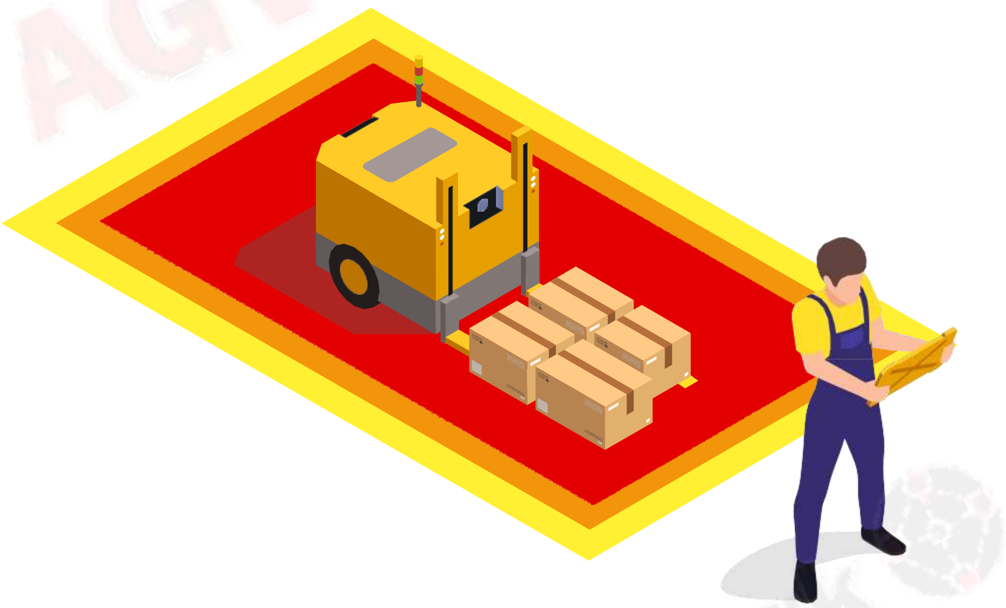
How does an AGV Safety System Work?

One of the main advantages of AGVs is that they are **safer** than manual transportation of material, such as manned forklifts. **AGVs don't harm people** or damage infrastructure, because they are provided with safety sensors that prevent them from running into people or things.



How does an automated guided vehicle increase safety?

With the aim to make AGVs safer for wide industrial and commercial use, there are **certain safety rules and AGV safety standards** that all AGVs must comply with.

In order to comply with these AGV safety rules, AGVs must include some **safety sensors and devices** to avoid and proactively prevent risks.

AGVs generally run smoothly and predictable, however on the rare occasion something doesn’t work properly, the safety system will halt the vehicle.

This whitepaper will provide you with some key concepts to help you understand what is behind an AGV safety system and how this safety system interacts with the rest of the working environment.

An AGV safety system is an important and complex matter that needs in-depth analysis from qualified suppliers, in fact, this white-paper has been developed in collaboration with SICK, Inc. a leading manufacturer of factory, logistics and process automation technology worldwide.

SICK
Sensor Intelligence.

Click here
to visit SICK Inc
webpage

SICK offers intelligent sensor solutions for smart material transport in production and logistics including Automatic Guided Vehicles (AGVs) and Autonomous Mobile Robots (AMRs).

Mobile material transport systems are used in nearly every single area of the production industry. No matter whether you use automatic guided vehicle systems, semi-automatic guided vehicle systems, transfer cars, manned forklift trucks, or narrow aisle trucks, a host of sensors are used in contour or reflector-based navigation, rough and fine positioning, measurement and identification, and optical data transmission.

Personnel safety is of course a priority; however, goods also need to be protected against collisions with these automatic vehicles, which are often traveling at speed and with heavy loads.

SICK safety products and systems protect people and prevent collisions with other vehicles and obstacles – with great flexibility, and according to the driving situation. Furthermore, they help reduce operational downtime, and therefore operating costs as well.

This document provides general information about AGV safety systems, answering questions such as: What are the AGV safety standards? What are the main types of safety sensors? How do AGV safety systems work?

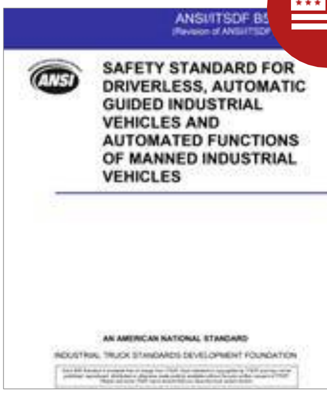
Table of Contents

1.What are the AGV safety standards?

The AGV Safety Standard in the US is ANSI/ITSDF B56.5-2019 and in EU EN ISO3691-4:2020.

AGV safety standard in the USA

The latest industry consensus standard for Safety Standard for Driverless, Automatic Guided Industrial Vehicles and Automated Functions of Manned Industrial Vehicles is ANSI/ITSDF B56.5-2019.



The American National Standards Institute (ANSI) is the governing body for the development of safety standards in the United States. The of ANSI-Accredited Standards Developer for safety standards related to industrial trucks is the Industrial Truck Standards Development Foundation (ITSDF).

AGV safety standard in the EU

AGV safety standards in Europe are found in EN ISO 3691-4:2020 “Industrial trucks — Safety requirements and verification — Part 4: Driverless industrial trucks and their systems”.

This document is applicable for mobile platforms including: AGV, tunnel tugger, under cart, etc.

This document supersedes EN 1525:1997.

Both documents are not an obligation. They basically provide the guidelines and standards for not only how to achieve acceptable residual risk on an automatic guided vehicle , but how to implement an overall safety system including elements of design, operation, and maintenance of mobile platforms.

Reputable manufacturers of mobile platforms choose to adhere to one or both of these documents.

