Guidelines for VNA storage systems. Operating industrial trucks in narrow aisles.

first in intralogistics

Get the most out of your VNA warehouse!

VNA (very narrow aisle) warehouses or systems enable an extremely compact warehouse layout. In other words, a huge amount of goods can be stored and handled in a relatively small area. Also, modern VNA trucks are easy to automate and offer impressive performance. In order for this to be used to the fullest extent the warehouse needs to satisfy certain guidelines.
Important basic conditions for optimal handling performance include, for example, a high-quality, stable and completely level floor. This guide for designing VNA warehouses consolidates all the relevant guidelines for you – from the floor conditions through to the rack layout and the implementation of guide systems.

STILL – always one step ahead.

Floor requirements

Strength and resistance

The floor slab must be designed with a concrete quality of at least B 25 in line with DIN 1045-2/-3 and in accordance with DIN 18202.
The floor must meet the requirements of stress group II (medium) as defined in DIN 18560-7 “Floor screeds – Part 7: Heavy-duty screeds (industrial screeds)”, Table 1.

The strength of the floor structure must comply with the limit values for VNA trucks in table 1 as defined in the FEM 4.103-1/ FEM 10.2.14-1 standard. This standard indicates the maximum permissible deformations under load for the different types of warehouses. In addition, the floor must be resistant to oil and grease.

Maximum tolerance to the vertical of the racking unit	Floor deformation class	Examples of suitable rack types	Maximum permissible degree of deformation, stiffness
1/350	700	• Standard pallet rack • Cantilever shelving • Single-level rack • Pallet rack serviced with VNA truck (<6 m)	1/700
1/500	1000	• Special pallet rack[1] • Drive in and drive through racking	1/1000
1/750	1500	• Pallet rack serviced with VNA truck (>6 m)	1/1500
1/1000	2000	• Pallet rack serviced with fully-automatic storage and retrieval system[2] • Small parts warehouse serviced with fully-automatic storage and retrieval system, especially in combination with load units on shuttles	1/2000

[1] Greater demands on the precision of the racking system must be coordinated with the floor supplier.
[2] Automated racking systems and storage and retrieval machines are not considered in greater detail in this guideline. Please contact your STILL dealer. The relevant standards are FEM 9.831-1, FEM 10.2.10 and FEM 9.832.

Table 1
Maximum permissible deformation of the floor for racking systems

Distributed load and wheel pressure

Your STILL VNA experts calculate the distributed load and wheel pressure for the specific truck.

Grip

The condition of the floor surface must ensure that the braking requirements under DIN ISO 6292 can be met.
This means that the surface must be low-slip and dry as well as free of dirt and oil films, as these can negatively affect the braking performance of industrial trucks.

Ground leakage resistance

The ground leakage resistance must be no more than 10^6 Ohm as defined in DIN EN 1081.

Flatness

A zero plane (artificial horizon) must be created for the screeding process. The area must comply with the necessary tolerances across the entire working aisle width within the aisle. Appropriate processes and particular care are required to achieve the flatness within the required tolerances. Repair and improvement activities must be possible within a reasonable time frame.
The appropriate manufacturing process for the screed floor must be selected in consideration of the local conditions.

Flatness tolerances

Outside aisles

Wherever VNA trucks are used outside the aisles, the requirements indicated in Table 2 based on FEM 4.103-1/ FEM 10.2.14-1 must be met. To assess the overall levelling of a warehouse, the entire area is covered in reference points in a virtual 3-metre grid. A maximum height difference of +/- 15 mm is permitted between these reference points (tolerance field = 30 mm).

Classification as per table 2	Maximum permissible height difference	Pitch under straight ruler			
		Ruler 1 m	Ruler 2 m	Ruler 3 m	Ruler 4 m
FM3	8.5 mm/m	4.0 mm	6.0 mm	8.0 mm	10.0 mm

Table 2
Floor tolerances for all areas in which VNA trucks are used (including under the racks)

Inside aisles

Inside aisles and in all areas in which trucks operate with raised loads, the tolerance values indicated in Tables 3 to 5 based on FEM 4.103-1/FEM 10.2.14-1 apply.

Permissible height difference between left and right side (dZ)

To ensure the necessary safety distances, positioning accuracy as well as the desired handling capability with the required truck performance, the local height differences between the right and left side of the truck must not exceed the values defined in the following tables.

Lift height	Z_{Slope} max. based on 1 m track width	
up to 15 m	1.0 mm	dZ(real) = Z(real) x Z_{Slope} (interpolated)
up to 10 m	1.5 mm	
up to 6 m	2.0 mm	

Interpolation is required for lift heights >6 m and for intermediate values. See Figure 2.

Table 3
Limit values of Z_{Slope}

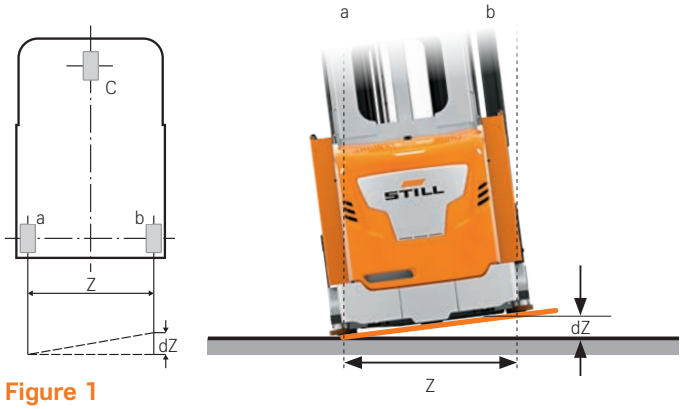


Figure 1
Determining dZ

Permissible height tolerance of the track width

- **a** Left load wheel
- **b** Right load wheel
- **c** Drive wheel
- **Z** Track width (distance between centre of left load wheel – centre of right load wheel)
- **dZ** Height difference between right and left side

The distance "Z" shown in Figure 1 indicates the track width. It is measured between the centre of the left (a) and the centre of the right load wheel (b). The values for the Z_{Slope} indicated in Table 3 describe the permissible gradient tolerance over the distance Z transverse to the aisle, depending on the lift height. The variable dZ is the resulting permissible height difference across the track width Z.

