ISO 3691-4:2020
A Standard for Automated
Guided Vehicles.

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ISO 3691-4 an adoption of ISO 13849 for driverless industrial trucks.

In recent years, the optimization of time and resources has become indispensable in the manufacturing industry. Nowadays, the usage of the driverless industrial trucks AGV (Automated Guided Vehicles) and the smallest AGC (Automated Guided Carts) become more prominent with the implementation of methodologies with Kanban cards (Lean Manufacturing) or POLCA (Quick Response Manufacturing) and other methodologies.

Human interaction with this equipment (i.e. working islands) poses hazards to humans with rising risks due to the increase of interactions with the AGV/AGC.

Until now, for these systems (AGV/AGC) there was no harmonized, listed standard available, although EN 1525:1997 was used by the truck manufacturers. This laid the basis for the definition, use and evaluation of the basic elements of protection, referring to the superseded EN 954, and therefore stipulating minimum Categories (B, 1, 2, 3 or 4) for some of them.

The ISO 3691-series covers the basic safety requirements for industrial trucks. ISO 3691-4 specifies these requirements as a Type C standard for driverless industrial trucks.
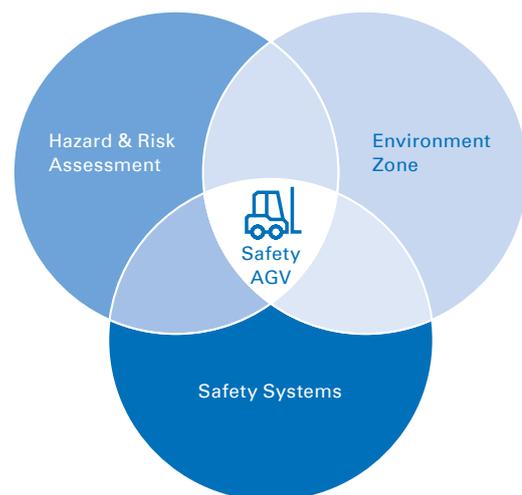
TOPICS TO CONSIDER FOR A SAFETY AGV

Figure 1

For a safe AGV/AGC the ISO 3691-4 describes three key aspects, as shown in Figure 1:

- the operating environment (i.e. defining the different zones where the truck operates and interacts with humans),
- the hazards and risk associated, and
- the correct implementation of the Safety (protection) Systems.

Road toward Safety.

A safety assessment is necessary for AGV/AGC. The following graphic shows which steps should be considered in which phase.

PILLARS OF THE ROAD TOWARD SAFETY

Risk Assessment	Safety requirements	Assessment SRP/CS	Verification	Documentation

- Acc. to ISO 12100:2010
- Hazards & risk. acc. to Annex B

- Protective measures, electrical, energy, guards, interlocks, ESPE…
- Zones acc. to Table 1 & 2 Annex A

- Safety Functions Table 1 chapter 4.11

- Type testing: Test A & B
- Stability tests
- Structural tests
- Functional verification
- Commissioning

