Container securing
FOREWORD

DNV GL class guidelines contain methods, technical requirements, principles and acceptance criteria related to classed objects as referred to from the rules.

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CHANGES – CURRENT

This is a new document.

Amendments February 2016

• General
  — Only editorial corrections have been made.

Editorial corrections
In addition to the above stated changes, editorial corrections may have been made.
CONTENTS

Changes – current.......................................................................................................................... 3

Section 1 General......................................................................................................................... 6
  1 Introduction............................................................................................................................... 6
  2 Objective................................................................................................................................. 6
  3 Scope..................................................................................................................................... 6
  4 Procedure................................................................................................................................. 6
  5 Symbols and definitions......................................................................................................... 6
  6 Assumptions............................................................................................................................. 7

Section 2 Design load combinations for container securing arrangements....................10
  1 General................................................................................................................................ 10
  2 Design loads.......................................................................................................................... 10
  3 Design load combinations..................................................................................................... 10

Section 3 ISO strength ratings and typical SWL values......................................................... 12
  1 General................................................................................................................................ 12
  2 Strength ratings for ISO containers..................................................................................... 12
  3 Typical SWL for container securing devices......................................................................... 13

Section 4 Strength evaluation of container securing arrangements with lateral non-rigid support.................................................................17
  1 General................................................................................................................................ 17
  2 Container stacks with twistlocks only.................................................................................. 17
  3 Container stacks with internal lashings............................................................................... 19
  4 Container stacks with external lashings................................................................................ 23
  5 Container stacks with vertical lashing................................................................................... 25

Section 5 Strength evaluation of container securing arrangements with lateral rigid support..........................................................................................26
  1 General................................................................................................................................ 26
  2 Container stacks with cell guides......................................................................................... 26
  3 Forces for shoring of containers in cargo holds without cell guides................................. 31

Section 6 Special container securing arrangements...............................................................34
  1 General................................................................................................................................ 34
  2 Stowage of 30’ and 40’ containers with one end only supported by cell guides.................. 34
3 Stowage of 45’ and similar containers above 40’ containers...........34

Appendix A Alteration of container securing arrangements..........................35
  1 Applicable rule edition........................................................................35
  2 Documentation requirements and class approval scope.....................35

Appendix B Weights, measurements and tolerances.........................................37

Appendix C Container-dimensions................................................................39

Appendix D Code of container position..........................................................40

Appendix E Height tolerances of container foundations..............................41

Appendix F Determination of the existing stack weight for mixed stowage (20’
and 40’ container) for the individual foundation points.............................43

Appendix G Calculation of a 5 tiers stack on deck........................................44
  1 Calculation example...........................................................................44

Changes – historic......................................................................................52
SECTION 1 GENERAL

1 Introduction
For ships assigned the ship type class notation Container ship or additional class notation Container, RU SHIP Pt.5 Ch.2 Sec.8 require that strength evaluation of container securing arrangements shall be carried out. This class guideline includes calculation methods for strength evaluation of container securing arrangements acceptable to the Society.

2 Objective
The purpose of this publication is to serve as an aid to those responsible for the planning and strength evaluation of securing arrangements for cargo containers on board ships. Acceptable assumptions and calculation procedures supplementing the general requirements stated in the rules for classification of ships are given.

3 Scope
The scope of this publication includes procedures for calculating of forces acting on container securing systems on board ships.

4 Procedure
To determine loads in the container lashing system, calculation methods according to Sec.4 to Sec.6 shall be applied depending on the arrangement and type of the lashing system. Input data are container gross weights, dimensionless acceleration factors and wind loads according to RU SHIP Pt.5 Ch.2 Sec.8, as well as parameters of the lashing system.

The results shall be checked against strength ratings for ISO-containers or safe working load (SWL) of the lashing fittings in accordance with Sec.3.

5 Symbols and definitions

5.1 Symbols
For symbols not defined in this class guideline, refer to RU SHIP Pt.3 Ch.1 Sec.4 [2].

\( \alpha \) = angle of lashing, in degrees, measured to vertical axis of ship’s coordination system

\( A \) = minimum effective gross area, in \( \text{cm}^2 \), of lashings

\( B_C \) = distance between bottom supports of container, in mm, measured at centre of ISO-holes

\( b_l \) = longitudinal dimensionless acceleration factor defined in RU SHIP Pt.5 Ch.2 Sec.8 [4.4.2]

\( b_q \) = transverse dimensionless acceleration factor defined in RU SHIP Pt.5 Ch.2 Sec.8 [4.3.2]

\( b_t \) = container position correction factor

\( b_v \) = vertical dimensionless acceleration factor defined in RU SHIP Pt.5 Ch.2 Sec.8 [4.5.3]

\( c_C \) = racking stiffness in, \( \text{cm/kN} \), of container end frame

\( CPL_{\text{found}} \) = vertical support force, in \( \text{kN} \), acting at bottom of a specific tier of container

\( f_{\text{route}} \) = route reduction factor defined in RU SHIP Pt.6 Ch.4 Sec.11

For ships assigned the additional class notation RSCS the transverse dimensionless acceleration factor, \( b_q \), shall be reduced by a route reduction factor, \( f_{\text{route}} \), defined in RU SHIP Pt.6 Ch.4 Sec.11.
\[ \text{CPL}_i = \text{calculated compressive force, in kN, in container post, equal to CPL}_\text{found}, \text{calculated at top of the container for which the container post is under investigation} \]

\[ E_Z = \text{overall modulus of elasticity, in kN/cm}^2, \text{of lashings including turnbuckle} \]

\[ F_{d} = \text{horizontal force, in kN, acting per container} \]

\[ F_{q,i} = \text{transverse container force, in kN, acting at level } i, \text{as given in RU SHIP Pt.5 Ch.2 Sec. 8 [4.3]} \]

\[ F_{\ell,i} = \text{longitudinal container force, in kN, acting at level } i, \text{as given in RU SHIP Pt.5 Ch.2 Sec.8 [4.4]} \]

\[ F_{T,\text{Found}} = \text{calculated transverse force, in kN, acting on foundation at bottom of the stack} \]

\[ F_w = \text{wind loads in, kN, defined in RU SHIP Pt.5 Ch.2 Sec.8 [4.2]} \]

\[ G = \text{container’s gross mass, in ton, as given in RU SHIP Pt.5 Ch.2 Sec.8 [4.2]} \]

\[ H_C = \text{height, in mm, of container} \]

\[ l = \text{length, in cm, of lashing} \]

\[ L = \text{rule length of the ship, in m, as given in RU SHIP Pt.3 Ch.1 Sec.4 [3.1.1]} \]

\[ = \text{in case the rule length is not available, length between perpendiculars } L_{PP} \text{ as defined in rules for RU SHIP Pt.3 Ch.1 Sec.4 [2.1] Table 2 may be applied} \]

\[ LF_{i} = \text{calculated tension force, in kN, in container post, calculated at bottom of the container for which the container post is under investigation} \]

\[ \mu = \text{friction coefficient} \]

\[ = 0.25 \text{ for cast steel combinations} \]

\[ = 0.5 \text{ for steel-steel combinations} \]

\[ = \text{other combinations will be considered on a case-by-case basis} \]

\[ v = \text{offset, in cm, caused by transverse shifting of bottom container} \]

\[ RF_{T,i} = \text{horizontal support force, in kN, acting at level } i \]

\[ x = \text{longitudinal coordinate, in m, of the stack center with respect to the reference coordinate system as defined in RU SHIP Pt.3 Ch.1 Sec.4 [3.6]} \]

\[ = \text{in case the length is not available, length between perpendiculars } L_{PP} \text{ as defined in RU SHIP Pt.3 Ch.1 Sec.4 [2.1] Table 2 may be applied in lieu of length } L \text{ for measurement of } x \]

\[ Z_i = \text{lashing force, in kN} \]

### 5.2 Definitions

For definitions not defined in this class guideline, refer to RU SHIP Pt.5 Ch.2 Sec.1 [1.5] and RU SHIP Pt.3 Ch.1 Sec.4 [3].