Figures 2 and 3 can be used to determine an intermediate value for Z_{Slope} and for the resulting height difference dZ via interpolation. **Example:** At a maximum lift height of 8 m, a maximum Z_{Slope} value of 1.75 is permissible.

The result: The truck in the example with a maximum lift height of 8 m and a track width (Z) of 1.5 m has a maximum permissible height difference between the right and left side (dZ) of 2.625 mm.

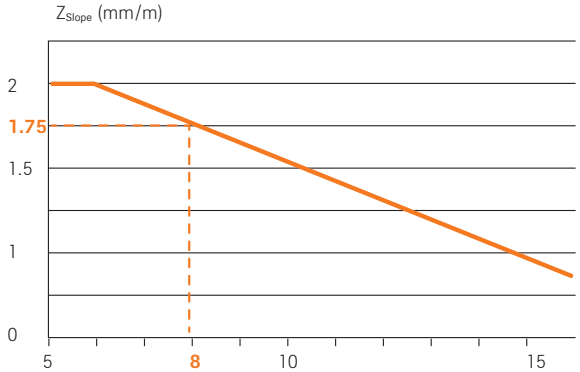


Figure 2
Interpolation to determine Z_{Slope}

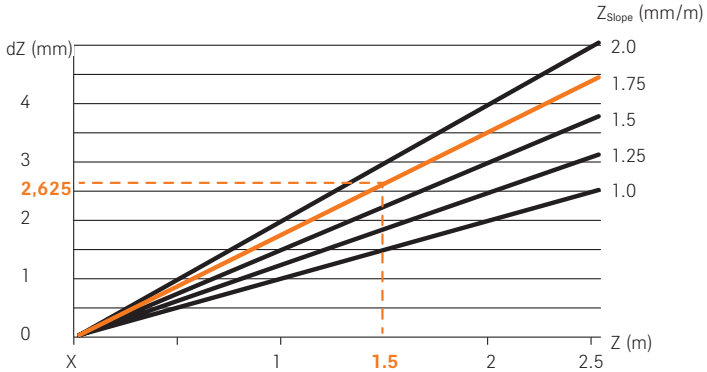


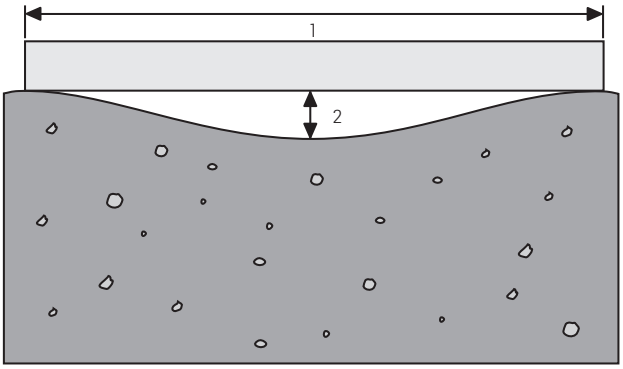
Figure 3
Determining dZ

Flatness in the longitudinal direction of the aisle

The flatness in the longitudinal direction of the aisle, especially in the drive tracks, has an influence on the positioning accuracy, driving behaviour and handling performance. To determine the flatness, you can use a ruler and measuring wedge to determine the highest pitch as shown in Figure 4. The maximum permissible deviations are provided in Table 4. Due to the physical limitations, a tolerance of 0.1 mm is permissible for this measurement method.

Distance of the reference points of the ruler	Maximum permissible pitch (gap) under the ruler
1 m	2.0 mm
2 m	3.0 mm
3 m	4.0 mm
4 m	5.0 mm

Table 4
Maximum permissible pitch under a straight ruler along the entire length of all tracks



1 Length of the ruler
2 Pitch, determined with measuring wedge

Figure 4
Determining the pitch in longitudinal direction

Corrugation

Corrugation describes the irregularities in the surface along the tracks within the aisles by means of the Fx value. The three reference values indicated in Table 5 are provided to determine the minimum necessary Fx values.
These need to be interpolated for different lift heights.

The higher the Fx value, the lower the corrugation and the more favourable the conditions for operating VNA trucks. Measurement and the resulting calculation must take place in line with FEM 4.103-1/FEM 10.2.14-1.

Lifting height	Fx or Fx_{avg}
up to 15 m	525
up to 10 m	400
up to 6 m	300

For lifting heights >6 m and for intermediate values, interpolation is required.

Table 5
Limit values for Fx and average Fx

Acquiring and evaluating the tolerance

General information

Standard FEM 4.103-1/FEM 10.2.14-1 provides information on the measurement methods and describes the measurement of ground tolerances as well as the evaluation of the measured data. Other methods are permissible as long as they offer the same level of accuracy and validity.

Evidence of compliance with the tolerances must be provided by the floor installer or by a neutral surveyor.

The applicable measurement and sampling methods must be defined by the warehouse floor planner in collaboration with the warehouse owner. We recommend consulting the operator of the VNA warehouse.

Time of measurement

In line with FEM 4.103-1/FEM 10.2.14-1, a new floor must be measured within one-and-a-half months of completion and prior to loading, in order to check whether the floor meets the prescribed specifications.

Note: Measurements must take place before the effects of time-dependent deformations become significant.

Measurement method

The measurement method that you choose to determine floor tolerances and their properties must be able to supply reliable data for comparison with the limit values indicated in FEM 4.103-1/FEM 10.2.14-1.