2. Risk Assessment and Performance Level applied to mobile platforms

SEVERITY	EXPOSURE	AVOIDANCE	OCCURENCE			
			O1 - O3	O1	O2	O3
S1	+	+		0	0	0
S2	F0	+	0 1			
	F1/F2	A1		0	0	1
		A2		0	1	2
S3	F0	+	1			
	F1	A1		1	2	3
		A2		2	3	4
	F2	A1		3	4	5
		A2		4	5	6
S4	F0	+	1			
	F1	A1		5	6	7
		A2		6	7	8
	F2	A1		7	8	9
		A2		8	9	10
			RISK INDEX			

Picture courtesy of SICK, Inc.

S SEVERITY OF HARM — negligible (1), slight (2), serious (3), severe (4)
F EXPOSURE TO HAZARD — prevented (0), low (1), high (2)
A POSSIBILITY OF AVOIDANCE — avoidable (0), not avoidable (2),
O PROBABILITY OF OCCURRENCE — low (1), medium (2), high (3)

Before getting into detail about mobile platform safety systems, it is important to understand some key concepts such as risk evaluation and performance levels.

Risk is defined as “the combination of the probability of occurrence of harm and the severity of that harm”.

Risk = severity of injury & probability of occurrence

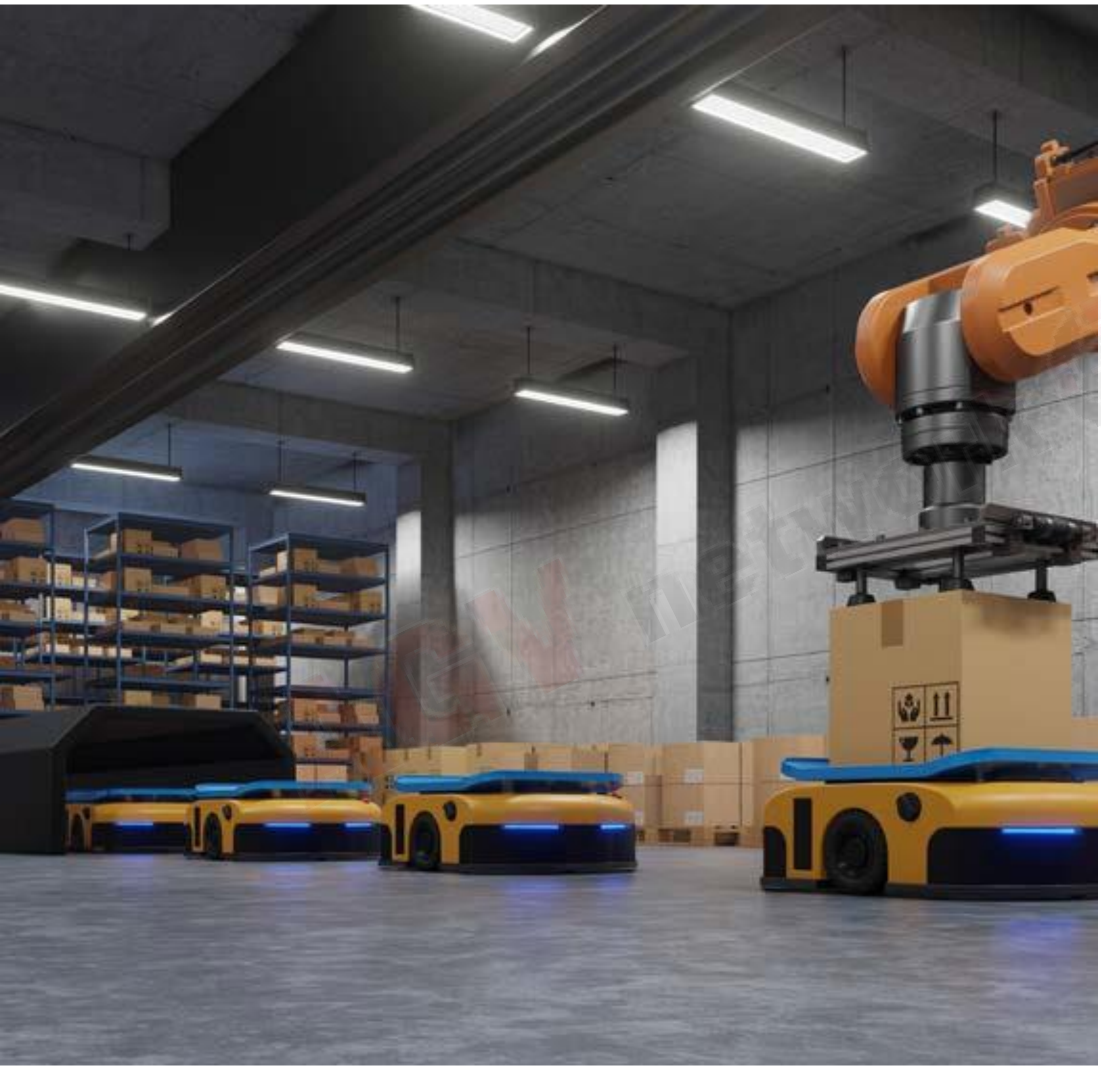
If we think about AGVs, we could have both, high risk and low risk situations in the same application.

As you can understand, an automatic forklift travelling at high speed with 1ton (2,200 lbs) has “potentially” higher risk than a small automatic guided cart at low speed carrying 100 kg (230 lbs).

Let’s say, for example:

- Forklift, high speed, heavy load à Severity Level 4
- Undercart, low speed, light load à Severity Level

If you see the risk matrix, we still must consider the Probability of Occurrence



2.1 What is the Performance Level (PL) of a device?

Safety-related components can be classified with a “Performance Level or PL”. The PL defines the ability of safety-related parts of control systems to perform a safety function under foreseeable conditions.

PL is defined by the **ISO 13849-1:2015** standard.

