FEDERATION EUROPEENNE DE LA MANUTENTION
Section IX
STORAGE AND RETRIEVAL MACHINES

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Calculation principles of storage and retrieval machines
Tolerances, deformations and clearances in the high-bay warehouse

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1 Introduction and aims

A high-bay warehouse, including S/R machines, forms a functional unit consisting of components which are subject to tolerances resulting from manufacture, erection, and deformations from operation.

S/R machines are designed to store unit loads into, and to retrieve them from, freely selected locations in complete operational safety. On the one hand, clearances which are too small constitute a risk to operational safety so that handling operations in a warehouse may have to be stopped. On the other hand, useful storage space is wasted where clearances are too large.

The aims of this document are to determine the admissible tolerances and deformations to be able to optimise the factors relating to the economical dimensioning, manufacturing and erecting required for the safe functioning of a high bay warehouse. Tolerances and deformations (if any) in a high-bay warehouse result from the following functional components:

- Floor slab
- Floor rail
- Upper guide rail
- Unit load
- Profile check
- Centring location (centring accuracy)
- S/R machine
- Rack structure

The influences contributed by the above are analysed in the following text and quantified as far as possible. Generally applicable data concerning floor slab deformation cannot be indicated. The definitive clearances can only be established when all the suppliers of the component parts of the system have been determined.

In order to ensure the functionality of the system, first the design concept of the machine (e.g. control mode, stability etc.) and the related rack classification have to be defined. Calculations for the clearances can be made based on quantified tolerances and deformations given in this document together with the individual values for tolerances, wear and deformations of the S/R machine. Using risk analysis the final clearances can be defined from the values resulting from the calculation in the worst case condition.

In principle it is possible to deviate from the figures stated in the document, for technical or economic reasons, if the functionality of the whole system can be guaranteed. However in this case clear agreements have to be reached on how the main aims of this document will be acheived i.e. "to define the interfaces between the components of a high bay warehouse".

2 Scope

These rules apply to high-bay warehouse served by S/R machines which travel on a floor mounted rail, are stabilized by an upper guide rail, are equipped with a mechanical load handling device, especially a telescopic fork, and are suitable for handling pallets or comparable load make-up accessories such as skeleton containers. It gives due consideration to steel rack structures, both the silo design and free standing racking. Within the scope of these rules and in connection with the type of control mode adopted for the S/R machines, the influence of the tolerances on the pallet fork entry and compartment clearances can be analysed i.e.:

A: manual control,
B: partially or fully automatic control for coordinate positioning system,
C: partially or fully automatic control with coordinate positioning and additional compartment precision positioning in y-direction only,
D: partially or fully automatic control with co-ordinate positioning and additional compartment precision positioning in x- and y-directions.

These examples and recommendations do not apply to automatic small parts warehouses and high density warehouses, (e.g. using mole truck devices). However, the structure and basis for calculation given here can be used analogously.

3 Definitions

Tolerances are permissible maximum deviations from nominal dimension, resulting from manufacture, erection and wear.

Deformations are deviations froms the basic position due to influence of forces:

Clearances are required nominal distances between fixed and moving parts and which, all individual tolerances and deformations considered, prevent collisions.

Entry Clearances are the clearances between the load make-up accessory and the load handling device.

Rack compartment clearances are the clearances between the unit load and the rack structure.

Aisle clearances are the clearances between the outer most edge of the S/R machine and the outer most edge of the rack structure or the load as well as the clearances at the rear of the stored load.

System axes:

x = Aisle length direction
y = Aisle vertical direction
z = Aisle lateral direction

4 Factors of influence

PRELIMINARY REMARKS: One common datum (reference point) in the longitudinal and elevation planes shall be defined for all trades by the persons responsible for the construction (see figure 3).

4.1 Floor Slab

4.1.1 Manufacturing tolerance, i.e. level of the surface on which the rack structure and floor rail are mounted. In the unloaded condition of the slab, the following values must be met:

With reference to an ideal horizontal system level datum the vertical floor tolerances in relation to the floor slab length are as follow:

up to	50 m	± 10 mm
up to	150 m	± 15 mm
more than	150 m	± 20 mm

4.1.2 Deformation due to settling and slab deflection, i.e. vertical deformation of the floor slab under load. From these deformations e.g. settling of the floor slab, settling of piles, supports etc., deflection of the floor slab which results in additional stresses and inclination of the rack structure can only be mentioned here in qualitative terms.

Taking into account certain geological factors deformation can be considerable, often amounting to centimetres, therefore it must be included at the planning stage in an evaluation of the tolerances and of the additional stresses.

All the following considerations used to determine the clearances are based on the assumption of a quasi rigid floor slab. This is regarded as the normal case providing the floor slab during operation produces a local slope no higher than $t\alpha = 5 \cdot 10^{-4}$. However, a judgement will have to be made for each individual case as and when this becomes necessary due to higher values.

4.2 Floor Rail

4.2.1 Alignment tolerances with reference to a vertical datum without tolerances, in the horizontal z-direction:

measured length = total rail length ± 3.0 mm
measured length = S/R machine wheel base ± 1.5 mm

Rail heads of different dimensions shall be made flush by grinding the side guide surfaces in the joint area, levelness of the joints over a measured length of 200 mm ≤ 0.5 mm.

4.2.2 Level tolerances of H_2 in the y-direction, in figure 3, with reference to a horizontal datum plane without tolerances in the vertical direction:

measured length < 100 m ± 2.0 mm
≥ 100 m ± 3.0 mm

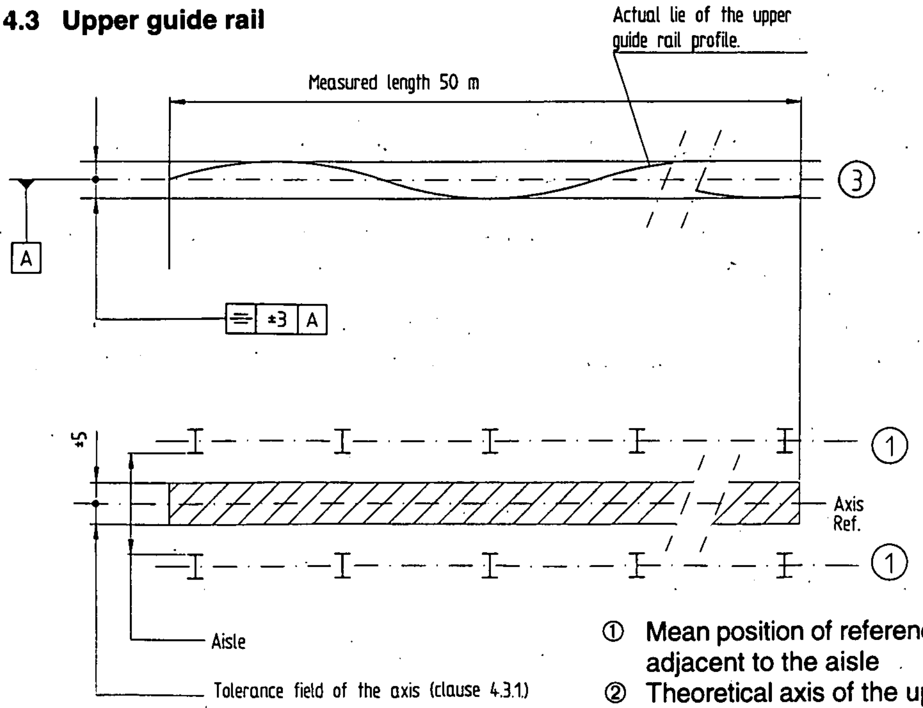
measured length = S/R machine wheel base ± 0.5 mm

Rail heads of different dimensions shall be made flush by grinding in the joint area; levelness of the rail and of the joints over a measured length of 100 mm shall be ≤ 0.1 mm.

4.2.3 The travel characteristics of the S/R machine can be influenced by the uneveness of the top and side guide surfaces of the rail. These surfaces must be even, i.e. there must be no pitting resulting from rust or rolling.

4.2.4 Dimensioning and anchoring of the floor rail is the responsibility of the equipment manufacturer in conjunction with the civil engineer and the installer of the rail.

4.3 Upper guide rail



① Mean position of 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 ± 5 mm relative to the reference axis ②.

Note: Two examples of permissable extremes.