This must be documented in a measurement report with the following content:

- measurement method
- measurement accuracy
- data analysis

Measurement accuracy

The measurement accuracy of the measuring equipment used must essentially be 10 times greater than the limit value to be determined.

Requirements

The measuring equipment must be able to:

- comply with the required measuring accuracy,
- provide reproducible measurement results,
- generate measurement results that can be used to verify compliance with the required tolerances.

Tools

These tools are usually used:

- precision spirit level
- rotating laser
- ruler (straightedge) and inside micrometre

Grinding and milling

If the required tolerances could not be met when installing the warehouse floor, this may be remedied by full-surface grinding or milling of the aisles. It is important that the entire width of the working aisles are machined and that no sharp edges are created.

After grinding or milling, the aisles are slightly deeper than the rest of the hall floor, necessitating a transition zone (ramp) to level out the difference and ensure the flawless use of the trucks. This transition zone must be at least four metres long and must not have any sharp edges.

Your STILL VNA experts can advise you on the areas that need to be machined.

Attention

Grinding and milling of the screed must:

- not cause the measurements for the distance to the reinforcing bars to fall below the tolerance values,
- not impair the load capacity of the screed (minimum thickness).

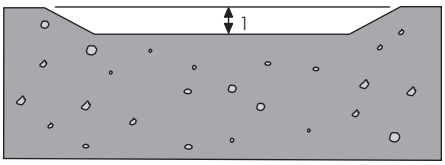


Figure 5
Aisle cross-section

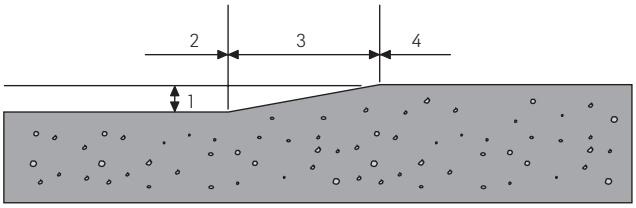


Figure 6
Aisle longitudinal section

1 Grinding depth
2 Narrow aisle
3 Transition zone (ramp) between narrow aisle and transfer aisle
4 Transfer aisle

Expansion joints and elevations

Expansion joints are necessary to prevent the concrete from cracking during the drying process and expansion.

Expansion joints and elevations in the driving tracks can have a negative influence on the driving behaviour of VNA trucks. As a result, we recommend working closely together with your rack planner and floor supplier from the very start of the project. This allows manufacturing tolerances and subsequent load-based deformations to be taken into account in the warehouse planning.

The ideal solution is to place expansion joints outside the travel areas. Where this is not possible, the joints should be reduced to a minimum. In addition, these expansion joints must comply with the tolerances defined in FEM 10.2.14-1/FEM 4.103-1.

Attention

Expansion joints may be subject to lateral displacements of 10 to 25 mm – in extreme cases even up to 40 mm. Take these possible displacements into account when placing your racking system.

Racking

Installation tolerances

The following maximum permissible tolerances are requirements as defined in standard EN 15620, which must be followed when installing racking systems. These tolerances apply for installed racking systems in their unloaded conditions.

Vertical limit deviations in the Y direction in mm

Measuring specification and description of the limit deviation		Installation limit deviations for racking class 300
		The larger of the following values applies:
GY	Straightness of the beam in the Y direction	± 3 or ± A/500
H1	Deviation of the upper edge height of a beam H1 above the lower beam height	300A: ± 5 or ± H1/500 300B: ± 3 or ± H1/1000
H1A	Deviation of the upper edge of the lower beam at every support from the floor height	± 7
H3	Limit deviation for the upper guide rail, if any	If any, defined by the supplier or the manufacturer of the forklift truck
HY	Deviation of the pick-up height of the load units between the front and rear beams in a compartment	± 10

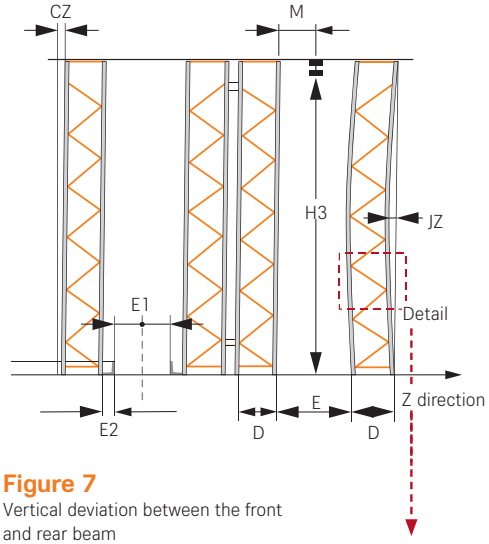


Figure 7
Vertical deviation between the front and rear beam

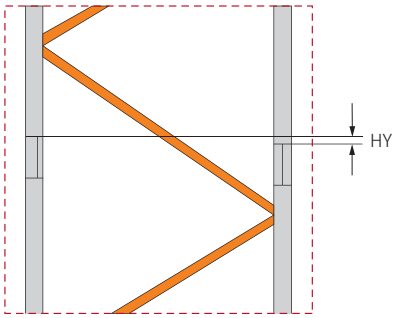


Figure 8
Horizontal deviation in the Z direction of a racking system (front view)

