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1 Introduction and Aims

In automatic small parts warehouses items are mainly stored by means of load carriers or load make-up accessories, such as boxes, storage trays and cases. Storage and retrieval is automatically achieved by a Storage and Retrieval (referred to as S/R in the continuing text) machine. Load handling devices operate with lift, pull or grabbing mechanisms. The racks are designed as single or multi-location systems. Their functionality depends on a number of system components. The interrelation of tolerances and deformations during operation requires sufficient clearance between moving loads or unit loads and fixed system components.

The aim of this document is to show the relation of the individual system components in respect of tolerances and deformations. Permissible practical tolerances and deformations shall be listed for typical system solutions. The aim is that the values for individual system components will result in clearly defined levels of responsibility in the event of interface problems.

Due to the tolerances and deformations quantified in this document as well as the additional data for tolerances, wear and deformation of the S/R machine and the load make-up accessories, calculations for clearances and entry clearances must be made. The method used is described in section 7.

The aim of this document is to determine the admissible deformations and tolerances in order to optimise the factors relating to the economical dimensioning, manufacturing and assembly required for the safe functioning of the overall system.

2 Scope

This document applies to automatic small parts warehouses (not silo design) with S/R machines which travel on a floor mounted rail and are stabilized by an upper guide rail. The storage locations in the rack must be filled as evenly as possible (random storage).

If there is to be a deviation from this guideline in a specific instance, clear arrangements must be made and evidence of functionality of the overall system in any given operating system produced, taking normal wear into account.

3 Definitions

Coordinate positioning: Positioning of the S/R machine using global coordinates.

Positioning via the Teach-in Process: Teach-in processes rely on calculating the position coordinates by means of an initial control of all storage locations. The actual coordinates calculated are stored in the control system and can be reproduced. Through permanent control points the system can monitor and correct itself where possible. Depending on the warehouse configuration the Teach-in Process can require considerable effort in calculating the individual coordinates.

Location fine positioning: Basic positioning of the S/R machine using global coordinates, followed by rack fine positioning via additional sensors for the X and/or Y coordinates. The greater accuracy this achieves is accompanied by a loss in performance.

System level: Plane without tolerances in XY direction, XZ direction and YZ direction, defined by clearly marked points or straight lines.

Tolerance: The permissible maximum deviation from nominal dimension, resulting from manufacture and assembly.

Deformation: Deviation from the basic position due to the effect of forces.

Clearance: The required nominal distance between fixed and moving parts and which, all individual tolerances and deformations considered, prevent collisions.

Entry Clearance: Clearance between the load handling device and the load make-up accessory or rack structure.

Rack compartment clearance: Clearance between respective unit loads and the rack structure.

Aisle clearance: Clearance between the outer most edge of the S/R machine and the outer most edge of the rack or the unit load and clearances at the rear of the stored unit load.

System axes: A fixed straight line between 2 points in the X direction (aisle length direction), Y direction (aisle vertical direction) and Z direction (aisle lateral direction).

Auxiliary level: Vertical or horizontal level without tolerances.

4 Factors of Influence

A common height plane as well as common horizontal axes shall normally be defined for all components by the persons responsible for the construction. These shall be marked clearly and permanently, and shall act as reference points for the project-related datum planes and axes.

When calculating the internal measurements of the building the negative effects of deformations and tolerances must be taken into account.

Persons responsible for the construction must be able to demonstrate its suitability for use and thus define the conditions (forces, tolerance, admissible deformations and clearances).

The constructors and sub-contractors shall ensure that individual components (e.g. floor slabs, racks, S/R machines) have sufficient capacity for the agreed loads and maintain the defined tolerances and deformations.

Tolerances and possible deformations will result from the following operating components of an automatic small parts warehouse:

- surface/foundations behaviour under load
- floor slab (manufacturing accuracy and behaviour under load)
- floor rail
- guide rail
- load make-up accessories incl. load
- profile check
- storage location
- S/R machine
- rack structure

In contrast to high bay storage where pallets are mainly used, automatic small parts stores are characterised by a wide range of solutions for load handling devices on S/R machines and load make-up accessories. The following types of load handling device can be used:

- I. Telescopic tables (used with lifting mechanism)
- II. Mechanical insertion/extraction (pulling device) at the front of the load make up accessory
- III. Lateral grabbing / pushing devices
- IV. Belt or conveyor pulling devices
- V. All other types: All requirements must be agreed by the contract parties.

Plastic containers, metal containers, trays, rigid plattens (e.g. wooden plattens), cardboard boxes etc. can be used as unit loads or load make-up accessories. As a rule, any given load make-up accessory will require a particular load handling device. The properties of these system components may require different clearances.

4.2.2 Vertical deformations of the floor slab / sub-structure under load

These deformations (e.g. adaptation of the floor slab to the settlement of the foundations, piles and/or supports, permanent deformation) can result in additional stresses and inclination from the vertical of the rack structure and the S/R machines. These are noted here only from a qualitative point of view.

Where certain types of surface and/or floor slab conditions exist it is, nevertheless, possible for deformations to such an extent (often to be measured in cms) to occur that they merit consideration when assessing clearances and additional stresses. If necessary, special design features should be implemented.

All the following considerations are based on a quasi-rigid floor slab for all storage component designs unless specific information is provided by the civil engineer or client.

A floor slab is quasi-rigid if the following vertical deformations are not exceeded:

- overall vertical deformation:
 - 1/3000 of the total storage length
 - 1/3000 of the total storage width
- local vertical deformations:
 - 1/2500 over distances up to $l = 3$ m in comparison to the reference plane in the X and Z directions in the rack area. l is the frame depth and/or width for stiffening towers.

The short-term and long-term behaviour of the floor slab/sub-structure must be taken into account when assessing these deformations.

4.3 Floor Rail

4.3.1 Type of floor rail

The sizing and selection of the type of floor rail and its method of fixing and its frequency is the responsibility of S/R machine manufacturer in association with the rail supplier and the engineer responsible for the floor slab.

NOTE: If the travel rail is installed after assembling the rack system, its lateral and vertical positioning should match the rack system axes.

The floor running rail positioning tolerance demands must be taken into account when selecting the rail profile (manufacturing tolerances for certain profiles may exceed the positioning tolerances).

The travel performance of the S/R machine can be influenced by any unevenness of the rail around the running surface and the lateral guides as well as by the manufacturing accuracy. The surface must be level in this area, i.e. without pitting (rust, holes etc.).

4.3.2 Tolerances of the floor rail in the Z direction

T19: Alignment accuracy of the floor rail in relation to a tolerance-free, vertical datum plane which must run parallel to the rack datum plane measured on the bearing surface of the guide rollers.

T24: Installation tolerance of the floor rail in relation to a tolerance-free, vertical datum plane which must run parallel to the rack datum plane measured on the bearing surface of the guide rollers.

Any variations of alignment at the joints of the guide roller running surface must be ground flat. Flatness of the rail and the joint over a measured length of 200 mm must be ≤ 0.5 mm.

Figures are given in chapter 6.

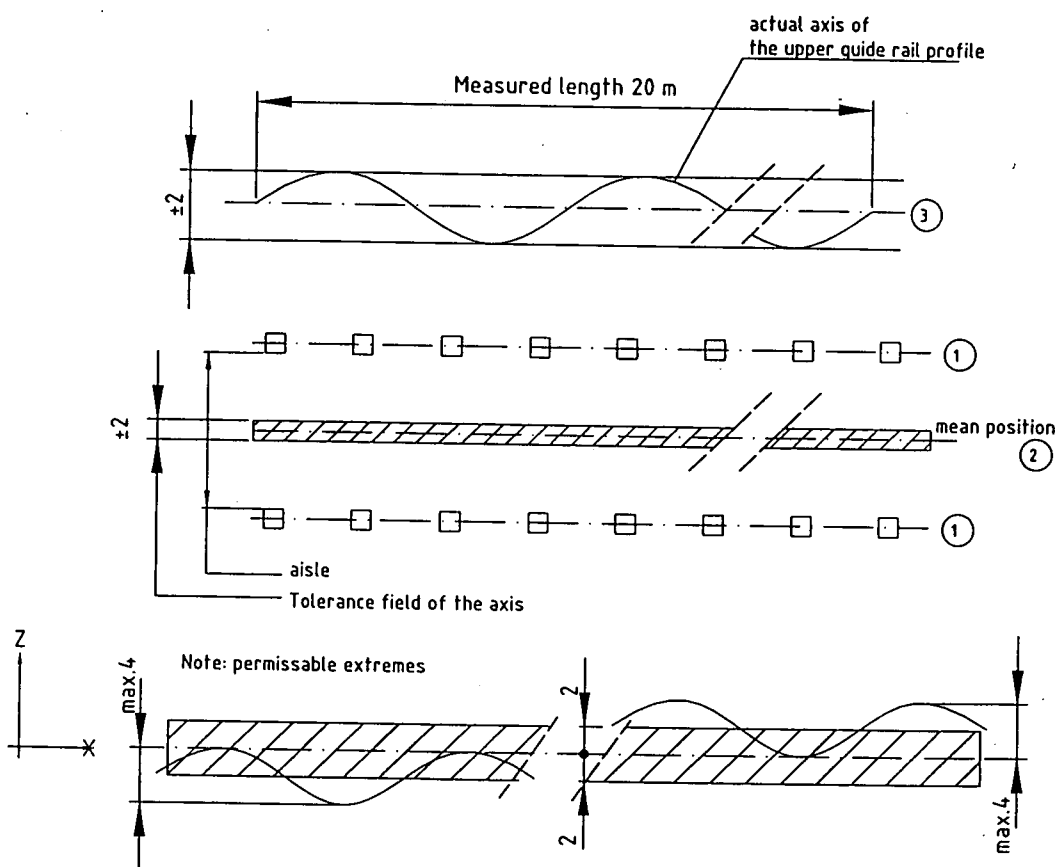
4.3.3 Tolerances of the floor rail in the Y-direction

T21: Height tolerances of the floor rail head in the vertical direction, in relation to a tolerance-free, horizontal datum plane.

Figures are given in chapter 6.

Any variations of levelness at the rail joints of the wheel running surface must be ground flat. Flatness of the rail and the joint over a measured length of 100 mm must be ≤ 0.1 mm.

4.4 Upper Guide Rail



Key:

- ① Mean position of the reference datums of the uprights adjacent to the aisle
- ② Theoretical axis of the upper guide rail relative to the rack upright axes
- ③ The actual axis of the upper guide rail. This axis shall lie inside the tolerance range of ± 2 mm relative to the reference position.

Figure 1: Tolerances for the upper guide rail (plan view)

4.4.1 The position of the longitudinal axis of the upper guide rail may not exceed the tolerances in relation to the mean of the centrelines of the top of the rack uprights along the aisle by ± 2 mm over a measured length of 20 m (see figure 1).

4.4.2 In the area of the guide rollers the horizontal deviation of the upper guide rail from its longitudinal axis (without load) shall not exceed ± 2 mm (see figure 1). Over a measured length of 2 m the horizontal deviation must lie within ± 1 mm.

4.4.3 Any variations in rail profile at joints in the running area of guide rollers over a length of 200 mm shall be ground flat. Flatness in a measured length of 200 mm shall be ≤ 1 mm.

4.4.4 There shall be no rolling inscriptions on the running surfaces.

4.4.5 The maximum lateral deformation (sagging and twisting) in the area of the guide rollers due to the reaction forces of the S/R machine between two fixing positions shall not exceed 3 mm (V11).

4.4.6 The lower edge of the guide rail shall not exceed the tolerance field $+5/-2$ mm (T22) in comparison to a tolerance-free datum plane when the racking is unloaded (see figure 3).

4.4.7 The sizing and selection of the type of guide rail and the method of fixing is the responsibility of the S/R machine manufacturer in conjunction with the supplier of the upper guide rail, (e.g. rack supplier).

The high demands on the positioning tolerances of the upper guide rail must be taken into account when selecting the guide rail profile (manufacturing tolerances for certain profiles may be greater than the positioning tolerances).

4.5 Unit Load

4.5.1 Load make-up accessories

Due to the number of different load make-up accessories or unit loads, it is impossible to give guidelines for tolerances and deformations.

Qualitatively, reference should be made e.g. to the following:

- deformation of the 4 sides of load make-up accessories (e.g. boxes, containers) when filling them with loose items
- sagging of the load make-up accessory or base when loaded
- squariness of the base of the load make-up accessory
- squariness of the side walls to the base of the load make-up accessory
- additional deformations during lengthy storage periods
- moulding burrs and deposits or unevenness from manufacture of plastic containers
- protruding or engraved text
- damage or wear resulting from use.

The S/R machine manufacturer, rack manufacturer and user shall agree on the type of load make-up accessory, its stability and quality. In the absence of other information, it is assumed that the edges of the load make-up accessory are resistant to bending, although the base is not specified as having to be resistant to warping.

4.5.2 Loading

If due to physical characteristics or operational requirements it is not possible to ensure that the load is within the parameters of the load make-up accessory (length, width, height), these factors must be taken into consideration and the loads passed through a profile check (see 4.6).

The S/R machine manufacturer, rack manufacturer and user shall agree on the position of the load centre of gravity. In particular, attention must be given to fluids or sliding loads which are critical in terms of stability.

4.5.3 Guidance into the aperture

If the clearances from the tolerance calculations are not obtained, bevels or radii on the rack uprights, load supports and load make-up accessories can allow the input and output of loads at the storage apertures under certain conditions. The main conditions for this are:

- a securely fixed load support profile member or at the least a strong positive connection between the load handling device and the load make-up accessory. Any tilt movement on the part of the load make-up accessory must be taken into account.
- bevels at a shallow angle of slope, so that the load make-up accessory does not move in an uncontrolled manner or becomes separated from the load handling device on impact.
- sufficiently large radii to act as guidance at an aperture entrance.
- that the friction coefficients between the materials used allow positive sliding into the apertures.
- no jamming can occur due to the twisting of the load on the load handling device when storing and retrieving.

The extent to which these influences shall be taken into account when calculating the clearance is solely the responsibility of the S/R machine manufacturer who is responsible for operational safety. The rack manufacturer shall be informed of the forces which are derived from this decision.

Figure 2 shows a recommendation for the calculation of slopes and radii for the clearances.

It is recommended that a permissible impact point is selected at about 2/3rds of the bevel "e". The bevel should not exceed a maximum of 30°.

