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Robotics — Safety requirements —

Part 1:
Industrial robots

Robotique — Exigences de sécurité —

Partie 1: Robots industriels

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 299, *Robotics,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 310, *Advanced automation technologies and their applications,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 10218-1:2011), which has been technically revised.

The main changes are as follows:

— additional requirements for design;

— mode requirements;

— clarifying requirements for functional safety;

— robot classification (Class I and Class II) for functional safety requirements;

— test methodology to determine the maximum force per manipulator for Class I robots;

— adding requirements for cybersecurity to the extent that it applies to industrial robot safety;

— incorporating safety requirements for industrial robots intended for use in collaborative applications (formerly, the content of ISO/TS 15066).

A list of all parts in the ISO 10218 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The ISO 10218 series has been created in recognition of the hazards that are presented by robotics in an industrial environment. This document addresses robots as partly completed machinery, while ISO 10218-2 addresses robots integrated into machinery (robot applications and cells).

This document is a type-C standard according to ISO 12100.

This document is of relevance for the following stakeholder groups representing the market players regarding robot safety:

— robot manufacturers (small, medium and large enterprises);

— robot application integrators (small, medium and large enterprises);

— health and safety bodies (regulators, accident prevention organisations, market surveillance, etc.).

Others can be affected by the level of safety achieved with the means of the document by the above mentioned stakeholder groups:

— robot application users/employers (small, medium and large enterprises);

— robot application users/employees (e.g. trade unions);

— service providers, e.g. for maintenance (small, medium and large enterprises);

The above-mentioned stakeholder groups have been given the possibility to participate in the drafting process of this document.

Robots and the extent to which hazards, hazardous situations or hazardous events are covered are indicated in the Scope of this document.

When provisions of a type-C standard are different from those that are stated in type-A or type-B standards, the provisions of the type-C standard take precedence over the provisions of the other standards for machines that have been designed and built in accordance with the provisions of the type-C standard.

In recognition of the variable nature of hazards with different uses of industrial robots, the ISO 10218 series is divided into two parts. This document provides requirements for safety of the robot. For safety of the integration and commissioning of industrial robot applications, ISO 10218-2:2025 provides requirements for the safeguarding of operators during integration, commissioning, functional testing, programming, operation, maintenance and repair.

The ISO 10218 series deals with robotics in an industrial environment, which is comprised of workplaces where the public is excluded and the allowed people (operators) are working adults. Other standards cover topics such as general characteristics, coordinate systems and axis motions, mechanical interfaces performance criteria and related testing methods, and end-effectors.

For ease of reading this document, the words “robot” and “robot application” refer to “industrial robot” and “industrial robot application” as defined in this document.

This document has been updated based on experience gained since the release of the ISO 10218 series in 2011. This document remains aligned with the minimum requirements of a harmonized type-C standard for robots in an industrial environment.

Where appropriate, ISO/TS 15066:2016 on the safety of collaborative robot applications was added to the ISO 10218 series. Because human-robot collaboration relates to the application and not to the robot alone, most of the requirements of ISO/TS 15066 have been incorporated into ISO 10218-2:2025. Safety functions that enable a collaborative task can be part of the robot or can be provided by a protective device, or a combination.

It is important to emphasize that the terms “collaborative operation” and “collaborative robot” are not used in this document. Only the application can be developed, verified and validated as a collaborative application.

Robotics — Safety requirements —

Part 1: Industrial robots

1 Scope

This document specifies requirements for the inherently safe design, risk reduction measures and information for use of robots for an industrial environment.

This document addresses the robot as an incomplete machine.

This document is not applicable to the following uses and products:

— underwater;

— law enforcement;

— military (defence);

— airborne and space robots, including outer space;

— medical robots;

— healthcare robots;

— prosthetics and other aids for the physically impaired;

— service robots, which provide a service to a person and as such where the public can have access;

— consumer products, as this is household use to which the public can have access;

— lifting or transporting people.

NOTE 1 Requirements for robot integration and robot applications are covered in ISO 10218-2:2025.

NOTE 2 Additional hazards can be created by robot applications (e.g. welding, laser cutting, machining). These hazards are addressed during robot application design. See ISO 10218-2:2025.

This document deals with the significant hazards, hazardous situations or hazardous events when used as intended and under specified conditions of misuse which are reasonably foreseeable by the manufacturer.

This document does not cover the hazards related to:

— severe conditions (e.g. extreme climates, freezer use, strong magnetic fields) outside of manufacturer's specifications;

— underground use;

— use that has hygienic requirements;

— use in nuclear environments;

— use in potentially explosive environments;

— mobility when robots or manipulators are fixed to or part of driverless industrial trucks;

- mobility when robots or manipulators are fixed to or part of mobile platforms;
- use in environments with ionizing and non-ionizing radiation levels;
- hazardous ionizing and non-ionizing radiation;
- handling loads the nature of which can lead to dangerous situations (e.g. molten metals, acids/bases, radiating materials);
- handling or lifting or transporting people;
- when the public, all ages or non-working adults have access (e.g. service robots, consumer products).

Noise emission is generally not considered a significant hazard of the robot alone, and consequently noise is excluded from the scope of this document.

This document is not applicable to robots that are manufactured before the date of its publication.

2 Normative references

The following documents are referred to in the text in such a way that some or all their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3864-1:2011, *Graphical symbols — Safety colours and safety signs — Part 1: Design principles for safety signs and safety markings*

ISO 3864-2:2016, *Graphical symbols — Safety colours and safety signs — Part 2: Design principles for product safety labels*

ISO 3864-3:2024, *Graphical symbols — Safety colours and safety signs — Part 3: Design principles for graphical symbols for use in safety signs*

ISO 3864-4:2011, *Graphical symbols — Safety colours and safety signs — Part 4: Colorimetric and photometric properties of safety sign materials*

ISO 4413:2010, *Hydraulic fluid power — General rules and safety requirements for systems and their components*

ISO 4414:2010, *Pneumatic fluid power — General rules and safety requirements for systems and their components*

ISO 7010:2019, *Graphical symbols — Safety colours and safety signs — Registered safety signs*

ISO 9283:1998, *Manipulating industrial robots — Performance criteria and related test methods*

ISO 12100:2010, *Safety of machinery — General principles for design — Risk assessment and risk reduction*

ISO 13732-1:2006, *Ergonomics of the thermal environment — Methods for the assessment of human responses to contact with surfaces — Part 1: Hot surfaces*

ISO 13732-3:2005, *Ergonomics of the thermal environment — Methods for the assessment of human responses to contact with surfaces — Part 3: Cold surfaces*

ISO 13849-1:2023, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

ISO 13850:2015, *Safety of machinery — Emergency stop function — Principles for design*

ISO 14118:2017, *Safety of machinery — Prevention of unexpected start-up*

ISO 14119:2024, *Safety of machinery — Interlocking devices associated with guards — Principles for design and selection*

ISO 14120:2015, *Safety of machinery — Guards — General requirements for the design and construction of fixed and movable guards*

ISO 19353:2019, *Safety of machinery — Fire prevention and fire protection*

ISO 20607:2019, *Safety of machinery — Instruction handbook — General drafting principles*

ISO 20643:2005/Amd 1:2012, *Mechanical vibration — Hand-held and hand-guided machinery — Principles for evaluation of vibration emission*

IEC 60073:2002, *Basic and safety principles for man-machine interface, marking and identification — Coding principles for indication devices and actuators*

IEC 60204-1:2016+AMD1:2021, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

IEC 60947-5-8:2020, *Low-voltage switchgear and controlgear — Part 5-8: Control circuit devices and switching elements — Three-position enabling switches*

IEC 61310-1:2007, *Safety of machinery — Indication, marking and actuation — Part 1: Requirements for visual, acoustic and tactile signals*

IEC 61310-2:2007, *Safety of machinery — Indication, marking and actuation — Part 2: Requirements for marking*

IEC 61310-3:2007, *Safety of machinery — Indication, marking and actuation — Part 3: Requirements for the location and operation of actuators*

IEC 61508-2:2010, *Functional safety of electrical/electronic/ programmable electronic safety-related systems — Part 2: Requirements for electrical/ electronic/ programmable electronic safety-related systems*

IEC 62061:2021, *Safety of machinery — Functional safety of safety-related control systems*

IEC 62745:2017, *Safety of machinery — Requirements for cableless control systems of machinery*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the terms and definitions given in ISO 12100:2010 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp;

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Terms and definitions

3.1.1 Robot, robot system, robot application, application

3.1.1.1
industrial environment
workplace where the public is restricted from access or not reasonably expected to be present for the intended tasks and *robot application(s)* (3.1.1.4)

Note 1 to entry: This includes manufacturing, laboratory, pharmaceutical, warehousing, logistics, and more.

3.1.1.2
industrial robot
robot
automatically controlled, reprogrammable multipurpose *manipulator(s)* (3.1.2.5), programmable in three or more *axes* (3.1.2.1), which can be either fixed in place or fixed to a *mobile platform* (3.1.2.8) for use in automation *applications* (3.1.1.5) in an *industrial environment* (3.1.1.1)

Note 1 to entry: The industrial robot includes:

— the *manipulator(s)* (3.1.2.5), including *robot actuators* (3.1.2.10) controlled by the robot control;

— the robot control; and

— the means to teach or program the robot, including any communications interface (hardware and software).

Note 2 to entry: This includes any axes that are integrated into the kinematic solution.

Note 3 to entry: A mobile robot consists of a *mobile platform* (3.1.2.8) with an integrated *manipulator* (3.1.2.5) or robot.

3.1.1.3
robot system
industrial robot system
industrial robot (3.1.1.2), *end-effector(s)* (3.1.2.3), and any end-effector sensors and equipment needed to support the *end-effector(s)* (3.1.2.3)

Note 1 to entry: Examples of equipment are vision systems, adhesive dispensing, weld control.

3.1.1.4
robot application
industrial robot application
machine comprising an industrial *robot system* (3.1.1.3), workpieces, *task program* (3.1.4.2), and machinery and equipment to support the *application* (3.1.1.5) and intended tasks

3.1.1.5
application
intended use and purpose of the *robot* (3.1.1.2) or *robot application* (3.1.1.4), i.e. the process, the task(s)

EXAMPLE Manipulating, processing, machining, inspection, spot welding, painting, assembly, palletizing.

3.1.1.6
collaborative application
applications (3.1.1.5) that contains one or more *collaborative task(s)* (3.1.1.7)

Note 1 to entry: *Collaborative applications* can include non-collaborative tasks.

3.1.1.7
collaborative task
portion of the robot sequence where both the *robot application* (3.1.1.4) and *operator(s)* (3.1.7.2) are within the same *safeguarded space* (3.1.9.5)

3.1.1.8
robot cell
industrial robot cell
one or more *robot applications* (3.1.1.4) including any obstacle or object that has influence on the risk assessment of the intended use, associated *safeguarded space(s)* (3.1.9.5) and *safeguards* (3.1.10.4)

3.1.2 Sub-assemblies and components

3.1.2.1
axis
actuated (e.g. rotating about a pivot, moving linearly) mechanical joint that provides at least one degree of freedom

3.1.2.2
auxiliary axis
axis (3.1.2.1) that is not physically part of the *manipulator* (3.1.2.5) and is controlled by the *robot* (3.1.1.2)

Note 1 to entry: Controlled means that there is a feedback signal(s) to enable closed loop control by the *robot* (3.1.1.2).

3.1.2.3
end-effector
device specifically designed for attachment to the *mechanical interface* (3.1.2.7) to enable the *robot application* (3.1.1.4) to perform its task

EXAMPLE Gripper, welding gun, spray gun.

Note 1 to entry: End-effectors are sometimes known as end-of-arm tooling (EOAT).

3.1.2.4
gripper
end-effector (3.1.2.3) designed for seizing and holding workpieces

Note 1 to entry: Various types of grippers and the terms grip, grasp, grasping and releasing are defined in ISO 14539:2000.

[SOURCE: ISO 14539:2000, 4.1.2, modified — Note 1 to entry has been added.]

3.1.2.5
manipulator
mechanism consisting of an arrangement of segments, jointed or sliding relative to one another

Note 1 to entry: *Robot actuators* (3.1.2.10) can constitute parts of a *manipulator*.

3.1.2.6
mass per manipulator
M
mass of all moving parts of the *manipulator* (3.1.2.5)

3.1.2.7
mechanical interface
mounting surface at the end of the *manipulator* (3.1.2.5) to which the *end-effector* (3.1.2.3) is attached

3.1.2.8
mobile platform
assembly of the components which enables locomotion and provides the structure to affix or integrate a *manipulator* (3.1.2.5) or *robot* (3.1.1.2)

3.1.2.9
payload
mass of all that is attached to the *manipulator* (3.1.2.5), including the *end-effector* (3.1.2.3) and workpiece

Note 1 to entry: The payload can be attached to, but is not limited to, the *mechanical interface* (3.1.2.7) of a *robot* (3.1.1.2).

3.1.2.10
robot actuator
powered mechanism that converts energy to effect motion

Note 1 to entry: Energy can be electrical, hydraulic, pneumatic or more.

3.1.2.11
tool centre point
TCP
point defined for a given *application* (3.1.1.5) relative to the *mechanical interface* (3.1.2.7) coordinate system.

Note 1 to entry: The TCP setting defines the location of the TCP relative to the *mechanical interface* (3.1.2.7).

3.1.3 Controls-related

3.1.3.1
control station
enclosure which contains one or more control devices intended to activate or deactivate functions

Note 1 to entry: The *control station* can be fixed in place (e.g. control panel) or can be movable (*pendant* (3.1.3.2) or *teach pendant* (3.1.3.3) which can be referred to as a portable control station).

3.1.3.2
pendant
hand-held *control station* (3.1.3.1)

3.1.3.3
teach pendant
pendant (3.1.3.2) with which a *robot* (3.1.1.2) can be programmed, moved or actuated

Note 1 to entry: Hand-held units or devices which only have the capability of displaying parameters (e.g. no motion and no actuation capabilities), are not considered to be *control stations* (3.1.3.1) or *teach pendants* (3.1.3.3).

Note 2 to entry: The *teach pendant* can be linked to the *end-effector* (3.1.2.3) and other parts of the *robot application* (3.1.1.4).

3.1.3.4
direct control
movement or operation effected by the *control station* (3.1.3.1) that is part of the *robot* (3.1.1.2)

Note 1 to entry: Previously direct control was known as local control of the *robot* (3.1.1.2).

3.1.3.5
external control
movement or operation effected by the *control station* (3.1.3.1) not a part of the *robot* (3.1.1.2)

Note 1 to entry: Previously external control was known as remote control of the *robot* (3.1.1.2).

Note 2 to entry: See ISO 10218-2:2025 for requirements of remote control.

3.1.3.6
singularity
occurrence whenever the rank of the Jacobian matrix becomes less than full rank

Note 1 to entry: Mathematically, in a singular configuration, the joint velocity in joint space can become infinite to maintain Cartesian velocity. In actual operation, motions defined in Cartesian space that pass near singularities can produce high axis speeds. These high axis speeds can be unexpected to an *operator* (3.1.7.2).

3.1.3.7
span-of-control
predetermined portion of a *robot* (3.1.1.2), *robot application* (3.1.1.4), *robot cell* (3.1.1.8) or machinery that is under control of a specific device for a *safety function* (3.1.8.1)

Note 1 to entry: *Protective devices* (3.1.10.5) and emergency stop devices could initiate a stop of a machine, a portion of a machine, or partly completed machinery, i.e. a *robot* (3.1.1.2).

3.1.3.8
simultaneous motion
motion of two or more *robots* (3.1.1.2) at the same time under the control of a single robot, which can be coordinated or can be synchronous

3.1.3.9
mode
operating mode
characterization of the way and the extent to which the *operator* (3.1.7.2) interacts with the control equipment

Note 1 to entry: Mode refers to the control state, e.g. *manual mode* (3.1.3.10), *automatic mode* (3.1.3.11).

3.1.3.10
manual mode
control state that allows control directly by an *operator* (3.1.7.2)

Note 1 to entry: Sometimes this is referred to as teach mode where program points, program logic and attributes are set.

3.1.3.11
automatic mode
control state that allows executing programmed tasks

3.1.3.12
masquerade
true source of a message is not correctly identified

Note 1 to entry: For example, a message from a non-safety element is incorrectly identified as a message from a safety element.

[SOURCE: IEC 61508-2:2010, 7.4.11.1]

3.1.4 Program-related

3.1.4.1
control program
inherent set of instructions that defines the capabilities, actions, and responses of a *robot* (3.1.1.2)

Note 1 to entry: This type of program is fixed and usually not modified by the *user* (3.1.7.3).

3.1.4.2
task program
set of instructions for motion and auxiliary functions that define the specific intended task of the *robot application* (3.1.1.4)

Note 1 to entry: This type of program is generated during *integration* (3.1.7.1) or by the use.

Note 2 to entry: The task program can include functions of other machinery within the *robot application* (3.1.1.4).

3.1.4.3
teach
programming of the task manually by positioning of the *manipulator* (3.1.2.5), or by using a *teach pendant* (3.1.3.3) to move the *robot* (3.1.1.2) through positions, or program without causing motion, or by using an external device for off-line programming

Note 1 to entry: Manually positioning can be referred to as "lead-through teaching" using hand-guided control (HGC).

3.1.4.4
program verification
execution of a *task program* (3.1.4.2) for confirming the *robot* (3.1.1.2) path and process performance

Note 1 to entry: Program verification can include the total path traced by the *tool centre point (TCP)* (3.1.2.11) during the execution of a *task program* (3.1.4.2) or a segment of the path. The instructions can be executed in a single instruction or continuous instruction sequence. Program verification is used in new *applications* (3.1.1.5) and in fine-tuning/editing existing *applications* (3.1.1.5).

3.1.5 Power-, energy-related

3.1.5.1
drive power
energy enabling the *robot actuators* (3.1.2.10) to apply force or torque

3.1.5.2
energy source
electrical, mechanical, hydraulic, pneumatic, chemical, thermal, potential, kinetic or other type of source that is capable of supplying power

3.1.6 Hazard-related

3.1.6.1
hazard
potential source of harm

Note 1 to entry: The term "hazard" can be qualified in order to define its origin (for example, mechanical hazard, electrical hazard) or the nature of the potential harm (for example, electric shock hazard, cutting hazard, toxic hazard, fire hazard).

Note 2 to entry: The hazard envisaged by this definition either

— is permanently present during the intended use of the machine (for example, motion of hazardous moving elements, electric arc during a welding phase, unhealthy posture, noise emission, high temperature), or

— can appear unexpectedly (for example, explosion, crushing hazard as a consequence of an unintended/unexpected start-up, ejection as a consequence of a breakage, fall as a consequence of acceleration/deceleration).

[SOURCE: ISO 12100:2010, 3.6, NOTE 3 has been deleted]

3.1.6.2
hazardous motion
movement that can cause personal physical injury or damage to health

3.1.6.3
hazardous situation
circumstance in which a person is exposed to at least one *hazard* (3.1.6.1)

Note 1 to entry: The exposure can result in harm immediately or over a period of time.

[SOURCE: ISO 12100:2010, 3.10]

3.1.7 Role-related

3.1.7.1
integration
act of combining a *robot* (3.1.1.2), with other equipment or another machine including additional *robot applications* (3.1.1.4) to form a *robot cell* (3.1.1.8) capable of performing useful work

Note 1 to entry: This act of machine building can include the requirements for the installation of the machinery and equipment associated with *applications* (3.1.1.5).

3.1.7.2
operator
person using, operating, adjusting, maintaining, cleaning, repairing, troubleshooting, transporting, commissioning and disassembling

Note 1 to entry: This definition includes person or persons that can be expected at or near machinery, even if not performing a task associated with the specific machine.

3.1.7.3
user
entity that uses *robot applications* (3.1.1.4) and *robot cells* (3.1.1.8) and is responsible for the *operator(s)* (3.1.7.2) associated with the *robot applications* (3.1.1.4) and *robot cells* (3.1.1.8)

3.1.8 Functional safety-related

3.1.8.1
safety function
function of the machine whose failure can result in an immediate increase of the *risk(s)* (3.1.10.1)

[SOURCE: ISO 13849-1:2023, 3.1.27]

3.1.8.2
emergency stop
emergency stop function
function that is intended to

— avert arising or reduce existing *hazards* (3.1.6.1) to persons, damage to machinery or to work in progress, and

— be initiated by a single human action

Note 1 to entry: ISO 13850 gives detailed provisions.

[SOURCE: ISO 12100:2010, 3.40]

3.1.8.3
protective stop
interruption of operation intended to reduce risks

3.1.8.4
monitored-standstill
safety function (3.1.8.1) that monitors the absence of motion while drive power is active

Note 1 to entry: Previously, “monitored-standstill” was called “safety-rated monitored stop”.