Horizontal limit deviations for the XZ plane in mm

Measuring specification and description of the limit deviation		Installation limit deviations for racking class 300
A	Deviation from the nominal dimension for the clear access width between two supports at any beam height	± 3
A1	Deviation from the nominal dimension for the overall length of the rack, cumulative for the number "n" of fields, measured as close as possible to the foot plate	± 3 n
		The larger of the following values applies:
B	Misalignment of the supports in the transverse direction of the aisle, cumulative for the number "n" of fields, measured at roughly floor height For class 300A, this only applies for aisle supports For class 300B, this applies for the aisle supports and the rear supports	± 10 or for class 300A: ± 1.0 n for class 300B: ± 0.5 n
B0	Deviation from the nominal dimension of the front of the rack at the end of the transfer point, based on the relevant "reference line for the racking system Z", measured at roughly floor height	± 10
CX	Deviation of the frame from the perpendicular in the X direction	± H/500
CZ	Deviation of the frame from the perpendicular in the Z direction	without fixed lift: ± H/500 with fixed lift: ± H/750 [a]
D	Deviation from the nominal dimension for the rack depth (single or double frame)	Single frame: ± 3 Double frame: ± 6
E	Deviation from the nominal dimension for the aisle width at roughly floor height	±5
E1	Deviation from the nominal dimension for the width between the guide rails	+5 0
E2	Deviation between the supports on one side of the guide rail	±5
F	Deviation from the nominal dimension for the aisle straightness, measured at roughly floor height in relation to the "reference line of the aisle system X" or as per the truck supplier's specifications	±10
F1	Deviation between neighbouring supports, measured at roughly floor height in the Z direction	±5
GZ	Straightness of the beam in the Z direction	± A/400
		The larger of the following values applies:
JX	Straightness of the supports in the X direction between beams, which are arranged at a distance HB to one another	± 3 or ± HB/750
JZ	Beginning curvature of an upright frame in the Z direction	± H/500
M	Limit deviation for the upper guide rail	Defined by the specification supplier or manufacturer of the forklift truck
T_w	Beam twist in the centre of the field	1° per m

[a] H/500 is also permissible, provided that the pallet runners or blocks protrude over the front beams by 75 mm or more and the pallet runners or blocks are supported by beams.

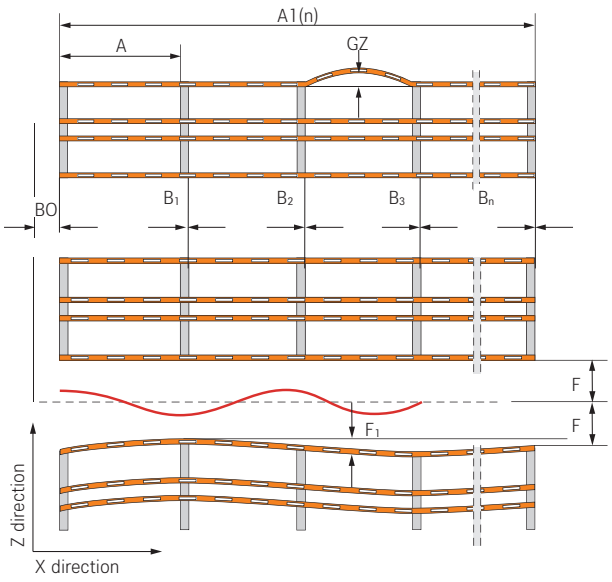


Figure 9
Horizontal deviation in the Z direction of a racking system (top view)

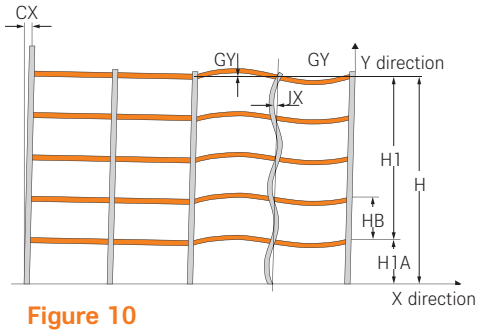


Figure 10
Horizontal and vertical deviation in the Y and X direction of a racking system (side view)

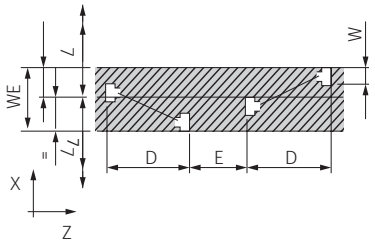


Figure 11
Horizontal deviation in the X direction of the racking unit (top view)

Clearances for adjustable pallet racks

Clearance means the nominal dimension between the load units and/or the rack components. To ensure safe storage and retrieval make sure that you comply with the clearances indicated in the following table. Tip: Use a centring aid at the transfer points; this will make it much easier to comply with the tolerances. In a double row rack, a minimum distance of 100 mm (Z) between the load units must be ensured. The space requirement for sprinkler pipes must also be taken into account.

Class	Name	Operation	Yn (mm)	Y (mm)	X (mm)	Z (mm)
300 A	Rack system as narrow aisle	Very narrow aisle truck (man-up)	3,000	75	75	100
			6,000	75	75	100
			9,000	75	75	100
			12,000	75	75	100
			15,000	75	75	100
300 B	Rack system as narrow aisle	Stacker truck (man-down)	3,000	75	75	100
			6,000	100	75	100
			9,000	125	75	100
			12,000	150	100	100
			15,000	175	100	100