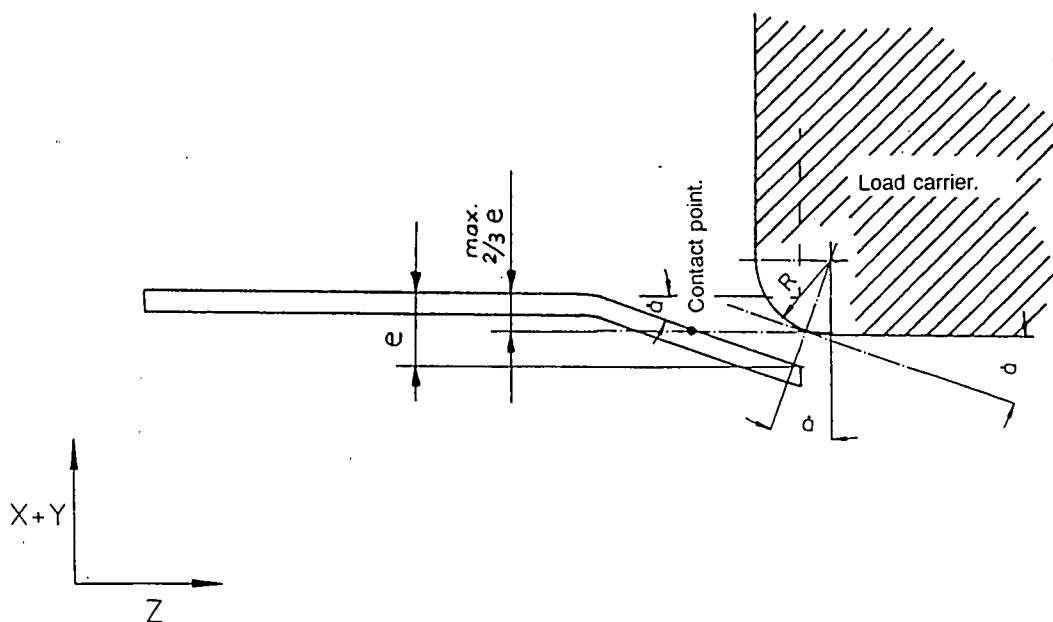


Figure 2: Entry guidance (side and height)

4.5.4 Friction between the load make-up accessory and supporting profile in the rack

In all systems where the load make-up accessory slides, frictional forces occur between the load support surfaces in the rack and the load make-up accessory. By appropriate material selection (to be ascertained by testing) frictional pairings and thus the frictional coefficient can be determined. It is preferable to keep these coefficients as low as possible to limit forces and deformations. Painted surfaces and plastics require particular attention. It should also be borne in mind that the frictional coefficient can change in certain conditions (e.g. frost, plastic packaging).

It is important to note that the transition from static friction to sliding friction cause impacts which can lead to vibrations of the S/R machine and the racking structure.

Rack vibrations can be ignored when calculating clearances in detail.

4.6 Profile Check

Profile checking may be necessary to monitor the height, width and length.

In general, devices with photocells measure the profiles with the following tolerances:

- height: ± 2 mm
- width: ± 3 mm per side
- length: ± 3 mm per side This may be increased for checking the load whilst moving.
- base: ± 2 mm

The lowest tolerance level should be the maximum contractually stipulated load dimension.

4.7 Storage location

The unit load shall be positioned at the storage location with the following tolerances except when positioning can take place on the machine:

Table 1

Load handling device	In X direction	In Z direction
Type I	± 2 mm	± 3 mm
Type II,III,IV	± 5 mm	LL ≤ 500 mm: ± 1 % from LL LL > 500 mm: ± 5 mm

where:

LL = Length of the load make-up accessory in the Z direction

4.8 S/R machine

The sum of the tolerances in the X, Y and Z directions caused by the S/R machine are considered in sections 4.8.1 to 4.8.3.

Due to considerable differences between different manufacturers' S/R machines in terms of dimensions, rigidity and other design features, this data cannot be specified within these rules. In each particular case this data shall be specified by the S/R machine manufacturer. On the basis of this data, the S/R machine manufacturer and/or the person responsible for the system shall check the overall tolerances in order to ensure the functioning of the system.

The S/R machine tolerances used in the calculation examples (see Annex A) can only be regarded as examples to demonstrate the effects tolerances have on the overall system.

4.8.1 System tolerances due to the S/R machine

Clearances can be influenced e.g. by the following:

- tolerances for the mast or the lifting carriage guides on the mast
- lifting carriage guide play
- load handling device tolerances
- play in the Z direction between the track and guide rollers in respect of the travel or guide rail
- mechanical wear

4.8.2 Elastic Deformation

Due to alternating load effects when retrieving and depositing load units, components such as the mast, lifting carriage, and load handling device are subject to deformation which is of importance for fork entry and rack compartment clearances and need to be taken into account when determining the clearances.

4.8.3 Positioning Tolerances

The positioning accuracy in the X, Y and Z directions is affected e.g. by the following factors of influence:

- positioning system and motor control
- positioning speed
- delay period of the control system
- brake application delay
- braking distance differences due to wear, temperature and changes of the coefficient of friction
- backlash in the drive units
- approach to destinations from either direction
- switching accuracy (e.g. hysteresis) of the positioning sensors (switches, photocells, proximity switches)
- deviation of an incremental transmitter system from the absolute dimensions
- When using positioning markers (control cams, reflective tape, inductive switches flags etc.) these shall be fitted to a tolerance of ± 1 mm (T23), relative to their nominal location.

In case of re-depositing of load units without an additional centering addition of positioning tolerances shall be taken into account.

4.9 Rack structure

The following information is applicable for rack structures in accordance with figure 3.

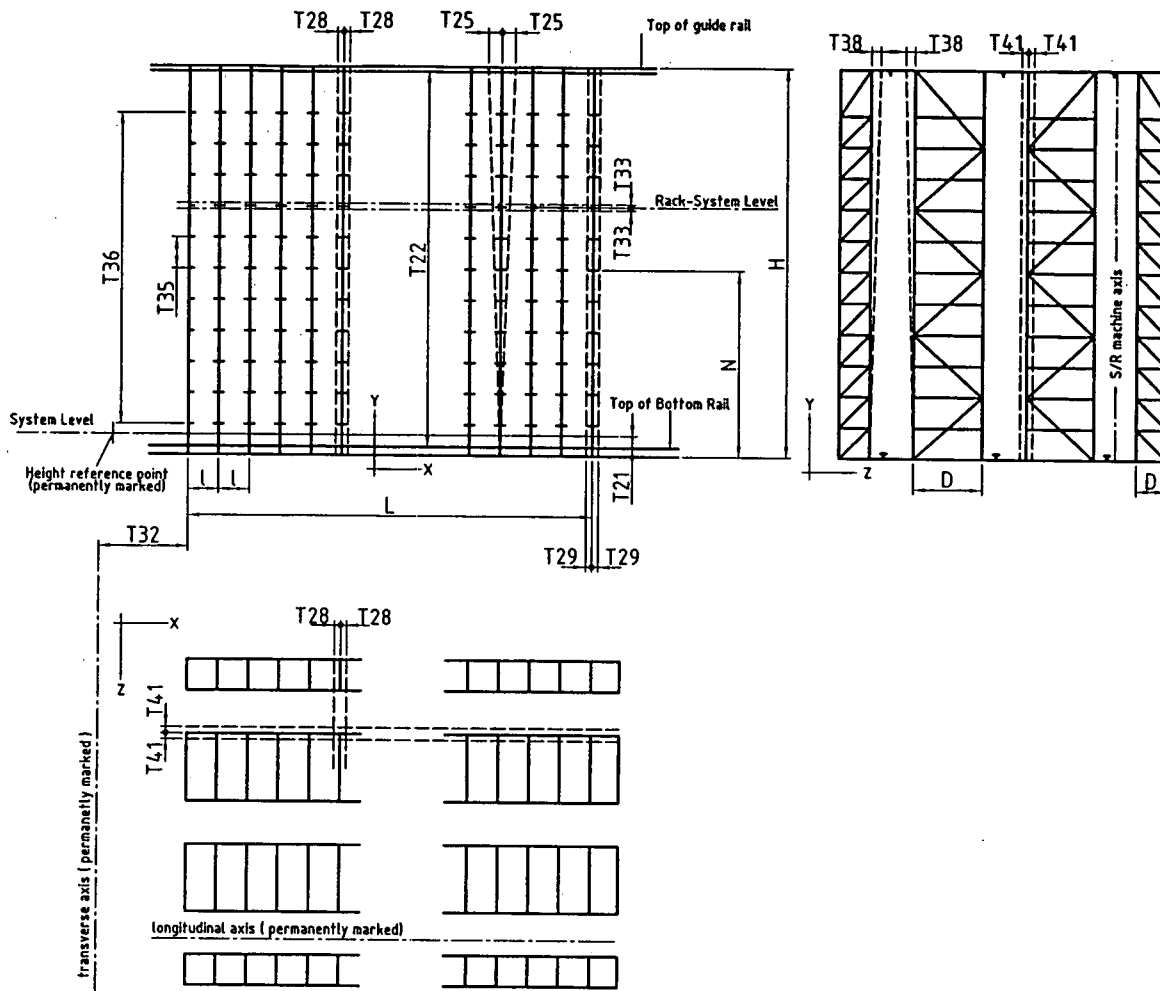


Figure 3: Rack structure (example of single location storage)

All the following details refer to free standing rack structures.

The load make-up accessories are stored on supporting profiles, e.g. supporting angles as illustrated in Figures 4 and 5.

A minimum support width of 5 mm must be maintained, taking into account the tolerances of the rack and the load make-up accessory.

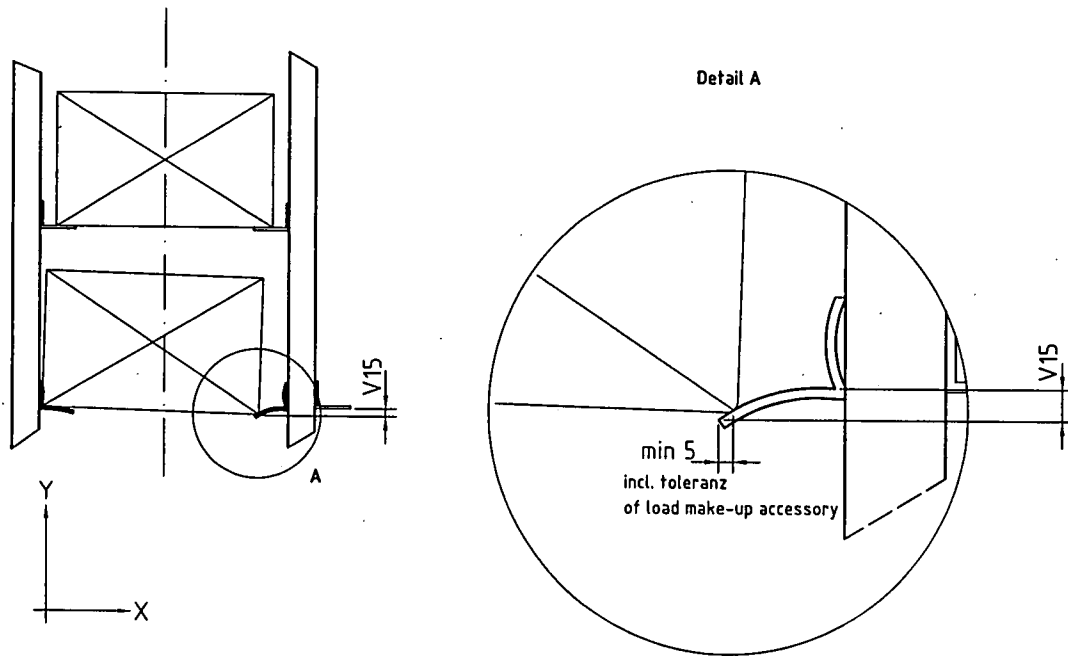


Figure 4: Deformation of the support profile

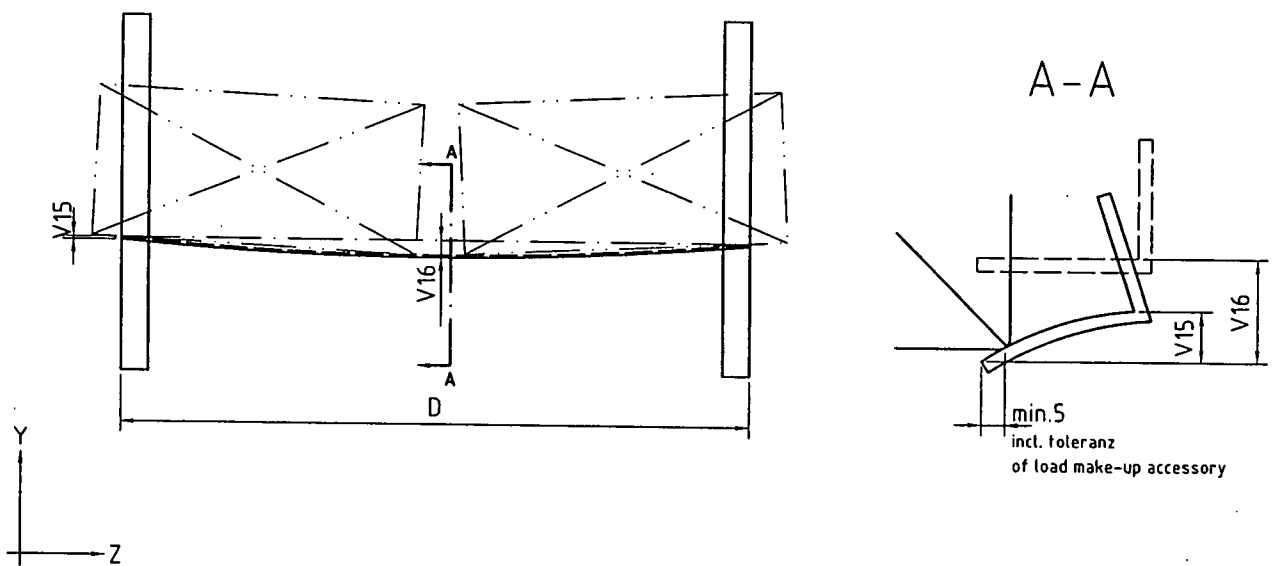


Figure 5: Deformation of the support profile e.g. twin-depth single location storage

4.9.1 Manufacturing and erection tolerances in the unloaded condition

4.9.1.1 Dimensions in the X direction

In the X direction the following tolerances shall be considered due to manufacturing and assembly of the rack (see figures 3 and 6) for:

- T25: deviation of the upright axis relative to a vertical datum
- T26: offset of the upright feet on the left and right-hand sides of the aisle
- T27: upright frame at right-angles to the aisle axis
- pre-bending of the upright (contained in T28)
- T28: sum of tolerances of T25, T26, pre-bending and T27
- T29: tolerance of the rack length L
- T30: tolerance of the rack entry width for the load make-up accessory
- T31: tolerance of the rack entry width for the load handling device
- T32: tolerance of the distance from the front upright axis to the vertical system plane

Figures are given in chapter 6.

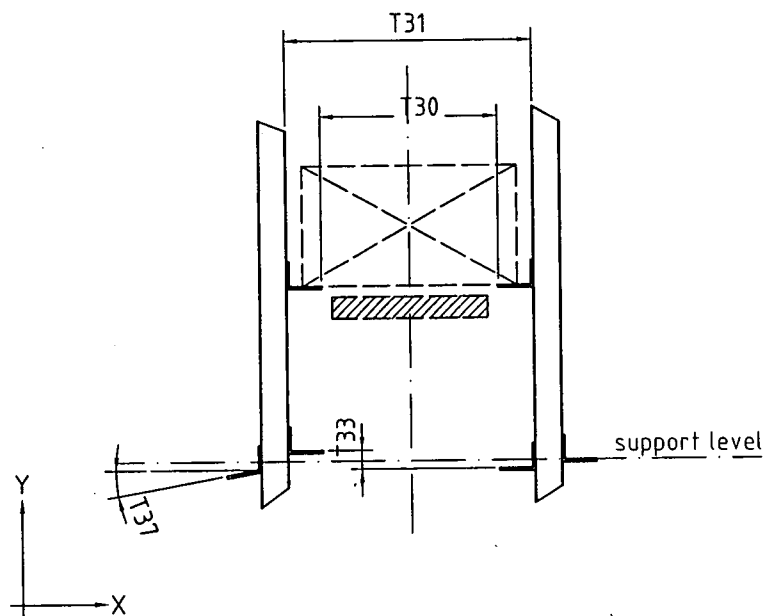


Figure 6: View of rack aperture

4.9.1.2 Dimensions in the Y direction

The rack system plane is specified by the rack manufacturer. Ideally, this plane should be half the rack height or a height above a joint.