3.1.8.5
monitored-speed
safety function (3.1.8.1) that limits the speed to a configured value

3.1.8.6
reduced-speed
safety function (3.1.8.1) that limits the speed to be no greater than 250 mm/s

3.1.8.7
single-point-of-control
single source of control
ability to operate such that initiation of motion is only possible from one source of control and cannot be overridden from another initiation source

3.1.8.8
software-based limiting
safety function(s) (3.1.8.1) with monitored limit(s) placed on the range of motion of the *robot* (3.1.1.2) or other equipment

3.1.8.9
safety function input
input signal having a specified safety-related performance

3.1.8.10
safety function output
output signal having a specified safety-related performance

3.1.9 Spaces, zones and distances

3.1.9.1
maximum space
space that can be reached by the moving parts of the *robot* (3.1.1.2)

Note 1 to entry: In the context of this document, maximum space applies to the *robot* (3.1.1.2). See Annex B, Figure B.2 for a figure of the *robot* (3.1.1.2) space.

Note 2 to entry: In the context of ISO 10218-2:2025, maximum space applies to either the *robot system* (3.1.1.3) or *robot application* (3.1.1.4). See Annex B, Figure B.1 and Figure B.3 for figures of spaces.

Note 3 to entry: In the context of *mobile platforms* (3.1.2.8), maximum space is indeterminate.

3.1.9.2
operating space
portion of the *restricted space* (3.1.9.3) that is used while performing all motions commanded by the *task program* (3.1.4.2)

Note 1 to entry: In the context of this document, operating space applies to the *robot* (3.1.1.2).

3.1.9.3
restricted space
portion of the *maximum space* (3.1.9.1) restricted by *limiting devices* (3.1.9.4)

Note 1 to entry: When the restricted space refers to the *robot system* (3.1.1.3), this includes the space reached by the *end-effector* (3.1.2.3), see ISO 10218-2:2025.

Note 2 to entry: When the restricted space refers to the *robot application* (3.1.1.4), this includes the space reached by the *end-effector* (3.1.2.3) and workpiece(s), see ISO 10218-2:2025.

3.1.9.4
limiting device
means that reduces the range of motion to a portion of the *maximum space* (3.1.9.1), resulting in the *restricted space* (3.1.9.3)

Note 1 to entry: ISO 12100:2010, 3.28.8 has a broader definition of a limiting device, which encompasses more than motion. In ISO 12100, it is a device that prevents a machine or hazardous machine condition(s) from exceeding a designed limit (such as space limit, pressure limit, load moment limit, etc.).

Note 2 to entry: Limiting device(s) can be fulfilled by *safety function(s)* (3.1.8.1), e.g. *software-based limiting* (3.1.8.8). See *safeguard* (3.1.10.4).

3.1.9.5
safeguarded space
space where *safeguards* (3.1.10.4) are active or where the perimeter safeguard provides protection

Note 1 to entry: This sometimes refers to the space within perimeter *safeguarding* (3.1.10.3).

Note 2 to entry: This can change dynamically.

3.1.9.6
separation distance
shortest permissible distance between any moving hazardous part of the *robot application* (3.1.1.4) and any *operator* (3.1.7.2)

Note 1 to entry: This value can be fixed or variable.

3.1.10 Risk reduction measures

3.1.10.1
risk
combination of the probability of occurrence of harm and the severity of that harm

[SOURCE: ISO 12100:2010, 3.12]

3.1.10.2
risk reduction measure
protective measure
measure intended to achieve risk reduction, implemented:

— by the designer (inherently safe design, *safeguarding* (3.1.10.3) and complementary protective measures, information for use); and/or

— by the *user* (3.1.7.3) (organization: safe working procedures, supervision, permit-to-work systems; provision and use of additional *safeguards* (3.1.10.4); use of personal protective equipment; training).

[SOURCE: ISO 12100:2010, 3.19, with addition of alternate term “risk reduction measure”]

Note 1 to entry: In the context of this document, “designer” is the robot manufacturer.

3.1.10.3
safeguarding
protective measure using *safeguards* (3.1.10.4) to protect persons from the *hazards* (3.1.6.1) that cannot reasonably be eliminated or *risks* (3.1.10.1) which cannot be sufficiently reduced by inherently safe design measures

[SOURCE: ISO 12100:2010, 3.21]

3.1.10.4
safeguard
guards or *protective devices* (3.1.10.5)

Note 1 to entry: *Protective devices* (3.1.10.5) include a broad range of means to reduce or control *risks* (3.1.10.1), for example:

— interlocking devices for guards;

— *sensitive protective equipment (SPE)* (3.1.10.6);

— *safety function* (3.1.8.1) that replace a *protective device* (3.1.10.5);

— *limiting devices* (3.1.9.4);

— limited movement control device.

[SOURCE: ISO 12100:2010, 3.26, modified — Note 1 to entry has been added.]

3.1.10.5
protective device
safeguards (3.1.10.4) other than a guard

Note 1 to entry: Examples of types of protective devices are provided in 3.28.1 to 3.28.9 of ISO 12100:2010.

[SOURCE: ISO 12100:2010, 3.18, modified — Note 1 to entry has been adapted.]

3.1.10.6
sensitive protective equipment
SPE
equipment for detecting persons or parts of persons that generates an appropriate signal to the control system to reduce *risk* (3.1.10.1) to the persons detected

[SOURCE: ISO 12100:2010, 3.28.5, modified — Note 1 to entry has been deleted.]

3.1.11 Verification and validation

3.1.11.1
verification
confirmation, through the provision of objective evidence, that specified requirements have been fulfilled

Note 1 to entry: Verification determines if the design meets its specification, e.g. through review, measurement, analysis, or inspection.

[SOURCE: ISO 9000:2015, 3.8.12, modified — modified by the deletion of Notes 1, 2, and 3 to entry and the addition of a new Note 1 to entry.]

3.1.11.2
validation
confirmation, through the provision of objective evidence, that the requirements for a specific intended use or *application* (3.1.1.5) have been fulfilled

Note 1 to entry: Validation determines if the specification accomplishes what was intended, e.g. that a specified limit is acceptable for its purpose. Validation includes functional testing.

[SOURCE: ISO 9000:2015, 3.8.13, modified —modified by the deletion of Notes 1, 2, and 3 to entry and the addition of a new Note 1 to entry.]

3.2 Abbreviated terms and symbols

Abbreviated term or symbol	Term
3P	3-position [*enabling device*]
Cat	Category
Class	Classification
DC	Diagnostic coverage
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
FMEA	Failure modes and effects analysis
F_{MPM}	maximum force per manipulator
HFT	Hardware fault tolerance
HGC	Hand-guided control
M	Mass per manipulator
n_{op}	Mean number of annual operations
PFH	Average frequency of a dangerous failure per hour
PFL	Power and force limiting
PL	Performance level
PL a	Performance level a
PL b	Performance level b
PL c	Performance level c
PL d	Performance level d

Abbreviated term or symbol	Term
PL e	Performance level e
SCS	Safety-related control system
SIL	Safety integrity level
SIL 1	Safety integrity level 1
SIL 2	Safety integrity level 2
SRP/CS	Safety-related parts of control system
SSM	Speed and separation monitoring
SPE	Sensitive protective equipment
TCP	Tool centre point
TCP/UDP	Transmission control protocol/ user datagram protocol

4 Risk assessment

A risk assessment in accordance with ISO 12100:2010 shall be performed for the robot.

NOTE 1 ISO 12100:2010 provides requirements and guidance in performing hazard identification and risk reduction.

NOTE 2 Annex A contains a list of hazards that can be present with robots. For robot application and robot cell requirements, see ISO 10218-2:2025.

5 Design and risk reduction measures

5.1 Robot design

5.1.1 General

The robot shall be designed in accordance with ISO 12100:2010.

For risk reduction measures concerning information, see Clause 7.

NOTE See IEC 60812:2018 and other similar standards for information about failure mode and effects analysis.

5.1.2 Materials, mechanical strength and mechanical design

5.1.2.1 General

Robots shall be designed and constructed to prevent hazardous situation(s) that result from failure due to fatigue and wear. Design and construction shall take into account the lifecycle of the intended use (e.g. transportation, installation, operating conditions and maintenance in accordance with the information for use).

5.1.2.2 Materials

The materials of the robot shall:

a) be selected to be appropriate for the intended use of the robot (e.g. resistance to corrosion, abrasion, impacts, temperatures, fatigue, brittleness, ageing);

b) not endanger persons' safety or health;

c) be non-toxic in all reasonably foreseeable conditions of use;

d) not be prone to brittle fracture, excessive deformation, or emission of toxic or flammable fumes;

e) retain their properties in the reasonably foreseeable range of climatic and workplace conditions, including temperature variations or sudden changes.

Where fluids are used, machinery shall be designed and constructed to prevent risks due to filling, use, recovery or draining.

5.1.2.3 Mechanical strength

The robot shall be designed and constructed to:

— withstand an overload in static tests without permanent deformation or patent defect, where strength calculations shall have a minimum static test coefficient of 1,25;

— undergo, without failure, dynamic tests using the maximum unit payload multiplied by the dynamic test coefficient, where the dynamic test coefficient shall be at least 1,1.

Dynamic tests shall be performed at the maximum speeds. If simultaneous motion can be programmed, the tests shall be done using the least favourable conditions.

5.1.2.4 Mechanical design

Robots shall be designed and constructed so that exposed sharp edges, sharp corners, and hazardous projections are reduced.

Hazardous mechanisms that enable motion (e.g. power transmission components) shall be installed or mounted inside the robot frame such that they are inaccessible.

Exposure to hazards caused by power transmission components such as motor shafts, gears, drive belts, or linkages that are not protected by integral covers (e.g. panel over a gear box) shall be prevented either by fixed guards or movable guards in accordance with ISO 14120:2015. The fixing systems of the fixed guards that are intended to be removed for routine service actions by users or operators shall remain attached to the robot or the guard. Movable guards shall be interlocked with the hazardous movements in such a way that the hazardous machine functions cease before they can be reached.

If these mechanical design measures are not practicable when considering the robot construction, then the information for use shall state that these risks shall be reduced during the integration.

NOTE Hazards derived from the movement of the robot application are addressed in ISO 10218-2:2025.

The design shall ensure that errors when fitting or refitting parts, that can be a source of risk, shall be prevented. If not practicable, the information for use shall be provided at least on the parts themselves and/or their housings.

5.1.3 Handling, lifting and transportation

Hazards due to sudden movements or instability such that tipping and falling-over during transport, lifting and handling of the robot or its component parts, shall be prevented if they are handled in accordance with the instructions for use.

One or more of the following measures shall be provided for lifting and shall be adequate for handling the anticipated load:

— appropriate design;

— additional support elements;

— adequate packaging.

Provisions for handling and lifting the robot and its associated components shall be provided and shall be adequate for handling the anticipated load.

EXAMPLE Lifting hooks, eye bolts, threaded holes, fork pockets.

For robots and any part of the robot intended to be handled separately whose weight does not exceed 23 kg and are designed for handling by one person, instructions may be sufficient for safe transport, lifting and handling.

NOTE See EN 1005-2 for manual handling of machinery and components parts of machinery.

5.1.4 Packaging

The robot, and any part of the robot intended to be handled separately, shall be designed or packaged such that the robot and its parts can be handled without injury and stored without damage when handled and stored in accordance with the information for use.

5.1.5 Stability

Robots shall be stable for installation, operation, use, disassembly and dismantling such that tipping and falling-over are prevented by specified mounting to affix the robot securely.

5.1.6 Temperature and fire risks

The design of the robot shall be such that the temperatures of accessible surfaces are in accordance with ISO 13732-1:2006 and ISO 13732-3:2005.

NOTE 1 ISO/TS 13732-2:2001 contains guidance on methods for the assessment of human responses to contact with surfaces at moderate temperatures.

Where there is a risk of fire or overheating, the design principles of ISO 19353:2019 shall be applied.

NOTE 2 Conforming with ISO 19353:2019 could require safety function(s).

5.1.7 Special equipment

Special equipment and accessories to enable the robot to be adjusted, maintained and used safely shall be supplied or made available.

NOTE Usual workplace equipment (e.g. ladders, spanners, screwdrivers, hexagonal keys) is not considered to be special equipment.

5.1.8 Position holding

If the loss of power can lead to a hazard due to gravity affecting the manipulator, the robot shall have a means for maintaining robot position without drive power (e.g. brakes, pins, or other technology).

The means for maintaining robot position without drive power shall use appropriate design margins in accordance with 5.1.2. A method shall be provided for testing the position holding means if failure of the position holding means can cause a hazardous situation, e.g. unexpected movement of the manipulator. A position holding monitoring safety function may be provided for testing of the position holding.

NOTE 1 See 5.3.4 for failure or fault detection when position holding is provided by a safety function.

NOTE 2 See 5.1.10 about power loss or change.

5.1.9 Auxiliary axis (axes)

Auxiliary axis (axes) is an optional capability. An auxiliary axis can be part of the robot's overall kinematic solution, allowing for coordination with the manipulator kinematics.

The means of position holding that is provided with auxiliary axis (axes) shall be in accordance with 5.1.8.

Auxiliary axes that are associated with lifting or holding a suspended mass, (e.g. machinery, sub-assemblies, equipment, the robot, a payload) shall conform with relevant requirements in this document (e.g. 5.1.1, 5.1.2, 5.1.8, 5.2, 5.3, 5.4, 5.5, 5.7). When the auxiliary axis motion affects the TCP speed in reduced-speed manual mode, the requirements of reduced-speed (5.5.3.1) shall apply to the auxiliary axis (axes).

When a monitored-speed safety function is provided with the robot, this safety function (see 5.5.3.2) shall also be provided for the auxiliary axis (axes).

Axis limiting shall be provided in accordance with 5.7 when the auxiliary axis (axes) is included in the three axes of greatest (largest) displacement motions.

5.1.10 Power loss or change

Loss or change of electrical, hydraulic or pneumatic power to the robot shall not result in a hazardous situation. Re-initiation of power shall not lead to a hazardous situation through

— any movement(s); or

— a change of safety-related parameters.

The robot shall conform to ISO 14118:2017 to prevent unexpected start-up.

NOTE See IEC 60204-1:2016+AMD1:2021 for electrical power supply requirements. See ISO 4413:2010 for hydraulics and ISO 4414:2010 for pneumatics requirements.

5.1.11 Component malfunction

Robot components shall be designed, constructed, secured, or contained in accordance with 5.1.2, so that risks caused by breaking, loosening, or releasing, including those related to stored energy, are reduced to an acceptable level.

5.1.12 Hazardous energy

Stored energy shall not cause hazardous situation(s). A means shall be provided to prevent uncontrolled or hazardous release of stored energy. If the hazardous energy is potential (e.g. spring balancer, gas balancer), the robot shall have means to secure it in a position that can be either the energized or de-energized position.

The robot shall be fitted with means to isolate it from all energy supply sources. This means shall be capable of being locked or secured.

Safe release or containment shall be provided in accordance with ISO 14118:2017.

A label shall be affixed to identify the stored energy hazard.

Where axes (e.g. robot, auxiliary) can move due to gravity, means shall be applied either to prevent axis motion or to ensure that resulting motions can be initiated and result in a de-energized position in a controlled way. Safety function(s) for position holding (see 5.1.8) may be provided to prevent uncontrolled or hazardous release of stored energy.

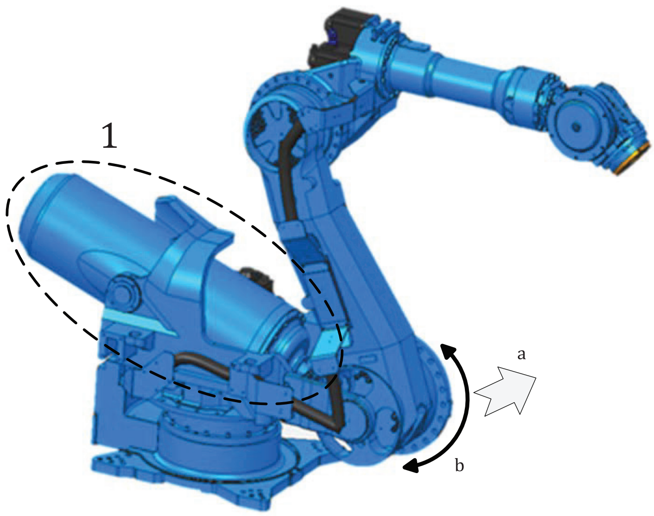
NOTE 1 Hazardous energy can take many forms, e.g. kinetic, gravity, electrical, pneumatic, hydraulic, thermal, chemical. The sources of these energies can sometimes be readily identified. However, often the sources are hidden or not obvious, e.g. accumulators, capacitors, batteries, springs, counterbalances, flywheels, heat as an outcome due to friction or other reactions.

NOTE 2 Energy saving capabilities, e.g., energy recovery or regeneration locally at the robot or back to the local mains electrical supply, can be a source of stored energy.

NOTE 3 This document does not cover hazards associated with nuclear, potential explosive environments, and radiation. See Scope 1.

NOTE 4 Preventing axis movement can be provided by securely fixing with bolts, holding brackets with sufficient design margin, etc.

NOTE 5 Figure 1 shows an example of stored energy in a spring balancer. A hazardous situation can occur when a motor is removed, even though the energy supply to the robot is isolated. Upon release, the unexpected motion of the robot due to the energy in the spring balancer can cause injury, e.g. crushing, entrapment.



Key

1 spring balancer

a Motor removal (direction of motion removal).

b Motion direction.

Figure 1 — Example of stored energy in a spring balancer

5.1.13 Electrical, pneumatic and hydraulic parts

The electrical parts shall be in accordance with the relevant requirements of IEC 60204-1:2016+AMD1:2021.

The pneumatic equipment shall be in accordance with the relevant requirements of ISO 4414:2010.

The hydraulic equipment shall be in accordance with the relevant requirements of ISO 4413:2010.

NOTE 1 For requirements related to specific sub-assemblies and components, see the relevant IEC or ISO standards (e.g. IEC 60269 series, IEC 60947 series, ISO 13850:2015).

Electrical, pneumatic and hydraulic connectors shall be selected to prevent erroneous connection when this can lead to a hazardous situation. Where this is not practicable, connectors shall be labelled to lessen the likelihood of erroneous connection(s).

NOTE 2 See IEC 60204-1:2016+AMD1:2021, 13.4.5 for requirements for plug-socket combinations.

Electrical, pneumatic and hydraulic connectors that can cause a hazard if they are separated or if they break away shall be designed and implemented to prevent unintended separation.

5.1.14 Tool centre point (TCP) setting

If a TCP setting is needed for a safety function, it shall be possible for a TCP setting to be entered in accordance with 5.3.5.

Failure to enter the TCP setting when required shall result in a warning to enter a value. Upon manual reset of the warning, the program may continue. After the manual reset of the warning, subsequent warnings are not required.

The range of acceptable values shall be limited.

If the robot has a TCP monitored-speed safety function, a TCP offset setting can be necessary.

NOTE 1 TCP settings are the dimensional values that define the location of the TCP relative to the mechanical interface to enable the TCP to be controlled (e.g. speed, pose, axis limits).

NOTE 2 If the robot and auxiliary axes are being operated in coordination with one another, each individual axis can move at different speeds, and this includes the auxiliary axis.

5.1.15 Payload setting

If a payload setting is needed for a safety function, it shall be possible for a payload setting to be entered in accordance with 5.3.5.

Failure to enter the payload setting when required shall result in a warning to enter a value. Upon manual reset of the warning, programming or parameterization may continue. After the manual reset of the warning, subsequent warnings are not required.

The range of acceptable values shall be limited.

5.1.16 Cybersecurity

A cybersecurity threat assessment shall be conducted. If the cybersecurity threat assessment identifies that a threat can result in safety risk(s), cybersecurity measures shall be provided to prevent unauthorized access to the control system of the robot plus its hardware, software, application software and related configuration data.

NOTE 1 The means to prevent unauthorized access can include the following:

— ability to disable access to communications ports, e.g. Transmission Control Protocol/ User Datagram Protocol (TCP/UDP) port;

— ability to change the TCP/UDP port number, e.g. logical connection;

— authenticated protection of the safety configuration;

— ability to change the default configuration (e.g. usernames user passwords, IP addresses, safety authentication);

— use of encrypted and authenticated protocols.

NOTE 2 For guidance about IT-security (cybersecurity) aspects and ISO 12100:2010, see ISO/TR 22100-4:2018.

NOTE 3 For information about security aspects related to functional safety, see IEC TS 63074: 2023.

NOTE 4 For information and requirements about the security risk assessment for system design, see IEC 62443-3-2:2020.

5.1.17 Robot class

Robots shall be classified as either Class I or Class II. Classification as a Class I robot shall be determined in accordance with Table 1, by the maximum capability of the manipulator without being limited by robot or safety functions, based on the following values:

a) mass per manipulator (M);

b) maximum achievable speed;

c) maximum force per manipulator (F_{MPM}) in accordance with the test methodology in Annex E.

NOTE 1 M, Maximum achievable speed, and F_{MPM} are not used for determining risk or suitability for use in collaborative applications (see ISO 10218-2:2025). These are factors solely used in determining if a robot is a Class I robot.

The mass per manipulator (M) shall be determined by measurement of the weight of the moveable parts of the manipulator without its fixed base. When the manipulator is intended to be used in applications where the base moves, the mass per manipulator including the base and its fastenings shall be provided.