PERFORMACE LEVEL (PL)	PROBABILITY OF DANGEROUS FAILURE PER HOUR (PFHd) 1/h
a	$\geq 10^{-5}$ and $<10^{-4}$ (0.001% to 0.01%)
b	$\geq 3 \times 10^{-5}$ and $<10^{-5}$ (0.0003% to 0.001%)
c	$\geq 10^{-6}$ and $<3 \times 10^{-5}$ (0.0001% to 0.0003%)
d	$\geq 10^{-7}$ and $<10^{-6}$ (0.00001% to 0.0001%)
e	$\geq 10^{-8}$ and $<10^{-7}$ (0.000001% to 0.00001%)

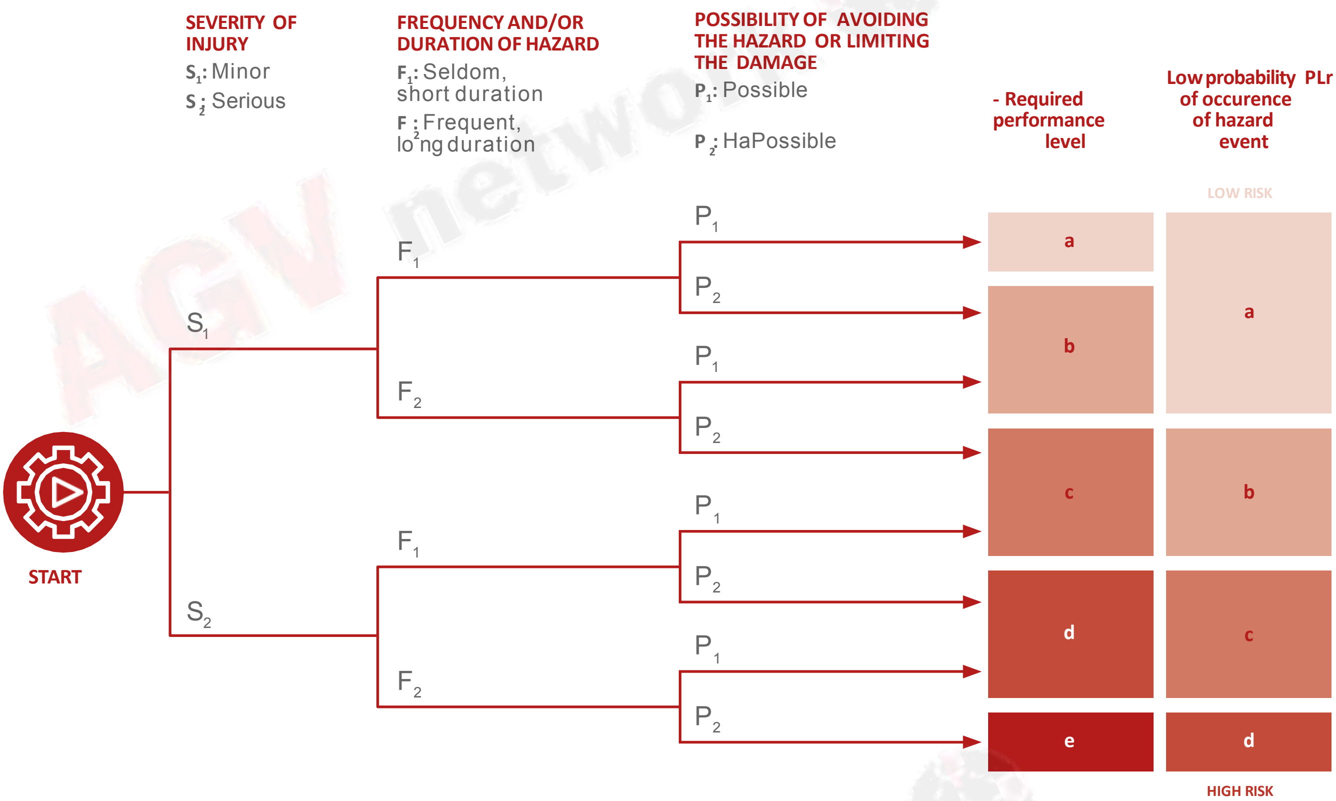
A device rated to PL e is more applicable to high risk applications than a device rated to PL a, because a device capable of achieving PL e is less likely to fail to a dangerous condition.

We could, for example, have a safety laser scanner rated PL b or PL d depending on the structure of its control system, the reliability of the components used, the ability to detect faults as well as the resistance to multiple common faults in multiple channel control systems.

Check the diagram below for a better understanding for determining the required PL of each safety function.

Required performance level (PLr) according to ISO 13849-1

This standard also uses a risk graph to determine the required safety level. The parameters S, F and P are used to determine the magnitude of the risk. The result of the procedure is a “required performance level” (PLr).



Picture courtesy of SICK, Inc.

Now, let’s talk about another concept: Performance Level Requirement (PLr).

2.2 What is the Required Performance Level (PLr)?

When you design a machine or device, you should perform a **Risk Assessment** which gives a comprehensive overview of what risks should be addressed and possible solutions.

One of the results of the Risk Assessment is the Required Performance Level (PLr) for each safety function identified. The required performance level (PLr) is the minimum performance level for each safety function of a machine to reduce risk to an acceptable level.

The PL achieved must be greater than or equal to the PL required **(PL ≥ PLr).**

Our Undercart AGV could have a PLr b, because it could be considered as a low-risk machine while our forklift could be PLr d. In this case, we could not have a forklift with a safety laser scanner rated lower than PL d.

2.3 Why is Performance Level important for mobile platforms?

As we have seen, depending on the mobile platform type and application we could have a different PLr value for safety functions on each vehicle.

If we define that a safety function for an AGV is requires a minimum PLr d (for example), all the safety-related parts of the control system (safety laser scanners, safety PLC, encoders, bumpers, etc.) must be capable of achieving (or exceeding) PL d.

The safety performance level must be understood a “safety chain”, its strength is equal to its weakest link.

All the concepts indicated above are analyzed into detail in Sick’s Risk Assessment and Risk Reduction whitepaper.... do not miss it!

