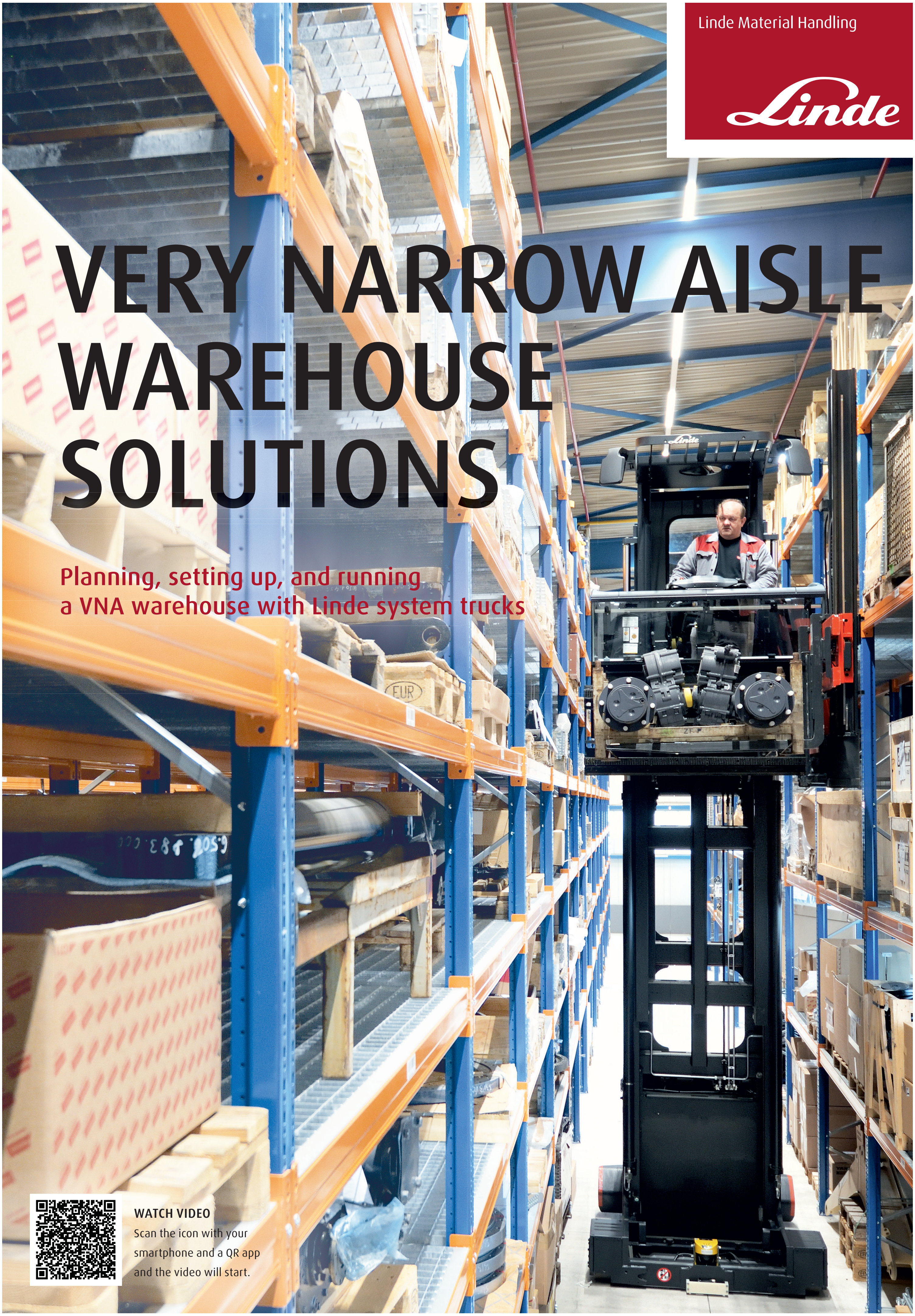
Linde Material Handling

Linde



VERY NARROW AISLE WAREHOUSE SOLUTIONS

Planning, setting up, and running a VNA warehouse with Linde system trucks

WATCH VIDEO
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Best Utilization of Space

BENEFITS OF VNA AT A GLANCE

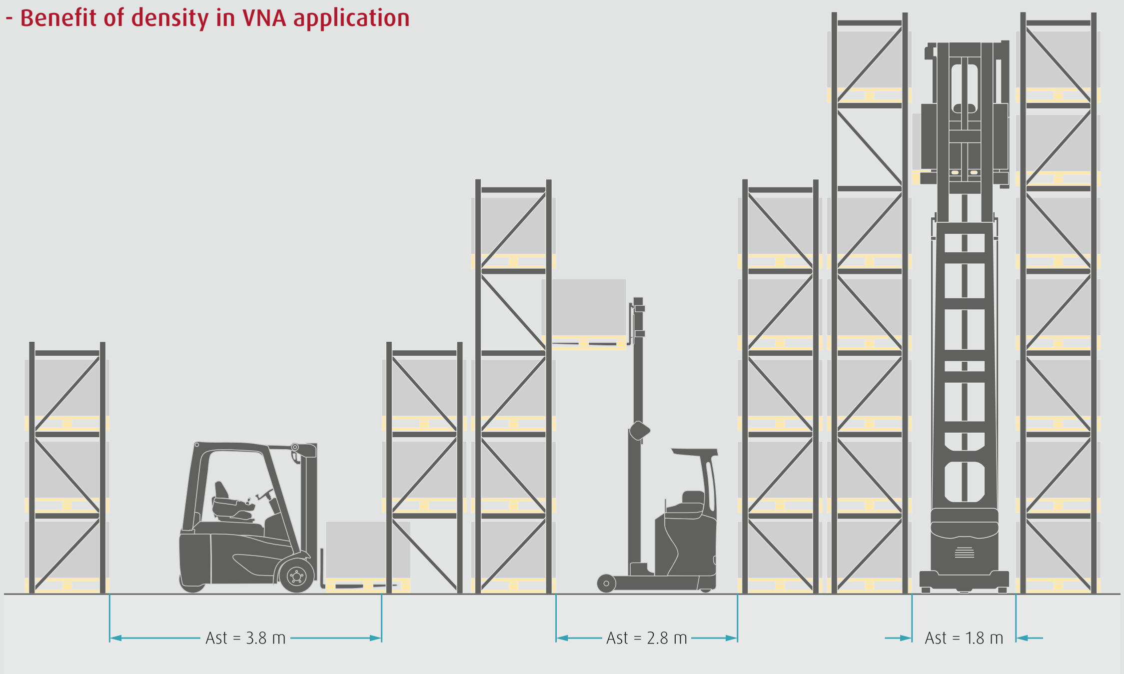
Very narrow aisle systems offer many advantages compared to conventional warehouses. VNA systems can make economic sense, especially if you are experiencing high pallet throughput or when increased storage capacity is required. Compared to shuttle systems or stacker crane systems, VNA systems have less investment costs and offer higher flexibility.

HOW VNA DELIVERS SPACE SAVINGS

Conventional counterbalance trucks require aisle widths over 3.8 m (see figure 1). A reach truck needs approximately 2.8 m space for efficient working, but aisles in a VNA warehouse are around 1.8 m wide. This alone represents a space gain of some + 25 %.

What's more, VNA racking can be constructed substantially higher. Where ceilings permit, goods can be placed up to 18 m high, achieving greater storage density. These two factors combined mean it is possible to increase storage capacity by 50 % for pallets with standard loads.

Figure 1 - Benefit of density in VNA application



THE PURPOSE OF THIS GUIDELINE

When planning a VNA warehouse, certain considerations are required. This brochure is a guide, providing you with the information you need to build a warehouse that is economical, safe, and functional. It also utilizes your floor space and spatial resources efficiently and ensures optimum implementation for truck, racking, and flooring interfaces in your premises. To optimize processes, Linde offers several safety-relevant and assistant systems, which will be explained.

Our recommendations and directives in the following should prevent bad investments as well as deficiencies in construction, delivering professional solutions. Every warehouse must be considered individual, especially when it comes to safety. Your Linde consultant will help you.

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Fundamentals for Safe and Efficient Operations

THE FLOOR

High rack storage areas where VNA trucks are used are technologically sophisticated systems today. The use of high level order pickers, racking trucks and order picking trucks in such warehouses does not start with high-tech industrial trucks, it starts with the floor.

To achieve the full driving performance of the VNA truck, a super-flat floor is required. The FEM[1] for use with VNA trucks defines the maximum tolerances of the floors in the aisles in chapter 9.2.3. Additionally, the floor tolerances in all other areas operated with VNA trucks must comply with the requirements set out in chapter 9.2.3.

Alternatively, to achieve full driving performance on floors that do not comply with the FEM Code, the compensation assistance system Active Stability Control can be used. The system continuously detects the floor surface and regulates if irregularities are detected. For further information, go to the chapter “Assistance Systems”.

Measuring the floor surface for evenness should be done after an appropriate period of time, and before beginning any subsequent work. Proof of compliance with the tolerances is provided by the floor installer or a neutral surveyor office.

GRINDING THE FLOOR

Milling or grinding individual wheel tracks in the aisle to achieve the necessary evenness standards is not recommended by Linde. The problem is the depth of grinding can cause edges along the ground tracks. In a worst case scenario, the truck drives on this edge and the “curb effect” causes the truck to become uncontrollable and unpredictable, creating an unsafe situation.

Recommendation: Where grinding a floor is the only option, full-surface milling or grinding of the aisles over the entire aisle width is recommended to achieve the required flatness. If only the lanes are to be milled or sanded, the manufacturer’s instructions must be observed. In addition, any noticeable and visible differences in height between the lanes and the other driving areas must be avoided. Track aisle grinding is defined in the FEM[3].

Floor Specifications for Optimal Drive and Lift Performance

The following listed values and tolerance ranges are essential for the maximum permissible driving speeds, lifting heights, a smooth ride and positioning accuracy for the trucks. Therefore, special attention should be given to the “floor tolerances”. To avoid possible misunderstandings, we recommend you make these directives part of your agreement with the floor installer and racking manufacturer.

THE GROUND REQUIREMENTS IN THE WAREHOUSE

Sub-flooring

The supporting subsoil is designed according to DIN EN 1045 part one and two using a concrete quality of at least C20 / 25 and DIN 18202 or rather EN 206.

Use Surface (Top Layer)

Load group II (middle) DIN EN 18560, Part 7, Table 1 (resistant against oils and grease) requires an approximately 10 – 30 mm thick industrial flooring.

The surface must be anti-skid (approximately μ 0.5), anti-slip, free of fluids, dirt, and oil films, and must not exhibit plastic deformation under load in order to achieve the braking distances according to ISO 6292. The resistance to earth RE must be a maximum of 10^6 ohm[4].

Discontinuities in the flooring, such as channels or shafts, require a minimum spacing of 200 mm to the wheel paths and should be avoided in the aisle whenever possible.

Make sure floor evenness in the traffic areas, including expansion joints and any other irregularities, never exceeds the allowed tolerances and meets the required level of technology (honing the floor finish over leveled guide rails typically does not guarantee the necessary floor tolerances for VNA trucks in the aisles).

1) FEM 4.103 – 1 and FEM 10.2.14 – 1
2) DIN 18202 | Chapter 5.4
3) FEM 4.103 – 2 and FEM 10.2.14 – 2 | Annex D
4) DIN EN 1081 | Chapter 5

INSIDE THE VERY NARROW AISLE

Stricter requirements apply for wheel tracks in very narrow aisles than in all other areas of the warehouse. This specification is based on the FEM 4.103 – 1 and FEM 10.2.14 - 1 directive "Tolerances, deformations, methods of measurement and additional requirements for VNA truck operation".

Evenness specifications for the very narrow aisle range are defined as follows (see figure 2):

1. Limit values across the aisle: Z_{SLOPE} and dZ
2. Limit values for flatness along the aisle
3. Surface irregularities along the aisle: Fx numbers

These three factors have a decisive influence on the driving performance and non-compliance can lead to a reduction in handling performance.

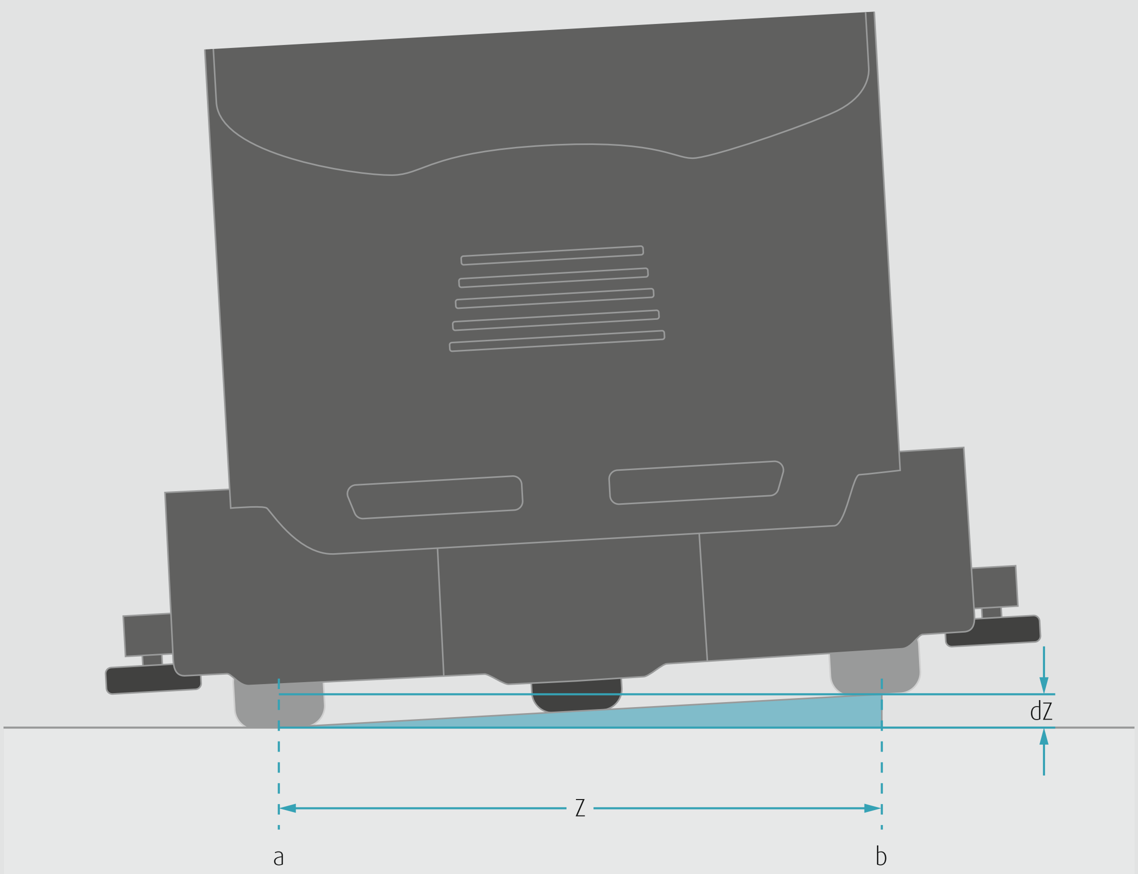
Limit Values across the Aisle: Z_{SLOPE} and dZ
Limit values across the aisle are defined by Z_{SLOPE} and dZ (see table 1).

→ Z_{SLOPE} is defined as dZ / Z [mm / m]: cross aisle slope between the centers of truck load wheels in mm / m.
Z is defined as the distance between the centers of the truck load wheels in m.
→ dZ is defined as elevational differences between the centers of load wheels of industrial trucks (a, b) in mm.

Table 1 - Limit values cross the aisle

Lift height (m)	Z_{SLOPE}	$dZ = Z \times Z_{SLOPE}$
till 6	2.0	Z × 2.0 mm / m
10	1.5	Z × 1.5 mm / m
15	1.0	Z × 1.0 mm / m

Figure 2 - Dimensions cross the aisle



Example for determining Z_{SLOPE}

Assumption

Lift height = 8 m

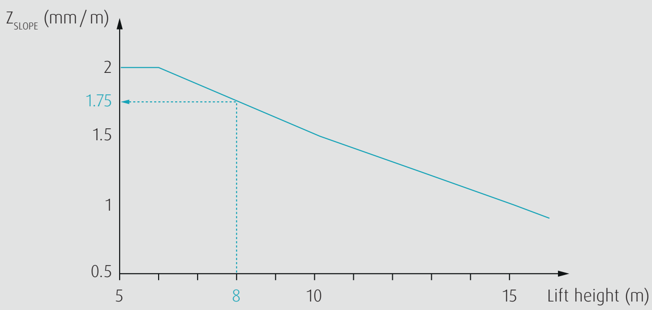
Z = 1.5 m (= b10 VDI[5])

Calculation of Z_{SLOPE} using figure 3

Lift height = 8 m

Z_{SLOPE} = 1.75 mm / m

Figure 3 - Determining Z_{SLOPE}



Example for calculation of dZ

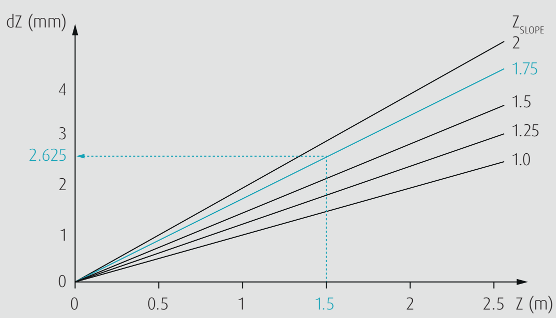
Calculation of dZ using figure 4

$dZ = Z \times Z_{SLOPE}$

dZ = 1.5 m × 1.75 mm / m = 2.625 mm

The maximum permissible height difference (dZ) in this case must not exceed 2.625 mm.

Figure 4 - Calculation of dZ



For Understanding: The Effect of dZ in Relation to Lateral Deviation

To get a feeling of the effect from the unevenness of dZ, this calculation can be done (see figure 5).

The effect of the lateral deviation of the truck becomes greater the higher the truck lifts.