Table 6
Clearances for adjustable pallet racks

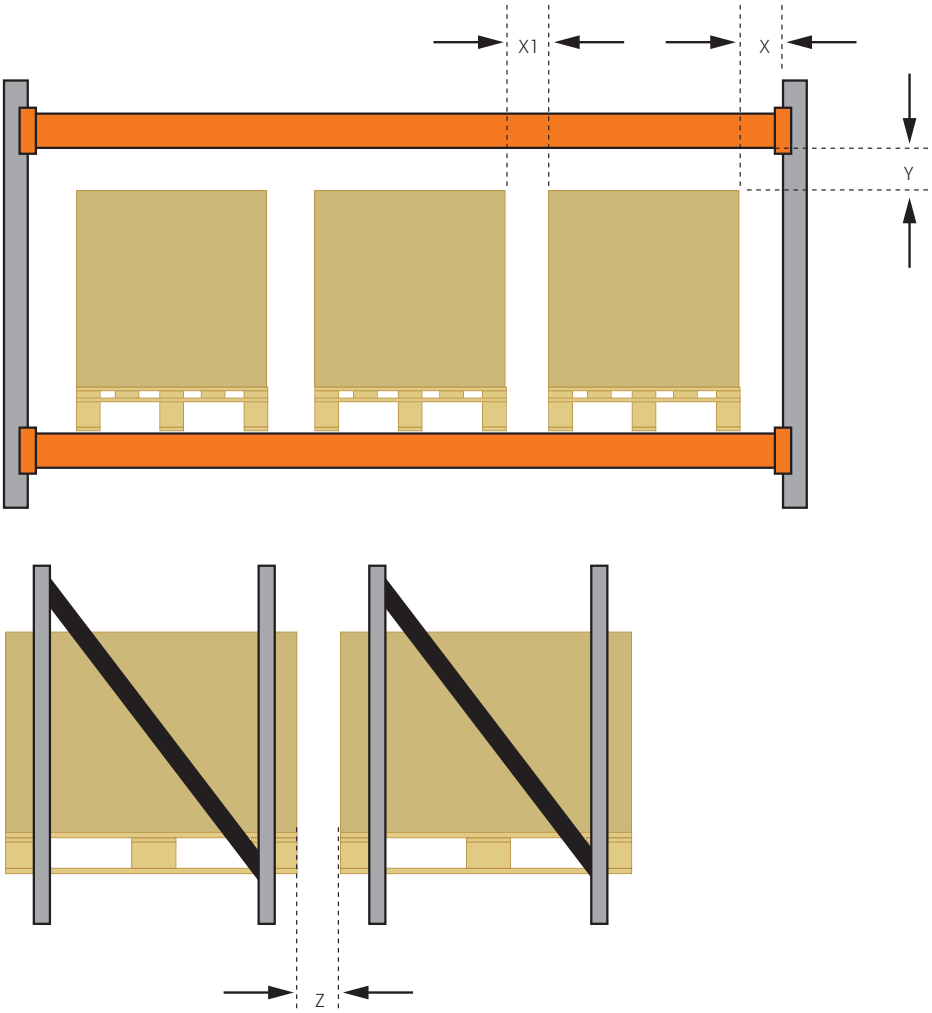


Figure 12
Minimum distance (Z) between the load units in double row racks

Transfer stations for semi- and fully-automated trucks

Semi- and fully-automated retrieval/storage requires the use of centring aids at the transfer stations and at the supply points. A check must also take place to confirm whether shape control is required for the load units at the supply point so that the required compartment clearances can be met.

Guide systems

Mechanical guidance

Rails

Mechanical guide systems are exposed to enormous forces.

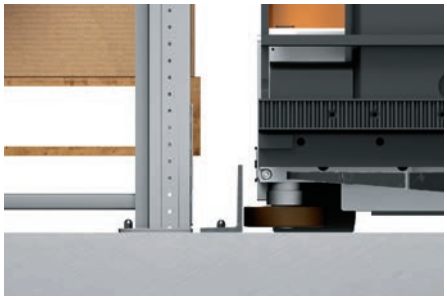
Appropriate steel profiles are:

- L section steel: 100 x 50 x 10 mm
- U standard section steel: 100 x 50 x 6 mm
- L section steel: 50 x 50 x 8 mm (In the entrance area, the L section 100 x 50 x 10 mm must be used and welded to the lower rail 50 x 50 x 8 mm)

When tapered forks and the latter section are used, sufficiently high pallets (e. g. Europallets) can be positioned directly on the hall floor behind the guide rail.

Entry guards

An entry guard in front of the rail guide enables easy entry to the aisle. Its strength is equivalent to that of the guide rails in use. As shown in Figure 14, the guard must be at least 300 mm long with an angle of 15 degrees. Every section of the entry guard must be fastened with at least four screws to ensure adequate stability. If possible, the entry section in front of the rack should be connected to the rail guide via a screwed or welded connection.



High guide rail (D 100)
not cast in, L section outside

High guide rail (D 100)
cast in, L section outside

High guide rail (D 100)
not cast in, L section outside,
frame depth < loading aid depth

High guide rail (D 100)
not cast in, L section inside

High guide rail (D 100)
cast in, U section outside

Low guide rail (D 50)
for storage with loading aids directly on the hall floor

Figure 13
Example of mechanical guide systems

Installing the rails

As defined in FEM 4.103-1/FEM 10.2.14-1, the rails and the mounting must be adequately dimensioned to withstand transverse forces when entering the aisle and lateral forces inside the aisle. The entry guard and the rail in the roughly 3,000 mm-long entrance area are exposed to the strongest horizontal forces – up to 25 kN. Once all guide rollers are inside the rail guide, the forces further along the aisle fall below 10 kN.

The various forces in the entrance and travel area require anchorage points at different distances. In the travel area, this distance is 500 mm (C2). In the entrance area, we recommend a distance of approx. 300 mm (C1) along the first 3,000 mm. The use of adhesive or expansion anchors are recommended for fastening the rails, as shown in Figure 9. The installation tolerances to be observed are indicated in table 6 and Figure 10.