### 6 Assumptions

#### 6.1 Hull support structures

Hull support structures are normally assumed rigid. In special cases, e.g. shoring forces at ship sides, it may be necessary to consider non-rigid supports.

#### 6.2 Strength and stiffness of containers

Calculations assume that containers have at least normal strength and stiffness, i.e. closed boxes, open-top boxes, tank containers.

#### 6.3 Orientation of containers
All containers in a stack or block are placed in the same directions, i.e. all containers have the doorless end facing the same direction.

### 6.4 Friction
Friction effects are not taken into account.
6.5 Pre-tensioning of lashings
Pre-tensioning of lashings is not considered.
SECTION 2 DESIGN LOAD COMBINATIONS FOR CONTAINER SECURING ARRANGEMENTS

1 General
Container lashing calculations as given in this publication shall be carried out with the design load combinations as given in RU SHIP Pt.5 Ch.2 Sec.8 [5], which are further detailed in the followings.

2 Design loads

2.1 Sea induced accelerations
Accelerations related to ship’s motion shall be calculated in accordance with RU SHIP Pt.5 Ch.2 Sec.8 [4.3] to RU SHIP Pt.5 Ch.2 Sec.8 [4.5]. For ships assigned the additional class notation RSCS, accelerations related to ship’s motion for the specific routes shall be calculated additionally in accordance with RU SHIP Pt.6 Ch.4 Sec.11.

2.2 Wind loads
Wind loads shall be applied in accordance with RU SHIP Pt.5 Ch.2 Sec.8 [4.2].

3 Design load combinations

3.1 General
Applicable design load combinations are listed in Table 1. In the subsequent sections the relevant design load combinations are described in some more detail.

Table 1 Load combination overview

<table>
<thead>
<tr>
<th>LC</th>
<th>Description</th>
<th>Vertical</th>
<th>Horizontal</th>
<th>Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Transverse loading</td>
<td>$g \cos(\theta)$ $^1$</td>
<td>$b_q$</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Longitudinal/vertical loading</td>
<td>$g + b_v$</td>
<td>$b_l$</td>
<td>No</td>
</tr>
</tbody>
</table>

1) The vertical load is already implicitly included in formulas for corner post compression and lifting force in Sec.4.

3.2 Transverse loading (LC1)

3.2.1 Forces in the lashing system shall be calculated by applying the transverse dimensionless acceleration factor, $b_q$, in accordance with RU SHIP Pt.5 Ch.2 Sec.8 [4.3].

3.2.2 For deck stowage extreme transverse accelerations are combined with the vertical component of acceleration of gravity acting downwards.
Wind loads shall be added to wind exposed containers.
See also Figure 1.

3.2.3 For hold stowage extreme transverse accelerations are combined with the vertical component of acceleration of gravity acting downwards.
See also Figure 1.

![Figure 1 LC1](image)

**3.3 Longitudinal/vertical loading (LC2)**

**3.3.1** Longitudinal dimensionless accelerations factor, $b_l$, in accordance with RU SHIP Pt.5 Ch.2 Sec.8 [4.4] shall be applied combined with vertical dimensionless acceleration factor, $b_v$, in accordance with RU SHIP Pt.5 Ch.2 Sec.8 [4.5].

**3.3.2** For deck/hold stowage extreme longitudinal accelerations are combined with the vertical acceleration $b_v$ and gravity acting downwards.

See also Figure 2.

![Figure 2 LC2](image)
SECTION 3 ISO STRENGTH RATINGS AND TYPICAL SWL VALUES

1 General

Container strength ratings shall be in accordance with recognized standards. In [2] strength ratings for ISO containers are given. Allowable forces in the container securing devices shall be taken as the certified safe working load (SWL). In [3] typical SWL for selected container securing devices are shown.

2 Strength ratings for ISO containers

Container strength ratings and container corner casting strength ratings shall be in accordance with required minimum (tested) strength values and capabilities given in recognized standards, e.g., ISO 1496-1 and ISO 1161.

Strength ratings for ISO containers are given in Table 1.

Table 1 Strength ratings for ISO containers, in kN

| Racking force (door frame / front wall frame) | 150 |
| Racking force side walls | 150 (75<sup>1)</sup>) |
| Corner post compression | 848 (942<sup>2)</sup>) |
| Vertical tension in upper corner (from locking device) | 250 |
| Vertical tension in lower corner (from locking device) | 250 |

Lashing loads in corner casting

| Type of lashing | Lashing angle | Lower corner | Upper corner |
| Vertical lashing | 0° ≤ α ≤ 10° | 300 | 125 |
| Long lashing | 10° < α ≤ 35° | 270 | 175 |
| Short lashing | 35° < α ≤ 60° | 245 | 245 |
| Horizontal lashing | 60° < α ≤ 90° | 225 | 225 |

Horizontal shoring forces on corners

| Lower corner, tension/compression | 400 |
| Upper corner, tension/compression | 250 |

1) for non-closed box containers
2) For containers stowed with both ends in cell guides, a corner post load of 942 kN may be applied, provided the containers in lowermost tier are certified for this load in accordance with ISO 1496-2.
3 Typical SWL for container securing devices

In Table 2, safe working load (SWL) values are shown as typical values for selected types of the container securing devices. For container securing calculation purposes, SWL values as given in the product certificates of actual devices shall be used as allowable limits.
## Table 2 Typical SWL values for container securing devices

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Figure</th>
<th>Safe Working Load (SWL), in kN</th>
<th>Proof Load (PL), in kN</th>
<th>Min. Breaking Load (BL), in kN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Deck SWL 1.25 SWL 2.0 SWL</td>
<td>Hold SWL 1.1 SWL 1.33 SWL</td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Lashing rod</td>
<td><img src="image" alt="Lashing rod" /></td>
<td>245</td>
<td>307</td>
<td>490</td>
</tr>
<tr>
<td>1.2</td>
<td>Lashing chain</td>
<td><img src="image" alt="Lashing chain" /></td>
<td>80</td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>1.3</td>
<td>Lashing steel wire rope</td>
<td><img src="image" alt="Steel Wire Rope" /></td>
<td>200</td>
<td>250</td>
<td>450</td>
</tr>
<tr>
<td>2</td>
<td>Turnbuckle</td>
<td><img src="image" alt="Turnbuckle" /></td>
<td>245</td>
<td>307</td>
<td>490</td>
</tr>
<tr>
<td>3</td>
<td>Penguin Hook</td>
<td><img src="image" alt="Penguin Hook" /></td>
<td>245</td>
<td>307</td>
<td>490</td>
</tr>
<tr>
<td>4</td>
<td>D-Ring</td>
<td><img src="image" alt="D-Ring" /></td>
<td>245</td>
<td>307</td>
<td>490</td>
</tr>
<tr>
<td>5</td>
<td>Lashing plate</td>
<td><img src="image" alt="Lashing Plate" /></td>
<td>245</td>
<td>307</td>
<td>490</td>
</tr>
<tr>
<td>6</td>
<td>Twist lock (single)</td>
<td><img src="image" alt="Twist Lock" /></td>
<td>210</td>
<td>263</td>
<td>420</td>
</tr>
</tbody>
</table>