3. What are the main risk reduction measures in a mobile platform system?

Now that we have understood how to measure risk and the performance level of a mobile platform, let's see what the key risk reduction measures are for a mobile platform.

The risk reduction measures in an automatic guided vehicle can be divided in two main categories:

- **Active risk reduction measures Passive**
- **risk reduction measures**

The main AGV **active** risk reduction measures or safety sensors are:

- Safety Laser scanner and/or collision avoidance system
- Pressure-sensitive bumpers
- Safety PLC

While the most important **passive** risk reduction measures are:

- Emergency stop devices
- Warning lights
- Audible warning/alarm signals
- Awareness signs on AGV Vehicle

Click here to download "Safe AGV Easy" brochure

3.1.Active AGV Safety Systems

Mobile platforms should count on personnel detection means (e.g., laser scanners or pressure-sensitive bumpers) that must at least operate over the observable area of the maximum width of the vehicle and its load.

Personnel detection means must be designed to stop the vehicle before colliding with a person.

If the conditions above cannot be guaranteed (such as with a bumper device), the speed in the movement direction must not exceed 0.3 m/s, and an additional emergency stop devices must be reachable within 600 mm from the hazardous point.

3.1.1 AGV Safety Laser Scanner or AGV Collision Avoidance System

SICK Safety Laser Scanner Range.
Picture courtesy of SICK, Inc.

Safety Laser scanners are also known as electro-sensitive protective devices (ESPEs) or active opto-electronic protective devices responsive to diffuse reflection (AOPDDRs).

If this type of safety system is used as the primary sensing device, such noncontact sensing device(s) must be fail-to-safe, including their operation and mounting.

When **sensing people** or an object in the path of the vehicle at a distance no less than the leading edge of the sensing field in the main direction of travel, these systems **must safely initiate a stop** command to the vehicle prior to contact between the vehicle structure and the people or objects.

Nowadays the "Safety Laser" is the BIG BOSS of the AGV safety system.

Safety laser scanners used in the AGV industry typically have at least two or three safety fields.

The first one is the "**warning field**", in case an obstacle is detected by the laser in this field, the AGV decelerates (the yellow area in the picture below).

AGV detecting an operator in the warning field (yellow).

Picture courtesy of SICK, Inc.

The second one, and most important, is the **"safety field" or "protective field"**, in case an obstacle is detected by the laser in this field, the AGV must achieve a complete stop (the red area in the picture above). This is the only field that contributes to AGV safety certification.

Some laser scanners could have more fields (see the orange one) that can be used as an additional warning field, for example, to have an intermediate speed reduction before stopping the vehicle.

These fields, warning field and safety field define the **"monitored area".**

The design of the safety field depends on many factors, such as surrounding area and stopping capability (e.g., vehicle speed, payload, and floor conditions).

Every point of the AGV path must have a specific protective field to ensure that time and distance to vehicle stoppage will avoid any contact with obstacles.

Time (and distance) needed to stop an AGV travelling at 2 meters/second with 1000 kg payload is completely different than the time needed to stop an AGV travelling at 1 meter/second with 200 kg payload. The inertia involved is completely different in both cases. Think back to your physics classes on momentum, velocity, acceleration, mass, and friction.

Of course, in the first case you will need a longer protective field in order to allow the AGV to stop in time before contacting the obstacle.

The mobile platform will continue with its automatic operation approximately three seconds after the obstacle is removed from the protective field.

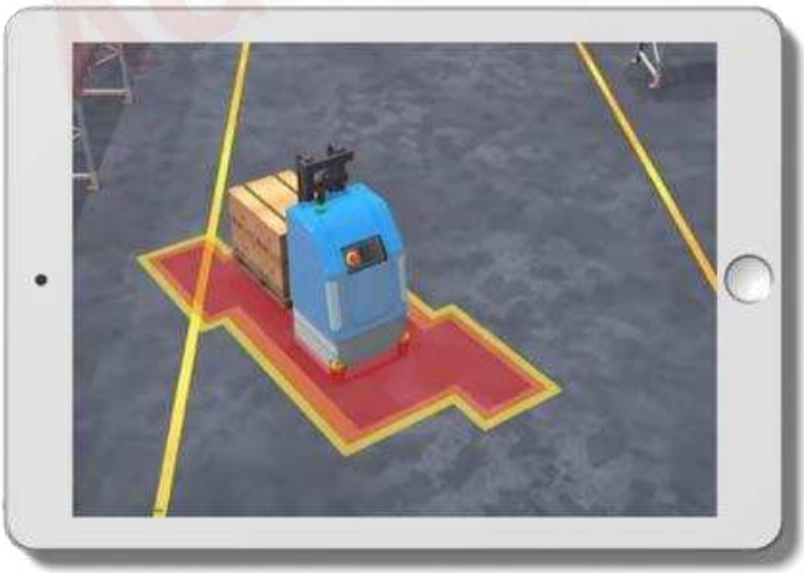
Video:
[Monitoring automatic guided vehicles (AGV) - with Safe Motion Control from SICK]

There are other factors to be taken into consideration regarding stopping distance such as braking torque, wheel material, coefficient of friction with the floor, slope, etc.

An AGV should continuously change its protective field while traveling depending on these factors.

The arrangement of protective fields must be done at the end of the installation phase by a skilled and experienced technician.

The protective fields must also be adapted to the surrounding environment. In some cases, protective fields must be shaped in non-symmetrical patterns because there is some element in the path that cannot be removed and should not prevent the AGV from continuing on travelling.



AGV with "variable" protective field shape. Picture courtesy of SICK, Inc.

Of course, in this case, AGV speed and manoeuvrability must be programmed according to all current industry safety standards.

