboard stack at the side of the vessel, and the rods require special heads with suitable offsets to permit the rods from adjacent stacks to cross over one another without interference.

(e) Combination Lashing Systems

As shown in Fig. 4-2, it is possible to combine lashing systems for specific locations where their effectiveness may permit higher stack ratings. For example, outboard stacks that are subject to a lateral design wind load are often limited by corner post tension. The addition of a vertical lash on the outboard side can enhance cargo stowage. Similarly, a single upper cross lash may be combined with a paired cross lash.

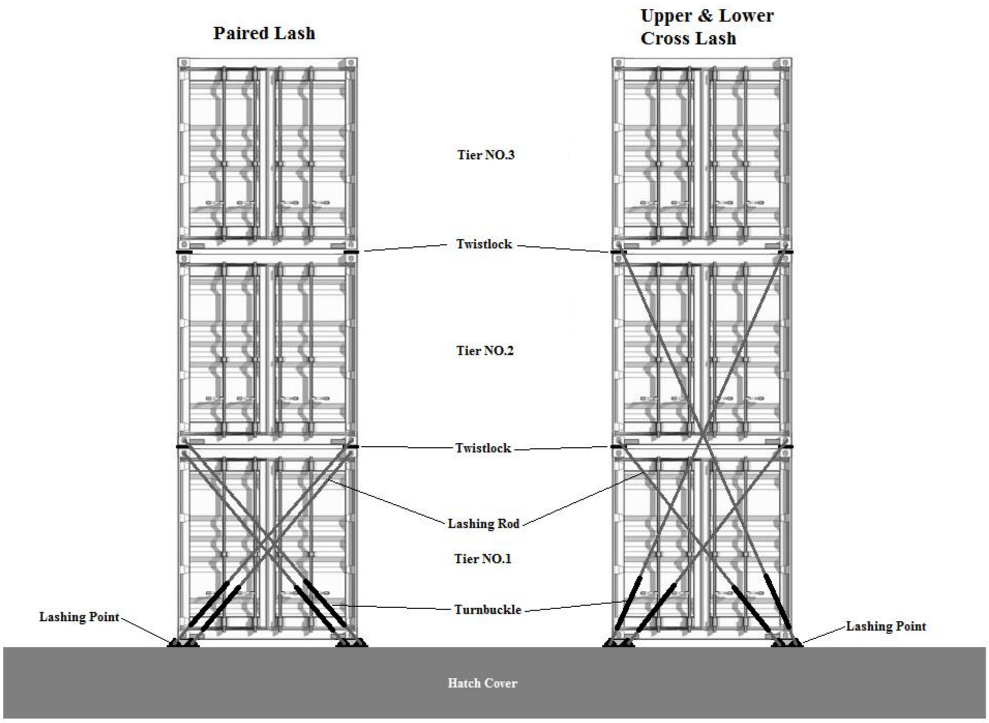


Fig. 4-1
Typical Lashing Arrangements

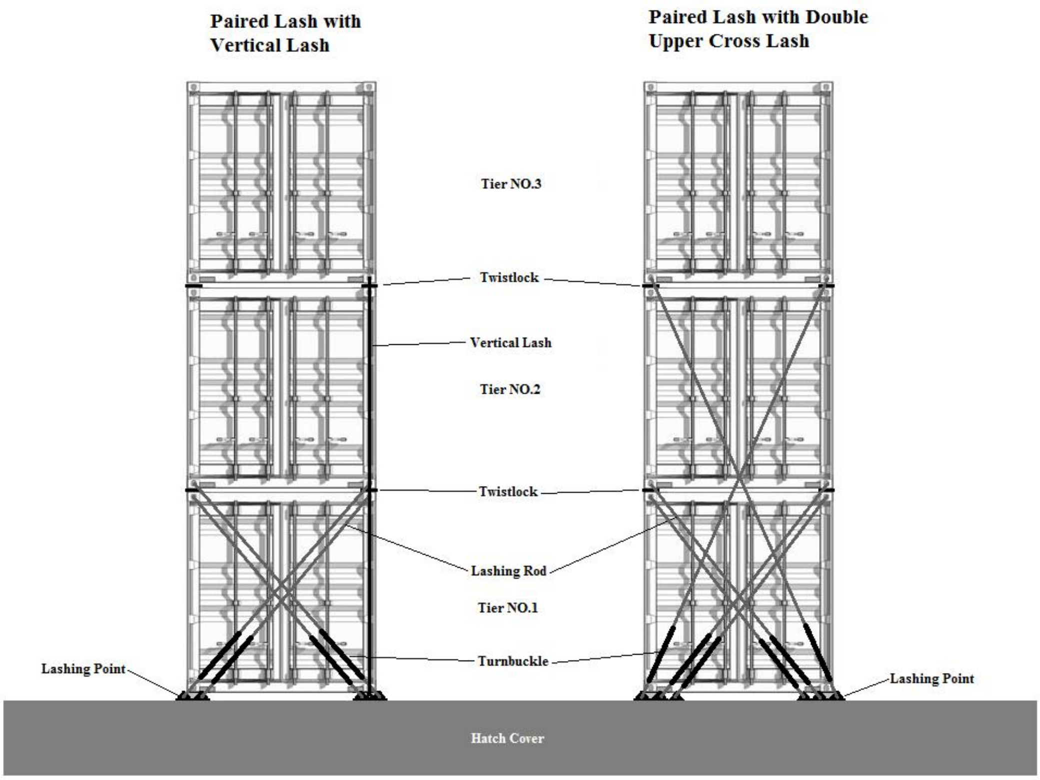


Fig. 4-2
Combined Lashing Systems

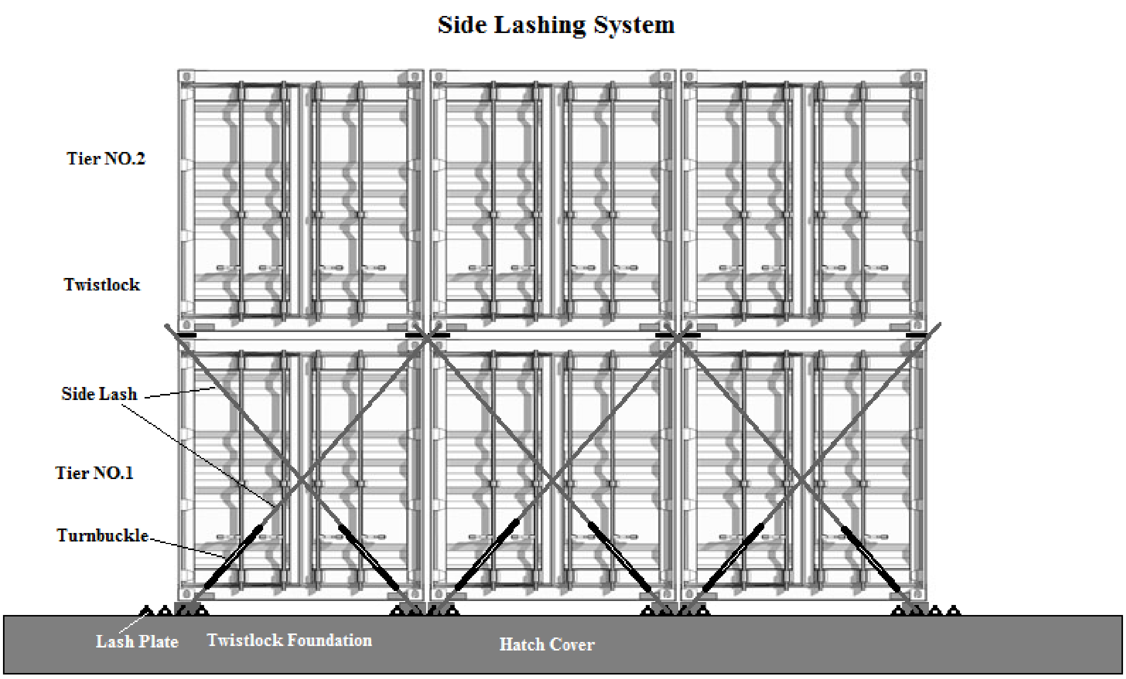


Fig. 4-3
Side Lashing System

4.3.2 Raised Lashing Platforms

Flexible lashing systems are more effective when the horizontal restraining component can be applied at a higher point in the container stack. Because of their weight and size, long lashing rods are more difficult to handle and install. Long lashing assemblies have less stiffness, and due to the steeper angle of application, the resulting horizontal force is reduced. For these reasons, raised lashing platforms or lashing bridges are often used when container stack heights and weight are not constrained by vessel stability or visibility. A raised lashing platform can offer the following benefits:

- Better lashing angles for shorter, more manageable lashing assemblies
- Higher allowable stack weights for given container and lashing assembly strength ratings
- Good access to monitor and maintain reefer containers in 1st and 2nd tiers
- Options for handy stowage of rods and turnbuckles

(a) Design Consideration

The following points should be considered when container stacks are lashed from elevated platforms between hatches.

(i) The securing assemblies are attached to lashing points on the raised platform, which may move as part of the vessel’s structure independent of the container stacks on the hatch covers. In a quartering seaway, torsional warping of the hull girder can result in relative movement between the container stacks and the lashing bridge. The resulting change in lash tension may impact the effectiveness of the lashing assembly.

(ii) Clearance is required between the hatch cover and the raised platform to reduce the risk of impact with the platform when handling the cover, and also to accommodate the hatch cover and hull movements at sea. This increases the longitudinal lead of the lashing assembly and reduces the effective lashing angle somewhat. For a bay with alternate stowage of 40-ft containers and 45-ft containers on the hatch cover, the longitudinal lead for the 40-ft containers becomes significant and impacts the effectiveness of the lashing assembly.

(iii) Lashing platforms are often narrow by design since they must suit the space available between container bays. This leads to lashing platforms that are somewhat flexible in the fore-and-aft direction. Depending upon the fore-and-aft distance between the lashing point and the face of the container stack, the stiffness of the highly elevated lashing platform (more than two tiers high) are to be specially considered when assessing the overall stiffness of the lashing assembly.

(iv) Lashing from an elevated platform to a higher point on the container stack requires that the lashing assembly have a larger adjustment in length to suit potential variations in container height in the tiers below. Standard height and hi-cube containers differ in height by 305 mm. For a connection at the top of the 3rd tier, the differential could be as much as 915 mm. Since tensioning devices typically have an adjustment of 300 to 500 mm, accommodating a full range of container heights may require the use of extension links for the lashing assembly or tension elements with multiple attachment points.

Structural design loads for a raised lashing platform shall include the application of the maximum safe working load (SWL) in each lashing assembly singularly for local structure and collectively for the overall structural design. In evaluating the structural design of the elevated lashing platform structure, the SWL of the lashing assemblies should be applied at each lashing point for both the forward and aft bays and also for the lashing loads on one side only.

4.3.3 Containers Secured with Different Lashings Systems at Each End

When container stacks are secured with different systems at each end, permissible container stack weights are governed by the end with the least effective system, unless it can be shown through calculation that the more effective system can share a greater portion of the load. For example, if two stacks of 20-ft containers are stowed on a 40-ft hatch cover, the ends away from the middle of the hatch cover might be secured from elevated lashing platforms while the ends of the 20-ft containers at mid hatch are lashed to the top of the hatch cover. In this case, permissible stack weights are generally governed by the lashing arrangement used to secure the 20-ft containers at the middle of the hatch cover.

4.3.4 Relative Movement of Support or Securing Points

Due to their large hatch openings, containerships are susceptible to torsional warping of the hull girder in oblique seas. This results in some relative movement between the hatch covers and the hull structure or between two adjacent hatch covers. It is not recommended to arrange the containers such that they are sitting on two parts with different movements.

(a) Containers Secured to Adjacent Structure

Container stacks stowed on a hatch cover may be lashed or secured to adjacent structure such as the hatch coaming or to an elevated lashing bridge. Depending upon the fore-and-aft lead of the lashing assembly and the estimated relative movement, the lashing arrangement shall be designed to accommodate this relative movement.

4.4 Cell Guides

A cell guide system consisting of vertical angles or Tees may be fitted in the cargo holds or on the weather deck to permit containers to be stacked vertically with no requirements for twistlocks or other portable securing fittings, see Fig. 4-4.

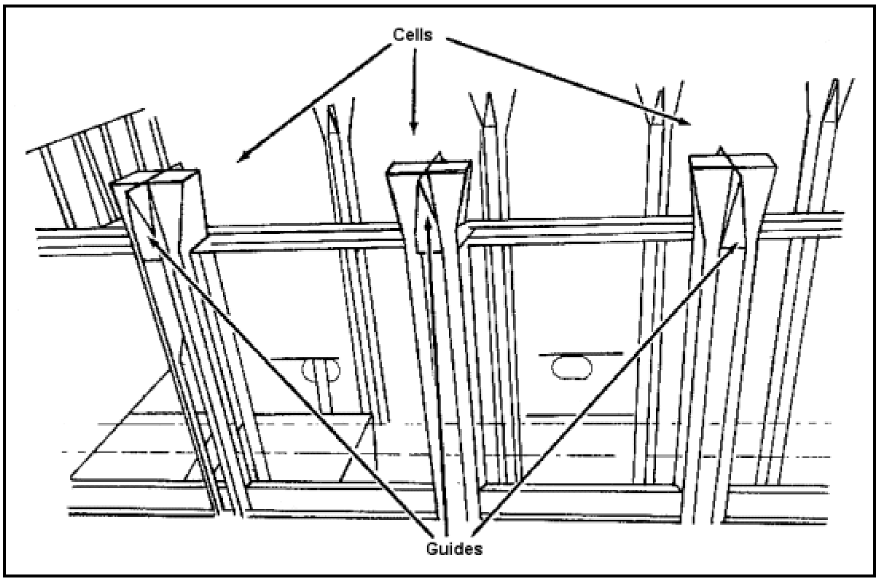


Fig. 4-4
Typical Hold Cell Guide Arrangement

4.4.1 Design Considerations

The cell guides and associated support structure shall provide lateral restraint in way of the container corner post assemblies in both the fore-and-aft and transverse directions. Their design shall consider the horizontal accelerations presented in Chapter 5, as well as the operational loads associated with the container loading and discharge operations.

The inside faces of the cell guides experience abrasion and wear in service, which may lead to accelerated corrosion. The thickness of the cell guides shall not be less than 12 mm. Maximum compression loads for the containers stacked within the cell guides are to be governed by the weight of the containers above and the design vertical accelerations presented in 5.2.4.

The top portion of the cell guides shall be designed to facilitate the entry process for loading containers or the crane spreader in a vertical cell and shall be robust in design and suitably reinforced to the vessel's structure for the impact loads that occur in this operation.

The cell guides are to be designed and fitted with controlled tolerances to ensure an even gap between the containers and the inside face of the guide. This will provide for smooth loading and discharge operations in normal conditions of trim and list. If the gaps are too large from poor control of tolerances, or the cell guides are bowed from damage in service, the potential to incur damage will be greater. It is recommended that the design gap or clearance between the inside face of opposing cell guides and the nominal container length and width does not exceed 38 mm in the fore-and-aft direction (lengthwise) and 25 mm transversely.

