# EN 15620:2021

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## Steel static storage systems - Tolerances, deformations and clearances

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**EN 15620**

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English Version

# Steel static storage systems - Tolerances, deformations and clearances

Système de stockage statique en acier - Tolérance, déformation et jeux

Ortsfeste Regalsysteme aus Stahl - Verstellbare Palettenregale - Grenzabweichungen, Verformungen und Freiräume

This European Standard was approved by CEN on 16 May 2021.

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# European foreword

This document (EN 15620:2021) has been prepared by Technical Committee CEN/TC 344 “Steel static storage systems”, the secretariat of which is held by UNI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2022, and conflicting national standards shall be withdrawn at the latest by January 2022.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 15620:2008.

This document includes the following significant technical changes with respect to EN 15620:2008:

— floor tolerances have been removed (reference is made to alternative sources);

— tolerances for Drive-In racking and Cantilever racking have been added;

— tolerances for crane racking have been removed (reference is made to alternative sources);

— the classification system for racking operated by industrial trucks has been removed.

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

# Introduction

The determination of the safe load bearing capacity of racking is a structural issue and therefore the Eurocodes are relevant, especially EN 1993 series. The most relevant parts for racking are EN 1993-1-1 and EN 1993-1-3.

In order to have reliable state of the art guidance for those involved in designing these products and due to the differences in the shape of the structural components, detailing and connection types, additional technical information to the Eurocodes is required.

The scope of CEN/TC 344 is to establish European Standards providing guidance for the specification, design, methods of installation, accuracy of build and also guidance for the user on the safe use of steel static storage systems.

This, together with the need for harmonized design rules, was the reason that FEM Product Group Racking and Shelving (FEM R&S) has taken the initiative for the CEN/TC 344. This TC is in the course of preparing a series of European Standards regarding Steel static storage systems.

# 1 Scope

This document specifies tolerances, deformations and clearances that pertain to the production, assembly and erection and performance under load of pallet racking and cantilever racking. These tolerances, deformations and clearances are important in relation to the functional requirements and ensuring the proper interaction of the handling equipment used by personnel, trained and qualified as competent, in association with the specific type of racking system. The interaction conditions are also important in determining the reliability of the storage system to ensure that the chance of mechanical handling equipment impact, pallet impact or a system breakdown is acceptably low.

This document is limited to:

— single deep adjustable beam pallet racking operated with industrial trucks;

— single and double deep adjustable beam pallet racking operated with stacker cranes;

— drive-in and drive through racking systems operated with industrial trucks;

— cantilever racking systems operated with industrial trucks.

This document does not apply to specialized types of equipment such as automated trucks, miniload, satellite systems, systems involving the use of articulated trucks, trucks using intrusive stacking methods or industrial truck serviced rack-clad buildings.

This document specifically excludes the tolerances and deformation of the industrial trucks, stacker cranes and floors.

It is the responsibility of the specifier in cooperation with the client or user to ensure that the tolerances, deformations and clearances, as quoted in this document are acceptable for safe operation of the overall system considering all factors of influence and the user informed by means such as operation instructions. The specifier can carry out appropriate design/calculations to vary some of the parameters provided that an equivalent safe operation is achieved.

This document gives guidance to be used in conjunction with mechanical handling equipment and floor information.

# 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 15512, *Steel static storage systems - Adjustable pallet racking systems - Principles for structural design*

EN 15629, *Steel static storage systems - Specification of storage equipment*

EN 15878, *Steel static storage systems - Terms and definitions*

# 3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 15878 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at https://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

**3.1**
**racking aisle width**
minimum dimension measured across the aisle at the floor and at any beam level between the rack structure

**3.2**
**deformation**
displacement due to external actions

**3.3**
**gangway**
transfer aisle
space for movement or transport which does not give access to the picking or loading faces of the storage racking

**3.4**
**fine positioning**
local adjustment of the machine with respect to the rack components in the X and/or Y directions using sensors on the crane and location devices on the rack

**3.5**
**intrusive stacking**
placement or retrieval of a unit load where the turning radius or length of an industrial truck is greater than the operating aisle width and part of the storage location concerned is used by the truck forks and load when turning to place or retrieve a unit load

**3.6**
**mechanical handling equipment**
**MHE**
mechanical or electro-mechanical equipment used to transport, lift, pick and deposit unit loads

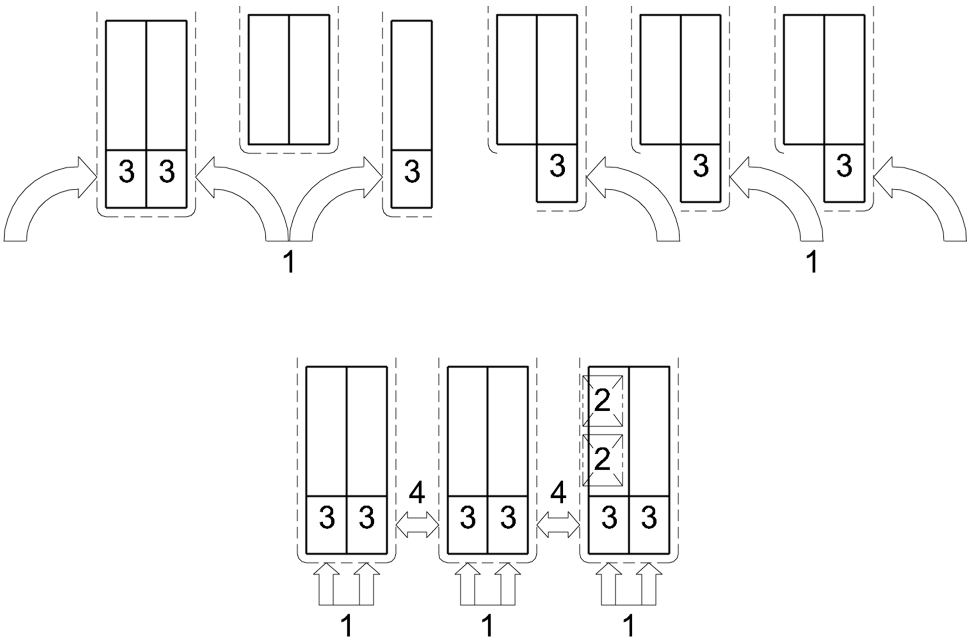
**3.7**
**free-movement truck**
industrial truck that is free to move in any direction in the aisle and make 90 ° turns into the rack face for loading and off loading

**3.8**
**upright protector**
component to protect the lower part of uprights against accidental impact from mechanical handling equipment

Note 1 to entry: Can be either free-standing or connected to the upright.

**3.9**
**pick up and deposit station**
**P & D station**
structure at the end of an operating aisle used as an interface between different types of mechanical handling equipment

Note 1 to entry: See Figure 1.




**Key**

1 free movement truck access

2 unit load positions in the racks

3 P & D stations

4 very narrow aisle racking (VNA)

**Figure 1 — Example of P & D stations**

**3.10**
**racking types**

**3.10.1**
**wide aisle racking**
pallet racking arranged to leave aisles of sufficient width for use with free-movement trucks

**3.10.2**
**narrow aisle racking**
pallet racking arranged in a similar way to wide aisle racking and for use with free-movement trucks, but having aisles of a reduced width for use with more specialist types of industrial truck

**3.10.3**
**very narrow aisle racking**
**VNA**
pallet racking arranged with aisles of a width to cater only for the truck and the unit load width plus an operational clearance where the truck cannot make 90° turns into the rack face for loading and off loading

**3.10.4**
**crane racking class 100 and 200**
pallet racking operated by a stacker crane

**3.10.5**
**drive-in racking**
**DIR**
system of racking that provides storage where pallets are stored two or more deep and where access is gained by driving an industrial truck into a lane with pallets supported along their sides on beam rails supported from the uprights

Note 1 to entry: In DIR, the industrial truck drives into a lane and reverses out.

**3.10.6**
**drive-through racking**
**DTR**
system of racking similar to DIR but where the industrial truck could drive through the lane if there are no pallets in the lane

Note 1 to entry: Drive-through racking lanes are not designed as access routes through the racking but allow full access for pallets to be placed from either end of the aisle, enabling the first-in first-out logistic principle.

**3.11**
**reference directions**
directions at 90° to each other related to the orientation of the racking

Note 1 to entry: X is the down aisle direction, Y is the vertical direction and Z is the cross aisle direction.

**3.12**
**specifier**
person or company that provides the supplier with a specification based on the user’s requirements

Note 1 to entry: The specifier may be a consultant, other specialist, the user or the equipment supplier acting as the specifier.

**3.13**
**stacker crane**
storage and retrieval machine running on a rail and stabilised at the top of the mast by an upper guide rail

**3.14**
**tolerances**
dimensional variations from the nominal dimension or position arising from manufacture, assembly and erection

**3.15**
**user**
company or person who manages and operates the installation on a daily basis and is responsible for the continuing safety of the installation

**3.16**
**cantilever arm**
load-carrying member connected at one end to the cantilever column in the cross-aisle direction

Note 1 to entry: Arms can either be fixed or adjustable dependent upon the type of racking.

**3.17**
**cantilever base**
horizontal structural component fixed to the bottom of the cantilever column and to allow load transfer and fixing to the floor

**3.18**
**cantilever column**
vertical member supporting the cantilever arms that can either be single sided or double sided

**3.19**
**datum**
reference point, line or plane

# 4 Symbols

For the purpose of this document, a number of the following symbols may be used together with standard subscripts.

Additional symbols and subscripts are defined where they first occur.

A symbol and subscript may have several meanings in this document.

In general, primary symbols are not defined with all the standard subscripts with which they may be used.

| | |
|---|---|
| A | manoeuvring clearance |
| A | clear entry between two uprights (pallet racking) |
| A | bay width (cantilever racking) |
| $A_t(n)$ | total length of the rack (comprising ‘n’ bays) |
| $A_{ST}$ | minimum operating aisle width |
| a | horizontal clearance in Drive-In racking |
| b | vertical clearance in Drive-In racking |
| B | misalignment of uprights across an aisle |
| BF | misalignment of rack uprights across a frame |
| $B_0$ | distance to system datum |
| $C_x$, $C_z$ | out-of-plumb of the member with respect to the relevant axis |
| D | rack depth |
| D | rack frame depth |

| | |
|---|---|
| D | 90 ° turning width of truck and load |
| $D_p$ | depth of unit load and pallet |
| E | racking aisle width |
| F | distance from aisle X datum to the rack |
| $F_1$ | variation between adjacent uprights measured near floor level in the Z direction |
| $G_x$, $G_y$, $G_z$ | curvature of the arm or beam with respect to the relevant axis |
| h | height of compartment |
| H | height from top of base plate to top of upright |
| $H_1$ | height from top of bottom beam level to top of any other beam level (pallet racking) |
| $H_1$ | height from the underside of the base to arm 1 (cantilever racking) |
| $H_{1A}$ | height from top of base plate to top of bottom beam level (pallet racking) |
| HB | height from top of beam level to top of beam level above (pallet racking) |
| HB | dimension between bracing beams (cantilever racking) |
| $J_x$, $J_z$ | curvature of the upright with respect to the relevant axis |
| L | centre to centre distance of uprights |
| L | beam span |
| L | cantilever arm length |
| L | maximum deviation of arm level with respect to the top of the baseplate level |
| M | maximum variation of pallet support level between both sides of the pallet |
| M | distance from front upright to centre of top guide rail |
| $T_w$ | beam twist at mid span |
| W | upright width |
| WE | tolerance field of mutually opposite frames |
| $W_p$ | width of unit load and pallet |
| X | clearance in the X direction (with a subscript) |
| Y | clearance in the Y direction (with a subscript) |
| Z | clearance in the Z direction (with a subscript) |
| $\delta_u$ | hogging deformation |
| $\delta_d$ | sagging deformation |
| $\delta_{VB}$ | deflection at the tip of a cantilever arm |
| $\delta$ | deflection of a cantilever upright in the X or Z direction |

# 5 Racking types

## 5.1 General

Erection tolerances, deformations and clearances have been divided into groups to cover the general requirements of the handling equipment. The racking for each group requires a different standard of installation tolerances, deformations and minimum clearances for safe operation. See Annex F and Annex A for more information on general safety philosophy.

## 5.2 Crane racking Class 100

Pallet racking arranged as for a very narrow aisle system but operated by a stacker crane. The aisles are wide enough only for the stacker crane or load width plus operational clearance as shown in Figure 2.

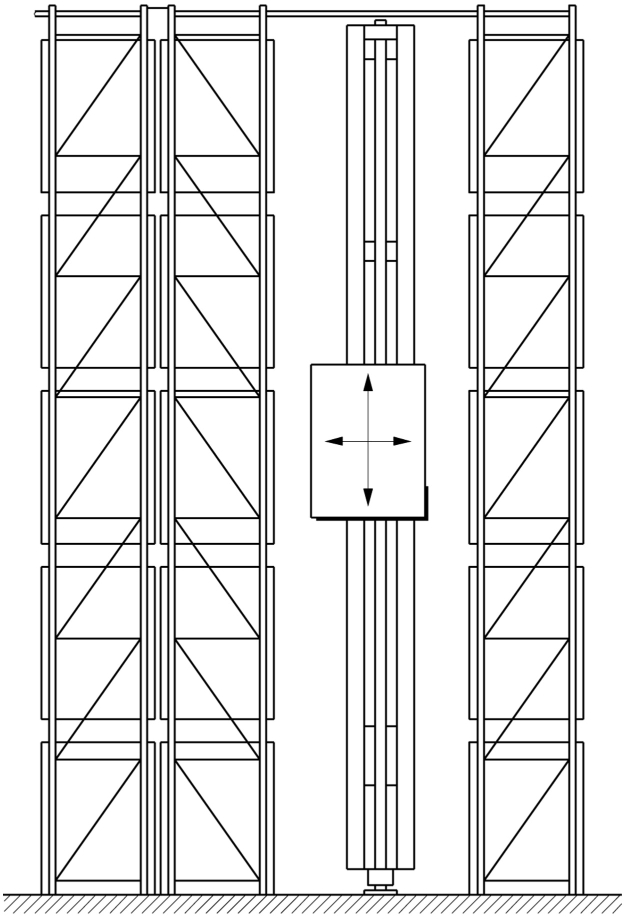


**Figure 2 — Crane racking**

The stacker cranes are automatically controlled, do not have a fine positioning system at the unit load storage positions.

## 5.3 Crane racking Class 200

Crane operated installations where the stacker cranes are automatically controlled and have fine positioning system at the unit load storage positions. Also includes installations where the stacker crane is manually controlled.

## 5.4 Very narrow aisle racking

### 5.4.1 General

Very narrow aisle pallet racking is arranged with aisles wide enough only for the truck and the unit load width plus operational clearance as shown in Figure 3.

The unit loads are handled within the aisles without the need for the truck to turn bodily into the rack face.

The trucks are usually guided into and along the aisle length and have fixed or rising cabs.

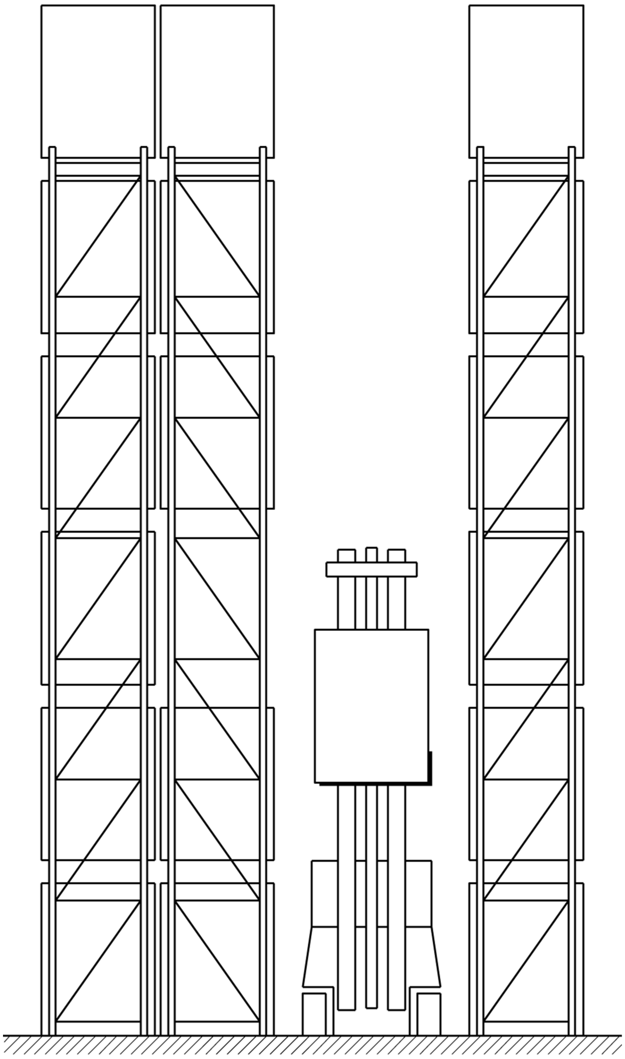


**Figure 3 — Very narrow aisle racking**

### 5.4.2 Very narrow aisle (operator up)

Very narrow aisle installations where the truck operator is raised and lowered with the unit load and has manual height adjustment to position the load. Alternatively, the operator remains at ground level and has the use of an indirect visibility aid such as closed-circuit television (CCTV) or an equivalent system to guide the operator.

### 5.4.3 Very narrow aisle (operator down)

Very narrow aisle installations where the truck operator remains at ground level 'man-down' and does not have the use of an indirect visibility aid.

### 5.4.4 Operation

In VNA operations the maximum stroke of the forks to pick or deposit the unit load once the truck has been positioned of the industrial truck is fixed individually for each application. The tolerances, deformations and clearances given in this document are based on an operational method whereby the VNA truck driver is trained and instructed to do fine-positioning in placing and retrieving the pallet.

## 5.5 Wide aisle and narrow aisle

### 5.5.1 Wide aisle

Wide aisle racking is arranged to leave aisles of sufficient width to allow forklift truck equipment to traverse the length of the aisle and make 90° turns into the rack face for loading and offloading as shown in Figure 4.

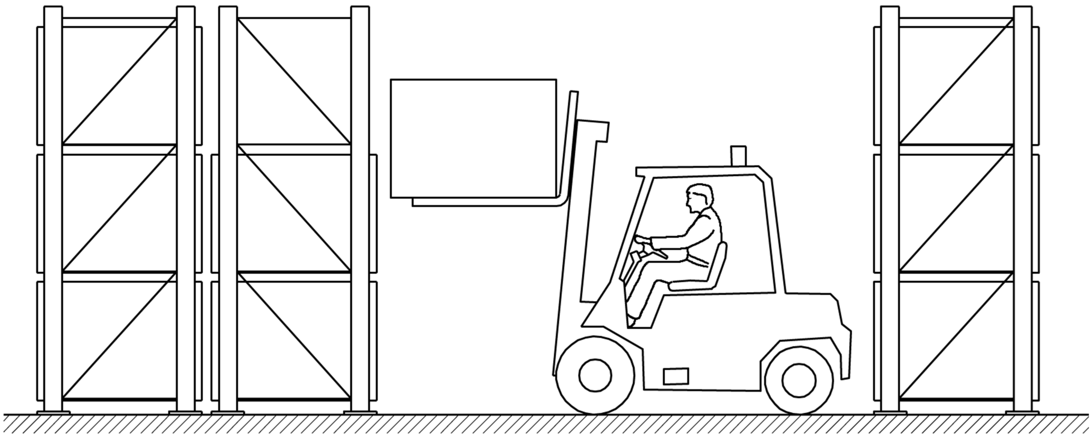


**Figure 4 — Wide aisle racking with counter balanced truck**

### 5.5.2 Narrow aisle

Narrow aisle racking is pallet racking arranged in a similar way to wide aisle racking but having aisles of a reduced width which can be used with more specialist types of lift truck as shown in Figure 5.