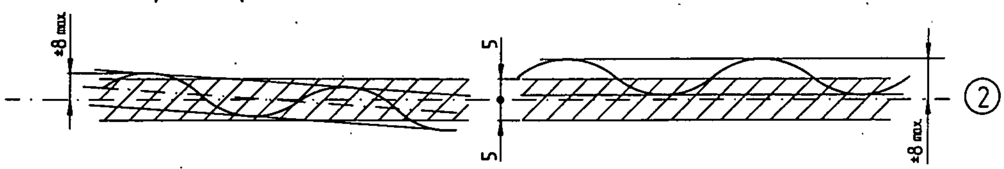


Figure 1: Tolerances for the upper guide rail (plan view)

4.3.1 The tolerance of the longitudinal axis of the guide rail in relation to the mean of the centrelines of the rack uprights along an aisle, shall not exceed ± 5 mm over a measured length of 50 m; see figure 1.

4.3.2 When unloaded, the horizontal deviation of the upper guide rail from its longitudinal axis shall not exceed ± 3 mm; see figure 1.

4.3.3 Any difference in rail section dimensions at joints in the running area of guide rollers, cable trollies etc. shall be ground flat. Flatness in a measured length of 200 mm shall be ≤ 0.5 mm.

4.3.4 There shall be no rolling inscriptions (i.e. raised lettering) on the running surfaces.

4.3.5 Maximum lateral deformation (sagging and twisting) in the area of the guide rollers resulting from horizontal forces with the load handling device extended and with the maximum load shall not exceed 6 mm.

4.3.6 The bottom edge of the guide rail shall not exceed the tolerance field H_3 = +10/-5 mm in relation to a tolerance-free datum plane when the racking is unloaded; see figure 3.

4.3.7 Vertical deformations resulting from loads such as rack loading (column compression) and snow loads shall be taken into account.

4.3.8 The sizing and selection of the type of fixings is the responsibility of the machine manufacturer in conjunction with the supplier of the upper guide rail, (e.g. rack supplier).

4.4 Unit Load

4.4.1 Load make-up accessories

For standardised load make-up accessories, the manufacturing tolerances of the relavant standard specifications shall be used. For non-standardised load make-up accessories, the tolerances shall be agreed between purchaser and manufacturer of the machine.

When using load make-up accessories made of timber, shrinkage resulting from drying out shall be taken into account in addition to manufacturing tolerances.

Where Euro pool pallets are used, the safe operation of the S/R machine must be guaranteed if the showed tolerances in figure 2, measured by placing the pallet on a rigid plane, are not exeeded.

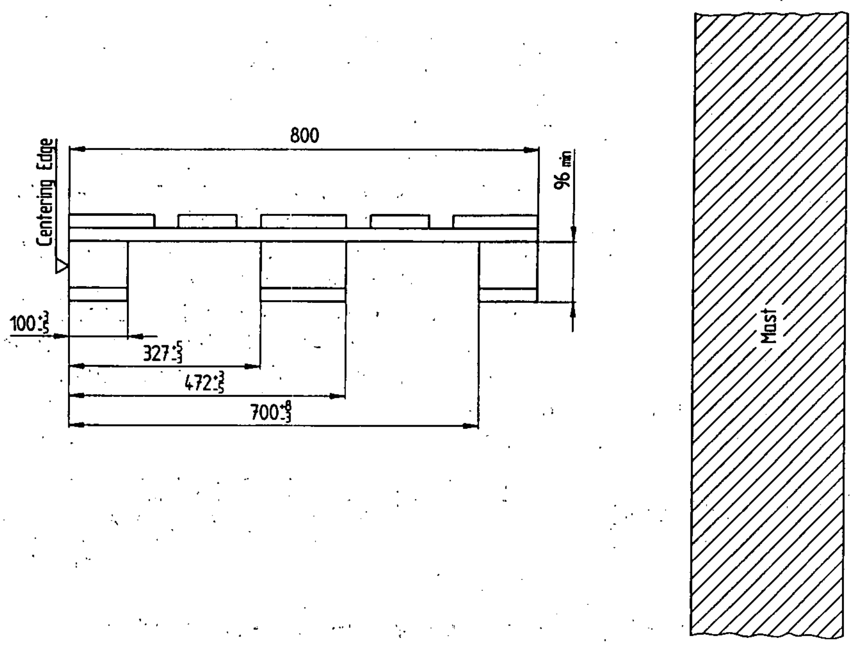


Figure 2: Tolerances of Euro-Pool-Pallets

Load make-up accessories may be subject to elastic and/or plastic deformation, even after they have passed the profile gauge, which could influence the entry dimensions. This deformation may increase over a longer period of storage. The amount of deformation depends on the applied load, the stabilizing effect of the load, the distance between supports and the condition of the load make-up accessory (e.g. humidity of wood).

Where no data is available relating to the load make-up accessory deflection, up to 6 mm[1] shall be allowed for in the vicinity of the load handling device with reference to the top of the rack support beam.

The ACTUAL dimensions of the Euro pool pallets (800 mm x 1200 mm) from experience shall be checked particularly in the area of the fork entry apertures due to the possiblity of reduced clearances, particularly in the case of forks used for heavy weights. The maximum allowable tolerances of the critical areas are shown in figure 2.

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[1] Figure determined from experience of Euro pallets 800 x 1200 mm consisting of wood with a 1000 kg load area, taking into account the stabilising effect of the load, 900 mm support width (= beam width), dwell time in the warehouse and timber humidity (see national standards).

4.4.2 Load

When defining the maximum dimensions of the load, the following criteria shall be given due consideration:

- slanting pile
- projections of the load securing means (crinkles of the wrapping foil, straps and strap locks etc).
- deformation of the load during handling
- deformation of the load during storage
- symmetry of the load

Testing may be necessary to define the effect of the above points on the dimensions.

4.5 Profile Check

Unit load dimensions can be checked by means of photocells within a tolerance of ± 5 mm. This tolerance may change if other methods are adopted for checking.

Profile checking is unnecessary if handling operations are manually controlled. It is, however, absolutely necessary for load handling by automatically controlled S/R machines, both for the fork clearance of the load handling device and the load parameters.

4.6 Centring location (pick up position only)

With reference to its nominal position the unit load should be aligned to the centring edge within a tolerance of ± 5 mm, in the x- and z-directions.

In automatic conveying systems with fixed stops and a constant load the position of the pallet in the pick up position is to be within a tolerance of ± 2 mm in the x-direction.

4.7 S/R machine

At the extremity of the extended load handling device, a tolerance zone of varying values in the x-, y- and z-direction can result from the sum of the influences enumerated in the following sections 4.7.1 to 4.7.3. Generally this data cannot be specified within these rules, since S/R machines supplied by individual manufacturers differ widely in dimensions, rigidity, and other design features. 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 typical calculation (see appendix) can only be regarded as examples to demonstrate the effects tolerances have on the overall system.

4.7.1 System tolerances due to the S/R machine

The entry and rack compartment clearances are affected by factors such as:

- tolerances of the mast and/or of the guides on the mast for the lifting carriage
- play between the lifting carriage and the guides on the mast
- misalignment of the load handling device with reference to the axis
- play in the z-direction between the bottom guide rollers and the upper guide rollers with reference to the floor rail and/or upper guide rail
- mechanical wear

4.7.2 Elastic deformation

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

4.7.3 Positioning tolerances

The positioning accuracy in the x-, y- and z-directions is affected by factors such as:

- positioning system and motor control
- positioning speed
- delay period of the control system
- brake application delay

- braking path 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

4.7.4 Tolerances of the positioning marks

With reference to their nominal position, positioning markers (switching cams, reflecting foils, inductive actuating tags etc.) shall be fitted within a tolerance of ± 1 mm. This nominal position refers to the actual dimensions of the racking.

4.7.5 Notes

Note 1: Critical entry of the telescopic fork in the fork apertures of the load make-up accessory can be mitigated by bevelling the fork tips at the top and sides.

Note 2: (particularly applicable to control system B)
When positioning the vertical aperture marks on the S/R machine, the position of the marks shall be determined from the relationship between the extended forks and the pallet aperture beam level. This eliminates any manufacturing tolerances of the S/R machine.

Note 3: (particularly important in the case of Euro pallets 800 x 1200 mm or pallets with fork entry apertures ≤ 230 mm wide)
The effect of deformation from a crane loaded cycle can be reduced (by up to half) when calculating pallet fork entry clearances if the position of the loaded pallet at the pick up point is offset by equivalent to half of the load cycle deformation. (i.e. pallet position adjusted in the direction of the mast or dimensions x_2 increased accordingly); see figure 5.

Note 4: The nominal location of the horizontal positioning markers at floor level (x axis) should be related to the horizontal position of the top apertures. In this way it is possible to partly compensate for the effects of any rack erection tolerances and mast deformation resulting from a crane loaded cycle.