NOTE 2 Applications where the base moves can include mounting the manipulator (including its base) to a mobile platform, track, gantry, etc.

Class I robots shall fulfil all the following requirements:

— mass per manipulator (M) shall be 10 kg or less; and

— maximum achievable speed shall be 250 mm/s or less; and

— maximum force per manipulator (F_{MPM}) shall be 50 N or less.

Robots may be classified as a Class II robot without performing testing in accordance with Annex E. In this case, the robot shall meet the requirements of Class II robots including the functional safety requirements in accordance with 5.3 and Annex C.

A robot shall be classified as Class II if it meets any one of the requirements for Class II in Table 1.

Table 1 — Robot class

Robot Class	Mass per manipulator (M) [kg]	Maximum force [a] per manipulator (F_{MPM}) [N]	Maximum speed [mm/s]
I	10 and under	50 and under	250 and under
II	Over 10	Over 50	Over 250

NOTE

M is the mass per manipulator.

See Annex E for M test methodology.

If multiple manipulators are provided, M is per manipulator.

See Reference [20] study in FP 0317 (Mainz Study) for derivation of the 50 N maximum force per manipulator value (F_{MPM}).

[a] Maximum force is with a manipulator minimum contact area of 1 cm^2[3],[20].

Reference [20] FP 0317 (Mainz Study): the third quartile of the 29 body parts that were considered (except head and neck) study FP 0317 shows that forces of around 50 N are below pain onset independent of pressure (except needles and knives). Therefore, the 50 N limit can be applied as a general borderline between robot class I and II.

5.2 Controls

5.2.1 General

Control systems shall be designed so that reasonably foreseeable human error during operation does not lead to hazardous situations.

5.2.2 Protection from unexpected start-up

The means for the prevention of unexpected start-up shall conform to ISO 14118:2017. Control functions to prevent unexpected start-up shall be implemented and control devices, if provided, shall be located appropriately.

Unexpected start-up due to a start command that is the result of a failure in or an external influence on the control system shall be avoided by appropriate control system design in accordance with the requirements of 5.3, 5.4 and 5.5.

Unexpected start-up due to a start command generated by inopportune action on a start control or other parts of the machine such as a sensor or a power control element shall be prevented by a start/restart interlock function in accordance with 5.5.2.1.

Unexpected start-up due to restoration of the power supply after an interruption shall be prevented by a start/restart interlock function in accordance with 5.5.2.1.

NOTE See Annex I and Figure I.1.

5.2.3 Singularity

Motions defined in Cartesian space that pass near singularities can produce unexpected axis speeds and motions. Prior to the occurrence of a singularity, the robot shall fulfil one of the following:

a) control motion and speed to avoid a singularity or have no hazardous motion while passing through the singularity;

b) task program execution stops without further motion, a warning is provided, and recovery from the stop requires a manual restart;

c) generate an audible or visible warning signal and continue to pass through the singularity with speeds limited in accordance with reduced-speed (5.5.3.1).

NOTE Risks due to singularity can occur in manual mode (5.2.7.2) and when capabilities used to enable collaborative applications (5.10) are active.

5.2.4 Interlocking devices

Interlocking devices associated with guards shall conform to ISO 14119:2024.

NOTE See 5.5.2.

5.2.5 Status indication and warning devices

Status of the robot shall be unambiguously indicated or signalled. When provided, indicators shall be suitable for the installed location and shall meet the requirements of IEC 60204-1:2016+AMD1:2021.

When provided, warning devices (e.g. audible and visual) shall be in accordance with ISO 12100:2010, IEC 60204-1:2016+AMD1:2021 and IEC 60073:2002.

NOTE IEC 60073:2002 contains the basic and safety principles for man-machine interface, marking and identification – coding principles for indication devices and actuators. IEC 61310 series is specific to safety of machinery with requirements for indication, marking and actuation. The IEC 61310 series is normatively referenced in IEC 60204-1:2016+AMD1:2021.

5.2.6 Labelling

Control devices, indicators and displays shall be labelled to clearly indicate their function (e.g. power on "|", power off "O", in accordance with IEC 60204-1:2016+AMD1:2021 and IEC 60073:2002).

NOTE See Annex F.

5.2.7 Modes

5.2.7.1 Automatic

The robot shall have an automatic mode for execution of the task program. When a task program is executed in automatic mode, the relevant configured safety functions shall be active. Any detected stop condition shall result in a stop for all moveable parts of the robot.

If HGC is provided for use while in automatic mode, movements using Hand-Guided Control (HGC) shall be in accordance with 5.10.2.

Initiating automatic operation shall be in accordance with 5.2.9.

5.2.7.2 Manual

5.2.7.2.1 General

Robot movements shall only be possible in accordance with 5.2.8 utilizing a single-point-of-control.

NOTE 1 For information about movement without drive power, see 5.8.

NOTE 2 For the requirements of single-point-of-control, see 5.5.1.

These movements can be manual movements by an operator or robot movements by the robot control.

If HGC is provided for use while in manual mode, movements using Hand-Guided Control (HGC) shall be in accordance with 5.10.2.

NOTE 3 Manual movement of the robot is when movement is caused by an operator using HGC (i.e. when HGC is active, the human effort of pushing/pulling causes the manipulator motion). Robot movements in manual mode using HGC are movements caused by the robot control (i.e. motion is initiated by HGC to the robot control for manipulator motion).

5.2.7.2.2 Reduced-speed

The robot shall have a reduced-speed manual mode for jogging, teaching, programming and program verification.

NOTE 1 For the requirements of speed limiting, see 5.5.3.

Robot movements using the teach pendant shall only be possible during the actuation of the 3P enabling device in accordance with 5.5.4 and with reduced-speed in accordance with 5.5.3.1.

Automatic operation shall be prevented when the robot is in manual mode.

NOTE 2 Previously, reduced-speed manual mode was also known as manual reduced-speed, T1 or teach.

5.2.7.2.3 High-speed

The robot may have a high-speed manual mode, where the speed may be greater than reduced-speed. High-speed manual mode is intended only for verification of programmed tasks (see ISO 10218-2:2025).

When high-speed manual mode is provided, the robot shall have all the following:

a) means to select and activate high-speed manual mode in accordance with 5.2.7.3;

b) means to manually increase the speed in multiple steps, starting from the reduced-speed setting which can be 250 mm/s or lower;

c) display of the actual speed;

d) monitored-speed safety function in accordance with 5.5.3.2 that is active;

e) separate start/stop control in conjunction with a 3P enabling device in accordance with 5.5.4;

f) speed limit that shall be no greater than the reduced-speed setting:

— upon selection or activation of high-speed manual mode;

— if the 3P enabling device is released for five (5) minutes or more, where the high-speed time limitation safety function has a minimum functional safety performance of PL a (Annex C, Table C.2);

g) safety function output when high-speed manual mode is active.

The robot may have one or both of the following capabilities:

— the means to disable high-speed manual mode;

— the means to set the monitored-speed limit to a value of 250 mm/s or lower.

NOTE This optional high-speed manual mode has previously been known as manual high-speed or T2.

5.2.7.3 Selection, activation and change of the operating mode

Selection of the operating mode shall require a deliberate manual action, e.g., use of a key switch, selection on a touch screen.

The means of mode selection is not required to conform to any functional safety requirements; it is out of the scope of the safety-related parts of the control system. See Figure 2.

NOTE 1 Figure 2 shows information flow and does not represent physical devices or architecture.

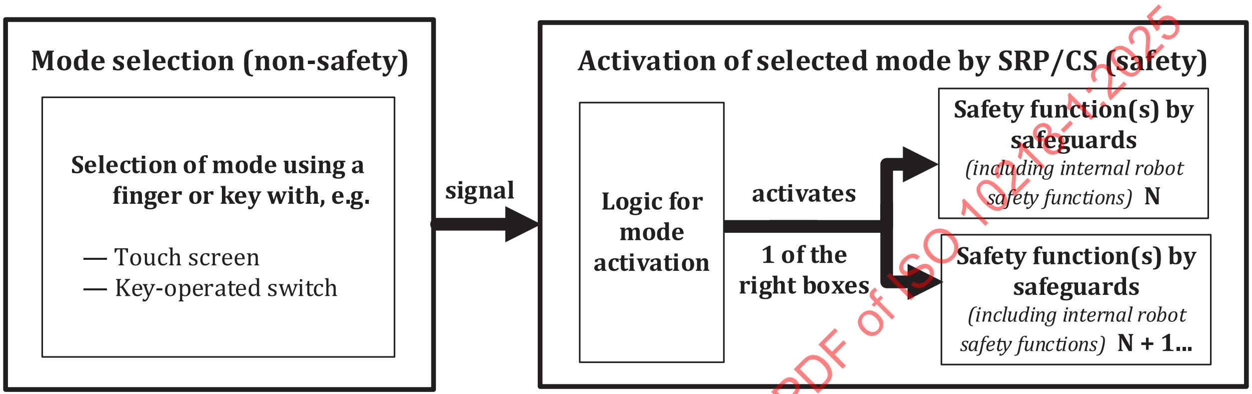


Figure 2 — Separation of mode selection and mode activation

Initiation of motion shall be in accordance with the requirements of start/restart interlocking (5.5.2.1). Only one operating mode shall be active at a time.

The active mode shall be:

— clearly identifiable;

— unambiguously indicated.

Unauthorized and/or inadvertent activation of mode shall be prevented by suitable means. The suitable means may include restricting access with a secured access means (e.g. key switch, access control systems or access codes) that limits the use of some modes or functions of the robot.

If the activation of a mode results in a change in the active safety functions or its parameters, the mode activation safety function shall conform with ISO 13849-1:2023, 5.2.2.9 and the following shall be fulfilled:

a) the activation of the selected mode shall be considered a safety function;

b) protective stop (5.4.3) shall be initiated;

c) activation of safety functions shall result from the output of the logic for mode activation;

NOTE 2 See Figure 2.

d) each mode shall activate the required safety functions active for that mode.

NOTE 3 Many robots implement manual mode so that the robot inputs for the "perimeter safeguard" are not active in manual mode (to allow entry), while "perimeter safeguard" would be active in automatic. This means that safety functions change when activating manual mode, such that the teach pendant 3P enabling device is activated while the perimeter safeguards could be deactivated. Optional mode indicator output(s) may be provided to indicate the active mode. When provided for safety-related purposes, the safety function output(s) shall conform to 5.3.

NOTE 4 Symbols for mode labelling are shown in Annex F.

5.2.8 Means of controlling the robot

5.2.8.1 General

The robot shall have the means to control, command, program/teach, configure and troubleshoot the robot. At least one of the following means shall be provided:

a) direct control (5.2.8.2) by a control panel or teach pendant;

b) external control capability (5.2.8.3).

Each control station, including teach pendant, that has the capability of initiating robot motion, shall have an emergency stop device in accordance with ISO 13850:2015, 4.3.5, for the initiation of an emergency stop function in accordance with 5.4.2.

When a control station is provided with the capability to initiate motion or hazardous functions, the control station shall have the capability to stop this motion and hazardous functions, i.e. normal stop in accordance with 5.4.4.

NOTE 1 Any unit linked to the robot, that only has the capability of displaying robot parameters is not considered to be a control station or teach pendant of the robot.

Where control stations are mounted onto or within the robot manipulator, hand-guided control (HGC) in accordance with 5.10.2 shall be provided.

Control panels shall be in accordance with IEC 61310-1:2007, IEC 61310-2:2007 and IEC 61310-3:2007.

A visual signal at the control station shall indicate the active status of a control station (e.g. an indicator light on a control panel or a teach pendant display).

For robots with external control capability, control stations shall indicate when external control is active.

NOTE 2 For requirements of single-point-of-control, see 5.5.1.

5.2.8.2 Direct control

When direct control is provided, it shall be in accordance with single-point-of-control (5.5.1). When the robot is under direct control, the following shall be prevented from external controls (5.2.8.3):

a) initiation of robot motion;

b) program changes;

c) changes of safety configuration;

d) change of control to another control station;

e) updates to the control program.

The activation of the direct control shall be the result of a deliberate manual action on a specific control device on the control station. The activation of the direct control shall always override any other sources of control.

NOTE 1 For means of controlling the robot by use of teach pendant(s), see 5.2.8.4 and 5.2.8.5.

NOTE 2 For means of controlling the robot by use of HGC, see 5.10.2.

5.2.8.3 External control

External control capability may be provided. When external control is provided, it shall be in accordance with single-point-of-control (5.5.1). If a means of programming is not provided with the robot, such that external means are required (e.g. by connection to a computer), those means shall be considered external controls. When external control is provided, the external control enable safety function shall have a minimum functional safety performance of PL a (Annex C, Table C.2).

When external control is provided in addition to direct control, the following shall be fulfilled in accordance with single-point-of-control (5.5.1):

a) a deliberate manual action shall be required at the direct control to enable the external control;

b) enabling of the direct control shall result in an immediate disabling of any external control.

NOTE For means of controlling the robot (5.2.8) which includes teach pendants, see 5.2.8.4.

5.2.8.4 Teach pendant(s)

Teach pendants may have a fixed connection (e.g. fixed attached cable) to the robot or a detachable connection (e.g. pluggable detachable cable or wireless connection) in accordance with 5.2.8.5. Any teach pendant that can initiate motion or cause movement(s) shall have an enabling function and a 3P enabling device in accordance with 5.5.4.

When in manual mode(s), a loss of communication shall result in a stop for all robots being controlled.

Teach pendants shall be provided with the following means or instructions:

— placement or stowage to minimize the possibility of damage that can result in a hazard;

— cable stowage, if applicable, to reduce entanglement and tripping hazards.

The mass and size of teach pendants shall not lead to fatigue and discomfort derived from the intended use.

NOTE EN 1005-5 gives guidance for the evaluation of handling machine parts with masses under 3 kg. EN 1005-2 gives guidance for the evaluation of handling machine parts with masses equal or larger than 3 kg over distances under 2 m.

5.2.8.5 Cableless or detachable teach pendant(s)

Teach pendants that have no cables connecting to the robot or where the cable can be detached, the following shall be fulfilled:

a) visual indication shall be provided to show that the teach pendant is active (e.g. at the teach pendant display);

b) visual indication shall be provided to indicate to which robot the teach pendant is connected (e.g. at the teach pendant display, on the manipulator, at the manipulator base);

c) loss of safety-related communication shall result in a stop in accordance with 5.3.4 for all robots being controlled;

d) restoration of safety-related communication shall not restart robot motion without a separate deliberate manual action;

e) an unambiguous means shall be provided to connect and disconnect the teach pendant from the robot (e.g. a deliberate manual action by the operator);

f) safety-related wireless communication (e.g. radio, infrared) of teach pendants shall be in accordance with IEC 62745:2017;

g) their emergency stop device(s) shall be in accordance with ISO 13850:2015, 4.3.8 to prevent confusion between active and inactive emergency stop devices.

5.2.9 Means of initiating automatic operation

Automatic operation shall not start until there is a deliberate manual action on a control device. The robot shall provide the means to:

— start automatic operation from a control device other than the teach pendant;

NOTE 1 This function can be achieved by the start/restart interlock, see 5.5.2.1.

— prevent robot automatic operation from being initiated only by the teach pendant.

NOTE 2 This can be provided by the integration (ISO 10218-2:2025) using an external input to the robot.

5.3 Safety functions

5.3.1 General

Safety-related control systems (electric, hydraulic, pneumatic, mechanical and software) shall conform to 5.3 and Annex C.

The safety-related control system performance of all safety functions of the robot shall be provided in accordance with 7.5.12.

NOTE 1 Table D.1 shows an example format to present the required information.

A robot may be provided with capabilities and safety functions in accordance with 5.10 to enable the implementation of collaborative applications in accordance with ISO 10218-2:2025.

NOTE 2 Safety-related control systems can also be called SRP/CS (safety-related parts of control systems) or SCS (safety-related control system).

5.3.2 Functional safety standards

Safety-related parts of the control system (SRP/CS or SCS) shall be designed in accordance with either ISO 13849-1:2023 or IEC 62061:2021.

NOTE ISO 13849-1:2023 and IEC 62061:2021 address functional safety using similar but different methods.

5.3.3 Performance

For Class I robots (5.1.17), the minimum functional safety performance for safety functions shall be in accordance with Annex C.

For Class II robots, the minimum functional safety performance for safety functions shall be at least one of the following:

— Performance Level (PL) d, category 3 architecture in accordance with ISO 13849-1:2023;

or

— Safety Integrity Level (SIL) 2, hardware fault tolerance (HFT) is equal to 1, with a mission time of no less than 20 years, in accordance with IEC 62061:2021;

or

— Performance Level (PL) d or SIL 2, with a PFH less than $4,43 \times 10^{-7}$/h.

Another criterion may be provided for a specific safety function in accordance with Table C.2.

NOTE A robot application can require safety function(s) meeting PL e (Cat 3) or SIL 3 (HFT 1). See ISO 10218-2:2025.

A robot may have safety functions with a higher functional safety performance than the required PL d or SIL 2 that may be integrated into safety function subsystems external to the robot using safety-related inputs and outputs.

Robot safety-related inputs and outputs associated with a PL d or SIL 2 safety function shall be redundant and capable of being implemented into an external control system with a redundant architecture.

5.3.4 Failure or fault detection

Any detected fault of the safety-related control system shall result in a reaction that is appropriate for the intended performance of the safety function. Depending on the safety function and the fault, the appropriate reaction can include finishing the cycle or initiating a stop that shall be a stop category 0 or 1 in accordance with IEC 60204-1:2016+AMD1:2021.

NOTE Triggering a safety function indicates that the safety function is working as intended. This is not a failure or fault of the safety function. The triggering of the safety function results in the defined behaviour of the safety function according to Annex C.

5.3.5 Parameterization of safety functions

The robot shall be provided with the means and capability for software-based parameterization of safety-related application software and for designing the safety-related application software. This shall be considered as a safety-related aspect as stated in ISO 13849-1:2023, 5.2.2.7 and 6.3 or IEC 62061:2021, 6.7.

A software tool that can directly influence the safety-related system during automatic mode shall be considered a software element of the safety-related system. Therefore, software on-line tools, as defined in IEC 61508-4:2010, 3.2.10, shall not be used.

NOTE 1 For guidance about on-line and off-line tools, see IEC 61508-3:2010, 7.4.4.1 and definitions 3.2.10 and 3.2.11 in IEC 61508-4:2010.

NOTE 2 Correct operation of a safety function is based on proper and reliable setting of a safety-related parameter(s) used in the safety function(s), especially for safety-related application software.

Once the safety function(s) is activated, the safety function(s) shall always be active upon turning power on and an identifier (e.g. checksum) shall be generated so that changes to these settings can be identified.

Manual change(s) to safety-related parameters shall require a restart of the robot after change(s). Safety-related parameters shall not be capable of being reconfigured during automatic execution of the task program.

For a specific parameter, a set of different values may be configured and a specific value of the different set automatically applied during a specific part of the task program.

Information on the active settings and configuration of the safety functions shall be capable of being viewed and documented, for example by showing the identifier's result on the user interface. Additional data may be provided (e.g. configuration information, authorized personnel, configuration date).

5.3.6 Communications

When data communications are used in the implementation of a safety function, the requirements of IEC 61508-2:2010, 7.4.11 shall be applied. The three permissible transmission categories are described in Table 2.

Table 2 — Categories of communications transmission systems

Transmission Category	Main characteristics
1	Designed for known and fixed maximum number of participants. All properties of the transmission system are known and invariable during the lifetime of the system. Negligible opportunity for unauthorised access.
2	Properties are unknown, partially unknown or variable during the lifetime of the system. Limited scope for extension of user group. Known user group or groups. Negligible opportunity for unauthorized access (networks are trusted). Occasional use of non-trusted networks.
3	Properties are unknown, partially unknown or variable during the lifetime of the system. Unknown multiple user groups. Significant opportunity for unauthorized access.

SOURCE: IEC 62280:2014 Table B.1, modified to delete the 3rd (right) column[a]

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NOTE 1 A transmission category 1 network typically has a fixed maximum number of participants, while a category 2 network is a less controlled network but has negligible opportunity for unauthorized access. A transmission category 3 network has unknown properties and a high risk of unauthorized access.

NOTE 2 For a description of communications categories, see IEC 62280:2014 or EN 50159:2010.

When a robot has an internal communication network, the network shall be considered as a transmission category 1 network in accordance with Table 2. When a robot has an external network, the network shall be considered as a transmission category 2 or category 3 network in accordance with Table 2. Table 3 describes countermeasures as described in IEC 62280:2014.

Table 3 — Robot network – countermeasure requirements

Transmission Category	Repetition	Deletion	Insertion	Resequence	Corruption	Delay	Masquerade
1	+	+	+	+	++	+	-
2	++	++	++	+	++	++	-
3	++	++	++	++	++	++	++

Key

- Threat can be neglected.

\+ Threat exists, but rare; weak countermeasures sufficient.

++ Threat exists; strong countermeasures required.