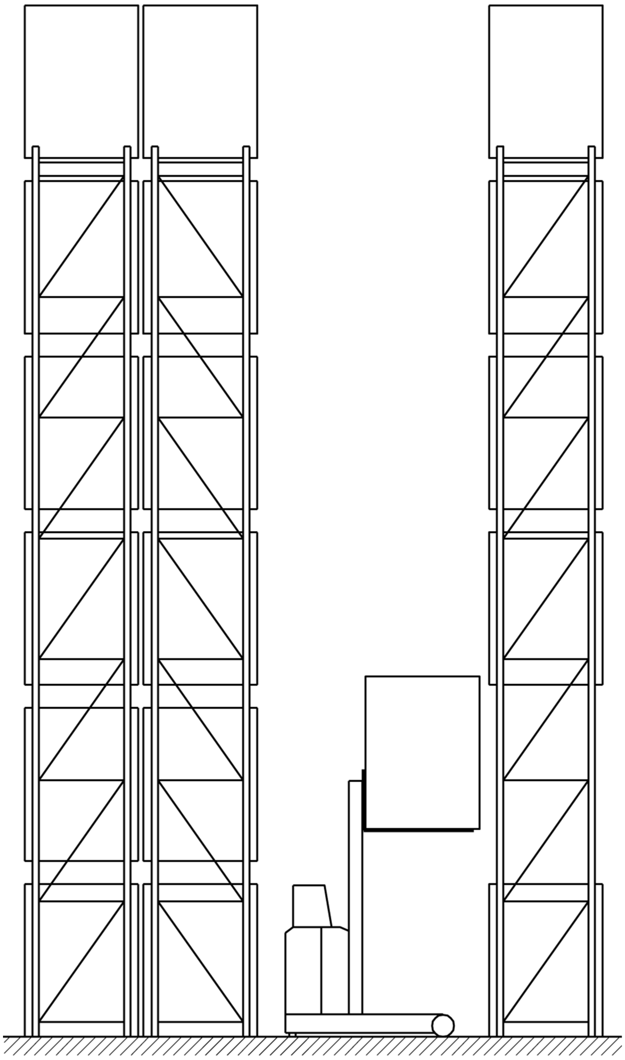


**Figure 5 — Narrow aisle racking with reach truck**

## 5.6 Cantilever racking

Cantilever racking is often used to store long or irregular items. Cantilever racking is normally serviced by powered handling equipment such as side loading or industrial trucks as shown Figure 6.

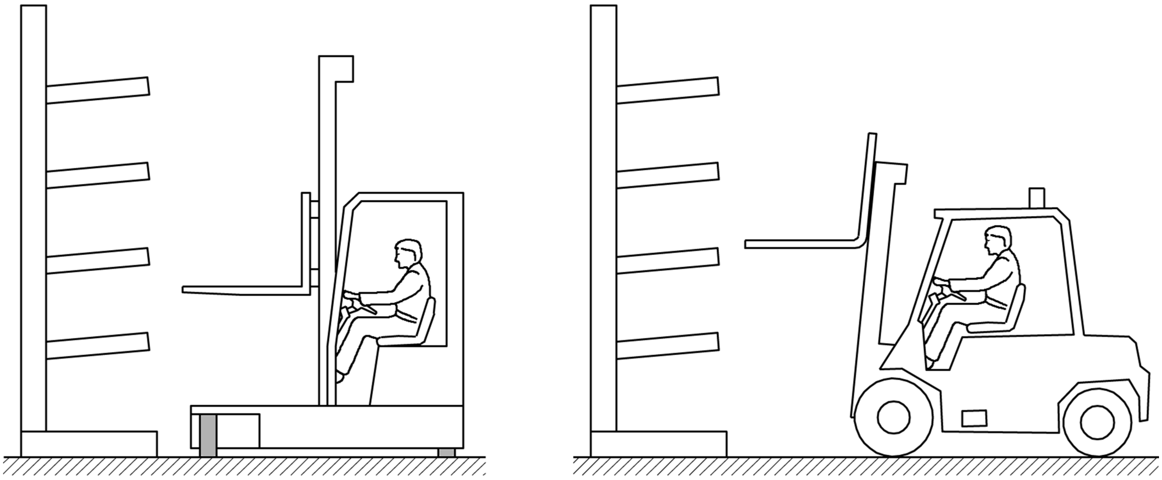


**Figure 6 — Cantilever racking**

## 5.7 Drive-In racking

Drive-In racking is arranged with lanes of a width to cater only for the truck and the unit load width plus operational clearance as shown in Figure 7.

The trucks are usually reach trucks or counterbalance trucks and are often guided into and along the aisle length by floor mounted guide rails.

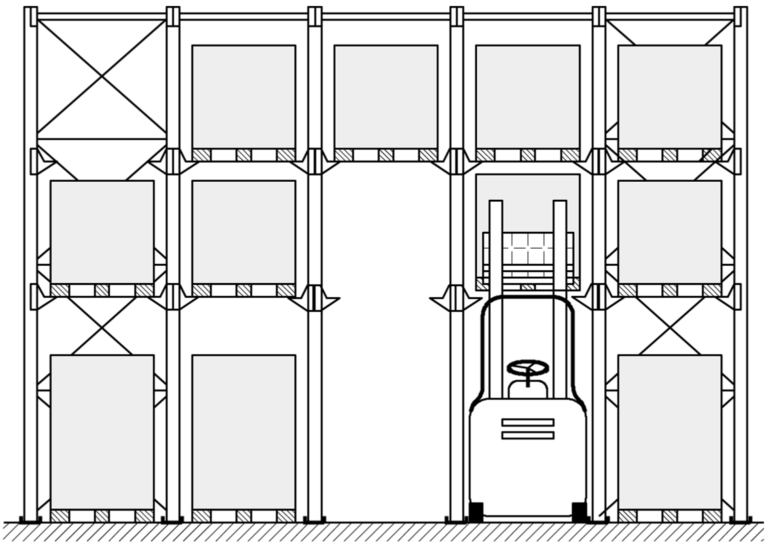


**Figure 7 — Drive-In (and drive-through) racking**

# 6 Racking used with Industrial trucks

## 6.1 Slab deformation due to settling and slab deflection

Deflection of the floor slab results in additional stresses and inclination of the rack structure.

Deflection of the floor slab shall be included at the planning stage by the specifier or client and added to the clearances and deformations as required for the specific project; reference should be made to EN 15512.

## 6.2 Installation tolerances

### 6.2.1 General

The maximum allowable tolerances after erection, with the racks in the unloaded condition, shall be as stated in Table 1, Table 2, Figure 8 and Figure 9.

NOTE The installation tolerances are also applicable if racking is dismantled and re-erected.

**Table 1 — Tolerances measured horizontally**

| **Horizontal tolerance limitations for X Z plane**<br>**mm** | | |
|---|---|---|
| **Measuring dimension code and description of tolerance** | **Installation tolerances for wide aisle and narrow aisle racking** | **Installation tolerances for VNA racking** |
| **δA** Variation from nominal dimension of the clear entry between two uprights at any beam level | ± 3 | ± 3 |
| **$δA_t$(n)** Variation from nominal dimension of the total rack length, cumulative with the number of bays 'n' measured near floor level | ± 3 n | ± 3 n |
| **B** misalignment of uprights on opposite sides of an aisle, cumulative with the number of bays 'n' measured near floor level<br>For operator up this applies for the aisle uprights only<br>For operator down this applies for the aisle and rear uprights | Not applicable | The larger value of the following<br>± 10<br>or<br>± 1,0 n<br>± 0,5 n |
| **$δB_0$** Variation from nominal of rack frontage or P&D end with regard to the installation 'system datum' concerned, measured near floor level | ± 10 | ± 10 |
| **BF** Misalignment of rack uprights across a frame (over full height) | 40 | Not applicable |
| **$C_x$** Out-of-plumb of each upright in the X direction [a] | ± H/350 | ± H/500 |
| **$C_z$** Out-of-plumb of each upright in the Z direction [a] | ± H/350 | ± H/500 |

| Horizontal tolerance limitations for X Z plane<br>mm | | |
|---|---|---|
| **Measuring dimension code and description of tolerance** | **Installation tolerances for wide aisle and narrow aisle racking** | **Installation tolerances for VNA racking** |
| **δD** Variation from nominal dimension of the rack depth | For single frame ± 6 | For single frame ± 3<br>For double frame ± 6 |
| **δE** Variation from nominal dimension of the racking aisle width near floor level | ± 15 | ± 5 |
| **$\delta E_1$** Variation from nominal dimension of the width between guide rails | Not applicable | See FEM 10.2.14–1 /4.103–1 [1] |
| **$\delta E_2$** Variation from uprights on one side to guide rail | Not applicable | ± 5 |
| **δF** Variation from nominal of the straightness of an aisle measured near floor level with regard to the 'aisle system X datum line' or as specified by the truck supplier. | ± 15 | ± 10 |
| **$F_1$** Variation between adjacent uprights measured near floor level in the Z direction | Not applicable | ± 5 |
| **$G_z$** Straightness of the beam in the Z direction | ± A/400 | ± A/400 |
| **$J_x$** Upright straightness in the X direction between beams spaced HB apart. | The larger tolerance of the following<br>± 3 or ± HB/400 | The larger tolerance of the following<br>± 3 or ± HB/750 |
| **$J_z$** Initial curve of an upright frame in the Z direction [a] | ± H/500 | ± H/500 |
| **δM** Tolerance of the top guide rail | Not applicable | Defined by the Specifier or truck manufacturer |
| **$T_w$** Beam twist at mid span (per m) | 1° | 1° |
| NOTE FEM10.2.14–1/4.103–1 gives guidance on this subject (see [1]).<br>[a] See Figure 8. | | |

**Table 2 — Tolerances measured vertically**

| Vertical tolerance limitations for Y direction<br>mm | | |
|---|---|---|
| **Measuring dimension code and description of tolerance** | **Installation tolerances, for wide and narrow aisle racking** | **Installation tolerances, for VNA racking** |
| | The larger value of the following | |
| $G_y$ Straightness of the beam in the Y direction | ± 3 or ± A/500 | ± 3 or ± A/500 |
| $\delta H_{1A}$ Variation of the top of the bottom beam level above the base plate | ± 10 | ± 7 |
| $\delta H_1$ Variation of the top of any beam level $H_1$ above the bottom beam level | ± 5 or ± $H_1$/500 | Operator up ± 5 or ± $H_1$/500<br>Operator down ± 3 or ± $H_1$/1000 |
| $\delta H_3$ Tolerance of the top guide rail | Not applicable | Defined by the Specifier or truck supplier |
| $H_y$ Variation of unit load support levels between the front and rear beams in a compartment | ± 10 | ± 10 |

A measurement survey may be used to measure the installation tolerances and clearances before the racking is loaded. The tolerances stated may not be applicable after the racking has been loaded. Measurement surveys are conducted when required by individual contracts (see Annex B).

The specifier should determine the overall system clearances using the clearances and tolerances as stated in this document. If different tolerances are required, they should be specified by the specifier (see Annex E).

### 6.2.2 Tolerance field of frames in X direction

This tolerance is only applicable to VNA (operator down) racking.

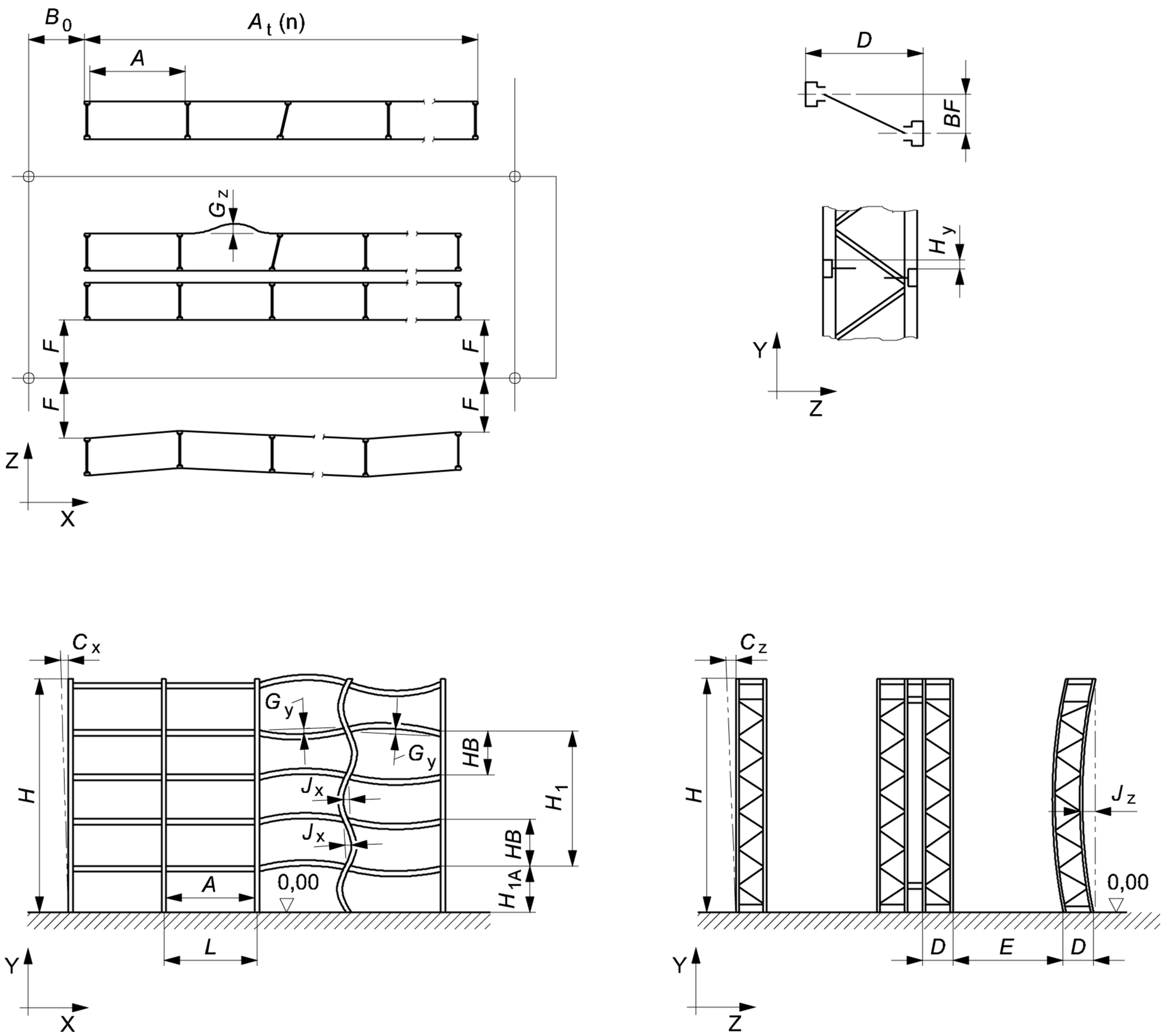
The tolerance field of mutually opposite frames resulting from offset of the upright, bases out-of-plumb and curvature of the upright sections shall not exceed WE (see Figure 9).

$$WE = W + 2C_x + B_{max} + 2J_x$$

where

- $WE$ is the tolerance field of mutually opposite frames resulting from offset of the upright, bases out-of-plumb and curvature of the upright sections;
- $W$ is the upright width;
- $C_x$ is the out-of-plumb of upright from Table 1;
- $B_{max}$ is 10 mm or 0,5 n from Table 1;
- $J_x$ is the upright straightness between beam levels from Table 1.

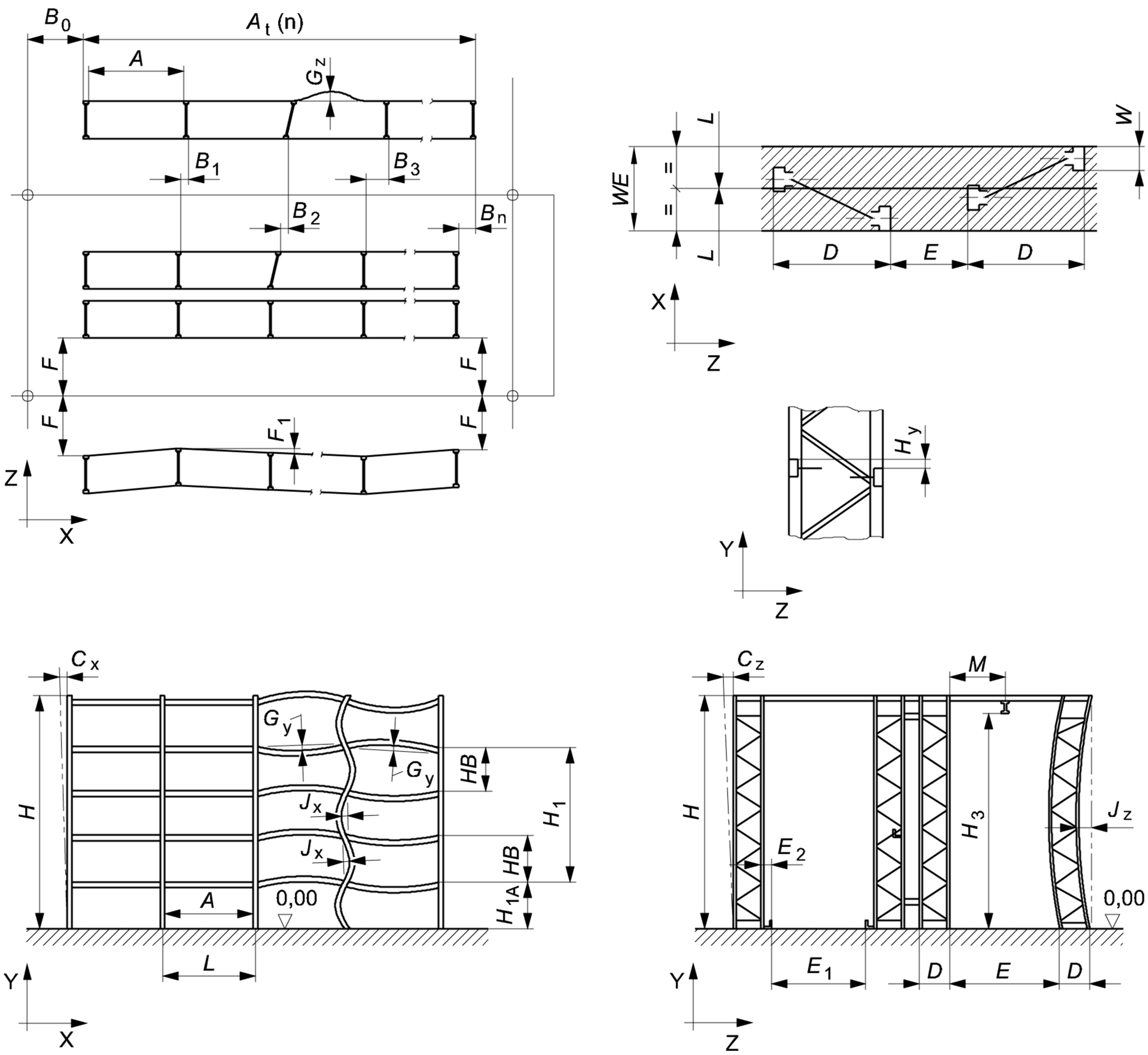
NOTE This tolerance assists the floor level operator in visibly locating the pallets using the mutually opposite locations.