In the Y direction the following tolerances shall be considered due to manufacturing and assembly of the rack (see figures 3 and 7):

- T33: level tolerance of the supporting beams facing the aisle at each level
- T34: difference in height between the front and rear supporting beams in single-depth single location storage
- T35: distance tolerance for two adjacent planes
- T36: tolerance of the distance from the lowest to the highest support levels
- T37: tolerance of supporting beam horizontal

Figures are given in chapter 6.

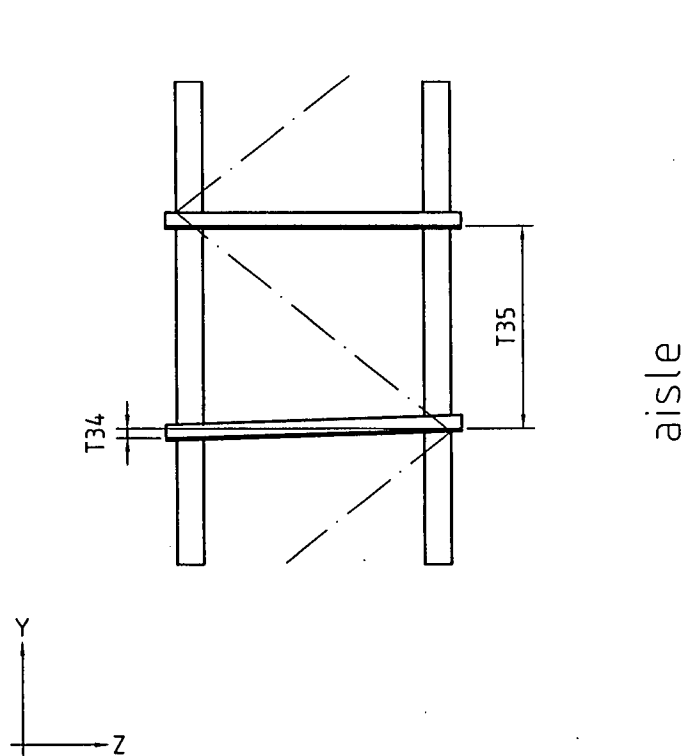


Figure 7: Tolerances of support in Y direction

4.9.1.3 Dimensions in the Z direction

In the Z direction the following tolerances shall be considered due to manufacturing and assembly of the rack (see figures 3 and 8):

- T38: deviation of the front upright axis from a vertical
- T39: upright foot deviation from the system axis in the X direction per aisle
- T40: pre-bending of the unloaded upright frame
- T41: sum of the tolerances of T38, T39 and T40
- T42: tolerance of the back stop to the front edge of the support
- T43: tolerance of the position of the rear obstructing edge connected to the rack (e.g. fences, sheets with trapezoidal corrugations and rigidity design)

Figures are given in chapter 6.

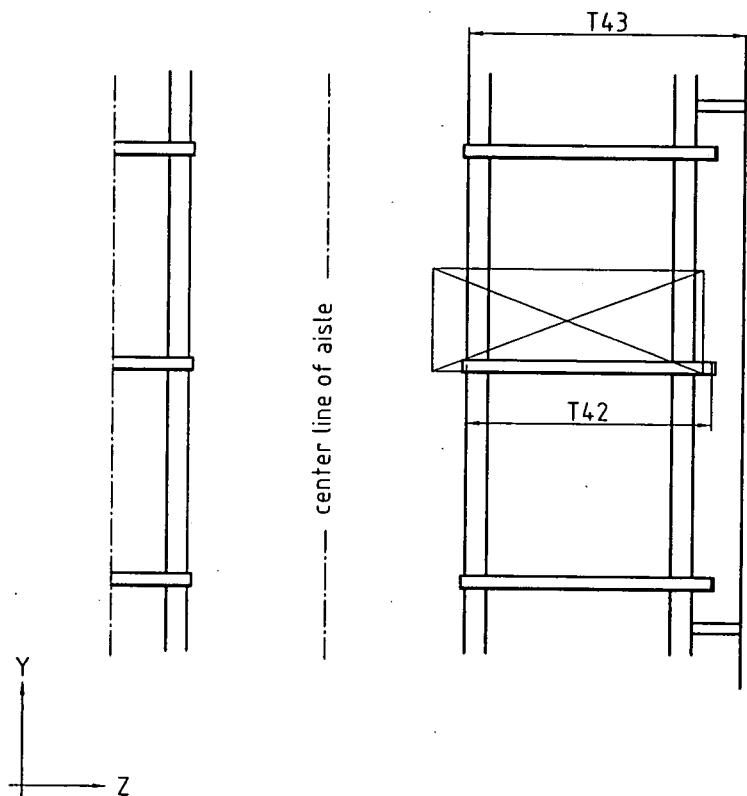


Figure 8: Rack end elevation

4.9.2 Deformations due to forces

Deformation of the racking can occur due to the following:

- the loads stored
- frictional forces of a unit load during storage or retrieval (pulling mechanism)
- additional load forces resulting from the tilting of the rack structure during erection
- reactional forces of the S/R machine on the guide rail in the following situations:
 - a) during travel
 - b) docking (directly prior to making contact with the load make-up accessory)
 - c) Storage / retrieval input/output of the racking
- temperature changes
- transfer of forces from neighbouring aisles or other warehouse equipment e.g. conveyors

The following deformations must be considered on an individual basis and incorporated in the system supplier's overall assessment of the system's suitability:

- deformation of the uprights and frames in the X, Y and Z directions
- deformation of the angle support

The deformation of the rack uprights depends on the physical properties of the material used, the rack height, buckling lengths and loading. The rack manufacturer should be able to provide estimated deformation data.

NOTE: The following deformation data can be used as a guideline:

Table 2

Rack height (m)	Uppermost rack deformation (mm)	
	Steel quality S235	Steel quality S355
6	1 to 1.5	1.5 to 2.5
10	1.5 to 2.5	2.5 to 4
16	2.5 to 4.5	4 to 6.5
20	3.5 to 5	5 to 8
24	4 to 6	6 to 10

In order to demonstrate functionality (deformation) in multi-aisle stores, the calculation must only be made with the force of a single S/R machine at the same X location. In general, the least favourable loading cases are relevant.

Unless otherwise agreed it is assumed that the loads in the rack are evenly distributed, i.e. no concentration of loads next to empty racks. In particular, when filling the warehouse for the first time, it has to be ensured that goods are stored in horizontal layers starting from the lowest level and working upwards. This can also ensure that the rack deformation is taken into account when setting the positioning markers.

4.9.2.1 Deformation values for uprights and/ or upright frame deformation

The following uprights or upright frame deformation must be considered:

- V13: side displacement of the highest point of the upright frame during operation due to external forces and payloads
- V17: deformation of uprights at the highest support plane
- V18: side displacement of the highest point of the upright frame diagonal to the aisle during operation due to external forces and payloads (calculation basis for force-acting: appr. 3 m behind the first upright inside the racking). In the furthest operating position the deflection must not be more than twice the value as given in table 3.

NOTE: It should be ensured by the use of horizontal bracing at the top of the uprights that the movement on both sides of the aisle is equal and in the same direction.

4.9.2.2 Deformation of the supporting angle with the load in the storage position

The following supporting angle deformation must be considered (see figure 4, 5, and 9):

- V14: deformation of the supporting beam with tension width l for multi-location storage
- V15: deformation of the supporting angle flange with a 100 % non-centrally arranged load around the support for single location storage
- V16: vertical lowering of the supporting beams with a 100 % non-centrally arranged load due to sagging, torsion and local bending of the profile

There should be no residual deformation from the entry angle due to the load if the load is positioned to its max. eccentricity in respect of the supporting angle.

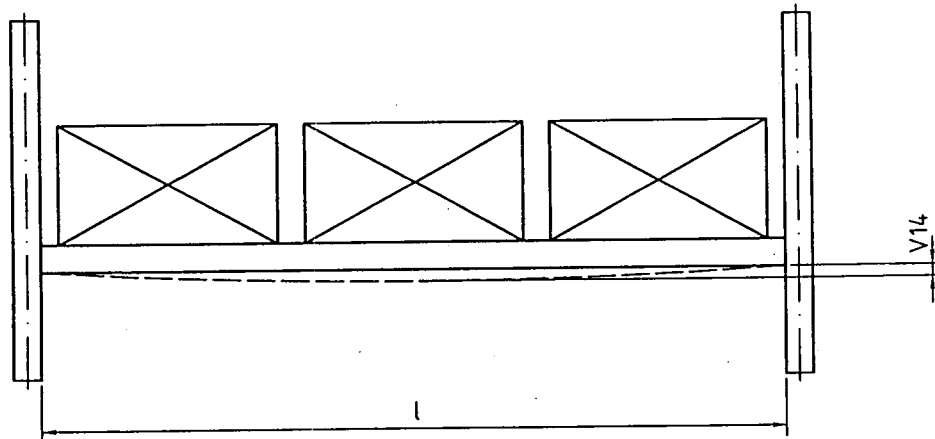


Figure 9: Deformation of the supporting beam in a multi-location warehouse

4.9.2.3 Deformation and loading on the supporting angle during storage and retrieval

When using the load handling device Type II (mechanical pulling mechanism) and in general Type III (lateral grabbing / pushing mechanisms), maximum forces for a unit load in the Y direction occur, depending on tolerances when inserting and removing the load make-up accessory at the aisle side ends of the supporting angles.

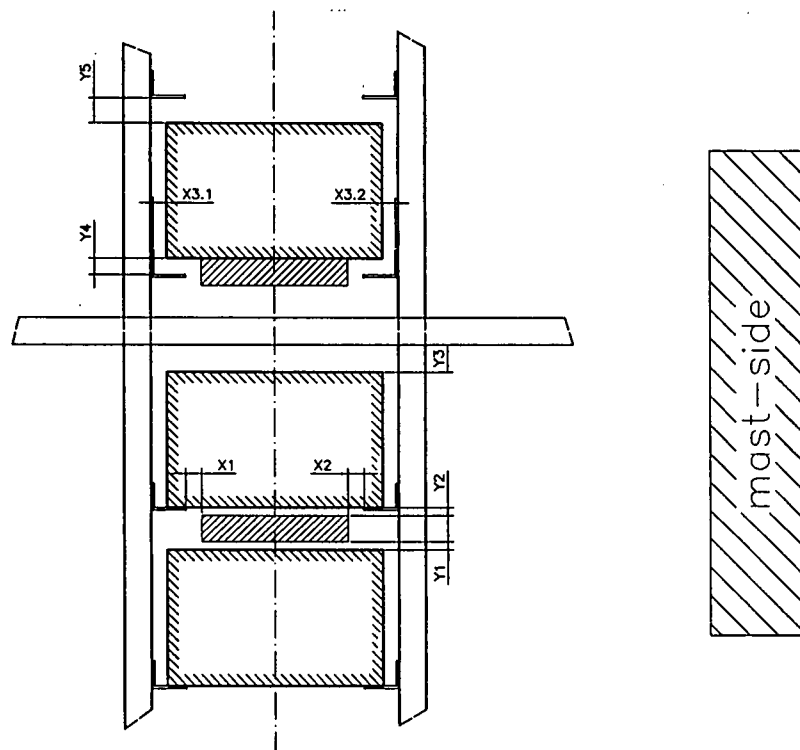
The supporting angles and their attachments to the aisle side upright must bear all the load forces of all the transferred unit loads without suffering permanent deformation. The deformation listed under 4.9.2.2. may be exceeded in this case.

5 Clearances

All clearances relate to a tolerance-free, unloaded system.

5.1 Entry clearances

Entry clearances are the clearances between the load handling device and the unit load, or between the load handling device and the rack. The respective largest entry cross-section of the load handling devices should be considered. Due to the mast deformation on single mast machines the clearances for the side facing and the side facing away from the mast (single mast machines) shall be calculated separately.



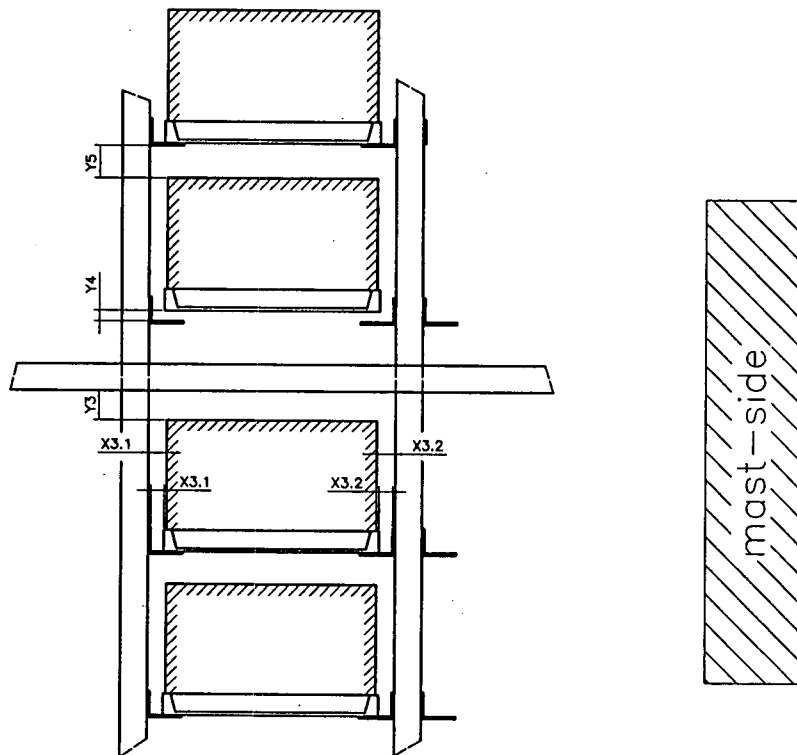
Key:

- X1 entry dimension between the load handling device and the rack obstructing edge
- X2 entry dimension between the load handling device and the rack obstructing edge
- X3.1 clearance between the unit load and the rack
- X3.2 clearance between the unit load and the rack
- Y1 entry dimension between the bottom edge of the load handling device and the top edge of the unit load
- Y2 entry dimension between top edge of the load handling device and the bottom edge of the unit load
- Y3 clearance between top edge of the unit load and the bar of the rack bracing
- Y4 clearance between the bottom edge of the unit load and the top edge of the supporting angle
- Y5 clearance between the top edge of the unit load and the bottom edge of the supporting angle

Figure 10: Entry dimensions and clearances for underclearance method

5.2 Rack compartment clearance

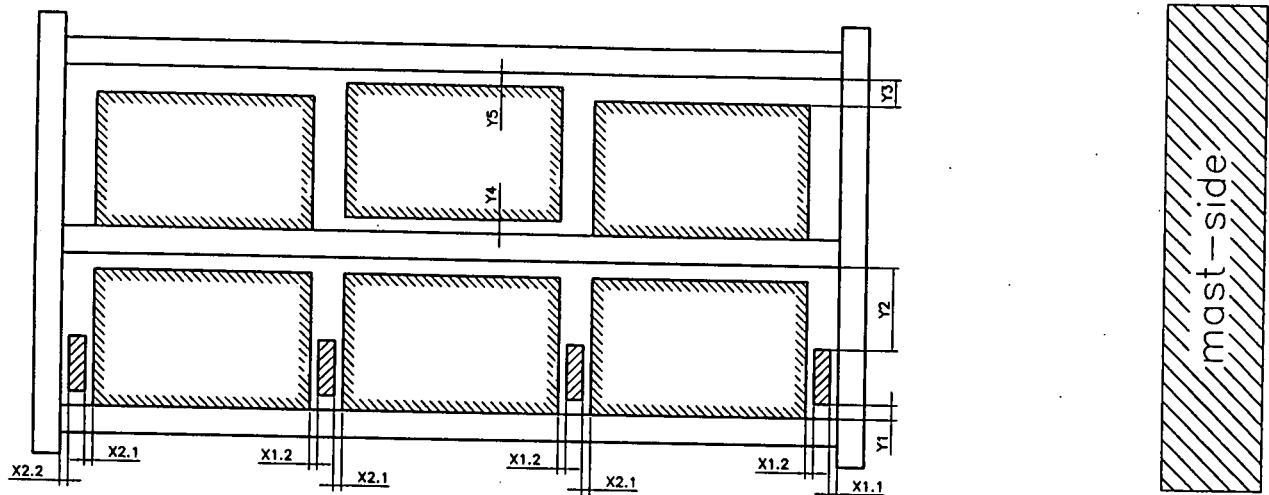
The rack compartment clearance is the minimum distance between the unit loads and the uprights, between the unit loads with reference to each other as well as between the top edge of the stored unit load and the rack structure or obstructing edge (e.g. sprinkler). Due to the mast deformation on single mast machines the clearances for the side facing and the side facing away from the mast shall be calculated separately.