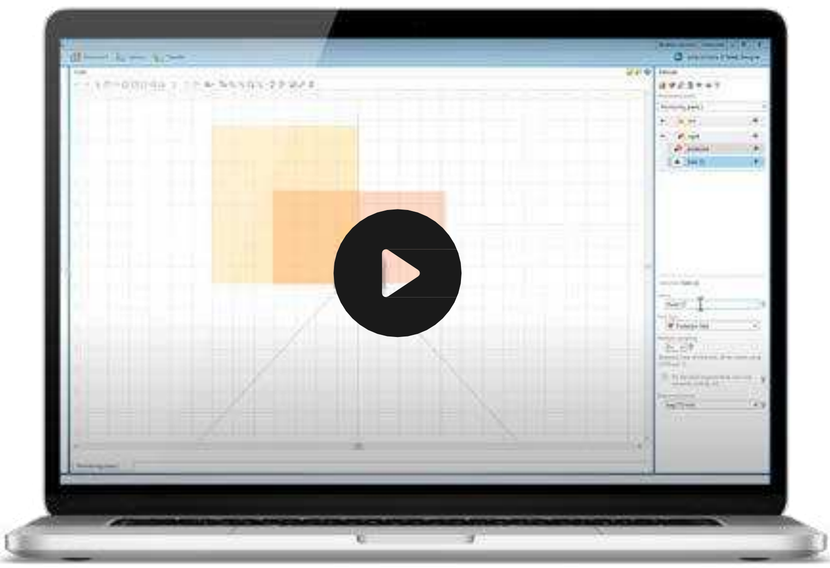
Imagine that you have an AGC, an automatic guided cart, that has to pass below a static rack to engage it with a pin hook.

In this case, the AGC going below the rack must adapt the protective field to a very narrow field of view, otherwise the protective field would "see" the cartwheels and will identify them as an obstacle stopping the AGC.

While the protective field is narrow, the AGC's speed must also be low. Once the AGC has engaged the cart and the protective field is outside of the rack profile (so it does not "see" the wheels), the AGC can speed up, and the protective field must be enlarged.

EN ISO 3691-4 indicates that changing the protective field size must be performed with a safety function achieving PL d to assure that the personnel detection is consistent with actual mobile platform speed. In case PL d cannot be achieved it is required to limit speed of the mobile platform to a maximum of 0.3 m/s.

The protective fields are directly programmed in to by the safety laser scanner with a software/tool provided by the device manufacturer.



Click the picture to watch the video:
SICK microScan3. Safety Designer and configuration

How does a mobile platform adapt a protective field along each point of the path?

Safety laser scanners can store a defined number of field sets. There are some safety laser scanners that allow it to have 4 field sets, while other safety laser scanners with 32 field sets or more.

A navigation system is able to indicate to the mobile platform **which field set it must use.** This info can be provided by predetermined coordinates, mainly in the mobile platform guided byfree navigation (slam or lidar, ecc). So, for example, in coordinate X=5/Y=23 it should use field set number 2.

Magnetic, wire and optic guided AGVs use tags or transponders situated on the floor or in the environment to indicate to the AGV which field set to use. For example, at transponder 5634, use field set number 4.

There are other more sophisticated methods able to **dynamically adapt the protective field** depending on how fast the AGV is moving. In this case, we need a **system (encoders, etc.)** that reliably indicates the actual speed of the mobile platform for use in a safety function with a defined **Performance Level** to be sure that the current speed matches the appropriate field set.

Click here to download SICK's catalogue of opto-electronic protective devices. Safety laser scanner selection will depend on your mobile platform needs and requirements.

There are several types of safety laser scannerss with different characteristics such as:

- Scanning range of the protective field
- Scanning angle
- Number of fields
- Number of monitoring cases
- Response time
- Performance Level (PL)
- Overall dimensions (safety laser scanner must be compatible with your mobile platform chassis)
- Possibility to be used as a navigation device in case you wish to have a contour-based navigation platform .

The selection of the right safety laser scanner is not easy.
We advise contacting SICK, Inc. for further support.

3.1.2 Pressure-sensitive bumpers for stopping an AGV

AGVs are not required to be covered 360° by a safety laser scanner to avoid collisions. In general, safety laser scanners cover the operating direction when AGVs meet a relevant speed. If the AGV is running fast, it must stop before contacting anything which could result in a hazard.

Safety laser scanners are not inexpensive

(around $2,000 - $2,500 USD each)

and the integration into the AGV system can increase price due to the requirements for highly accurate programming, integration in the safety PLC, commissioning (verification and validation), etc.

In case you wish to know how much an average AGV system costs, you can consult this article that explains each cost factor influencing the total AGV system investment.

Many AGVs include safety bumpers on sides or edges not monitored by safety laser scanners.

AGV safety bumper dimensions depend on the force applied by the obstacle and the stopping distance of the AGV.

The principle is simple: if an AGV touches something, it must not damage itself or the obstacle.

Pressure-sensitive bumpers are also known as safety edges, contact sensing devices or safety sensing bumpers.

If used as an object sensing device, a bumper must be fail-to-safe in its operation and mounting, and it must not exert a force that could harm someone if applied parallel to the floor and opposing the direction of travel with respect to the bumper.

Bumper activation must safely stop the vehicle within the collapsible range of the bumper (i.e., before vehicle structure contact).

The only way to avoid injury is for contact to happen at very low speeds. For this reason, bumpers are located on portions of the AGV that might contact something at very low speeds, typically lower than 0.3 m/s (18 m/min) where a collision avoidance system is not required (a safety laser scanner is not mandatory).

3.1.3 AGV Safety PLC or Relay

All the safety components indicated above must be monitored by a safety PLC or safety relays that monitor all the safety-related components which result in achieving a Performance Level.

Its main function is to reliably initiate a vehicle stop command whenever needed.