### Twist locks and deck connections

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---
<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Safe Working Load (SWL), in kN</th>
<th>Proof Load (PL), in kN</th>
<th>Min. Breaking Load (BL), in kN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Figure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Flush ISO socket</td>
<td>250</td>
<td>313</td>
<td>500</td>
</tr>
<tr>
<td>8</td>
<td>Pedestal ISO socket</td>
<td>250</td>
<td>313</td>
<td>500</td>
</tr>
<tr>
<td>9</td>
<td>Dove tail socket with twist lock</td>
<td>Tension</td>
<td>250</td>
<td>313</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shear</td>
<td>210</td>
<td>263</td>
</tr>
<tr>
<td>10</td>
<td>Stacker (single)</td>
<td>210</td>
<td>263</td>
<td>420</td>
</tr>
<tr>
<td>11</td>
<td>Stacker (double)</td>
<td>560</td>
<td>620</td>
<td>730</td>
</tr>
<tr>
<td>Item</td>
<td>Type</td>
<td>Figure</td>
<td>Safe Working Load (SWL), in kN</td>
<td>Proof Load (PL), in kN</td>
</tr>
<tr>
<td>------</td>
<td>---------------------</td>
<td>--------</td>
<td>--------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>12</td>
<td>Linkage plate</td>
<td></td>
<td>150</td>
<td>188</td>
</tr>
<tr>
<td>13</td>
<td>TP Bridge fitting</td>
<td></td>
<td>210</td>
<td>263</td>
</tr>
<tr>
<td>14</td>
<td>Buttress</td>
<td></td>
<td>Between tiers: 650 715 850</td>
<td>Top tier: 250 275 325</td>
</tr>
</tbody>
</table>
SECTION 4 STRENGTH EVALUATION OF CONTAINER SECURING ARRANGEMENTS WITH LATERAL NON-RIGID SUPPORT

1 General
Container stacks secured with twistlocks, with or without lashings, are considered as container securing arrangements with lateral non-rigid support. Strength evaluations of such container securing arrangements are given in:
— container stacks with twistlocks only: [2]
— container stacks with lashings: [3].
The strength evaluation shall be carried out applying both design load combinations given in Sec. 2.

2 Container stacks with twistlocks only

2.1 Transverse racking force
The transverse racking force, $RF_T$, in kN, on each container end frame in the $i^{th}$ tier shall be taken as:

$$RF_{Ti} = RF_{Ti+1} + 0.275 \cdot F_{q,i+1} + 0.225 \cdot F_{q,i}$$

2.2 Longitudinal racking force
The longitudinal racking force, $RF_L$, in kN, on each container side frame in the $i^{th}$ tier shall be taken as:

$$RF_{Li} = RF_{Li+1} + 0.275 \cdot F_{c,i+1} + 0.225 \cdot F_{c,i}$$

2.3 Corner post force
The corner post force, $CPL$, in kN, on the upper corner casting of a container in the $i^{th}$ tier shall be taken as:

$$CPL_i = CPL_{i+1} + RF_{Ti+1} \cdot \frac{H_{c,i+1}}{B_c} + \frac{1}{4} \cdot G_{i+1} \cdot b_i \cdot 9.81 \cdot \cos 30^\circ$$

The container position correction factor, $b_t$, depending on the longitudinal coordinate $x$, is given by:

$$b_t = 1.15 + \frac{80.5 - 0.75 \cdot x - 105 \cdot \frac{x}{L_{pp}}}{L_{pp} + 70}$$

for $AE$ to $0.2L$
2.4 Lifting force on bottom corner casting
The lifting force, $L_F$, in kN, on the bottom corner casting of a container in the $i^{th}$ tier shall be taken as:

$$L_{Fi} = L_{Fi-1} + R_{F_{i,1}} \frac{H_{c,i}}{B_c} \frac{4}{1} G_i \cdot b_i \cdot 9.81 \cdot \cos 30^\circ$$

2.5 Vertical forces in way of container foundations
The vertical forces, in kN, on each foundation point of a container or container stack shall be taken as:

$$CPL_{\text{found}} = CPL_{i} + R_{F_{T,1}} \frac{H_{c,i}}{B_c} + \frac{4}{1} G_i \cdot b_i \cdot 9.81 \cdot \cos 30^\circ \quad \text{at stack's compressed side}$$

$$L_{F_{\text{found}}} = L_{F_i} \quad \text{at stack's tensioned side}$$

2.6 Transverse force in way of container foundation
The transverse force, $F_{T,\text{found}}$, in kN, on a foundation point shall be taken as:

$$F_{T,\text{found}} = R_{F_{T,1}} + 0.275 \cdot F_{q,i}$$

If this force is not intended to be determined separately, a maximum value of 210 kN shall be assumed.

For container stanchions provided with a sliding plate or an athwartships arranged "dove tail base", the transverse force, $F_{T,\text{found}}$, on a foundation point shall be calculated as a friction force resulting from the vertical compressive force, $CPL_{\text{found}}$, acting on this foundation point and shall be taken as:

$$F_{T,\text{found}} = \mu \cdot CPL_{\text{found}}$$
The horizontal force need not be taken greater than the force causing the stanchion’s transverse deflection equal to the transverse clearance of the bottom locking device (usually, abt. 10 mm). In case of significant deformations of hatches - e.g., with long hatches - these are to be taken into account in connection with the container’s horizontal shift.

2.7 Longitudinal force in way of container foundation
The longitudinal force, $F_{L,found}$, in kN, on container’s foundation shall be taken as:

$$F_{L,found} = \sum_{i=1}^{n} F_{i,j}$$

3 Container stacks with internal lashings

3.1 Transverse racking force

3.1.1 Transverse racking force taken into account lashing force
The transverse racking force, $RF_{T}$, in kN, on a container in the $i^{th}$ tier shall be calculated according to [2.1], additionally taking into account transverse components of lashing forces, if any, on top of this container and on bottom of the container above as follows:

$$RF_{T,i} = RF_{T,j+1} + 0.275 \cdot F_{q,i} + 0.225 \cdot F_{q,i} - Z_{top,i} \cdot \sin \alpha_{top,i} - Z_{bottom,i+1} \cdot \sin \alpha_{bottom,i+1}$$

where:

$Z = \text{total lashing force, in kN, obtained in accordance with [3.1.6].}$

The transverse racking forces acting on container end frames and the lashing forces on these frames shall be calculated by solving the system of linear equations based on compatibility of deflections of container corners and lashing elements at their corresponding positions.

Where the arrangement of container stacks is such that tilting may occur, forces induced in the lashing elements are to be specially considered.

In general, static forces caused by pretension of lashings are neglected, see Sec.1 [6.5]. If these forces represent a significant portion of the total loads on containers and container securing equipment, special consideration is required.

3.1.2 Deflections of container corners
Load increase on some lashing elements caused by horizontal shifting of containers owing to clearance at, e.g., cone adapters and lower shifting locks shall in general be taken into account as follows:

— a transverse displacement of containers in the first and second layers of 0.4 cm each shall be considered for the stack’s door end
— for the front end, in general, a transverse displacement of containers shall not be considered
— if more than three container stacks placed side by side are coupled by double cone adapters to a container block, it is assumed that containers will not shift horizontally.
3.1.3 Deflections of lashing bridges
Lashing forces shall be calculated by taking into account maximum deformations of lashing bridges. The maximum deformations of the lashing bridges in ship’s transverse direction are given in RU SHIP Pt.5 Ch.2 Sec.8 [8.2.2].

If strength evaluation of lashing bridges result in greater deformations these shall be applied in the strength evaluation of the container stacks, see RU SHIP Pt.5 Ch.2 Sec.8 [8.1.2].

3.1.4 Overall modulus of elasticity of steel lashing rods
For calculation of the lashing forces according to [3.1.6] the standard values of overall modulus of elasticity, in kN/cm², given in Table 1 shall in general be applied for steel lashing rods (including tensioning device and eyes) depending on their design.

For unusual lashing geometries, i.e. deviations of more than 5% in either lashing angle or length of lashings, these individual values have to be applied instead of values given in Table 1.

In case of unusual characteristics of the lashing arrangement, overall modulus of elasticity for calculation of lashing forces shall be obtained by a separate test of the lashing configuration including turnbuckle. The test results shall be submitted to the Society.

Table 1 Typical values for lash parameters

<table>
<thead>
<tr>
<th>Lashing to</th>
<th>Length of lashing l, in cm 1)</th>
<th>Angle of lashing α in deg 1)</th>
<th>E-module of lashing rod Eₚ, in kN/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st tier top</td>
<td>354</td>
<td>43°</td>
<td>1.4 \times 10⁴</td>
</tr>
<tr>
<td>2nd tier bottom</td>
<td>365</td>
<td>41°</td>
<td>1.75 \times 10⁴</td>
</tr>
<tr>
<td>2nd tier top</td>
<td>560</td>
<td>24°</td>
<td>1.9 \times 10⁴</td>
</tr>
<tr>
<td>3rd tier bottom</td>
<td>575</td>
<td>22°</td>
<td>-</td>
</tr>
<tr>
<td>3rd tier top 2)</td>
<td>710</td>
<td>19°</td>
<td>-</td>
</tr>
<tr>
<td>4th tier bottom 2)</td>
<td>725</td>
<td>18°</td>
<td>-</td>
</tr>
</tbody>
</table>

1) The stated standard values for the length and the angle of lashing are valid for 8’ 6” high containers. For other container heights, these values have to be adjusted accordingly.