The formula for determining the approximately lateral deviation:

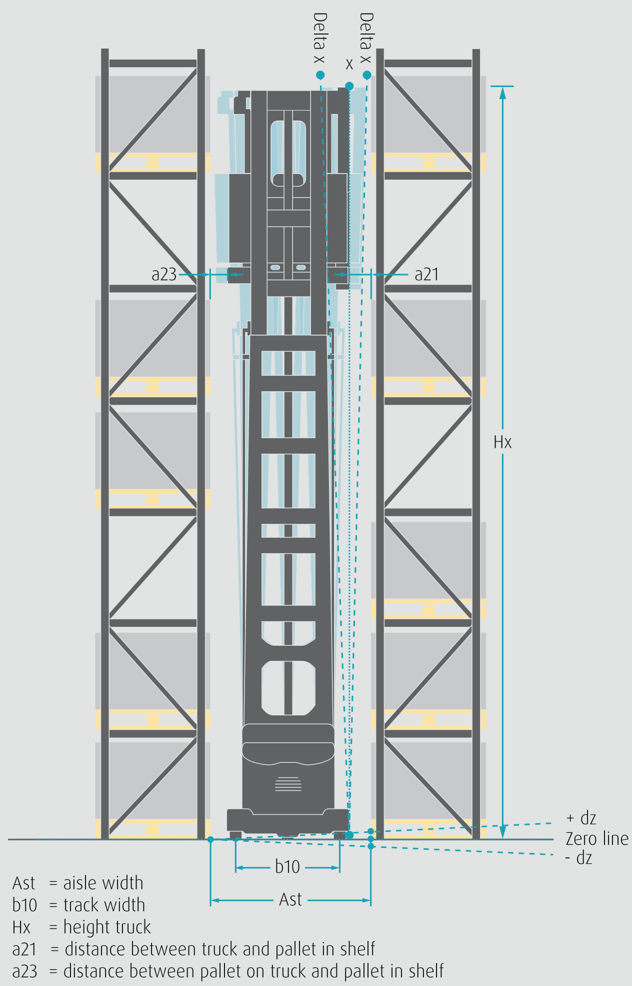
$\Delta X = Z_{SLOPE} \times h$

ΔX = 1.75 mm / m × 8 m

ΔX = 14 mm

Besides the lateral deviation of the mast, a small mast deflection has to be considered. All this calculation work for safety distances a21 and a23 is done by Linde's project planning tool.

Figure 5 - Example for lateral deviation



5) Same dimension: Truck width Z = b10

Limit Values for Flatness along the Aisle

The limit values in Table 2, described in the FEM, for a deviation (gap) below a straight line along all wheel tracks.

Table 2 - Limit values along the aisle

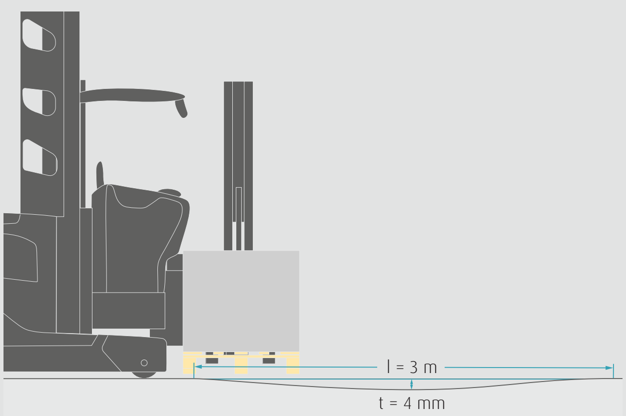
Distance between contact points l	Gap under the ruler t
1 m	2 mm
2 m	3 mm
3 m	4 mm
4 m	5 mm

Example for determining Z_{SLOPE}

Example

The gap below a 3 m long straight line must not be greater than 4 mm (see figure 6).
The measurement must be performed as described in the FEM[6].

Figure 6 - Dimensions along the aisle



Surface Irregularities along the Aisle: Fx Numbers

In addition to the requirements for absolute height differences in very narrow aisles, there are also requirements for regularly reoccurring uneven surfaces.

No rippled uneven surfaces or regular changes in lateral inclination may occur, as they lead to the industrial trucks oscillating or rumbling. Ripple variations are defined by the height differences between two adjacent points along the wheel tracks and are calculated in "Fx values". This is determined from a series of height differences of multiple adjacent readings according to a specified algorithm. The smaller the Fx value, the larger the ripple variation at greater amplitudes or the more uneven the floor (see table 3).

In the FEM directives, the calculation of this key figure is described in detail; a table calculation is also offered for download, enabling automatic calculation from the raw data.

The directive and the calculation tool mentioned can be found on the homepage of the VDMA.

The ripple variation factor Fx calculated in this way must be complied with as per table below.

Table 3 - Limit ripple values along the aisle

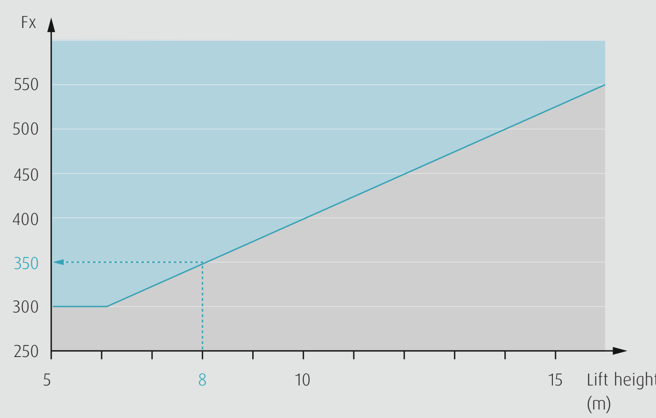
Lift height (m)	FX or 0 / -FX
15	≥ 525
10	≥ 400
up to 6	≥ 300

Example of calculation

Assumption: lift height = 8 m; load wheel track width Z = 1.5 m
Calculation of Z_{SLOPE} using figure 3: 1.75 mm / m
Calculation of dZ using figure 4: $Z \times Z_{SLOPE}$ = 2.625 mm
Calculation of Fx using figure 7: Fx ≥ 350

More information about determination, calculation, and measuring is given in the FEM[7].

Figure 7 - Dimensions for ripple variation factor Fx



6) FEM 4.103 – 1 and FEM 10.2.14 – 1 | Chapter 8.1.2 based on clause 14.3

7) FEM 4.103 – 1 and FEM 10.2.14 – 1 | Chapter 9.2.3.2 | Chapter 9.2.3.3 | Chapter 9.3

OUTSIDE THE VERY NARROW AISLE

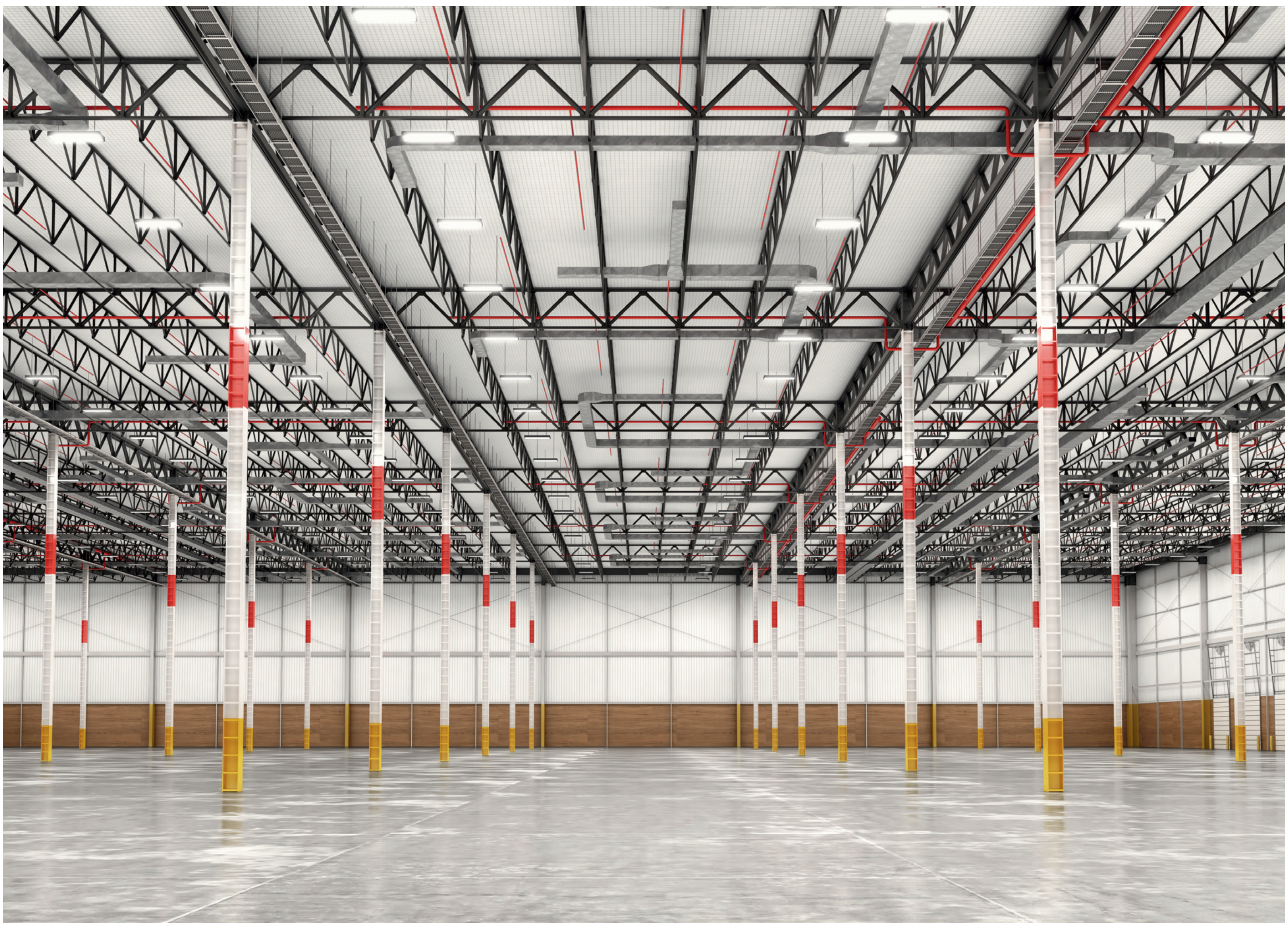
Outside the aisle, lower requirements for the floor unevenness are possible.

The tolerances are defined in the FEM Chapter 9.2.2, which largely comply with DIN 18202 Table 3 Line 3 (industrial floor). These minimum flatness conditions for the floor are required for all VNA truck driving areas, including areas under the racking (see table 4).

Table 4 - Limit values outside the aisle[8)]

Classification	Elevational difference (mm)	Gap under straight edge (mm)			
	over 1 m	1 m straight edge	2 m straight edge	3 m straight edge	4 m straight edge
FM3	8.5	4.0	6.0	8.0	10.0

All elevational differences of the measured points on the floor in the area concerned must be within ± 15 mm (tolerance field = 30 mm) from a datum.



8) FEM 4.103 – 1 and FEM 10.2.14 – 1 | Chapter 8.1.2

Requirements in Designing Storage Solutions

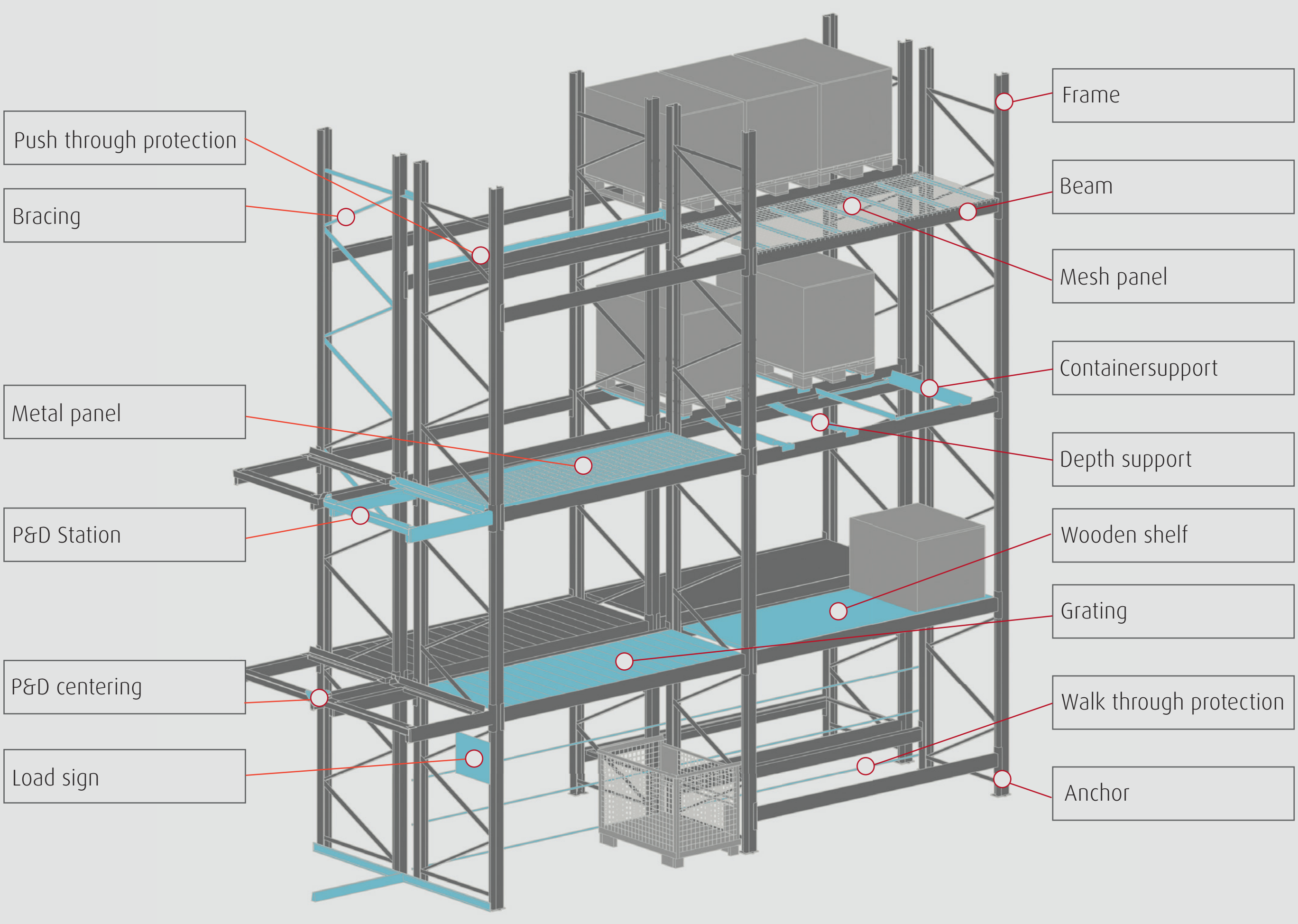
THE RACKING

Pallet racking systems for VNA applications available on the market can be adapted exactly to the most varied requirements and warehouse characteristics. This means that the weights and load dimensions used, the loading equipment, and the industrial trucks used are the most important parameters when designing racking. VNA solutions have the advantage that they can be used in all manual and automated VNA applications and facilitate direct access to all goods locations for storage and order picking.

OVERVIEW OF VNA RACKING

Lifting heights up to 18 m mean higher requirements for the racking.
VNA racks need special equipments to ensure safety (see figure 8).

Figure 8 - Overview of VNA racking



SPECIAL REQUIREMENTS FOR VNA RACKING

Basically, all pallet racks consist of vertical uprights and horizontal beams. Furthermore, the fundamental standards are given in DIN EN 15512[10], DIN EN 15620[11], DIN EN 15629[12], and DIN EN 15635[13].
The flatness of the floor under the racks is also defined by the FEM[14]. Please have a look in the chapter "The floor".

Types of Racking

Normally, VNA racks consist of single and double shelf racks. To use maximum storage space, both types should be used. Single shelves are accessible from only one side, so they are best placed on the walls in the outer aisles. Double shelving allows access from both sides, so they deliver their full potential in the inner aisles of your racking. An exception is double deep storage, in which two pallets are placed one behind the other.

Picking and Depositing Station (P&D Station)

P&D Stations are the transfer stations or the interface between the freely movable forklifts and the VNA trucks. These can be either directly on the floor or at different heights as exposed shelf spaces outside the rack aisles. The shelf is often extended by a few places into the freely movable space. For an efficient and safe pallet transfer, we always recommend equipping these transfer points with pallet centering devices. This saves time and avoids collisions during storage and retrieval in the aisle.

Safety Clearances in the Rack

Safety clearances between the loads in the bay are also defined. A distinction is made between distances between stored pallets and the next bridge piece (dimension Y) and between stored pallets and upright or the next standing pallet (dimension X), or also between the pallet backs to each other (dimension Z).

Regarding Y: Linde recommends a higher distance of 200 mm if possible to achive higher performance and safe load handling (see figure 9).

For fully automatic rack operation, special requirements must be taken into account. For example, centering of the pallets is a prerequisite and safety clearances must be higher.

Further Requirements Specially for Germany

In Germany, insurance policies often require further standards. Linde also recommends these specifications:

To protect employees from falling objects, a shelf frame is prescribed at the end of the shelf, which is 500 mm higher than the upper edge of the highest crossbar[15] (see figure 10). For individual lines standing freely in space, Linde recommends a back wall grille to protect employees against falling objects. A minimum height of 2000 mm is required for all passages in the shelf. In addition, the height of the passages of the industrial trucks used in each case should be at least 200 mm higher than the forklift truck.

The width of the escape route depends on the potential use by personnel. The minimum width of 800 mm of the escape route must always be clear of obstacles[16]. The clear height of an escape route must be at least 2000 mm.

Figure 9 - Distances in the rack

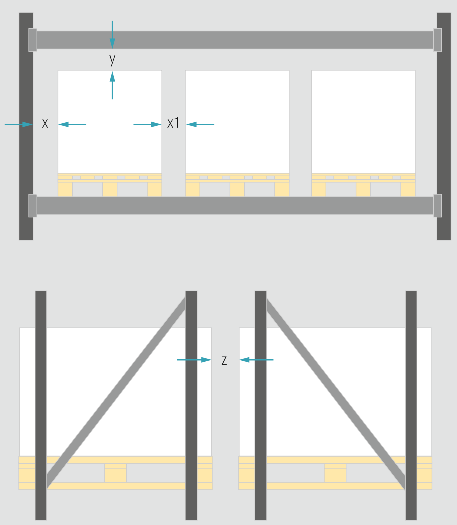
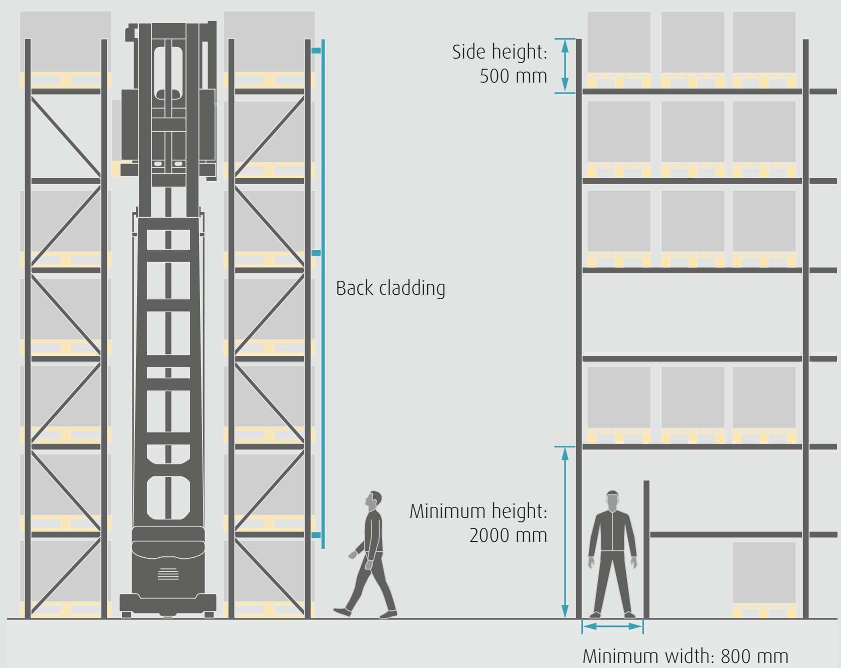


Figure 10 - Further safety requirements



10) DIN 15512 11) DIN EN 15620 12) DIN 15629 13) DIN 15635 14) ASR 2.3 Item 5 | Chapter 3 | Chapter 4
15) DIN EN 15620 | Chapter 4.4 16) ASR 2.3 Item 5 | Chapter 3 | Chapter 4

ASSEMBLY TOLERANCES FOR RACKS AND PERMISSIBLE DEFORMATIONS

Per DIN EN 15620[16], pallet racks for very narrow aisle trucks are divided into two different classes:

Rack class 300 A:
Man-up narrow aisle truck with "man up" operation.