4.8 Rack Structure

Tolerances and deformations of the racking influence operating safety. To some extent, the permissible values depend on the 4 control modes described in clause 2 (scope), the load handling device and the type of load make-up accessory (dimensions of the fork entry apertures). For the sake of simplicity, however, only 2 tolerance categories are defined for the rack design.

> NOTE: In certain circumstances, diagonal bracing in the x-direction can be dispensed with when using free standing racking (not clad rack). In this case, the relevant effects on assembly tolerances and deformations must be agreed contractually with the person responsible for the system.

Class 100: (Lower tolerance and deformation values)
For control system B in conjunction with S/R machines <u>without</u> positioning aids at the storage position. Usually for storage systems of light weights and low to medium height (max. 18 metres).

Class 200: (Higher tolerance and deformation values)
For control systems A, C and D in conjunction with S/R machines having positioning aids at the storage position or manually controlled.

In the case of an automatic system, a calculation should be made by the person responsible for the design of the system. From this a decision can be made to determine the classification and control mode.

The following considerations mainly refer to rack structures where the unit loads are supported by longitudinal beams (see figure 3); for other types of racking, the appropriate adjustments should be made.

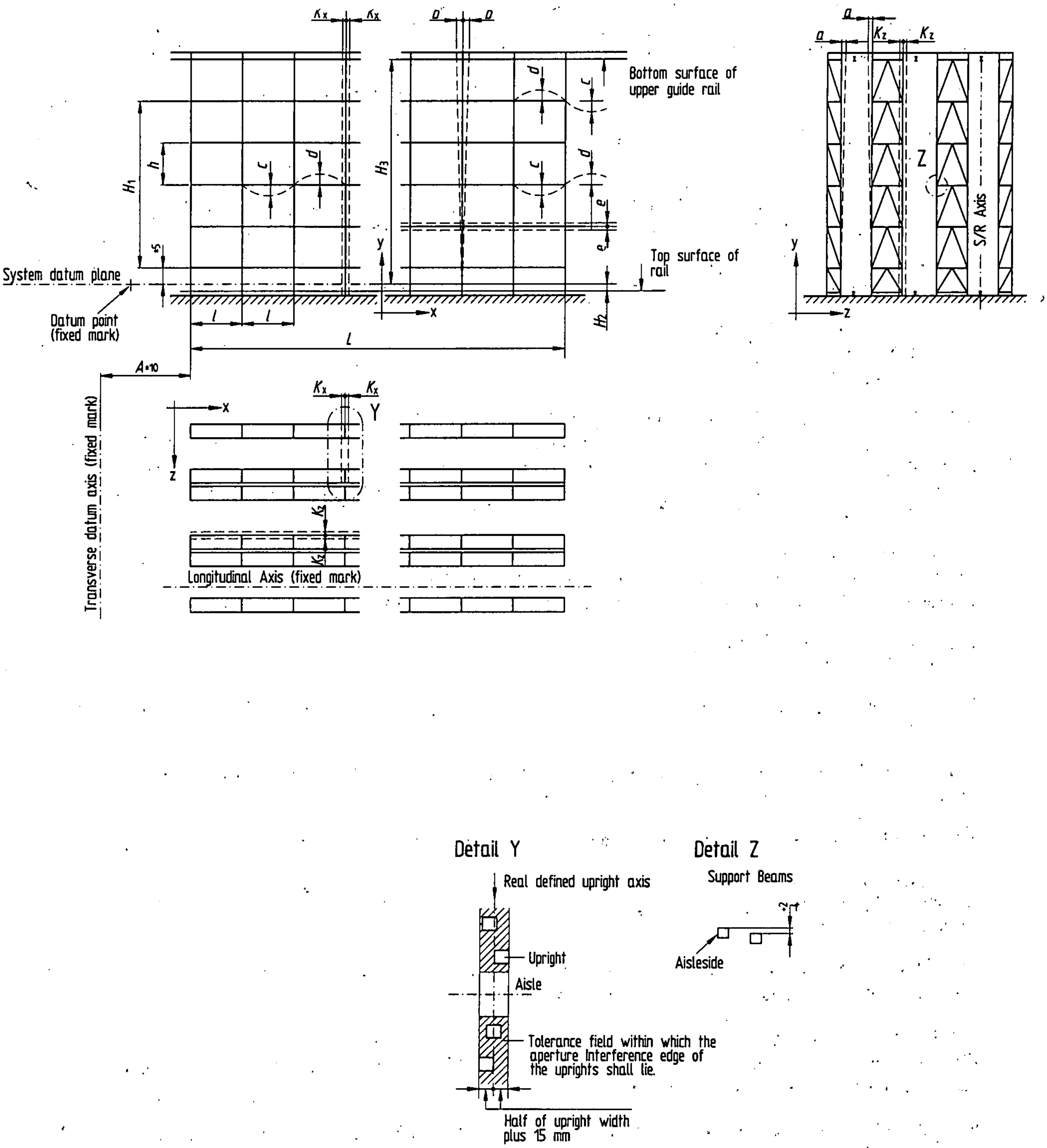

Figure 3: Rack structure

4.8.1 Manufacturing and erection tolerances in the unloaded condition

4.8.1.1 Dimensions in the x direction (for classes 100 and 200):
The tolerance field K_x of mutually opposite uprights, resulting from offset of the upright feet, slanting, precurvature of the supports and frames over the total height must not exceed 15 mm, (see figure 3).

The pitch of individual rack aperture uprights (l) shall lie within a tolerance of ± 3 mm.

The centreline of the first rack upright shall lie within a tolerance of ± 10 mm in relation to the horizontal transverse datum.

Up to a length of 40 m, the overall length (L) of the rack structure shall not deviate from the nominal dimension by more than ± 20 mm or, in the case of longer rack structures, by more than ± 0.5 ‰ .

Following erection, the individual axes of the uprights have to be fixed in accordance with the actual dimensions on site however the tolerances of the following dimensions must be maintained:

- first row of racking uprights (dim. A, figure 3)
- rack aperture l
- overall length L

4.8.1.2 Dimensions in the z-direction (for classes 100 an 200):
The outer extremity of the uprights and the beams on the aisle side shall lie within a tolerance of K_z = ± 15 mm in relation to the vertical, tolerance-free aisle datum plane (x-y). Mechanical devices (e.g. back stops) at the rear of pallets to prevent them being pushed through the racking must be fixed within a tolerance of ± 5 mm in relation to the edge of the upright (see figure 7).

4.8.1.3 Dimensions in the y-direction:
The level tolerance at each individual level of all support beams situated in individual aisles and all aisles served by the same machine are to be within the following values:

Class 100: e = ± 5 mm
Class 200: e = ± 10 mm

The distance (h) between two adjacent beam levels shall not deviate from the nominal dimension by more than ± 5 mm.

The height (H_1) between the lowest and highest beam level, determined from the actual situation, may have a total tolerance of ± 0.5 ‰ of the height H_1.

The level tolerance of the lowest beam level in relation to the fixed level datum may be ± 5 mm.

If possible, within the area of a storage location, the top surface of the rear spporting beam should not be higher, but no more than 4 mm lower, than the top surface of the foremost beam. Positive tolerances of + 2 mm are allowed.

4.8.1.4 When checking tolerances for clad rack construction, the effect from wind and temperature during the checking period shall be taken into account.

4.8.2 Deformation due to external forces

External forces such as snow loads, reaction forces of S/R machines, temperature influences and particularly wind pressures result in various deformations.

In the case of silo structures, wind forces in the z-direction may lead to critical deformations of the outer racks. Equally, wind forces in the x-direction are capable of generating critical deflections on the gable end. Attention should be given to the size and direction of individual deformations resulting from the direction from which the wind is coming and the surrounding environment. Depending on the circumstances this may require that the following restrictions be imposed in order to ensure safe operation of the store. This particularly applies to any effect on the structure at the outer rack storage positions or at the top of the racks.

- no redistributions (i.e. transferring pallets from one position to another)
- discontinuation of the store operation in specific zones at a predetermined wind velocity and direction (i.e outer aisles or top levels)

NOTE: Unless otherwise agreed or stipulated in legal requirements, the functionality of the system should be guaranteed in all areas of the warehouse up to wind velocities of 70 % (dynamic pressure 50 %) of the values stated in national rules relating to the design loads for buildings. This reduced value corresponds to a wind velocity of approximately 80 to 100 km/hour.