2) These long lashings are not permitted according to IMO Res. A.714 Code of Safe Practice for Cargo Stowage and Securing Annex 14.

3.1.5 Racking resilience of container end frames
For calculation of lashing forces, where the racking resilience values of the container end frames are unknown, the mean values according to Table 2 can be used for steel frame containers.

Table 2 Mean values for racking resilience

<table>
<thead>
<tr>
<th>Door frame</th>
<th>Front wall frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Racking resilience cᵢ, in cm/kN</td>
<td>2.7 \times 10⁻²</td>
</tr>
</tbody>
</table>

For aluminium containers values of cᵢ will be specially considered.

3.1.6 Determination of transverse racking forces and lashing forces
Determination of transverse racking forces and lashing forces is demonstrated below by means of a simple example for a container stack consisting of two tiers lashed to the bottom of the second tier (see Figure 1). A further calculation example is given in AppG.
Figure 1 Example

Racking force, in kN, on top of upper tier:

\[ RF_{T,2} = 0.225 \cdot F_{q,2} \]

Racking force, in kN, on top of lower tier:

\[ RF_{T,1} = RF_{T,2} + 0.275 \cdot F_{q,2} + 0.225 \cdot F_{q,1} - Z \cdot \sin \alpha \]

Total lashing force, in kN:

\[ Z = Z_0 + \Delta Z \]

\[ \Delta Z = c_z \cdot \Delta \ell \]

\[ c_z = \frac{E_z \cdot A}{\ell} \]

\[ \Delta \ell = \delta \cdot \sin \alpha \]
3.2 Longitudinal racking force
The longitudinal racking force, $RF_L$, on a container’s side frames shall be calculated according to [2.2].

3.3 Corner post force
The corner post force, $CPL$, in kN, on the upper corner casting of a container in the $i^{th}$ tier shall be calculated according to [2.3], additionally taking into account vertical components of lashing forces, if any, on top of this container and on bottom of the container located above as follows:

$$CPL_i = CPL_{i+1} + RF_{T,i+1} \cdot \frac{H_{c,i+1}}{B_c} + \frac{1}{4} \cdot G_{i+1} \cdot b_i \cdot 9.81 \cdot \cos 30^\circ + Z_{top,i} \cdot \cos \alpha_{top,i} + Z_{bottom,i+1} \cdot \cos \alpha_{bottom,i+1}$$

3.4 Lifting force on bottom corner casting
The lifting force, $LF$, on the bottom corner casting of a container in the $i^{th}$ tier shall be calculated according to [2.4].

3.5 Vertical forces in way of container foundations
The vertical force, in kN, on each foundation point of a container or container stack at the compressed side shall be calculated according to [2.5], additionally taking into account the vertical component of the lashing force, if any, acting on top of the lowermost container as follows:

where:

$Z_0 = \text{pretension force, in kN}$

$\Delta Z = \text{increase of lashing force, in kN}$

$c_z = \text{tension stiffness, in kN, of lashing element}$

$\ell = \text{length, in cm, of lashing}$

$\Delta \ell = \text{elongation, in cm, of lashing element}$

$A = \text{effective cross-section, in cm}^2, \text{of lashing}$

$E_z = \text{overall modulus of elasticity, in kN/cm}^2, \text{of lashing according to [3.1.4].}$

Transverse deflection of lashed container corner:

$$\delta = c_c \cdot RF_{T,1} + \nu$$

where:

$c_c = \text{racking resilience, in cm/kN, of the container’s transverse frame according to [3.1.5]}$

$\nu = \text{transverse offset, in cm, caused by shifting of bottom container according to [3.1.2]}.$
The vertical force on each foundation point of a container or container stack at the tensioned side shall be calculated according to [2.5].

3.6 Transverse force in way of container foundation
The transverse force, $F_{T,\text{found}}$, on a foundation point shall be calculated according to [2.6].

3.7 Longitudinal force in way of container foundation
The longitudinal force, $F_{L,\text{found}}$, on container's foundation shall be calculated according to [2.7].

4 Container stacks with external lashings

4.1 Internal lashing and external lashing
For container stacks under lateral loads, the tripping moment induced by these loads will result in vertical reaction forces on container posts - compression forces on one side and tension forces on the other side. For internal lashing, the acting lashing bars are secured to the corner casting on the post with compression reaction forces. For external lashing, the acting lashing bars are secured to the corner casting on the post with tension reaction forces. See illustrations in Figure 2 and Figure 3.

For container stacks secured by external lashing, when the corner casting (where the acting lashing bar is secured to) is under tension force, the twistlock will not bear the loads before the clearance between twistlock cones and corner casting is closed. In such a case, the acting lashing bar will take more loads when considering additional deformation due to closing of the clearance. This phenomenon shall be taken into consideration during container securing calculations for external lashing system in accordance with [4.2].

![Figure 2 Internal lashing (left) and external lashing](image-url)
4.2 Calculation procedure for external lashing system

4.2.1 General  
For external lashing systems the vertical twistlock clearance shall be considered in way of the corner casting.  
Strength evaluation of external lashing systems should be carried out as follows:  
— first step: lashing force, \( Z \), and lifting force on bottom corner casting, \( LF \), should be calculated in accordance with [3]  
— second step: determination of \( Z_{\text{total}} \) as given in [4.2.2]  
— third step: numerical iteration determining force equilibrium according to [4.2.2] by applying \( Z_{\text{total}} \) instead of \( Z \) in [3] in order to calculate all forces related to the container securing arrangement.

4.2.2 Numerical iteration  
Container and lashing forces should be determined by force equilibrium conditions considering the force \( Z_{\text{total}} \) in kN, calculated as an external force aside from wind and acceleration loads given by:

\[
Z_{\text{total}} = Z + 0.7 \cdot \Delta Z
\]

\[
\Delta Z = c_Z \cdot \Delta l
\]

\[
\Delta l = \delta_{\text{eff}} \cdot \cos(\alpha)
\]
where:

\[ c_Z = \text{tension stiffness, in kN, of lashing element according to [3.1.6]} \]

\[ \delta_{\text{eff}} = \min (\delta_{\text{actual}}, \delta_{\text{eff,max}}), \text{in mm} \]

\[ \delta_{\text{actual}} = \text{geometric vertical clearance of twistlock between corner casting according to RU SHIP Pt.5 Ch.2 Sec.8 [2.3.6]. Clearance values given below apply as long as the clearance for the actual twistlock does not exceed these values significantly, otherwise the larger value should be used in calculations:} \]

- conventional and semi-automatic twistlocks: 12mm
- fully automatic locks: 20mm
- lashing rods with spring elements or similar are fitted: 0 mm may be applied

\[ \delta_{\text{eff,max}} = \frac{LF}{0.3 \cdot c_Z \cdot \cos^2(\alpha)} \]

\[ Z = \text{lashing force, in kN, according to [3.1.6]} \]

\[ LF = \text{lifting force, in kN, on bottom corner casting according to [3.4].} \]

## 5 Container stacks with vertical lashing

### 5.1 General

For container stowage where vertical lashings are applied (lashing bar angle \( 0^\circ \leq \alpha \leq 10^\circ \)) with spring element to equalise clearance between twistlocks and corner castings, the strength ratings given in Sec.3 [2] shall be complied with, applying the following exception:

- for all twistlocks below the vertical lashing, the lifting force, \( LF \), shall not exceed 375kN.
SECTION 5 STRENGTH EVALUATION OF CONTAINER SECURING ARRANGEMENTS WITH LATERAL RIGID SUPPORT

1 General

Cell guides, buttress and similar are considered as container securing structures with lateral rigid support for container stacks. Strength evaluations of such container securing structures are given in:

— container stacks with cell guides: [2]
— forces for shoring of containers in cargo holds without cell guides: [3].