Key:

- X3.1 clearance between the unit load and the rack obstructing edge
- X3.2 clearance between the unit load and the rack obstructing edge
- Y3 clearance between the top edge of the load and the rack's longitudinal bar, or the supporting beam above it
- Y4 clearance between the bottom edge of the unit load and the top edge of the supporting beam
- Y5 clearance between the top edge of the unit load and the bottom edge of the supporting beam

Figure 11: Clearances for pulling mechanism



Key:

- X1.1 entry clearance between load handling device and rack structure
- X1.2 entry clearance between load handling device and load make-up accessories
- X2.1 entry clearance between load handling device and load make-up accessories
- X2.2 entry clearance between load handling device and rack structure
- Y1 entry clearance between the bottom edge of the load handling device and the top edge of the supporting beam
- Y2 entry clearance between the top edge of the load handling device and the bottom edge of the supporting beam
- Y3 clearance between the top edge of the unit load and the bottom edge of the supporting beam
- Y4 clearance between the bottom edge of the unit load and the top edge of the supporting beam
- Y5 clearance between the top edge of the unit load and the bottom edge of the supporting beam

Figure 12: Clearances for lateral pull mechanisms, multi location storage

5.3 Aisle clearance

The following aisle clearances should be checked (see figure 13):

- Z1.1 between the unit load and the front obstruction (e.g. front bar, downpipe, back stops, rack brace design, etc.)
- Z1.2 between the unit load and the inside racks of the rack structure (e.g. rack brace design, sprinkler)
- Z2.1 between the outer most point of the lifting carriage or the unit load on the lifting carriage and the nominal position of the stored load or the rack obstructions if load is stored to the back; rack edge.
- Z2.2 as above, centre rack side.
- Z3.1 between fixed obstructions on the S/R machine (e. g. lifting mechanisms, platforms etc.) and the stored load or the rack obstruction; rack edge.
- Z3.2 as above, centre rack side.
- Z4.1 between the back stop and rear edge of the unit load; rack edge.
- Z4.2 as above, centre rack side.

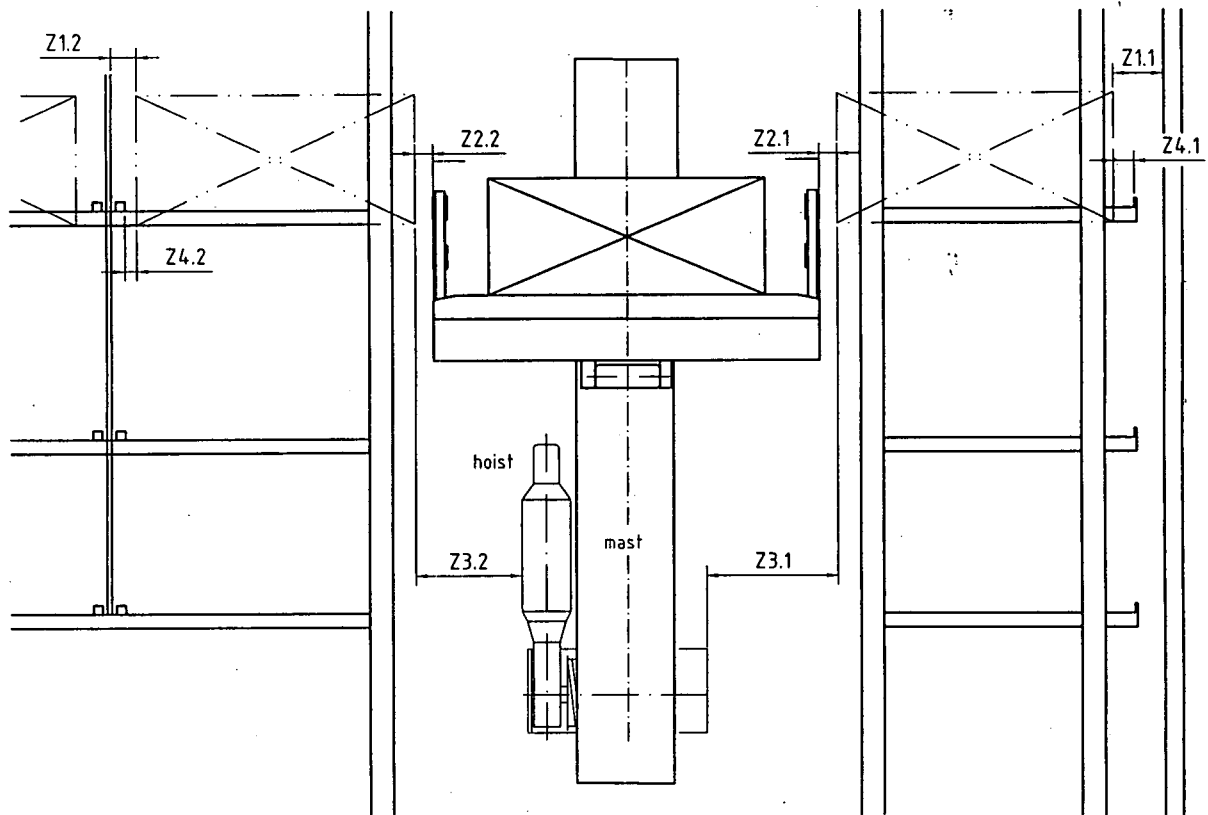


Figure 13: Aisle clearance

5.4 Special Obstructions

The following shall be considered in the planning phase and in particular when calculating clearances:

- arrangement of sprinklers and smoke alarm systems
- utility installations (cables, lighting, routing, pipes etc.)
- minimum distances (e.g. to the sprinkler nozzles)
- variation of the profile dimensions depending on the rack system
- protruding components (screw heads, supports, transmitters etc.)
- modification of unstable loads during storage

6 Data Table for all Factors of Influence

(T: Tolerance field. V: Deformation value)

Table 3 (continued)

No.	Factor of influence/Relating to	Rack type				Fig.
		Single Location System Store Height		Multi-Location System Store Height		
		≤12m	>12 m ≤24 m	≤ 12 m	>12 m ≤24 m	
Load and profile check (4.6)						
T1	Tolerance of load width (measurement accuracy)	± 3 per side	± 3 per side	± 3 per side	± 3 per side	
T2	Tolerance of load length (measurement accuracy)	± 3 per side	± 3 per side	± 3 per side	± 3 per side	
T3	Tolerance of load height (measurement accuracy)	± 2	± 2	± 2	± 2	
Unit load (4.5)						
T4	Positioning accuracy in X direction					
T5	Positioning accuracy in Z direction					
V1	Deformation of load make-up accessory, measured between supporting profiles					
		Depends on load handling device; see 4.7				
S/R machine (4.8)						
T6	Positioning accuracy in X direction					
T7	Positioning accuracy in Y direction					
T8	Positioning accuracy of load handling device in Z direction					
T9	Positioning accuracy of load handling device centering					
T10	Mast manufacturing accuracy in X direction, e.g. alignment, straightness of vertical guide rail					
T11	Mast manufacturing accuracy in Z direction					
T12	Horizontal twisting of the lifting carriage due to mast guide tolerances					
T13	Inclination of the load handling device top edge in X direction in relation to the horizontal datum					
T14	Inclination of the load handling device top edge in Z direction, with reference to the horizontal datum, resulting from erection tolerances, roller clearances, floor and upper guide rail tolerances					
T15	Side guide roller play, bottom					
T16	Erection accuracy of the height positioning markers with reference to the rack compartment levels					
T17	Load handling device deflection, unloaded (roller clearance and wear)					
T18	Wheel and floor rail wear					
V2	Mast deflection resulting from oscillations in X direction					
V3	Mast deformation in X direction at the top rack aperture level (load transfer deformation)					

„continued“

Table 3 (continued)

No.	Factor of influence/Relating to	Rack type				Fig.
		Single Location System Store Height		Multi-Location System Store Height		
		≤12m	>12 m ≤24 m	≤ 12 m	>12 m ≤24 m	
V4	Load deflection in Z direction due to distortion of the mast, lifting carriage and load handling device due to static load moments and oscillation (depends on the height of the unit load)					
V5	Load oscillation in Z direction during travel due to the bending and torsional oscillations of the mast					
V6	Displacement of end of the load handling device in X direction during load handling device extension due to lifting carriage torsion					
V7	Deformation of end of the load handling device under nominal load with max. load handling device extension due to load handling device deformation					
V8	Deformation of end of the load handling device under nominal load with max. load handling device extension due to lifting carriage and mast deformation					
V9	Displacement of end of the load handling device in X direction during load handling device extension due to mast torsion					
V10	Extension of suspension element due to payload					
		Data is set by the S/R manufacturer for each project. Annex A contains calculation examples.				
Aisle Equipment						
T19	Alignment accuracy of the floor rail (4.3.2)	± 2	± 2	± 2	± 2	
T20	Alignment accuracy of the upper guide rail axis and horizontal deviations of the guide rail relative to this axis; measured length of 20 m; region of the guide rollers/measured length of 2 m (4.4.1; 4.4.2)	± 2; ± 2/± 1	± 2; ± 2/± 1	± 2; ± 2/± 1	± 2; ± 2/± 1	1
T21	Height tolerance of the floor rail head; total length/wheelbase (4.3.3)	± 1.5/± 0.5	± 1.5/± 0.5	± 1.5/± 0.5	± 1.5/± 0.5	
T22	Height tolerance of the upper guide rail (4.4.6)	+5/-2	+5/-2	+5/-2	+5/-2	3
T23	Installation accuracy of the positioning marker in the X direction (4.8.3)	± 1	± 1	± 1	± 1	
T24	Installation tolerance of the floor rail in Z direction in relation to the vertical plane datum; total length/wheelbase (4.3.2)	± 2/± 1	± 2/± 1	± 2/± 1	± 2/± 1	
V11	Deflection of the upper guide rail in Z direction with the load extended (4.4.5)	3	3	3	3	
V12	Deformation of the floor rail in Y direction					
		Data is set by the S/R manufacturer for each project. Annex A contains calculation examples.				

„continued“

Table 3 (continued)

No.	Factor of Influence/Relating to	Rack type				Fig.
		Single Location System		Multi-Location System		
		Store Height		Store Height		
		≤12m	>12 m ≤24 m	≤ 12 m	>12 m ≤24 m	
Rack structure in X direction (4.9.1.1)						
T25	Deviation of upright axis relative to a vertical datum	± 7	±10	±7	±10	3
T26	Offset of the upright feet on the left and right-hand aisle sides	3	3	3	3	
T27	Upright frame at right-angles to the aisle axis	Contained in T28	Contained in T28	Contained in T28	Contained in T28	
T28	Sum of tolerances of T25, T26, pre-bending and T27 max.	± 8	± 12	± 8	± 12	3
T29	Tolerance of the rack length L	±1‰ of L	±1‰ of L	±1‰ of L	±1‰ of L	3
T30	Tolerance of the rack entry width for the load make-up accessory	± 4	± 4	± 4	± 4	6
T31	Tolerance of the rack entry width for the load handling device	± 4	± 4	± 4	± 4	6
V13	Side displacement of the highest point of the upright frame during operation due to external forces and payloads (4.9.2.1), with: H = Nominal height from top edge ground to bottom edge cross bar	± 4	± H/3000	± 6	± H/3000	
T32	Tolerance of the distance from the front upright axis to the vertical system plane	± 5	± 5	± 5	± 5	3
Rack structure in Y direction (4.9.1.2)						
T33	Level tolerance of the supporting beams facing the aisle at each level	± 3	± 5	± 5	± 5	
T34	Difference in height between the front and rear supporting beams in single-depth single location storage	± 2	± 2	± 2	± 2	7
T35	Distance tolerance for two adjacent planes	± 2	± 2	± 2	± 2	7
V14	deformation of the supporting beam with tension width l for multi-location storage (4.9.2.2)	--	--	l/375 max. 8	l/375 max. 8	9
T36	Tolerance of the distance from the lowest to the highest support level, with: H = Nominal height from top edge ground to bottom edge cross bar	± 0.5‰ of H	± 0.5‰ of H	± 0.5‰ of H	± 0.5‰ of H	3
T37	Tolerance of the supporting beam horizontal	± 1°	± 1°	± 1°	± 1°	6
V15	Deformation of the supporting angle flange with a 100 % non-centrally arranged load around the support for single location storage (4.9.2.2)	3	3	--	--	4
V16	Vertical lowering of the supporting beams with a 100 % non-centrally arranged load due to sagging, torsion and local bending of the profile (4.9.2.2), with: D = Frame depth	3+D/150 but ≤10	3+D/150 but ≤10	8+D/200 but ≤15	8+D/200 but ≤15	5
V17	Deformation of uprights at the highest support plane (4.9.2.1)	See table 2	See table 2	See table 2	See table 2	

„continued“

Table 3 (concluded)

No.	Factor of influence/Relating to	Rack type				Fig.
		Single Location System Store Height		Multi-Location System Store Height		
		≤12m	>12 m ≤24 m	≤ 12 m	>12 m ≤24 m	
Rack structure in Z direction (4.9.1.3)						
T38	Deviation of the front upright axis from a vertical	± 6	± 10	± 6	± 10	3
T39	Upright foot deviation from the system axis in X direction per aisle	± 3	± 3	± 3	± 3	3
T40	Pre-bending of the unloaded upright frame	Contained in T41	Contained in T41	Contained in T41	Contained in T41	3
T41	Sum of Tolerances of T38, T39 and T40 max.	± 8	± 12	± 8	± 12	3
T42	Tolerance of the back stop to the front edge of the support	± 2	± 2	± 2	± 2	8
T43	Tolerance of the position of the rear obstructing edge connected to the rack (e.g. fences, sheets with trapezoidal corrugations and rigidity design)	± 15	± 15	± 15	± 15	8
V18	Side displacement of the highest point of the upright frame diagonal to the aisle during operation due to external forces and payloads (4.9.2.1), with: H = Nominal height from top edge ground to bottom edge cross bar	± 4	± H/2000	± 4	± H/2000	
Construction and Miscellaneous (ignored in the subsequent calculation examples)						
T44	Dimensional constraints resulting from, e.g. fixing materials, sprinklers, smoke detectors, heating pipes, electrical cables, ventilation, lighting, brackets of hook-in type beams and rainwater pipes etc.					
V19	Dimensional changes of the load during storage					
V20	Additional deformation of the load make-up accessory					
V21	Deformation and deflection of the floor slab resulting in the inclination of the S/R machine and the racking					
V22	Building deformations due to wind and roof stresses					

7 Calculation Check

7.1 Interrelationships

A verifying calculation should be carried out by the person responsible for the system in each individual case to determine that the defined clearances, taking into account known tolerances and deformations, will allow the system to function reliably.