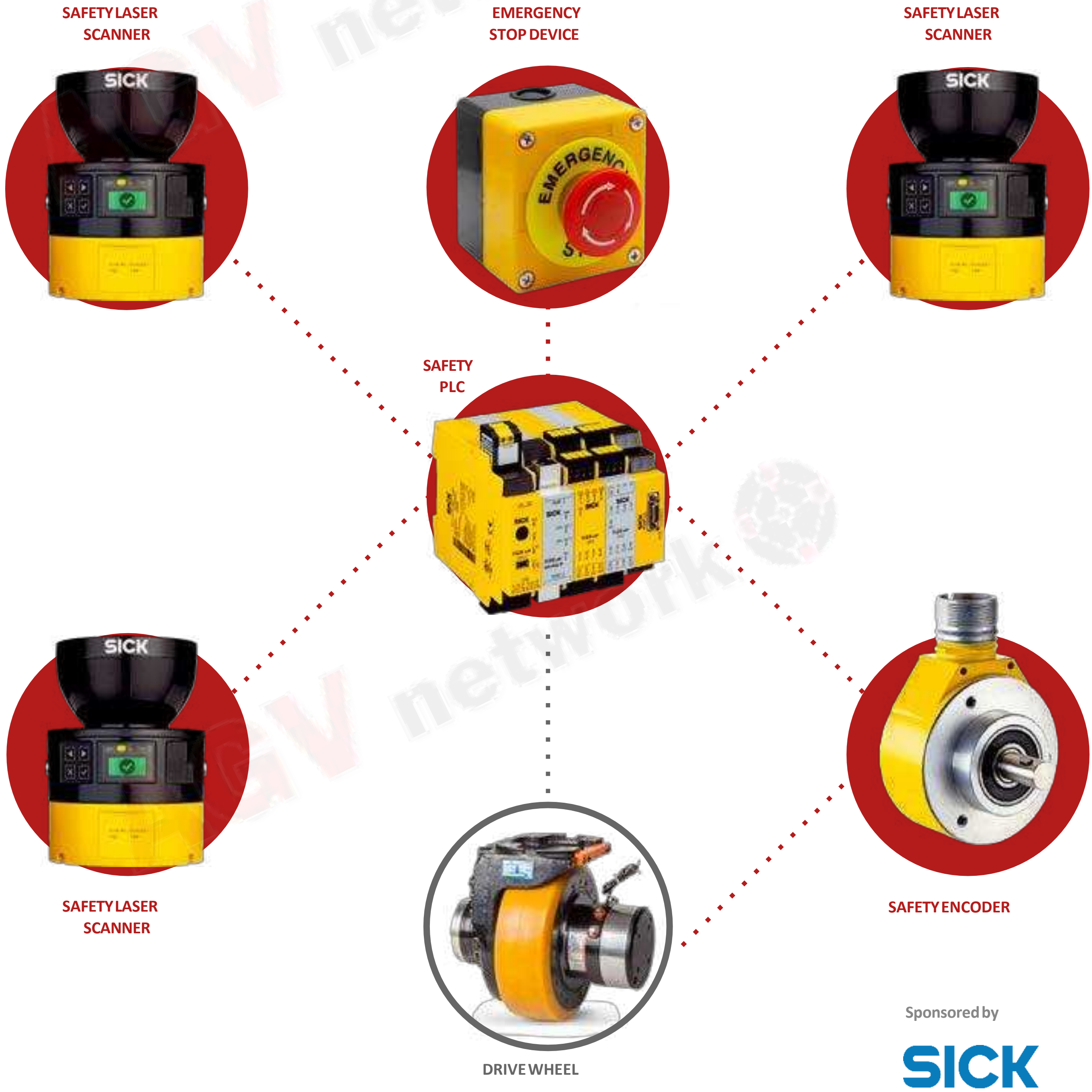
Click Video:
[Sensor Demo of AGV Person Protection]

In this video:

- The **Safety Encoder** monitors the driving speed as well as steering angle of the vehicle. This info is provided to the Safety PLC.
- The **Safety PLC** (or safety controller) receives the info from the **Safety Encoder** and sets the safety field needed to stop the vehicle if some obstacle is detected in the protective field or to slow down the AGV if something enters in the warning field.

- The **Safety Laser Scanners** monitor the associated protective field following the instructions given by the Safety PLC.
- The **Safety PLC** must cut the power to the motor wheel for stopping the vehicle whenever needed.

If we had safety-related **bumpers** or **inclinometers** or **single-beam photoelectric safety switches**, etc., all of them would be linked and monitored by the Safety PLC.



3.2 Passive AGV risk reduction measures

Visual and audible signals indicate AGV presence and vehicle status. These signals must be designed with consideration for the environmental conditions of the operating location while not introducing new hazards (line-of-sight, ambient lighting and noise levels, unambiguous indication, etc.).

Emergency Stop Devices

Emergency stop devices **are required on each AGV** according to EN ISO 3691-4 and ANSI/ITSDF B56.5.

The number and position of emergency stop devices are defined by the AGV shape and dimensions. Emergency stop devices must be clearly visible, distinguishable and easy to reach from any side of the AGV and at defined operator positions with controls. Whatever happens, an operator must be able to actuate an emergency stop device located on the AGV.

When an emergency stop device is activated, the AGV enters an emergency stop condition and all motion becomes inactive until a manual restart is performed.

Warning Lights

When the AGV is approaching a turn, specifically a turning light, indicate that the AGV is going to turn in a certain direction and alerts personnel in the area of the AGV's intention to branch right or left on the guide path.

AGVs can have other kinds of visual signals to indicate several different AGV statuses: stopped by the safety laser scanner, AGV running, AGV problem, etc.

An AGV's warning lights must be readily visible.

Audible Warning/ Alarm Signals

Distinct tones, songs or melodies are used during the vehicle's operation, including an acknowledge tone and an alarm tone.

The AGV emits different kinds of tones during normal operation to indicate several different AGV statuses.

The alarm tone sounds when an alarm is active.