SOURCE: IEC 62280:2014 Table B.2, modified to delete the note[a]

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5.3.7 Electromagnetic compatibility (EMC)

EMC of the safety-related control system shall conform to the electromagnetic interference (EMI) and EMC requirements of ISO 13849-1:2023 or IEC 62061:2021 as applied.

NOTE This requirement is relevant to functional safety. Other EMC standards can be required by other standards.

5.4 Stopping functions

5.4.1 General

Every robot shall have

— a normal stop function whereby the robot can be brought safely to a complete stop;

— a protective stop function; and

— an independent emergency stop function.

Each stop function shall have provision for the connection of external devices.

The robot shall be designed such that stop functions have precedence over any other control functions. When a stop function has been initiated, no other control functions shall enable robot movement until the absence of motion has been achieved.

The functional safety performance shall be in accordance with 5.3 and Annex C. Table 4 compares the stop functions.

Table 4 — Comparison of the stop functions

Parameter	Emergency stop (5.4.2)	Protective stop (5.4.3)	Normal stop (5.4.4)
Purpose	Emergency situation	Safeguarding	Stopping, off
Effect	Cease hazardous movements and hazardous functions in a safe manner, then remove energy	Safely control the safeguarded hazard(s) then initiate a monitored-standstill (5.5.5) if the protective stop is a stop category 2	Bring the robot safely to a complete stop and if applicable, stop all hazardous functions, then remove energy to robot actuators
Initiation	Manual activation of the emergency stop device	Manual, automatic or automatically initiated by safety-related I/O or safety function(s)	Manual activation of the normal stop device
Stop category in accordance with IEC 60204-1:2016+AMD1:2021	0 or 1 *See also ISO 13850:2015*	0, 1, or 2 Only 0 or 1 if used for Normal Stop	0 or 1
Safety-related control system performance	5.3 and Annex C, Table C.2	According to 5.3 and Annex C, Table C.1	According to Table C.2
Reset	Manually disengaged	Manual or Automatic Can vary with each safety function that initiates a protective stop	Not applicable
Use frequency	Infrequent	Variable: from ongoing (e.g. internal robot safety functions) to infrequent	Frequent

5.4.2 Emergency stop

5.4.2.1 General

The robot shall have an emergency stop function, with either stop category 0 or stop category 1, in accordance with IEC 60204-1:2016+AMD1:2021. The emergency stop function and emergency stop device(s) shall be in accordance with ISO 13850:2015. The emergency stop function shall fulfil the following:

a) take precedence over all other controls and stop functions;

b) cause all hazards within the span-of-control to stop;

c) remove drive power from the robot actuator(s);

d) remain active until it is reset;

e) be in accordance with 5.3 and Table C.2 with a minimum functional safety performance of PL c or SIL 1.

The emergency stop function shall only be reset by a deliberate manual action. The deliberate manual action does not cause a restart after resetting; it shall only permit a restart, of operation or the task program, to occur.

The robot shall include the capability for the connection of an external emergency stop device for use by the robot application, see ISO 10218-2:2025.

5.4.2.2 Control station

Any control station that has the capability of initiating robot motion or other hazardous situations shall have a manually initiated emergency stop function.

5.4.2.3 Emergency stop output

When a safety function output for an emergency stop is provided, the following shall be fulfilled:

a) the output shall remain operative when power is turned off and then turned on;

b) fault detection shall be in accordance with 5.3.4;

c) functional safety performance shall be in accordance with 5.3 and Table C.2.

5.4.3 Protective stop

5.4.3.1 General

The robot shall have one or more protective stop functions that have the capability to be initiated by an internal safety function or external protective device(s).

The protective stop safety function shall:

a) cause a stop of all robot motion;

b) be a stop category 0, 1 or 2, in accordance with IEC 60204-1:2016+AMD1:2021;

c) if the protective stop is a stop category 2 in accordance with IEC 60204-1:2016+AMD1:2021, it shall result in a monitored-standstill in accordance with 5.5.5.

This stop may be initiated manually or automatically.

5.4.3.2 Protective stop output

When a safety function output for a protective stop is provided, the output shall continue to function or generate a protective stop upon removal of power.

5.4.4 Normal stop

The robot shall be provided with a means to initiate a normal stop function which stops the robot and if applicable stops its hazardous functions.

The normal stop function, when activated, initiates a stop category 0 or 1 in accordance with IEC 60204-1:2016+AMD1:2021. The protective stop function may be used as the normal stop function when it conforms with a stop category 0 or 1 of IEC 60204-1:2016+AMD1:2021.

The normal stop safety function shall be in accordance with 5.3 and shall have a minimum functional safety performance of PL b (Annex C, Table C.2).

Stop category 2 according to IEC 60204-1:2016+AMD1:2021 shall not be used for a normal stop function.

5.5 Other safety functions

5.5.1 Single-point-of-control

Only one source of control shall be accepted at one time.

Assuring a single-point-of-control shall be implemented as a safety function in accordance with 5.3 and Annex C, Table C.2 with a minimum functional safety performance of PL a.

NOTE Single-point-of-control is a “single source of control”.

The access system is not required to conform to any safety function and is out of the scope of the safety-related parts of the control system. See Figure 3.

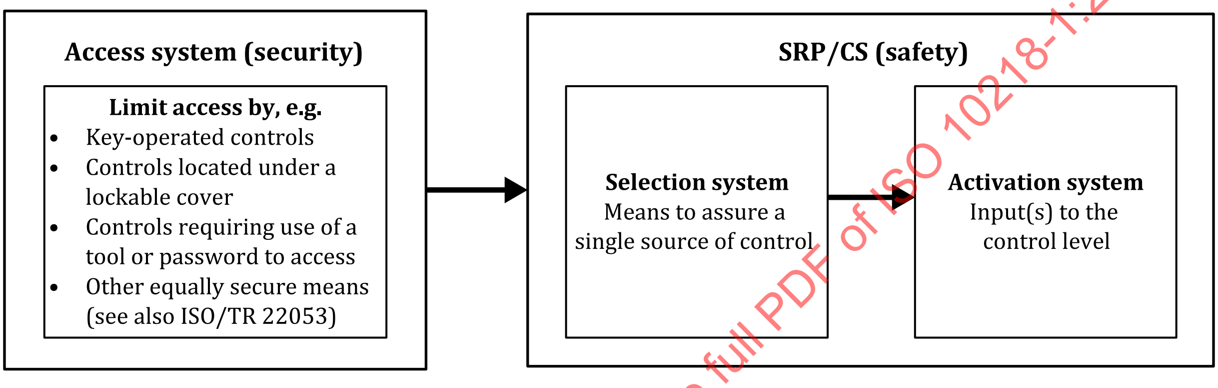


Figure 3 — Example of the access system (security) and SRP/CS

5.5.2 Start/restart interlock and reset

5.5.2.1 Start/restart interlock

The robot shall have a start/restart interlock safety function to prevent automatic start of the robot

— when the energy supply to the robot is switched on or is interrupted and restored;

— after a change of the active mode from:

a) automatic mode to manual mode;

b) reduced-speed manual mode to high-speed manual mode and vice versa (i.e. from high-speed manual mode to reduced-speed manual mode);

c) modes described in 5.2.7 to other modes and vice versa, when the automatic start can lead to a hazard.

The start/restart interlock shall be in accordance with 5.3 and Annex C, Table C.1, with a minimum functional safety performance of PL d. Automatic restart shall conform with ISO 13849-1:2023, 5.2.2.4.

NOTE See Annex I and Figure I.1.

5.5.2.2 Reset

A reset safety function shall be provided to:

a) reset the start/restart interlock which may be reset by either:

— a deliberate manual action of a specific control device in a control station of the robot (e.g. an electro-mechanical pushbutton in a control panel, a virtual pushbutton on the touch screen in a teach pendant); or

— initiation externally;

b) allow the resetting of internal robot safety functions:

— if required for internal robot safety functions; and

— if the resetting is not part of start/restart interlock.

The reset safety function shall be in accordance with 5.3 and Annex C, Table C.2, with a minimum functional safety performance of PL b.

The manual reset safety function shall conform to ISO 13849-1:2023, 5.2.2.3.

Unintended reset shall be prevented by either accepting the release of the actuator from its energized (on) position or another suitable method (e.g. two activation zones on a touch sensitive screen).

NOTE See Annex I and Figure I.1.

5.5.3 Speed limit(s) monitoring

5.5.3.1 Reduced-speed

The robot shall have a reduced-speed safety function to enable limiting the speed(s) to 250 mm/s or less. With the reduced-speed safety function active, the speed of the TCP and any exposed part of the manipulator shall not exceed 250 mm/s including the effects of any auxiliary axis.

NOTE 1 This can be achieved by monitoring the TCP and the speed of the joints.

The robot shall have the capability to select a speed lower than 250 mm/s as the maximum limit parameter for reduced-speed monitoring.

NOTE 2 For parameterization requirements, see 5.3.5.

Reduced-speed functional safety performance shall be in accordance with 5.3. This safety function shall be active in reduced-speed manual mode (see 5.2.7.2.2).

NOTE 3 See ISO 10218-2:2025 for manual mode reduced-speed requirements of the robot application.

5.5.3.2 Monitored-speed

Monitored-speed shall be in accordance with 5.3. The robot may have a monitored-speed safety function(s) to enable limiting the speed to the configured value(s).

NOTE 1 Monitored-speed is required for HGC, SSM and PFL, according to 5.10.2, 5.10.3 and 5.10.4.

With the monitored-speed safety function active, the speed of the TCP and any exposed part of the manipulator shall not exceed the set (monitored) speed including the effects of any auxiliary axis.

NOTE 2 This can be achieved by monitoring the TCP and the speed of the joints.

The monitored-speed setting may be greater than the reduced-speed (5.5.3.1) setting.

When a monitored-speed safety function is provided, the robot may have the capability to disable the monitored-speed safety function. Disabling this safety function shall be in accordance with 5.3.

5.5.4 Enabling function

5.5.4.1 General

An enabling function shall be active in manual mode in accordance with 5.2.7.2. The enabling function is an interlock manually activated by one or more enabling devices. When the enabling function is active, it shall fulfil the following:

a) when enabled, allows robot motion to be initiated by a separate start control; and

b) when not enabled, the enabling function

— initiates a protective stop function; and

— prevents initiation of robot motion.

NOTE When used, an enabling function permits robot motion while in manual mode.

5.5.4.2 Enabling device

The enabling device shall be a 3-position type in accordance with IEC 60204-1:2016+AMD1:2021, 10.9, with the functionality in accordance with 5.5.4.3. The enabling device shall be equipped with three-position enabling switches in accordance with IEC 60947-5-8:2020. When non-electro-mechanical switches are used in the 3P enabling device, they shall conform to equivalent requirements.

If HGC is active, according to 5.10.2, and HGC is used in manual mode, then hold-to-run shall be active and a 3P enabling device is not required.

Class I robots, in accordance with 5.1.17, shall be designed such that foreseeable tasks (e.g. maintenance, troubleshooting, and other tasks) can be performed safely without a 3P enabling device. If these foreseeable robot tasks:

a) cannot be performed safely without using a 3P enabling device, then a 3P enabling device shall be provided with the robot;

or

b) can be performed safely without using a 3P enabling device, then the following shall apply:

— a 3P enabling device is not required to be provided with the robot; and

— safety function input(s) shall be provided for the integration of an external 3P enabling device (e.g. a grip-type 3P enabling device).

5.5.4.3 Functionality

The 3P enabling safety function shall have a functional safety performance in accordance with 5.3.

When continuously held in a centre “on” position, the 3P enabling safety function shall permit robot motion.

NOTE 1 For a 3-position (3P) enabling device, centre “on” position is the enabled position while OFF is the released and compressed positions.

The 3P enabling device shall have the following functionality:

a) release of all 3P enabling devices on the same teach pendant shall cause a protective stop;

NOTE 2 If two (2) 3P enabling devices, on the same teach pendant, are being held in the centre “on” position, it cannot be distinguished if one of them is intentionally released or it is unconsciously released.

b) release of any active 3P enabling devices that are not integrated to the teach pendant shall cause a protective stop;

c) full compression of any 3P enabling device shall cause a protective stop in accordance with 5.4.3;

d) after compression past the centre "on" position of the 3P enabling device to the "compress OFF" position, the following shall be fulfilled:

   1) going from fully compressed (compress OFF) to the centre "on" position shall not permit robot motion;

   2) robot motion shall only be permitted after the 3P enabling device has been fully released ("release OFF" position) after being in the "compress OFF" position; and

   3) robot motion shall not be permitted until the 3P enabling device is moved to the centre (ON) position;

e) change from automatic mode to manual mode when the 3P enabling device is in the centre "on" position, shall require that the 3P enabling device be released (release OFF) and re-enabled (centre "on") before robot motion is permitted.

NOTE 3 It is important to consider the ergonomic issues of sustained exertion of manual activation force in the design and integration of the 3P enabling device into the teach pendant.

5.5.5 Monitored-standstill

When a monitored-standstill is needed to prevent unintended motion, the following shall be fulfilled:

a) the standstill position shall be monitored and maintained according to 5.3;

b) any unintended motion of the robot from the standstill position shall result in a stop category 0 or 1 in accordance with IEC 60204-1:2016+AMD1:2021;

c) a detected failure shall conform to 5.3.4.

Monitored-standstill shall be provided for the following:

— hand-guided control (HGC) in accordance with 5.10.2;

— power and force limiting safety functions in accordance with 5.10.4.

This safety function may be initiated externally (e.g. from protective devices).

Capability of a safety function output shall be provided for when monitored-standstill is active.

5.5.6 Stopping time limiting

Stopping time limiting is an optional safety function which may be provided. Stopping time limiting monitors the motions performed by the robot and prevents motions which would exceed the stopping time limit to stop the robot.

When provided, the stopping time limiting safety function:

a) shall be in accordance with 5.3;

b) shall continuously monitor the robot motions, such that motions shall not be performed which would exceed the stopping time limit;

c) shall initiate a stop category 0 or 1 in accordance with IEC 60204-1:2016+AMD1:2021 when motions exceed the stopping time limits.

5.5.7 Stopping distance limiting

Stopping distance limiting is an optional safety function which may be provided. Stopping distance limiting monitors the motions performed by the robot and prevents motions which would exceed the stopping distance limit to stop the robot.

When provided, the stopping distance limiting safety function:

a) shall be in accordance with 5.3;

b) shall continuously monitor the motions of all moving part of the robot as well as the TCP, such that motions shall not be performed which would exceed the stopping distance limit;

c) shall initiate a stop category 0 or 1 in accordance with IEC 60204-1:2016+AMD1:2021 when motions exceed the stopping distance limits.

5.6 Simultaneous motion

Multiple manipulators may be linked to a single teach pendant, where the teach pendant has the capability to move manipulators independently or in simultaneous motion. When configured for simultaneous motion and in manual mode, the following shall be fulfilled:

a) all robot functions shall be under the control of the one teach pendant;

b) manipulators to be included in simultaneous motion shall be selected before the manipulator(s) can be moved;

c) to be selected for simultaneous motion, the selected manipulators shall be in the same operating mode (e.g. reduced-speed manual mode);

d) an indication shall be provided at the point of selection (e.g. at the pendant, control cabinet, or manipulator) of the manipulator(s) that have been selected for simultaneous motion;

e) only selected manipulators(s) shall be capable of being moved.

Unexpected start-up (5.2.2) shall be prevented of any manipulators not selected.

5.7 Limiting robot motion

5.7.1 General

A means to limit the motion of the robot to be less than the maximum space shall be provided. The means shall limit the three (3) axes of greatest (largest) displacement motions. The robot shall conform to one or more of the following: 5.7.2, 5.7.3, or 5.7.4.

NOTE 1 The greatest displacement motions are typically the three axes with largest movements.

NOTE 2 In the context of this document, auxiliary axes are part of the robot.

For Class I robots in accordance with 5.1.17 and Table 1, limiting robot motion is optional.

Class II robots shall limit motion by either of the following:

— not moving beyond the limit (e.g. limiting device(s) position, software-based limit setting); or

— upon reaching the limit (e.g. limiting device(s) position, software-based limit setting), a protective stop (5.4.3) shall be initiated. If the protective stop is a stop category 2 in accordance with IEC 60204-1:2016+AMD1:2021, a reset shall be required in accordance with 5.5.2.2.

NOTE 3 See Annex C, Table C.1.

The means of limiting, in accordance with 5.7.2, 5.7.3, and 5.7.4, shall have capability to stop robot motion without assisted stopping under the following conditions:

— maximum payload;

— maximum speed;

— pose that results in the maximum strain to the means of limiting motion.

The motion limit shall be defined as being one of the following:

a) at the actual expected position after reaching a mechanical limiting device, including the case of dynamic overshoot or deformation of a mechanical stop;

b) at the actual expected stopping position that includes the stopping distance travel after reaching any of the following:

    1) electro-mechanical limiting (5.7.3) actuation position;

    2) software-based limit (5.7.4) where the protective stop is initiated;

c) at the software-based limit when the stopping distance travel is included to ensure the limit is not exceeded.

NOTE 4 For c) above, the stopping distance is not a consideration in determining the restricted space in this situation because the safety function includes the stopping distance.

5.7.2 Mechanical limiting

The robot shall have provisions for the attachment and integration of adjustable mechanical limiting when electro-mechanical limiting (5.7.3) or software-based limiting safety function(s) (5.7.4) are not provided.

NOTE 1 Adjustable limiting allows the user to configure the size of the restricted space.

NOTE 2 Mechanical stops, e.g. hard stops, are manually adjusted and then manually secured with fasteners.

The provision of instructions for obtaining and utilizing limiting motion fulfils the requirements of this clause.

Mechanical limiting shall be capable of stopping robot motion.

5.7.3 Electro-mechanical limiting

Where electro-mechanical means of limiting are provided, the functional safety performance shall conform to the requirements in 5.3.

5.7.4 Software-based limiting

Safety functions that limit motion shall conform to the requirements in 5.3.

Software-based limiting safety functions are software-defined limits to robot motion which can include geometric shapes to limit robot motion to be inside a defined shape, or to prevent the robot from entering a defined shape.

Software-based limiting safety functions may be used to limit motion and to define the restricted space (see ISO 10218-2:2025).

The software-based limiting may be temporarily disabled in reduced-speed manual mode (5.2.7.2.2) to allow a recovery after a limit is exceeded. The limits shall be enabled upon recovery.

The settings for software-based limiting safety functions shall be safety-related parameter(s) in accordance with 5.3.5.

NOTE 1 A combination of several safety function limits can be used to create dynamic restricted spaces.

NOTE 2 Software-based limiting safety functions can be particularly useful in controlling motion in irregular shaped restricted spaces or protecting against pinch-points created by obstructions, see ISO 10218-2:2025.

5.7.5 Dynamic limiting

Dynamic limiting automatically modifies the restricted space.

Dynamic limiting safety function(s) are optional. When provided, dynamic limiting shall conform to 5.3 and may be accomplished by parameterization in accordance with 5.3.5.

NOTE Requirements that were associated with dynamic limiting in ISO 10218-1:2011 and ISO 10218-2:2011 are now addressed by muting requirements in ISO 10218-2:2025.

5.8 Movement without drive power

Means shall be provided so that the axes can be moved without the use of drive power in emergency or abnormal situations.

NOTE 1 Some robots can be moved with or without drive power by one operator.

Where practicable, moving the axes shall be carried out by a single operator. The means of providing movement without drive power shall be readily accessible but be protected from unintended actuation.

NOTE 2 Some robots require external equipment for movement (e.g. crane, lift truck), that is not provided with the robot.

5.9 Lasers and laser equipment

When robots are optionally provided with integral laser equipment, the following shall be fulfilled:

— the design and integration of the laser equipment shall prevent any accidental radiation; and

— laser equipment shall be safeguarded such that hazardous situations due to exposure to effective radiation, radiation produced by reflection or diffusion and secondary radiation are prevented.

Optical equipment for the observation or adjustment of laser equipment shall not create a hazardous situation from its use.

5.10 Capabilities for collaborative applications

5.10.1 General

To develop a collaborative task in accordance with ISO 10218-2:2025, robot capabilities, including safety functions, can be necessary for the intended collaborative task. Inherently safe design and safety functions can be useful for risk reduction in accordance with ISO 12100:2010 and ISO 10218-2:2025.

5.10.2 Hand-guided control (HGC)

Robots with hand-guided control shall have all the following safety functions in accordance with 5.3 and Annex C:

a) monitored-speed (5.5.3.2) safety function for HGC where the HGC speed limit setting shall have a maximum HGC speed limit when HGC is active and the limit setting can be configured to a lower value during integration in accordance with ISO 10218-2:2025;

b) software-based limiting (5.7.4);

c) monitored-standstill (5.5.5);

d) hold-to-run such that

1) activating (ON position) the hold-to-run control device shall enable motion;

2) deactivating (OFF position) the hold-to-run control device shall initiate a protective stop in accordance with 5.4.3.

Hold-to-run controls shall be in accordance with IEC 60204-1:2016+AMD1:2021, 9.2.3.7 and the relevant requirements of 5.5.4.