**Key**

| | |
|---|---|
| A | clear entry between two uprights |
| $A_t(n)$ | total length of the rack (comprising ‘n’ bays) |
| $B_0$ | distance to system datum |
| BF | misalignment of rack uprights across a frame |
| $C_z$, $C_x$ | out-of-plumb of upright in the Z and X directions respectively |
| D | rack frame depth |
| E | racking aisle width |
| F | distance from aisle system X datum to front face of upright |
| $G_z$, $G_y$ | straightness of the beam in the Z and Y directions respectively |
| H | height from top of base plate to top of upright |
| HB | height from top of beam level to top of beam level above |
| $H_y$ | variation of support levels between the front and rear beams in a compartment |
| $H_{1A}$ | height from top of base plate to top of bottom beam level |
| $H_1$ | height from top of bottom beam level to top of any other beam level |
| $J_x$ | upright straightness in the X direction between adjacent beam levels |
| $J_z$ | initial straightness of an upright in the Z direction |
| L | distance from centre to centre of uprights |

**Figure 8 — Horizontal and vertical tolerances for Wide aisle and Narrow aisle**




**Key**

| | |
|---|---|
| A | clear entry between two uprights |
| $A_t(n)$ | total length of the rack (comprising ‘n’ bays) |
| $B_0$ | distance to system datum |
| $B_1$, $B_2$, $B_3$, $B_n$ | misalignment of uprights across an aisle in bays 1, 2, 3 and n respectively |
| $C_z$, $C_x$ | out-of-plumb of upright in the Z and X directions respectively |
| D | rack frame depth |
| E | racking aisle width |
| $E_1$ | distance between guide rails |
| $E_2$ | distance between guide rail and front of upright |
| F | distance from aisle system X datum and front face of upright |
| $F_1$ | variation between adjacent uprights measured near floor level in the Z direction |
| $G_z$, $G_y$ | straightness of the beam in the Z and Y directions respectively |
| H | height from top of base plate to top of upright |
| HB | height from top of beam level to top of beam level above |
| $H_y$ | variation of support levels between the front and rear beams in a compartment |
| $H_{1A}$ | height from top of base plate to top of bottom beam level |

| | |
|---|---|
| $H_1$ | height from top of bottom beam level to top of any other beam level |
| $H_3$ | height from top of base plate to underside of top guide rail |
| $J_x$ | upright straightness in the X direction between adjacent beam levels |
| $J_z$ | initial straightness of an upright in the Z direction |
| L | distance from centre to centre of uprights |
| M | distance from front of upright to centre of top guide rail |
| W | upright width |
| WE | is the tolerance field of mutually opposite frames resulting from offset of the upright, bases out-of-plumb and curvature of the upright sections |

**Figure 9 — Horizontal and vertical tolerances VNA**

## 6.3 Deformation limits

### 6.3.1 Beam deformation limits in the Y direction

Limiting deflection values shall be agreed with the specifier on a project by project basis, taking into account the specific requirements of the installation.

Maximum deformation of supporting beams under load shall not exceed the serviceability criteria.

Where beam spans are effectively continuous over two or three bays, both sagging and hogging beam deformations should be taken into account (see Annex C).

In the absence of any specific requirements, the limiting deflection values shown in Table 3 should be used.

**Table 3 — Maximum deformation of supporting beams under load (mm)**

| Beam type | Wide aisle and Narrow aisle | VNA (operator up) racking | | VNA (operator down) racking | |
|---|---|---|---|---|---|
| Flexural deformation | | Sagging | Hogging | Sagging | Hogging |
| Normal beam | L/200 [a] | L/200 [a] | L/200 [a] | L/200 [a]<br>max. 10 mm for beam levels above 6 m | L/200 [a] |
| Cantilever beam [c] | L/100 [b] | L/100 [b]<br>max. 15 mm | | L/100 [b]<br>max. 15 mm<br>max. 10 mm for beam levels above 6 m | |

[a] L is the beam span (centreline to centreline of upright).

[b] L is the cantilever length from centreline of upright.

[c] The deflection limit specified here is applicable to pallet racking. Limits for cantilever racking are given in Clause 8.

#### 6.3.2 Frame deformations

Limiting deflection values shall be agreed with the specifier on a project by project basis, taking into account the specific requirements of the installation.

In the absence of any specific requirements, the following limiting deflection values should be used.

Sway (movement) deformation of rack uprights in the X or Z directions should not exceed 1/200 of the rack height

NOTE 1 This is to be measured from the unloaded racking upright positions on completion of erection.

NOTE 2 For example, a 15 m high rack could deflect laterally by ± 75 mm.

#### 6.3.3 Upright shortening

The y-axis deformation of any beam level depends upon the accumulation of compression strain in the individual upright lengths between the beam levels below the level being considered and shall be taken into account by the specifier when considering the height selection system of a VNA application.

These values shall be provided by the rack supplier.

#### 6.3.4 Guide rail deformation (VNA applications)

The deformation of the top and bottom guide rails is influenced by the type of very narrow aisle truck. The rail section and the size and fixing requirements shall be obtained by the specifier from the mechanical handling equipment supplier.

### 6.4 Clearances for unit loads and truck handling equipment in adjustable pallet racking

#### 6.4.1 Clearances relating to the placement of unit loads

The clearances shall be considered in relation to the maximum dimensions of the unit load which shall be specified by the specifier or user. If there is no project specific values the following clauses shall be used and the specifier shall ensure that the values are acceptable in accordance with the overall system requirements.

The following considerations should be given special attention in making any decisions on clearances in the design of VNA racking layouts:

— The deformation of the VNA truck increases as the load height and reach increases. Both the moving and stacking situations should be considered. Wear on the truck mechanisms, tyres, etc. affects these deformations in all X, Y and Z directions;

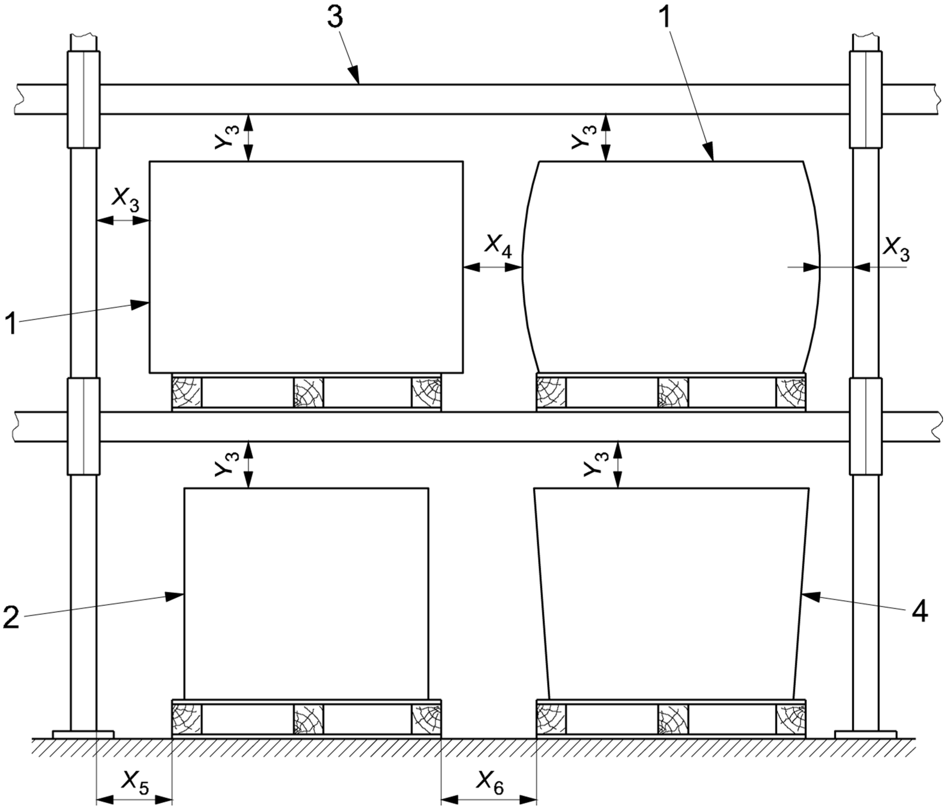
— The verticality of the truck in both the X and Z directions changes as the truck moves along the aisle because of small variations in floor levels. The verticality is exaggerated by increasing heights of VNA installations.

#### 6.4.2 Horizontal and vertical clearances in a bay

##### 6.4.2.1 General

The horizontal and vertical clearances for trucks shall not be less than the values shown in Figure 10 and Table 4.

Larger clearances may be provided to achieve higher performance or to maintain safe working conditions in high risk areas, (see A.3).




**Key**

1 pallet with load overhang

2 pallet without load overhang

3 beam shown without deflection

4 pallet with load overhang

$X_3$ clearance between upright and unit load

$X_4$ clearance between unit loads

$X_5$ clearance between upright and pallet

$X_6$ clearance between pallets

$Y_3$ clearance between underside of beam and unit load

**Figure 10 — Horizontal and vertical clearances for trucks**

**Table 4 — Horizontal and vertical clearances**

| | Wide aisle and Narrow aisle racking mm | | VNA (operator up) racking mm | | VNA (operator down) racking mm | |
|---|---|---|---|---|---|---|
| **Beam height from ground up to (mm)** | $X_3$ $X_4$ $X_5$ $X_6$ | $Y_3$ | $X_3$ $X_4$ $X_5$ $X_6$ | $Y_3$ | $X_3$ $X_4$ $X_5$ $X_6$ | $Y_3$ |
| 3 000 | 75 | 75 | 75 | 75 | 75 | 75 |
| 6 000 | 75 | 100 | 75 | 75 | 75 | 100 |
| 9 000 | 75 | 125 | 75 | 75 | 75 | 125 |
| 12 000 | 100 | 150 | 75 | 75 | 100 | 150 |
| 15 000 | 100 | 175 | 75 | 75 | 100 | 175 |
| Over 15 m | Not applicable | Not applicable | 75 | 75 | Not applicable | Not applicable |

For other values of beam height the clearances can be obtained by linear interpolation.

#### 6.4.2.2 VNA trucks

The clearance $Y_3$ to the first beam level in Table 4 shall be increased by the height of the guide rail if the truck has to place the bottom unit load on the floor over a floor mounted guide rail.

#### 6.4.2.3 Trucks with visual aids

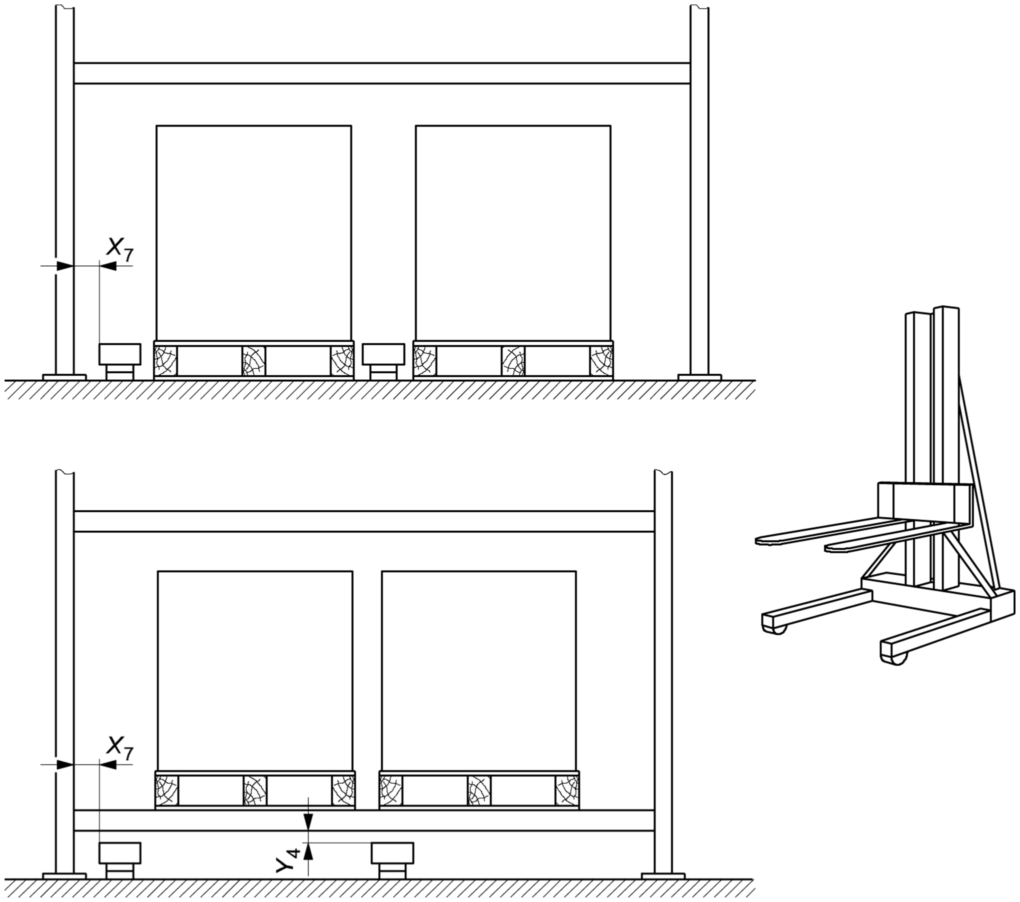
Smaller values of $Y_3$, $X_3$, $X_4$, $X_5$ and $X_6$, but not less than 75 mm, may be used subject to an indirect visibility aid such as closed-circuit television (CCTV) or an equivalent system to guide the operator. Marks on the truck mast shall not be considered to be adequate justification.

#### 6.4.2.4 Reach trucks

At floor level the minimum clearance shall be 75 mm plus $Y_b$ where $Y_b$ is the required space between the floor and underside of the pallet when retrieving or depositing, as in the case of a reach truck to accommodate the height of the outriggers if the pallet or its load is wider than the dimension between the legs of the outriggers. $Y_b$ shall be provided by the truck supplier.

#### 6.4.2.5 Straddle stacker trucks

When picking up or depositing a unit load on the floor a clear space is left on either side of the pallet to permit the straddle legs to pass either side of the load. The straddle leg shall be clear of the frame uprights by a minimum of 75 mm as shown in $X_7$ in Figure 11. If a bottom beam is present, the straddle leg shall be clear of the underside of the beam by a minimum of 40 mm as shown in $Y_4$ in Figure 11.




**Key**

$X_7$ distance between the upright and the straddle truck leg

$Y_4$ distance between the underside of the beam and the straddle truck leg

**Figure 11 — Clearance dimensions for straddle trucks**

### 6.4.3 Clearances for upright protectors

Upright protectors shall not reduce the minimum operating aisle width or the minimum gangway width.

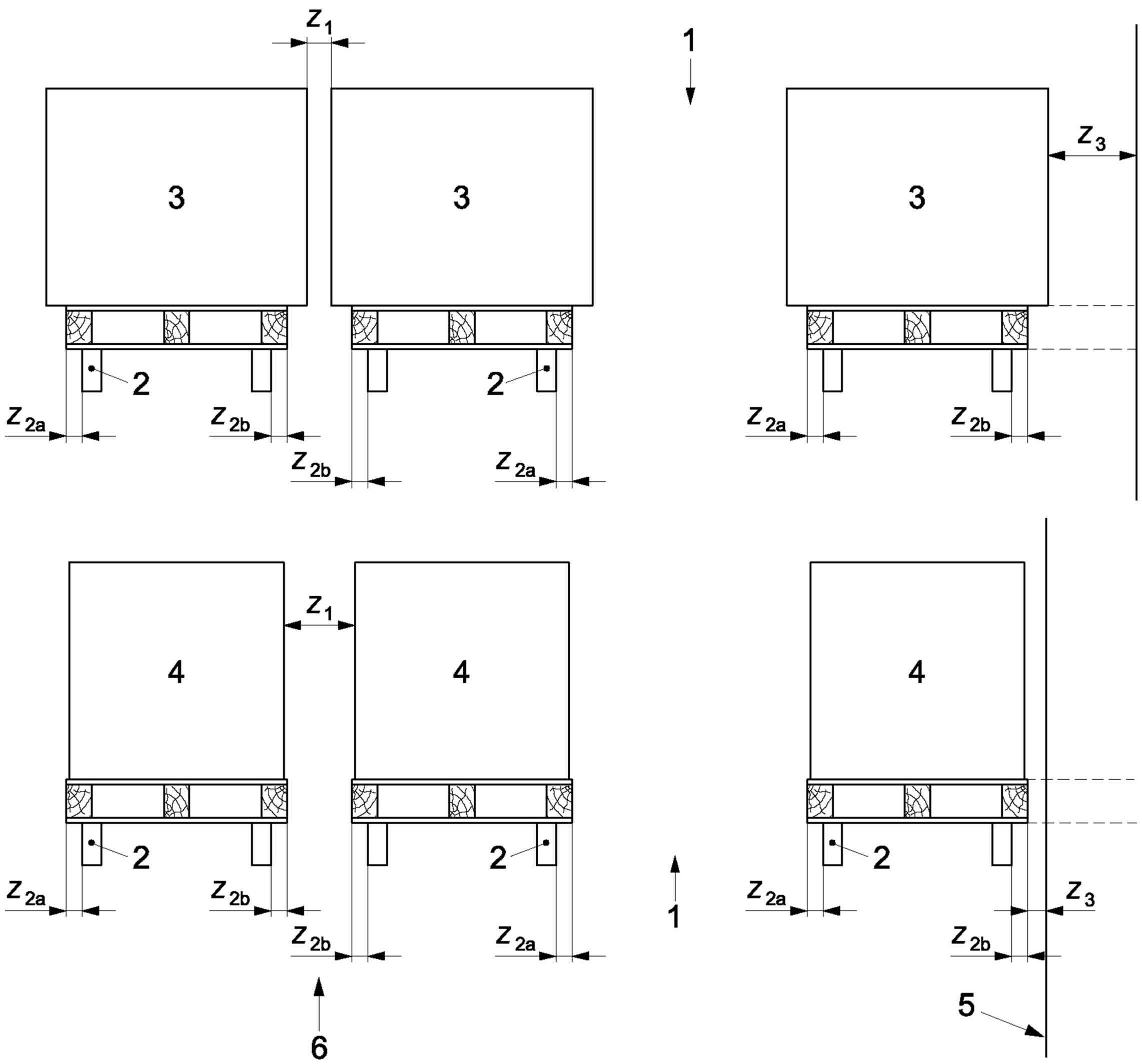
NOTE Clearances for upright protectors are given in FEM 10.2.16 (See [2]).

Retrofitting of protectors could reduce clearances. The User should be aware of the implications of retrofitting protection devices which can, in some circumstances, lead to more difficult MHE operating conditions due to decreased clearances and an increase in the amount of damage.