Support brackets and chocks shall be spaced at intervals to provide adequate support throughout the length of the cell for varying container heights and arrangements. Closer spacing of reinforcing structure is recommended in way of the entry guide and the section of cell guides just below this region since this is where damage occurs most frequently in operations.

4.4.2 Container Cell Guides at Only One End

Cell guides restrain transverse movement through contact with the corner post corner castings and are generally designed for stowage of one length of container. There are some exceptions for alternative stowage and two examples are discussed in the Subparagraphs below.

(a) 20-ft Containers within 40-ft Cell Guides

Since 20-ft containers are 1.5 inches (38 mm) short of 20 feet, there is room to stow two 20-ft containers within 40-ft container cell guides. Many container ships are designed for this alternate stowage arrangement. The fore-and-aft spacing between the two 20-ft containers will be 76 mm (3 inches) while still maintaining the standard clearance in way of the cell guides at both ends. In order to ensure that the first tier of 20-ft containers is correctly positioned within the 40-ft cell guides, some additional fittings should be installed at the base of the stack. In way of the 40-ft cell guides, centering cones are typically installed on top of the base plate to capture and correctly position one end of the 20-ft containers in the fore-and-aft direction. At the mid-hatch or "free" end of the 20-ft containers, transverse guides are typically installed between adjacent stacks to position the containers and to provide transverse restraint. See Fig. 4-5.

In order to maintain alignment and to transfer lateral loads to the containers below, at the free end, each tier is normally loaded using stackers. The permissible stack weights are typically limited by the racking strength of the bottom tier container at the free end. Since the mid-hatch end is not restrained above the base and is free to deflect, a larger share of the transverse load will be supported at the cell guide end due to the torsional rigidity of the containers. See 5.4.6 for the permissible stack weights for paired 20-ft container stowage. Note that paired 20-ft container stacks may be over-stowed with 40-ft containers and this arrangement ensures that the ends of the 20-ft containers in the uppermost tier remain within the shadow of the restraining cell guide.

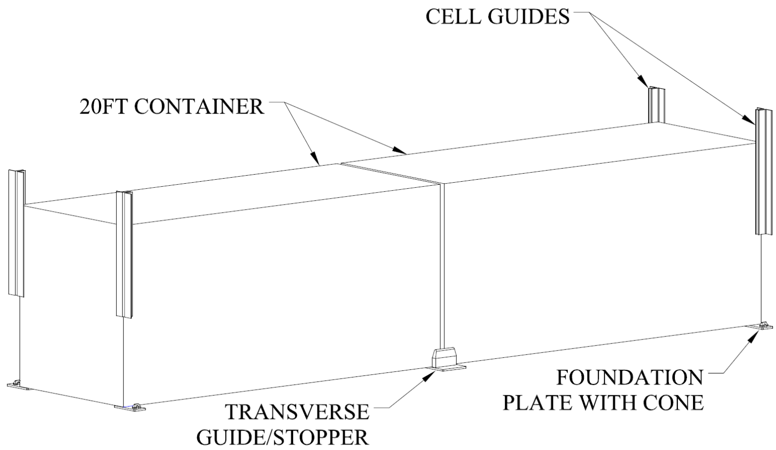


Fig. 4-5
20-ft Container Stowage in 40-ft Cell Guides

Due to the tolerance between the stacking fittings and the apertures in the bottom and top corner castings, there is the potential for the 20-ft containers in one stack to shift toward mid-hatch, reducing the overlap with the cell guide at the ends. A review of this tolerance shall be considered when determining how many tiers high paired 20-ft containers may be stowed without over-stowing with a 40-ft container.

(b) 40-ft Containers within 45-ft Cell Guides

Alternate stowage of 40-ft containers within 45-ft cell guides requires that similar fittings be installed at the base of the stack to guide and position the bottom container. Due to the longer length of the 40-ft containers, the portion of the lateral load restrained at the cell guide end in excess of 50% would have to be determined by calculation. The free end of the 40-ft stack could be accessed and it may be possible to secure this end with locking fittings and lashings. Maintaining the overlap within the cell guides at one end is more difficult since the 40-ft containers can not be over-stowed like the paired 20-ft containers. As fore-and-aft accelerations generally cause stacks to shift forward, utilization of the forward 45-ft cell guides is generally preferred.

4.5 Systems Combining Flexible and Rigid Elements

Container securing systems combining flexible and rigid elements shall be specially considered. In general, the element providing the lowest stack weights shall govern, except where it can be shown that the stiffer, rigid element can support a greater portion of the restraining load. A common example of a securing system combining both rigid and flexible securing elements is an arrangement where one end of a container stack is restrained within fixed cell guides and the other end is secured with twistlocks or with a standard lashing system.

4.6 Other Fixed or Rigid Securing Systems

Buttresses and shoring systems are other structures fixed to the vessel that support transverse and longitudinal loads from the containers stacks. They can be hinged, lift on/lift off, or otherwise moveable frames that engage all or part of each tier in a stack of containers. When so configured, they do not assist with loading and discharge to guide containers into place. Rigid securing systems other than cell guides shall be considered separately. Such systems may offer enhanced stack ratings or reduced stevedoring costs but also impose special stowage restrictions. Systems, such as a stacking frame and tower system or a hinged stacking frame and tower system, require that all containers in each tier be the same height and therefore reduce stowage flexibility.

4.7 Block Stowage of Containers

Block stowage, which is more prevalent on vessels other than cellular container ships, entails securing a number of adjacent stacks to each other at one or more levels. Shoring or lateral restraint is provided in way of the corner castings at these same levels, at the outboard sides of the combined stack. These restraints reduce racking and compressive loads into the containers and prevent tipping. Rows of containers are stacked in close proximity with a set transverse spacing to facilitate connecting the containers and container stacks. In this way, the block of containers is restrained as a unit. First tier containers are positioned and laterally restrained with stacking cones or lock fittings at the base. Additional tiers are typically stowed utilizing stacking cones to maintain alignment. At specific tiers, adjacent stacks may be connected with double stacking cones. Inboard and outboard of the container block stowage shoring shall be used to provide lateral restraint at these levels. A prerequisite is that the same container height at each level is maintained for all containers stowed in that tier. The tops of the uppermost tiers of containers are connected using bridge fittings. At both sides of the block of containers, lateral restraint is typically provided utilizing bridge struts. The bridge struts and shoring devices may be permanently attached, hinged or portable type and either flexible or rigid.

4.8 Stacks of Mixed Length and Width

Containers that are longer and wider than standard ISO 40-ft containers have been introduced to maximize the volume of the containers in integrated rail and trucking transport operations. Stowage and securing of such containers requires that base support points be provided on the vessel for each unique length and width. However, the demand and throughput may not warrant dedicated space for these unique containers as a fixed design would limit a vessel’s flexibility and deployment in other services. Since below-deck stowage on cellular container ships utilizes a rigid cell guide system which offers limited flexibility for alternate stowage, longer containers and especially over-wide containers are typically stowed above deck. Hatch openings and hatch covers designed for 40-ft container stowage below deck may not permit stowage directly on the hatch covers for containers longer than 40-ft. Containers such as 48-ft and 53-ft containers shall therefore extend to support points on pedestals or adjacent hatch covers. On larger container ships with elevated lashing platforms, it may not be possible to stow the longer containers in the first, second or even third tiers on deck.

Containers longer than a standard ISO 40-ft container are typically fitted with corner posts and castings at the 40-ft points. Note that the transverse spacing of the aperture openings in the castings for lifting or vertically stacking the containers is based on the ISO standard. Refer to Table 2-2. This design feature allows the longer containers to be stacked above a standard 40-ft container with an equal portion of the container extending beyond at both ends. In the case of 48-ft and 53-ft containers, which are wider (2.591 m or 8'-6") as well, they may also extend roughly 76 mm (3 inches) on each side. This presents some unique considerations when stowing 48-ft containers and 53-ft containers above 40-ft containers:

- The internal 40-ft corner posts of 48-ft containers and 53-ft containers are narrow by design to maximize and facilitate cargo stowage within the container. As the container corner castings are spaced per ISO standards for 8-ft wide containers, a couple or moment is introduced through the bottom structure of the over-wide container and into the twistlock and top of the 40-ft container directly below.
- 40-ft containers rows are typically spaced transversely with approximately 25 mm clearance between stacks to enhance stowage and loading. In this case, the over-wide containers may only be stowed above the 40-ft containers in every other stack.
- In some stacks, the longer 48-ft or 53-ft containers is to be secured to the container below using twistlocks at the end corner castings. The lowest 48-ft or 53-ft container shall be capable of supporting the load of the containers above and to pass that load in shear and bending through the side walls of the container to the 40-ft container below.

Options for securing over-wide containers and containers longer than 40 ft in length are often unique and shall be specially considered. In general, flexible lashing assemblies are not to be applied to the ends of the overhanging containers.

CHAPTER 5 SECURING SYSTEM DESIGN PRINCIPLES

5.1 General

The forces acting on the containers and the loads on the container securing systems are to be determined for all conditions of operation. If the operating and sea conditions for a specific service are known and the vessel response data determined by calculation, then the forces and loads may be specially considered. If, however, the vessel is intended for unrestricted service, then the forces and loads acting on the containers are to be determined using the method described in this Chapter. In turn, the securing systems and associated vessel support structure shall be evaluated for these loads in order to determine the operation envelope of the container stacking arrangement.

5.2 Design Loads

5.2.1 General

The basic loads to be taken into account in container securing calculations include gravitational forces, dynamic forces associated with ship motions, wind forces, and lashing or other securing forces. Sea loads and green water impact are not explicitly considered in the securing system design criteria. Adequate protection from green water impact shall be provided.

5.2.2 Wind Loads

(a) Wind Load

Wind forces are to be applied to exposed containers. The wind pressure, P_w, shall be taken as:

$$P_w = 1.08 \text{ kN/m}^2$$

The wind load is assumed equally distributed over the side of the container. The vertical center of pressure should be taken at the mid height of the container, and the longitudinal center of pressure should be taken at the mid length of the container.

(b) Fully Exposed Outboard Stacks

The wind load shall be applied to all containers in an outboard, unprotected stack.

(c) Partially Protected Stacks

Any container with more than one-third of its lateral area exposed to the wind, either above the top or beyond the ends of adjacent containers or with 5 meters or more transverse separation from an adjacent container stack, shall be considered an exposed container, and the wind load is to be applied over the entire lateral area of the container. When less than one-third of the lateral area is exposed, the wind effect may be ignored.

(d) Inboard Stacks with Adjacent Stacks Empty

Where the clearance to containers in the adjacent stack exceeds 5 m on one or both sides, a container shall be considered exposed to the weather and the wind load shall be applied over the entire lateral area of the container stack.

5.2.3 Design Ship Motions

For service without restrictions, the accelerations and loads on containers are to be determined from the ship motions. The formulas for ship motions and accelerations assume that parametric rolling is avoided, either through design or through vessel operations.

(a) Ship Conditions

GM	=	transverse metacentric height for the actual load condition, in m. Where calculations are carried out for representative conditions for presentation in the Cargo Securing Manual, GM values should be evaluated over the expected operating range.
d	=	draft to the summer load line, in m

(b) Ship Motions

(i) Roll Motion. The natural roll period (full cycle) is to be obtained from the following equation:

$$T_R = \frac{k_1 k_r}{\sqrt{GM}} \ sec$$

where

k_1	=	2 for k_r, GM in m.
k_r	=	roll radius of gyration, in m, and may be taken as 0.40B
GM	=	transverse metacentric height, in m

The roll angle (single amplitude) is to be obtained from the following equation:

$$\theta = \frac{3150C}{B + 75} \quad deg$$

where

B = molded breadth of the vessel, in m

For vessels with bilge keels

C = 0.75, if $T_R \geq 18\ sec$

C = $0.75 + 0.10(18 - T_R)$, if $T_R \geq 18sec$, but need not be taken greater than 0.9

For vessels without bilge keels

C = 1.0

For vessels with active stabilizing systems, C may be specially considered.

The roll center, R_{CTR}, is to be taken at the vertical center of gravity of the vessel, measured in m above baseline. When the calculated vertical center of gravity of the vessel is not submitted, R_{CTR} may be estimated from the following formula:

$$R_{CTR} = \frac{D}{4} + \frac{d}{2} \text{ m above baseline}$$

where

D = molded depth at side, m

d = draft as defined in 5.2.3(a)

(ii) Pitch Motion. The natural pitch period (full cycle) is to be obtained from the following equations:

$$T_P = 7 + 0.0123 \times (L - 183) \text{ sec, for L in m}$$

The single pitch amplitude to be taken as:

$\phi = 7$ deg where $L \leq 120$ m

$\phi = 6$ deg where $120 \text{ m} < L < 275$ m

$\phi = 5$ deg where $L \geq 275$ m

Where

L = length between perpendiculars, in m

The pitch center of the vessel P_{CTR} is to be taken at the longitudinal center of flotation. When the calculated longitudinal center of floatation is not submitted, P_{CTR} may be estimated as 0.45L forward of the aft perpendicular.

5.2.4 Accelerations

Containers and their securing systems shall be capable of withstanding the forces generated by the following load combinations for unrestricted service:

Condition A: The maximum roll condition generating maximum across-the-deck accelerations, expected in quartering stern or beam seas.

Condition B: The maximum pitch condition generating maximum normal-to-deck accelerations, expected in head or near head seas.

The designer is to ensure that the stowage system satisfies all of the strength criteria for both Condition A and Condition B accelerations. For conventional lashing systems on the deck with containers having properties as listed in Table 2-3, Condition A governs and Condition B need not be evaluated. For containers stowed in cell guides, Condition B governs and Condition A need not be evaluated. For other configurations, including block stowage in the holds of bulk carriers, Condition A and Condition B are to be evaluated.