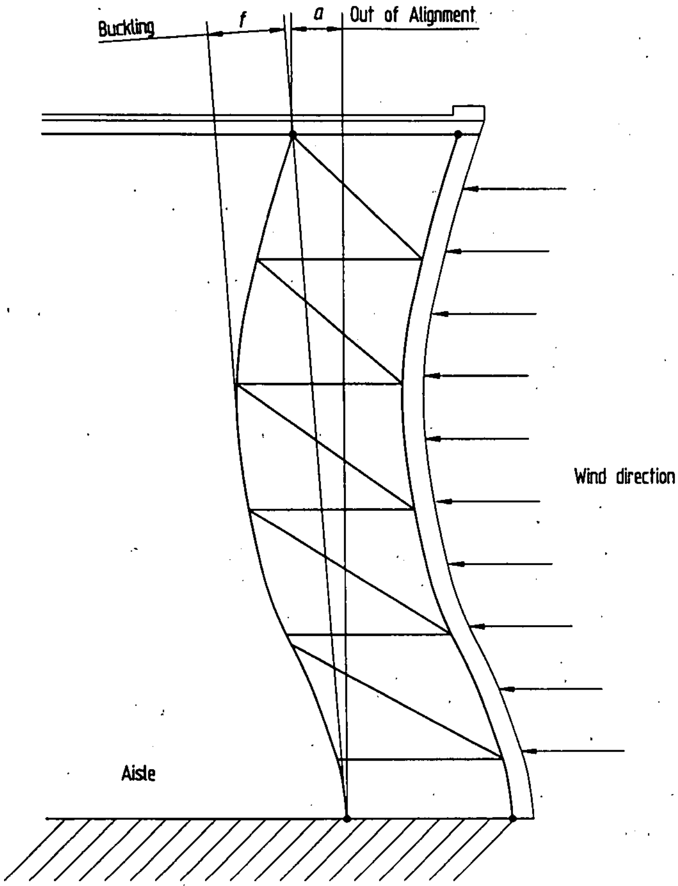

Figure 4: Deformation of rack side frames under wind pressure

In the conditions of lateral wind forces being imposed in the outer rack structure, deformations as shown in figure 4 would occur. If deformation of the rack uprights of f > 15 mm (i.e. buckling measured from a line drawn between the base centre point and the top of upright centre point to the extremity of the deflection), this can necessitate the increase of the clearance between the aisle width load faces. If the storage conveyor structure is connected in any way to the rack structure at the outer rack position it will affect the Pick up position in the z-axis.

In a highbay warehouse of the silo/clad rack type using 800 x 1200 mm Euro pool pallets, the fork entry clearances x_1 and x_2 are particularly critical at the upper levels. If deflections of ± 10 mm are likely to occur in operational conditions, consideration should be given to the following measures to ensure the operational viability of the system (e.g. fine positioning in the x axis related to the aperture or strengthening of the rack structure in the longitudinal direction or reduction of the fork width to give increased clearances (x_1 and x_2). For warehouses using load make-up accessories having adequate fork entry clearances x_1 and x_2, deflections at the top of the rack structure resulting from payloads and external forces (e.g. wind velocity see note above) may be in accordance with the values given in table 1.

Table 1: Permissible deformations based on the working limits (e.g. wind velocities as per note in 4.8.2). To be read in conjunction with Figure 3. Dimensions for intermediate heights to be interpolated.

Warehouse height (m)	Dimension a (mm) in z-direction	Dimension b (mm) in x direction		
		Euro-Pool-Paletts 800 x 1200 mm		load make-up accessory with fork entry apertures having a width of 260 mm min.
		Type of control system A/D	B/C	Type of control A/B/C/D
bis 15	15	12	10	12
20	20	16	10	16
25	25	20	10	20
30	30	20	10	24
35	35	20	10	28
40	40	20	10	32

For calculation of the deflections in the x-direction the stabilising effect of the longitudinal cladding may be taken into account, but the type and design of these items must be suitable for the application. In any case the calculation of the load carrying capacity of these items must comply with the relevant national standards for calculations and assumptions.

Any deformations resulting from earthquakes or crane buffer impact loads at the top of a rack structure need not be taken into account.

4.8.3 Deformation due to working load

Pallet loads placed within rack apertures cause the support beams to deflect and the rack uprights to compress. This deflection and compression results in a downward movement of the structure in the y-direction. This compression is cumulative over the total height of the rack structure.

The supporting beams deflect in different ways depending on the load distribution and type of design (single span or multiple span beams). In the case of the worst load conditions, continuous supporting beams can be expected to deflect as shown in figure 3.

The permissible deflections in the area of the fork tips are listed in table 2. However, the permissible bending and twisting rigidity of the beams must not be exceeded.

Table 2: Maximum deformation in mm of supporting beams under load (in the area of the fork tips)

	Class 100		Class 200	
	c	d	c	d
Span of the beam	$\frac{1}{300} \cdot l$ max. 10	max. 7	$\frac{1}{200} \cdot l$ max. 15	max. 9
Cantilever beam	In the case of single position cantilever beams the deflection at the end of the cantilever beams will be less than that of an adjacent three position aperture (simply supported) but will be 20 % larger than an adjacent two position aperture (simply supported). This is on the basis that all the beam cross sections are the same.			
c: sagging d: hogging l: span (centreline to centreline of upright)				

Possible maximum upward deflection (hogging) of unloaded spans of continuous beams should be taken into account when loaded pallets are placed in an adjacent aperture. In the case of retrieval it is assumed that the hogging effect cancels out due to the weight of the load and compression of the rack columns.

4.8.4 Additional deformations as a result of column inclination
The inclination of columns resulting from external forces and/or erection can lead to additional horizontal deformations. These "second order" deformations shall be taken into account in the design of the structure.

4.8.5 Permissible deformations
The application of permissible deformations a and b (see figure 3) are as listed in table 1 (i.e. for operating conditions which are not extreme e.g. wind velocities as per note in 4.8.2). These values are for conditions measured at the top most point of the rack uprights (upper guide rail level). For determination of the tolerances the following are to be taken into account: deformations due to external forces based on the working limits (4.8.2), deformations due to working load (4.8.3) and additional deformations (4.8.4).

Where Euro pool pallets are used in some applications (particularly with pallet loads over 800 kgs, with respect to wider telescopic forks), it will be necessary to consider the entry clearances x_1 and x_2 in some detail from which corresponding measures may need to be taken.

COMMENT: In the case of silo/clad rack constructions for Euro pool pallets 800 x 1200 mm with control modes B and C (see chapter 4.8.2 and table 1 column 4) special provision for longitudinal stiffening will probably be necessary for the rack structure.

In the case of free standing rack structures the horizontal deformation (at the top) due to the weight of the stored goods is assumed to act in one direction only due to vertical misalignment, i.e. plumbness. This deformation will not be reserved as in the case of clad rack structures, which may occur due to wind loading. It is possible to adjust the positioning marks of the S/R machine due to the deformation after start up of the system.

NOTE: Rack Structures of Concrete Construction
As a rule highbay warehouses constructed of concrete will be of substantially stiffer construction in the longitudinal direction than those constructed of steel. This will have a particular effect on deformation resulting from external forces and working loads (slight deflections and practically no compression). On the other hand, the manufacturing and erection tolerances are likely to be substantially higher, whereby tolerances of ± 3 mm can be achieved in the height of the pallet apertures depending on methods of adjustment and erection (e.g. by use of the S/R machine for installation of the beams). However, it should be noted that aperture span lengths are generally larger resulting in a possible greater beam deflection which must be allowed for. Consideration of all inter-related disciplines is mandatory.

5 Clearances

All clearances refer to the unloaded system without tolerances.

5.1 Entry clearances

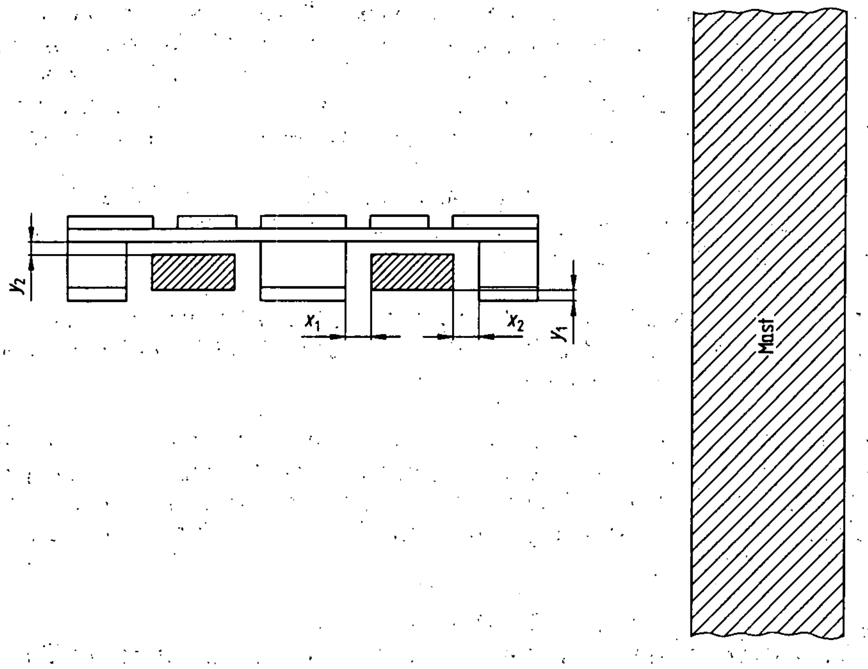

Figure 5: Fork entry clearances

Entry clearances are the clearances between the load handling device and the load make-up accessory.