For containers secured with different methods at the two ends, e.g., one end with cell guide and the other end with stackers, or one end with lashings and the other end with twist locks, strength evaluation shall be carried out for both ends respectively.

2 Container stacks with cell guides

2.1 Containers stacks with both ends supported by cell guides

For container stacks with both ends supported by cell guides, strength evaluation for containers and relevant container securing devices shall be checked based on design load combination 2 given in Sec. 2.

2.1.1 Longitudinal force transferred into cell guides

The longitudinal forces due to pitching motions are transferred by compression of the container’s corner castings against the cell guide rails. Each container corner casting will transfer:

\[ F_{CG, long} = \frac{F_{li}}{4} \]

2.1.2 Vertical compression of lower most container in stack

The vertical compression force acting on the lowermost container in the stack due to pitching motions shall not exceed maximum permissible corner post compression. Each container corner post load can be calculated as:

\[ CPL_1 = \frac{(\Sigma G \cdot g \cdot b_p)}{4} \]

where:

\( G \) = gross mass of containers, in tons, of containers stowed on top of lowermost tier.

2.2 Containers stacks with one end only supported by cell guides

For 20’ container stacks stowed in 40’ container cell guides permissible stack weights shall be established in accordance with [2.3].

For 30’ and 40’ container stacks with one end only supported by cell guides, the calculation methods given in Sec.6 [2] apply.
2.3 Stowage of 20’ containers in 40’ cell guides

2.3.1 Stowage with lateral support in 20’-gap
Where 20’ containers are stowed in 40’ cell guides, in general, container ends in the 20’ gap shall be secured against shifting in the lowermost tier on both sides of the stacks. For the lowermost tier, the 20’ container bottom shall also be secured by single cones at cell guide ends.

For other tiers above, the 20’ containers shall be secured to each other by single stackers at the gap end.

2.3.2 Stowage of 20’ containers without lateral support in 20’-gap not topped by 40’ containers
For stowage of 20’ containers not topped by 40’ containers, the maximum permissible stack weights are listed in Table 1.

Table 1 Permissible stack weight, in tons, of 20’ containers not topped by 40’ containers

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$\ddot{b}_q$ = transverse acceleration factor calculated for the middle of stack height (see RU SHIP Pt.5 Ch.2 Sec.8 [4.3]).
Container securing

2.3.3 For stowage of 20’ containers topped by 40’ containers, the maximum permissible stack weights are listed in Table 2.

Table 2 Permissible stack weight, in tons, of 20’ containers topped by 40’ containers

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Note:
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2) Calculated transverse acceleration factor $\bar{b}_q$ shall be rounded up to two decimal places.
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<td>94.1</td>
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<td>96.5</td>
<td>98.5</td>
<td>100.2</td>
<td>101.7</td>
</tr>
</tbody>
</table>

$\bar{b}_q$ = transverse acceleration factor calculated for the middle of stack height (see RU SHIP Pt.5 Ch.2 Sec.8 [4.3]).
3 Forces for shoring of containers in cargo holds without cell guides

3.1 General

Where a largely rigid shoring of a container block may be assumed on account of the ship's construction, the transverse shoring forces on lateral supports and corner castings at corresponding positions may be determined, with sufficient accuracy, as given below. Hull deformations, if significant, shall also be taken into account.

The total transverse load on container layers positioned between two support levels shall be assumed to be completely distributed between these supports. The total transverse load is shall be assumed to be equally distributed in the longitudinal direction, i.e., between supports at the container ends. In the vertical direction, i.e., between both support levels, the total transverse load shall be assumed to be distributed according to the vertical distance of these supports from the centre of the total transverse load:

\[
F_{\text{shore},j} = \frac{1}{2} \cdot F_{q,\text{total}} \cdot \frac{d_j}{d_1 + d_2}
\]

\[
F_{\text{shore},2} = \frac{1}{2} \cdot F_{q,\text{total}} \cdot \frac{d_1}{d_1 + d_2}
\]

where:

- \( F_{\text{shore},j} \) = transverse shoring force, in kN, on a support point at support level \( j \)
- \( d_j \) = vertical distance, in m, of centre of the total transverse load from support level \( j \)
- \( F_{q,\text{total}} \) = sum of transverse loads, \( F_q \), in kN, according to RU SHIP Pt.5 Ch.2 Sec.8 [4.3] on containers in layers between both support levels.

In the following, the determination of shoring forces is demonstrated for a simple example, considering a container block with two supports consisting of five layers and \( n \) stacks as shown in Figure 1. In this example, the same transverse load, \( F_g \) (see RU SHIP Pt.5 Ch.2 Sec.8 [4.3]) is assumed for each container in the container block.

The load from the container layers is to be distributed ideally to the supports.

The total transverse load from the two uppermost container layers, \( F_{\text{shore,upper}} \) in kN, induces the following shoring force on each support point of the upper and the lower supports:
The lower support, $F_{\text{shore,lower}}$, in kN, is additionally loaded with the proportional share from the three lower container layers. Thus, each of the lower supports is loaded with:

$$F_{\text{shore,lower}} = \frac{5 \cdot n}{4} F_q$$

The remaining share of the total transverse load is transmitted into the double bottom.

![Diagram showing the distribution of shoring forces](image)

**Figure 1 Example for determination of shoring forces**

### 3.2 Reduction in transverse shoring forces for block with more than four stacks

Where the number of stacks in the container block is greater than four, the transverse shoring forces calculated according to [3.1] may be reduced by the following factor $f_r$:

If

$$(n - m) \leq 4,$$

the factor

$$f_r = 1 - \frac{(n - 4)^2}{2 \cdot n \cdot m}$$

$$(n - m) > 4,$$

the factor

$$f_r = \frac{8 + m}{2 \cdot n}$$

where:
where:

\[
m \quad = \quad \text{number of container layers} \\
n \quad = \quad \text{number of container stacks to be supported at the respective shoring point.}
\]

Where two opposite shoring points are designed to act simultaneously in tension and compression, \( n \) shall be taken as half the number of stacks.

If the container block is not complete, e.g., due to the container bench structures in holds, the number of container layers, \( m \), and the number of container stacks, \( n \), shall be determined as follows:

**Number of layers \( m \):**

1) maximum number of layers of the considered block / 3 = \( A \) (whole numbers, not rounded) 
2) original total number of layers to be reduced by \( A \).

The layers having fewer rows than \( A \) are not considered.

This gives the corrected number of layers.

**Number of stacks \( n \):**

1) corrected number of layers (see above) / 2 = \( B \) (whole number, not rounded) 
2) Stacks for which number of layers is smaller or equal to \( B \) are to be neglected. Tank steps still existing are not considered.

The corrected number of layers and stacks is to be inserted into the formula for the reduction factor, \( f_r \), as described above.

The reduction is admissible, provided the following requirement is met:

\[
0.3 \cdot m \cdot G_{\text{aver}} \cdot 9.81 \cdot (1 - f_r) \leq 150 \text{ kN}
\]

where:

\[
G_{\text{aver}} \quad = \quad \text{average gross weight, in tons, of containers to be supported by support point under consideration.}
\]
SECTION 6 SPECIAL CONTAINER SECURING ARRANGEMENTS

1 General
Calculation procedure for typical container securing arrangements is given in Sec. 4 and Sec. 5. Calculation procedures for container securing arrangements other than those in Sec. 4 and Sec. 5 are described in this section.

2 Stowage of 30’ and 40’ containers with one end only supported by cell guides
For container stacks with one end only supported by cell guides, strength for containers and relevant container securing devices shall be checked in accordance with Sec.5 [2.1] for the end with cell guide. The other end with lateral non-rigid support shall be checked in accordance with Sec. 4.
For container stowage with one end only supported by cell guides, the acceptance criteria as given in Sec.3 [2] shall be complied with, applying the following exception:
— the maximum permissible transverse racking force on the lowermost container is 185 kN and 170 kN for 30’ and 40’ containers, respectively.