The following definitions apply to both the Condition A and the Condition B load combinations:

x_C = longitudinal distance to the center of gravity of the container, in m, forward of the aft perpendicular

$|x_C - P_{CTR}|$ = absolute value of the longitudinal distance from the vessel's pitch center to the center of gravity of the container, in m

y_C = transverse distance to the center of gravity of the container, in m, from the vessel's centerline

$|y_C|$ = absolute value of the transverse distance from the vessel's centerline to the center of gravity of the container, in m

z_C = vertical distance to the center of gravity of the container, in m, from the vessel's baseline

$|z_C - R_{CTR}|$ = absolute value of the vertical distance from the vessel's roll center to the center of gravity of the container, in m

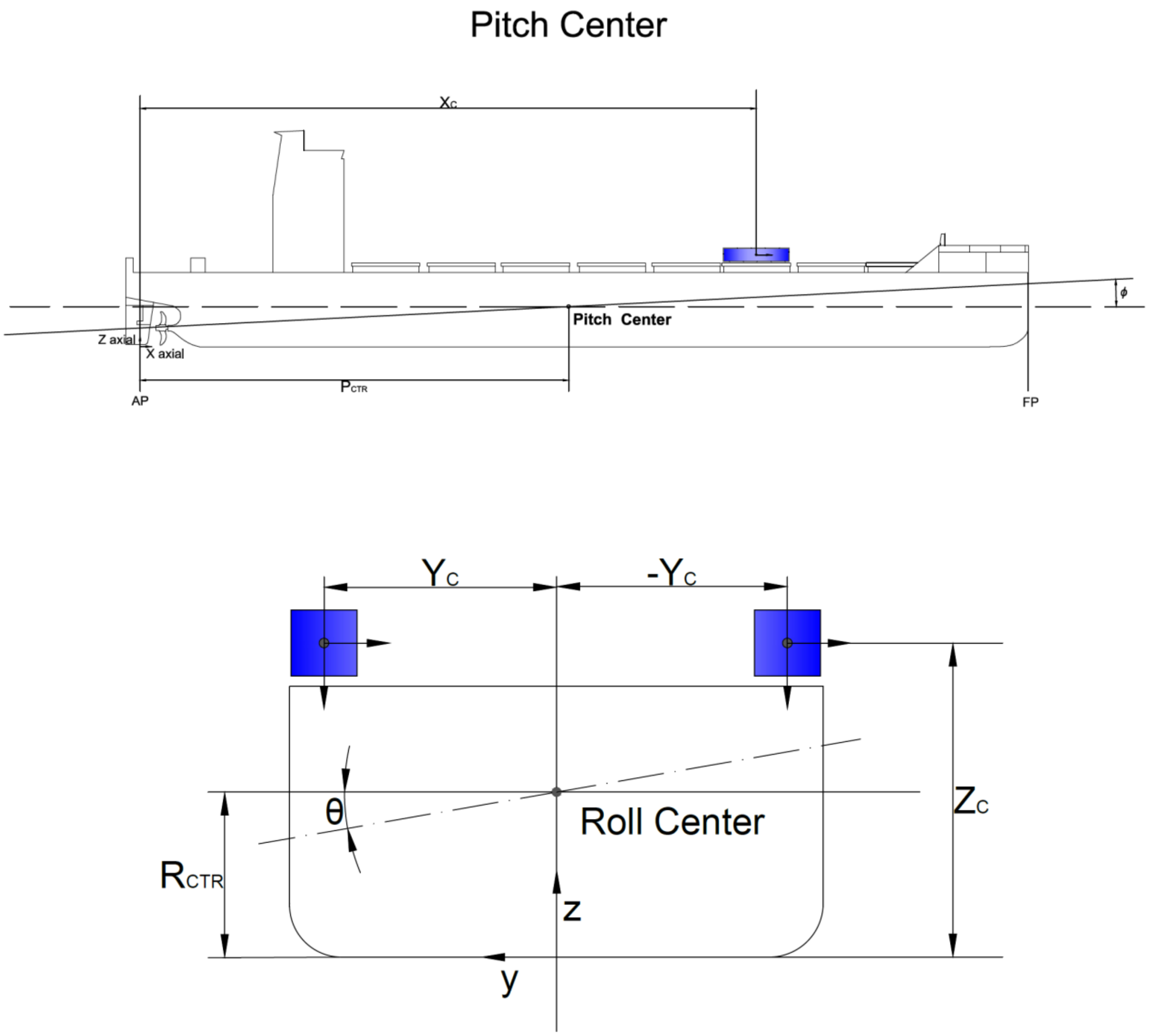


Fig. 5-1
Forces Due to Gravity and Ship Motions

a_0 = common acceleration parameter, in g's (not to be taken less than 0.0)

= 0.2012 for $B \le 32.2$ m

= $0.2012 + \dfrac{\left(0.0618\sqrt{GM} - 0.2125\right)(B - 32.2)}{7.8}$ for $32.2\text{ m} < B < 40\text{ m}$

= $0.1407 + 0.0618\sqrt{GM} - 0.0038B$ for $B \ge 40.0$ m

k_C = 0.0701 for x_C, y_C, z_C in m

k_3 = force factor accounting for longitudinal position of container stack, where

= $0.5 \times \left(\dfrac{0.2L - x_C}{0.2L}\right)$ for $x_C < 0.2L$

= 0.0 for $0.2L \le x_C \le 0.7L$

= $0.7 \times \left(\dfrac{x_C - 0.7L}{0.3L}\right)$ for $x_C > 0.7L$

(a) Condition A – Roll and Heave

The transverse and vertical accelerations at any point are to be obtained from the following formulas. The longitudinal accelerations are taken as zero for this condition.

The transverse acceleration is obtained from the following equation:

$$A_T = a_{GT} + k_C a_{RT} + (1 + k_3) a_0 sin\theta$$

The maximum vertical acceleration is obtained from the following equation:

$$A_{VMAX} = a_{GRV} + k_C a_{RV} + (1 + k_3) a_0 cos\theta$$

The minimum vertical acceleration is obtained from the following equation:

$$A_{VMIN} = a_{GRV} - k_C a_{RV} + (1 - k_3) a_0 cos\theta$$

A_{VMIN} is not to be taken greater than 1.0

where

a_{GT}	=	transverse static gravitational acceleration component, in g's
	=	$sin\theta$
a_{RT}	=	transverse roll acceleration component, in g's
	=	$\frac{\theta}{T_R^2}\lvert z_C - R_{CTR}\rvert$
a_{GRV}	=	vertical static gravitational acceleration component, in g's
	=	$cos\theta$
a_{RV}	=	vertical roll acceleration component, in g's
	=	$\frac{\theta}{T_R^2}\lvert y_C\rvert$

(b) Condition B – Pitch and Heave

The longitudinal and vertical accelerations at any point are to be obtained from the following formulas. The transverse accelerations are taken as zero for this condition.

The longitudinal acceleration is obtained from the following equation:

$$A_L = a_{GL} + k_C a_{PL} + a_0 sin\phi$$

The maximum vertical acceleration is obtained from the following equation:

$$A_{VMAX} = a_{GPV} + k_C a_{PV} + a_0 cos\phi$$

The minimum vertical acceleration is obtained from the following equation:

$$A_{VMIN} = a_{GPV} - k_C a_{PV} + a_0 cos\phi$$

A_{VMIN} is not to be taken greater than 1.0

where

a_{GL}	=	longitudinal static gravitational acceleration component, in g's

	=	$sin\phi$
a_{PL}	=	longitudinal pitch acceleration component, in g's
	=	$\frac{\phi}{T_R^2}\lvert z_C - R_{CTR}\rvert$
a_{GPV}	=	vertical static gravitational acceleration component, in g's
	=	$cos\phi$
a_{PV}	=	vertical pitch acceleration component, in g's
	=	$\frac{\phi}{T_P^2}\lvert x_C - P_{CTR}\rvert$

(c) Accelerations for Route-Specific Trade

For typical route-specific trades, the transverse accelerations A_T obtained for Condition A, for unrestricted service in 5.2.4(a), can be reduced by the following route-specific reduction factors. Maps of the typical route-specific trades are shown in Appendix 1.

	Route	Reduction Factor
0	Unrestricted	1.00
1	Asia - Europe	0.87
2	Pacific - Atlantic	0.96
3	North Pacific	0.95
4	North Sea - Mediteranean	0.94
5	North Atlantic	1.00
6	Asia - South America (West Coast)	0.95
7	South America (East Coast) - Africa	0.73
8	Africa - East Asia	0.86
9	Europe - Africa	0.90
10	Europe - South America (Brazil)	0.90
11	North America (East Coast) - South America (Brazil)	0.73

As an alternative to using the above reduction factors for the listed trade routes, or for trade routes not listed in the table, accelerations may be obtained by direct calculations according to 5.2.5.

5.2.5 Optional Direct Calculation of Accelerations

As an alternative to the formulas in this Chapter, CR may consider direct calculations of ship motions and accelerations or values obtained from model tests. In such a case, accelerations should be determined with a reference service life of 20 years. As the base case, the IACS Recommendation No. 34 wave scatter diagram for the North Atlantic is to be applied for unrestricted service. In addition to the base case, route-specific criteria may also be considered. For route-specific trades other than the typical trading routes as shown in 5.2.4(c) and Appendix 1, the combined wave scatter diagram or table, to be developed by combining the wave data along each leg of a specific route, is to be submitted for review. Direct calculations or model tests are to be provided as justification if credit for motion reduction from stabilizing systems is requested.

5.2.6 Mass Distribution and Center of Gravity of Containers

The transverse, longitudinal, and vertical force components due to gravity and ship motions are to be applied at the center of gravity of the container.

For design purposes, the center of gravity of container may be taken as follows:

- Vertical center of gravity at 45% of the height of the container
- Longitudinal center of gravity at the mid-length of the container
- Transverse center of gravity at half the width of the container

Where the center of gravity differs significantly from these values, documentation of the actual center of gravity shall be submitted and included in the Cargo Securing Manual.

5.2.7 Distribution of Loads Acting on Containers

The transverse, longitudinal, and vertical force components due to gravity and ship motions are to be applied at the center of gravity of the container. The wind force is to be equally distributed over the side of the container. To facilitate the calculations, the forces may be resolved into force components acting at the ends and sides of the container:

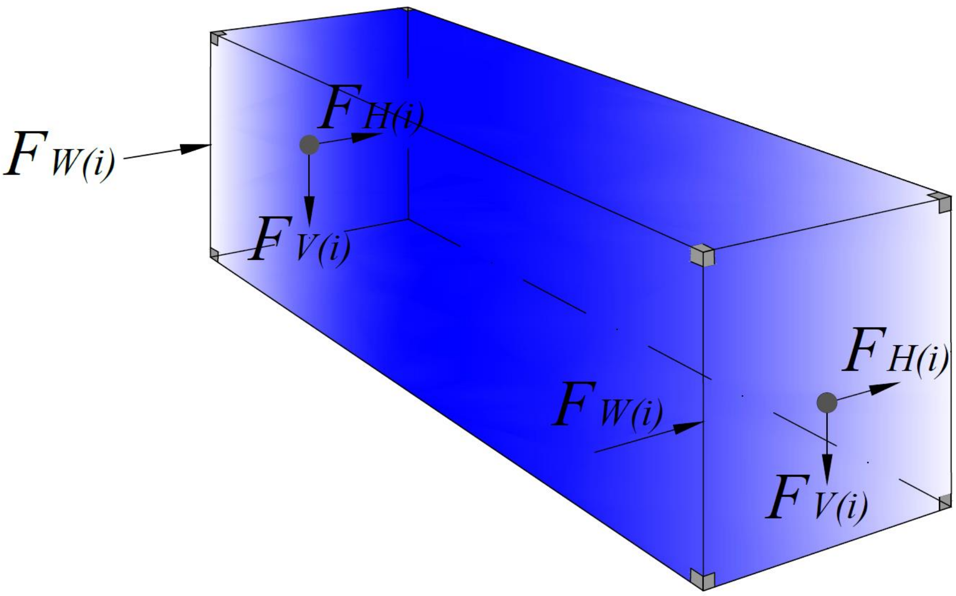


Fig. 5-2
Application of Forces to Ends and Sides of Container

(a) Horizontal Force Component

The horizontal force component acting at the ends of each container is obtained from the following formula:

$F_{H(i)} = 0.5 W_{(i)} A_{T(i)}$ kN

where

$F_{H(i)}$	=	horizontal (across the deck) force per end of container in tier i due to gravity and ship motions.
$W_{(i)}$	=	weight of container in tier i, in kN
$A_{T(i)}$	=	transverse acceleration at tier i, in g's

Self-racking of the container in way of the end panel is calculated assuming 45% of the horizontal force, $F_{H(i)}$, acts across the top of the container, and 55% of the horizontal force, $F_{H(i)}$, acts across the bottom of the container.

(b) Longitudinal Force Component

The longitudinal force component acting at the sides of each container is obtained from the following formula:

$$F_{L(i)} = 0.5W_{(i)}A_{L(i)} \quad \text{kN}$$

where

$F_{L(i)}$	=	longitudinal (parallel to deck) force per side of container in tier i due to gravity and ship motions.
$A_{L(i)}$	=	longitudinal acceleration at tier i, in g's

Self-racking of the container in way of the side panel is calculated assuming 45% of the longitudinal force, $F_{L(i)}$, acts across the top of the container, and 55% of the longitudinal force, $F_{L(i)}$, acts across the bottom of the container.

(c) Vertical Force Component

The vertical force component acting at the ends of each container is obtained from the following formula:

$$F_{V(i)} = 0.5W_{(i)}A_{VMAX} \quad \text{kN} \quad \text{to be applied when evaluating corner post compression}$$
$$F_{V(i)} = 0.5W_{(i)}A_{VMIN} \quad \text{kN} \quad \text{to be applied when evaluating corner post tension}$$

where

$F_{V(i)}$	=	vertical (normal-to-deck) force per end of container in tier i due to gravity and ship motions.
A_{VMAX}	=	maximum vertical acceleration, in g's
A_{VMIN}	=	minimum vertical acceleration, in g's

(d) Wind Load

The wind load acting at the ends of each container is obtained from the following formula:

$$F_{W(i)} = 0.5P_W L_{C(i)} H_{C(i)} \quad \text{kN}$$

where

$F_{W(i)}$	=	wind force per end of container in tier i
P_W	=	1.08 kN/m^2
$L_{C(i)}$	=	length of container in tier i, in m, as defined in Table 2-1
$H_{C(i)}$	=	height of container in tier i, in m, as defined in Table 2-1

Self-racking of the container in way of the end panel is calculated assuming 50% of wind force, $F_{W(i)}$, acts across the top of the container, and 50% of the wind force, $F_{W(i)}$, acts across the bottom of the container.

5.3 Calculation Methodology for Flexible Restraints

5.3.1 General

For each container, the following loads are to be evaluated:

- Racking of the container end wall
- Corner post compression (into the top of the corner post)
- Vertical tension (acting at the top of the corner post and on the adjacent twistlock)
- Vertical tension (acting at the bottom of the corner post and on the adjacent twistlock)

For each lash, the following loads are to be evaluated:

- Tension in the lash
- Force exerted by the lash on the container corner fitting

5.3.2 Container End Wall Racking

The transverse force acting across the top of each end of the container at tier i, when no transverse lashing restraint is considered, is obtained with the following formula:

$$Q_{(i)} = r_T F_{H(i)} + r_W F_{W(i)} + \sum_{j=i+1}^{n} \left(F_{H(j)} + F_{W(j)}\right) \quad \text{kN}$$

where

i = container tier being evaluated

n = number of tiers

r_T = portion of the horizontal force, $F_{H(i)}$ acting on container i that is considered to contribute to the racking force on container i (to be taken as 0.45 as defined in 5.2.7(a)).

r_W = portion of the wind force, $F_{W(i)}$, acting on container i that is considered to contribute to the racking force on container i (to be taken as 0.5 as defined in 5.2.7(d)).

For stacks without lashings or other transverse restraints, or where all lashings are attached to the containers at or below the bottom of container *i*, the racking force on container *i* is obtained with the following formula:

$$R_{(i)} = Q_{(i)} \quad \text{kN}$$

where

$R_{(i)}$ = racking force acting on container i

When lashings or other transverse restraints are secured to the corner fittings at the top of the container in tier i or to containers above tier i, the racking force is reduced by the horizontal component of these lash forces.

$$R_{(i)} = Q_{(i)} - \sum_{j=k}^{m} F_{lH(j)} \quad \text{kN}$$

where

$F_{lH(j)}$ = horizontal component of lash tension from lash *j*, in kN

k = first lash secured at or above the corner fittings at the top of the tier *i* container

m = uppermost lash secured at or above the corner fittings at the top of the tier *i* container

The racking forces are to be evaluated for each container in the stack. The racking force, $R_{(i)}$, acting on each container is to be less than or equal to the End Wall Racking design load for that container.