When considering the individual clearances, the individual allowable tolerances and deformations will depend on the positioning process and the load handling device used. Calculation examples are given in Annex A.

Certain tolerances and in particular deformations occurring in the same direction can be reduced by adjusting the S/R machine, e.g. positioning the S/R machine mast in the X direction parallel to the rack or setting the upper Y positioning markers deeper after part-filling the store and taking account of any compression of the uprights.

7.2 Calculation

The worst case condition occurs with all tolerances and deformations at a maximum value and in the least favourable direction. To optimise the overall system, the suppliers (S/R machine, aisle equipment and rack) ensure that the overall tolerances are at the worst, 70% of the total tolerances according to the worst case condition. The overall tolerances as per the worst case method are the sum of the tolerances to be considered in the clearances and entry clearances calculation in accordance with chapter 6. The reduced rack/entry clearances from equation 1 can be used to design the system.

$$f_{\text{real}} = 0.70 \sum T_{i\text{max}} + \sum V_{i\text{max}} \quad (1)$$

where:

$T_{i\text{max}}$: Sum of max. admissible individual tolerances of a single component (data from chapter 6)

$V_{i\text{max}}$: Sum of max deformations from calculations and data within a component

Annex A

Calculation Examples

The following examples can be used to explain the interrelationships with numerical values.

As demonstrated in 4.8, the values for the S/R machines are only examples which show the effects on the overall system. These values must not be used under any circumstance for tolerance calculations. The actual values must be calculated by the equipment manufacturer or the person responsible for the system.

The following possible influencing factors are ignored in the calculation examples:

- uneven wheel wear
- uneven rail deformation due to different loads on each wheels
- residual oscillation amplitudes after settling period
- uneven ground settings
- floor slab deformation greater than described in chapter 4.2.2
- deformation of the load after passing the profile check

All dimensions in the tables given are given in mm.

Used abbreviation:

LHD: Load handling device

Annex A.1

Underclearance Method for Single Location Storage

Table A.1.1: Entry clearances X1 and X2 between LHD and rack structure

Factor of influence	Significance	Positioning system Store Height No.:	Coordinates		Teach In	Rack fine pos.
			10 m	20 m	20 m	20 m
S/R machine	Positioning accuracy	T6	2.0	2.0	2.0	2.0
	Mast manufacturing accuracy	T10	1.0	1.0	0.0	0.0
	Lifting carriage twisting due to mast guide	T12	1.0	1.0	0.0	0.0
	Side guide roller clearance	T15	1.0	1.0	1.0	1.0
	Upper mast deformation due to load transfer	V3	4.0	10.0	10.0	10.0
	Lifting carriage twisting due to load transfer	V6	1.0	1.0	1.0	1.0
	Mast deflection due to oscillation	V2	1.0	2.0	2.0	2.0
	Deflection from mast torsion	V9	1.0	3.0	3.0	3.0
	Installation accuracy of the positioning markers	T23	1.0	1.0	0.0	0.0
Aisle equipment	Alignment accuracy of the floor rail	T19	1.0	1.0	0.0	0.0
	Height tolerance of the floor rail head	T21	3.0	6.0	0.0	0.0
Racking	Upright tolerance field	T28	8.0	12.0	0.0	0.0
	Tolerance of the rack entry width	T31	4.0	4.0	4.0	4.0
	Deformation due to payload	V13	4.0	6.5	6.5	0.0
	Entry dimension	X1 X2	33.0	51.5	29.5	23.0
	Entry dimension at 70% tolerance	X1 X2	26.4	42.8	27.4	20.9

Table A.1.2: Rack compartment clearances X3.1 and X3.2 between the unit load and rack structure

Factor of influence	Significance	Positioning system Store Height No.:	Coordinates		Teach In	Rack fine pos.
			10 m	20 m	20 m	20 m
Load make-up accessory	Positioning accuracy	T4	2.0	2.0	2.0	2.0
	Tolerance of load width	T1	3.0	3.0	3.0	3.0
S/R machine	Positioning accuracy, 2x	T6	4.0	4.0	4.0	4.0
	Mast manufacturing accuracy	T10	1.0	1.0	0.0	0.0
	Lifting carriage twisting due to mast guide, 2x	T12	2.0	2.0	0.0	0.0
	Side guide roller clearance, 2x	T15	2.0	2.0	1.0	1.0
	Upper mast deformation due to load transfer	V3	4.0	10.0	10.0	0.0
	Lifting carriage twisting due to load transfer	V6	1.0	1.0	1.0	1.0
	Mast deflection due to oscillation	V2	1.0	2.0	2.0	2.0
	Deflection from mast torsion	V9	1.0	3.0	3.0	3.0
	Installation accuracy of the positioning markers, 2x	T23	2.0	2.0	0.0	0.0
Aisle equipment	Alignment accuracy of the floor rail	T19	1.0	1.0	0.0	0.0
	Height tolerance of the floor rail head	T21	3.0	6.0	0.0	0.0
Rack system	Upright tolerance field	T28	8.0	12.0	0.0	0.0
	Tolerance of the rack entry width	T31	4.0	4.0	4.0	4.0
	Deformation due to payload	V13	4.0	6.5	6.5	0.0
	Entry dimension	X3.1 X3.2	43.0	61.5	36.5	20.0
	Entry clearance at 70% tolerance	X3.1 X3.2	33.4	49.8	32.3	15.8

Table A.1.3: Entry clearance Y1 between the top edge of the load make-up accessory and the bottom edge of the LHD

Factor of influence	Significance	Positioning system Store height No.:	Coordinates		Teach In 20 m	Rack fine pos. 20 m
			10 m	20 m		
						n/a
Load make-up accessory	Tolerance of load height	T3	2.0	2.0	2.0	
S/R machine	Positioning accuracy	T7	2.0	2.0	2.0	
	Load handling device tilt in X direction	T13	1.0	1.0	1.0	
	Load handling device tilt in Z direction	T14	1.0	1.0	1.0	
	Erection accuracy of height positioning marker	T16	1.0	1.0	0.0	
Aisle equipment	Load handling device deformation	T17	2.0	2.0	2.0	
	Floor rail deformation	V12	0.0	0.0	0.0	
	Height tolerance of the floor rail head	T21	1.5	1.5	0.0	
Racking	Level tolerance of the supporting beams	T33	3.0	5.0	0.0	
	Entry clearance	Y1	13.5	15.5	8.0	
	Entry clearance at 70% tolerance	Y1	9.5	10.9	5.6	

Table A.1.4: Rack compartment clearance Y2 between the top edge of the LHD and the bottom edge of the load make-up accessory

Factor of influence	Significance	Positioning system Store Height No.:	Coordinates		Teach In 20 m	Rack fine pos. 20 m
			10 m	20 m		
						n/a
Load make-up accessory	Deformation of load make-up accessory	V1	3.0	3.0	3.0	
S/R machine	Positioning accuracy	T7	2.0	2.0	2.0	
	Load handling device tilt in X direction	T13	1.0	1.0	1.0	
	Load handling device tilt in Z direction	T14	1.0	1.0	1.0	
	Erection accuracy of height positioning marker	T16	1.0	1.0	0.0	
Aisle equipment	Height tolerance of the floor rail head	T21	1.5	1.5	0.0	
Racking	Level tolerance of the supporting beams	T33	3.0	5.0	0.0	
	Difference in height between the front and rear supporting beam	T34	4.0	4.0	4.0	
	Deformation of the supporting angle flange	V15	3.0	3.0	3.0	
	Deformation of rack upright	V17	2.0	4.0	4.0	
	Entry clearance	Y2	21.5	25.5	18.0	
	Entry clearance at 70% tolerance	Y2	17.5	20.9	15.6	

Table A.1.5: Rack compartment clearance Y4 between the top edge of the support profile and the bottom edge of the load make-up accessory

		Positioning system Store Height	Coordinates		Teach In 20 m	Rack fine pos. 20 m
Factor of influence	Significance		10 m	20 m		
		No.:				n/a
S/R machine	Positioning accuracy	T7	2.0	2.0	2.0	
	Height positioning marker	T16	1.0	1.0	0.0	
	Load handling device deformation	T17	1.0	1.0	1.0	
	Load handling device deformation	V7	1.0	1.0	1.0	
	Lifting carriage and mast deformation	V8	1.0	1.0	1.0	
	Suspension element extension	V10	2.0	4.0	2.0	
Aisle equipment	Height tolerance of the floor rail head	T21	1.5	1.5	0.0	
	Floor rail deformation	V12	0.0	0.0	0.0	
Racking	Level tolerance of the supporting beams	T33	3.0	5.0	0.0	
	Rack compartment clearance	Y4	12.5	16.5	7.0	
	Rack compartment clearance at 70% tolerance	Y4	10.0	13.4	6.1	

Table A.1.6: Rack compartment clearance Y5 between the top edge of the load make-up accessory and the bottom edge of the support profile

		Positioning system Store height	Coordinates		Teach In 20 m	Rack fine pos. 20 m
Factor of influence	Significance		10 m	20 m		
		No.:				n/a
Load make-up accessory	Deformation of load make-up accessory	V1	0.0	0.0	0.0	
	Tolerance of load height	T3	2.0	2.0	2.0	
S/R machine	Positioning accuracy	T7	2.0	2.0	2.0	
	Erection accuracy of height positioning marker	T16	1.0	1.0	0.0	
	Load handling device tilt in X direction	T13	1.0	1.0	1.0	
	Load handling device tilt in Z direction	T14	1.0	1.0	1.0	
Aisle equipment	Height tolerance of the floor rail head	T21	1.5	1.5	0.0	
Racking	Level tolerance of the supporting beams	T33	3.0	5.0	0.0	
	Difference in height between the front and rear supporting beam	T34	4.0	4.0	4.0	
	Distance tolerance of two adjacent planes	T35	2.0	2.0	2.0	
	Deformation of supporting angle flange	V15	3.0	3.0	3.0	
	Deformation of rack upright	V17	2.0	4.0	4.0	
		Rack compartment clearance	Y5	22.5	26.5	19.0
	Rack compartment clearance at 70% tolerance	Y5	17.3	20.7	15.4	

Table A.1.7: Distance Y3 between the top edge of the load make-up accessory and the bottom edge of the supporting profile

		Positioning system Store height	Coordinates		Teach In 20 m	Rack fine pos. 20 m
Factor of influence	Significance		10 m	20 m		
		No.:				n/a
	Entry clearance	Y2	21.5	25.5	18.0	
	Entry clearance at 70% tolerance	Y2	17.5	20.9	15.6	
	Rack compartment clearance	Y4	12.5	16.5	7.0	
	Rack compartment clearance at 70% tolerance	Y4	10.0	13.4	6.1	
	Rack compartment clearance	Y5	22.5	26.5	19.0	
	Rack compartment clearance at 70% tolerance	Y5	17.3	20.7	15.4	
	Minimum distance	Y3	56.5	68.5	44.0	
	Minimum distance at 70% tolerance	Y3	44.7	54.9	37.1	

Table A.1.8: Clearances Z1.1 and Z1.2 between the rear edge of the load make-up accessory and the rack / building

		Positioning-system Store height	Coordinates		Teach In 20 m	Rack fine pos. 20 m
Factor of influence	Significance		10 m	20 m		
		No.:			n/a	n/a
Load make-up accessory	Tolerance of load length	T2	3.0	3.0		
	Positioning accuracy	T5	3.0	3.0		
S/R machine	Load handling device positioning accuracy	T8	3.0	3.0		
	Mast manufacturing accuracy	T10	2.0	3.0		
	Lifting carriage twisting due to mast guide	T12	1.0	2.0		
	Side guide roller clearance	T15	0.0	0.0		
	Load handling device tilt in Z direction	T14	1.0	1.0		
	Load deflection in Z direction	V4	3.0	6.0		
Aisle equipment	Floor rail alignment accuracy	T19	2.0	2.0		
	Guide rail side accuracy	T20	4.0	4.0		
	Guide rail deflection	V11	3.0	3.0		
	Installation tolerance of the floor rail	T24	2.0	2.0		
Racking	Upright tolerance field	T41	8.0	12.0		
	Tolerance of rear obstructing edge rack	T43	15.0	15.0		
	Tolerance of rear obstructing edge building	T44	20.0	20.0		
	Rack edge clearance	Z1.1	55.0	64.0		
	Rack centre clearance	Z1.2	50.0	59.0		
	Rack edge clearance at 70% tolerance	Z1.1	40.3	47.5		
	Rack centre clearance at 70% tolerance	Z1.2	36.8	44.0		

Table A.1.9: Clearances Z2.1 and Z2.2 between the aisle-side load and parts of the lifting carriage

		Positioning-system Store height	Coordinates		Teach In 20 m	Rack fine pos. 20 m
Factor of influence	Significance		10 m	20 m		
		No.:			n/a	n/a
Load make-up accessory	Tolerance of load length	T2	3.0	3.0		
	Positioning accuracy	T5	3.0	3.0		
S/R machine	Load handling device positioning accuracy	T8	3.0	3.0		
	Side guide roller clearance	T15	0.0	0.0		
	Load oscillation	V5	2.0	4.0		
Racking	Difference in height between the front and rear supporting beam	T34	0.0	0.0		
	Rack edge clearance	Z2.1	11.0	13.0		
	Rack centre clearance	Z2.2	11.0	13.0		
	Rack edge clearance at 70% tolerance	Z2.1	8.3	10.3		
	Rack centre clearance at 70% tolerance	Z2.2	8.3	10.3		

Table A.1.10: Clearances Z3.1 and Z3.2 between the aisle side load and parts of the automatic S/R machine

		Positioning-system Store height	Coordinates		Teach In	Rack fine pos.
			10 m	20 m	20 m	20 m
Factor of influence	Significance	No.:			n/a	n/a
Load make-up accessory	Tolerance of load length	T2	3.0	3.0		
	Positioning accuracy	T5	3.0	3.0		
S/R machine	Load handling device positioning accuracy	T8	3.0	3.0		
	Side guide roller clearance	T15	0.0	0.0		
	Load oscillation	V5	5.0	8.0		
Racking	Difference in height between the front and rear supporting beam	T34	0.0	0.0		
	Rack edge clearance	Z3.1	14.0	17.0		
	Rack centre clearance	Z3.2	14.0	17.0		
	Rack edge clearance at 70% tolerance	Z3.1	11.3	14.3		
	Rack centre clearance at 70% tolerance	Z3.2	11.3	14.3		

Table A.1.11: Clearances Z4.1 and Z4.2 between the load make-up accessory and the back stop