A 3P enabling device and function may be used instead of a hold-to-run device and function, if both the following are fulfilled:

— the 3P enabling device conforms to 5.10.2 d) and 5.5.4;

— the design and integration into the robot shall address ergonomic risks due to sustained actuation of the 3P enabling device in the centre-on position.

NOTE See 5.2.8.1 for the requirements of control stations.

When HGC is active, the following shall be applied:

— single-point-of-control (5.5.1);

— direct control (5.2.8.2); and

— the configured monitored-speed limit value for HGC.

For HGC, the robot shall move in a smooth manner such that harmful vibration does not transmit to the person. Vibration testing shall be performed in accordance with ISO 20643:2005/Amd 1:2012.

The device provided for hand guiding shall be located or be provided for installation at a location close to the mechanical interface, to which the end-effector will later be installed (see ISO 10218-2:2025).

HGC shall be designed considering the user operation of controlling the robot such that pinching, crushing, sharp edges and other "caught-in" or "compressed by objects" injury risks are reduced or eliminated through design.

EXAMPLE The following are examples but not the only means for accomplishing the above:

— two positions (e.g. front and rear or a ring with more than one hold-to-run control device position);

— a separate hold-to-run control device;

— by having the means to configure the hold-to-run controls, physically or by safety function(s), at integration;

— by positioning and arrangement of the hold-to-run control device.

5.10.3 Speed and separation monitoring (SSM)

With SSM, the robot and operator may move concurrently within the safeguarded space.

When provided in the robot, the robot shall maintain the separation distance from the operator(s), in accordance with ISO 10218-2:2025, 5.14.5.3 by one or both of the following:

— decrease the speed (e.g. down to speed zero); and/or

— change pose(s) and/or trajectory of the robot.

The speed and separation monitoring safety functions shall conform to 5.3. Failure to maintain the separation distance shall result in a stop in accordance with 5.3.4.

Detection of operator(s) can be integral to the robot or external or provided by a combination of the robot and external means.

NOTE SSM safety function can be implemented using several methods, for example:

— external sensor system supplies the robot with operator position and velocity data for internal calculation of a motion plan to maintain the separation distance;

— external sensor system provides the robot with a motion plan to maintain separation distance.

5.10.4 Power and force limiting (PFL)

Accomplishing PFL can be by inherently safe design or safety functions.

Where PFL is achieved by inherently safe design, the limits shall be fixed, not adjustable and not configurable.

Where PFL is achieved by safety functions, the following shall be fulfilled:

a) the power and force limiting safety function(s) limit values shall be adjustable;

b) active power and force limit values shall

    1) not be exceeded; or

    2) when exceeded, a protective stop shall be initiated (5.4.3) and if this is a stop category 2 in accordance with IEC 60204-1:2016+AMD1:2021, a reset in accordance with 5.5.2.2 shall be provided;

c) the following safety functions shall be provided:

    1) monitored-speed (5.5.3.2);

    2) software-based limiting (5.7.4);

    3) monitored-standstill (5.5.5).

The power and force limiting safety functions of a robot shall be in accordance with 5.3.

6 Verification and validation

6.1 General

In accordance with the requirements in Clauses 4 and 5, the robot manufacturer shall verify and validate the design of their robots including any inherent, integrated or associated safety functions and risk reduction measures.

6.2 Verification and validation

Annex G lists the requirements of Clause 5 and the means to verify and validate whether these requirements have been met. Using one or more methods, each requirement shall be verified or validated, or both verified and validated.

NOTE It is the manufacturer's responsibility to ensure that all applicable items are verified or validated or both verified and validated.

7 Information for use

7.1 General

Information for use shall be provided in accordance with ISO 12100:2010 for appropriate integration of the robot into a robot application (see ISO 10218-2:2025). Information for use shall inform the user about reasonably foreseeable misuse.

Information for use is an integral part of a robot and consists of:

a) signals and warning devices;

b) markings, signs (warning labels) and written warnings;

c) accompanying documents (e.g. instruction handbook).

For hydraulic systems, the information for use shall conform to the requirements of ISO 4413:2010. For pneumatic systems, the information for use shall conform to the requirements of ISO 4414:2010.

The language of the information for use shall be provided in accordance with ISO 20607:2019, 6.2.

7.2 Signals and warning devices

Where provided, a description and meaning of visual (e.g. flashing lights) and audible signals (e.g. buzzers) shall be provided.

7.3 Marking

Each robot shall be marked in a distinct, legible and durable manner with:

a) the manufacturer's information including the following:

- business name;
- full address;
- if an authorized representative or authorized supplier is applicable, then their business name and full address;

b) robot information including the following:

- type of robot (e.g. industrial robot);
- robot series name or designation, if applicable;
- model number or reference number (if any);
- the year of manufacture;
- the mass and/or weight of the robot manipulator;
- the maximum reach and payload capacity;

c) supply data for electrical and, where applicable, hydraulic and pneumatic systems (e.g. minimum and maximum pneumatic pressures);

d) lifting points for transportation and installation purposes, where applicable.

Markings, nameplates, labels and identification plates shall be prominently positioned, legible and be of sufficient durability to withstand the physical environment involved (e.g. water resistant). Where there is insufficient space on the robot to affix the above required markings, the business name and a code (e.g. bar, QR, identification number) that contains the required marking information shall be affixed to the robot. See ISO 10218-2:2025.

NOTE For font size guidance, see IEC/IEEE 82079-1:2019, 9.10.1.

These requirements can also apply to the parts and components that are provided but not fitted to the robot.

For the electrical equipment, the requirements of IEC 60204-1:2016+AMD1:2021, Clause 16 shall be applied.

7.4 Signs (pictograms) and written warnings

Signs and written warnings shall conform to ISO 12100:2010, 6.4.4.

Registered signs in accordance with ISO 7010:2019 shall be used as far as applicable. Where no registered signs are applicable, safety signs and markings with written warnings shall be in accordance with the principles of ISO 3864-1:2011, ISO 3864-2:2016, ISO 3864-3:2024 and ISO 3864-4:2011.

7.5 Instruction handbook

7.5.1 General

The manufacturer shall provide an instruction handbook in accordance with ISO 12100:2010, 6.4.5 and ISO 20607:2019. The handbook shall contain instructions on the location and function(s) of all controls necessary for setup, installation, integration and maintenance.

For the electrical equipment, the related information shall conform to the requirements of IEC 60204-1:2016+AMD1:2021, Clause 17. Diagrams shall be provided of the interfaces of electrical, hydraulic and pneumatic systems necessary for setup, installation, integration and maintenance.

In addition, the instruction handbook shall contain information in accordance with 7.5.2 to 7.5.18.

Some of the required information can be stated in other written instructions (for example, on the packaging).

7.5.2 Identification

Information shall be provided about the manufacturer as follows:

a) the business name;

b) full address;

c) contact information of the manufacturer (e.g. telephone number, service/support website address);

d) if an authorized representative or authorized supplier is applicable, also provide the business name, full address, and contact information;

e) the designation of the robot as marked on the robot itself, except for the serial number.

7.5.3 Intended use

The following descriptions shall be provided:

a) the robot and its components (e.g. manipulator, control, teach pendant);

b) the limitations of robot use;

c) the intended use(s) as well as the reasonably foreseeable misuse(s) and prohibited usage(s) of the robot;

d) the limits for the

— range of motion;

— payload capacity, including maximum mass;

— TCP;

e) how to install and connect an end-effector;

f) the residual risks that cannot be eliminated by the risk reduction measures implemented in the robot;

g) the risks that shall be reduced during integration if the mechanical design measures according to 5.1.2.4 were not implemented due to the robot construction;

h) mass per manipulator (M) and if the manipulator is intended to be used in applications where the base moves, the mass per manipulator includes the base and fastenings;

i) for Class I robots in accordance with 5.1.17, Table 1, the F_{MPM} value;

j) for HGC, provide guidance about:

— positioning HGC and hold-to-run devices;

— configuring HGC and hold-to-run devices;

— intended positioning of operators during use of HGC;

— prohibited positioning and use of HGC;

k) the laser, if provided, and if any personal protective equipment is to be used.

7.5.4 Installation

The following installation information shall be provided:

a) description of the installation;

b) description of the installation requirements (e.g. mounting requirements, utility needs, floor loading, environmental conditions);

c) a description of the parts that can be a source of risk (5.1.2.4) when fitting or refitting;

d) instructions that fixed control stations provided with the robot shall be:

— located outside of the safeguarded space such that the operation of their control devices does not to cause additional risks;

— located out of reach of operators from inside the safeguarded space;

— located to provide visibility of the robot;

e) instructions that location of direct control and external control means shall provide visibility of the robot(s) being controlled.

Guards, protective devices and other parts that are provided with the robot but not yet fitted shall be clearly described or identified and installation instructions shall be provided. If parts that can be a source of risk (5.1.2.4) when fitting or refitting, the information for use shall be provided at least on the parts themselves and/or their housings.

7.5.5 Stopping

Information about stopping functions, devices and integration with external equipment shall be provided.

For robots without one or both stopping distance and stopping time limiting safety functions, the following shall be provided:

— stopping time and either distance or angle from initiation of stop signal of the three axes with the greatest relevant displacement and motion in accordance with Annex H;

— recommended periodic interval for stopping time and either stopping distance or stopping angle testing.

7.5.6 Commissioning and programming

Instructions for commissioning, programming and how the initial test and examination of the robot and its risk reduction measures shall be provided to enable testing to be carried out:

— before first use; and

— before being placed into production.

This includes functional testing of the safety function parameter settings, e.g. reduced-speed manual mode speed limiting value.

7.5.7 Operation and setting

Instructions shall be provided for the safe operation and setting, including safe working practices and the training required to achieve the necessary skill level to perform these tasks.

7.5.8 Singularity

Information about singularities shall be provided and include the following:

— what singularity protection is provided with the robot according to 5.2.3;

— instructions on how to avoid singularities during programming which can be used for developing training programs.

7.5.9 Hazardous energy

The following information about hazardous energy shall be provided:

— the sources of energy;

— the types of energy;

— any stored energy.

Instructions shall be provided about how to:

a) isolate the energy including the isolation means;

b) lock or otherwise secure the isolation means in the de-energized position;

c) perform maintenance tasks safely;

d) secure an axis when removal of a component (e.g. motor) can cause hazardous motion due to gravity or the release of hazardous energy (e.g. spring).

NOTE See example shown in Figure 1.

7.5.10 Movement without drive power

Movement without drive power shall be described and include the following:

a) a description of this capability;

b) instructions for how to move the robot without drive power;

c) whether robot damage would result after movement without drive power and if repair is needed before resumption of robot use;

d) recommendations for training operator(s) on responding to emergency or abnormal situations (e.g. situations that can require movement without drive power);

e) warning of the potential hazard(s);

f) warnings that gravity and the release of braking devices can create additional hazards.

7.5.11 Cybersecurity

Information shall be provided about the cybersecurity features that have been implemented in the robot.

The need to develop organizational measures shall be stated.

7.5.12 Functional safety

7.5.12.1 General

Each safety function shall be described by specifying its functionality, triggering event, intended result, functional safety performance, availability, the limits and conditions of use in accordance with ISO 13849-1:2023, 5.2.1.3 or IEC 62061:2021, 10.3, as applicable. Safety-related parameters shall be provided (e.g. PL, category, SIL, HFT, DC, response time, stop category, PFH, test rate, assumptions, comments).

An example table format is provided in Table D.1.

Instructions shall be provided about the location and function of all control systems including diagrams of the interface of electrical, hydraulic, and pneumatic systems necessary for setup and installation.

NOTE This does not include schematics of robot or other controls, components or proprietary property.

7.5.12.2 Software and safety-related parameterization of software

The following information about safety-related parameterization of software shall be provided:

a) how safety parameters are secured;

b) safety functions affected by manually set parameters, such as payload, TCP;

c) what robot safety function(s) are included in the identifier (e.g. checksum);

d) how to view and document the settings and parameters;

Information shall be provided about robot settings and software limitations related to safety function configuration if such functionality is provided. The importance of verifying and validating safety function parameters before starting the use of the robot application shall be emphasized. This includes the initial setting and any changes to parameters.

7.5.12.3 Response time of safety functions

If the robot has safety function inputs, the maximum response time shall be provided. This response time is measured from the input state change until the safety function becomes active.

If the robot has safety function outputs, the maximum response time of safety function outputs shall be provided. This response time is measured from the safety function initiation until the output changes state.

The maximum response time for a parameter (5.3.5) change or selection to become effective shall be provided for each safety function having parameterization capability. This requirement does not apply when the parameter change requires a manual restart.

The time required to change from one defined safety monitored-speed limit to another when multiple speed limits are provided shall be provided.

Response time for the detection of the loss of the communication signal for cableless pendants shall be provided.

NOTE The response time of the safety function is different than the stopping time needed to achieve a safe state.

7.5.12.4 Stop functions

The information about the stop category (i.e. stop category 0, 1 or 2) in accordance with IEC 60204-1:2016+AMD1:2021 for all stop functions (5.4) shall be provided.

Information about the effect of the stopping functions shall be provided, including the emergency stop in relation to the manipulator, external input(s) and safety function input(s).

7.5.12.5 External inputs and outputs

The following information about each external input and output shall be provided:

a) the specifications;

b) instructions for use;

c) fault detection measures implemented, if any;

d) instructions, if required, for the provision of external fault detection means.

7.5.12.6 Operating modes

Instructions and warnings shall be provided that the tasks in reduced-speed manual mode should, where practicable, be performed with all operators outside the safeguarded space. Instructions and warnings shall be provided that high-speed manual mode, if used, shall be integrated such that tasks shall be performed only when no person is inside of the safeguarded space.

Instructions shall be provided:

— that prior to selecting automatic mode, any disabled safeguards shall be returned to their full functionality; and

— about how to use the manual mode (e.g. reduced-speed or high-speed) and the associated residual risks of the use of the mode(s).

7.5.12.7 Enabling device(s)

Enabling device information shall include a description of the operation of each 3P enabling device. If additional 3P enabling devices can be used, the following shall be provided:

a) the number of additional 3P enabling devices that can be integrated with the robot;

b) integration and installation information;

c) data and criteria necessary to determine the safety-related control system performance.

If the robot has a 3P enabling device input, instructions shall be provided for how to install the 3P enabling device.

If the robot has a 3P enabling device output, installation instructions and safety-related performance shall be provided.

If the Class I robot has no 3P enabling device, instructions shall be provided stating that the application risk assessment, in accordance with ISO 10218-2:2025, shall determine whether a 3P enabling device is required for risk reduction.

7.5.12.8 Axis limiting

Axis limiting capabilities [e.g. mechanical limiting, electro-mechanical limiting, software-based limiting safety function(s)] and how to use these capabilities shall be described and provided.

a) When axis limiting is provided by mechanical limiting devices, the following shall be provided:

   1) how to install or re-locate;

   2) what is installed/provided with the robot;

   3) the number of mechanical limiting devices;

    4) locations of the mechanical limiting devices:

b) When axis limiting is provided by electro-mechanical limiting devices, the following shall be provided:

    1) number, location and implementation of any electro-mechanical limiting devices;

    2) the allowed adjustment of mechanical and electro-mechanical limiting devices;

    3) the stopping time at maximum speed including monitoring time until a full stop is achieved;

    4) the stopping distance at maximum speed before a full stop is achieved;

    5) the means to verify the limits with a simple test, to be used at implementation;

c) When axis limiting is provided by software-based limiting, the following shall be provided:

    1) the tolerances, if any, of safety functions for software-based limiting;

    2) the means to verify the limits with a simple test, to be used at implementation;

    3) the stopping time and stopping distance/angle in accordance with Annex H, at the maximum payload, when axis and space limiting safety functions generate a stop upon exceeding a limit;

        i) this stopping time shall include the monitoring time until a full stop is achieved;

        ii) this stopping distance shall be until a full stop is achieved;

d) when dynamic limiting (5.7.5) is provided with the robot, the following information shall be provided:

    1) if outputs are provided for use in a dynamic restricted space application, the functional safety performance;

    2) the transition time for a limit change to be effective.

If robot motion can continue beyond the limiting device(s) position or beyond the limit setting(s), guidance for determining the restricted space shall be provided.

The following information shall be provided:

— how to apply axis limiting (5.7) for auxiliary axis (axes) according to 5.1.9;

— functional safety performance.

7.5.12.9 Position holding device(s)

The following shall be provided about position holding device(s):

a) procedures to inspect and/or verify the position holding device (5.1.8);

b) description of the holding capability (5.1.8) including:

    — the maximum distance of movement(s), if any, when the position holding device is engaged;

    — instructions for how to test the movement.

7.5.13 Teach pendants

Instructions shall be provided describing the proper storage of

— cableless or detachable pendants, if so configured, to prevent confusion between active and inactive emergency stop devices;

— pendants with cables, if so configured, to lessen the risks of tripping or falling due to the cables.

Information shall be provided about how to select high-speed manual mode using the pendant, if this capability is provided.

7.5.14 Change or addition of component parts

Instructions shall be provided of any tests or examinations necessary after change of component parts or addition of optional equipment (both hardware and software) to the robot that can affect the safety-related functions, including an emergency stop output signal as in 5.4.2.3 and common 3P enabling function in accordance with 5.5.4.

If guarding according to 5.1.2.4 is not practicable when considering the robot construction, then the information for use shall describe these risks for integration.

7.5.15 Standards

Information shall be provided about the standards that the robot meets.

NOTE Approvals and certificates can be provided.

7.5.16 Maintenance

The following shall be provided:

a) instructions for safe maintenance, including safe working practices and the training required to achieve the necessary skill level to perform the maintenance tasks;

b) the intervals and frequency for the required inspections and maintenance;

c) a method for testing the position holding means if a failure can cause a hazardous situation;

NOTE 1 See 5.1.8.

d) instructions and procedures to avoid errors of fitting during maintenance of the machine;

e) specification for any fluids or lubricants to be used in lubrication, braking, or transmission system internal to the robot, including guidance on correct selection, preparation, application and maintenance of expendables, when these fluids or lubricants are intended to be changed by operators;

f) specifications of the spare parts to be used, when these affect the health and safety of operators (e.g. safety-related parts of the control system).

If special equipment and accessories to enable the robot to be adjusted, maintained and used safely is not provided with the robot, information for use shall describe how the special equipment can be obtained.

NOTE 2 See 5.1.7.

7.5.17 Abnormal and emergency situations

Where trapping cannot be avoided, guidance to safely rescue the trapped person shall be provided:

— guidance on the means for the release of operator(s) trapped in or by the robot;

— information and recommendations for training operator(s) on responding to emergency or abnormal situations.

7.5.18 Handling, lifting and transportation

Instructions for handling, lifting and stable transportation and storage of the robot and its associated components shall be provided. Instructions shall include the lifting point(s) and posture required of the manipulator, where applicable.

Annex A
(informative)

List of significant hazards

Table A.1 provides a list of significant hazards for robots before integration into a robot application.

NOTE See ISO 10218-2:2025, Annex A for hazards of the robot application and robot cell.