5.3.3 Lash Tension

(a) Lash Geometry

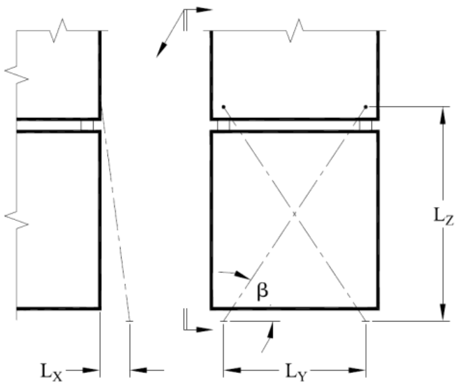


Fig. 5-3
Lash Angle and Lash Length

(i) The lash length is determined based on the actual geometry of the lash, see Fig. 5-3.

$$L_l = \sqrt{L_X^2 + L_Y^2 + L_Z^2}$$

where

L_l	=	length of lash, in mm
L_X	=	longitudinal extent of lash, in mm , to be taken as the longitudinal distance from the attachment point on the hatch cover, deck, or lashing bridge to the face of the container end panel. Where this longitudinal distance is less than or equal to 400 mm, L_X may be taken as zero.
L_Y	=	transverse extent of lash, in mm, to be taken as the transverse distance from the attachment point on the hatch cover, deck, or lashing bridge to the corner fitting of the container.
L_Z	=	vertical extent of lash, in mm, to be taken as the vertical distance from the attachment point on the hatch cover, deck, or lashing bridge to the corner fitting of the container.
β	=	lash angle, in degrees

(ii) The horizontal component of the lash spring constant is obtained from the following formula:

$$K_{lH} = K_l \left(\frac{L_Y}{L_l}\right)^2 \quad \text{kN/mm}$$

where

K_l = lash spring constant, as defined in 3.2.3(b), in kN/mm

(iii) The horizontal and vertical components of the lash force are obtained from the following formulas:

$$\mathrm{F}_{l\mathrm{H}} = T_l\left(\frac{L_Y}{L_l}\right) \quad \text{kN}$$
$$\mathrm{F}_{l\mathrm{V}} = T_l\left(\frac{L_Z}{L_l}\right) \quad \text{kN}$$

where

T_l = tensile force in the lash, in kN

(iv) Where L_X is taken as zero, the components of spring constant and lash force may be calculated as follows:

$$\beta = \cos^{-1}\left(\frac{L_Y}{L_l}\right) \quad \text{deg}$$
$$\mathrm{K}_{l\mathrm{H}} = K_l \cos^2 \beta \quad \text{kN/mm}$$
$$\mathrm{F}_{l\mathrm{H}} = T_l cos\beta \quad \text{kN}$$
$$\mathrm{F}_{l\mathrm{V}} = T_l sin\beta \quad \text{kN}$$

(b) Calculation of Lash Tension

(i) The horizontal displacement at the top of container tier i may be expressed as a function of the racking force and container spring constant:

$$\Delta_{(\mathrm{i})} = \frac{R_{(i)}}{K_{C(i)}} + \Delta_{(i-1)} \; or \; \Delta_{(i)} = \sum_{j=1}^{i} \frac{R_{(j)}}{K_{C(j)}} \quad \text{mm}$$

where

$\Delta_{(\mathrm{i})}$ = horizontal displacement at the top of tier i, in mm

$\Delta_{(i-1)}$ = horizontal displacement at the top of the tier immediately below tier i, in mm

$R_{(i)}$ = transverse racking force acting across the top of each end wall, in kN, as defined in 5.3.2

$K_{C(i)}$ = racking spring constant of tier i container, in kN/mm

(ii) The horizontal displacement at the top of container tier i may also be expressed as a function of the horizontal component of lash force and spring constant:

$$\Delta_{(\mathrm{i})} = \frac{F_{lH(j)}}{K_{lH(j)}} \quad \text{mm}$$

where

$F_{lH(j)}$ = horizontal force component of lash j, in kN

$K_{lH(j)}$ = horizontal component of the spring constant of lash j, in kN/mm

(iii) The horizontal component of the spring constant of the lash is obtained with the following equation:

$$\mathrm{K}_{l\mathrm{H(j)}} = K_{l(j)} \cos^2 \beta_{(j)} \quad \text{kN/mm}$$

where

$K_{l(j)}$ = spring constant of the lash, as defined in 3.2.3(b)

$\beta_{(j)}$ = angle of the lash, in degrees

(iv) The horizontal displacement induced by the racking force as defined in 5.3.3(b)(i) must equal the horizontal displacement relative to the elongation of the lash as defined in 5.3.3(b)(ii). The load into each lashing can be determined by combining these equations and solving for the horizontal lash force at eachlashing.

The tension in the lash is obtained with the following equation:

$$T_{l(j)} = \frac{F_{lH(j)}}{cos\beta_{(j)}} \quad \text{kN}$$

The calculated lash tension for each lash is to be less than or equal to the design load of the lash. Asdescribed in 3.4, the design load is determined by dividing the minimum breaking strength of the lash by the safety factor given in Table 3-3. For the purposes of calculating the racking, compression, and tension loads acting on the containers, the horizontal component of lash tension may be assumed to be acting along the top of the container.

(c) Lash Tension Equation for Single Lash to Deck

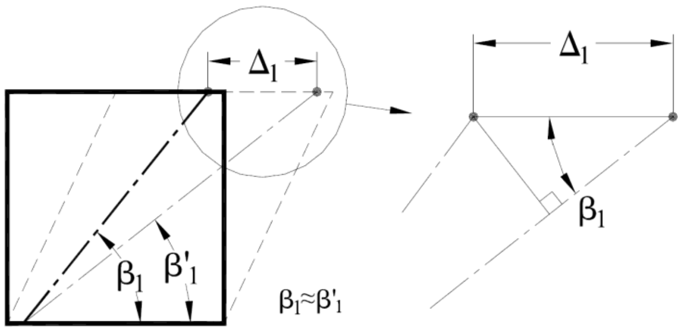


Fig. 5-4
Lash Elongation at First Tier Container

The lash equation for a stack secured with a single cross lash system to the deck is derived as shown below, See Fig. 5-4.

The horizontal displacements of the 1st tier container may be expressed as a function of the racking force and container spring constant.

$$\Delta_1 = \frac{R_1}{K_{C1}} = \frac{Q_1 - F_{lH1}}{K_{C1}} \quad \text{mm}$$

where

Δ_1 = horizontal displacement at the top of the 1st tier, in mm

R_1 = end wall racking force across the top of the 1st tier, as defined in 5.3.2, in kN

Q_1 = end wall racking force across the top of the 1st tier when the contribution from lashings is not considered, as defined in 5.3.2, in kN

K_{C1} = racking spring constant of the 1st tier container, in kN/mm

The horizontal displacements of the 1st tier container may be expressed as a function of the horizontal component of the lash force and the horizontal component of the lash spring constant.

$$\Delta_1 = \frac{F_{lH1}}{K_{lH1}} \quad \text{mm}$$

where

F_{lH1} = horizontal force component of the lash, in kN

K_{lH1} = horizontal component of the spring constant of lash, in kN/mm

The horizontal displacement induced by the racking force equals the displacement relative to the elongation of the lash.

$$\frac{\mathrm{F}_{lH1}}{K_{lH1}} = \frac{Q_1 - F_{lH1}}{K_{C1}}$$

$$\mathrm{F}_{lH1} = Q_1\left(\frac{K_{lH1}}{K_{C1} + K_{lH1}}\right)$$

The tension in the lash is obtained as follows:

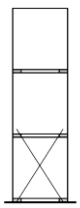
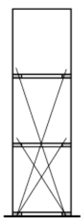
$$\mathrm{T}_{l1} = \frac{F_{lH1}}{cos\beta_1} = \frac{Q_1}{cos\beta_1}\left(\frac{K_{lH1}}{K_{C1} + K_{lH1}}\right) \qquad \mathrm{kN/mm}$$

(d) Lash Tension Equations

Lash tension should be evaluated based on these principles for the actual arrangement under consideration. Three typical equations are presented in Table 5-1:

- Single Cross Lash to Deck
- Double Cross Lash to Deck
- Single Cross Lash to Lashing Bridge

Table 5-1
Lash Equations for Typical Arrangements

Type	Lash Tension Equation
Single Lash to Deck 	Lash from deck to top of 1st or bottom of 2nd tier $\mathrm{F}_{lH1} = Q_1\left(\frac{K_{lH1}}{K_{C1} + K_{lH1}}\right)$ $\mathrm{T}_{l1} = \frac{F_{lH1}}{cos\beta_1}$
Double Lash to Deck 	Lash from deck to top of 1st or bottom of 2nd tier $\mathrm{F}_{lH1} = K_{lH1}\left[\frac{(Q_1 - Q_2)K_{lH2} + Q_1 K_{C2}}{(K_{C1} + K_{lH1})(K_{C2} + K_{lH2}) + K_{C2}K_{lH2}}\right]$ $\mathrm{T}_{l1} = \frac{F_{lH1}}{cos\beta_1}$ Lash from deck to top of 2nd or bottom of 3rd tier $\mathrm{F}_{lH2} = K_{lH2}\left[\frac{K_{C2}Q_1 + Q_2 K_{C1} + Q_2 K_{lH1}}{(K_{C1} + K_{lH1})(K_{C2} + K_{lH2}) + K_{C2}K_{lH2}}\right]$ $\mathrm{T}_{l2} = \frac{F_{lH2}}{cos\beta_2}$
Single Lash to Single Tier Lashing Bridge	Lash from the lashing bridge to the to the top of 2nd or bottom of 3rd tier $\mathrm{F}_{lH2} = K_{lH2}\left[\frac{K_{C2}Q_1 + K_{C1}Q_2}{K_{C1}(K_{C2} + K_{lH2}) + K_{C2}K_{lH2}}\right]$ $\mathrm{T}_{l2} = \frac{F_{lH2}}{cos\beta_2}$

(e) Analysis of Paired Lashings

A paired lash system may be analyzed by combining the horizontal components of the spring constants of the two lashings. If 1A is the designation for the lash to the top of the first tier and 1B is the designation for the lash to the bottom of the 2nd tier, then:

$K_{lH1A} = K_{l1A} \cos^2 \beta_{1A}$ horizontal lash spring stiffness for top of 1st tier

$K_{lH1B} = K_{l1B} \cos^2 \beta_{1B}$ horizontal lash spring stiffness for bottom of 2nd tier

$K_{lH1} = K_{lH1A} + K_{lH1A}$ combined horizontal lash spring stiffness

By applying the combined spring constant for $K_{lH(j)}$ in the equations in Table 5-1, $F_{lH(j)}$ is the transverse force exerted by the combination of the two lashings. The lash tension of the individual lashings can be resolved from $F_{lH(j)}$:

$$F_{lH1A} = F_{lH1} \frac{K_{lH1A}}{K_{lH1}} \qquad T_{l1A} = \frac{F_{lH1A}}{cos\beta_{1A}}$$

$$F_{lH1B} = F_{lH1} \frac{K_{lH1B}}{K_{lH1}} \qquad T_{l1B} = \frac{F_{lH1B}}{cos\beta_{1B}}$$

5.3.4 Lashing Force on Container Corner Fitting

The force on the corner fitting should be evaluated for each lash. The calculated lash tension, $T_{l(j)}$, must be less than or equal to the design load for the corner fitting. The design load for the corner fitting, $F_{CF(k)}$, is determined as a function of the lash angle, β:

$$F_{CF(k)} = \frac{C_{FH}}{cos\beta_{(j)}} \quad \text{kN}$$

$F_{CF(k)}$ is not to be taken greater than C_{FV}

where

C_{FH}	=	design lashing force on corner fitting, horizontal, as defined in 2.2, in kN
C_{FV}	=	design lashing force on corner fitting, vertical, as defined in 2.2, in kN
$\beta_{(j)}$	=	lash angle for lash j
k	=	container tier to which lash j is attached

5.3.5 Corner Post Compression

The forces that are considered when determining the compressive force acting on the bottom and top of the 1st tier container are shown in Fig. 5-5. Compressive forces are calculated by summing moments about point Z_A.

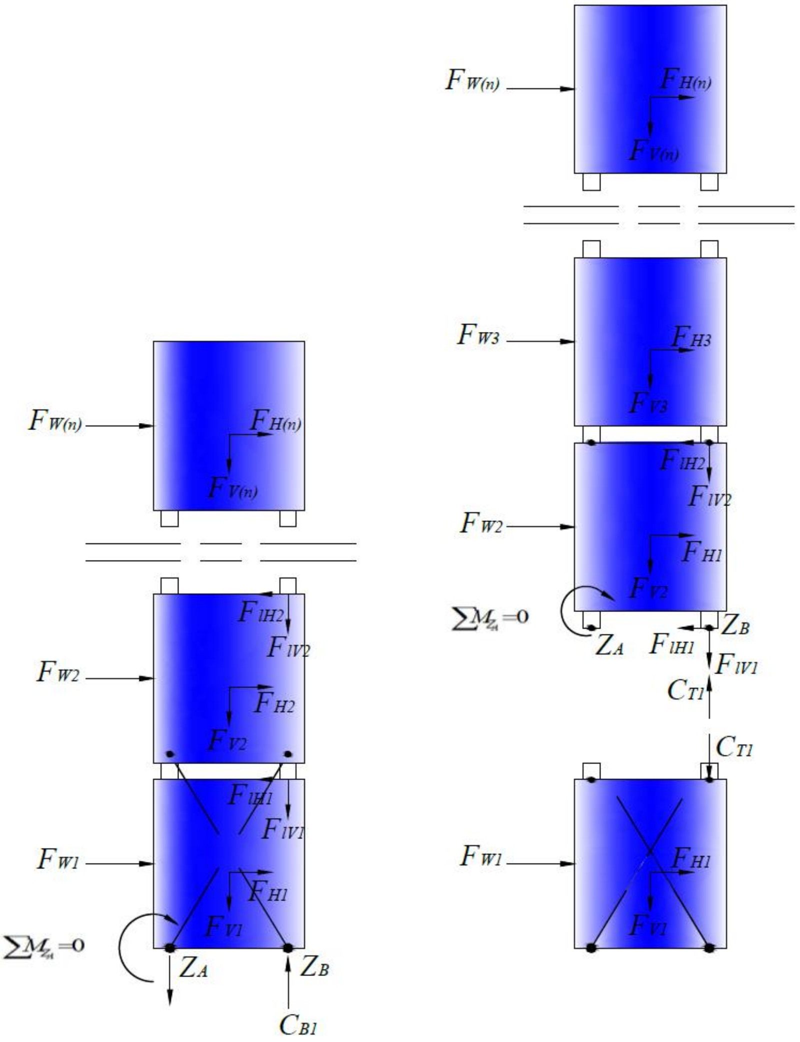


Fig. 5-5
Corner Post Compression

The compressive load at the base of each container is obtained with the following formula:

$$C_{B(i)} = \frac{\sum_{j=i}^{n} h_{C(j)} F_{H(j)} + \sum_{j=i}^{n} b_C F_{V(j)} + \sum_{j=i}^{n} h_{W(j)} F_{W(j)} - \sum_{j=k}^{m} h_{l(j)} F_{lH(j)} + \sum_{j=k}^{m} b_{l(j)} F_{lV(j)}}{b_{CF}}$$

The compressive load at the top of each container is obtained with the following formula:

$$C_{T(i)} = \frac{\sum_{j=i+1}^{n} h_{C(j)} F_{H(j)} + \sum_{j=i+1}^{n} b_C F_{V(j)} + \sum_{j=i+1}^{n} h_{W(j)} F_{W(j)} - \sum_{j=k}^{m} h_{l(j)} F_{lH(j)} + \sum_{j=k}^{m} b_{l(j)} F_{lV(j)}}{b_{CF}}$$

where

$C_{B(i)}$ = compression into bottom of container at tier i, in kN

$C_{T(i)}$ = compression into top of container at tier i, in kN

i = tier of the container being evaluated for corner post compression

n = number of containers in the stack

k	=	first lash secured at or above the corner fittings at the top of the tier i container
m	=	uppermost lash secured at or above the corner fittings at the top of the tier i container
$F_{H(j)}$	=	horizontal (across-the-deck) force per end of container j, due to gravity and ship motions, in kN
$F_{V(j)}$	=	vertical (normal-to-deck) force per end of container j, due to gravity and ship motions, in kN
$F_{W(j)}$	=	force per end of container due to wind load acting on the side of the container j, in kN
$F_{lH(j)}$	=	horizontal force component of lash j, in kN
$F_{lV(j)}$	=	vertical force component of lash j, in kN

Point Z_A is taken at the top or bottom of the container being evaluated. When evaluating loads imposed on the 1st tier container, the distances from point Z_A to the centers of forces acting on the containers are as shown in Fig. 5-6.