### 6.4.4 Horizontal clearance in the depth

#### 6.4.4.1 Requirements

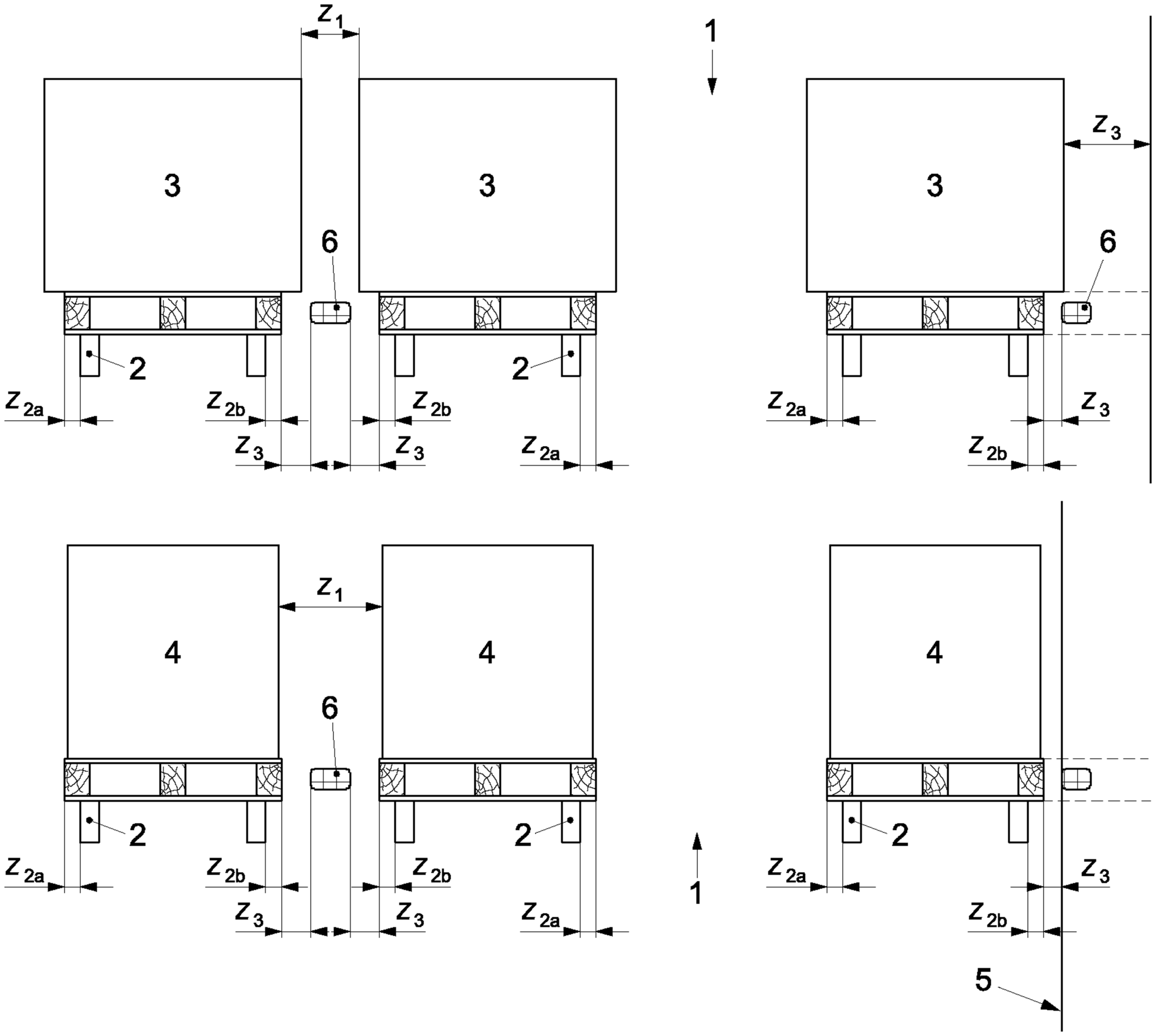
The horizontal clearances in the depth are shown in Figure 12 and Figure 13.




**Key**

| | |
|---|---|
| 1 | aisle |
| 2 | beams |
| 3 | pallet with load overhang |
| 4 | pallet with no load overhang |
| 5 | obstructing elements (e.g. bracing, safety back stop...) or wall behind unit loads |
| 6 | no obstructions behind unit loads |
| $Z_1$ | clearance between back to back pallets or load make up accessory |
| $Z_{2a}$, $Z_{2b}$ | overhang of the pallet from the front and rear beams respectively |
| $Z_3$ | clearance between pallet or LMA and safety back stop, obstructing bracing or wall behind loads |

**Figure 12 — Horizontal clearances in the depth**




**Key**

| | |
|---|---|
| 1 | aisle |
| 2 | beams |
| 3 | pallet with load overhang |
| 4 | pallet with no load overhang |
| 5 | obstructing elements (e.g. bracing, safety back stop...) or wall behind unit loads |
| 6 | safety back stop |
| $Z_1$ | clearance between back to back pallets or load make up accessory |
| $Z_{2a}$, $Z_{2b}$ | overhang of the pallet from the front and rear beams respectively |
| $Z_3$ | clearance between pallet or LMA and safety back stop, obstructing bracing or wall behind loads |

**Figure 13 — Horizontal clearances in the depth with a back stop or obstructing element**

The horizontal clearance in the depth Z is related to:

a) the maximum load overhang at the back of the rack;

b) placement tolerance of the load in the Z direction ($Z_2$).

In the case of back to back racks fitted with run spacers, the clearance $Z_1$ between two back to back pallets and/ or the load make up accessory shall be greater than or equal to $2Z_2$ but at least 100 mm.

Where back to back runs do not have run spacers the clearance $Z_1$ shall be a minimum of $2Z_2$ or 100 mm added to H/100 (where H is the height of the top beam level).

Where there is a safety back stop behind the unit load, $Z_3$ shall be greater than or equal to $Z_2$ but at least 50 mm.

#### 6.4.4.2 Symmetrical situation, manual Z positioning

In the situation where the pallet is placed symmetrically in the depth of the rack with:

a) unit load supported by a pair of racking beams front and back;

b) overhang of the load make up accessory (pallet) equal at the front and back beams with the nominal overhang $Z_2$ = 50 mm with respect to the beam.

If the distance between the upright face and beam face is less than 5 mm then the overhang may be considered with respect to the upright face.

The placement tolerance in the Z direction shall be ± 50 mm from the nominal position.

In the case of back to back racks fitted with run spacers, the nominal clearance $Z_1$ between two back to back unit loads shall be greater than or equal to 100 mm ($2Z_2$).

Where back to back runs do not have run spacers the clearance $Z_1$ shall be a minimum of $2Z_2$ or 100 mm plus H/100 (where H is the height of the top beam level).

#### 6.4.4.3 Non-symmetrical situation and/or $Z_2 \neq 50$ mm

These are non-symmetrical situations where the unit load overhang at the front or the back of the beams is specified by the specifier or truck supplier.

The placement tolerance in the Z direction from the nominal position shall be specified by the specifier or truck supplier.

In the case of back to back racks, the nominal clearance $Z_1$ between two back to back unit loads shall be greater than or equal to twice the placement tolerances in the Z direction as specified by the specifier or truck supplier but at least 100 mm.

Where back to back runs do not have run spacers the clearance $Z_1$ shall be a minimum of $2Z_2$ or 100 mm plus H/100 (where H is the height of the top beam level).

Accessories may be used such as pallet support bars or timber decking which result in a far greater range of acceptable depths.

See Annex E and Annex F for additional information.

### 6.4.5 Aisle width clearances (wide and narrow aisle racking)

#### 6.4.5.1 Minimum aisle clearance for 90° truck turning

The 90 ° turning width of truck and load shall be determined by the truck supplier incorporating the specified design dimensions of the unit load (see Annex A).

The minimum aisle clearance shall be defined by the specifier on the basis of a risk assessment with a minimum manoeuvring allowance of 200 mm i.e. a minimum clearance on both sides of 100 mm (see Annex A).

NOTE FEM 4.005 gives guidance on this subject (see [3]).

Where there is a two-way traffic system in an aisle the clearance requirements of 6.4.6 shall also apply.

#### 6.4.5.2 Lowest unit load

The aisle clearances are based on the requirement that the lowest unit load shall be placed in order not to encroach on the clear width of the aisle.

### 6.4.6 Clearances for gangways

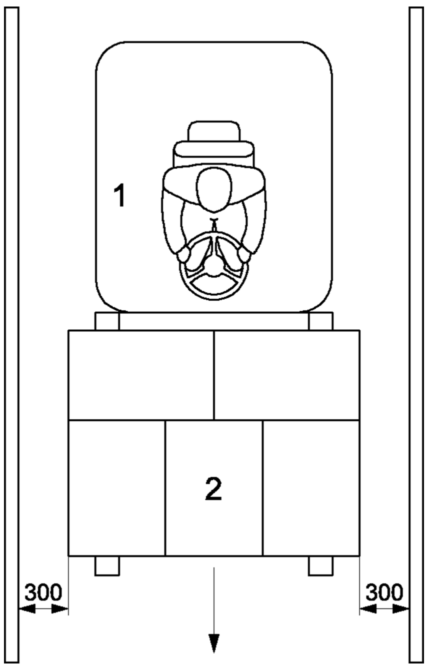
For one-way only truck gangways the minimum gangway width shall be the greater of the overall truck or load width, plus 600 mm as shown in Figure 14.

For two-way truck gangways the minimum gangway width shall be the greater of twice the overall truck or twice the load width, plus 900 mm as shown in Figure 15.

Pedestrian traffic should be segregated from powered vehicle traffic whenever it can be and this could be a national requirement. Where pedestrian traffic cannot be segregated, a minimum clearance of 500 mm shall be provided on at least one side as shown in Figure 16.

NOTE National Regulations could require other minimum values than given in this Clause.

Dimensions in millimetres



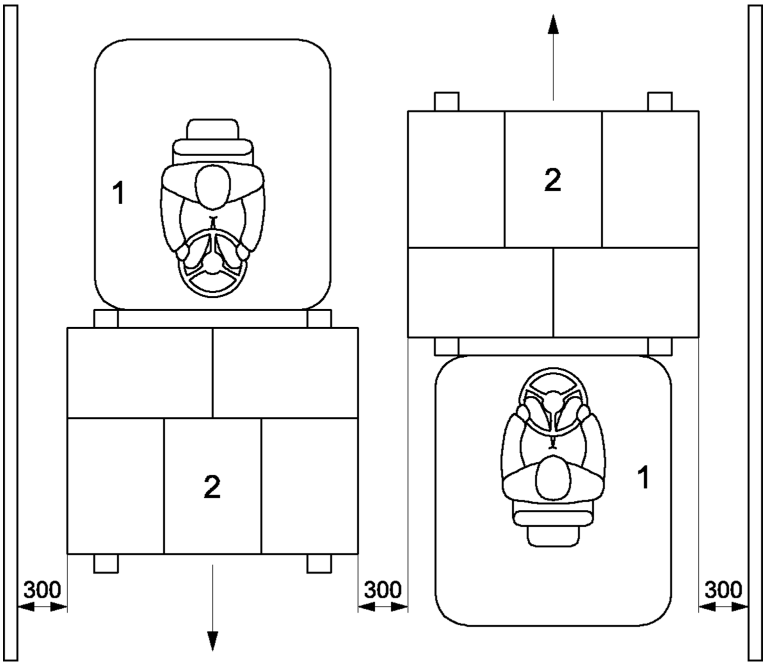

**Key**

1 powered vehicle

2 unit load

**Figure 14 — Gangway clearances for a truck one-way system with no pedestrian traffic**

Dimensions in millimetres



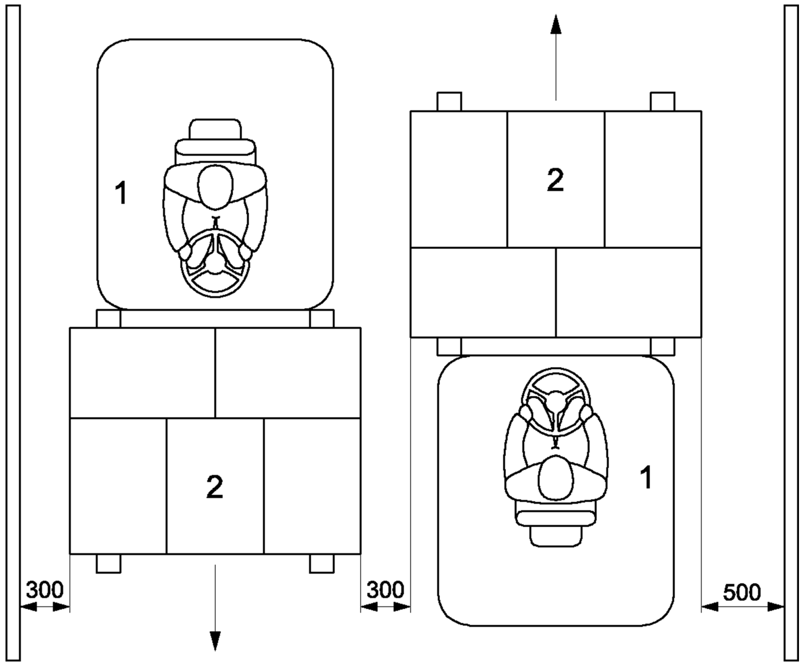

**Key**

1 powered vehicle

2 unit load

**Figure 15 — Gangway clearances for a truck two-way system with no pedestrian traffic**

Dimensions in millimetres




**Key**

1 powered vehicle

2 unit load

**Figure 16 — Gangway clearances for a truck two-way system with pedestrian traffic**

### 6.4.7 Aisle width clearances (VNA)

#### 6.4.7.1 Minimum aisle clearance for truck and load

The minimum aisle clearance shall be defined by the specifier or truck supplier incorporating all factors of influence (see Annex E).

#### 6.4.7.2 Lowest unit load

The aisle clearances are based on the requirement that, the lowest unit load shall be placed in order not to encroach on the operating width of the aisle.

## 6.5 Pick up and deposit stations

The design of the P & D stations in relation to the specified use of the VNA truck and the operational procedures shall be in accordance with the tolerance limits in X and Z direction of the load unit on the VNA truck, used in the determination of the minimum aisle and compartment clearances.

The tolerances, deformations and clearances and method of use of the P & D station shall be the responsibility of the specifier, user or supplier of the VNA truck.

NOTE The VNA truck driver is trained and instructed to position the unit load in the correct position on the VNA truck at the P&D station and, therefore, the P&D station is not required to act as a positioning aid.

# 7 Crane racking classes 100 and 200

## 7.1 General

Reference shall be made to FEM 9.831-1 / 10.3.01-1 [4] for tolerances of class 100 and 200 crane operated racks.

## 7.2 Floor tolerances

The racks shall be levelled to a datum plane (horizontal or sloping).

As the stacker crane on the crane rail and the rack on shims or grout are both levelled independent of the floor level, a wider range of floor tolerances may be used.

## 7.3 Slab deformation due to settling and slab deflection

Deflection of the floor slab results in additional stresses and inclination of the rack structure.

Deflection of the floor slab shall be included at the planning stage by the specifier or client and added to the clearances and deformations as required for the specific project; reference should be made to EN 15512 and FEM 9.831-1 / 10.3.01-1 [4].

## 7.4 Top guide rail manufacturing and assembly tolerances

The fabrication and assembly tolerance requirements for the top guide rail are specified in FEM 9.831-1 / 10.3.01-1 [4].

## 7.5 Installation tolerances (single deep and double deep)

The maximum allowable tolerances after erection, with the racks in the unloaded condition, shall be as stated in FEM 9.831-1 / 10.3.01-1 [4].

The installation tolerances, deformations and clearances are also applicable if racking is dismantled and re-erected.

A measurement survey may be used to measure the installation tolerances and clearances before the racking is loaded. The tolerances stated may not be applicable after the racking has been loaded. Measurement surveys are conducted when required by individual contracts (see Annex B).

## 7.6 Deformation limits

### 7.6.1 Beam deformation limitations in the Y direction

Maximum deformation of supporting beams under load shall not exceed the serviceability criteria.

Limiting deflection values shall be agreed with the specifier on a project by project basis, taking into account the specific requirements of the installation.

In the absence of any specific requirements, the limiting deformation values given in FEM 9.831-1 / 10.3.01-1 [4] should be used in the location of the fork tips.

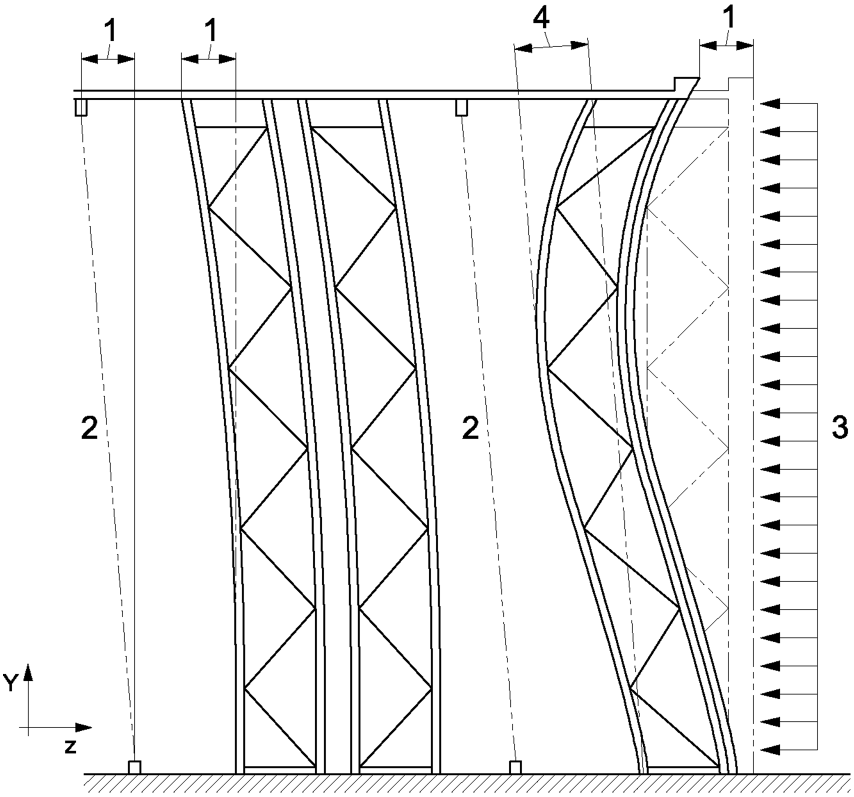
### 7.6.2 Frame deformations in the X and Z directions

The maximum frame deformations based on the serviceability limit state shall be as stated in FEM 9.831-1 / 10.3.01-1 [4]. The calculation of the deformations shall be carried out using EN 15512 and other relevant European Standards.

NOTE The initial out-of-plumb of the frames when first erected increases under gravity loads, crane forces and wind loads and does not completely return to the original installed tolerance.

### 7.6.3 Frame deformations in the X and Z directions for clad rack buildings and wind loads

Unless specified otherwise in the project design specification, the limiting values for frame deflections ‘1’, mast inclination and edge frame bow deflection '4’ should be as given in FEM 9.831-1 / 10.3.01-1 [4] (see Figure 17).




**Key**

1 frame and mast deflection

2 crane mast inclination

3 wind

4 edge frame deflection (measured from a straight line between the bottom and top of the upright)

**Figure 17 — Wind load deformation of the rack structure in the Z direction**

If deformations exceed the limiting values the rack designer shall provide the specifier and/ or crane manufacturer with the calculated deflection values.

Deflection limits, other than those given above, may be specified depending upon the type of unit load to be stored and the load handling techniques adopted.

### 7.6.4 Elastic shortening of uprights

The y-axis displacement of any beam level depends upon the accumulation of compression strain in the individual upright lengths between the beam levels below the level being considered and shall be taken into account by the specifier or crane supplier when considering the height selection system.

These values shall be provided by the rack supplier.

## 7.7 Safety back stop

### 7.7.1 Deformations

The horizontal deformation of the safety back stop shall be specified by the crane supplier or specifier and limited to ensure safe support of the unit load on the structure (see EN 15629).

### 7.7.2 Clearances

The clearance from the unit load to the safety back stop shall be specified by the crane supplier (see FEM 9.831-1 / 10.3.01-1) [4].

# 8 Cantilever racking

## 8.1 Installation tolerances

The maximum allowable tolerances after erection, with the cantilever rack in the unloaded condition, shall be as stated in Table 5 and Table 6 and shown in Figure 18 and Figure 19.