- x_1 on the side of the load handling device which is furthest from the mast
- x_2 on the side of the load handling device which is closest to the mast

for twin mast S/R machines, x_2 shall be used for either side.

- y_1 between the load handling device and the load supporting beam
- y_2 between the load handling device and the load make-up accessory

for which, in all cases, the largest cross-section of the load handling device entering the load make-up accessory shall be taken into consideration.

5.2 Rack compartment clearance

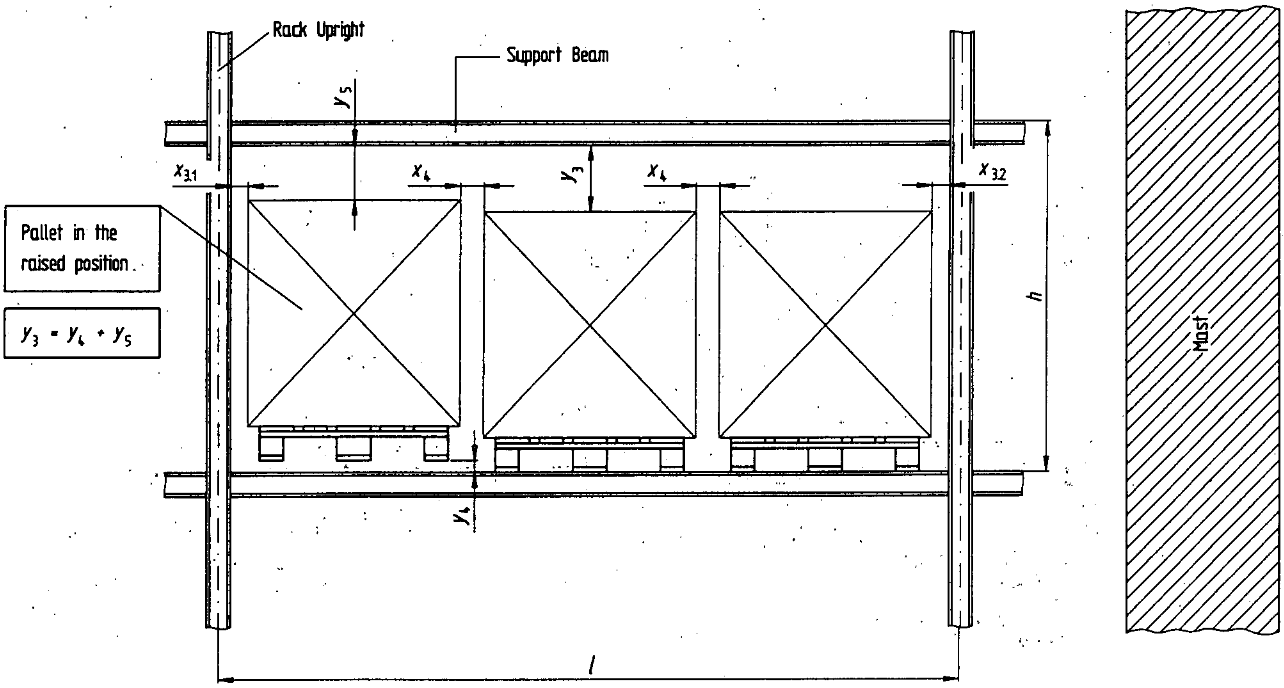

Figure 6: Aperture clearances

Rack compartment clearances are the minimum distances

- $x_{3.1}$ between the unit loads and the uprights on the side which is furthest from the mast
- $x_{3.2}$ between the unit loads and the uprights on the side which is closest to the mast
- x_4 between the individual unit loads
- y_3 between the top of the unit load and the rack structure and/or other obstructions (e.g. sprinkler). Rack compartment clearance y_3 consists of the lower dimension y_4 (top of lower support beam to the underside of the raised load handling devide) plus clearance y_5 (top of raised load to underside of upper support beam), see figure 6.

5.3 Aisle clearance

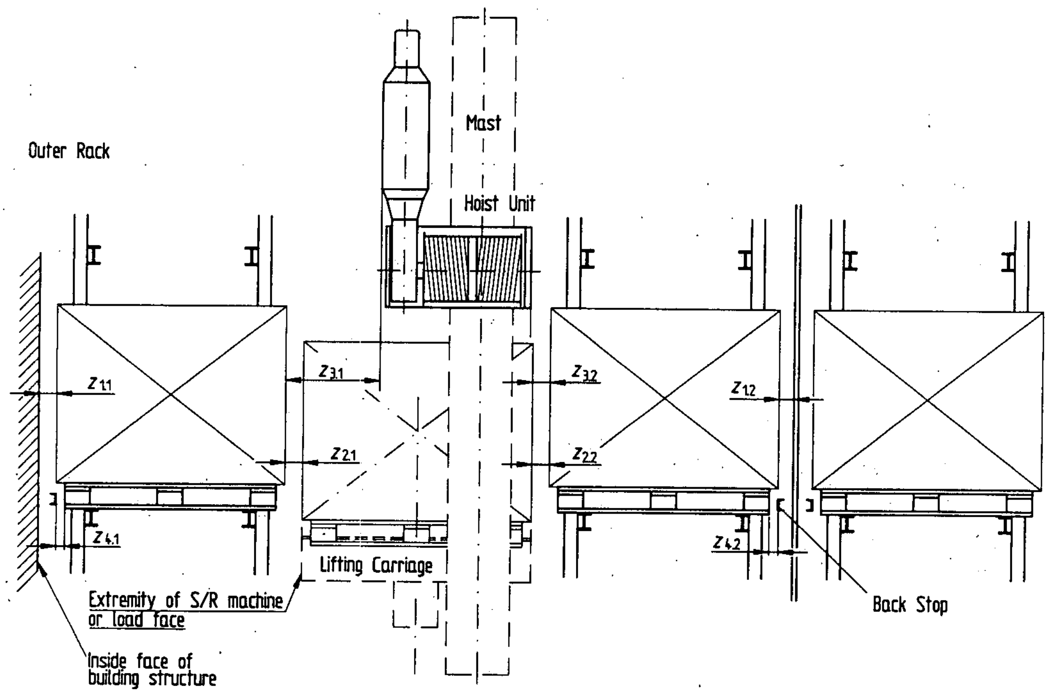

Figure 7: Aisle clearances

Aisle clearances are the minimum distances:

- $z_{1.1}$ between the unit load and any obstruction on the building side (e.g. building structure, rainfall pipe)
- $z_{1.2}$ between the unit load and rack structure inner racks
- $z_{2.1}$ between the outermost point of the lifting carriage or the unit load on the lifting carriage and the nominal position of the stored load or the rack structure with a protruding load in the stored position. Outer rack side.
- $z_{2.2}$ ditto, inner rack side.
- $z_{3.1}$ between fixed obstructions on the S/R machine (e.g. lifting mechanism or platform) and the stored load or the rack structure. Outer rack side.
- $z_{3.2}$ ditto, inner rack side.

5.4 Special obstructions

Among other things, the following special conditions shall be taken into account in defining the clearances. This shall be carried out at an early stage of the planning phase and particularly prior to the specification of the clearances.

- arrangement of fire sprinklers and smoke alarm systems
- domestic installations (pipes, lighting, ductwork)
- statutory minimum clearances (e.g. from sprinkler nozzles)
- variations in profile thicknesses depending on rack structure design
- protruding single items (bolt heads, holders, transmitters etc.)
- variations in unstable loads during placement in storage or during the storage period.