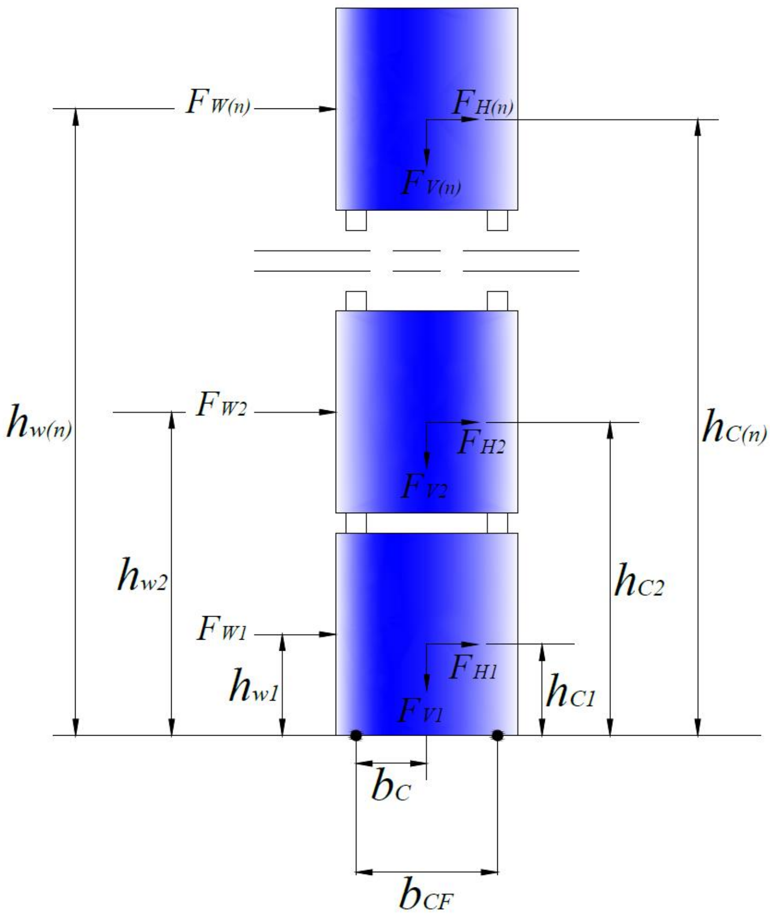


Fig. 5-6
Distances to Forces Acting on Containers

$h_{C(j)}$	=	vertical distances measured from the location being analyzed (either the top or bottom of the container) to the center of gravity of container j, in m
$h_{W(j)}$	=	vertical distances measured from the location being analyzed (either the top or bottom of the container) to the center of wind pressure on container j, to be taken to the mid-height of the container j, in m
b_{CF}	=	transverse distance between centers of the container corner fittings, to be taken as 2.259 m
b_C	=	transverse distances measured from Z_A to the center of gravity of the container, to be taken to the mid-width of the container, in m

$h_{l(j)}$ = vertical distances, in m , measured from the location being analyzed (either the top or bottom of the container) to the attachment point of lash j. Where the lash is attached to the upper container corner fittings, $h_{l(j)}$ may be taken to the top of the container to which it is attached. Where the lash is attached to the lower container corner fittings, $h_{l(j)}$ may be taken to the top of the container immediately below the container to which it is attached.

$b_{l(j)}$ = transverse distances measured from Z_A to the attachment point of lash j, in m

Corner post compression is to be evaluated at the top of each container in the stack. When all containers have equal strength properties, it is generally sufficient to evaluate compression for the 1st tier container only.

The compressive force, $C_{T(i)}$, acting at the top of each container is to be less than or equal to the Corner Post Compression design load for that container.

The compressive force, $C_{B(i)}$, acting at the base of the stack may be used for the design of the hatch cover.

5.3.6 Corner Post Tension

The forces that are considered when determining the tension loads acting on the bottom and top of the 1st tier container are shown in Fig. 5-7. The tension loads are calculated by summing moments about point Z_B.

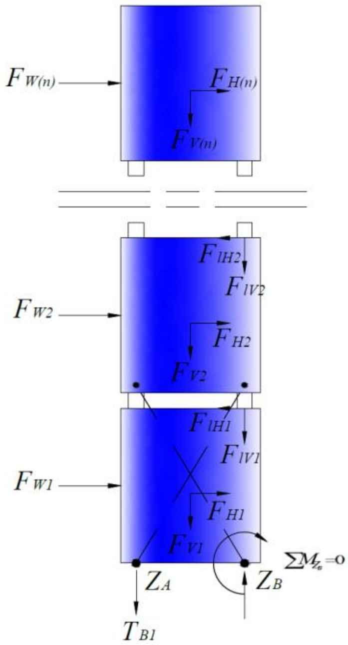


Fig. 5-7
Corner Post Tension (about bottom of 1st tier container)

The tensile load at the base of each container is obtained with the following formula.

$$T_{B(i)} = \frac{\sum_{j=i}^{n} h_{C(j)} F_{H(j)} - \sum_{j=i}^{n} b_C F_{V(j)} + \sum_{j=i}^{n} h_{W(j)} F_{W(j)} - \sum_{j=k}^{m} h_{l(j)} F_{lH(j)} - \sum_{j=k}^{m} b_{l(j)} F_{lV(j)}}{b_{CF}}$$

The tensile load at the top of each container is obtained with the following formula.

$$T_{T(i)} = \frac{\sum_{j=i+1}^{n} h_{C(j)} F_{H(j)} - \sum_{j=i+1}^{n} b_C F_{V(j)} + \sum_{j=i+1}^{n} h_{W(j)} F_{W(j)} - \sum_{j=k}^{m} h_{l(j)} F_{lH(j)} - \sum_{j=k}^{m} b_{l(j)} F_{lV(j)}}{b_{CF}}$$

where

$T_{B(i)}$	=	force (+ tension) acting on the bottom of the container at tier i, in kN
$T_{T(i)}$	=	force (+ tension) acting on the top of the container at tier i, in kN
i	=	tier of the container being evaluated for corner post tension
n	=	number of containers in stack
k	=	first lash secured at or above the corner fittings at the top of the tier i container
m	=	uppermost lash secured at or above the corner fittings at the top of the tier i container

The force components $F_{H(j)}$, $F_{V(j)}$, $F_{W(j)}$, $F_{lH(j)}$ and $F_{lV(j)}$ are as defined in 5.3.5. The distances to the centers of forces $h_{C(j)}$, $h_{W(j)}$, b_{CF}, b_C, $h_{l(j)}$ and $b_{l(j)}$ are similar to those shown in Fig. 5-6 and described in 5.3.5, except that the distances are measured from point Z_B.

Corner post tension is to be evaluated at the top and bottom of each container in the stack. The tension force, $T_{B(i)}$, acting at the base of each container is to be less than or equal to the vertical tension on bottom corner fitting design load for that container. The tension force, $T_{T(i)}$, acting at the top of each container is to be less than or equal to the vertical tension on top corner fitting design load for that container.

5.4 Design Application

5.4.1 General

For securing systems with adjustable and flexible securing components, such as a lashing assembly, pretensioning is to be kept to a minimum. Where pretensioning is an integral part of a securing system, it is to be specially considered. For each stack or block of containers, the wind loads and forces acting on the containers are to be determined in accordance with 5.2.

5.4.2 Stacks Secured with Twistlocks Only

For a stack of containers that is secured using only twistlocks between containers and the base, the loads on the containers in each tier are to be analyzed for end wall racking, corner post compression and corner post tension following the methodology described in 5.3.2, 5.3.5 and 5.3.6.

5.4.3 Stacks Secured with Cross Lash or Side Lash Systems

Independent stacks of containers secured with a flexible cross lash or side lash system are to be analyzed using the methodology described in 5.3.

5.4.4 Stacks Secured with Vertical Lashings

The restraining force of a vertical lash may be analyzed in a similar manner to the procedure presented in 5.3.3 and 5.3.4, except that this force will act in conjunction with the container corner post tension loads that restrain vertical uplift. Sharing of this load is dependent upon the stiffness of each component but is also a function of the tolerance between the lock fittings (twistlocks) and the contact surface of the container corner castings. All lock fittings are designed and manufactured with a small tolerance or gap to the mating surfaces of the container corner castings, and therefore a small amount of sliding or uplift occurs until contact between bearing surfaces occurs and load is transferred. A vertical lash that is made taut when installed supports the entire vertical uplift load initially and then stretches to a distance equivalent to the sum of the tolerances for all of the lock fittings. For example, for a vertical lash to the bottom corner casting of the third tier, the stretch in the lash would have to exceed the tolerances for three lock fittings before these fittings and the container corner posts would begin to provide vertical restraint. However, because the container corner posts are significantly stiffer than the vertical lash, most of the load above that threshold would be borne by the container.

5.4.5 Container Stacks within Cell Guides

The wind loads and forces resulting from the ships motions are to be applied to the containers in the stack and thence to the cell guides and support structure assuming contact in way of the upper and lower container corner castings. Since the lateral loads and therefore also tipping are restrained by the cell guides, the primary container load to check is corner post compression. Also, the corner post compression load at the bottom of the first tier container must not exceed the strength of the support structure below.

The lateral loads are to be applied to the cell guides in a manner that represents the most severe arrangement of different height containers anticipated for the intended service. For example, for a cell guide system designed with horizontal supports at a spacing equivalent to the height of a standard container, a severe condition would be to assume a half height container in the first tier such that all of the horizontal forces are applied roughly midway between supports.

5.4.6 Carriage of 20-ft Containers in Cell Guides Designed for 40-ft Containers

(a) General

20-ft containers may be carried in cell guides designed for 40-ft containers provided the requirements in 5.4.6(b) are met.

(b) Arrangement

For 40-ft container cells that are also intended to periodically carry 20-ft containers, cones fixed to the tank top or similar arrangements are to be provided at the four corners of the cell in way of the guides. Also, means are to be provided at mid-cell to restrict transverse sliding of the bottom tier of the 20-ft container stacks. See Fig. 4-5. Container securing devices are to be provided between each tier of the 20-ft containers and between the top tier 20-ft containers and an over-stowed 40-ft container to prevent transverse sliding between tiers. The loads on the securing devices between the tiers are not to exceed the safe working loads of these devices nor the container strength limits. The following two methods of securing the 20-ft containers may be employed.

(i) Fore-and-aft double stacking cones may be fitted at mid-cell essentially forming the two 20-ft containers in each tier into an effective 40-ft container. In general, 20-ft containers with a maximum stack weight of 120 tonnes per stack may be stowed in this manner. Any additional positions available in the cell above the 20-ft containers may be filled with 40-ft containers up to the corner post compression limit of the lowest tier of 20-ft containers.

(ii) Alternatively, for the second tier of 20-ft containers and above, stacking cones may be applied to the bottom corner fittings of the 20-ft containers before they are lifted aboard ship. In general, two 20-ft container stacks of equal height are to be stowed in the same row and supported by the forward and aft 40-ft cell guides.

If the 20-ft container stacks are not topped by 40-ft containers, the permissible weight of each 20-ft container stack (excluding the lowest tier) may be determined from Table 5-2 for the given number of tiers and transverse acceleration at the roll center. If the 20-ft container stacks are topped by at least one 40-ft container, the permissible weight of each 20-ft container stack (excluding the lowest tier) may be determined from Table 5-3. The weight of each 20-ft container is not to exceed its rating.

Alternate arrangements for the stowage of 20-ft containers in 40-ft container cells are to be specially considered. The acceptance of the above loading methods is subject to national regulations of the port where vessel regularly visits for trading.

(c) Shipboard Safety System

A fall protection system for personnel is required onboard the vessel when working on top of a container under the operating area of container gantry cranes. Unless a specific shipboard safety system is required by the port terminal union, where the vessel regularly visits for trading, the fall protection system shall be provided and in compliance with the requirements specified in the CR Rules for Steel Ships or other recognised standard.