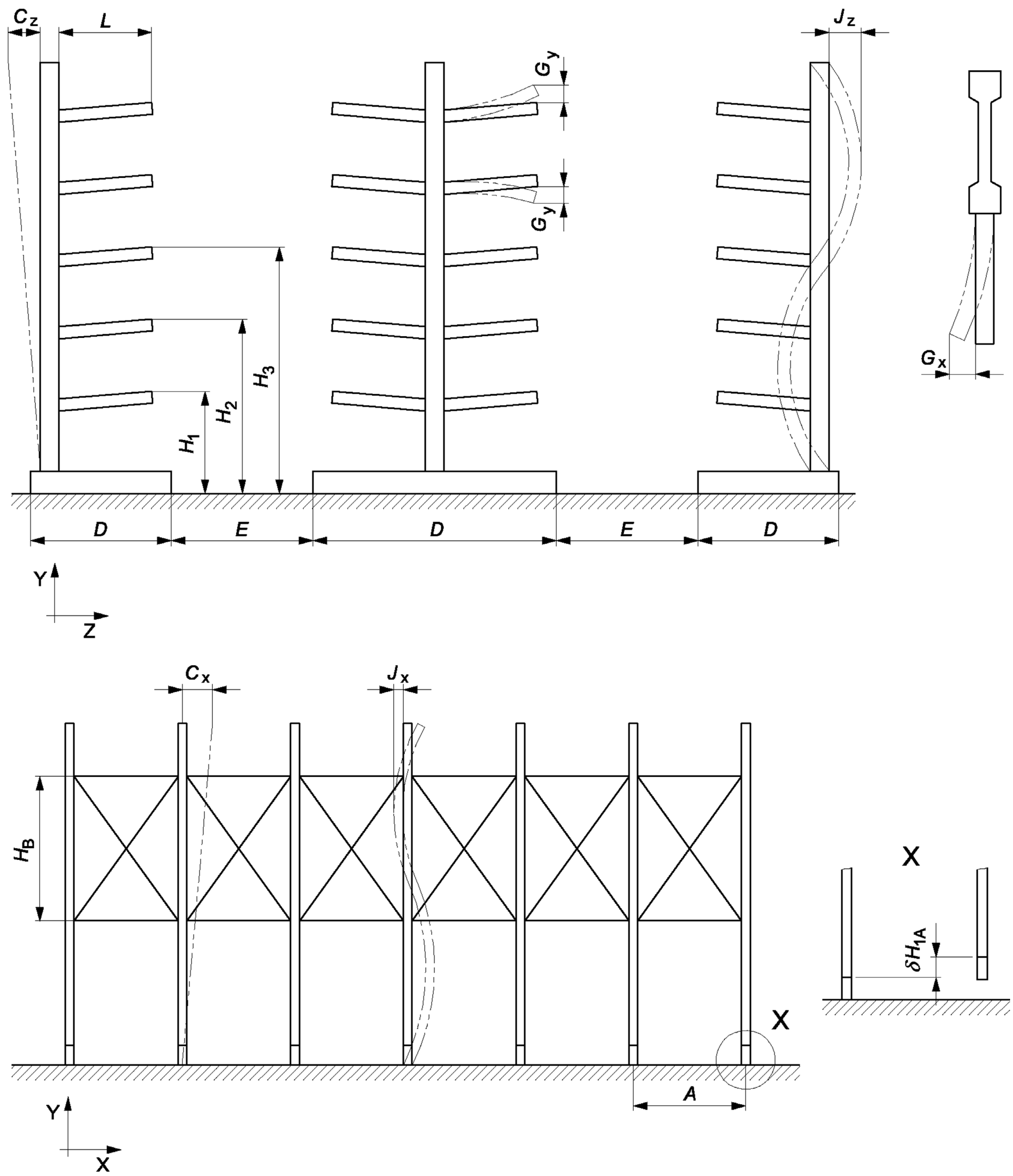
**Table 5 — Horizontal tolerances for X Z plane (mm)**

| **Measuring dimension code and description of tolerance** [a] | **Installation tolerances for cantilever racking** |
|---|---|
| **δA** Variation from nominal dimension of the bay width between two cantilever columns at any arm level | ± 5 |
| **$\delta A_t$(n)** Variation from nominal dimension of the total cantilever length, cumulative with the number of bays 'n' measured near floor level | ± 3 n |
| **$\delta B_0$** Variation from nominal of cantilever frontage with regard to the 'system datum' concerned, measured near floor level | ± 10 |
| **$B_A$** Misalignment of opposing cantilever columns across an aisle, measured near floor level | ± 25 |
| **$C_x$** Out-of-plumb of each cantilever column in the X direction | ± H/500 |
| **$C_z$** Out-of-plumb of each cantilever column in the Z direction | ± H/500 |
| **δD** Variation from nominal dimension of the cantilever depth | ± 6 |
| **δE** Variation from nominal dimension of the racking aisle width near floor level | ± 15 |
| **δF** Variation from nominal of the straightness of an aisle measured near floor level with regard to the 'datum line' | ± 15 |
| **$G_x$** Straightness of the cantilever arm or cantilever base in the X direction | ± L/100 |
| **$J_x$** Cantilever column straightness in the X direction between bracing beams spaced $H_B$ apart | The larger tolerance of the following<br>± 5 or<br>± $H_B$/300 |
| **$J_z$** Initial curve of a cantilever column in the Z direction | ± H/500 |
| a Refer to Figure 18 and Figure 19. | |

**Table 6 — Vertical tolerances for Y direction (mm)**

| **Measuring dimension code and description of tolerance** [a] | **Installation tolerances, for cantilever racking** |
|---|---|
| **$G_y$** Deviation of cantilever arm from nominal position in Y direction | ± L/250 |
| **$\delta H1_A$** Variation in the height of the top of adjacent cantilever bases | ± 5 |
| **$\delta H_1$** Variation of the top of the lowest arm above the cantilever base<br>**$\delta H_2$** Variation of the distance between adjacent cantilever arms | ± 10<br>± 10 |
| [a] Refer to Figure 18 and Figure 19. | |

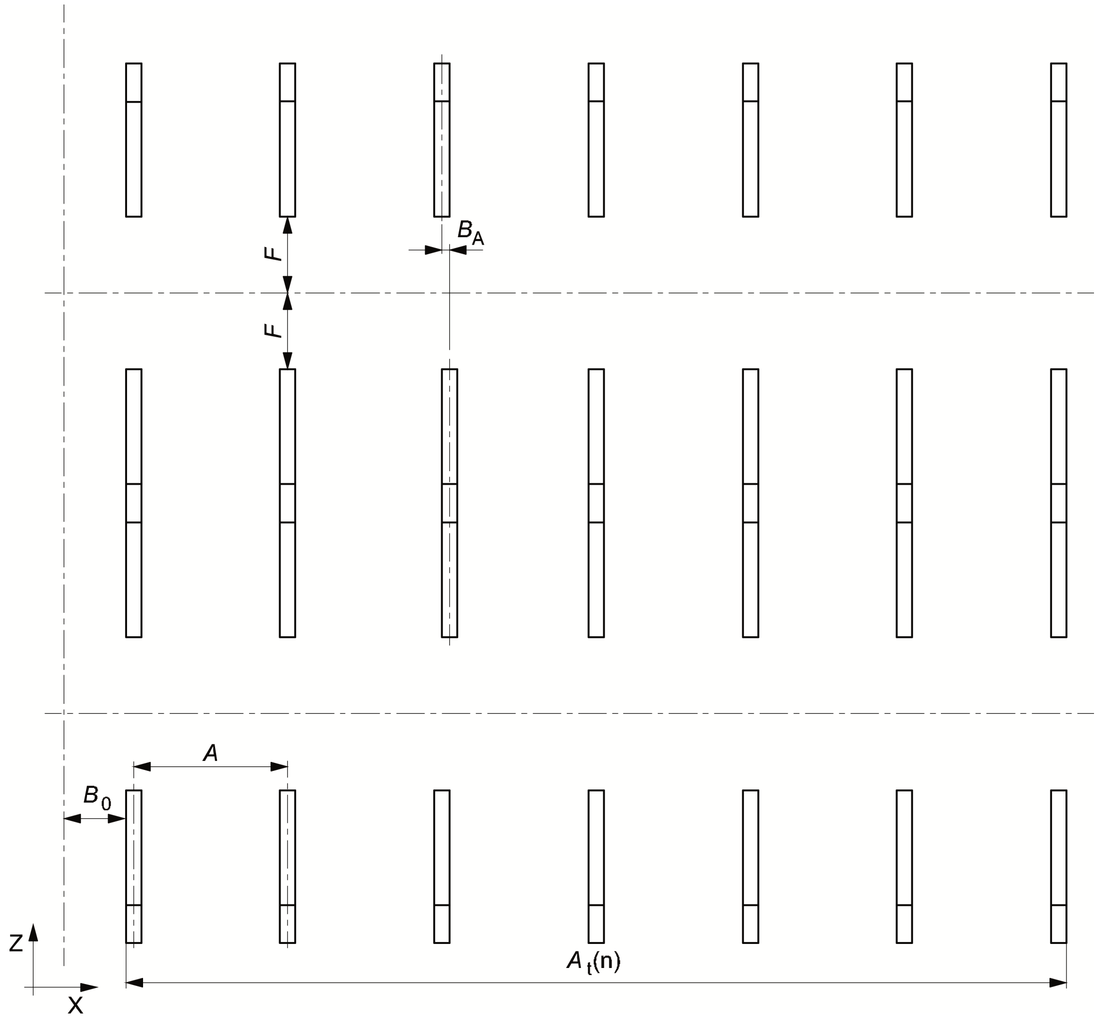
A measurement survey may be used to measure the installation tolerances and clearances before the racking is loaded. The tolerances stated in this document may not be applicable after the racking has been loaded. Measurement surveys may be completed when required by individual contracts.




**Key**

| | |
|---|---|
| A | is the bay width |
| $C_x$ | is given in Table 5 |
| $C_z$ | is given in Table 5 |
| D | is the overall length of the cantilever base |
| E | is the racking aisle width |
| $G_x$ | is given in Table 5 |
| $G_y$ | is given in Table 6 |
| $H_1$, $H_2$, $H_3$ | is the height above the underside of the base of arms 1, 2 and 3 |
| $H_B$ | is the dimension between bracing beams |
| $J_x$ | is given in Table 5 |
| $J_z$ | is given in Table 5 |
| $\delta H_{1A}$ | is given in Table 6 |
| L | is the arm length |

**Figure 18 — Tolerances**




**Key**

A bay width

$A_t$(n) length of run

$B_0$ dimension to system datum

$B_A$ misalignment of opposing cantilever columns across aisle

F dimension from the cantilever base to the aisle system X datum line

**Figure 19 — Horizontal and vertical tolerances**

## 8.2 Verticality tolerances with regard to design and assembly

The maximum out-of-plumb of the cantilever column is given in Table 5 and is measured in the unloaded condition immediately after installation.

If the designer specifies an initial out-of-plumb imperfection the installation process shall be controlled in order to ensure that the design assumptions are not exceeded.

## 8.3 Cantilever racking deformation limits

### 8.3.1 General

The following limiting deflection values should be used unless more onerous requirements are specified.

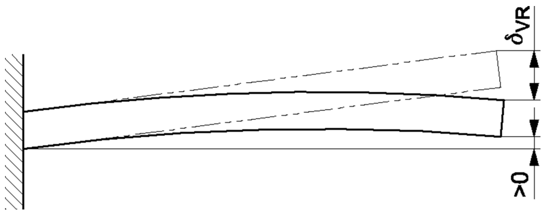
### 8.3.2 Arm deformations

— Maximum twist in an arm = 6 °.

— Maximum deflection = Arm length /200 (for the arm plus connection neglecting the effect of the upright).

It is recommended that the cantilever arm should not deflect below the horizontal (see Figure 20). If the arm does deflect below the horizontal then adequate measures should be taken to ensure that all unit loads which may be stored do not move due to this deflection.

NOTE An upward cant of the arm in the unloaded condition of more than 3 ° could cause operational problems of placement and retrieval.




**Key**

$\delta_{VR}$ is the deflection at the tip of the cantilever arm

**Figure 20 — Deflection of Cantilever arm (neglecting upright deflection)**

## 8.4 Cantilever column deformations in the X and Z directions

The permissible deformation of cantilever columns in X or Z directions, due to the applied loads, should not exceed the following values.

— Deflection of a cantilever column in the X (down-aisle) direction $\delta = \frac{H}{200}$

— Deflection of a cantilever column in the Z (cross-aisle) direction as follows (see Figure 21)

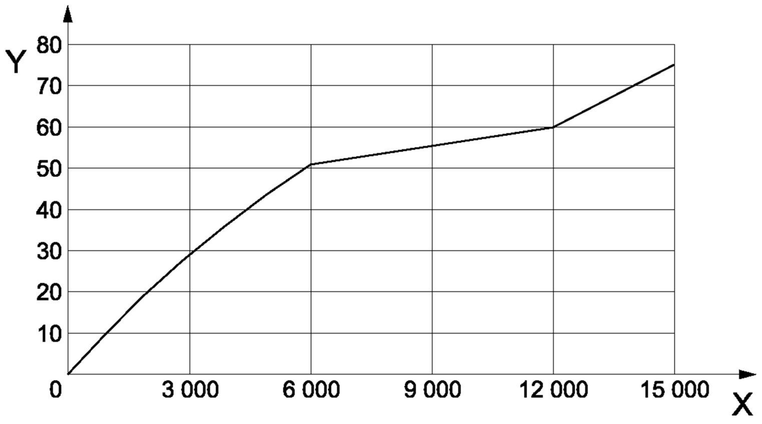
— Up to 6m $\delta = \frac{H}{100 + \frac{H^2}{2000000}}$

— Between 6m and 12m $\delta = 41,6 + \frac{9,2H}{6000}$

— Over 12m $\delta = \frac{H}{200}$

where

H is the height (in mm)




**Key**

X height (mm)

Y deflection (mm)

**Figure 21 — Cantilever column cross-aisle deflection**

## 8.5 Clearances for unit loads and truck handling equipment

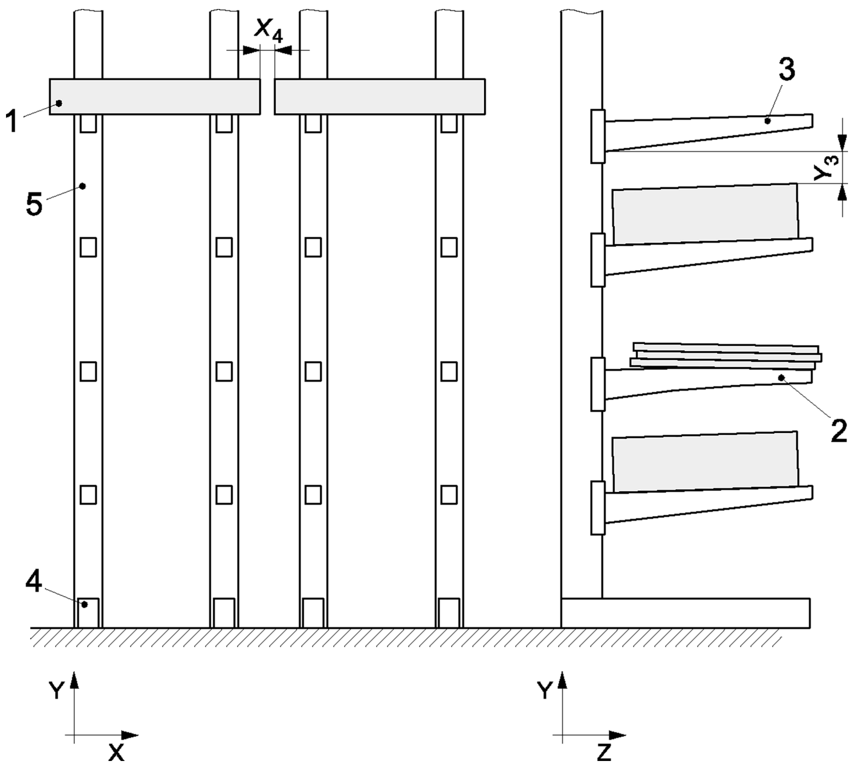
### 8.5.1 Clearances relating to the placement of unit loads

The clearances shall be considered in relation to the maximum overall measurement of the unit load (i.e. including any load overhang).

### 8.5.2 Horizontal and vertical clearances in a bay

The horizontal and vertical clearances shall not be less than the values shown in Figure 22 and Table 7.

NOTE In high risk environments (see A.3) as defined by the specifier, larger clearances could be required to maintain safe working conditions.




**Key**

1 unit load with load overhang

2 cantilever arm shown with deflection

3 cantilever arm shown without deflection

4 cantilever base

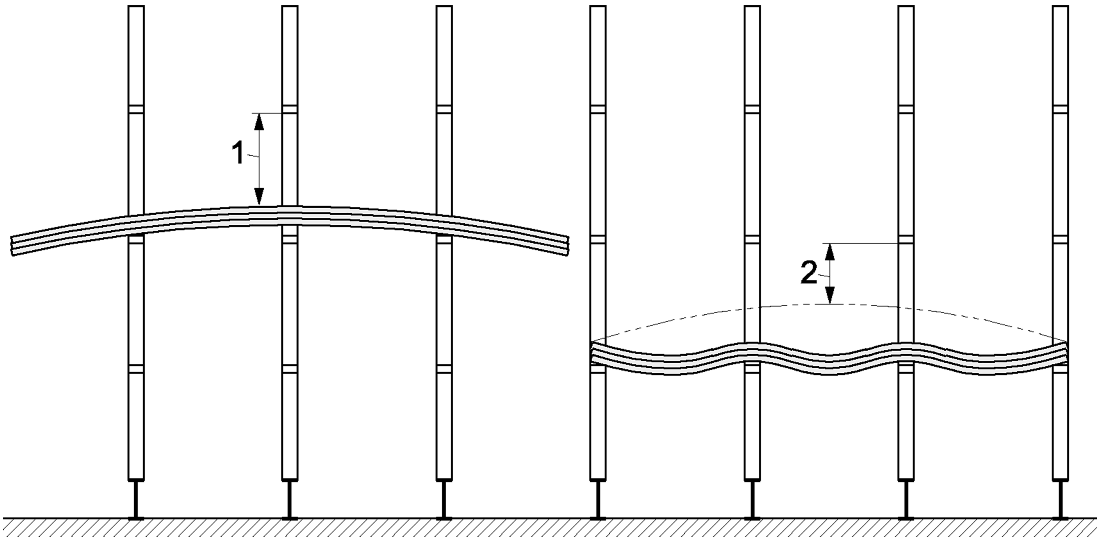
5 cantilever column

**Figure 22 — Horizontal and vertical clearances**

**Table 7 — Horizontal and vertical clearances**

| Arm height mm<br>From ground up to arm level | $X_4$ mm<br>Unit load length up to 3m | $X_4$ mm<br>Unit load length 3m to 6m | $X_4$ mm<br>Unit load length over 6m | $Y_3$ mm |
|---|---|---|---|---|
| 3 000 | 200 | 250 | 300 | 75 |
| 6 000 | 250 | 300 | 350 | 100 |
| 9 000 | 300 | 350 | 400 | 150 |
| 13 000 | 400 | 450 | 500 | 200 |

Consideration shall be given to increasing $Y_3$ for flexible loads (see Figure 23). For other values of $Y_3$ the clearances can be obtained by linear interpolation.