6 Control calculation

6.1 Summary of influencing factors on the clearances

(T: tolerance field, V: deformation value)

Ref.	Influencing factor / relating to	clause
	Load and Profile Check	4.4.2
T1	maximum width (measurement accuracy)	4.5
T2	maximum length (measurement accuracy)	
T3	maximum height (measurement accuracy)	
	Load Make-up Accessory	4.4.1
T6	pallet dimensions reference to centring edge	figure 2
T7	positioning accuracy in x-direction	
T8	positioning accuracy in z-direction	
T9	reduced height of fork entry apertures (wear and shrinkage)	
V1	sagging of load Make-up Accessory, measures between beams	
	S/R machine	4.7
T12	positioning accuracy in x-direction	
T13	positioning accuracy in y-direction	
T14	positioning accuracy of fork extension	
T15	positioning accuracy of fork centring	
T16	mast manufacturing accuracy in x-direction e.g. alignment and straightness of the guide rails	
T17	mast manufacturing accuracy in z-direction	
T18	parallelism of the fork axes relative to the centring edge of the pallet	
T19	horizontal twisting of the lifting carriage due to the mast guide rail tolerances	
T20	inclination of the forks top surface in x-direction in relation to the horizontal datum	
T21	inclination of the forks top surface in z-direction in relation to the horizontal datum resulting from erection tolerances, roller clearances, floor and upper guide rail tolerances	
T22	clearances of the side guide rollers on the bottom carriage	
T23	erection accuracy of the height positioning markers with reference to the rack compartment levels, (see note 2 clause 4.7.5)	
T24	fork sag, unloaded (due to roller clearances and wear)	
T41	wear of wheels and rails	
V5	mast deflection resulting from mast oscillations in the x direction	
V6	mast deformation in the x-direction at the top rack aperture level (load transfer deformation)	
V7	load displacement in z-direction due to distortion of the mast and lifting carriage due to static load moments and oscillation during deceleration of the mass	
V8	displacement of the load in the z-direction during travel due to the bending and torsional oscillations of the mast	
V9	twisting of the lifting carriage in the x-direction, (load transfer deformation), measured at the fork end	
V10	fork deflection when loaded excluding T24 (sagging of forks)	
V12	tip of fork deformation in the y-direction with the load extended	
V13	horizontal deformation in the x-direction of the extended fork tip owing to the torsional oscillations of the mast due to acceleration of the load in the z-direction	

Ref.	Influencing factor / relating to	clause
	Aisle Equipment	4.2, 4.3
T25	alignment accuracy of the floor rail	figure 1
T26	alignment accuracy of the upper guide rail axis and horizontal deviations of the guide rail relative to this axis	
T27	height tolerance of the floor rail	
T28	installation accuracy of the positioning marker in x-direction	
T29	installation of the floor rail in the z-direction in relation to the vertical plane datum	
V16	deflection of the upper guide rail with the load extended in the z-direction	
V17	deflection of the floor rail in the y-direction	
	Rack structure	4.8
		figure 3
	in the x-direction	figure 6
T30	tolerance range of opposite uprights	
V20	permissable verticality resulting from external forces and loads under operating conditions	
	in the y-direction	figure 3
T31	level tolerance of the front supporting beams	figure 6
T32	height difference between the front and rear supporting beams	
T33	distance tolerance between two beam levels	
V21	upright compression	
V22	deformation of the supporting beams	
	in the z-direction	figure 3
T34	tolerance of any obstruction at the rear of the load	figure 4
T35	tolerance of the back stop relative to the edge of the adjacent rack upright	figure 6
T36	installation tolerance of the upright	
V23	deformation of the racks under operating conditions as a result of external forces and loads (dimension f)	figure 7
V24	displacement of the pallet pick-up position as a result of wind forces on the exterior of the building (only when attached to the rack structure)	
	construction and miscellaneous (ignored in the subsequent calculation examples)	
T40	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.	
V30	dimensional changes of the load during storage	
V31	additional sagging of the load make-up accessory	
V32	sagging and deflection of the floor slab resulting in the inclination of the SR machine and the racking	
V33	deformations due to temperature influences	

6.2 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 supplier 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 control mode and racking classification. An example of a calculation of clearances is given in the tables A.1 to A.12 of the annex.

Experience and the law of probability indicate that not all maximum tolerances and deformations will occur in the same position, in the same direction and at the same time.

In some cases tolerances and deformations which combine in one direction may be compensated for by adjustments on the S/R machines e.g. alignment of the mast in the x-direction to the rack structure or by adjusting the y-axis marks at the upper levels after partly filling the racking to take account of any compression of the uprights.

In silo or clad rack structures which store Euro pool pallets type I (800 x 1200 mm) the lateral clearances for fork entry in the fork apertures are to be considered as particularly critical. If loaded pallets are heavy such that they necessitate the use of forks having large cross section dimensions it could be possible that the system may not function under conditions of maximum tolerances and deformations at the top pallet level (particularly high wind forces in the x-direction). Under these circumstances special measures may have to be taken such as reducing the tolerance values given in table 1, increasing the wind bracing or even restricting operations when severe wind conditions in the x-direction prevail.

6.3 Calculation methods

The worst case condition occurs with all tolerances and deformations at a maximum value and in the least favourable direction. The result is a dimension which must be related correctly to the required clearance. If the supply and erection of the individual components of the system are divided between separate suppliers it is advisable to use the clearances derived from the worst case condition.

The following calculation example (see Annex) fundamentally assumes coincidence of the least favourable maximum values.

Annex

Calculation example
The interrelationships outlined in the main text are explained using numerical values on the basis of the following example. Use is made of the maximum permissible values detailed in chapters 4.1 to 4.6 and 4.8. The values can be varied for different applications if the variations in the figures are agreed between the system designer and the supplier of the relevant sub-system. The following lists are given as examples of machine tolerances to show their influence on the total sytem. The figures shown in *italics* have to be determined by the machine manufacturer or the person responsible for the design of the system.

In accordance with the explanation given in chapter 4.8 control system B is only selected for heights up to 18 metres. In order that the following calculation models make sense for class 100 rackings and control system B a second warehouse example has been taken. Additionally by means of special measures individual tolerances and deformations may be reduced compared to the values indicated (see footnote).

Technical data of the assumend warehouses
Example 1 Racking class 200, control mode A, C, D:
- silo/rack clad construction with pallet racking
- clear building height 24 m, rack length 80 m
- single-mast S/R machine
- maximum rated load 1000 kg
- wheel base of the S/R machine 3.0 m
- Euro pool pallet load make-up accessory
- maximum dimensions of the unit load x, z, y = 900 x 1300 x 1750 mm
- three unit loads per rack aperture
- no long term deformation of the load make-up accessory and of the load
- pallets presented to S/R machine (at floor level) by means of a conveyor system with a fixed stop

Example 2 Racking class 100, control mode B:
- free standing racking
- building height 16 m, racking length 51 m
- single mast S/R machine
- maximum rated load 1000 kg
- wheel base of the S/R machine 2.4 m
- Euro pool pallet load make-up accessory
- maximum dimensions of the unit load x, y, z = 900 x 1300 x 1100 mm
- three position pallet aperture
- pallets presented to S/R machine by means of conveyor with a fixed stop

The following possible influencing factors are excluded from the calculation examples:
- unequal wheel wear
- unequal rail deflection as the result of different loads on both wheels
- residual oscillation amplitudes after the settlement time
- maximum deformation values for extreme external forces (wind velocities higher than those in 4.8.2)
- unequal floor settlement
- deformation of the floor slab greater than those given 4.1.2
- deformation of the load after passing the profile check

NOTE: In all the following tables the first column (racking class 100, control mode B) refers to example 2, the other three columns refer to example 1.