Rack class 300 B:
Man-down narrow aisle truck with "man down" operation.
The assembly tolerances are shown in figure 11; the associated tolerances description per DIN EN 15620 can be found in table 5 and table 6 on the next page.

Table 5 - Racking classification for VNA

<table>
<tr><th rowspan="3">Beam height Y_h from ground up to (mm)</th><th colspan="2">Rack class 300 A</th><th colspan="2">Rack class 300 B</th></tr>
<tr><th>X</th><th rowspan="2">Y</th><th>X</th><th rowspan="2">Y</th></tr>
<tr><th>X_1</th><th>X_1</th></tr>
<tr><td>3000</td><td rowspan="5">75</td><td rowspan="5">75</td><td rowspan="3">75</td><td>75</td></tr>
<tr><td>6000</td><td>100</td></tr>
<tr><td>9000</td><td>125</td></tr>
<tr><td>12000</td><td rowspan="2">100</td><td>150</td></tr>
<tr><td>15000</td><td>175</td></tr>
</table>

Figure 11 - Rack assembly tolerances

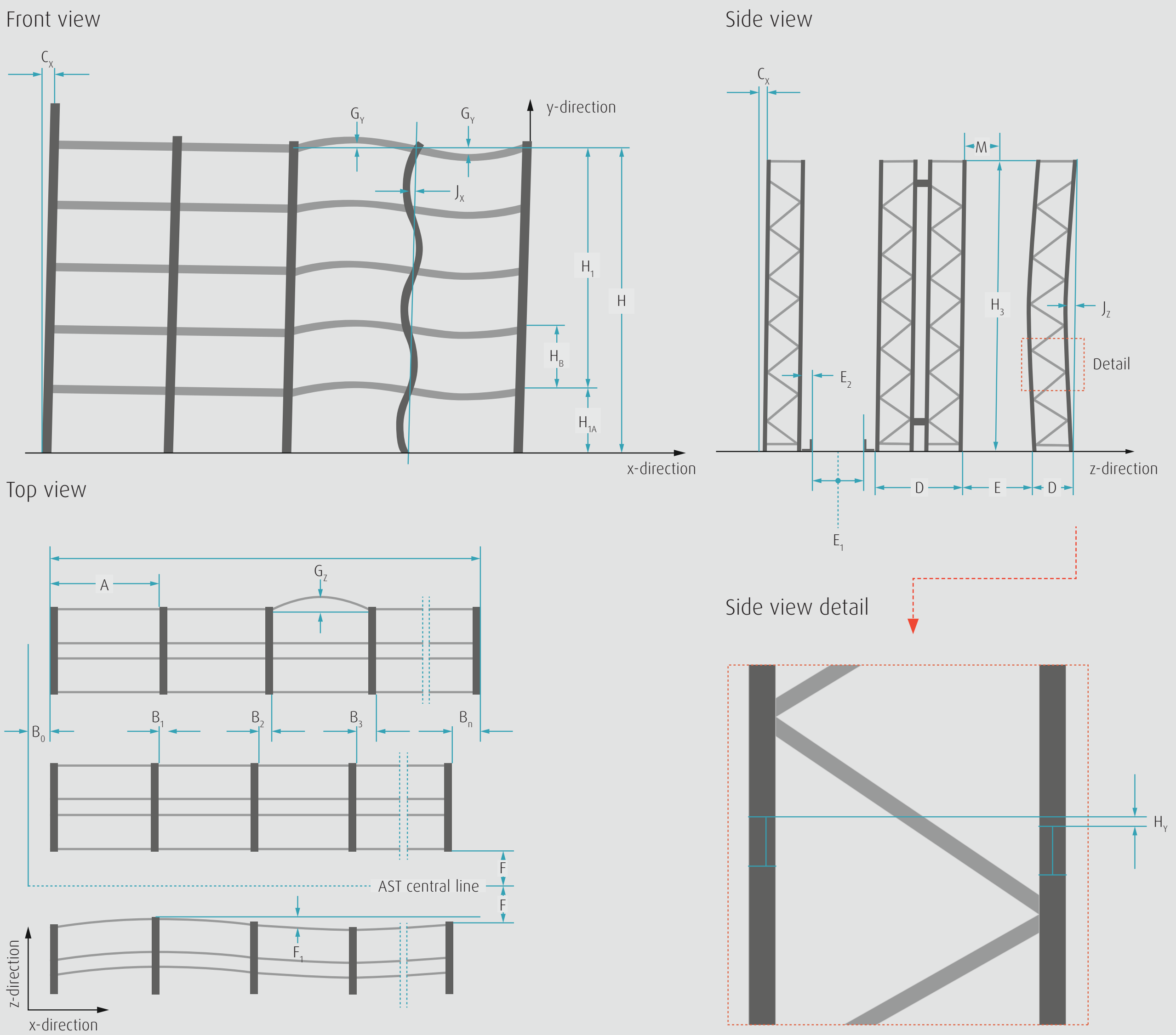


Table 6 - Installation tolerances and permissible deformations of the racks according to DIN EN 15620

Horizontal tolerances for the X Z plane (mm)		
	Measurement specification and description of the cross deviation	Building cross deviation for racking class 300
A	Deviation from the nominal size of the access width between two support uprights in any beam height	± 3
A_1	Deviation from the nominal value for the total length of the racking, cumulative number "n" for the fields, measured as close as possible to the base plate	± 3 n
B_0	Deviation from the nominal size of the racking front at the transfer aisle the respective reference line of the racking system Z, measured near ground level	± 10
C_X	Deviation from the perpendicular of the frame in the X direction	± H / 500
C_Z	Deviation from the perpendicular of the frame in the X direction	Without fixed Hub: ± H / 500 With fixes Hub: ± H / 750a
D	Deviation from the nominal depth of the racking (Single or double frame)	Single frame: ± 3 Double frame: ± 6
E	Deviation from the nominal size for the aisle width about ground level	± 5
E_1	Deviation from the nominal size for the width between the rails	+ 5 0
E_2	Deviation between the supports on one side of the guide rail	± 5
F	Deviation from the nominal size of the aisle straightness measured approximately at ground level with respect to the "reference line aisle system X" or according to the specifications of the truck supplier	± 10
F_1	Deviation measured between next to each other uprights around ground level in the Z direction	± 5
G_Z	Straightness of the beam in the Z direction	± A / 400
J_X	Straightness of the beams in the X direction between supports in a distance HB from each other	± 3 or ± H_B / 750*
J_Z	Initial curvature of a stator frame in the Z direction	± H/500
M	Deviation limits for the upper guide rail	Is set by the truck supplier or the author of the specification
T_W	Beam rotation in the middle of the field	1° per m

Vertical tolerances in the Y direction (mm)		
	Measurement specification and description of the cross deviation	Mounting tolerances for racking class 300
G_Y	Straightness of the beam in the Y direction	± 3 or ± A_{15} / 500*
H_1	Deviation of the top level of any beam over the H_1 lower support level	300 A: ± 5 or ± H_1 / 500 300 B: ± 3 or ± H_{10} / 1000*
H_{1A}	Deviation of the top edge of the lower beam on each upright against ground level	± 7
H_3	Deviation limits for the upper guide rail, if available	If available, set by the supplier or manufacturer of the truck
H_Y	Deviation of the heights of the load unit between the front and rear beam in one compartment	± 10
H	Height from the top of the foot stand level to top of the racking support	
H_B	Height from the top stand level to the next higher stand level	

*The greater of the following values is valid a H / 500 is also permitted, provided the overhang of the pallet skids or blocks at the front bars is 75 mm or more and the skids or blocks are supported by the beams.


YV
YU
ONLY ONE
TRUCK IN A
NARROW AISLE
AT ANY ONE TIME

FIRE PROTECTION

Requirements for fire protection are an important factor when building racking storage. We recommend contacting your Linde partner at an early stage. Spatial requirements for fire protection as well as other safety clearances in the racking will be discussed. It might be necessary to speak to your insurance partner.

Different Systems According to Fire Hazards
At the start of the planning stage, a fire protection system must be defined.

To dimension a sprinkler system, a fire hazard class must be determined at the planning stage. The FM Global[17)] guidelines and the VdS CEA 4001[18)] define these standards.

The fire hazard of stored goods depends on the flammability of the stored material, the packaging, and the type of storage.

There are further possibilities to ensure safety in a warehouse. For example: Gas-based suppression systems. For more details, please have a look at FM Global[19)].

ESCAPE ROUTES, RESCUE ROUTES, AND CROSSWAYS

Escape routes, rescue routes, and crossways should be provided in each warehouse according to the local regulations. In Germany, the ASR defines a maximum distance of 35 m from any point in a warehouse to the next fire compartment or outdoors[20)].

INSPECTION

According to the European standard EN 15635[21)], the owner of the warehouse is obliged to protect its installations and to have them checked by qualified persons within the required inspection periods.

Damaged parts must be replaced according to the regulation mentioned.

17) VdS CEA 4001
18) FM Global: Carbon dioxide extinguishing systems
19) ASR 2.3: Escape routes and emergency exits, escape and rescue plan
20) EN 15635: Adjustable Pallet Racking - Guidelines for Safe Work
21) FEM 4.103 – 1 and FEM 10.2.14 – 1 | Chapter 9.4.2.2

Safe Driving in the Very Narrow Aisle

GUIDANCE SYSTEMS

To take optimum advantage of the spatial requirements in the very narrow aisle, the appropriate industrial trucks make work easier with a very short distance to the rack. DIN EN ISO 3691 part 3 prescribes a minimum safety distance of 90 mm. Driving and simultaneously steering freely in very narrow aisles is no longer practical. This is the reason why a guidance system is required for safety reasons. Basically, there are two different guidance systems: inductive wire and mechanical guidance. Depending on parameters such as pallet size, truck type, and guidance system, the safety clearance can also be higher.

MECHANICAL RAIL GUIDANCE

The mechanical rail guidance has side rollers attached to the truck and steel profiles mounted to the floor to guide the VNA truck. The laterally mounted rollers (2 rollers per truck side) hold the truck between the guiding profiles in the aisle center.

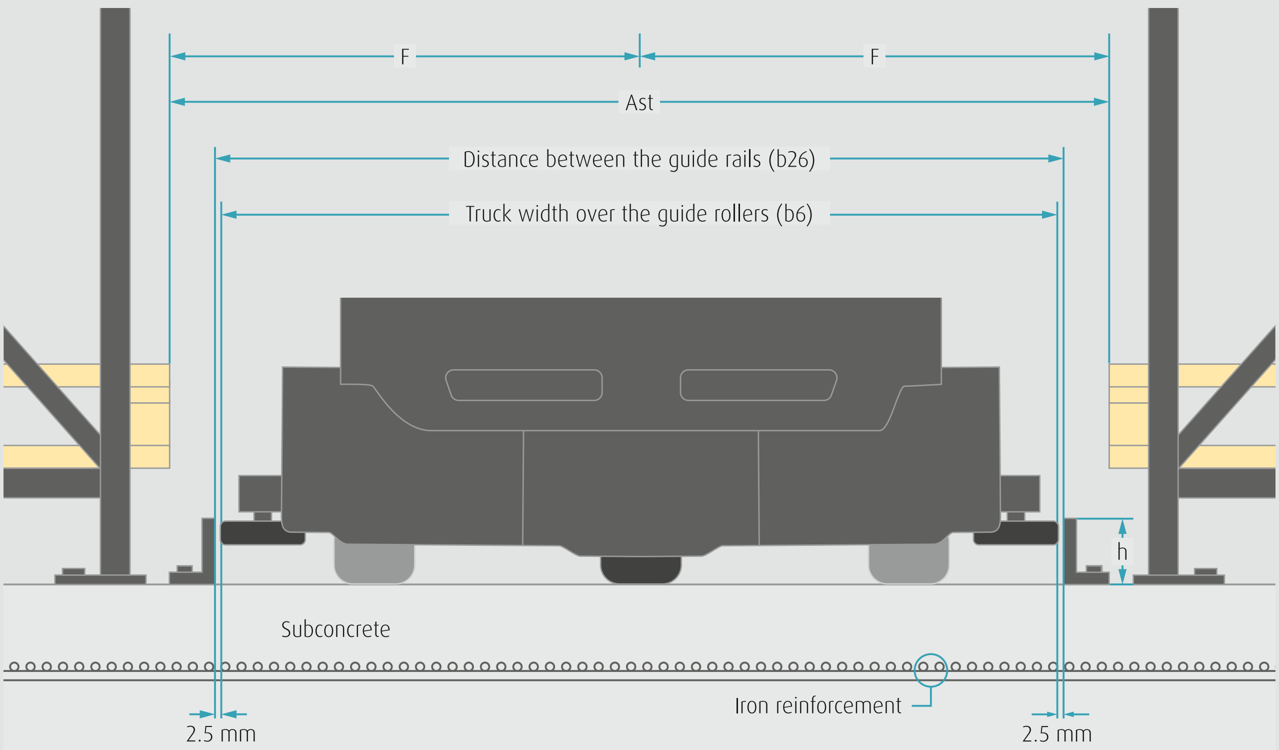
Figure 12 shows the clear space width of the aisle (Ast) taking into consideration the relevant parameters. With mechanical guidance a speed of 14 km / h in the aisle can be possible. Each warehouse must be planned individually.

Safety Clearances for Mechanical Guidance

Safety clearances between all lifting truck parts (e.g., forks) or the load on the truck to the aisle width (normally pallets in the rack) are defined as a21 / a23 (see figure 13). DIN EN ISO 3691 Part 3 requires a minimum safety clearance for a21 / a23 = 90 mm. Depending on parameters such as pallet size, rack height, and guidance system, for optimum and maximum performance larger safety clearances are required.

A higher safety distance gives the prerequisite for higher performance. Every warehouse or truck must require individual and tailor-made project planning. With Linde's configuration and project planning tool, it is possible to achieve an individual, tailor-made truck that is ideal for your application.

Figure 12 - Distances for mechanical rail guidance



Ast
Working aisle width, clear space between loads or racks

F
Deviation of working aisle width from center line over 20 m
- F = ± 5 mm[22)]

b26
Rail to rail distance, clear space between rails

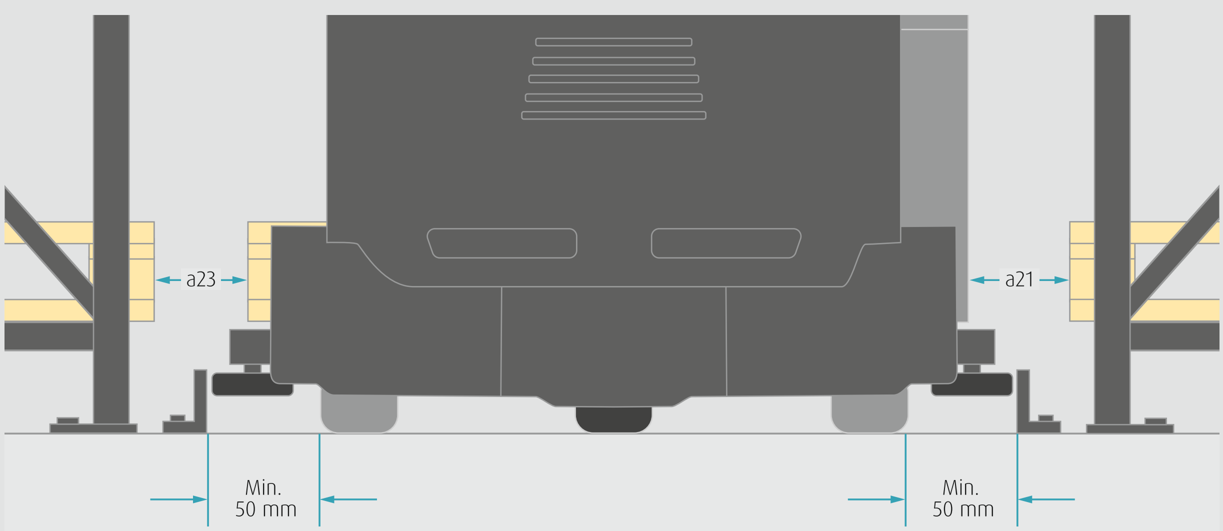
Permissible deviation:
→ over the entire length: 0 / + 5 mm
→ over 1 meter length: 0 / + 2 mm

b6
Width between guide rollers, outside-to-outside dimensions at truck side
b6 = b26 – 5 mm

h
Rail guidance height (typically classes: 50 mm or 100 mm)
The minimum limit of rail height is 35 mm.

General recommendation for the rail height: The higher the guide rail is, the more functional and safer the guidance.

Figure 13 - Safety clearances for mechanical guidance



22) FEM 4.103 – 1 and FEM 10.2.14 – 1 | Chapter 9.4.2.2

Rail Guidance Variants

There are multiple variants of rail guidance (see figure 14). The most common profiles used in the market are L rails with a profile height of 100 mm (high-profile rails) or 50 mm (low-profile rails).

The functional advantage of the low-profile rail is to negate the requirement for a bottom beam level in the racks. The pallets can be placed directly on the floor. To pick up pallets on the floor level, special low-profile knife forks (that are thinner and wider than the standard forks) are required. The greatest lateral forces are generated during the threading of the truck into the rail guide. This area of the rail guide must also be reinforced in accordance with the specifications in the FEM.

Recommendation: Whenever possible, for more stability, better guidance function, and greater safety, Linde recommends using an L profile 100 mm × 50 mm with a thickness of 10 mm.