3 Stowage of 45’ and similar containers above 40’ containers
3.1 Acceptance criteria
For container stowage where 45’ containers are stowed on top of 40’ containers, the acceptance criteria given in Sec.3 [2] shall be complied with, applying the following exception:
— for all 45’ containers, the corner post compression shall not exceed 270 kN.
This may be applied for 48’, 49’ and 53’ containers similarly, provided that the 48’, 49’ and 53’ containers are certified equal to strength ratings for 45’ ISO containers.

3.2 Adaptive frames
In case adaptive frames are used for stowage of 48’, 49’ and 53’ containers, these frames shall be certified according to certification standard for container securing devices. Each adaptive frame should be placed on top of one 40’ container and designated deck area. It should be avoided to position any adaptive frame on different hatches or locations where relative deformations are expected.
APPENDIX A ALTERATION OF CONTAINER SECURING ARRANGEMENTS

1 Applicable rule edition
All measures given below are considered as alterations and not conversions. For a further definition of alterations and conversions, see RU SHIP Pt.1 Ch.1 Sec.3 [2.6].

2 Documentation requirements and class approval scope
Documentation requirements and class approval scope for typical alterations of container securing arrangements are given in Table 1.

Table 1 Alteration of container securing arrangements - documentation requirements and class approval scope

<table>
<thead>
<tr>
<th>Measure</th>
<th>Rules for Ships and Class Guideline references</th>
<th>DocReq</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
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</tr>
<tr>
<td>1.1</td>
<td>Additional GM values</td>
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</tr>
<tr>
<td>2</td>
<td>Strength evaluation of container securing arrangement based on specific routes</td>
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</tr>
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<td>2.1</td>
<td>Container Securing Arrangement</td>
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</tr>
<tr>
<td>2.2</td>
<td>Lashing computer system</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Increasing nominal container capacity by higher stacks</td>
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</tr>
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<td>3.1</td>
<td>Container Securing Arrangement</td>
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</tr>
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<td>3.2</td>
<td>IMO visibility line</td>
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<td>Trim &amp; stability booklet (including longitudinal strength)</td>
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</tr>
<tr>
<td>3.4</td>
<td>Loading computer system</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Alterations in lashing arrangement</td>
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</tr>
<tr>
<td>4.1</td>
<td>Container Securing Arrangement</td>
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<td>Cargo Securing Manual (if 4.3 and 4.4 are applicable)</td>
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</tr>
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<td>Additional loose container securing devices</td>
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<td>Additional fixed container securing devices</td>
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<td>4.4</td>
<td>Supporting structures of additional fixed container securing devices</td>
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<td>Measure</td>
<td>Rules for Ships and Class Guideline references</td>
<td>DocReq</td>
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<td>---------</td>
<td>-----------------------------------------------</td>
<td>--------</td>
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<td>5.1</td>
<td>Container Securing Arrangement RU SHIP Pt.5 Ch.2 Sec.8 and CG 0060</td>
<td>H190</td>
</tr>
<tr>
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<td>Structure modification RU SHIP Pt.5 Ch.2 Sec.8 and CG 0060</td>
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</tr>
<tr>
<td>6</td>
<td>Increased stack weights on hatch covers&lt;sup&gt;8)&lt;/sup&gt;</td>
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</tr>
<tr>
<td>6.2</td>
<td>Hatch cover strength RU SHIP Pt.3</td>
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<td>6.5</td>
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<td>C030&lt;sup&gt;6)&lt;/sup&gt;</td>
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<td>7</td>
<td>Increased stack weights in holds&lt;sup&gt;8)&lt;/sup&gt;</td>
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<tr>
<td>7.1</td>
<td>Container Securing Arrangement RU SHIP Pt.5 Ch.2 Sec.8 and CG 0060</td>
<td>H190</td>
</tr>
<tr>
<td>7.2</td>
<td>Strength of cell guides RU SHIP Pt.5 Ch.2 Sec.8</td>
<td>C030&lt;sup&gt;6)&lt;/sup&gt;</td>
</tr>
<tr>
<td>7.3</td>
<td>Supporting structures of fixed container securing devices RU SHIP Pt.5 Ch.2 Sec.9</td>
<td>C030&lt;sup&gt;6)&lt;/sup&gt;</td>
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</tbody>
</table>

1) For a full definition of documentation requirements, see RU SHIP Pt.1 Ch.3 Sec.3.
2) Applies only to ships contracted for construction from 1. January 2007. If only wind area is increased by higher stacks on deck, then equipment letter normally remains unchanged as the wind profile area has limited impact on the equipment letter. Upon request will, the Society may update the equipment number calculation and check if the equipment letter remains unchanged.
3) Revised T&S booklet may not be required to be submitted. Initially, print-outs and stored data from the loading instrument may be provided and reviewed by the Society. Depending on ship’s stability characteristics and existing and new container distribution on deck, this may be sufficient to document that the loading instrument can be used for loading conditions with additional container stack height. Where requirements given in RU SHIP Pt.3 Ch.15 Sec.1 [4.2] (weather criteria dependent on wind profile) is the most critical criteria, additional documentation may be required.
4) Not required for ships installed with a certified loading computer system for longitudinal strength.
5) Revised structural drawing(s) only needed to be submitted if strength analysis identifies need for strengthening.
6) Review limited to strength analysis of increased container loads only. Sea pressures etc. need not to be considered.
7) If resulting in increased draught applicable approval scope is specified in DNVGL CG 0156 Conversion of Ships.
8) Only relevant if additional container securing devices; sufficient to submit updated inventory list only.
9) If the higher stacks do not interfere with the existing field of vision line it is sufficient to document this by providing print-outs from the loading instrument.
# APPENDIX B WEIGHTS, MEASUREMENTS AND TOLERANCES

## Table 1 Weights, measurements and tolerances

<table>
<thead>
<tr>
<th>ISO designation of container</th>
<th>Max. permitted gross weight [kg]</th>
<th>External dimensions</th>
<th>Distance between centres of holes in corner fittings</th>
</tr>
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<td>Length L [mm]</td>
<td>Height H [mm]</td>
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<td>12.192⁻⁰⁻¹₀</td>
<td>2.591⁻₀⁻⁵</td>
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<tr>
<td>1 AA</td>
<td></td>
<td>2.896⁻₀⁻⁵</td>
<td></td>
</tr>
<tr>
<td>1 A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 AX</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1 BBB</td>
<td>25.400</td>
<td>9.125⁻₀⁻¹₀</td>
<td>2.591⁻₀⁻⁵</td>
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<tr>
<td>1 BB</td>
<td></td>
<td>2.896⁻₀⁻⁵</td>
<td></td>
</tr>
<tr>
<td>1 B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 BX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 CC</td>
<td>24.000 (30.480)³</td>
<td>6.058⁻₀⁻₆</td>
<td>2.591⁻₀⁻⁵</td>
</tr>
<tr>
<td>1 C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 CX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISO designation of container</td>
<td>Max. permitted gross weight [kg]</td>
<td>External dimensions</td>
<td>Distance between centres of holes in corner fittings</td>
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<td>-----------------------------</td>
<td>---------------------------------</td>
<td>--------------------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Length L [mm]</td>
<td>Longitudinally S [mm]</td>
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<tr>
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<td>10.160</td>
<td>2.991&lt;sub&gt;_5&lt;/sub&gt; 0</td>
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<tr>
<td>1 D</td>
<td>&lt;2.438</td>
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<tr>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>1 EEE</td>
<td>30.480</td>
<td>13.716&lt;sub&gt;_10&lt;/sub&gt; 0</td>
<td>2.896&lt;sub&gt;_5&lt;/sub&gt; 0</td>
</tr>
<tr>
<td>1 EE</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) allowable difference of the diagonals of whole center of the corner castings of bottom and roof areas and side walls
2) allowable difference of the diagonals of hole center of the corner castings of front walls, see following sketch
3) This max. gross weight can be used in lashing calculations except for lineload stowage of containers see class notation Container RU SHIP Pt.6 Ch.5 Sec.1.