**Key**

1 $Y_3$ reduced due to load flexibility

2 $Y_3$ reduced due to load flexibility during placement/retrieval

**Figure 23 — Flexible load on cantilever racking**

No requirement is given for the clearance in the cross-aisle direction between the rear of the load and the column. Care should be taken during load placement and retrieval to ensure that no impact loads are applied to the face of the cantilever column. The cantilever column is not considered to be a buffering back stop as defined in EN 15512.

# 9 Drive-In racking

## 9.1 Installation tolerances

The maximum allowable tolerances after erection, with the racks in the unloaded condition, shall be as stated in Table 8 and Table 9 and Figure 24.

NOTE The tolerance limits are based on the operational method for DIR/DTR given in EN 15635.

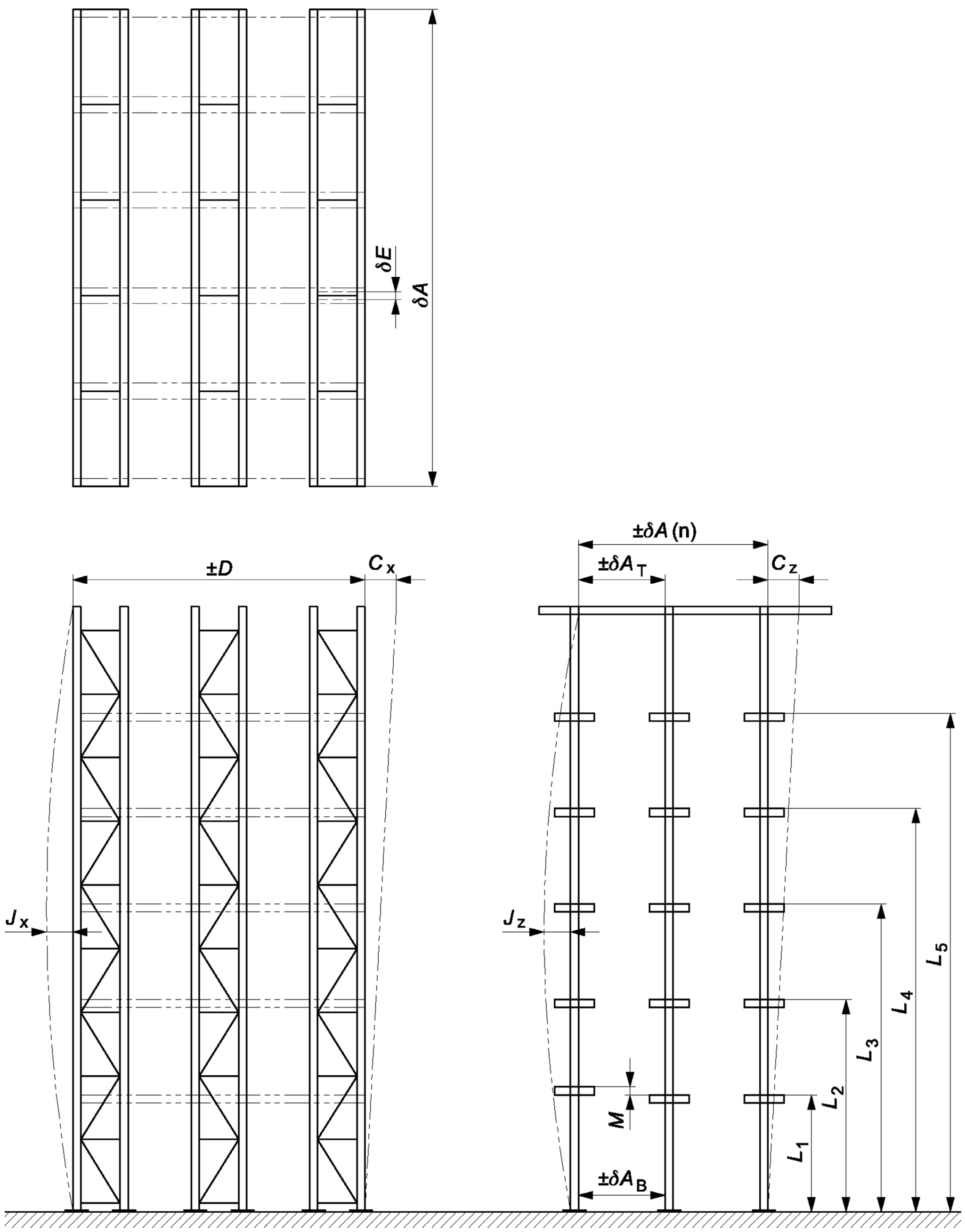
**Table 8 — Tolerances measured horizontally**

| | **Description** | **Limit value** |
|---|---|---|
| $\delta A_T$ | Maximum variation in width of individual lane (at top) (mm) | ± 1,5 |
| $\delta A_B$ | Maximum variation in width of individual lane (at bottom) (mm) | ± 5,0 |
| $\delta A_T$ (n) | Total deviation in rack length cumulative at top or bottom (mm). Where n is the number of lanes | ± 2,0 n |
| δE | Frame alignment in the down-lane direction (measured separately at top and bottom) (mm) | ± 3,0 |
| $C_z$ | Maximum out-of-plumb upright in the cross-lane direction | H/500 |
| D | Rack depth (mm) | ± 5,0 per frame |
| $J_x$, $J_z$ | Maximum bow imperfection of upright | H/1 000 |
| $C_x$ | Maximum out-of-plumb upright in the down-lane direction | H/500 |

**Table 9 — Tolerances measured vertically**

| | **Description** | **Limit value** |
|---|---|---|
| $L_1$, $L_2$, L …$L_n$ | Maximum deviation of arm level with regard to the top of baseplate level (mm) | ± H/250 |
| M | Maximum variation of pallet support level between both sides of the pallet (mm) | 6,0 |

A measurement survey may be used to measure the installation tolerances and clearances before the racking is loaded. The tolerances stated in this document may not be applicable after the racking has been loaded.




**Key**

| | |
|---|---|
| $\delta A_T$ | maximum variation in width of individual lane (at top) |
| $\delta A_B$ | maximum variation in width of individual lane (at bottom) |
| $\delta A(n)$ | total deviation in rack length cumulative at top or bottom. Where n is the number of lanes |
| $C_x$ | maximum out-of-plumb upright in the down-lane direction |
| $C_z$ | maximum out-of-plumb upright in the cross-lane direction |
| D | rack depth (mm) |
| $\delta E$ | frame alignment in the down-lane direction (measured separately at top and bottom) |
| $J_x$ | maximum bow imperfection of upright in the down-lane direction |
| $J_z$ | maximum bow imperfection of upright in the cross-lane direction |
| $L_1$, $L_2$, $L_3$…$L_n$ | maximum deviation of arm level with regard to the top of baseplate level |
| M | maximum variation of pallet support level between both sides of the pallet |

**Figure 24 — Horizontal and vertical tolerances**

## 9.2 Deformation limits

### 9.2.1 Beam rail deformation limits in the Y direction

Maximum deformation of supporting beams under load shall not exceed the serviceability criteria.

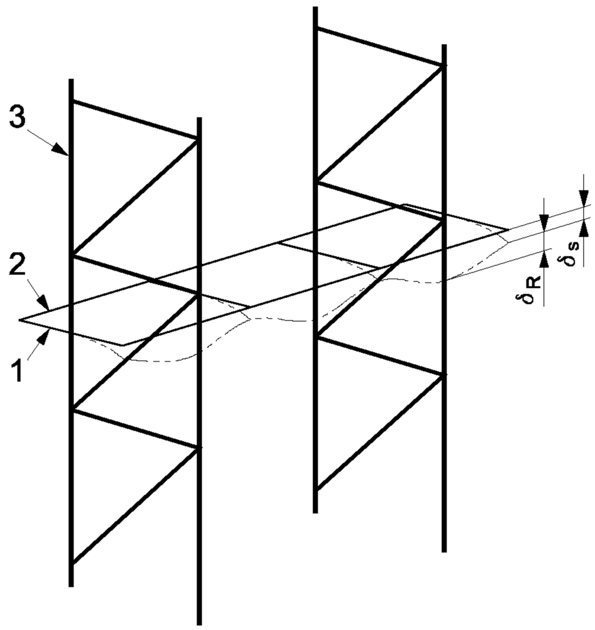
Limiting deflection values shall be agreed with the specifier on a project by project basis, taking into account the specific requirements of the installation.

In the absence of any specific requirements, the limiting deflection values given below and shown in Figure 25 should be used:

— $\delta_s \leq$ the larger of 5 mm or 1/100th of the length of the arm;

— $\delta_R \leq$ 10 mm (at any position on the beam rail);

— maximum twist = 6 °.




**Key**

1 cantilever arm

2 beam rail

3 frame

$\delta_s$ cantilever arm deflection

$\delta_R$ beam rail deflection

**Figure 25 — Deflection of the load support**

NOTE The deformation limits are based on the operational method for DIR/DTR given in EN 15635.

### 9.2.2 Frame deformations

#### 9.2.2.1 Sway

Limiting deflection values shall be agreed with the specifier on a project by project basis, taking into account the specific requirements of the installation.

In the absence of any specific requirements, the following limiting sway deflection values of rack uprights in the X or Z directions, due to the applied loads should be used:

— $\frac{H}{200}$ in general

— $\frac{H}{350}$ for the vertical bracing (if present)

— $\frac{H}{350}$ for unbraced racks

In some cases more stringent limits may be specified to suit the use of the installation.

NOTE The deformation limits are based on the operational method for DIR/DTR given in EN 15635.

#### 9.2.2.2 Upright bow

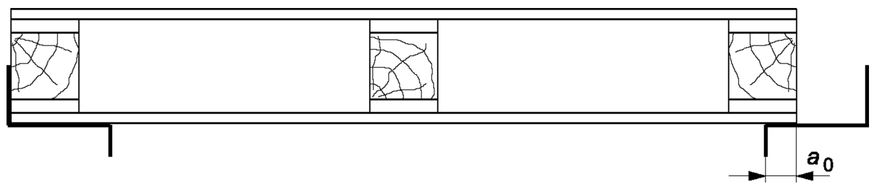
The bow deflection of the upright and tolerance of the lane width shall be limited such that the minimum pallet bearing specified in 9.3 is achieved.

NOTE The deformation limits are based on the operational method for DIR/DTR given in EN 15635.

## 9.3 Minimum pallet bearing

For pallets with a width tolerance of less than ± 10 mm the bearing width ($a_0$) shall be at least 25 mm (see Figure 26).

For pallets with a width tolerance of less than ± 5 mm the bearing width ($a_0$) shall be at least 20 mm (see Figure 26).




**Key**

$a_0$ bearing width of the pallet

**Figure 26 — Minimum pallet bearing $a_0$**

## 9.4 Clearances for unit loads and truck handling equipment

### 9.4.1 Industrial truck requirement

Industrial trucks shall be equipped with side-shift for operation at storage levels above 6 m.

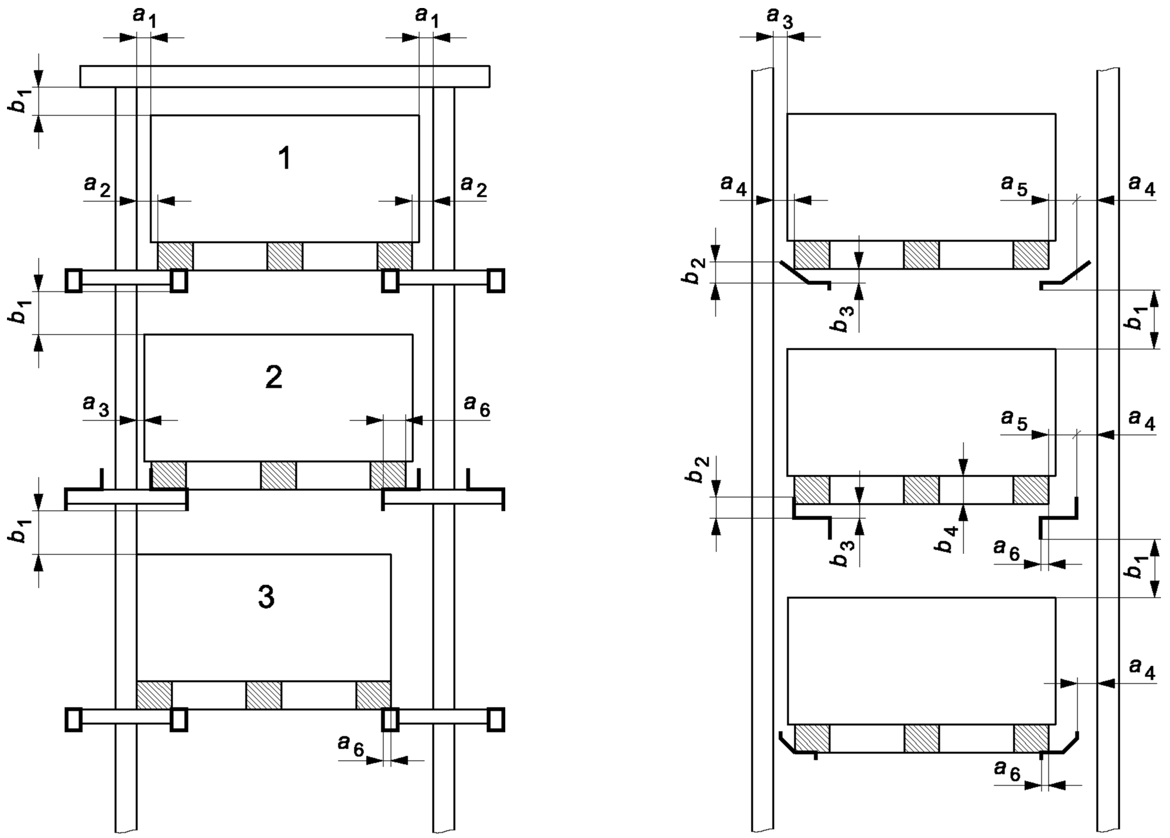
This assists to correctly deposit the pallet on the pair of beam rails and it is recommended for all applications.

### 9.4.2 Clearances relating to the placement of unit loads

The clearances shall be considered in relation to the maximum dimensions of the unit load which shall be specified by the supplier or user. If there is no project specific values the following clauses shall be used and the specifier shall ensure that the values are acceptable in accordance with the overall system requirements.

### 9.4.3 Horizontal and vertical clearances

The minimum horizontal and vertical clearances shall be as stated in Figure 27 and Table 10.




**a) Placement of pallets** **b) Beam guard rails**

**Key**

1 pallet central between uprights – beam rail without guides

2 pallet at extreme position against beam rail (with integral pallet guide)

3 pallet at extreme position against the upright where no pallet guides are provided

$a_4$ clearance between the pallet load or pallet and the upright during placement

$a_6$ pallet bearing width

$b_1$ clearance between the unit load and bottom of the rack cantilever arm or beam rail, whichever is the lowest

$b_2$ height of the pallet guard

$b_3$ insertion position of the pallet

$b_4$ pallet height

**Figure 27 — Vertical and horizontal spacing and clearances**

The height of the pallet guard (b2) should comply with:

$b_2 \geq 45$ mm $\leq b_4$

$b_2 \leq b_4$ (If there is load overhang)

**Table 10 — Horizontal unit load clearances in case no pallet rail guards**

| | Description | Minimum value | Note |
|---|---|---|---|
| $a_1$ | Clearance between load and upright | 75 mm | Height to topmost level less than 8m |
| | | 100 mm | Height to topmost level more than 8m and truck not guided |
| | | By risk analysis | High throughput |
| $a_2$ | Clearance between pallet and upright | 75 mm | Height to topmost level less than 8m |
| | | 100 mm | Height to topmost level more than 8m and truck not guided |
| | | By risk analysis | High throughput |
| $a_3$ | Clearance between the pallet load or pallet and the upright during placement | 45 mm | |
| $a_4$ | Clearance between the pallet load or pallet and the upright during placement | 45 mm | When the pallet is positioned 25 mm ($b_3$) above the horizontal support surface of the beam rail |
| $a_5$ | Clearance between the pallet and a guard rail side | 50 mm | When the pallet is positioned 25 mm ($b_3$) above the horizontal support surface of the beam rail |

In fast moving operations and when indicated by a risk analysis minimum clearances should be increased (see Annex A).

### 9.4.4 Horizontal clearances in the depth

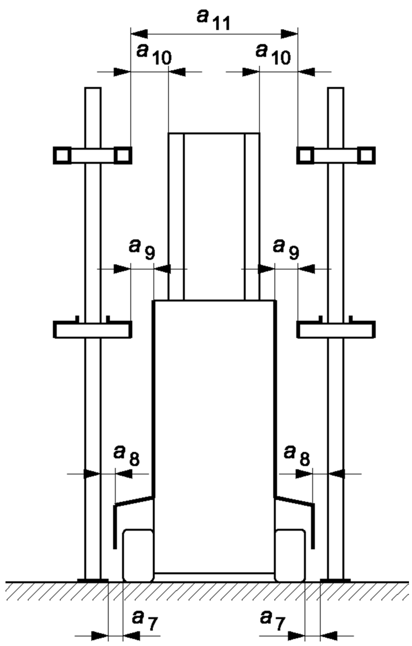
The spacing between unit loads (including any specified load overhang) supported on the beam rails shall be at least 25 mm. At floor level this may be reduced.

### 9.4.5 Horizontal truck clearances

The minimum horizontal and vertical clearances shall be as stated in Figure 28 and Table 11.

**Table 11 — Clearances for non-guided industrial trucks**

| | Description | Minimum value | Note |
|---|---|---|---|
| $a_7$ | Clearance between the wheels of the industrial truck and the side of the base plates or floor rail | 50 mm | |
| $a_8$ | Clearance between the wheels or body of the industrial truck and the side of the uprights | 50 mm | |
| $a_9$ | Clearance between truck and beam rail | 60 mm | At the lowest arm level |
| $a_{10}$ | Clearance between truck mast and beam rail | 75 mm | Second and subsequent arm levels with storage (rail) levels up to 6 m |
| | | 100 mm | Second and subsequent arm levels with storage (rail) levels over 6 m |




**Key**

$a_7$ is given in Table 11

$a_8$ is given in Table 11

$a_9$ is given in Table 11

$a_{10}$ is given in Table 11

$a_{11}$ is the nominal dimension between pallet rails

**Figure 28 — Clearances between truck and rack in cross-lane direction**

### 9.4.6 Vertical clearances

The minimum horizontal and vertical clearances shall be as stated in Figure 27 and Table 12.

**Table 12 — Vertical clearances**

<table>
<tr><th></th><th>Description</th><th>Minimum value</th><th>Note</th></tr>
<tr><td rowspan="3">$b_1$</td><td rowspan="3">Clearance between the top of the pallet load and bottom surface of the rack cantilever arm or beam rail, whichever is the lowest</td><td>100 mm</td><td>Up to a storage level of 6 000 mm</td></tr>
<tr><td>125 mm</td><td>At a storage level of 9 000 mm</td></tr>
<tr><td>150 mm</td><td>At a storage level of 13 000 mm</td></tr>
<tr><td colspan="4">NOTE Linear interpolation is allowed.</td></tr>
</table>

## 10 Racking to warehouse interface

The rack shall be so positioned that the possibility of an unintended clash between the rack or stored goods and the building is prevented.

The following shall be considered in the planning stage:

1) Rack tolerances and horizontal deformations.

2) Placement tolerances of the unit loads in the rack.

3) Warehouse building tolerances and deformations, such as position of the columns, horizontal deflection, deflection of the roof etc. (see EN 15629).

Seismic sway deformations of the racking and the warehouse building shall be considered where applicable.

When sprinklers are a part of the storage system it is likely that increased clearances could be required both between the unit loads, unit loads and racking and between the building and unit loads/rack. See Annex G.