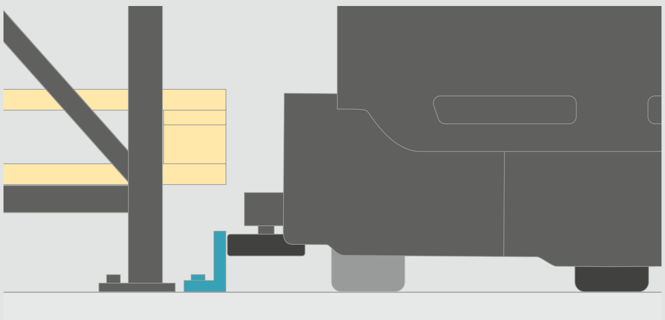
Regardless of the disadvantages, other heights can be implemented up to the smallest possible rail height of 35 mm. The profile rails can be both free standing as well as integrated in a concrete base (cast guide rail). If the guide rail can absorb the lateral forces required by FEM, alternative profiles and installations are possible.

Due to the different heights of guide rails, the heights of the side guide rollers on the VNA truck must be adapted, which has to be defined before ordering.

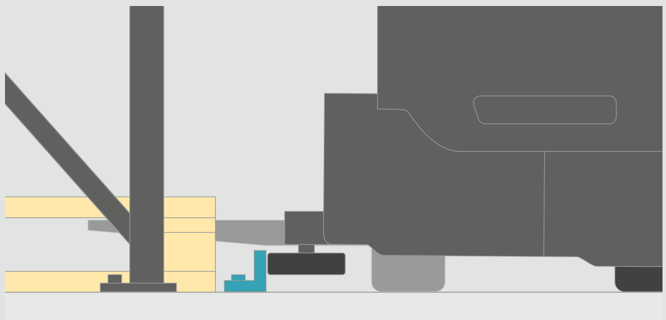
Available heights between roller and floor

26 – 50 mm for high guide rails
10 – 26 mm for low guide rails

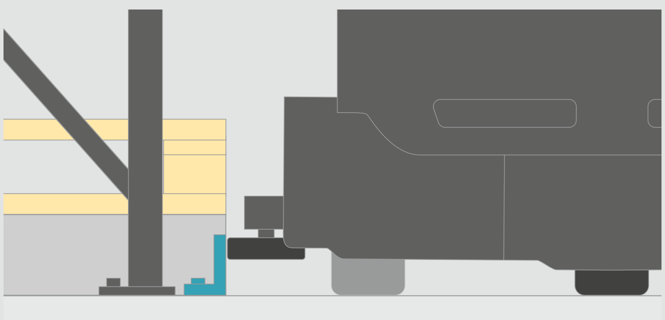
Figure 14 - Different rail guidance systems



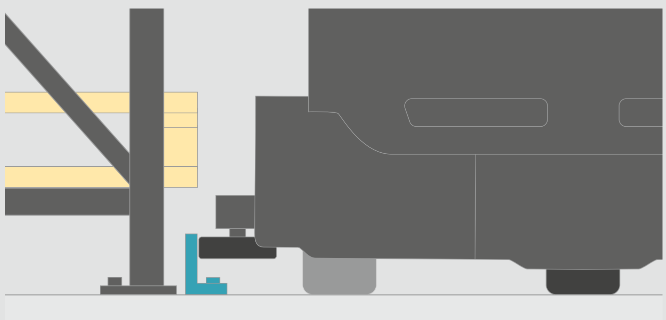
High-profile rails



Low-profile rails



Concreted profile rails



High-profile rails turned

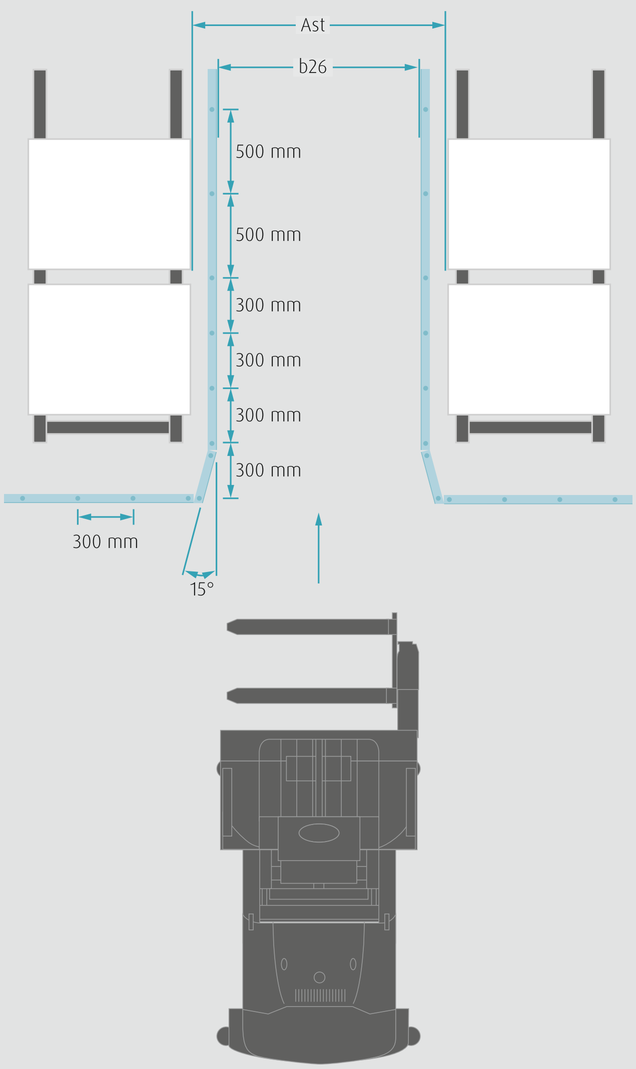
Design and Assembly of Guide Rails

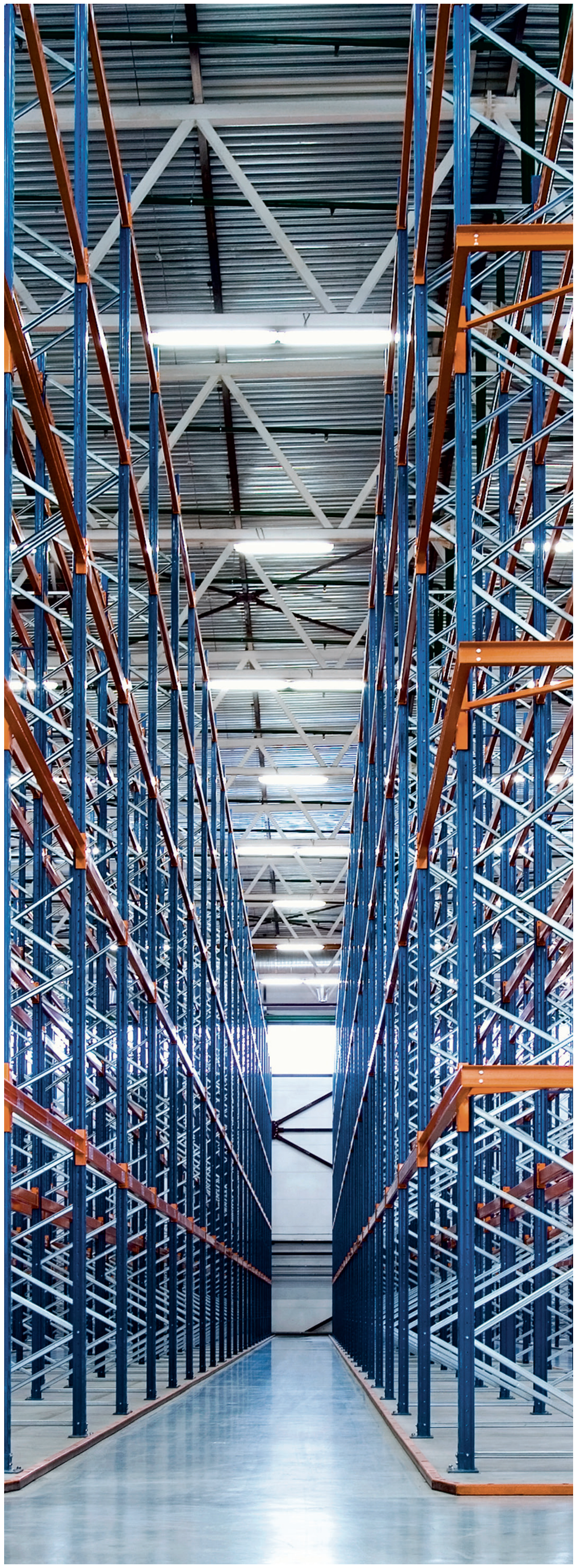
It is crucial for the accuracy in the warehouse that the guide rails are laid parallel to the racks to guide the truck in the middle of the aisle. To make threading easier to adjust the truck in very narrow aisles, the start of the aisle has an entry funnel of approximately 300 mm in length with an opening angle of 15°. The strongest lateral force is achieved in this funnel and the first meters afterwards, the approximately 2500 mm long threading area. This force of up to 25 kN can occur if the VNA truck is manually inaccurately guided (non-accidental). After the rear rollers get into the rail guidance, the forces are reduced as the aisle is traveled to approximately 4 – 10 kN[23]. It is recommended to consider 10 kN for all VNA truck types to be on the safe side.

23) FEM 4.103 – 1 and FEM 10.2.14 – 1 | Chapter 9.4.2.2

To ensure secure track adjustment, we recommend using a funnel with a high profile. The guide rails are anchored in the floor after being installed. The different effects of force in the driving area and threading area require different doweling distances. In the driving area, the distance is 500 mm. In the threading area, it is recommended to reduce it to approximately 300 mm for the first 4 dowels. This dowel spacing also applies to the front of the rail for the transfer aisle (see figure 15). The guide rail thickness should be a minimum of 10 mm to avoid deformations due to lateral forces.

Figure 15 - Design and assembly of guide rails





INDUCTIVE WIRE GUIDANCE

The inductive wire guidance system is an alternative system to the mechanical rail guidance. A guide wire laid on the middle of the aisle in the floor is the guiding line for the VNA truck. The guide wire is fed by a frequency generator with low voltage current. The magnetic field formed around the guide wire is scanned by antennas mounted centrally under the truck. The inductive steering system processes the antenna signals and steers the truck fully automatically through the very narrow aisle at speeds of up to 10 km/h, centrally above the guide wire.

Laying an Inductive Guide Wire

The guide wire is laid as a closed loop, and its beginning and end are connected to the frequency generator. An uneven number of aisles requires the installation of an additional return.

To avoid interferences, the FEM[24] defines minimum distances (manufacturing tolerances included)

- → 200 mm between guide wire and other metal elements (e.g., cable channels, horizontal movement joints)
- → 150 mm distance for magnets of other truck suppliers (200 mm distance to center of magnet)
- → 1500 mm between guide wires using the same frequency
- → If an additional screed is foreseen on the structural concrete slab, the nominal thickness and thickness tolerances of that screed must be considered as well

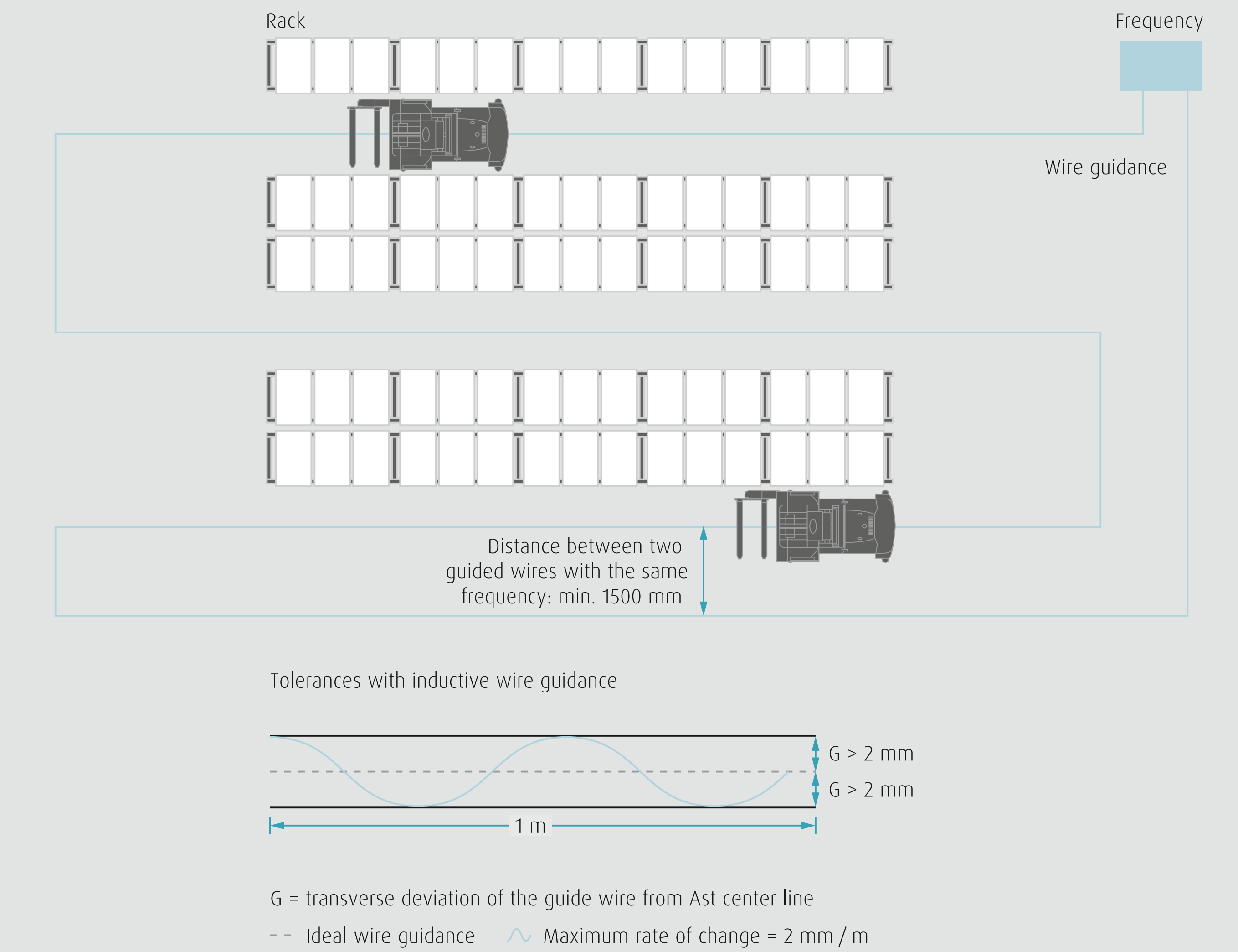
System Requirements and Tolerances with Inductive Wire Guidance

The FEM[25] also stipulates that a horizontal deviation of the guide wire from the nominal center line over the entire aisle length of ± 5 mm is within the tolerance range. A maximum rate of change of 2 mm per m is acceptable. We recommend assembling the racks first before cutting the floor and laying the guide wire. It is crucial for the accuracy in the warehouse that the guide wire is laid centered to the racks in the middle of the aisle.

Distance between Two Guide Wires

Wires which have the same frequency need a safety distance of min. 1500 mm (see figure 16). If this distance is not met, the inductive guidance may malfunction (exception: return lines that are not laid in the wheel tracks area).

Figure 16 - Laying inductive guide wires



24) FEM 4.103 – 1 and FEM 10.2.14 – 1 | Chapter 9.4.2.3

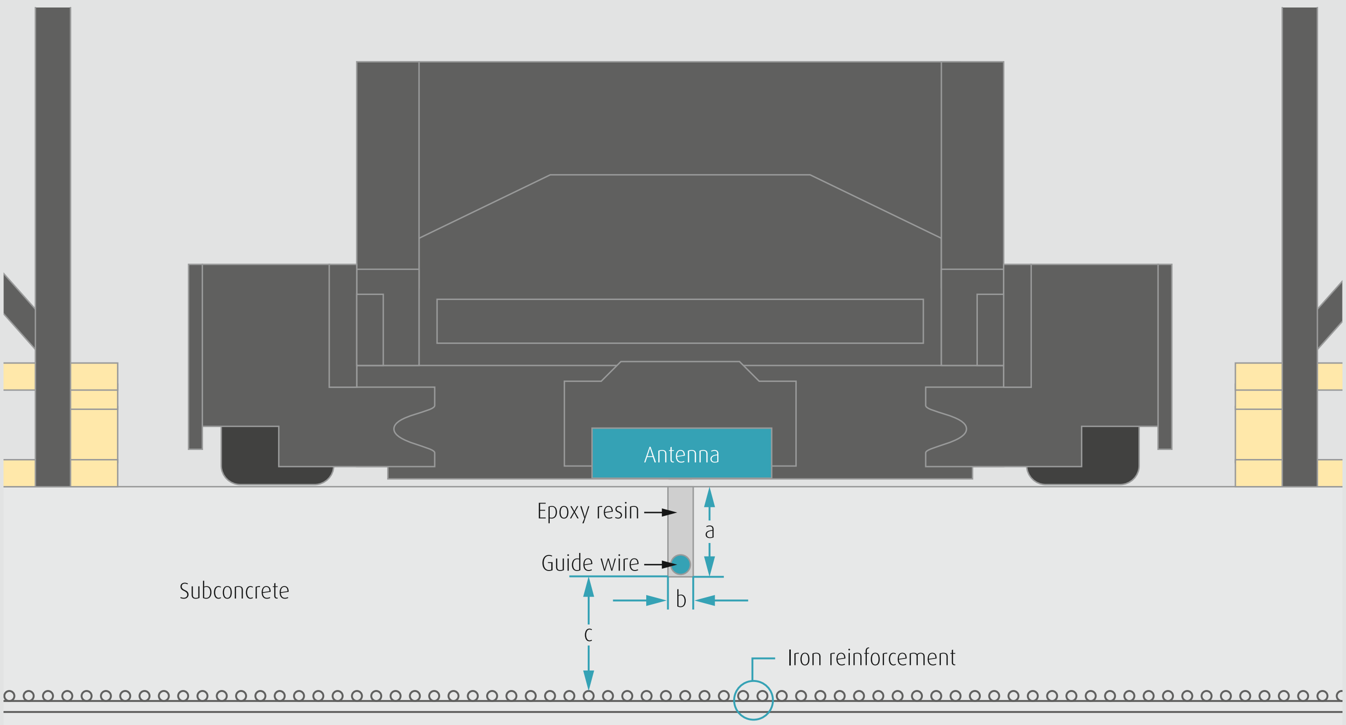
25) FEM 4.103 – 1 and FEM 10.2.14 – 1 | Chapter 9.4.2.3

Distances for Inductive Guide Wire

As a rule, the distance from the steel reinforcement to the guide wire (c) must be at least 50 mm (see figure 17). A smaller distance between reinforcement and guide wire is possible but individual circumstances should be considered. Metal (cable ducts, expansion joints, etc.) must be kept at least 200 mm away from the left and right of the guide wire.

By using steel fibers instead of iron reinforcement, the maximum amount of iron fibers in the concrete must not exceed 30 kg/m^3. The equal distribution of the steel fibers in the concrete must be enforced. The wire has a cross section of 1.5 mm^2 and must be double shielded. Once laid in the slide, the wire is sealed with epoxy resin.