**In certain countries there are legal limitations to the overall height of vehicle and load.
## APPENDIX C CONTAINER-DIMENSIONS

### Table 1 Typical Dimensions of Containers

<table>
<thead>
<tr>
<th>Type side view</th>
<th>L</th>
<th>B</th>
<th>H</th>
<th>Weight (max. gross)</th>
</tr>
</thead>
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<td></td>
<td>ft</td>
<td>mm</td>
<td>ft</td>
<td>mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>53'</td>
<td>16150</td>
<td>4933</td>
<td>2591</td>
<td>96'6&quot;</td>
</tr>
<tr>
<td>49'</td>
<td>14935</td>
<td>2600</td>
<td>96'5&quot;</td>
<td>2896</td>
</tr>
<tr>
<td>24'/1/2</td>
<td>2x24'/1/2</td>
<td>7430</td>
<td>2600</td>
<td>96'5&quot;</td>
</tr>
<tr>
<td>48'</td>
<td>14630</td>
<td>8'6&quot;</td>
<td>2591</td>
<td>96'6&quot;/2&quot;</td>
</tr>
<tr>
<td>45' ISO</td>
<td>13716</td>
<td>8'</td>
<td>2438</td>
<td>96'5&quot;</td>
</tr>
<tr>
<td>43'</td>
<td>13103</td>
<td>8'</td>
<td>2438</td>
<td>96'5&quot;</td>
</tr>
<tr>
<td>40' ISO</td>
<td>12192</td>
<td>8'</td>
<td>2438</td>
<td>96'5&quot;</td>
</tr>
<tr>
<td>40' EURO 40' Bell</td>
<td>12192</td>
<td>2500</td>
<td>96'5&quot;</td>
<td>2591 2743</td>
</tr>
<tr>
<td>30' ISO</td>
<td>9125</td>
<td>8'</td>
<td>2438</td>
<td>96'5&quot;</td>
</tr>
<tr>
<td>24' Matson</td>
<td>7430</td>
<td>8'6&quot;</td>
<td>2438</td>
<td>96'5&quot;</td>
</tr>
<tr>
<td>20' ISO 20' ISO</td>
<td>6058</td>
<td>8'</td>
<td>2438</td>
<td>96'5&quot;</td>
</tr>
</tbody>
</table>

### Tolerances

- 20'-24' 0" +0mm -6mm
- 30'-53' 0" +0mm -10mm
- 8'0" +0mm -5mm
- 9'0" +0mm -5mm
- *old values
APPENDIX D CODE OF CONTAINER POSITION
APPENDIX E HEIGHT TOLERANCES OF CONTAINER FOUNDATIONS

For ISO 1496 container types, following tolerances are recommended in order to distribute loads evenly as much as practical to container foundations.

a) height tolerances of container resting levels
   - transversely:
     - one point is zero (reference point), the other ± 3 mm
   - longitudinally:
     - one point is zero (reference point), the other ± 6 mm

b) distance tolerances for transverse and longitudinal distances of aperture centrelines of container foundations
   - transversely:
     ± 3 mm for 20’ and 40’ containers
   - longitudinally:
     ± 3 mm for 20’ containers and
     ± 4 mm for 40’ containers.

For other container types, the tolerance may be obtained by linear interpolation based on container length (see also ISO 668).
Example in mm
A = 0
B + C = -3
D = -6
E = -9
F + G = -6
H = -3

In general the following tolerances have to be kept

<table>
<thead>
<tr>
<th>Longitudinal</th>
<th>Transversal</th>
</tr>
</thead>
<tbody>
<tr>
<td>A to B</td>
<td>A to H</td>
</tr>
<tr>
<td>C to D</td>
<td>B to G</td>
</tr>
<tr>
<td>A to D</td>
<td>C to F</td>
</tr>
<tr>
<td>H to G</td>
<td>D to E</td>
</tr>
<tr>
<td>F to E</td>
<td></td>
</tr>
<tr>
<td>H to E</td>
<td></td>
</tr>
</tbody>
</table>

This foundation to be levelled in relation to A with ±6 mm and in relation to G with ±3 mm

Transverse:
1 point is reference, the others ±3 mm
Longitudinally:
±6 mm to reference point
APPENDIX F DETERMINATION OF THE EXISTING STACK WEIGHT FOR MIXED STOWAGE (20' AND 40' CONTAINER) FOR THE INDIVIDUAL FOUNDATION POINTS

\[
\begin{align*}
A &= 18.0 \cdot 3 + 30.0 = 84.0 \cdot t \\
B &= 18.0 \cdot 3 = 54.0 \cdot t \\
C &= 10.0 \cdot 2 + 5.0 = 25.0 \cdot t \\
D &= 10.0 \cdot 2 + 5.0 + 30.0 = 55.0 \cdot t
\end{align*}
\]

At foundation A and D, the stackweight at 40'-ends of the bay are calculated whereas results for B and C show 20'-stackweight only.
APPENDIX G CALCULATION OF A 5 TIERS STACK ON DECK

1 Calculation example

1.1 General
The determination of deformations respect. lashing and racking forces is done according to Sec. 4.

1.2 Determination of transverse components $F_{qi}$

Acceleration according to DNV GL StowLash for above mentioned vessel.

The transverse components $F_{qi}$ are stated without additional wind forces.

<table>
<thead>
<tr>
<th>Top 1st tier</th>
<th>Bottom 2nd tier</th>
<th>Bottom 3rd tier</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L$</td>
<td>$x$</td>
<td>$B$</td>
</tr>
<tr>
<td>$217.0$ m</td>
<td>$128.9$ m from AP</td>
<td>$37.32$ m</td>
</tr>
<tr>
<td>$T_{Sc}$</td>
<td>$T_D$</td>
<td>$v$</td>
</tr>
<tr>
<td>$12.5$ m</td>
<td>$11.0$ m</td>
<td>$22.5$ kn</td>
</tr>
<tr>
<td>$Z_{bottom}$</td>
<td>$21.5$ m</td>
<td>$GM$</td>
</tr>
<tr>
<td>$21.5$ m</td>
<td>$12.5$ m</td>
<td>$2.0$ m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lashing angle $\alpha$ [°]</th>
<th>Lashing length [cm]</th>
<th>E-modulus [kN/cm$^2$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>43</td>
<td>354</td>
<td>14000</td>
</tr>
<tr>
<td>41</td>
<td>365</td>
<td>14000</td>
</tr>
<tr>
<td>22</td>
<td>575</td>
<td>17500</td>
</tr>
</tbody>
</table>
1.3 Determination of transverse dislocations (door side)

The dislocations are determined according to Sec.4. With the standard values specified therein for length, angle and module of elasticity and a given lashing bar diameter of $d = 26$ mm, the horizontal stiffness of the lashings assigned can be calculated.

\[ C_{Z,\text{hor}} = \frac{A \cdot E \cdot \sin^2 \alpha}{l} \]

\[
\begin{align*}
d &= 2.6 \text{ cm} \\
A &= 5.309 \text{ [cm}^2]\end{align*}
\]

1. tier top: $C_{Z,\text{hor}}$ (1o) = 97.657 [kN/cm]
2. tier bottom: $C_{Z,\text{hor}}$ (2u) = 87.646 [kN/cm]
3. tier bottom: $C_{Z,\text{hor}}$ (3u) = 22.674 [kN/cm]

The horizontal supporting force from lashings $Z_{\text{hor}1}$ and $Z_{\text{hor}2}$ result as follows:
\[
Z_{\text{hor}1} = \delta_1 \cdot [C_{Z,\text{hor}}(10) + C_{Z,\text{hor}}(2u)] = \delta_1 \cdot 185.303 \\
Z_{\text{hor}2} = \delta_2 \cdot C_{Z,\text{hor}}(3u) = \delta_2 \cdot 22.674
\]