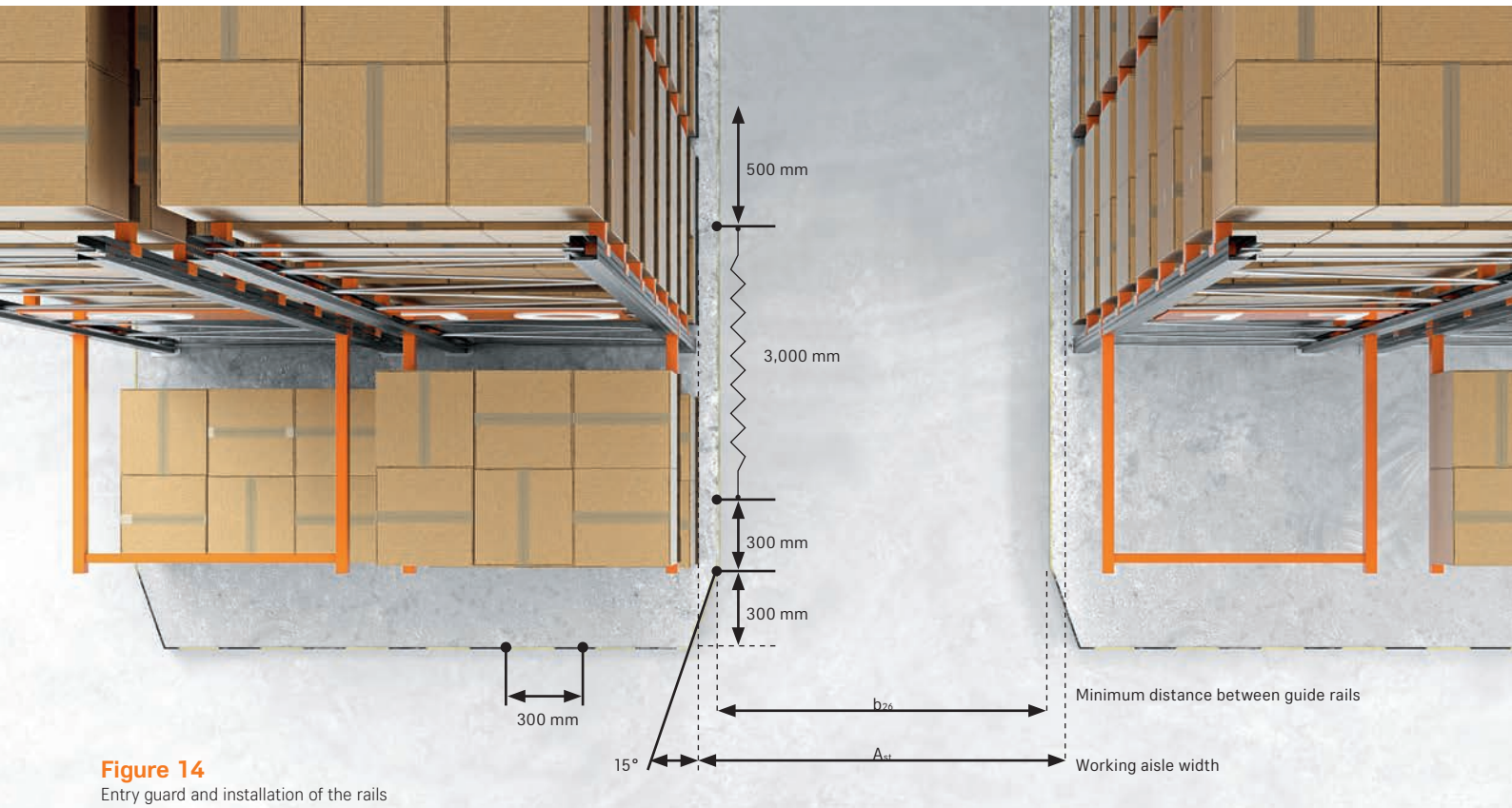


Figure 14
Entry guard and installation of the rails

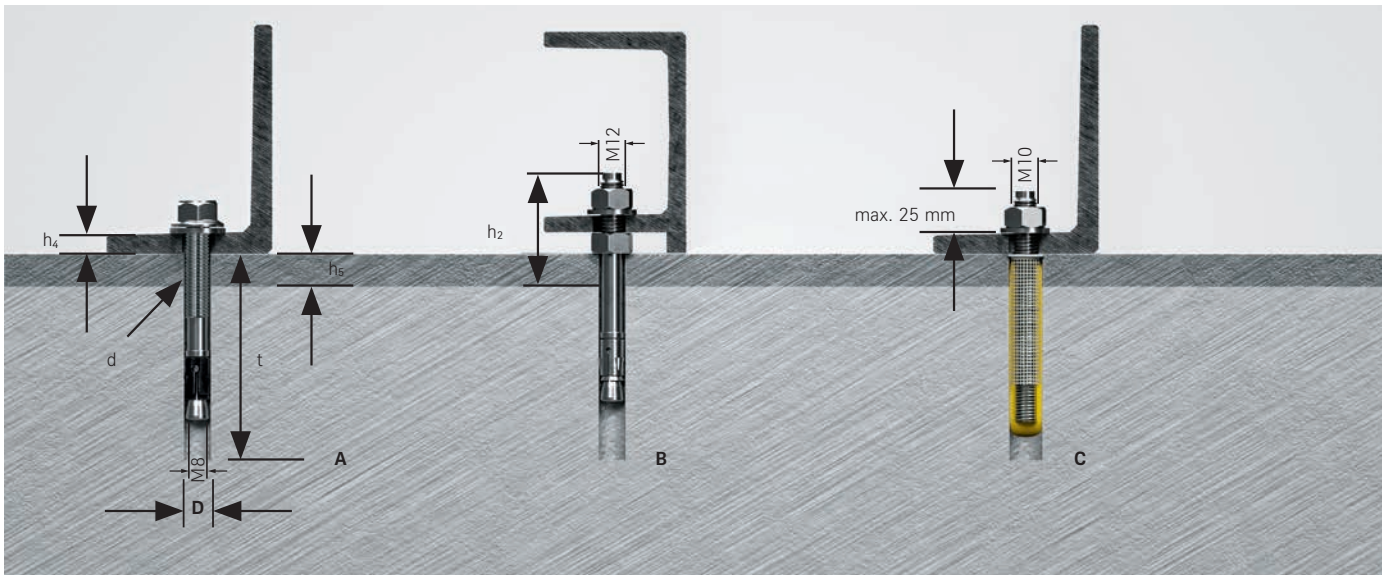


Figure 15
Types of anchors

A Expansion anchor
B Expansion anchor
C Adhesive anchor for high guide rails (D 100), not cast in, L section inside
D Hole diameter based on the anchor manufacturer's specifications
d Anchor depth marking
t Hole depth based on the anchor manufacturer's specifications
h_2 As per the anchor manufacturer's specifications
h_4 Thickness of the rail
h_5 Thickness of the screed/insulation