Table 5-2
Permissible Average Weight of 20-ft Containers Stowed in 40-ft Cell Guides
(without 40-ft Container Topping)

Transverse Acceleration (g)	Permissible Average Weight (MT)								
	3 Tiers	4 Tiers	5 Tiers	6 Tiers	7 Tiers	8 Tiers	9 Tiers	10 Tiers	11 Tiers
0.35g	40.3	28.8	22.4	18.2	16.5	15.4	14.6	13.8	13.2
0.36g	39.6	28.2	21.9	17.9	16.2	15.1	14.3	13.6	13.0
0.37g	39.0	27.7	21.4	17.5	16.0	14.9	14.0	13.4	12.7
0.38g	38.3	27.1	20.9	17.2	15.7	14.6	13.8	13.1	12.5
0.39g	37.6	26.5	20.4	16.8	15.4	14.4	13.5	12.9	12.3
0.40g	37.0	25.9	20.0	16.4	16.4	14.1	13.3	12.6	12.1
0.41g	36.3	25.4	19.6	16.2	14.9	13.9	13.1	12.4	11.9
0.42g	35.6	24.9	19.2	15.9	14.7	13.7	12.9	12.2	11.7
0.43g	35.0	24.4	18.8	15.7	14.4	13.5	12.7	12.0	11.5
0.44g	34.3	23.9	18.4	15.4	14.2	13.3	12.5	11.8	11.3
0.45g	33.6	23.4	18.0	15.2	14.0	13.1	12.3	11.6	11.1
0.46g	33.1	23.0	17.7	15.0	13.8	12.9	12.1	11.5	11.0
0.47g	32.6	22.6	17.4	14.8	13.6	12.7	12.0	11.3	10.8
0.48g	32.0	22.2	17.1	14.6	13.4	12.5	11.8	11.1	10.6
0.49g	31.5	21.8	16.8	14.4	13.2	12.4	11.6	11.0	10.5
0.50g	30.9	21.4	16.4	14.2	13.0	12.2	11.5	10.8	10.3
0.51g	30.5	21.1	16.2	14.0	12.8	12.0	11.3	10.7	10.2
0.52g	30.0	20.8	15.9	13.8	12.7	11.9	11.2	10.5	10.1
0.53g	29.5	20.4	15.6	13.6	12.5	11.7	11.0	10.4	9.9
0.54g	29.1	20.1	15.4	13.4	12.4	11.6	10.9	10.3	9.8
0.55g	28.6	19.7	15.1	13.3	12.2	11.4	10.7	10.1	9.6
0.56g	28.2	19.5	14.9	13.1	12.0	11.3	10.6	10.0	9.5
0.57g	27.8	19.2	14.6	13.0	11.9	11.1	10.5	9.9	9.4
0.58g	27.4	18.9	14.4	12.8	11.8	11.0	10.4	9.8	9.3
0.59g	27.0	18.6	14.2	12.7	11.6	10.9	10.2	9.7	9.2
0.60g	26.6	18.3	14.0	12.5	11.5	10.7	10.1	9.5	9.1
0.61g	26.3	18.1	13.8	12.4	11.4	10.6	10.0	9.4	9.0
0.62g	25.9	17.8	13.6	12.2	11.2	10.5	9.9	9.3	8.9
0.63g	25.6	17.6	13.4	12.1	11.1	10.4	9.8	9.2	8.8
0.64g	25.2	17.3	13.3	11.9	11.0	10.2	9.6	9.1	8.7
0.65g	24.9	17.1	13.1	11.8	10.9	10.1	9.5	9.0	8.6

Note:
1 The lowest 20-ft container in the stack is included in the counting of 20-ft container tiers.
2 The weight of each 20-ft container is not to exceed its rating.

Table 5-3
Permissible Average Weight of 20-ft Containers Stowed in 40-ft Cell Guides
(with 40-ft Container Topping)

Transverse Acceleration (g)	Permissible Average Weight (MT)								
	3 Tiers	4 Tiers	5 Tiers	6 Tiers	7 Tiers	8 Tiers	9 Tiers	10 Tiers	11 Tiers
0.35g	42.2	32.0	26.4	22.2	19.3	17.2	15.6	14.2	13.1
0.36g	41.7	31.6	25.9	21.8	18.9	16.9	15.2	13.9	12.9
0.37g	41.2	31.1	25.4	21.4	18.5	16.5	14.9	13.6	12.7
0.38g	40.7	30.7	24.9	20.9	18.1	16.2	14.6	13.3	12.4
0.39g	40.3	30.2	24.4	20.5	17.8	15.8	14.3	13.0	12.2
0.40g	39.8	29.8	23.9	20.1	17.4	15.5	14.0	12.8	12.0
0.41g	39.3	29.3	23.5	19.7	17.1	15.2	13.8	12.5	11.8
0.42g	38.9	28.8	23.0	19.4	16.8	14.9	13.5	12.3	11.6
0.43g	38.4	28.3	22.6	19.0	16.5	14.6	13.3	12.1	11.4
0.44g	38.0	27.8	22.2	18.7	16.2	14.3	13.0	11.9	11.2
0.45g	37.5	27.3	21.8	18.3	15.9	14.1	12.8	11.7	11.0
0.46g	37.0	26.9	21.5	18.0	15.6	13.8	12.5	11.5	10.9
0.47g	36.4	26.5	21.1	17.7	15.4	13.6	12.3	11.4	10.7
0.48g	35.9	26.1	20.8	17.4	15.1	13.4	12.1	11.2	10.6
0.49g	35.4	25.7	20.4	17.2	14.9	13.1	11.9	11.0	10.4
0.50g	34.8	25.2	20.1	16.9	14.6	12.9	11.7	10.9	10.2
0.51g	34.4	24.9	19.8	16.6	14.4	12.7	11.5	10.7	10.1
0.52g	33.9	24.5	19.5	16.4	14.2	12.5	11.4	10.6	10.0
0.53g	33.4	24.2	19.2	16.1	13.9	12.4	11.2	10.4	9.8
0.54g	33.0	23.8	18.9	15.9	13.7	12.2	11.0	10.3	9.7
0.55g	32.5	23.4	18.6	15.6	13.5	12.0	10.9	10.1	9.5
0.56g	32.1	23.1	18.4	15.4	13.3	11.8	10.7	10.0	9.4
0.57g	31.7	22.8	18.1	15.2	13.1	11.6	10.6	9.9	9.3
0.58g	31.3	22.5	17.9	15.0	13.0	11.5	10.5	9.7	9.2
0.59g	30.9	22.2	17.6	14.8	12.8	11.3	10.3	9.6	9.1
0.60g	30.5	21.9	17.4	14.6	12.6	11.1	10.2	9.5	9.0
0.61g	30.1	21.6	17.2	14.4	12.5	11.0	10.1	9.4	8.9
0.62g	29.8	21.4	17.0	14.2	12.3	10.8	10.0	9.3	8.7
0.63g	29.4	21.1	16.7	14.0	12.1	10.7	9.9	9.2	8.6
0.64g	29.0	20.8	16.5	13.9	12.0	10.6	9.8	9.0	8.5
0.65g	28.7	20.6	16.3	13.7	11.8	10.5	9.7	8.9	8.4

Note:
1 The lowest 20-ft container in the stack is included in the counting of 20-ft container tiers.
2 The weight of each 20-ft container is not to exceed its rating.
3 40-ft topping containers are not included in the number of tiers in Table 5-3.

5.4.7 Other Rigid Securing Systems

Other systems which rigidly support containers and provide lateral restraint against forces due to the ship motions or wind loads are to be separately considered.

5.4.8 Combining Securing Systems

Most securing systems are generally applied at both ends of a container stack. However, there may be stowage arrangements which, for flexibility or other reasons, utilize different systems at each end. The interaction between systems which might impact the permissible stack weight is to be specially considered. When such an analysis is not practical, the permissible stack weight and container weight at each tier are to be based on the requirements of the securing system that provides the lowest permissible container weights.

(a) Rigid and Flexible Securing Systems

When combining a rigid securing system, such as cell guides, at one end with a flexible lashing system at the other end, the stack ratings would be based upon the lashing system.

If one system, by design, supports a greater portion of the lateral load, acceptance is to be based on a review of supporting documents and calculations.

(b) Two Flexible Securing Systems

Some stacks of containers may be secured with different flexible securing systems at each end. For example, a stack of containers may be secured using cross lashing assemblies at one end but only twistlocks at the other end. The permissible stack ratings are to be determined by the lowest rated system. In this example, the permissible container stowage weights would be based on a twistlocked stack.

5.4.9 Block Stowage

The forces and loads on containers stacked and secured in blocks shall be determined from 5.2. The assessment of this type of stowage arrangement shall be specially considered and shall reflect:

- The strength and flexibility of the containers
- The strength, interaction, and tolerance of the fittings connecting adjacent stacks
- The flexibility and strength of the buttress fittings, including their ability to support both tensile and compressive loads

5.5 Acceptance Criteria

5.5.1 General

For each stowage arrangement, the permissible stack rating is to be governed by the permissible loads in the containers at each tier, in the securing fittings, and in the fixed or rigid support elements.

5.5.2 Containers

Container loads are not to exceed the design loads given in Table 2-3. As noted in 2.5, higher strength ratings are to be specially considered when verified by formal testing as described in the Rules for Freight Containers.

5.5.3 Securing Fittings

Loads in securing fittings are not to exceed the safe working load of the fitting based upon the safety factors presented in Table 3-3 and the minimum breaking strength determined by testing. Values for the SWL and MBS shall be given on an CR test report provided by the manufacturer for each fitting and included in the Cargo Securing Manual.

5.5.4 Fixed Cell Guides, Shoring, Buttresses and Other Rigid Supports

Loads in these components and attached hull structure shall not exceed the following permissible stresses:

$$f = 0.80Y$$
$$q = 0.53Y$$

where

f = maximum normal stress, in kN/cm^2

q = nominal permissible shear stress, in kN/cm^2

Y = minimum specified yield point of the material, in kN/cm^2

For higher strength steels, *Y* is not to be taken as greater than 72% of the specified minimum tensile strength.

5.6 Design Considerations for Hull Structure

5.6.1 Design Loads

Calculated securing forces are to be less than the safe working load of the fitting. When evaluating the support structure for fixed securing fittings, the assessment shall be based on the maximum safe working load or container design load (from Table 2-3).

5.6.2 Allowable Stresses

Allowable stresses for evaluating hull structure are to be determined from the pertinent sections of the CR Rules for Steel Ships, including Part II and III.

CHAPTER 6 Materials and Weldings

6.1 General

Materials for container securing devices permanently attached to the hull structure are to be documented by tests and witnessed by the surveyor. The material physical properties are to be compatible with the hull materials in way of the attachment, and the chemical composition is to be such as to ensure welds of acceptable quality. Securing devices may be accepted on the basis of testing and inspection as specified in Chapter 7.

6.2 Materials

The requirements in this Chapter are applicable to rolled steel, cast, and forged material used for container securing devices. The requirements of Part XI of the CR Rules for Steel Ships are to be applied, unless there are specific requirements in this Guidelines.

6.2.1 Rolled Steel

For shapes and plates used in the construction of cell guides, buttress towers, container foundations on deck, etc., the steel is to satisfy the requirements specified in Part XI of the CR Rules for Steel Ships. Other structural steels are to be subject to special consideration.

6.2.2 Cast and Forged Securing Components

Steel castings and forgings are to be in accordance with the requirements of Part XI of the CR Rules for Steel Ships or an acceptable equivalent specification. Use of high strength and alloy steels is to be subject to special consideration. Ferritic nodular cast iron may be used for loose gear not subject to welding.

6.2.3 Chain

Unstudded short-link chain is to be in accordance with Part XI of the CR Rules for Steel Ships. Other chains are to be specially considered.

6.3 Welding

Welding is to be in accordance with Part XII of the CR Rules for Steel Ships. Alternate welding procedures and specifications are to be specially considered.

For cast or forged securing elements which are to be welded, the carbon content is not to exceed 0.35% unless specially approved.

6.4 Impact Properties

Container securing devices used at low temperatures are to have adequate fracture toughness. For container securing devices intended to be used at design service temperature of –10°C and below, the materials are to be tested for Charpy impact properties unless the parts are subject to compressive stresses only without any tension or shear stresses. The design service temperature is to be taken as the lowest mean daily average air temperature in the area of operation. The requirements for the preparation and procedure of a Charpy V-notch impact test are defined in Chapter 2 of Part XI of the CR Rules for Steel Ships. Charpy impact properties are tested at a temperature 10°C below the design service temperature. The results of the test are to meet the requirements of Part XI of the CR Rule for Steel Ships or other recognized standards.

CHAPTER 7 TESTING, INSPECTION, AND APPROVAL OF SECURING DEVICES

7.1 Drawings

Drawings of container securing devices and fittings showing dimensions, materials, test procedures, and manufacturer's markings are to be submitted for approval according to the requirements in this Guidelines. The design breaking loads, proof loads, and safe working loads are to be clearly indicated on the drawings. Proof loads are not to be less than 1.1 times the safe working loads for individual pieces.

7.2 Testing

7.2.1 Type Testing

Prior to testing, the Surveyor is to verify that the materials and dimensions of the test pieces are in accordance with the approved drawings and Part XI & XII of the CR Rules for Steel Ships or other recognized standards. In the presence of the Surveyor, types of each securing device and fitting are to be tested to and withstand the design breaking loads indicated on the drawing. Three samples of a securing device are to be tested for each applicable loading: tension, compression, and shear. The tests are to simulate, as closely as practical, actual service conditions. No permanent deformation is permissible up to the proof load indicated on the approved drawings. The type tests required for typical securing devices are given in Table 7-1. The Surveyor will issue a test report upon satisfactory completion of the type tests.

For fully automatic twistlock (FAT) operational testing shall be carried out in addition to type testing. Operational testing shall be performed on at least two test specimens in the presence of the Surveyor. The test arrangement shall present realistic stowage of ISO container secured by FAT. The load scenario shall demonstrate that the FAT is capable of withstanding transverse racking forces in combination with lifting forces induced by rolling within the given MSL values.

7.2.2 Product Testing

Container securing devices to be used as part of a securing system are to be tested in accordance with the following subparagraphs.

(a) General

Castings and forgings are to be inspected by the Surveyor to ensure that they are free from defects. Samples of adjustable securing devices such as turnbuckles, twistlocks, etc. are to be checked for ease of operation.

(b) Proof Tests

For all container securing devices, except lashing wire or chain, a sample of one piece in fifty is to be tested, in the presence of the Surveyor, to the proof load indicated on the drawing. For items produced in quantities of less than fifty, one sample is to be proof tested. After testing, the securing component is to be examined and verified free from damage or permanent deformation. Securing devices need not be proof tested in compression.

(c) Breaking Tests

Lashing devices and bridge struts are to be tested, in the presence of the Surveyor, to the design breaking load indicated on the drawing, as follows.

- Lashing wire and chain, one piece in fifty (1/50).
- Bridge struts and other lashing devices such as rods, turnbuckles and lashing points, one piece in two hundred fifty (1/250).

For items produced in quantities less than those indicated, one sample is to be break tested. Securing devices subjected to breaking tests are to be discarded.

The Surveyor will issue a test report upon satisfactory completion of the production tests. This report is to include the name of the vessel on which the gear is to be employed, if available. For each type of securing device and fitting, the following information is to be included: the number of devices in the production run, the number of devices proof tested with proof loads indicated, and the number of devices break tested with design breaking load indicated.

7.3 Marking of Securing Devices

All container securing devices are to be permanently marked with the manufacturer's name and identification number.

7.4 Type Approval

7.4.1 General

The Type Approval includes design assessment and manufacturing assessment. The Type Approval Certificate is to be issued upon satisfactory completion of the design assessment and manufacturing assessment, which will be entered into CR lists of Approved Marine Products..

7.4.2 Design Assessment

The design assessment review requires following drawings and technical documents, but not limited to, are to be submitted for examination:

- Detailed design drawings;
- Documents stating specifications;
- Performance information;
- Material specification;
- Test procedures;
- Applicable standards; and
- Other necessary engineering calculation and analysis reports.

both the product design plan review and type testing. The product design plan review is engineering evaluation of the product design for meeting design specifications indicated in Chapter 3. The Surveyor needs to witness type testing indicated in 7.2.1.

7.4.3 Manufacturing Assessment

All manufacturers of the products with the same design are required to be audited by the Surveyor. The Surveyor is to evaluate the quality assurance and quality control system of the manufacturing facilities in order to assess and verify their capability to meet the manufacturer's specified level of product quality consistently and satisfy the requirements of the CR Rules for Steel Ships, this Guidelines and/or other acceptable standards.

7.4.4 Type Approval Certificate

Upon satisfactory completion of the evaluation of design assessment and manufacturing assessment, the Type Approval Certificate can be issued. The Type Approval Certificate is valid for 5 years and the intermediate and renewal audit are to be carried out in accordance with CR Guidelines for Survey of Products for Marine Use.