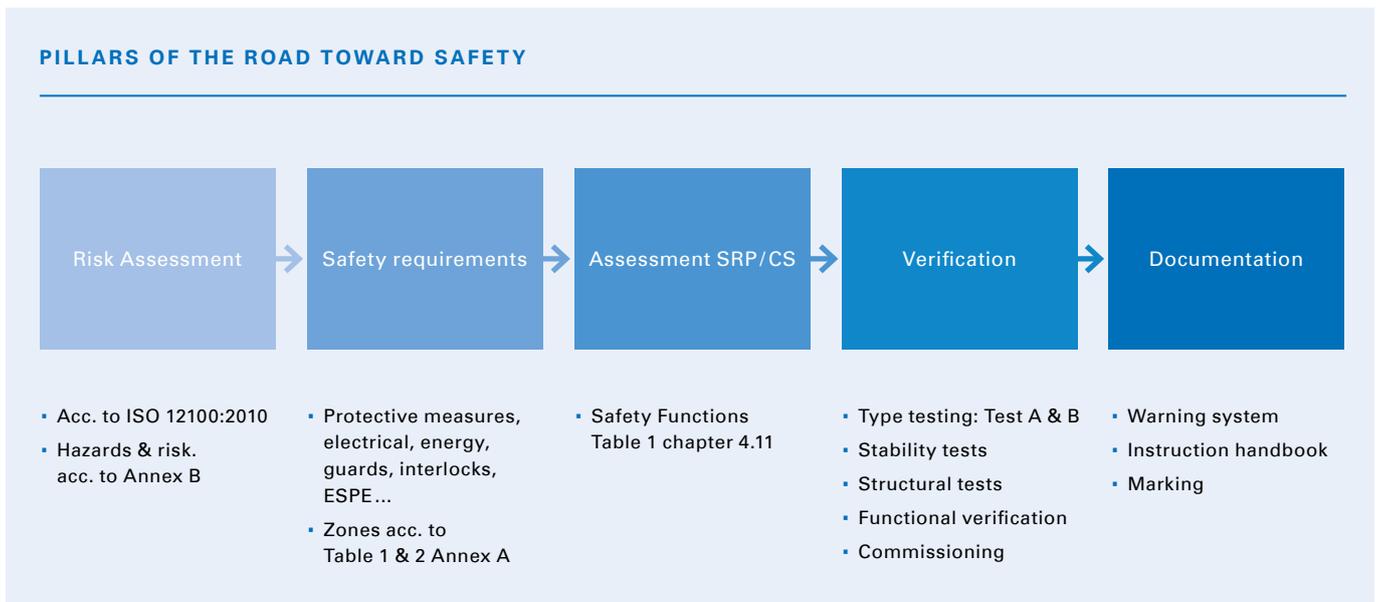- Warning system
- Instruction handbook
- Marking

Figure 2

As usual in the safety assessments, the way starts with hazard analysis and risk estimation.
This can be accomplished with the help of the table of ISO 3691-4, Annex B where hazards and their possible consequences are listed.

REMARK

The standard does not cover the estimation of hazards resulting from extreme climates, nuclear, explosive, military and specific environments.

During the design process of the protective functions, it is of main importance to put the focus on the complete system.
This contains the understanding of the relationship of the different functions and Safety Functions for the overall safety of the AGV.

The following diagram shows the Safety protective measures stated by ISO 3691-4 and their relationship.

SAFETY PROTECTIVE MEASURES RELATIONSHIP

Warning System 6.2

Braking System 4.2

Stability 4.7

Steering 4.6

Personnel Detection System 4.8.2

Load Handling 4.5

Speed Control 4.3

Truck access to/from the confined zone A.2.4.3

Emergency Stop Function 4.8.1

Automatic, manual and maintenance Modes 4.9
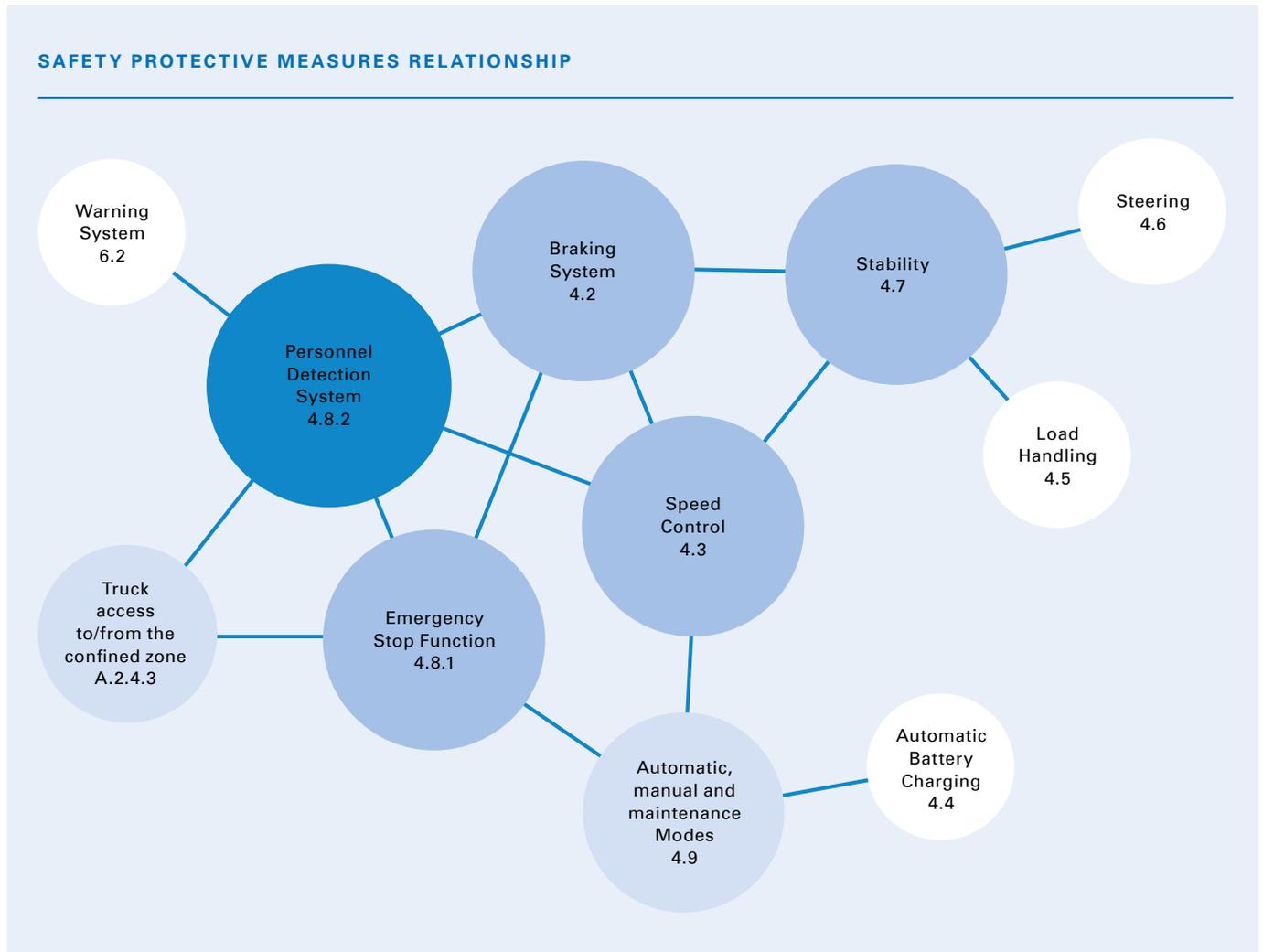
Automatic Battery Charging 4.4