Installation tolerances

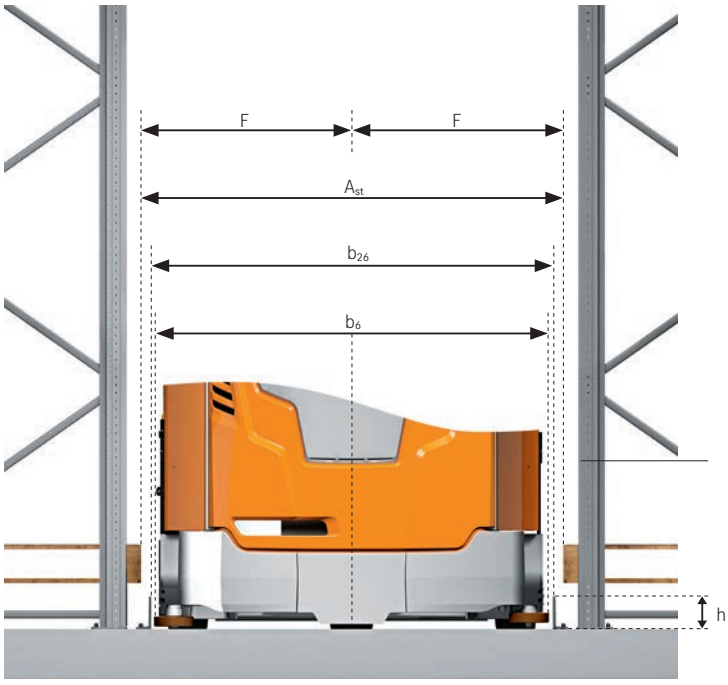


Figure 16
Dimensions of the mechanical guide system

Dimensions	Definition	Tolerance
b_6	Truck width above guide rollers	
b_{26}	Clearance between the rails across the entire length	+5 mm for every 1 m + 2 mm
$F = A_{st}/2$	Maximum deviation between the theoretical centre of the racking aisle and the actual centre between the racks	for every 20 m ± 5 mm
A_{st}	Working aisle width, minimum distances between the stored load units or the racks	± 10 mm
h	Height of the guide rail	

Table 7
Tolerances for the mechanical guide system in Figure 16

Inductive guidance

Arrangement

Your STILL VNA experts prepare a customised installation plan for every warehouse with inductive guidance.

The earlier that STILL is involved in planning a high rack warehouse, the better the local conditions can be taken into account. The transfer aisle width is calculated for the specific truck and is based on the truck length, including load, as well as an additional margin of around 1,700 mm (see Figure 17).

We recommend first setting up the racking system and then using this as a guide for measuring the groove for the wire. This allows any dimensional deviations to be compensated.