The Type Approval Certificate will indicate the following items.

- Name and identification number of the part
- Manufacturer's name and location, which include all welding and subcontracting shops
- Materials
- Test report No. and name
- Minimum breaking loads, proof loads and safe working loads.

Table 7-1
Required Type Tests

Item No.	Securing Devices	Tension	Compression	Shear	Notes
1	Lashing	X			
2	Tensioning Device	X			e.g., turnbuckle
3	Penguin Hook			X	Also bending test
4	Lashing Point	X			1. Test loads to be oriented at working angle of lashing. 2. For lashing points with multiple openings, simultaneous test loads are to be applied if simultaneous loads occur in service.
5	Lock Fitting	X		X	e.g., twistlock
6	Single Stacking Cone			X	
7	Double Stacking Cone	X			Test to be set up such that loading is applied through cones.
8	Base Socket – Flush	X	X		For sockets with multiple openings, simultaneous test loads are to be applied if simultaneous loads occur in service. If headers are to be welded directly to the socket supporting each socket opening, however, only one opening need be tested.
9	Base Socket – Raised	X	X	X	See Note, Item 7
10	Base Socket – Breech Base or "Dove Tail"	X		X	See Note, Item 7
11	Bridge Fitting	X			
12	Bridge Strut	X	X		Test to be set up such that loading is applied through cones.

CHAPTER 8 CONTAINER SECURING MANUALS

8.1 General

A Container Securing Manual (the "Manual") is to be prepared and submitted for approval. This manual serves as the official Cargo Securing Manual for the vessel as required by SOLAS and the IMO Code of Safe Practice for Cargo Stowage and Securing (Appendix 3 [6] – [8]). All containers shall be stowed and secured throughout the voyage in accordance with the Manual. A copy of the Manual, approved by CR on behalf of the Flag Administration, is to be retained onboard the vessel for examination and/or reference by the Surveyors, Port/Flag State inspectors, and those involved with safe stowage and securing of cargoes carried.

In general, the items identified in the following sections are to be included in the Manual. However, nothing in this Chapter replaces or alters the requirements of the SOLAS Convention or Code.

8.2 Contents of the Container Securing Manual

An acceptable Manual shall at the minimum, include the following information addressing stowage and securing of containers. If the vessel carries semi-standardized cargo (packaged goods, vehicles, trailers, etc.) or non-standardized cargo (project cargo) stowage guidance as required by the IMO Code (Appendix 3 [2]) is also to be provided.

8.2.1 General

The following points describe how the Manual is to be developed, used, maintained, and updated. These points shall be included in Chapter 1, "General" of the Manual:

- The guidance given herein shall by no means rule out the principles of good seamanship, neither can it replace experience in stowage and securing practice. The Master shall ensure that cargo carried in the vessel is stowed and secured in a proper manner, taking into account prevailing conditions and the general principles of safe stowage.
- The information and requirements set forth in this Manual are consistent with the requirements of the vessel's trim and stability booklet, International Load Line Certificate (1966), the hull strength loading manual (if provided) and with the requirements of the International Maritime Dangerous Goods (IMDG) Code (if applicable).
- This Container Securing Manual specifies arrangements and container securing devices provided onboard the vessel for the correct application to and the securing of containers, based on transverse, longitudinal and vertical forces which may arise during adverse weather and sea conditions, as well as the strength of the container, securing devices and vessel structure. The purpose of this Manual is to provide guidance to the Master and crew on board the vessel with respect to the proper stowage and securing of containers throughout the voyage.
- It is imperative to the safety of the vessel and the protection of the cargo and personnel that the securing of the containers is carried out properly and that only appropriate securing points or fittings should be used for cargo securing.
- The container securing devices mentioned in this manual should be applied so as to be suitable and adapted to the quantity, type, and physical properties of the containers to be carried. When new or alternative types of container securing devices are introduced, the Container Securing Manual should be revised accordingly. Alternative container securing devices introduced should not have less strength than the devices being replaced.
- There should be a sufficient quantity of reserve container securing devices onboard the vessel.
- Information on the strength and instructions for the use and maintenance of each specific type of container securing device, where applicable, is provided in this manual. The container securing devices should be maintained in a satisfactory condition. Items worn or damaged to such an extent that their quality or operability is impaired should be replaced.
- The information contained in this Manual is in an approved form in accordance with MSC/Circ 745, Guidelines for the Preparation of the Cargo Securing Manual (Appendix 3 [8]). This Manual has been prepared in accordance

with the International Convention for the Safety of Life at Sea, 1974 (SOLAS), Chapters VI and VII (Appendix 3 [6]), and the IMO 2003 Edition of the Code of Safe Practice for Cargo Stowage and Securing, (Appendix 3 [7]).

- A copy of this Manual, approved by CR on behalf of the Flag State, shall be retained onboard the vessel for examination or reference by the Surveyors, Port/Flag State inspectors, and those involved with safe stowage and securing of cargoes carried.
- In the event the provisions of this Manual are revised, or the container securing devices described herein are significantly modified or altered, this Manual shall be revised and resubmitted for review and approval by CR. All such changes are to be documented as Revisions.

8.2.2 Container Stowage Arrangements

Each container stowage location on the vessel is to be identified, and the characteristics of each cell provided. This can be done in the form of drawings, sketches, or tables of information. At a minimum, the following should be included.

- Container Arrangement Plan showing IMO bay/stack/tier numbering and all possible container stowage configurations (optional lengths, heights, overstows, etc.)
- Capacity tables giving total slot capacities in applicable container stowage configurations
- Visibility restrictions at a range of drafts and trim
- Hazardous cargo stowage locations, limitations and required segregations as applicable
- Clear heights in holds
- Location of refrigerated container stowage locations and outlets
- Section diagrams showing each unique stack configuration and stack base height

8.2.3 Fixed and Portable Securing Components

(a) Description and Storage of Securing Components

A list of all securing equipment shall be provided with a sketch of each component, its key dimensions, material, manufacturer's identification number, and quantity. Class Type Approval certificates are to be provided for each securing component showing the minimum breaking strength, proof load, and safe working load for each type of applicable design load – tension, compression and/or shear. In case Type Approval is not available, a type testing report will be acceptable, see 7.2.1.

The location of each fixed securing device in holds and on deck shall be shown in a drawing or table. A list of all tools and accessories for use with the securing components shall be provided.

(b) Inspection and Maintenance of Securing Components

Instructions shall be given for inspection, maintenance, and lubrication of securing components. All components shall be inspected and inventoried regularly. If any components are found defective, they shall be marked and removed from service. Inspections, inventory, and ordering of replacement of portable securing components shall be recorded in an Inspections and Maintenance Log. When overhauled or repaired securing components are received they shall be inspected and an entry made in the log book.

Fixed cargo securing devices shall be visually inspected annually for damage such as cracking or deformation. In way of fixed cargo securing devices, vessel's structure that is visible shall also be inspected regularly for damage such as cracking or deformation. This is to include hatch cover structure (such as top plates in way of base sockets, and girders and beams under base sockets) and cell guides.

(c) Use and Installation of Securing Components

The Manual shall include sketches and descriptions that show how each portable securing component is used. This includes installation, locking or tightening, unlocking, handling, and storage. It is especially important to include notes on how to determine if securing components are fully locked and engaged, or unlocked.

For vessels with platforms or other fixed means of access to container stacks that are used for lashing or reefer maintenance, guidance on the use of portable hand railings, lights, and other safety features shall be provided.

(d) Hatch Cover Arrangement, Weight, and Stacking

It is quite useful to include information about the hatch covers in the Manual, such as hatch cover weights and guidance for stacking covers on the quay or on other covers.

8.2.4 Diagrams of Approved Container Securing Systems

Diagrams of available and approved securing systems for stacks of containers on deck and in holds that show the proper use of the securing components are to be provided. This shall include all available lashing patterns (single lash, double lash, no-lash, etc.) and indications of where these can be used (for example, only outboard stacks, at ends of paired 20-ft containers, from lashing bridges, etc.). Container stowage arrangement plans for each hold, hatch cover, or stowage location can be shown with securing devices indicated.

8.2.5 Presentation of Permissible Container Stack Weights

Container stack weights are limited by the strength of the hull structure and the securing system . For the most part, stack weight limits defined by hull structure and rigid securing systems do not change with operating condition characteristics or stack configuration. The maximum permissible gross stack weight imposed due to the strength consideration to the hull structure for each stack onboard are to be provided in the Manual. It is to be noted in the Manual that the maximum permissible stack weight can vary greatly depending on location or container length. Stack weight limits imposed by the securing system for free standing stacks lashed with flexible securing systems are dependent on many factors, including the following:

- Vessel characteristics and loading condition (length, beam, draft, and GM)
- Stack location onboard
- Stack configuration (type, number, and size of containers and how they are they are connected)
- Container strength and stiffness
- Lashing configuration
- Lashing component strength and stiffness
- Exposure to wind
- Container weights within the stack

The number of solutions possible with so many input variables is considerable, resulting in a wide range of allowable stack weights for the available lashing configurations.

It is also recognized that there is an operational imperative to keep the lashing as simple as possible to minimize time and cost in port. Therefore, it is essential that the Manual present clear and explicit guidance on permissible stack weights that cover the normal range of operating conditions, and stack and lashing variables noted above. This guidance shall permit the vessel’s crew to assess the acceptability of applied securing systems to each stack considering the actual container weights, stack location, GM, and wind exposure. Where approximations or assumptions are required to limit the information to a manageable level in the Manual, the resulting guidance shall be prudently conservative in nature.

Direct and precise calculations of permissible stack weights for each stack using actual values instead of simplifying assumptions may be performed by a suitable computer program that uses the methodologies defined in this Guidelines. Refer to 8.2.5(d).

(a) Presentation of Stack Weight Limits Due to a Flexible Securing System

The Manual shall include diagrams of each possible stack and lash configuration for every location onboard along with the allowable container weights in each tier. The format is to allow the crew to quickly assess lashing requirements for operating conditions they may encounter in service.

Permissible container weights for homogenous and stratified container stacks shall be provided. Results are to be provided for a normal full load GM and part load (higher) GM. Permissible stack weights for each GM shall be applicable for all operating conditions with a lower GM. The higher GM shall be selected to represent a near upper bound on all possible operating conditions because it represents an upper bound on the loads that are not to be exceeded.

(b) Background Information for Calculated Stack Weight Limits

The values used to determine the permissible stack weights presented in the Manual as discussed in 8.2.5(a) shall also be provided in the Manual. This is to inform the crew and also allow verification calculations to be performed with all the correct data.

At least the following information should be included

- The drafts and GMs assumed
- The calculated maximum roll and pitch angles, and roll, pitch, and heave periods
- A note regarding the transverse, vertical, and longitudinal accelerations applied at each tier and stack should be derived from this Guidelines or from other sources.
- The container and lashing assembly strength ratings and spring constants
- The lash geometry and any movement or sliding due to vessel hull torsional deflection, hatch cover movement or lashing bridge flexibility
- Container geometries assumed (heights) and stack configuration
- The applied wind load
- Any deviations from other assumptions or calculation methodology presented in this Guidelines

(c) Assessing Stack Weight Limits for Alternative Stack Configurations

In order to help the crew assess the stack weight limits and securing requirements for stacks that deviate from the configurations presented as described in 8.2.5(a), general guidance shall be provided that discusses the impact of variability in the input parameters. Providing sample stacks with maximum weights that result from altering each of the following parameters one at a time is suggested.

- GM: Consider a higher GM as an upper bound on forces and accelerations.
- Wind Exposure: Consider 1, 2, or 3 of the upper tiers exposed in an otherwise wind protected stack.
- Stratification: Consider reverse stratified stacks with heavier containers above lighter ones.
- Container Strength and Stiffness: Consider special containers with greater flexibility (such as open ended containers or containers with one door removed) or lower strength ratings.

Discussion of the results of these variations and rules of thumb, such as the following, shall also be provided.

- The higher the GM, the greater the forces acting on the containers. If the vessel is partially loaded and has a particularly high GM, loads on the containers and securing system can increase significantly.
- Weather effects increase the loading into the containers and lashing components. For tall stacks, the wind load on the upper tiers that may be exposed imposes an overturning moment which can significantly increase the tension and compression in the bottom container of an otherwise wind protected stack.
- The location of the stack has an influence on the accelerations and forces acting on the containers. Stacks located at the ends of the vessel experience the highest accelerations. Outboard stacks experience higher accelerations than inboard stacks.
- The container strengths do vary, particularly the values for corner-post tension and corner-post compression.
- Raising portions of the stack by using taller containers in lower tiers will increase the acceleration loads on the stack and reduce the permissible weights.
- Forces into the lashing system and containers are reduced when the stack is vertically stratified, with the heaviest containers located in the lower tiers. Reducing the weight of containers in the bottom tiers, even if still heavier than containers above, can increase loads into the container and/or securing system.
- Expected accelerations are based on extreme sea states and unrestricted service. Operation in near coastal waters or calm weather will result in lower accelerations and higher permissible stack weights.
- The maximum safe working load (SWL) of the lashing assembly is taken at 50% to 60% of the minimum breaking strength (MBS).

Because generally conservative assumptions are included in the calculation methodology, it is possible to apply the simplified permissible stack weights to actual stacks if the crew is alerted to the limitations of the assumptions and effect of differences from the assumed values as described above.

(d) Lashing Calculations by Computer Based Programs

It is quite common for vessel stow planning to be done with an onboard container securing program that can calculate the maximum permissible stack weights for each individual stack based on the provided container lashings. If such a program is used, it shall be certified based on the methods and assumptions of this Guidelines and be referenced and described in the Container Securing Manual. A container securing program onboard a vessel having an installed container securing system certified by CR is to be certified in accordance with Appendix 2 of this Guidelines, and the vessel assigned the notation CSP for container securing program. A certified onboard computer lashing program is mandatory if it is also capable of performing calculations for specific voyage routes to obtain possible reduction in accelerations, see . The suffix RSS shall be added to the container securing program notation, CSP-RSS, to signify the certification of the container securing programs capability to address both unrestricted service and specific voyage routes.

The Manual shall include sample stack weight calculations from the program and provide full documentation of assumptions so that the calculations can be checked. These sample cases could also be used periodically to confirm the results provided to the vessel from a shore side planner. For the CSP or CSP-RSS notation, the permissible container stack weights are to be included for the lower and upper bound GMs as described in 8.2.5(a) and one intermediate GM value.

For reference, representative GM ranges for typical ship breadths are listed below:

Breadth	GM Range
≤ 32.2 m	0.5 m ~ 3.0 m
> 32.2 m	0.8 m ~ 4.0 m
> 37 m	1.0 m ~ 5.0 m
> 40 m	1.0 m ~ 6.0 m
> 42 m	1.0 m ~ 7.0 m
> 48 m	1.0 m ~ 8.0 m
> 51 m	1.0 m ~ 9.0 m

A separate supporting document is to be prepared that describes the container securing program and assumptions, and provides calculation examples. This document is to be submitted for review when the Manual is submitted for review and approval. The supporting document is to also be placed on board the vessel as background for the crew. The container weight limits given by the container securing program are to be strictly followed in practice.