# Annex A
(informative)

# General safety philosophy

## A.1 General

The safety philosophy of storage equipment is based on the following:

a) the use of the storage system is in accordance with the specification prepared by the specifier (see EN 15629);

b) the workplace environment is maintained in a good condition (good housekeeping);

c) loads are secure and stable;

d) pallets and other load handling accessories are used within their design limitation;

e) the consideration of the operational interface between racking and MHE resulting in the clearances, complies with this document;

f) mechanical handling equipment is correctly serviced and maintained;

g) industrial truck drivers are skilled, and trained for the work environment;

h) the working environment is identified as a 'standard' risk environment by the specifier;

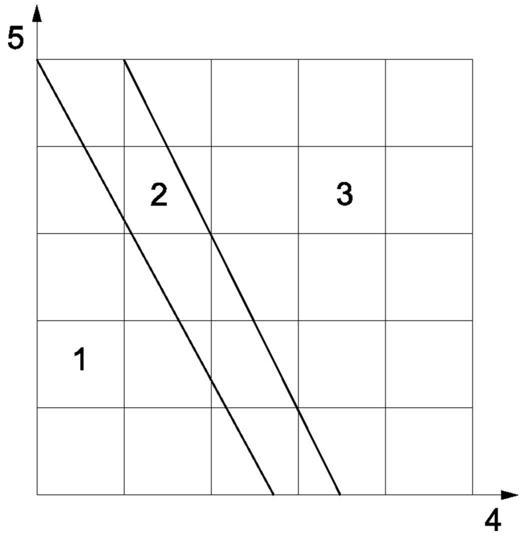
i) floor tolerances and deformations (as specified in FEM 10.2.14/4.103 [1]) are appropriate to the operations taking place;

j) a person responsible for safety (PRRS) is appointed as recommended in EN 15635;

k) an inspection regime as recommended in EN 15635 is in place;

l) a maintenance regime as recommended in EN 15635 is in place.

If any of these factors are not realized in practice then there is an increased frequency of accidents and magnitude of damage to the racking, etc. This results in an increased risk which will lead to a need for other preventative or remedial actions to take place to maintain a safe working environment. Such provisions may include greater clearances, reduction in throughput, protection to the racking, etc., shown diagrammatically in Figure A.1.




**Key**

1 zone of low risk operation
2 area of medium risk operation
3 area of high-risk operation
4 increasing magnitude of damage
5 increasing frequency of accidents

**Figure A.1 — Risk**

## A.2 Wide and narrow aisle width manoeuvring clearance

The aisle clearances are based on the requirement that in those situations where the lowest unit load is supported on the concrete floor, the pallet or its load shall be placed in order not to encroach on the operating width of the aisle.

The manoeuvring clearance is the dimension by which the operating aisle width, based on the dimensions and the manoeuvring properties of the industrial truck and the load, is increased. A minimum value of 200 mm is used for 90 ° stacking.

Where the lowest unit load in a rack is supported on the floor, a permanent line drawn down each side of each aisle to mark this position could help to control the position of the unit load.

## A.3 Environments with additional risk

In high risk environments (as defined by the specifier), larger clearances could be required to maintain safe working conditions.

For example, in a wide or narrow aisle installation the minimum aisle clearance could need to be increased from 200 mm to 350 mm or more for safety due to the following factors:

a) load units not rigid;

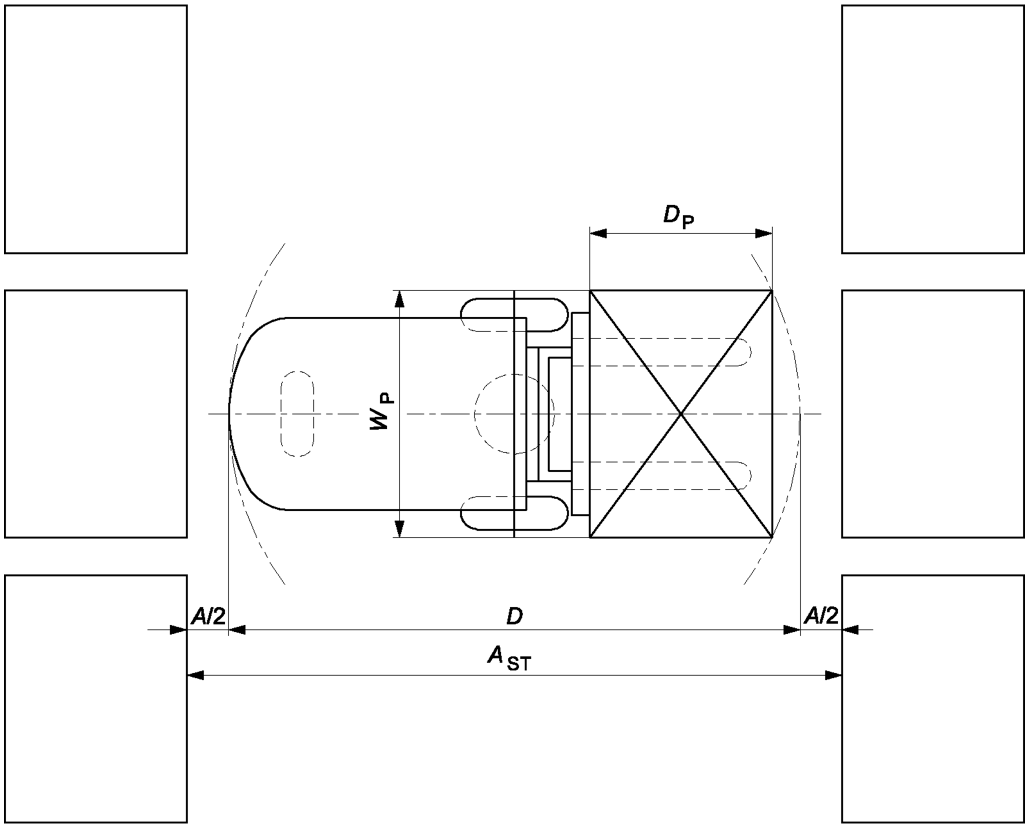
b) large load dimensions that make precise driving approaches more difficult;

c) fast throughput.

## A.4 Truck requirements

A typical example of the operating aisle width requirements for adequate 90 ° stacking truck manoeuvrability is shown in Figure A.2.

For minimum operating aisle widths see FEM 4.005 [3]. The 90 ° truck turning dimensions are dependent on the design of the industrial truck and the manufacturer should be consulted for accurate operating aisle width dimensions.




**Key**

A manoeuvring clearance

$D_p$ depth of unit load and pallet

D 90 ° turning width of truck and load

$A_{ST}$ minimum operating aisle width

$W_p$ width of unit load and pallet

**Figure A.2 — Operating aisle width dimension**

The nominal position of the unit load on the floor may be indicated by floor marking.

The dimension $A_{ST}$ should make allowance for load overhang. Industrial truck data sheets are typically based on standard pallet sizes i.e. 1 200 mm × 800 mm and 1 200 mm × 1 000 mm, without load overhang.

## A.5 Floor tolerances and deformations

### A.5.1 Sloping floors

Racking erected on sloping floors follows the slope unless corrected by shimming or grouting the upright base plates. If erected to follow the floor slope, the racking inclines to the vertical at the same angle as the floor slope.

Floors are assumed not to be sloping unless specified otherwise.

The industrial truck supplier should be contacted to check the effect of a sloping floor on the interface between truck and rack.

### A.5.2 Quasi-rigid floors

If, due to movement of the floor slab, the floor slopes such that it can no longer be considered to be a rigid slab (see EN 15512) then the industrial truck supplier should be consulted for aisle clearance information.

# Annex B
(informative)

# Racking measurement surveys

## B.1 General

The measurement survey will usually measure the installation tolerances and clearances before the racking is loaded. The tolerances stated in this document might not be applicable after the racking has been loaded.

Measurement surveys are conducted when required by individual contracts.

## B.2 Agreed grid lines and datums

Before erection of an installation commences, a basis for the measurement survey grid lines and datums should be agreed between the parties.

## B.3 Principal grid lines and datums

The main survey grid lines and datum point are:

— the System X datum lines parallel to the rack aisles;

— the System Y datum point;

— the System Z datum line perpendicular to the rack aisles.

## B.4 Measurement survey reports

### B.4.1 General

The survey should be based on the grid layout of the racks in the X Z plane and according to beam level in Y direction. Surveys should be recorded and reported.

If appropriate, ambient conditions such as temperature and wind speed should also be recorded.

### B.4.2 Measuring conditions

If the environmental conditions can affect the measurements then an appropriate correction factor should be used.

# Annex C
(informative)

# Effects of beam hogging and sagging deformations on clearances

## C.1 Effects of beam hogging and sagging deformations on clearances $X_3$, $X_4$ and $Y_1$, $Y_2$ and $Y_3$ for non-cantilevered beams

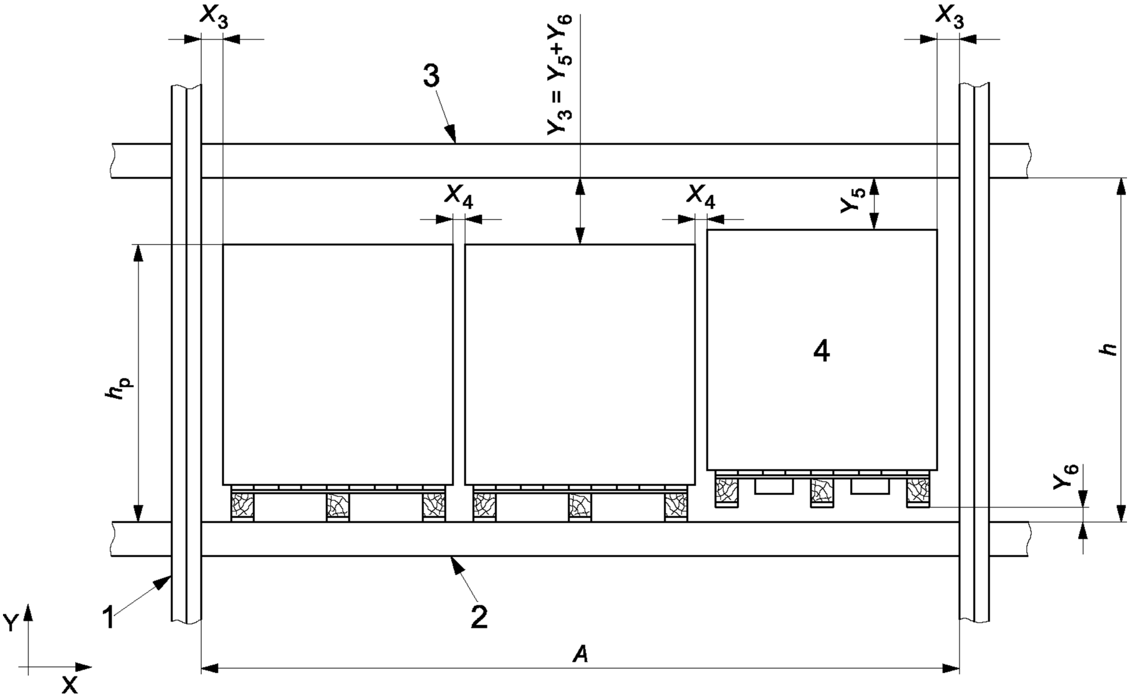
The beam deflection will reduce the nominal $X_4$ clearance; this is generally not an issue for unit loads under 3 m height. In extreme situations the slope of the load should be calculated and the clearances increased accordingly.

Unit load and rack X and Y clearances are shown in Figure C.1. $Y_6$ is determined by:

— vertical level tolerance between aisle–sided and back beam;

— MHE dynamics during depositing or picking;

— placement operation.




**Key**

1 upright

2 beams

3 beams shown without beam deflections

4 unit load on raised forks

$h_p$ height of unit load and pallet

h height of compartment

A clear entry between two uprights

$X_3$ clearance between upright and unit load

$X_4$ clearance between unit loads

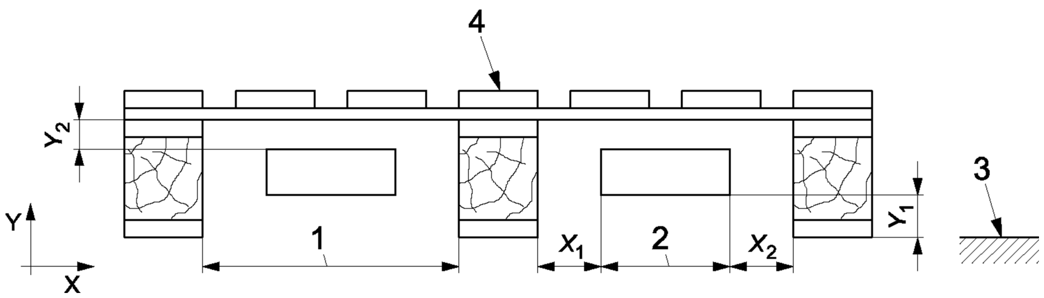
$Y_3$ clearance between top of unit load and underside of beam

$Y_5$ clearance between top of unit load and underside of beam when depositing unit load

$Y_6$ clearance between bottom of pallet and top of beam when depositing unit load

**Figure C.1 — Unit load and rack X and Y clearances**

Mechanical handling equipment fork and unit load clearances over the rack beam are shown in Figure C.2. A small pallet has a smaller aperture and the associated fork clearance shall be considered allowing for the smaller aperture.

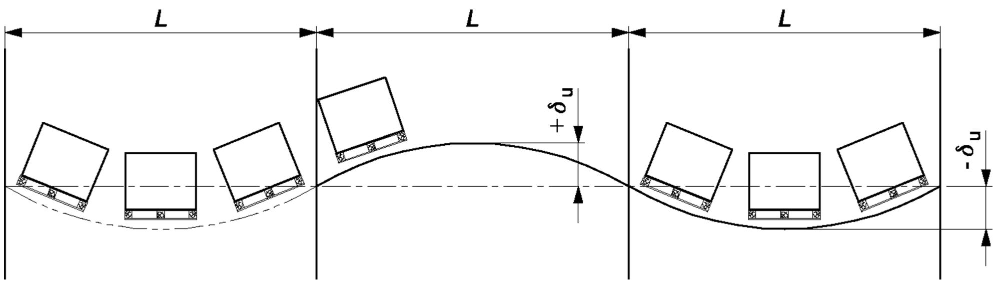



**Key**

| | |
|---|---|
| 1 | fork entry aperture |
| 2 | MHE fork width |
| 3 | top of beam |
| 4 | single deck pallet |
| $Y_1$ | fork clearance over beam |
| $Y_2$ | fork clearance under pallet |
| $X_1$ and $X_2$ | horizontal fork clearance to pallet |

**Figure C.2 — Mechanical handling equipment fork and unit load clearances over the rack beam**

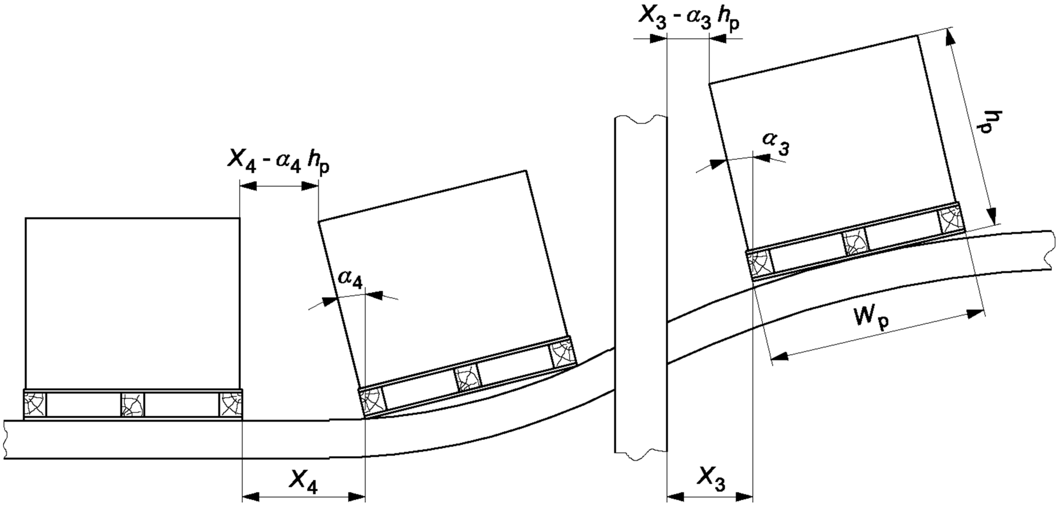
The effects of beam hogging and sagging deformation on $X_3$, $X_4$, and $Y_1$, $Y_2$ and $Y_3$ are shown in Figure C.3 and Figure C.4.




**Key**

| | |
|---|---|
| L | distance between upright centres |
| $\delta_u$ | hogging deformation |
| $\delta_d$ | sagging deformation |

**Figure C.3 — Effects on clearances of beam deformations**




**Key**

$h_p$ height of unit load and pallet

$W_p$ width of unit load and pallet

$X_3$ clearance between upright and unit load

$X_4$ clearance between unit loads

$\alpha_3$, $\alpha_4$ angles of load in compartments 3 and 4 respectively

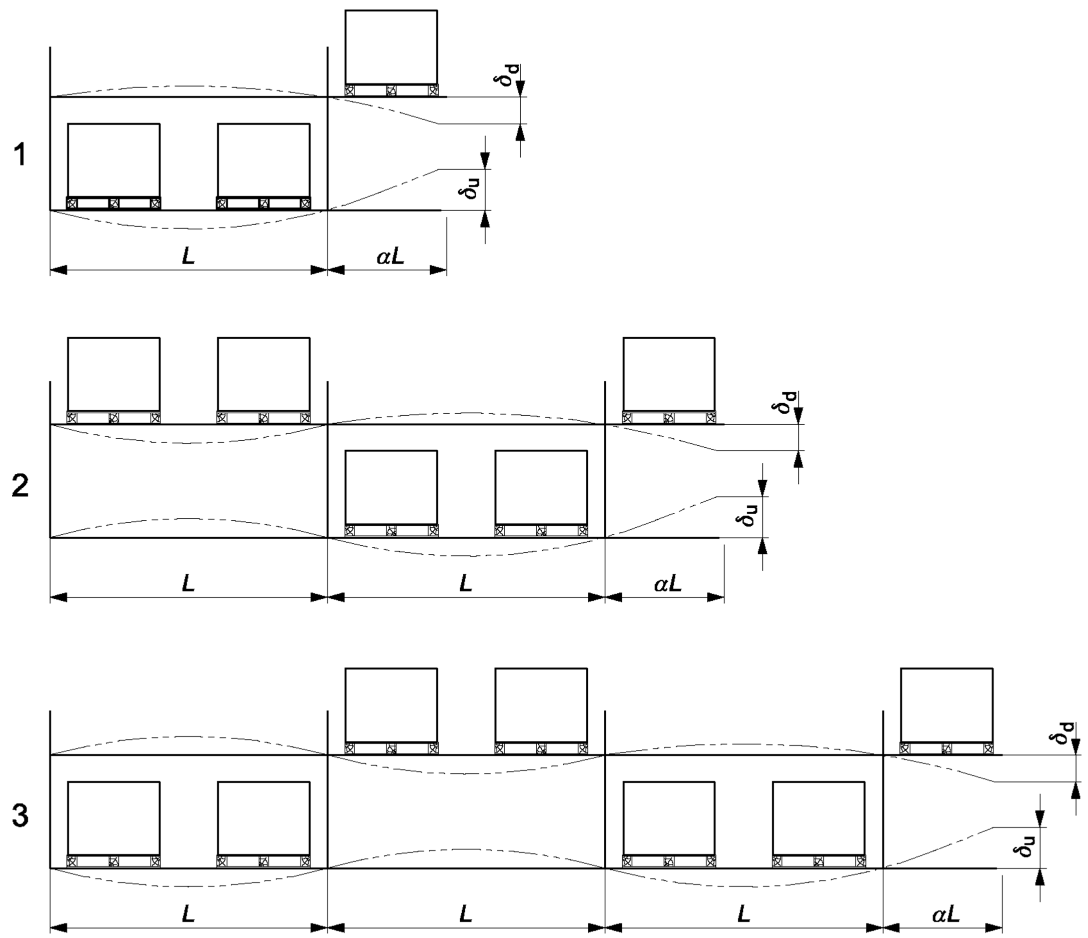
**Figure C.4 — Enlarged detail of unit load displacements**

The displacement $\alpha_4 \times h_p$ needs to be taken into account twice in a two-unit load situation.