Figure 3

The Control System of the AGV/AGC needs to deal with Safety and non-Safety Functions, taking into account that some Safety Functions may affect Safety as well as Non-Safety ones.

The AGV/AGC control system has to safely control the speed, stability, load and steering. Some of its functions, for example, rely on the safe functioning of the Braking System and especially the Personnel Detection System.

The Performance Level (PL) for the different Safety Functions (Protection Measures) are based on Hazards listed in ISO 3691-4, Annex B, the resulting PLs are listed in ISO 3691-4, Table 1 of the standard (see Figure 4 on the next page).

Main improvements in respect to EN-1525.

PL INSTEAD OF CATEGORY

The first improvement is that the ISO 3691-4 is, as state of the art, aligned with the ISO 13849 with the PL$_r$ (required Performance Level) requirements instead of Categories only.

Table 1, in section 4.11 describes the Safety Function (27 in total), the associated risk and the minimum PL$_r$ acc. to ISO 13849-1.

EXAMPLE OF TABLE 1 SECTION 4.11 ISO 3691-4

Chapter	N°	Cross-reference in this document	Description of Safety Function	Main Risk	Note	Min. PL$_r$ acc. to ISO 13849-1
4.2 Braking system	1	4.2	Braking system control	- Collision with persons	PL function controls the deceleration function.	d
	2	4.2 d)	Parking braking system control	- Unintended motion of the truck: Risk of collision. - Reduction of braking performance if the battery is disconnected (unlikely).	PL function controls that brake is dis-engaged in order to avoid continuous braking when travelling. (Wear and release of the brake to be checked with periodic maintenance).	b

Figure 4

Figure 4 shows the abstract Table 1, presenting two Safety Functions related to the Braking System. Derived from the nature of the associated risks, a specific PL acc. to ISO 13849-1 is required, PL$_r$ d for Safety Function number 1 (Braking System) and PL$_r$ b for Safety Function number 2 (Parking Braking System).

THE ISO 3691-4 SPECIFIES THE NORMAL CLIMATIC CONDITIONS

- Avg. ambient temperature continuous duty: +25 °C
- Max. ambient temperature, short term (up to 1h): +40 °C
- Lowest ambient temperature, normal use indoor: +5 °C
- Lowest ambient temperature, normal use outdoor: -20 °C
- Altitude: 2,000 m

Like EN 1525, the ISO 3691-4 states that for severe conditions (e. g. extreme climates, freezer applications, strong magnetic fields,…) the designer needs to evaluate the risks. This means that there is no clear limit for the outdoor use of AGV/AGC, but if the conditions are outside, for the normal climatic conditions an additional assessment has to be performed.