Figure 17 - Functional principle of wire guidance

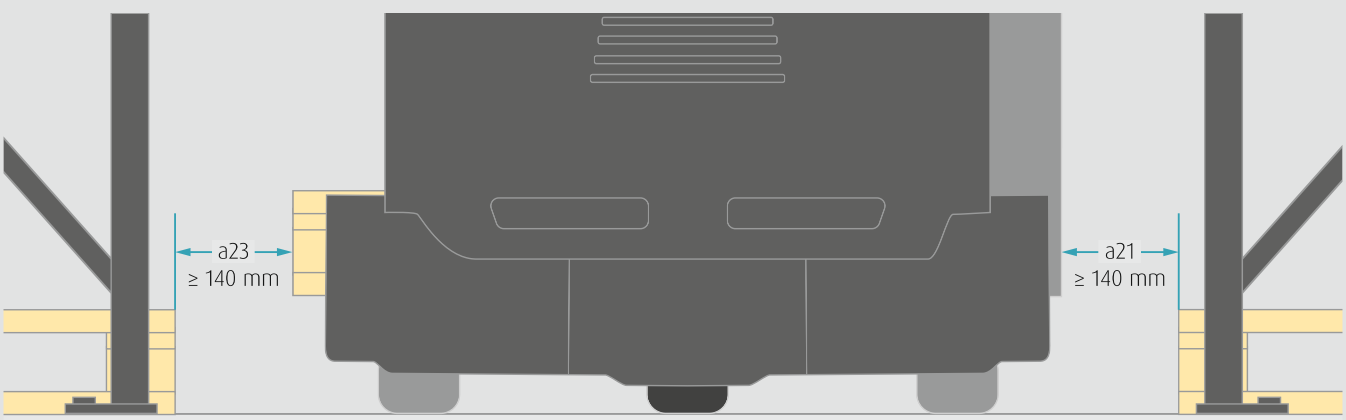


a = depth of guidance wire slot, maximum 15 mm
b = width of guidance wire slot between 3 mm and 6 mm
c = distance between bottom of guidance and top of steel, minimum 50 mm

Safety Clearances for Inductive Guidance

To drive with full performance in a wire guidance aisle, a safety side clearance between loads in the racks and the truck or load on the truck of at least 140 mm is required[26] (see figure 18).

Figure 18 - Minimum safety clearance for inductive guidance



26) Linde: If using a smaller distance, the speed of the truck will be reduced

The Linde frequency generator
The frequency generator has connections for a maximum of eight separate loops with each up to 2000 m, with a maximum total of 16000 m. It feeds the guide wire with high frequency AC. If a single wire loop is damaged, this loop then fails entirely. Therefore, to reduce downtime, it is recommended to split the wire guidance in a warehouse in different loops.

A protected, easily accessible position in the storage area should be selected for assembly of the frequency generator. If there is a power failure, an independent power source (buffer battery) can be used as an emergency power supply and sustain operation for approximately 2 additional hours. This might be of interest in countries where energy supply is not constantly available.

The supply voltage is 230 V AC at 50 Hz or 115 V AC voltage at 50 Hz. The guide frequency can be specified between 300 Hz and 20 kHz in 10 Hz steps. Between 30 mA and 110 mA can be selected as the adjustable loop current.

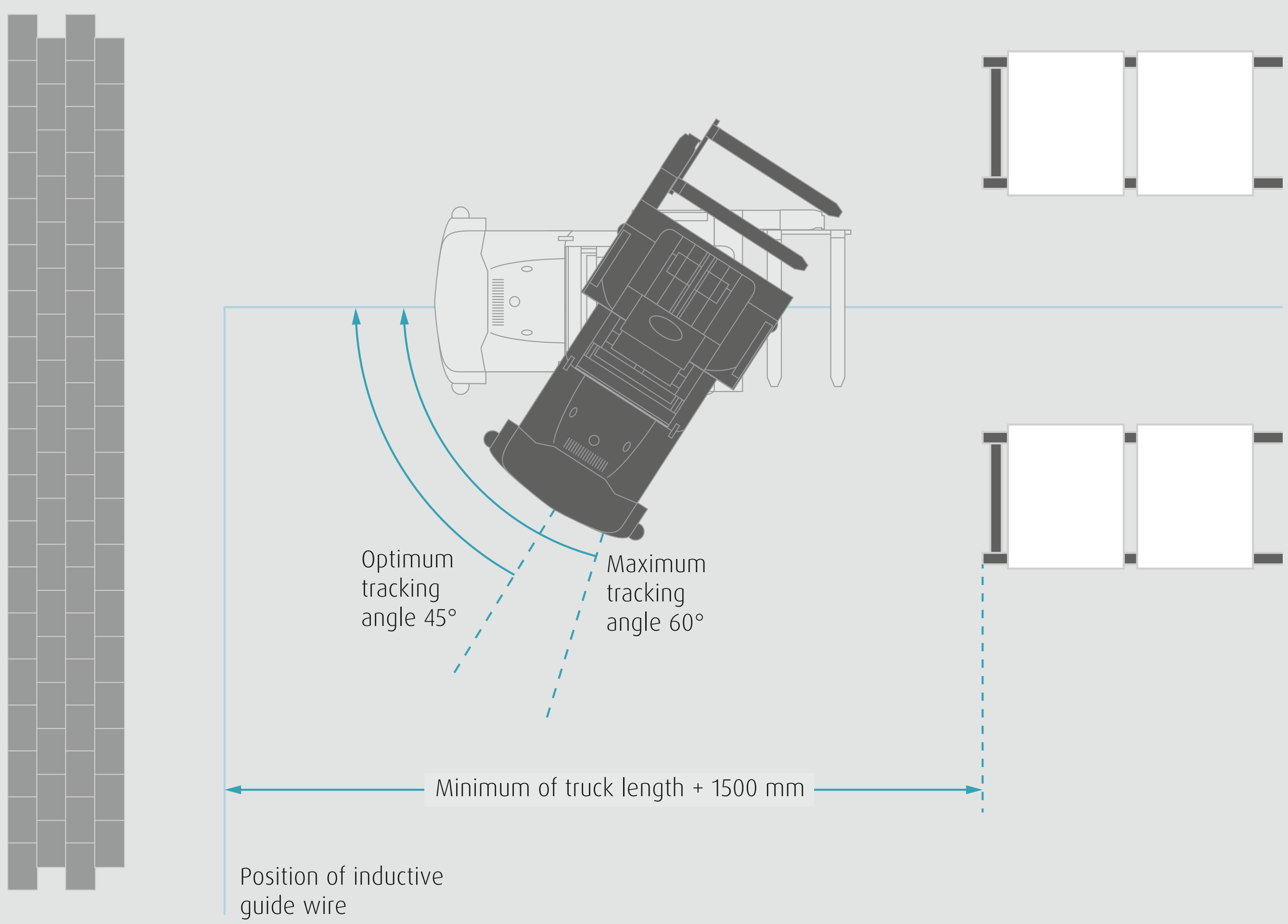
ENTERING AND EXITING THE AISLE / CHANGING AISLES

The assistance function to track on and off the wire is displayed by optical and acoustical messages.

Entering the Aisle
In the transfer aisle, the operator drives the truck at an angle < 60° in the direction of the guide wire and switches to automated operation. The smaller the tracking angle, the faster the truck tracks on the wire. The guide wire should be laid in as far as possible in the transfer aisle. The minimum recommended dimension between the beginning of aisle and the end of the inductive wire in the transfer aisle is the diagonal truck length plus 1500 mm. For details please contact our Linde team (see figure 19).

Exiting the Aisle
After exiting the aisle, the operator switches back to manual steering and the truck can be driven freely.

Figure 19 - Entering the changeover aisle



CHECKLIST TO FIND THE RIGHT GUIDANCE

The following table gives an overview of the aspects that should be considered (see table 7) to select the guidance system according to the application.

Functionally, there is no wrong system decision if the requirements and individual preferences have been met. The most economical solution must be determined individually. Our Linde system consultants will provide professional and binding assistance.

Table 7 - Checklist to find the fitting guidance

Aspects	Mechanical guidance	Inductive guidance
Functional differences	Maximum possible speed: 14 km / h Entering the aisle: Manual steering required for threading into the aisle	Maximum possible speed: 10 km / h Entering the aisle: Supported by an assistance function (semi-automatic)
Safety differences	Simple safe technology through positive locking, truck rollers to rails	Technology ensures safety which is guaranteed through redundant system architecture and a fully automatic steering system in the racking aisle
Economical aspects	Tends to be the cheaper solution, when fewer trucks and a small sum of the aisle length is needed	Tends to be the cheaper solution, when several trucks and a large sum of the aisle length is needed
Operational differences	The guide rails are installed on the floor in the shelf aisle and partly outside → Access to cleaning is made more difficult → Access to the shelf with other trucks e.g. pallet trucks or stackers	The floor laying wire offers barrier-free access → Easier to clean → Load change directly from the floor with other trucks is possible e. g. pallet trucks or stackers Environmental conditions like the steel share in the concrete must meet the requirements

Options for more Performance, Comfort and Safety

ASSISTANCE SYSTEMS

Of course, all Linde trucks fulfill the necessary requirements of norms and standards. But Linde is ahead when it comes to understanding customers needs. This is the reason why a huge portfolio of safety-relevant and assistant systems, which deliver greater performance and comfort, is provided. This often makes the difference in everyday life. With new functions the work is getting more productive and safer. Linde invented different systems which set standards in the market. This chapter gives you an overview of the outstanding systems and describes them from a technical perspective.

LINDE SYSTEM CONTROL – PROCESS OPTIMIZATION WITH EVERY LOAD

The Linde System Control (LSC) optimizes your handling process and assists the operator for convenient and confident work. For example, one of many advantages of the LSC is the integrated height measurement system. The display shows current maximum load capacity in accordance with the height of the forks. The maximum travel speed is also adapted according to the lift height. The Linde Curve Assist feature guarantees safety when changing the aisles by reducing truck travel speed based on the steering angle (see figure 20).

Figure 20 - Dynamic residual load capacity

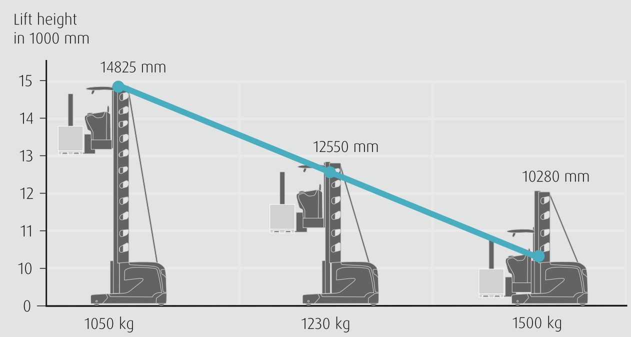
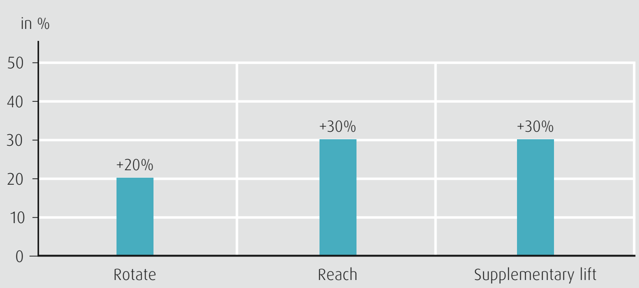


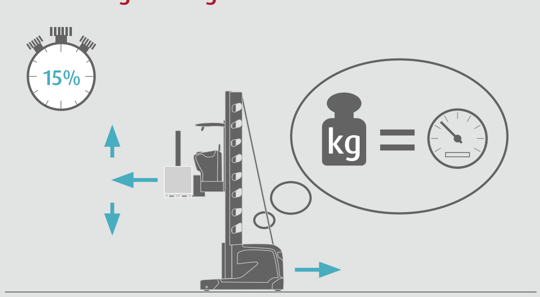
Figure 21 - Load recognition



To increase performance and operator assistance, trucks can be equipped with additional LSC Load. A sensor indicates if the forks are carrying a load. LSC Load combines this information with the current lift height to optimise functions such as reach, rotate and supplementary lift. This allows the truck to operate up to 30 % faster when without a load (see figure 21).

Trucks which are equipped with LSC Weight recognise the total weight of the pallet and its load, and optimise all truck operations accordingly. Light loads can be moved faster than heavy ones. This feature is particularly advantageous in scenarios where loads of differing weights are being handled (see figure 22).

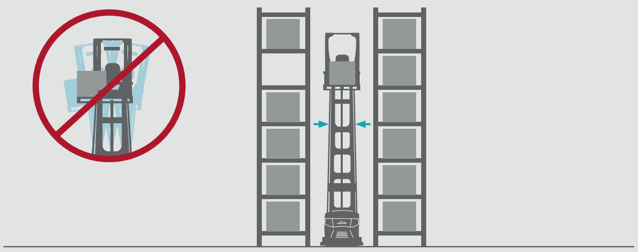
Figure 22 - Weight recognition



DYNAMIC REACH CONTROL – PROCESS OPTIMIZATION DURING REACHING

Dynamic Reach Control (DRC) combines all LSC functions and adds intelligent load stabilization. When putting away or retrieving loads, it adjusts reach according to current load weight, and eliminates lateral mast oscillations. This enables loads to be moved faster, and reduces damage to loads and racking (see figure 23).

Figure 23 - Dynamic Reach Control



How DRC Works

The motor that shifts the goods into the rack is controlled in a special way. The initial movement that causes the mast to oscillate is brought to rest by an active counter steering of the motor. Of course, the patented system takes the load weight and the lift height of the truck into consideration.

The benefit is up to 20 % greater throughput compared with LSC Standard for an increased level of productivity and load handling confidence.

ACTIVE STABILITY CONTROL – THE ALTERNATIVE FOR SUB-STANDARD FLOORS

As described in the chapter "The Floor", the quality of the floor surface plays a crucial role in VNA warehouses. Full performance and high driving comfort with a VNA truck can be achieved when the floor fulfills the requirement of the FEM 4.103-1 / FEM 10.2.14-1.

Because of the greater effort required for the floor, the price of a FEM floor compared to an industrial floor differs by roughly 30 %.

A possiblity to achive this VNA requirements is given in grinding. Beside the high costs of grinding, the warehouse will be blocked for operation during construction time. If grinding is not an option, the customer has to deal with a performance loss due to the speed reduction of the truck. Essentially, a planning gap either in investment or in warehouse efficiency has to be accepted. With Active Stability Control full performance on a normal industrial floor can be possible.

Your Solution: Active Stability Control

Active Stability Control (ASC) is an excellent alternative, because the truck takes the unevenness into account and actively compensates it. The patented system was developed to ensure maximum stability and maximum productivity of the truck, even when the floor does not fulfill the FEM specifications. ASC can compensate a difference in height between the left and right load wheels (dZ) of up to 10 millimeters (see figure 24). Nevertheless, it is possible to safely handle materials at heights of up to 18 meters, and to drive at speeds of up to 14 km / h. It greatly reduces mast swaying and helps create an ergonomic working environment for the operator (see figure 25).

Lindes man up truck (K-truck) can be supplied with ASC ex works, but trucks can also be preconfigured to allow the system to be retrofitted at a later date.

Figure 24 - Compensable height difference

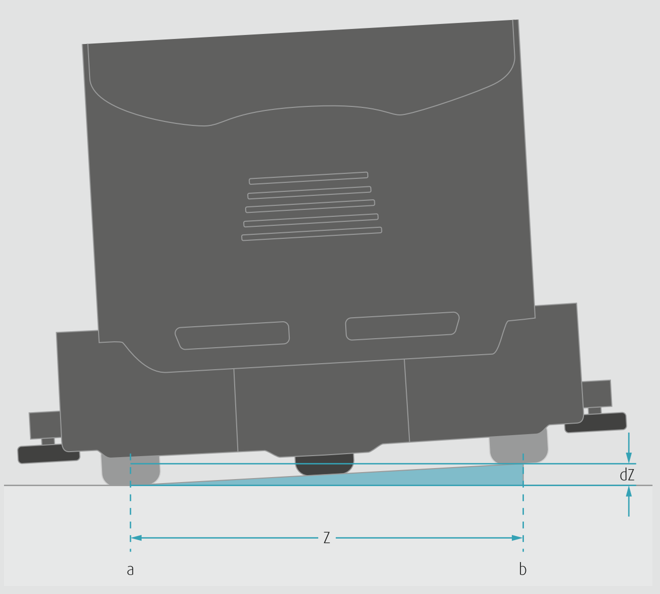
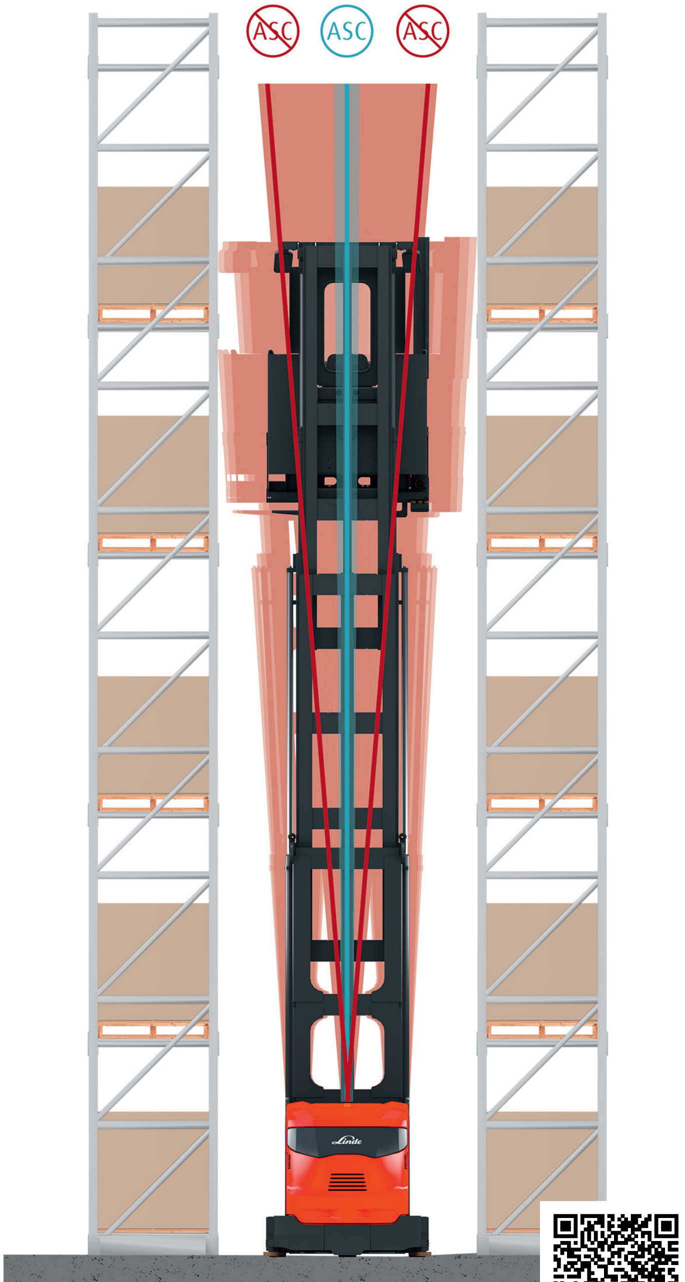


Figure 25 - ASC reduces mast swayings to a minimum



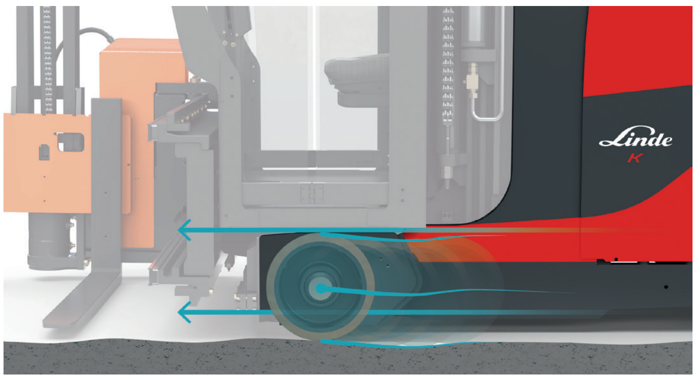
How ASC works

Based on precise sensor technology, the wheels are adjusted in real time by an active reacting control system.