		Positioning-system Store height	Coordinates		Teach In	Rack fine pos.
			10 m	20 m	20 m	20 m
Factor of influence	Significance	No.:			n/a	n/a
Load make-up accessory	Tolerance of load length	T2	3.0	3.0		
	Positioning accuracy	T5	3.0	3.0		
S/R machine	Load handling device positioning accuracy	T8	3.0	3.0		
	Mast manufacturing accuracy	T11	2.0	3.0		
	Lifting carriage twisting due to mast guide	T12	1.0	1.0		
	Side guide roller clearance	T15	0.0	0.0		
	Load oscillation	V5	5.0	8.0		
Aisle equipment	Alignment accuracy of the floor rail	T19	2.0	2.0		
	Guide rail side accuracy	T20	4.0	4.0		
	Guide rail deflection	V11	3.0	3.0		
	Installation tolerance of the floor rail	T24	2.0	2.0		
Racking	Difference in height between the front and rear supporting beam	T34	0.0	0.0		
	Tolerance of the back stop	T42	2.0	2.0		
	Upright tolerance field	T41	8.0	12.0		
	Rack edge clearance	Z4.1	38.0	46.0		
	Rack centre clearance	Z4.2	38.0	46.0		
	Rack edge clearance at 70% tolerance	Z4.1	29.0	35.5		
	Rack centre clearance at 70% tolerance	Z4.2	29.0	35.5		

Annex A.2

Pulling Mechanisms for Single Location Storage

Table A.2.1: Rack compartment clearances X3.1 and X3.2 between the unit load and rack structure

Factor of influence	Significance	Positioning-system Store height No.:	Coordinates		Teach	Rack fine
			10 m	20 m	In 20 m	pos. 20 m
Load make-up accessory	Tolerance of load width	T1	0.5	0.5	0.5	3.0
S/R machine	Positioning accuracy	T6	2.0	2.0	2.0	4.0
	Mast manufacturing accuracy	T10	1.0	1.0	1.0	0.0
	Lifting carriage twisting due to mast guide	T12	1.0	1.0	1.0	0.0
	Side roller guide clearance	T15	1.0	1.0	1.0	1.0
	Upper mast deformation due to load transfer	V3	4.0	10.0	10.0	0.0
	Lifting carriage torsion due to load change	V6	1.0	1.0	1.0	1.0
	Mast deflection due to oscillations	V2	1.0	1.0	1.0	1.0
	Deflection due to mast torsion	V9	1.0	1.0	1.0	1.0
	Installation accuracy of the positioning marker	T23	2.0	2.0	0.0	0.0
Aisle equipment	Alignment accuracy of the floor rail	T19	1.0	1.0	0.0	0.0
	Height tolerance of the floor rail head	T21	3.0	6.0	0.0	0.0
Racking	Upright tolerance field	T28	8.0	12.0	0.0	0.0
	Tolerance of rack entry width	T31	4.0	4.0	4.0	4.0
	Deformation due to payload	V13	4.0	6.5	6.5	0.0
	Entry clearance	X3.1 X3.2	34.5	50.0	29.0	15.0
	Entry clearance at 70% tolerance	X3.1 X3.2	27.5	40.9	26.2	11.4

Table A.2.2: Rack compartment clearance Y4 between the top edge of the supporting profile and the bottom edge of the load make-up accessory

Factor of influence	Significance	Positioning-system Store height No.:	Coordinates		Teach	Rack fine
			10 m	20 m	In 20 m	pos. 20 m
S/R machine	Positioning accuracy	T7	2.0	2.0	2.0	
	Erection accuracy of the height position marker	T16	1.0	1.0	0.0	
	Load handling device deformation	T17	1.0	1.0	1.0	
	Lifting carriage and mast deformation	V8	1.0	1.0	1.0	
	Suspension element extension	V10	2.0	4.0	2.0	
Aisle equipment	Height tolerance of floor rail head	T21	1.5	1.5	0.0	
	Floor rail deformation	V12	0.0	0.0	0.0	
Racking	Level tolerance of the supporting beams	T33	3.0	5.0	0.0	
	Rack compartment clearance	Y4	11.5	15.5	6.0	
	Rack compartment clearance at 70% tolerance	Y4	9.0	12.4	5.1	

Tabelle A.2.3: Rack compartment clearance Y5 between the top edge of the load make-up accessory and the bottom edge of the supporting profile

		Positioning-system Store height	Coordinates		Teach In	Rack fine pos.
			10 m	20 m	20 m	20 m
Factor of influence	Significance	No.:				n/a
Load make-up accessory	Deformation of load make-up accessory	V1	0.0	0.0	0.0	
	Tolerance of load height	T3	2.0	2.0	2.0	
S/R machine	Positioning accuracy	T7	2.0	2.0	2.0	
	Erection accuracy of height positioning marker	T16	1.0	1.0	0.0	
	Load handling device tilt in X direction	T13	1.0	1.0	1.0	
	Load handling device tilt in Z direction	T14	1.0	1.0	1.0	
Aisle equipment	Height tolerance of the floor rail head	T21	1.5	1.5	0.0	
Racking	Level tolerance of the supporting beams	T33	3.0	5.0	0.0	
	Difference in height between the front and rear supporting beam	T34	4.0	4.0	4.0	
	Distance tolerance of two adjacent planes	T35	2.0	2.0	2.0	
	Deformation of supporting angle flange	V15	5.0	5.0	5.0	
	Deformation of rack upright	V17	2.0	4.0	4.0	
	Rack compartment clearance	Y5	24.5	28.5	21.0	
	Rack compartment clearance at 70% tolerance	Y5	19.3	22.7	17.4	

Table A.2.4: Distance Y3 between the top edge of the load make-up accessory and the bottom edge of the supporting profile

		Positioning-system Store height	Coordinates		Teach In	Rack fine pos.
			10 m	20 m	20 m	20 m
Factor of influence	Significance	No.:				n/a
	Rack compartment clearance	Y4	11.5	15.5	6.0	
	Rack compartment clearance at 70% tolerance	Y4	9.0	12.4	5.1	
	Rack compartment clearance	Y5	24.5	28.5	21.0	
	Rack compartment clearance at 70% tolerance	Y5	19.3	22.7	17.4	
	Minimum distance	Y3	36.0	44.0	27.0	
	Minimum distance at 70% tolerance	Y3	28.3	35.1	22.5	

Table A.2.5: Clearances Z1.1 and Z1.2 between the rear edge of the load make-up accessory and the rack/building

		Positioning-system Store height	Coordinates		Teach	Rack fine
Factor of influence	Significance		No.:	10 m	20 m	20 m
					n/a	n/a
Load make-up accessory	Tolerance of load length	T2	3.0	3.0		
	Positioning accuracy	T5	3.0	3.0		
S/R machine	Load handling device positioning accuracy	T8	3.0	3.0		
	Mast manufacturing accuracy	T10	2.0	3.0		
	Lifting carriage twisting due to mast guide	T12	1.0	2.0		
	Side guide roller clearance	T15	0.0	0.0		
	Load handling device tilt in Z direction	T14	1.0	1.0		
	Load deflection in Z direction	V4	3.0	6.0		
Aisle equipment	Floor rail alignment accuracy	T19	2.0	2.0		
	Guide rail side accuracy	T20	4.0	4.0		
	Guide rail deflection	V11	3.0	3.0		
	Installation tolerance of the floor rail	T24	2.0	2.0		
Racking	Upright tolerance field	T41	8.0	12.0		
	Tolerance of rear obstructing edge rack	T43	15.0	15.0		
	Tolerance of rear obstructing edge building	T44	20.0	20.0		
	Rack edge clearance	Z1.1	55.0	64.0		
	Rack centre clearance	Z1.2	50.0	59.0		
	Rack edge clearance at 70% tolerance	Z1.1	40.3	47.5		
	Rack centre clearance at 70% tolerance	Z1.2	36.8	44.0		

Table A.2.6: Clearances Z2.1 and Z2.2 between the aisle side load and parts of the lifting carriage

		Positioning-system Store height	Coordinates		Teach	Rack fine
Factor of influence	Significance		No.:	10 m	20 m	20 m
					n/a	n/a
Load make-up accessory	Tolerance of load length	T2	3.0	3.0		
	Positioning accuracy	T5	3.0	3.0		
S/R machine	Load handling device positioning accuracy	T8	3.0	3.0		
	Side guide roller clearance	T15	0.0	0.0		
	Load oscillation	V5	2.0	4.0		
Racking	Difference in height between the front and rear supporting beam	T34	0.0	0.0		
	Rack edge clearance	Z2.1	11.0	13.0		
	Rack centre clearance	Z2.2	11.0	13.0		
	Rack edge clearance at 70% tolerance	Z2.1	8.3	10.3		
	Rack centre clearance at 70% tolerance	Z2.2	8.3	10.3		

Table A.2.7: Clearances Z3.1 and Z3.2 between the aisle side load and parts of the automatic S/R machine

		Positioning-system Store height	Coordinates		Teach In	Rack fine pos.
			10 m	20 m	20 m	20 m
Factor of influence	Significance	No.:			n/a	n/a
Load make-up accessory	Tolerance of load length	T2	3.0	3.0		
	Positioning accuracy	T5	3.0	3.0		
S/R machine	Load handling device positioning accuracy	T8	3.0	3.0		
	Side guide roller clearance	T15	0.0	0.0		
	Load oscillation	V5	5.0	8.0		
Racking	Difference in height between the front and rear supporting beam	T34	0.0	0.0		
	Rack edge clearance	Z3.1	14.0	17.0		
	Rack centre clearance	Z3.2	14.0	17.0		
	Rack edge clearance at 70% tolerance	Z3.1	11.3	14.3		
	Rack centre clearance at 70% tolerance	Z3.2	11.3	14.3		

Table A.2.8: Clearances Z4.1 and Z4.2 between the load make-up accessory and the back stop

		Positioning-system Store height	Coordinates		Teach In	Rack fine pos.
			10 m	20 m	20 m	20 m
Factor of influence	Significance	No.:			n/a	n/a
Load make-up accessory	Tolerance of load length	T2	3.0	3.0		
	Positioning accuracy	T5	3.0	3.0		
S/R machine	Load handling device positioning accuracy	T8	3.0	3.0		
	Mast manufacturing accuracy	T11	2.0	3.0		
	Lifting carriage twisting due to mast guide	T12	1.0	1.0		
	Side guide roller clearance	T15	0.0	0.0		
	Load oscillation	V5	5.0	8.0		
Aisle equipment	Alignment accuracy of the floor rail	T19	2.0	2.0		
	Guide rail side accuracy	T20	4.0	4.0		
	Guide rail deflection	V11	3.0	3.0		
	Installation tolerance of the floor rail	T24	2.0	2.0		
Racking	Difference in height between the front and rear supporting beam	T34	0.0	0.0		
	Tolerance of the back stop	T42	2.0	2.0		
	Upright tolerance field	T41	8.0	12.0		
	Rack edge clearance	Z4.1	38.0	46.0		
	Rack centre clearance	Z4.2	38.0	46.0		
	Rack edge clearance at 70% tolerance	Z4.1	29.0	35.5		
	Rack centre clearance at 70% tolerance	Z4.2	29.0	35.5		

Annex A.3 Side Grabbing Device for Multi-Location Storage

Table A.3.1: Entry clearances X1.1 und X2.2 between LHD and rack structure

		Positioning-system Store height	Coordinates		Teach	Rack fine
			10 m	20 m	In	pos.
Factor of influence	Significance	No.:			20 m	20 m
S/R machine	Positioning accuracy	T6	2.0	2.0	2.0	2.0
	Mast manufacturing accuracy	T10	1.0	1.0	0.0	0.0
	Lifting carriage twisting due to mast guide	T12	1.0	1.0	0.0	0.0
	Side roller guide clearance	T15	1.0	1.0	1.0	1.0
	Upper mast deformation due to load transfer	V3	4.0	10.0	10.0	10.0
	Lifting carriage twisting due to load transfer	V6	1.0	1.0	1.0	1.0
	Mast deflection due to oscillations	V2	1.0	2.0	2.0	2.0
	Deflection due to mast torsion	V9	1.0	3.0	3.0	3.0
	Installation accuracy of the positioning markers	T23	1.0	1.0	0.0	0.0
Aisle equipment	Alignment accuracy of the floor rail	T19	1.0	1.0	0.0	0.0
	Height tolerance of the floor rail head	T21	3.0	6.0	0.0	0.0
Racking	Upright tolerance field	T28	8.0	12.0	0.0	0.0
	Tolerance of the rack entry width	T31	4.0	4.0	4.0	4.0
	Deformation due to payload	V13	4.0	6.5	6.5	0.0
	Entry clearance	X1.1 X2.2	33.0	51.5	29.5	23.0
	Entry clearance at 70% tolerance	X1.1 X2.2	26.4	42.8	27.4	20.9

Tabelle A.3.2: Entry clearances X1.2 and X2.1 between LHD und load make-up accessory

		Positioning-system Store height	Coordinates		Teach	Rack fine
			10 m	20 m	In	pos.
Factor of influence	Significance	No.:			20 m	20 m
S/R machine	Positioning accuracy, 2x	T6	4.0	4.0	4.0	4.0
	Mast manufacturing accuracy	T10	1.0	1.0	0.0	0.0
	Lifting carriage twisting due to mast guide	T12	1.0	1.0	0.0	0.0
	Side guide roller clearance	T15	1.0	1.0	1.0	1.0
	Upper mast deformation due to load transfer	V3	4.0	10.0	10.0	10.0
	Lifting carriage twisting due to load transfer	V6	1.0	1.0	1.0	1.0
	Mast deflection due to oscillations	V2	1.0	2.0	2.0	2.0
	Deflection due to mast torsion	V9	1.0	3.0	3.0	3.0
	Installation accuracy of the positioning markers	T23	1.0	1.0	0.0	0.0
Aisle equipment	Alignment accuracy of the floor rail	T19	1.0	1.0	0.0	0.0
	Height tolerance of the floor rail head	T21	3.0	6.0	0.0	0.0
Racking	Deformation due to payload	V13	4.0	6.5	6.5	0.0
	Entry clearance	X1.2 X2.1	23.0	37.5	27.5	21.0
	Entry clearance at 70% tolerance	X1.2 X2.1	19.4	33.0	26.0	19.5

Table A.3.3: Entry clearance Y1 between LHD and the top edge of the supporting profile

Factor of influence	Significance	Positioning-system Store height No.:	Coordinates		Teach In 20 m	Rack fine pos. 20 m
			10 m	20 m		
S/R machine	Positioning accuracy	T7	2.0	2.0	2.0	
	Load handling device tilt in x direction	T13	1.0	1.0	1.0	
	Erection accuracy of height positioning marker	T16	1.0	1.0	0.0	
	Load handling device deformation	T17	0.0	0.0	0.0	
	Wheel and floor rail wear	T18	0.0	0.0	0.0	
	Load handling device deformation	V7	0.0	0.0	0.0	
	Lifting carriage and mast deformation	V8	0.0	0.0	0.0	
Aisle equipment	Height tolerance of the floor rail head	T21	1.5	1.5	0.0	
	Floor rail deformation	V12	0.5	0.5	0.0	
Racking	Level tolerance of the supporting beams	T33	5.0	5.0	0.0	
	Difference in height between the front and rear supporting beam	T34	4.0	4.0	0.0	
	Rack compartment clearance	Y1	15.0	15.0	3.0	
	Rack compartment clearance at 70% tolerance	Y1	10.7	10.7	2.1	