Table A.1 — List of significant hazards

No.	Type or group	Example of hazards		Corresponding requirement	
		Origin	Potential consequences		
1	**Mechanical hazards**	— movements (normal or unexpected) of any part of the manipulator (including back) — movements (normal or unexpected) of additional axis — movement of robot parts — rotational motion of any axes — failure of a safety function to perform as expected — loose clothing, long hair — between joints of the manipulator — unintended motion or activation of auxiliary axes — unexpected release of potential energy from stored sources	— crushing — shearing — cutting or severing — entanglement — drawing-in or trapping — impact — stabbing or puncture — friction, abrasion — high-pressure fluid/gas injection or ejection	4 5.1 5.2 5.3 5.4 5.5 5.6 5.7 5.8	Risk assessment Robot design Controls Safety functions Stopping functions Other safety functions Simultaneous motion Limiting robot motion Movement without drive power
2	**Electrical hazards**	— contact with live parts — confusion of various voltages — contact with discrete components in the electrical (electronic) circuitry, e.g. capacitors — exposure to arc flash	— electric shock — burn or scald — inhalation of toxic fume — eye damage by electric spark — influence on pacemaker	4 5.1 5.2 5.3	Risk assessment Robot design Controls Safety functions
3	**Thermal hazards**	— hot surfaces — cold surfaces — radiation from heat sources	— burns — fire, explosion — inhalation of toxic fumes — dehydration	4 5.1	Risk assessment Robot design

Table A.1 *(continued)*

No.	Type or group	Example of hazards		Corresponding requirement	
		Origin	Potential consequences		
4	**Vibration hazards**	— stepping or motion during hand-guiding can cause vibration	— fatigue of mechanical components leading to failure — loosening of connections, fasteners, components resulting in unexpected stopping or expulsion of parts — neurological damage — vascular disorder	4 5.1 5.10	Risk assessment Robot design Capabilities for collaborative applications
5	**Material/ substance hazards**	— filling, use, recovery or draining of fluids — servicing, lubrication and changing components that are covered in fluids; — cooling and process fluids — unexpected failures to the mechanical and electrical components of the robot — access to radiation source(s)	— poisoning — inhalation of corrosive fumes and dust — burns — radiation from laser	4 5.1 5.9	Risk assessment Robot design Lasers and laser equipment

Table A.1 *(continued)*

No.	Type or group	Example of hazards		Corresponding requirement	
		Origin	Potential consequences		
6	**Ergonomic hazards**	— poorly designed teach pendant, human-machine interface (HMI) touch screen or operator panel — poorly designed 3P enabling devices — inappropriate location of controls — inadvertent operation of controls — hard to reach, exposure to additional hazards due to inappropriate location of operating controls — hard to reach, exposure to additional hazards due to inappropriate location of components that require access for anticipated maintenance actions (troubleshooting, repair, adjustment) — components in enclosures that block existing lighting — HMI units placed too high or low for convenient viewing — warning signals and status inductors are not understood or operational — incorrect use due to misplaced or missing labels	— fatigue — impact — falling — loss of awareness — stress — human error — operator error	4 5.1 5.2 5.2.8 5.3 5.5 5.10	Risk assessment Robot design Controls Means of controlling the robot Safety functions Other safety functions Capabilities for collaborative applications
7	**Combinations of hazards**	— incorrect fitting and refitting of parts — incorrect connection of energy sources — unexpected movements of robot — tipping or falling-over — loss of power — parameters not set or incorrectly set — parameters changed in an uncontrolled way	— crushing — external influences on the power source — unanticipated start — impact — stress — injury from the expelled part	4 5.1 5.2 5.2.8 5.3 5.4 5.5	Risk Assessment Robot design Controls Means for controlling the robot Safety functions Stopping functions Other safety functions

Table A.1 *(continued)*

No.	Type or group	Example of hazards		Corresponding requirement	
		Origin	Potential consequences		
		— safety function data is lost or incorrectly transmitted — access to stored energy when means to isolate or secure are not available or applied — unpredictable behaviour of controls due to electromagnetic interference (EMI) or surges in energy source — unexpected robot start — misinterpretation motion of multiple robots during simultaneous motion — robot speed can be adjustable resulting in various tasks being done at a variety of speeds — malfunctions of the control with consequent release of manipulator brake; release of brake causes robot elements to move under residual forces (inertia, gravity, spring/energy storage means) unexpectedly — unexpected movements of robot or auxiliary axis — failure of a safety function to perform as expected — breaking, loosening or releasing causes component malfunction — loose unsecured hoses and components separate or whip about — components improperly installed creating unexpected motion/hazard — high speed rotational parts breaking or disengaging from part retention equipment — overload of manipulator or associated equipment resulting in breaking or buckling of mechanical components — unrestrained robot (maintained in position by gravity) falls or overturns		5.6 5.7 5.8 5.10	Simultaneous motion Limiting robot motion Movement without drive power Capabilities for collaborative applications

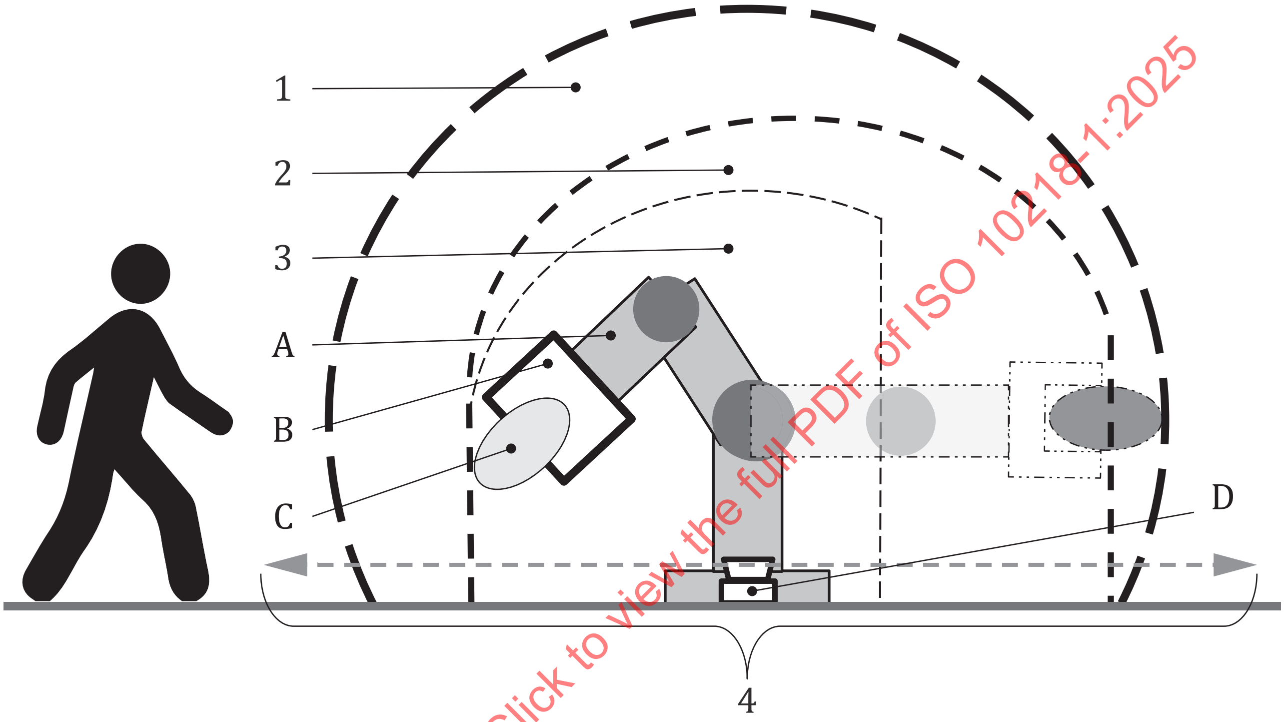
Table A.1 *(continued)*

No.	Type or group	Example of hazards		Corresponding requirement	
		Origin	Potential consequences		
		— handling mishaps during commissioning or decommissioning — parts can fall off if not properly attached or installed improperly — unauthorized access due to poor or lack of cybersecurity implementation — power and force limiting incorrect calculations			

Annex B
(informative)

Illustrations of spaces

Figure B.1 shows an overview of all the various "spaces" associated with a robot application. This figure shows concepts without dimensions, and it is not shown to scale.



Key

1 maximum space
2 restricted space
3 operating space
4 safeguarded space
A manipulator
B end-effector
C workpiece
D protective device

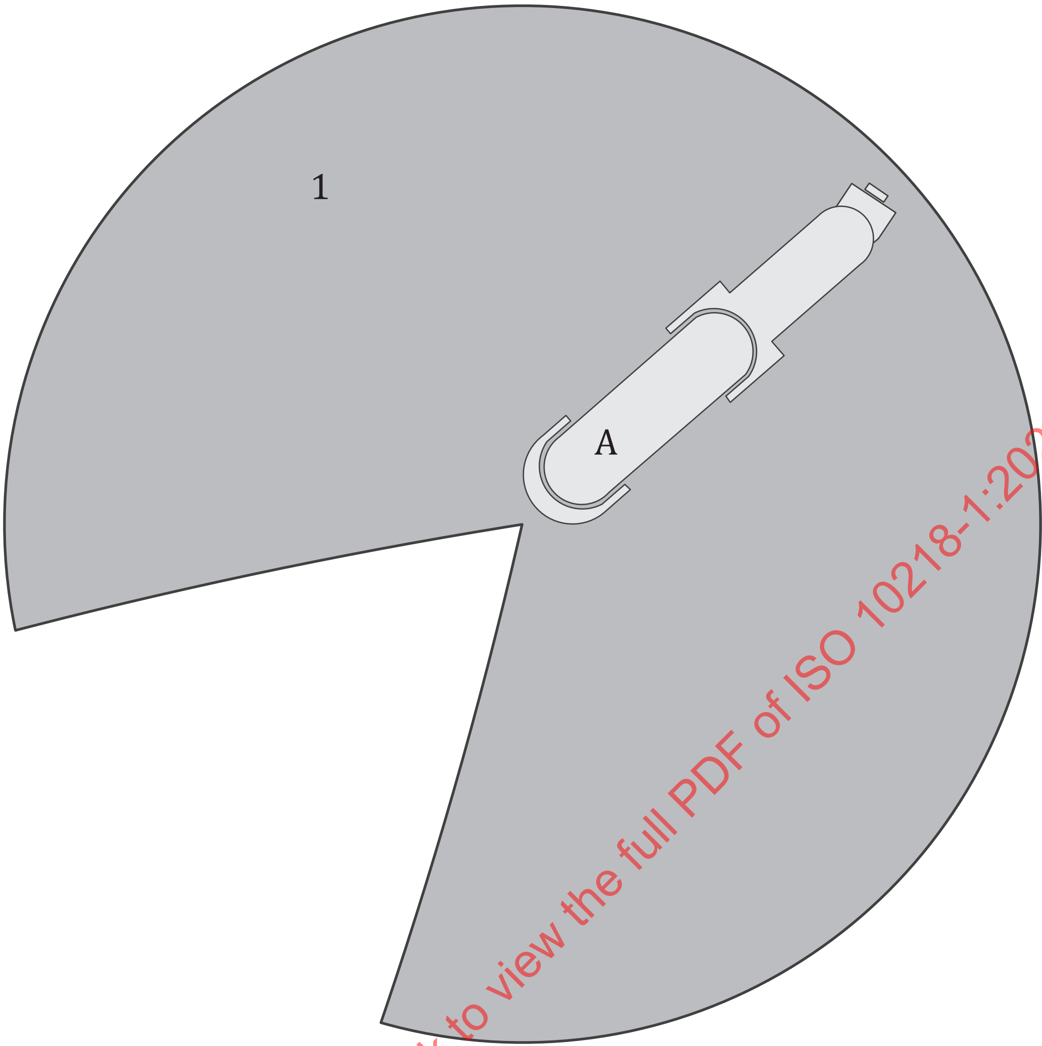
NOTE 1 The maximum space is greater or equal to the restricted space and the restricted space is greater or equal to the operating space.

NOTE 2 This figure shows concepts without dimensions, and it is not shown to scale. The safeguarded space border can be closer to the restricted space.

NOTE 3 Protective device (D) is a safety laser scanner. It is shown only for illustrative purposes.

Figure B.1 — Spaces

Figure B.2 shows the spaces associated with a robot, where there is no end-effector and no workpiece. There is no restricted space and no operating space until the robot is integrated into an application.



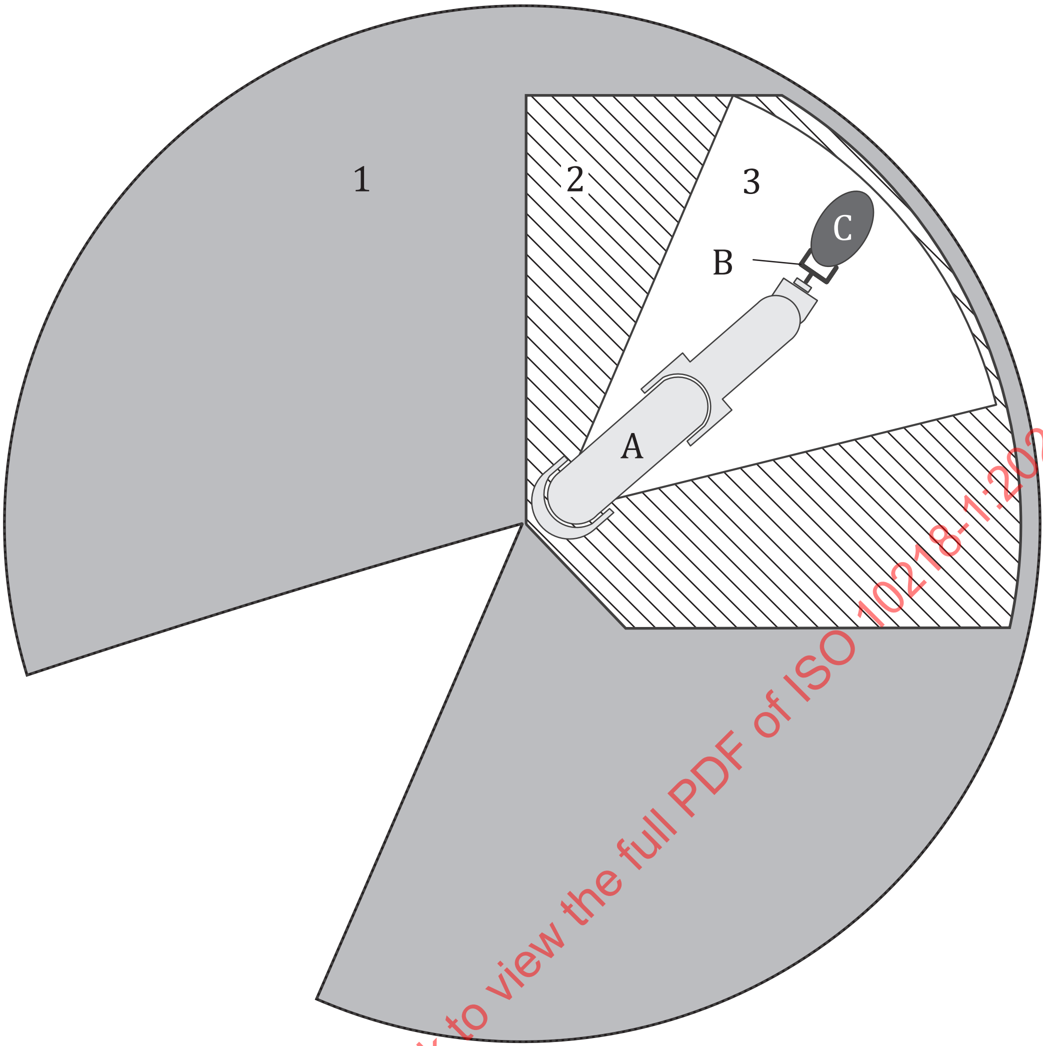
Key

1 maximum space

A manipulator

Figure B.2 — Maximum space of a robot (without end-effector and without workpiece)

Figure B.3 shows the spaces associated with a robot application (robot, end-effector and workpiece) without reference to a specific application.



Key

1	maximum space	A	manipulator
2	restricted space	B	end-effector
3	operating space	C	workpiece

Figure B.3 — Spaces of a robot application (robot, end-effector and workpiece) without reference to a specific application

Annex C
(normative)

Safety functions

Table C.1 details the robot safety functions that shall be in accordance with 5.3.3, except Class I robot (5.1.17) safety functions which shall be at least PL b or SIL 1. Table C.2 contains the safety functions which may be provided with different functional safety performance.

NOTE The robot application can require safety function(s) meeting PL e (Cat 3 or Cat 4) or SIL 3 (HFT 1).

Table C.1 — Robot safety functions

Clause where referenced	**Mandatory OR Conditional OR Optional**[1]	**Safety Function Name**	**Possible Triggering Event**	**Intended Result** *unless "or" is stated within a given row, all are required*
5.1.8	**Conditional** required if position holding monitoring is provided	**position holding monitoring**	Robot exceeds movement tolerance after robot drive power is removed while the robot is stopped	After power is restored, the robot does not move until there is a deliberate manual action to reset or acknowledge
5.1.9	**Conditional** required if any auxiliary axis is provided	**position holding monitoring of auxiliary axis**	Auxiliary axis exceeds movement tolerance after drive power is removed while the axis is stopped	After power is restored, the auxiliary axis does not move until there is a deliberate manual action to reset or acknowledge
5.2.4	**Conditional** if interlocking functions are provided	**interlocking**	Opening or removing the guard (e.g. cover)	Cease all hazardous robot functions
5.2.7.2.1	**Mandatory**	**manual mode activation**	Activation of manual mode	Automatic mode is prevented and 3P enabling device active on control station
5.2.7.2.2	**Mandatory** for Class II robots	**manual mode, reduced-speed**	Reduced-speed manual mode activated	Reduced-speed (5.5.3.1) active
5.2.7.2.3	**Conditional** required for high-speed manual mode	**manual mode, high-speed**	High-speed manual mode activated	Monitored-speed (5.5.3.2) active
5.2.7.2.3	**Conditional** required if high-speed manual mode is provided	**manual mode, high-speed time limitation**	See Table C.2 for characteristics and minimum functional safety performance	
5.2.7.3	**Conditional** required if there is a change in active risk reduction with mode activation	**mode activation**	Activation of the selected mode	— Protective stop (5.4.3); — Activation of safety functions appropriate for each mode; — Initiation of motion is in accordance with start and restart interlocking (5.5.2).
5.2.8.3	**Conditional** required if external control is provided	**external control enable**	See Table C.2 for characteristics and minimum functional safety performance	
5.4.2	**Mandatory**	**emergency stop**	See Table C.2 for characteristics and minimum functional safety performance	

Table C.1 *(continued)*

Clause where referenced	**Mandatory OR Conditional OR Optional**[1]	**Safety Function Name**	**Possible Triggering Event**	**Intended Result** *unless "or" is stated within a given row, all are required*
5.4.3	**Mandatory**	**protective stop**	Internal safety function triggers OR Actuation of a related protective device that is connected to the protective stop input	Cease all hazardous robot functions intended to be controlled by a protective device
5.4.4	**Mandatory**	**normal stop**	See Table C.2 for characteristics and minimum functional safety performance	
5.5.1	**Conditional** required if there is the capability of more than one source of control	**single-point-of-control**	See Table C.2 for characteristics and minimum functional safety performance	
5.5.2.1	**Mandatory**	**start/restart interlock**	— Energy supply is switched on; — After an interruption and restoration of power; — Change of active mode (5.5.2.1); — After a protective stop while in manual mode (5.2.7.2)	Prevent automatic start until a reset (5.5.2.2)
5.5.2.2	**Mandatory**	**reset**	See Table C.2 for characteristics and minimum functional safety performance	
5.5.3.1	**Mandatory**	**reduced-speed**	Activation of reduced-speed manual mode	Speed is limited to the reduced-speed parameter, which is no greater than 250 mm/s, then: — prevent the robot from exceeding the reduced-speed limit by slowing or stopping before the limit is exceeded; — stop category 0 or 1 if the speed limit is exceeded.
5.5.3.2	**Conditional** required for — Auxiliary axis (axes) (5.1.9) — High-speed manual mode (5.2.7.2.3) — HGC (5.10.2) — PFL by safety functions (5.10.4)	**monitored-speed**	Robot exceeds the configured limit. Continuous monitoring until reaching the point where a stop is initiated so that the configured limit will not be exceeded	Speed is limited to the monitored-speed parameter, then: — prevent the robot from exceeding the monitored-speed limit by slowing or stopping before the limit is exceeded; and — stop category 0 or 1 if the speed limit is exceeded.
5.5.4	**Mandatory**	**enabling function**	Release or compression of the 3P enabling device	Protective stop (5.4.3)

Table C.1 *(continued)*

Clause where referenced	**Mandatory OR Conditional OR Optional**[1]	**Safety Function Name**	**Possible Triggering Event**	**Intended Result** *unless "or" is stated within a given row, all are required*
5.5.5	**Conditional** required for — HGC (5.10.2) — PFL by safety functions (5.10.4) — Simultaneous motion (5.6) if an unselected manipulator has power	**monitored-standstill**	— Internal safety function triggers; — Actuation of a protective device that is connected to the protective stop input; — Manipulator is powered and not selected for simultaneous motion.	— Robot stops or is already stopped; — Position is monitored and maintained; — Stop category 0 or 1 if there is unintended motion; The monitored-standstill output indicates that the robot standstill is maintained
5.5.6 7.5.5	**Optional** required if the safety function is provided	**stopping time limiting**	Exceed the limit.	Stop category 0 or 1 if the limit is exceeded. .
			Ensure that the limit will not be exceeded (e.g. decrease speed, initiate a stop)	Prevent the robot from exceeding the set limit by slowing the robot or by a protective stop (5.4.3)
5.5.7 7.5.5	**Optional** required if the safety function is provided	**stopping distance limiting**	Exceed the limit.	Stop category 0 or 1 if the limit is exceeded.
			Monitor to ensure that the limit will not be exceeded (e.g. decrease speed, initiate a stop)	Prevent the robot from exceeding the set limit by slowing the robot or by a protective stop (5.4.3)
5.6	**Optional** required for simultaneous motion	**simultaneous motion**	Selection of robots to be under simultaneous motion	— Only robots in the same mode can be selected for simultaneous motion; — Any robot not selected is in a monitored-standstill (5.5.5).
5.7.1	**Conditional** required for Class II robots (5.1.17)	**axis limiting** See 5.7.3 and 5.7.4	Exceed the limit(s)	Protective stop (5.4.3). A reset (5.5.2.2) is required if the protective stop is a stop category 2 according to IEC 60204-1:2016+AMD1:2021.
5.7.3	**Conditional** required for Class II robots (5.1.17) and if electro-mechanical limiting is the means of axis limiting	**electro-mechanical limiting**	Exceed the limit(s)	Protective stop (5.4.3). A reset (5.5.2.2) is required if the protective stop is a stop category 2 according to IEC 60204-1:2016+AMD1:2021.
			Reach the point where a stop is initiated so that the limit will not be exceeded	Protective stop (5.4.3)

Table C.1 *(continued)*

Clause where referenced	**Mandatory OR Conditional OR Optional**[1]	**Safety Function Name**	**Possible Triggering Event**	**Intended Result** *unless "or" is stated within a given row, all are required*
5.7.4	**Conditional** required for Class II robots (5.1.17) and required for — HGC (5.10.2) — PFL (5.10.4) by safety functions	**software-based limiting**	Exceed the limit(s).	Stop category 0 or 1 OR Protective stop (5.4.3). A reset (5.5.2.2) is required if the protective stop is a stop category 2 according to IEC 60204-1:2016+AMD1:2021
			Monitor to ensure that the limit will not be exceeded (e.g. decrease speed, initiate a stop so the limit will not be exceeded)	Prevent the robot from exceeding the set limit. A stop can be initiated so that the limit will not be exceeded.
5.7.5	**Optional** *switching of limiting (5.7) settings*	**dynamic limiting**	**One or both of the following:** — Safety-related input to switch active limit(s) (5.7) — Safety function initiates change of limiting	Switch active axis limit(s) (5.7) and only 1 set of axis limits is active at a time
5.10.2	**Conditional** required for robots with HGC	**hand-guided control (HGC)**	Activate HGC	The following safety functions are activated: — Monitored-speed (5.5.4.2) for HGC; — Monitored-standstill (5.5.5); — Software-based limiting (5.7.4); — Hold-to-run (5.10.2).
5.10.2	**Conditional** required for robots with HGC	**hold-to-run control**	Release of hold-to-run control device	Protective stop (5.4.3)
5.10.3	**Conditional** required for robots with SSM safety functions/ capabilities	**speed and separation monitoring (SSM)**	Position of the human relative to the robot triggers safety functions to maintain the separation distance	One or more of the following happens: — A stop is initiated so that the separation distance is maintained; — Change robot speed (e.g. down to speed zero) before contact; — Change pose(s) and/or trajectory of the robot to prevent contact

Table C.1 *(continued)*

Clause where referenced	**Mandatory OR Conditional OR Optional**[1]	**Safety Function Name**	**Possible Triggering Event**	**Intended Result** *unless "or" is stated within a given row, all are required*
5.10.4	**Conditional** required for robots with PFL safety functions/ capabilities	**power and force limiting**	Exceeds the limit(s)	— Protective Stop (5.4.3) is initiated, and a reset (5.5.2.2) is required if the protective stop is a stop category 2;
			Monitor to ensure that the limit will not be exceeded (e.g. decrease speed, initiate a stop so that the limit will not be exceeded)	If the PFL safety function initiates a stop to prevent exceeding the limit, the following is required: — Protective Stop (5.4.3) is initiated; — Optionally, the robot moves to a position further away from a potential contact, then a protective stop (5.4.3) is initiated
[1] Mandatory: shall be provided. Conditional: shall be provided if certain conditions are met according to referenced clause. Optional: not required and can be provided as an option.				