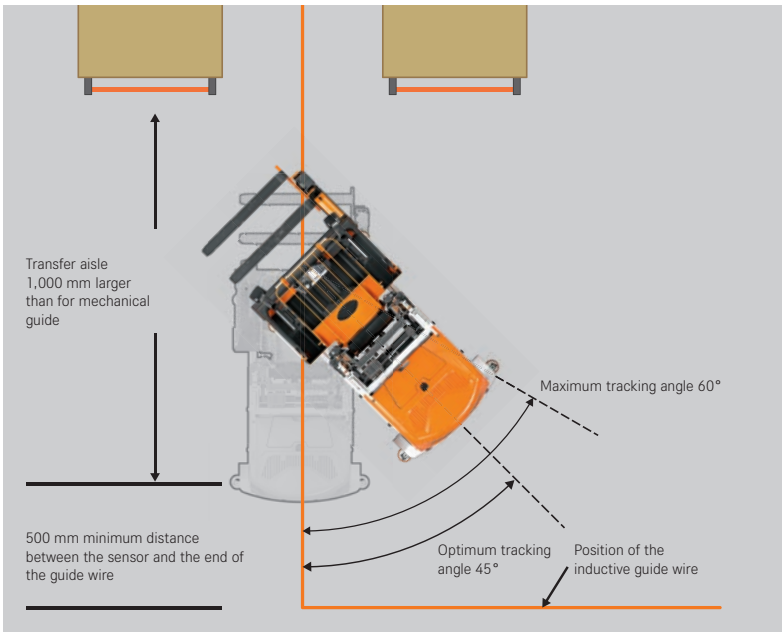


Figure 17
Transfer aisle in inductive guidance

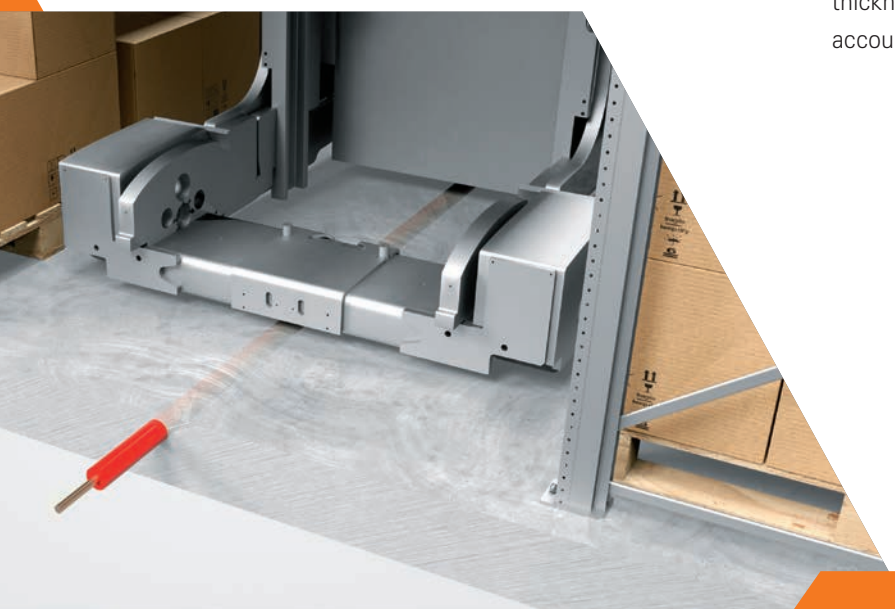
Installation instructions

The inductive guidance of very narrow aisle trucks in the aisle takes place via a wire installed in the floor, which is supplied with alternating voltage by a frequency generator. This creates an inductive guide signal, which the trucks receive with special antennae and which enable the precise guidance of the truck. The guide wire starts and ends at the frequency generator to form a closed loop.

The precision of the installation of the guide wire and the quality of the inductive signal have a direct impact on the operational safety and performance.

To prevent interference with the transmitted inductive signal, it is important to note the following:

- Minimum 50 mm distance between the reinforcing bars of the reinforced concrete and the guide wire (see dimension c in Figure 19).
- If concrete reinforced with steel fibre is used, the amount of steel fibre must not exceed 30 kg/m³.
- The steel fibres must be evenly distributed in the concrete.
- Steel plates, manhole covers and cable ducts must not be located along the guide wire's route. The distance to these kinds of steel or iron parts must be at least 200 mm.
- At least 1,500 mm distance between guide wires that use the same frequency, e. g. between the outgoing and return parts of the guide wire.
- Other live cables also generate induction fields that can disrupt the guide signal. As a result, the distance between such cables installed in the floor or near the guide wire must be as large as possible.
- Machines with strong electric drives and their power supply lines also generate inductive signals.
- The placement of these machines must be included in the planning activities for a racking system with inductive guidance.
- If an additional screed is planned on the concrete slab, the thickness and tolerance of the screed must be taken into account.



Distances and tolerances

The guide wire must be installed in consideration of the tolerances as indicated in Table 8 below.

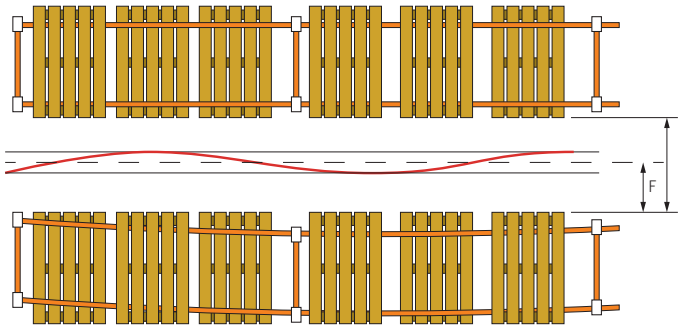


Figure 18
Position of the guide wire

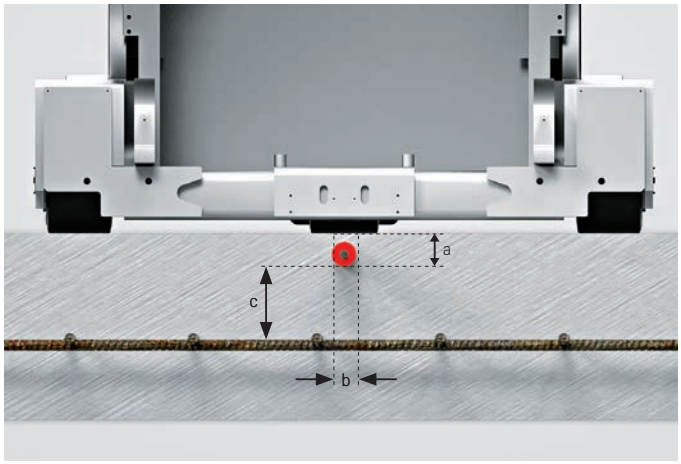


Figure 19
Distances and tolerances of the guide wire

Dimensions	Definition	Tolerance
a	Maximum depth of the groove for the guide wire	15 mm
b	Width of the groove for the guide wire	3 mm – 6 mm
c	Minimum distance between the guide wire and reinforcing bars	50 mm
G	Maximum lateral deviation from the theoretical centre line between the racks	± 5 mm 2 mm/m
$F = A_{st}/2$	Maximum deviation between the ideal centre of the racking aisle and the actual centre between the racks	± 5 mm
A_{st}	Working aisle width, minimum distances between the stored load units or the racks	± 10 mm

Table 8
Distances and tolerances for installing the guide wire

Normative references

EN 15620 Chapter 6.2 and 6.3

Stationary storage systems made of steel – Tolerances, deformations and clearances.

DIN 1045/A1

Concrete and reinforced concrete – Design and construction.

DIN 18202

Tolerances in building construction – Buildings.

DIN 18560 Part 7

Floor screeds – Heavy-duty screeds (industrial screeds).

DIN EN 1081

Determination of the electrical resistance.

VDMA Guideline

Floors for use with VNA trucks.

DIN 15185 Part 2

Warehouse systems with guided industrial trucks – Safety requirements when using industrial trucks in narrow aisles.

ISO 6292

Powered industrial trucks and tractors – Brake performance and component strength.

FEM 4.103-1/FEM 10.2.14-1

Warehouse floors – Storage system areas operated by industrial trucks –
Part 1: Tolerances, deformations, methods of measurement and additional requirements for VNA truck operation.

FEM 10.2.14-2

Warehouse floors – Storage system areas operated by industrial trucks –
Part 2: Requirements for design and possible remedial actions – Interfaces with racking.

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