Table A.3.4: Entry clearance Y2 between LHD and bottom edge of the supporting profile

Factor of influence	Significance	Positioning-system Store height No.:	Coordinates		Teach In 20 m	Rack fine pos. 20 m
			10 m	20 m		
S/R machine	Positioning accuracy	T7	2.0	2.0	2.0	
	Load handling device tilt in X direction	T13	1.0	1.0	1.0	
	Erection accuracy of height positioning marker	T16	1.0	1.0	0.0	
	Load handling device deformation	T17	0.0	0.0	0.0	
	Wheel and floor rail wear	T18	0.0	0.0	0.0	
	Load handling device deformation	V7	0.0	0.0	0.0	
	Lifting carriage and mast deformation	V8	0.0	0.0	0.0	
Aisle equipment	Height tolerance of the floor rail head	T21	1.5	1.5	0.0	
	Floor rail deformation	V12	0.5	0.5	0.0	
Racking	Level tolerance of the supporting beams	T33	5.0	5.0	0.0	
	Difference in height between the front and rear supporting beam	T34	4.0	4.0	0.0	
	Distance tolerance of two adjacent planes	T35	2.0	2.0	2.0	
		V14	6.5	6.5	6.5	
	Deformation of the rack upright	V17	2.0	4.0	4.0	
	Rack compartment clearance	Y2	25.5	27.5	15.5	
	Rack compartment clearance at 70% tolerance	Y2	20.6	22.6	14.0	

Tabelle A.3.5 Rack compartment clearance Y4 between top edge of the supporting profile and bottom edge of the load make-up accessory

		Positioning-system Store height	Coordinates		Teach In 20 m	Rack fine pos. 20 m
Factor of Influence	Significance		10 m	20 m		
		Nr.:				n/a
Load make-up accessory	Deformation of load make-up accessory	V1	0,0	0,0	0,0	
S/R-machine	Positioning accuracy	T7	2,0	2,0	2,0	
	Erection accuracy of the height position marker	T16	1,0	1,0	0,0	
	Load handling device deformation	T17	0,0	0,0	0,0	
	Lifting carriage and mast deformation	V8	0,0	0,0	0,0	
	Suspension element extension	V10	2,0	4,0	4,0	
Aisle equipment	Height tolerance of floor rail head	T21	1,5	1,5	0,0	
	Floor rail deformation	V12	0,5	0,5	0,5	
Racking	Level tolerance of the supporting beams	T33	5,0	5,0	0,0	
	Difference in height between the front and rear supporting beam	T34	4,0	4,0	0,0	
	Rack compartment clearance	Y4	16,0	18,0	6,5	
	Rack compartment clearance at 70% tolerance	Y4	12,0	14,0	5,9	

Tabelle A.3.6: Rack compartment clearance Y5 between top edge of the supporting profile and bottom edge of the load make-up accessory

		Positioning-system Store height	Coordinates		Teach In 20 m	Rack fine pos. 20 m
Factor of Influence	Significance		10 m	20 m		
		Nr.:				entfällt
Load make-up accessory	Tolerance of load height	T3	2,0	2,0	2,0	
S/R-machine	Positioning accuracy	T7	2,0	2,0	2,0	
	Erection accuracy of height positioning marker	T16	1,0	1,0	0,0	
	Load handling device tilt in X direction	T13	1,0	1,0	1,0	
	Load handling device tilt in Y direction	T14	1,0	1,0	1,0	
Aisle equipment	Height tolerance of floor rail head	T21	1,5	1,5	0,0	
Racking	Level tolerance of the supporting beams	T33	3,0	5,0	0,0	
	Difference in height between the front and rear supporting beam	T34	4,0	4,0	0,0	
	Distance tolerance of two adjacent planes	T35	2,0	2,0	2,0	
	Deformation of supporting angle flange	V15	5,0	5,0	5,0	
	Deformation of rack upright	V17	2,0	4,0	4,0	
	Rack compartment clearance	Y5	24,5	28,5	17,0	
	Rack compartment clearance at 70% tolerance	Y5	19,3	22,7	14,6	

Tabelle A.3.7: Rack compartment clearance Y3 between top edge of the load make-up accessory and bottom edge of the supporting profile

		Positioning-system Store height	Coordinates		Teach In 20 m	Rack fine pos. 20 m
Factor of Influence	Significance		10 m	20 m		
		Nr.:				entfällt
	Rack compartment clearance	Y4	16,0	18,0	6,5	
	Rack compartment clearance at 70% tolerance	Y4	12,0	14,0	5,9	
	Rack compartment clearance	Y5	24,5	28,5	17,0	
	Rack compartment clearance at 70% tolerance	Y5	19,3	22,7	14,6	
	Rack compartment clearance (= Y4+Y5)	Y3	40,5	46,5	23,5	
	Rack compartment clearance at 70% tolerance	Y3	31,3	36,7	20,5	

Table A.3.8: Clearances Z1.1 and Z1.2 between the rear edge of the load make-up accessory and the rack / building

		Positioning-system Store height	Coordinates		Teach In 20 m	Rack fine pos. 20 m
			10 m	20 m		
Factor of influence	Significance	No.:			n/a	n/a
Load make-up accessory	Tolerance of load length	T2	3.0	3.0		
	Positioning accuracy	T5	3.0	3.0		
S/R machine	Load handling device positioning accuracy	T8	3.0	3.0		
	Mast manufacturing accuracy	T10	2.0	3.0		
	Lifting carriage twisting due to mast guide	T12	1.0	2.0		
	Side guide roller clearance	T15	0.0	0.0		
	Load handling device tilt in Z direction	T14	1.0	1.0		
	Load deflection in Z direction	V4	3.0	6.0		
Aisle equipment	Floor rail alignment accuracy	T19	2.0	2.0		
	Guide rail side accuracy	T20	4.0	4.0		
	Guide rail deflection	V11	3.0	3.0		
	Installation tolerance of the floor rail	T24	2.0	2.0		
Racking	Upright tolerance field	T41	8.0	12.0		
	Tolerance of rear obstructing edge rack	T43	15.0	15.0		
	Tolerance of rear obstructing edge building	T44	20.0	20.0		
	Rack edge clearance	Z1.1	55.0	64.0		
	Rack centre clearance	Z1.2	50.0	59.0		
	Rack edge clearance at 70% tolerance	Z1.1	40.3	47.5		
	Rack centre clearance at 70% tolerance	Z1.2	36.8	44.0		

Table A.3.9: Clearances Z2.1 and Z2.2 between the aisle side load and parts of the lifting carriage

		Positioning-system Store height	Coordinates		Teach In 20 m	Rack fine pos. 20 m
			10 m	20 m		
Factor of influence	Significance	No.:			n/a	n/a
Load make-up accessory	Tolerance of load length	T2	3.0	3.0		
	Positioning accuracy	T5	3.0	3.0		
S/R machine	Load handling device positioning accuracy	T8	3.0	3.0		
	Side roller guide clearance	T15	0.0	0.0		
	Load oscillation	V5	2.0	4.0		
Racking	Difference in height between the front and rear supporting beam	T34	0.0	0.0		
	Rack edge clearance	Z2.1	11.0	13.0		
	Rack centre clearance	Z2.2	11.0	13.0		
	Rack edge clearance at 70% tolerance	Z2.1	8.3	10.3		
	Rack centre clearance at 70% tolerance	Z2.2	8.3	10.3		

Table A.3.10: Clearances Z3.1 and Z3.2 between aisle side load and parts of the automatic S/R-machine

		Positioning-system Store height	Coordinates		Teach In 20 m	Rack fine pos. 20 m
Factor of influence	Significance		10 m	20 m		
		No.:			n/a	n/a
Load make-up accessory	Tolerance of load length	T2	3.0	3.0		
	Positioning accuracy	T5	3.0	3.0		
S/R machine	Load handling device positioning accuracy	T8	3.0	3.0		
	Side roller guide clearance	T15	0.0	0.0		
	Load oscillation	V5	5.0	8.0		
Racking	Difference in height between the front and rear supporting beam	T34	0.0	0.0		
	Rack edge clearance	Z3.1	14.0	17.0		
	Rack centre clearance	Z3.2	14.0	17.0		
	Rack edge clearance at 70% tolerance	Z3.1	11.3	14.3		
	Rack centre clearance at 70% tolerance	Z3.2	11.3	14.3		

Table A.3.11: Clearances Z4.1 and Z4.2 between load make-up accessory and the back stop

		Positioning-system Store height	Coordinates		Teach In 20 m	Rack fine pos. 20 m
Factor of influence	Significance		10 m	20 m		
		No.:			n/a	n/a
Load make-up accessory	Tolerance of load length	T2	3.0	3.0		
	Positioning	T5	3.0	3.0		
S/R machine	Load handling device positioning accuracy	T8	3.0	3.0		
	Mast manufacturing accuracy	T11	2.0	3.0		
	Lifting carriage twisting due to mast guide	T12	1.0	1.0		
	Side guide roller clearance	T15	0.0	0.0		
	Load oscillation	V5	5.0	8.0		
Aisle equipment	Alignment accuracy of the floor rail	T19	2.0	2.0		
	Guide rail side accuracy	T20	4.0	4.0		
	Guide rail deflection	V11	3.0	3.0		
	Installation tolerance of the floor rail	T24	2.0	2.0		
Racking	Difference in height between the front and rear supporting beam	T34	0.0	0.0		
	Tolerance of the back stop	T42	2.0	2.0		
	Upright tolerance field	T41	8.0	12.0		
	Rack edge clearance	Z4.1	38.0	46.0		
	Rack centre clearance	Z4.2	38.0	46.0		
	Rack edge clearance at 70% tolerance	Z4.1	29.0	35.5		
	Rack centre clearance at 70% tolerance	Z4.2	29.0	35.5		

Measurement and Acceptance Report
(Appendix B to FEM 9.832)

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Measurement and Acceptance Report

Order Number:

Rack Location:

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Aisle: No.

Customer

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Project Manager:

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Supplier

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Assembly Manager:

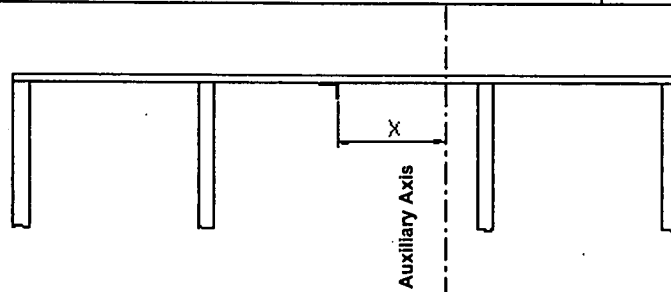
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- 5 Level T33 support tolerance for multi-location storage systems
 - 5.1 Rack height \leq 12 m
 - 5.2 Rack height $>$ 12 m
- 6 Support displacement for foot T26
- 7 Rack distance T35
- 8 Measurement Report
- 9 Partial Acceptance
- 10 Complete Acceptance

1 Guide Rail



General

- Screw head underneath / shaft above
- Rail joints welded, ground and primed
- Evenness in guide roller area over a measured distance of 200 mm \leq 1.0 mm
- No engraved text in guide roller area
- Length and position of guide rail

Tolerance "x"

On measured length
20 m

Tolerance
 \pm 2 mm

Measuring points at approx. 2 m intervals

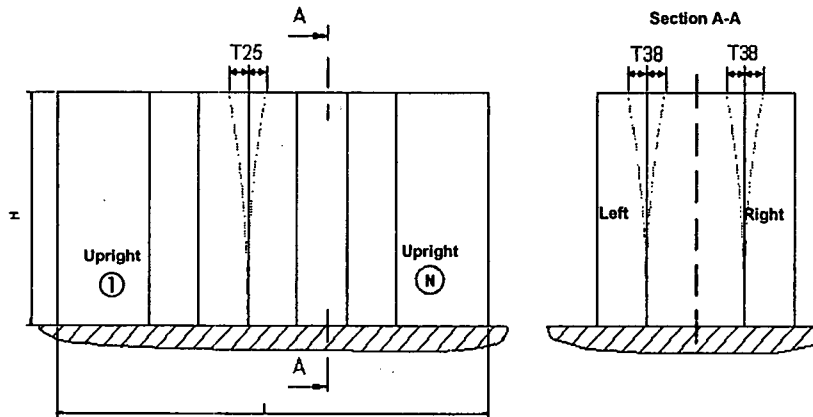
Measuring point	Dim. "x" (rated)	Deviation
	mm	mm
Upright 01		
Upright 05		
Upright 10		
Upright 15		
Upright 20		
Upright 25		
Upright 30		
Upright 35		
Upright 40		

Measuring point	Dim. "x" (rated)	Deviation
	mm	mm
Upright 45		
Upright 50		
Upright 55		
Upright 60		
Upright 65		
Upright 70		
Upright 75		
Upright 80		

2 Vertical Deviation T25 and T38 for single location storage systems

2.1 Rack height ≤ 12 m

Aisle side upright only (in respect of upright head)



T25 Tolerance
= ± 7 mm

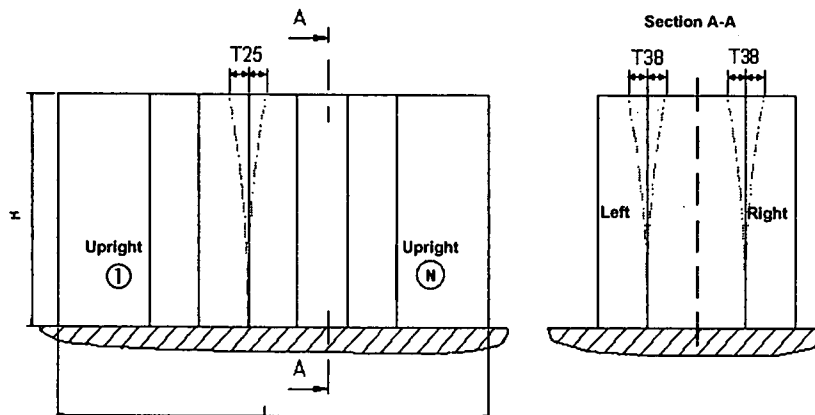
T38 Tolerance
= ± 6 mm

Measuring point	Left T25 (mm)	Right T25 (mm)
Upright 01		
Upright 05		
Upright 10		
Upright 15		
Upright 20		
Upright 25		
Upright 30		
Upright 35		
Upright 40		
Upright 45		
Upright 50		
Upright 55		
Upright 60		
Upright 65		
Upright 70		
Upright 75		
Upright 80		

Measuring point	Left T38 (mm)	Right T38 (mm)
Upright 01		
Upright 05		
Upright 10		
Upright 15		
Upright 20		
Upright 25		
Upright 30		
Upright 35		
Upright 40		
Upright 45		
Upright 50		
Upright 55		
Upright 60		
Upright 65		
Upright 70		
Upright 75		
Upright 80		

2 Vertical Deviation T 25 and T 38 for single location storage systems
2.2 Rack height > 12 m

Aisle side upright only (in respect of upright head)