Table C.2 states the functional safety performance requirements that may differ from the minimum requirements of Table C.1 and 5.3.3.

Table C.2 — Robot safety functions with less than PL d required

Clause	Mandatory OR Conditional OR Optional[2]	Safety Function Name	Possible Triggering Event	Intended Result	Minimum Functional Safety Performance
5.2.7.2.3	**Conditional** required if high-speed manual mode is provided	**manual mode, high-speed time limitation**	Exceeding 5 minutes of 3P enabling device released	Separate action required to resume the previously selected higher speed	**PL a**
5.2.8.3	**Conditional** required if external control is provided	**external control enable**	Request for external control of robot	Local action required to enable external control	**PL a**
5.4.2	**Mandatory** See 5.2.8.1	**emergency stop**	Manual actuation of an emergency stop device	Stop hazardous movements and operations immediately and remove energy sources to all hazards	**PL c SIL 1**
5.4.4	**Mandatory**	**normal stop**	Manual actuation of a normal stop device	Stop robot motion and hazardous functions. Remove energy sources to all hazards	**PL b**
5.5.1	**Conditional** required if there is the capability of more than one source of control	**single-point-of-control**	Request to or change of active source of control	Robot shall respond only to the active source of control	**PL a**
5.5.2.2	**Conditional** if required for internal robot safety functions AND if the resetting is not part of start/restart interlock	**reset**	Actuation of a reset control device	Re-establishment of safety function and cancellation of the stop command	**PL b**

Annex D
(informative)

Safety function information

Table D.1 is an example format that can be used to present the information for each safety function. More information can be provided.

NOTE The required safety function information is detailed in 7.5.12.

Table D.1 — Safety function information example

Clause *if applicable*	**Included in checksum**	Safety function **name**	**Active in mode(s)**	**Triggering event**	**Span-of-control**	**Intended result**	Stop category and description, ***if applicable*** [b]	Intended result ***Reaction on detected fault in safety function*** [c]	**Reset required** [d]	**Assumptions and conditions of use** [e]	**Diagnostic coverage**	**Functional safety performance** [a]		**PFH**	**Response time(s), Test rate** [f]
												PL and Category	**SIL and HFT**		
Example: 5.4.3.1	*Yes*	*Protective stop or "safeguard stop"*	*Configurable*	*internal safety function or external protective device*	*robot*	*Stop followed by monitored - standstill*	*Stop Category 2*	*Robot stops. While stopping trajectory is maintained. Upon stopping, a monitored-standstill initiated.*	***Configurable****: automatic or manual reset* ***Reset*** *is at teach pendant or by use of an external input*	1) *external protective device fulfils same functional safety requirements* 2) *dual inputs*	*medium*	*PL d, Cat 3*	*----*	*1.20E-07 without external protective device*	*Time to stop depends on stopping time safety function setting*

[a] In accordance with either ISO 13849-1:2023 or IEC 62061:2021

[b] Stop category according to IEC 60204-1:2016+AMD1:2021. Examples of descriptions are in IEC 61800-5-2.

[c] For example, inhibit restart. See 5.3.4 for Failure or fault detection.

[d] Example: Where is the reset? Is the reset manual or automatic?

[e] Assumptions: n_{op}, shared outputs, fault exclusion, and any resulting installation requirements that lessen a fault. Conditions of use: configuration parameters, maximum activation frequency, diagnostics tests, etc.

[f] Describe applicable response time(s), test rate(s) or both.

Annex E
(normative)

Test methodology for Class I robots – Maximum force per manipulator (F_{MPM})

E.1 General

For a specified robot model or series to be a Class I robot, the methodology in this annex shall be used. Robot class I determination, in accordance with 5.1.17, is based on the F_{MPM}. F_{MPM} shall be measured to determine the maximum vertical (downward) and horizontal (sideways) clamping forces.

If greater forces can occur with other motions, the motions shall be described, and the resulting forces (F_{MPM}) shall be provided.

In accordance with 5.1.17, the F_{MPM} is applied over a minimum contact area of 1 cm^2. It shall be documented in the information for use (7).

The force measurement device shall be calibrated.

E.2 Test methodology for Class I robots

Measurement collection shall be performed as follows to minimize the effects of Inertia and Impact conditions:

1) The force measuring device shall have an elastic element with a resulting spring constant of k = 75 N/mm on the measurement surface.

2) Movement parameters:

   a) for vertical movement testing:

      — position the measurement device contact surface 'midpoint of reach' as represented in C in Figure E.1, Figure E.2, or Figure E.3;

      — align the centre of the mechanical interface plate over the centre of force measurement device surface area;

      — position the robot such that mechanical interface is 1 mm above the centre of the force measurement device contact surface;

      — initiate robot motion vertically down using the maximum speed and acceleration capabilities;

      — record the maximum force measured by the force measurement device.

   b) for horizontal movement testing:

      — position the measurement device contact surface as represented in C of Figure E.4, Figure E.5, or Figure E.6;

      — align the centre of the force measurement device contact surface with the centre the mechanical interface;

      — position the robot such that mechanical interface is separated by 1 mm from the force measurement device contact surface;

      — initiate robot motion horizontally using the maximum speed and acceleration capabilities;

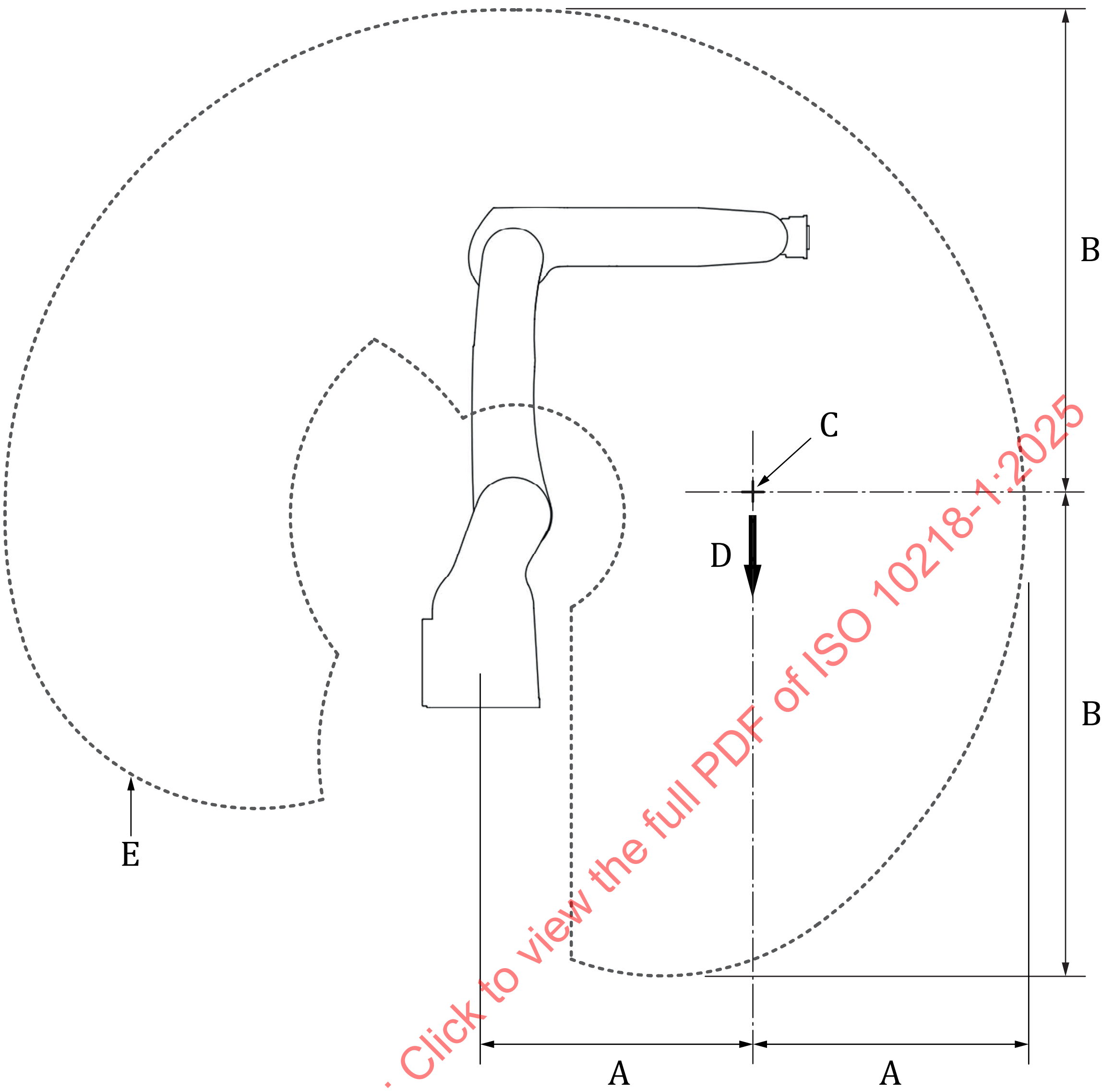
— record the maximum force measured by the force measurement device.

3) Perform a minimum of three (3) tests vertically and horizontally, until achieved results have no more than a 10 % variance between test values.

4) Record the measured values as shown in Table E.1. The horizontal and vertical F_{MPM} shall be the average of the respective measured values.

Table E.1 — F_{MPM} test results

Test	**Dimensions**					F_{MPM} average
	A	**B**	**C**	**D**	**E**	
Vertical						
Horizontal						
Other (describe)						



Key

A dimension of the maximum space in the “X” dimension, measured from the centre of the robot base to the maximum space border (A dimensions are equal)

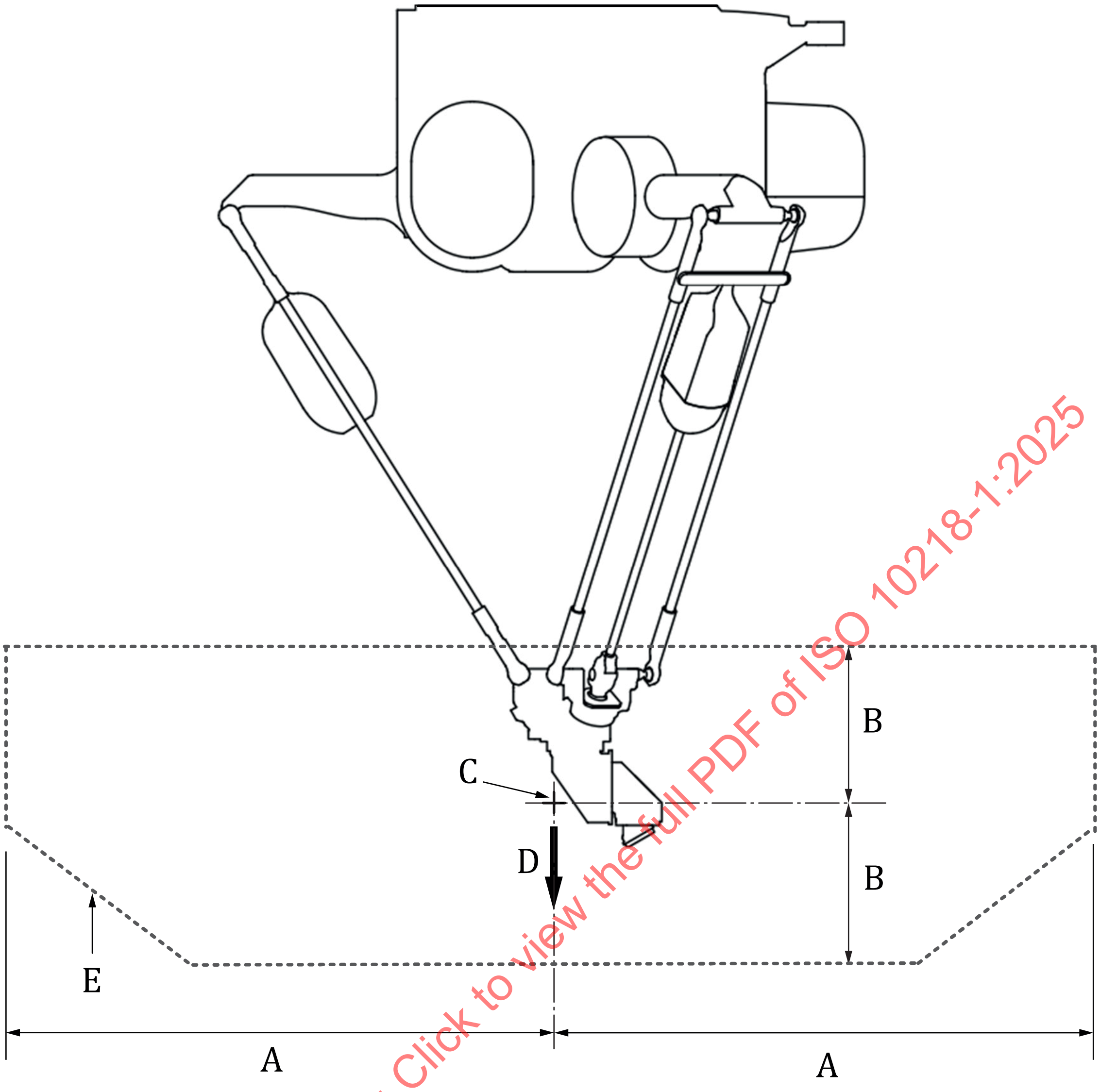
B dimension of the maximum space in the “Z” dimension, measured the borders of the maximum space (B dimensions are equal)

C location of the contact surface of the force measurement device

D direction of movement (downwards) towards the force measurement device

E border of the maximum space, side view

Figure E.1 — Example vertical (downwards) measurement location for a 6-axis articulated robot



Key

A centre of maximum, in the “X” dimension space (A dimensions are equal)

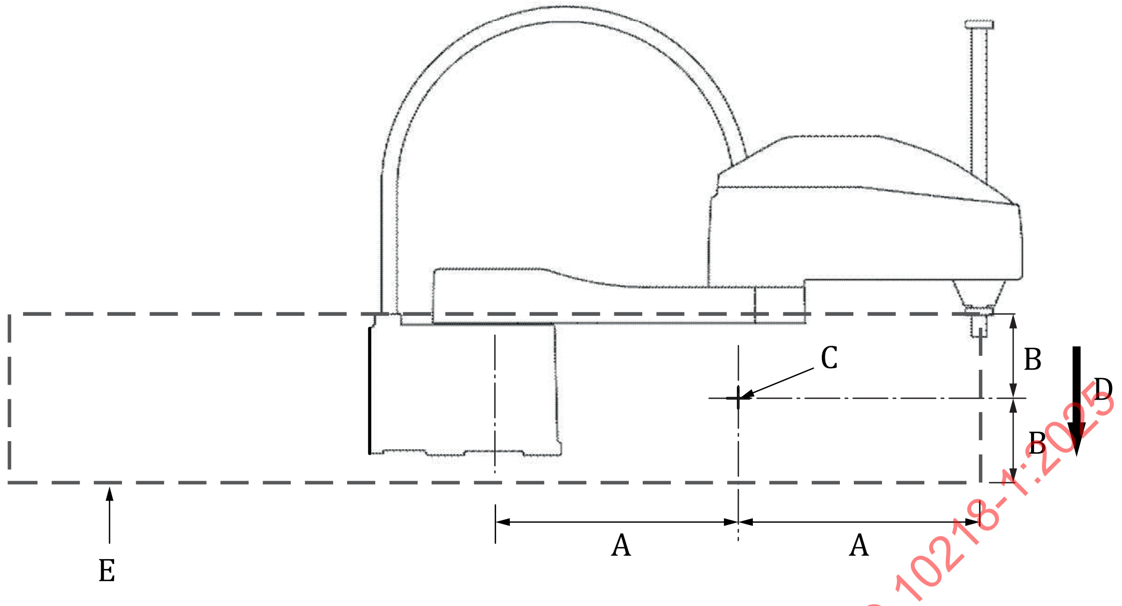
B centre of maximum space, in the “Z” dimension (B dimensions are equal)

C location of the contact surface of the force measurement device

D direction of movement (downwards) towards the force measurement device

E border of the maximum space, side view

Figure E.2 — Example vertical (downwards) measurement location for a Delta robot



Key

A dimension of the maximum space in the “X” dimension, measured from the centre of the robot base to the maximum space border (A dimensions are equal)

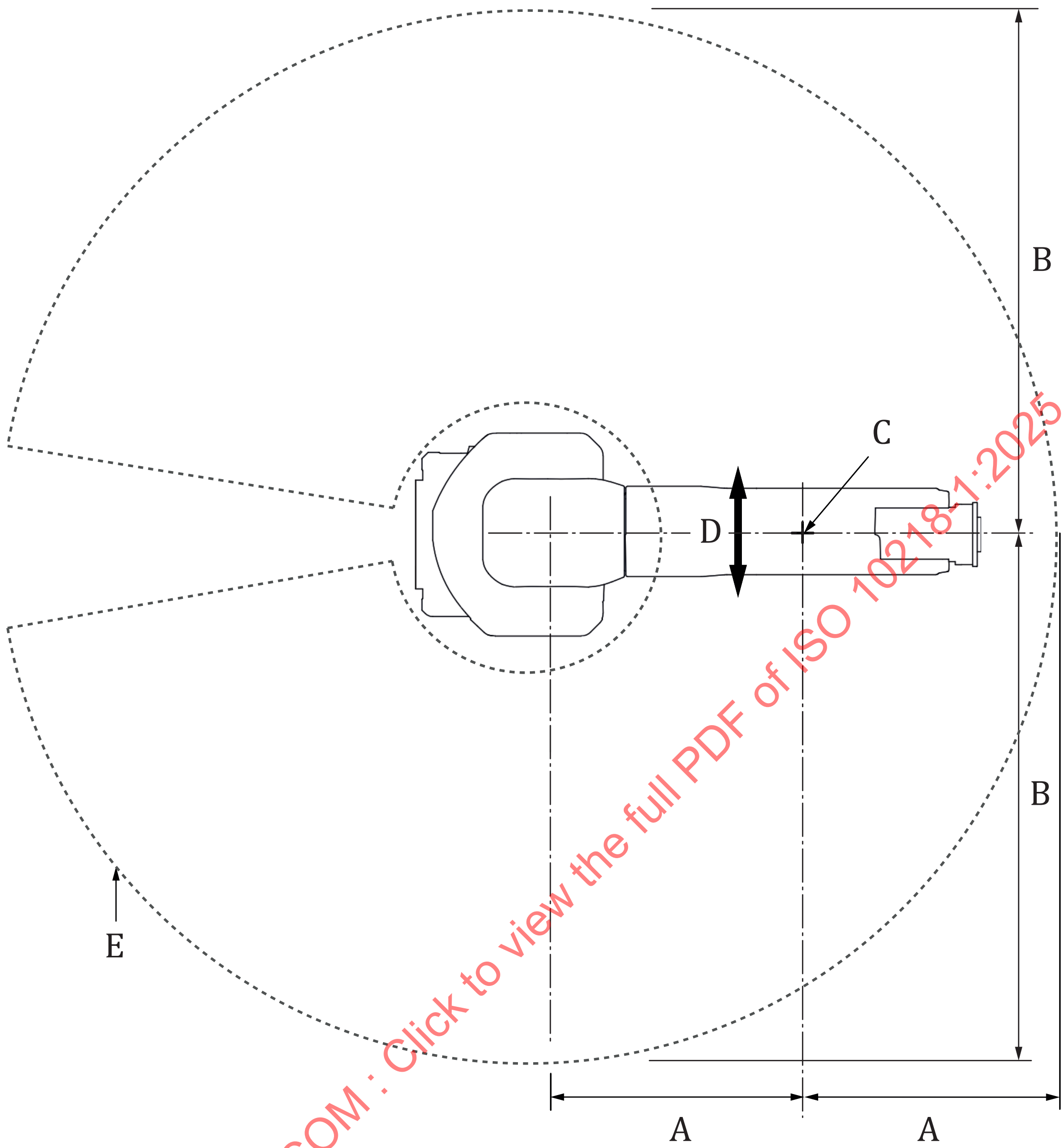
B dimension of the maximum space in the “Z” dimension, measured the borders of the maximum space (B dimensions are equal)