From this result two systems of equations for door and front side of the stack considered with the unknown deformations \( \delta_1 \) and \( \delta_2 \) following statement:

I. \[ \delta_1 = c_c \cdot RF_{T1} + v_0 \]

with

\[ \delta_2 = c_c \cdot RF_{T1} + v_0 + c_c \cdot RF_{T2} + v_1 \]

you get:

II. \[ \delta_2 - \delta_1 = c_c \cdot RF_{T2} + v_1 \]

\( \delta_1, \delta_2 \) = total dislocation of the containers at top level 1. respect 2. tier
\( v_0, v_1 \) = taken dislocations between the foundation and container corner casting respect between the corner castings
\( c_c \) = resilience of the container transverse frame (see Sec.4 [3.1])
\( RF_{T1}, RF_{T2} \) = resulting racking forces in container transverse frame

In the present case \( RF_{T1} \) and \( RF_{T2} \) are determined as follows:

\[
RF_{T1} = \frac{1}{2} (F_{q2} + F_{q3} + F_{q4} + F_{q5}) + 0.225 \cdot F_{q1} - Z_{\text{hor}1} - Z_{\text{hor}2} [kN]
\]

\[ = 163.67 - Z_{\text{hor}1} - Z_{\text{hor}2} \]

\[
RF_{T2} = \frac{1}{2} (F_{q3} + F_{q4} + F_{q5}) + 0.225 \cdot F_{q2} - Z_{\text{hor}2} [kN]
\]

\[ = 105.35 - Z_{\text{hor}2} \]
Front side:

\[ I. \delta_1 = 0.006[163.67 - \delta_1 \cdot 185.303 - \delta_2 \cdot 22.674] \]

\[ II. \delta_2 - \delta_1 = 0.006[105.35 - \delta_2 \cdot 22.674] \]

→ \( \delta_1 = 0.407 \, [\text{cm}] \), \( \delta_2 = 0.914 \, [\text{cm}] \)

Door side:

\[ I. \delta_1 = 0.027[163.67 - \delta_1 \cdot 185.303 - \delta_2 \cdot 22.674] + 0.4 \]

\[ II. \delta_2 - \delta_1 = 0.027[105.35 - \delta_2 \cdot 22.674] + 0.4 \]

→ \( \delta_1 = 0.564 \, [\text{cm}] \), \( \delta_2 = 2.346 \, [\text{cm}] \)

In the following the racking-, lashing-, lifting- and pressure forces of the stack are calculated exemplarily for the door side.

1.4 Determination of racking forces (door side)

\[ RF_{T1} = \frac{\delta_1 - v_0}{c_c} = \frac{0.564 - 0.4}{0.027} = 6.07 \, [kN] \]

\[ RF_{T2} = \frac{\delta_2 - \delta_1 - v_1}{c_c} = \frac{2.346 - 0.564 - 0.4}{0.027} = 51.19 \, [kN] \]

1.5 Determination of lashing forces (door side)

1.5.1 In the model (idealization) of a lashed container stack two "parallel" lashing bars (i.e. at 1. tier top plus 2. tier bottom or 2. tier top plus 3. tier bottom) are taken calculatorily via the addition of the horizontal
stiffness as one lashing. The details of the parallel bars can be determined through the relations of the individual horizontal stiffness.

1.5.2 Lashing forces 2. tier bottom – Z (2u) 1. tier top – Z (1o)

\[ C_{Z,\text{hor}} (1o+2u) = 185.303 \, [\text{kN/cm}] \]

\[ Z_{\text{hor}1} = 0.564 \cdot 185.303 = 104.51 \, [\text{kN}] \]

\[ \frac{C_{Z,\text{hor}} (1o)}{C_{Z,\text{hor}} (1o+2u)} = \frac{97.657}{185.303} = 0.527 \]

\[ \frac{C_{Z,\text{hor}} (1o)}{C_{Z,\text{hor}} (1o+2u)} = \frac{87.646}{185.303} = 0.473 \]

\[ Z(1o) = \frac{Z_{\text{hor}1} \cdot 0.527}{\sin 43^\circ} = \frac{104.51 \cdot 0.527}{\sin 43^\circ} = 80.76 \, [\text{kN}] \]

\[ Z(1o) = \frac{Z_{\text{hor}1} \cdot 0.527}{\sin 43^\circ} = \frac{104.51 \cdot 0.527}{\sin 43^\circ} = 80.76 \, [\text{kN}] \]

1.5.3 Lashing forces 3. tier bottom – Z (3u)

\[ Z_{\text{hor}2} = 2.436 \cdot 22.674 = 55.23 \, [\text{kN}] \]

\[ Z(3u) = \frac{Z_{\text{hor}2}}{\sin 22^\circ} = \frac{55.23}{\sin 22^\circ} = 147.44 \, [\text{kN}] \]

1.6 Determination of the lifting force and pressure force at lower level of 1. tier, \( LF_{\text{found}} \) and \( CPL_{\text{found}} \) (door side):

1.6.1 Without influence of the lashing

Forces, according to formula in Sec.4 [2.5]:

\[ b_t = 1 + \frac{70}{217 + 70} = 1.244 \]
\[ CPL_{\text{found}} = 403.85 + 220.62 = 624.47 \text{ [kN]} \]
\[ LF_{\text{found}} = 403.85 - 220.62 = 183.23 \text{ [kN]} \]

**Figure 2** Lever arms and heights of the application points of lashing in the stack (for containers with 8’6” = 2.591 [m] height)

- **twistlock height** = 25 [mm] (assumed, height may be adjusted acc. to fitting to be used)
- **centre of gravity of container** = VCG 45% = 1.166 [m] above lower level container (8' 6'’)

**1.6.2 Influence of lashing forces on \( LF_{\text{found}} \) and \( CPL_{\text{found}} \) (door side):**

a) Lashing 1. tier top:

\[ Z(1o) = 80.76 \text{ [kN]} \]
\[ Z(1o/hor.) = Z(1o) \cdot \sin 43^\circ = 55.08 \text{ [kN]} \]
\[ Z(1o/vert.) = Z(1o) \cdot \cos 43^\circ = 59.06 \text{ [kN]} \]
Figure 3

b) Lashing 2. tier bottom:

\[ Z(2u) = 75.35 \text{ [kN]} \]
\[ Z(2u/\text{hor.}) = Z(2u) \cdot \sin 41^\circ = 49.43 \text{ [kN]} \]
\[ Z(2u/\text{vert.}) = Z(2u) \cdot \cos 41^\circ = 56.87 \text{ [kN]} \]

c) Lashing 3. tier bottom:

\[ Z(3u) = 147.44 \text{ [kN]} \]
\[ Z(3u/\text{hor.}) = Z(3u) \cdot \sin 22^\circ = 55.23 \text{ [kN]} \]
\[ Z(3u/\text{vert.}) = Z(3u) \cdot \cos 22^\circ = 136.70 \text{ [kN]} \]

d) Resulting lifting force \( LF_{\text{found}} \):

\[
LF_{\text{found (res)}} = 183.23 - \frac{2.604}{2.260} (55.08 + 49.43) - \frac{5.220}{2.260} \cdot 55.23 = 183.23 - 247.98 \\
= -64.75 \text{ [kN]} \text{ (compressive force)}
\]

e) Resulting pressure forces \( CPL_{\text{found}} \):

\[
CPL_{\text{found (res)}} = 624.47 - 247.98 + 59.06 + 56.87 + 136.70 \\
= 629.12 \text{ [kN]} \text{ (compressive force)}
\]
Figure 4 Dislocations and deformations in container stacks

Given dislocations between the tiers.

Door side:
\( v_0 = 0.4 \text{ cm} \)
\( v_1 = 0.4 \text{ cm} \)

Front side:
\( v_0 = 0.0 \text{ cm} \)
\( v_1 = 0.0 \text{ cm} \)

Given points of application for lashings for the lashing force calculation at:

1) lashing bars at 1. tier top and 2. tier bottom
2) lashing bars at 2. tier top and 3. tier bottom
CHANGES – HISTORIC

There are currently no historical changes for this document.
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