Independent of the direction of travel, the truck measures the height difference between the left and the right load wheel perpendicular to the floor. Shortly before and shortly after the load wheel, the surface is measured. Of course, the measurement system has a dirt guard protecting the sensors from small parts. If the system detects surface irregularities, the load wheels are adjusted immediately to prevent the truck from oscillating. Unevenness is compensated electromechanically in real time and at the full truck speed of 14 km/h (see figure 26).

Lateral vibrations and fluctuations have not the possibility to enter the truck. All solutions that passively damp the swaying in the truck will always end up with lower efficiency than ASC.

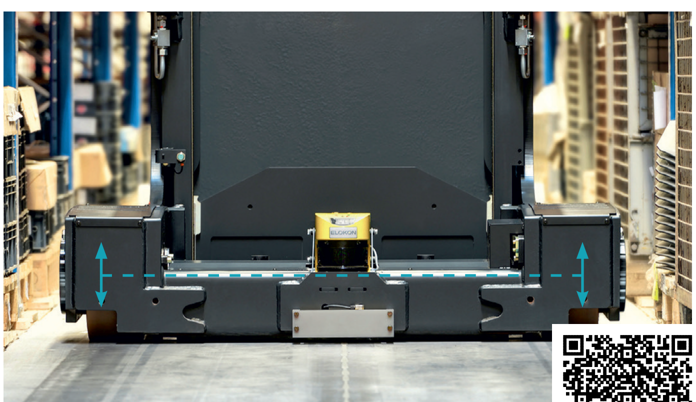
Figure 26 - Compensation of uneveness



The Adjustment Mechanism

Unlike a normal VNA truck, the load wheels are mechanically connected to an axle (see figure 27). The load wheels on the axle are eccentrically mounted in opposite directions. Nevertheless, they are freely movable due to the ball bearings. If the axle is rotated, one load wheel moves downward and the opposite one upward. The adjustment range of 5 mm in each case allows a total of 10 mm of unevenness to be compensated.

Figure 27 - Functionality of ASC



Performance of ASC

The basis of the innovative system is its fast responsiveness. ASC works in real time and compensates unevenness between the left and the right load wheel track dZ maximum 10 mm. No sideway movements are tangible. Thanks to the compensation of unevenness on the truck, the lower flatness requirements defined in DIN 18202 Table 3 Line 3 (4) may suffice (see table 8). The redundant system provides full performance for higher throughputs and increases driving comfort for the operator.

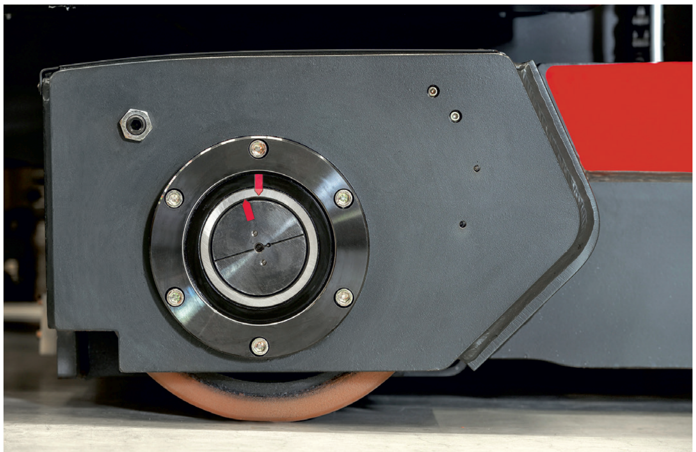
Irrespective of the type of guidance (inductive or mechanical), a smooth ride with full performance on a bad floor can be possible. Because the load wheel axle of the truck always remains horizontal thanks to ASC, another positive aspect comes to light. The storage depth of the goods is at the same level, irrespective of the height. Mast deflection is compensated by the option Linde System Control Standard (see figure 28).

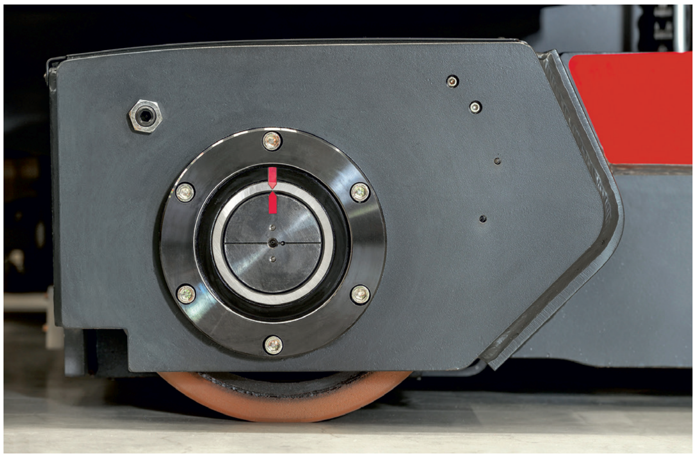
Table 8 - Limit values for an industrial floor

Column	1	2	3	4	5	6
Group	Reference	Permitted position deviations, in mm, for distances between measuring points, in m, up top				
		0.1	1[a]	4[a]	10[a]	15[a b]
...						
3	Finished floors (e.g. screed as wearing courses or screed to receive flooring, flooring including tiled, trowelled or bonded floorings)	2	4	10	12	15
4	As for Group 3, nut subject to more stringent requirements (e.g. self-levelling compounds)	1	3	9	12	15
...						

a: Intermediate values shall be taken from Figures 5 and 6 and shall be given to the nearest mm
b: The values in Column 6 also apply to distances between measuring points of over 15 m

Figure 28 - Perfect storage with ASC





ASC as a Retrofit Solution

Despite great planning and careful constructions, sometimes a floor in the VNA warehouse does not meet the planned flatness requirements for VNA trucks. This incident can be prevented by using a truck that is pre-configured with ASC. Linde’s configuration tool can check upfront whether ASC will be possible for later installation.

This possibility of an ASC retrofit solution should always be considered.

Limits of the System

Nevertheless, ASC also has its limits. Expansion joints cannot be compensated. The system allows the operator to drive over short-wave uneveness defined in the FEM, but ASC itself does not compensate it.

Deep holes need to be professionally renovated. It cannot be guaranteed that ASC will run over them without damage. Each VNA warehouse must be considered individually. The professional consultancy program from Linde helps you to find the best solution for your application.

AISLE SAFETY ASSIST – INCREASE OPERATIONAL SAFETY

The Aisle Safety Assist (ASA) system knows about all defined limitations, restrictions, and conditions of each very narrow aisle and controls truck functions accordingly.

Similar to a operator assistance system in a car, ASA supports the operator inside the very narrow aisles, helping to avoid accidents. In doing so, ASA helps to avoid damage to the truck, the load, and the working environment. The system enables optimum and confident operator performance even under time pressure.

How ASA Works

RFID transponders or barcodes are employed to indicate the truck's exact horizontal position. The contours of the truck are calculated with the vertical position of the cabin and forks via the integrated lift height measuring system. By entering a predefined zone, it is possible to impose corresponding restrictions on truck movements, such as travel and lift speed, lift height, and fork reach, in accordance with potential dangers.

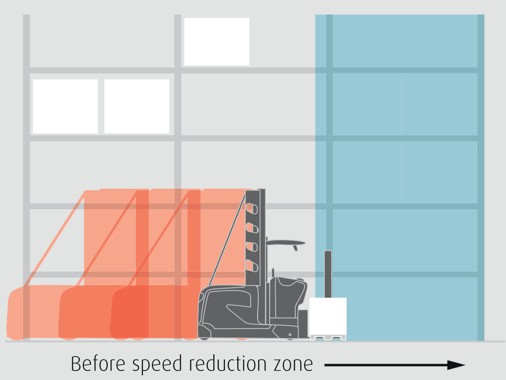
In very narrow aisles, there may be restrictions on how the truck is permitted to operate (obstacles, building or roof limits, floor quality, etc.). Height limits are common, for instance, as a result of lighting or roof beams, but only in certain areas in the aisles or only in certain aisles. ASA functions are defined exclusively by the interfering contours present in the very narrow aisles and their vertical and horizontal positions or by the start and end of a function / restriction. ASA functions are automatically calculated and triggered for each very narrow aisle defined in this way on the current truck outer contour.

Fast Commissioning of the System

All restrictions in the aisles must be defined by a service technican. To enable fast commissioning, standard functions are stored in the system and, once they have been created, they can be copied and pasted to the different aisles. This also has the great advantage that once very narrow aisles have been defined, the same functions / restrictions are considered for all trucks with ASA and can be copied to the truck control.

For the ASA definition of very narrow aisles / warehouses, Linde has specially developed warehouse configuration software that is used for project planning, commissioning, and later adaptations.

Figure 29 - Dynamic speed reduction with ASA



Defining very narrow aisles with individual characteristics for the Aisle Safety Assist has the following benefits:

- → Permanent obstacles, such as steel joists or sprinklers, will not be at risk of damage from the truck
- → Locally restricted speed reduction:
  Figure 29 shows the speed of the truck before and within a braking zone. In defined braking zones, the truck reduces its speed to a defined value. This reduces damage to goods and the truck
- → Dynamic braking at the end of the aisle:
  As seen in figure 30 ASA always brakes the truck at the optimal time in order to reach the desired speed or stop at the end of the aisle
- → Collision prevention by defining obstacles:
  By defining the obstacles' dimensions precisely – horizontally and vertically – in the ASA software, the truck can be prevented from entering this area
- → Truck behavior can be aligned with the requirements and constraints of specific aisles, ensuring safe and efficient operation at all times (see figure 31)
- → A lot of other useful additional functions and restrictions like rotation lock, side shift reductinon or steering lock outside aisle are available. A high degree of flexibility and easy adaptation to any warehouse changes are guaranteed

Figure 30 - Dynamic braking with ASA

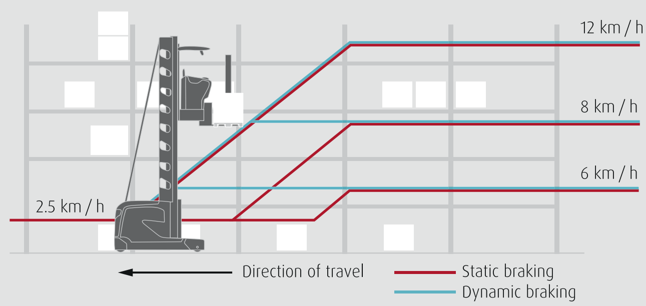
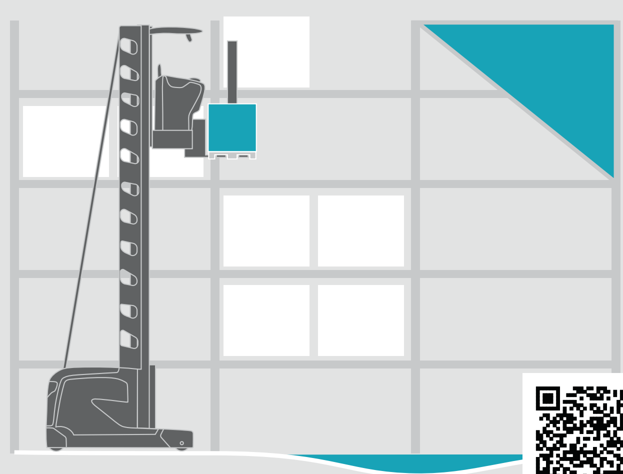


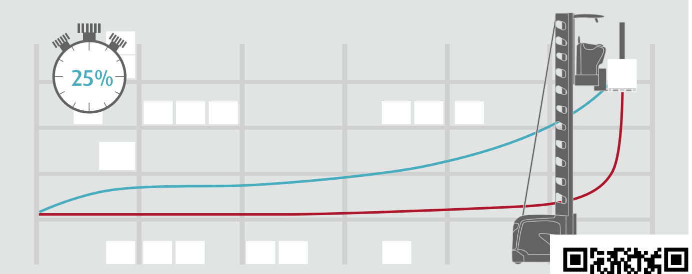
Figure 31 - Individual configuration of restrictions with ASA



LINDE VNA NAVIGATION – THE FASTEST ROUTE TO THE NEXT PALLET

Safety and speed do not need to be in conflict. The Linde Warehouse Navigation system allows increased throughput and, at the same time, safe pallet handling by preventing operator errors. The truck is notified of the next pallet put-away or retrieval location, and then moves the pallet by the fastest possible combination of lift and travel (see figure 32).

Figure 32 - Linde warehouse navigation



Assisted navigation can deliver time savings of up to 25 %. The blue line indicates the ideal line of travel, requiring the least time and energy.

You have reached your destination: Linde Navigation enables time savings of up to 25 % and shows operators the fastest possible route to their destination.

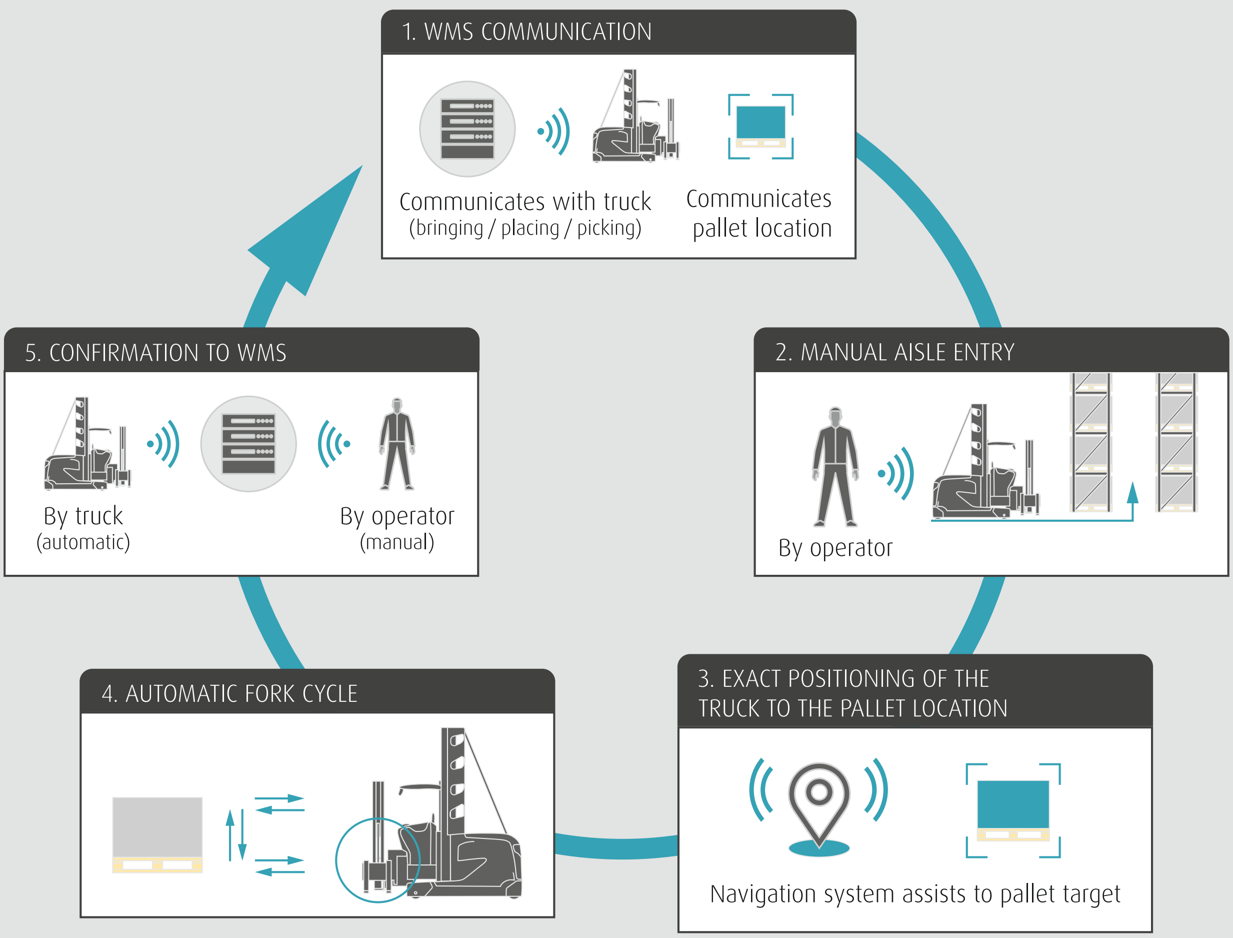
Process Optimization

The Linde Warehouse Navigation system enables the truck to receive orders directly from the warehouse management system. Like a navigation system in a car, Linde Navigation supports the operator in his daily work by leading him to the correct pallet location in the fastest way (see figure 33).

The truck display shows the operator his current position as well as the destination in the aisle. Arrows showing horizontal and vertical directions guide him to his destination. When the truck arrives at the target position, the aisle coordinates are transmitted back to the WMS by remote data transfer (usually Wi-Fi). Mistakes like wrong placement or pickings are avoided. This supported process leads to reduced strain on the operator and higher throughput irrespective of the individual operator's skills.

Figure 33 - Process of navigation

The customer's warehouse is mapped by the Linde Warehouse Navigation software, which can be easily adapted to any changes in layout.



How Linde Navigation Works

Every load handling command (storage, removal, or order picking) comes from the warehouse management system. The intelligence as well as the strategy of which jobs the truck has to do is given by the WMS.

The information for the next position is transmitted via a radio data terminal to the truck. The terminal mounted on the truck communicates via the standard RS232 interface to the truck.

As soon as the truck has received the order, the current position of the truck and the target position are displayed on the truck display. Within the aisle, in addition, the direction (horizontal and vertical) in which the target position is located is displayed.