Table A.1 Entry clearances x_1 (mm)

		Nr.				
	Example		2		1	
	Racking class		100		200	
	Type of control system		B	A	C	D
Load make-up accessory	- centred position	T7	2	-	2	2
	- pallet tolerance	T6	3	3	3	3
S/R machine	- positioning accuracy times 3, excepting col. A	T12	*9*	*5*	*9*	*9*
	- fork parallelity	T18	*1*	*1*	*1*	*1*
	- deflection at fork tip due to guide roller clearance	T22	*1*	*1*	*1*	*1*
	- torsional oscillation - mast oscillation	V13 V5	*2*	*3*	*3*	*3* [1)]
Rack structure	- verticality	V20	10	3[2)]	10	3[2)]
Entry clearances		**x_1**	**28**	**16**	**29**	**22**

Table A.2 Entry clearances x_2 (mm)

		Nr.				
	Example		2		1	
	Racking class		100		200	
	Type of control system		B	A	C	D
Load make-up accessory	- centred position	T7	2	-	2	2
	- pallet tolerance	T6	3	3	3	3
S/R machine	- positioning accuracy times 3, excepting col. A	T12	*9*	*5*	*9*	*9*
	- fork parallelity	T18	*1*	*1*	*1*	*1*
	- guide roller clearance reduced at fork tip	T22	*1*	*1*	*1*	*1*
	- mast deformation at the top	V6	*3*[3)]	-	*5*[3)]	-
	- lifting carriage deformation	V9	*1*[3)]	*2*	*1*[3)]	*2*
	- torsional oscillation - mast oscillation	V13 V5	*2*	*3*	*3*	*3* [1)]
Rack structure	- verticality	V20	10	3[2)]	10	3[2)]
Entry clearances		**x_2**	**32**	**18**	**35**	**24**

Table A.3 Entry clearance y_1 (mm)

		Nr.				
	Example		2		1	
	Racking class		100		200	
	Type of control system		B	A	C	D
S/R machine	- positioning accuracy	T13	*2*	*6*	*4*	*4*
	- tilting of the fork in x-direction	T20	*1*	*1*	*1*	*1*
	- tilting of the fork in z-direction	T21	*3*	*3*	*3*	*3*
	- height positioning marker or tolerance of the beam	T23	*1*	-	*1*	*1*
	- fork sag	T24	*4*	*6*	*6*	*6*
Aisle equipment	- deflection of the floor rail	V17	*1*	-	-	-
	- height tolerance of the floor rail	T27	2	-	-	-
Rack structure	- supporting beam level (plus tol.)	T31	5	-	-	-
	- supporting beam height difference (plus tol.)	T32	2	2	2	2
Entry clearance		**y_1**	**21**[13)]	**18**	**17**	**17**

ASSUMPTION: With continuous beams, the effect of beam hogging is ignored because the possibility of only empty pallets being stored next to a fully loaded span can practically be excluded.

ASSUMPTION: The negative height of the rear supporting beam is compensated by the fork sag T24.

Table A.4 Entry clearance y_2 (mm)

	Example Racking class Type of control system	Nr.	2 100 B	1 200 A	 C	 D	
Load make-up accessory	- reduced height fork entry	T9	4	4	4	4	
	- deflection of pallet	V1	2	6	6	6	
S/R machine	- positioning accuracy	T13	*2*	*6*	*4*	*4*	
	- tilting of the fork in x-direction	T20	*1*	*1*	*1*	*1*	
	- tilting of the fork in z-direction	T21	*0*	*0*	*0*	*0*	5)
	- positioning marker	T23	*1*	*-*	*1*	*1*	4)
Aisle equipment	- height tolerance of the floor rail	T27	2	-	-	-	
Rack structure	- supporting beam level (minus tolerance)	T31	5	-	-	-	
	- deflection of the supporting beams	V22	6[15)]	-	-	-	
	- upright compression	V21	1[14)]	-	-	-	
	- height difference between supporting beams	T32	2	2	2	2	6)
Entry clearance		**y_2**	**26[13)]**	**19**	**18**	**18**	

Table A.5 Rack aperture clearances $x_{3.1}$ (mm)
(for the side of the pallet which is furthest from the mast)

	Example Racking class Type of control system	Nr.	2 100 B	1 200 A	 C	 D
Profile check	- width	T1	5	5	5	5
Load make-up accessory	- centring	T7	2	-	2	2
S/R machine	- positioning accuracy times two except A	T12	*6*	*5*	*6*	*6*
	- mast manufacture	T16	*3*	*-*	*3*	*-*
	- torsion of the lifting carriage	T19	*1*	*2*	*1*	*2*
	- load vertically due to sloping of the forks	T20	*3*	*3*	*3*	*3*
	- bottom guide roller clearances	T22	*1*	*1*	*1*	*1*
	- mast deformation B and C times 1.5	V6	*15[3)]*	*-*	*15[3)]*	*-*
	- mast deformation A and D	V6	*-*	*10*	*-*	*10*
Aisle equipment	- accuracy of floor rail	T25	1	1	1	1
	- mast tilting due to height tolerance of the floor rail	T27	3	-	3	-
	- position markers, times 2	T28	2	-	2	2
Rack structure	- tolerance field of uprights	T30	15	-	15	-
	- verticality	V20	10	3[2)]	10	3[2)]
Rack aperture clearances		**$x_{3.1}$**	**67**	**30[17)]**	**67**	**35**

ASSUMPTION: With continuous beams, the effect of beam hogging is ignored because the possibility of only empty pallets being stored next to a fully loaded span can practically be excluded.

Table A.6 Rack aperture clearances $x_{3.2}$ (mm)
(for the side of the pallet which is closest to the mast)

	Example	Nr.	2	1		
	Racking class		100	200		
	Type of control system		B	A	C	D
Profile check	- width	T1	5	5	5	5
Load make-up accessory	- centred position	T7	2	-	2	2
	- offset of the positioning marker at the centring location (see[3])		3	-	5	-
S/R machine	- positioning accuracy times 2, except col. A (times one)	T12	6	5	6	6
	- mast manufacture	T16	3	-	3	-
	- twisting of the lifting carriage	T19	2	2	2	2
	- load verticality, sloping of forks	T20	2	3	3	3
	- guide roller clearances, influence to the fork tip	T22	1	1	1	1
	- torsion of lifting carriage	V9	3	4	4	4
Aisle equipment	- fork tip deflection due to accuracy of the floor rail	T25	1	1	1	1
	- mast tilting due to height tolerance of the floor rail	T27	3	-	3	-
	- position markers, times 2	T28	2	-	2	2
Rack structure	- tolerance field of uprights	T30	15	-	15	-
	- slanting	V20	10	3[2)]	10	3[2)]
Rack aperture clearances		$x_{3.2}$	**58**	**24[17)]**	**62**	**29**

Table A.7 Rack aperture clearances x_4 (mm)

	Example	Nr.	2	1		
	Racking class		100	200		
	Type of control system		B	A	C	D
Profile check	- width 2 times	T1	10	10	10	10
Load make-up accessory	- centred position times 2	T7	4	-	4	4
S/R machine	- positioning accuracy times 4, except A	T12	12	10	12	12 [12)]
	- mast deformation	V6	0	-	0	-
	- torsion of the lifting carriage	V9	3	4	4	4
	- guide roller clearances, influence to the fork tip, times 2	T22	2	2	2	2
Aisle equipment	- mast inclination due to height tolerance of the floor rail, times 1 1/3	T27	4	-	4	-
	- position markers, times 3	T28	3	-	3	-
Rack structure	- verticality, times 2	V20	10[16)]	6[2)]	20	6[2)]
	- load verticality due to deflection of the supporting beams	V22	12	22	22	22
Rack aperture clearances		x_4	**60**	**54[17)]**	**81**	**60**

Table A.8 Rack aperture clearances y_3 (mm)

	Example	Nr.	2	1			
	Racking class		100	200			
	Type of control system		B	A	C	D	
Profile check	- height	T3	5	5	5	5	
Load make-up accessory	- reduced height fork entry	T9	4	-	4	4	
S/R machine	- positioning accuracy height, times 2	T13	4	12	6	6	9)
	- height positioning marker or tolerance of the beam, times 2	T23	2	-	2	2	9)
	- fork sag unloaded	T24	4	6	6	6	
	- fork deflection loaded	V10	16	16	16	16	
	- wear of wheels, and floor rail	T41	1	-	1	1	
	- lifting carriage deformation	V12	4	6	6	6	
Aisle equipment	- height of the floor rail, times 2	T27	4	-	4	4	8)
	- deflection of the floor rail	V17	1	1	1	1	8)
Rack structure	- supporting beam level, times 2	T31	10	20	20	20	7)
	- height difference between supporting beams (plus tol.)	T32	2	2	2	2	
	- distance between supporting beams	T33	5	5	5	5	
	- deformation of the supporting beams	V22	10	15	15	15	
	- upright compressor	V21	2[14)]	-	4	4	
Other	- sum of the resultants in y-direction, from V16, T22, T25, T26 and T29 max. times 2		2	4	4	4	9)
Rack aperture clearances		y_3	**76**	**92**	**101**	**101**	

Table A.9 Rack aperture clearance $z_{1.1}$ and $z_{1.2}$ (mm)
(calculation at approx. half the height of the racking)