Prior to initiation of vehicle movement or remote reactivation from a sleep or inactive condition, a warning device (integrated with or separate from the mobile platform) must be activated, either audible, visual, or a combination, indicating the imminent movement of the mobile platform under automatic control. The warning light(s) must be readily visible

Mobile platforms must provide a warning indication, either audible, visual, or a combination thereof, during all motion.

Signs on the Automatic Guided Vehicle

AGVs must have sings and symbols indicating operating hazard zones. All vehicle signs must be in accordance with local legislation and must be highly durable.

4. AGV Operating Zone Classification

Until now, we have provided and described details about the risk reduction measures of the AGV vehicle itself. But what about safety related to the whole AGV application? More specifically, what about safety related to the AGV installed in a defined environment?

There are some best practices that AGV integrators should follow while installing an AGV system.

In some cases, it is not possible for the AGV manufacturer to fulfill all of the safety requirements. Therefore, every AGV application should have a subsequent risk assessment performed and agreed upon between the integrator and user.

It is very important to develop and delivery training to allindividuals exposed to the AGV application.

4.1 What are the different AGV Operating Zones?

We can distinguish five different AGV operation zones depending on the safety system conditions:

- Operating Zone
- Operating Hazard Zone
- Restricted Zone
- Confined Zones
- Load Transfer Area

These zones depend on:

- The clearance between the AGV (or its load) contour and the nearest fixed structure.
- The presence of an active safety-related detection device in the travel direction.

Hazard and/or restricted zones shall be designated as such by the user and system integrator during the design, installation, and start up phases. After installation, it is the responsibility of the user to make sure that these zones are continually and clearly marked by floor/ground markings, lights, or other designations.

Confusion with other awareness markings and signs must be avoided to provide the highest level of understanding by the exposed individuals.

Areas of clearance of less than 0.5 m may present a risk to personnel. Before the mobile platform enters hazard zones and restricted areas, speed must be reduced and an audible warning must be activated.

The table below shows zone classification depending on clearances, speed, and status of the safety device(s).

C1 (in mm)	C2 (in mm)	C3 (in mm)	Safety device	Zone Type	Speed (m/s)
>500	>500	>500	Active	Operating	Rated Speed
			Inactive	Hazard	0.3
>500	>500	<500	Active	Hazard	0.7
			Inactive	Hazard	0.3
>500	<500 and >100	>500	Active	Hazard	1.2
			Inactive	Hazard	0.3
>500	<500 and >100	<500	Active	Hazard	0.7
			Inactive	Hazard	0.3
>500	<100	>500	Active	Operating	Rated Speed
			Inactive	Hazard	0.3
>500	<100	<500	Active	Hazard	0.7
			Inactive	Hazard	0.3
<500 and >100	<500 and >100	>500	Active	Hazard	1.2
			Inactive	Restricted	0.3
<500 and >100	<500 and >100	<500	Active	Hazard	0.3
			Inactive	Restricted	0.3
<500 and >100	<100	>500	Active	Hazard	1.2
			Inactive	Restricted	0.3
<500 and >100	<100	<500	Active	Hazard	0.3
			Inactive	Restricted	0.3
<100	<100	>500	Active	Hazard	Rated Speed
			Inactive	Hazard	0.3
<100	<100	<500	Active	Hazard	0.3
			Inactive	Restricted	0.3

C1 and C2 are the clearance between the truck and the continuous fixed closed structure.

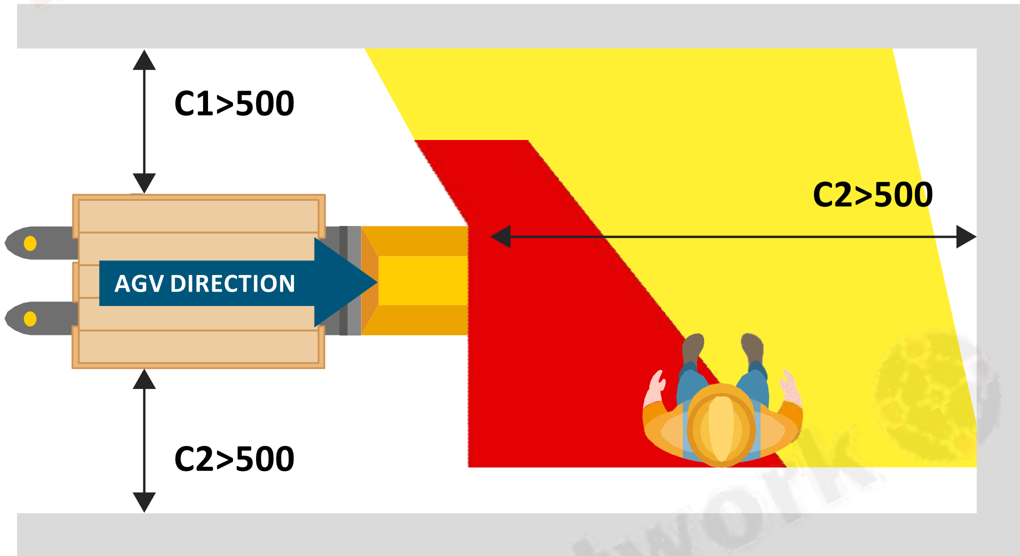
C3 is the clearance from the current position to the fixed closed structure/object in the direction of travel.

4.1.1 Operating Zone

The recommended clearance between an AGV including its load, and any external structure must be a minimum of 0.5 m (19.7 inches). This clearance must be maintained between obstructions and vehicles (including loads).

In the operating zones, the safety device in the direction of movement must be active.

As you can see in the table above, if we have one side with clearance less than 100 mm, the zone is considered operating if the other two clearances are wider than 500 mm and the safety device is active.



In this case, the Automatic Pallet Mover is running close to a wall with clearance less than 100 mm.

On the other side, the clearance is more than 500 mm.

The safety laser scanner is active with the protective field long enough to detect a person and stop before contact.

The max speed permitted is the rated speed.