The VNA truck is manually driven into the corresponding aisle. When the truck is tracked up in the aisle, it drives the optimal way to the next target position only by ergonomically deflecting the lever for driving the control panel. The other hand must touch the control panel for safe two-handed operation.

The truck is equipped with an encoder on the load wheel to measure the distance driven. As a check, the truck references itself against every RFID transponder or barcode it passes so that it knows which aisle it is in and exactly where it is in that aisle. The exact height of the truck is given by a measurement system.

Knowing its current position and the target position, the truck can calculate the optimum combination of traction and lift movements to get to the destination by the most efficient route.

The truck stops automatically after reaching the target position (horizontal and vertical) and emits a visual and acoustic signal. The target position is achieved with an accuracy of ± 20 mm. The operator can correct the position of the truck after reaching the target position within the target window. The target window is in the standard setting vertically limited to ± 200 mm and horizontally to ± 300 mm. Depending on requirements, the target window can be parameterized vertically in a range of ± 100 – 1000 mm and horizontally in a range of ± 100 – 1500 mm.

The optional automatic fork cycles ensure a fast and safe load change at the target position. Together with the load recognition, a high level of safety and optimal handling performance is guaranteed.

Overview of advantages

Efficiency
- Handling operations are optimized by coordinating traction and lifting together for each pallet move. This saves time, leading to higher throughput by up to 25 %
- The picking list is transmitted to the data terminal which is connected via a RS232 plug to the truck. A data communication with the WMS is given

Reliability
- By precisely identifying pallet locations, incorrect pallet selection or placement is impossible
- Full transparency of load movements. All operating paths and maneuvers in the high bay racking can be tracked in real time
- Parameter changes to cope with extensions or changes to the warehouse layout can be made quickly and easily by a service technican
- Height and load-dependent reach adjustment:
  Mast deflection at high lift heights can be compensated for by decreasing the depth of the reach movement. Load-dependent constraints can also be taken into account individually depending on the particular circumstances
- The load handling can be locked at incorrect storage locations (outside the defined target window). As a result, the highest storage quality can be guaranteed

Safety
- The truck works to ± 20 mm accuracy when stopping at a pallet position. This avoids damage to goods, trucks and racking
- Areas of different roof heights, aisles of different lengths, and different racking beam heights can be combined: The whole Warehouse Navigation system is freely programmable and based on a modular program concept
- Definition of individual lift heights and reach movement by pallet location: Depending on the individual storage location, various parameters such as decreased reach movement can be defined

Interface for Linde Warehouse Navigation
The terminal mounted on the truck receives the orders from the customer's WMS and sends it via the serial interface RS232 to the truck control. The trucks control software can only process one specific programming language in which a clearly defined syntax describes the position. Translating individual orders for the customer's warehouse management system into the correct syntax of the programming language often posed a challenge in the past.

With the Navigation Interface, Linde offers a standard software which can be used for most of the WMS systems. In addition, also order lists as excel file can be imported directly. The Navigation Interface enables the communication between the customers IT System (ERP, WMS) and the Linde Warehouse Navigation. Linde also offers a Warehouse Management System. For more information, please ask your Linde consultant.

Avoiding Accidents

SAFETY PROTECTION SYSTEMS

VNA trucks must meet basic requirements like the DIN EN ISO 3691-1 and DIN EN ISO 3691-3. These norms set standards regarding all industrial trucks. In addition further requirements like personaly safety equipement are obligatory.

The DIN EN ISO 13854 defines a minimum required side clearance of 50 cm on each side of the industrial truck. Pedestrians and trucks should never be present in the same very narrow aisle at the same time. Every possible hazardous operation and situation in a very narrow aisle should be proactively avoided.

According to DIN EN ISO 3691-3, warehouses with trucks which lift the platform higher than 3 m must be able to prove the presence of a rescue chain[27)]. All Linde trucks where a rescue chain is required are equipped with a abseiling system, which fulfills this standard.

Depending on the country, further specific norms and standards may have to be met. In Germany, for example, the Industrial Safety Regulation (BetrSichV) and, in certain circumstances, DGUV 208-030 and DGUV 68 chapter F are obligatory.

END OF THE AISLE SAFETY FEATURES – SAFETY BY LEAVING THE AISLE

End of the aisle safety features mean stopping or braking the industrial truck without input by the operating person at the end of the very narrow aisle. The standard defines a maximum speed of 2.5 km/h when a truck leaves the very narrow aisle. This measure also applies to cross aisles, except for those expressly provided as escape routes which cannot be entered from outside.

Zones and Functions

Driving speed reduction

→ From the beginning of the aisle end zone to the end of aisle The speed is reduced from Vmax to Vred = 2.5 km/h

→ When driving out of the aisle Vred = 2.5 km/h

Driving Stop

→ Temporary stop

→ At the beginning of the aisle end zone, the truck is braked to a standstill. After 2 seconds, there is a new drive release in the direction of the end of aisle with Vred = 2.5 km/h

Absolute stop

→ Braking with absolute stop is done when the end of aisle is closed

→ When braking ends, the truck is stopped. A positioning move in the direction of the end of aisle can be done using the "Q" button (acknowledgment button pressed and held) with Vred = 1 km/h

→ With the RFID technology, the absolute stop speed is configurable between 0 and 2.5 km/h

PERSONAL SAFETY EQUIPMENT

The DIN 15185-2 defines different possibilities to ensure safety in the aisle. Linde offers solutions to ensure this safety level. The warehouse operator stays responsible for operation in the VNA warehouse

→ Constructional separation of this warehouse area

→ Stationary warning system (stationary PSE)

→ Protection device on the truck

Furthermore, organizational measures should be taken to maintain high levels of safety. This can be done via operation instruction, training for personnel, written instruction to the operators, or internal traffic regulations with signs in the warehouse.

Constructional Separation of This Warehouse Area

Warehouses where only trucks are operating and no pedestrians are walking can be structurally separated with walls, fences, doors, or continuous conveyors (see figure 34). These barriers must be a minimum of 2 m high. Opening a door into the separated area must only be possible with a key, meanwhile the way out should always be freely possible.

Any hazards in areas where loads are handled to the outside of this area must be planned safely. There must not be any crush or shear hazards for pedestrians.

Stationary Warning System

Stationary protection uses a photo sensor system that is mounted on the rack and can distinguish between people and industrial trucks. Figure 36 shows, the defined height of the lasers as well as the differentiation system are shown (see figure 35).

This differentiation is not necessary when the system is designed so that only one person or truck is allowed to enter the aisle. The system triggers an alarm when two objects move in one aisle.

In a warning situation, the system must be clearly audible and visible. The visual alarm must be displayed at the entrance of each aisle and the sound has to be audible in the whole warehouse section.

Figure 34 - Constructional separation of this warehouse area

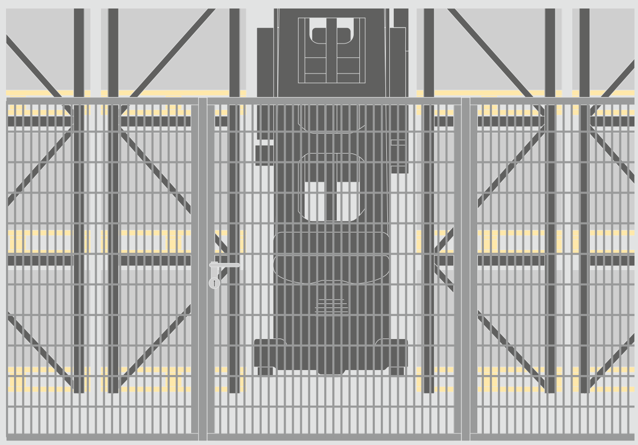
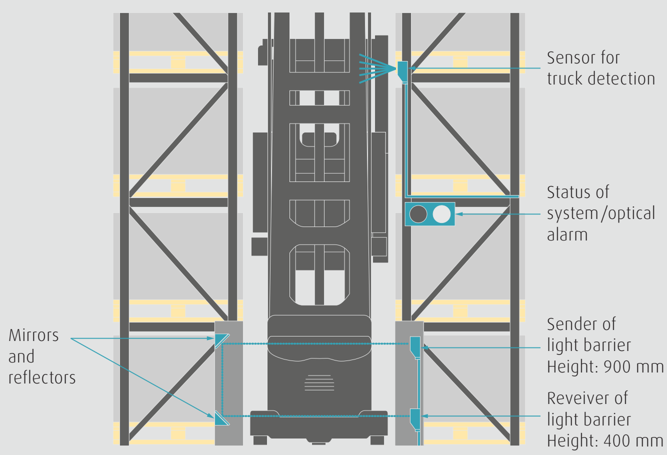


Figure 35 - Stationary warning system



27) DIN EN ISO 3691-3 Chapter 5.7.1

The warning system has to automatically check its function at least every hour. A negative test result triggers a visual and audible alarm.

Position detection can be performed using reflected light sensors with coded reflection marks on the rack or using aisle magnets with magnet operated switches. The first coding is located at the access to the very narrow aisle. When this coding is detected, the protection system is initialized, i.e., the drive direction sensor starts the distance measurement and determines the drive direction. The protective fields are activated.

Protection Device on the Truck

Today, mobile personal protection systems have often become the standard to safely operate in narrow aisles (see figure 36).

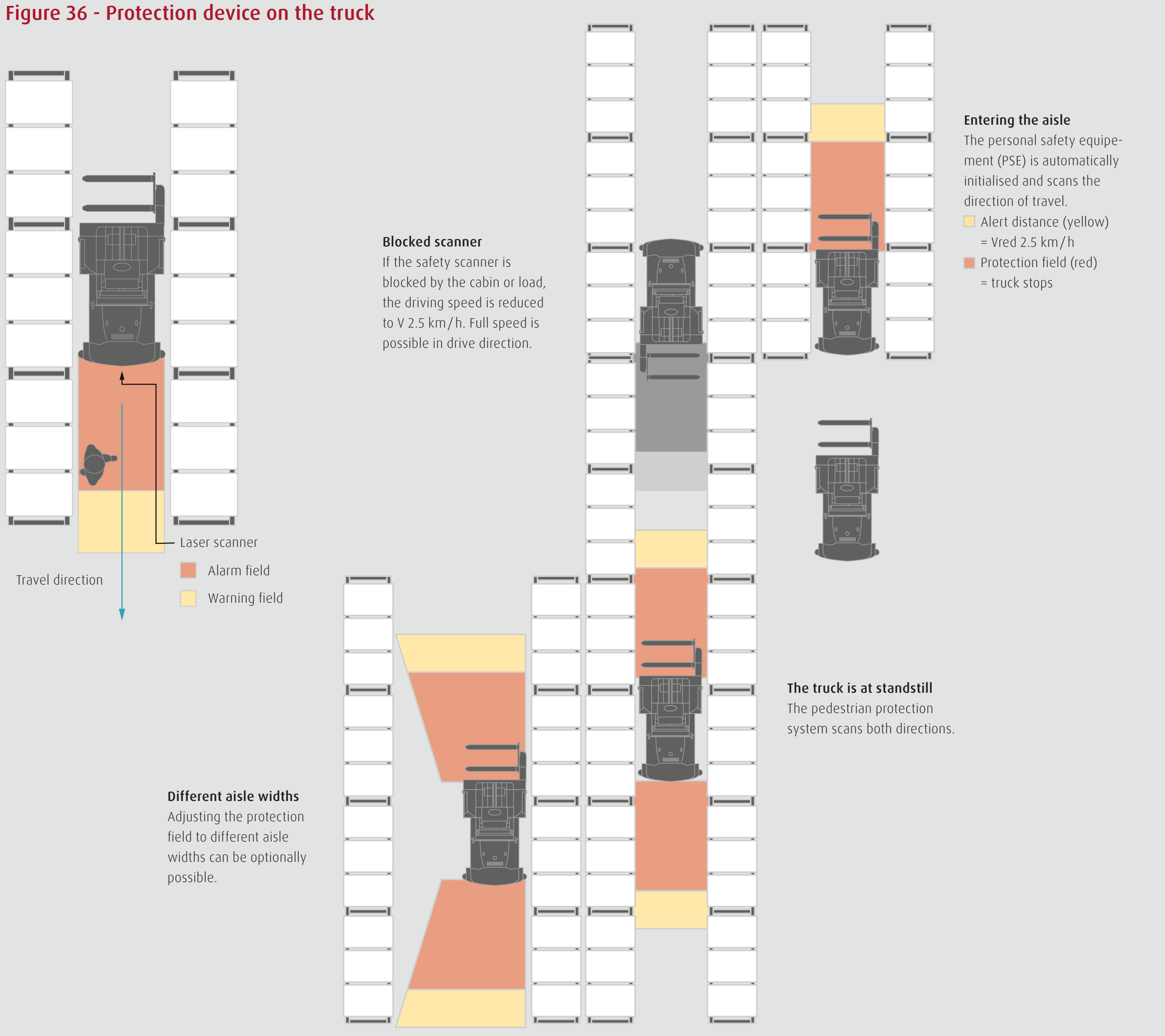
The industrial truck is equipped with laser sensors on load side and drive side. These monitor the aisle in a horizontal scan layer between 20 and 50 cm above floor. If something e.g. a person is detected in the warning field, the truck speed is automatically reduced to creep speed (maximum 2.5 km/h). If a person is detected in the alarm field, an alarm is triggered and the truck brakes automatically to a standstill. The system considers the maximum speed of the truck combined with the maximum load of the truck.

If the truck is traveling at maximum speed and is at maximum load, the truck must brake to a stop before the detected obstacle is reached. For safety reasons, the alarm can only be reset by the operator after the truck is completely at a standstill. The monitoring equipment is not active outside the very narrow aisles.

Assembly of the Scanner

Due to space constraints, the scanner can only be attached to the front side behind the fork. This means that if the fork is lowered, there is no view and no safety function. In this case, the industrial truck may only drive at creep speed (maximum 2.5 km/h). An operated switch on the mast determines if the scanner has an unencumbered view. The scanner is then activated. If there are no other speed limitations (cross aisles or the end of the very narrow aisle), the industrial truck can move at maximum allowed speed by the Personal Safety Equipment in the very narrow aisle.

Figure 36 - Protection device on the truck



Assembly of the Scanner

Position detection can be performed using reflected light sensors with coded reflection marks on the rack. The first coding is located at the access to the very narrow aisle. When this coding is detected, the protection system is initialized, i.e., the drive direction sensor starts the distance measurement and determines the drive direction. The protective fields are activated.

Commissioning

To increase safety, additional functions are implemented using the drive direction sensor. At commissioning, the braking distance of the industrial truck is measured from full speed to standstill. Braking distance and delay are then saved in the controller. During each braking process, the actual braking distance is measured and compared with the stored braking distance. The operator is notified of diminishing braking efficiency via the terminal. Afterwards, the truck can only be operated at creep speed for safety reasons.

LINDE BLUESPOT™ – THE SILENT SAFETY SIGNAL

Whether employees are driving a truck or walking, they quickly lose sight of potential risks when working. They may either be inattentive or absorbed in their work. Loud noises are distracting and can drown out important warning signals. This can all cause dangerous accidents on business premises. The innovative Linde BlueSpot™ driving path warning system minimizes risk without making a sound.

The electrical components in the driving path warning system have been certified as IP 67. An easy way to increase safety outside the aisle.

Truck Localization

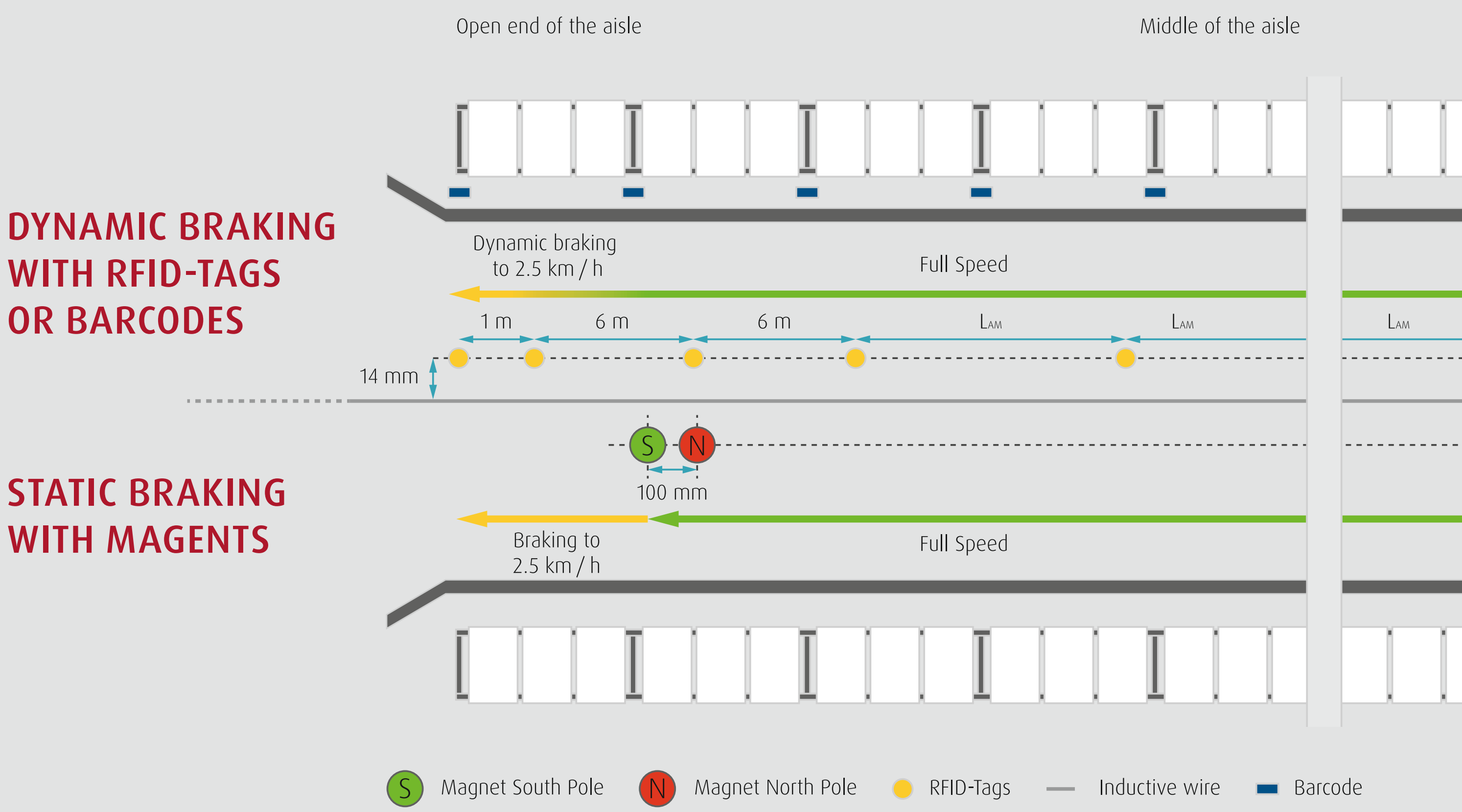
TECHNOLOGIES FOR DETERMINING POSITION

Assistance systems in very narrow aisles need orientation. The different systems need different accuracies. Orientation aids in combination with measuring roller sensors provide a horizontal orientation of up to 5 mm.