	Example	Nr.	2	1			
	Racking class		100	200			
	Type of control system		B	A	C	D	
Profile check	- length of load	T2	5	5	5	5	
Load make-up accessory	- centred position	T8	5	5	5	5	
S/R machine	- fork extension, times 2	T14	4	4	4	4	
	- mast manufacture z-direction	T17	3	3	3	3	
	- torsion of lifting carriage	T19	1	1	1	1	
	- clearance of side guide rollers	T22	1	1	1	1	
	- verticality of the load from V10,T41,V12,V13 and T24		25	32	32	32	
	- mast deformation	V7	6	8	8	8	
Aisle equipment	- alignment accuracy of floor rail x 1/2	T25	2	2	2	2	11)
	- lateral accuracy of guide rail x 1/2	T26	4	4	4	4	11)
	- deflection of guide rail x 1/2	V16	3	3	3	3	11)
Rack structure	- resultant from support beam height difference	T32	-	-	-	-	10)
	- tolerance of rear obstruction	T34	15	15	15	15	
	- deformation of inner racks	V23	5	5	5	5	
	(outer racks)		(5)	(15)	(15)	(15)	
	- displacement of the pallet pick-up point	V24	-	-	-	-	
Rack aperture clearance	**inner racks**	$z_{1.2}$	**79**	**88**	**88**	**88**	
	outer racks	$z_{1.1}$	**79**	**98**	**98**	**98**	

Table A.10 Aisle Clearances $z_{2.1}$ and $z_{2.2}$ (mm)
Outer Edges: pallet in rack to pallet on S/R machine
(Calculation at approx. half the height of the racking)

	Example Racking class Type of control system	Nr.	2 100 B	1 200 A	 C	 D
Profile check	- length of load	T2	10	10	10	10
Load make-up accessory	- centred position in z-direction, times 2	T8	10	10	10	10
S/R machine	- fork travel, times 2 - side guide roller clearances - mast oscillation	T14 T22 V8	*4* *1* *6*	*4* *1* *6*	*4* *1* *6*	*4* *1* *6*
Rack structure	- inclination due to height difference between front and rear beams - deformation of inner racks (outer racks e.g. cladding) - transfer position (P & D)	T32 V23 V24	4 *5* *(5)* -	4 *5* (15) -	4 *5* (15) -	4 *5* (15) -
Clearances	**inner racks** **outer racks**	$z_{2.2}$ $z_{2.1}$	**40** **40**	**40** **50**	**40** **50**	**40** **50**

Table A.11 Aisle Clearances $z_{3.1}$ and $z_{3.2}$ (mm)
Outer edges: pallet in rack to fixed part of S/R machine
(Calculation at approx. 4 m above crane rail)

	Example Racking class Type of control system	Nr.	2 100 B	1 200 A	 C	 D
Profile check	- length of load	T2	5	5	5	5
Load make-up accessory	- centred position	T8	5	5	5	5
S/R machine	- fork travel - side guide roller clearance - mast oscillation at 4 m high	T14 T22 V8	*2* *1* *2*	*2* *1* *2*	*2* *1* *2*	*2* *1* *2*
Rack structure	- tilted position due to difference in height of front to rear beams - deformation of inner racks (outer racks) - transfer position (P & D)	T32 V23 V24	4 *4* *(5)* -	4 *5* (15) -	4 *5* (15) -	4 *5* (15) -
Clearances	**inner racks** **outer racks**	$z_{3.2}$ $z_{3.1}$	**23** **24**	**24** **34**	**24** **34**	**24** **34**

Table A.12 Aisle Clearances $z_{4.1}$ and $z_{4.2}$ (mm)
(Calculation at approx. half the height of the racking)

	Example	Nr.	2	1			
	Racking class		100	200			
	Type of control system		B	A	C	D	
Load make-up accessory	- Tolerance of length of load make-up accessory		3	3	3	3	
	- centred position	T8	5	5	5	5	
S/R machine	- fork travel	T14	2	2	2	2	18)
	- mast manufacture z-direction	T17	2	2	2	2	
	- lifting carriage twisting	T19	2	2	2	2	
	- side guide roller clearance	T22	1	1	1	1	
	- load displacement	V7	4	6	6	6	
Aisle equipment	- floor rail alignment tolerance, times 1/2	T25	2	2	2	2	11)
	- top guide rail alignment tolerance, times 1/2	T26	4	4	4	4	11)
	- deflection of upper guide rail, times 1/2	V16	3	3	3	3	11)
Rack structure	- accuracy of back stop	T35	5	5	5	5	
	- accuracy of rack upright	T36	15	15	15	15	
	- deformation inner racks	V23	5	5	5	5	
	(outer racks)		(5)	(15)	(15)	(15)	
	- transfer position (P & D)	V24	-	-	-	-	
Clearances	**inner racks**	$z_{4.2}$	**53**	**55**	**55**	**55**	
	outer racks	$z_{4.1}$	**53**	**65**	**65**	**65**	

Footnotes

1) This may be influenced by the time required to settle.

2) Change in rack deflection during fork exit.

3) When taking off pallets at the P & D, the entry clearance x_2 is increased by half of the load cycle deformation.

4) For cases C or D height tolerances of the beam profile or for case B tolerance of the height positioning marker.

5) Inclination of the fork top surface away from the side to which the fork is to be extended will be compensated for by the sagging of the extended fork.

6) The downward offset of 4 mm on the rear beam will produce 2 mm at the critical position of the centre board on the pallet.

7) Plus tolerance of the lower beam and minus tolerance of the upper beam in relation to the horizontal level datum.

8) If the fine positioning for the storage is not effective (normal case) these tolerances are to be included in the calculation.

T27: plus tolerance for the upper beam, minus tolerance for the lower beam.

9) Plus tolerance for the upper beam, minus tolerance for the lower beam.

10) This can be omitted because the influence of this item is smaller than that resulting from the inclination of the load (V13 and T24).

[11] Half of the value is taken because the effect is being considered at half the height of the aisle.

[12] In this example, incorrect positioning of the pallet created by the deformation resulting from the change in load status of the machine, i.e. loaded to unloaded or vice versa, will be compensated for by the inclination of the load (V22).

In the case of pallets with less height, the greater of the following two values should be taken into account: mast deformation (1.5 x V6) or inclination of the racking (2 x V20).

[13] With the calculated pallet entry clearances y_1 and y_2 used in conjunction with a standard Euro-pallet this would result in a fork thickness of 53 mm. However in this worst case situation if the ends of the forks are chamfered and the edge of the beams radiused then a slightly thicker fork section could be used.

[14] 2/3 of the rack compression can be compensated for by placing the positioning marks in a lower position.

[15] Part of this deflection (approx. 30 %) can be compensated for by the lowering of the position at which the forks are retracted.

[16] The maximum free standing rack inclination is only possible in one direction, (no possibility of change in force direction due to wind loading).

[17] This value does not include any additional clearance to take into account driver error.

[18] In this calculation example the mast oscillation V8 has been excluded because contact between the pallet and the back stop can be tolerated.

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Zu beziehen durch das oben angegebene Sekretariat oder durch die folgenden Nationalkomitees der FEM
Available from the above secretariat or from the following committees of the FEM
En vente auprès du secrétariat ou des comités nationaux suivants de la FEM

Belgique
Comité National Belge de la FEM
Fabrimétal
Rue des Drapiers 21
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Deutschland
Deutsches Nationalkomitee der FEM
VDMA
Fachgemeinschaft Fördertechnik
Postfach 71 08 64
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España
Comité Nacional Español de la FEM
Asociación Nacional de Manutención (AEM)
ETSEIB-PABELLON F Diagonal, 647
E-08028 Barcelona

Finland
Finnish National Committee of FEM
Federation of Finnish Metal, Eng. and Electro-techn. Industries (FIMET)
Eteläranta 10
SF-00130 Helsinki

France
Comité National Français de la FEM
Syndicat des industries de matériels de manutention (SIMMA)
39/41 rue Louis Blanc - F-92400 Courbevoie
cedex 72 - F-92038 Paris la Défense

Great Britain
British National Committee of FEM
British Materials Handling Federation
Bridge House, 8th Floor
Queensway, Smallbrook
GB-Birmingham B5 4JP

Italia
Comitato Nazionale Italiano della FEM
Federazione delle Associazioni Nazionali dell'Industria Meccanica Varia ed Affine (ANIMA)
Via L. Battistotti Sassi 11
I-20133 Milano

Luxembourg
Comité National Luxembourgeois de la FEM
Fédération des Industriels Luxembourgeois
Groupement des Constructeurs et Fondeurs du Grande-Duché de Luxembourg
Boîte Postale 1304
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Vereniging FME
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Norge
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Portugal
Comissão Nacional Portuguesa da FEM
Federaçao Nacional do Metal
FENAME
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Schweiz / Suisse / Svizzera
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Verein Schweizerischer Maschinen-Industrieller (VSM)
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Sverige
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Sveriges Verkstadsindustrier
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