CHAPTER 9 SURVEYS

9.1 Initial Installation Survey

All work is to be in accordance with approved plans and the Surveyor is to be satisfied with the materials, workmanship, and welding procedures employed during initial installation. Production test reports and either Type Approval Certificates or type test reports attesting to the strength of the fittings, lashings, and tensioning devices, etc. are to be obtained and reviewed for completeness and accuracy. All components are to be checked for consistency with the approved Container Securing Manual. Upon satisfactory completion of this survey the Container Securing System Certificate will be issued by the Surveyor.

9.2 Container Securing Manual

An approved copy of the Container Securing System Manual as noted in Chapter 8, copies of the Type Approval Certificates or type test reports, copies of production test reports covering all the securing gear, and the Initial Installation Survey Certificate are to be carried aboard the vessel for use by the vessel's personnel.

9.3 Maintenance in Service

The proper maintenance of the container securing equipment in service does not rest upon CR.

APPENDIX 1　MAPS OF ROUTE-SPECIFIC TRADES

A1.1　Asia - Europe

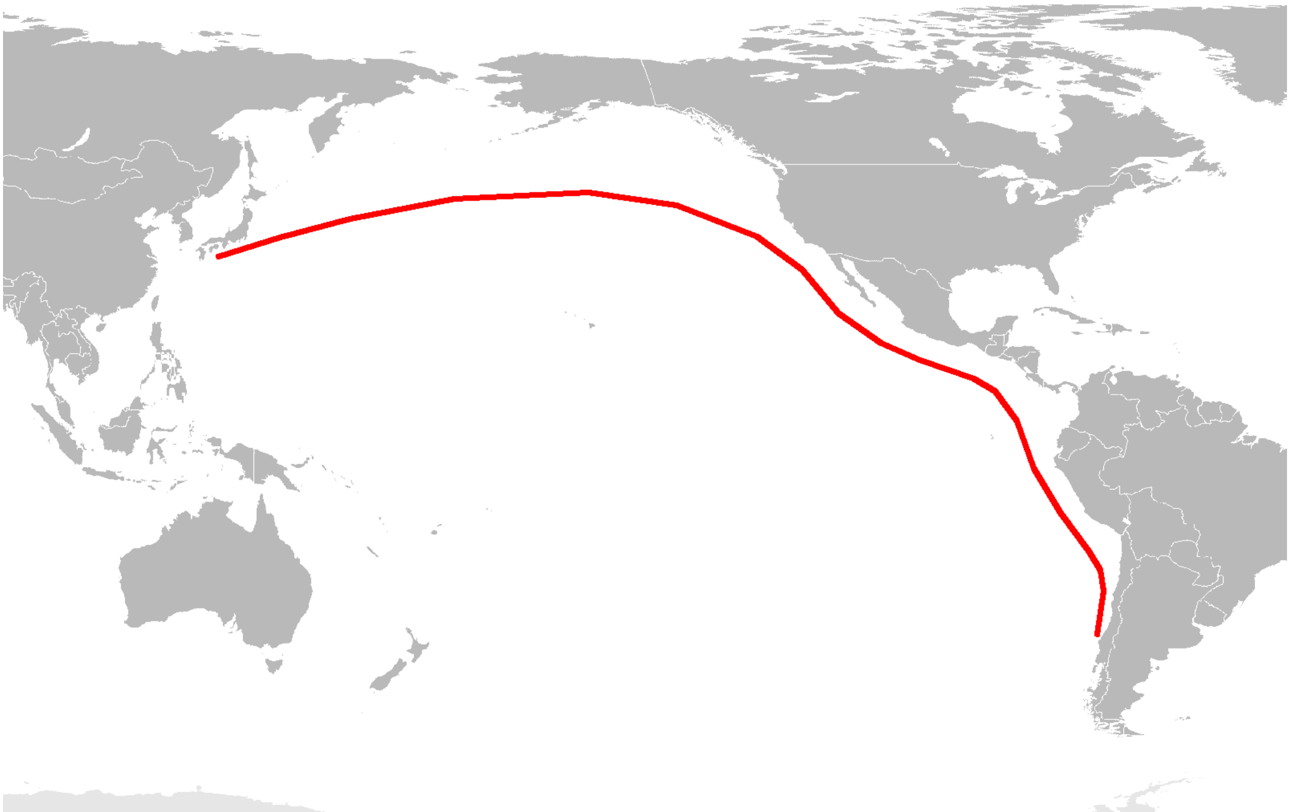
A1.2 Pacific - Atlantic

A1.3 North Pacific

A1.4 North Sea - Mediterranean

A1.5 North Atlantic

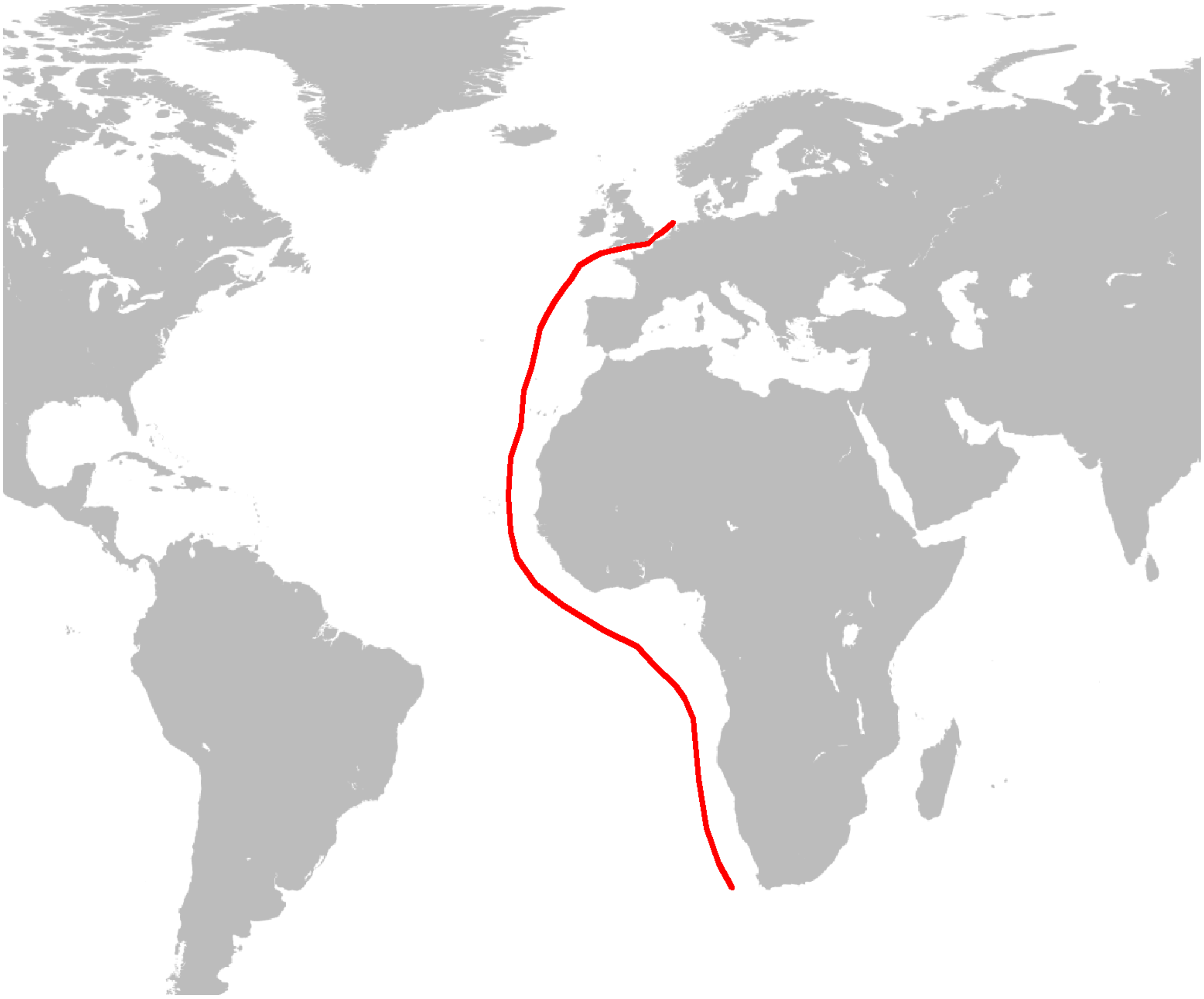
A1.6 Asia - South America (West Coast)



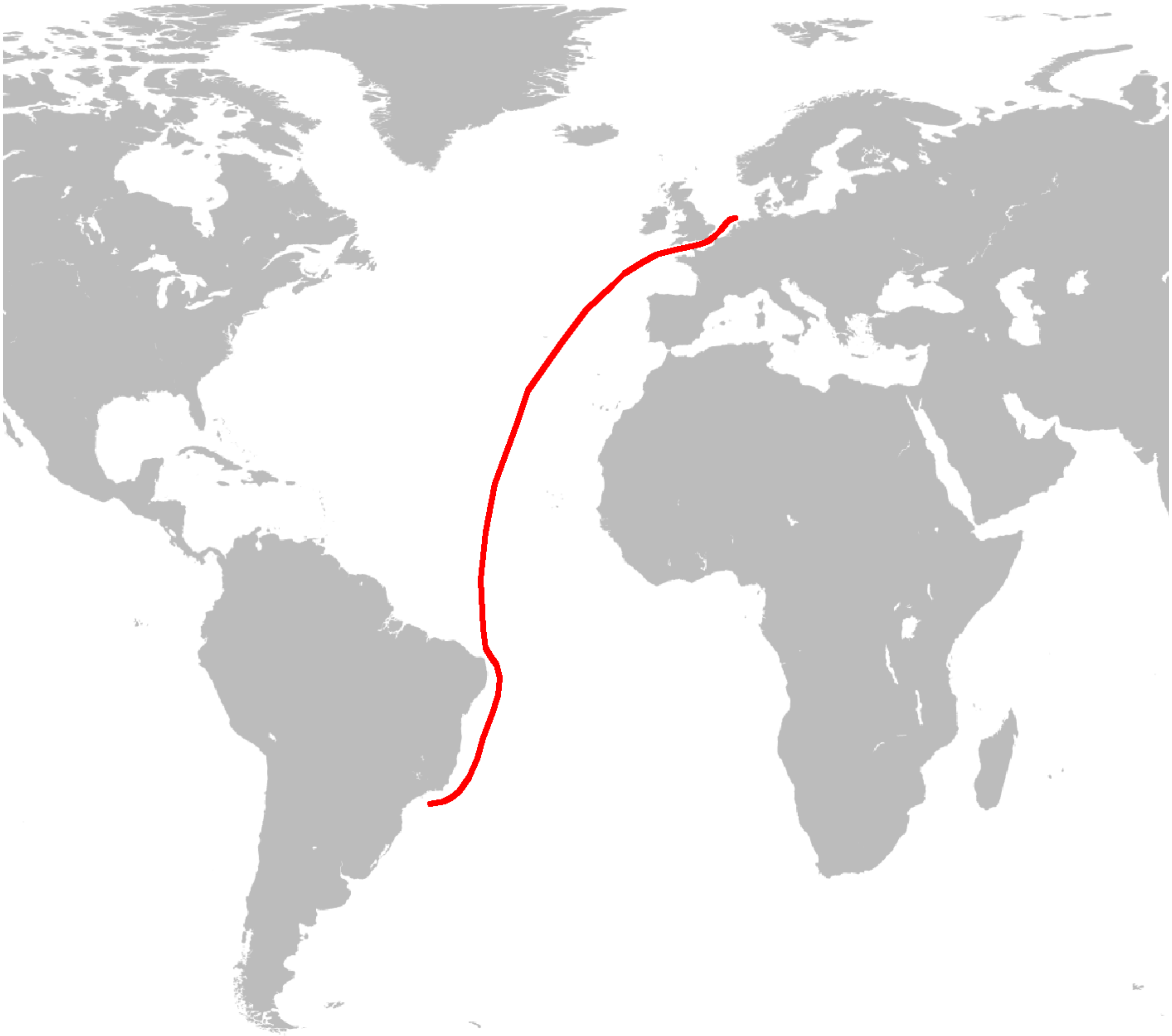
A1.7 South America (East Coast) - Africa

A1.8 Africa - East Asia

A1.9 Europe - Africa



A1.10 Europe - South America (Brazil)



A1.11 North America (East Coast) - South America (Brazil)

APPENDIX 2 ONBOARD COMPUTERS FOR CONTAINER SECURING CALCULATIONS

A2.1 General

Container securing calculation software is used to calculate and verify that the container securing arrangements are in compliance with the applicable strength requirements and acceptance criteria in this Guidelines. The software is at least to include all information and perform all calculations or checks as necessary for compliance with the applicable container securing requirements.

A2.2 General Requirements

A user's manual is to be provided for the container securing software and kept onboard.

The onboard computer for container securing calculations is ship specific equipment and the results of the calculations are only applicable to the vessel for which it has been certified.

In case of modifications implying changes in the ship's design or container securing arrangement, the software is to be modified accordingly and re-certified.

The calculation program is to be able to calculate for any container bay whether the stowage of containers and securing arrangements are within the approval limits, and show the obtained values and the conclusions (criteria fulfilled or not fulfilled).

The calculation program is to include a graphical representation of the containers and lashing arrangements.

For each container arrangement the software output should indicate:

- GM value
- Roll period
- Maximum roll angle
- Container racking stiffness
- Position of each stack
- Gross container weight
- Actual stack weight
- Container securing arrangement
- Transverse, vertical and longitudinal accelerations of each container
- Lifting forces
- Lashing forces
- Transverse and longitudinal racking forces
- Corner post loads
- Pressure loads at bottom

A2.3 Certification of Computer Software

A general description of the container securing program and a user's manual are to be submitted for review. Container lashing test cases that show the following results are also to be submitted for review:

- Complete lashing cases required by 8.2.5(a) of this Guidelines
- A test case resulting in unacceptable excessive stack weight
- A test case resulting in unacceptable excessive lash forces
- A test case resulting in unacceptable excessive corner post compression
- A test case resulting in unacceptable excessive racking forces
- Mixed 20 ft and 40 ft container stow

For a ship assigned the route-specific CSP-RSS notation, additional cases for the specified routes are to be submitted. Test cases for a minimum of three bays are to be submitted for each route.

APPENDIX 3　REFERENCES

The following common international standards are applicable to containers and container securing systems. Their requirements are not duplicated in this Guidelines, but included by reference where appropriate.

[1] ISO 1496-1:2013, Series 1 Freight Containers, Specification and Testing, Part 1 General Cargo Containers for General Purposes

[2] ISO 668:2013, Series 1 Freight Containers, Classification, Dimensions and Ratings, as amended 2005(E)

[3] ISO 1161:1984, Series 1 Freight Containers, Corner Fittings Specification

[4] ISO standard 9711-1:1990, Information Related to Containers on Board Vessels, Part 1, Bay Plan System

[5] IMO International Convention for Safe Containers (CSC), 1972, as amended

[6] IMO International Convention for the Safety of Life at Sea (SOLAS) 1974, Chapters VI and VII, as amended

[7] IMO 2003 Edition of Code of Safe Practice for Cargo Stowage and Securing

[8] IMO MSC/Circ 745, Guidelines for the Preparation of the Cargo Securing Manual

[9] ABS GUIDE FOR CERTIFICAION OF CONTAINRE SECURING SYSTEMS 2010