The additional clearance $\alpha \times h_p$ to be used in the calculation of the total clearances for $X_3$ and $X_4$ depends upon the relative vertical deflections of the unit load support points along the beam that effect the verticality of the unit load. The way in which this can be accurately calculated is shown in Figure C.4. Similar procedures can be followed for various worst case combinations of pattern loading for any number of unit loads on a pair of beams and any degree of continuity of beams by rigid or semi-rigid connections to the rack uprights.

## C.2 Effects of beam hogging and sagging deformations on $X_3$ $X_4$ and $Y_1$, $Y_2$ and $Y_3$ for cantilevered beams (P & D stations)

The effects of continuous beam cantilever deflections on clearances are illustrated in Figure C.5.




**Key**

1 one bay

2 two bays

3 three bays

L distance between upright centres

$\delta_u$ hogging deformation

$\delta_d$ sagging deformation

αL distance between upright centre and end of cantilever

**Figure C.5 — Effects on clearances of cantilever beam deformations**

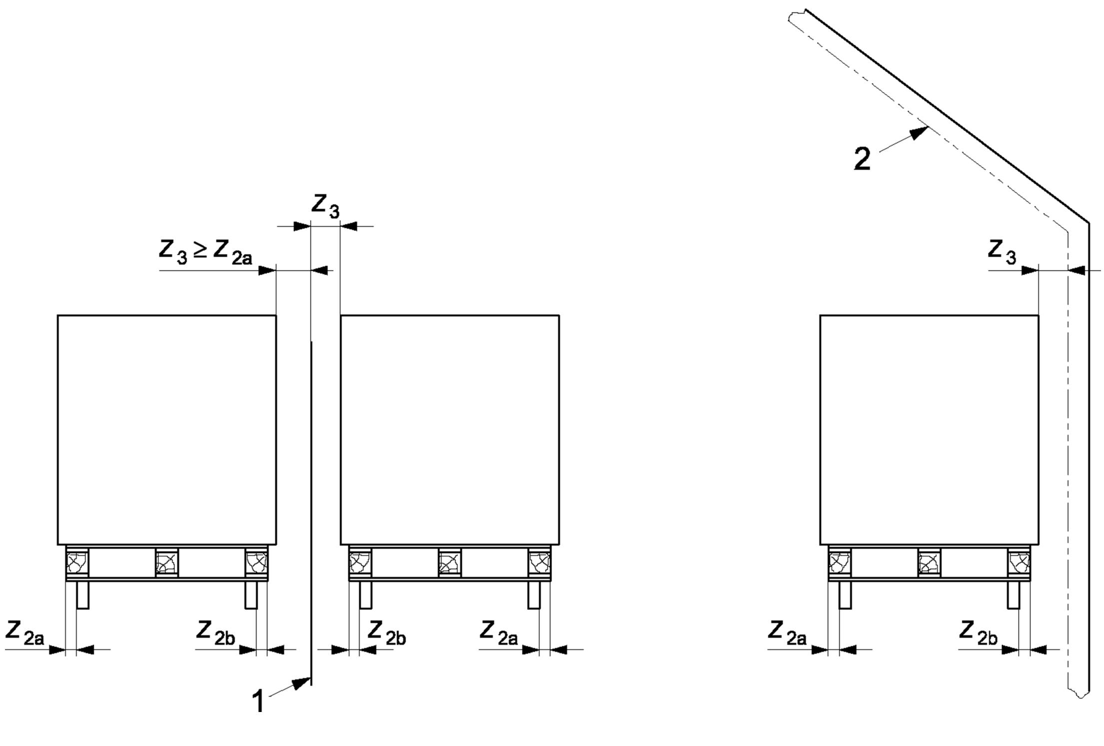
# Annex D
(informative)

# Additional information for determining dimensions and clearances in the depth of the rack (Z direction) in case of palletised loads

## D.1 Placement tolerances in the depth of the rack

The dimensions and clearances in the depth of the rack (Z direction) are shown in Figure D.1. Ideally a pallet should be placed symmetrically on a pair of beams in a pallet rack compartment. Placement tolerances in the Z direction need to be taken into account when determining the unit load clearances.

The industrial truck driver takes his placement bearings for the pallet from the front face of the aisle beam when placing the pallet. This means that placement tolerances increase with larger values of $Z_{2a}$ because a greater overhang permits greater inaccuracy.




**Key**

1 obstruction in its worst position including building movement as appropriate

2 obstruction in its worst position including building movement as appropriate

$Z_{2a}$, $Z_{2b}$ overhang of the pallet from the front and rear beams respectively

$Z_3$ clearance between unit load and obstruction

**Figure D.1 — Clearance to building obstruction due to placement tolerance (Z direction)**

The values can be different from the values given in 6.4.4.

For instance:

— $Z_{2a}$ is greater than or equal to 50 mm and less than or equal to 100 mm;

— $Z_{2b}$ is greater than or equal to 50 mm and less than or equal to 100 mm;

— $Z_{2b}$ is equal to $Z_{2a}$.

The minimum values are to ensure sufficient pallet support on the beams. However, when secondary supports are provided between the beams $Z_{2a}$ and $Z_{2b}$ may be less than zero however the distance between back to back unit loads should still be a minimum of 100 mm and $Z_3$ should still be a minimum of 50 mm.

## D.2 Larger values of $Z_{2a}$ and $Z_{2b}$

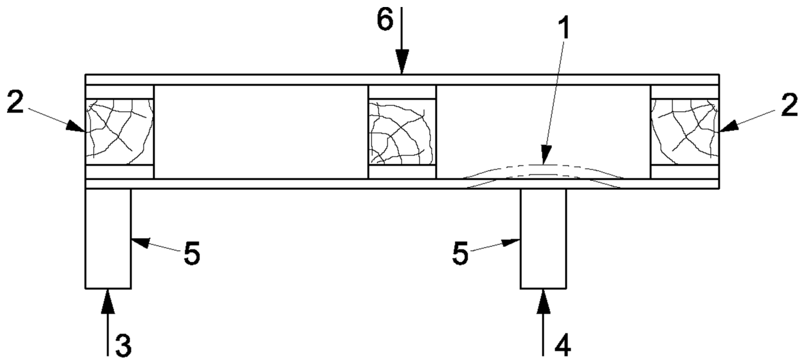
Larger values of $Z_{2a}$ and $Z_{2b}$ than 50 mm can also be used, however, in such cases the following should be considered:

a) a larger clearance between back to back unit loads ($Z_1$) and to any obstruction ($Z_3$) should be provided because placement tolerances can increase with larger values of $Z_{2a}$;

b) with larger placement variations, the difference between the loads supported by the two beams increases and should be taken into account in the design;

c) the bottom deck boards of the pallet could be incorrectly loaded.

Bottom board deformation due to incorrect pallet placement is shown in Figure D.2.




**Key**

1 deformed bottom board

2 pallet block

3 smaller beam load

4 larger beam load

5 beams

6 load

**Figure D.2 — Bottom board deformation due to incorrect pallet placement**

Larger values of $Z_{2a}$ and $Z_{2b}$ than 50 mm (e.g. 75 mm) are normally only considered in order to reduce the deflection of the pallet between the beams, as could be the case with stacker cranes or VNA trucks fitted with telescopic forks which have a height of 40 mm to 60 mm, depending on the pallet type, weight and depth.

However, such types of pallet handling equipment generally have good control of the pallet positioning:

1) the position of the equipment with respect to the racking is fixed;

2) the pallets used in association with stacker cranes should be consistent high quality; otherwise the crane and/or the pallet handling (conveyor) system would be unreliable.

Because of 1) the placement tolerance in the depth (Z direction) is much smaller compared to counterbalance or to reach truck situations.

# Annex E
(informative)

# Additional information for very narrow aisle trucks in adjustable pallet racking

## E.1 Considerations for the Z direction

The location of the unit load, when deposited, depends upon a number of factors including:

1) the verticality of the rack frames in the Z direction;

2) the manual placement tolerance in the Z direction; in the cross aisle direction, $Z_{2a}$ (see 6.4.4 and Annex D).

The aisle clearance should include the following factors:

— the location of the unit load in the rack;

— the level of the floor across the aisle causing the truck to lean;

— the location of the unit load on the truck;

— the static and dynamic mast sway of the truck;

— the differential wear and deflection of the truck tyres;

— looseness in the truck mechanism, which increases with wear;

— the tolerance of the guidance system;

— the unit load tolerances.

## E.2 Considerations in the Y direction

Generally, very narrow aisle trucks are fitted with fixed forks, but there are some truck designs with telescopic forks.

A fixed fork is about 40 mm deep whereas a telescopic fork is about 60 mm to 70 mm deep, therefore a fixed fork can operate with a smaller vertical opening than a telescopic fork.

## E.3 Considerations in the X direction

In the down aisle direction the tolerance depends on the instruction to the operator, e.g. 25 mm.

# Annex F
(informative)

# Consideration of tolerances and deformations in determining clearances

## F.1 General

The reliability of a storage system is usually ensured by the system designer calculating the "worst case" summation of all the parameters that affect the safe interaction of the handling equipment, unit load and racking. These are considered in addition with any other equipment, for example a sprinkler system, which might need to be taken into account.

The "worst case" calculation means that if all agreed tolerances and deformations are at their maximum value and are all affecting the parameter concerned at the same time in the most unfavourable direction, the clearances between moving and stationary parts to the system are sufficient to avoid collisions.

The statistical probability that the worst case could arise in reality is relatively small because a relatively large number of variables is involved. Therefore, storage systems can function entirely satisfactorily even when one or two tolerances and deformations are marginally larger than specified.

The values stated in this document may be amended for technical or economic reasons, if the functionality and safe operation of the whole system can be guaranteed.

## F.2 Storage systems other than single deep adjustable pallet racking

In racking systems that are different from single deep adjustable pallet rack arrangements, such as double deep racks or open-face (cantilever beamless racks), these recommendations should be reviewed and adjusted to meet the safe practical operational requirements of the storage system being designed.

# Annex G
(informative)

# Sprinkler systems

Sprinklers used in storage systems are generally either fixed to the roof of the building and/or integrated into the racking.

In both cases the sprinkler system can only be effective if the water can spread as required and this requires that sufficient clearances are available between the sprinklers, stored unit loads, rack and building.

The clearances depend upon the design of the sprinkler system and should take into account the worst position of the stored goods and placement tolerances. The procedure is generally as follows:

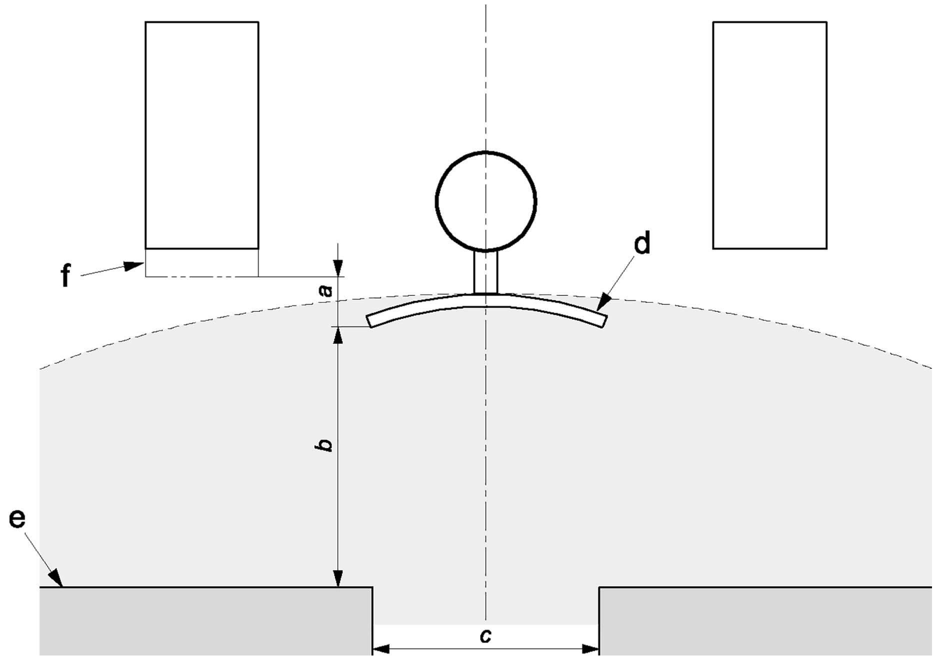
— User/specifier defines the load, unit load sizes and placement tolerances.

— Rack supplier defines rack information including deflection and tolerances.

— The specifier (or body responsible for the fire design) provides the free space dimensions and sprinkler requirements with respect to the rack sprinkler interface such as, clearances, flue space dimensions, actions induced by the sprinkler system and position of sprinkler to rack connections.

— Rack supplier provides a suitable rack arrangement for acceptance by specifier.

Typical locations where clearances due to sprinklers may be specified are shown in Figure G.1, Figure G.2 and Figure G.3.




**Key**

a dimension of sprinkler deflector below deflected position of beam

b minimum vertical dimension between unit load and sprinkler deflector

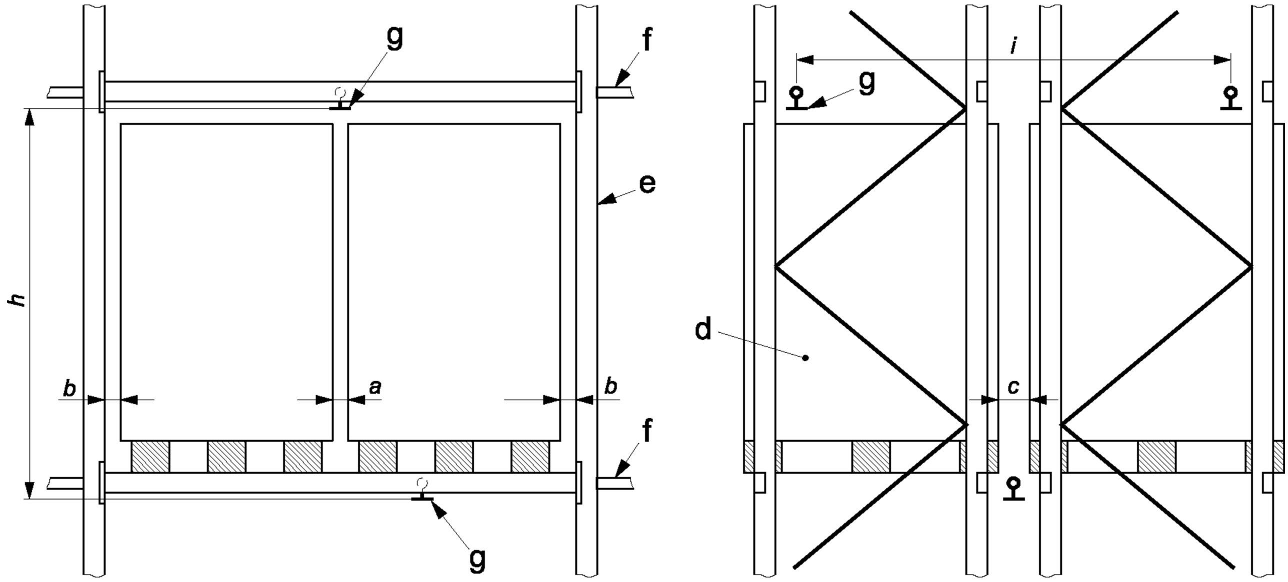
c minimum horizontal dimension between unit loads (with loads in most disadvantageous position)

d sprinkler head (deflector)

e unit load

f design deflected position of beam

**Figure G.1 — In-rack sprinklers — Critical dimensions with beam deflection**




**Key**

a minimum horizontal dimension between unit loads

b minimum horizontal dimension between unit load and rack

c minimum horizontal dimension between unit loads (with loads in most disadvantageous position)

d unit load

e rack frame

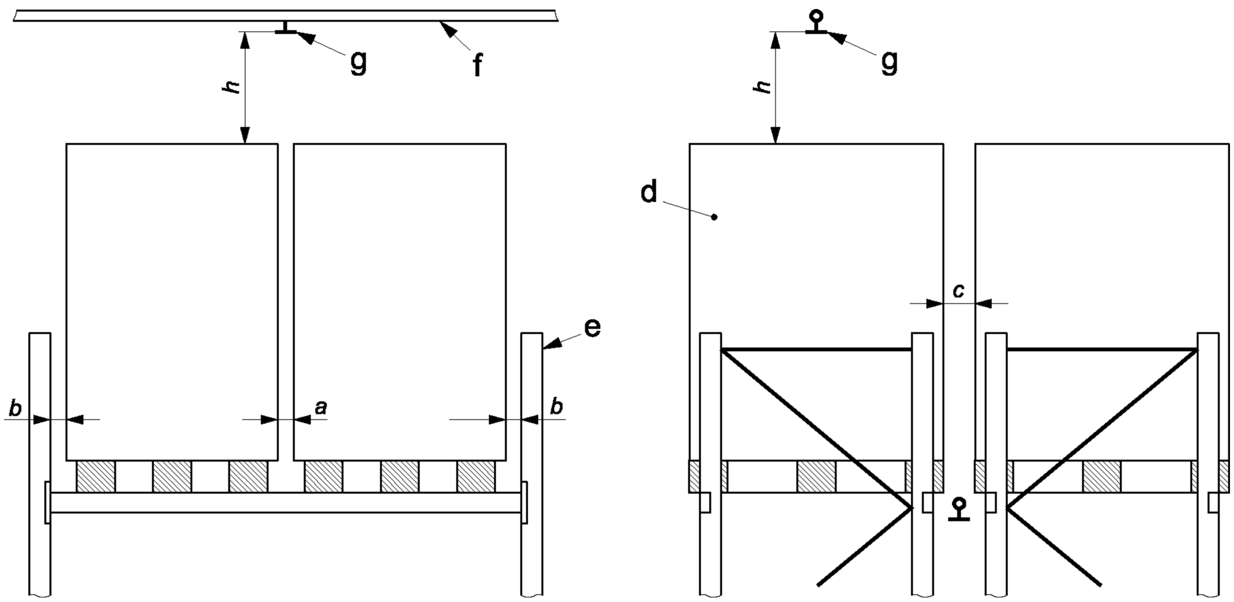
f sprinkler pipe

g sprinkler head

h maximum vertical dimension between sprinkler heads

i maximum horizontal dimension between sprinkler heads

**Figure G.2 — In–rack sprinklers — Critical dimensions**




**Key**

a minimum horizontal dimension between unit loads

b minimum horizontal dimension between unit loads and rack

c minimum horizontal dimension between unit loads (with loads in most disadvantageous position)

d unit load

e rack frame

f roof sprinkler pipe

g sprinkler head

h vertical dimension between load and sprinkler (both minimum and maximum)

**Figure G.3 — Roof sprinklers — Critical dimensions**

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