BETTER DEFINITION AND CLASSIFICATION OF THE ZONES

EN 1525 in Annex A defines only two zones for the equipment as Restricted Zone and Hazard Zone – now with the ISO 3691-4 additionally the Confined Zone is defined. Furthermore, the requirements for every zone are better defined than in EN 1525 (e.g. truck speed).

In addition to Annex A Table1 of ISO 3691-4, the classification of zones are also distinguished between active or inactive Personnel Detection means.

EXTRACT OF TABLE A.1

In addition to Table A.1 of ISO 3691-4, the classification of zones are also distinguished between active or inactive Personnel Detection means.

	Clearance between truck and continuous fixed closed structure		Clearance from current position to the fixed closed structure/ object in the direction of travel, C3 mm	Personnel Detection means in travel direction active (PL D)	Max speed[5]	Required zone classi-fication	Reachable stop function required within 600 mm	Floor/ ground marking or extra warnings Required	Automatic restart permitted
	Clearance on one side, C1 (mm)	Clearance on the other side, C2 (mm)							
1a	>500	>500	>500	Active	Rated speed	Operating	NO	NO	NO
1b				Muted	0,3 m/s	Operating hazard	NO	YES	-b

b - In these specific cases, automatic restart is permitted without personnel detection means if side clearance is >500 mm on at least one side or clearance is > 500 mm from the current position to the fixed closed structure/object in the direction of travel if determined to be acceptable by a risk assessment.

Figure 5

CONDITIONS TO MUTE, OVERRIDE OR DEACTIVATE THE PERSONNEL DETECTION MEANS ARE GIVEN

Following the requirements of section 4.8.2.3 if such function is possible. The EN 1525 only specifies that the Bypass of Safety Functions has to fulfill Category 2.

THE INTERACTION WITH CONVEYORS FITTED TO A TRUCK IS DESCRIBED

Understanding that AGV/AGC interact with conveyors, the ISO 3691-4 includes this topic and defines requirements accordingly (see section 4.13.).

BRAKING SYSTEM CONTROL DEFINED AS AN SRP/CS

The Braking System acc. to EN 1525 needs to fulfill some functional requirements but has no dedicated Category requirement. The ISO 3691-4 maintains these requirements and adds the Control of the Braking System to the list of SRP/CS with respective PL requirements (see Table 1).

Limitations.

THE ISO 3691-4 ALSO HAS SOME LIMITATIONS, AS DESCRIBED BELOW

- Humans approaching the truck or stepping sideways into the path of the truck or out of scope (see section 1 'Scope')

- There is no PL_r or even Category (as in the former EN 1525) specified for the steering (see table 1 in ISO 3691-4), although the PL and tolerable speed depends on the direction of travel (see Safety Functions for Personal Detection System in table 1).

Major Differences.

Although the adoption of the new ISO 3691-4 instead of EN 1525 represents a change of the general approach for the assessment of AGV/AGC, the requirements where it has a more direct impact on is related to the Detection of Persons and the Braking System.

In EN 1525, the Safety Function "Detection of persons on the travelling path" is defined in section 5.9.5.1 point b) as "They shall generate a signal enabling the truck to be stopped by the braking system…" but without further requirements concerning Category or Performance Level.

According to Annex A Table 1 of ISO 3691-4, there are safety requirements for the Safety-Related Parts of a Control Systems (SRP/CS) for the Personnel Detection System and the Braking System (Control) in reference to ISO 13849-1. This is one major difference to EN 1525.

The other key difference is the definition of the Safety Function "Detection of persons in the guide path" as "They shall be so designed that trucks shall stop before contact between the rigid parts of the truck or load and a stationary person…".

The difference lies in "generate a signal" (EN 1525) and "stop" (ISO 3691-4). This makes mandatory to assess the overall system including the Braking System.

The standard clarifies that the SRP/CS of the **Detection of Personnel** and the **Braking System** have to comply with a level of PL_r d.

Compliance.

ISO 3691-4:2020 is a new Type C standard, well aligned with ISO 13849 and will be a good guide to carry out safety assessments of the entire AGV/AGC. Complying with this standard will lead to safer self-driving vehicle environments like factories or logistics centres.

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