T25 Tolerance
= ± 10 mm

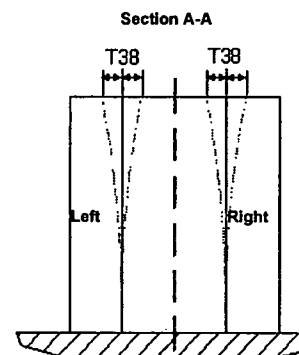
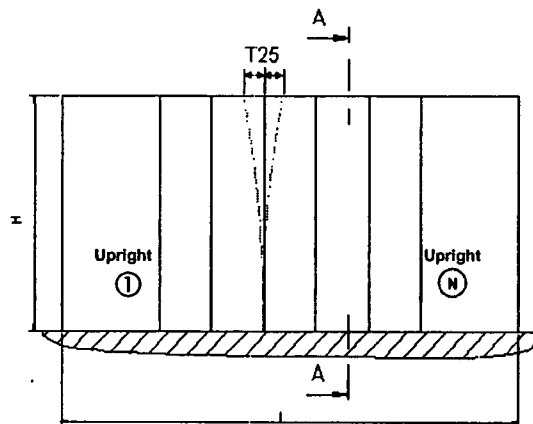
T38 Tolerance
= ± 10 mm

Measuring point	Left T25	Right T25
	(mm)	(mm)
Upright 01		
Upright 05		
Upright 10		
Upright 15		
Upright 20		
Upright 25		
Upright 30		
Upright 35		
Upright 40		
Upright 45		
Upright 50		
Upright 55		
Upright 60		
Upright 65		
Upright 70		
Upright 75		
Upright 80		

Measuring point	Left T38	Right T38
	(mm)	(mm)
Upright 01		
Upright 05		
Upright 10		
Upright 15		
Upright 20		
Upright 25		
Upright 30		
Upright 35		
Upright 40		
Upright 45		
Upright 50		
Upright 55		
Upright 60		
Upright 65		
Upright 70		
Upright 75		
Upright 80		

3 Vertical Deviation T25 and T38 for multi-location storage systems
3.1 Rack height ≤ 12 m

Aisle side upright only (in respect of upright head)



T25 Tolerance
 = ± 7 mm

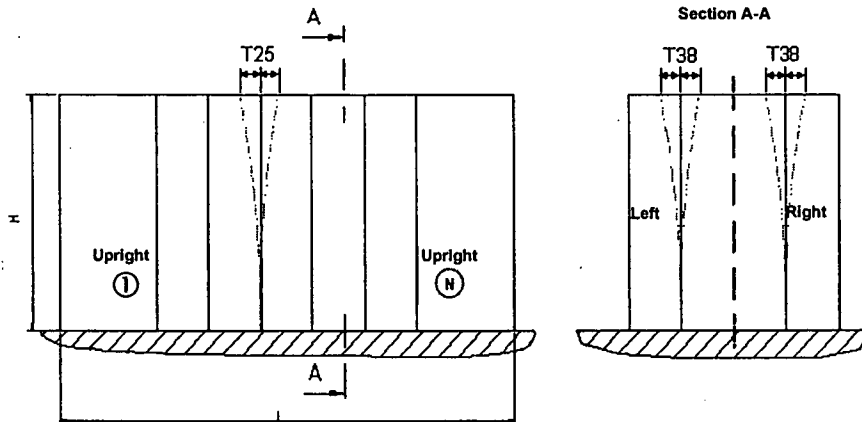
T38 Tolerance
 = ± 6 mm

Measuring point	Left T25 (mm)	Right T25 (mm)
Upright 01		
Upright 05		
Upright 10		
Upright 15		
Upright 20		
Upright 25		
Upright 30		
Upright 35		
Upright 40		
Upright 45		
Upright 50		
Upright 55		
Upright 60		
Upright 65		
Upright 70		
Upright 75		
Upright 80		

Measuring point	Left T38 (mm)	Right T38 (mm)
Upright 01		
Upright 05		
Upright 10		
Upright 15		
Upright 20		
Upright 25		
Upright 30		
Upright 35		
Upright 40		
Upright 45		
Upright 50		
Upright 55		
Upright 60		
Upright 65		
Upright 70		
Upright 75		
Upright 80		

3 Vertical Deviation T25 and T38 for multi-location storage systems
3.2 Rack height > 12 m

Aisle side upright only (in respect of upright head)



T25 Tolerance
= ± 10 mm

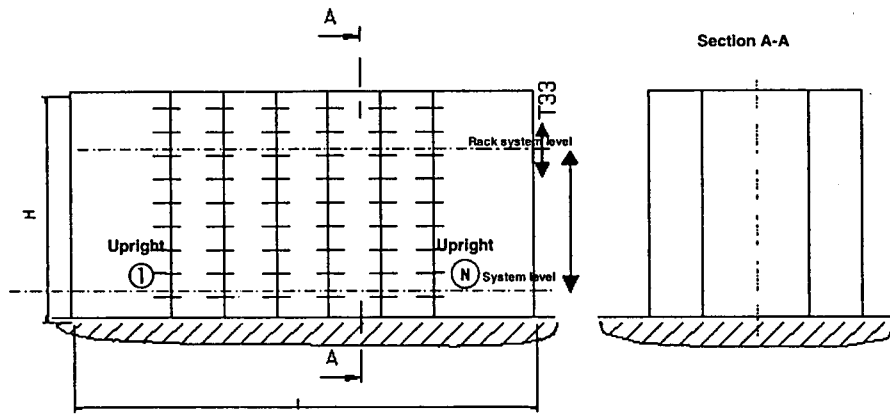
T38 Tolerance
= ± 10 mm

Measuring point	Left T25 (mm)	Right T25 (mm)
Upright 01		
Upright 05		
Upright 10		
Upright 15		
Upright 20		
Upright 25		
Upright 30		
Upright 35		
Upright 40		
Upright 45		
Upright 50		
Upright 55		
Upright 60		
Upright 65		
Upright 70		
Upright 75		
Upright 80		

Measuring point	Left T38 (mm)	Right T38 (mm)
Upright 01		
Upright 05		
Upright 10		
Upright 15		
Upright 20		
Upright 25		
Upright 30		
Upright 35		
Upright 40		
Upright 45		
Upright 50		
Upright 55		
Upright 60		
Upright 65		
Upright 70		
Upright 75		
Upright 80		

4 Support Tolerance Level T33 for single location storage systems
4.1 Rack height ≤ 12 m

Aisle side upright only



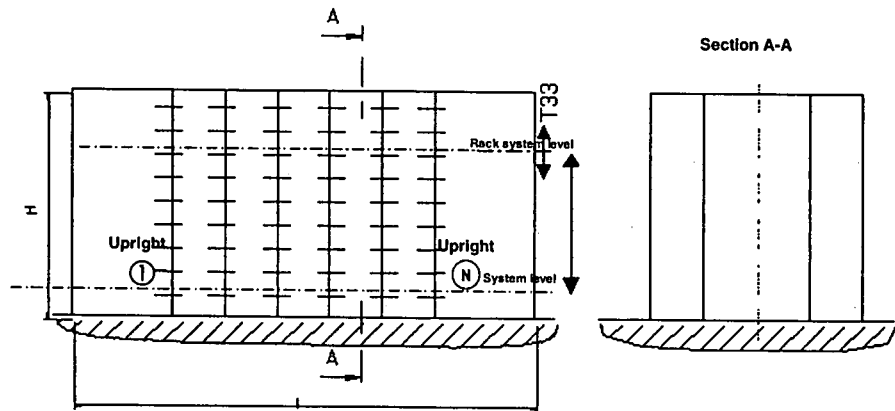
T33 Tolerance
= ± 3 mm

Upright	LH Tolerance Level			RH Tolerance Level		
	T33	T33	T33	T33	T33	T33
	Lowest Level	Above joint	Highest Level	Lowest Level	Above joint	Highest Level
1						
5						
10						
15						
20						
25						
30						
35						
40						
45						
50						
55						
60						
65						
70						
75						
80						

- The measurements are within the admissible tolerance range.
- The measurements are outside the admissible tolerance range.

4 Support Tolerance Level T33 for single location storage systems
4.2 Rack height > 12 m

Aisle side upright only



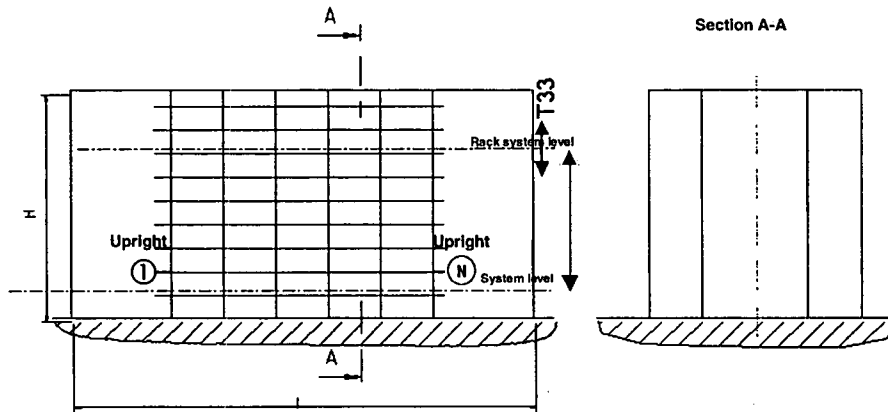
T33 Tolerance
= ± 5 mm

Upright	LH Tolerance Level			RH Tolerance Level		
	T33	T33	T33	T33	T33	T33
	Lowest Level	Above joint	Highest Level	Lowest Level	Above joint	Highest Level
1						
5						
10						
15						
20						
25						
30						
35						
40						
45						
50						
55						
60						
65						
70						
75						
80						

- The measurements are within the admissible tolerance range.
- The measurements are outside the admissible tolerance range.

5 Support Tolerance Level T33 for multi-location storage systems
 5.1 Rack height ≤ 12 m

Aisle side upright only



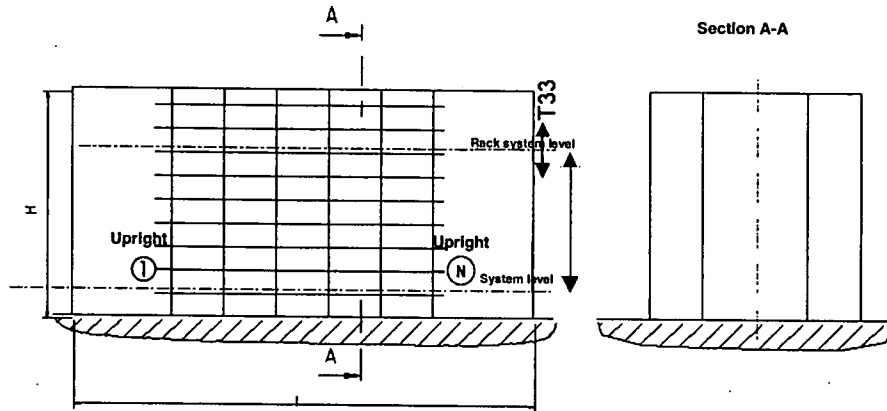
Tolerance T33
 = ± 5 mm

Upright	LH Tolerance Level			RH Tolerance Level		
	T33	T33	T33	T33	T33	T33
	Lowest Level	Above joint	Highest Level	Lowest Level	Above joint	Highest Level
1						
5						
10						
15						
20						
25						
30						
35						
40						
45						
50						
55						
60						
65						
70						
75						
80						

- The measurements are within the admissible tolerance range.
- The measurements are outside the admissible tolerance range.

5 Support Tolerance Level T33 for multi-location storage systems
5.2 Rack height ≥ 12 m

Aisle side upright only



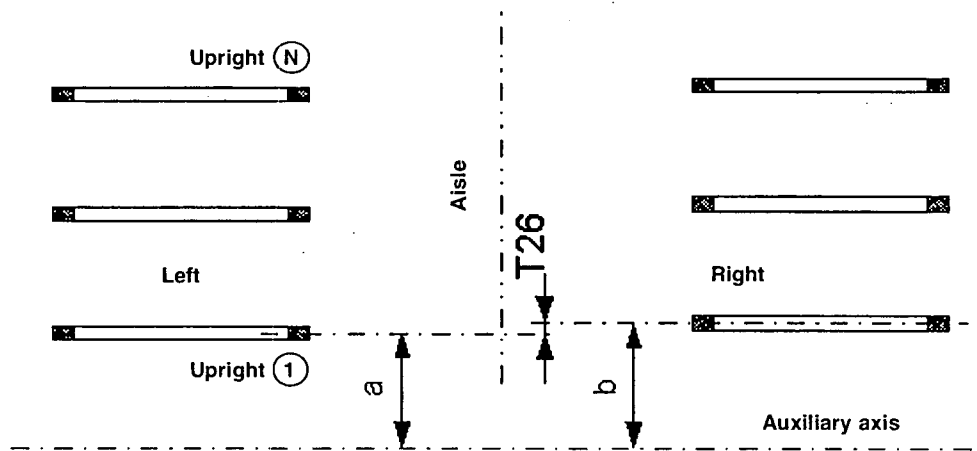
T33 Tolerance
= ± 5 mm

Upright	LH Tolerance Level			RH Tolerance Level		
	T33	T33	T33	T33	T33	T33
	Lowest Level	Above joint	Highest Level	Lowest Level	Above joint	Highest Level
1						
5						
10						
15						
20						
25						
30						
35						
40						
45						
50						
55						
60						
65						
70						
75						
80						

- The measurements are within the admissible tolerance range.
- The measurements are outside the admissible tolerance range.

6 Support Displacement Foot T26

Aisle side/ Axis 1 only



T26 Tolerance
= 3 mm

Foot a) (mm)	Foot b) (mm)

7 Rack Distance T35

One measurement / aisle only

Measuring point

Upright No.:

Side (left or right)

Rack Distance T35 Tolerance

= ± 2 mm

	Rated	Actual
Level	(mm)	(mm)
y 01		
y 02		
y 03		
y 04		
y 05		
y 06		
y 07		
y 08		
y 09		
y 10		
y 11		
y 12		
y 13		
y 14		
y 15		
y 16		
y 17		
y 18		
y 19		
y 20		

8 Measurement Report

Page B.14

Job number:

Rack location:

Customer:

Supplier:

Aisle:

- The agreed tolerances have been met
 not been met

- Responsible for the accuracy of the measurement report

.....
Company

.....
Contact

.....
Signature Date

- Random Testing Completed

.....
Company

.....
Contact

.....
Signature Date

9 Partial Acceptance

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Job number:

Rack location:

Customer:

Supplier:

Aisle:

• **The following approval measures were taken**

- Delivery complete as per order: Yes No
- Integrity of delivery: Yes No
- Quality of erection work: Satisfactory Not satisfactory
- Dimensions and tolerances: Met Not met
- Assembly work completed: Yes No
- System in clean and tidy condition: Yes No
- Documentation available: Yes No

• **Defects**

-to be rectified by.....
-to be rectified by.....
-to be rectified by.....
-to be rectified by.....
-to be rectified by.....

Complete acceptance to be granted after rectification of defects or the completion of assembly work and when the system is ready for approval.

.....
Date

.....
Customer

.....
Supplier

10 Complete Acceptance

Job number:

Rack location:

Customer:

Supplier:

Aisle:

• **The following approval measures have been successfully completed**

- Delivery complete as per order
- Integrity of delivery
- Satisfactory quality of assembly work
- Dimensions and tolerances met
- Assembly work complete
- System in clean and tidy condition
- Documentation available

System is approved

• **Conditions**

Acceptance is dependent on the final approval by the owner

.....
.....
.....
.....
.....

.....
Date

.....
Customer

.....
Supplier

References

Established by the Committee "S/R-machines and stacker cranes" of Section IX and working group 3 "Racking - Tolerances, Deformations, Clearances" of Section X of the Fédération Européenne de la Manutention (FEM).

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