MAGNETS

Linde magnets are very small and therefore simple and cost-effective to install. Two magnet pairs are installed in the floor one behind the other. Depending on if the south pole or the north pole magnet is driven over first, the truck detects the direction in which the truck is moving and if and how the truck must brake. Magnets are ideal in storage areas where simple traction and lift reductions are necessary.

Figure 37 - Plan for end of aisle braking



In the following, we would like to provide a brief overview of the various systems. Each of these systems has advantages and disadvantages, so no general recommendation for every warehouse can be given.

Table 9 - Systems for determining position

	End of the aisle safety features	Lift and traction cut-outs	Aisle Safety Assistant	Linde Navigation
Magnets	x	x		
Bar codes	x	x	x	x
RFID	x	x	x	x

RFID

Linde RFID tags are especially small and can be installed very quickly and easily in the floor with a standard drilling machine. They work at a frequency that enables fast reading and writing on the tags. Even if the tags get wet, they are protected and retain their function. Together with the distance sensor located on the load wheel, the truck knows its exact horizontal position. By driving over a RFID tag, the truck sets its new position.

BARCODE

Compared to a RFID tag with barcode technology, no drilling of the floor is necessary. Linde barcodes are attached approximately 50 cm above the floor on all rails. The truck scans the barcode and determines its position in the storage area. The truck also has the same distance sensor as an RFID-equipped truck with the redundant measurement system. With every barcode, the truck's new position is set.

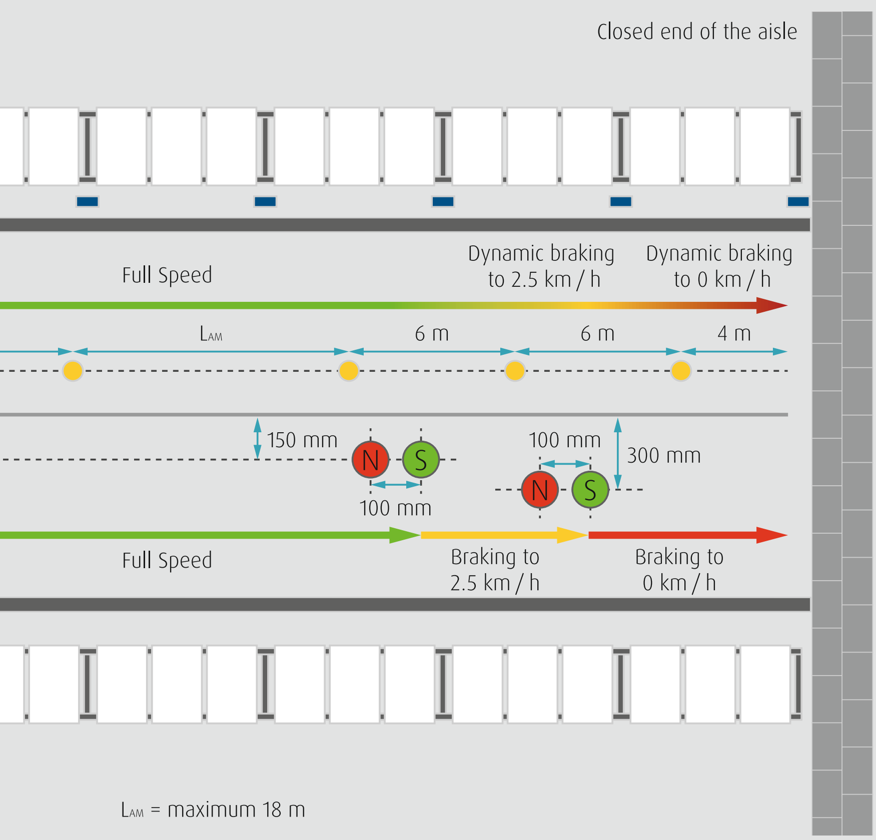


Figure 38 - Installation depth of RFID Tags

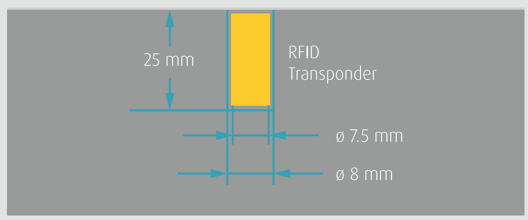
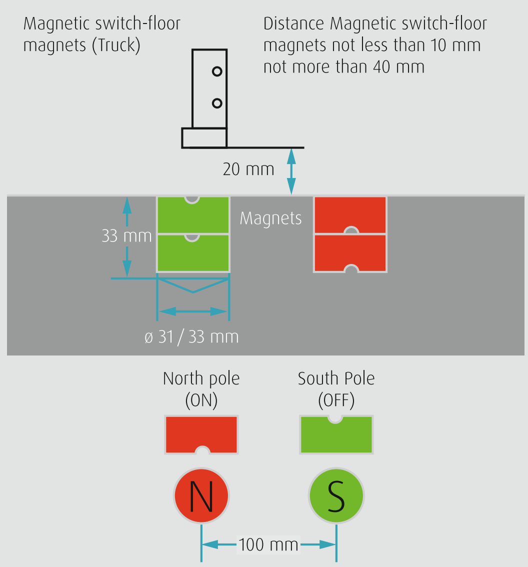


Figure 39 - Installation depth of Magnets



Intelligent Power Solutions

ENERGY

VNA trucks must overcome a variety of challenges, including the need for high availability and cost-effectiveness. All VNA trucks in the warehouse are electrically driven. The energy technology should also be considered, because this has great influence on the investment and operating costs.

ENERGY CONSUMPTION OF THE TRUCKS

Energy savings are of great importance when it comes to cost development. Also the CO_2 footprint is becoming more relevant.

Due to unpredictable energy costs and new legal requirements, warehouse operators will also have to pay more attention to energy efficiency in warehouse planning and management in the future to comply with the new energy saving regulations and remain competitive.

Thanks to Linde's modular construction system with a variety of millions of possibilities, every truck is optimized individually, also with respect to energy consumption. Linde's consulting software uses defined cycles (VDI 3561) to calculate individual energy consumption for each truck and pallet throughput depending on parameters such as shift times, proportion of single or double play, dimensions of the load or shelves.

In order to permanently reduce the energy consumption to the known low level, the Linde VNA trucks have

→ Regenerative braking and regenerative lowering leads to effective energy recovery
→ Active energy management for low current flow
→ Active battery management for low current peaks
→ High-efficiency hydraulic systems

AVAILABLE BATTERY TYPES FOR VNA

VNA trucks can be equipped with lead-acid as well as Li-ION batteries. Depending on the application Linde has the right energy for your specific need.

Lead-acid batteries are well known since decades in the market and have low investment costs. With the existing infrastructure, it can make sense to continue with lead acid. It can be said that if a customer drives a single shift and manages the day with one battery charge, lead acid should be the preferred option. If he has to change it, Lithium-ion batteries makes sence.

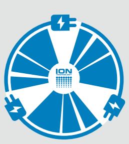
Li-ION technology is the state of the art, because of many reasons which should be considered: Linde Li-ION batteries offer fast charging, high energy efficiency, and a very long product service life, as well as zero maintenance and emissions (see figure 40).
Experts expect that in near future Lithium technology will be the standard in the market.

The Linde Li-ION technology was developed in close collaboration with battery manufacturers to achieve highest performance and safety. One key highlight regarding lifetime are minimum 2500 full charging cycles with at least 80 % residual capacity. In combination with higher battery efficiency, this guarantees altogether more usable capacity for the customer and his application. The system as a whole, consisting of truck, battery, and charger, is system harmonized.

To identify the best solution for each customer, Linde has developed a calculator. This cosultancy tool, simulates the application of the customer in detail and provides the perfect combination of battery and charger for the application.

A rough overview of the benefits of Li-ION technology
Linde provides an energy consultancy tool which helps you to find the right battery and capacity for your application. Please ask your Linde sales person.

Figure 40 - The key benefits of Li-ION technology



Short, fast top-up charging
Battery can be charged during short breaks, resulting in higher truck availability.

Reduced emissions
No leaking of hazardous battery gases and acids.

No more battery replacement
Save time and costs as spare batteries and battery changing areas are no longer necessary.

Maintenance-free operation
No need to clean or fill with water.

BATTERY CHARGING AND CONDITIONS OF CHARGING ROOMS

Charging the Battery

In addition to parking the truck and charging a lead-acid battery for a longer period of time, it is possible to change the battery. In this case, the discharged battery is replaced with a fully charged lead-acid battery. After a couple of minutes, the truck is ready for further use. Linde offers battery replacement equipment for this purpose. The discharged battery can be charged in a separate space containing a Linde charging system fitting individual energy supply needs. This additional space needed in the form of a separate room needs to be considered in planning.

One benefit of the Li-ION batteries is the intermediate charging. A second plug at the truck offers fast charging possibilities. As a rule of thumb it can be said that 10 minutes charging time result in 60 minutes driving. Plugged in at the charger, the truck as well as the terminal and printers remain switched on. The Linde Li-ION charger communicates with the battery and prevents the truck from being moved during charging.

Charging Room Requirements

For the organization of charging stations and rooms, special safety requirements need to be considered. Depending on the technology and country different standards must be fulfilled.

THE VDMA provides a document on the homepage for dealing with Li-ION batteries. All other standards are defined in DIN EN 62483-3.

BUSBAR FOR ONBOARD CHARGING

Busbar systems are suitable for multi-shift operation or automated trucks with lead acid batteries. By charging during operation, any impairment to service life can be reduced to a minimum. In addition to the time saved, it is also possible to dispense with the charging space provided for lead-acid batteries. Due to the high level of investment required, busbar systems are less commonly used.

Functionality

During the guided operation, a current collector / arm automatically inserts into the conductor rail, which is attached to the racking shelf. This is usually mounted in the aisle on storage racks at a height of approximately 2 – 3 meters. The mobile battery charger attached to the truck now charges the battery while driving. Chargers are available in 48 V and 80 V versions.

Two systems, the "closed and open busbars", have proven themselves on the market, and are mainly offered by Wampfler and Vahle (see table 10).

Table 10 - Comparison between closed and open busbar

	Closed busbar	Open busbar
Functionality	With the closed busbar, the current collector is guided through an entry funnel into the closed U-profile of the rail.	With the open system, contact by the collectors is on the front side of the busbar.
Characteristics	Low contamination of the busbars No loss of space within the aisle due to entry funnel Optimum control of power collector at truck.	Low construction on the rack into the aisle. Better access for visual maintenance and repair.
Investment	Tends to be cheaper	Tends to be more expensive

Prerequisites for the Busbar

The quality of the floor must comply with the FEM standard described in the chapter "The Floor". The deviating tolerances between busbar and busbar guidance and guidewire must be ± 5 mm. For the beams, a maximum deflection of 9 mm is allowed. A distribution box must be installed on the shelf between the customer's power supply and the power supply of the busbar by means of cables and wires. For safety reasons, a residual current circuit breaker (RCCB) must be installed. An RCCB is electrical wiring that interrupts the circuit when the current is not balanced.

Individual Truck Design for your Application

SPECIAL VNA SOLUTIONS

Hardly any narrow aisle warehouses are the same. Thanks to the modular design of the Linde VNA trucks, Linde offers the widest range of VNA trucks in the market. Over million K trucks can be ordered through the standard process.

COLD STORE APPLICATION

Trucks in cold store applications are subject to one of the toughest requirements. It is a great opportunity to show the strength of Linde VNA trucks. The Linde trucks can be operated in a continuous minus temperature range of down to -30 °C. In addition to special oils and greases, other components make the truck suitable for refrigerated warehouses.

The Linde cold store cabin guarantees a pleasant temperature in the workplace at outside temperatures of down to -30 °C. The cabin will be individually equipped for you with thermostatic heating, radio technology, emergency exit, and ventilation system.

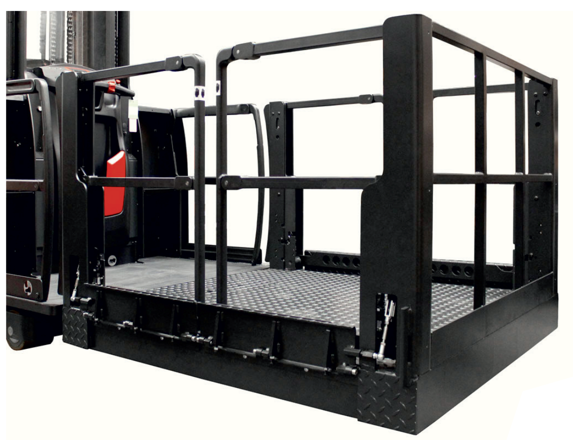
Considerations for cold store application

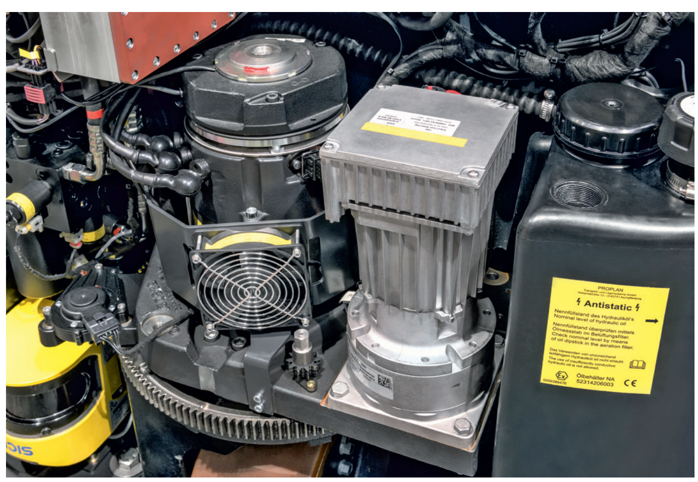
- → The truck must be dry before entering the cold store
- → Alternate operation (warm / cold / warm / cold) is not permitted
- → Batteries can be changed in the cold store
- → Li-ION technology is possible ex works when it is given, that the truck is charged in warmer areas (-20 °C – 0 °C)
- → Cold storage trucks can only be used to a limited extent in the "normal" area
- → Maintenance intervals approximately every 500 operating hours
- → Reduced battery life (additional fan heaters, seat heaters, etc.)
- → Partially prolonged repair times due to the conditions of use must be considered

CUSTOMIZED OPTIONS

Of course, we deliver every truck in every color. But also, constructional changes or concept changes are possible. It is one of the strengths of Linde Material Handling to find the perfect solution for your application. Many special solutions for VNA trucks have been delivered to our customers. A brief overview:

- → Different attachments, for example: clamps for goods traded as "white goods" or forks for double deep stacking
- → Trucks for EX protection zone 2
- → Guidance for different rackings, e.g.: mobile racking systems
- → Order Picker with more than 17 m picking height
- → Individual platforms and trolleys





STANDARDS

FLOOR

DIN EN 1045 Part 2
Concrete, reinforced and prestressed concrete structures - Part 2: Concrete - Specification, properties, production and conformity

DIN EN 1081
Resilient floor coverings - Determination of the electrical resistance

DIN EN 1045 Part 3
Concrete, reinforced and prestressed concrete structures - Part 3: Execution of structures

DIN EN 18560 Part 7
Floor screeds - Part 7: Heavy-duty screeds (industrial screeds)

DIN 18202
Tolerances in building construction - Buildings

FEM 4.103 - 1 and 10.2.14 - 1
Warehouse floors – Storage system areas operated by Industrial Trucks –Tolerances, deformations, methods of measurement and additional requirements for VNA truck operation (once DIN 15185-1 and VDMA directive)

RACKING

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

DIN EN 15620
Steel static storage systems - Adjustable pallet racking - Tolerances, deformations and clearances

DIN EN 15635
Steel static storage systems - Application and maintenance of storage equipment

DIN EN 15629
Steel static storage systems - Specification of storage equipment

ISO 6292
Powered industrial trucks and tractors — Brake performance and component strength

VdS CEA 4001
Guidelines for sprinkler systems - Planning and installation

SAFETY

DIN 4102 Part 1–5
Fire behavior of building materials and components

DIN ISO 6292
Powered industrial trucks and tractors – Braking performance and component strength

DIN EN ISO 13849 Part 1
Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design

DIN EN ISO 1385
Safety of machinery – Minimum gaps to avoid crushing of parts of the human body

DIN EN ISO 3691 Part 1
Industrial trucks – Safety requirements and verification – Self-propelled industrial trucks, other than operatorless trucks, variable reach trucks and burden carrier trucks (ISO 36911: 2011, including Cor 1:2013)

DIN EN ISO 3691 Part 3
Industrial trucks – Safety requirements and verification - Additional requirements for trucks with elevating operator position and trucks specifically designed to travel with elevated loads

DIN EN ISO 3691 Part 6
Industrial trucks – Safety requirements and verification – Burden and personnel carriers (ISO 36916: 2013

DIN 15185 Part 2
Industrial trucks – safety requirement – Part 2: Use in narrow aisles

ENERGY

DIN EN ISO 50001
Energy management systems - Requirements with instructions for use

VdS 2259
Guidelines for damage prevention - Battery charging systems for electric trucks

EN 16247
Energy audits – General, buildings, processes, transport

DIN EN 62483 Part 3
Intelligent transport systems - DATEX II data exchange specifications for traffic management and information

VDMA Directive
Lithium-ion battery systems in industrial trucks

VDI 3561 Cycle times
Cycles for performance comparison and acceptance of industrial trucks

ASR A1.8
Technical rules for workplaces - Traffic routes

ASR A2.3
Technical rules for workplaces - Escape routes and emergency exits, escape and rescue plan

DGUV Regulation 68
Industrial trucks (formerly BGV D27)

DGUV Regulation 108-007
Storage facilities and equipment (formerly BGR 234)

DGUV Regulation 208-030
Use of industrial trucks in narrow aisles

Industrial Safety Regulation (BetrSichV)
Is the German implementation of the Work Equipment Usage Directive 2009/104/EC and regulates the provision of work equipment by the employer, the use of work equipment by employees at work and the operation of systems requiring monitoring in the context of occupational health and safety.

For Germany
Arbeitstättenverordnung (ArbStättV) Technische Regel für Arbeitsstätten (ASR A1.8 – Verkehrswege)

Linde Material Handling GmbH, a KION Group company, is a globally operating manufacturer of forklift trucks and warehouse trucks, and a solutions and service provider for intralogistics. With a sales and service network that spans more than 100 countries, the company is represented in all major regions around the world. In the 2019 financial year, the Linde MH EMEA Operating Unit (Europe, Middle East, Africa) recorded a total revenue of roughly EUR 3.5 billion, with approximately 12,000 employees. Global sales of Linde trucks amounted to approximately 135,000 in 2019.

LINDE - FOR YOUR PERFORMANCE

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Linde Material Handling

Linde

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