C location of the contact surface of the force measurement device (at the centre of the A and B dimensions)

D direction of movement (downwards) towards the force measurement device

E border of the maximum space, side view

Figure E.3 — Example vertical (downwards) measurement location for a SCARA robot



Key

A dimension of the maximum space in the “X” dimension, measured from the centre of the robot base to the maximum space border (A dimensions are equal)

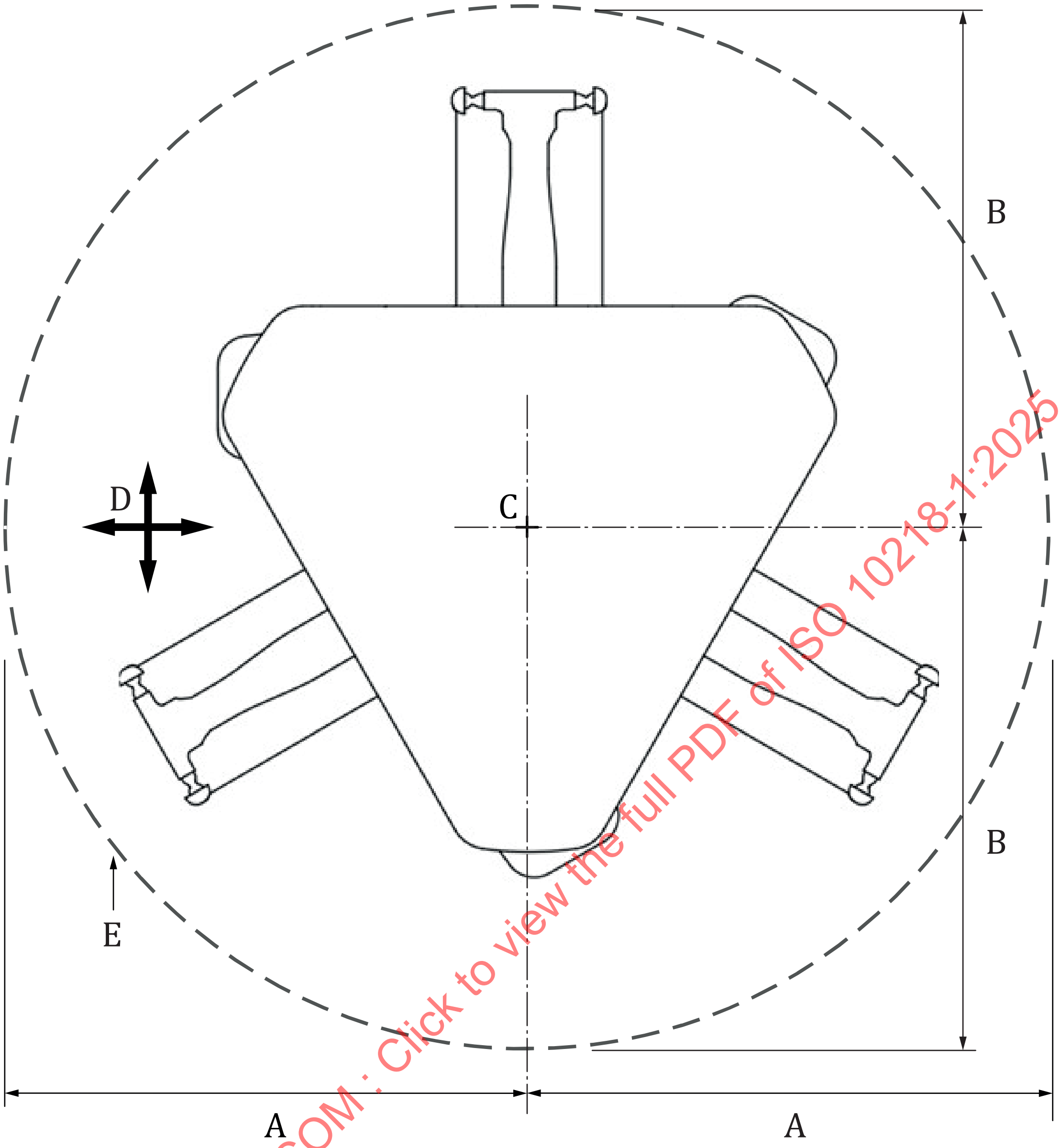
B dimension of the maximum space in the “Z” dimension, measured the borders of the maximum space (B dimensions are equal)

C location of the contact surface of the force measurement device

D direction of movement (sideways) towards the force measurement device

E border of the maximum space, top view

Figure E.4 — Example horizontal (sideways) measurement location for a 6-axis articulated robot



Key

A dimension of the maximum space in the “X” dimension, measured from the centre of the robot base to the maximum space border (A dimensions are equal)

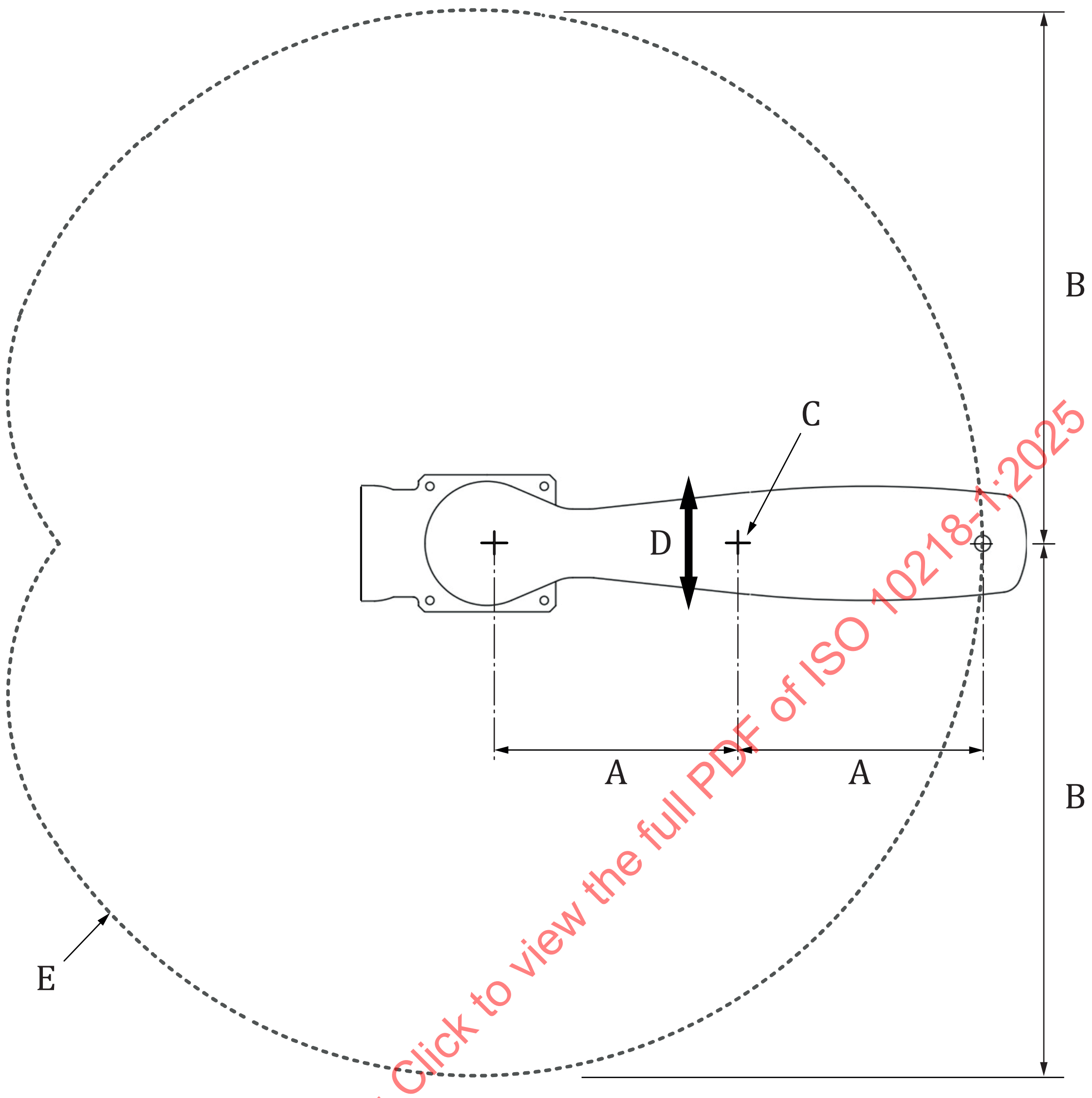
B dimension of the maximum space in the “Z” dimension, measured the borders of the maximum space (B dimensions are equal)

C location of the contact surface of the force measurement device (at the centre of the A and B dimensions)

D direction of movement (sideways) towards the force measurement device

E border of the maximum space, top view

Figure E.5 — Example horizontal (sideways) measurement location for a Delta robot



Key

A dimension of the maximum space in the "X" dimension, measured from the centre of the robot base to the maximum space border (A dimensions are equal)

B dimension of the maximum space in the "Z" dimension, measured the borders of the maximum space (B dimensions are equal)

C location of the contact surface of the force measurement device

D direction of movement (sideways) towards the force measurement device

E border of the maximum space, top view

Figure E.6 — Example horizontal (sideways) measurement location for a SCARA robot

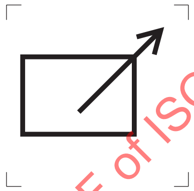
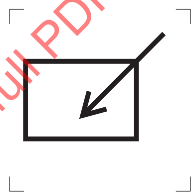
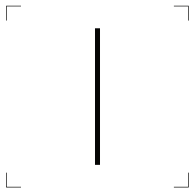
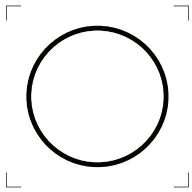
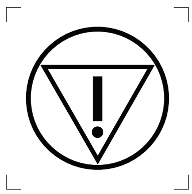
Annex F
(informative)

Symbols

Table F.1 provides guidance for symbols for modes, direct control, external control, power on and power off. Other symbols can be used for the speed, program and more.

Additional text can be included with the symbols.

Table F.1 — Symbols

Subclause	Description	Symbol	Reference
5.2.7.1	**Automatic mode** To indicate any automatic closed loop function		**7000-0017** Automatic control (closed loop)
5.2.7.2	**Manual mode** To identify a manually operated control. To identify the switch position that places the equipment under manual (as opposed to automatic) control. To identify the control that activates manual control. To indicate that the equipment is in manual control mode.		**7000-0096** Manual mode Manual control
5.2.8.3	**External control ON** **Activate** To identify the control for changing over to external control		**7000-1108** Remote control, switch on Remote control, activate
5.2.8.3	**External control OFF** **Deactivate** **(Direct control ON)** To identify the control for changing over to direct control		**7000-1109** Remote control, switch off Remote control, deactivate
5.2.6	**Power ON** To indicate connection to the mains, at least for mains switches or their positions, and all those cases where safety is involved.		**IEC 60417-5007** “ON” (power)
5.2.6	**Power OFF** To indicate disconnection from the mains, at least for mains switches or their positions, and all those cases where safety is involved.		**IEC 60417-5008** “OFF” (power)
5.4.2 Figure I.1	**Emergency stop** To identify an emergency stop control device		**IEC 60417-5638** Emergency stop

Annex G
(informative)

Means of verification and validation of the design and risk reduction measures

Table G.1 lists requirements of Clause 5 and the acceptable means to verify and validate whether these requirements have been met.

Verification and validation can be performed using one or more of the below methods in Table G.1.

Table G.1 — Means of verification and validation of the design requirements and risk reduction measures in Clause 5

Clause	Applicable design requirements and risk reduction measures	Method **A** visual inspection **B** practical test(s) **C** measurement **D** observation during operation **E** review of schematics, circuit diagrams & design material **F** review of risk assessment and/or FMEA **G** review of specifications and information for use						
		A	**B**	**C**	**D**	**E**	**F**	**G**
5.1	**Robot Design**							
5.1.1	Designed in accordance with ISO 12100:2010						X	
5.1.2	**Materials, mechanical strength, and mechanical design**							
5.1.2.1	Designed and constructed to prevent hazardous situation(s) that result from failure due to fatigue and wear		X	X		X	X	
5.1.2.1	Design and construction take into account the lifecycle of the intended use		X	X		X		
5.1.2.2	**Materials**							
5.1.2.2	Are appropriate for the intended use of the robot		X	X		X		
5.1.2.2	Do not endanger persons' safety or health					X		
5.1.2.2	Are non-toxic in all reasonably foreseeable conditions of use		X	X		X		
5.1.2.2	Are not prone to brittle fracture, excessive deformation, or emission of toxic or flammable fumes		X	X		X		
5.1.2.2	Retain their properties in the reasonably foreseeable range of climatic and workplace conditions, including temperature variations or sudden changes		X	X		X		
5.1.2.1	Where fluids are used, machinery is designed and constructed to prevent risks due to filling, use, recovery or draining		X	X		X	X	
5.1.2.3	**Mechanical strength**							
5.1.2.3	Robot is designed and constructed to withstand an overload in static tests without permanent deformation or patent defect, where strength calculations have a minimum static test coefficient of 1,25		X	X				
5.1.2.3	Robot can undergo, without failure, dynamic tests using the maximum unit payload multiplied by the dynamic test coefficient, where the dynamic test coefficient is at least 1,1		X	X				
5.1.2.3	Tests are performed at the maximum speed		X	X				
5.1.2.3	If simultaneous motion can be programmed, tests are done using the least favourable conditions		X	X				
5.1.2.4	**Mechanical design**							
5.1.2.4	Exposed sharp edges and corners, and hazardous projections are reduced	X		X				

Table G.1 *(continued)*

Clause	Applicable design requirements and risk reduction measures	Method **A** visual inspection **B** practical test(s) **C** measurement **D** observation during operation **E** review of schematics, circuit diagrams & design material **F** review of risk assessment and/or FMEA **G** review of specifications and information for use						
		A	**B**	**C**	**D**	**E**	**F**	**G**
5.1.2.4	Hazardous mechanisms that enable motion (e.g. power transmission components) are installed or mounted inside the robot frame such they are inaccessible	X		X				
5.1.2.4	Exposure to hazards caused by power transmission components such as motor shafts, gears, drive belts, or linkages which are not protected by integral covers are prevented either by fixed guards or movable guards in accordance with ISO 14120:2015	X						
5.1.2.4	The fixing systems of the fixed guards intended to be removed for routine service actions by users or operators remain attached to the robot or the guard		X			X		
5.1.2.4	Movable guards are interlocked with the hazardous movements in such a way that the hazardous machine functions cease before they can be reached		X			X		
5.1.2.4	If these mechanical design measures are not practicable in the robot construction, then the information for use states that these risks are reduced during the integration					X	X	X
5.1.2.4	Errors when fitting or refitting parts, that can be a source of risk, are prevented. If not practicable, the information for use provides information on the parts themselves and/or their housings		X			X	X	X
5.1.3	**Handling, lifting and transportation**							
5.1.3	Hazards due to sudden movements or instability such that tipping and falling-over during transport, lifting and handling of the robot or its component parts, are prevented if they are handled in accordance with the instructions for use		X					
5.1.3	Measures are provided for lifting and are adequate for handling the anticipated load, including appropriate design, additional support elements and/or adequate packaging		X	X		X		
5.1.3	Provisions for handling and lifting the robot and its associated components are provided and are adequate for handling the anticipated load		X	X		X		
5.1.4	**Packaging**							
5.1.4	Robot, and any part of the robot intended to be handled separately are designed or packaged such that the robot and its parts can be handled without injury and stored without damage when handled and stored in accordance with the information for use		X			X		X
5.1.5	**Stability**							
5.1.5	Robot is stable for installation, operation, use, disassembly and dismantling such that tipping and falling-over are prevented by specified mounting to affix the robot securely		X			X		
5.1.6	**Temperature and fire risks**							
5.1.6	Temperatures of accessible surfaces are in accordance with ISO 13732-1:2006 and ISO 13732-3:2005		X	X				
5.1.6	Where there is a risk of fire or overheating, the design principles of ISO 19353:2019 are applied		X	X		X	X	
5.1.7	**Special equipment**							
5.1.7	Special equipment and accessories to enable the robot to be adjusted, maintained and used safely are supplied or made available	X	X					X
5.1.8	**Position holding**							

Table G.1 *(continued)*

Clause	Applicable design requirements and risk reduction measures	Method **A** visual inspection **B** practical test(s) **C** measurement **D** observation during operation **E** review of schematics, circuit diagrams & design material **F** review of risk assessment and/or FMEA **G** review of specifications and information for use						
		A	**B**	**C**	**D**	**E**	**F**	**G**
5.1.8	If loss of power can lead to hazard due to gravity, the robot has means to maintain robot position without drive power (e.g. brakes, pins, other technology)		X	X		X		
5.1.8	Appropriate design margins are used for position-holding means in accordance with 5.1.2		X	X		X		
5.1.8	A method is provided for testing the position holding means if failure can cause a hazardous situation		X	X				X
5.1.9	**Auxiliary axis (axes)**							
5.1.9	Position holding means provided with auxiliary axis (axes) is in accordance with 5.1.8		X	X		X		
5.1.9	Auxiliary axes associated with lifting or holding a suspended mass conform with relevant requirements in this document.		X	X		X		
5.1.9	When the auxiliary axis motion affects the TCP speed in reduced-speed manual mode, the requirements of reduced-speed (5.5.3.1) apply to the auxiliary axis (axes)		X			X		
5.1.9	When monitored-speed safety function (5.5.3.2) is provided for the robot, it is also provided for the auxiliary axis (axes)		X			X		
5.1.9	Axis limiting is provided in accordance with 5.7 when the auxiliary axis (axes) is included in the three axes of greatest (largest) displacement motions		X	X		X		
5.1.10	**Power loss or change**							
5.1.10	Loss or change of electrical, hydraulic, or pneumatic power to the robot does not result in a hazardous situation		X			X	X	
5.1.10	Re-initiation of power does not lead to a hazardous situation through any movement(s) or change in safety-related parameters		X			X		
5.1.10	Robot conforms with ISO 14118:2017 to prevent unexpected start-up		X			X		
5.1.11	**Component malfunction**							
5.1.11	Robot components are designed, constructed, secured, or contained in accordance with 5.1.2, so that risks caused by breaking loosening, or releasing, including those related to stored energy, are reduced to an acceptable level		X			X	X	
5.1.12	**Hazardous energy**							
5.1.12	Stored energy does not cause hazardous situations		X	X		X		
5.1.12	Means are provided to prevent the uncontrolled or hazardous release of stored energy		X	X		X		
5.1.12	If hazardous energy is potential (e.g. spring balancer, gas balancer), the robot has the means to secure it in a position that can be either the energized or de-energized position		X	X		X		
5.1.12	Robot is fitted with means to isolate it from all energy supply sources		X	X		X		
5.1.12	Means are capable of being locked or secured	X	X			X		
5.1.12	Safe release or containment is provided in accordance with ISO 14118:2017		X			X		
5.1.12	A label is affixed to identify the stored energy hazard	X						
5.1.12	Where axes (e.g. robot, auxiliary) can move due to gravity, means are applied either to prevent axis motion or to ensure that resulting motions can be initiated and result in a de-energized position in a controlled way		X			X		
5.1.13	**Electrical, pneumatic, and hydraulic parts**							