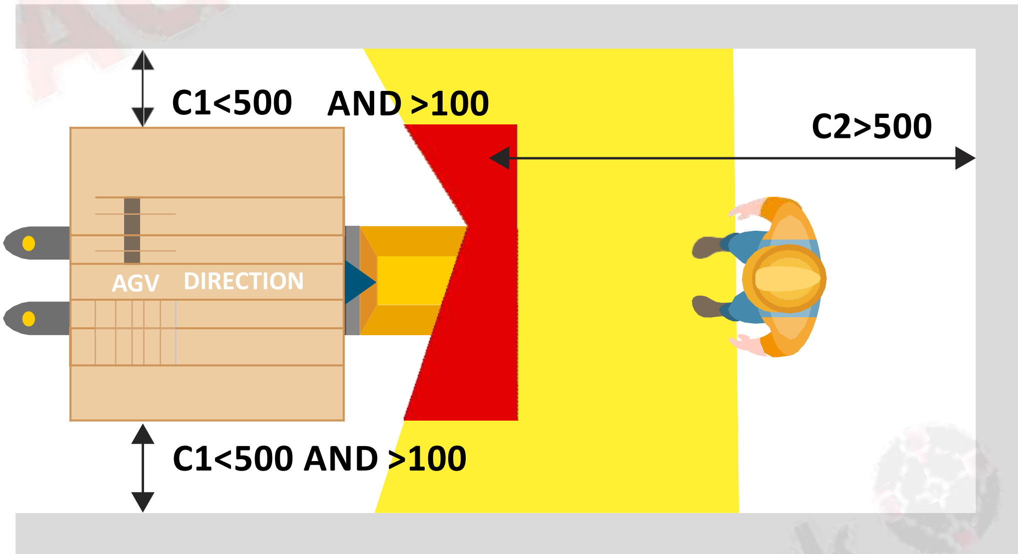
When the vehicle stops, the person can always leave the area along the C1 side. There is an “escape route”.

4.1.2 Operating Hazard Zone

A hazard zone is an area where the clearance is slightly less than half a meter, but you can still manoeuver in the aisles between the vehicle.

A hazard zone is an area with inadequate clearance or a zone which cannot be protected by personnel detection means.

If there is no active safety laser scanner, the maximum allowed speed is 0.3 m/s. In this case, all the zones are classified as hazard zone.



In this case the Automatic Pallet Mover is running close to both walls with clearance less than 100 mm.

The operator still has some space to escape, but it is limited.
The safety laser scanner is active with the protective field long enough to detect a person and stop before contact. This is clearly a hazardous operation, and the max speed should be 1.2 m/s.

If the safety laser scanner is not active, the zone should be classified as restricted with max speed allowance of 0.3 m/s.

Hazard zones:

- Must be clearly indicated by suitable signs or ground markings.
- AGVs must emit additional audible and / or visual warnings.

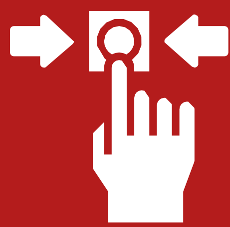
4.1.3 Restricted Areas

A zone with inadequate clearance that can't be protected personnel detection means, must be designated "restricted zone".

If there isn't an escape route for a pedestrian, the vehicle path must be considered a restricted area.

The user and system integrator must agree on appropriate risk reduction measures for this situation.

If an emergency stop device can be fitted, it must be located on the vehicle within a 600 mm reach of the operator.



In cases where the emergency stop device can't be reached (e.g., a forked vehicle traveling in reverse for load deposit), personnel must be subject to verifiable safety and operating training.

Examples are Block storage and Very Narrow Aisle

Restricted zone should:

a) be clearly marked
b) limit access to authorized trained personnel
c) be contained within perimeter fixed guards with a moveable guard for access by authorized personnel

4.1.4 Confined zones

Confined zones are zones inside perimeter safeguarding without speed limitation and where vehicles do not have any personnel detection device.

Basically, vehicles run as fast as possible because personnel are not present.

4.1.5 Load Transfer Area

The load transfer can take place only in the designated position. If the area is not designed to prevent personnel to be endangered, the area shall be considered as an operating hazard zone.

5. Other important elements related to mobile platform safety

This whitepaper refers to some of the key elements in a mobile platform safety systems. There are other important elements and considerations mentioned in both safety standards ANSI/ITSDF B56.5-2019 and EN ISO 3691-4:2020.

5.1 Braking System

The mobile platform must be equipped with a braking system designed to:

- Stop the vehicle within the operating range of the personnel detection devices. So the mobile robot must stop if the safety laser scanner detects an obstacle (we'll see this point later on).
- Operate in case of interruption of power supply.

5.2 Stopping Distance

Braking systems in conjunction with the object detection system and the response time of the safety control system are built to cause the vehicle to stop prior to impact between the vehicle's structure and other mounted equipment, including its intended load, and a detected obstruction ahead of the moving platform in the main direction of travel.

5.3 Automatic Charging

In case of a mobile platform equipped with on-line or opportunity charging elements, reachable charging contacts must be activated only when the mobile platform is connected to the charging device.

3. Load Handling

The load must remain in the position defined by the manufacturer.

If the load is not in the defined position, the mobile platform must be equipped with means that prevent it from moving.

4. Stability

The mobile platform must remain stable in all the operation conditions.

6. Conclusions and advice about mobile platform safety systems

- Choose a **reliable mobile platform supplier** with proven expertize in functional safety and with mobile platforms complying with applicable standards

- This whitepaper begins the discussion of some of the key points related to mobile platform safety. **You are encouraged to purchase the standards** to gain a wider understanding about potential risks and solutions.

- **Risk assessment must be performed** for each application and in collaboration with your own **Health and Safety department**. Do not forget to involve them from the beginning.

- A new safety standard for Industrial Mobile Robots (IMR, also known as AMR), **ANSI/RIA R15.08-1-2020**, has been published in January 2021.